Stereoscopic Photography

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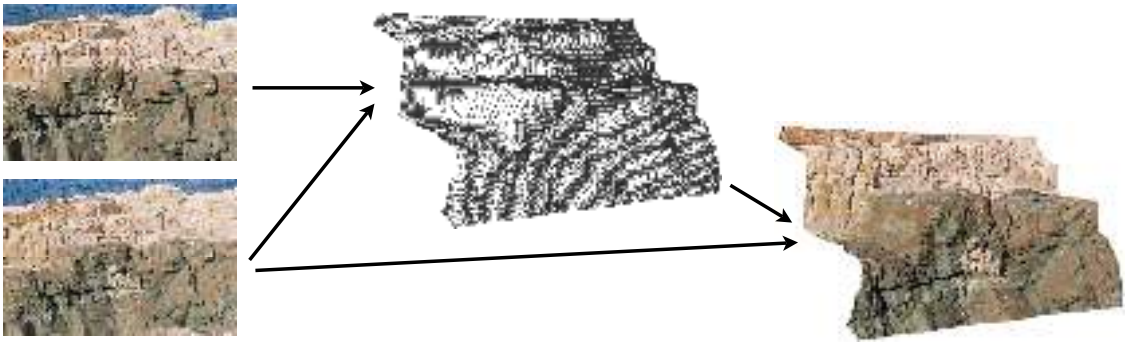
Outline

- Distinction between stereo photographic for image viewing and for geometry reconstruction (Sirovision).
- Brief history.
- Projection principles.
- Description of parallax and the effect on viewing.
- Choosing an appropriate camera separation.
- Example processing two images.
- Tricks of the trade, what to look out for.
- Workflow and preparing material for viewing on the system in the Discovery Centre.
- Toe-in cameras for stereo pair capture.
- Stereoscopic panoramic pairs.
- Examples in the projection theatre, chance to experiment.

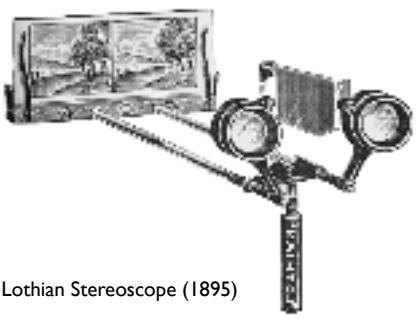
Distinction between stereo pairs for Sirovision and viewing



- Sirovision uses the parallax information in a stereo pair to reconstruct the geometry of the terrain, one image can then be draped over the mesh to give a realistic 3D model.
- Stereo photography (discussed here) is concerned with (simply) creating an image that when viewed in a stereoscopic projection system appears to have depth. Interaction is limited to panning around or zooming within a larger stereoscopic image pair.
- In general, stereo pairs captured for Sirovision are not suitable for viewing! The main difference is the camera separation required by Sirovision for surface reconstruction is much wider than is suitable for viewing.
- The remainder of my discussion concerns the successful capture of stereo photography.

Stereoscopic photography has been around for a while

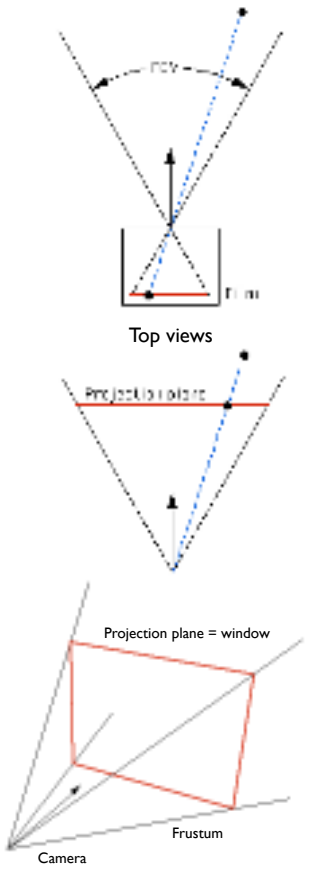
- Been around since the early days of photography. Popularised by the interest shown by the Queen Victoria at the 1851 world fair in London.
- Sir Charles Wheatstone presented two perspective drawings independently to each eye with a mirror system around 1833.
- Estimated that in the 1920s one in four households in the USA owned a stereoscope.
- Stereoscopic photography gave way to movies, anaglyph 3D movies became less popular when colour filming became possible .... there was no viable colour stereoscopic movie technology until relatively recently (eg: IMAX 3D and digital techniques).



