Digital technology extends the boundaries of panoramic photography



Panorama image of the path along the cemetry, with the TU Delft Assembly Hall across the water, February 2004. The distorted horizon makes it more difficult to see that this is in fact a 360° picture (the left edge connects to the right edge).

by Joost van Kasteren

In 1881 Hendrik Willem Mesdag painted his famous Panorama of the fishing village of Scheveningen. The panorama covers a cylinder 14 metres high with a circumference of 120 metres. It is in fact an early form of virtual reality, giving the viewer the illusion of participating in life on the seashore. Like a modern Mesdag, Aldo Hoeben, part-time lecturer at the ID-StudioLab of the faculty of Industrial Design, creates digital panoramas that draw the viewer into events such as the funeral of Queen Juliana or a visit to the jungle of a zoo. The techniques used and developed by Hoeben for his panoramas can help designers to visualise their ideas and concepts. At the ID-StudioLab at the TU Delft faculty of Industrial Design, one of the research subjects is 'inspiration engineering'; the development of tools and techniques to support designers in the development of ideas and concepts during the early stages of the design process, including the communication with other designers as well as clients. For this purpose, Hoeben is designing a digital sketchbook that, like a paper pad, enables designers to develop and evaluate their ideas through internal and external dialogues (see frame text). On the face of it, developing a digital sketchbook would seem a far cry from making panoramic views of a zoo or the Market Square in Delft, but there is more to it than meets the eye, according to Hoeben. "In both cases I am trying to get the imitation inside the computer to match what people are used to seeing in real life. For instance, the most-used sketches in the digital sketchbook get dog-eared like pages of a paper pad. In my panoramic view I am trying to use software to increase the level of apparent reality, for example by facilitating natural movements and through gradual transitions from light to dark.

In both cases the main thing is not to spoil the user's expectations through technical flaws," says Hoeben.

"Panoramic photographs are an interesting aid for industrial designers and students," he adds. "They can be used to give an impression of the surroundings in which future products are to be used. To develop such an image most people still use a collage or 'mood board'. Another option is to make a video collage as used in the TRI system, which was also developed at the ID-StudioLab (see Delft Outlook 2004-3). A panoramic photograph is a bit of both. It is relatively easy to make, though it takes more time than a video collage does, and it offers a lot of spatiality and conveys the atmosphere."

Crooked perspective Besides his part-time job as a TU Delft lecturer, Hoeben works in his own company, fieldOfView, where he develops and markets techniques for panorama photography. Photographers used to think that panoramic photographs were a hobby that got out of hand. Special

12

Digital sketchbook

He has forsaken his pencil, pen, and paper. Aldo Hoeben now uses a digital sketchbook, based on a Tablet PC with a touch screen. This makes him a walking prototype of the designer of the future, entrusting his ideas and concepts to a digitiser rather than putting them on paper.

Hoeben: "The computer already plays a major role in the design process, both for industrial designers, architects and graphical designers, but mostly at the end of the design process, when ideas are converted into working drawings and 3-D images. During the initial stages, when designers are still searching, they prefer to put their ideas onto paper."

Tablet PCs offer new possibilities, in particular now that their price has started to go down. "But," Hoeben says, "They will succeed only if we manage to tune into the designer's methods during the initial stages."

This means for example that to start with the digital sketchbook display is empty, without any tool bars or other aids that purport to make things easier but in fact do nothing but force another person's aesthetics onto the user. There is no array of virtual pens either, just a quartet of scribbles in the lower right corner made by the user himself — virtually speaking — using a black and a red fine liner, a blue marker, and a grey pencil. Hoeben: "We teach our students to start a drawing by making a scribbles at the bottom to see whether a pen or marker still works. This is mimicked by the digital sketchbook. All you have to do is touch a squiggle to change the stylus from a fine liner into a marker or vice versa."

Dog-eared

A key property of the paper sketchbook is that you can get an idea of the design history just by turning its pages, going from the first tentative jottings to more detailed sketches later on. Of course, turning pages on an electronic display is always a bit cumbersome. You may have to switch from page to page, or you may be using a scroll bar that does not show which page you end up on until you release it. In the lower right-hand corner of Hoeben's digital sketchbook there is a thumbnail view of a sketch page on



cameras were used to create panoramic views of large groups of people but the technique was costly and cumbersome. Of course, you can always resort to sticking together separate photographs to form a panorama, but the results are strictly for the family album only. The problem is that the lines of perspective of such composite panoramas are all wrong. Unless the subject is a wide landscape view, the perspective effect will always be slightly off. Thanks to the advent of the digital camera and image-processing software the panorama photograph has made a full comeback. Not only do the new techniques make it much easier to create panorama photographs with the correct perspective, but additional software has been developed that enables you to walk through the panorama, as it were. You could visit an estate agent's web site to walk through a house without disturbing the occupants. Just as we can experience late nineteenth century Scheveningen by visiting Mesdag's Panorama in The Hague, so modern digital panorama photography now enables us to feel the atmosphere of a wintery day in Holland, or a pavement in Washington, DC.

