Free DVD inside

Image Sharpening • Lens Error Correction • Photo Apps • DSLR Video

c't Digital Photography

The in-depth quarterly for the photo enthusiast

Special Offer! 50 % off Nikonians Membership

Image Editing

iPhone & Android Photo Apps
Mobile fun and photo tools

Bit Depth Explained
Are 16 or 32 bits better than 8?

Free DVD

Photoshop Plug-ins
3D Photography Video Tutorials
Full and Special Version Software

Creative Corner

DSLR Video
From storyboard to finished film
Editing software test
Image stabilizer test

3D Photography Special
Shooting techniques and image processing
Cameras, lenses and displays

Camera Test

DSLR vs. Mirrorless
Panasonic, Pentax, Olympus, Samsung

Better Photos

How to Correct Lens Errors
Distortion and perspective correction software test

Sharpen Your Image!

Preventing Image Softness, Sharpening Tools Review

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The in-depth quarterly for the photo enthusiast

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www.photoplusexpo.com

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Next to the Nikon Booth

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Welcome to Issue 5 of *c't Digital Photography*!

This issue sees us enter our second year of publication, and we would like to thank our readers for their encouragement and positive feedback in recent months. Support for the magazine already extends beyond our readership to a number of well-known online forums, including nikonians.org, who are offering readers of this issue an exclusive 50 percent discount on a year's Gold Membership (see page 9).

If you would like to meet us in person, you can visit our booth (901A) at the PhotoPlus International Conference in New York (www.photoplusexpo.com) in October, and it is now easier than ever to tell us what you like (or what you don't like) about the magazine online at www.facebook.com/ct-digiphoto, twitter.com/ctDigiPhoto or in a mail to me at editor@ct-digiphoto.com. I promise to answer all of your queries!

Have fun with this issue's great mix of articles, workshops and in-depth know-how. This time around, you can learn how to correct lens errors and how to get the best possible sharpness out of your images. And if two dimensions or non-moving images aren't enough, we show you how to take and process 3D images as well as how to shoot DSLR video like the pros. For the smartphone users among you, we also give you the low-down on which apps are available for the iPhone, the iPad and Android, and tell you which made it onto our list of personal favorites.

Juergen Rink

P.S. Due to the many requests we have received, we are pleased to announce that subscriptions to *c't Digital Photography* are now available worldwide. See the card on page 35 for details or visit www.ct-digiphoto.com/subs

Portfolio

Maak Roberts' advertising and editorial photos give reality a bizarre twist.

Correcting Lens Errors

Most lenses produce visibile distortion of one sort or another. We explain the causes of distortion and how to minimize its effects while shooting, or later using a computer.

3D Photography Special

This series of articles takes an in-depth look at how to shoot and process 3D images, as well as some of the 3D hardware currently on offer. We also provide an overview of the 3D display market.

iPhone & Android Photo Apps

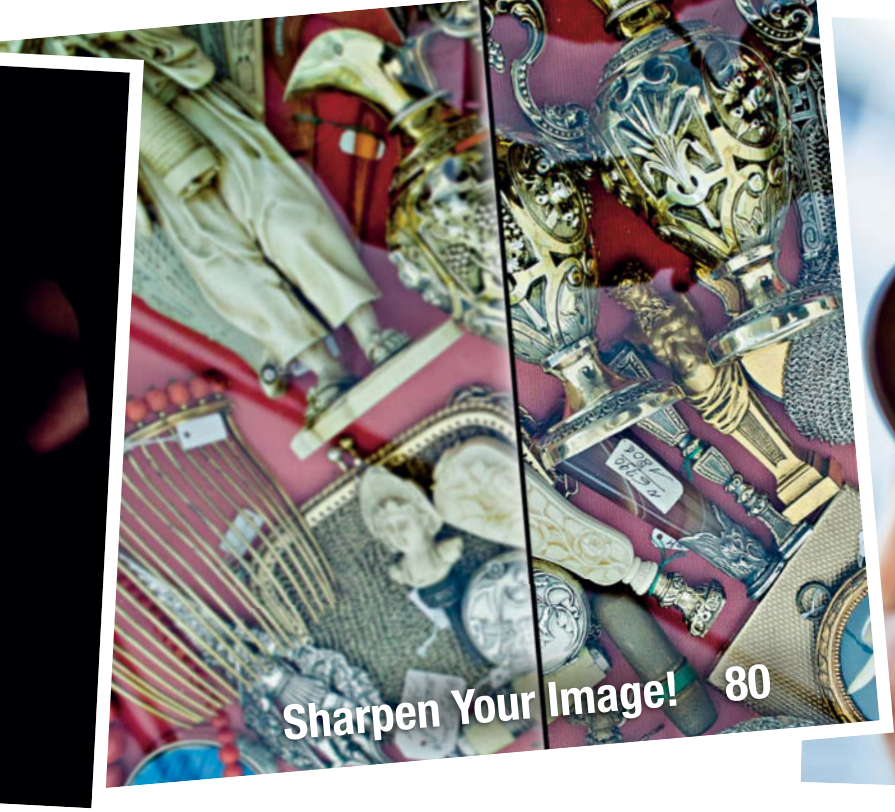
Photo apps come in a huge range of shapes and sizes and transform Smartphones into versatile image creation machines.

Sharpen Your Image!

Sharpening can produce just as many artifacts as it eliminates. This article explains how to avoid shooting unsharp photos and how to get maximum sharpness out of your images using software tools.

Shoot Video Like a Pro

Many of today's DSLRs have built-in high-end video functionality. Camera operator Kumaran Herold explains how to use this capability to shoot professional-looking video, taking us step by step from the concept to the finished clip. Plus: editing software and image stabilizers.



Bit Depth Explained

How much color depth do you really need? Are 32 bits per channel really better than 16? This article provides all the answers as well as some useful insights into the way computers handle color.

Camera Test: DSLR vs. Mirrorless

To see how well today's mirrorless cameras shape up against the DSLR competition, this issue's camera test lines up the Pentax K-5 and K-r models with the Olympus E-5 and pits them against the Panasonic Lumix DMC-GH2, the Olympus PEN E-PL2 and the Samsung NX100.

About Us

Free DVD

Highlights of this issue's free DVD include sample images from the many of the articles in the magazine, a special membership offer at nikonians.org and a wealth of free software. This includes a five-part 3D photography tutorial, a 3D photo/video playback application and an interview with our very own editor-in-chief, Juergen Rink.

Readers' Letters

Adapters for Canon A1 lenses

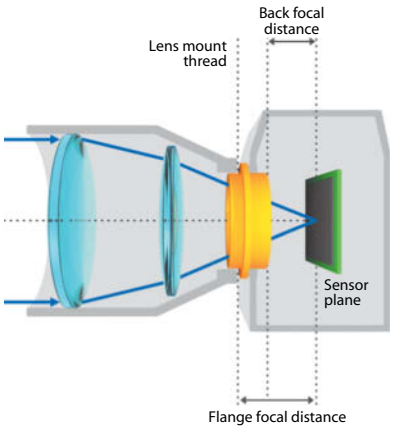
I just discovered your marvelous magazine (issue 4). I am an amateur photographer, and I think it is just great.

I have a question regarding issue 4, Manual lens adapters: I have an old Canon A1 with about seven lenses. Can you recommend a source of adapters to use those lenses in a Canon Rebel EOS DSLR?

Steve B.

Canon A1 lenses are tricky to use with adapters because of the dimensions of the FD lens mount, which has a flange focal distance of about 42 mm, while that of the EOS mount measures 44 mm.

What this means is that you can only use FD lenses with an adapter that contains additional optical elements, and these are difficult to find and complicated to use. Generally, if you want to use legacy lenses with adapters, we recommend that you use a camera body with a shallower flange focal distance than the body the lens was originally designed for.



Differences in flange depth mean that the thickness of the adapter determines the focusing accuracy of your combined camera/lens unit

Excellent balance of technical and non-technical articles

You are publishing the best magazine on digital photography without question … Each magazine on photography has their own purpose and following. Too many are copies of one another, but your magazine has an excellent balance of technical and non-technical articles that rises far above the rest. I sadly missed edition issue 2, but have thoroughly enjoyed the other editions.

I very much disagree with someone who thought the article in the first issue on comparing lenses was too long. That was an absolutely ridiculous comment. It was a thorough investigation of the subject that required every page that few magazines would have devoted to the subject … Keep up the good work. I enjoy every page of your magazine and look forward to receiving the next issue. I plan to subscribe and be a devoted reader.

Thomas G.

… and what people are saying about us on the Web:

I've recently been made aware of a new photography magazine that's hit the North American market. Jack Howard, author of Practical HDRI and Practical HDRI 2nd Ed let me know about it a few weeks ago. The mag is c't Digital Photography.

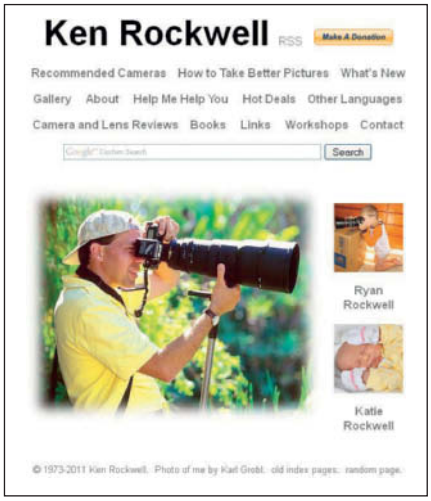
In general, I've thought for years that European photo publications were superior to what we get here in N.A. Much of what we have here is more sizzle than steak. There are a few exceptions but I'm speaking in generalities. Based on the copy I have, c't Digital Photography makes a good impression too. The first thing that struck me was the physical size. European mags are larger than in N.A. and that's really due to the different paper sizes. The next thing that struck me was the paper quality. Every page is heavyweight, glossy stock. Definitely better quality than what we get in N.A.

Moving beyond the physical aspects, the content is outstanding. A recent issue of Outdoor Photographer had an article on geotagging. The article was two pages of which barely one page was text. By comparison, the issue of c't I received also has an article on geotagging. The c't piece is 14 pages and goes into a great deal of depth about the process and the available tools. There's a 14 page article on studio lighting complete with numerous examples and lighting setup diagrams. An 18 page article on travel photography gives incredible insight into this genre of photography. A 17 page article on filters is more a small book than an article. All of the articles are well written, comprehensive studies of the subjects.

While it is more expensive than 'local' mags … the quality of the content should make it worth the additional cost because the content is simply outstanding. (http://rf-photography.ca/photo-mag-market/)

RF-Photography

If you want to learn about photography itself and how to make better pictures, Bruce Barnbaum's *The Art of Photography* is the best book ever written. For well under $30, I consider The *Art of Photography* as required reading if you're interested enough to read this website and have a genuine desire to take great pictures, as opposed to just buying up all the gear you can.



If you want to read all about lenses, flash technique, panorama stitching, Linux photo tools, macro, graphics tablets, Lightroom, and even get a free DVD crammed with eBooks on macro shooting, Photoshop workshop videos, plug-ins and more, c't Digital Photography Magazine is for you. (www.ken-rockwell.com/tech/00-new-today.htm)

Ken Rockwell's blog

Tell us what you think:

We are always happy to receive your comments and suggestions in a letter, an e-mail to editor@ct-digiphoto.com or at www.facebook.com/ct-digiphoto. We reserve the right to abbreviate your input for publication. Our comments are printed in italics.

PDN PhotoPlus Expo

October 2011 sees the 29th PDN PhotoPlus Expo open its doors to the *Who's Who?* of the photo and imaging scene. For three days, the event gives you exclusive access to emerging trends, technology, and talent, as well as providing a range of informative seminars and a forum for meeting and exchanging ideas.

The annual New York event has taken place every year since 1983, and uses the unique space frame structure of the Jacob K. Javits Conference Center to provide a meeting place for imaging professionals from all areas of the trade. The PDN PhotoPlus International Conference + Expo 2011 is one of the most important photo trade fairs in the USA and attracts many national and international exhibitors and visitors. One of the reasons for the fair's success is its wide range of themes gathered under one roof. Exhibitors include all major camera manufacturers, equipment suppliers, printer manufacturers, and many other companies associated with photography and imaging.

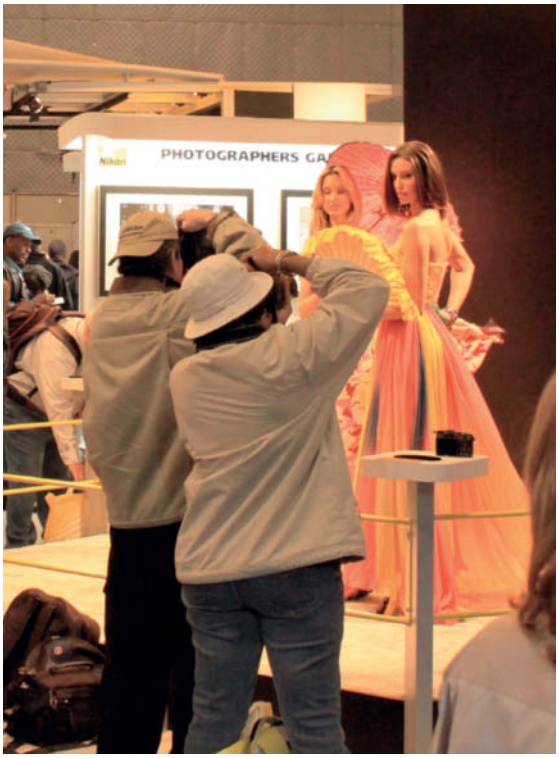
The name says it all and, along with the product booths and shows, this year's International Conference + Expo offers more than a 100 specialist seminars given by well-known photographers and other stars of the scene. Subjects such as "Location Flash Lighting" or "Experiential Wedding Photography" can be found alongside software-based themes like "Digital Workflow Live with Adobe Lightroom 3" or business topics like "Delivering What You Promise on Global Assignments".

The major camera manufacturers offer free, often educational shows during the event and are complemented by booths run by major lens and accessory suppliers such as Carl Zeiss, Tamron, Sigma, Manfrotto and Lowepro.

c't Digital Photography is, of course, part of this major event, and you can find us together with our partner *Rocky Nook Publishing* at booth 901A. We're looking forward to seeing you there, and don't forget to bring a tote bag!

Additional information:

www.photoplusexpo.com,
www.javitscenter.com



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INTERNATIONAL CONFERENCE + EXPO

Dates & Times

Expo

Thursday, Oct 27:	10:00am - 5:00pm
Friday, Oct 28:	10:00am - 5:00pm
Saturday, Oct 29:	10:00am - 4:00pm

Seminars

Thursday, Oct 27:	8:45am - 7:45pm
Friday, Oct 28:	8:45am - 7:45pm
Saturday, Oct 29:	8:45am - 5:45pm

DVD Highlights

Highlights of this issue's free DVD include sample images from the articles in the magazine, a special membership offer at nikonians.org and a wealth of free software. This includes a five-part 3D photography tutorial, a 3D photo/video playback application and an interview with our very own editor-in-chief.

3D Photography Video Tutorials

c't Digital Photography 3D special: Andreas Fischer uses clear examples to explain the basics of shooting and viewing 3D photos.

This five-part series of tutorials is normally only available to subscribers to FotoTV (www.fototv.com) and explains how to get started with 3D photography. Andreas Fischer is an experienced 3D photographer and explains everything you need to know to start taking your own "stereoscopic" images. He uses straightforward examples to explain various shooting techniques.

You don't need a special camera to take 3D photos, and you can create 3D images of stationary subjects by using a conventional camera to take two slightly offset source images. Fischer introduces various ways of producing stereoscopic photos and explains what to watch out for to be sure of getting effective three-dimensional results.

The best-known way to capture 3D snapshots is to use two synchronized cameras attached to a special bracket, and we even show you how to build your own. Firing both shutters simultaneously is a great way to capture fast-moving subjects in 3D.

How you process your 3D photos will depend on how you want to view them: some 3D images only appear three-dimensional if you view them using special glasses, while others only require you to train your eyes to see the hidden third dimension. (anm)

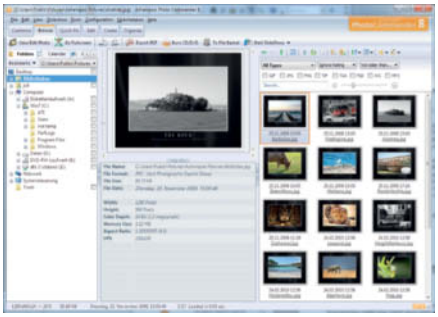


Photo Commander 8.5 (full version)

This package gives you the functionality you need to efficiently view, manage, optimize and export your digital images.

If you take a lot of digital photos, you will know how difficult it can be to keep track of your work and find just the image you are looking for. This is where Ashampoo Photo Commander steps in, giving you a wealth of display modes and other really useful features.

The program window gives you a clear overview of your stored data alongside a preview window, metadata display and a thumbnail view that updates quickly and smoothly when you switch folders. As well as all popular image formats, the program also supports a range of video formats that play back in real time in the preview window when selected. Pressing "Enter" switches to a maximized preview window and Alt+Enter switches the program to full-screen mode. There are also tools for burning video projects to CD or DVD, creating Web galleries, exporting to PDF and much more besides.

Version 8.5 of the program is included on our free DVD. Once you have registered online, you will receive an activation code that allows you unlimited use of the software. Plus, if you update to the even more powerful version 9 directly from the program's interface, you will receive a 60 percent discount on the program's normal retail price. (jub)

Stereoscopic Player (c't edition)

c't Digital Photography special version software: This player displays a range of 3D video formats, including DVD.

The article on page 40 explains various types of 3D images in detail and the pitfalls to watch out for while shooting. But that's not all – once you have captured them, 3D Photos and videos require their own special methods of display. 3D Videos usually have to be written to a specific file format, making it necessary to create multiple files for display in different formats. Stereoscopic Player works around this problem by converting files in real time during playback. This means that you only require a single video file for viewing 3D films with red/green 3D glasses, active shutter glasses or using the glasses-free cross-eye technique.

The c't Digital Photography special version 1.7.2 of Stereoscopic Player is included on our Free DVD and gives you unlimited anaglyph video viewing functionality for videos stored on hard disk. If you install a DirectShow decoder (available separately), the player can also play back all popular 3D or 2D formats from DVD. Additionally, the program offers real time Web stream viewing during download and access to cameras and other capture devices. The 3D photo and slideshow playback feature is a great bonus for photographers and a command-line interpreter allows extensive automation and customization. (jub)

Nikonians Gold Membership

Special Offer: The voucher included with this issue gives you a 50 percent discount on a year's Gold Membership at nikonians.org, the premier online photo community.

Nikonians (www.nikonians.org) is a manufacturer-independent online community founded by Nikon-loving photographers, and which is open to anyone interested in any aspect of digital or analog photography. nikonians.org is said to be the largest Nikon user community in the world and invests all of its income in maintaining and expanding its online activities. The site was founded 11 years ago and now has more than 350,000 registered members. Its stated aim is "to provide a friendly, creative and inspiring atmosphere for ambitious photographers of all skill levels."

Forum access, newsletters, podcasts and the site's online eZine are free, while all of the other Nikonians features and benefits require annual membership, either at Silver (US$25), Gold (US$75) or Platinum (US$200) levels. Gold membership costs just US$37.50 if you register before February 29th 2012 using the voucher code ctniken2011. Further information and links to the nikonians.org site are included on our free DVD.

Gold members are allowed to upload images to forums, have access to fine art galleries and forums, can send mail to other members, are allowed to edit the Nikonians Wiki and receive invitations to participate in photo tours, workshops and contests. (jr)

3D Tools

3D Processing Sample Images
AnaBuilder 2.46.2
c't 3D Presentation (executable)
c't 3D Presentation (WMV)
c't AviSynth Script for converting 2D videos to 3D
Free 3D Photo Maker 2.0.11
StereoMasks 1.2.0.1
Stereoscopic Player (c't edition 1.7.2)

Image Processing Tools

Artweaver Free 1.22
GIMP 2.6.11
GIMP portable 2.6.11
GREYC's Magic Image Converter (G'MIC) 1.4.9.5
Image Analyzer 1.33
ImageJ 1.44
ImageMagick 6.7.0-6
ImageMagick portable 6.7.0
JDraw 1.1.5
Mosaizer Pro 8.2.89
Paint.NET 3.5.8
Pencil 0.4.4beta
PSPI 1.0.7
RegiStax 6.1.0.0

Photo Tools

CombineZP 1.0
EnfuseGUI 2.1
ExifTool 8.60
FastStone Image Viewer 4.6
FastStone Image Viewer portable 4.6
GeoSetter 3.4.16
Hugin 2011.0.1
Insight3D 0.3.2
IrfanView 4.30
IrfanView PlugIns 4.30
IrfanView portable 4.30
Phocus 2.6.3
Phocus Sample Images
Photo Commander 8.50 (full version)
Photobie 7.2.10
PhotoME 0.79R17
RadCor 2.05
Raw Therapee 2.4.1

Photoshop Plug-ins

Actions:
- 2-Strip Technicolor CS5
- Aged Type CS3
- Fake Depth of Field Instantly CS3
- Pro Sharpening Actions CS5
- Skin Smoothing CS4
- Vignetting CS4

Brushes:
- Bubble Wobble Brushes CS3
- Cloud Set CS4
- Flourish Brush Set CS3
- Flowers CS2
- Handwritten Alphabet CS4
- Kaiju 2 CS2
- Mistletoe Brushes CS5
- Splatter Brushes CS4
- Tattoo Art CS2
- Toy Soldier Brushes CS3

Sample Images

3D Camera Test Sample Images
Camera Test Sample Images
Distortion Correction Test Images

Video Editing

DSLR Video Workshop
AviSynth 2.5.8
AviSynth MT 0.7
Bitrate Viewer 2.2
Deshaker 2.7
MediaInfo 0.7.46
MKVToolnix 4.8.0
MVTools 2.5.11.2
Open Codecs 0.85.17777
VirtualDub 1.9.11
VirtualDub portable 1.9.11

Videos

FotoTV Interview with Juergen Rink, c't Digital Photography's editor-in-chief
3D Photography Video Tutorials

Special Offer

Gold Membership at nikonians.org

Portfolio

Maak Roberts

Though his work is familiar to millions, his photos are rarely exhibited or seen hanging in galleries, for Maak Roberts takes photos for magazines, billboards and advertising campaigns.

In addition to commissioned work, Roberts also works on projects of his own, but unlike many of his colleagues, he does not make a clear division between art and commerce. As far as he is concerned, advertising photography and artistic self-fulfilment go hand in hand.

However, he does not see himself as an artist. He believes that self-confrontation and analysis of social issues are part of the artistic vocation, which is a role he does not fulfill. This self-analysis is perhaps too severe for someone whose photos have such obvious artistic value.

Roberts' photos speak volumes. He has the knack of making an image tell an entire story – for example, describing the tortuous path of an orange through a muscle-powered juice press. Many of his subjects portray absurd situations: a man riding an enormous cardboard seahorse in an empty swimming pool or lighting a cigarette from a drawing of a lighter on his T-shirt. There's always something unusual to be discovered, and it is often just a tiny detail that transforms the everyday into the absurd. The viewer is compelled to linger and engage with the photo.

The images are put together with the greatest of care, and teams in London, Hamburg, Berlin and Paris sometimes spend weeks preparing a shoot. The polyglot Roberts was born to an English father and a German mother, and is constantly on the move. He grew up in Germany, Australia, England and France and now lives in London and Berlin. Following various internships and after assisting a number of established photographers, he trained as a photo designer. The strict confines of the academic world were not for him and he left college without completing the course. He quickly began to get freelance work shooting for record companies and magazines, and later for advertising agencies, too, as his reputation grew.

The absurd scenes that are his trademark fit very well into the advertising world, but Maak Roberts also manages, thanks to his use of recurring stylistic elements, to put his personal signature on images that are ultimately controlled by corporate policy. He understands how to subtly grab the viewer's attention so that the message only hits home at a second glance. This style could be an eminently suitable vehicle for challenging his own attitudes and views, as well as those of society, although this isn't Roberts' stated aim. But who knows where a photographer's creative journey may lead? (jr)

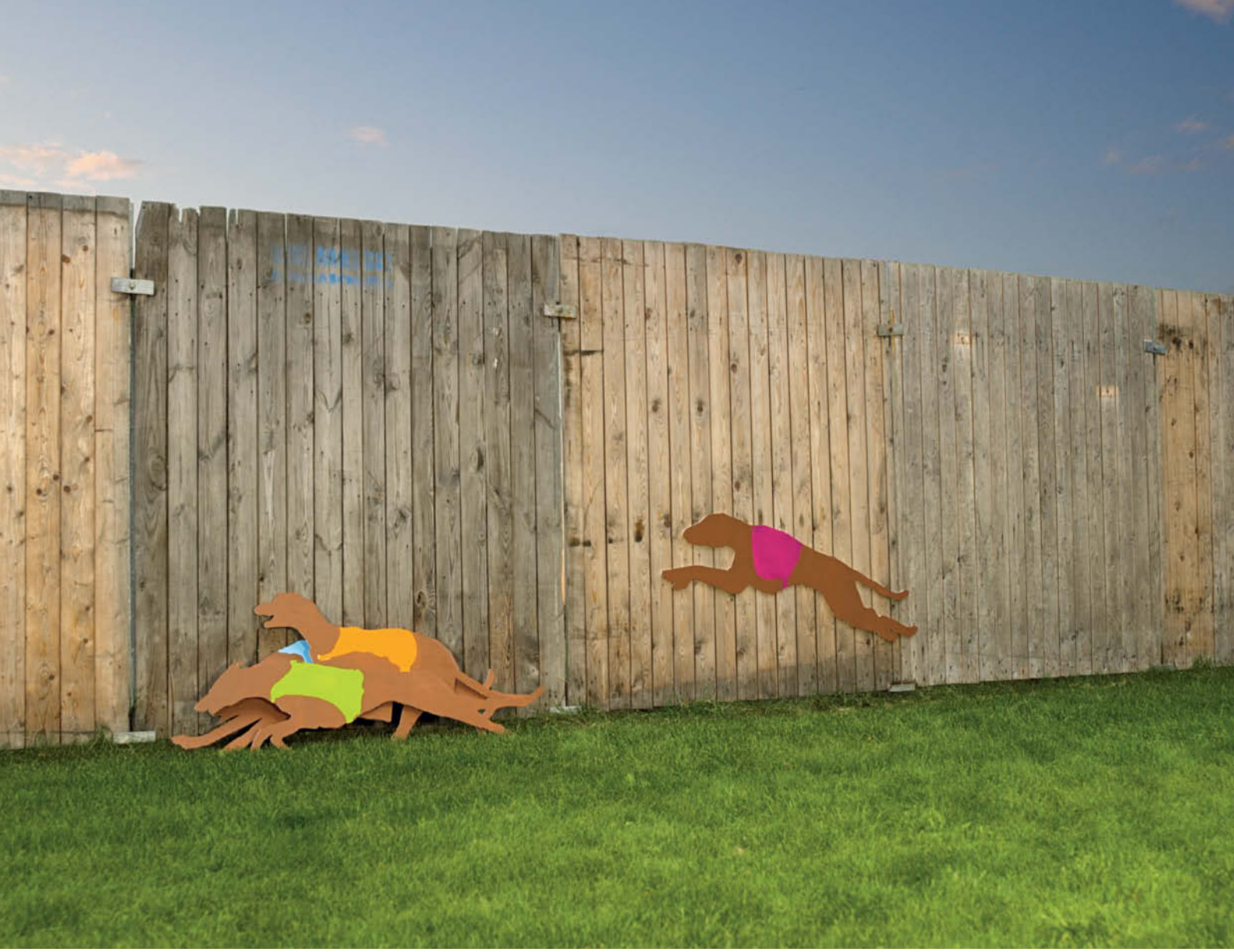
"The man in this photo sells a newspaper for homeless people in Buenos Aires. The photo came about during a project I shot in collaboration with a good friend who was living there for a while. She designed the T-shirts specially for this shoot."

"Shot at the zoo in Berlin for the magazine *J'N'C* – the source of some of my favourite freelance commissions. I had read Eugène Ionesco's *Rhinocéros* and somehow came up with the idea of putting animal heads on people and photographing them in everyday situations."

"This series was shot in collaboration with Miguel Gonzalez, who works at a London advertising agency. People often use pens to drum on tables when they're bored, and Miguel developed this habit into the slogan 'Used by the Worst Drummers in the World'. The resulting photos received an award in the 2010 Creative Review Photography Annual."

"Part of a shoot for *J'N'C*: I'm often asked whether the illustrations were created electronically after the shoot. In fact, one of my assistants designed the window and the cupboard and painted them on white cardboard. Whenever possible, I like to compose my photos in front of the camera rather than on paper or on a computer."

"The orange juice machine was created for a shoot organised by the Ligalux advertising agency for their client Uniplan. In the advertising world, it's very rare that the photographer gets the opportunity to be involved in developing the concept for a shoot. I'm still chuffed that the creative director, Jan Kruse, took up my idea, which I came up with during a sleepless night!"



"These dogs were actually made for a different photo. I had leant them against the wooden fence while I was getting set up, and suddenly realized that they made a great photo on their own."

"The magazine Emotion commissioned me to shoot a photo series with the working title 'Follow Your Heart'. Some of the ideas, including the one shown here, came from the editorial team, while others were developed by myself, the team and the artist who constructed the figures." c't


2.30

Sascha Steinhoff

Correcting
Lens Errors

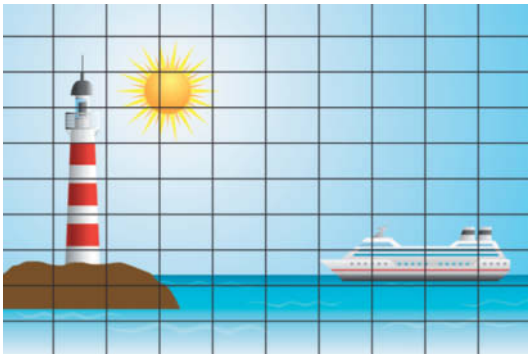
Whether zoom or fixed focal length, value or high-end, most lenses produce visibile distortion of one sort or another. Effects that make no difference in a photo of a cloudscape become a serious problem if you want to take a shot of a chess board. This article explains the causes of distortion, how to minimize its effects while shooting and how to reduce or eliminate its effects digitally using special programs and plug-ins or a RAW converter. Our test images and software to experiment with are included on this issue's free DVD.

In this article

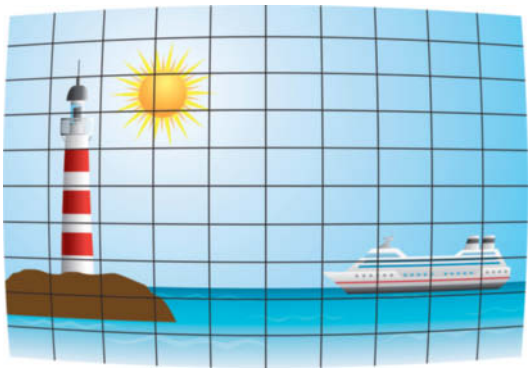
Distortion and Perspective Errors

All lenses produces varying degrees of optical distortion and perspective errors. Different types of distortion requiredifferent approaches to minimize or correct them.

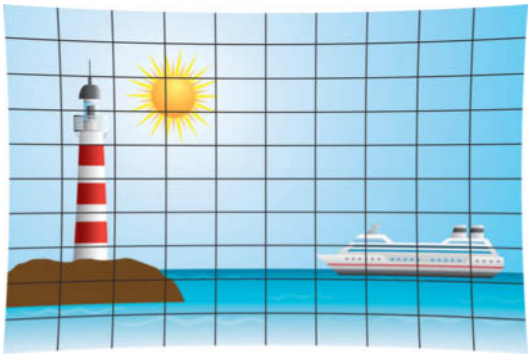
The two phenomena of distortion and deformation are seen as one and the same thing. Although this is largely true, it is nevertheless important to distinguish between purely optical distortion and the type of visual deformation caused by errors in the two-dimensional representation of perspective. Optical and perspective distortion often appear together – for example, if you use a wide-angle lens to shoot a photo of a skyscraper from street level. They are nevertheless two independent phenomena that have to be considered and treated separately.



Sample image with no distortion – all horizontal and vertical lines are perfectly straight



Barrel distortion causes the ends of straight lines to curve toward the middle of the frame. Only the lines that pass through the very center of the frame remain straight.



Pincushion distortion curves straight lines away from the center of the frame. Here too, the lines that pass through the center of the frame are straight.

Optical Distortion in Detail

Aberrations caused by the design of a lens cause optical distortion and occur regardless of the camera position or the type of subject. Apart from physically swapping the lens for a different model, there is no way to directly influence these types of effects. Whether distortion actually spoils an image depends largely on the nature of the subject. If you use a lens with strong distortion characteristics to photograph cumulus clouds, there are no straight lines to reveal distortion and the effects will probably remain unnoticed. If, however, you use the same lens to photograph a chess board, the highly geometric structure of the subject makes any distortion immediately and gratingly obvious.

The degree of distortion a lens produces does not depend on its focal length. This is the reason we were able to use the same grid pattern to test distortion for focal lengths from 18 mm right up to 200 mm. However, wide-angle lenses usually produce much stronger distortion than longer lenses.

Optical distortion is easiest to detect in two-dimensional subjects, such as a poster that includes a grid pattern shot head-on. If you photograph a two-dimensional subject at an angle, it will automatically include a third dimension and will be subject to additional perspective distortion.

Barrels, Pincushions and Waves

Optical distortion causes various types of image errors, the most common of which are “barrel” and “pincushion” distortion. Every lens has is own center of distortion, which is usually located in the center of the frame. All straight lines that do not pass through this center point will be captured curved by a lens that produces any degree of distortion. Barrel distortion makes straight lines appear to curve inward toward the middle of the frame, while pincushion distortion has the opposite effect, and makes straight lines appear to curve outward and away from the center of the image. Barrel distortion is very common in wide-angle and ultra-wide-angle lenses, while pincushion distortion is more prevalent

in telephoto lenses. In addition to these major types of distortion, lenses can also produce sub-types of distortion, often in the form of waves which are superimposed on the already bowed lines in an image.

Perspective Distortion

The degree of perspective distortion present in a photo depends on the subject, the camera position and the lens being used. In contrast to optical distortion, the quality of the lens plays no significant role in the production of persective distotion. Perspective distortion only occurs in three-dimensional subjects – for example in nearly all photos of tall buildings. If you want to take a photo of the entire façade of a building that is 300 meters tall without producing perspective distortion, the ideal location for the camera is halfway up the building at a height of 150 meters. Shot head-on from there, the lens will produce no detectable perspective distortion and the theoretical minimum subject distance will depend on the focal length of the lens at hand. A 50mm standard lens with an angle of view of 46 degrees would require a subject distance of 353 meters to capture the entire height of the building (see also our sample calculations in the box on page 24). However, because this ideal location is not usually available, most photographers end up shooting from a building's forecourt and angle the camera upward until the building more or less fits into the viewfinder. The results of shooting this way display strong perspective distortion, with converging vertical lines that appear to stretch endlessly upward.

The closer you are to your subject and the wider the angle of view of your lens, the more pronounced this effect becomes. While optical distortion is hardly ever consciously used

An atmospheric photo shot using a 21mm Zeiss Distagon and a Canon EOS 550D/Rebel T2i. For an ultra-wide-angle, this lens produces astonishingly little distortion (see also the interview later in this article). The only obvious distortion in this image is perspective distortion.

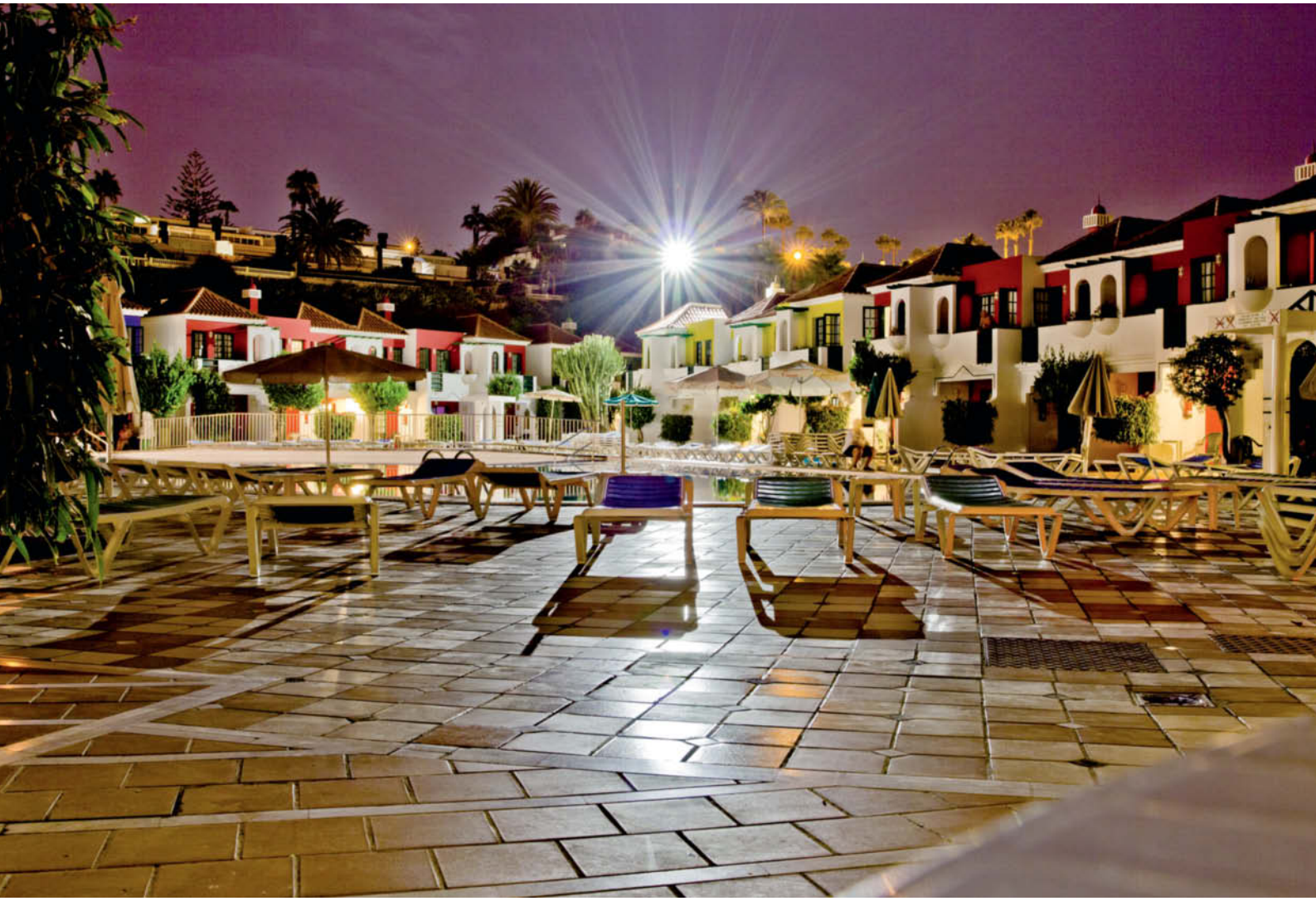
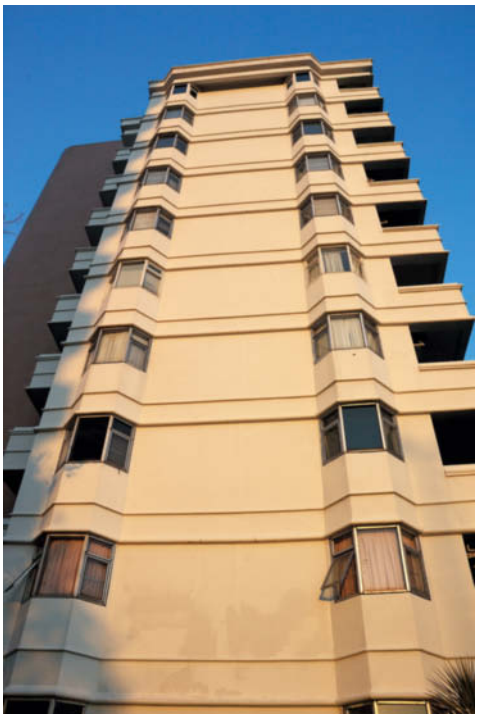
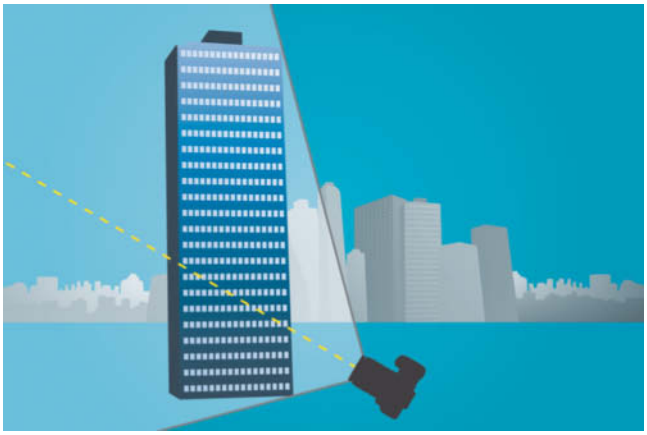


Photo: Stefan Arand



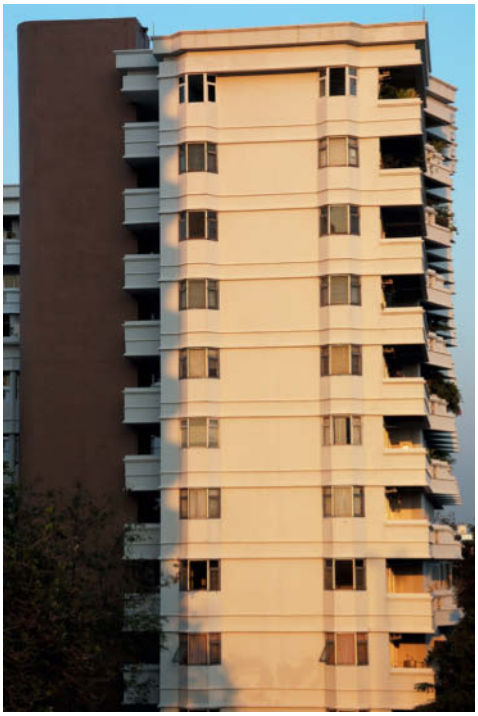


You need to use an ultra-wide-angle lens to capture the entire height of a tall building from close up. If you are shooting from a low viewpoint, the camera has to be tilted at a greater angle – ideal conditions for producing severe perspective distortion.

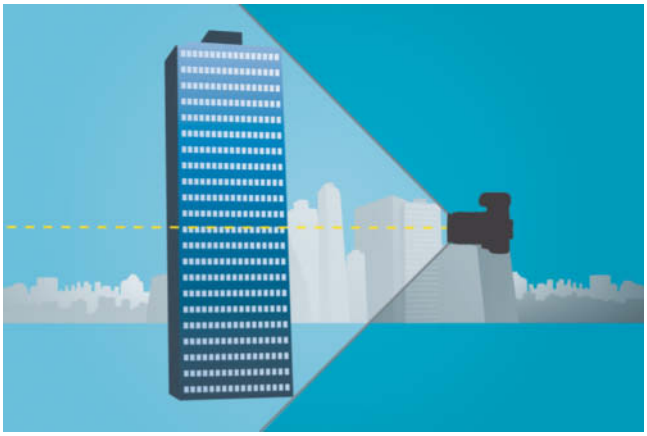
Photographing buildings from close up using a wide-angle lens always produces perspective distortion and obvious converging lines. The 18mm setting of the Nikon zoom lens we used here also produced additional barrel distortion.

for artistic purposes, perspective distortion is often employed deliberately to enhance the effect of an image. Opinion is often divided on whether the resulting effect is aesthetically pleasing but is, as always in such cases, purely a matter of personal taste.

Even if the ideal camera position isn't attainable – as is usually the case – there are various ways to control, or at least minimize, perspective distortion. The simplest method is to increase the distance between the camera and the subject, which automatically reduces the angle of tilt of the camera and allows you to use a longer focal length lens. This helps to reduce perspective distortion, but cannot eliminate it completely. Tilt/Shift lenses are a costly alternative approach that allows you to directly influence the angle of the sensor/film plane in relation to the optical axis of the lens. Adapted from the world of



The same building photographed from further away using a longer lens and a raised viewpoint. Here, perspective distortion has been all but eliminated. Despite the different lens and viewpoint, the pincushion distortion created by the 55mm setting of our Nikon zoom lens is still visible.



A camera position halfway up the building and at a sufficient distance allows us to shoot without tilting the camera, thus preventing perspective distortion in the effectively two-dimensional façade

large-format photography, this technique is available in the form of specialty lenses to photographers who use full-format, DX format or APS-C cameras. Tilt/Shift lenses visibly minimize perspective distortion and converging lines and can, in some cases, eliminate these effects completely. For more about converging lines and how to avoid them, see our architectural photography workshop in Issue 1 of *c't Digital Photography*.

Distortion in Portraits

Even if you manage to shoot precisely head-on, three-dimensional subjects can still end up displaying perspective distortion. Portrait photos are a perfect example of this type of problem, and in the past 35mm photographers often used short telephoto lenses with 80mm (or longer) focal lengths to take portrait shots. High-quality lenses of this type not only prevent perspective distortion, but are often corrected to eliminate optical distortion too. Nowadays, this approach to portrait photography is considered to be outdated, and contemporary portraits are often taken from much closer using all sorts of lenses.

It has recently become accepted that journalistic portraits are taken from close up using wide-angle lenses that deliberately distort the subject's features to add impact to the finished photo. This technique produces portraits with exaggeratedly large eyes, noses and mouths, while other features, such as ears or haircuts, recede into insignificance in the background. Wide-angle lenses also give human heads a slightly egg-shaped appearance, especially if you use them to shoot head-on. Many wide-angle lenses also produce obvious optical distortion in addition to this already pronounced perspective distortion. The two illustrations on the next page show the differences that focal length can make to the appearance of a face in a photo. The illustrations are based on real photos and the proportions they show are 100 percent accurate. Technically, the only way to mini-

Photo: Stefan Arand

This architectural photo, shot using a Canon EOS 60D and a Sigma 12-24mm lens set to 12 mm, contains lens-based errors and perspective distortion, and is an ideal candidate for manual correction

This illustration shows the perspective produced in a portrait by a 75mm (35mm equivalent) lens. There is no visible distortion and the proportions match our expectations.

A 27mm (35mm equivalent) focal length significantly alters the proportions and, as a result, the perceived facial expression. The subject's mouth, eyes and nose all appear disproportionately large, while the hairline appears to recede.

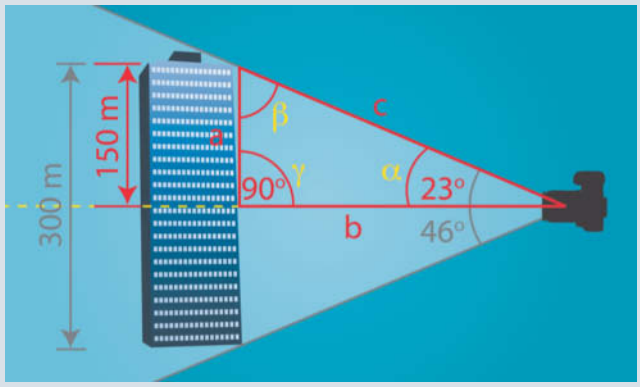
mize this type of perspective distortion is to use a longer lens.

The best way to correct perspective distortion after shooting is using specialized software such as *ShiftN* or *Perspective Transformation*. Although optical distortion effects and perspective distortion often occur together, their actual causes have nothing to do with each other. The photographer can largely influence the occurrence and degree of perspective distortion in a photo by choosing a different shooting technique, whereas optical distortion is purely a result of physical imperfections in the lens itself. In this case, the photographer often simply has to make do with the optical quality offered by the lens that is most appropriate to the situation at hand. If you are using a fixed focal length lens, there is nothing you can do to influence optical distortion while you are shooting, except to swap the lens for a more appropriate one. With a zoom lens, you can alter focal length to minimize distortion without having to swap lenses.

Calculating Subject Distance

A little advance planning can save a lot of time during a shoot, especially when it comes to capturing architectural subjects without perspective distortion. It is possible to calculate the ideal camera position if you know the angle of view of your lens and the exact height of your target building. Our example shows a 300-meter skyscraper that we want to photograph using a 50mm standard lens with a 46-degree angle of view. If we position the camera at the ideal "half height", the optical axis of the lens forms a right-angled triangle with the upper half of the building's façade. The angle between sides **a** and **b** is 90 degrees and the one between sides **b** and **c** is 46/2 = 23 degrees. Side **a** is 150 meters long (= 300 m/2). Using this information, you can either use your school trigonometry or an online tool such as http://www.calculator.net/triangle-calculator.html to calculate the length of the other long side of the triangle, which just happens to be the subject distance we are looking for. The values in our example result in a minimum subject distance of 353.38 meters if we want to capture the entire height of the building without perspective distortion.

If you know the height of the building you are photographing (here, 300 meters) and the angle of view of your lens (in this case, 46°), it is simple to calculate the minimum subject distance required to prevent perspective distortion



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Correcting Lens Errors In-camera or Using a Computer

There is no such thing as a distortion-free lens, so if the anomalies your lens produces spoil the effect of your image, you will have to correct them manually after shooting. As with many types of image processing, correcting distortion produces its own side-effects. Correcting pincushion or barrel distortion produces results that have to be cropped to make the edges of the resulting image straight. This makes the finished image smaller than the original.

Distortion correction filters also cause data loss due to additional data interpolation during stretching or compression routines. This often causes a reduction in sharpness in the resulting image. The quality of a software tool determines whether interpolation artifacts or a lack of sharpness become visible following processing. Different lenses cause widely varying distortion effects, making it virtually impossible to construct effective generic correction tools – especially if the lens in question also produces wave distortion.

Optimum correction therefore requires the use of individual lens profiles or, in the case of zoom lenses, several lens profiles that correspond to different focal length settings. The distortion produced by the Nikon 18-200mm zoom we used changes from pincushion to barrel over the course of the zoom range. See the following pages for more information on how to create custom lens profiles.

In-camera Distortion Correction

Many interchangeable-lens cameras have built-in distortion correction. The Nikon D90 was one of the first such models to be introduced and many other manufacturers quickly followed suit. New lens profiles can be added via firmware updates.

Most camera manufacturers only offer lens profiles for their current range of lenses, and don't usually provide profiles for third-party lenses or even for older lenses of their own. A camera has much less computing power than a home computer, and the monitor-based interface is limited in its scope for entering adjustments. However, some of the more refined built-in correction tools allow the camera to produce corrected images directly while shooting, which saves you having to make additional corrections at the post-processing stage.

Whether built-in correction tools are a blessing or a curse depends on how well they are implemented and on your own expectations. Ideally, automatic correction can be switched on or off at will and can, at least in the case of RAW image files, be undone if necessary. This is, however, not always the case. For example, the latest Olympus Micro Four Thirds cameras have automatic correction permanently switched on, even in live view mode.

This makes it impossible to realistically test the optical properties of such lenses, and some lens review websites no longer review Micro Four Thirds lenses for exactly this reason. It has even been suggested that this is a deliberate ploy on the part of the manufacturers to help them mask the true capabilities of their products.

The Olympus E-PL2 costs about US$550 with the 14-42mm kit lens – i.e., about the same as a good entry-level DSLR with a kit zoom.

The permanent in distortion correction built into the Olympus does justice to neither its price nor the expectations of potential buyers of this class of camera.

Computer-based Distortion Correction

Computer-based distortion correction has been around for a long time, or at least it has when compared to the fast-moving world of IT and image processing. Most current distortion correction tools are based to a certain extent on the famous *PanoTools* written by Professor Helmut Dersch. This suite of panorama processing tools was first published in 1998 and was designed, amongst other things, to counteract the manifold distortions that are part and parcel of the panorama creation process.

There are now many different types of distortion correction software available that are based on various approaches to the problem. The first that spring to mind are dedicated tools such as *PTLens*, *Image Iron* and *LensFix*, to name just a few. Many standalone tools are also available as plug-ins for image editors and RAW converters.

Many image editing programs and RAW converters, such as Adobe's *Photoshop* or *Lightroom* packages, also include lens error correction functionality that can be used to correct distortion. Some camera manufacturers provide proprietary RAW converters that include lens error correction functionality for their own lenses, while *Lightroom* includes an ever-expanding range of manufacturer-independent profiles.

The test that follows aims to find the optimum stage in the digital photo workflow for applying lens corrections. To achieve this, we tested a selection of programs and plug-ins and ended up with some surprising results. But one thing remains true throughout our investigation: corrections only make sense if you are in possession of inside knowledge about the structure of your lens. For this reason, the next section begins by explaining the ins and outs of creating lens profiles.

How to Create Lens Profiles

Every lens has its own particular distortion characteristics. In order to provide the best correction, we need to create individual lens profiles tailored to the needs of each lens. Only a very few programs offer profile creation functionality, and most simply provide ready-made profiles for a range of common lenses. In theory, zoom lenses require a separate profile for each focal length setting – an option that is not practically possible to implement. In practice, every lens profile represents some degree of compromise.

Basic pincushion and barrel distortion can be corrected roughly using generic filters and tools. The precision of the results is affected by various factors. The center of distortion is not always located exactly in the center of the lens, and lens errors don't adhere to mathematical formulae, making it necessary for correction software to store details of the optical characteristics separately for each lens.

Some software manufacturers have risen to the challenge and offer functionality for creating and embedding custom lens profiles. Ready-made profiles also have the disadvantage that they don't take manufacturers' tolerances into account, either in the lenses themselves or the slight variations in production quality of camera bodies. This can be critical for the quality of the resulting images, as they are captured using a complete system that is comprised of a specific camera/lens combination.

Creating your own profiles for a camera/lens unit is an elegant way to avoid these types of inaccuracies, although it has to be said that the process involves a lot of work and is not always completely reliable. Even the most experienced digital photo processing experts have to make compromises, and correcting lens errors is a constant process of comparing the effort involved with the real, perceptible improvements in image quality that can be achieved.

Sensor Sizes

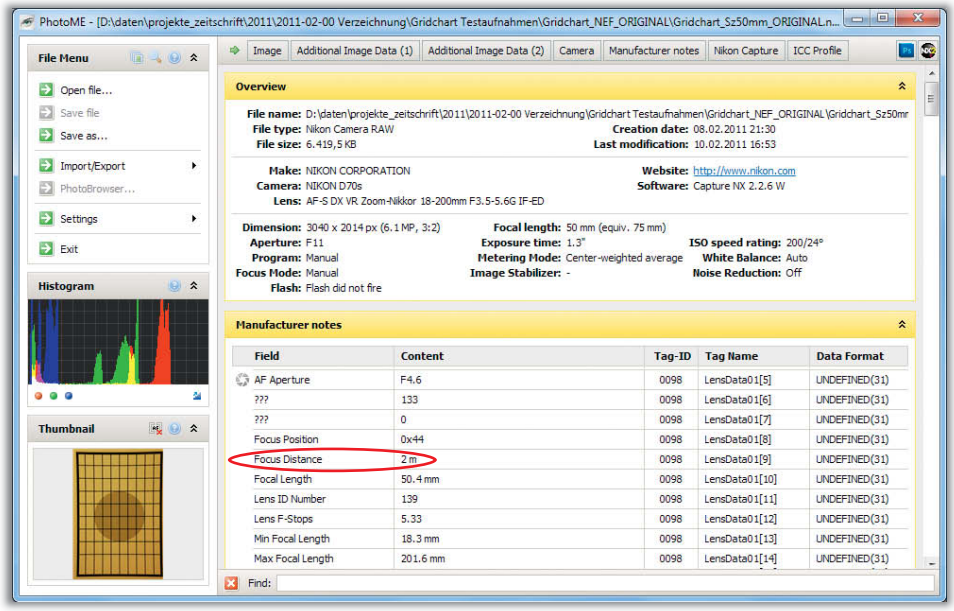
Major camera manufacturers such as Sony, Nikon and Canon all produce a range of prograde cameras with full-format sensors alongside mid-range and hobby models with DX (or similar) format sensors. The question here is whether a profile created for a full-format sensor can also be used cropped for cameras with smaller sensors, or whether it is preferable to create a separate profile for every camera/lens combination.

Software manufacturers have developed various approaches to this question. While some programs provide a single profile for each lens and uses either its full scope or a cropped version, depending on the size of the sensor in the camera used to shoot the image being corrected. This makes applying profiles relatively simple: all you have to do is select your lens and your sensor format and that's it. Adobe takes the more complex path of producing individual profiles for specific camera/lens combinations, which of course creates a much larger number of profiles that have to be produced and administered.

The sheer number of possible camera/lens combinations makes it quite likely that your chosen software won't actually have a profile for your particular setup, making it necessary to use a similar profile designed for use with the same sensor format but a different lens. For example, you might end up using a Nikon D90 profile for correcting a photo shot using a D300. This is, of course, only possible if your software allows you to choose – DxO is one example of a program that doesn't.

Profiles for "Rubber" Lenses

In bygone times, when most lenses had fixed focal lengths and were made of metal, early zoom lenses were dismissed as "rubber" lenses. With respect to lens errors, this is still very much the case, and the optical characteristics of most zooms change significantly at different focal length settings. For example, the distortion produced by our 18-200mm test zoom changes from strong pincushion at its 18mm setting to strong barrel at 35mm via a 24mm setting that shows virtually no distortion at all.



Information relevant to the correction of distorted Nikon NEF files – here, the focus setting – can be displayed and edited using tools like *PhotoME*

To profile a lens like this accurately, we therefore have to analyze its characteristics at various focal lengths. Most software manufacturers provide profiles for the zoom settings engraved on the lens itself – in our case 18, 24, 35, 50, 70, 135 and 200 mm, although some provide fewer and still others a more extensive selection. Technically speaking, you can only produce really accurate results if you create individual profiles for every millimeter of focal length covered by a zoom lens, although working to such a degree of precision makes no real, practical sense.

The Importance of Focus Settings

In addition to the zoom setting, the focus setting is an important factor in determining the type and degree of optical distortion that a lens produces. A close focus setting can produce a very different effect from focusing at infinity. This effect is seldom documented by lens manufacturers, making it difficult to take focus settings into account when creating and applying lens profiles. Camera and lens manufacturers have yet to agree on a standardized form for saving focus settings as metadata, in spite of the fact that the technical prerequisites already exist. DxO and other software manufacturers, too, advertise their software's ability to take focus settings into account while creating lens profiles. However, the a lack of appropriate software settings makes it impossible to check whether this is actually true.

The Exif metadata standard includes a predefined field for recording focus settings that is used by only a very few camera manufacturers. Most manufacturers instead save focus settings in their own proprietary MakerNotes, where they mostly sit doing nothing, hidden from the photographer's view. The focus settings saved with our NEF test image files cannot be read by Nikon's own *Capture NX 2* software or by other manufacturer-indpendent programs such as *Exif Viewer*. The *PhotoME* metadata tool included on this issue's DVD can read NEF focus settings directly, along with an impressive range of other metadata fields that normally remain hidden.

But knowing the focus setting is only half of the story, and you need to create lens profiles for each focus setting for them to be of any use. Additionally, creating lens profiles for different focus settings requires different sized reference charts – and this is where things start to get really complicated!

Reference Charts

Creating lens profiles requires the use of standardized reference charts that have to be photographed under controlled conditions. The profiling software then compares your photo of the chart with a saved reference version and uses the discrepancies it detects to create a profile. Some software manufacturers sell ready-made reference charts, while others deliver them in the form of files that you can print yourself. Reference charts have to be flat and sufficiently large and, the larger they are, the easier it is to photograph them precisely head-on. A tripod is essential when photographing a reference chart and, if you work carefully and methodically, you will be able to produce usable results in a home environment in spite of the slight errors that are bound to creep into the process.

The distance between your camera and the reference chart is determined by the focal length of the lens you are profiling. The shorter your lens, the closer you will have to get. This means that the actual focus setting you use is more or less a byproduct of the whole process. We used a single reference chart for our test shots and simply increased or decreased the distance between the camera and the chart for each focal length

If you want to create profiles for various focus settings you will have to use different sized reference charts, but even then, you will have to accept compromises in quality. For example, a reference chart for an ultra-wide-angle lens focused at infinity would theoretically have to be as big as the wall of a house to produce perfectly accurate results. And even for lenses with smaller angles of view, the effort involved in producing correctly sized reference charts for every zoom and focus setting would still be prohibitive. As far as we know, no profiling software manufacturer currently produces charts at this level of detail.

Tilt/Shift Lenses

In conventional lenses, distortion is largely influenced by focal length and focus settings, while in the case of tilt/shift lenses, the fact that you can alter the position of the optical axis also plays a significant role in determining the nature of the distortion they produce. Here, it is essential to create a separate lens profile for each individual shift setting. Assigning the right profile to your photos can be tricky, as tilt/shift lenses don't save their shift settings with image metadata. The easiest ways to record tilt and shift settings are using paper and a pencil or your camera's voice recording function.

Photo: Nikon

Tilt/Shift lenses allow you to compensate for perspective distortion by shifting the optical axis of the lens. This movement also shifts the center of distortion away from the middle of the lens, making it necessary to create an individual lens profile for each shift setting.

Test Criteria

All of the programs we tested had to correct a series of distorted images of our standardized 24 × 36-inch (61 × 91cm) test grid. At this size, all distortion is easily recognizable. The white border was included so that the entire grid remained visible after corrections were made.

Our test lens was a Nikkor AF-S DX 18-200mm f/3.5-5.6G ED VR zoom. Optically, this lens is identical to the newer VR II version and produces strong distortion at various settings throughout its 11.1x zoom range. We used it to shoot test images at 18, 24, 35, 50, 70, 135 and 200mm focal length settings with the lens positioned at exactly 90 degrees to the test grid. This method ensured that all results were directly comparable. Because the test chart is two-dimensional, perspective distortion played no role in the test.

We used images shot using a fixed focal length AF Nikkor 50mm f/1.8D lens as a reference. This lens costs around US$130 and produces virtually no distortion.

It is impossible to completely eliminate slight inaccuracies due to discrepancies in the angle between the lens and the test grid, especially at focal lengths that produce heavy distortion. These resulted in slight perspective distortion in some of our test images, although it was not significant enough to make a difference to our overall results. The lower weight and additional precision of our fixed focal length reference lens made it easier to orient it precisely to the plane of the test grid.

The AF-S DX Nikkor produced mixed but generally poor results with regard to distortion – in other words, it produced ideal images for our software test. At its 18mm setting it produces strong barrel distortion, there is virtually no detectable distortion at 24mm, and pincushion distortion begins to appear at around 35mm and remains visible throughout the rest of the range. The task we set all of our test programs was to undo the geometric anomalies caused by these effects.

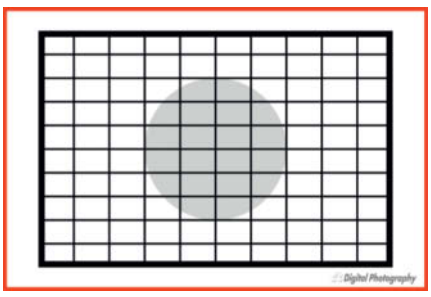
We also corrected a selection of snapshots to check how our test lenses captured everyday subjects. We used randomly picked images to check for image quality loss due to interpolation errors and compared original TIFF images with their corrected counterparts. It is virtually impossible to usefully compare NEF (RAW) original with the corrected version as most RAW converters automatically apply noise reduction filters that falsify the results. We converted our RAW image files once with and once without applying filters, which at least allowed us to check whether filtering caused image quality loss in each individual program.

We tested all Windows programs in a 32-bit environment and Mac programs in OS X. Both systems were freshly installed with all current updates. We tested standalone versions of each program where appropriate and plug-in versions if no standalone was available. We also installed the original Nikon NEF codec on our Windows system (it is pre-installed in OS X), and left it to each individual software manufacturer to decide whether to use built-in code or their own routines to convert Nikon RAW data.

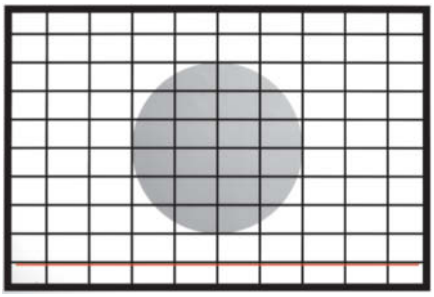
Due to differences in the quality of individual lens profiles, it is impossible to apply our results directly to other lenses. However, they still deliver strong indications as to which programs really do help and whether it is better to use a RAW converter or a dedicated program/plug-in to correct your images. The bottom line is that any program that failed our test is probably not worth using under any circumstances.

Test Images on DVD

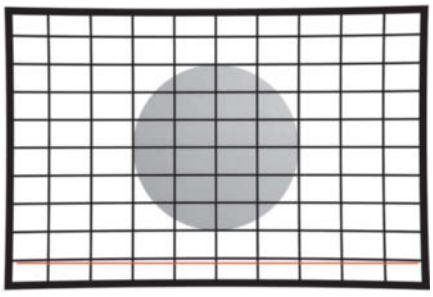
This issue's free DVD includes all of our test images and a high-resolution version of the test grid for you to print. In addition to shots of the test grid, the test material includes corrected versions of everyday subjects and illustrates that geometric perfection doesn't necessarily improve the overall effect of an image. The test images are also available for download at www.scanguru.info/en



This is the grid that we used to conduct our test. The various programs were set the task of correcting any distortion present in the test images. The white border serves as a crop margin.



