HumanEyes Technologies Ltd.

The OmniStereo® Technology for Panoramic Stereo is the core of HumanEyes's products

1 Stereoscopic Imaging

Our two eyes, which are located approximately 6-7 cm apart, provide our brain with two slightly different images of a scene. Similarly, a stereo pair consists of two images of a scene from two slightly different viewpoints. The brain "fuses" the two stereo views to obtain a sense of depth. The perceptual result is that instead of seeing two different views, we see a single, three dimensional, view.

Figure 1. A traditional stereo camera by Kodak.

The brain can fuse the stereo pair if the images are taken from locations which are separated in a similar way to our eyes. Namely, the separation between the views is sideways relative to the viewing direction. No stereo fusion will occur with views that are taken from locations one in front of the other. This effect limits stereo imaging into a narrow field of view, and therefore stereoscopic panoramic imaging was considered impossible.

HumanEyes Israel

HumanEyes Technologies Ltd.
1-4 High Tech Village
Edmond Safra Campus
The Hebrew University, Givat Ram
POB 39063
91390 Jerusalem
Israel

Tel: +972-2-651-8999
Fax: +972-3-725-6356
Email: info@humaneyes.com

HumanEyes USA

HumanEyes Technologies Inc.
366 North Broadway, suite 410
Jericho, NY 11753

Tel: 516-942-2040
Fax: 516-908-7761
Email: info@humaneyes.com

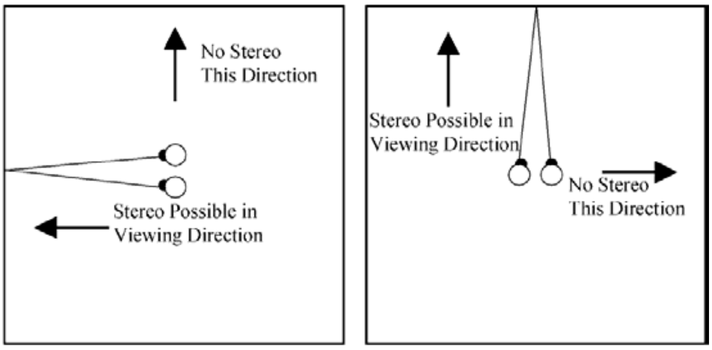

Figure 2. No arrangement of two images can give stereo in all viewing directions. For upward viewing, the two cameras should be separated horizontally and for sideways viewing, the two cameras should be separated vertically.

The effect between the stereo views that carries the 3D information is the parallax: the difference in location of an object point between the left-eye view and the right-eye view. Points having zero parallax are considered to be on the image plane. Points with positive parallax, whose location in the right image is to the right of their location in the left images, are perceived to be behind the image plane. Points with negative parallax, whose location in the right image is to the left of their location in the left images, are perceived to be in front of the image plane. The amount of parallax controls the amount of perceived depth.

1.1 Multi-View Stereo

While the brain needs only two stereo views for 3D perception, availability of multiple stereo views allows more freedom in viewing. For example, autostereo displays like lenticular imaging (see figure below) or parallax barrier allows stereo viewing with no glasses. In lenticular imaging the different views (usually 8-20 views) are interlaced together and placed behind a lenticular lens. Each eye sees a different view behind the lenticular lens, creating a stereo effect. The interlacing process is carefully matched to the property of the lenticular lens.

