History of stereo photography
http://www.arts.rpi.edu/~ruiz/stereo_history/text/historystereog.html
http://online.sfsu.edu/~hl/stereo.html
Dates of development
http://www.arts.rpi.edu/~ruiz/stereo_history/text/visionsc.html
Math
http://drt3d.blogspot.com/2008/02/basic-stereoscopic-equation.html
http://nzphoto.tripod.com/stereo/3dtake/fbercowitz.htm
Info
http://www.photostuff.co.uk/stereo.htm
http://www.stereoscopy.com/faq/

The History of Stereo Photography

Early context

In 280 A.D., Euclid was the first to recognize that depth perception is obtained when each eye simultaneously receives one of two dissimilar images of the same object. In 1584 Leonado da Vinci studied the perception of depth and, unlike most of contemporaries, produced paintings and sketches that showed a clear understanding of shading, texture and viewpoint projection. Around the year 1600, Giovanni Battista della Porta produced the first artificial 3-D drawing based on Euclid's notions on how 3-D perception by humans works. This was followed in 1611 when Kepler's *Dioptrice* was published which included a detailed description of the projection theory of human stereo vision.

Early stereo photography

Queen Victoria visited the World's Fair in London in 1851 and was so entranced by the stereoscopes on display that she precipitated an enthusiasm for three-dimensional photography that soon made it a popular form of entertainment world-wide.

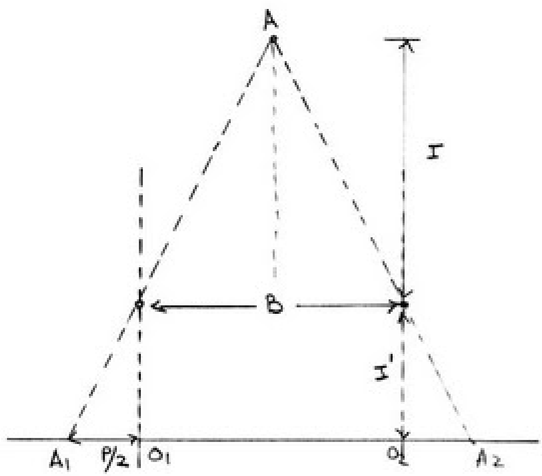
It was Sir Charles Wheatstone who in 1833 first came up with the idea of presenting slightly different images to the two eyes using a device he called a reflecting mirror stereoscope. The invention of the Brewster Stereoscope by the Scottish scientist Sir David Brewster in 1849 provided a template for all later stereoscopes. This in turn stimulated the mass production of stereo photography which flourished alongside mono-photography.

The discovery of anaglypic 3-D appeared in the 1850's as the result of experiments by the Frenchman Joseph D'Almeida. Color separation took place using red/green or red/green filters and early anaglyphs were displayed using glass stereo lantern slides.William Friese-Green created the first 3-D anaglypic motion pictures in 1889 which first went on show to the public in 1893.

In 1932, Edwin H Land patented a process for producing polarized filters that eventually led to the development of full color 3-D movies. This was possible because the left/right separation could be achieved using the polarizing filters rather than the color channel.

(Also more pictures of the Civil War were done in stereo than regular photography.)

Basic Stereoscopic Equation



$$\frac{B/2}{I} = \frac{P/2}{I'} \Rightarrow \frac{P}{B} = \frac{I'}{I} = M \Rightarrow \boxed{P = MB}$$

Consider an object A at a distance I from the lenses of the stereo camera, which are separated by B (stereo base). An object at infinity is formed at O1 on the left side and at O2 at the right side, while the image of A is A1 and A2. The situation is symmetric so half the stereoscopic deviation (or parallax) is P/2. From similar triangles we have:

B/2 / I = P/2 / I' or P/B = I'/I (1)

From our previous posting we know that the ratio I'/I is the magnification M. So we get:

P = M B (2)

This is the basic stereoscopic equation. I cannot help but make the following analogy: Variables in the image space (with prime ') are related to variables in the object space through the magnification. For example, I' = M I, s' = M s, and here we have P = M B, so we can think of P as B', in other words, the **stereoscopic deviation is the “image space” equivalent of the object space stereo base**.

If the subject is far away from the lens we can use the **low magnification approximation** and write (2) as follows:

P = FB / I (3)

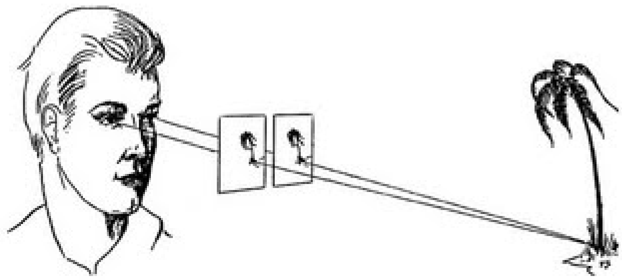
Equation (3) gives the parallax with respect to infinity (remember, we measured P from point O which is a point at infinity). If we have a near object at Imin and a far object at Imax, then the stereoscopic deviation equation can be written more generally as:

$$P = F\ B\ (I/min - Imax) \quad (4)$$

The stereoscopic deviation is proportional to the focal length, the stereo base, and inversely proportional to the distance.

Posted by DrT at 9:35 PM
Labels: Theory

Stereo Photography Viewing Variables



The three "**recording" variables** F, B, and I, affect the way the stereo image is recorded on film but they also affect the way the stereo image is perceived, i.e. how it appears during stereoscopic observation.