Our fixed focal length Nikon 50mm f/1.8 produced no visible distortion. We used this as our reference shot for all subsequent tests. The red line served as a straight-line comparison.



The Nikon 18-200mm AF-S DX zoom produced obvious pincushion distortion at its 50mm setting. The object of our test was to find software that is capable of reliably correcting this type of error.

Software Test: Dedicated Tools

Many programs promise to eliminate lens distortion. We tested a range of dedicated tools that use individual lens profiles to achieve this. All the other programs we looked at are reviewed in the quick test table on page 34.

An initial look at the world of distortion correction software brings an extremely wide range of tools to light, although closer inspection reveals many of these to be legacyware that is of no real use in the current digital photographic environment. There are a number of reasons not to use various tools – such as *LensDoc*, *ImageIron*, *Elcovision* or the Rosenman plug-ins – as part of your active photo workflow. You can review the results we achieved using these and other tools in the Quick Test table on page 34.

Our in-depth test covers six programs that passed our quick test with flying colors. All of these tools are designed for application after RAW conversion, so we used TIFF source images rather than RAW image files for our test.

LensFix

LensFix, by Kekus Digital, is the second Mac-only tool in our test. The program cannot be used to create lens profiles, and the ones included with it come largely from the *PTLens* database. The package only includes profiles for camera manufacturers' lenses. The trial version of the software works for 15 days and embeds a watermark in processed images. The full version costs US$30.

LensFix offers some individual settings for correcting perspective errors and, in contrast to *PTLens,* uses image metadata to automatically assign an appropriate profile to an image.

Our test version of the program produced a blurred preview image every time we made any adjustments to our image settings. This bug doesn't actually affect the image data, but is nevertheless an unacceptable hindrance in an image processing tool.

The quality of the corrections and the resampled image data the program delivered was comparable to that produced by *PTLens*. The only major difference between the two programs is that *LensFix* leaves any distorted edges in place after correction, whereas *PTLens* colors them black or crops them.

The limitations mentioned above combined with the fact that *PTLens* can be also used with Windows makes *LensFix* a less attractive option. The program's plus points include full metadata usage (for TIFF files too) and RAW viewing capability (if appropriate drivers are installed).

The Photoshop Lens Correction Filter

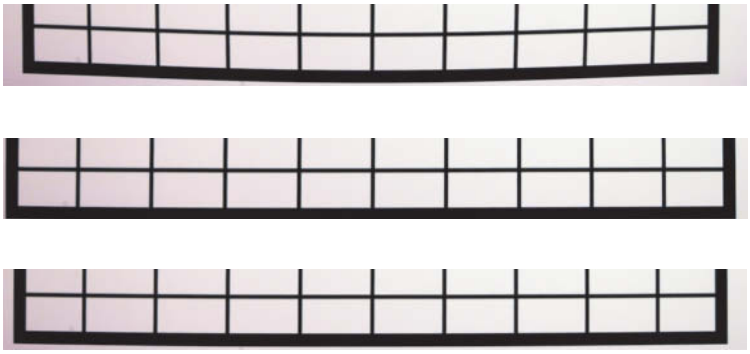
Photoshop CS5 and *Lightroom 3* both address the subject of optical distortion with renewed vigor in the guise of the latest version of *Adobe Camera Raw (ACR)* and the Lens Correction filter. The filter is only really designed for use with the JPEG or TIFF images that *Photoshop* can open natively, whereas *ACR* is capable of processing RAW image data too. There are more details on the results produced by *ACR* in the RAW converters section at the end of this article, which also takes a detailed look at the Lens Correction filter.

It is, of course, possible to convert RAW files to JPEG or TIFF using *ACR* and then apply the Lens Correction filter. However, *ACR* has its own built-in Lens Corrections tools, and correcting RAW image data is always preferable to adjusting JPEG or TIFF files.

Adobe maintains two lens profile databa es: one for use with JPEG and TIFF images and the other for processing RAW data in *ACR* and *Lightroom*. By the way, *Lightroom* can also process JPEG and TIFF images, and random checks showed that it delivers identical results to the *Photoshop* Lens Correction filter for these types of images. Remember, different profiles can produce different results when applied to a single image, depending on whether you are editing a RAW or a JPEG/TIFF version of the file.

In our test, the filter was only able to recognize metadata for JPEG files. With TIFF files, it only recognized the focal length data and all other attributes had to be entered manually. The filter allows you to assign camera and lens models separately, which turned out to be necessary, as the Nikon DX camera setting only offers a choice of the D300s or the D90.

When you select a lens, the filter only displays the appropriate (or next most appropriate) data values, which is great if your image file contains lens metadata, but can be annoying if it doesn't. If you use a zoom lens to



Once corrections have been applied, some tools perform significant cropping to ensure that the resulting image remains rectangular. For example, Adobe's Lens Correction tool crops a fair portion of the test chart outside of the black frame (from top to bottom: original, Adobe Lens Correction, *PTLens*).

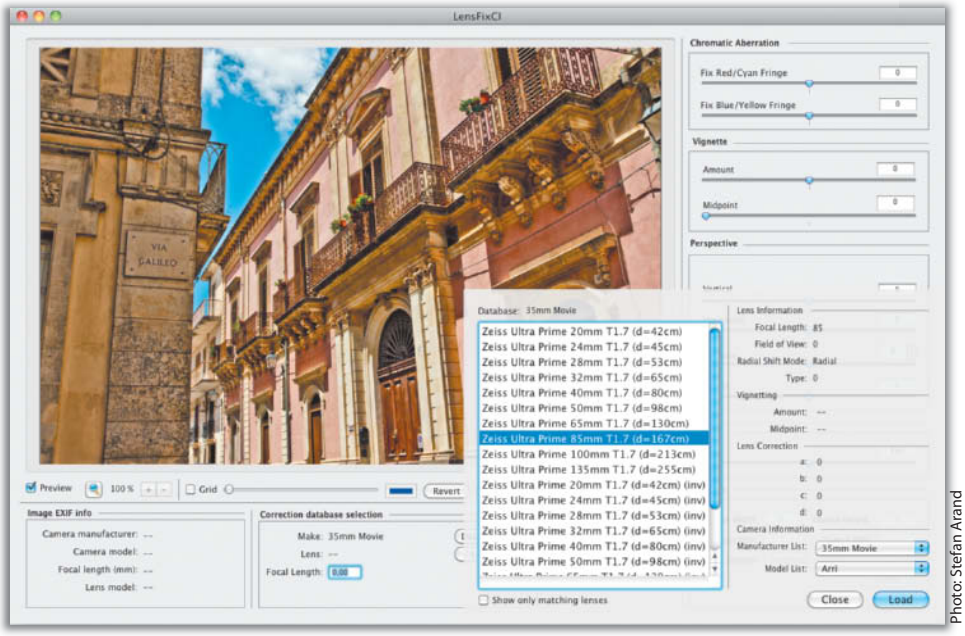


Photo: Stefan Arand

LensFix **doesn't have a lens database of its own and instead uses profiles provided by** ***PTLens*****. The range of included profiles even covers exotic devices such as Arri 35mm movie cameras, and the results it produces are just as good as those produced by** ***PTLens*****.**

shoot your image, and it contains no focal length metadata, you can select a focal length bracket but not a precise value. In practice, in spite of the existence of an appropriate profile, this meant that we were unable to correct an image taken using a12-24mm Sigma lens because we couldn't explicitly select a 12mm setting.

The user interface also contains some anomalies. For example, for images shot using a Sigma lens and a Canon camera, we had to select "Sigma" for our camera make and "All" for our lens model to get the appropriate list of lenses to pop up. Assigning a profile is much easier if an image does contain focal length metadata. The filter offers a wide range of profiles for Sigma, Nikon and Canon lenses, but does not include other popular third-party manufacturers, such as Tokina or Tamron. The RAW lens profiles accessible via *ACR* and *Lightroom* include profiles for a broader range of third-party lenses.

Missing profiles can often be found on the Internet and the free Adobe *Lens Profile Creator* allows you to create your own and make them available to the online community via the *Lens Profile Downloader* function. The Community functionality is still having teething troubles, but is nevertheless a welcome sign that Adobe is increasingly involving its users in the active development of its products. Even if it is currently still at the development stage, the Community is sure to become a favorite port of call for vintage lens enthusiasts.

The filter produced slightly better results than *PTLens*, while the RAW processing options produced markedly better results. The filter's effects were not quite as convincing when applied to the strong barrel distortion produced by our test lens at focal lengths

Photo: Stefan Arand

The Adobe Lens Correction module recognizes a wide range of lenses from camera manufacturers and third-party suppliers. If an image contains no focal length metadata, it is impossible to select a specific focal length for zoom lenses. We liked the ***Photoshop*** **Lens Correction filter, but** ***Adobe Camera Raw*** **and** ***Lightroom*** **produce even better results due to the use of RAW data and the superior RAW-based lens profiles.**

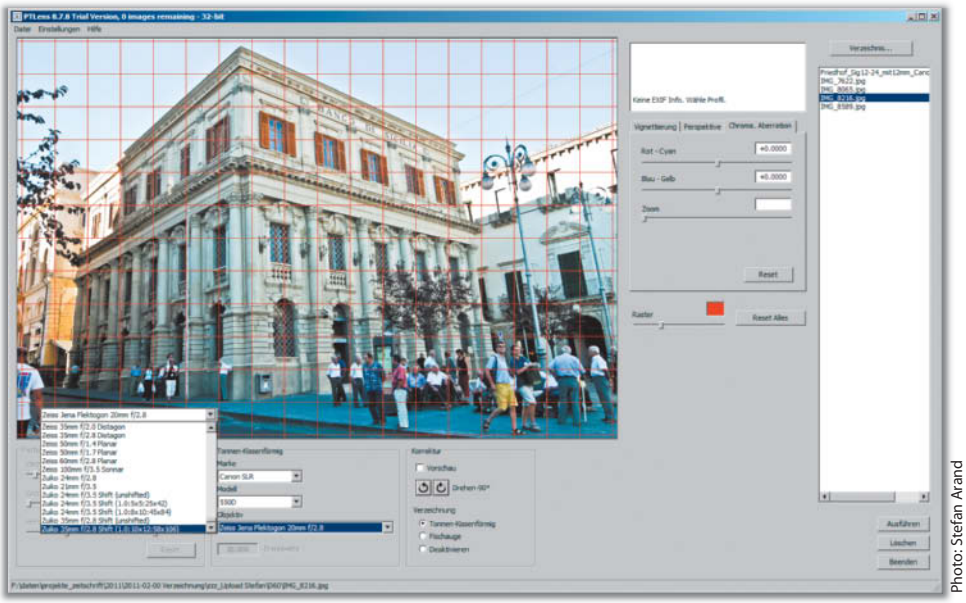


Photo: Stefan Arand

***PTLens* has a huge database of lens profiles that includes a number of tilt/shift and other rare lenses. This great value tool is user-friendly and delivers excellent results.**

below 24 mm. At longer focal lengths where there is less distortion to correct, the results were visibly improved. Adobe, too, is subject to image quality loss during interpolation, but the tools generally produce better results than *PTLens*.

The Adobe Lens correction filter is squarely aimed at photographers who want to perform their image processing in Photoshop. the program's internal workflow simply hands the image being processed over to the main program and back again. If you want to process large numbers of images, *Lightroom* offers more efficient handling while applying the same lens profiles as the Lens Correction filter to JPEG and TIFF files.

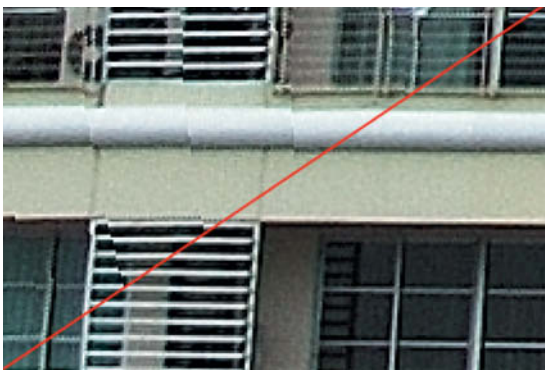
click of a single button, although this feature only works reliably for images shot using a single camera/lens combination. Always check the results of batch processes – if the program's automatic metadata detection doesn't work for any reason, it simply applies the last active profile whether or not it is appropriate to the selected images. We observed the same behavior when batch processing folders that contained mixed JPEG and TIFF files.

Unfortunately the program doesn't draw the user's attention to potential errors, and you have to check whether it is using the correct (or any) metadata by looking in the dropdown menus. It only detected the

allows the user access to all metatdata fields if its automatic detection functionality fails. The broad range of lens profiles included with the program includes a number of exotic and unusual lenses.

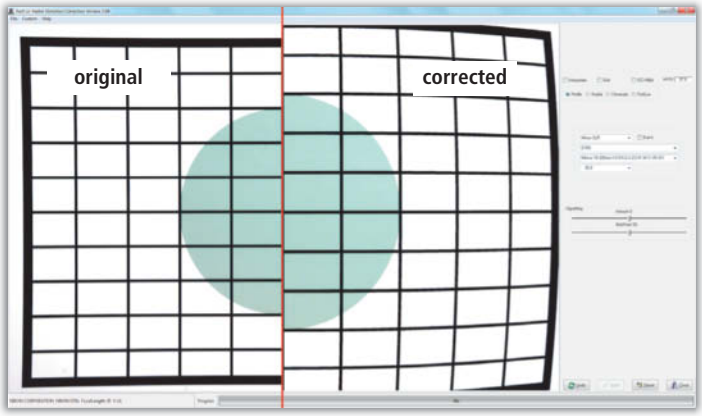
PTLens generally produces very good results. It couldn't completely eliminate the distortion in our 18mm test image, but neither could the much more expensive Nikon *Capture NX 2*. Beyond the 24mm setting the results are comparable with but not quite as good as the results produced by the Adobe and *DxO* RAW converters. A reduction in sharpness caused by interpolation is only visible in PTLens results at 100% magnification.

***RadCor* default result**



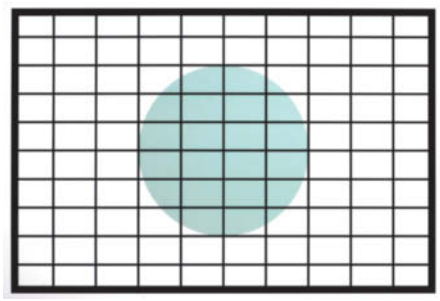
***PTLens* default result**

***RadCor*'s default settings do not interpolate the corrected image, which leads to the presence of strong artifacts. Our favorite *PTLens* automatically activates interpolation during processing.**

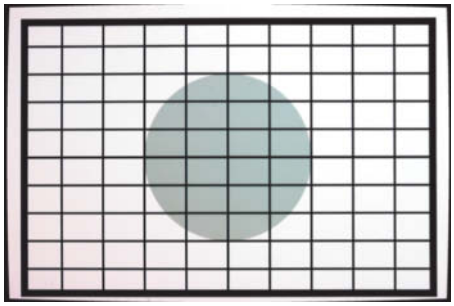


***S*urprise! This illustration shows the original alongside an image corrected using *RadCor*. Here, the program applied the wrong profile and produced correspondingly strange results.**

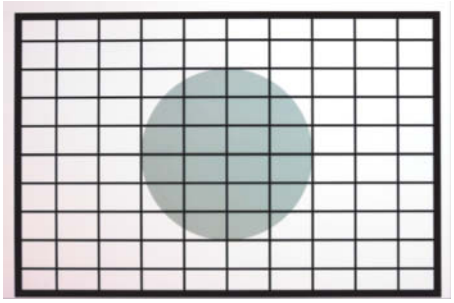
Fixed focal length reference image



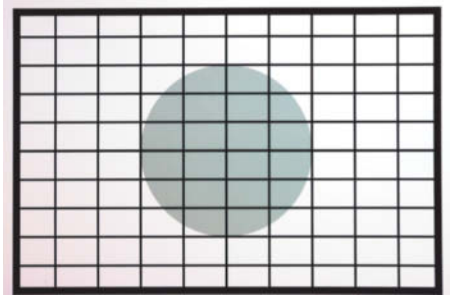
PTLens



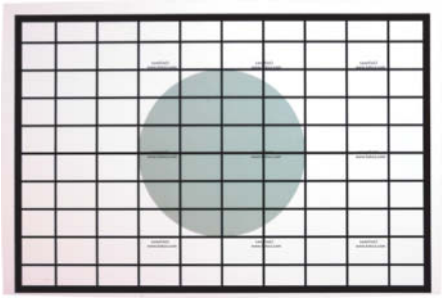
RadCor



Adobe Lens Correction



LensFix



Comparing corrected images shot using the 50mm setting on our 18-200mm Nikkor test zoom with our reference image shot using a 50mm f/1.8D Nikkor. The quality of the reference image is superior to all of the corrected images. Distortion correction is without doubt an extremely useful tool, but a low-distortion prime lens is always the better option if you have the choice.

The advantages of the program listed at the beginning of this section have made *PTLens* a firm favorite with many digital photographers. Although the program is hard-wired to produce output in the same format as its input material, it nevertheless produces excellent JPEG results with a minimum of fuss. The lack of focal length recognition for TIFF images is not ideal. If you prefer to shoot in a RAW format, you will probably be able to find more accurate and up-to-date profiles in your RAW converter package of choice. The downside of using RAW converters is that they generally have access to fewer lens profiles and are much more expensive than *PTLens*.

RadCor

RadCor was originally developed at the Department of Archaeology at the University of Cologne/Bonn in Germany and has sadly not been updated since 2007. However, its freeware status and its use of the *PTLens* profile database make it worthy of inclusion in our test.

The user interface has some quite severe drawbacks and only works in full screen mode. Handling is quite tricky but, once you have got used to it, the program can be used to produce acceptable results. The lens

Test: Dedicated Distortion Correction Tools

Program	LensFix 4.7	Photoshop CS5 (12.03)	PTLens 8.7.8	RadCor 2.0.4
Manufacturer	Kekus	Adobe	ePaperPress	Bonn Archaeological Software Package (BASP)
URL	www.kekus.com	www.adobe.de	http://epaperpress.com/ptlens	www.uni-koeln.de/~al001/radcor.html
Tested as	Mac standalone	Windows standalone	Windows standalone	Windows standalone
Lens profiles included / user-defined	yes / no	yes / yes	yes / no	yes / yes
JPEG: view / save	yes / yes	yes / yes	yes / yes	yes / yes
TIFF (8-bit): view / save	yes / yes	yes / yes	yes / yes	yes / yes
TIFF (16-bit): view / save	yes / no	yes / yes	yes / yes	yes / no
NEF: view / save	yes / no	no / no	no / no	yes / no
JPEG automatic metadata detection: Camera / Lens / Focal Length	yes / yes / yes	yes / yes / yes	yes / yes / yes	yes / no / yes
TIFF automatic metadata detection: Camera / Lens / Focal Length	yes / yes / yes	no / no / yes	yes / no / yes	yes / no / yes
NEF automatic metadata detection: Camera / Lens / Focal Length	yes / yes / yes	n/a	n/a	yes / no / yes
Mac OS X	Standalone, Photoshop plug-in,external editor for Lightroom and Aperture	Standalone	Standalone, external editor for Lightroom, Aperture and iPhoto, Photoshopand Aperture plug-in	–
Windows	–	Standalone	Standalone, external Lightroom editor, PS plug-in	Standalone
Linux	–	–	–	–
Price	US$30 (Trial version with 15-day limit and watermarks)	US$700 (30-day trial version availble)	US$25 (Trial version processes a maximum of 10 images)	Freeware

Quick Test: Legacy Distortion Correction Tools[1]

Program	DigitalPhotoShifter	Distortion Matrix, Distortion Remove	Elcovision Lens Distortion Correction	GIMP	ImageIron	Lens Corrector Pro	Lens Distortion Corrector	LensDoc
Manufacturer/Author	Frank Heinig	Stoske und Bertling	PMS (Photo Mess Systeme AG)	GIMP	NaturalGrafix	Richard Rosenman	Richard Rosenman	Andromeda
URL	www.deraltenburger.de	www.stoske.de/digicam/	www.elcovision.com	www.gimp.org	www.naturalgrafix.com	richardrosenman.com	richardrosenman.com	www.andromeda.com
Version	10.15.0	0.8	1.0	2.6.11	2.10.0	1.2	1.2	3.1
Tested as	Windows standalone	Windows standalone	Windows standalone	Windows standalone	Windows standalone	Photoshop plug-in	Photoshop plug-in	Photoshop plug-in
Good	Generic lens corrections and a range of manual distortion adjustments	Freeware for Mac and Windows, allows creation of custom lens profiles	Free	Freeware, dedicated filter lens profiles, generic corrections possible, perspective correction possible with EZ Perspective plug-in	In-depth documentation for creating custom lens profiles, reference charts available	Wide range of settings	Free	Includes genericand specific lens profiles, automatic focal length detection
Not so good	Demo version only saves BMP files, no lens profiles included	No lens profiles included	No updates since 2004, doesn't run in Window 7 (not even in compatibility mode)	No lens profiles included, very small previews	Onlya few lens profiles included, no updates since 2007	No lens profiles included, wide range of generic correction options, tiny preview window virtually useless, trial version provides no file output	No 16-bit file support, tiny program window and preview image, no lens profiles included, few features	Poor GUI, produces error messags with newer versions of Photoshop, trial version provides no file output, assigns detected focal length to random prfile with same focal length, poor preview, no updates since 2007
Conclusion	Interesting tool for performing generic distortion correction but too expensive for what's on offer	Good background study information on distortion correction, software aimed more at experimental rather real-world usage	–	Small preview window makes distortion and results difficult to judge, of limited use	Interesting tool, but no longer up to date	Many correction options, but poor preview functionality makes it difficult to recommend	Plug-in interface practically unusable	Out of date, limited-functionality, much too expensive for what's on offer
Price (approx.)	US$50 (demo version offers only BMP output)	Freeware	Freeware	Freeware	US$100 (30-day trial version available)	US$30 (Trial version without file output)	Freeware	US$119 (Trial version without file output)

[1] These tools are either outdated or so tricky to handle that we only gave them a quick look for completeness' sake

profile database included with the software is the same as the one used by *PTLens*, although this version hasn't been updated since April 2006. If you want access to the latest *PTLens* database, you will have to spend US$30 on a current copy of the program.

RadCor detects camera model and focal length metadata automatically, but the user has to add specific lens data manually.

If exactly the right profile isn't available, you can always try your luck with profiles for other models from the same camera manufacturer that have the same sensor format. In addition to its lens profiles, the program also includes some generic correction filters of its own – for example, for use with fisheye lenses. The program allows the user to create custom profiles using its built-in filters, but doesn't support the use of reference charts. You simply have to experiment with the generic filters until you find the right settings. We even managed to get it to open our NEF test images files by installing the NEF codec first. *RadCor* offers a good range of output formats, but this unfortunately doesn't include 16-bit TIFF. The program detects zoom focal lengths automatically and also allows you to enter specific focal lengths manually – the correction effect adjusts automatically to the value entered.

A word of warning: *RadCor* sometimes behaves like a kind of data-destroyer if used with its default settings. In this case, it simply undistorts the image without interpolating it at all, which produces distinct row shift artifacts and unusable results. If you manually activate the program's interpolation functionality, the artifacts disappear, but the resulting image is visibly less sharp. This type of image quality loss is an integral part of distortion correction processes, but is especially prevalent when using *RadCor*.

The corrections themselves sometimes worked perfectly (for example, for our 50mm test image) and sometimes produced completely useless results (for example, for our 35mm image). Basically, the program is a great free solution for experimenting with, but is not suitable for use within an everyday photo workflow.

Dedicated Tool Conclusions:

In general , dedicated tools are more complicated to use than the correction functionality built into many RAW converters (see also the RAW converter test on the following pages).

Where these programs really score is for use with JPEG or TIFF image files. PTLens remains the best of the non-RAW tools we tested, although Adobe's Lens Corrections filter provides a fresh approach to this type of correction task. The drawback with using Adobe is that you have to accept *Photoshop*'s inherent design weaknesses in order to progress. The latest version of *Lightroom* (see also the article in Issue 4 of *c't Digital Photography*) is a powerful alternative for making technical corrections to your images.

In spite of the advantages offered by the Community function and other gimmicks, *Photoshop*'s lack of freely assignable focal lengths means that the user cannot assign profiles to any image. The relatively primitive and much cheaper *PTLens* not only has a larger profile database, but also allows the user to assign profiles freely to images, even if the appropriate metadata isn't present or detectable. The downside of the cheaper program is its relatively elementary profile creation functionality. However, apart from specialist applications such as photographing high-precision test patterns, *PTLens* produces great results in a wide range of situations.

Software Test: Distortion Correction using RAW Converters

RAW converters nowadays include an increasing number of image correction tools and functions. This section takes a look at the distortion correction functionality built into some of today's most popular RAW conversion software packages.

Today's RAW converters are truly multi-talented and include a wide range of features designed to help you produce high-quality photographic output. Software manufacturers are putting a lot of effort into expanding the range of tools and functionalities in their products, and distortion correction is now beginning to hit the mainstream. Programs that don't yet have this type of functionality include *Lightzone*, Google *Picasa* and Apple's *Aperture*. *Raw Therapee* and *Silkypix Developer Studio* offer generic distortion correction filters, but do not include profile-based functionality, which is why we didn't include them in our test. *Capture One* is capable of applying lens profiles, but only actually includes a very few designed for use with medium format equipment.

Camera and lens manufacturers such as Canon, Nikon, Olympus and Sony all offer their own proprietary RAW converters with built-in distortion correction functions. These programs only include profiles for each manufacturer's own lenses, making it difficult to compare them objectively. We nevertheless tested Nikon's *Capture NX 2* to provide some insight into the way camera manufacturers approach building RAW processing software. We chose to review the Nikon product because it is the only proprietary program that actually costs money and therefore aims to compete with other commercial products from Adobe and others.

Bibble

Bibble has a built-in lens correction tool and is the only one of our test candidates that is available in Windows, Mac and Linux versions. In contrast to Nikon's apparent secrecy policy, the program's manufacturer publishes a current list of compatible lenses on the Web. However, we found that the software itself is more up to date than the published list and we recommend that you install a trial version of the software to check whether your lens really is supported. If you still can't find the profile you are looking for, you can always send a couple of photos of geometric objects shot with your chosen lens to the program's developers, who will then create a profile for inclusion in the program.

Bibble detects RAW image metadata extremely efficiently, and automatically assigns camera, lens and focal length data to image files. Lens data has to be manually selected for JPEG and TIFF files, which also allows you to find and use the right profile even if crucial metadata is missing and prevents the program from automatically selecting an inappropriate profile. The program also allows you to select focal lengths manually, which helps you to get a feel for the way distortion changes in the course of large zoom ranges.

Bibble also has its own generic distortion filter that uses three sliders to correct images that have no appropriate lens profile of their own. The adjustments are made via tiny "+" and "–" buttons that are actually quite tricky to hit with the cursor! The filter tab in the program window displays the correction values being applied, whether these are automatically generated by a profile or manually entered.

Bibble corrected our test images passably in the range between 18 and 35mm and generally coped better with the slight pincushion distortion at longer focal lengths than it did with the distinct barrel distortion present at the shorter end of the range. Overall, *Bibble* produced results that were comparable with Nikon's, but not as good as those produced by Adobe or *DxO*. The program did tend to produce a loss of image quality during interpolation that was particularly obvious when comparing "before" and "after" versions of images at 100% magnification. In this respect, *Bibble* is comparable with Adobe, but is not as good as *DxO* or *Capture NX 2*. The program produced good overall results, but was not quite as accurate as some of the competition.

Camera Raw

The RAW converter included with *Photoshop* is called *Adobe Camera Raw* (or *ACR* for short) and is, in fact, a plug-in that the program uses to open, process and hand over RAW files. Since the release of *Photoshop CS5*, *ACR* includes a powerful built-in distortion correction tool.

The combination of ACR for use with RAW image data and the Lens Correction filter for use with TIFF and JPEG images (see also our test starting on page 30) gives Adobe users everything they need to combat optical distortion. Although still in prerelease at the time of writing, Adobe is promising to soon make the Lens Profile Creator technology a standard feature of the entire Adobe family of applications.

The program had no problems assigning the metadata stored in our NEF test files. All you have to do is activate profile-based corrections and the program does everything else automatically. It is also possible to assign lens profiles manually, which can also be necessary if automatic metadata detection fails. Unlike the Lens Correction filter, the *ACR* distortion correction feature doesn't allow the user to manually select a camera model or zoom setting. The automatic nature of the *ACR* tool prevents the use of inappropriate profiles, but limits the extent to which the user's curiosity can be satisfied. If you try to apply a profile with an obviously incorrect focal length, the tool simply refuses to function.

The results produced for our 50mm test image and all other longer focal lengths were virtually identical to those produced by *Capture NX 2*, although Adobe coped better than Nikon with strong barrel distortion. Overall, the Adobe tools were effective throughout the entire zoom range

ACR and *Lightroom* use the same set of lens profiles to perform corrections and consequently produce very similar results. However, the *Photoshop* Lens Correction filter has a weaker overall effect and produces results with visible residual distortion. This discrepancy is due to the differences between the profiles used to correct RAW or JPEG/TIFF images.

The downside of Adobe's efficient RAW correction tools is a degree of visible image quality loss due to interpolation, and the results are obviously less sharp than Nikon's at 100% magnification. The same effect is also present in the results we produced using the Adobe Lens Correction filter.

Adobe's strengths lie in its effective distortion correction and its wide range of lens

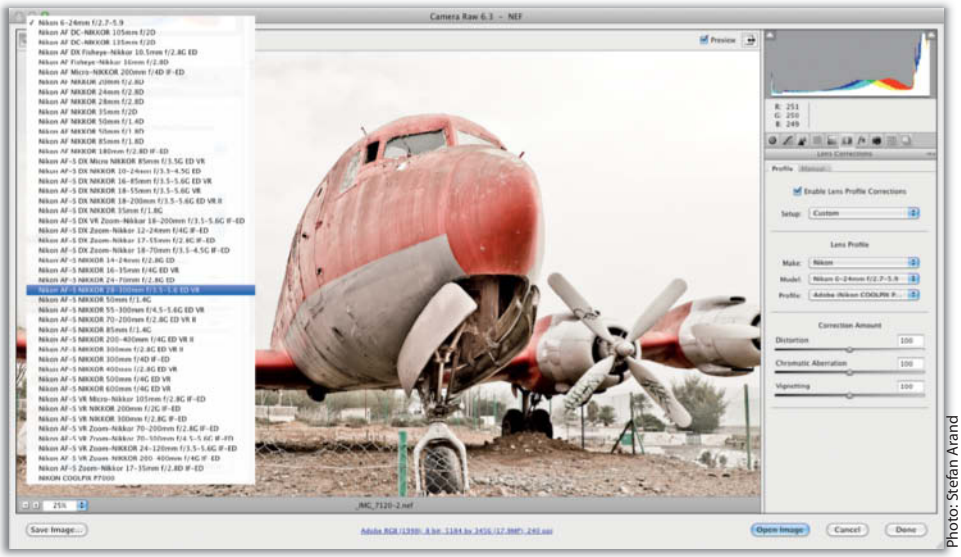


Photo: Stefan Arand

The *Adobe Camera Raw* module included with *Photoshop* includes a wide range of lens profiles for models from various manufacturers. The program cannot automatically read metadata for images shot using legacy lenses like the f/2.8 80-200mm (non-D) Nikkor used here, but the user can nevertheless select an appropriate profile manually.

profiles, while overall image quality still has room for improvement.

Capture NX 2

Nikon has built two separate distortion correction tools into its RAW conversion software in a rather illogical way. The tool that is easiest to find is located in the program's menu system under Adjust > Correct > Distortion Control. This tool is, however, a simple generic pincushion/barrel distortion correction filter with no lens-specific functionality, and always opens images with the same default settings, regardless of image type or the nature of any embedded metadata. These settings do correct distortion to a certain degree, but don't provide the kind of targeted correction functionality that we were looking for, especially in the case of our test images. The second, much more useful, tool is called Auto Distortion and can be found hidden away under the Camera & Lens Corrections heading in the Develop section of the Edit List palette. The program's default settings leave the tool deactivated but, once you have activated it, it automatically assigns the correct profile to the current image.

This difference obviously escaped the attention of the Nikon developers, and this

Nikon *Capture NX 2* includes the powerful Auto Distortion correction tool that is not even documented in the user manual. The generic Distortion Control tool produces only sub-standard results.

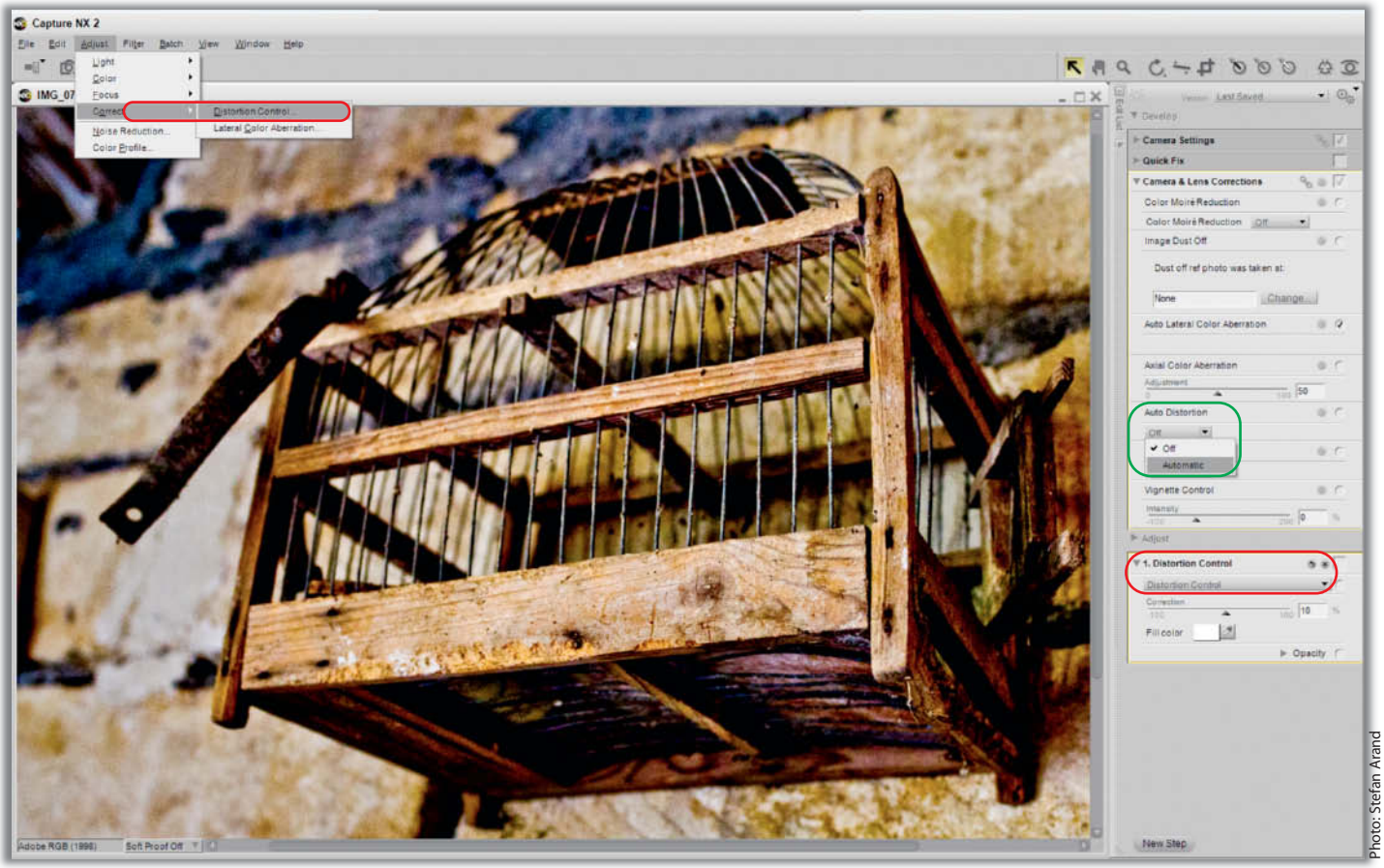
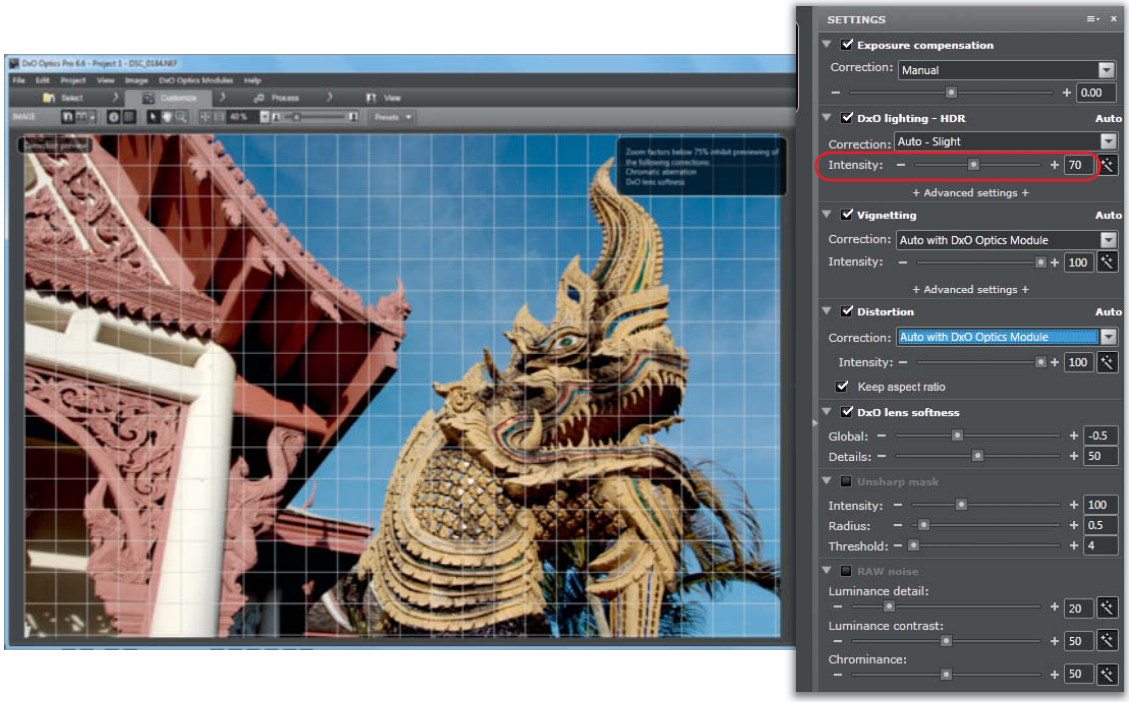


Photo: Stefan Arand



***DxO* allows the user to regulate the strength of the applied correction. The grid overlay in the preview window is a fantastic aid for making precise distortion corrections.**

superior tool is not even mentioned in the program's user manual. Additionally, the tool's control button is only visible if the currently active image includes lens metadata that the software can identify.

Capture NX 2 doesn't support all Nikkor lenses (our 80-200mm non-D f/2.8, for example), although it does recognize the only slightly younger 24-50mm f/3.3-4.5D. As Nikon doesn't publish its list of lens profiles, the only way to find out whether your particular lens in supported is to load an image taken using it and check whether the Auto Distortion option is grayed out. It is unlikely that Nikon will support other manufacturers' lenses any time soon.

Once you have applied Auto distortion to a JPEG or TIFF image, the option grays out, making it impossible to unintentionally apply multiple corrections.

Applying the tool is a simple matter of switching it on, and there are no user-adjustable settings or profiles for you to play with.

Capture NX 2 corrected our 50mm test image satisfactorily, but left a lot of residual distortion untouched when correcting the 18mm image. *DxO* and the Adobe RAW tools use more rigorous correction algorithms and produce better results when correcting strong barrel distortion. However, *Capture NX 2* almost completely eliminated the pincushion distortion that appears from the 35mm setting onward.

Sharpness errors are negligible due to the moderate nature of the Nikon filters. The more you correct, the more your software has to interpolate the results and the more likely you are to experience a loss of sharpness in the results. Nikon's "soft" approach to distortion correction makes it possible to simply leave the filter permanently switched on for images shot using problem lenses like our 18-200mm zoom.

Capture NX 2's Auto Distortion tool is great for Nikon photographers who use reasonably current lenses, but we would still like to see better barrel distortion correction and more options for user intervention during the correction process.

DxO

The *DxO* RAW converter is a special case in our test series, as it doesn't use conventional lens profiles, but instead uses its own proprietary technology to create individual correction modules for specific camera/lens combinations. This approach can be a blessing or a curse, depending on the use you want to put it to. If you own just one or two camera bodies and a modest range of lenses, you only have to download and install a small number of modules to give yourself a powerful and flexible automatic distortion correction environment. The more cameras and lenses you use the more complex the exercise becomes, and the size of the modules you will have to download quickly runs into gigabytes.

If you work with exotic combinations of cheap cameras and high-end lenses (or vice versa), you simply have to hope that your particular setup is included in one of the regular updates that the manufacturer publishes.

The module creation process is a closely guarded secret and the program prevents the user from manually assigning them, even if you want to use a module that is based on a different camera model with a same-sized sensor. We assume that the distortion data for such profiles must be identical, but it is simply impossible to check. There is no useful compatibility information on the *DxO* website, but it is very easy to check via the program's interface once the software is installed.

Once you have installed the right module, *DxO* is simple to use. The program detected the metadata in our JPEG and NEF test images and automatically assigned the appropriate profile. This functionality does not work for TIFF image files, and the program offers the user a generic correction filter instead. A unique and very useful feature here is the Intensity slider that allows you to adjust the strength of the correction you apply – a unique feature among the programs we tested.

Correction was extremely good throughout the entire zoom range, even at "problem" focal lengths at the extreme ends of the scale, and the results surpassed even those produced by the Adobe tools. Interpolation errors remained on the verge of negligibility, even at 100% magnification.

All in all, *DxO* produced the best results of all the programs we tested. Its lens-specific adjustment functionality is more powerful than most and the Intensity slider is a real bonus.

All manufacturers of this type of software have their own compatibility problems and *DxO* is unfortunately no exception. We would like to see functionality that allows the user

The Before and After views in the *Lightroom* preview window are a great tool for judging the potential results of your adjustments. This approach helps you to judge not only the degree of distortion correction, but also the frequency of artifacts that interpolation will produce in the finished image.

to create custom profiles, and the use of unique camera/lens profiles inevitably leads to gaps in the available range.

Lightroom

Lightroom belongs officially to the *Photoshop* family of products, although most users only ever use the word "Photoshop" to describe the image processing program of yore. *Lightroom*, as a relatively young standalone RAW converter, is a completely different beast, and offers similarly comprehensive conversion and correction functionality to the *Adobe Camera Raw* (*ACR*) module included with *Photoshop*. If you are not intent on performing high-end creative tasks, *Lightroom* is perfectly adequate for processing JPEG and TIFF images too. However, this test concentrates on the program's distortion correction capabilities in a RAW context.

Lightroom includes the same wide range of built-in profiles as *Photoshop* and automatically detected the metadata for our JPEG, TIFF and NEF images, assigning the correct profile automatically when an image was opened. The functionality and quality of the results were identical to those we found in *ACR*, so we will not go into any further detail here.

However, *Lightroom* is simpler and more intuitive to use than *ACR*. *Photoshop* corrects image data irreversibly and hands files back and forth between the main program and the *ACR* module (or, in the case of JPEG/TIFF files, the Lens Correction filter) several times during the correction process. In contrast, *Lightroom* is an integrated workflow tool that offers non-destructive adjustments that can be undone and redone at any stage in the correction process. If you need to regularly correct distortion in large numbers of images (whether JPEG/TIFF or RAW), we recommend that you use *Lightroom* in preference to *Photoshop*. The quality of the available profiles makes processing in RAW preferable to JPEG/TIFF and we recommend that you only correct JPEG and TIFF images for publication if you have no alternative.

Test: Correcting Distortion using RAW Converters

Program	Adobe Lightroom 3.3	Adobe Camera Raw 6.3	Bibble 5.2.0	DxO Optics Pro 6.5.3	Capture NX 2 2.2.6
Manufacturer	Adobe	Adobe	Bibble Labs	DxO Labs	Nikon
URL	www.adobe.de	www.adobe.de	http: / / bibblelabs.com	www.dxo.com	www.nikon.de
Tested as	Windows standalone	Photoshop plug-in	Windows standalone	Windows standalone	Windows standalone
Lens profiles: built-in / custom	yes / yes	yes / yes	yes / no	yes / no	yes / no
JPEG: view / save	yes / yes	no / no	yes / yes	yes / yes	yes / yes
TIFF (8-bit): view / save	yes / yes	no / no	yes / yes	yes / yes	yes / yes
TIFF (16-bit): view / save	yes / yes	no / no	yes / yes	yes / yes	yes / yes
NEF: view / save	yes / no	yes / no	yes / no	yes / no	yes / yes
JPEG automatic metadata detection: Camera / Lens / Focal Length	yes / yes / yes	n/a	yes / no / yes	yes / yes / yes	yes / yes / yes
TIFF automatic metadata detection: Camera / Lens / Focal Length	yes / yes / yes	n/a	yes / no / yes	no / no / no	yes / yes / yes
NEF automatic metadata detection: Camera / Lens / Focal Length	yes / yes / yes	yes / yes / yes	yes / yes / yes	yes / yes / yes	yes / yes / yes
Mac OS X	Standalone	Photoshop plug-in	Standalone	Standalone, or as external editor in Lightroom	Standalone
Windows	Standalone	Photoshop plug-in	Standalone	Standalone, or as external editor in Lightroom	Standalone
Linux	–	–	Standalone	–	–
Price	US$300 (or 30-day trial)	US$700 (as part of Photoshop)	US$100-200 (or 14-day trial)	US$130-240 (or 31-day trial)	US$180 (or 60-day trial)

Conclusions

Distortion correction is often necessary but always involves a loss of image quality. Correction software has to stretch and/or compress an image to counteract distortion effects, and our tests show that the interpolation processes this involves reduce sharpness in the resulting images. This effect was less prevalent in the better tools we tested, but you will always be able to find interpolation artifacts in corrected images if you look hard enough. In most cases, images viewed at normal magnification and normal distances don't contain visible artifacts and you can compensate for them if necessary using an unsharp mask filter. But remember, these types of artifact are simply part and parcel of the distortion correction process.

Once you are familiar with the potential drawbacks, you can produce good results for most images that contain slight to medium distortion – the slight discrepancies between our 50mm reference image and our corrected test images bear witness to this. The most obvious difference was the low resolution of our test zoom, which was further reduced by the correction process. The reduced area of the corrected images is another obvious and unavoidable factor. The dimensions of our test images (measured in pixels) were mostly identical to those of the originals, but only because the software automatically enlarged the cropped results after processing.

The entire process becomes more complex for the more extreme distortion that our test zoom produced at settings below 24 mm. Current software is simply not sufficiently powerful to completely eliminate this type of distortion, and interpolation errors are rife.

Surprisingly, the quality and detail of the reference image used to profile a lens is not necessarily crucial to the quality of the results. *PTLens* and *Bibble* both managed to produce great results in a range of situations without relying on precision profiling techniques. In fact, Tom Niemann at *PTLens* has built up a database of lens profiles that is comprehensive enough to make even a software giant like Adobe quite envious.

From a photographer's point of view, the deciding factor is whether a profile can be smoothly integrated into the overall photo processing workflow. *PTLens*' cheap price and simplicity of use make it easy even for beginners to correct entire folders full of images in seconds. In contrast, *Photoshop* is much more expensive and a lot more complicated and time-consuming to use. A RAW converter will always be the tool of choice for advanced photographers. Automatically controlled correction processes require more computing power, but do not involve additional effort on the user's part.

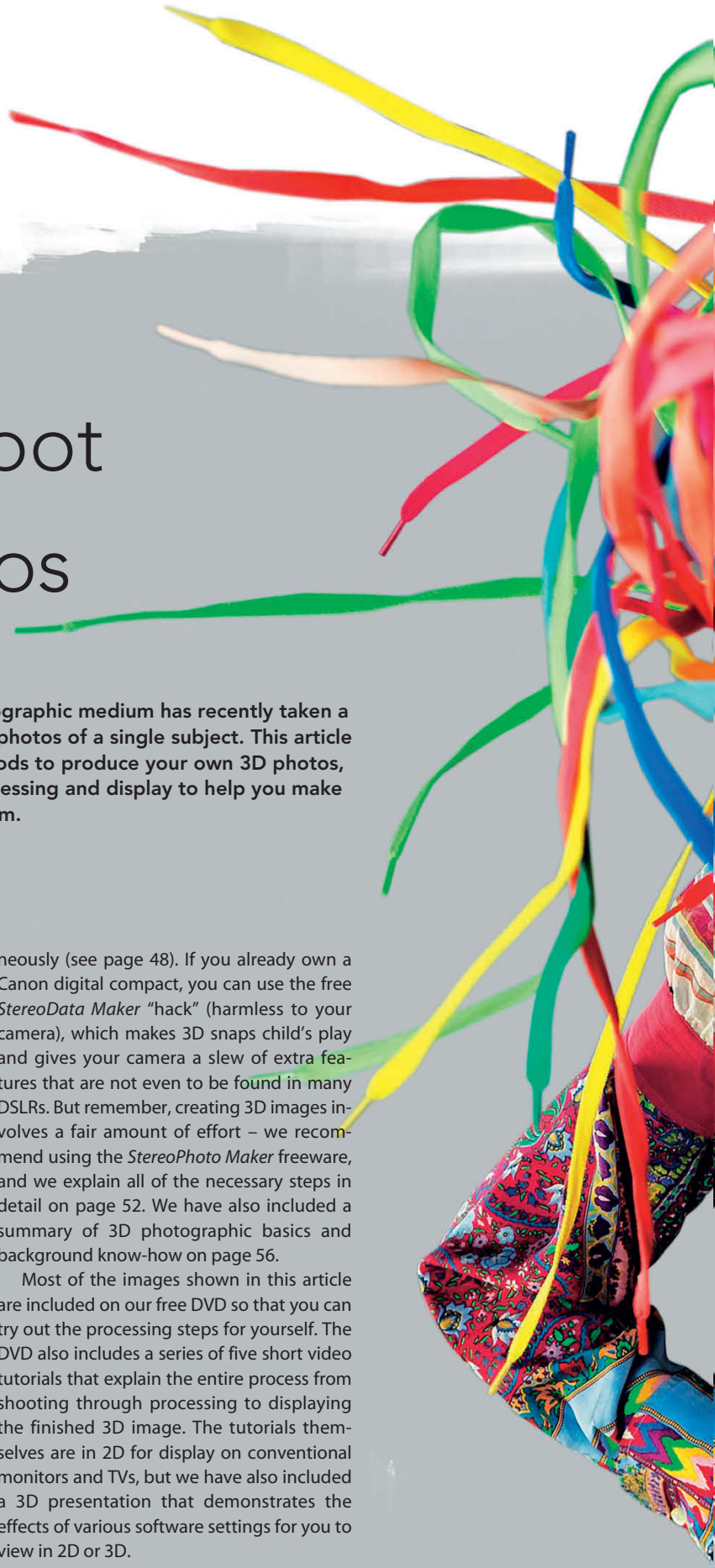
In general, distortion correction is a good thing. Our test showed that RAW converters produce the best results and of these, Adobe and *DxO* were definitely the best of the bunch. We recommend that you always shoot and process in RAW if you can, although JPEG is a usable format if you don't have the choice. The problems associated with metadata detection for TIFF files make it a less practical alternative.

Dedicated tools like *PTLens* come to the fore when it comes to processing JPEG images. *PTLens* is not particularly pretty to look at, has limited functionality and only limited processing power, but is cheap, easy to use, produces good results and includes the best profile database of all the programs we tested. In fact the profile database makes this piece of anachronistic code a program that is still the best of its kind in a number of situations. Adobe, with its online community of profile creators, is the only other manufacturer with the potential to equal this achievement. (jr) c't

Not every distorted image needs correcting. The lower image was corrected using *Lightroom* and certainly looks different from the original, but it is debatable whether it has actually been improved.

Ralph Altmann

How to Shoot 3D Photos



Traditionally two-dimensional, the photographic medium has recently taken a leap into the third dimension using two photos of a single subject. This article explains how to use cheap, simple methods to produce your own 3D photos, and gives you important tips on 3D processing and display to help you make the most of this new and exciting medium.

Our two eyes allow us to see in three dimensions, and the same principle applies to 3D (or "stereoscopic") photography. Using two separate images allows us to capture the spatial depth of a subject and reproduce it later. 3D source images have to be captured a certain distance apart (the distance between our eyes is a good starting point), and need to be displayed so that our left and right eyes see only the appropriate left or right image of the pair. Commercial manufacturers are still working hard to produce high-powered but user-friendly 3D display technology (see also the article on page 62), but it is already clear that 3D movies and photos are here to stay. While techniques for shooting and viewing 3D photos have been around for a long time, the latest boom in viewing technology presents photographers with a great opportunity to experiment with this simple but effective medium.

This article explains how to take stereoscopic shots of stationary objects using a single camera and how to take 3D snapshots of moving subjects using two cameras simultaneously (see page 48). If you already own a Canon digital compact, you can use the free *StereoData Maker* "hack" (harmless to your camera), which makes 3D snaps child's play and gives your camera a slew of extra features that are not even to be found in many DSLRs. But remember, creating 3D images involves a fair amount of effort – we recommend using the *StereoPhoto Maker* freeware, and we explain all of the necessary steps in detail on page 52. We have also included a summary of 3D photographic basics and background know-how on page 56.

Most of the images shown in this article are included on our free DVD so that you can try out the processing steps for yourself. The DVD also includes a series of five short video tutorials that explain the entire process from shooting through processing to displaying the finished 3D image. The tutorials themselves are in 2D for display on conventional monitors and TVs, but we have also included a 3D presentation that demonstrates the effects of various software settings for you to view in 2D or 3D.

In this article:

Shooting Stereoscopic Photos using a Single Camera

You don't need any extra gear to start taking your own 3D photos and, because you always have your eyes with you, you don't even need to carry a ruler!

Shooting stereoscopic photos with a normal camera isn't rocket science. If your camera has a viewfinder, all you have to do is take two photos of your subject – one looking through the viewfinder with your left eye and one with your right. And that's it – you already have two stereoscopic source images in the bag. We will explain how to process them later.

The Cha-Cha Method

The "cha-cha" technique requires a little practice, but can be used with any camera.

Once you are standing on firm ground, all you have to do is move your camera into position and shift your weight slightly to your right leg. Then release the shutter and shift your weight to your left leg to take a second photo. Make sure that your upper body and your camera only move sideways (not up and down) during the maneuver. The distance between the two shots will depend on how tall you are and how far apart you position your feet while shooting. The further apart they are, the smaller the distance will be. This flexibility allows you to adjust the base distance, or "stereo base" as it is known, to fit the situation at hand.

Both of these methods produce 3D source images with a time delay, making them less appropriate for 3D snapshots of moving subjects, but very suitable for spontaneous 3D shots of non-moving subjects.

3D Equipment

It is often easier to take precision 3D photos using a tripod and a purpose-built 3D mounting bracket. There is a wide range of brackets available in various sizes and for all budgets, and many can also be used as an aid to taking conventional macro photos too. Using a bracket enables you to shoot pairs of photos at a precisely reproducible distance and without altering the vertical position of the camera. A tripod-mounted bracket is indispensible for shots that involve long shutter speeds and for shooting stereoscopic macro images whose stereo base is measured in centimeters or even millimeters. In such cases, it is essential for the subject to remain absolutely still while you shift the camera.

Stereoscopic Landscapes

Even the longest support bracket won't be sufficiently large for shooting source images for 3D landscapes. The best way to support your camera for this type of image is to look for two points that are a fair distance apart but at the same height, such as two points on the guard rail of a look-out tower. Again, make sure that you don't allow too much time to elapse between your shots so that changes in lighting or cloud formations don't spoil the effect of the finished image. Remember to note a couple of significant details at the edges of the frame to help you find the right position for your camera at both locations. If you own a Canon camera, an alternative is to use the *StereoData Maker* camera "hack", which is compatible with most Canon compacts.

StereoData Maker

StereoData Maker (SDM) is based on the Canon Hack Development Kit (CHDK), which can be used to tweak a wide range of Canon compact cameras to include functionality that is not even available in high-end DSLRs. The software is free, but is not (yet) available for all the latest Canon models. The software is stored on a specially prepared memory card that loads the extra functions when the camera is powered on. The technique does not make permanent changes to the camera's firmware and returns the camera to its original state when it is switched off and the memory card removed, thus leaving the manufacturer's warranty intact.

SDM and CHDK are both model-specific and are constantly being developed by an enthusiastic worldwide community. A list of the currently supported cameras is available at http://stereo.jpn.org/eng/sdm/cams.htm. Instead of searching for the appropriate SDM version for your camera, you can also use the ACID (Automatic Camera Identifier and Downloader) Java program written by David Mitchell to automatically identify and download the appropriate version. All you have to do is start the program (available at www.zenoshrdlu.com/acid/acid.html) and load an image taken with the camera in question. ACID then uses the Exif metadata stored

This Somikon 3D camera bracket is a simple model for beginners

3D Viewing and Display Techniques

An anaglyph 3D display (on the left) requires the use of a special pair of red/cyan glasses for viewing. The interlaced display method (on the right) requires the use of polarizer glasses and a monitor that is capable of displaying rows and columns with differing polarizations.

The basic trick that allows us to see in three dimensions involves providing separate images of the same subject for our right and left eyes. Most conventional "stereoscopes" achieve this by alternately blocking our view of one or other of two source images printed next to one another. In fact, it is possible to achieve this "fusing" effect without any mechanical help at all.

"Wall-eyed" viewing requires you to look "through" the source images while your eyes' optical axes remain parallel.

"Cross-eyed" viewing swaps the two source images and requires you to look at them, as the name suggests, with both of your eyes angled inward so that you view the right-hand image with your left eye and vice versa.

Colored Filters

Using colored filters positioned in front of your eyes to automatically separate the source images allows you to view 3D images of any size without eye muscle strain. This "anaglyph" technique is cheap and simple, and involves printing the two source images on top of one another in different colors (usually red and cyan). The viewer then dons a pair of glasses with lenses colored the same as the images. For images with a white background, the viewer's left eye then only sees the cyan-colored image through the red lens and the right eye the red image through the cyan lens. The effect is reversed for images with black backgrounds.

Interlacing

Full-color 3D can be achieved using polarizing techniques. In this case, the 3D glasses have lenes that are actually polarizer filters oriented in different directions (see Issue 3 of *c't Digital Photography* for an explanation of polarization). The rows of pixels displayed by the monitor contain different polarizations and the paired source images are transmitted woven into one another using a technique known as "interlacing" that reduces vertical resolution by half. Alternatively, the source images can be transmitted alternately at a high frequency (120 Hz is usually sufficient to prevent flicker) using a technique called page-flipping. The source images are separated using "active shutter" glasses that darken the lenses alternately in time with the transmitted images. If the images are polarized too (as they often are in 3D movies), you can use cheaper polarizer glasses to view them.

Glasses-free 3D viewing is possible based on lenticular stereoscopy or "wiggle" techniques. Here, multiple images are combined to extend the angle of view for the finished image, which in turn reduces resolution by up to two thirds. All of the techniques described are subject to ghosting and errors caused by the angle 3D images are viewed from.

A left-right-left view of a pair of stereoscopic images for viewing using wall-eye or cross-eye techniques

Stereoscopic images shot using a single camera are often subject to problems caused by the unavoidable time delay that occurs between exposures. In this example, the effect is obvious in the smoke coming from the chimneys and the moving cars on the streets. This is nevertheless an effective 3D image that can be viewed using the "cross-eye" technique. The errors mentioned can be counteracted using the *StereoPhoto Maker* Clone Brush tool.

with the image to identify the camera and firmware version and automatically downloads the appropriate SDM or CHDK package. The program doesn't work for all Canon compacts, but you can go to the SDM homepage at http://stereo.jpn.org/eng/sdm/index.htm. to find more information and download the software manually. Each package comprises the Common_Files.zip file (which contains the SDM program itself) and an additional ZIP file that contains the boot file for your specific combination of camera model and firmware.

Installation

Once you have downloaded and unzipped the files, copy the boot file (diskboot.bin) to the common_files folder and start the SDMinst.exe stored in the same folder. Now insert an SD card (up to 4GB) into your card reader, click New Install and follow the on-screen instructions. The process formats the memory card, so be sure to transfer all valuable data to your hard disk before using SDM. If you are using SDM with two cameras, remember to enter "right" and "left" data during setup and label the memory cards accordingly. These settings can all be adjusted later if necessary.

Once you have installed the software, remove your memory card from your reader and set the write protect switch – if you don't, SDM will not load when you power up your camera. And don't worry, the software ensures that you can shoot and save images, even with the write protect switch in the on position.

All SDM settings are saved in a configuration file called CHDK.CFG (possibly with a number too) in the CHDK folder. Replacing this file with one of the camera-specific files from the common_files/CONFIGS folder after installation will save you some effort when you first use the program and ensures that the camera is properly set up. Remember to periodically save any CFG files that you create. As well as being safer, this also allows you to transfer your settings to other memory cards. If you format your memory card in-camera, SDM will be deleted and you will have to re-install it and start again, so, if you need to delte images, do so only using the camera's dedicated Delete button.

The Edge Overlay settings in the SDM menu. You can adjust visibility above the threshold, here set to the default value of 40.

Initial Settings

To initialize the SDM menu, insert your primed memory card, switch on the camera, then press the ALT button (usually the Direct Print button) followed by the Menu button. If necessary, you can change the menu language using the Advanced Menu > Visual Settings > Language command. There is a file with a list of the most important shortcuts in the CHDK/TEXTS folder, which you can display on the camera monitor by navigating to Stereo > Shortcut or using the Text File Reader > Open New File command in the Advanced Menu. Stereoscopic settings can be found in the Stereo entry in the SDM main menu. This is where you can adjust the left/right camera position. Other functions are explained below.

Main SDM Functions

Once you have switched your camera to ALT mode (indicated by an icon at the lower edge of the monitor), you can directly apply most SDM functions. The left/right buttons are used to toggle through the SDM OSDs (On Screen Displays) that include all sorts of useful information about the program's various functions and stereo "rangefinder" mode.

The program's default settings use the camera's USB socket for camera control in two-camera mode, and therefore do not allow for USB data transfer. If you need to, you can temporarily reactivate USB data transfer by switching to playback mode, pressing the ALT button and pressing the Set button until the UL (for UpLoad) icon appears on the monitor. You can now transfer images normally using a USB cable. You can switch back to standard SDM mode either by pressing the same sequence of buttons in the reverse order or by switching the camera off and back on again. You can permanently activate serial communication by unchecking the *Deactivate USB Download* option in the Advanced Menu.

Edge Overlay

In Edge Overlay mode, SDM marks the edges of the object while taking the first image of a stereo pair, allowing you to precisely align your second shot with the first.

- Activate Edge Overlay by switching to ALT mode and pressing FuncSet until you hear a beep
- Frame your subject and press the shutter button halfway to display the subject outline on the camera monitor. You can repeat this step as often as you like until you are happy with your framing.
- Press the shutter button fully to capture your image and "freeze" the overlay frame
- Shift the camera to superimpose the nearest point detail on the overlay frame. The distance between your furthest points and the overlay frame should not be more than about 2-3mm (depending on the size of your monitor). If you find the offset to be larger, your stereo base was probably too long.
- Take your second shot. The overlay frame will now disappear.

You can save overlay frames on your memory card and reload them later – a feature that is especially useful for shooting extreme high-speed sequences. Zoom settings are saved along with the frame and the camera zooms automatically to the correct setting when you load a saved overlay.

Quick 3D Panoramas

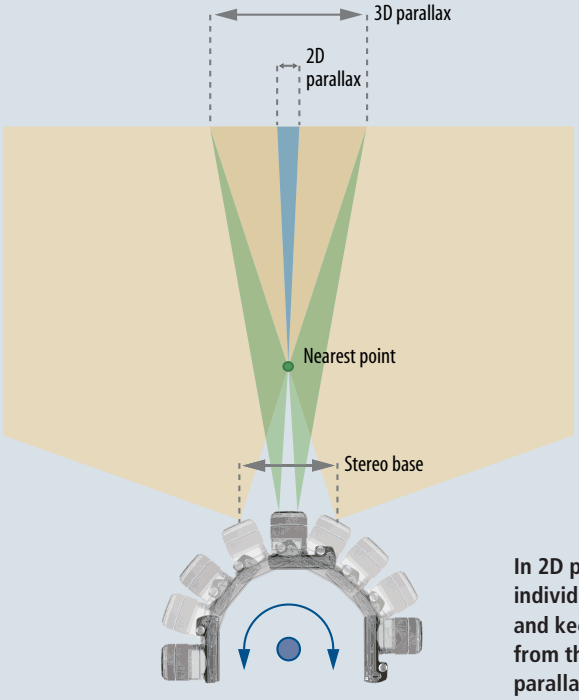
The sweep panorama technology introduced by Sony in 2009 is now built into a wide range of digital cameras and is no longer really "new". Recently, 3D sweep panoramas have given this old trick a new lease of life. Here, the image pair is created while the photographer rotates the camera around his/her own axis and requires no complex double-lens or camera shift technology. You can create conventional-width 3D images either by cropping the results or by sweeping only a section of the scene. 3D sweep panoramas have relatively low vertical resolution, although 1,000 pixels are still sufficient for Web display.