Tracing To make his panoramic photographs Aldo Hoeben uses a fish-eye lens on his digital camera. This type of lens captures a hemispherical view, covering just over 180 degrees in any direction.

A photographer pointing the camera straight ahead will also see the toes of his shoes. To make a complete panorama, Hoeben does an about-turn with the camera and takes four pictures within the space of ten seconds to record a full view of the surroundings. Using special software the four overlapping photographs are then combined into a single image. A special feature of the software enables the user to correct the distortion introduced by the fish-eye perspective, so crooked towers can be straightened out. Adding several fisheye photographs together produces what is known as an equi-rectangular panorama in which the surroundings are recorded not only 360 degrees around in the horizontal plane, but also 180 degrees from top to bottom. The result is like projecting a view of the entire surroundings onto the inside



13





To preserve the largest possible area of the display for sketching, some of the action has been relegated to the corners of the screen. In the bottom left-hand corner of each page is a set of scribbles that the designer can use as a palette to select various types of pen. The sketchbook pages can be leafed through by clicking in the lower right-hand corner and dragging the styles across a thumbnail image of the current page. To make a page easier to find, the top right-hand corner of the page can even be dog-eared by the designer.

which you can just about make out the individual sketches.

Hoeben: "If the sketches and drawings are your own, you can recognise them from the thumbnail."

Clicking and dragging the thumbnail makes the previously filled pages of the sketchbook appear in a fixed order. Pages that are checked more often remain slightly longer in view than the other pages. After a while, these pages even become dog-eared. Hoeben: "These are all simple aids to make the digital sketchbook conform to the expectations of the designer."





Fish-eye view of the interior of the Mesdag Panorama in The Hague. To increase the panorama's illusion, the edges of the painting are hidden from view.

An important element is the so-called 'faux terrain', a physical stretch of landscape that practically seamlessly blends in with the painted panorama. Visitors view the Mesdag Panorama from a beach pavilion surrounded by a section of imitation dunescape.





Panorama painters soon discovered that the standard tricks for creating a (central) perspective did not work on the curved surface of a panorama. To ensure that the paintings appeared natural, they developed a new trick. The artist sat with his head inside a large glass cylinder onto the surface of which he traced the surrounding view. The glass cylinder used by Mesdag is on display at the Mesdag Panorama Museum.

A fish-eye lens is an extreme wide-angle lens, with a horizontal field of view of just over 180°. Unlike a normal wide-angle lens, it introduces a characteristic distortion that shows straight lines as curves.



Some estate agents already use interactive panoramas on their web sites to show the interiors of the houses they have on offer. Whereas separate photographs on an estate agent's web site often give the idea that they show a single view of the house at its most advantageous, a panorama also reveals what is on the other side of the room.



When taking photographs for a panorama, it is vital to rotate the camera around the nodal point of the lens. Hoeben (shown here on The Binnenhof, the seat of the Dutch government in The Hague) uses a plumb bob instead of the usual tripod. It enables him to easily maintain a fixed position and height for each exposure.

The fish-eye images form sections of a sphere. By combining the separate fish-eye views — 4 in this case — a full view of the surroundings can be recorded. The overlap between the various photographs is used to fit the views seamlessly together. In spite of the fact that these pictures record the entire surroundings, the photographer himself is not included in the picture as he stood behind the camera for each exposure.

Modern Mesdag fits the world into his computer

of a sphere that is then reworked to create a flat surface. In fact, a similar process was used to create the Mesdag Panorama. Just like other panorama painters of his day, Mesdag traced the contours of the view he wanted to paint onto the inside of a glass cylinder surrounding his head. The actual cylinder he used can still be seen in the Mesdag Panorama Museum in The Hague. Using this aid, Mesdag managed to get the perspective of a circular painting just right. This is not a trivial matter, since the lines of perspective, which normally extend as straight lines to the vanishing points on the horizon, are now curved along a cylinder or spherical projection. Once the contours had been sketched on the inside of the cylinder, they could be traced onto a long rectangular sheet of paper to produce a flat version.