Lothian Stereoscope (1895)

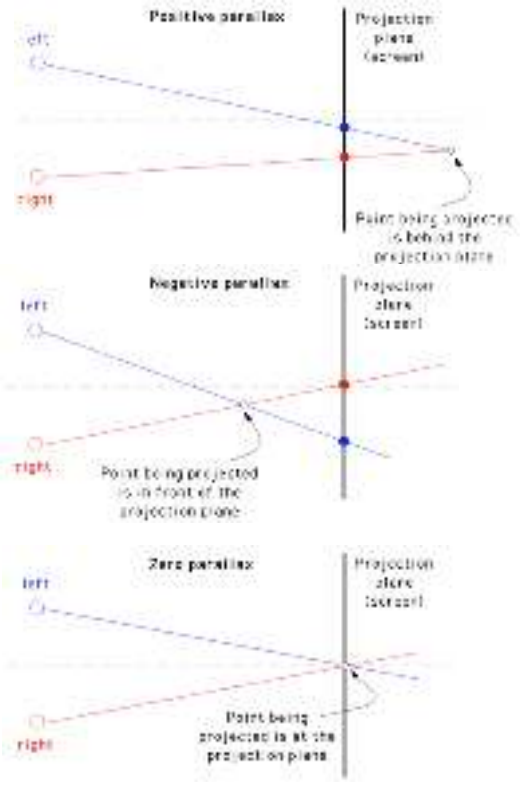
Principles (Perspective and Pinhole Camera)

- Pinhole (perspective) camera model.
- Determine where a point is drawn on the projection plane (film) by drawing a straight line from the point, through the camera position (pinhole), and see where it intersects the projection plane (film).
- Projection plane can be located anywhere perpendicular to view direction.
- View frustum is the rectangular cone with edges from the camera through each corner of the projection plane. The view frustum defines those parts of the scene that can be "seen".
- Consider two cameras (eyes) and a single projection plane: correct model to think about this is a window through which the world is viewed.
- Note that if the camera/eye/observer moves the view changes. This is not normally accounted for in a projection system and explains the "shearing" effect when one moves when viewing stereo image pairs.

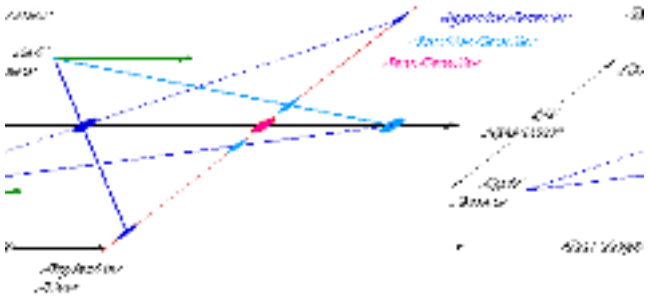


Parallax, +'ve, 0, and -'ve

- There are three relationships that a point in space can have with the projection plane and the camera.
- They are classified depending on the orientation of the projection onto the plane compared to the cameras.
  - negative parallax = objects closer than projection plane
  - positive parallax = objects behind the projection plane
- The greatest possible positive parallax occurs when the point is at infinity, the parallax separation is the same as the eye separation.
- It is the distance at which objects appear to be at zero parallax that forms the link between the virtual (or photographed world) and the environment into which the images are viewed. Objects at zero parallax will appear to be at the screen depth.