Sweep panoramas are created by stitching together small strips taken from source photos shot at a rate of about 10 frames per second. The differences in width of the individual strips are due to variations in sweep speed.

But how does the technique actually work? Technically speaking, panorama and 3D techniques are not compatible and require completely different approaches to shooting. Panoramas require a point of rotation that is as close as possible to the entry pupil (or "nodal point") of the lens, and any deviation produces parallax errors that spoil the optical cohesion of the results (see Issue 4 of *c't Digital Photography* for more information on panorama photography). On the other hand, 3D images require their own built-in "parallax error" (i.e., the distance between the viewer's eyes) to function at all. Nominally, a 3D sweep panorama requires the photographer to shoot two separate panoramas that are rotated precisely around the camera's nodal point and with the tripod shifted to opposite ends of the stereo base.

But some compacts and Sony Alpha DSLRs don't seem to be bothered by these complex requirements. What they do is shoot a large number of single images that overlap to an unusually large degree during the sweep. The finished image includes only a small strip from the middle of each image, similar to the way gigapixel panoramas are created from countless telephoto shots. For a 180-degree panorama made of 50 source images, each strip has an angle of rotation and an angle of view of just 3.6 degrees, which is equivalent to shooting using a 570mm telephoto lens! The smaller the angle of rotation, the smaller the parallax error caused by the offset between the point of rotation and the nodal point.

This explains the relatively high quality of conventional sweep panoramas. 3D sweep panoramas are created by the camera's firmware, which automatically processes two strips for every source image, with the second strip offset slightly from the first. The firmware then stitches one series of source images into a left-hand panorama image and the other into a right-hand one. The angle between the two strips of a single source image is the same as the angle through which the camera has to be rotated to capture the same segment of the subject slightly later. This offset, combined with the sweep radius, gives us the effective angle required to form the stereo base.



In 2D panoramas, reducing the angle of rotation between individual source images reduces the width of the individual strips and keeps parallax errors to a minimum. Using source strips taken from the far edges of each (wide-angle) source image gives us the parallax necessary to create an effective 3D panorama.

Rangefinder

SDM is also capable of detecting your subject's nearest and furthest points and calculating the appropriate base length and other settings.

- Press the ALT button in shooting mode and switch to the Single Camera OSD, then press ALT again
- Zoom right in on your subject, aim at the nearest point and press the shutter button halfway until the nearest point value is updated
- Repeat the previous step for your furthest point. The menu will then display the optimum distances for your nearest and furthest points as well as the hyperfocal distance and the maximum stereo base that is tolerable for your near/far measurements. The *Av min* value is the minimum aperture value that will allow you to capture all detail that lies between your nearest and furthest points in sharp focus.
- If you zoom to your desired focal length, SDM now automatically calculates a new stereo base value for the new setting and the minimum aperture value that you can then set manually. If the nearest point value is displayed in red, you are too close to the nearest point for the chosen base value.

The values calculated by the software are based on a *deviation factor* value that you enter in the Stereo menu. The default value is 25, which represents a shift of 1/25 of the width of the image. The near-subject factor that is entered in the same menu has a default value of 15 and represents the maximum amount of distortion you are prepared to accept for your chosen base value. The lower the value you set, the greater the convergence of the lens axes can be for your chosen nearest point, and the greater the trapezoidal distortion in the finished image will be. The rangefinder calculates the current nearest point factor based on the distance to the nearest point and the current base measurement. If this value is lower than the threshold value, the nearest point value is displayed in red to remind you to increase the distance between the camera and your subject.

Tricks with Mirrors

The use of mirrors makes it possible to shoot both components of a stereo image in a single shot. This technique can thus also be used to capture moving subjects in 3D. There are various construction guides available on the Internet, and the Loreo *Lens in a Cap* is a commercial product designed to achieve the same effect (see also our test on page 62).

A compact camera and a vertical mirror attached to a bracket. Front surface (FS) mirrors are ideal for this type of setup, as they prevent the creation of unwanted surface reflections. This 3D shooting method is particularly suitable for macro subjects, as in the example shown below.

Photos: Albrecht Klöckner

The simplest technique involves placing a single vertical mirror in front of your camera's lens. A front surface (FS) mirror is preferable if you want to completely avoid producing double reflections. Ideally, you will capture the original subject on one half of the sensor, and its mirror image on the other. As the size of the mirrors you can use is limited, this technique is especially suitable for use in macro situations. Albrecht Klöckner gave us some tips on what to look out for when making this type of photo, and you can see some examples of his work on the web page listed at the end of this article.

A mirror not only reverses the orientation of the subject, but also produces trapezoidal distortion, making it necessary to correct both of these factors during processing. Halving the sensor surface and cropping the results leads to a drastic reduction in resolution, but you will still be able to display your work adequately on the Internet or an HD TV.

Focus at a distance that is equidistant between the original and the mirrored subject. You can then use the *StereoPhoto Maker* Multi Conversion tool to convert the results into conventional side-by-side 3D images. Simply select the *Side-by-side* input file type option and select Horizontal Flip for your left or right images (depending on the orientation of your mirror). Deactivate auto alignment and correct any trapezoidal distortion using SPM's separate alignment dialog. Once you have found your ideal settings, you can save them as a preset for future use.

A more flexible way to achieve similar results is to place a folded mirror directly in front of the lens. This results in two source images that are both reversed and that are photographed at near-identical distances. Relatively small mirrors can be used to focus all the way to infinity. Adding an additional flat mirror makes it possible to shoot in a conventional "head on" fashion. In both cases, the virtual stereo base can be adjusted by changing the distance between the mirrors. There are comprehensive instructions on how to use mirrors to create a 3D image at www.lhup.edu/~dsimanek/3d/stereo/3dgallery16.htm.

Shooting 3D Photos using Two Cameras

A two-camera setup not only makes you stand out from the crowd, but also equips you to shoot 3D videos and sponataneous 3D snapshots of moving subjects.

The main requirement of a two-camera 3D setup is that the cameras can be fired simultaneously. Once again, *StereoData Maker* (SDM) comes to our aid, this time with a clever trick that adds extra functions to the USB socket of many Canon cameras when an electrical current is applied. This technique can also be used to trigger exposure metering, focus settings and even simultaneous zooming for paired cameras.

USB Remote Release

To perform the USB remote release "trick" you need an active remote release device that provides an appropriate voltage. You can either build this yourself using cheap components, or purchase a ready-made model, such as the Ricoh CA-1 (approx. US$26), which you will then have to customize by soldering an additional release cable to the handgrip. digi-dat (digi-dat.de) manufactures a remote release with two USB plugs (approx. US$60) as well as a so-called "Z-bar" for mounting two cameras rotated at 180 degrees to one another (approx. US$110-130, depending on camera model). Using a Z-bar allows you to reduce the distance between the optical axes of your camera to as little as 60-75mm, while parallel mounting demands at least 2cm more. The brackets are slotted to allow you to lengthen the stereo base to as much as 17cm, which should be sufficient even for architectural shots.

To make successful 3D macro photos, we need to bring the optical axes of our cameras even closer together, for example diagonally opposite to each other on brackets designed for one-camera shooting. We gained a further 1cm this way. The other advantage of working this way its that the cameras can be rotated towards each other, which Z-bars don't allow. You only need to take the slight difference in subject distance into account if you are focusing manually, and differences in image size are automatically counteracted by the *StereoData Maker* (SDM) software. We managed to construct a 65mm stereo base using two Canon Powershot S90s. For cameras with a tripod mount located directly beneath the lens axis (which is the case with the S90), you can use a sawn-off 1/4-inch bolt and a couple of washers to mount two cameras directly bottom to bottom. The disadvantage of this type of setup is that it produces portrait format images with parallel optical axes. As a comparison, using two S90s with their shortest possible 27mm (equivalent) focal length and a 55mm stereo base gives us depth of focus that stretches from 1.2m to infinity, or from 50 to 70cm (with 20cm stereo depth). The closer your nearest

A stereo setup using two different Sony DSLRs (an Alpha 550 and an Alpha 580) and two different lenses. This is not an ideal combination, but nevertheless produced acceptable results.

point is, the shallower the usable stereo depth will become.

Reducing the stereo base further requires the use of special mirrored setups, such as digi-dat's Macrobox (from US$750).

Simultaneous Firing

Triggering two bridge or DSLR cameras is easier if they have built-in remote release sockets. You can either build your own double cable release or purchase a ready-made solution, such as the releases made by Adidt (www.enjoyyourcamera.de), which can be coupled using an additional cable. We tested two Adidt M1 cables and a sync cable with two Sony DSLRs and found that we could release both shutters not only using both remote releases, but also using both camera shutter buttons. You can also use any radio-controlled remote release system that allows multiple releases to be triggered by a single transmitter.

Depending on when they are switched on, digital cameras aren't always perfectly synchronized, and their inner electronic "heartbeat" shifs over time anyway. A remote release that is also capable of switching your cameras on simultaneously will therefore provide better release synchronization. Sony and Canon video cameras (and some Sony stills cameras) can be controlled via their LANC sockets using the digi-dat ste-fra LANC unit (from US$660), which also includes a (mis)sync display but cannot actually force synchronization by delaying one camera's release.

Using SDM to simultaneously fire two cameras produces negligible time lags of 1/10,000 second or less. SDM also includes a release delay feature designed for use in flash situations, which you can use to ensure that the second camera's shutter is not released before the first camera's flash has reached its full intensity.

Two-camera SDM

Once you have installed SDM on both cameras (see page 44 for instructions), you have to enter their positions (left or right), the length of the stereo base and their orientation (if you are using a Z-bar). SDM status displays have a red background for the left-hand camera and a blue background on the right. Now all you have to do is connect the USB cables and you are ready to shoot. instead of halfway and fully-pressed positions, the digi-dat remote release uses a short button press to trigger exposure and focus metering and a long press to release the shutters. If the short press reveals that your camera settings need adjustment, you can reset the release using a short half-press of the camera shutter button. To take a photo, press the remote release button until both camera monitors go black and the cameras emit a beep – releasing the button then releases both shutters in perfect synchronization. If you are sure your settings are OK, you can release the shutters directly without using the "check" step. The procedure is the same if you are using flash, and SDM automatically reduces the output of the left-hand flash by four stops.

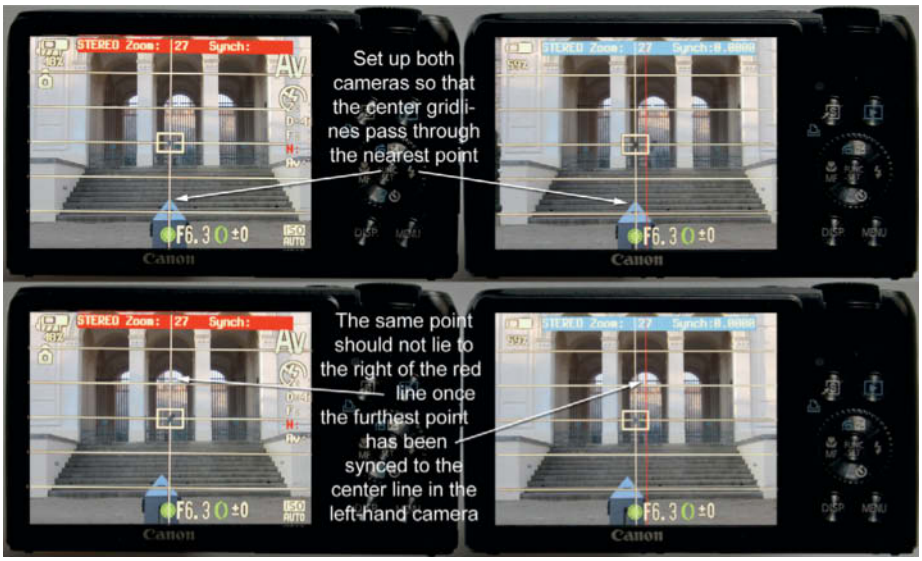
Because the USB sockets cannot be used to transmit data from one camera to the other, synchronized zooming requires you to switch the *SynchZoom* option in the SDM Stereo menu to the Cont setting. The *Zoom time-out* option determines how long the selected sync mode remains active once the zoom rocker has been pressed. If you press the remote release button once inside the

Extremely close mounting of two Canon Powershot S90s using a conventional single-camera bracket. It is easier to control the angle of convergence using this type of setup than it is using a Z-bar (shown at far right).

3D snapshots of moving subjects only work if you can release the shutters of both cameras simultaneously. This shot was taken using *SDM*, two Canon Powerhot S90s mounted on a Z-bar (from digi-dat.de) and a double remote release. The 3D effect can be viewed using the cross-eye technique.

timeout period, both lenses will zoom in by one step, while continued pressing of the button zooms the lenses to the end of the range. Make sure both cameras are zoomed to the same setting before you start.

SDM provides a grid for checking stereo depth. The grid can be loaded via the SDM menu using Advanced > OSD Parameters > Grid Settings > Load Grid, and displayed using the Show Grid command. Various grids in popular aspect ratios are stored in the Grids folder. All of the settings mentioned here have to be made once each for both cameras and are then stored in the software's configuration files. Make sure that both cameras are set up so that the center vertical gridline passes through the nearest point. Now pan the entire unit (without altering the position of the bracket) so that the gridline in the left-hand monitor passes through the furthest point. The parallax effect will cause the same point to lie to the right of the center line. SDM now displays an additional red line at the point of maximum tolerable deviation. If the furthest point lies between the two lines, everything is OK, but if it is to the right of the red line, the resulting stereo depth will be too great. You can counteract this by reducing the distance between the cameras, by increasing subject distance, or by simultaneously reducing the focal length setting on both cameras.



Using SDM to check stereo depth tolerances. The red line on the right-hand display indicates a four percent offset (deviation). You first have to sync the center gridline with the nearest point (top), and then pan the entire two-camera setup so that the furthest point lies on the center line in the left-hand monitor image. If the deviation in the right-hand monitor lies between the center and red lines, stereo depth will be acceptable. In this example, the deviation is OK for all but the most distant details.

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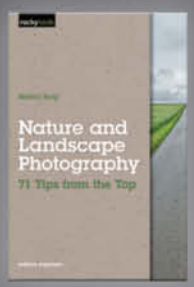

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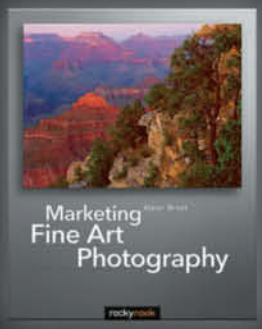

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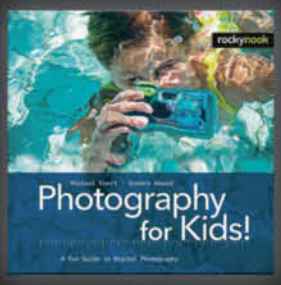

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3D Image Processing

A 3D image is by no means finished once it has been shot. Source images photographed using conventional cameras have to be aligned and mounted, and images shot using specialized cameras can benefit from a number of 3D post-processing techniques.

The *StereoPhoto Maker* (*SPM*) freeware includes functionality for most common 3D processing steps and outshines many commercial programs in terms of its ease of use and build quality. Comprehensive online help is available at http://stereo.jpn.org/eng/stphmkr/.

The following steps describe a typical 3D image processing workflow:

1. Load an image pair

3D photos shot using conventional cameras consist of two images of a single subject photographed with a slight perspectival offset. To process an image pair, use File > Open Left/Right Images. If your paired images are stored in separate folders, *SPM* remembers where to find them. Press the space bar to open additional pairs.

2. Select a view

SPM is capable of viewing all common 3D image formats, including side-by-side, reversed side-by-side (for cross-eye viewing), above/below, interlaced (for polarized viewing), anaglyph (for various types of glasses or using custom settings) and as a page-flipping image for viewing using active shutter glasses.

Regardless of which view you select, the side-by-side view is best for comparing color and brightness in images pairs, while the anaglyph view is best for aligning them.

3. Aligning images

The Alt+A keystroke aligns image pairs automatically, including corrections for image height and size, as well as trapezoidal distortion. The program works quickly and the results are often extremely good. The steps it takes are recorded in number form in a log window, the most important being the "disparity of the infinity points" (i.e., deviation) value. The value is given as a fraction of the width of the image and as a number of pixels. The program warns you if you exceed the default value of 1/25.

You can also align your images manually by pressing the **J** key. The alignment dialog shows images pairs as red/cyan anaglyphs, which makes distinguishing and aligning them quick and simple. Clicking the Edge Detection button produces line sketches of each image, for which you can then adjust size, rotation, barrel or pincushion distortion, and horizontal and vertical perspective. This allows you to align image pairs shot using different lenses. Alignment values can be saved in *SPM*'s own DAS file format, making it simple to apply the same settings to entire image sequences. This functionality is also great for making lens corrections. If you select the *link both rotations together* option, all the sliders in all of the adjustment tabs are linked, making it simple to change distortion and perspective simultaneously.

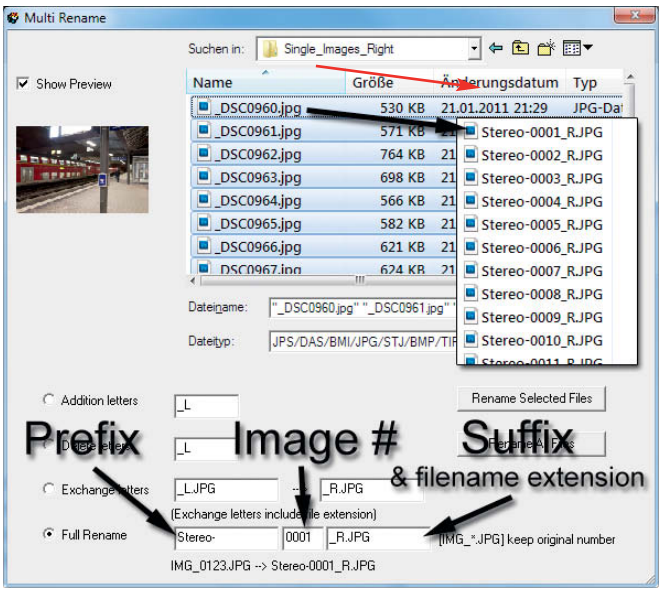
4. 3D depth adjustment

Once you have aligned your images, the 3D effect should be easily visible. If the depth effect is "the wrong way around", press the **X** key to reverse the image order. If you used the program's automatic alignment functionality, the image order will depend on the settings you made under Edit > Preferences > Adjust.

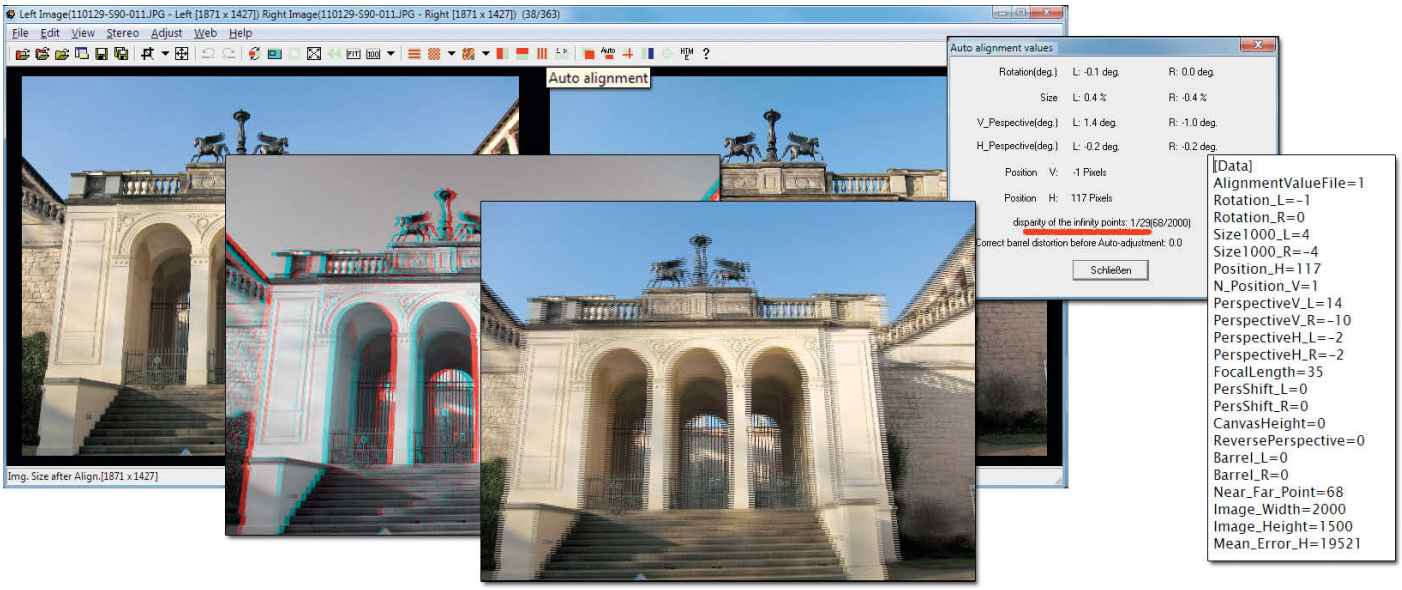
We recommend that you use the *mount near points to the stereo window* option. This positions the entire image behind the monitor plane, which prevents window violations from occurring. You can then use the left and right arrow keys to shift your image forward or back relative to the stereo window to allow selected details to project. The size of each adjustment step (in pixels) can be set in the dialog window. The stereo window itself remains on the monitor plane. The up/down arrow keys shift the image up or down, and pressing Pos 1 restores the original settings. Depth alignment is at its best when details that touch the edges of the frame are positioned as close as possible to the stereo window but slightly behind it.

5. Color corrections

Even if you use the same exposure values to shoot your source images and the lighting remains the same between shots, there are often slight differences between the colors



The *StereoPhoto Maker* Multi Rename dialog showing consecutive numbering settings for the individual files (stored in separate left and right folders). If you leave the Image number field empty, the program automatically uses the original file numbers.



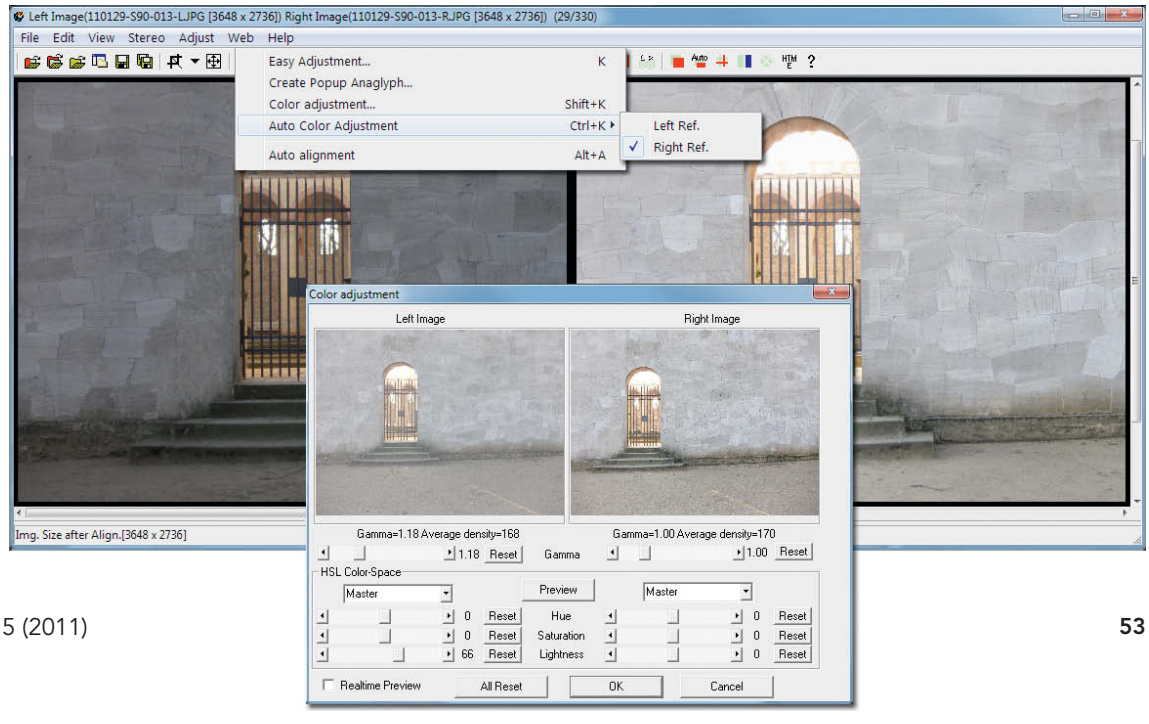
StereoPhoto Maker **includes functionality for all common 3D viewing methods and can align source images fully automatically. The adjustment values applied are saved in a plain text file with the ALV filename extension. The dialog box displaying these values is shown on the right.**

captured by two supposedly identical cameras. *SPM*'s Adjust menu includes an Auto Color Adjustment tool that helps to counteract such discrepancies. The dialog allows you to select the left or right-hand image as a reference for any corrections. It is important to wait until after alignment and distortion correction to perform color corrections, otherwise you may end up producing significant color errors. The Color Adjustment tool is designed for correcting slight errors and for giving images a final polish, although it often produces better results than the manual Gamma correction tool found in the same menu. Apart from basic sharpening functionality, there are no other tools for making adjustments simultaneously in both source images, so you will have to perform any adjustments to shadows, highlights, contrast etc. in a separate image processing program, before or after processing in *SPM*.

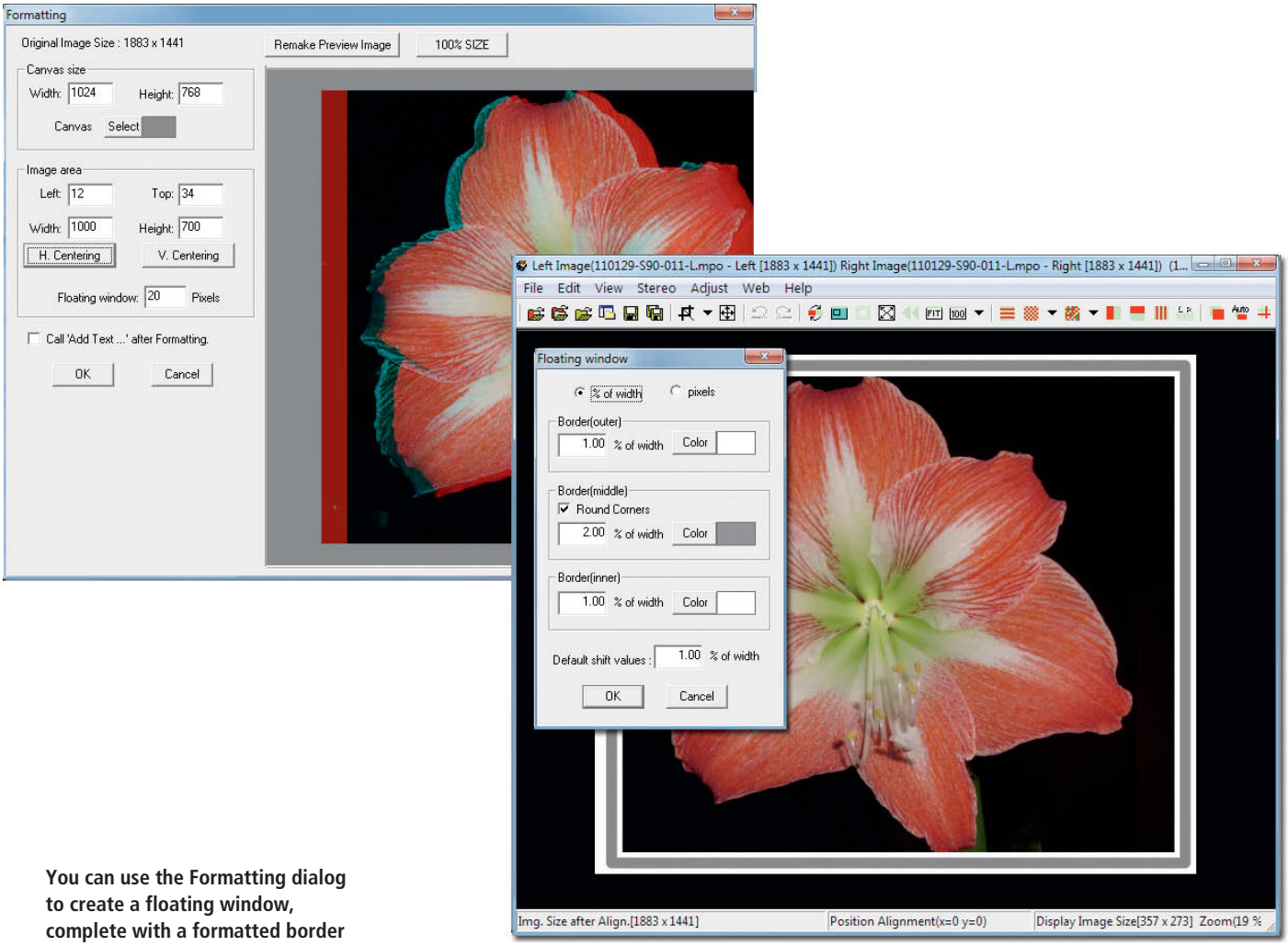
6. Cropping and sizing

The program's cropping and sizing tools all preserve depth effects and stereo window alignment, but crop floating windows and borders. Select Edit > Crop > Free Cropping and draw a marquee by keeping the mouse button pressed. You can set a fixed aspect ratio and/or a target image size (in pixels). Preset aspect ratios can also be entered using keyboard shortcuts.

Cropping can reduce the depth effect in a 3D image, making it easier to view. Try to crop all details that extend too far into the foreground, including the ground if necessary. If you choose to perform a repeat automatic alignment, make sure you select the *No* option in the dialog that asks if the existing report file should be used.



Here, the program's automatic color correction functionality coped well with a significant difference in exposure caused by erroneous camera settings. Our attempts to adjust the Gamma settings manually simply resulted in a flat-looking left-hand image (center).



You can use the Formatting dialog to create a floating window, complete with a formatted border

7. Floating windows

For projection sizes that are wider than 1.6 m or images with significant depth, it can be necessary to visually position the stereo window in front of the projection plane – i.e., to cause it to "float". This is necessary for furthest point distances in excess of 6.5 cm (on the projection surface) in order to avoid window violations. A floating window (if necessary, with a formatted border) can be an aesthetically more pleasing alternative that is also more comfortable to view.

SPM includes two floating window commands. In the Formatting dialog (Edit > Format), you can select a custom Canvas size and Image Area. The Image Area determines the size of the stereo window, which can then be dragged to a location in front of the canvas. The program then automatically creates a simple border (on the same level as the monitor) around the floating image. You can create and format floating borders using the Edit > Floating Window command.

The width, color, corner rounding and offset (shift value) are all set in the tool's dialog. In this case, the complete 3D image will also be moved forward by the same shift value. If you don't want to create a visible border, you have to set all border values to zero and all colors to black (or the background color if this is not black). For shift values greater than the default value of 1%, viewing images produces a kind of "peep show" effect. Negative values shift the stereo window to a position behind the projection plane – an option that makes no practical sense.

You can create an asymmetrical stereo window by cropping a symmetrical window on one side. Before cropping, make sure that you move the entire image backward or forward (using the arrow keys) so that the image edge at the new stereo window edge depth will be on the same level as the monitor. This is easiest to do using the anaglyph or interlace view (without glasses).

8. Retouching

The only retouching tool provided with *StereoPhoto Maker* is a clone brush, activated by pressing the shift key in anaglyph or side-by-side view mode. The Shape, Size and Edge settings can be adjusted in the Clone Brush Setting dialog in the Edit menu.

The tool copies pixels from the left-hand image into the right-hand one. Stereoscopically, copying pixels this way means that the copied areas are shifted to the monitor level. You can work around this by shifting the entire image so that your target depth is on the monitor plane before you clone, and shifting the image back to its original position once you have finished cloning.

You can use the clone brush to correct images in which moving objects spoil the depth effect. For example, leaves or water

nearly always move between shots if you are shooting with a single camera. Using the technique described above, you can shift a tree to the monitor level, remove all the movement-based anomalies using the clone brush and then return it to its original depth position. You can also use this technique (perhaps combined with a little luck) to correct or remove moving cars in street scenes.

9. Inserting text or a logo

Text inserted into a 3D image is also subject to a depth effect that can make it collide with other objects if you are not careful. The Edit > Add Text dialog gives you the options you need to position text at the appropriate depth. The Depth setting in the Add Text dialog actually means the horizontal offset, and changing the value by one point alters the offset by two pixels. The simplest way to ensure that you position your text at the right depth is to shift the image (using the arrow keys) before you add text so that the appropriate depth is on the monitor plane. At the appropriate depth, all details will be superimposed (i.e., completely sharp) if you view the image without using glasses. You can now enter your text and format it using a Depth value of zero. This positions the text on the monitor plane and allows you to shift it to the appropriate depth with the rest of the image once you are finished. *SPM* re-crops the edges of the image to remove the temporary offset when you insert text, so it is a good idea to keep your image slightly larger than necessary and to crop it to size later when including text.

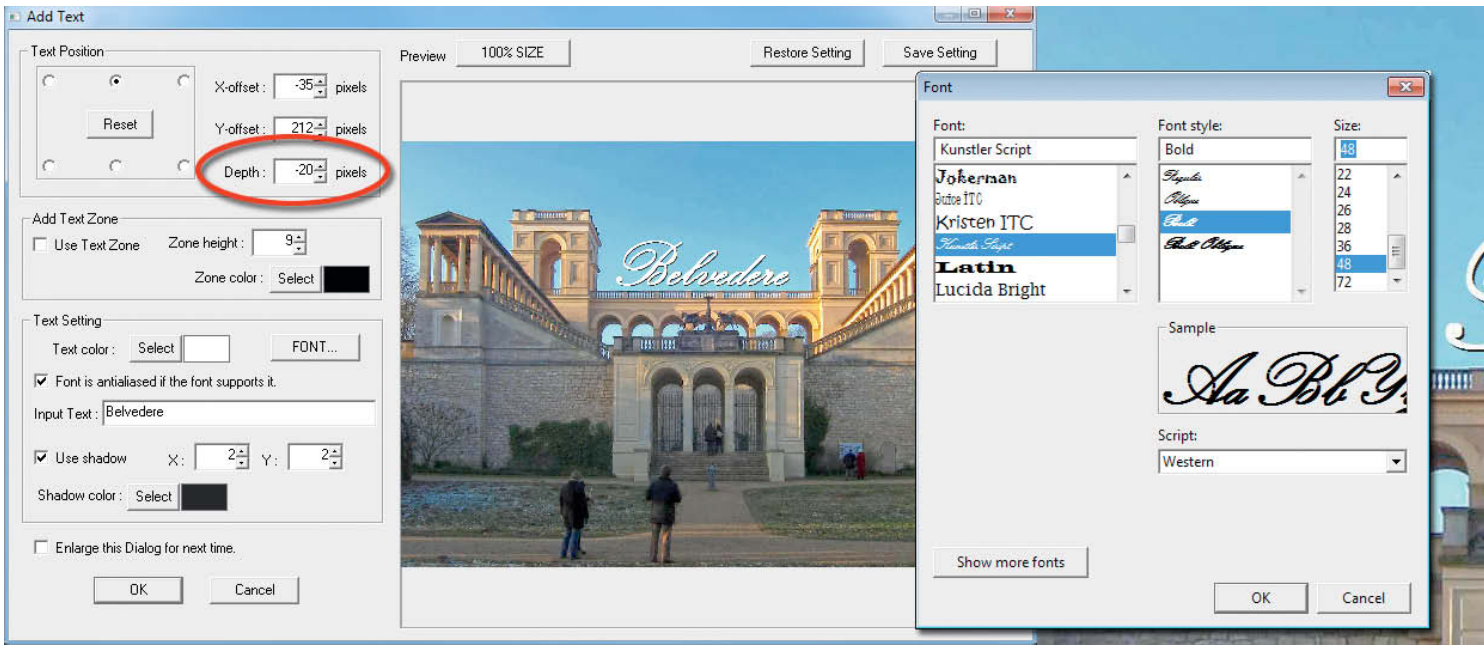
You can use the same techniques to insert a logo into your image, with selected colors displayed as transparent. *SPM* is not capable of shifting or altering text once it has been inserted, so if you want to produce special effects, such as diagonal text that projects out of the image, you will have to prepare it in another program and convert it to an image format that can be inserted using *SPM*.

10. Saving your images

When you have completed processing, save your image by pressing Ctrl+S or using the Edit > Save Stereo Image command. You can save images to conventional image formats, such as JPEG or TIFF, or to stereo formats such as JPS or STJ.

Note that *SPM* always saves images as they are displayed in the current view. i.e., if you want to save your images in side-by-side format, you first have to switch to a side-by-side view. All adjustments, crops, borders, text etc. are permanently resampled into the image data when you save an image. The program's proprietary DAS format is designed to save processing steps independently and non-destructively, but didn't work smoothly in the 4.32 version of the program that we tested. *SPM* also supports the Fujifilm MPO (Multi Picture Object) 3D format, and can save to the universal L-R-L 3D format, as well as to animated GIF, Raster3D or mosaic formats. The program's excellent Multi Convert (i.e., batch conversion) feature allows you not only to convert images between multiple formats, but also to apply automatic alignment and processing effects to multiple images, which enables you to process entire sequences shot using a two-camera setup in one go.

SPM also has slideshow creation and playback functionality, and can create HTML files in which you can embed 3D images using Java or Flash applets via the dedicated Web menu. This allows beginners and experienced users alike to set up Web galleries in which the viewer decides which format to use for viewing images.



Negative Depth values shift text backward, while positive values move it forward. With the text positioning method described opposite, you can use a zero Depth value, which is more intuitive. While the *shadow* option doesn't produce a convincing shadow effect, it does give text a three-dimensional look.

3D Know-how

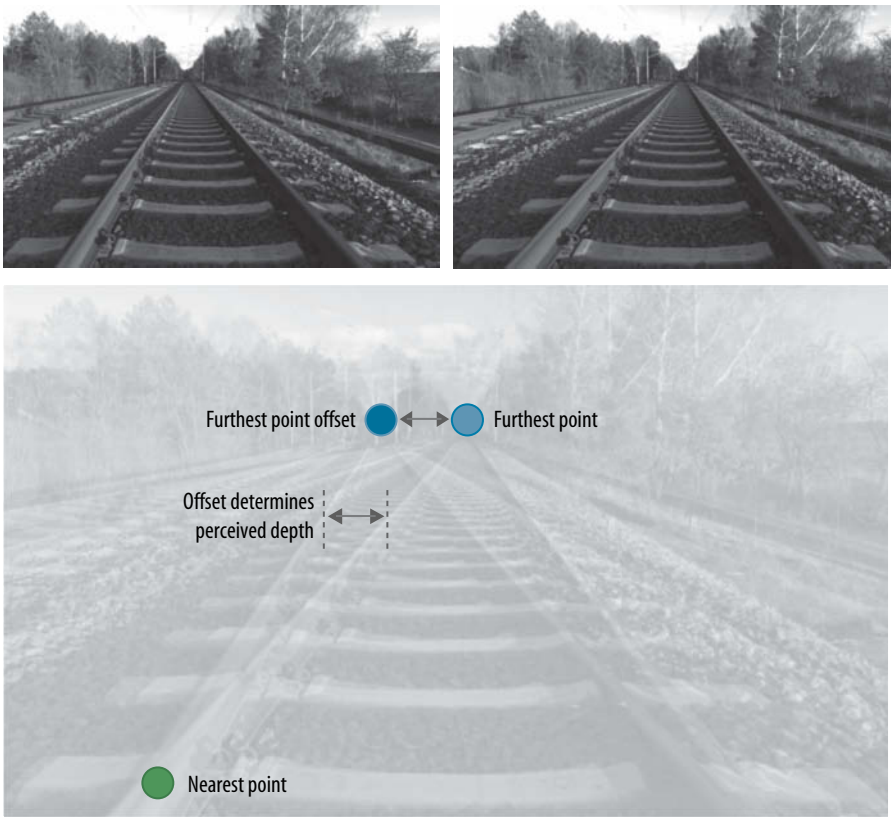
You don't need expensive special equipment to shoot 3D photos and videos. You can produce excellent results using conventional digital cameras, free software and a little applied know-how. This section gives you the grass-roots knowledge you need to get started.

Before digital photographic techniques became widespread, shooting in 3D required an extremely high degree of precision while framing, exposing and mounting slides. Today's digital technology gives us a great deal of freedom while shooting and processing 3D source images. Nevertheless, basic laws of physics and optics have to be adhered to if we are to shoot effective 3D images that are not uncomfortable to look at. Our eyes deliver the raw material, but it is our brain that constructs the 3D image from the two slightly different two-dimensional source images. The brain constructs a feeling of depth from the lateral offset, or "stereopsis", of corresponding points in an object. In other words, the differing perspective within the source images creates the magical 3D effect. However, while this offset tells us about the relative depth of the subject, it says nothing about its distance from the camera. In order to interpret distance, the brain uses its knowledge of the size of known objects in combination with other factors. The most important of these are:

– The angle of view of our eyes. The closer a subject is, the more we have to cross our eyes to focus on it; the effects caused by swiveling our eyes outwards do not occur in nature, but can be produced by incorrectly mounted 3D cameras
– The focusing power (accommodation) of the lenses in our eyes
– The apparent relative movement of foreground and background objects that occurs when we shift our point of view

The last two effects are also apparent in monocular (one-eyed) viewing situations, making it possible for people with only one eye to see 3D effects too.

All of these various pieces of visual information come together when we view real-world objects. This interplay is, however, not absolutely necessary and, theoretically, can even make it impossible to view 3D effects. The accommodation of our eyes delivers visual informationat a constant, relatively close distance (i.e., from the paper or monitor we are looking at), while our eyes' angles of view deliver contradictory information – for example, if we are viewing a stereo landscape image using the cross-eye technique. With a little practice, the brain is able to interpret the depth effect with the help of the horizontal offset of the source images alone, even if all other information delivered by the eyes is saying something different. This is why 3D images are often referred to as stereo images, as they are not really three-dimensional. The apparent movement of foreground and back-



Stereoscopy in practice. In this case, the nearest point lies precisely on the projection plane (i.e., on the paper). This is confirmed by the fact that the nearest point offset is zero when the two source images are superimposed on one another. The corresponding deviation is therefore precisely the same as the furthest point offset – in this case well above the threshold value, but nevertheless tolerable at about 1/14 of the width of the image. This sample image is included on this issue's free DVD.

ground that occurs when we shift our point of view is an optical illusion.

This fragile illusion is based on incomplete visual information and quickly falls apart if we don't adhere to a few simple rules during shooting, mounting and presentation. The following sections describe how to apply these rules to the creation of digital stereo images.

Shooting

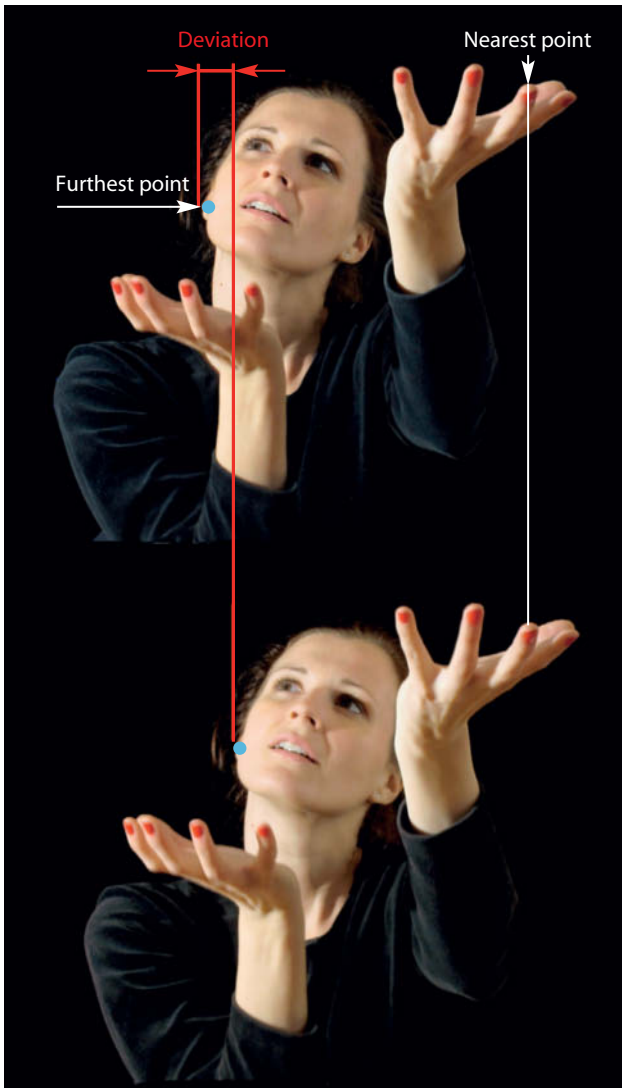
There are limits to the usable depth covered by the distance between the nearest and furthest points in your subject. We often read that if the furthest point lies at infinity (i.e. on the horizon), the nearest point shouldn't be closer than two-and-a-half to three meters from the camera. However, this is only true for equivalent standard focal lengths of around 50 mm and a standard stereo base of about 65 mm. This rule can be summarized in a generalized fashion as: Nearest Point Distance = Stereo Base/Focal Length. This equates to a tolerable minimum nearest point distance of 3.25 meters for a standard lens and a 65mm stereo base. Closer distances can also work and are sometimes even necessary to underscore the 3D effect in an image, but can be more strenuous to look at. If 3D depth is too great, it leads to ghosting and eventually to the complete disintegration of the depth effect.

Moving away from the subject and zooming in doesn't help either, as this doesn't alter the relationship between nearest point distance and focal length. Reworking the equation we set out above reveals that focal length directly affects the length of the usable stereo base, i.e., Stereo Base = Nearest Point Distance/Focal length.

Basically, it doesn't matter what combination of distance and focal length you use to photograph your subject, as long as you don't exceed the maximum usable stereo base. You can use a narrower base to photograph objects with greater overall depth, but this will reduce the impact of the 3D effect. For landscape situations in which the foreground is several hundred meters away, it is actually advisable to use a stereo base that is several meters long to ensure that the depth effect remains convincing. The closer you move to your subject, whether on foot or using a zoom, the narrower the required stereo base will be. In this case, you can visualize the base as the distance between a virtual observer's eyes.

If the furthest point in your subject isn't located at infinity, the nearest point can also be located closer to the camera, as long as you stick to the rules outlined above. The actual amount is difficult to calculate because the value that determines the harmoniousness of a stereo effect is the deviation (see the illustration above). A useful rule of thumb is to remember, for a standard lens and a 65 mm base, that a nearest point distance of about 1.6 meters is sufficient if the overall depth (from nearest point to furthest point) of your subject doesn't exceed the same 1.6 meters. Halving the nearest point distance reduces the tolerable subject depth by about one fifth, and at a distance of 16 inches, the usable depth is just 2 inches.

The only information relating to depth that is included in stereo images is the varying horizontal offset of details that are located at different depths in the original. This is the information that the brain uses to construct an apparently three-dimensional image from the source image pairs.

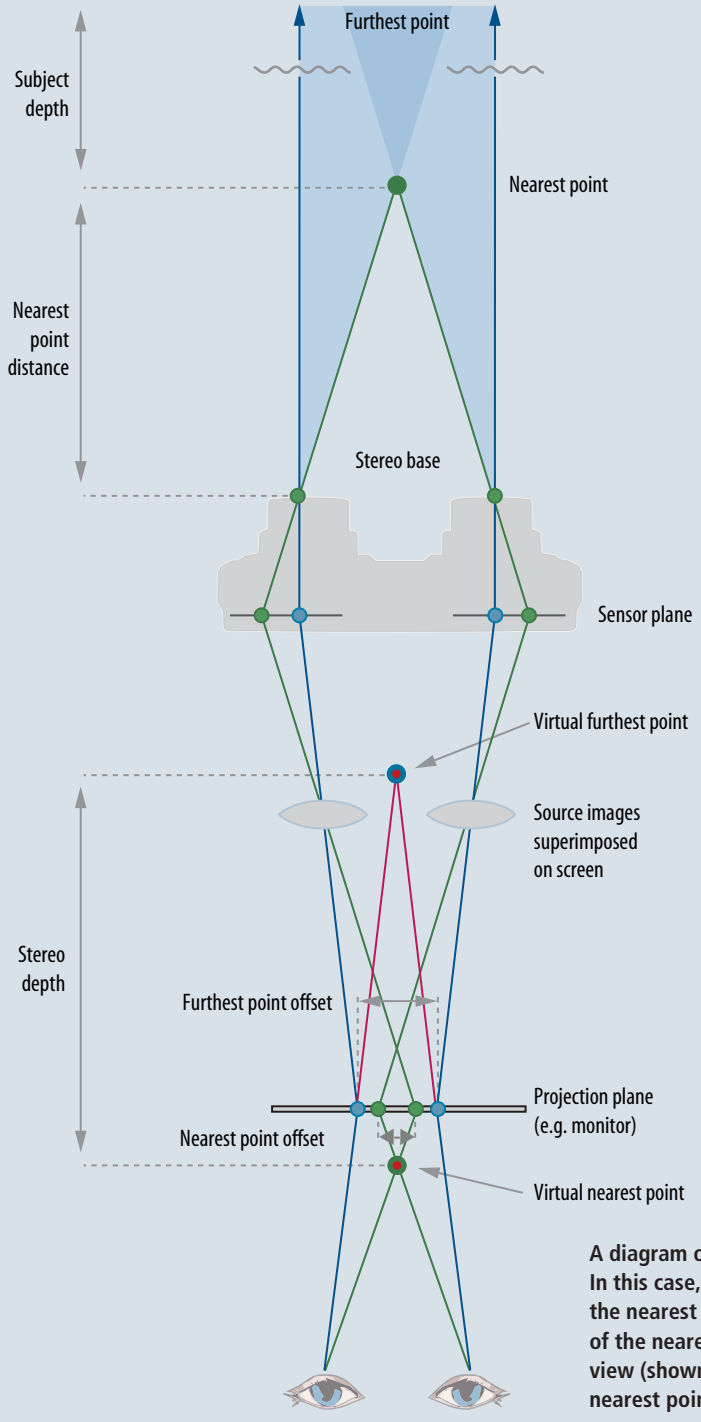


In macro situations, the reproduction ratio determines the usable subject distance. The usable subject depth is determined by the shallow depth of field and is often as little as just a few millimeters. Here, the only factor you can significantly vary is the stereo base. In this case, the appropriate formula is: Stereo Base <= 1.2 x Nearest Point Distance/(Reproduction Ratio x Subject Depth). Focal length is no longer relevant and we can generalize our rule to state that: Stereo Base <= Nearest Point Distance/20. This gives us a minimum subject distance of about 1.3 meters, which is usually sufficient for taking photos with a macro-capable telephoto lens at a minimum subject distance of about three feet and a reproduction ratio of 1:2. We managed to produce images with no ghosting using an over-long 65 mm macro base, which gave us a pleasantly shallow depth range of about 40 mm. By the way, nearest point distance is measured to the entrance pupil of the lens, not to the camera or the sensor.

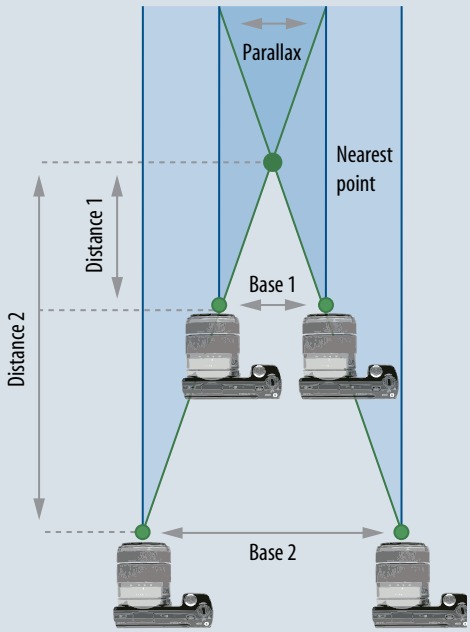
It is necessary to move nearer to the subject to achieve the same reproduction ratio using a shorter focal length lens. If we then reduce the stereo base accordingly, the offset between the source images (and with it the image depth) remains the same. However, the subjective effect of an image shot using a shorter lens will be different due to

the increased depth that the optical construction of wide-angle lenses produces. In extreme close-up situations, the optimum stereo base can measure as little as just a few millimeters.

Deviation is another value that you need to pay attention to. This represents the difference between the offset of the nearest and furthest points in the two stereo source images and is used to state the depth of the subject as displayed in the stereo image (not in the subject itself!). This value is usually stated as a fraction of the width of the image, so a deviation of 1/25 means that the relative offset is 1/25 of the width of the image, regardless of the size at which the image is displayed. 1/25 is often given as the maximum allowable value and is certainly a good guide value, as it incorporates not only our shooting rule but also the optimum projection angle of 40 degrees (which also happens to be the horizontal angle of view of a standard lens). If you can determine deviation while shooting, you will no longer have to concern yourself with distances and focal lengths, so the generally applicable shooting rule is: deviation should not exceed 1/25 of image



A diagram of how a stereoscopic image is shot and displayed. In this case, the furthest point appears to be behind the monitor, while the nearest point floats in front of the monitor. The deviation is the sum of the nearest point and furthest point offsets. The differences in angle of view (shown in blue and red for the furthest point and green for the nearest point) create the impression of differing depths.



If the furthest point lies at infinity, the nearest point distance and the stereo base are proportional. If you move away from the subject and increase the length of the stereo base, neither the angle of parallax nor the nearest point distance change.

width. Older publications often list the more rigorous guide value of 30 (i.e., 1.2 mm for a 35mm frame). *Stereo-Data Maker* is capable of calculating threshold deviation values and displaying them in the form of gridlines on the camera monitor The 1/25 value represents 2 or 3 mm, depending on the size of your camera's monitor, so this is the maximum distance by which the furthest point can shift while you are fixing your nearest point, and vice versa.

Because the threshold deviation value takes image display into account, cropping one side of an image will (theoretically) alter the deviation value but – as long the nearest and furthest point are not affected by the crop – not the apparent depth. If, however, you move closer to the subject or zoom in to increase image width to its previous value, the perceived depth increases along with the angle of view between corresponding points. The same things happen if you increase focal length – the subject moves closer, increasing deviation and perceived visual depth. This is what makes deviation such a good guide value while shooting.

If you discover that you can comfortably view stereo images with deviations of 1/10 and more, you have probably simply got used to looking at over-the-top 3D effects. Try to avoid showing such images to 3D beginners or during slideshows, as they can be hard work for the uninitiated.

Parts of the subject that project outside the image frame should be positioned behind the stereo window. Only free-standing objects should project beyond the confines of the window.

More Shooting Tips

Generally, depth of field should cover the entire subject depth. An exception is a background that lies outside the depth range but that can be focused on using the current stereo base. Such a background should remain unfocused – otherwise, the viewer's eyes will attempt to focus on it, causing the stereo effect to disintegrate. Blurred foreground details are generally taboo, although they can enhance depth effects in large projections. You should nevertheless try to limit blur to peripheral or repeated details that are displayed in focus elsewhere in the image. This way, blur doesn't leave the viewer feeling dissatisfied.

Try to shoot both source images using identical camera settings. Set metering and focus to manual. If you are shooting with two cameras, use the same focal length and/or zoom setting. Some image processing programs can compensate for discrepancies, but image quality usually suffers in the process.

The lighting should remain the same for both source images, and the light source should remain stationary, even if you shift your camera between shots. Don't use built-in flash unless you are sure you can fire both flashes simultaneously.

Make sure that you shoot both source images from the same vertical position, or you will find that your results contain unwanted vertical parallax in addition to the horizontal parallax that you need to create your 3D effect. The only way to counteract vertical parallax is by viewing the resulting image with your head tipped at an angle.

It is no longer necessary to keep the optical axes exactly parallel during shooting as it was in the days of slide-based 3D, and you have to angle your cameras inwards anyway when you are shooting close up. Today's software makes it relatively simple to correct the trapezoidal distortion that results.

Basically, it is important to make sure that all differences between stereo source images are based only on differences in horizontal perspective. For moving subjects, this can only be achieved using twin cameras or lenses that are capable of shooting precisely simultaneously.

Mounting Tips

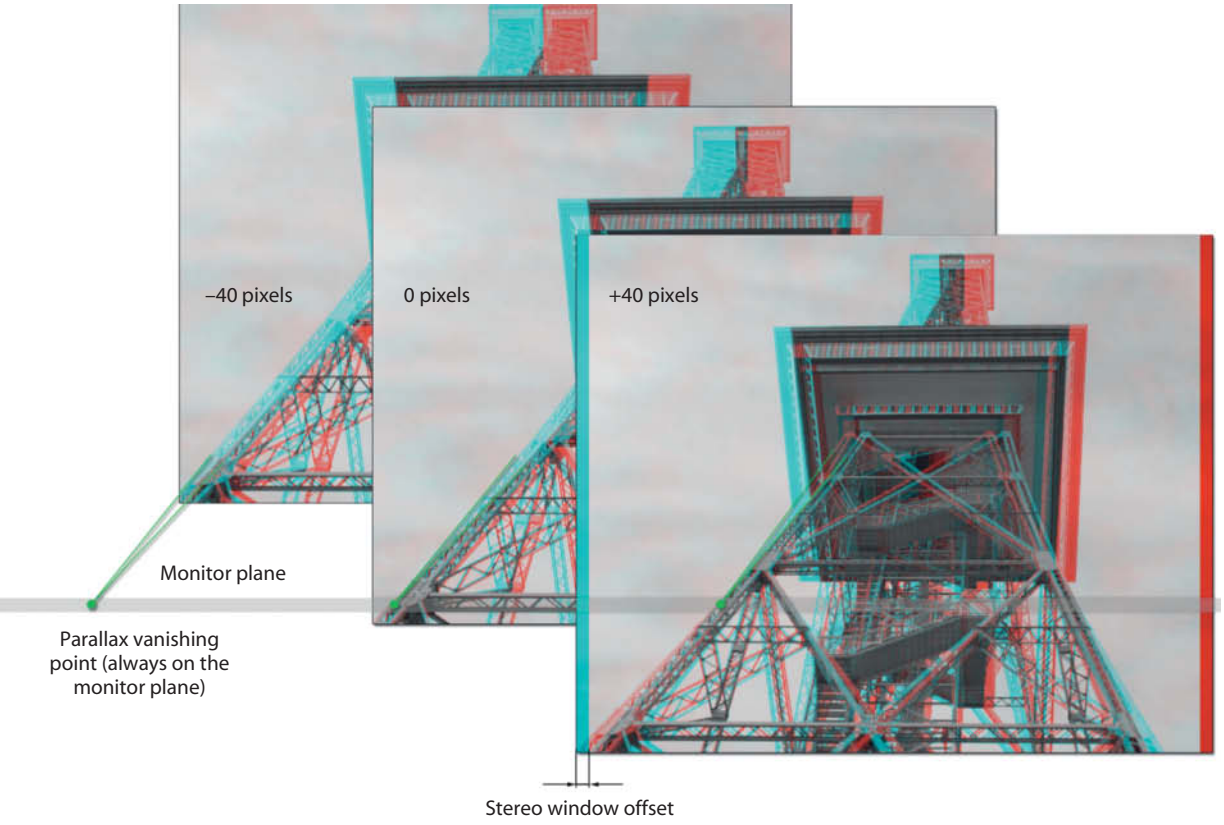
Photos and videos are always presented within a frame or border, and stereo photos have two borders – one for each source image – which have to be just as precisely

Stereo Shooting Rules

Furthest point at infinity:
Nearest Point Distance ≥ Stereo Base × Focal Length
Or: Stereo Base ≤ Nearest Point Distance/Focal Length

Close-up and macro:
Stereo Base ≤ 1.2 × Nearest Point Distance/(Reproduction Ratio × Subject Depth)
Simply put: Stereo Base ≤ Nearest Point Distance/20

Generally:
Maximum Deviation ≤ Image Width/25



Aligning the stereo window involves shifting the source images until the desired points on the subject appear on the monitor plane. This is achieved where there is no offset (the green points). The left-hand image is located a fair distance behind the monitor plane, while the center image shows the nearest point on the monitor plane and the foreground detail in the right-hand image projects beyond it, along with the stereo window. The floating window was created in *StereoPhoto Maker* using a 40-pixel offset.

superimposed as the image details they contain. To prevent visual contradictions, it is important that both frames are the same size, although there are exceptions to this rule , as we will see later on.

The superimposed frames form the "stereo window" through which we view the 3D illusion. The window itself is located at a virtual distance that is not necessarily the same as the distance to the projection plane. Such "floating windows" have their practical uses, but frame-filling 3D images viewed on a computer monitor are framed by the frame of the monitor itself, which, by definition, cannot float.

The relative locations of the stereo window and the source images determine the apparent depth at which the subject appears within the window. Usually, we adjust the source images to appear behind the level of the window, so that we look "through" it like a normal window. In this case, the nearest point lies on the same plane as the (virtual) distance the frame is located at. If we view anaglyph or interlaced images without glasses, the details that lie on the plane of the frame (i.e. where the two source images are precisely superimposed) will be sharp. The edges of details that are located further back are no longer precisely registered and move further apart the further back they are. Our eyes don't have to cross as far to focus on them, which is why we perceive them as being further away.

StereoPhoto Maker (*SPM*) allows you to shift each image back and forth using the arrow keys and to view the results directly on the monitor while automatically keeping the stereo window on the monitor plane. The depth of the 3D effect can no longer be altered at this stage, as it has already been determined by the length of the stereo base used while shooting. What you can do, though, is make individual details appear to "stick out" of the stereo window. This effect is most impressive for objects such as a ball, a swimming fish or a flying bird that don't touch the edges of the frame. Objects that are cropped by the image frame but still appear to project forward into space present an optical contradiction and are irritating for the viewer. Once again, there is a simple rule: all objects that touch the edges of the stereo window should lie behind the window plane. Strictly applied, this rule is valid for all four sides of the window, although the problem is always less irritating when it occurs at the top or bottom edges of the frame.

This rule also makes processing images shot using perfectly parallel cameras unavoidable. If two such (anaglyph or interlaced) source images are mounted so that they are precisely superimposed, the entire scene (along with the horizon) will appear to float in front of the stereo window on the monitor plane. *SPM*'s preferences allow you to decide where the automatic alignment feature positions the subject relative to the stereo window, and to fine-tune the setting using the arrow keys. You can achieve the opposite effect if you shift the source images apart by the distance between your eyes. This causes your eyes to "uncross" and the horizon to appear a very long way away. Additionally, if the stereo window lies on the monitor plane, its edges become the nearest point, making the entire scene appear unnecessarily deep and far away – all of which counteracts all the effort you have made to optimize your nearest point and your stereo base while shooting. The best approach is simply to position the stereo window slightly in front of any objects that touch its sides.

Other Framing Issues

The view through a virtual stereo window is subject to the same issues as a view through a real window, although a vertical frame element crops stereo source images differently

depending on how they are registered. This difference increases the further behind the stereo window the scene is located, and causes the viewer to see the edges of the window doubled. You can prevent this from happening if you make sure that image details at both sides of the frame are exactly the same distance from the lens while shooting and you position these details on the stereo window plane during processing. This kind of "tunnel image" can be very attractive but, in the end, most subjects still have details at different depths in the center and at the edges of the frame. It is possible to manually color the image frames so that they both show exactly the same crop detail, although this produces a skewed, floating stereo window. If you simply want to distinguish a horizon from a deep, flat foreground, you can use a virtual horizontal mask like the ones produced by the *Stereomasken* freeware (www.stereomasken.de).

Cropping source images asymmetrically can help to prevent edge anomalies (also known as "retinal rivalries"), as demonstrated with *StereoPhoto Maker* elsewhere in this article. The program also includes Fuzzy Border functionality for masking irritating details, highlights or border violations that occur in only one of the two source images.

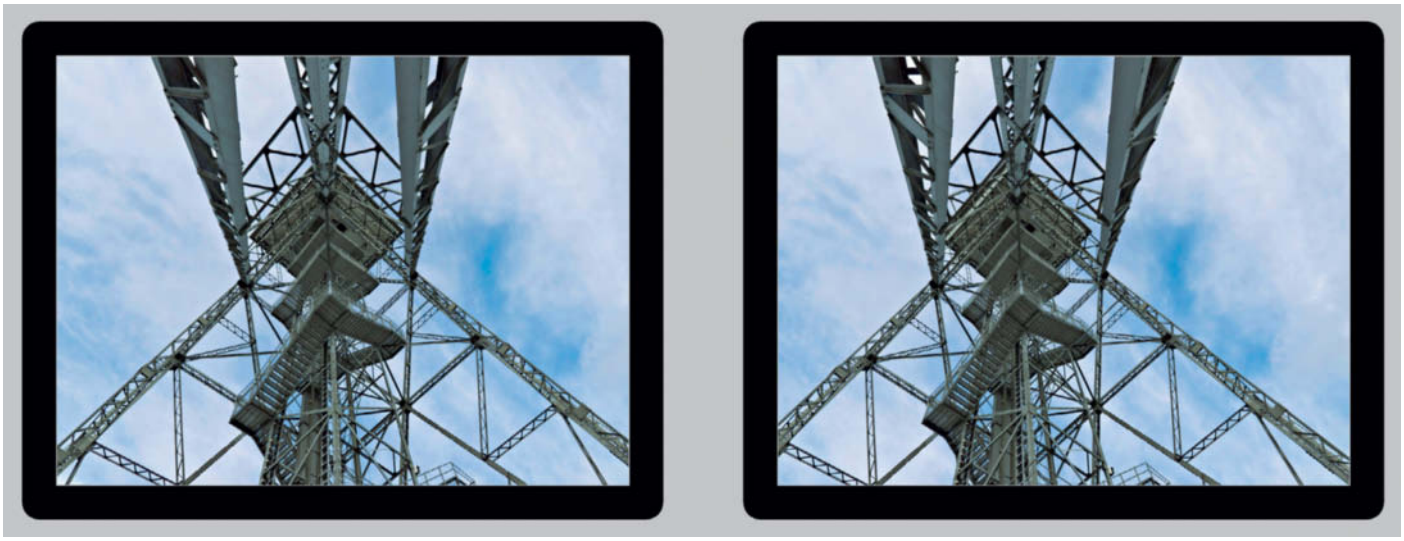
Display Tips

The most important 3D display rule only really applies if you are displaying your images on a very large monitor or a projection screen. It states that corresponding furthest points in an image pair shouldn't be projected more than 6.5 cm (2.55 inches) apart.