Horizon to sinusoid In addition to spheres and cylinders, other geometrical shapes can also be used as projection screens for images of the surroundings. Hoeben shows a photograph of the interior of a church in Dordrecht, in which the raw image has been projected onto a cube which was then unfolded to produce a cross. Another example is a photograph of the Scheveningen Fireworks Festival featuring a hyperbolic perspective. In the resulting image of this seaside event, the full horizon has become a circle, with buildings, and the fireworks display sticking out of the almost planetoid scene. Cylindrical projection also offers plenty of scope. Standing on the north side of the Market Square in Delft, Hoeben took several photographs shortly before the arrival of the funeral procession of Queen Juliana. A cylindrical projection of the panorama produces an image in which both the town hall and the church can be seen from the front even though they are on opposite sides of the square. At first sight, it appears to be a normal picture. But the fact that the guard of honour is arranged in a horseshoe shape rather than in a straight line makes the viewer aware of the considerable distortion involved. A very interesting effect can be created by putting the virtual cylinder at an angle rather than vertically. This turns the horizon into a sinusoid. To illustrate the effect Hoeben shows a picture of a dog he took last winter near the cemetery behind the University's Assembly Hall.

Hoeben: "The little dog got a bit lost in the original picture, so I tilted the axis of the cylinder at an angle that put the animal in the upper half of the photograph, the centre of attention. As an additional effect, the horizon became distorted into a sinusoid."

The photograph also illustrates the time dimension involved. A woman approaching along the path from the right can be seen walking into the distance to the left in the same picture.

Hoeben: "Panorama photography enables you to capture not just three, but even four dimensions on a flat surface."

Patents cause stagnation The software used to convert the different projections was created by German mathematician Helmut Dersch. Hoeben was involved in its development on the user side. Sadly, developments in the panorama software sector are threatened by stagnation as a result of a patent granted to an American company, IPIX. Like many U.S. patents, its scope is rather wide, and even though the patent in itself does not apply to Europe (where software patents did not become possible until very recently), the company has a policy of aggressively tackling any party they suspect of infringing it.

Hoeben: "As a result of this aggressive policy, few companies are interested in improving the software for creating panoramic views. Consequently, a number of panorama photographers all over the world have decided to develop the required programs themselves, either as open source software in large groups, or commercially in small, elusive companies.

Hoeben himself is one such developer. His fieldOfView company offers the SPi-V Engine, short for Shockwave Panorama Viewer, and known as Spiffy. It enables the user to use a mouse to click on the image and then drag the image from left to right or up and down (see also www.fieldofview.nl). It feels like standing at the viewpoint and looking all around you, just like in the Mesdag panorama. The SPi-V Engine is based on Macromedia's Shockwave technology, and according to Hoeben it does not infringe the IPIX patent being entirely based on techniques that had been published before the patent application was submitted.

These techniques were, and still are, used to display three-dimensional

objects in games like Doom, or feature films like Terminator II. The drawback of classic 3-D objects is they either lack realism or require huge amounts of processing power.

Hoeben: "The SPi-V Engine on the other hand enables you to create a very realistic environment in real time based on photographs in which you can look all around you. What I am trying to do is add elements that will enhance the realistic viewing experience."

Soft braking One of these elements is an inertia effect in movements. In other panorama viewers the image halts rather abruptly as soon as you stop moving the mouse. Hoeben developed software that continues the movement for a fraction of a second. According to Hoeben, this feels much more natural, because in the physical world a person's neck does not stop instantly either. To test his theory, he asked a number of students to look around in a panorama photograph with and without the inertia effect.

"When people view the image without the inertia effect, nobody notices anything wrong. The same applies when they subsequently view the image with the inertia applied. However, if we reverse things to test the inertia effect first, and then view the image without it, they do notice a difference. Some even felt the lack of the inertia effect in their necks. This shows that a built-in inertia effect is a closer match for the way people actually move, and consequently, it makes viewing the image a more natural experience." Another addition is the transition from light to dark sections of the image. The full dynamic range, which is the difference between the brightest white and the darkest black, is easily covered by the human eye, which gradually adapts to changing lighting conditions in a matter of 1-1.5 seconds. A panorama photograph may contain a very wide range of values from light to dark. Hoeben shows a photograph of a cave in the Jordanian desert where the sole source of light is the entrance of the cave. The aperture is brightly lit, but the inside of the cave remains too dark to distinguish objects. Hoeben has developed software that gradually adapts the image in the same way that the human eye gradually adapts to changing lighting conditions. The interior now lights up to reveal a number of objects, including a person in a corner.