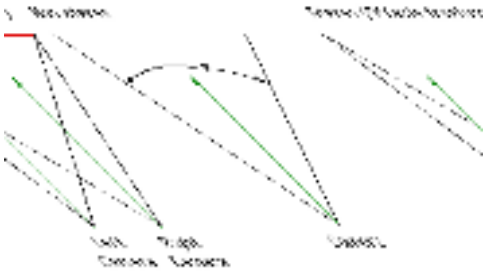
Negative parallax, the danger zone

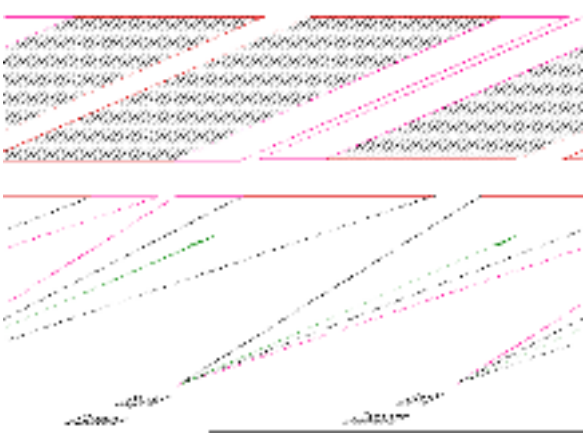


- As an object comes closer to the camera the negative parallax goes to infinity.
- The degree to which an observers visual system will fuse large negative parallax depends on the quality of the projection system (degree of ghosting) .... but it will always eventually fail.
- High values of negative parallax is a key contributor to eyestrain.
- When the point in question is half way between the cameras and the projection plane, the negative parallax is the same as the camera separation. This is generally considered to be the maximum "safe" parallax.

Offaxis projection frustums from a symmetric camera lens

- We are used to thinking about view frustums that are symmetric about the view direction.
- Consider the view through a window, each camera (eye) position has a slightly different view of the world.
- Frustums for stereo pairs are not symmetric, see diagram top right. But cameras (generally) only have symmetric frustums.
- An asymmetric frustum can be achieved by taking photos with two parallel cameras and sliding the resulting images horizontally with respect to each other and removing the non-overlapping bands.
- The sliding/cropping effectively adjusts the distance to zero parallax.





Example: Aligning 0 parallax of two images

- Two examples from UWA that should be familiar.
- Each has very different characteristics, Socrates has very subtle parallax (small eye separation), the rock is at the limit of acceptable separation (note the ghosting on the background high contrast objects).
- One doesn't need to worry about which image is the left and which is the right. This can be determined after the images have been aligned. {Demonstrate this with the rock].
- For well captured objects there should be minimal vertical parallax, another source of eyestrain.

Camera separation - rule of thumb

- There are two options for choosing camera (eye) separation
  1. Use human eye separation.
  2. Use a separation relevant to the scale of the objects being captured.
- (1) is the only approach that can give a correct sense of scale and distance. Perfectly appropriate for objects on our scale.
- (2) is often required in order to give any sense of depth. For example: if capturing something a great distance away, there will be no sense of depth without an exaggerated camera separation. For example, a distant cityscape, the moon .... we don't get depth information in real life of distant objects but we may want to induce a sense of depth.
- The rule of thumb is to choose the object and therefore distance that you want zero parallax to occur (the distance at which the object will appear to be at the screen depth) and choose a camera separation no greater than 1/30 of that zero parallax distance.
- Our eyes are on average 6.5cm apart, so the above suggests that is suitable for the objects at zero parallax to be around 2m away. This makes sense since objects up to a 5m radius are those for which we enjoy good depth perception. When you look at an objects further away while you can appreciate parallax depth cues with respect to closer objects, you don't necessarily get parallax depth cues within a distant object.

Things to watch out for

- Objects that have negative parallax but cut the image border. These in general will not appear 3D since our visual system clearly knows the frame border is at 0 parallax. This often leads to the ground or walls limiting the zero parallax distance and therefore the eye separation.
- Our visual system is very sensitive to differences in brightness and/or colour levels between the two views. For example, polaroid filters must be aligned at the same angle on each camera.
- Specular highlights. Specularity (eg: shiny metal objects) depends on the relative position of the camera to the light sources, thus a specular highlight can occur in one camera view and not the other.
- Good depth perception of objects without well defined borders is difficult. For example smoke, fog, clouds ... good depth perception requires some vertical structure.
- Parallax is preserved on reflection by a planar mirror, so one can photograph mirrors. This is not the case for curved mirror surfaces.
- Low resolution images (eg: some mobile phones) may not provide enough pixels to represent a range of parallax distances. This results in images that appear to be made up of layers of depth rather than continuous depth range.