This measurement corresponds to the distance between our eyes and prevents exotropia (i.e. outwardly crossed eyes). In order to stick to this rule, we have to know the size of the projection in advance. The distance between corresponding furthest points increases when you zoom into an image, which means that an image that looks fine on a 21-inch monitor can lose its integrity when viewed on a 46-inch screen. We would like to see software that automatically detects the size of the projection screen and adjusts the offset between corresponding furthest points accordingly. As far as we know, no such program exists yet, so the solution is to mount your images with a built-in margin for error. If you stick to the shooting tips we explained earlier (i.e., you shoot with a maximum deviation of 1/25), you will only exceed the 6.5cm threshold value if your projection is wider than $6.5 \times 25 = 162$ cm. And remember, if the nearest point lies behind the stereo window plane, you will reach the threshold value more quickly. This means that the conditions are always met if you view your images on a conventional home computer monitor, but remember to crop your images before you align them, as zooming into already aligned images spoils the 3D effect.

Even for projections that are larger than two meters wide, you have to adhere to the 6.5 cm deviation threshold for furthest points, and shifting the projectors simply brings the stereo window closer to the viewer. It is less important if the nearest point offset is greater than 6.5 cm, as we perceive these as being in front of the projection screen, and crossing our eyes normally (i.e., inwards) doesn't cause the same visual problems that exotropia does. 3D movies use deviation limited to 1% in order to avoid overtaxing viewers in the front few rows. This is the main reason why 3D movies viewed on a home TV screen are not as spectacular as they appear on a large screen. The other reason for this effect is the proportionally greater distance between the viewer and the screen. Because of the greater proximity to the screen, the angle of parallax at which we view a widescreen movie is much greater than when we are looking at a 36-inch screen at a distance of 12 feet, which gives the 3D effect much more impact, even if we are viewing the same film.

The effectiveness of the 3D illusion depends a lot on the viewer's position. The most "natural" looking view is from the point where the camera stood. Viewed from any other position, an image will almost certainly contain perspective and depth distortion. Fortunately, the brain compensates instinctively for most of these anomalies based on its knowledge of how objects should look. Details in the surroundings that have nothing to do with the 3D image, such as the power LED on a monitor or reflections on the monitor's surface, are much more irritating for the viewer and should be avoided if possible. (keh)



Viewing this image using the cross-eye method causes the black border and the upper girders to "float" in front of the gray background. To prevent viewing irritation, floating frames like these should be at least as thick as the stereo window offset. This and other sample images are included on this issue's free DVD. c't

Martin Biebel, Ralph Altmann

3D Cameras and Lenses

Twin-lens cameras, new shooting techniques and 3D lenses make stereoscopic photography simpler than ever before. We took a look at some of the latest hardware to hit the market and tested its suitability for shooting home-made 3D content.

The popularity of 3D images has seen a huge increase since Jim Cameron's blockbuster "Avatar" hit the movie screens and proved that you no longer need a huge IMAX setup to produce a spectacular 3D viewing experience. Television manufacturers are currently redoubling their attempts to make their way into our living rooms, but the double whammy of immature technology and a lack of interesting content is still making their lives difficult. So why not give yourself a head start and shoot your own 3D photos and videos?

Stereoscopic images have been around for decades and today, thanks to digital technology, it is easier than ever to make your own, even using "normal" cameras and shooting techniques (see also our article on shooting in 3D on page 40). However, most of these techniques still involve relatively complex computer-based post-processing.

Shooting in 3D only becomes really simple if you use dedicated stereoscopic hardware. Beginners and experienced photographers alike are itching to get their hands on a high-quality but user-friendly entry ticket to the fascinating world of 3D. This article aims to give you an overview of the principles involved in 3D shooting and of some of the dedicated hardware that is already available.

The Early Bird ...

Fujifilm's FinePix Real 3D W1, introduced in 2009, was the first commercially available twin-lens 3D camera with a usable 10-megapixel sensor. This model is still popular today, and sells for as much as US$300 on eBay. Fuji's W1 and its successor, the W3, were the only cameras of this type on the market for quite a while, but Olympus has now thrown down the gauntlet by announcing a whole range of 3D-enabled compacts, and Rollei has recently introduced the Powerflex 3D twin-lens entry-level model. Sony doesn't want to miss the boat either and recently announced a 3D HD camcorder and the Bloggie 3D mini video camera, both of which use twin lenses. In spite of these advances, the consumer trend seems to be heading towards single-lens cameras with built-in software-based 3D functionality. In its 3D mode, the new Panasonic DMC-ZS10 (TZ20 in some markets) shoots a sequence of 20 photos and saves two of them – one for each eye. This principle is already used in cameras that support 3D sweep panorama functionality (see page 68).

Our Test Candidates

The Panasonic wasn't available at the time of writing, so we looked at the Sony NEX-5 with its 3D Sweep Panorama function instead. We also put the Fujifilm 3D W3, with its large monitor and HDMI 1.4 TV-out socket, through its paces.

The tiny Aiptek i2, manufactured in Taiwan, is another twin-lens camera. About as large a medium-sized cellphone, it has a minimum of features, costs about US$250 and is extremely easy to operate.

Panasonic sells the H-FT012 interchangeable 3D lens for its mirrorless Lumix range. The lens is about 2 cm thick and contains two small 12.5mm lenses located 1.5 cm apart that project two separate images onto the camera's sensor. Loreo uses the same principle of splitting the light path in its 3D Lens in a Cap products, while simultaneously broadening the stereo base using mirrors located within the device's housing. We tested all of these devices under virtually identical conditions and the results are summarized in the table at the end of this article.

Aiptek i2 3D Camcorder

In addition to its on/off button, the Aiptek i2 camcorder's interface consists of four clearly labeled buttons and a joystick. The menu system is just as simple as the controls and offers the user the options of switching between 50 and 60 fps (frames per second) and giving each clip a time stamp. All other settings are made automatically with no options for manual tweaking. We would like to have been able to adjust at least white balance manually, especially as our test model produced obvious blue color casts in outdoor clips. The other obvious drawback is the size of the twin 1/2.5" sensors, which quickly begin to produce noisy footage as soon as the strength of the ambient light dips below 200 lux.

The camcorder doesn't divulge which ISO and shutter speed settings it is using, and the fixed-focus lenses have a single aperture setting of f3.0, which reproduces everything between one meter away and infinity in sharp focus. Our test revealed that objects as close as 50 cm were also in adequate focus. The focal length of the lenses is 43 mm (equivalent), and the unit has a 4x digital zoom that reduces the quality of any zoomed footage accordingly.

In 2D mode, the right-hand sensor records five-megapixel photos (2592×1944 pixels) or 720p HD videos at 1280×720 pixels. Strangely, the camera splits this resolution between both sensors in 3D mode, although the second sensor actually has the capacity to record a separate high-resolution image. Stereoscopic stills are recorded in compressed side-by-side JPEG format and videos as MP4s, giving photos an effective horizontal resolution of just 1296 pixels – which is not enough to produce adequately sharp images on a 1920×1080-pixel HD TV.

The 4cm stereo base represent more than half the distance between the viewer's eyes and works well for snapshots. Many of our test photos were comfortable to view, even if the background appeared more two-dimensional than it did in the shots we made using the Fujifilm W3 or the larger Loreo. Unfortunately, the Aiptek produces images with unnaturally high contrast and obvious zig-zag patterns in diagonal lines. The lack of a deflicker function means that clips shot under gas discharge lamps or viewed on high-frequency monitors are marred by flicker stripes.

The Aiptek i2's monitor is designed for 3D viewing, but the camera itself produces only average quality stereoscopic video clips

The Fujifilm Real 3D W3 captures separate left and right-hand images using twin sensors and merges them in-camera into a single 3D image. The 7.5cm stereo base is slightly wider than the distance between an average person's eyes.

The Fujifilm W3's wide stereo base delivers effective 3D images of close and distant subjects.

The monitor measures 6 cm diagonally and has a resolution of 480×240 pixels. It is covered with a striped plastic gel that uses the parallax barrier technique to enable 3D viewing without the use of glasses. The horizontal resolution is reduced by half in 3D mode, giving a total effective resolution of 57,600 pixels. This level of monitor quality makes it difficult to judge 3D effects adequately before shooting.

The i2's big plus is its live view HDMI socket – a feature we would like to see in more digital cameras. This allows you to view a real-time 3D live view on any 3D-compatible monitor. The downside of the fully automatic control system is that it powers down automatically after three minutes. A pair of 3D glasses for viewing images on 2D monitors is included with the package, but you have to convert your photos and clips to the appropriate anaglyph format using the software provided first.

There is a built-in fold-out USB plug for transferring image data to your computer and charging the unit's battery, so you don't have to carry a separate charger. The 128 MB of built-in memory is enough to get started and you can use SD cards (up to 32 GB) to expand your shooting capacity.

All in all, the i2 incorporates a lot of good ideas, but delivers only limited quality results. It is great as a fun camera to keep in your pocket for shooting YouTube or flickr material, but it is too expensive for what it provides, and you are probably better off spending a little more if you are serious about shooting in 3D.

Fujifilm FinePix Real 3D W3

The W3 is only slightly larger than the Aiptek i2, but weighs almost twice as much, giving an indication of its more complex inner workings. It is also twice as expensive! The 7.5cm stereo base is wide enough to produce convincing 3D effects in central background objects. The 3.5-inch monitor works on the lenticular principle and displays 3D images with an effective resolution of 190,000 pixels (2D images are displayed at double this resolution). The 3D effect is thus clearly and comfortably visible in-camera.

The twin internal-focus lenses cover an equivalent focal length range of 35-105 mm and the twin 1/2.3" sensors capture 4:3 images at 10 megapixels (other aspect ratios capture slightly less). There are no differences between 3D and 2D capture modes. Aperture, shutter speed, exposure correction, ISO speed and all other important settings can be controlled automatically or manually via the rather unwieldy menu system. The camera is also capable of simultaneously taking two 2D images with different zoom, color or ISO settings.

The closest wide-angle subject distance is 60 cm (or 8 cm in macro mode). At close macro distances, 3D no longer works because the subject is no longer located within the area of overlap between the lenses' twin fields of view. The manufacturer recommends distances between 30 and 70 cm for taking 3D close-ups, and a red icon lights up on the monitor if you get too close or accidentally cover one of the lenses with your finger. If you are photographing outdoor scenes that include the horizon, make sure that the nearest point in your subject is at least 1.3 m away (for wide-angle shots) or 4.1 m (for telephoto shots).

In Advanced 3D mode, the W3 is capable of taking 3D images using two offset images shot with the left-hand lens alone at a preset interval of between 0.5 and 10 seconds. This helps with framing for fast-moving subjects or if you are shooting from a moving train or aircraft.

In Individual Shutter 3D mode, the photographer shifts the camera manually between shots to create the desired stereo base (see our article on 3D shooting on page 42). This way, you can create stereo bases that range between just a few millimeters (for macro shots at very close distances) to many meters. The only precondition for taking this type of photo is that your subject doesn't move between shots. The monitor displays a translucent version of your first shot to help you frame the second and preserves your selected exposure settings automatically. You cannot make any manual settings or expo-

sure corrections in Advanced 3D mode and the camera doesn't make any automatic corrections to the vertical image position, in spite of the errors that almost always creep into the process when you are shooting handheld. The solution here is to use either *StereoPhoto Maker* or the *MyFinePix Studio* software included with the camera to fine-tune your images later.

The W3's default settings automatically align the source images horizontally (a function Fuji calls Auto Parallax Control), which you can switch off if you want to align your images manually using the dedicated parallax control button on the top of the camera body. The button allows you to shift the 3D effect in your image relative to the edges of the monitor, giving you the ability to make parts of your subject project out from the monitor surface or to shift your image backward to counteract window violations. You can save the settings you have made via the playback menu, but images processed this way can no longer be viewed on a conventional 3D TV.

The W3 saves stereoscopic photos in the MPO (Multi Picture Object) format and you can set it up to save an additional 2D JPEG version of each shot. MPO is supported by a wide range of programs and devices. With the exception of the manual adjustment case mentioned above, our Panasonic Viera TX-P50VT20 3D TV had no problems handling the format, and we even manged to play back MPO images on a PlayStation 3. The W3 can capture HD video at a maximum resolution of 1280×720 pixels and saves clips in3D-AVI format.

Panasonic 3D Lumix G Lens

The fascinating concept of shooting 3D images with a single shot from a single camera took a step nearer reality with the introduction of the H-FT012, which Panasonic claims is the world's first 3D interchangeable lens. It is designed to fit Micro Four Thirds mount lenses and we tested it on a 12-megapixel Lumix G2, which we reckoned was powerful enough to capture twin high-resolution stereoscopic source images.

The lens incorporates two mini-lenses that project two side-by-side stereo source images onto the camera's sensor. The G2's 13 x 17.3 mm sensor is slightly smaller than an APS-C model. Transforming two portrait format source images into a single 3D landscape image only uses a small portion of the sensor's total surface area. Depending on the aspect ratio you select (1:1 , 4:3, 3:2 or 16:9), the resolution of the finished 3D image ends up being about two megapixels at a maximum width of 1600 pixels. This means that a 1600 x 1200-pixel 4:3 image just about fits into the resolution of our Panasonic Full HD TV. The 1:1 format, with its 1440×1440 pixels, makes the most effective use of the sensor area. The Lumix G2H, which also supports the 3D lens, produces 3D images with a slightly higher maximum resolution of 2.7 megapixels.

The H-FT012 has an equivalent focal length of 65 mm and a close focus distance of 60 cm. It has a fixed aperture setting of f12 that reproduces everything between the nearest point and infinity in sharp focus. Nearly all the camera's manual settings are deactivated once the lens is attached to the camera, with Program Shift being the only exception.

The distance between the mini-lenses, and therefore the stereo base, is just 1.5 cm, which is sufficient for shooting relatively close subjects such as people, but doesn't produce worthwhile 3D effects for buildings shot at normal sightseeing distances. The illusion of depth disappears for objects that are just a few meters away. Such a narrow stereo base is, theoretically, ideal for shooting close-up and macro 3D photos, but this idea fails due to the 60cm close focus distance. The laws of 3D optics simply make it impossible to produce enough depth at distances close enough to the camera (see the *Shooting Rules* box on page 59).

3D Test Shots on DVD

The test/comparison images we made with the cameras and lenses described in this article are included on this issue's free DVD. These are mostly the original side-by-side JPEG or MPO files. All of these images can be viewed and manipulated using the *StereoPhoto Maker* software or viewed on most 3D TVs.

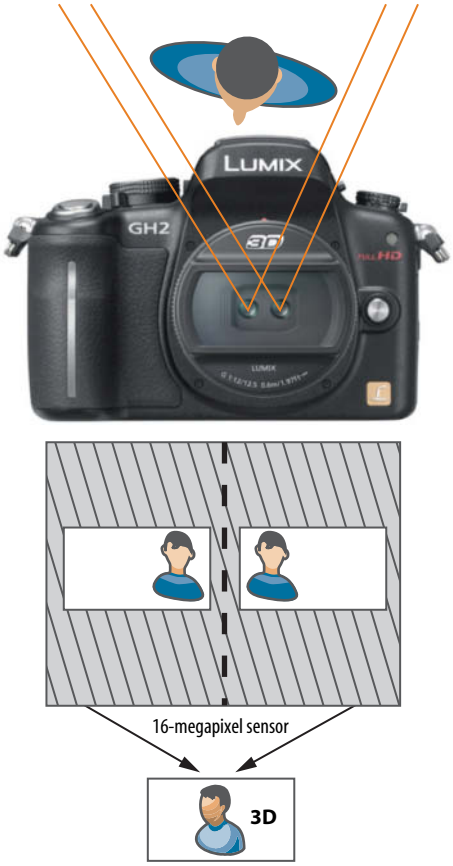
We shot test images from close up (about 3 m from the nearest point) as well as from further away to produce frame-filling results. We kept the distance to the mill sails constant for the close-up shots, which accounts for the variations in framing of the close-up shots.

We used a Canon EOS 550D/Rebel T2i to shoot the Loreo Lens in a Cap shots. The two stereo base measurements used in the Loreo shots can be identified by the numbers "6" and "9" in the filenames. We used the shortest available setting for devices with variable focal length, and we also took test shots at two different telephoto focal lengths using the Fuji W3. In this case, the "mm" numbers in the filenames represent the focal length setting we used.

There are two variants for each of the sweep panoramas we made using the Sony NEX-5: we shot one with our arms bent (the "normal" way to hold a camera) and one with our arms outstretched.

We used *StereoPhoto Maker* to deskew and align the anamorphically distorted original images we captured using the Aiptek i2, so you can view the images without having to do any further processing.

These windmills are the subject of the 3D test/comparison images included on this issue's free DVD



A schematic illustration of the principle of twin-lens 3D photography. Two 16:9, 2:3, 4:3 or 1:1 format images are cropped from the two wide-angle, portrait-format shots that are projected onto the sensor by the lenses.

Panasonic introduced the world's first interchangeable 3D accessory lens in early 2011. The H-FT012 costs about US$230 and is designed to fit the Micro Four Thirds bayonet.

The camera's monitor displays only the left-hand source image, making it impossible to judge your results until you have transferred your images to a computer. We would have liked to see at least an anaglyph in-camera display option.

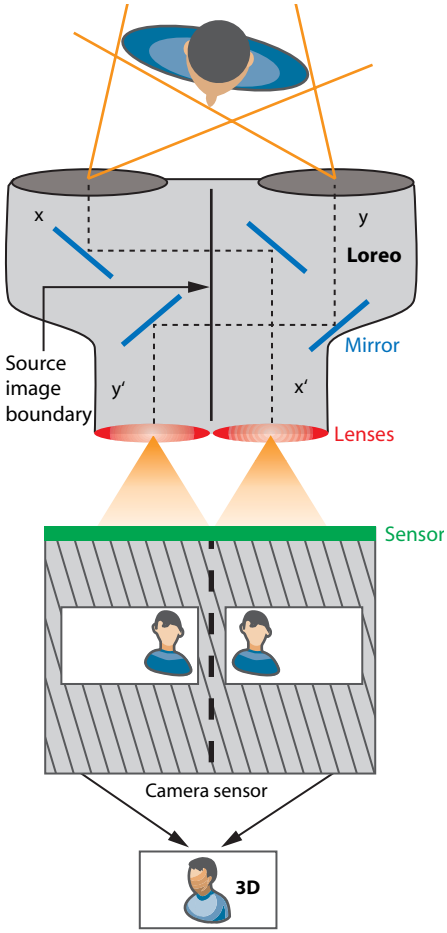
Video mode is deactivated by default when you attach the 3D lens, but you can work around this by covering the 4th and 5th pins (from the left) on the lens bayonet with a small piece of sticky tape, switching the *Shoot w/o Lens* option to ON and switching Intelligent Auto mode off. You can now use your "customized" lens with the Lumix G2 and even with the AF100 pro camcorder. With the modded lens, the monitor displays a double image exactly like the one formed on the sensor.

Used with the Lumix G2H, the lens also produces a maximum horizontal resolution of 720 pixels. Video mode causes its own reduction in resolution, and the source images have to be cropped from an original image with a total width of 1920 pixels (or from 1280 pixels in the G2, which isn't HD-compatible). The lens makes it easy to create interesting 3D videos, and a quick search for "3D" on YouTube reveals a wealth of great examples.

If you cover the 4th and 5th pins on the bayonet of the Panasonic 3D lens with sticky tape, the camera saves the resulting double images as they appear on the sensor

Loreo 9005 and Lens in a Cap

The Loreo lenses we tested work on the same principle as the H-FT012, but use four internal mirrors to lengthen the stereo base and work around the close focus restrictions that plague the Panasonic. We tested two models



How Loreo lenses work: the light path entering each lens is twice reflected through 90 degrees while keeping the length of both paths precisely equal. The left-hand side of the image passes through the right-hand lens and the right-hand side of the image through the left-hand lens. The second mirror in the Y light path is also used to split the sensor area into two. Because this mirror is actually located very close to the rear lenses, the overlap area between the two images appears blurred.

The Loreo Lens in a Cap gives many DSLRs 3D functionality. The larger model shown here costs US$150 and its smaller predecessor US$120.

with Canon bayonets, but Loreo also produces models that fit APS-C, full-frame and Four Thirds cameras from most popular manufacturers. Make sure you select the right model for your particular sensor format – an APS-C model won't fully use the surface area of a full-frame sensor, and a full-frame model is likely to produce insufficient image overlap if you use it with a small-sensor camera.

The Loreo lenses have no electronic contacts and thus cannot be recognized by modern DSLRs, which only allow you to shoot in manual mode with a Loreo attached. This was the case with our EOS 40D and 550D/Rebel T2i test cameras. Live view mode is an advantage when using these lenses, as it allows you to perform a rudimentary exposure check on the camera's monitor. Otherwise, you will have to rely on the meter readout in the viewfinder or on test shots and histograms to help you judge your shots.

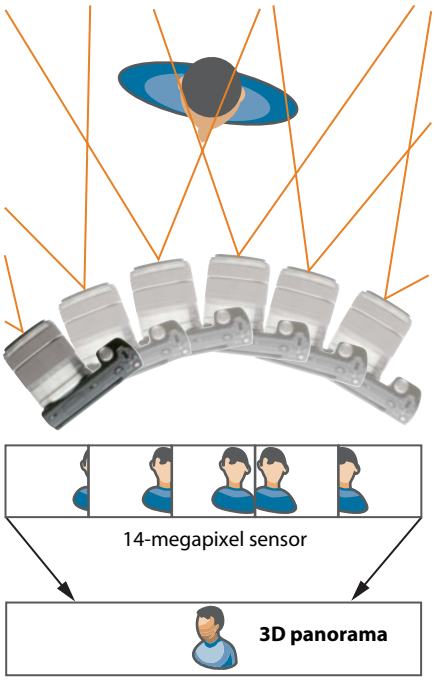
The larger Loreo has a 90mm stereo base and an equivalent focal length of 40 mm, which produced a 64 mm equivalent focal length on our test camera. The aperture can be manually set to f11, f16 or f22. There is also a mechanical focus lever which shifts one of the internal mirrors and thus the degree of convergence of the lenses. The optical axes of the lenses are parallel at their "infinity" setting, whereas they converge significantly at the minimum focus distance of 1.5 m. This feature, known as parallax compensation, is designed to keep the subject within the field of view of both lenses. Information on the Loreo website states that this mechanism can lead to a reduction in the depth of the 3D effect in your images, but this is not strictly true, due to the very slight degree to which the mechanism reduces the stereo base.

A wide stereo base is an advantage if you want to photograph landscapes or cityscapes, but the relatively long focal length (for small-sensor cameras) is actually a disadvantage, as moving back to get the whole subject into the frame reduces the depth of the 3D effect. The stereo base is almost too large for a close focus distance of 1.5 m, and you will only be able to include background detail in an image if it is less than 3 m away. If you want to include the horizon in your image, you should select an aperture of f11 and a distance setting of 5 m while making sure that you don't photograph any details that are closer than 2.8 m away.

The smaller Loreo Lens in a Cap model is better suited for photographing a wide range of subjects, thanks to its 60mm stereo base. This model has a 35mm focal length coupled with f11 and f16 aperture settings and a close focus distance of 1.5 meters. Loreo also manufactures a dedicated (APS-C) macro model called the 9006, which has a 20mm stereo base and an equivalent focal length of 60 mm that focuses sharply to between 23 and 85 cm. The plastic lenses offer fair image quality and sharpness but still bely their origins in the market for cheap 3D postcard viewers.

The Loreo system captures two portrait format images, but doesn't crop them to landscape format by default the way Panasonic's technology does. You can, of course, crop Loreo source images to landscape format, but you will lose a lot of image data in the process. The format of a stereoscopic image depends largely on the maximum resolution of your camera's sensor. Photos taken with the 10-megapixel Canon EOS 40D, with its 3888-pixel sensor width, can still fill the 1920-pixel width of a Full HD screen if you

The exterior of Sony's NEX-5 gives no hint of its built-in 3D capability, although the 3D sweep functionality actually works very well. The current price for the camera and 18-55mm kit lens is about US$700.

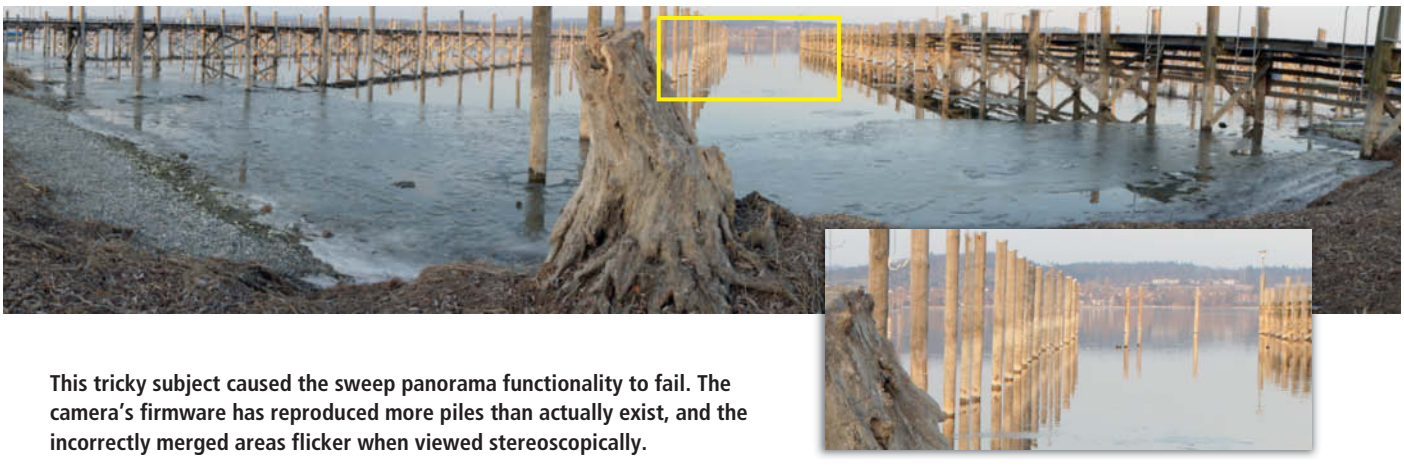


How 3D sweep panoramas work: Keeping the angle of rotation between the individual shots in a sequence as narrow as possible reduces the breadth of each image "strip" and keeps the parallax errors between shots to a minimum. A 3D sweep panorama is constructed by merging the far left- and right-hand edges of each wide-angle image into two separate 3D source panoramas. The resulting parallax then creates a 3D offset and a corresponding depth effect.

keep cropping to a minimum. You will often have to crop a little more than this to remove the blurred overlap between the source images, although the Loreo lenses generally produce only slight vignetting effects. Last but not least, the Loreo lenses can be used to shoot 3D video with any camera that has a video mode.

Sony 3D Panoramas

For Sony, 3D functionality is a simple byproduct of its already well-known Sweep Panorama technology (see also the box on page 46). Depending on you camera's firmware version, you may have to perform an update to get this functionality working. The camera's virtual shooting mode dial will then include the 3D Sweep Panorama function. The sweep direction and capture format have to be set elsewhere within the menu system. The NEX-5 offers Wide (7152×1080), Standard (4912×1080) and 16:9 (1920×1080) panorama formats. The 16:9 option represents the exact size of a Full HD frame – a further format that the camera supports. However, Sweep Panorama mode uses the camera's 7 fps continuous shooting mode rather than video mode to capture a scene. This is clearly audible in the repeated sound of the shutter opening and closing. Using Wide format and the 16mm lens captures a panorama that covers an angle of view of more than 220 degrees, but you still have to rotate the camera through 180 degrees or more to create a 16:9 panorama using the same lens. The sweep technique makes it difficult to capture a specific subject by pointing and shooting the



This tricky subject caused the sweep panorama functionality to fail. The camera's firmware has reproduced more piles than actually exist, and the incorrectly merged areas flicker when viewed stereoscopically.

way you can with still photos, and is not at all suitable for shooting videos either.

The plus side of the idea is that it lets you use any camera-compatible lenses at all of their zoom settings while shooting in 3D. The longer the lens you use, the more advisable it is to use a tripod, as even slight shakes can cause image errors or even a function crash. The camera selects exposure values automatically in 3D mode, but allows the user to set compensation values of ±2EV. The program always sets the shortest possible shutter speed, so always try to shoot in bright situations to prevent it selecting too wide an aperture. Otherwise, the camera-controlled depth of field will be too shallow.

The stereo base and the corresponding depth effect depend directly on the radius of your sweep, so you can influence the effect you create by shooting either with outstretched arms (with a stereo base between 4 and 5 cm) or with the camera close to your body. The latter method reduces the stereo base the same way as increasing the focal length does, because it reduces the offset between the individual image strips that are later merged to become the stereo image.

Slow sweeps are preferable to moving the camera too fast, which creates narrow image strips. However, if you move the camera too slowly, the function can fail in the middle of a sweep and leave the rest of the image black. Any black portions of an incomplete panorama can easily be cropped, and aren't displayed at all if you use a PlayStation 3 to view your image. Wide panoramas are generally unsuitable for viewing on a TV, as they are always displayed at full width and end up looking like a very thin stripe on an overly large black background.

In contrast, viewing a panorama on the PlayStation is a real event. The device automatically zooms into the image and, starting at the left-hand end, pans through the entire panorama at frame-filling resolution. You can even use the joystick to control the direction of pan and the magnification. Sony 3D sweep panoramas are not nearly as sharp as those produced by the Fujifilm W3 or the Lumix lens. This is due on the one hand to the relatively low vertical resolution of 1080 pixels and on the other to the motion blur that is inherent in the sweep process.

Conclusions

The only "serious" 3D camera we tested was the Fujifilm FinePix Real 3D W3, with its wide stereo base, close and distant capture capability and croppable 10 megapixel sensor resolution. The W3's monitor produces usable 3D previews, but is rather prone to the negative effects of stray light. The downside of this model is its relatively basic 2D functionality, especially when compared with pure 2D cameras in the same price class.

If you simply want to display your 3D images as a slideshow or a Web gallery withou t processing them first, we recommend that you use a 2D camera with a twin accessory lens. In spite of their plastic lenses, the stereo effects produced by the Loreo devices are far superior to the Lumix results. The Loreos have the added advantage of being available for a wide range of cameras, whereas the Lumix lens only fits two or three specific Panasonic models.

Sony's 3D Sweep Panorama function is great for experimenting with, but requires several attempts before you can be sure of getting acceptable results. The technique is not at all suitable for snapshots, which is where the Aiptek i2 steps in, even if the image quality it produces isn't necessarily commensurate with its price. None of the solutions we tested was really persuasive, especially when it comes to producing convincing depth effects at varying subject distances. As a next step, we would like to see cameras with an adjustable stereo base. (pen)

3D Cameras and Lenses

Model	i2 3D Camcorder	Finepix Real 3D W3	3D Lumix G Lens H-FT012	Lens in a Cap 9005	Lens in a Cap 9004	3D SweepPanorama (NEX-5)
Manufacturer	Aiptek	Fujifilm	Panasonic	Loreo	Loreo	Sony
Website	www.aiptek3D.com	www.fujifilm.com	www.panasonic.com	www.loreo.com	www.loreo.com	www.sony.com
Type	Stereo camera/camcorder	Stereo camera	Stereo lens	Stereo lens	Stereo lens	Firmware tool
Sensor	2 × 1/3.2" CMOS	2 × 1/2.3" CCD	Micro Four Thirds (G2)	– [1)]	– [1)]	APS-C (NEX-5)
Effective resolution	5 megapixels	10.17 megapixels	12.1 megapixels (G2)	– [1)]	– [1)]	14.2 megapixels (NEX-5)
Maximum Resolution	2592 × 1944	3648 × 2736	–	– [1)]	– [1)]	4592 × 3056
3D photo resolution	1296 × 1944 (compressed)	3648 × 2736	1448 × 1448 (on a G2)	– [1)]	– [1)]	1920 × 1080 (16:9)
3D video resolution	1280 × 720	HD 1280, 640, 320	–	– [1)]	– [1)]	–
Image formats	3:2	4:3, 3:2, 16:9	1:1, 4:3, 3:2, 16:9 (G2)	– [1)]	– [1)]	Wide, Standard, 16:9
Lens	2x fixed focus	2x Fujinon zoom	2x fixed focus	2x	2x	User selected
Stereo base	40 mm	75 mm	15 mm	90 mm	60 mm	Variable
Focal length (35mm equiv.)	43 mm	35-105 mm	65 mm	~40 mm (depends on camera)	~40 mm (depends on camera)	Depends on lens being used
Aperture	f3	f3.7, f5, f8 (wide-angle)	f12	f11, f16, f21	f/11, f/16	Automatic
Manual settings	–	✓	–	depends on camera model	dpends on camera model	–
Close focus	1 m	60 cm (8 cm in macro mode)	60 cm	1.5 m	1.5 m	Depends on lens being used
3D monitor resolution (pixels)	2.4" / 480 × 240 lenticular	3.5" / 382,000 lenticular	–	–	–	–
3D photo format	JPG side-by-side	MPO	MPO	side-by-side[1]	side-by-side[1]	MPO
3D video format	MP4	3D-AVI	–	side-by-side[1]	side-by-side[1]	–
Interfaces	USB, HDMI	USB, HDMI, A/V out	USB, HDMI, A/V out (G2, G2H)	– [1]	– [1]	USB, HDMI (NEX-5)
Other features	–	Interval 3D Shooting mode Individual Shutter 3D mode	–	–	–	–
Price (approx.)	US$250	US$340	US$235	US$150	US$120	US$700 (NEX-5)

[1] depends on camera model ✓ included – not included

Jan-Keno Janssen

3D Monitors and Projectors

Your 3D photos are in the bag and you've already given them some finishing touches on your computer – so how do you display them to the waiting world? This article will guide you through the huge (and possibly confusing) range of available 3D output devices.

However well your latest 3D snapshot turned out, the "Wow!" effect will quickly disappear if you view it using a pair of cardboard 3D glasses. The "anaglyph" process that these glasses were designed for used to be the only simple way to view images in 3D. Now, the 3D boom has just about every part of the entertainment industry firmly in its grip, and there are huge numbers of consumer 3D viewing devices available. Most 3D photographers find this situation confusing, as virtually all manufacturers concentrate on producing devices for projecting moving 3D images, in spite of the fact that most of these devices can be used to display 3D photos too.

The simplest way to display 3D photos is using a Windows PC and a 3D monitor or projector. The 3D Vision*TM technology developed by Nvidia has become fairly standard in the last two years, although this proprietary system only works with Nvidia's own graphics cards and 3D glasses. The advantage of this complete system is that it allows you to get instant results without having to install drivers or tweak your equipment first. The system requires a GeForce graphics card and a "3D Vision Kit" comprising wireless active shutter glasses, an infrared transmitter that connects to your PC via USB and a software package. The transmitter synchronizes the glasses and the display unit. Your monitor or projector has to support at least 120 Hz and should be 3D Vision-ready so that the driver can adapt to the device's latency and switching speed characteristics. The Nvidia driver supports all Direct3D content, including games, and includess software that is compatible with 3D Blu-ray discs and photos.

Passive, side-by-side 3D TVs like this LG 47LD950 have lower resolution than active shutter models, but work with glasses that are much cheaper and lighter

3D on a Computer

The world's other major graphics cad manufacturer, AMD, ignored 3D developments until recently and has only just started to gain a foothold in the market. At the time of writing, the ViewSonic V3D241wm was the only AMD 3D-certified monitor available, but there are a number of compatible projectors already on the market. Most DLP-based projectors are capable of displaying 120 Hz signals, whereby the active shutter glasses are synchronized with the image using an intermittent white frame that is transmitted with the images at a frequency that is invisible to the human eye. This signal is interpreted by a photodiode built into the glasses.

The basic principle is the same for all the systems mentioned: the display/projector produces left and right eye images one after the other and the shutter glasses synchronize the darkening of the matching lens 120 times per second.

Living Room 3D

Current home entertainment technology is also largely based on active shutter techniques. However, while computer monitors and projectors expect left/right images that alternate at 120 Hz, many living room devices use the alternative HDMI 1.4a specification. This standard allows three different types of 3D signal transmission, the most popular of which is the original "frame packing" format, which transmits both left and right eye images together in a double bandwidth

The Nvidia 3D Vision system (shown here with a compatible Samsung monitor) has become the de facto standard for 3D computer imaging. The system's active shutter glasses are synchronized using a separate USB transmitter.

"mega-frame". The standard also allows for transmission of right/left images that are compressed either above or beside one another at standard 2D resolution. These two formats are called either "over/under" or "side-by-side", depending on the orientation of the two sub-frames. This technique halves the resolution of the complete 3D image, but allows the use of older 2D media players.

Viewing Photos in 3D

A similar side-by-side format has become established in the field of modern 3D (or "stereoscopic") imaging, in which the left- and right-hand images are stored next to each other in a single JPEG image file. These files are often named using the JPS ("S" for "Stereoscopic") filename extension. JPS 3D images can be composed of two source images of any size, whereas HDMI 1.4a source images have to be compressed to fit into a standard-sized video frame (see the examples on the following page).

The format is less relevant if you want to view your 3D images using a compatible computer monitor or projector, as the accompanying software ensures that your output is compatible with your hardware. One example of such software is the popular *StereoPhoto Maker* freeware. The program has a somewhat cryptic user interface, but is capable of providing 3D monitors with appropriate input via Nvidia or AMD graphics cards using the *Page-flip for 3D Shutter Glasses* option in the Stereo menu. Make sure that you have first selected either Win3D (for AMD) or 3D Vision (for Nvidia) in the Stereo > Page-flip Setup dialog.

The more user-friendly *Stereoscopic Player* displays your photos in 3D simply by selecting Software Pageflipping (for AMD) or Nvidia 3D Vision (for Nvidia) in the Viewing Method section of the View menu.

In addition to JPS files, both programs also support single left/right images as well as the MPO ("Multi Picture Object") format used by some 3D cameras, which is, in fact, a container for multiple JPEG images. MPO files that are renamed to JPG are handled as conventional image files and the additional images within the container are simply ignored.

3D TV

3D images are more spectacular when viewed on a large, 3D TV instead of on a computer monitor, and the simplest way to achieve this is to link your computer directly to your TV. Nvidia graphics cards and both programs mentioned above are capable of displaying 3D photos using the frame packing HDMI 1.4 format without sacrificing resolution. The necessary driver – called *3DTV Play* – costs US$39.99 and can be purchased directly from the Nvidia website. If you already own a 3D Vision kit, the driver functionality is included for free. Used this way, the infrared transmitter acts as a copy protection dongle. The latest AMD HD 6000 series graphics cards also support HDMI 1.4, although at the time of writing, we were unable to test whether this functionality supports 3D photo output too.

If you are happy with half the maximum possible resolution, you can display 3D images using conventional graphics cards and without having to install any drivers. If the

The Acer H5360 projector doesn't offer Full HD resolution but does provide high-quality 3D output

image you want to display is stored in compressed form, all you have to do is use appropriate software and switch your TV or projector to "side-by-side" mode. The simplest package to use is *Stereoscopic Player*. To display images in side-by-side mode, simply select View > View Method > Side-by-Side, and File > Aspect Ratio > Default, Half Height.

If you don't want to display your images on a computer, you can save them as compressed 1920 x 1080-pixel JPGs on a USB stick – a process that can even be automated in *Photoshop*. These images can then be played back using a simple media player, such as the popular WD TV or any Blu-ray player. Many contemporary TVs have USB-sockets, but not all of these support 3D playback. Most Samsung 3D TVs do support this feature and Panasonic 3D plasma TVs can even read MPO files direct from USB.

The Future

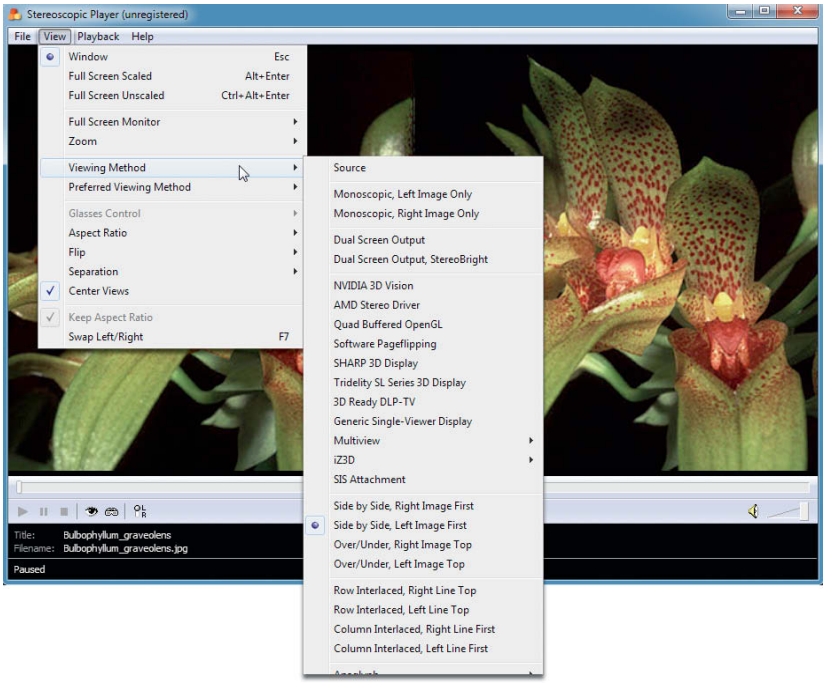
Nearly all current 3D display devices use active shutter technology. Shutter glasses are expensive (US$100 and more), heavy, often uncomfortable and usually only compatible with hardware from the same manufacturer. Perhaps most importantly many 3D TVs and monitors have problems with ghosting if the left and right-hand images are not properly separated. In extreme cases, this can completely spoil the 3D effect and you simply end up "seeing double". Some plasma TVs, as well as DLP and LCoS projectors, provide better channel splitting, but produce darker images as a result.

Manufacturers such as LG, Philips and Toshiba are promising to invest more in passive, polarized 3D technology. Here, the glasses are lighter than active shutter models and cheap enough for you to order a dozen for a 3D photo evening with friends. LG's US$1,300 47-inch 47LD950 TV uses polarizer technology, and Zalman and Hyundai already manufacture and sell 3D computer monitors that work on the same principle. The greatest disadvantage of this display method is that only half of the monitor's resolution is available to the left and right-hand images. If you display a 3D image on a 1920 x 1080-pixel monitor, only 1920 x 540 pixels are available to each source image. Nevertheless, many people find that polarizer glasses make for a more pleasant 3D viewing experience than shutter glasses. We recommend that you try out both before making a purchase.

Technology is already being developed that displays stereoscopic images without the use of additional glasses but, until it is sufficiently well developed for commercial use, 3D glasses are here to stay! (jkj)

The left-hand and right-hand images used by conventional side-by-side formats (such as JPS) are displayed undistorted and at full resolution

HDMI 1.4a-compatible TVs and projectors use compressed side-by-side images. This technique provides images with only half their potential resolution but which can be displayed using conventional 2D media players.



The extremely practical *Stereoscopic Player* software recognizes all popular 3D formats and can display them on a wide range of output devices

André Kramer

Photo Apps

for Android and the iPhone

A quick snap taken on your smartphone gives you no time to edit your image before you upload it to the Web, right? Wrong! Smartphones are powerful computers, and there are increasing numbers of apps out there that transform them into versatile image creation machines – from shooting and editing right up to applying special effects and uploading the results to the Internet.

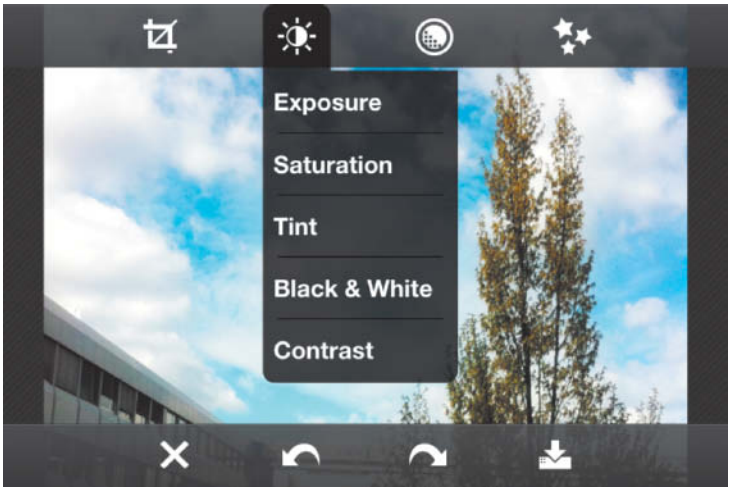
The PC as the central node of our digital lives is already a thing of the past. Sure, we still use DSLRs to capture high-quality photos of important events, but the complex process of shooting, downloading and processing images on a computer is simply too much work for a snapshot taken at a party or an object found while out on a walk. The "cloud" generation has discovered fast food photos and instant uploads to Facebook, Twitter and the like.

As yet, neither the iPhone nor Android-based smartphones offer image processing and upload software as standard, and their camera apps are only really good for saving the data captured by the sensor as a JPEG file. But photo apps are beginning to fill the gaps, offering extra functionality for shooting, enhancing and uploading your snaps. You can, of course, still upload your images using a Web front end in your smartphone's browser, but this is a task that often requires patience and very small fingers.

The range of apps on offer is enormous, with Apple's App Store alone listing 2,200 entries in the "Photography" category. The younger Android Market offers 500 different titles, although some of these are little more than just photos of Asian girls.

We took a look at a selection of apps which we selected based on the number of downloads and the quality of the feedback they had received, although for the specialized tools we checked out, we were more interested in the quality of the implementation.

BeFunky **isn't really a serious image editing tool, but still includes some cool effects**



Photoshop Express **uses gestures to manipulate brightness, saturation and contrast, as well as to rotate and crop the results**

One thing is for certain: the sheer variety of apps available makes it impossible to list all of the ones that are either well made or simply a lot of fun.

Cross-platform Compatibility

Although the Android and iOS ecosystems are largely autonomous, many apps are available for both. These don't actually control the camera and are designed purely for editing and uploading images.

Photos shot using camera phones are often flat-looking, badly cropped and lacking in contrast. Most photo apps seem to combat these drawbacks by offering a couple of correction tools and a whole load of filters to pep up the look of an image or convert it to black and white.

Adobe's *Photoshop Express* app is dedicated purely to image processing, with tools for correcting exposure, saturation, brightness and contrast. It can also convert photos to black and white or tone them with just about any color you like with a single tap. Apart from the Black & White tool, which offers no options, effects are applied by selecting a tool and swiping from left to right across all or just part of the screen. The screen itself serves simultaneously as preview window and adjustment slider, and you can confirm or discard your changes when you're done. If you are not happy with your results, a tap on the Undo button moves you back a step.

The Rotate and Crop functions do what they're meant to, and it is quick and easy to use gestures to straighten a photo that has ended up at a tilt. You can also choose to lock the aspect ratio while cropping.

You can select effects such as soft focus or vintage tints, and there is also a range of simple, versatile frames on offer. Adobe now offers in-app upgrades for a small additional fee. For example, the Camera Pack includes a self-timer and a noise reduction tool and costs US$1.99. The app uploads your photos to Photoshop.com (where every user has access to up to 2 GB of webspace), or to Facebook or TwitPic.

The mobile implementation of the *BeFunky* cloud application offers many more filters than genuine image editing tools. You can use *BeFunky* to adjust brightness, contrast, tone and saturation, as well as to rotate and crop your images (albeit without locking the aspect ratio). The app also includes a range of gaudy retro filter effects with strong vignetting and a number of really effective black-and-white variations. And to cap it all, you can add a Polaroid-style frame or stamp-like perforations to your finished image and upload it to Facebook or Flickr.

Camera Illusion applies the effect you select in real time, enabling you to judge the effect it will have on a scene before shooting. The app uses a dice icon to randomly toggle through its preset filters, and you can manually combine effects such as Chalk Board or Sepia with borders and distortion effects. The filters on offer are a mixed bunch and, while some are just plain clunky, others, such as ASCII Art, are really clever.

One-trick Ponies

Many apps do just one thing. For example, *Color FX* converts a photo to black and white and then lets you use gestures to recolor selected details. One example we liked was a bright yellow oilskin jacket recolored against

its newly monochromed background. You can use either the original color or freely selectable tones that you then add to your image using a mask.

Pro HDR creates HDR images in iOS or Android devices in either automatic or manual mode. In manual mode, you use the camera preview to select bright and dark areas in your scene. The app then captures two photos exposed accordingly, aligns them and opens a simple tone mapping dialog. In automatic mode, the app regulates the exposure of the two originals itself. You can then select saturation, contrast, brightness, warmth and tint settings before the app merges your source images. The results are not quite like the HDR images you may be used to, but are nonetheless usable. The free version of the program saves images at VGA resolution and includes a program watermark in the finished photo.

PixelPipe is designed to simplify media uploads to the Web. Once you have registered your account details, all you have to do is add your login data for Dropbox, Facebook, Flickr, Foursquare, Picasa, Snapfish, TwitPic, Twitter, Facebook or any of the dozens of supported services. In Android, the app interfaces directly with the camera app, and allows you to upload an image with a single tap. Your smartphone does everything else automatically while your friends are busy starting up their Facebook apps.

iPhone Apps

Just like Android, iOS controls photo and video recording, as well as switching between front and rear cameras and flash usage. However, in spite of all their automatic functionality, smartphone cameras are far from perfect. Photos often turn out too dark or blurred, while the size and weight of the device make it tempting to "shoot from the hip" with no regard for level horizons.

Apple's App Store offers loads of aids to better iPhone photography. *Darkroom* is a useful alternative to the image stabilizer lacking in just about all the camera phones that we know. All you have to do is open the app, touch the camera button and the application does the rest, waiting until your iPhone is perfectly still before releasing the shutter.

Camera+ (not to be confused with the less user-friendly *Camera Plus*) adds a number of useful extensions to your iPhone's camera app. The package includes a digital image stabilizer (like the one offered by *Darkroom*) and a self-timer. The app's interface includes functions for shifting the autofocus frame and operating the digital zoom (both of which are included in the iPhone's native camera app), but also adds a thirds grid for perfect alignment and optionally activates geotagging. It has its own image viewer called Lightbox, which allows you to save your photos on your phone, post them on Flickr, Facebook and Twitter, or send them as e-mail attachments.

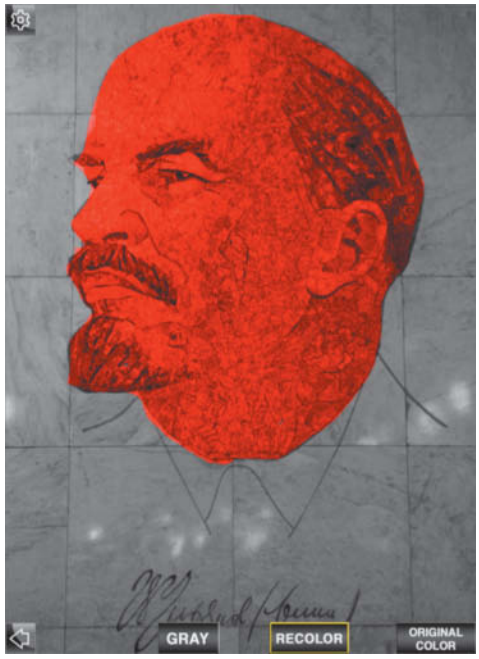
ProCamera includes an artificial horizon that is not unlike the aircraft equivalent to look at, as well as anti-shake, a self-timer, geotagging functionality, white balance control and a thirds grid.

Fun Photos

Alongside these "technical" apps, there are many apps available that are dedicated to the fun side of photography and the application of simple but striking effects. These apps do not offer any manual settings, but deliver really nice photos in exchange.

If you are a fan of analog photography and old-school equipment, *Hipstamatic* is the app for you. The standard version simulates a camera body and includes three different film types, three lenses and three different flashes. You can then make in-app purchases of additional camera models, flash effects and film types for US$0.99 each. The look of the "hardware" has been lovingly recreated and the quality of the results is great. You can either upload your square, white-framed *Hipstamatic* images to Facebook, Flickr and Tumblr, or send them as e-mail attachments.

Instagram is an effects app with its own community for displaying the results. The app crops images to a square format and offers you a range of 14 filters – from black and white to Lomo – for altering the look of your photos. You can upload the results to Flickr, Facebook and Twitter, or share them directly with other *Instagram* members. You can also follow the work of other members (like you can in Twitter) or simply view people's favorite snaps.



Color FX **(available for Android and iOS) converts images to black and white and lets you recolor them using finger gestures**

Image Editing

As well as *Photoshop Express* (see above), there are various other apps available for editing images on smartphones. *Perfectly Clear* is one of the better ones we have seen. The app consists of a collection of patented image correction algorithms that automatically enhance the quality of digital images. It has been available for a while as a plug-in for

Hipstamatic **uses a lovingly created interface to simulate analog cameras, films and lenses on the iPhone**

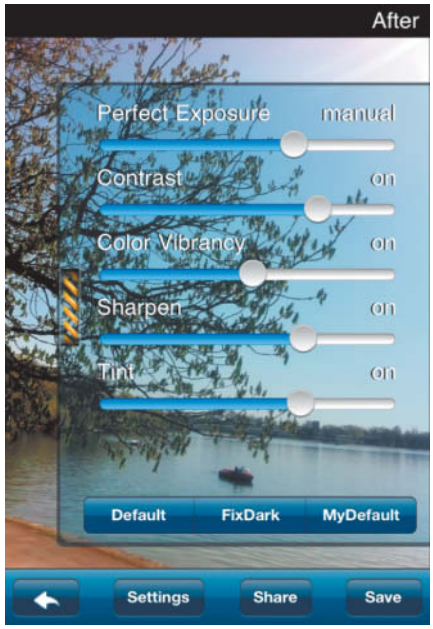
Photoshop and *Lightroom* (US$199 each) and is now available for the iPhone and the iPad as well as in a (beta) standalone version.

The idea behind this app is the fact that digital cameras and image editing programs disregard the basic physics of human vision. If we digitally brighten an image, the colors become paler. *Perfectly Clear* takes a different approach and simulates the way the human eye adapts to the dynamic range in a scene. The app automatically processes images you capture and the interface includes sliders called Perfect Exposure, Contrast, Color Vibrancy, Sharpen and Tint for tweaking the processed photo. The results are extremely good and make genuine improvements to most images. You can save your settings as a preset and there are upload wizards for Facebook and TweetPhoto.

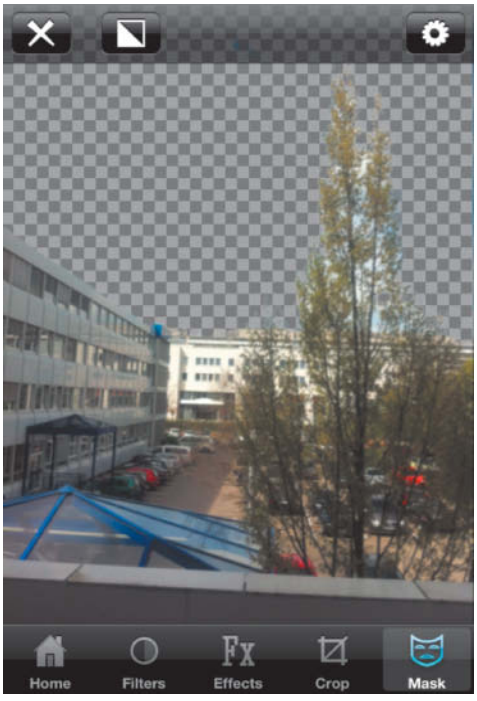
PhotoCurves is another impressive tool for the iPhone. The app offers Curves-type adjustments for composite images as well as for individual RGB color channels. You can create and drag control points on the curve using either finger gestures or the Contrast and Tone sliders.

US$0.99 buys you the comprehensive *PhotoForge* app, which includes curves and tonal adjustments for the CMYK and L*a*b* color models as well as an unsharp mask filter, noise reduction, automatic and manual exposure correction, white balance adjustment, soft focus effects and a whole range of other tools and filters. The app also offers eraser, clone brush, fill and paintbrush tools. You can use it to rotate an image in one-degree steps. The app can be tricky to use on the iPhone screen, but you can undo any processing steps that don't work out as planned. Results can be saved at various resolutions.

Instagram **applies one of a range of 14 effects to your images and presents the results on the Web or in its own community**



Perfectly Clear **automatically improves iPhone photos and allows you to manually adjust the results**



PhotoWizard **specializes in making selective corrections to iPhone photos. The magic wand tool detects color regions and allows you to create complex masks using multiple taps.**

PhotoWizard doesn't require quite such a fine touch, and gives you various filter to play with, such as sepia tint, sharpening, soft focus, color enhancement, pointilism and antique borders, all of which are accessed via their own icons. It also includes masking functionality – a feature rarely seen in smartphone apps. Simply select a color by tapping; the app then automatically selects your chosen area to create a mask, which you can then use to selectively apply filters and effects.

Pretty Pictures

AutoStitch iPhone finally proves that seamless panoramas are no longer the preserve of PC and Mac users. The app automatically detects overlaps in selected images, merges them and corrects perspective in the merged image. The results are excellent and can be cropped, saved and distributed via mail or Facebook.

Photosynth shows that you don't even have to shoot photos to create panoramas. All you have to do is pan your iPhone across a scene and the app does the rest. Green and red frames indicate whether you have moved your phone too far since the last shot was taken. Completed panoramas are enlarged automatically, and the results are very good, even if the seams are sometimes less than perfect. You can share your results on Facebook or at photosynth.net. If you want to crop your finished panoramas, you will have to use an additional app, such as *Photoshop Express* or *PhotoForge*. Strangely, this Microsoft app is not available for Windows Phone 7 or Android.

Comic Touch is one of the more gimmicky apps out there. It is designed for adding speech balloons and "joke" distortions to photos. There is an ad-funded free version of the app and a commercial version with more features.

Color Splash is a commercial app that bascially offers the same functionality as the free Color FX described earlier. You first convert a photo to black and white and then color it in or preserve color details using masks. The app offers the option of coloring your selection in red to enable precise masking.

Spica – Super Monochrome is a quick way to convert your photos to grainy, high-contrast black and white. There are no options, just shoot, convert, Twitter upload.

TiltShift does exactly what it says and simulates tilt/shift lens effects which you can apply to photos shot directly from the app or

selected from your library. It can also add Gaussian blur or lens blur to your images. The image area you want to adjust is selected using an ellipse, and you can adjust saturation and contrast in the finished image before saving it.

Oldbooth is another sure-fire candidate for the "gimmicks" department. It takes portraits shot with the camera or taken from your library and converts them to black and white before adding hairstyles, glasses and other paraphernalia from bygone eras. The results can be scaled and you can adjust brightness before sharing them via Facebook or Twitter.

Color Lava **adds a palette to *Photoshop* where you can mix colors the way you would on a real artist's palette**

iPhone Tools

The home computer version of the jAlbum Web gallery program has a rather old school look, while the iPhone/iPad version is much more up-to-date. The app creates Web albums for upload or online viewing. The interface shows an overview of your saved galleries and allows you to surf other people's uploaded images.

LightTrac is a definite recommend for outdoor photographers. This app helps you to plan outdoor shoots in advance by telling you ahead of time how the lighting conditions will be at your chosen location. Simply enter your desired location and date/time coordinates – the app then displays the sun's position and the angle of its incident light superimposed on a Google map. It also provides the dates and times of upcoming full, new and half moons.

PhotoWall is designed for creating collages. All you have to do is select images from your library, arrange them on the background and save the result to your phone or Facebook. The free version saves up to three images, but requires registration before further use.

Remote Control for Photoshop

Three Adobe touch apps for the iPad enable you to interact with *Photoshop* within a network. Use the Edit > Remote Connections command to activate the server and select a password. You can then use the same data to access *Photoshop* via the apps.

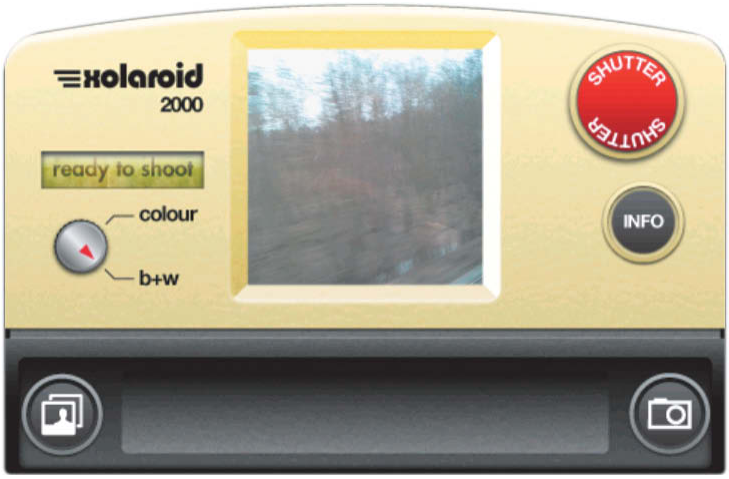
Color Lava is a color palette alternative to the program's conventional color picker. Selecting colors using the Hue, Saturation and Brightness sliders can be tricky, but once you have found the right colors, mixing them in the palette is easy. You can also load photos directly into the palette and adjust the colors there. You can mix colors from up to five color wells, and *Color Lava* can save your mix as a local preset or transfer it to Photoshop.

Eazel is designed to bring finger painting techniques to the iPad. The app opens with a completely blank screen and only reveals its controls if you touch the screen with all five fingers. The undo button is under your thumb, tonal selection under your index finger, your middle finger controls the brush, your ring finger opacity, and the little finger button is for making program settings. The interface works right and left-handed. You can mix colors and then see them "dry" over time. You can also transmit the results to *Photoshop*, which interpolates your images to double their original size.

Adobe *Nav* uses a network connection between your iPad and your computer to customize the *Photoshop* toolbar in the iPad interface. A tool selected in the iPad interface then becomes the active tool in *Photoshop*. You can also browse, reorder, view and zoom in on up to 200 open *Photoshop* documents on your iPad's screen.

Android Apps

Camera Zoom FX is an advanced alternative camera app for Android phones, that includes a self-timer, white balance options and various focus settings. You can set the app as your default camera app and use it to change the resolution of your photos or increase the JPEG compression level. There are also golden ratio, crosshairs and thirds grid overlays that you can opt to show or hide. The image stabilization function displays camera shake in the form of a graph (a great visual incentive to hold still) and only releases the shutter when the camera is no longer moving. There are also various filters included for adjusting colors, adding borders or giving your photo a painted look.



Retro Camera **simulates the look and feel of a range of classic cameras for the Android interface**

Select an effect and shoot – *FxCamera* is the easy option for Android users

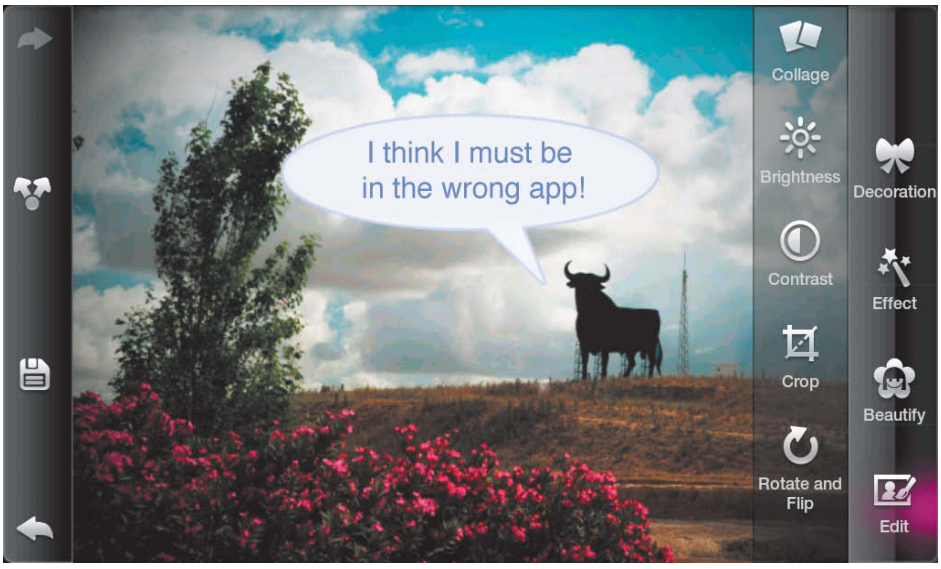
Vignette is a kind of Swiss Army Knife for cellphone photographers. The full version can adjust resolution, change filenames, delay the shutter release and control flash output. You can also use it to make multiple exposures that the app then merges into strips like the ones that are made by passport photo machines. The free version has a wide range of filters that includes black-and-white conversion, vignetting, HDR simulation, bleach bypass, tilt/shift, cross processing and color swap effects.