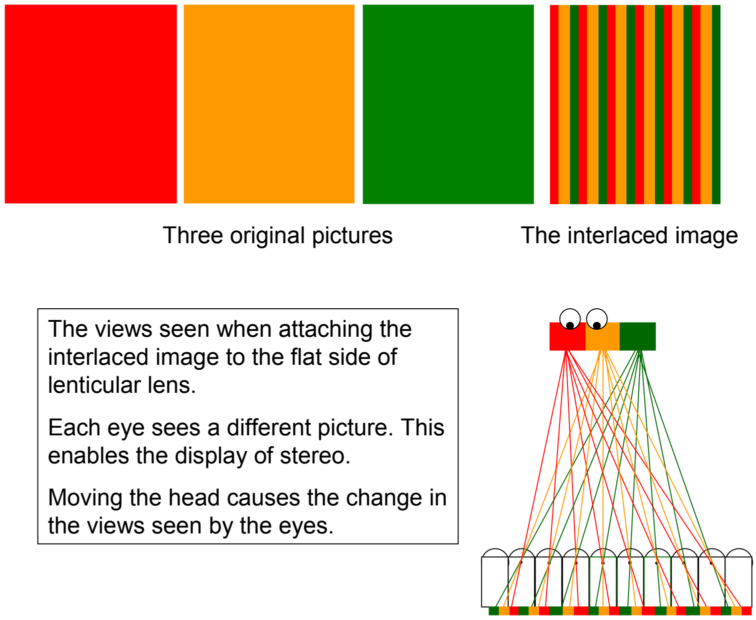

Figure 3. Autostereo viewing using Lenticular Imaging.

While multiple views are very convenient for autostereo viewing, their photography is difficult. In the next figure we show a famous attempt to create a multiple view camera for lenticular printing, the Nimslo Camera. This camera captures four different views on film, and a special photographic process was used to interlace and print these images.

Figure 4. The Nimslo stereo camera with four views, made for lenticular 3D prints.

Since four views are not really sufficient for comfortable autostereo viewing, and since the process of printing the lenticular prints was expensive and complicated, 3D printing with the Nimslo camera did not catch on. The difficulty in photographing multiple stereo views made it necessary to use rendering methods to get the multiple views from graphical objects or from layers.

2 The OmniStereo Technology

The creation of pictures in photography is done through a process called "projection", which maps the three-dimensional world onto a two dimensional picture. The common projection used in existing photography is the "Perspective Projection", where rays coming from a scene pass through a single point and are projected onto the planar picture. A simple example is the pinhole camera model.

The core of the OmniStereo technology is the invention of "circular projection", where rays do not pass through a single point, but are tangent to a circle.

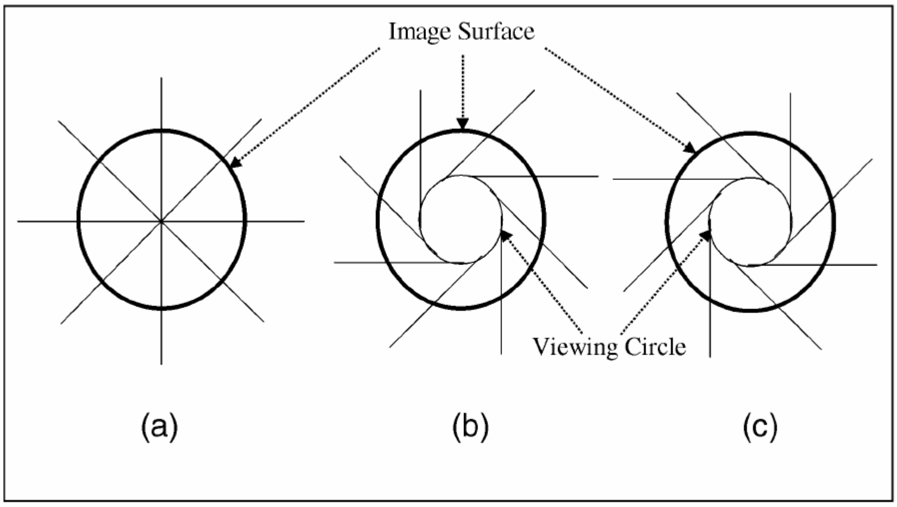

Figure 5. Circular projections. The projection from the scene to the image surface is done along the rays tangent to the viewing circle. (a) Projection lines passing through the optical center create the traditional panoramic image. (b) and (c) Families of projection lines tangent to the inner viewing circle create the muliple-viewpoint circular projections used in OmniStereo Imaging.

While normal cameras can create only perspective images, the OmniStereo technology creates panoramic images having a circular projection by mosaicing a sequence of input images taken by a camera rotating on an arm. Mosaicing for the creation of panoramic stereo pairs provides the ability to create panoramic pictures of up to 360º.

We now review several approaches for obtaining the circular projection, and the new capabilities that were not previously possible.