Seattle Besides enhancing existing objects in the panorama photograph, virtual objects can be added to enhance the image. A special example of this technique has the Seattle Space Needle as its subject. Standing on the tower's observation deck Hoeben shot photographs of the view using his fish-eye lens. He then added an image of the Space Needle itself, or rather, a computer-generated image he created using classic three-dimensional graphic modelling techniques. Using a technique developed by Paul Debevec at the Institute for Creative Technology of the University of Southern California, Hoeben adjusted the lighting of the virtual tower to match the ambient lighting. The technique uses each pixel in the panorama as a light source with a certain colour and intensity. Not only do you see sunlight shining on the tower just like it does on the surrounding area, but you also get reflected light illuminating it, from a blue sky for example. The result is extremely convincing.

"So much so," Hoeben says, "that many people think I actually flew around the Space Needle in a helicopter. They even ask me how I managed to get permission, since aircraft have been banned from airspace close to tall buildings ever since 9/11."

Animation Apart from these almost imperceptible additions, the inclusion of a small animation may help to liven up the image, according to Hoeben. He shows a panoramic photograph of a so-called boardwalk exhaust, where a central heating plant releases its exhaust gases over a pavement somewhere in Washington, DC. Using a particle generator, a piece of software that generates moving particles, he can show smoke coming from the pipe, and even vary the direction and force of the wind. A small moving element brings the entire image to life. Another example is a movie of a talking woman that has been added to a panorama photograph of a building interior. Hoeben: "Panorama photographs are often used to show what a room looks like, for example a hotel room or the living room of a house an estate agent is trying to sell. However attractive the room may be, the image still looks empty if it does not include people. A little movie like this, which in this case runs as



surroundings onto a flat surface, the sphere is cut along the back as it were, folded open en stretched to produce an equi-rectangular perspective.

> The panorama can now be projected onto any geometrical shape, for example a cylinder, as in the Mesdag Panorama, or even a cube. As long as the viewer stands in the exact centre of the sphere or cube, and if the lighting were to be perfectly even, the sphere and the cube would both give the same view. In a cylinder the only difference would be that parts of the bottom and top views will be missing.

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Any normal wide-angle lens can also be used to create a 360° × 180° panorama, although it requires more exposures. The first row of 16 photographs together form a cylinder. By photographing several rows, rotating the camera around its focal point, the entire surroundings can be recorded. In this example, a total of 52 exposures is required.

Modern Mesdag fits the world into his computer

16

a permanent loop, adds authenticity to the image." Authenticity is what it is all about.

Hoeben: "People should not be distracted by the technology, however beautiful or innovative. Whether you are looking around inside a panorama photograph or, as a designer, jotting down ideas in a digital sketchbook, the main thing is that you can really experience the space and objects."

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> Relevant web sites: www.fieldofview.nl www.fieldofview.nl/events/outlook



The panorama Hoeben shot at the funeral of Queen Juliana in Delft shows how a panorama need not be a wide view of a landscape. In this case, the view of the crowd accurately expresses the elated, though at the same time subdued, mood of the occasion.

For web sites as used by estate agents, Hoeben came up with additional featuress for panoramas. In this case he has added some video footage of a woman to an interior view of a large house. She could be an estate agent explaining the layout or the history of the building to the virtual visitor. Note that the woman in the picture never actually entered the building; she was edited in later using digital processing software.







⁻OTOGRAPH: GREG DOWNING,

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is overexposed. Hoeben's software dynamically creates mixed lighting conditions depending on the direction of view in the panorama. The resulting lighting matches that observed by the human eye, which constantly adapts to differences in lighting levels.

In his panorama of the Scheveningen fireworks festival Hoeben converted the spherical perspective into a hyperbolic perspective in which the virtual camera points vertically downwards. Lenses that can produce such a hyperbolic perspective do not actually exist.

Most panorama

photographers regard it as a challenge to achieve a good exposure throughout a scene. In the upper image the exterior view has the correct lighting conditions, whereas the interior of the cave is far too dark. On the lower of the two pictures, the lighting inside the cave is perfect, but the outside view



For the Space Needle demo Hoeben took photographs from the observation deck of the 180 metre high tower in Seattle. These enabled him to create a panorama of the area surrounding the Space Needle, although it did not include the tower itself. He then reconstructed a view of the tower using traditional 3D software and photographs he found on the Internet. The panorama not only provided a photo realistic background, it also helped to create the correct lighting conditions for the tower reconstruction. If — as in the upper view the panorama and the lighting effects are removed, the tower becomes instantly recognisable as a product of traditional computer graphics software. The magic is in the combination of the panorama and the effect of the ambient lighting on the reconstructed tower.

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