To understand the stereoscopic impression when we view a stereo image, we also need to know the focal length of the viewing lens, Fv, and the interpupillary distance (eye spacing) of the observer, Bv. Fv and Bv are now our **viewing variables**.

Finally, even if we know the recording variables and the viewing variables, what we actually perceive also depends on our brain & experience, what we call "**peception**". So, we can say that:

3d image perceived = (recording variables) + (viewing variables) + (Perception)

There are two conditions that, when satisfied, viewing the stereo image most closely imitates viewing directly the original scene: 1) Stereo base is equal to the interpupillary spacing (B=Bv, approximately 65mm or 2.5") and 2) focal length of the recording lens is equal to the focal length of the viewing lens (or viewing distance), F=Fv. This is known as “ortho stereo”.

Ortho Stereo: B = Bv & F = Fv

General-use stereo cameras are well-suited for this type of stereo photography which explains the choice of lens separation in Realist-format cameras. The focal length of the recording lens is not important as long as it is matched by the viewing lens. Most 35mm film viewer lenses have a FL of 40-50mm. The 35mm FL lens in many stereo cameras is a compromise, offering good depth of field, decent field of view, and near-ortho viewing conditions.

Any deviation from these conditions will result in a visual impression that deviates from reality. We will explore some of these situations in subsequent postings.

Posted by DrT at 11:01 PM
Labels: Theory

Stereo Photography Recording Variables

This blog is based on my Tutorial “Beyond the Stereo Camera”. You can purchase the entire collection of my stereo Tutorials by going to: http://www.stereotutorials.com/

There are three variables which affect the way images are recorded on film:

1) **Focal length (F)** of recording lens.
2) **Stereo base (B)** of stereo system.
3) **Distance (l)** of the camera to the subject.

These three variables affect three “metric” (measurable) aspects of the recorded image:

1) **On-film size of an object** (or magnification).
2) Relative sizes of objects at different distances from the camera (this is also known as linear or geometric **perspective**).
3) **Stereoscopic deviation**.

Metric/ Variable	Size $s' = s\ f/l$	Perspective $ds = dl\ /\ l$	Deviation $p = FB/l$
Focal Length F	+		+
Stereo Base B			+
Closeness 1/ l	+	+	+

These effects are summarized in the Table reproduced here. Note the formulas that express the relationship between the recording variables and the metric aspects of the recorded image:

- Magnification: $M = s'/s = f(l\text{-}f) \sim f/l$, or on film size $s' = s\ f\ /\ l$, only depends or object size, focal length and distance.
- Perspective: $ds/S = dl/l$, only depends on subject distance. (ds is a change in image size due to a change in image distance dl)
- Stereoscopic Deviation: $p = FB/l$, depends on F, B and l

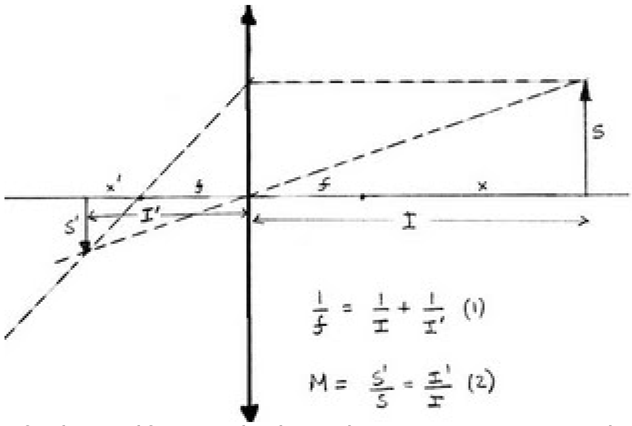
Some comments:

- **The focal length acts as a magnification factor**. It magnifies the size of the recorded image without altering the perspective. It also increases the stereoscopic deviations.
- **The stereo base is the only variable unique to stereo photography** and it only affects the stereoscopic deviations, which is the only metric aspect unique to stereo.
- **The distance of the camera to the subject, essentially the only variable available in a standard stereo camera, affects all three aspects of the recorded image**. The effects are proportional to the inverse distance (1/l) which we can call “closeness to the subject”. By coming closer to the subject you 1) increase the on-film size of the subject, 2) intensify the perspective (make closer objects appear larger than further objects) and 3) increase the stereoscopic deviations. **That's a good argument for getting closer!**

Posted by DrT at 10:36 PM

Labels: Theory

Basic Lens Equation



I find myself using the basic lens equation quite a bit so I would like to derive some important formulas. Consider a lens of focal length f. The object is at distance I from the lens, while the image is formed at distance I'. The size of the object is s, the size of the image is s'. See the diagram here.

The basic lens equation is: $1/f = 1/I + 1/I'$ (1)

The magnification by definition is $M = S'/S = I'/ I$ (2)

If we use equation (2) to solve for either I or I' and substitute it in equation (1), we obtain these two useful formulas:

$M = f/x$ (3) and $M = x'/f$ (4)

From (3) and (4) we can write (1) as: f**2 = x x'

If the subject is far away from the lens (low magnification) then I >> f and I = x, I' = f, so the magnification is approximately equal to **M = f/I**. This is the **low magnification approximation**.

At high magnifications I gets close to f, and I' gets very large, so I' = x' and **M = I'/f**. this is the **high magnification approximation**.

An interesting situation occurs at **M = 1**, then x = x' = f, and the subject is at distance 2f from the lens and the image is formed at distance 2f from the lens. In this case the total distance from the object to the film plane is the smallest possible (4f).

Posted by DrT at 9:28 PM

Prepared by E. Mitofsky