2.1 Stereo Scanning

A panoramic stereo picture can be generated from a short video clip, or a sequence of still pictures, scanning the scene. The process involves two steps:
(i) Computation (in software) of the camera motion between the frames in the video clip.
(ii) The combination of all frames to the appropriate left and right panoramic images using an image mosaicing technique.

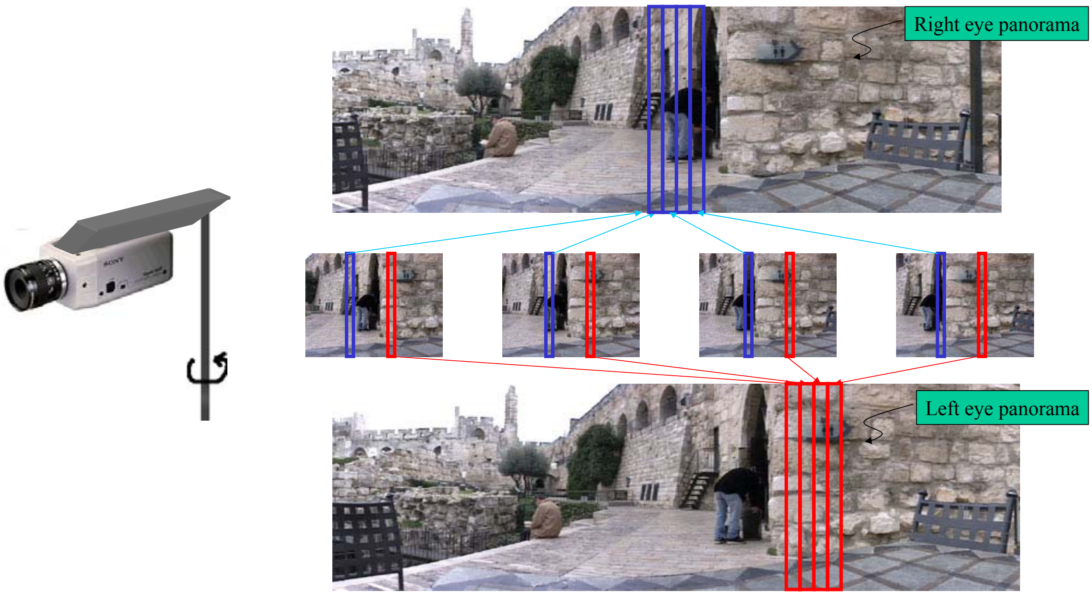

Figure 6. Generating panoramic stereo pair by mosaicing. The input image sequence is taken by a camera rotating off-axis. Strips from the left side of the input image sequence are mosaiced to form the panorama for the right eye, and strips from the right side of the input image sequence are mosaiced to form the panorama for the left eye.

OmniStereo mosaicing provides the easiest way to create stereo - just scan the scene by panning a regular camera. Now, anyone can create stereo! The field of view can be as wide as desired, up to a full 360º. This is in contrast to common stereo photography suitable only for a few professionals, giving narrow field of view images.

2.2 Multiple Stereo Views

The OmniStereo technology can produce multiple stereo views with the same ease that two stereo views are generated. We can show this by using the "Space-Time Volume" representation in the following figure. The image frames taken by the rotated camera are stacked together to form a 3D volume. The original left-eye panorama, generated by stitching together strips from the right side of the input images, is depicted as a vertical slice on the right side of this volume. The original right-eye panorama is depicted as a vertical slice on the left side of this volume. Any vertical slice of this volume gives a panoramic image of the scene, and any two different slices are a stereo pair.