Retro Camera is one of the more addictive fun apps we have come across. It simulates five classic cameras, including Polaroid and pinhole models. The interface is very attractive and includes notes on the characteristics and idiosyncrasies of each camera type, including scratches on the lens and simulated light leaks. The effects are well implemented and you can "hang" your last 10 photos on the app's own drying line. You can upload your results to Facebook and Twitter or share them as e-mail attachments. The free version is ad-supported.

Fun Effects

BentoCam! shoots four "toy camera" photos in quick succession, arranges them in a grid, desaturates them, adds a vignette and saves the whole kit and kaboodle to your phone's flash memory. The app is simple to use, has just a few options and delivers interesting results.

If you like spending time in passport photo booths, then *Multicamera* is the app for you. The app includes various preset borders, which you can fill with two to eight shots taken one after the other. You can adjust the width of the border and the color of the background.



***PhotoWonder* offers photo effects and filters with an Asian slant**

Camera360 is a lot more versatile. You select an effect first and then take your photo. The available effects include an effective tilt/shift implemenation, HDR simulation, retro look, Lomo look, washed-out colors called "Japanese Style", two black-and-white filters and a filter for creating highly saturated, high-contrast images. The free version has a pop-up that asks for a donation once an image has been processed.

FxCamera is a great choice for spontaneous snaps. The app has just a few effects that are easy to apply and produce effective, but sometimes fairly drastic results. The menu contains Toycam, Polandroid, Fisheye, SymmetriCam, Warhol and Normal options.

Messing and Merging

PhotoWonder takes a rather Asiatic approach to image editing, offering filters for smoothing skin and enlarging the eyes of portrait subjects. There are also tools for adjusting brightness, contrast and cropping, as well as Lomo, soft focus and "Blue Tone" effects. You can also add comic eyes, ribbons and speech bubbles to complete your photo makeover. *PhotoWonder* supports uploads to MySpace, Facebook, Twitter, Flickr and a number of Chinese sites.

The *Pho.to Lab* cloud app sticks to simple effects and image borders for jazzing up your photos, and includes Justin Bieber, Shrek and Superman amongst its wide range of colorful offerings.

PicSay has a couple of effects on offer, but is basically designed for adding speech and thought bubbles to photos. The app hands over finished images to Facebook, PixelPipe and a number of other services for upload.

AndroPan is an Android-based stitching app. Once you have taken one photo, the app requests that you take another while it displays the right-hand edge of the previous photo at the left-hand edge of the phone's screen. Alignment is left to the user in the free *ManualStitcher* version, but is dealt with automatically in the commercial *AutoStitcher*. The app does attempt to correct perspective, but doesn't blend the image overlaps, leaving obvious edges in the finished panoramas, which you can also crop using the app's built-in tools.

PhotoStitch is another panorama app that stitches two images together in its free version and up to five if you pay. In contrast to *AndroPan, Photostitch* softens the edges of the merged images, making the transitions less jarring. Nevertheless, the results are still a long way from being "seamless".

Viewers and other Tools

Photography Calculator is a useful tool for DSLR owners, and calculates depth of field and hyperfocal distances for the combination of camera, focal length, aperture and subject distance entered by the user. The app displays the results as a graph.

Photo Tools performs similar advanced level photo functions and is also capable of displaying the latitude and longitude data of your current position. The app uses the built-in gyroscope to help you orientate your phone. The whole package is free and extremely extensive, but not particularly user-friendly.

If you like to shoot your photos in flattering morning or evening light, *Golden Hour* uses GPS to calculate the times of sunrise and sunset at your current location.

Android's built in Gallery feature can quickly get too full if you use it to view your locally stored photos and your Picasa Web Albums. *QuickPic* is an alternative gallery viewer that keeps things tidier, with four-image folder previews and full-screen viewing for individual photos.

The *JustPictures!* app displays photos from your local library or ones you have stored on Facebook, Flickr, Picasa or Windows Live Album. The app also sorts your photos clearly according to account, album and filename. You can upload locally stored gallery images and download the ones you have stored online.

Conclusions

iOS apps are generally of higher quality than Android apps, which are, on the whole, cheaper or completely free. There is a good range of shooting apps for both platforms, so you won't have to make do with your system's default camera app. Uploads are much quicker using dedicated tools like *PixelPipe* than they are using a Web interface or the Facebook app. If you want to upload a snap of your current cocktail, a funny street sign or the piece of graffiti you have just found to the Web, this is a great tool that you can set up as a permanent part of your workflow.

The iPhone is still in the lead as far as image editing is concerned, and there is a much greater variety of quality image editing apps available for the Apple platform than for Android. Preset effects and filters are more the order of the day in the Android camp. Fortunately, *Photoshop Express* is available for both. Android is generally better for saving your photos to the cloud, either via its own built-in *Picasa Web Album* or using the services offered by Flickr, Facebook and Windows Live. (akr)

Photo Apps for Android and iOS

App	Manufacturer	Price (US$)	Features
Android / iPhone			
BeFunky Photo Editor	KTH	free / 1.99	Photo editing, effects, borders (requires Adobe Air)
Camera Illusion	Mobile Illusion	2.99[1] / 2.99[1]	Approx. 30 effects, upload to Facebook, Twitter, Gmail
Color FX / Effects	Daniel Cota	free	Black-and-white conversion, plus recoloring
Photoshop Express	Adobe	free	Photo editing, effects and borders, upload to the Web
PixelPipe	PixelPipe	free	Uploads to Flickr, Twitter, Facebook, Dropbox etc.
Pro HDR	eyeApps	1.99[1] / 1.99[1]	Creates HDR images from two source images
Retro Camera	Urbian	2.99[1] / free	Simulates analog toy cameras
iPhone / iPad			
Shooting			
Darkroom	Stepcase	0.99[1] / –	Delays shutter release until iPhone is held still
Camera	Apple	free / –	Preinstalled photo/video recording software
Camera Plus	Global Delight	1.99[1] / –	Adds image stabilizer, digital zoom and self-timer
Camera+	tap tap tap	0,99 / –	Image stabilizer, digi-zoom, self-timer, effects, uploads
ProCamera	daemgen.net	2.99 / –	Anti-shake, artificial horizon, self-timer
Editing and Effects			
Color Splash	Pocket Pixels	0.99 / 1.99	Black-and-white conversion plus recoloring
Comic Touch	plasq	2.99[1] / –	Adds speech and thought bubbles to photos
Hipstamatic	Synthetic Corp	1.99 / –	Simulates cameras, films, flashes and lenses
Instagram	Burbn	free / –	Collection of 15 effect filters, uploads to the Web
Oldbooth	GetApp	1.99[1] / –	Adds retro effects to portraits
Perfectly Clear	Athentech Imaging	2.99 / 4.99	Image editing using proprietary algorithms
PhotoCurves	GhostBird	1,99[1] / –	Curves adjustments (CMYK and L*a*b* cost extra)
PhotoForge	GhostBird	0.99 / 0.99	Curves, tonal adjustments, exposure adjustment, brush effects, clone tool
PhotoWizard	Pankaj Goswami	0.99 [1] / 2.99	Applies colors and effects to whole images or selectively
Spica – Super Monochrome	Daisuke Nogami	0.99 / –	Black-and-white conversion with strong grain and high contrast
Tilt Shift	Michael Krause	1.99 / 2.99	Creates and applies tilt/shift effects
Panoramas, Uploads and Tools			
Autostitch Panorama	Cloudburst Research	1.99 / –	Merges source images to panoramas
jAlbum	jAlbum	free / free	Uploads and displays photo albums on jAlbum
LightTrac	Rivolu Pte	4.99 / –	Calculates sun's position for date, time and place
Photo Wall	iAppStreet	2.99[1] / 2.99[1]	Creates collages and uploads them to Facebook
PhotoCalc	Adair Systems	2.99 / –	Calculates aperture, shutter speed, depth of field and flash settings
Photosynth	Microsoft	free / –	Creates seamless panoramas using sweep movement
Photoshop Remote Touch Apps			
Color Lava	Adobe	– / 2.99	Advanced color picker and mixer for Photoshop
Eazel	Adobe	– / 4.99	Painting program, exports results to Photoshop
Nav	Adobe	– / 1.99	App for organizing Photoshop tools and documents
Android			
Editing and Effects			
BentoCam!	Unnawut Leepais.	free	Takes a series of 4 images and stitches them together
Camera 360	PinGuo	2.99[1]	HDR, tilt/shift, black-and-white etc. effects
Camera Zoom FX	androidslide	4.49	Comprehensive set of camera settings, effects, geotagging
FxCamera	ymst	free	Polaroid, toy camera, fisheye, mirror effect
Multicamera	David Erosa	1.49[1]	Applies borders to strips of photos
Pho.to Lab	VicMan	free	Many effects, borders and photo templates
PhotoWonder	PhotoWonder	free	Speech bubbles, clip art, some editing, effects
PicSay	Shinycore	3.99[1]	Editing, speech bubbles, wigs, distortion
Vignette	neilandtheresa	4.49[1]	Borders and effects (Lomo, Polaroid, cross process)
Panoramas, Uploads and Tools			
AndroPan	Claude Heyman	3.57[1]	Stitches panoramas
Golden Hour	Marco Dehmel	free	Calculates "golden hour" using position data
JustPictures!	Kounch	free	Loads photos to and from Facebook, Flickr, Picasa, Windows Live
Photo Tools	HCPL	free	Calculates various DSLR photographic data
Photography Calculator	Starfighter Pilot	2.99	Calculates depth of field and hyperfocal distance
PhotoStitch	Jupe	1.41[1]	Creates panoramas from two or five source images
QuickPic	alensw.com	free	Clear interface for viewing local image files

[1] free basic version available – not available for iPhone/iPad

Ralph Altmann

Look **Sharp!**

Check out your latest batch of photos, and you'll often see a lot of unsharp images. Your first reaction may be to fire up your favorite sharpening tool, but be warned: sharpening can produce just as many artifacts as it eliminates. This article explains how to avoid shooting unsharp photos in the first place and gives you some tips on the tools to use to squeeze the very last drop of sharpness out of your subject.

We generally expect a digital camera to reproduce subject details with the greatest possible resolution and sharpness. These two aspects of a photo have very different roots but are nevertheless very closely related. As manufacturers try to cut costs and increase sales by squeezing ever-increasing numbers of megapixels onto their sensors, the result is often only a slight increase in resolution and can even reduce overall image sharpness.

A number of factors influence the sharpness of an image. On the hardware side, these are the optical quality of the lens, the size and resolution of the sensor and the quality of the interpolation algorithms built into the camera's firmware. Many cameras have an anti-aliasing filter located in front of the sensor which helps to prevent moiré effects from spoiling your photos, but also has a gentle soft-focus (i.e., de-sharpening) effect on the images it captures. These are all factors you can no longer influence once you have purchased a camera and lens, but you can still adjust your results using the hardware settings.

Keeping Things Sharp

Don't underestimate the importance of setting focus correctly – an apparently trivial task in this autofocus era. The phase detection mechanisms used by many autofocus systems aren't always as precise as we'd like and only a few high-end camera models offer autofocus correction functionality. Mirrorless cameras that use contrast data from the (live view) image captured by the sensor to set focus usually focus more accurately.

Regardless of which autofocus system your camera uses, it is often difficult to focus on a specific point. For example, if you are using a telephoto lens with the aperture wide open, it makes an enormous difference to the results whether you focus on your subject's eyes or ears. Stopping the aperture down is a reliable way to increase depth of field, but not necessarily sharpness too. Generally speaking, sharpness increases toward medium aperture values, but drops off again at small apertures due to refraction effects.

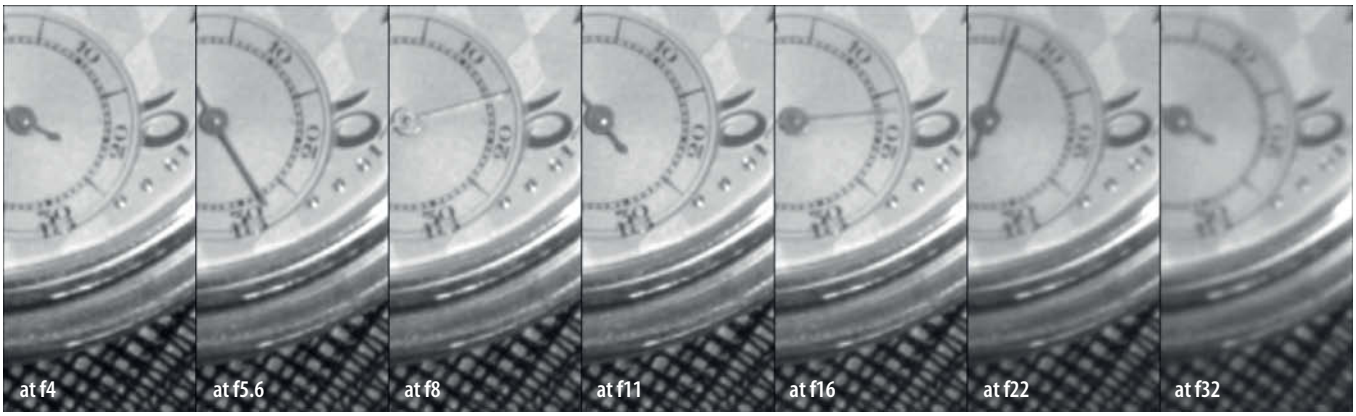
Maximum image sharpness is usually achievable between aperture values of f5.6 and f11, although in practice, it is often difficult to stick to these values due to the largerapertures required to keep the shutter speed short enough to prevent blurring. Increasing the ISO value quickly produces more image noise and reduces the dynamic range of your camera/lens setup. In spite of these incontrovertible facts, some camera manufacturers still try to sell automatic ISO increase functionality as a kind of "digital image stabilization".

Simple camera shake is the second most common of unsharp photos, and the most easily avoided. Recent developments in sensor- and lens-based image stabilizing techniques have increased the shutter speeds that you can successfully shoot handheld by a factor of four or more. A robust tripod is also a reasonably foolproof tool for preventing camera shake, although the movement of the mirror in some DSLRS is sufficient to cause visible camera shake in a shutter speed range between 1/25 and 1 second, even when the camera is mounted on a tripod. In such cases, using mirror lock-up – a feature normally reserved for high-end cameras only – is the only practical solution. For completeness' sake, we should mention that a moving subject can also cause unsharp results, and is best compensated for using either flash or a very short shutter speed.

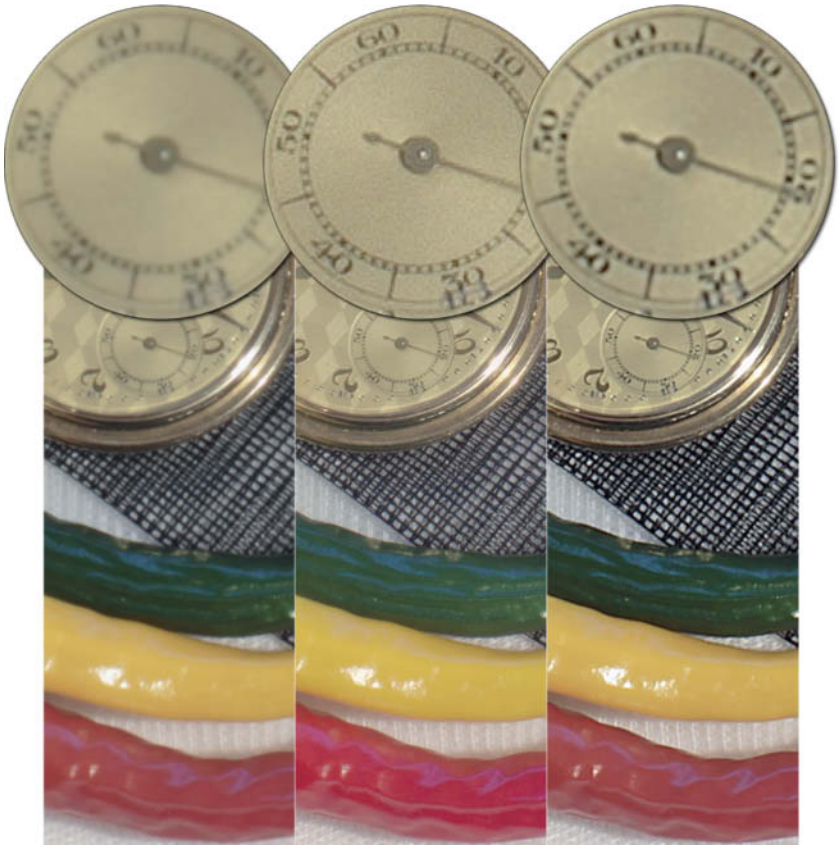
A less well-known method of counteracting camera shake is to shoot a sequence of images of a subject and to select the sharpest results later. Some compact cameras take this idea a step further and shoot a sequence, select the sharpest image and delete the remaining images automatically – all at a single press of the shutter button. For situations in which framing and exposure settings remain constant, you can be fairly sure that the largest file in a sequence will contain the sharpest image with of the most "high frequencies" that are difficult for the camera's firmware to compress. All types of unsharpness and camera shake cause a loss of image data that in turn makes the resulting image easier to compress. This effect is often visible in RAW file sizes too, but is not as pronounced as it is for JPEG images.

Sharp isn't Always the Same as Sharp

Technically speaking, an image is sharp if subject contrast is retained right up to the limits of the camera's resolution. A digital image in which individual pixels are visible and which remains sharp, even at extremely large magnifications, is probably an artificially generated computer graphic and not a photograph. The hardware limitations we have already mentioned usually cause high-contrast edge detail to "smear" across multiple pixels, and this zone of unsharpness increases in size with the number of megapixels the sensor contains. Lens quality simply cannot keep up with increasing numbers of megapixels on ever-smaller sensors. "Technical" sharpening of image softness caused by hardware or photographer errors is required if we want to produce effective enlargements. Our aim is to make blurred or unsharp details easier to recognize – i.e., we want to improve visible image detail.



How aperture settings influence image sharpness: the 17-35mm wide-angle zoom used to take these photos produced its sharpest results at f11 (we converted the images to black and white to make it easier to compare them). www.dpreview.com offers a comprehensive list of sharpness performance data for a wide range of lenses.



The original image, as produced by the camera is shown on the left

An effective sharpening process (shown in the center image) should accentuate details without producing additional halo effects or other artifacts when the image is enlarged.

Output sharpening (on the right) is adjusted to suit the intended size of the output medium. This version appears sharper although the details are not actually as well defined.

about any size. It is recommended that you keep any increase in edge contrast that you apply to a minimum in order to avoid producing visible "halo" effects. This initial sharpening step is usually built into the camera firmware and its strength can be user-controlled. It is usually applied to JPEG images automatically, and we will discuss whether this is a good thing later in this article.

The second sharpening step, known as output sharpening, takes place once you have made a copy of your original image and adjusted its size for output. You can apply an Unsharp Mask (USM) filter to increase edge contrast (see also the box on page 84). Here, the strength and breadth of the sharpening process need to be adjusted to suit the chosen output scale.

However, high resolution and good detail reproduction alone do not automatically produce good visual sharpness. The amount of detail the human eye can resolve is limited, and we always perceive details with a diameter of less than 0.3 mm as sharp at normal viewing distances. This degree of tolerance increases with viewing distance, so, strictly speaking, all you have to do is enlarge unsharp images less to help them retain an appearance of sharpness. Perceived sharpness is affected more by edge contrast than the actual sharpness of the individual details, and it is possible to deliberately deceive the viewer into thinking that an image is sharper than it is by applying exactly this type of adjustment. This is the basic method used by most sharpening tools.

It is important to make sure that this type of sharpening is adjusted to suit the size of the output media, and you can sharpen small-format images much more heavily than large-format images without causing unwanted visual side-effects. The important factors here are the apparent size and viewing angle of the viewed object, which result from the combination of its real, physical size and the distance at which it is being viewed. The type of output medium is also important, and images printed at 300 ppi need to be more heavily sharpened than small-scale images that are intended for Internet viewing on a monitor with resolution of 100 ppi or less.

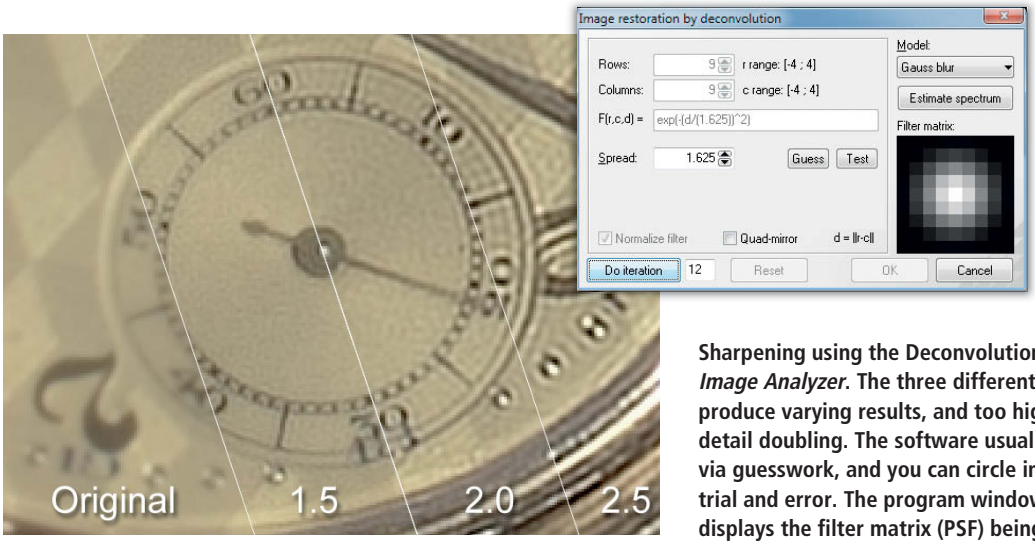
Because it is not usually clear at the moment they are taken how and at which size they will be displayed, most digital photos end up being sharpened twice. The camera's firmware automatically counteracts the technical shortcomings of its hardware immediately after shooting and optimizes the image for reproduction at 100% magnification – an output size that you shouldn't usually exceed. This is the type of sharpening we will mostly be considering on the following pages. If your image looks pin sharp on your monitor at 100% (or, better still, 200%) magnification, it is suitable for output at just

Convolution and Deconvolution

USM filters orient their effects on pixels that are physically present in the image and increase edge contrast "blindly", regardless of how this contrast actually came into being. For this reason, if you use them at all, USM filters should remain an emergency measure at the initial, in-camera sharpening stage. If you don't explicitly apply threshold values or use them with masks, USM filters increase image noise and pixelize otherwise homogenous image areas. In spite of these shortcomings, they still help to increase overall image sharpness, regardless of how the original softness came into being.

Common causes of image softness, such as refraction effects caused by light hitting the aperture blades or the circles of confusion caused by imprecise focusing, can be relatively easily reconstructed, whether mathematically or physically. The process used here is known as "convolution", and involves the application of a mathematical function that describes how a single point of light is affected by unsharpness. Poor focus, refraction and lens errors have different effects on the way a point is reproduced, and subject movements or camera shake add additional distortion. This Point Spread Function (or PSF) represents a kind of "softness profile" and is similar to the way a lens profile documents the optical anomalies of a particular lens (see also our article on lens error correction on page 18).

The magical thing about the convolution process is that it can be reversed in a process called "deconvolution". If you have access to an appropriate PSF, you can, in theory, recreate a sharp original from an unsharp image. In practice, calculating the right PSF can be tricky, or even impossible. Digital image softness is usually caused by a mix of factors with differing PSFs that depend on the lens, the size and type of the camera's sensor and the camera settings. Even if you are in a position to precisely determine the PSF for a specific camera/lens combi-



Sharpening using the Deconvolution filter included with *Image Analyzer*. The three different Spread values used here produce varying results, and too high a value produces detail doubling. The software usually finds a useful value via guesswork, and you can circle in on a better value by trial and error. The program window (shown on the right) displays the filter matrix (PSF) being used.

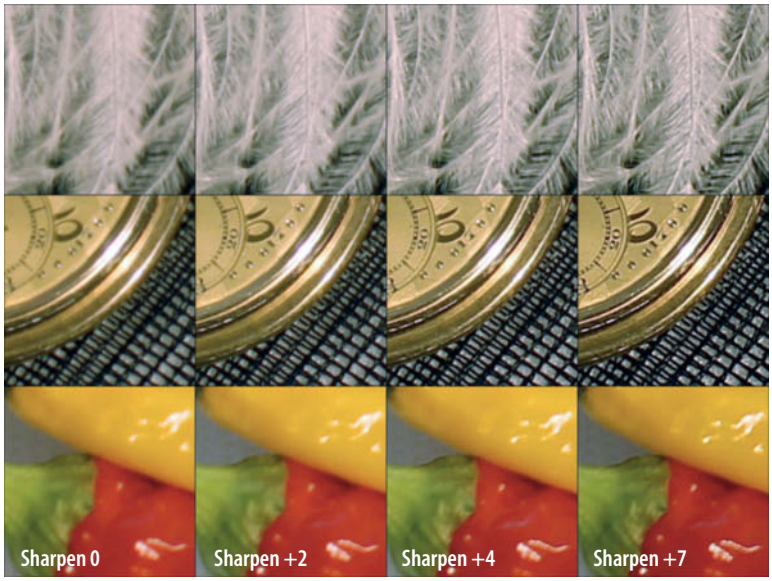
nation (a common practice in astronomical and military circles that often produces astounding results), you still won't be able to fully reconstruct the sharpness of the original. The limited resolution of the camera's sensor alone produces enough imprecision to make it impossible to produce an accurate PSF.

However, it is still possible to sharpen images using deconvolution without precise knowledge of the appropriate PSF – a process called "blind deconvolution" that, in spite of its name, is not as"blind" as some conventional sharpening methods. The process involves estimating a PSF and improving the results in the course of a number of iterations. There are a few more or less usable experimental software packages available that use this technique. Our favorites are *Image Analyzer* (included on this issue's free DVD) and BiaQIm (www.bialith.com).

Some well-known programs offer deconvolution-based sharpening without mentioning it by name. *Photoshop*'s Smart Sharpen tool is an example. Before we take a closer look at individual programs and sharpening tools, we would like to have a quick look at in-camera sharpening. Sharpening at the shooting stage is best done in-camera, as the manufacturers themselves know more about the potential sources of image softness in their products than anyone else.

In-camera Sharpening

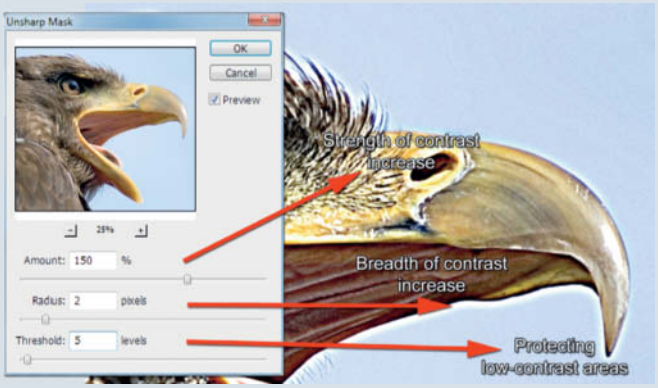
It is certainly possible that camera manufacturers use deconvolution tehcniques in their RAW-compatible models, but it is as good as impossible to get hold of any relevant information on the subject. The same is true of the internal sharpening algorithms that manufacturers often build into their equipment and which are usually adjustable to one of several levels. This type of sharpening is permanently interpolated into JPEG image data and is usually a default option in RAW image files. You can adjust the strength of the effect later using a RAW converter. The most important question for the photographer is to establish whether the quality of the camera's internal sharpening is as



The Canon EOS 550D/Rebel T2i has seven degrees of internal sharpening. Here are the results produced by three of those magnified to 300% and shown in comparison with the original image.

Sharpening with softness – how USM filters work and how to apply them

The most common technique used to sharpen digital images has its roots in the traditional analog darkroom and is called "unsharp masking". The technique involves creating a deliberately soft, negative version of the original image and enlarging both versions together. Digital unsharp mask filters work the same way, using a deliberately softened version of the original image to achieve the desired sharpening effect. The technique increases the light/dark contrast at the edges of image details by darkening the dark side and lightening the brighter side. The overall visual sharpness is thereby increased without actually improving detail rendition. In fact, the technique can even lead to a deterioration in the quality of image detail. The breadth of the area affected by the filter depends on the strength of the softening effect you use.



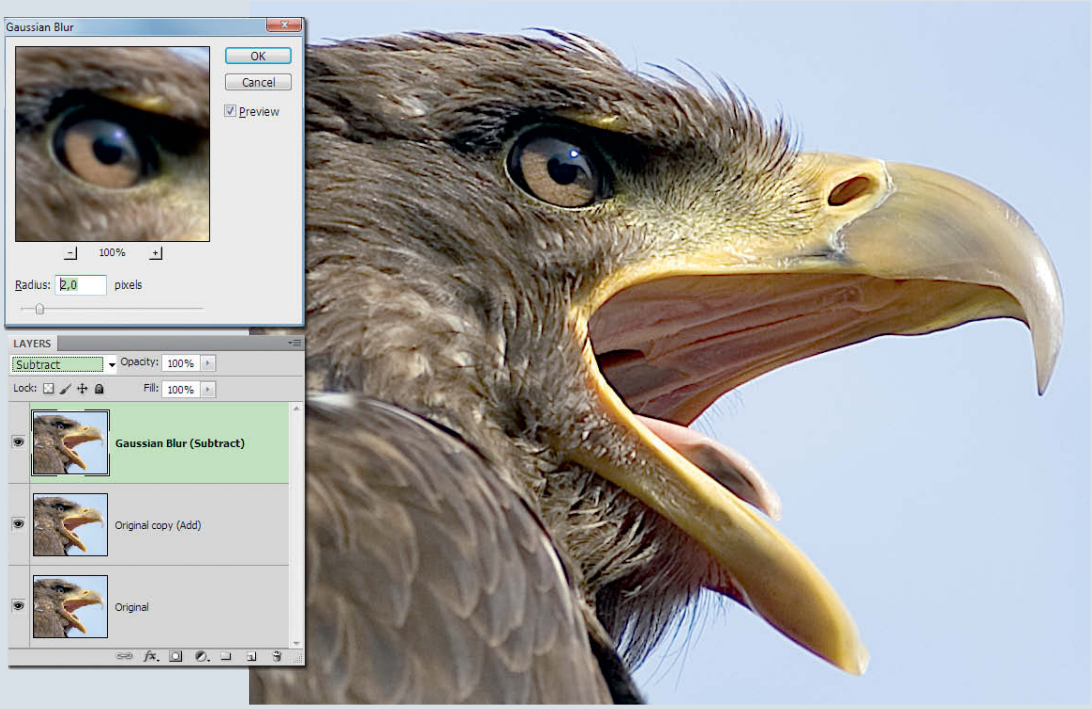
A deliberately over-the-top example of the *Photoshop* USM filter's effect

This principle can be applied using various image processing programs, but is particularly simple using any version of *Photoshop* that has 32-bit support (see the illustrations below). Layer interpolation simply doesn't work at lower bit depths, although you can simulate the effect using a two-step approach and the program's Apply Image command. The result is the same as you get when using the USM filter, and it is also possible to simulate a high pass filter effect this way.

You can, of course use optical alternatives to Gaussian Blur to create your softened image copy – for example, the Lens Blur or Motion Blur settings in the Smart Sharpen filter can be more effective than Gaussian Blur USM methods for certain types of images.

The downside of USM filters is that they increase sharpness everywhere, rather than only where improvements are needed. They also increase contrast between pixels caused by image noise, thus increasing the noise effect. You can counteract this undesired side-effect by excluding low-contrast details from the filter's effect. This is achieved by adjusting the Threshold value slider built into most USM filters. The problem with adjusting the threshold is that low-contrast details that could do with sharpening get left out of the process. The default threshold value in some USM filters causes the difference between sharpened and non-sharpened image areas to become too obvious. For a free tool for testing the effects of various sharpening filters on differing edge contrast, see http://simpelfilter.de/en/.

A better alternative to adjusting threshold values is to use an edge mask. This applies a sharpening effect selectively to edges within an image. Edge mask creation functionality is a standard feature in most image processing programs and some, such as *Photoshop Lightroom* or *RawTherapee*, have built-in edge mask functionality. A threshold value is effectively a way of automatically creating a mask



Unsharp masking adds a copy of the original image to the original itself and then subtracts a deliberately softened version of the same image. The Layers structure shown here only works if you process your images using *Photoshop*'s 32-bit mode.

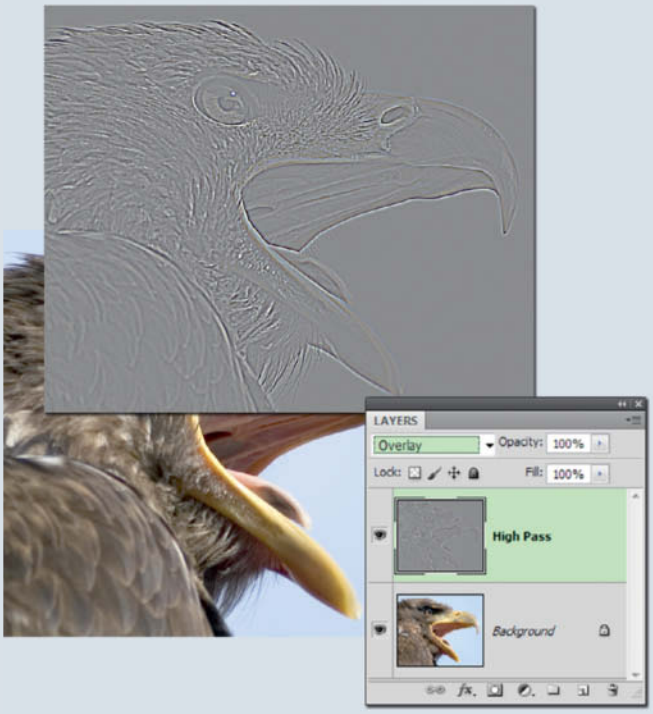
Edge masks can be used to selectively copy sharpened details into an image. This technique involves sharpening a copy of your image globally using a USM filter (high values can actually help here). Normally, only the edges that are displayed in white in the mask (in the upper layer) are sharpened, as shown on the left-hand side of our sample image. If the edges are shown in black (as on the middle layer), low-contrast details, such as skin imperfections or image noise, tend to be emphasized, as shown in the right-hand half of the image.

anyway, although edge mask tools use specially developed edge detection algorithms and produce more accurate masks as a result. Manually created masks can be fine-tuned using black or white brushes before being applied to a globally sharpened image in the form of a layer mask.

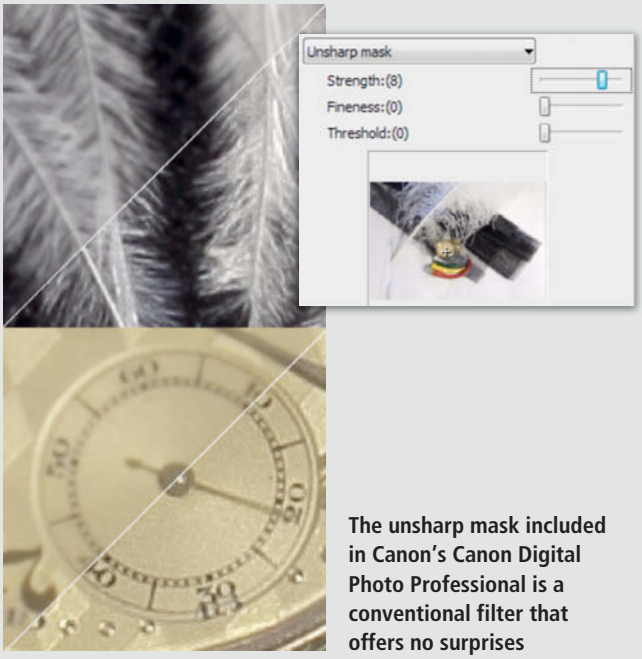
High-contrast edges require little or no additional sharpening, which can be a problem when using conventional USM filters, as these increase contrast in relation to the amount of contrast already present. The result is often "over-sharpening" with obvious bright and dark lines within the image, which can even end up forming pure black or white lines called "halos" along the edges of objects. Bright halos are usually more irritating than dark ones. One way to counteract bright halos is to use Darken mode for the Fade Unsharp Mask command in combination with reduced layer opacity. This dampens the overall sharpening effect. Lighten mode helps to reduce dark halo effects, while Soft Light mode helps to prevent over-sharpening for highlights and shadows (although this also increases overall contrast).

In a best case scenario, a sharpening filter will automatically limit how much it sharpens high-contrast details – functionality that we have so far only found in *Lightroom*. In its advanced mode, the *Photoshop* Smart Sharpen filter also includes halo reduction functionality. High Pass USM sharpening is also a popular technique because it produces very few halo artifacts. If you need to sharpen faint details but leave high-contrast edges untouched, you can use an inverted edge mask, as shown in the illustration above.

Like most image processing tools, USM filters work in the RGB color space and therefore sharpen all three color channels separately. This approach not only strengthens some existing color errors, but can also produce new ones of its own, especially at the edges of highlights. To prevent this from happening, it is often recommended that you convert your image to the L*a*b* color space and sharpen just the **L** (Lightness) channel. However, you can achieve the same effect in a simpler fashion by using Luminosity mode for the Fade Unsharp Mask command and blending your original image with a sharpened copy on a separate, upper layer.



Applying a high pass filter manually. Duplicate the layer containing the original image and apply the high pass filter using your own manually selected Radius setting. The Hard Light, Soft Light and Overlay blending modes work well with this technique.

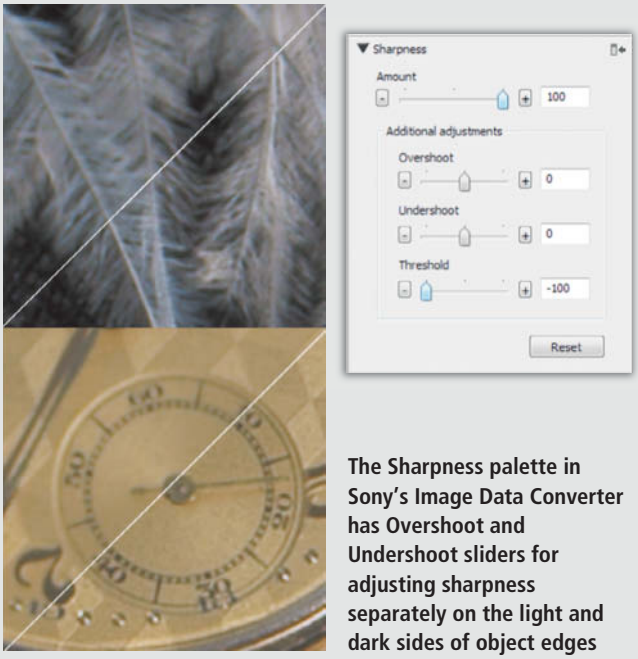


The unsharp mask included in Canon's Canon Digital Photo Professional is a conventional filter that offers no surprises

Canon DPP

Canon's *Digital Photo Professional* (DPP) RAW converter offers the simplest sharpening tools of those we looked at. You can choose between Sharpen and Unsharp Mask on the RAW tab in the Tool Palette. The Sharpen tool offers a single slider and sharpens gently while preserving low-contrast detail and preventing an increase in noise levels. The Unsharp Mask tool offers three sliders called Strength, Fineness and Threshold. There is also a Sharpness slider in the RGB tab, the effect of which is added to any sharpening you may apply during RAW conversion.

The tool's gentle sharpening doesn't cause any color shifts and we assume that it is applied to the brightness channel of the RAW tool's own internal color space. The Fineness slider has the same function as Radius sliders in other USM tools (see also the box on page 84), whereby the maximum "10" setting represents a Radius value of about 3. The slider's name is slightly confusing, as higher values make the sharpening effect coarser, and increase the breadth of the halo artifacts it produces.



The Sharpness palette in Sony's Image Data Converter has Overshoot and Undershoot sliders for adjusting sharpness separately on the light and dark sides of object edges

Sony IDC

Instead of the usual Radius slider, Sony's *Image Data Converter* (IDC) has two sliders called Overshoot and Undershoot, which allow you to adjust sharpness separately on the dark and light sides of object edges. Shifting the overshoot slider to the left reduces the the bright halos that USM filters often produce. Selecting too low a value reduces sharpness too much and tends to make images look dull. Our Attempts to counteract this effect by increasing sharpness on the dark side simply led to a smudged, blotchy look.

The default setting in the center of the scale represents "half on" and the far left setting (-100) switches the effect off completely. The threshold slider works the other way around, with negative values at the left of the scale producing the strongest effect. The default value (0) is too high. The tool's effect is generally on the weak side and we weren't able to visibly improve our test image (shot at f16) at all.

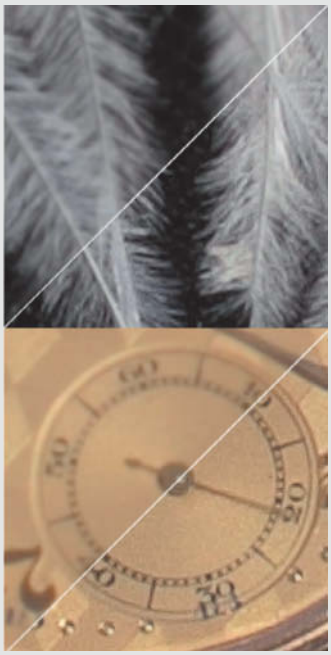
good as that which can be achieved using sharpening tools at the image processing stage.

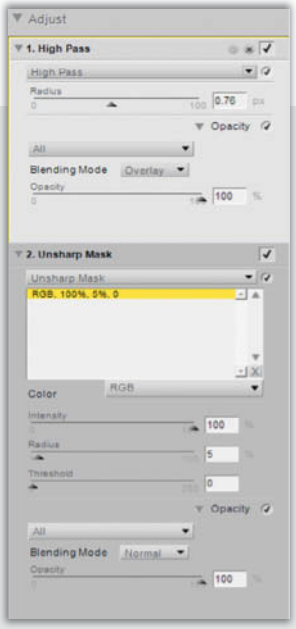
The answer to this question varies from camera to camera. Comparing samples shot using the Canon 550D/Rebel T2i and the Sony A580 with those sharpened using each manufacturer's own RAW conversion software resulted in a resounding "no". The JPEG images appeared a little sharper at first, but we discovered on closer inspection that this was due to the more prevalent edge halos they contained, i.e., the unwanted side-effects of in-camera sharpening. However, these differences were often subtle and only really visible at magnifications of well over 100%.

Generally, the higher you wish the quality of your results to be, the lower the in-camera sharpening level you should select. It can even be a negative value. Always sharpen your images after shooting, especially if your camera can only output JPEG files. The only caveat here is that the rule only applies if you have access to a sharpening tool that is more powerful than your camera's built-in sharpening functionality. Otherwise, the camera's built-in sharpening – which is performed on uncompressed image data with greater bit depth and a linear color space – will be the better choice.

Sharpening during RAW Development

We tested the sharpening capabilities of five RAW converters: our findings are in the boxes on these pages. The sharpening tools built into RAW converters usually function losslessly, so you can always undo or adjust the effect once you have applied it. Sony's *Image Data Converter*, Canon's *Digital Photo Professional* and *Nikon's Capture NX 2* are all only compatible with the manufacturers' own proprietary RAW formats. In contrast, *Adobe Camera Raw* (ACR) and



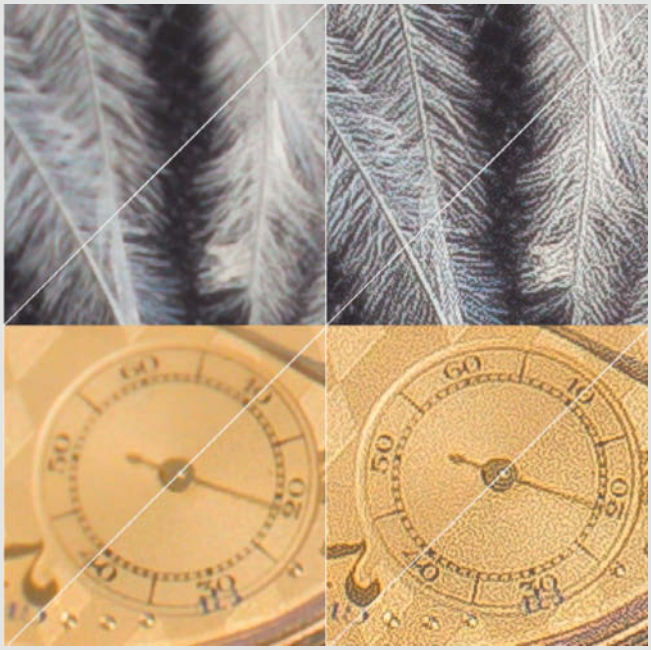


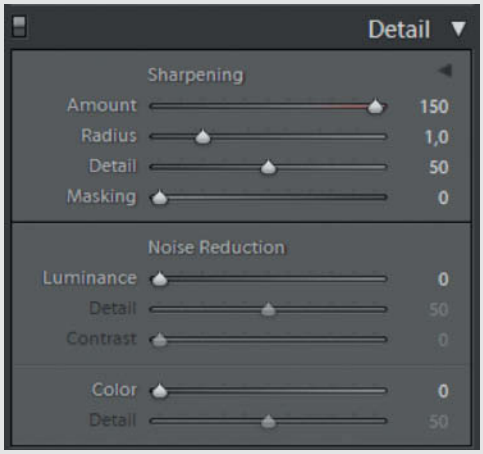
Capture NX 2 offers both a USM and a High Pass filter for sharpening. In the example shown here, the two effects were combined.

Nikon Capture NX 2

Nikon's commercial Capture NX 2 RAW converter offers both USM and High Pass filters that can be used separately or in combination. However, the High Pass tool only has a sharpening effect if you use the Overlay blending mode. Hard Light and Soft Light modes are not available for this tool. Slight High Pass sharpening (with a Radius of less than 1 pixel) combined with USM sharpening with an intensity set to 100%, Threshold 0 and a 5% Radius (the default value) produced thoroughly acceptable results when applied to our test image.

The USM filter also offers Lighten and Darken blending modes that work in a similar fashion to Sony's Overshoot and Undershoot sliders. The tool also allows you to adjust the level of sharpness for indivdual RGB channels or for the chrominance or luminance channels – features normally only found in more established image processing programs. Nevertheless, they still only increase contrast without actually recovering lost detail the way deconvolution-based tools do.





The *Lightroom* Detail panel and the results of sharpening without (left) and with (right) an increased Detail value. The Amount/Detail/Radius/ Masking values we used for each of the four versions (from left to right) were: unsharpened;150/1.0/0/0; 150/1.0/50/0; 50/1.0/100/0.

Adobe Camera Raw/Lightroom

The sharpening tools included with *ACR* and *Lightroom* are grouped with the noise reduction tools in the Details panel, which maeks good sense, as reducing noise first often increases the effectiveness of sharpening processes. To keep our results consistent, we didn't use any additional noise reduction during our tests.

Both sharpening tools include Amount, Detail, Radius and Masking sliders. If you leave the values of the last two sliders at zero, the tool works like an optimized USM filter, leaving low-contrast and very high-contrast details untouched. Sharpening high-contrast details nearly always produces unwanted bright white and dark black halo artifacts.

However, the tool behaves very differently if you shift the Detail slider to the right – details that were previously invisible suddenly appear in your image. Members of various forums have posited the theory that Adobe uses deconvolution techniques to achieve this magical effect, but we are convinced that it results from a relatively simple overemphasis on fine differences in brightness. The result is, of course, an illusion, but nonetheless an effective one. It uses a technique similar to adding grain to increase visual sharpness, but instead of adding additional grain, it produces a grain effect based on existing pixels.

The Detail slider determines whether USM or "grain"-type sharpening dominates, while the Radius slider affects both types. Instead of sing a threshold setting, Adobe has introduced the Masking slider, which performs the same task of confining sharpening to high-contrast edges. Pressing the Alt key (or the command key on a Mac) while you move the sliders displays a preview of the effect.

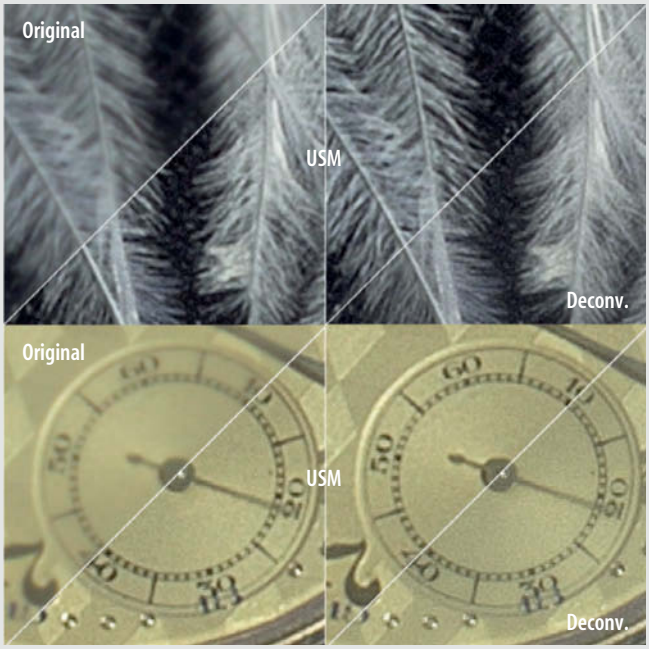
Take care when applying Detail adjustments to images that include large, single-color shapes and patterns, but use them generously for images with multiple textures. Fine textures profit greatly from this type of (apparent) detail enhancement. And please note: the Adjustment Brush tool built into the version of *ACR* included with *Photoshop* allows you to apply sharpening effects selectively but, unlike the *Elements* and *Lightroom* versions, uses just a single slider to regulate the effect.

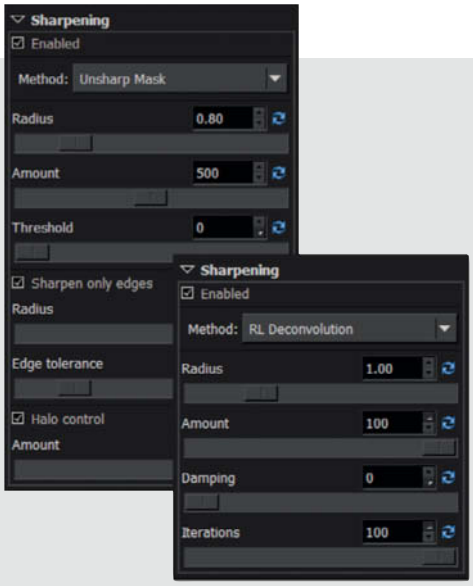
RawTherapee are universal tools designed for use with a wide range of cameras and formats. *ACR* and *Lightroom* have identical processing functionality.

RawTherapee, *DPP* and *IDC* are all free and are either available for download or are included with a camera purchase. *Capture NX 2* and *Lightroom* are commercial offerings, and *ACR* is included with *Photoshop* (or in a reduced-functionality version with *Photoshop Elements*).

With the exception of *IDC* and *DPP*, all of the tools we tested use the same sharpening tools with JPEG/TIFF and RAW files, which allowed us to use the same sample image throughout our test. Sharpening is most often performed after demosaicing (the conversion of raw data into RGB image data). The *RawTherapee* documentation confirms this assumption and Sony also confirmed it when asked. However, Canon, Nikon and Adobe refused to give us any information on the subject.

Because this image of an derelict factory in Odda, Norway contains almost no single-color surfaces, we were able to use an increased Detail value of 50% to emphasize the shapes and textures. We used *Photoshop*'s Smart Sharpen tool (Amount 100%, Radius 1.5 pixels) to sharpen the image for ouput and the Fade Amount slider to reduce shadow sharpness to a minimum and to emphasize the bright edges and minor details.





RawTherapee **offers Unsharp Mask and Deconvolution sharpening tools. The additional resolution provided by the deconvolution method is especially obvious in the fine barbules of the ostrich feathers.**

RawTherapee

We tested the 3.0 development version of the *RawTherapee* freeware, and the stable 2.4 version is included on this issue's free DVD *RawTherapee* can process most RAW and JPEG/TIFF formats. The program code, and therefore the internal workflows, are open source, and reveal that sharpening and noise reduction take place in an internal, 16-bit L*a*b* color space. Sharpening takes place after luminance noise has been removed, but before color noise processing.

The Sharpening panel offers USM and R-L (Richardson-Lucy) Deconvolution options. The USM tool includes the usual Radius, Amount and Threshold sliders as well as additional *Sharpen only edges* and *Halo control* options. Strangely, instead of just suppressing the usual USM-based halos, Halo Control also manages to increase their incidence if you use high Amount values. At low value settings, the slider also increases the contrast of low-contrast details and produces artifacts similar to the artificial detail produced by *ACR* and *Lightroom*. The Sharpen Only Edges option includes its own Radius and Edge Tolerance sliders, but doesn't provide a preview of their effects. It is tricky to get the hang of the effects the various sliders have and to find the best settings for each image. In the end, we decided not to apply either of the additional options to our test image, as they produced an unnatural look and actually reduced sharpness in the finest details.

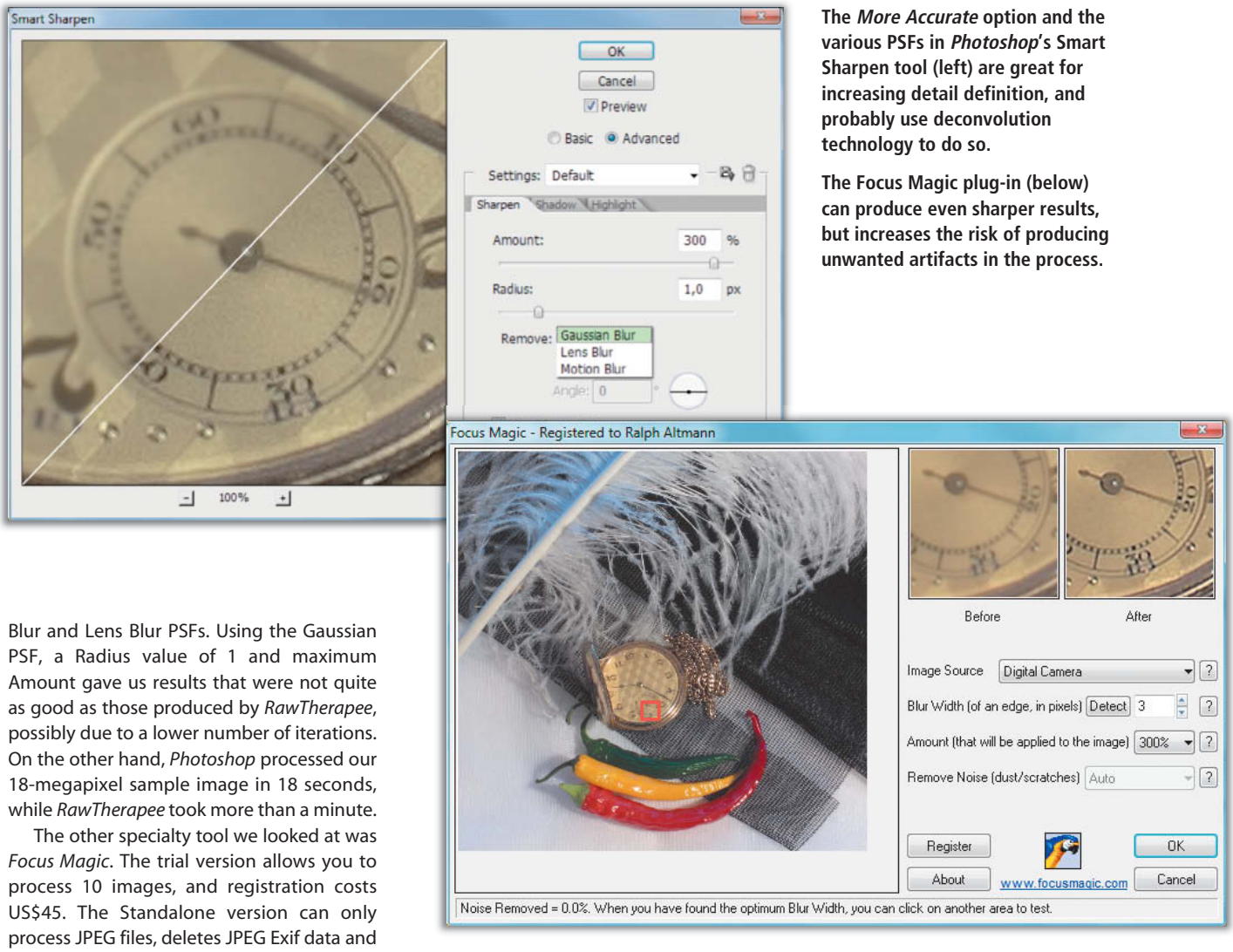
The default settings for the Deconvolution method produced results that were much better than any we managed to get using the USM filter. This difference was especially obvious in the fine barbules of the ostrich feathers, where the process brought more detail to the fore than any of the other methods we tried. Here, the Radius setting must match the radius of the softness present in your image exactly, or it will quickly produce halo effects. The Damping setting is equivalent to a USM threshold setting, and smooths low-contrast image areas. Higher Iterations values produce more effective overall sharpening but increase the risk of producing individual artifacts. The Deconvolution method is especially well suited to removing Gaussian blur and is particularly good at reducing anti-aliasing and small-aperture refraction effects. It is less effective for combating motion blur and soft focus errors.

Sharpening during Post-processing

If you shoot exclusively in JPEG format, you will not usually need to use a RAW-based sharpening tool – a standard USM filter like those found in most image processing programs will suffice (see also page 84). The following section introduces two alternatives to conventional sharpening tools.

The *Photoshop* Smart Sharpen tool has been around since the CS2 version of the program was released but is still not very popular. Even so, we recommend that you forget the USM filter and use Smart Sharpen only. Using the default Remove > Gaussian Blur setting and without checking the *More Accurate* option makes it work exactly like the USM filter. There is no threshold slider, and the threshold value is always equivalent to zero, which is ideal for the basic sharpening we wish to perform. An edge mask feature like the one found in *ACR* and *Lightroom* is prefereable to using threshold values anyway. If you check the Advanced radio button, two additional Shadow and Highlight tabs appear with individual Amount and Radius sliders for preventing oversharpening at high-contrast edges. These work much like Sony's Undershoot/Overshoot sliders, but are easier to use and more precise.

These settings very much represent conventional, optimized USM filter functionality, but the More Accurate option is actually the front end for an additional deconvolution filter. Selecting this option usually produces better results, although the radius and type of softness in your image need to be roughly equivalent to those addressed by the filter's PSF to work effectively. The filter includes Gaussian Blur, Motion



The *More Accurate* option and the various PSFs in *Photoshop*'s Smart Sharpen tool (left) are great for increasing detail definition, and probably use deconvolution technology to do so.

The Focus Magic plug-in (below) can produce even sharper results, but increases the risk of producing unwanted artifacts in the process.

Blur and Lens Blur PSFs. Using the Gaussian PSF, a Radius value of 1 and maximum Amount gave us results that were not quite as good as those produced by *RawTherapee*, possibly due to a lower number of iterations. On the other hand, *Photoshop* processed our 18-megapixel sample image in 18 seconds, while *RawTherapee* took more than a minute.

The other specialty tool we looked at was *Focus Magic*. The trial version allows you to process 10 images, and registration costs US$45. The Standalone version can only process JPEG files, deletes JPEG Exif data and color profiles while saving, has only a 100% preview function and kept giving us error messages about too little memory during our test, in spite of the 8 GB installed in our test computer. However, the package also includes a (64-bit) *Photoshop* plug-in. The plug-in, too, has only two small 100% preview windows (200% is much better for judging image sharpness), but can process RAW files and doesn't interfere with image metadata.

The plug-in can only adjust lens or motion blur, while the standalone includes soft focus, despeckle and enlargement functionality. The plug-in also allows you to fine-tune the sharpening algorithm using a preselected image as a pattern, and also includes a noise reduction filter. The program can be set to automatically select a Blur Width value, but not the amount of motion blur it removes. The small preview window makes it difficult to judge results accurately, but it is possible to limit the size of the area the plug-in affects before applying your settings.

Focus Magic isn't designed to remove Gaussian blur, so we chose to test its out-of-focus correction mode instead using a Radius value of 2 and an Amount of 300%. These settings produced acceptable results of a quality that lay somewhere between those produced by the better USM filters and *Photoshop*'s Smart Sharpen. *Focus Magic*'s real strength is its ability to sharpen seriously defocused images – a capability that neither *Photoshop* nor *RawTherapee* can even imitate. *Focus Magic* is also better than *Photoshop* for correcting motion blur.

Conclusions

No program can reconstruct a perfectly sharp photo from out-of-focus image data, but it is still amazing just how much detail deconvolution methods can squeeze out of apparently unrescuable pixels – especially if you are prepared to tolerate an extra artifact or two in the finished image.

However, the technique is only of limited use for our intended task of ironing out the limitations of photographic hardware or compensating for imprecision on the part of the photographer. It is still something of a niche method, is tricky to apply and often produces the artifacts that we really want to avoid. However, in cases where the softness characteristics of an image match the characteristics of one of the available PSFs, the results are often much better than those produced by conventional USM filters. Some programs, such as *Image Analyzer*, even allow you to tweak the PSF yourself, which is great for experimenting but not necessarily suitable for use in your daily workflow.

RawTherapee was our favorite amongst the deconvolution-based tools we tested. *Focus Magic* was the best choice for counteracting slight defocusing, even if it was a bit tricky to use. Even conventional USM filters can be effectively tweaked, as demonstrated by edge masking options and the *Lightroom* Detail function, but remember: when all is said and done, the quality of the effect is always more important than how you go about achieving it. (anm) c't

Kumaran Herold

Shoot Video Like a Pro

If you own a DSLR or mirrorless camera with an HD video function, then this is the article for you. Camera operator Kumaran Herold takes us step by step from the concept to the finished clip, explaining the shooting script and storyboard as well as the actual shooting process, including the individual shots, stylistic devices and addition of the soundtrack. You'll find all the scenes and the finished film on the free DVD that came with this issue, along with sample videos that demonstrate a variety of shooting techniques.

Filmmakers and photographers have a great deal in common– not only do they both aim to make a statement with their images, but also use some of the same artistic techniques to do so. But there is a crucial difference: for photographers, it is a single moment that has to be captured and into which the intended message needs to be compressed. Filmmakers, on the other hand, can and must link a vast number of widely varying images, each of which has additional scenes before and after it.

But that is not the only reason why filmmakers have a large amount of additional equipment at their disposal. Whether they are shooting a short drama, a documentary, or some other type of film, they are able to capture a feeling or tell a story not only by making clever use of camera and subject movement, but also by portraying the passage of time itself.

A multitude of guidelines have been devised to help filmmakers achieve their desired aims. There are libraries full of books on filmmaking and you can even study for a degree in it. But for most amateurs, all you need to do is master a few basic principles to get your own film projects off the ground.

Planning a Film

Digital video is often used simply to capture a brief happening or the surroundings of a photo. But you may have a bigger story to tell, more than just a fleeting impression – perhaps you're advertising a product, documenting an event or performing a sketch. If that is the case, it is not enough just to press the video button on your camera and start filming. It takes a bit more thought than that! You will need to consider in advance the different aspects of the subject you want to capture and how to divide the action up into separate scenes. For more complex film projects, shooting on location is just the start. The real work comes at the post-production stage, when you sit down at the editing table to deal with a mountain of footage.