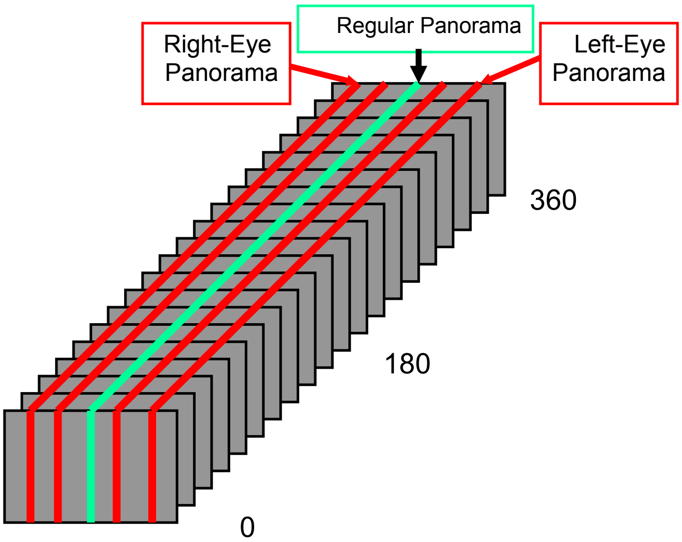

Figure 7: Multiple stereo views can be generated by taking multiple vertical slices of the space-time volume. Every two different slices are a stereo pair.

3 Applications

3.1 Lenticular Printing

As described earlier, in **Lenticular printing,** pictures from several (8-20) views are combined into a single “interlaced” picture. When covered with a lenticular plastic sheet, the interlaced picture exhibits stereoscopic “depth”, as each eye sees a different view. This is done without using any glasses. Obtaining the multiple views necessary for stereo viewing was traditionally a severe problem in photography. With the Omnistereo technology and a short video sequence scanning of a real scene, everyone can generate multiple stereo views for lenticular printing in seconds.

Lenticular prints can be prepared from professional photographic images and used from large posters to flyers and business cards. In addition consumer cameras can be used for creation of small prints on a home ink-jet printer.

3.2 Auto-stereoscopic Displays

Auto-stereoscopic displays are now becoming popular, from desktop displays to laptops to cellular telephones. Whether the display needs two views or multiple views, the OmniStereo technology is available for the generation of photographic 3D content.

4 The Future

The circular projection generated by the OmniStereo mosaicing can also be generated by optical means such as a lens. This can overcome the main drawback of stereo mosaicing: time. It takes from a few seconds to scan a scene with video, to several minutes with a professional still camera. During this time the scene should remain mostly stationary. Initial designs for optical means to create the circular projection are described in [1].

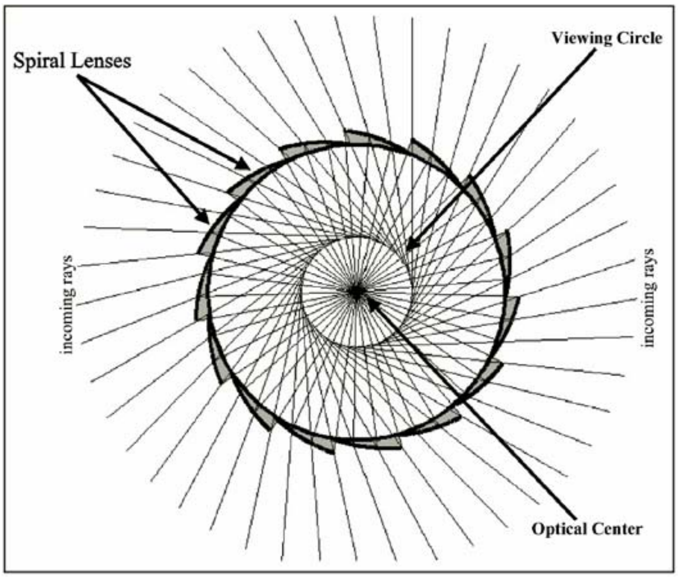

Figure 8. Circular projection can be obtained by a Fresnel-like lens. Capturing the panorama can be done by an Omni Camera at the center of the viewing circle.

5 References:

[1] S. Peleg, M. Ben-Ezra, and Y. Pritch, *OmniStereo: Panoramic Stereo Imaging*, IEEE Trans. on PAMI, March 2001, pp. 279-290.

[2] US Patent 6,665,003, *System and method for generating and displaying panoramic images and movies*.

[3] US Patent 6,532,036, *Generalized panoramic mosaic*.

[4] US Patent 6,434,280, *System and method for generating super-resolution-enhanced mosaic images* .