We'll use our own film to show you the most important things you need to know about making a movie using a DSLR. As well as giving hints on what to think about before shooting, we show why it's a good idea to use a storyboard, and that you don't have to be an artist in order to draw one. There are practical tips too: what to do about focus (which plays a very important role in film work), how to use of movement to create tension and how to keep post-production (editing) in mind as you work. We've put all of our clips on this issue's free DVD and you can use these to edit your own version

The Shooting Script

Blind Date, the short film we put together especially for this workshop, illustrates the basics of film making very well. The story is a simple one: a man hurries into a café, obviously late. He joins a young woman sitting alone and starts talking to her. She seems surprised at first but then listens to him with increasing interest. Then he gets a text message, looks at his phone and reads: "You're sitting at the wrong table! Hello from your blind date!" Surprised, he looks past the woman at his table and sees another woman in the corner of the café, looking annoyed and waving her phone at him …

We divided our short film into three scenes:

– Thomas hurries to the café, looks at his cellphone and goes inside
– Thomas enters the café and sits down … until he realizes that he is sitting with the wrong woman.
– Thomas leaves the café with the both women

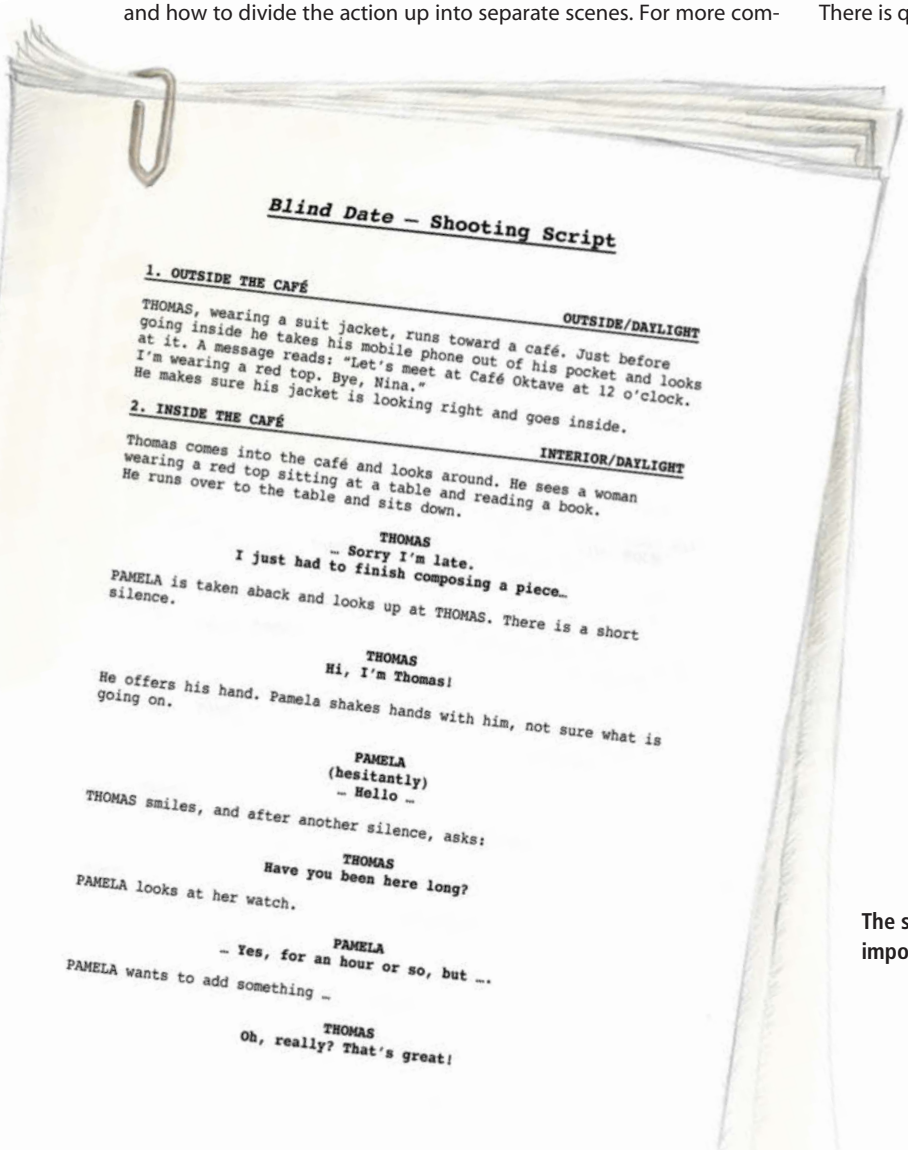
There is quite a lot to think about before we can shoot this film based on the shooting script. Let's start with organizing the shoot and preparing the equipment.

The minimum equipment you would need for this short film is a camera with a lens, a good video tripod, three actors who are available for as long as it takes, and a café that will allow you to shoot there. In our case, it was enough to discuss the project with the café proprietor a few days beforehand. For productions that may be used commercially or are at least destined for public screening, avoid unwelcome surprises by allocating plenty of time to arranging the location, even if it is a public building.

Good preparation goes a long way toward ensuring that a shoot goes smoothly. Above all, everyone should enjoy the experience. A motivated team, with everyone in a good mood, can be the key to achieving excellent results. There is nothing worse than a chaotic shoot with everyone on edge because the proper equipment isn't available.

Expect the Unexpected

As any filmmaker will tell you, "it always takes longer than you think". Professional filmmakers shoot in large teams, but still only shoot a few minutes or even seconds of footage per



Blind Date – Shooting Script

1. OUTSIDE THE CAFÉ — **OUTSIDE/DAYLIGHT**

THOMAS, wearing a suit jacket, runs toward a café. Just before going inside he takes his mobile phone out of his pocket and looks at it. A message reads: "Let's meet at Café Oktave at 12 o'clock. I'm wearing a red top. Bye, Nina." He makes sure his jacket is looking right and goes inside.

2. INSIDE THE CAFÉ — **INTERIOR/DAYLIGHT**

Thomas comes into the café and looks around. He sees a woman wearing a red top sitting at a table and reading a book. He runs over to the table and sits down.

THOMAS
– Sorry I'm late.
I just had to finish composing a piece…

PAMELA is taken aback and looks up at THOMAS. There is a short silence.

THOMAS
Hi, I'm Thomas!

He offers his hand. Pamela shakes hands with him, not sure what is going on.

PAMELA
(hesitantly)
– Hello …

THOMAS smiles, and after another silence, asks:

THOMAS
Have you been here long?

PAMELA looks at her watch.

PAMELA
– Yes, for an hour or so, but ….

PAMELA wants to add something …

THOMAS
Oh, really? That's great!

The shooting script sets out the story, together with important instructions for shooting

day. Shooting a film is a highly complex process, and all sorts of unexpected things can go wrong. Always allow extra time. Otherwise, before you know it, you can find yourself shooting a daylight scene in the evening – a real challenge to your creativity.

At the same time, contemplate how to turn your shooting script into a movie. Captured in a single shot – say from medium close up – our dialog scene would be quite dull in the finished film. To make a scene more interesting, try dividing it into a series of shots using different focal lengths and perspectives. In cinematography, distinct types of shot have different names, such as wide, long, medium, close-up or detail. The main shot types are summarized in the box on page 98.

Using different types of shot is one of the most important means of telling a story in film, since this determines the feel of the shot and the information it conveys. In the making of a major motion picture, entire days of footage end up on the cutting room floor because, with the wisdom of hindsight, it becomes clear that they do not help tell the story. It's often said that the real film doesn't take shape until it is edited, so it's worth shooting the same action in several different shots to make the editor's job easier later.

This means you have to film a whole scene once through, then again several times from different perspectives. A good editor can then create the desired mood or key dramatic moment during post-production by skillfully combining the right choice of shots. Digital editing makes it possible to adjust the timing in a movie by expanding or compressing the length of individual scenes. Sometimes, passages of dialog that read well in the shooting script turn out to be superfluous or a hindrance to the action; these can simply be cut out by the editor or replaced by alternative takes.

The Storyboard

Once you have considered the shooting script in depth, it is time to transfer it to the storyboard, which presents the shots in each scene in the form of a sketch. All of the shots required for the film are pictured, numbered and described in words. A storyboard is a really effective way of defining a day's work and organizing the schedule. Need to know how much time will be needed to film a particular shot? The storyboard has the answer – and much more. It keeps you sane when things get stressful, as it helps you make sure you don't leave any shots out by mistake. Just tick off each picture on the storyboard after it has been done.

Even for simple sequences, a storyboard is useful for keeping track, especially if you are not shooting chronologically. In such situations, the storyboard helps to preserve an overview of where you are in the action.

If there are people involved in a production who are not familiar with the film world – the subject of a documentary or the client for an advertisement, for example – the storyboard can help to give them a better idea of how a scene will look.

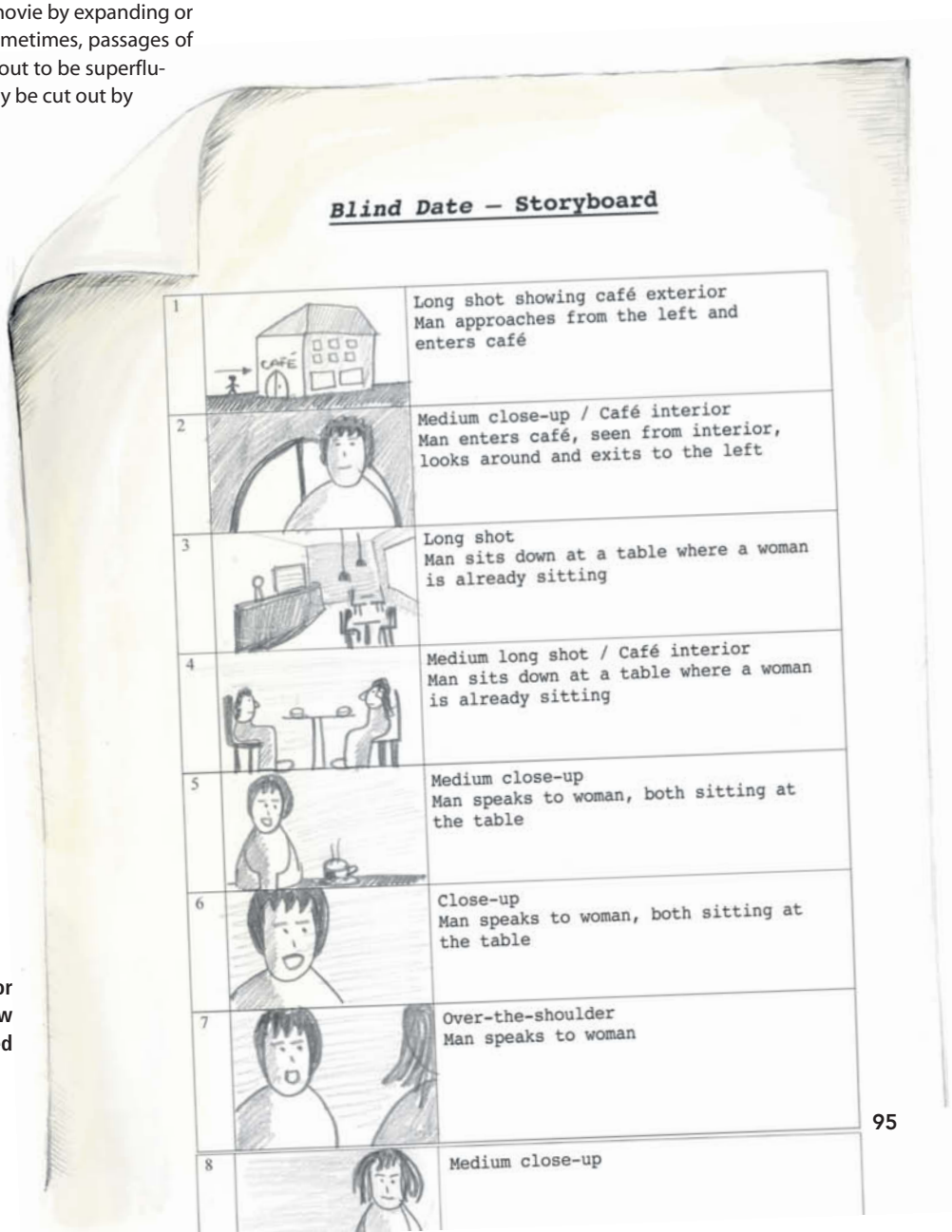
Shot lists that provide detailed information about the camera angle, movements, lens and framing are often sufficient for everyday work. Professionals don't usually need detailed sketches to show them what is meant and simple stick-figure drawings are often all that is required.

One last thing: the order of shots is important when filming. A basic rule is to start with a long shot before moving in closer. Long shots usually involve more work as far as scenery, props and extras are concerned. Once the long shots are a "wrap" you can start work on the detail.

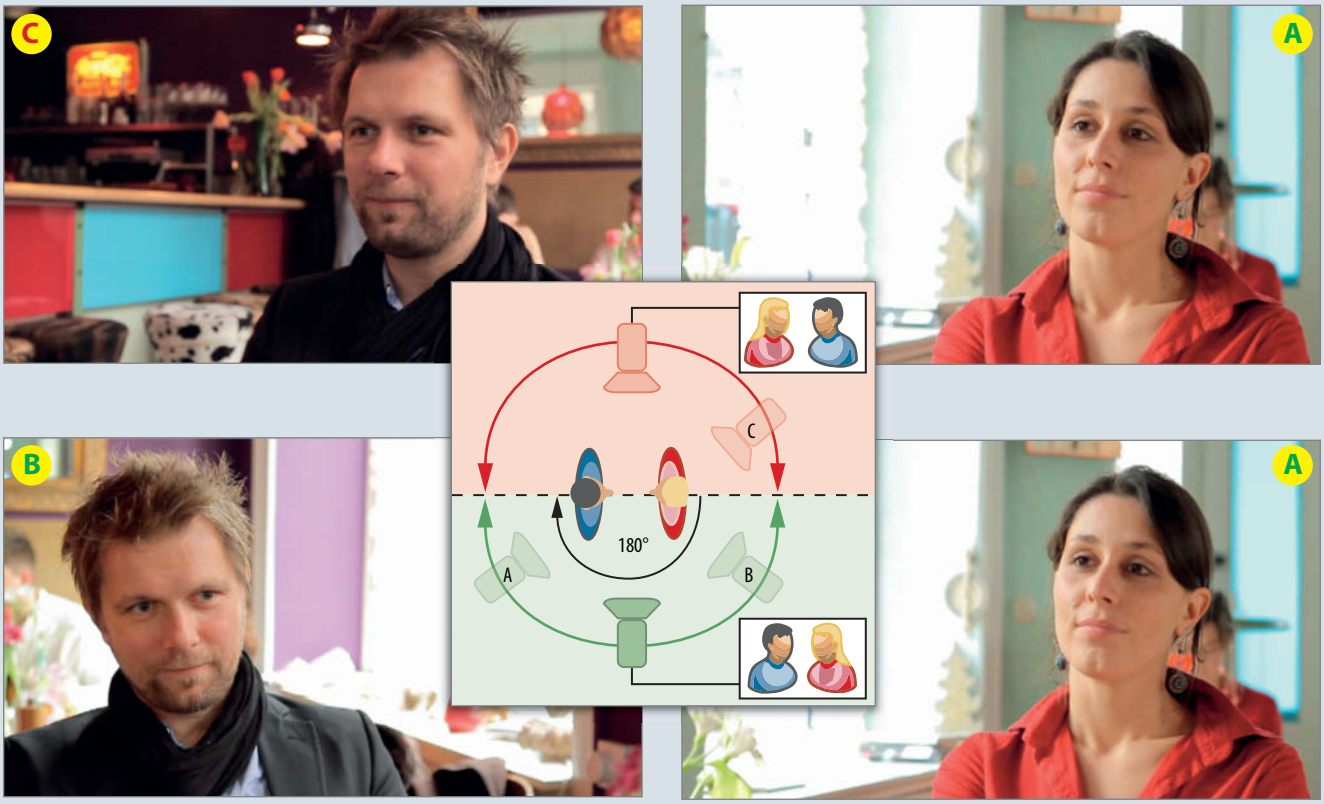
Shot/Reverse Shot and Crossing the Line

When you are shooting a scene, bear in mind that viewers are not familiar with the room where the action is taking place. They need some way of orienting themselves in the space so that they know who is sitting where and who the protagonist is looking at.

An imaginary line running between two actors provides this orientation. In our sample scene, the two protagonists are seated opposite each other in conversation. The camera should stay on one side of the axis and all subsequent shots should be taken from there.



Using a storyboard makes it simple for everyone involved to get an overview of how the shooting script will be implemented



To prevent "crossing the line", keep the camera on the same side of the interaction between the protagonists. As long as the camera stays on the same side of this imaginary line (in position A or B) for the shot and the corresponding reverse shot, the protagonists will appear to be talking to each other. Otherwise, if the camera moves from position A to position C, they will both appear to be looking in the same direction.

This way, all the shots will flow together properly. The editor can mix and match close-ups shot from this angle and the actors will still appear to be looking at each other while they are talking.

If the camera "crosses the line" during the scene, this creates the impression that the actors are no longer looking at each other but instead past each other. This is quite distracting as viewers are subconsciously aware that something is not quite right and are busy trying to figure out who the speaker is looking at.

Sometimes, directors deliberately cross the line to produce an edgy feel to a scene or accentuate a turning point in a conversation. If you want to help your viewers understand the story and allow them to concentrate on the plot, it's best not to use this type of effect.

However, if there is no option but to change sides during a shoot, it's not a disaster. Simply insert a long shot of the whole room (that you cleverly remembered to shoot, just in case), and the camera can move to the other side of the axis for the next shot without any problems.

Introducing Movement

Just like a great photograph, a static shot in a movie has to be well composed to be effective. But the essence of film is movement – whether this is movement of an actor within the frame or movements performed by the camera itself. This is what makes a film more interesting to watch. However, since different movements have different effects, movement has to be used very carefully if you want to convey the right message.

Panning gives the viewer an overview similar to casting your eye over a landscape or a laid table. It can also create a connection between subjects – for example, panning from a protagonist's face to a painting she is looking at on the wall creates more interest than filming the scene as a long shot in which we can see both the actress and the painting. As the professionals put it – panning "tightens" a shot.

Put simply, framing defines the shot. The image within the frame is part of the total visual environment in which the scene takes place. Tight framing draws our attention to certain visual information, which doesn't necessarily correspond to the way we would naturally see things but helps to make the action clearer or more dramatic.

In a pan, the viewer first sees a person looking at something, but doesn't know what they are looking at. It is a way of raising a question that the viewer would like to have answered – it gets the viewer interested. At the end of the pan the tension is resolved when we see the object in question. This is just one example of how to use simple artifice to maintain a viewer's interest.

When filming a pan shot, you need to spend a few seconds in the starting position, then begin the pan, find a suitable finishing position and remain there for a few seconds before making a cut. The timing of the finished scene is best determined during the digital editing process rather than during the shoot. If you are shooting under time pressure, the usual tendency is to cut a shot too short. But remember, shortening a shot later is much easier than lengthening it, as there will probably be no suitable material available.

We don't really notice the other person in the picture until focus is shifted from the foreground to the background

Choosing the Right Lens

Your preparations should include thinking about what hardware will be needed. Top of the list, after the camera, of course, are lenses. Zoom lenses allow you to work fast because you can simply zoom from a long shot to a close-up without having to change lenses. Fast shot switches are especially useful in documentary situations –from children's birthday parties to weddings – and help to ensure that you don't miss the crucial moment.

However, using zoom lenses gives you less creative headroom. Maximum apertures of f2.8 or f4 (such as those available on the Canon EF 24-70mm f/2.8L USM or EF 24-105mm f/4.0L USM) increase depth of field markedly compared with that produced by 50mm f/1.4 fixed focal length lens used wide open. But it is precisely the ability to obtain nice background blur that makes DSLRs so popular with filmmakers. Thanks to the larger sensor, DSLRs can produce much shallower depth of field than conventional video cameras with their 1/3" or 2/3" sensors.

Fixed focal length lenses with larger maximum apertures are therefore more useful when you are shooting calmer scenes, such as "beauty shots", when you know that you will have enough time to change lenses between shots. Bright fixed focal lengths do present a special challenge, however, if you are using a DSLR with a full-frame sensor, such as the Canon EOS 5D MK II. In this case, the depth of focus becomes so small at maximum aperture that it becomes difficult to focus on the actor's eyes. The only options are to stop down or use a lens with a wider angle of view.

Pulling Focus

When filming, the camera operator deliberately shifts focus to the part of the scene which is the center of attention – usually the main actor. By shifting focus, it is possible to shift the viewer's attention to some other detail within the frame. Changing the focal plane within a scene is also called "pulling focus" or "racking" and, along with depth of field, is a much-discussed topic in the film world.

Focus pulling becomes critical when the protagonist moves toward the camera from some distance away. The focus has to shift continuously with the actor's movement. If this is not done properly, the protagonist's face will move in and out of focus. The viewer will notice immediately and feel that something is wrong. It would be great if camera autofocus could perform this task, but unfortunately, DSLR autofocus systems are not designed for use with moving pictures. Even in the professional film world, pulling focus is one of the most difficult jobs, and is usually undertaken by the camera assistant, sometimes called the focus assistant. Usually, marks are taped to the ground (as long as it is not also being filmed) at predetermined distances and corresponding marks are made on the focus ring on the lens for each position. The focus puller can then concentrate on adjusting focus to the correct setting at each point during the shot.

Focus marks on the ground and the lens help the focus puller to make focus follow the action precisely during a shot

It takes a lot of practice to track focus correctly. Trickier shots, such as ones that use long lenses and wide apertures, tax everyone's patience, and often require a number of takes until everything turns out just right.

If you are planning a scene that involves focus pulling, it is possible to use the zoom to shift focus. Simply define two or three points the actor passes and mark the corresponding zoom positions on the lens using colored sticky tape. A few run-throughs help everyone get the positioning right before you make the actual take. If you cannot be sure that your lens doesn't judder while zooming, it's probably better not to use this technique at all.

The greater the focal length of the lens you are using, the shallower the depth of field will be and the more difficult it becomes to pull focus. It can be easier to use a wide-angle lens and a narrow aperture, assuming that there is sufficient light. This combination will increase depth of field and make it easier to focus.

The focus rings on some photo lenses have no precise infinity or close-up stops, making it possible to move it beyond the ends of the focus range (like the Canon lens we used). If you have applied marks to this type of focus ring, you must be careful not to rotate it too far, otherwise the marks on the lens no longer correspond to those on the ground.

The Zeiss Compact Primes CP.2 series of lenses is designed specifically to meet the needs DSLR filmmakers. These lenses have stopped focus rings with helical gearing and calibrated distance scales to help you work accurately.

Viewfinders

After a difficult take, it's a good idea to check your results on a large monitor. This is the only way to be sure that the focus is correct all the way through. Nothing is more frustrating than discovering that a se-

quence has been messed up when you are back home in front of the computer with no way of doing a re-take.

It can be difficult to check focus using the camera monitor or a 7 inch accessory monitor. A large, external monitor is very useful but can use up large part of your budget. You can, of course, transfer the memory card to a notebook computer to review your most recent take, but a cheaper, more effective alternative is to use a magnifying viewfinder that attaches directly to the monitor on the back of the camera. This makes it easier to monitor focus during and after a shot.

If sharp focus is more important to you than natural-looking images, you can turn your camera's built-in sharpening feature up to maximum. This will make the camera's image processor intensify edge definition while you are shooting. The resulting footage then appears more sharply focused than in reality, but gives it an artificial look that can be quite "hard".

Despite the obstacles to be overcome, I recommend that everyone tries using focus pulling as a stylistic device. Some shots can benefit greatly from a focus pull form complete blur to fully sharp, or vice versa. This type of technique is often used to create visual transitions in movies.

Shallow Depth of Field in Bright Light

It is relatively easy for stills photographers to achieve shallow depth of field, even when shooting outdoors, by using a wide aperture and adjusting the shutter speed accordingly. Similarly, you can use shorter shutter speeds to increase the working aperture when shooting video. A shutter speed of 1/50 s is usually used to create natural-looking movement. However, in the bright situations, the shutter speed can easily be as low as 1/250 or even 1/1000 s if you are using a wide aperture, which then results in jerky, unnatural-looking movements. Fast shutter speeds can be useful for filming sports and allow better analysis of movement, but they are not suitable for filming drama.

To make it possible to shoot using normal shutter speeds while keeping the aperture open, it is necessary to reduce the amount of incident light. This can be achieved with a neutral density (ND) filter, which reduces the amount of light entering the lens without affecting its color. To avoid the hassle of having to change the filter every time the light changes, cinematographers often use Vari-ND filters, which allow you to vary the degree of transmittance by rotating the filter's outer ring.

Shutters

Take care not to pan too quickly. Depending on the frame rate you are using, vertical patterns like those in a garden fence or the front of a house can create "judder" in the finished shot. If this happens, your only options are to pan more slowly or try shooting from a different angle.

The "rolling shutter" effect, which is especially prevalent in in DSLRs or digital compacts that have CMOS sensors, causes wobble, skew or smearing effects in footage of moving subjects. CMOS sensors record

Comparing the very basic focus scale of the Canon EF 50mm f/1.2L USM (below) with the fine, calibrated scale of a Zeiss CP.2 50mm/T 2.1 EF (above) in the 0.6 to 0.8-meter range. The advantages of using a specialist video lens for focus pulling are obvious.

visual information by scanning the exposable area of the sensor 25 or 50 times a second, which means that not all information in a single frame is recorded at exactly the same moment. Consequently, movements in the subject or made by the camera during the 20 or so milliseconds it takes to record a frame become visible in the captured clip. The effect often takes the form of diagonal lines or warped wheels and propeller blades.

A Vari-ND Filter like the LightCraft Workshop model shown above allows you to control the amount of incident light almost steplessly, making it possible to film with an open aperture without adjusting your shutter speed, even in very bright situations

Dolly Shots

A smooth dolly shot is more complex to put into effect than a pan shot from a tripod. Professional film teams use expensive rails and dollys so that the camera can glide through the scene, but you can achieve similar results if you get a member of your team to wheel the camera operator about on a chair with wheels. There are also special casters available that can be attached to the bottom of a tripod. A smooth floor is vital to the success of any of these methods.

Shooting Handheld

Filming handheld also creates movement in the image and creates a strong sense of authenticity, because viewers have the feeling that they are participating in the action. When filming handheld it is important to keep the camera as still as possible. Large video cameras are constructed to be held comfortably while filming, but DSLRs are designed primarily for stills photography and are difficult to hold still

Optical viewfinders like the Zacuto Z-Finder Pro make it easier to monitor focus while you are filming. Enjoyyourcamera and other suppliers offer less expensive models.

A custom DSLR rig will help you to shoot shake-free footage handheld. The one shown here is made by the Dutch firm Vocas, and consists of hand grips, support rails, a shoulder support and a matte box.

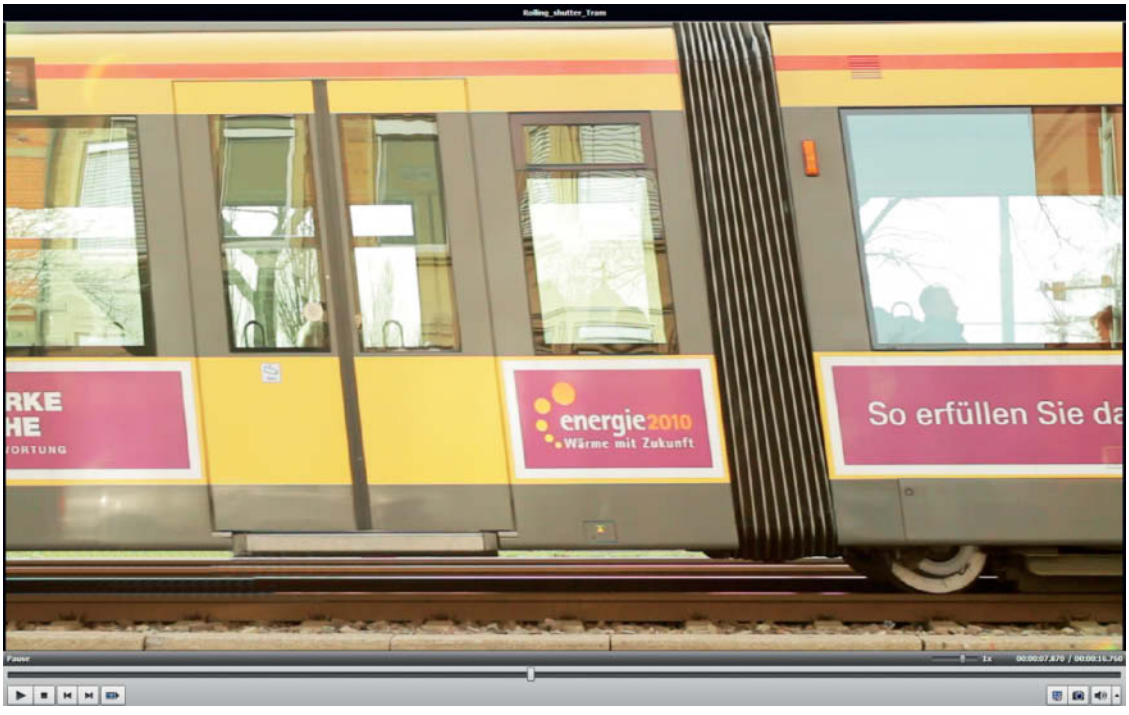
while filming. The longer your lens, the more likely you are to produce camera shake, and it is virtually unavoidable if you make adjustments to camera settings during a shot.

Some manufacturers offer special rigs for shooting movies with DSLRs. These have shoulder supports and grips that help keep the camera steady and make it possible to shoot simple pans and dolly shots handheld.

You can also artificially stabilize your footage by deliberately shooting at low (720p50) resolution. You can reduce the 50 frames per second to 25 during editing, thereby creating a slight slow motion effect, with each second of original footage becoming two seconds in the finished clip. This technique is often used to give adverts a softer look and helps to mask any camera shake that was produced during the shoot.

The downside of this technique is that he lower resolution (1280 × 720 compared to 1920 × 1080) means that moiré effects are more likely to occur in the parts of the frame where fine textures are present. Shot rom an unsuitable angle, even a tiled roof can cause distracting flicker, so it's always a good idea to make some test shots in advance and view them on a reasonably large monitor so you don't get any nasty surprises further down the line.

Last but not least, pulling focus, as described above, also creates a sense of movement in a film.



Even if the camera is set up vertically, CMOS sensors used to film pans or fast-moving subjects produce warped or slanted lines

At lower HD resolution (1280 × 720), fine textures can cause slight moiré effects

Ergonomic Limits

As we have seen, a DSLR is not ideally suited to shooting movies, especially when it comes to pulling focus or shooting handheld. But if you want to exploit the advantages of large sensors and interchangeable lenses, you have to come to terms with the less than ideal ergonomic aspects of this type of camera.

Currently there is no DSLR alternative to specialized anti-shake tools such as Sony's Super SteadyShot for video cameras. Nor do lenses have buttons or levers for performing smooth, shake-free zooms during a take. The viewfinder in a DSLR is fixed, whereas video cameras have tiltable viewfinders that can be adjusted to suit the camera position. There are accessories to compensate for most of these shortcomings, although they can be very expensive.

Lighting

Camera operator training teaches people to use the available natural light as much as possible. For outdoor filming, the sun and clouds will dictate the conditions, although it helps to add light to the shadow side of an actor using a reflector. For interior filming during the day, increased contrast presents more of a problem. When a scene is being set up, the camera operator will check which position in the room offers the best lighting for the actor. The light coming through the window is usually brighter than the light reflected within the room and contributes to the high-contrast nature of many indoor situations.

However, before you reach for the reflector, whether inside or out, first consider whether you can actually turn the lighting to your advantage. If the actor's face is still too dark, a reflector comes in handy. These come with a silver side and a white side for neutral light or one gold and one black side. Gold coatings create a warmer mood.

If the location is simply too dark, or you want to use light as a stylistic device, you will need additional lighting gear. Small LED panels that attach to the camera's flash shoe are great for shooting documentaries, although they have a similar effect to flash and leave the background dark. For larger rooms, use 300W or 800W lamps. If speed is of

The closer the microphone (shown here attached to a boom) is to the actors, the clearer the recorded sound will be

the essence, you can direct a strong light toward the (hopefully white!) ceiling to get some extra light, similar to using bounce flash.

The Soundtrack

Audio is one of the weaker points to shooting video with a DSLR. Because we can't see sound, we often forget about it. It is all too easy to forget to activate the camera's sound recording function before you start shooting, and your birthday gathering will be a "silent movie" for ever! Pro video cameras have sound level controls built into the monitor, but most video-capable DSLRs don't.

While DSLRs do have built-in microphones, these are usually of fairly low quality and often amplify the noises produced when you make changes to camera settings. An accessory microphone mounted on the flash shoe gives you the upper hand when battling extraneous noise, provided that your camera has an appropriate socket.

It is helpful to wear headphones to monitor dialog during recording. This way, you will immediately be aware if distracting sounds like the loud coffee machine in our café make your actors inaudible so that you can organize a second take before it's too late. It is also advisable to do a test run for the soundtrack and check it before you start filming.

Using a separate, external recording device gives you greater control over your sound. This allows you to set the recording level manually. Adding a boom allows you to position the microphone closer to the actors but still outside the frame, filtering out unwanted noises even more effectively.

Filming with a separate soundtrack requires the use of a clapperboard. The purpose of a clapperboard is to synchronize the soundtrack being captured by the recording device with the images filmed by the camera. The key points that you need to write on the clapperboard are the date, project name, scene name and take number.

Once you have confirmed the details, hold the clapperboard in front of the camera, read the information out loud (with the camera running) and close the clapper so that it is audible on the soundtrack. The click in the soundtrack can then be synchronized with the picture during editing.

Atmosphere

The atmosphere in a film is created not just by the choice of shot and mood of the lighting, but also by ambient noise or "atmos" – snippets of audio recorded separately, on location, usually for several minutes at a time. They may relate to the main theme or simply come from the general surroundings, perhaps children playing, a train passing by, public announcements in a railway station or the buzz of conversation and background music in a café.

Atmos are very useful if it is not possible to use the camera audio because of camera noise or audible instructions from the director. Interference of this type can be masked during editing using atmos. In our café scene, we had a different problem: when we started filming, the café was almost empty but it gradually filled up toward lunchtime and the background noise increased considerably. If the editor were to cut together takes from the quiet morning phase and the busy lunchtime phase of the shoot, the effect would be quite disconcerting for the viewer.

Since we could not control the number of people in the café, we recorded a "soundscape" of several minutes of busy café noise, which the editor used later to even out the sound levels.

Classic films demonstrate just how important sound can be when creating atmosphere. Think of Hitchcock's Psycho: the absence of a soundtrack during the famous shower scene would make the whole film much less dramatic. (pen)

A purpose-built stereo microphone such as this shock-mounted Røde model provides much better sound than the camera's built-in microphone

The equipment we used

Camera
1 × Canon EOS 7D
2 × LP E6 batteries
3 × CF 16GB memory cards

Lenses
1 × Canon EF 24-70mm f/2.8 L USM
1 × Canon EF 16-35mm f/2.8 L USM
1 × Canon EF 50mm f/1.2 L USM

Accessories
1 × MOVIEtube LT rig
3 × Chrosziel AC focus rings for photo lenses
1 × Chrosziel follow focus
1 × Matte box
1 × Sachtler video tripod
1 × Accessory monitor: TV Logic LVM-071 W
3 × LightCraft Workshop ND filters (clear 3, 6, 9)

Sound
1 × Røde stereo DSLR microphone
1 × Quick Pole microphone boom
1 × Zoom H4n sound recorder
1 × Headphones
1 × Clapperboard

Joachim Sauer, Philip Mohaupt

Video Editing Software

Most movies only really take shape during computer post-production. We tested five programs in the US$100 range that promise to make editing a snap for beginners and even more fun for experienced users.

Programming video editing software is something of a tightrope walk between providing simple handling and maximum functionality. Many manufacturers choose to hide some functions to keep their interfaces clean and user-friendly, especially for beginners. This helps keep the learning curve shallow and makes it easier to achieve satisfactory results within a short space of time.

Software companies put a lot of effort into programming complex wizards that are designed to do a lot of the preparatory and editing work automatically and give the user the greatest possible freedom to concentrate on the creative part of the editing process. At the same time, they want to keep their products interesting by constantly adding new and exciting functionality – 3D editing tools are the latest to hit the market.

The number and complexity of the wizards on offer is constantly growing and, with the exception of the Sony offering, all the programs we tested include fully automated editing tools. As an example, Adobe *Premiere Elements* analyzes footage during import, detects scenes that contain camera shake and indicates which scenes it thinks are usable. Some programs have built-in scene detection functionality and constantly search through loaded clips for beach scenes, landscapes, faces and other typical subjects. This type of feature is aimed at helping the user to assemble videos quickly and easily. The results may not deserve an Oscar, but are certainly preferable to subjecting your audience to endless uncut material.

A Question of Computing Power

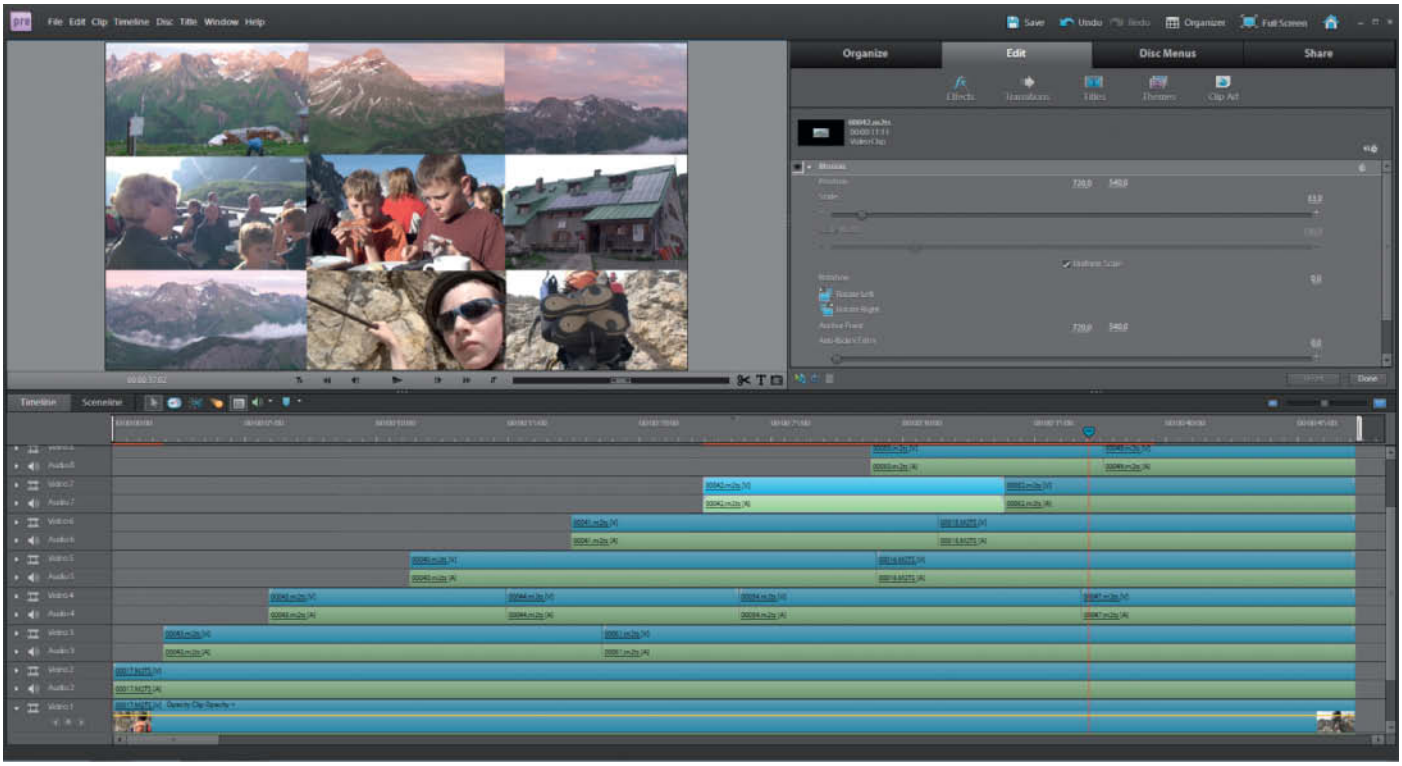
All contemporary video editing software supports DV and HDV formats and usually AVCHD too. However, the large numbers of MP4 formats in current use are not so well covered. Videos shot on pocket camcorders, cellphones and some compact stills cameras often present otherwise stable editing programs with a serious challenge. To keep file compression and processing efficient, computer-based editing software requires an ever-increasing number of specialized codecs and increasingly powerful hardware. Nevertheless, software manufacturers consistently claim that their new products are more powerful than their predecessors.

However you look at it, you will need a computer with a high-speed CPU, at least 4 GB of RAM and separate hard disks for system and video files to keep a Full HD editing package running smoothly. In an emergency, you can still cobble a video together using a 2.4 GHz Core2Duo system, even if it limits you to working on a single track. But, if you want to work creatively, you should really use a Quad-Core processor. Not all editing programs are 64-bit-compatible, so you will usually be fine with 4 GB of RAM.

We tested the entire workflow, from import to output, using an Apple Mac Pro (2 x Intel Xeon 2.8 GHz Quad-Core, 4 GB RAM, Nvidia GeForce 8800 GT running MAC OS X 10.5.8) and a fast Windows PC (with a 3.2 GHz Intel Core i7-960 and 8 GB of RAM running 64-bit Windows 7). We used a timeline with a large number of additional tracks containing a picture-in-picture image scaled to 33 percent. The more of these tracks a program can handle without dropping any frames the better.

We imported AVCHD footage as well as HDV and DV material, various MPEG-2 clips and a bunch of other exotic formats from various camcorders. Alongside the programs' real-time processing power, we also kept a keen eye on how each program behaved with a fully loaded timeline. Does the timeline update quickly and easily when we cut or move shots? A forced refresh can help if the preview is no longer automatically smooth after making these types of edits, although not all of our test programs allow the user to refresh manually. In practice, other factors make a difference too, such as whether the timeline shifts automatically when you move a shot and whether the most important edit modes (paste, split, overwrite etc.) can be

Like its predecessor, the *Premiere Elements 9* interface is clean and very similar to the one found in other Adobe programs



The *Pinnacle Studio* Import wizard offers a choice between importing individual files or complete folders.

addressed directly from the timeline. Diversity is the order of the day at the export stage, too, and many programs now include templates or dedicated tools for uploading video to portable devices, YouTube or Facebook. Last but not least, an editing program should include tools for burning your videos to DVD or Blu-ray.

Adobe Premiere Elements 9

At long last, version 9 of Adobe *Premiere Elements* now includes a Mac port that is compatible with OS X 10.5.8 and later. The program is available in a bundle with *Photoshop Elements* for US$150 or as a standalone for US$100.

Adobe's great asset management functionality puts it ahead of many of its competitors. The Organizer's keyword functionality makes it simple to find individual clips buried in large amounts of data and offers various functions for saving your data, even if media analysis takes longer than it does in other programs. The built-in Facebook upload tool doesn't work with unedited HDV or AVCHD and we would like to see it integrated directly into the edit interface, like the YouTube share function. The Media tab in the Organize panel also includes the Instant Movie function, which guides you step by step through the selection and editing part of movie creation and helps you to add effects, titles, transitions and audio. The finished instant movie can then be fine-tuned in the timeline.

The interface will be familiar to Adobe users, and we didn't find any differences between the Windows and Mac versions. We found the clip scaling dialog with its dark typeface on a gray background confusing.

There are some similarities in handling for *Premiere* and *Premiere Elements*, especially in the effects department. Here, Adobe uses its proven and flexible keyframe functionality, but still allows you to drag simple transitions directly from the media browser to the timeline. Beginners will most likely prefer to work in the Sceneline (storyboard) window.

Adobe has added some new effects by *NewBlueFX* to appeal to advanced *Premiere Elements* users. These include the Cartoon effect, which gives real-life movie clips a cartoon-like look and feel. The built-in image stabilizer comes from *NewBlueFX* too, and has been well integrated into the editing workflow. It works fairly well, but zooms quite strongly for the degree of stabilization it produces. Strangely, it also produced some hitherto non-existent rotational effects in the stabilized footage. For more detail on this tool, see our article on image stabilizers on page 112.

During our test, *Premiere Elements* coped well with a five-track test timeline. If you want to work on a shake-free timeline with more than five tracks, you will have to render your material first – a task that takes a significant amount of time. The program took over an hour to render a two-minute scene constructed from nine separate source files.

Premiere proved itself to be somewhat bullheaded when handling AVCHD files. It reacted with a strong delay to a timeline filled with 20 minutes of AVCHD clips, but nevertheless managed to playback a three-track test video without significant shake. Again, it took about an hour to render a two-minute,

3D on YouTube

Editing and outputting 3D video is still very much at the beta stage. The only "real" 3D movie formats available are supported by Blu-ray and YouTube. YouTube's 3D player is still in beta after more than a year's testing, but is still capable of playing videos uploaded in side-by-side format in various 3D output formats.

As usual when things at YouTube haven't been finalized, you simply have to do it yourself. To get 3D playback working, you have to add a tag that looks like this: *yt3d:enable=true* to your file's description. This activates the 3D playback options button beneath the playback window.

Unfortunately, automatic aspect ratio detection doesn't yet work, which means that you have to enter the appropriate data manually. Using either the variable *yt3d:aspect=16:9* or *yt3d:spect=4:3* ensures that your clip is played back in the right format.

***PowerDirector 9* includes a wide range of effects and transitions for every taste, and for beginners as well as advanced users**

nine-track test video. The same test performed on a Mac resulted in successful four-track AVCHD playback.

Another aspect of our test involved creating transparency in a two-minute clip. Adobe managed this in Windows in 36 seconds (equivalent to a rate of 83.3 fps), but took 81 seconds in Mac OS (i.e., at 37.01 fps). Exporting the same file took 82 seconds in Windows (at 36.6 fps) and 113 seconds in OS X (at 26.55 fps) – a difference of almost 30 percent. 64-bit and multi-core support is obviously still not completely sorted out.

Adobe uses primarily MainConcept codecs for exporting media and has built a fairly clear-cut dialog for selecting export settings and formats. There is no preset for 50p material, but you can select H.264 compression for the QuickTime codec and then select Full HD resolution and your desired frame rate manually.

Export to a Web environment takes place via the Web DVD tool, which creates a Flash video and an HTML index page in a single folder. The index page then provides navigation in an interface that is similar to a conventional DVD menu.

Avid Pinnacle Studio 15 HD Ultimate

A complete installation of *Pinnacle Studio 15* takes a very long time, but includes a clear and comprehensive step-by-step introductory tutorial. The Avid interface and handling concept is not the most up to date and includes the familiar Album (media browser) at top left, the Player (too small) at top right and the over-large timeline across the bottom of the window. The preview window can only be scaled to 16:9, but the program does support dual-monitor setups with a full-screen preview on one side.

Importing is smooth and supports all popular video formats, including tape. Electronic media can be imported directly from the media browser, whereas tape footage has to be imported via the Import From dialog.

The movie window still has only two video tracks, plus titles, sound effects and music. The timeline can be converted to storyboard view, which then displays larger and more detailed thumbnails than the timeline.

Pinnacle Studio uses the second video track to create picture-in-picture effects and further "virtual" tracks are available as part of the Motion Titler tool, which enables you to create animated text and graphics layers. Avid has also managed to squeeze up to 12 additional effects tracks into its Montage Themes tool but these are no substitute for extra "real" video tracks. On the plus side, the tool does allow you to create impressive animated titles, and includes more than 150 genuinely useful templates.

The *Pinnacle* package includes a number of adjustment and correction filters and has its own image stabilizer, as well as support for Red Giant plug-ins. The downside of all this variety is that only a few of the available effects are described in any detail in the program's documentation.

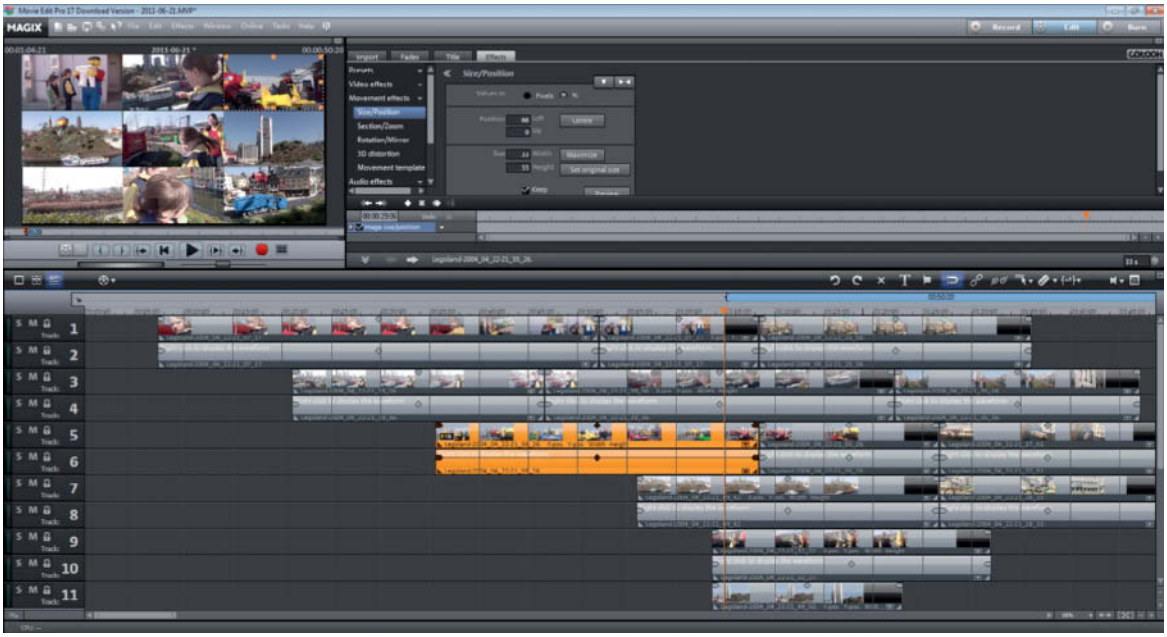
There is also a wide range of built-in audio effects, which you can use to enhance your movies in funny or dramatic ways. If you are using a fast computer, we recommend that you switch off the default background rendering, as this speeds up editing and helps to keep timeline playback smooth. However, it makes sense to leave it switched on and working in older computers which cannot play back the timeline smoothly in real-time anyway.

Pinnacle Studio 15's two video tracks had no problems dealing with our test footage and played back our AVCHD, HDV and DV clips without stutter. This version of the program has a new, pro-grade feature that allows you to export complete projects, including all uncut raw material, into a separate folder. This helps not only to keep your main computer tidy, but also makes it simple to switch computers mid-project. Avid also guarantees cross-tool data compatibility, for example with its new Avid Studio editing package.

The program offers a range of preset Disc Menu templates that can be dragged to the timeline, where you can edit the background picture, buttons and sounds. Movies can be exported to Blu-ray or DVD formats, as well as burned to disc in all popular file formats (MPEG-2, MPEG-4, DivX or Flash) using preset or custom parameters. Web export options are limited to YouTube and Yahoo! Video.

Cyberlink PowerDirector 9

Cyberlink's *PowerDirector* series has always been more of a beginner's than an advanced editor's tool, although many experienced users appreciate its wide range of effects and keyframe animations. With version 9 of the program, Cyberlink has confirmed its intention



The Magix *Movie Edit Pro 17* program window. The Media Pool and the Timeline can be freely scaled or displayed in full-screen mode. All three main areas can be freely arranged and support dual-monitor viewing.

to aim higher and has revamped its 64-bit support (for improved HD editing) as well as introducing support for up to 100 video tracks.

The program's interface looks identical to its predecessor and the preview, timeline and media library windows follow the industry standard arrangement. Adding additional audio or video tracks manually quickly clutters up the overview, and we found ourselves scaling the preview, timeline and media browser windows up and down several times during more complex projects. We would like to see a more flexible overall interface architecture.

The Import Media button imports your media directly into the virtual library. The program imported AVCHD clips exspecially quickly and coped well with all of our test formats, including 50fps full-frame footage. Editors who use a lot of raw material should select the *Import Entire Folder* option. If you are using an older, less powerful computer, you can convert your files to a low-resolution proxy format that uses less disk space and processing power. This method keeps the editing process smooth and the software reverts back to using the original, high-resolution files during output. The only potential disadvantage of this technique is that you might not be able to control image sharpness as well as you can when editing full-resolution clips.

There is no dedicated trim window, so you are limited to trimming on the timeline using the Multi Trim feature, which can be confusing even for experienced editors. Thumbnails are sharp and can be zoomed to a usefully large size, and the timeline scrolls forward automatically when you drag a new clip to the leading edge of an existing thumbnail. Unusually, the playback marker automatically jumps to the beginning of a selected clip, which makes it impossible to arrange the entire film around the current playback marker position – a standard feature in most other editing programs.

Creating picture-in-picture animations is simple and intuitive and uses the preview window to position and scale the overlay clip. Keyframe functionality makes animating overlays quick and easy. *PowerDirector* includes a wide range of effects, transitions and filters, including "particle" effects, falling snowflakes, animated lightning bolts and fireworks.

Version 9 is the first that allows you to separate the incoming audio and video tracks. You can then edit your sound independently in the new WaveEditor tool. The tool opens in a separate window and minimizes the other program windows automatically, leaving just the audio track visible. This then makes synchronized editing of separate audio and video tracks impossible.

We particularly liked the new real-time Full HD preview function, which worked smoothly for all but the most effect-ridden footage. If you use the new Pre-render function, things stay smooth and glitch-free all the time.

In our test, *PowerDirector* played back five AVCHD tracks shake-free on our 64-bit Windows 7 system. It also managed seven HDV and 13 DV tracks. Output to Blu-ray, DVD and electronic file formats was quick and easy. The program now supports export to external media and direct uploads to YouTube and Facebook.

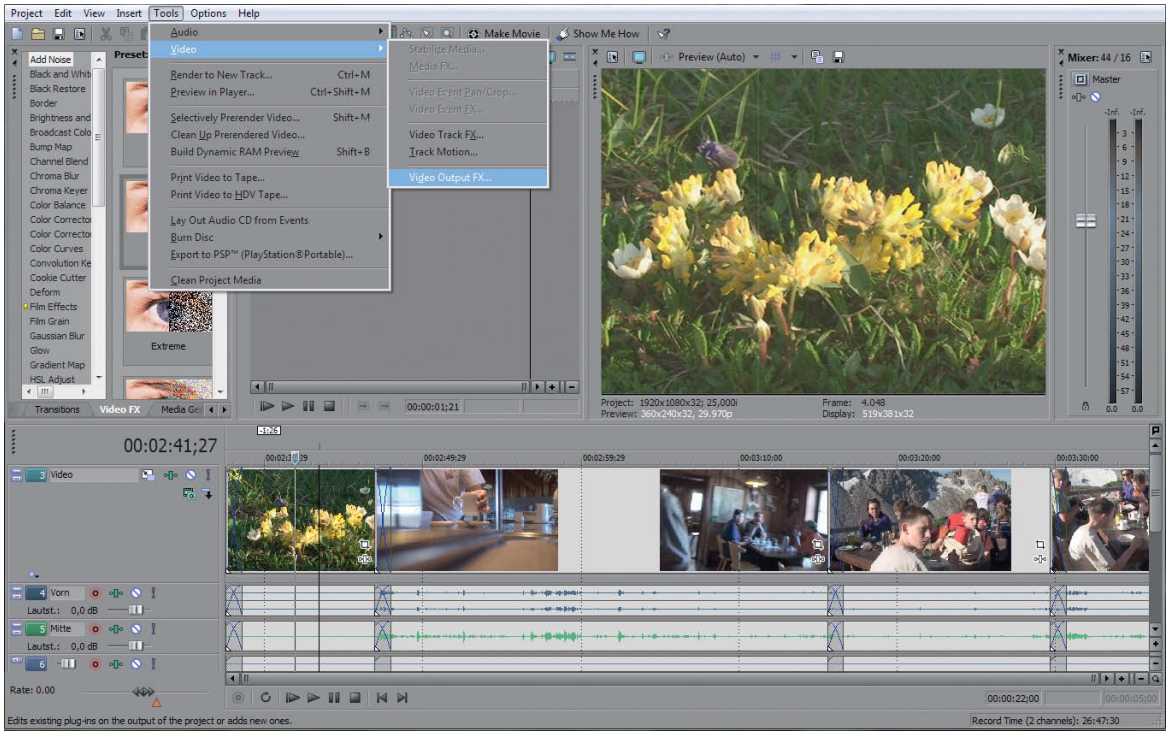
Magix Movie Edit Pro 17

The latest version of the Magix *Movie Edit Pro* editing software remains true to the company's guiding concept of combining maximum functionality with maximum user-friendliness. The market leader in consumer 3D editing, Magix not only constantly expands the range of functions it offers, but also continually improves base functionality, such as the installation routine, which now performs a near-complete installation in less than nine minutes. You still have to register individual codecs manually, which keeps Magix' license costs down but requires you to be connected to the Internet the first time you load any file types that require new codecs.

Unlike most other manufacturers, Magix still includes comprehensive printed and PDF manuals with the product. The digital documentation also includes video tutorials for multimedia beginners. The Magix interface has definitely improved since its last iteration, but still appears busier than those provided by the competition and has a number of rather small buttons.

The Plus version of the program includes its own image stabilization tool that works well for footage with slight shake, but is simply not as powerful as Avid's Stabilize function when it comes to counteracting serious wobbles.

Editing work centers around the Media Pool window, where you can load and adjust



The Sony Movie Studio 10 interface can be arranged freely. All windows are scalable and can be individually shown or hidden.

settings for video files, audio files, fades, effects and even entire projects. The Soundtrack Maker and other features can only be reached via separate windows. If you are serious about video editing, we recommend that you purchase either a second monitor or a large Full HD monitor, especially in view of the fact that *Video Edit Pro* can accomodate 100 video tracks.

This version of the program is much faster than its predecessor and works smoothly with a full timeline, positioning the playback marker and starting playback without delay. The timeline scrolls smoothly with the mouse if you insert a new clip outside the visible window area. Magix hasn't included preview rendering, so you can't preview slow-motion or backward play effects without stutter. Preview rendering would also be a great help during 3D editing. The way things are, it is quite difficult to position 3D titles within a frame, as you can only judge the effects you are creating in a jittery preview.

The 3D editing tools assume that you recorded your footage using twin lenses or cameras, so 2D footage cannot be converted to 3D. Magix advertizes its 3D editing functionality in conjunction with the Panasonic HDC-SDT 750 camcorder, which records synchronized footage using side-by-side frames with half the horizontal resolution. *Video Edit Pro* displays an anaglyph preview which you can view in 3D using the glasses provided. Color rendition in the 3D preview is not very good, but improves if you use a second monitor to preview your clips. The program also works with active shutter glasses if your graphics card supports them.

Experience has shown that the human brain isn't particularly irritated by the significant loss of resolution or increase in noise inherent in viewing 3D video. Editing in 3D does, however, require a lot more computing power than 2D work, especially if you are using additional effects. 3D effects can be found in the transitions directory in the Media Pool. Be careful when using them, as combining 3D with too many effects quickly makes a movie look strange. An example of some footage shot with the Panasonic SDT 750 and edited using *Movie Edit Pro* can be found at the link listed under [1] at the end of this article.

Layer masks are new and can be scaled, moved and animated using keyframes, but quickly cause the preview to stutter. Using alpha masks to influence the sharpness of your footage is a good example of an effective masking trick.

If you are happy to leave the hard work to the software, you can simply use the program's automatic MovieShow Maker editing function. This works fairly well and allows you to adjust the results manually later.

This version of the program is much faster than the last and managed to play back either eight HDV test tracks with picture-in-picture overlays or six AVCHD tracks, which should be more than sufficient for most hobby-grade projects. During rendering, the program only used 20 percent of the available processor capacity, so there is still room for improvement in overall performance.

Magix now offers the option of exporting finished movies to 50 full frames per second, and 3D movies can be exported in side-by-side or anaglyph formats. Side-by-side export took almost four times as long as normal, real-time export. There is an option for direct upload to YouTube, which automatically sets the tags described on page 106.

Sony Vegas Movie Studio HD Platinum 10

Like its predecessors, this latest version of Sony's entry-level editing program is firmly based on its pro-grade big brother, *Vegas 10*. As a consequence, the program does not offer any wizards to guide beginners through their first editing steps, although the video tutorials included with the package do provide some help.

The timeline takes up the entire lower half of the program window. The freely scalable preview window is located on the right and the media browser (which Sony calls the window docking area) on the left. To keep playback fluid on slower computers, you can select a range of resolutions for the preview window. The window docking area is used to access project files, effects, transitions and memory media. The new Explorer can be used to search through all memory media and camcorders that are currently connected to

Video Editing Software

	Adobe Premiere Elements 9	Pinnacle Studio 15 HD Ultimate Collection	PowerDirector 9 Ultra64
Manufacturer	Adobe, www.adobe.com	Avid, www.pinnaclesys.com	Cyberlink, www.cyberlink.com
Operating System	Windows XP, Vista, 7, Mac OS X 10.5.8 and later	Windows Vista, XP, 7	Windows XP, Vista, 7
Handling			
Storyboard/Timeline	✓/✓	✓/✓	✓/✓
Tracks: Video/Audio	unlimited/unlimited	2/4	unlimited/unlimited
Insert / Overwrite / Three-point / Slip	–/✓/✓/✓	–/–/✓/✓	–/✓/✓/✓
Undo steps	unlimited	unlimited	unlimited
Background rendering / HD preview	–/Overlay	✓/Overlay, DVI	–/Overlay, DVI
Automatic editing	✓	✓	✓
Import / Recording			
Video	AVCHD, AVI, DVD, Flash, MOV, MPEG-2, MPEG-4, WMV	AVCHD, AVI, DVD, MOV, MPEG2, MPEG4, WMV	AVCHD, AVI, DVD, Flash, MOV, MPEG2, MPEG4, WMV
Audio	AAC, AC3 , AIFF, MPA (M2A/MPEG-2-Audio), MP3, WAV	AAC, AC3 , CDA, MPA (M2A/MPEG2-Audio), MP3, WAV	AAC, CDA, MP3, WAV
Graphics	BMP, GIF, JPG, PNG, PSD, TIFF, WMF	BMP, GIF, JPG, PNG, PSD, TIFF, WMF	BMP, GIF, JPG, PNG, TIFF,
Batch capture	✓	✓	–
Scene detection: According to tape or file info / Content	✓/✓	✓/✓	✓/–
16:9 Processing / Transcoding to	✓/–	✓/MPEG-1, MPEG-2	✓/MPEG-1, MPEG-2
Title generation			
Text color / Shadow / Transparency /3D	✓/✓/✓/✓	✓/✓/✓/–	✓/✓/✓/–
Keyframe editing / Templates	✓/✓	✓/✓	✓/✓
Animation	Crawling titles, Rolling titles, Text animation	Crawling titles, Rolling titles, Text animation	Crawling titles, Rolling titles, Text animation
Effects			
Transitions / of those, in 3D	107/16	More than 500/More than 500	150/35
Brightness / Contrast / Saturation	✓/✓/✓	✓/✓/✓	✓/✓/✓
Color correction / Softening / Sharpening	✓/✓/✓	✓/✓/✓	✓/✓/✓
Keyframe editing	✓	✓	Partial
Slow motion / High speed / Backwards	✓/✓/✓	✓/✓/✓	✓/✓/✓
Picture-in-picture / Chroma keying / Mixing	✓/✓/✓	✓/✓/✓	✓/✓/✓
Audio functionality			
Wave form / Rubber band	✓/✓	✓/✓	✓/✓
Voice-over / Original sound separation / Effects	✓/✓/23	✓/–/More than 250	✓/✓/12
Filters (Noise / Low pass / High pass/ Equalizer)	✓/✓/✓/–	✓/–/–/✓	✓/✓/✓/✓
Output			
Video formats	AVI, Flash, HDV, MPEG-1/2, MPEG-4/H.264, QuickTime, WMV	AVCHD, AVI, Flash, HDV, MPEG-1/2, MPEG4/H.264, QuickTime, Real, WMV,	AVCHD, AVI, HDV, MPEG-1/2, MPEG4/H.264, QuickTime, WMV,
MPEG rate selectable / Variable	✓/✓	✓/✓	✓/✓
DVD sound format / Bit rate	AC3, MPA, PCM	AC3, MPA, PCM	AC3, PCM
MPEG quality selectable / Smart rendering	✓/✓	✓/✓	✓/✓
Built-in authoring / DVD menu editor / Menu templates	✓/✓/✓	✓/✓/✓	✓/✓/✓
Animated menus / Animated buttons	✓/✓	✓/✓	✓/✓
Burn formats (VCD / SVCD / MiniDVD / DVD)	✓/✓/✓/✓	✓/✓/✓/✓	✓/✓/✓/✓
HD burn formats (DVD / Blu-ray)	✓/✓	✓/✓	✓/✓
Editing power			
Number of tracks HDV / AVCHD[1]	4/4 (3)[2]	2/2	6/5
Ratings			
Manual / Overall handling	⊕/⊕	○/⊕	○/⊕
Recording / Import	⊕/⊕	⊕/⊕	⊕/⊕⊕
Smart rendering MPEG-2 / AVCHD	⊕/⊕	⊕/⊖⊖	⊕/○
SD / HDV / AVCHD processing	⊕/⊕/○	⊕/⊕/○	⊕/⊕/⊕
Effects and compositing	⊕⊕/⊕⊕	○	⊕
Sound / Output / Authoring	⊕/○/⊕	⊕⊕/⊕/⊕	○/⊕/⊕
Price (approx.)	US$100	US$100	US$100

[1] see article text [2] under Windows only three real-time tracks ⊕⊕ excellent ⊕ good ○ stisfactory ⊖ poor ⊖⊖ inadequate ✓ included – not included n/a not applicable

your computer, and you can use the preview window to sort your material so that you only import the clips you really want to edit.

You can arrange the main windows in any order you like and save your favorite setup as a custom desktop. The program also has a separate Trimmer window that can be opened and closed independently or attached to the docking area while you are not using it. This flexible approach lets you use custom desktop setups that are tailored to each individual project.

In place of the four tracks supported by the previous version, this version now supports up to 10 audio and video tracks, which is a great advantage to experienced users. The entire timeline (complete with thumbnails) can be enlarged or reduced steplessly to help you view the details of a clip or to give you a better overview of the active project.

In general, Sony has preserved the look and feel of the interface. If you move two clips together, the program automatically creates a crossfade between the two, which you can then customize or replace with one of 25 preset transitions. There are also 49 video filters included as standard, giving you

	Magix Movie Edit Pro 17 Plus	Sony Vegas Movie Studio HD 10
	Magix, www.magix.com	Sony, www.sonycreativesoftware.com
	Windows XP, Vista, 7	Windows XP, Vista, 7
	✓/✓	–/✓
	unlimited/unlimited	10/10
	✓/✓/✓/✓	✓/✓/✓/✓
	unlimited	unlimited
	–/Overlay, DVI	–/Overlay, DVI
	✓	–
	AVCHD, AVI, MOV, MPEG-2, MPEG-4, WMV	AVCHD, AVI, DVD, Flash, MOV, MPEG-2, MPEG-4, WMV
	AC3, AIFF, MPA (M2A/MPEG-2-Audio), MP3, OggVorbis, WAV	AAC, AC3 , AIFF, CDA, MPA (M2A/MPEG-2-Audio), MP3, OggVorbis, WAV
	BMP, GIF, JPG, PNG, PSD, TIFF	BMP, GIF, JPG, PNG, PSD, TIFF
	✓	–
	✓/✓	–/✓
	✓/MPEG-1, MPEG-2	✓/–
	✓/✓/✓/✓	✓/✓/✓/✓
	✓/✓	✓/✓
	Crawling titles, Rolling titles, Text animation	Crawling titles, Rolling titles, Text animation
	358/98	229/12
	✓/✓/✓	✓/✓/✓
	✓/✓/✓	✓/✓/✓
	✓	✓
	✓/✓/–	✓/✓/✓
	✓/✓/✓	✓/✓/✓
	✓/✓	✓/✓
	✓/✓/61	–/✓/39
	✓/✓/✓/✓	✓/✓/✓/✓
	AVI, HDV, MPEG-1/2, MPEG-4/H.264, QuickTime, WMV	AVCHD, AVI, Flash, HDV, MPEG-1/2, MPEG-4/H.264, QuickTime, Real, WMV
	✓/✓	✓/✓
	AC3, MPA, PCM	AC3, MPA, PCM
	✓/✓	✓/✓
	✓/✓/✓	✓/✓/–
	✓/–	✓/✓
	✓/✓/✓/✓	✓/✓/✓/✓
	–/✓	✓/✓
	4/4	4/4
	⊕⊕ / ⊕	⊕ / ○
	⊕ / ⊕	⊕ / ⊕⊕
	⊕ / ⊕	⊕ / ⊖⊖
	⊕ / ⊕ / ⊕	⊕ / ⊕ / ⊕
	⊕⊕ / ⊕	⊕⊕ / ○
	⊕ / ⊕ / ⊕	⊕ / ○ / ○
	US$90	US$100

a wide range of adjustment and correction options right from the start.

You can apply multiple filters to a single clip, and the result differs depending on the order they are applied in. This is great for experimenting with, but tends to make results difficult to reproduce. A further bonus is the Track FX tool, which allows you to apply effects to an entire track at the click of a mouse – for example, to convert movies to black and white. Thirty-nine preset audio filters and extensive codec support ensure perfect sound. The audio track can be independently edited, but keyframe effects are quite tricky to apply and require some practice.

Vegas played back four AVCHD tracks without any trouble, and only Magix *Video Edit Pro 17* managed more. *Vegas* also rendered HDV footage faster than in real time, which is seriously fast. AVCHD Smart Rendering didn't work on our test system, regardless of whether we used footage shot with a Canon HF100, a Panasonic HDC-SD5 or a Sony HDR-SR8.

Automatic YouTube upload is built in, but all other burn/export tools are part of the separate *DVD Architect Studio 5* authoring program included with the package. This has a slightly different interface from the main program and includes a rather confusing array of buttons and tools. There are no DVD menu templates, so you simply have to create your own manually.

Conclusions

User-friendly AVCHD video editing for the masses has arrived. A full timeline always used to involve a test of the editor's patience, but Sony's *Vegas Movie Studio* and Magix *Video Edit Pro 17* prove that speed is now available in the hobbyist sector. The Sony interface is obviously based on pro software, and gives the user the maximum number of knobs to twiddle. The drawbacks of the overall concept are the low number of available tracks and the lack of wizard-guided use for beginners. The program is a stable and reliable solution for all levels and users.

Magix scores highly with its many wizards and automatic editing functionality, and even includes 3D editing tools. In its latest version, *Movie Edit Pro Plus* provides a stable, easy-to-use package that is not far off being a genuine pro-grade editing solution. Preview rendering was the only feature we really missed.

Adobe's offering is fine for editing DV and HDV clips and offers one of the best user interfaces currently available. On the downside, the program is still not nearly as powerful as we'd like it to be.

Avid and Cyberlink have both delivered incremental improvements in the new versions of their packages. *Pinnacle Studio* is still well suited to entry-level use, although nowadays, two video tracks are often not enough. Cyberlink provides many more tracks, but trades overall (and especially trimming) flexibility for speed. On the positive side, *PowerDirector* offers a wide range of effects and settings for creative and inquisitive users who like to create short, dynamic movies. (pen)

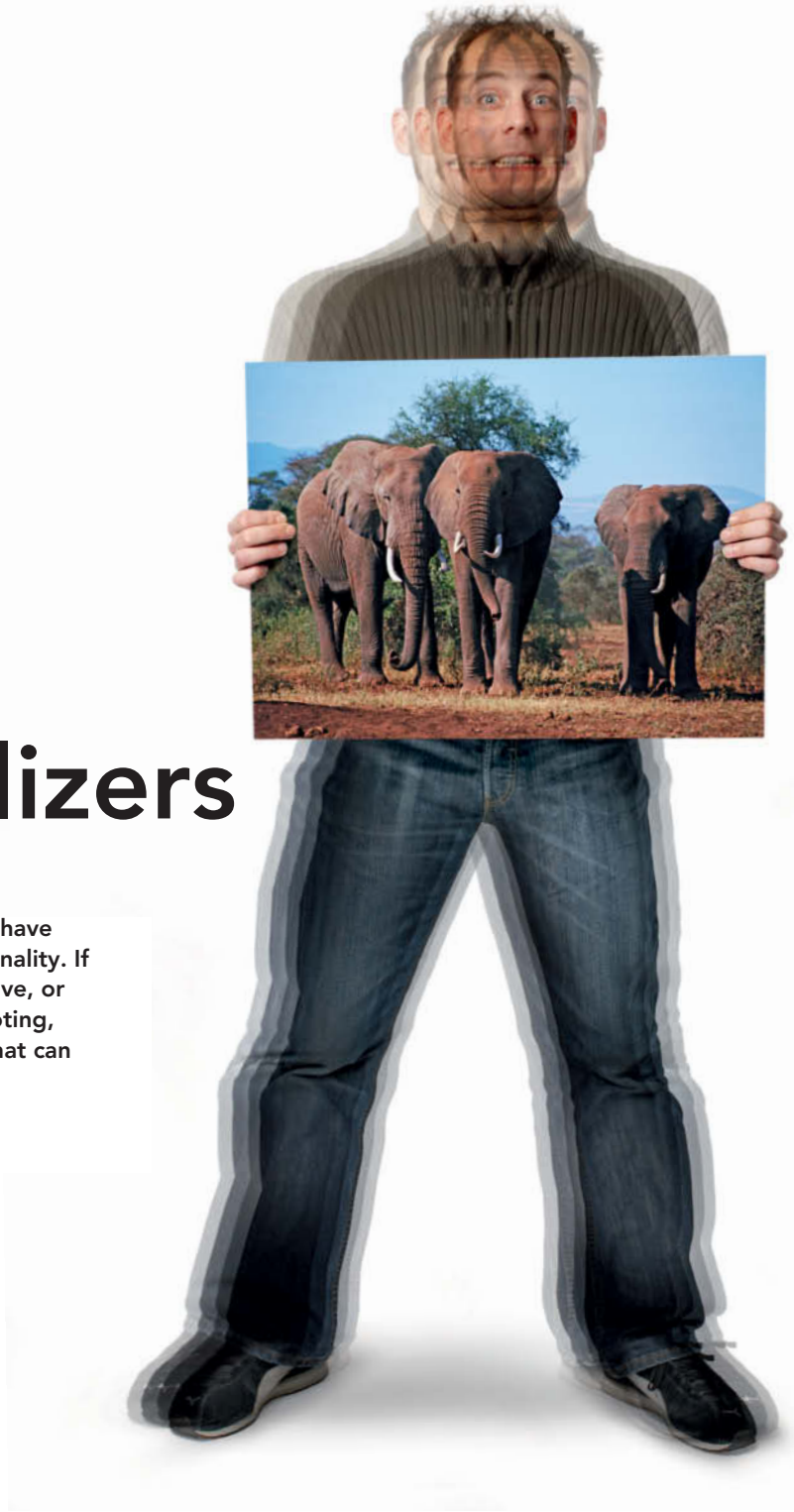
References

[1] youtube.com/watch?v=S8Ah9LlgfRk c't

Joachim Sauer

Video and HD

Image Stabilizers



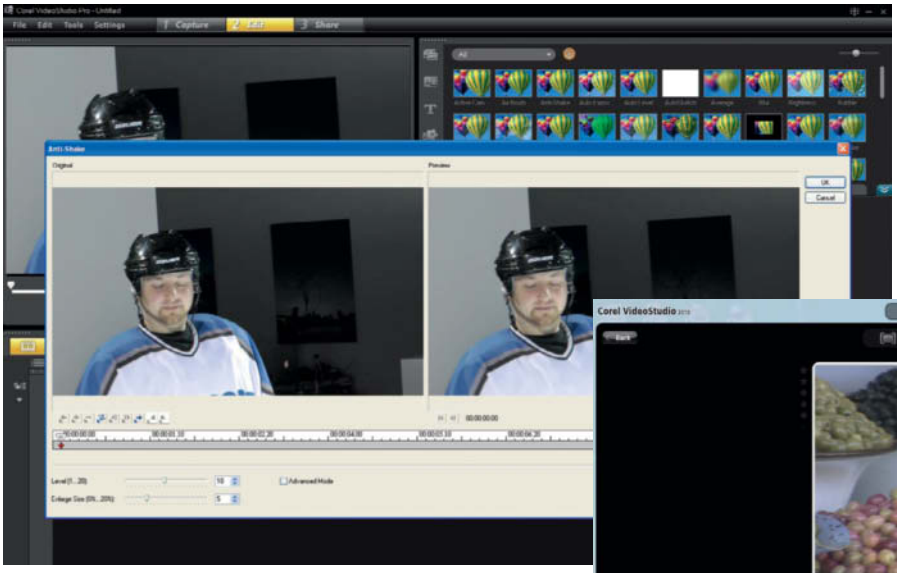
Most camcorders and video-capable digital cameras have built-in optical or electronic image stabilizing functionality. If your camcorder's built-in tool isn't sufficiently effective, or if you forgot to switch your stabilizer on before shooting, there are a number of software solutions available that can help you make shaky footage smoother.

Whether it's your best friend's wedding or your grandma's 80th birthday, it's a shame if your videos of a once-in-a-lifetime occasion are spoiled by camera shake. Software-based image stabilizing can help you to improve shaky footage, although it does have the downside of visibly reducing the quality of your clip.

Software stabilization techniques are based on a simple trick: the program zooms into the captured image to create a buffer made of pixels that lie outside the visible frame. The individual frames are then shifted according to the amount of shake that has been captured. If the camera moved to the left, the software correspondingly shifts the frame to the right. The resulting visible frame consists of the original pixels with the buffer pixels subtracted. The larger the buffer, the more serious the shake that can be eliminated.

To create a larger buffer, the software has to zoom farther into the image, further reducing the quality of the stabilized footage. Smoothing algorithms are used to counteract this loss of image quality, but they use unsharp masking techniques to hide the graininess of the corrected frames and actually reduce overall image quality even more.

Software stabilizers are not a real alternative to optical image stabilizers, which function losslessly by physically adjusting the path of the light on its way through the lens, i.e., before it reaches the analog/digital converter in the sensor chip. The latest optical image stabilizers are extremely effective and can even compensate for slight camera rotation. In spite of these developments, most video clips still include shake, but it can be dealt with using software tools. Removing residual camera shake is a complex task, but comes with a bonus, as the buffers these tools use can be used as a basis for removing wobbly pans and zooms too.



Finding the image stabilization function in the Corel *Pro X3* interface is like looking for a needle in a haystack. Once you have found it, Anti-Shake offers a very antiquated settings window.

The *VideoStudio Express* version of the Corel tool has only one slider for adjusting the effect up or down

Our Test Methods

Any current PC should be sufficiently powerful to remove most shake artifacts digitally. For this article, we confronted a range of plug-ins and standalone stabilization programs with video sequences ranging from slightly shaky to seriously wobbly. The results are summarized in the table on page 117.

All of our test candidates dealt reasonably well with simple, handheld video sequences in which the videographer used a wide-angle lens setting and careful movements to keep things as stable as possible. The slight shakes that remained, caused mostly by the camera operator's breathing, were easy to remove.

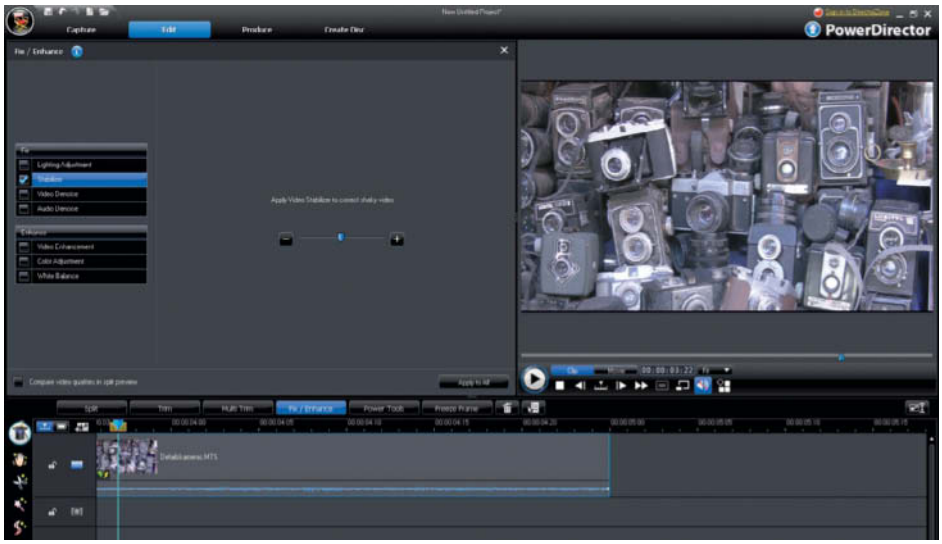
Counteracting the effects of short, sharp movements such as those caused by collisions with passers-by or the camera operator shifting position is more difficult. in these cases, the software has to delve deeper into the existing pixels to produce a cure.

Sequences shot while the camera operator was walking or running include not only general camera shake but also motion blur, and presented our test programs with a serious challenge. If this type of scene is shot in low light, there is simply no scope for compensation.

Mercalli, manufactured by proDAD GmbH, is a pure image stabilization package that also includes functionality for eliminating the rolling shutter effects that occur when CMOS sensors are used to film fast-moving subjects. The sensor captures visual information row by row, and the slight delay between rows sometimes causes vertical lines within the sequence to appear skewed. *Mercalli* is also unique among our test candidates in that it is available either as a standalone application or as a plug-in for most popular video editing programs.

DeShaker 2.5 is freeware that requires VirtualDub (also free) to run. The software is functional, but you may find it difficult to achieve usable results.

We tested each program with all of our test clips and using various program settings. The best results for each were then viewed on a 42-inch television screen, as the programs' own preview windows are not large or precise enough to judge the quality of a clip effectively.



CyberLink *PowerDirector* doesn't require much setting up, but provides only mediocre results

All of our test programs work on the basis of a pixel buffer (outlined in red) that provides the software with the necessary "raw material" for making adjustments. The remaining pixels (outlined in green) are then scaled to fit the original frame size (shown on the right), which causes unavoidable losses in image quality.

Some of our test runs took quite a long time, even though we used a PC equipped with a 3.2 GHz Core i7 processor and 8 GB of RAM (see the table overleaf). Ideally, we would like to be able to load a sequence, switch on the stabilizer and let it run. Long processing times and complex settings make multiple test runs less appealing.

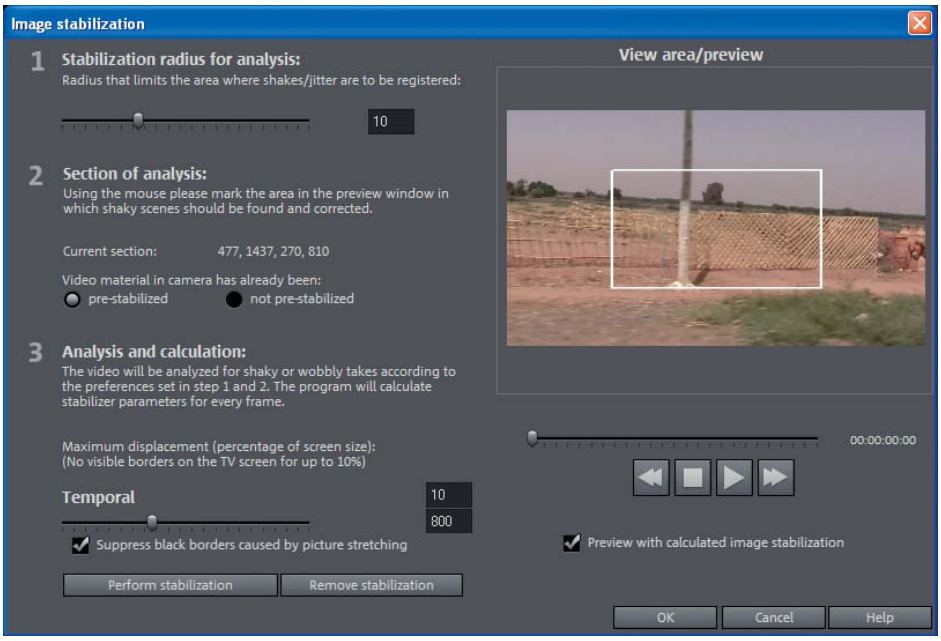
Corel VideoStudio Pro X3

Corel's video editing suite offers a wide range of tools and functions, but is quite easy to use, even for beginners. Something that takes a bit of getting used to is that , in order to keep the main program window simple and functional, many buttons and tools are hidden. For example, Corel has tucked the built-in image stabilization tool away amongst the program's filters and calls it Anti-Shake. The tool is applied by dragging and dropping it to the active clip in the Timeline. Initially, it seems like nothing at all is happening, then the preview window starts to shake or freeze and the volume of the clip's sound is reduced, making it impossible to judge the effects the tool is producing. Adjusting some of the other settings makes life easier: clicking on the file itself brings up a list of the current filter settings in the Library panel and an additional click in the Settings menu opens a new window.

Unfortunately, the program reminded us at this point of a Windows 3.1 application. In fact, Anti-Shake is almost as old as Windows 3.1 and originally appeared in the now defunct MediaStudio package. You can adjust the size of the buffer and the degree of stabilization manually using key frames, but again, it is difficult to judge the results of your settings due to the faltering preview image.

VideoStudio also includes another image stabilizing tool as part of the *VideoStudio Express* media management software included with the package. The five-position Reduce Shake slider is located in the Toolbox at the right-hand side of the program window. This version is much easier to apply but here too, the software provides only a jerky preview image. The stabilized clip is saved to the active media folder and can be viewed by moving it to the media library in the main application where you can then export it to various formats using the Share options. The rendering times here were slightly longer than those required by Cyberlink's *PowerDirector*, but nevertheless pleasantly short.

Both Corel tools produce poor results, as does the Cyberlink product. Obvious half-frame shifts make clips that include marked movements unusable. Slight movements also caused the stabilized clips to pulse in and out of focus. These factors make it difficult to recommend the Corel solution.



***Magix* includes a wizard that guides you step by step through the image stabilization process. Some aspects of the process are not immediately obvious, so you have to experiment to get usable results.**

CyberLink PowerDirector 8

Version 8 of Cyberlink's *PowerDirector* includes a wider range of tools than its predecessors and allows you to import media files either using the Import Media button or via drag-and-drop from the Explorer window. Once your clip is active in the timeline, click the Fix/Enhance button and select Magic Fix

to stabilize your clip. The strength of the effect can be regulated using a stepless slider, and the preview window displays the (somewhat pixelatd) results in real time. *PowerDirector* stabilized and saved our test file in two minutes and twenty seconds.

The program is certainly user-friendly, but delivers poor results. Its algorithms often zoom too far into the image to produce a buffer, which leads to visible blur in the results. It also brightened one test clip so much that it ended up looking unnatural and produced visible artifacts in fast pans. In short, most of the stabilized clips turned out unusable.

Magix Movie Edit Pro 17

Like its predecessors, version 17 of the Magix package uses a proprietary image stabilization tool with a three-stage program window. The first step involves setting a stabilization radius. The larger the value, the more coarse the shake that can be corrected. We used the default value of 10 for our tests. The second stage involves selecting the parts of the frame in which a stable image is most important to the action. The program also asks whether the footage you are editing has already been stabilized in the camera. The third stage involves entering decimal values that define the maximum allowable shift in the finished clip and setting your desired degree of smoothing using a slider.

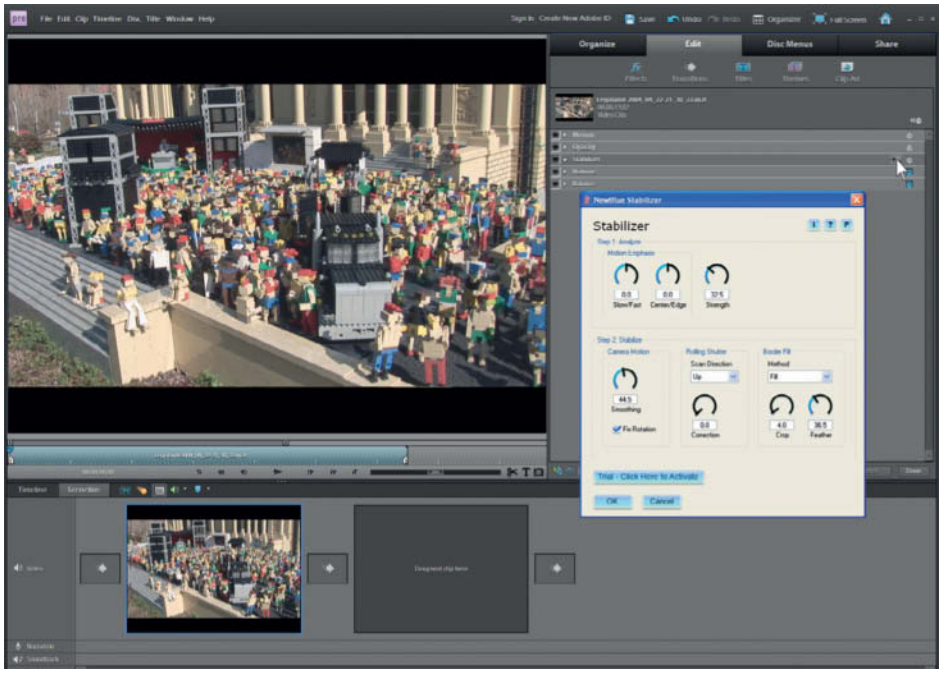
The program then processes the clip frame by frame. It took 8 minutes and 40 seconds to stabilize our 60-second test clip. Our attempts using our own settings took much longer.

Compared with Pinnacle (see below), *Magix* produces slightly less stabilized but sharper results. The program successfully counteracted most movements, provided that they weren't too severe. Overall sharpness deteriorated noticeably in stabilized clips that were shot at the long end of the telephoto range handheld or while walking. The overall results weren't perfect, and pronounced movements in the source material caused partially visible dithering in the stabilized footage. In general, *Movie Edit Pro* produced satisfactory results.

NewBlueFX Stabilizer

The *NewBlueFX* stabilizer plug-in is available for most popular video editing programs. It is included with *Adobe Premiere Elements*, fits perfectly into the Adobe interface and is easy to use once you have had a little practice.

Once you have imported your clips into a project you can drag them into the Sceneline window. The Stabilizer can be found in the Video Effects dropdown in the ***fx*** view in the Edit window. Click Apply to apply the effect to the selected clip. The Zoom and Smoothing parameters can be adjusted using the Properties command. *Premiere Elements* is fairly slow if you activate background rendering, and we recommend that you disable this feature in the program's preferences. If you leave it switched on, the preview image becomes pixelated and quickly comes to a complete standstill, making it impossible to judge the effects of the stabilizer. It is best to select the Render Work Area setting in the Timeline menu. This approach produced a shake-free preview of our 60-second test clip in 4 minutes and 13 seconds. Exporting the finished clip took a further 9 and a half minutes.

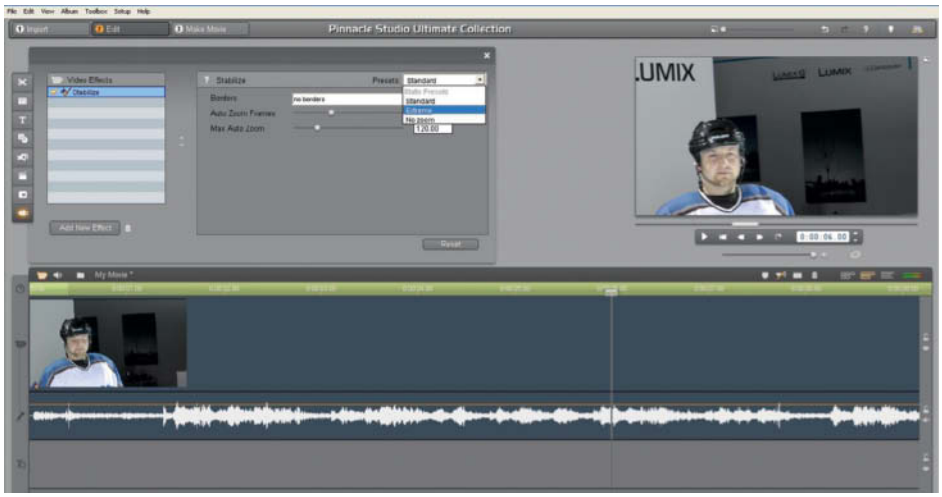


NewBlueFX **has a clean interface and includes more functionality than most of the other tools we tested. We tested the plug-in with *Adobe Premiere Elements*.**

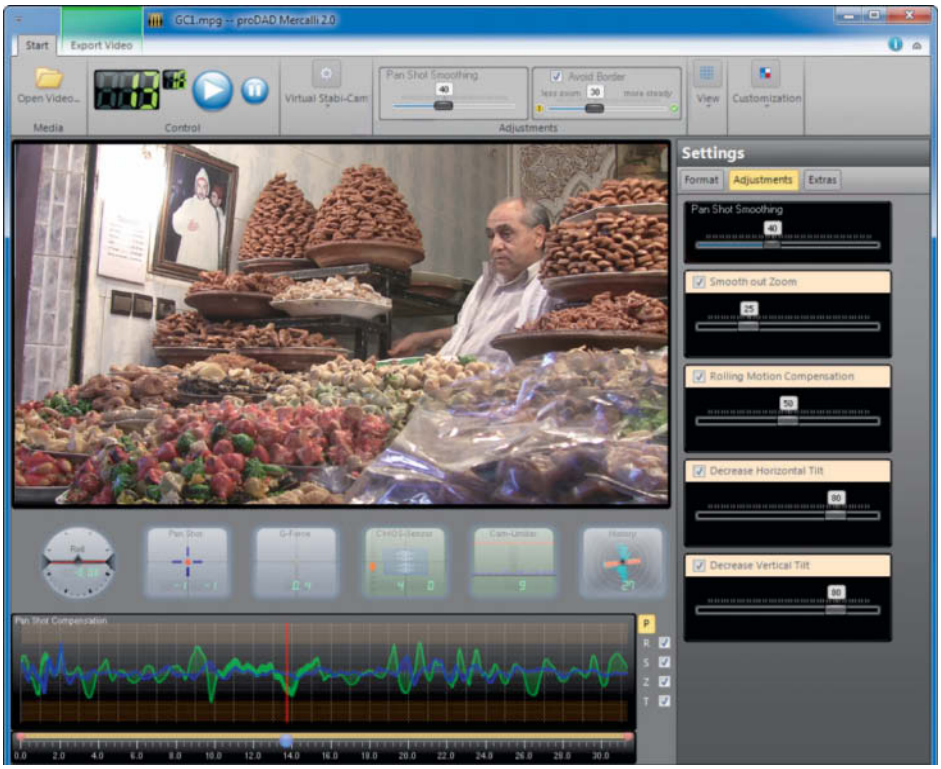
Using its default settings, *NewBlueFX* zooms a long way into the original frame and often produces blurred results. Some of the original camera shake was visible in the stabilized clip, and conspicuous movements or footage shot while walking turned out virtually useless. Alarmingly, it also produced inexplicable rotation movements that were not present in the original material!

Pinnacle Studio 14 HD Ultimate Collection

Avid claims that its *Pinnacle Studio* software is extremely simple to use, and underscores this assertion by taking the user directly to the edit

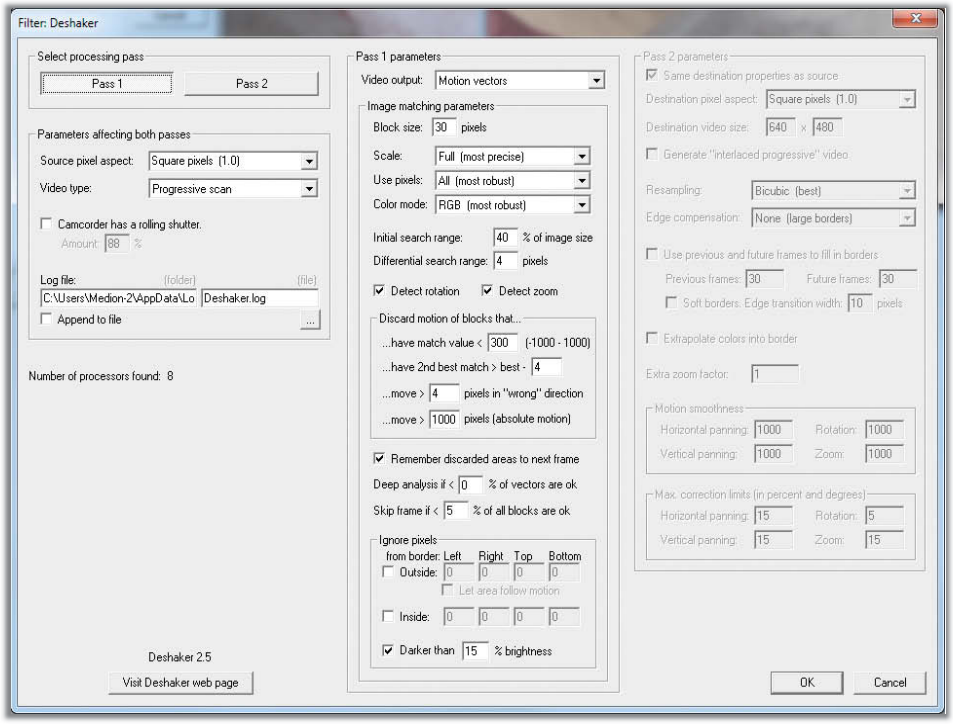


Pinnacle Studio **has a clear, easy-to-use interface and produces great results**



The red warning frame and the exclamation points built into the *Mercalli 2* interface indicate when you have to manually intervene in the stabilization process

window once the source material has been imported. The Stabilize video effect offers three preset zoom profiles: Standard, Extreme and No Zoom. The no zoom setting is the same as the standard setting, but leaves the black buffer zone visible at the edges of the frame. The only two user-adjustable settings are the size and the reaction time for the buffer frame.



***Deshaker* offers so many options that experimenting is the only way to find out what really works**

If you want to view changes in the small, real time preview window you simply need to be patient. It is more effective to set the program to render in the background, and our one-minute test file was finished in 1 minute and 50 seconds. As soon as the display in the timeline indicates that processing is finished, you can view the stabilized clip in the preview window. Once we had chosen the filename and the target format, rendering the test file for output took 11 minutes and 10 seconds.

The results were very good. Small jogs and wobbles were thoroughly and effectively eliminated. Even potentially unusable clips ended up smooth and clear. In some places, the software zoomed in quite a long way to achieve these results. The zoom speed depends on the reaction time you set. The effects produced by the program's default settings were balanced and showed few signs of quality loss.

proDAD Mercalli 2

The *Mercalli Pro 2* package by proDAD is the only product in our test that is available as a standalone or as a (more expensive) plug-in for most popular video editing programs. Once it is started, the program immediately displays a direct import button in the preview window. You can also drag clips directly into the preview window from the Explorer. Once you have imported a clip, *Mercalli* starts analyzing it as soon as you click the OK button. On our test system, the analysis was performed in real time, without long waits.

The new, redesigned interface has a dashboard that helps visualize the stabilizing process and includes a timeline that indicates how long the correction phase lasts or if the software reaches its processing limits. If an exclamation point pops up, you need to adjust your settings manually using one of the program's two sliders.

The standalone version of this software relies on the codecs already installed on your system to analyze and export clips. The process was relatively speedy, and rendered our one-minute sample in 4 minutes and 30 seconds.

The program coped well with two of our smaller shakes while still preserving sharpness, but couldn't completely eliminate the effects of strong camera shake or clips shot while walking. The beta standalone version we tested produced some substandard results due to an error in its MainConcept codec that has since been remedied by the manufacturer. *Mercalli* also produced some dropout and additional color artifacts at the upper edge of the frame, while on the plus side, its built-in rolling shutter correction option works very well and straightens even highly distorted verticals.

Deshaker 2.5

The *VirtualDub* freeware and its newly revised *Deshaker* module offer a free alternative to the commercial packages we have described so far. Additional codecs are required if you want to process AVCHD clips and the subsidiary *DshowInputDriver* plug-in to perform image analysis. The complex interface cannot really be compared with that of the other programs we tested and requires curiosity and patience to get the best out of the many options it offers. There are a number of user guides available on the Internet (see [1] below).

Once you have imported your clip, *Deshaker* first spends a great deal of time and uses a lot of computing power analyzing the footage before applying the results to your video. Changes you make to the settings are visible in real time in the preview window, although previews often lack sound.

The extremely wide range of options and settings can be daunting for beginners. *Deshaker* allows you to determine precisely what it does with your video, but the sometimes vague correlation between the settings and the effects they have make it too easy to get lost along the way.

If you don't install additional codecs, *VirtualDub* is only capable of exporting video to the AVI format. The results for short sequences of a few seconds or more were perfectly acceptable and were sharper than most of those produced by Magix, although some jitter was visible in places. We were unable to correct complex scenes with heavy movements, whichever settings we used and however long we tried, and we often ended up with jerky, almost stop-motion-like results.

Conclusions

Image stabilizing software is designed to pick up where the built-in functionality in camcorders leaves off, and the results produced by the Avid tool prove that this is an achievable aim. The latest version of the Stabilize tool takes time to do its job, but produces reliable results that often allow you to rescue otherwise useless footage.

Avid produced by far the best results in our test, while some of the tools we tried out – those from Corel and Cyberlink, for example – produced unsharp results with artifacts that were worse than the original errors. Magix and proDAD delivered results that were at least partially comparable to Avid's, but also quickly reached their limits with sequences that included strong shake artifacts.

Mercalli Pro 2 scored on two fronts: speed and rolling shutter correction. Unfortunately, its stabilizing results were only of average quality. (uh)

Additional Information

[1] vimeo.com/groups/avchdlight/forumthread:8538

Video Image Stabilizing Software

	Corel VideoStudio Pro X3	CyberLink PowerDirector 8	Magix Movie Edit Pro 17	NewBlueFX Stabilizer	Pinnacle Studio HD Ultimate Collection 14	proDAD Mercalli Pro 2	Deshaker 2.5
Manufacturer	Corel	Cyberlink	Magix	NewBlueFX (Adobe)	Avid	Prodad	Gunnar Thalin
URL	www.corel.com	www.cyberlink.com	www.magix.com	www.newbluefx.com	www.pinnaclesys.com	www.prodad.com	www.guthspot.se
Import formats	AVCHD, AVI, DVD, Flash, MOV, MPEG2, MPEG4, WMV	AVCHD, AVI, DVD, MOV, MPEG2, MPEG4, WMV	AVCHD, AVI, DVD, MOV, MPEG2, MPEG4, Real, WMV	AVCHD, AVI, DVD, Flash, MOV, MPEG2, MPEG4, WMV	AVCHD, AVI, DVD, MOV, MPEG2, MPEG4, WMV	Depends on installed codecs	Depends on installed plug-ins
Export formats	AVCHD, AVI, Flash, HDV, MPEG1/2, MPEG4/H.264, WMV,	AVCHD, AVI, HDV, MPEG1/2, MPEG4/H.264, QuickTime, WMV	AVI, Flash, HDV, MPEG1/2, MPEG4/H.264, QuickTime, Real, WMV	AVI, Flash, HDV, MPEG1/2, MPEG4/H.264, QuickTime, WMV	AVCHD, AVI, Flash, HDV, MPEG1/2, MPEG4/H.264, QuickTime, Real, WMV	Depends on installed codecs	Depends on installed plug-ins
Plug-in compatible with	–	–	–	Adobe After Effects and Premiere 7.0 and later, Premiere Elements 3.0 and later, Premiere Pro; Apple Final Cut Pro 6.0 and later, Final Cut Express 4.0 and later, Motion; Avid AVX V2 and later; Corel VideoStudio V9 and later; Pinnacle Studio V10 and later; Sony Vegas Pro & Vegas Movie Studio (32-bit) V4 and later, Vegas Pro (64-bit) V8.1 and later; Thomson Grass Valley Edius 5.0 and later	–	Adobe Premiere Elements, Premiere Pro CS1 and later; Apple Final Cut Pro 7.x, Final Cut Express 4.x; Magix Movie Edit Pro 16; Pinnacle Studio 12/14; Sony Vegas 7.0 and later; Thomson Grass Valley Canopus Edius NEO 1.0 and later, Canopus Edius 4.0 and later	VirtualDub version 1.9.9 and later
Processing times							
Analysis (60-second scene)	–	–	08:40 minutes	–	–	01:00 minute	24:10 minutes (Pass 1)
Correction (60-second scene)	04:50 minutes	02:20 minutes	04:20 minutes	13:40 minutes[1]	11:10 minutes	04:30 minutes	01:50 minutes (Pass 2)
Total	04:50 minutes	02:20 minutes	13:00 minutes	13:40 minutes	11:10 minutes	05:30 minutes	26:00 minutes
Scores							
Handling	⊖	⊕	○	○	⊕	⊕⊕	⊖⊖
Effectiveness when correcting							
Pan/zoom shake	⊖	⊖⊖	○	⊖	⊕	⊖	⊖⊖
Slight shake/jitters	○	○	⊕	⊕	⊕⊕	⊕	⊕
Pronounced shake	⊖	⊖	○	○	⊕	⊖	⊖⊖
Telephoto shot	⊖	⊖⊖	⊖	⊖	⊕	⊖	○
Footage shot while walking	⊖⊖	⊖⊖	⊖	⊖⊖	○	⊖⊖	⊖⊖
Price (approx.)	US$90	US$90	US$120	US$100[2]	US$100	US$150/US$250[3]	Freeware

[1] Including 4:10 mins preview rendering [2] Free with Adobe Premiere Elements [3] Plug-in version

⊕⊕ excellent ⊕ good ○ adequate ⊖ poor ⊖⊖ very poor ✓ included – not included n. a. not applicable

Ralph Altmann

JPEG Color Depth

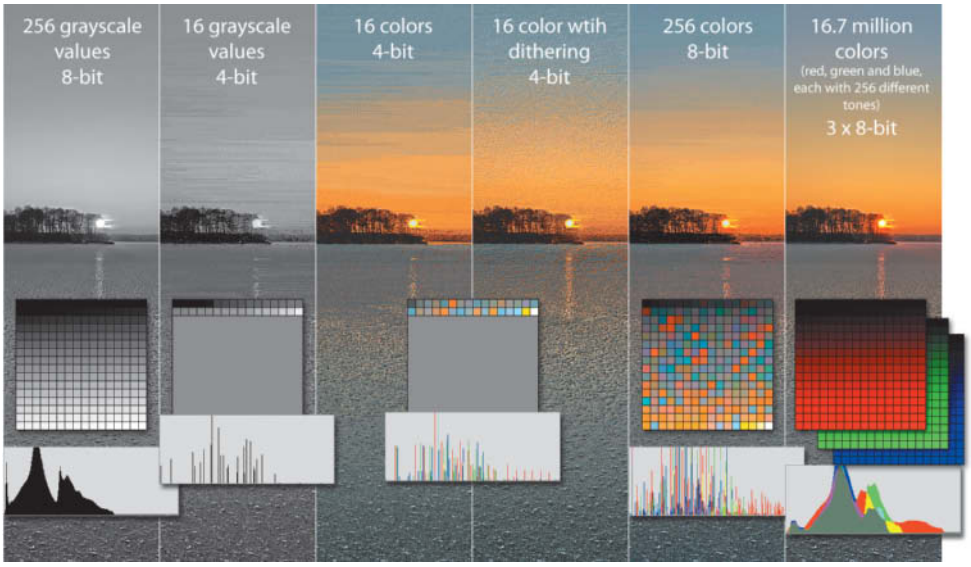
How computers make the most of digital image data

JPEG images have "8-bit color depth", and the "16 bits" that RAW formats provide give us better quality images – or so we hear. HDR processes even offer "32-bit" dynamic range. But what do these terms actually mean? This article will help you to discover the ins and outs of bit depth and what more bits can do for you and your photos.

A well-taken photo will exactly reproduce the mood or impression that encouraged the photographer to press the shutter button in the first place. Technically speaking, in addition to sufficient resolution, you also need to be able to faithfully reproduce the colors and tonal range in your scene if you want your photo to end up looking realistic. And, while you are at it, it is useful to have your image files take up as little memory (i.e., bits per pixel) as possible.

The eight bits that make up a byte can be used to reproduce 2^8 (=256) different tonal values. This is sufficient to reproduce all of the tones present in a high-quality grayscale image. If we apply color values instead of grayscale values to an 8-bit image, we end up with a relatively low-quality color image (usually in GIF format) of a kind that is widespread on the Internet, Many computer graphics and high-contrast photos contain only a narrow range of colors and can be stored using a minimum of disk space.

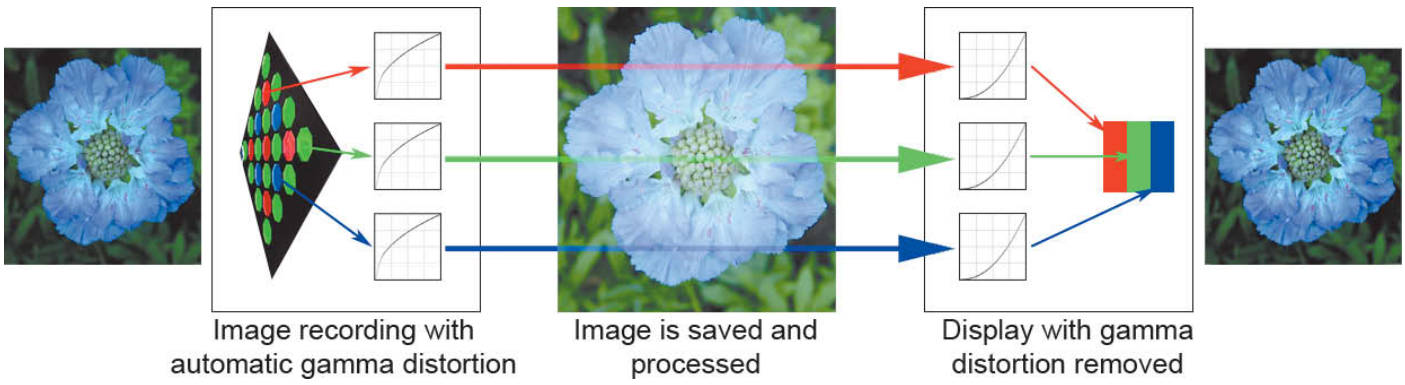
While a grayscale or GIF image can contain a maximum of 256 different tonal values, RGB images are constructed in a way that allows an "8-bit" image to contain 256 different tonal values for each of the three primary color channels. The actual colors in an image are created by mixing colors from these primary "palettes". These three sets of 256 tonal values allow us to create a range of 256^3 (=16.7 million) different colors, which is the range covered by the "True Color" computing standard. The introduction of the True Color standard marked the beginning of the digital image processing era. Today, the older "High Color" standard, with its 65,536 colors, and other less color-rich, RGB-based standards have already been consigned to the history books.



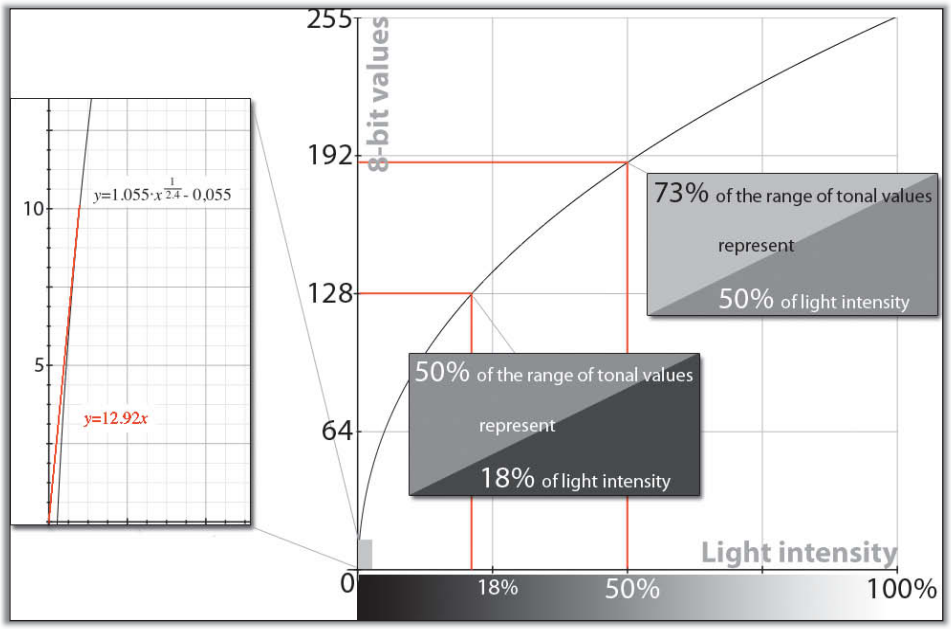
256 different gray tones are sufficient to produce high-quality grayscale images, although less can be used to produce acceptable images if you are prepared to accept obvious transitions between tones. Tricks such as dithering – which uses randomly placed colored dots to make transitions between colors less obvious – can also be used to produce color images using a narrow range of tonal values, although these are generally of poor quality. The 16.7 million colors offered by the RGB color rendition system give us enough tones to produce smooth transitions like the ones in the sky in this image.

The Human Eye Sees More than a Camera

We often read that True Color images contain more colors than the human eye can differentiate. This is true for the colors, but not for the range of brightness an image contains. The ability of our pupils to adapt to a wide range of brightness enables us to perceive a far larger dynamic range (i.e., the difference between the brightest and darkest points in a scene) than an image with 256 tones per channel can render. If we consider the difference between black and white to represent a range of 0-100 percent, the human eye is capable of differentiating between values of less than just one tenth of a percent. This ability is, however, reduced with increasing ambient brightness, and we can only differentiate one percent brightness in image highlights. The non-linear nature of human perception has led to the establishment of an



Gamma distortion is performed automatically by the camera immediately after shooting and is removed again before the image is displayed



The actual gamma distortion in a digital image is linear at the lower end of the curve and is based on a modified exponential function with an exponent of 1/2.4 further up (shown on the left). The curve shifts all tonal values toward the upper end of the scale in a way that is similar to the natural brightness compensation performed by the human eye (shown by the values given in the lower gray triangles).

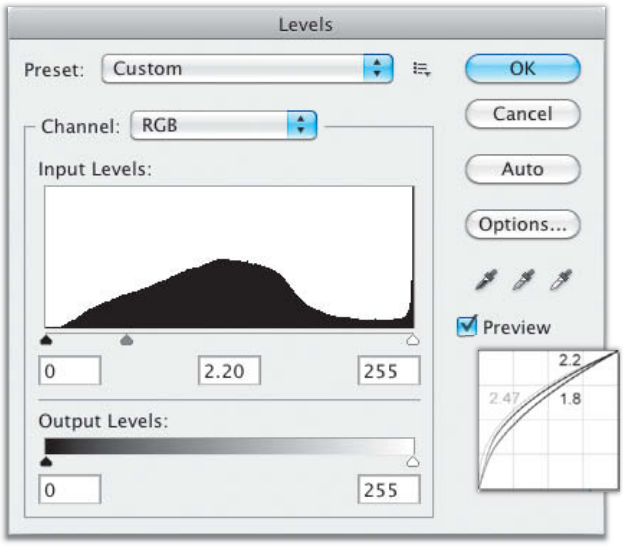
"average" gray value of 18 percent – i.e., a surface that reflects 18 percent of any white light that reaches it. As a comparison, we perceive 50 percent gray as "very bright".

A non-linear approach is therefore also useful when we are converting real-world tonal values into values that can be processed digitally. If we were to assign linear values to the 256 possible 8-bit tonal values, the smallest possible difference between two tones (the "quantization increment") would be precisely 1/255 – i.e., about two-fifths of one percent. This is simply too coarse to make a visible difference, especially for darker tones. For this reason, the tonal values captured by a digital camera are normally recomputed using an exponential "gamma curve" immediately after shooting. This technique causes quantization to take place in smaller increments for the darker parts of the image. A gamma curve is stated mathematically using the formula: $y = x^{(1/gamma)}$. Widely used gamma values range between 1.8 (until recently the default value for Mac computer systems) and 2.2 for PC and video usage. Firmware-based gamma distortion has to be reversed before images are displayed. CRT monitors do this virtually automatically, as the relationship between the control voltages they use and the brightness of the screen dots they produce is governed by a kind of "inverse gamma curve" with a default value of 1/2.4. In CRT monitors, the difference between this value and a standard gamma value was counteracted using electrical resistors – a task that is now performed digitally using look-up tables (LUTs). The simple fact that we perceive 18 percent gray as averagely bright allows us to calculate a theoretical "eye gamma" of 2.47, although the sensitivity curve of the human eye is complex rather than exponential.

A simple gamma curve is, technically speaking, not ideal. We know that the smallest possible difference between two tonal values on an 8-bit scale is 1/255. At the lower end of the scale (for example, between 0 and 1), this difference, coupled with a gamma of 2.2, results in a quantization increment of $(1/255)^{2.2}$, which is equal to about five millionths of the maximum difference. In turn, this gives us a total dynamic range of about 1:200,000, which is much too broad to be of practical use. Widely-used color spaces, such as sRGB and Adobe RGB therefore use modified gamma curves that are linear for the lowest 10 tonal values and are represented by an exponential function with an exponent of 1/2.4 for higher values (see the illustration on the next page). The resulting curve is similar to one produced using an exponential function with an exponent of 1/2.2, which is why the curve's effect is often represented by a gamma value of 2.2.

This modified gamma curve gives us a theoretical dynamic range of 1:3,300 (i. e., 11.7 f-stops) in the shadow areas – a range that modern sensors can capture without difficulty.

A single tonal step at the upper end of the scale (for example, between 254 and 255) represents a difference in brightness of just one percent when combined with a gamma of 2.2. This means that the local dynamic range is reduced to just over 1:100, but is almost exactly equal to the differences in brightness that the human eye can perceive at the bright end of the scale. A modified gamma distortion curve is thus perfectly suited for use with 8-bit digital photos. What more could we ask for?



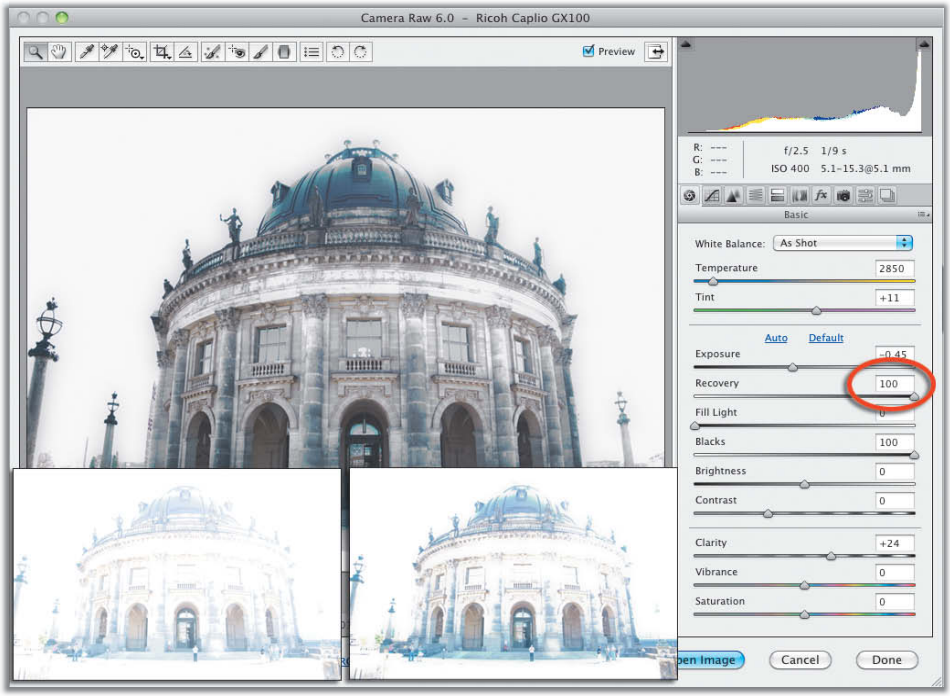
The two most widely used standard gamma values simulated using Photoshop Levels. Photoshop also attenuates the steep exponential curve with a linear portion at its lower end (the flat section in the lower quarter of the illustration). As a comparison, we have also included a mathematically exact curve for a gamma value of 2.47 (our theoretical "eye gamma"), shown here in gray.

Eight Bits Are not Enough

But all this theory doesn't take image noise or adjustments to contrast into account. The problem with increasing brightness in shadow areas is that there are no "spare" tonal values available between the digital values assigned to the tonal values present in the original subject. As soon as we stretch the histogram curve in the darker parts of an image we end up with gaps in the histogram, which then appear as angular breaks in color transitions in our image.

Image noise also reduces the usable dynamic range of digital images, especially for those shot using high ISO values. Even in complete darkness, photographic image sensors produce random electrical signals that the camera's electronics (which are themselves not entirely noise-free) cannot distinguish from the signals caused by light hitting the sensor. It is only when the strength of the signal caused by incident light is greater than that produced by this background noise that a usable image can be produced. At ISO 100, every photoreceptor in the 16-megapixel sensor of a Canon 1D Mark IV records an average of 22.2 electrons of noise. The photoreceptors are saturated (i.e., they begin to overexpose irreversibly) when a level of 55,600 electrons is reached. The quotient of these two values gives us the camera's dynamic range of 1:2,505, which is equivalent to 11.3 f-stops (see also http://www.clarkvision.com/articles/evaluation-canon-1div/index.html). If you "map" the tonal values in your subject carefully to digital values that lie above the level of background noise (as do some Nikon cameras by default), you can successfully squeeze this kind of dynamic range into an 8-bit sRGB image. Generally though, camera firmware leaves noise alone in the darker bits of an image, which further reduces the effective dynamic range of 8-bit images. This can be useful if you want to merge a series of noisy images to produce a single image with more shadow detail but, on the whole, we simply require more bits per image if we want to successfully record the entire range of tonal values that modern image sensors can detect. So how many bits do we really need?

The analog-to-digital converters built into high-end DSLRs digitize visual information with 12 or 14 bits. Fourteen-bit digitizing means that an image has access to 16,384 tonal values per color channel – values that make it relatively easy to shoot photos with a dynamic range of 12 f-stops and more without using additional gamma distortion. The JPEG file format has a built-in limit of 8-bit color depth, so greater bit depth can only be stored

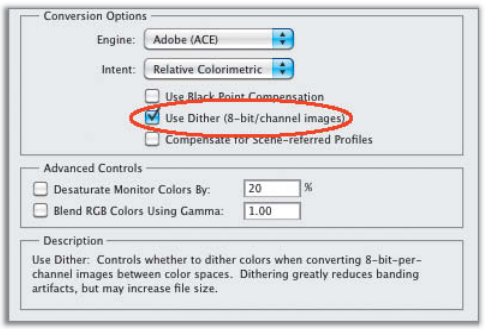


RAW headroom: the Adobe Camera Raw Recovery tool allows us to squeeze a lot of apparently lost detail out of our RAW image files, even if the result is not a well-balanced photo. The original image is shown at bottom left, with our analog attempt to darken the JPEG's highlights next to it.

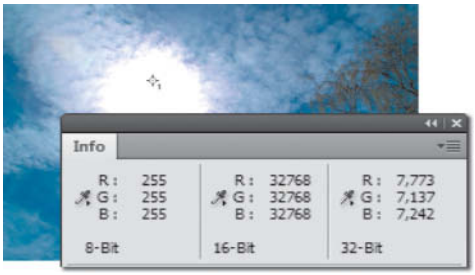
using RAW file formats. RAW files are encoded using a "linear gamma" value of 1 – i.e., without gamma distortion. If you process RAW images in the same linear color space – for instance, using *Photoshop Lightroom* – you can avoid producing the artifacts that occur when you process gamma-distorted images.

Gamma curves are applied to 8-bit and 16-bit image files during RAW development. Even though they don't actually contain 16 bits of color depth data, 16-bit image files are used because it is simpler to work with two whole bytes of data rather than with the one and a half bytes of a 12-bit image. Even 12-bit or 14-bit color depth often represents a waste of disk space and processing power. If only we could adjust bit depth individually to match the subject at hand, we could save a lot of memory and processing power, and shoot much faster image sequences too.

A 16-bit image differs from an 8-bit image only in the subtlety of the quantization process used to digitize it. The effects of these differences only become evident if you perform radical adjustments that "stretch" an image's tone curve (for instance, to brighten shadows), or when the range of contrast of the subject exceeds 11 f-stops and is recorded using a camera that has just as broad a dynamic range. Photographers are often disappointed when they find that 16-bit images don't automatically have better shadow detail than their 8-bit counterparts. If the darker



To reduce the effects of color loss during conversion to and between 8-bit color spaces, Photoshop introduces random colors into converted images by default. This process is called "dithering" and can be deactivated in the Edit > Color Settings > More Options dialog.



Where 8-bit and 16-bit images consist purely of burned out highlights (i.e., when all RGB tonal values have reached their maximum of 255 or 32,768), 32-bit images can still contain reproducible detail, shown by the differing 32-bit values in the Photoshop Info window reproduced here.

8 bits of a 16-bit image contain only noise, increasing bit depth simply increases the amount of visible noise.

Sixteen-bit processing is nevertheless becoming increasingly important, even if the image in question doesn't use the entire potential of the process. Many experts recommend that you convert your images to the L*a*b* color space before performing sharpening or color corrections using Photoshop, but be warned: depending on the color profile you are using, the conversion process can destroy up to 85 percent of the color nuances in an image if you don't convert it to 16-bit mode before processing. The reason for these losses is the poor "efficiency" of the L*a*b* system of coordinates. Only a small proportion of the L*a*b* values represent visible, reproducible colors. Discrepancies are negligible for 16-bit per channel images with their potential 35 billion colors, but missing tonal values can become very obvious in 8-bit images.

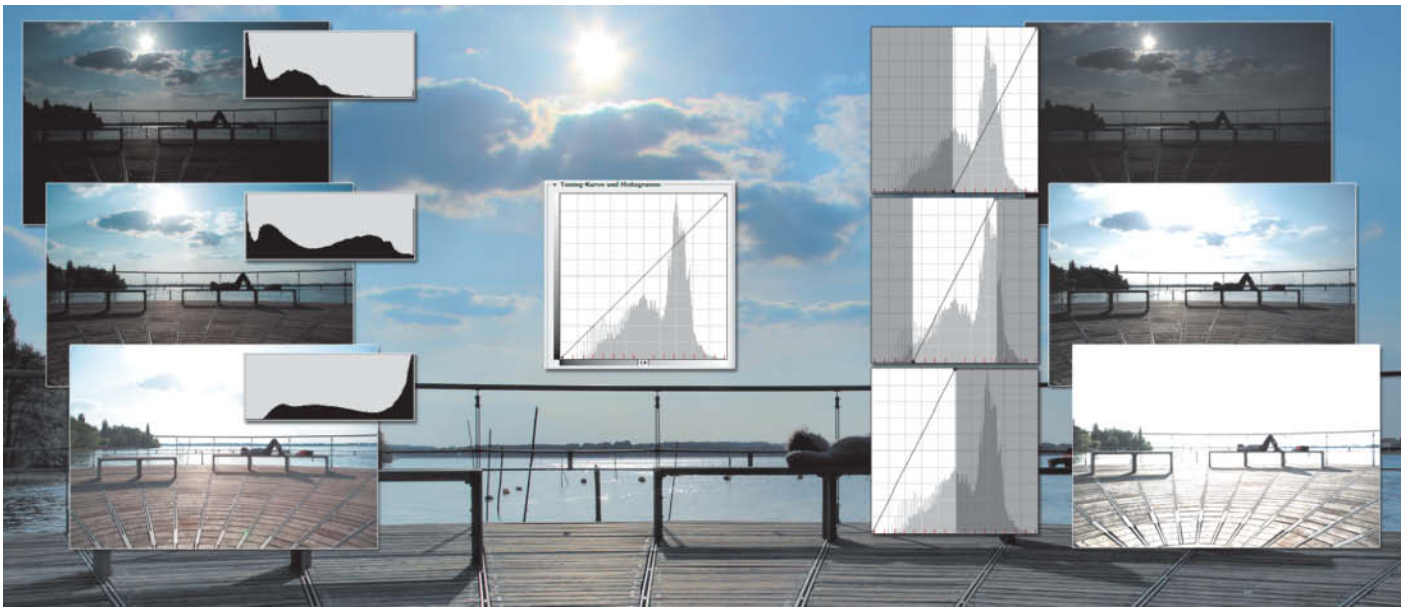
Photoshop doesn't actually include native 16-bit color support. The range of tonal values the program supports is limited to "15 bits + 1" (i.e., the 32,769 values between 0 and 32,768). This type of pseudo-16-bit processing is a relic of older image processing methods and serves to accelerate processing for large amounts of image data. *PaintShop Photo Pro, Photoline* and most RAW converters include true internal 16-bit support and are capable of saving 16-bit data to PNG and TIFF formats.

Because the reproduction of most images doesn't require true 16-bit color depth, this *Photoshop*-based limitation doesn't have any practical effects on image quality. However, because the open *Photoshop* plug-in interface has become the accepted standard for "Photoshop-compatible" plug-ins, many plug-ins don't function properly with other programs if you are processing true 16-bit images. *PaintShop Photo Pro* locks such plug-ins out completely for 16-bit images, whereas *Photoline* has a built-in Photoshop-compatible conversion mode.

So What is the Point of 32-bit Image Data?

The maximum range of contrast in a true 16-bit image is about 15 f-stops, increasing to more than 18 stops (i.e., in excess of 1:400,000) if the data is saved using gamma distortion. The range of contrast in nature can, however, be even greater than this. A normal pastoral scene in bright midday sun can have contrast of up to 1:1,000,000 (20 f-stops), and additional light sources within the frame can increase this value even further. While image sensors cannot record that much contrast in a single shot, they can be used to shoot bracketing sequences of differently-exposed images that can be merged into a single high-dynamic-range (HDR) image later.

HDR images have been in use for more than 20 years in the construction of three-dimensional virtual worlds for the movies, and



HDR images are constructed using the tonal values from a sequence of differently-exposed source images, shown here on the left. These produce an image with more than 16 stops of contrast, illustrated here by the histogram in the middle. Each red mark on the horizontal axis represents one f-stop. Most monitors and printers are only capable of reproducing part of this range, illustrated by the three images on the right that cover different 8-stop excerpts from the complete HDR image. These three images have similar exposures to images that a standard digital compact would produce if it were used to photograph the same scene. It is only when we use tone mapping to compress the overall tonal range and selective increases in local contrast that we can produce an image that looks like the original scene, shown here in the background.

many photographers have developed a taste for the surreal effects that HDR tone mapping techniques can produce. Tone mapping involves converting an image whose dynamic range is too large to be displayed on a conventional monitor to a more manageable format.

The process also takes place behind the scenes when we record and display 8-bit or 16-bit images, and can also take place in the other direction: for example, if a photo of a low-contrast subject is adjusted using an automatic correction tool which makes the monitor image look crisper than the original.

It also takes place behind the scenes when we convert images from 8-bit to 16-bit, although in this case the process converts the data in the other direction from a format with a smaller dynamic range to one that can display more tones.

In a theoretical, perfectly-exposed digital image, shadows will be pure black (i.e., they will have the tonal value 0), and the brightest points in the frame will be 100 percent bright (i.e., they will have an 8-bit value of 255 or a true 16-bit value of 65,535). Theoretically, it is also possible for the surroundings to contain even darker or even brighter points, but this doesn't affect our current considerations. The same procedure is used to display a "perfect" image on a monitor, with 0 representing the darkest tone the monitor can reproduce and 255 (or 65,535) the brightest.

HDR processes handle digital tonal values in a different way. An HDR converter uses the Exif metadata in an image sequence to determine the differences between the individual exposures. The black pixels in an underexposed image will be much brighter than the gray pixels in an image that was exposed for longer, and the HDR converter will take these discrepancies into account to produce balanced results. The tonal values in an HDR image are not stored as fixed values within a range (such as 0 to 255), but instead as floating-point numbers that can be very large or negative. This procedure allows us to produce tones that are "blacker than black" or which cover an extremely broad dynamic range. *Photoshop* uses values between 0.000 and 1.000 to store the tonal values contained in 8-bit and 16-bit RGB images, while specialized HDR converters are capable of converting Exif exposure data into physical brightness values.

Computers store and process these floating-point numbers using 32 data bits, which is why images of this type are called "32-bit" images. However, this nomenclature means something quite different to the "8-bit" and 16-bit" RGB color depth we discussed earlier. Here, the 32 bits refer to the precision with which the range of tonal values in an image can be described and stored, making the potential range itself dependent on the degree of precision involved.

Thirty-two-bit encoding is logarithmic (i.e., non-linear) and provides us with a dynamic range of $1{:}10^{79}$, or more than 260 f-stops, making additional gamma distortion completely unnecessary. Such dynamic range is far larger than that which occurs in the natural world, but can be stored digitally using HDR formats like the popular OpenEXR format, which is capable of saving data with a dynamic range of up to 35 f-stops. This is sufficient for most everyday and a number of exotic photographic applications.

Because genuine HDR images cover a dynamic range that is far broader than can be displayed on a conventional monitor (i.e., they can only be displayed with curtailed highlights and shadows), tone mapping is the indispensible last step in the HDR creation process. A reduction of dynamic range can be achieved by using a simple compression algorithm like the ones used to convert light entering a camera lens into JPEG data that can be printed or viewed on a monitor. However, this method only produces satisfactory results if the original dynamic range is not too large. The local contrast increases that are part of many typical HDR images are easier to manipulate selectively, but are more prone to unwanted artifacts. It is difficult to outsmart physics, although monitors capable of displaying extended, HDR-style dynamic range are now beginning to appear on the market.

As far as we know, *Photoshop* is the only currently available program that is capable of both producing and processing 32-bit HDR images. Earlier versions of this functionality were quite limited in their scope, but layer support has been included since the CS3 version was introduced. This makes it possible to produce HDR images in *Photoshop* by simply adding up the tonal values of images stored on multiple layers instead of using the built-in HDR converter.

As long as there are no affordable cameras available that produce and output native HDR images, post-shoot merging is still the best way to produce images of very high contrast scenes. We would like to see 32-bit processing support in more image processing programs, even if it remains the preliminary processing stage for 8-bit or 16-bit output, the way RAW formats are used today. (anm) c't

Contrast: The Interplay of Light and Shade

The generally accepted unit used to measure the strength of light is the **candela** (cd), based on the theoretical brightness of a single candle. What humans perceive as brightness is the luminance of a source of radiation, the strength of which depends on its distance from the observer and its size. Irrespective of whether the light source itself radiates (like the Sun) or reflects light (like the Moon), luminance is measured in candelas per square centimeter (cd/m^2). The Sun has luminance of more than a billion cd/m^2, in contrast to a nighttime scene lit only by the stars, which is likely to measure 0.001 cd/m^2 or less. The human eye is capable of adapting to enormous ranges of luminance while still differentiating between the details in a scene, although we can no longer discern color at light levels below 0.01 cd/m^2.

Wide tonal ranges suddenly become manageable if they are displayed logarithmically. Base 10 and base 2 logarithmic scales are used widely to describe the dynamic range of photographic devices. For example, a scanner that records the luminance of a slide or a negative has a dynamic range of 10,000:1, which equates to a value of 4 expressed using a base 10 logarithmic scale ($\log.10{,}000 = 4$). Using this scale, an increase of 1 unit represents a 10-fold increase in the tonal range that a device can capture or record.

Usually, the dynamic range of photographic devices is described in terms of EV (Exposure Value), with 1 EV being equivalent to one f-stop. These values use a base 2 logarithmic scale, and an increase of 1 EV is equivalent to doubling the amount of light entering the lens, either by lengthening the shutter speed or increasing the aperture. In this case, a dynamic range of 3 (i.e., 1,000:1) represents a little less than 10 EV ($2^{10} = 1024$). F-stop values are more difficult to calculate as they are stated using an inverse quadratic function. Doubling the aperture value from f2.8 to f5.6 reduces the diameter of the aperture by half (-2 EV) and the amount of light entering the lens by a factor of 4.

Dr. Klaus Peeck

Interchangable-lens Cameras

We wanted to see just how well today's mirrorless cameras shape up against the DSLR competition, so this issue's camera test lines up the Pentax K-5 and K-r models with the Olympus E-5 and pits them against the Panasonic Lumix DMC-GH2, the Olympus PEN E-PL2 and the Samsung NX100.

The Panasonic Lumix DMC-GH2 and the Olympus PEN E-PL2 both represent the latest generation of interchangeable-lens cameras that are not only mirrorless, but also look very similar to traditional analog compacts. Combined with collapsible kit lenses, these models are hardly larger than comparable compacts like the Canon PowerShot G12 or the Nikon CoolPix P7000, although these mostly offer 5x or 7x zoom capability compared with the 3x range built into most interchangeable kit lenses.

Lenses

While compact cameras limit you to the quality of their built-in lenses, the great advantage of our test cameras is the interchangeability of their lenses. Kit lenses are usually relatively cheap and not particularly powerful. The Samsung's standard lens has only a 2.5x zoom range that starts at a poor 30 mm (equivalent). Both 18-55mm Pentax kit lenses need to be stopped well down before they produce acceptable results, but the others all worked pretty well at larger apertures. Olympus offers the new "II" version of its 14-42mm kit lens with the E-PL2, which focuses much faster and more quietly than its loud, juddery predecessor. The flatness of the new front element also makes attaching filters much easier. The Panasonic 14-42mm Vario lens offers stepless aperture settings and a very quiet AF motor that is well matched to the GH2's video capabilities.

The Olympus and Panasonic Micro Four Thirds lenses are interchangeable, although the Olympus preference for sensor shift image stabilization means that you will have to do without stabilization functionality if you use Olympus lenses on a Panasonic body. Like Panasonic, Samsung uses floating lens elements to combat camera shake, but hasn't built the functionality into the standard kit zoom or pancake lenses. All three of the DSLRs we tested use sensor shift image stabilization.

The US$1,700 Olympus E-5 is sold as a body only – probably to preserve its prosumer image. The 12-60mm f/2.8-4.0 lens we tested is available separately and costs about US$1,000.

Both Pentax cameras transmit aperture settings to the lens using a tried and trusted lever mechanism, while a motor-driven drive shaft in the camera body sets autofocus, giving you the choice between many newer lenses with built-in ultrasonic motors or older non-AF lenses.

The lenses in mirrorless cameras are positioned closer to the sensor than in cameras that have reflex mirrors. The resulting shallow flange depth means that these lenses are generally more compact than their reflex-compatible cousins, although the longer the zoom range, the less of an advantage this becomes. Truly pocket-sized 10x zoom lenses are still only available built into compact cameras.

Sensors

All six test cameras are equipped with CMOS or the latest Live MOS sensors, which allow faster data transfer rates and use less power than CCDs. The pixels in the Panasonic and Olympus Live MOS sensors have a larger light-sensitive area in relation to the total pixel area and are almost as sensitive as their CCD counterparts. This makes up to some degree for the small size of Micro Four Thirds sensors, which are as much as 40 percent smaller than the APS-C sensors used in the Pentax DSLRs and the Samsung NX100.

What this means is that the Live MOS sensors we tested here have about five times as much light-sensitive area as the 1/1.7" sensors found in quality compact cameras such as the Canon PowerShot G12 or the Nikon CoolPix P7000. However, the Olympus has only two megapixels more nominal resolution, which means that each individual pixel is a lot larger. In turn, this means that the Olympus sensors have lower pixel density, are much more light-sensitive and are much less prone to generating image noise than their compact equivalents.

Maximum achievable contrast is in inverse proportion to the density of pixels on a sensor, and larger sensors also allow more precise depth of field control. APS-C sensors have further format-based advantages regarding their noise characteristics. This edge was especially obvious in our visual noise test results, especially for the Pentax models, which produced excellent results, even at high ISO values. On the other hand, the signal-to-noise (S/Nx) ratio test showed no particular advantage for the APS-C sensors, which is probably due to the conservative noise reduction strategy used by Pentax. This contrasts strongly with the aggressive denoising used in the Four Thirds cameras. The result is an improvement in S/Nx values at the price of increasing visual noise.

The latest Pentax models use Sony sensors, whereas the older K-7 used a Samsung sensor with poorer noise characteristics that are, logically, similar to those found in the NX100.

Monitors

The only thing that is possiby evil about the latest EVIL cameras is their lack of a viewfinder, although some do offer expensive optional viewfinders that attach to the camera's accessory shoe. The Panasonic was the only

The Olympus Micro Four Thirds sensor (on the left) is approximately 40 percent smaller than the Samsung's APS-C model (on the right)

Interchangeable-lens Cameras: Test Results, Part 1

	Sensor Resolution [lp/h] better▶	Relative center resolution (ISO 100, wide-angle) / sensor resolution [%] better▶	Center resolution (ISO 100) [lp/h] better▶	Center resolution (ISO 400) [lp/h] better▶	Center resolution (ISO 1600) [lp/h] better▶	Center resolution (ISO 3200) [lp/h] better▶	Center resolution (ISO 6400) [lp/h] better▶
Olympus E-5 w/Zuiko Digital ED f/2.0 50mm Macro	1512	97	1461	1402	1263	1200	889
Olympus E-PL2 w/ M.Zuiko Digital 17mm f/2.8 Pancake	1512	100	1512[2]	1444	1343	1339	1095
Panasonic Lumix DMC-GH2 w/Lumix G 20mm f/1.7	1728	89	1546[3]	1521	1489	1414	1284
Pentax K-5 w/SMC D FA f/2.8 100mm Macro (1:1)	1632	82	1343	1333	1293	1263	1194
Pentax K-r w/SMC D FA f/2.8 100mm Macro (1:1)	1424	86	1231	1200	1188	1199	1168
Samsung NX100 w/EX-S30NB 30mm f/2.0 NX	1528	98	1499	1407	1352	1210	1071

[1] Measured using standard kit lenses (Olympus E-5 with 12-60mm system lens) [2] At ISO 200 [3] At ISO 160
Resolution was determined visually in units of line pairs measured over the height of the image [lp/h]. The larger the value, the sharper the image.

Interchangeable-lens Cameras: Test Results, Part 2

	Signal-to-noise ratio [S/Nx] 100 ISO better▶	Signal-to-noise ratio [S/Nx] 400 ISO better▶	Signal-to-noise ratio [S/Nx] 1600 ISO better▶	Signal-to-noise ratio [S/Nx] 3200 ISO better▶	Signal-to-noise ratio [S/Nx] 6400 ISO better▶	Signal-to-noise ratio [S/Nx] 12800 ISO better▶
Olympus E-5 w/Zuiko Digital ED f/2.0 50mm Macro	55	44	35	29	20	–
Olympus E-PL2 w/ M.Zuiko Digital 17mm f/2.8 Pancake	62[2]	53	43	33	24	–
Panasonic Lumix DMC-GH2 w/Lumix G 20mm f/1.7	34[3]	34	28	22	22	14
Pentax K-5 w/SMC D FA f/2.8 100mm Macro (1:1)	53	34	32	26	17	16
Pentax K-r w/SMC D FA f/2.8 100mm Macro (1:1)	44[2]	38	30	28	20	16
Samsung NX100 w/EX-S30NB 30mm f/2.0 NX	60	39	22	18	16	–

[1] Measured using standard kit lenses (Olympus E-5 with 12-60mm system lens) [2] At ISO 200 [3] At ISO 160
Higher signal-to-noise ratio values indicate better image reproduction with less unwanted noise

one of our test cameras with a built-in electronic viewfinder, and is correspondingly shaped like a kind of mini SLR with a viewfinder hump on the top of its body. The Panasonic viewfinder is excellent, with its 1.5 million-dot resolution and 1.42x magnification.

Other advantages of electronic over optical viewfinders include built-in magnifiers, comprehensive camera and exposure information, and a range of brightness levels. The cameras' built-in LCD monitors all have similar capabilities and all three DSLRs are equipped with live view. The DSLR monitors all have 3-inch diagonals and 920,000-dot resolution that ensure bright, crisp viewing. The Panasonic has a tilt/swivel, touch sensitive monitor with half the resolution of the ones built into the DSLRs. The E-5's monitor can be swiveled and tilted too. The E-P2 has 460,000 dots of monitor resolution, while the Samsung has slightly more, with its 614,000-dot OLED.

The E-5 and the K-5 both have pentaprism viewfinders with 100 percent frame coverage and without the "tunnel" feeling that the viewfinders in some mirrorless models engender. The simpler pentamirror-type viewfinder built into the K-r is perfectly adequate for a camera of its class.

Handling

Four of our test cameras earned a "good" in terms of handling and we rated two as "excellent", although we did have to use slightly different criteria to judge the particularly compact Olympus PEN E-PL2 and Samsung NX100 models when comparing them with larger DSLRs.

Exposure settings would be easier to make if Olympus had included a second control dial, especially considering how easily its existing dial can be accidentally moved. The comprehensive settings the photographer can make means that the menus are often very long, so a second dial and a more logical menu system would definitely have helped. Having said all that, everyday handling is still pleasant and quick. The Samsung only just managed a "good" rating, thanks mainly to its great overall handling concept that combines main and submenus with the exclusive i-Function feature based on the multifunction ring around the lens. The drawbacks of the system are that the available functions vary depending on the lens you are using and – at least in the case of the standard kit lens – the gearing is too high, making it too easy to turn the ring too far.

The Pentax K-5 earned an "excellent" rating with its cleverly arranged and assigned controls and its extensive but scroll-free menu system. It is simple to navigate through the system using the twin control dials and exclusive functions such as the Hyper-program mode, which switches directly to the appropriate exposure mode when you make adjustments to your basic camera settings. There are a couple of ergonomic bloopers, including the fiddly lock on the main e-dial and the small AF mode lever, which is too difficult to operate, but these didn't spoil the camera's overall ease of use. The K-r has a similar look and feel, but has less dedicated controls in accordance with the market segment it is aimed at. It has fewer levers and only one e-dial that is, unfortunately, speed-sensitive, making it difficult to know exactly when to stop moving it. The K-r's handling is certainly "good", but doesn't quite rate as "excellent".

The Panasonic DMC-GH2 is our other test candidate with top-notch handling, and has a versatile user interface with direct function access via the main menu, the proprietary Quick Menu function or a touch-screen control system. On the downside, some of the lists in the main menu are very long, the cursor buttons are small and the main mode dial has too many functions assigned to it.

Instead of the more familiar dedicated mode dials, the pro-grade Olympus E-5 uses a combination of buttons and dials to select operating modes – a system mirrored by the Canon EOS 1D, the Nikon D3S and other pro cameras. The buttons themselves are smaller than we would like and are positioned a little too close to the viewfinder housing on the top of the camera body. The camera is protected against moisture, and the rubber gaskets give the cursor buttons on the arrow pad a rather spongy feel. The menus are similar to those found in the E-PL2, and are often very long, but handling is otherwise simple and intuitive. Overall build quality is excellent.

Center resolution (ISO 12800) [lp/h] better▶	Contrast range/ subject range ISO 100 [f-stops] better▶	Contrast range/ subject range ISO 400 [f-stops] better▶	Contrast range/ subject range ISO 1600 [f-stops] better▶	Contrast range/ subject range ISO 3200 [f-stops] better▶	Contrast range/ subject range ISO 6400 [f-stops] better▶	Contrast range/ subject range ISO 12800 [f-stops] better▶	Real subject range [toanl values] better▶	Color Checker SG ΔE ◀better
–	9.3	8.3	7.3	7.0	6.3	–	251	6.7
–	9.3[2]	9.3	7.7	7.0	6.7	–	247	8.7
1186	8.7[3]	9.3	8.7	7.7	7.0	6.3	255	8.4
1059	9.7	9.0	8.7	8.0	7.0	6.3	256	5.9
1091	9.0[2]	8.3	8.0	7.7	7.0	6.0	255	6.3
–	7.7	7.0	5.7	5.7	5.3	–	255	7.2

The logarithmic density, D, represents the camera's dynamic range in terms of the ratio between the brightness of the subject and the corresponding recorded tonal values. Higher values are better. Real subject range represents the range of tonal values contained in an 8-bit rendition of a test image.

Visual noise OECF20 ISO 100 ◀better	Visual noise OECF20 ISO 400 ◀better	Visual noise OECF20 ISO 1600 ◀better	Visual noise OECF20 ISO 3200 ◀better	Visual noise OECF20 ISO 6400 ◀better	Visual noise OECF20 ISO 12800 ◀better	Startup time [s][1] ◀better	Shutter lag [s][1] ◀better
0.9	1.3	2.3	3.1	5.3	–	1.0	0.22
0.8[2]	1.0	1.8	2.4	3.9	–	1.5	0.56
1.1[3]	1.3	1.7	3.0	5.2	8.6	0.8	0.34
0.7	1.2	1.4	2.1	3.1	5.2	0.7	0.33
0.9[2]	1.2	1.6	2.1	3.4	6.5	0.5	0.42
0.7	1.5	3.4	3.5	8.1	–	0.9	0.44

"Visual noise" is a phsysiologically-based judgement of how "irritating" certain image noise artifacts appear to the viewer. The values are calculated based on the intensity, the frequency, and the color of the perceived noise aritfacts. Values below 0.8 represent virtually noise-free images, values below 2 mean low-noise reproduction, while values between 2 and 3 represent visible but acceptable noise levels. Values above 3 represent disruptive noise levels. Values of 5 and above represent extreme, inaccptable noise.

Focus

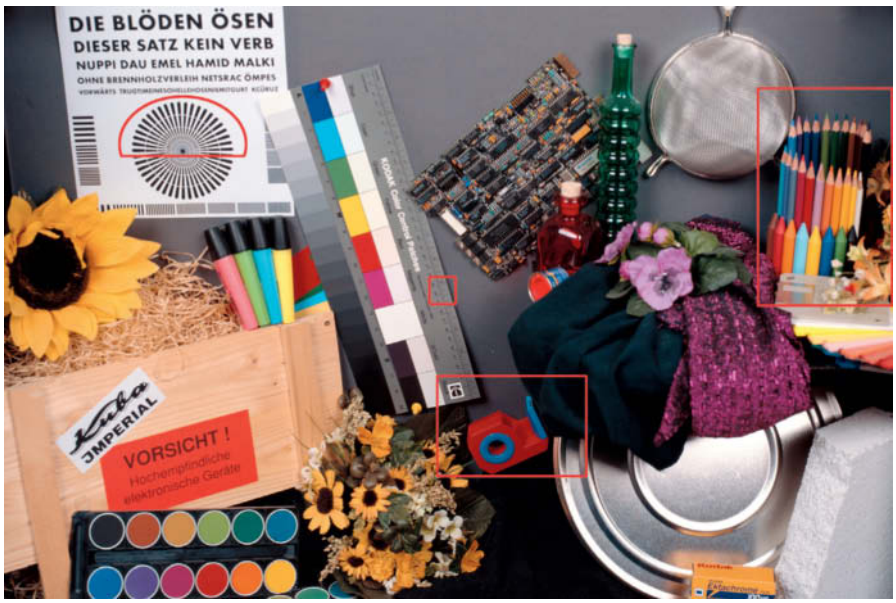
The unbeatable speed of phase detection autofocus, with its dedicated sensors, is rapidly becoming a thing of the past. Although the E-5's fast ultrasonic focus motor and phase detection AF was the fastest system in our laboratory test, with a shutter lag of just 0.22 seconds. The Panasonic, with its image sensor-based contrast measurement AF, was almost as fast as the Pentax K-5's dedicated phase detection system at 0.34 seconds. (This test was performed using the standard shaft-driven Pentax kit lens.) The Lumix' contrast measurements are accelerated by its Live MOS sensor, which transmits data to the camera's powerful processor 50 times per second. The Samsung NX100 managed a lag time of 0.44 seconds, which was directly comparable with that of the K-r. Bottom of the heap was the Olympus E-PL2, at 0.56 seconds, although even this doesn't seem slow in real-world use.

The contrast measurement AF that the DSLRS use in live view mode is much slower, especially in the case of the E-5. In video mode, focus is adjusted using the AEL/AFL button, which prevents the lens from "searching" for the subject while you are filming. Pentax and Samsung counteract this problem by simply offering no AF in video mode. The Olympus E-PL2 focuses quickly and precisely in video mode, but once again, the Panasonic is the best of the bunch, even if its focusing capability is not up to camcorder standards.

Contrast-based AF circumvents the well-documented discrepancies between front and back focus settings that phase detection systems often produce, and the DMC-GH2 indicates that it won't be long before contrast-based AF completely overtakes phase detection systems in the stills arena. Advanced focusing functions such as face recognition only work with sensor-based AF anyway.

Moving Pictures

The Panasonic delivered by far the best video results. The clips are sharp, with good color rendition and negligible artifacts, even dur-



The c't test shot contains some serious technical challenges as well as some random objects that were selected for their high recognition value. The details mentioned in the test results are outlined in red.

The monitors built into the Olympus E-5 and the Panasonic DMC-GH2 are tilt/swivel models, which are especially useful for shooting video

ing pans and zooms. Exposure control is subtle and effective and the built-in capsule microphones produce sound of good quality. The Pentax K-5 produced Full HD video at a "good" level, but neither of the Olympus cameras produced clips that were sufficiently sharp. Rolling shutter effects for pans or moving subjects were also painfully evident in the Olympus footage. The 720p resolution limit and MJPEG file compression left us no alternative but to give Olympus a "satisfactory" overall video rating.

All of the cameras with built-in microphones produce unremarkable, rather muffled sound. The Pentax K-r is the best of these, and only just missed a "good" rating. The Samsung just managed a "good" for sound, although it records in mono at a relatively low level. Both produce only satisfactory video results – the Pentax with good color saturation but poor detail and interference in pans and zooms, and the Samsung with only adequate sharpness and detail rendition.

Conclusions

Our test cameras are the product of a mature market and demonstrate a high degree of technical finesse. They all produce great images using standard kit lenses, although the lenses developed specially for the mirrorless systems from Olympus, Panasonic and Samsung all deliver more uniform results than the conventional APS-C lenses offered by Pentax. The lens sold with the K-r costs just US$50 extra but only produces good results at medium to small apertures. Like the Samsung lens, the Pentax offerings also produce fairly flat-looking results at their wide-angle settings.

Autofocus speeds are on the rise across the board, thanks especially to the new Olympus 14-42mm lens and the high-speed data transfer speeds offered by the Live MOS sensor built into the Panasonic. Pentax has learned from the good reports earned by the Sony sensors it builds into its entry-level cameras, and has used Sony hardware to improve the K-5's noise performance. The K-r benefits from its lovely 921,000-dot monitor and the optical AF-area confirmation that most other manufacturers already include as standard (and was sorely missed in the K-x and K-m models).

The pro-grade Four Thirds Olympus E-5 also offers a combination of fast autofocus and a high-resolution monitor. This camera has a larger sensor and a faster processor than its predecessor (the E-3) which allows it to record and process 720p HD video, and Olympus has finally ditched its proprietary xD memory card format in favor of SDHC and SDXC cards. The extremely robust, splash-proof body is the same as that of the E-3 and the very resilient shutter unit puts the Olympus just ahead of the Pentax K-5 in the pro equipment stakes.

Samsung hasn't managed to do justice to the large APS-C sensor built into its NX100 mirrorless compact and lags behind the equally compact Olympus E-PL2 (with its Micro Four Thirds sensor) in terms of noise characteristics and image contrast. The Samsung also loses ground due to its lack of a built-in flash and its non-stabilized kit lens. On the plus side, the Samsung produced some of the better results in our studio test scenario and is now available at very reasonable street prices. Nevertheless, the E-PL2 still offers the better overall package.

We can thoroughly recommend all of the other test models for one purpose or another. The Olympus is predestined for hardcore pro and semi-pro action, and is sure to find a place on the wish lists of Olympus owners who want to put their existing lenses to even better use. If you are looking to purchase your first top-notch camera, the robust and highly configurable (APS-C format) Pentax K-5 has a lot to offer, while its sister model, the K-r, is a great entry-level model that offers stiff competition to similar models from Canon, Nikon and Sony and benefits from its compatibility with Pentax lenses of all ages. If you do choose a Pentax, we recommend that you invest a little extra money in a mid-market lens.

The Panasonic Lumix DMC-GH2 is neither a real pocket camera nor a "full-grown" DSLR, but still offers great all-round functionality and very flexible handling. Its excellent viewfinder and very fast autofocus are guaranteed to win friends in the DSLR arena, and its first-rate video capability is a big bonus for movie fans. If video is your bag and you happen to have US$1,500 to spare, the GH2 combined with the video-optimized 14-140mm Vario zoom will take you one step closer to Hollywood. (pen)

Olympus E-5

A particularly robust, large Four Thirds SLR with a 12-megapixel sensor, flexible monitor, 720p HD video recording and SD/CF card slots.

Good: Easy-to-handle, high-quality magnesium body; protected against damp, well rubberized. Sensor shift stabilization and ultrasonic dust removal. Extensive user-controllable settings. Excellent 920,000-dot viewfinder with live view and electronic spirit level; large angle of view and "Super Control Panel" direct settings screen. Illuminated control panel, large, clear viewfinder (for a Four Thirds camera). Very fast single target AF in good light, with optional manual override. AF tracking ("Target Selection"). Anti-shock mirror lock-up, 5fps continuous shooting and fast data transfer rates. Four custom white balance presets and Kelvin WB setting. Powerful Li-ion battery, optional AC adapter battery grip. HDMI Out socket. "Pop Art" filters for stills and video modes. Multiple exposures and contrast enhancement. Manually adjustable flash output, wireless flash control and X-sync socket. Bright, dustproof and splashproof internal focus 12-60mm lens (24-120mm equivalent) with very quiet ultrasonic motor.

Not so good: Major functions not selectable via mode dial, instead via three buttons on top of the camera body. Very long configuration menu with functions that are not always intuitively labeled or assigned. Slow "wandering" focus in low light, especially when using multiple targets. Slow contrast measurement AF in live view mode (phase detection also available). Splashproofing makes arrow buttons spongy. Obligatory sensor dust-off slows down power-up. Inflexible self-timer. No permanent battery status display. HD video clips with seven-minute maximum length, MJPEG compression. Stereo sound only with accessory microphone. Expensive.

Test results: Very good maximum contrast up to ISO 200, still good up to ISO 800. Favorable noise characteristics up to ISO 800. Visual noise acceptable up to ISO 3200. For a 12-megapixel sensor, very good central resolution up to ISO 400, not so good thereafter. Very little shutter lag.

Image quality: Tested using a Digital ED 12-60mm f/2.8-4.0 SWD lens. Bright, consistent color rendition with slightly warm tones in daylight. Test sticker deeply salmon-colored. Good, even definition stopped down, very good detail for a 12-megapixel sensor. Balanced, slightly variable exposure. Clean images at ISO 100, with slight loss of texture and slightly grainy grays at ISO 200. ISO 400 causes fringing, loss of detail and slight color noise, increasing towards ISO 800. Fine details disappear and violet color noise appears above ISO 800,. also slight moirés on our line chart and test sieve. Otherwise very few artifacts.

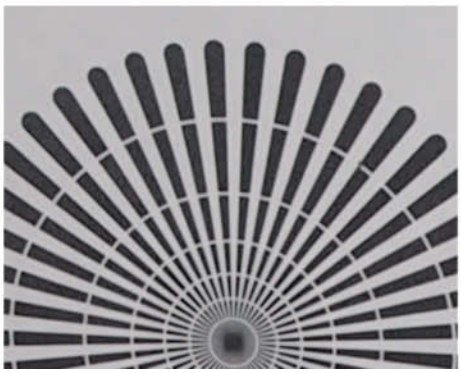
Good outdoor color rendition and exposure control. Very good sharpness and detail at medium focal length and slightly stopped down. Noise only slight up to ISO 200, acceptable up to ISO 400. Loss of detail (in grass, for example) only above ISO 400. Slight fringing tendency.

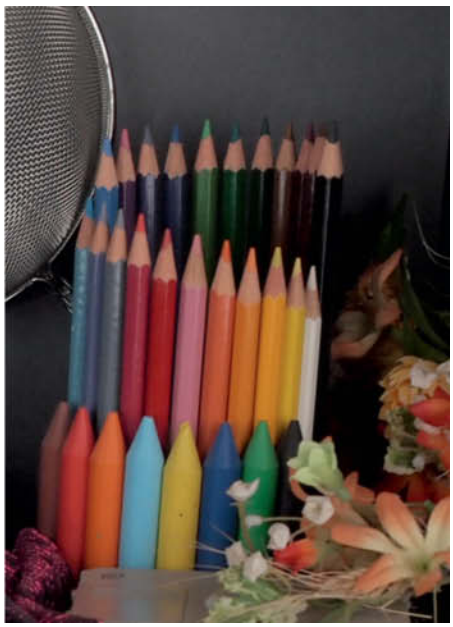

ISO 200


ISO 400


ISO 1600


ISO 6400





Olympus E-PL2

Compact, mirrorless Micro Four Thirds camera with built-in flash unit and improved kit lens.

Good: Solid, rubberized body with metal front plate. Sensor shift image stabilizer with three modes (vertical, horizontal, bi-directional) and ultrasonic dust-off. Generally good ergonomics with a well-featured mode dial and arrow pad with control dial. Main functions also accessible via monitor icons. Sharp 3-inch monitor with twice the resolution of the E-PL1 version. Zoom function with dedicated button. Improved kit lens with faster, quieter focusing, good in low light even without AF-assist lamp. Manual focus with override. Fast flash recycle time and wireless flash control. Multi-function accessory shoe with TTL flash control. SDHC and SDXC-compatible. 720p video recording with dedicated record button and stereo microphone socket.

Not so good: Control dial too easy to shift unintentionally. Loudspeaker directly under thumb position. No viewfinder. Optional electronic viewfinder occupies flash shoe. Monitor colors fade quickly when viewed at an angle. Long, over-complex configuration menu. Fairly loud shutter. Only 3fps continuous shooting, inflexible self-timer. Weak built-in flash. Combined battery/card compartment too near to tripod thread and card slot too close to the compartment lid. HD video clips with maximum seven-minute length and saved using memory-hungry MJPEG compression. Built-in microphone not stereo.

Test results: High maximum contrast at ISO 200 and 400, still OK at ISO 800. Noise characteristics good at ISO 1600, visual noise levels still good at ISO 3200. Little center resolution fall-off at ISO 3200, very fast fall-off thereafter. Short, not very fast image sequences. Medium startup time and shutter lag.

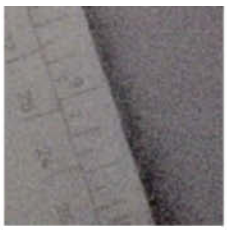
Image quality: Tested using an M.Zuiko Digital 14-42mm f/3.5-5.6 II lens. Good color rendition with slightly warm tones in daylight. Test sticker salmon colored. Good sharpness slightly stopped down and good detail reproduction for a 12-megapixel sensor. Very slight overexposure but consistent. Only slight moiré artifacts. Low noise at ISO 200 with well-defined textures and only slightly rough edges in the test text. Slight sharpness and detail fall-off at ISO 400 but with consistent texture quality. Loss of sharpness and detail with fringing above ISO 800, but still adequate for full-screen viewing. Strong grain and violet color noise above ISO 1600. Unsharp above ISO 3200 with dirty, smudgy noise. Slight fringing on the test sieve and text chart, otherwise few artifacts.

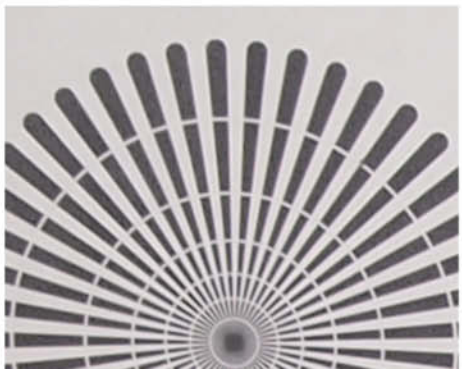
Outdoor colors slightly too warm. Good sharpness and very good detail at medium apertures. Dependable exposure. No noise problems at ISO 200 and 400, loss of detail (grass, bricks etc.) above ISO 800. Very little fringing.


ISO 200


ISO 400


ISO 1600


ISO 6400



Panasonic Lumix DMC-GH2

Mirrorless system-based camera in mini-SLR format with excellent electronic viewfinder, fast autofocus and outstanding video functionality.

Good: Compact, well-formed, rubberized body. 16-megapixel Live MOS sensor with 50p refresh rate. Many dedicated controls; two mode dials, focus mode lever, drive mode lever, configurable function buttons, thumb wheel (rear dial) with button function. Flexible handling via classic menu system, Custom Menu or Quick Menu, optionally via pressure-sensitive touch-screen. Large, flexible 1.5 million-dot monitor, very good for manual focus in conjunction with the magnifier function. Excellent AF; kit lens fast. Quiet, precise and functional in low light. SDXC-compatible card slot on camera side, very fast data transfer. Very good Full HD video functionality with 50i, stereo sound and accessory microphone socket.

Not so good: Long menu sequences, over-burdened main mode dial. Small cursor buttons. Glossy monitor with narrow angle of view. AF-assist lamp too easily covered. Inflexible self-timer, relatively long flash recycle time. Uses a lot of battery power. Battery compartment too near tripod thread. Video AF not up to camcorder standards, sometimes unreliable, tends to "search". Fairly expensive.

Test results: Average maximum contrast values at ISO 160, increasing (!) towards ISO 400/800, fall-off only obvious beyond ISO 1600. Medium signal-to-noise ratio, increases slightly towards ISO 800 then drops off sharply. Visual noise typical for this class of camera, indicating that noise reduction is intense and sensitivity-based. Center resolution OK and consistent right up to ISO 1600. Short image sequences. Very slight SLR-grade shutter lag. Quick startup time.

Image quality: Tested using a Lumix G Vario 14-42mm f/3.5-5.6 Asph. / MEGA O.I.S. lens. Bright, slightly green/yellow tinged colors in daylight. Test sticker acceptably orange. Good sharpness that doesn't improve when stopped down. Detail adequate for a 16-megapixel sensor. Good, slightly variable exposure. Apart from slight iridescence in the line chart, no detectable moiré tendency. Clean, highly detailed images with good texture at ISO 160 and 200. Slight drop-off in fine detail quality and slight central softness above ISO 400, otherwise good. Obvious loss of detail above ISO 800, but consistent and not too destructive. Further reduction in sharpness above ISO 1600 with slightly rough, muddy-looking areas – still good enough for full-screen display. Images very smudgy and lacking in detail above ISO 3200. Few other artifacts, very good fringing compensation.

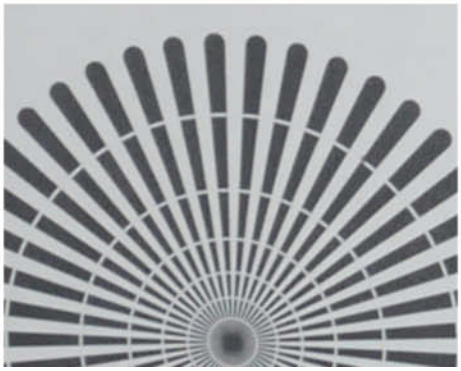
Slight yellow cast and mid-range sharpness in outdoor images (not as good as the Olympus E-PL2). Reliable exposure. Noise not a problem below ISO 400, acceptable at ISO 800 and usable at ISO 1600 for low magnifications. No detectable fringing.


ISO 200


ISO 400


ISO 1600


ISO 6400



Pentax K-5

Very robust, classically-shaped DSLR with an improved 16-megapixel CMOS sensor and top-notch specifications for advanced amateur photographers.

Good: Sensor shift shake reduction and Horizon Correction functionality. Well-balanced, rubberized, splash-resistant magnesium body. Many dedicated controls and exclusive functions, including Hyper-program mode with direct aperture/shutter priority mode access. Excellent high-resolution monitor with broad angle of view. Two-level illuminated control panel. Good viewfinder with 100% coverage. Extensive but easily navigable menu system (switching from tab to tab and page to page using e-dials). Quiet mirror mechanism; mirror and shutter control separate, resulting in very quiet continuous shooting. Various bracketing options. Interval shooting, multiple exposure and HDR capabilities. Noise reduction individually selectable for all ISO values. White balance adjustable after shooting. Very quick flash recycle, wireless flash control, X-Sync socket.

Not so good: Mode dial lock too complicated. AF area lever too stiff. AF speed acceptable in everyday situations, shaft-driven AF too loud. No autofocus during video recording. Fiddly SD card slot, no SDXC support. Retail price too high (street price lower).

Test results: Very good contrast at ISO 100 and only slight fall-off up to ISO 800, still good at ISO 1600. Signal-to-noise ratio good up to ISO 200, visual noise conservatively handled up to ISO 1600 with little destructive noise reduction. For a 16-megapixel sensor, average but consistent sharpness up to ISO 1600. Fast continuous shooting, quick startup, very short shutter lag.

Image quality: Tested using a DA 18-55mm f/3.5-5.6 AL WR lens. Daylight images difficult to judge due to consistent underexposure. Once compensated manually, with bright well saturated colors, test sticker salmon-colored. Resolution and sharpness only fair stopped down for this class of sensor. Slight interference on our line chart and some moirés. Images clean up to ISO 100, some slight roughness at ISO 200. Some dullness and color noise at ISO 400. Sharpness drops off and grain increases toward ISO 800. Obvious color noise and reduction in sharpness at ISO 1600. Thereafter further loss of texture and detail. Obvious fringing on our sieve and the text chart with noise reduction switched off. Some pixel errors on the line chart, otherwise few artifacts.

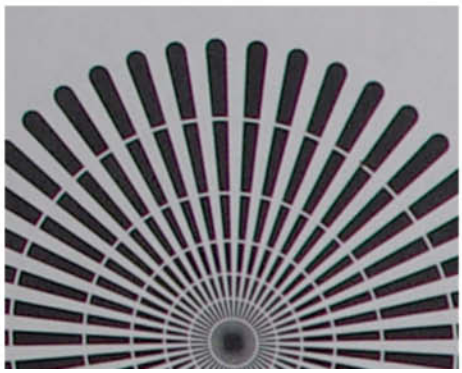
Outdoor colors highly saturated with a slight tendency to yellow. Wide-angle shots with reduced sharpness, medium focal lengths OK. Reliable exposure. Image noise slight up to ISO 400, acceptable up to ISO 1600, still OK for full-screen viewing at ISO 3200. Fringing tendency without electronic noise reduction.


ISO 200


ISO 400


ISO 1600


ISO 6400



Pentax K-r

Compact, well-equipped entry-level DSLR with 12-megapixel CMOS sensor, fast continuous shooting and bright 3-inch monitor.

Good: Rubberized body with smooth detailing. Sensor shift image stabilizing. Precise four-way controller and large mode dial. High-resolution monitor with quick access to various functions and scalable magnifying function (also in live view mode). Fast, accurate AF in phase detection mode, with optical AF area confirmation (unlike the K-x). Clear, scroll-free menu system. Highly configurable for this price segment. HDR, interval shooting, multiple exposure and fast continuous shooting functionality. Wide range of digital filters. Noise reduction adjustable for individual ISO values. White balance adjustable after shooting. Fast data transfer and quick startup. Automatic and manual exposure, plus Sensitivity Priority mode. Short flash recycle, wireless flash control, various power options (Li-ion, conventional battery or AC adapter).

Not so good: Imprecise e-dial doesn't always respond. Glossy monitor. Kit lens with loud shaft-driven AF. Viewfinder OK, but diopter adjustment flimsy. Relatively high power consumption. No AF in video mode, sound 32 kHz mono, video saved to memory-hungry MJPEG. No HDMI Out in spite of HD capability. Gimmicky infrared data transfer between Pentax cameras. No SDXC support. Recommended price too high.

Test results: High maximum contrast only at ISO 200, still OK at ISO 800 compared with Four Thirds competition. Slight fall-off above ISO 1600. Low noise characteristics at ISO 200, otherwise comparable with the K-5's conservative noise reduction approach. Fairly good, consistent center resolution, even at high ISO values. Fast continuous shooting and quick startup. Shutter lag OK but not great.

Image quality: Tested using an 18-55mm f/3.5-5.6 DA-L lens. Bright, authentic, slightly cool colors in daylight. Test sticker a deep salmon pink. For a 12-megapixel sensor, good sharpness at small apertures and fair detail reproduction. Slight color bars in the line chart, and otherwise slight moirés. Slight edge artifacts at ISO 200, otherwise very clean. Slight roughness at ISO 400. ISO 800 with more grain but surprisingly good preservation of detail. Little detail destruction at ISO 1600, but some loss of texture. Obvious luminance noise at ISO 3200, but still OK for full-screen viewing. Slight saw-tooth artifacts in text areas, tape dispenser and color chart. Without noise reduction, color fringing on sieve and text chart.

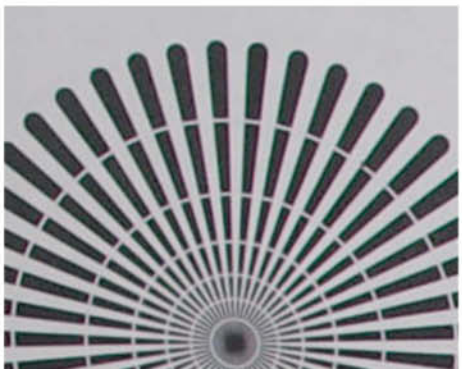
Outdoor colors neutral and reliably exposed. Wide-angle results slightly dull, medium focal length detail and sharpness good at small apertures. Noise not a problem up to ISO 400 and still acceptable at ISO 800. Thereafter only good at small magnifications. Some fringing.


ISO 200


ISO 400


ISO 1600


ISO 6400



Samsung NX100

Mirrorless compact system-based camera with a 14-megapixel APS-C CMOS sensor. No built-in flash, kit lens not stabilized.

Good: Light, compact body with APS-C sensor and ultrasonic dust-off. Large mode dial, useful four-way rotating navigation button. "i-Function" lenses with setting support via focus ring. Bright, sharp 3-inch OLED monitor with 640,000 dots. Clear menu system with one screen per tab. Quiet shutter, only slight shutter lag and flexible self-timer. Powerful battery. Great value with-standard 20-50mm kit lens. Kit lens compact in collapsed position.

Not so good: Plastic body smooth and appears rather cheap. Kit lens not stabilized and with poor zoom range. Optional pancake lens also not stabilized. Monitor has good angle of view, but colors aren't consistent if viewed from an angle. No built-in viewfinder or flash. Accessory shoe only accommodates flash, GPS unit or (low-resolution) viewfinder. "i-Function" lens ring too sensitive, too easy to rotate too far. Low-light AF slow and sometimes inaccurate. Continuous shooting slow, sequences short. Medium data transfer speeds. No SDXC support. Type D HDMI socket. No AF in video mode, mono sound. Camera crashed twice during our test. Retail price bears no relation to real street price.

Test results: Low maximum contrast from ISO 100 on. Noise characteristics good at ISO 100, still good at ISO 400, sharp fall-off at ISO 1600. Center resolution very good at ISO 400 and still good at ISO 1600. Very quick startup and minimal shutter lag.

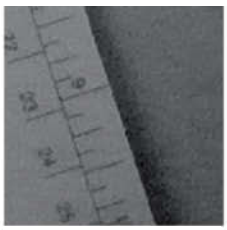
Image quality: Tested using a Samsung NX 20-50mm f/3.5-5.6 ED iFn lens. Bright, somewhat cool colors in daylight. Test sticker almost orange. Consistently good sharpness, even at wide apertures. Overall image detail good for a 14-megapixel sensor. Slight overexposure, no really deep blacks. Slight moiré tendency. Images very clean at ISO 100, only slight loss of detail at ISO 200. Slight roughness at ISO 400, with a little loss of detail and texture. ISO 800 much noisier, with further loss of detail, but still OK for full-screen viewing. ISO 1600 very noisy with blue speckles. Beyond ISO 1600 smudgy and washed out. Virtually no other artifacts.

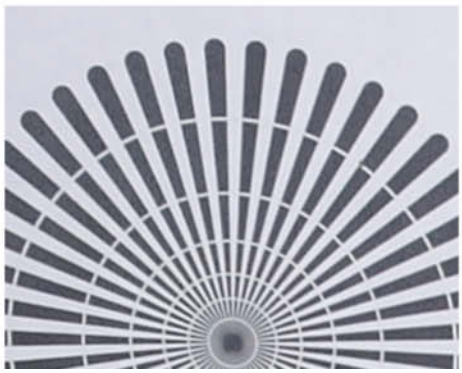
Outdoor colors neutral. Good sharpness and detail from medium focal lengths onward (better than Pentax). Wide-angle images rather dull. Reliable exposure. Noise not a problem up to ISO 400, grain acceptable at ISO 800. Heavy loss of image quality above ISO 1600. No obvious fringing.


ISO 200


ISO 400


ISO 1600


ISO 6400



Interchangeable-lens Camera Test

Manufacturerer / Model	Olympus E-5	Olympus E-PL2	Panasonic Lumix DMC-GH2
URL	www.olympus.com	www.olympus.com	www.panasonic.com
Digitization			
Native resolutions (in pixels)	4032 × 3024, 3200 × 2400, 2560 × 1920, 1600 × 1200, 1280 × 960, 1024 × 768, 640 × 480 (4:3, 16:9, 3:2, 6:6, 5:4, 7:6, 6:5, 7:5 and 3:4 selectable for each)	4032 × 3024, 3200 × 2400, 2560 × 1920, 1920 × 1440, 1600 × 1200, 1280 × 960, 1024 × 768, 640 × 480 (4:3, 16:9, 3:2 and 6:6 selectable for each)	4608 × 3456, 4752 × 3168 (3:2), 4976 × 2800 (16:9), 3456 × 3456 (1:1), 3264 × 2448, 3360 × 2440 (3:2), 3520 × 1984 (16:9), 2448 × 2448 (1:1), 2336 × 1752, 2400 × 1600 (3:2), 1920 × 1080 (16:9), 1744 × 1744 (1:1)
Sensor type, Effective # of pixels / Size / Auto dust-off	Live MOS, 12.2m / Four Thirds (17.3 × 13.0 mm²) / ✓	Live MOS, 12.2m / Four Thirds (17.3 × 13.0 mm²) / ✓	Live MOS, 15.9m[10] / Four Thirds (17.3 × 13.0 mm²) / ✓
Image format(s) / Compression levels / Video format	RAW, JPEG, RAW+JPEG / 4 / MJPEG	RAW, JPEG, RAW+JPEG / 4 / MJPEG	RAW, JPEG, RAW+JPEG / 2 / AVCHD, MJPEG
Video: Max. resolution [pixels], Clip length, fps	HD 720p, 2 GB or 7 min., 30	HD 720p, 2 GB or 7 min., 30	HD 1080i, 2 GB or 29 min. 59 s, 50
Memory card: Type / File size [3]	CF I/II + SD(HC/XC) (2 slots) / 5.4 MB	SD(HC/XC) / 5.8 MB	SD(HC/XC) / 8.3 MB
Features			
Crop factor (35mm equiv.) / Bayonet	approx. 2x / Four Thirds	approx. 2x / Micro Four Thirds	approx. 2x / Micro Four Thirds
ISO settings	auto (200–upper limit), 100–6400 in 1/3 or 1/1 steps	auto (200–upper limit selectable), 200–3200 in 1/3 or 1/1 steps	auto (upper limit up to 3200), 160-12800 in 1/3 steps
Shutter speeds [s] / Default flash sync [s]	bulb, 60-1/8000 / 1/250 (variable)	bulb, 60-1/4000 / 1/180 (variable)	bulb, 60-1/4000 / 1/160
Focusing / Image stabilizing	AF (one-shot, continuous, tracking), MF / ✓ (sensor shift)	AF (one-shot, continuous, tracking), MF / ✓ (sensor shift)	AF (one-shot, continuous, tracking), MF / ✓ (with certain lenses)
AF focus areas / Focus assist lamp	11, group of 5 or 1 (11 positions) / ✓ (multiple flash)	11, group of 5 or 1 (11 positions) / –	23 or 1 (selectable size, free positioning) / ✓ (orange)
Metering: Multi- / Center-weighted / Spot	✓ (49 zones) / ✓ / ✓	✓ (324 areas) / ✓ / ✓	✓ (144 areas) / ✓ / ✓
Programmed auto / Scene modes / Custom Presets	✓ (with shift) / – / ✓ (4 memories)	✓ (with shift) / 22 / ✓ (4 memories)	✓ (with shift) / 13 / ✓ (3 memories)
Exposure: Aperture priority / Shutter priority / Manual	✓ / ✓ / ✓	✓ / ✓ / ✓	✓ / ✓ / ✓
Exposure compesation [EV] / Depth-of-field preview	±5 EV in 1/3, 1/2 or 1/1 steps / ✓	±3 EV in 1/3, 1/2 or 1/1 steps / –	±5 EV in 1/3 steps / ✓
Bracketing: Exposure / WB / Focus / Interval timer / Sound	✓ / ✓ / – / – / ✓ (16-bit, mono [8], 44,1 kHz)	✓ / ✓ / – / – / ✓ (16-bit, mono[8], 44,1 kHz)	✓ / ✓ / – / – / ✓ (16-bit, stereo, 48 kHz)
Self-timer / Continuous shooting speed, # of frames[6]	10 or 2 s / 5.0 fps, 31 shots	10 or 2 s / 3.0 fps, 16 shots	10 or 2 s or 3 shots / 5.0 fps, 7 shots
White Balance: Auto + Man. / Presets / Fine-tuning	✓ (4 memories) / 7 / ✓ (plus Kelvin setting)	✓ / 7 / ✓ (plus Kelvin setting)	✓ (4 memories) / 5 / ✓ (plus Kelvin setting)
Sharpness, Contrast, Saturation adjustable / Color spaces	✓ / sRGB, Adobe RGB	✓ / sRGB, Adobe RGB	✓ / sRGB, Adobe RGB
Viewfinder: Type / Magnification / Coverage	Pentaprism / 1.15x / 100 %	– (optional electronic or optical) / – / –	electronic, (1.5 MP) / 1.42x / 100 %
Monitor: Diagonal / Resolution [dots] / No. of brightness settings	3.0″ (tilt/swivel) / 920,000 / 15	3.0″ / 460,000 / 15	3.0″ (touch, tilt/swivel) / 460,000 / 7
Live View / With AF using sensor / Dedicated sensors	✓ / ✓ (with face detection) / ✓	✓ / ✓ (with face detection) / –[7]	✓ / ✓ (with face detection) / –[7]
Body material / Control panel / Auto monitor rotations	Magnesium, splashproof / ✓ (green illumination) / –	Aluminium + plastic / – / –	Plastic / – / –
4-way selector / Multi selector / Command dials	✓ (5 buttons) / – / 2	✓ (+ OK button) / 1 / 1 (dail around arrow buttons)	✓ (5 buttons) / 2 (+ 2 levers) / 1 (with button function)
Flash guide number (ISO 100) / Charge time / Connector	13 / 4.3 s / ✓ (TTL shoe + X-sync socket)	7 / 3.2 s / ✓ (TTL shoe)	14 (ISO 160) / 6.5 s / ✓ (TTL shoe)
Playback			
Multiple [# of images] / Zoom / Histogram	100, 25, 9 or 4 or calendar / ✓ (up to 14x) / ✓	100, 49, 25, 16, 9 or 4 or calendar / ✓ (up to 14x) / ✓	30 or 12 or calendar / ✓ (up to 16x) / ✓
Connectors / Dimensions			
Power source(s)	AC adapter (proprietary), Li-ion battery, 3 × CR123A (with opt. Adapter), optional battery grip	Li-ion battery	AC adapter + Adapter (proprietary), Li-ion battery
Interfaces / A/V out / HDMI / Remote release	USB 2.0 / ✓ / ✓ (Typ C) / ✓ (IR + cable)	USB 2.0 / ✓ / ✓ (Typ C) / ✓ (cable)	USB 2.0 / ✓ / ✓ (Typ C) / ✓ (cable)
Diemensions (W/H/D) / approx. weight[6] Body, with test lens	143 × 117 × 75 mm / 895 g, 1470 g	115 × 73 × 42 mm / 365 g, 480 g	124 × 90 × 76 mm / 450 g, 620 g
What's in the Box			
Manual / User guide	Manual	Manual	Manual
Included accessories	Li-ion battery BLM-5 (7.4 V, 1620 mAh, 12 Wh), charger, body cap, shoulder strap, USB and AV cable	Li-ion battery BLS-5 (7.2 V, 1150 mAh, 8.3 Wh), charger, body cap, carrying strap, USB and V cable, some bundles wtih kit lens(es)	Li-ion battery PS-BLS1 (7.2 V, 1200 mAh, 8.6 Wh), charger, body cap, carrying strap, USB and V cable, some bundles wtih kit lens(es)
Optional accessories	memory cards, camera bag, flash unit, interchangeable lenses, E system accessories	memory cards, camera bag, flash unit, interchangeable lenses, microphone adapter, underwater housing and accessoires, PEN system accessories	memory cards, cable remote release, AC adapter, ever-ready case, flash unit, interchangeable lenses, filters, Four Thirds adapter
Software			
Standalone software (platform)	Olympus Viewer 2 (Win/Mac)	Olympus ib (Win), Olympus Viewer 2 (Win/Mac)	PHOTOfunSTUDIO 6.0 BD Edition, Super LoiloScope (Demo) (Win), Silkypix Developer Studio 3.1SE (Win/Mac)
Ratings			
Test images[1] (c't test image shot in daylight)	Tested with ZUIKO DIGITAL ED 12-60mm f/2.8-4.0 SWD	Tested with M.ZUIKO DIGITAL 14-42mm f/3.5-5.6 II	Tested with LUMIX G VARIO 14-42mm / F3.5-5.6 ASPH. / O.I.S.
Color rendition / Exposure	⊕ / ⊕	⊕ / ⊕	⊕ / ⊕
Sharpness / Detail rendition	⊕⊕ / ⊕	⊕ / ⊕	⊕ / ⊕⊕
Image noise / Other artifacts[2]	○ / ⊕⊕	○ / ⊕	⊕ / ⊕⊕
Ease of Use[4] / Printed manual	⊕ / ⊕	⊕ / ⊕	⊕⊕ / ⊕
Feature set[4, 5] / Included accessories[4]	⊕⊕ / ○	⊕⊕ / ○	⊕⊕ / ○
RRP: Body / With test lens (approx. in US$)	1,700 / 2,700	– / 550	900 / 1000

[1] judged by eye on a calibrated monitor
[2] artifacts, noise, moirés, color fringing
[3] average, using largest native image size and best JPEG quality
[4] relative to similar class of camera
[5] photographic features only
[6] measured
[7] no dedicated AF sensors, measurement using image sensor
[8] stereo available with accessory microphone
[9] i-Fn lens with additionl multi-function ring
[10] gross 18 megapixels, pro rata "Multi-aspect" usage depends on image format

⊕⊕ excellent ⊕ good ○ satisfactory ⊖ poor ⊖⊖ inadequate ✓ included – not included n/a not applicable

Interchangeable-lens Camera Test

Manufacturerer / Model	Pentax K-5	Pentax K-r	Samsung NX100
URL	www.pentax.com	www.pentax.com	www.samsung.com
Digitization			
Native resolutions (in pixels)	4928 × 3264, 3936 × 2624, 3072 × 2048, 1728 × 1152	4288 × 2848, 3936 × 2624, 3072 × 2048, 1728 × 1152	4592 × 3056, 3872 × 2592, 3008 × 2000, 1920 × 1280 (3:2, 16:9 or 1:1 selectable)
Sensor type, Effective # of pixels / Size / Auto dust-off	CMOS, 16.1m / APS-C (23.6 × 15.7 mm²) / ✓	CMOS, 12.2m / APS-C (23.6 × 15.8 mm²) / ✓	CMOS, 14m / APS-C (23.4 × 15.6 mm²) / ✓
Image format(s) / Compression levels / Video format	RAW, JPEG, RAW+JPEG / 4 / MJPEG	RAW, JPEG, RAW+JPEG / 3 / MJPEG	RAW, JPEG, RAW+JPEG / 3 / MPEG-4 H.264
Video: Max. resolution [pixels], Clip length, fps	HD 1080p, 4 GB or 25 min., 25	HD 720p, 4 GB or 25 min., 25	HD 720p, 25 min., 30
Memory card: Type / File size [3]	SD(HC) / 11.0 MB	SD(HC) / 5.2 MB	SD(HC) / 6.3 MB
Features			
Crop factor (35mm equiv.) / Bayonet	approx. 1.5x / Pentax KAF3, KAF2, KAF, KA	approx. 1.5x / Pentax KAF3, KAF2, KAF, KA	approx. 1.5x / Samsung NX
ISO settings	auto (limits freely selectable), 80–51200 in 1/3, 1/2 or 1/1 steps	auto (upper limit selectable), (100)200-12800(25600) in 1/3, 1/2 or 1/1 steps	auto (100–200/400/800/1600), 100–6400 in 1/3 or 1/1 steps
Shutter speeds [s] / Default flash sync [s]	bulb, 30-1/8000 / 1/180	bulb, 30-1/6000 / 1/180	bulb, 30-1/4000 / k. A.
Focusing / Image stabilizing	AF (one-shot, continuous, predictive), MF / ✓ (sensor shift)	AF (one-shot, continuous, predictive), MF / ✓ (sensor shift)	AF (one-shot, continuous), MF / – (with certain lenses)
AF focus areas / Focus assist lamp	11 (9 cross type sensors), 5 or 1 (11 positions) / ✓ (green)	11 (9 cross type sensors), 5 or 1 (11 positions) / ✓ (green)	15 (close-up: 35) or 1 (195 positions) / ✓ (green)
Metering: Multi- / Center-weighted / Spot	✓ (77 areas) / ✓ / ✓	✓ (16 areas) / ✓ / ✓	✓ (247 areas) / ✓ / ✓
Programmed auto / Scene modes / Custom Presets	✓ (with shift and special modes) / – / ✓ (5 memories)	✓ (with shift and special modes) / 16 / –	✓ (with shift) / 14 / –
Exposure: Aperture priority / Shutter priority / Manual	✓ / ✓ / ✓	✓ / ✓ / ✓	✓ / ✓ / ✓
Exposure compesation [EV] / Depth-of-field preview	±5 EV in 1/3 or 1/2 steps / ✓ (lever)	±2 EV in 1/3 or 1/2 steps / ✓ (configurable)	±3 EV in 1/3 steps / ✓ (electronic)
Bracketing: Exposure / WB / Focus / Interval timer / Sound	✓ / ✓ / – / ✓ / ✓ (16-bit, mono[8], 32 kHz)	✓ / – / – / ✓ / ✓ (16-bit, mono, 32 kHz)	✓ / ✓ / – / – / ✓ (16-bit, mono, 48 kHz)
Self-timer / Continuous shooting speed, # of frames[6]	10 or 2 s / 6.2 fps, 21 shots	10 or 2 s / 6.0 fps, 27 shots	2-30 s / 2.9 fps, 8 shots
White Balance: Auto + Man. / Presets / Fine-tuning	✓ (3 memories) / 10 / ✓ (auch Kelvin/Mired, 3 memories)	✓ / 10 / ✓	✓ / 7 / ✓ (plus Kelvin setting)
Sharpness, Contrast, Saturation adjustable / Color spaces	✓ / sRGB, Adobe RGB	✓ / sRGB, Adobe RGB	✓ / sRGB, Adobe RGB
Viewfinder: Type / Magnification / Coverage	Pentaprism / 0,92x / 100 %	Pentamirror / 0,85x / 96 %	– (optional electronic) / – / –
Monitor: Diagonal / Resolution [dots] / No. of brightness settings	3.0" / 921,600 / 15	3.0" / 921,000 / 15	3.0" / 614,000 / 15
Live View / With AF using sensor / Dedicated sensors	✓ / ✓ (with face detection) / ✓	✓ / ✓ (with face detection) / ✓	✓ / ✓ (with face detection) / –[7]
Body material / Control panel / Auto monitor rotations	Magnesium, splashproof / ✓ (green illumination) / ✓	Plastic / – / –	Plastic / – / –
4-way selector / Multi selector / Command dials	✓ (5 buttons) / 1 (+ 3 levers) / 2	✓ (5 buttons) / 1 / 1	✓ (+ OK button) / 1 / 2 (1 dial around cursor buttons)[9]
Flash guide number (ISO 100) / Charge time / Connector	12 / 2,4 s / ✓ (TTL shoe, X-sync socket)	12 / 2.4 s / ✓ (TTL shoe)	– / – / ✓ (TTL shoe)
Playback			
Multiple [# of images] / Zoom / Histogram	81, 36, 16, 9 or 4 or calendar / ✓ (up to 32x) / ✓	81, 36, 16, 9 or 4 or calendar / ✓ (up to 16x) / ✓	20, 9 or 3, each with calendar / ✓ (up to approx. 7x) / ✓
Connectors / Dimensions			
Power source(s)	AC adapter (proprietary), Li-ion battery, battery grip	AC adapter (proprietary), Li-ion battery, 4 × AA (with opt. adapter)	AC adapter (proprietary), Li-ion battery
Interfaces / A/V out / HDMI / Remote release	USB 2.0 / ✓ / ✓ (Typ C) / ✓ (IR or cable)	USB 2.0 / ✓ / – / ✓ (IR)	USB 2.0 / ✓ / ✓ (Typ D) / ✓ (cable)
Diemensions (W/H/D) / approx. weight[6] Body, with test lens	131 × 97 × 73 mm / 745 g, 980 g	125 × 97 × 68 mm / 600 g, 815 g	121 × 71 × 35 mm / 340 g, 460 g
What's in the Box			
Manual / User guide	Manual	Manual	User Guide, Manual (PDF only)
Included accessories	Li-ion battery D-LI90 (7.2 V, 1860 mAh, 13.4 Wh), charger, body cap, eyepiece cover, accessory shoe cover, carrying strap, USB cable, AV cable, some bundles wtih kit lens(es)	Li-ion battery D-LI109 (7.4 V, 1050 mAh, 7.3 Wh), body cap, accessory shoe cover, carrying strap, USB cable, some bundles wtih kit lens(es)	Li-ion battery BP1310 (7.4 V, 1300 mAh, 9.6 Wh), charger, body cap, accessory shoe cover, carrying strap, USB cable, Kit lens(es)
Optional accessories	memory cards, AC adapter, battery grip, IR + cable remote release, camera bag, Pentax system accessories	memory cards, AA battery adapter, charger, AC adapter, IR remote release, eyepiece cover, AV cable, camera bag, Pentax system accessories	memory cards, AC adapter, cable remote release, GPS receiver, electronic viewfinder, camera bag, Samsung NX system accessories
Software			
Standalone software (platform)	Camera Utility 4 (Win/Mac)	Camera Utility 4 (Win/Mac)	Samsung Intelli-Studio (Win), RAW Converter (Win/Mac)
Ratings			
Test images[1] (c't test image shot in daylight)	Tested with SMC DA 18-55mm f/3.5-5.6 AL WR	Tested with SMC DA L 18-55mm f/ 3.5-5.6 AL	Tested with Samsung NX 20-50mm f/3.5-5.6 ED iFn
Color rendition / Exposure	⊕ / ○	⊕ / ○	⊕ / ⊕
Sharpness / Detail rendition	○ / ○	⊕ / ⊕	⊕⊕ / ⊕⊕
Image noise / Other artifacts[2]	○ / ⊕	⊕ / ○	⊕ / ⊕⊕
Ease of Use[4] / Printed manual	⊕⊕ / ⊕	⊕ / ⊕	⊕ / ○
Feature set[4, 5] / Included accessories[4]	⊕⊕ / ○	⊕⊕ / ○	○ / ○
RRP: Body / With test lens (approx. in US$)	1,330 / 1,450	590 / 625	– / 500

[1] judged by eye on a calibrated monitor
[2] artifacts, noise, moirés, color fringing
[3] average, using largest native image size and best JPEG quality
[4] relative to similar class of camera
[5] photographic features only
[6] measured
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⊕⊕ excellent ⊕ good ○ satisfactory ⊖ poor ⊖⊖ inadequate ✓ included – not included n/a not applicable c't

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Coming up in Issue 6 ...

The Timeless Fascination of Monochrome

Even if the actual processing takes place later on a computer, you still have to learn to see appropriate opportunities and apply the right shooting techniques if you want to be sure of capturing successful black-and-white images.

This major article introduces a variety of techniques and tools for converting color images to black-and-white and optimizing the results. It also gives you tips on how to digitally apply old-school darkroom effects, such as dodging and burning, or artistic touches like solarizing and hand-coloring.

Extreme Macro Depth of Field

The smaller and closer your subject, the shallower the available depth of field. In macro situations, even the smallest apertures don't provide sufficient depth to present the subject in the right light.

The solution is to use a computer to merge a stack of images taken using varying focus settings into a single, extended-depth-of-field image. We introduce the hardware and software you need and explain how to shoot and process your source images.

Fun with Unusual Lenses

Most lenses are designed for ease of use and to produce the best possible image quality in everyday photographic situations. Alongside these conventional lenses, there is a wide range of oddball and "fun" lenses available for creating special effects and shooting unusual images.

We take you through the ins and outs of using tilt/shift, fisheye and pinhole lenses, via the weird and wonderful world of plastic lenses and Lensbabys. The possibilities are endless!

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