Typical workflow (eg: using PhotoShop)

- Combine the left and right image as two layers within a single file.
- Make the top layer 50% transparent.
- Correct for any rotational errors or colour differences, one aims for this not to be necessary.
- Translate images horizontally to set the desired zero parallax.
- Save as a two layer image file, this is the document that should be stored as an archival version from which stereo pair images of different aspect ratio and resolution can be derived.
- Crop to remove inappropriate -'ve parallax parts of the image.
- Pad or crop to create the desired aspect ratio, 4:3 for the projection system at the WASP or Discovery Centre.
- Scale to the native resolution of the projection system. This is 1024x768 for the current projection system at the WASP or Discovery Centre. The future WASP system or the current projection system at IVEC is 1400x1050 pixels, still 4:3 aspect.
- Remove transparency and save each layer to a separate file, each containing an indication in the file name of which is the left and right eye.

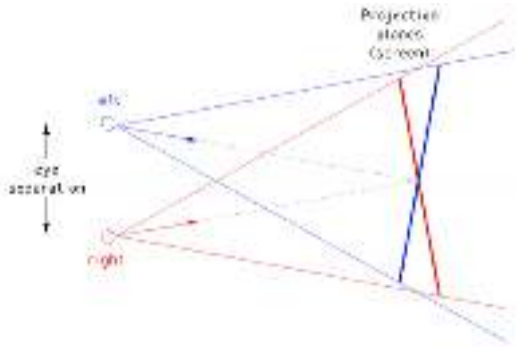
Preparing files for viewing

- Any program can be used that will display two images aligned left/right and full screen.
- Option 1. glslides
  A Mac OS-X or Linux viewer written by myself.
  Allows one to create a slide show from a series of TGA stereo pairs.
  UNIX style scriptable, arrow keys to movie forwards and backwards between slides.
  Create a text file (eg: "list.txt") containing a list of the file names in the slide show.
  UNIX command line: glslides -f -ss list.txt
- Option 2. QuickTime Pro player
  Images can be joined together externally and imported to form a slide show.
  QuickTime Pro player runs in fullscreen mode.
  Alternatively a left and right eye slide show can be created and aligned left/right within the QuickTime Pro player. This has the advantage of creating a monoscopic slide show at the same time.
  In both cases the images need to be sequentially numbered
  Or example, left1.tga, left2.tga, left3.tga .... and right1.tga, right2.tga, right3.tga .....

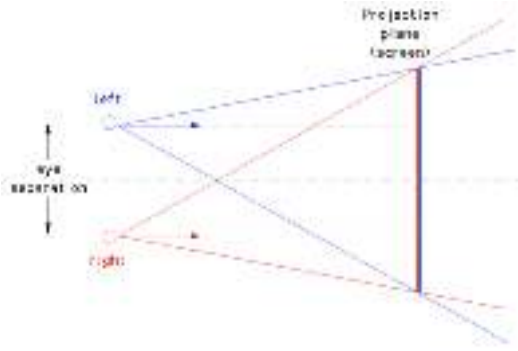
  [Demonstration using QuickTime Pro]

Alternative approach: Toe-In

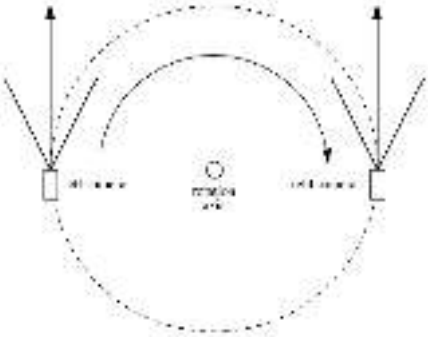
- In the photography and filming industry (less so in the computer generated stereo pairs) it has been common practice historically to not use parallel cameras.
- The cameras are turned inwards such that they converge at the distance of zero parallax.
- Toe-In introduces vertical parallax towards the corners increasing eyestrain.
- Toe-In has advantages for low resolution capture (eg: video) since pixels are not discarded horizontally.
- Toe-In has simpler processing requirements, no trimming so images are ready immediately after capture.
- Parallel cameras has a simpler alignment procedure, zero parallax can be adjusted over a wider range in post production.

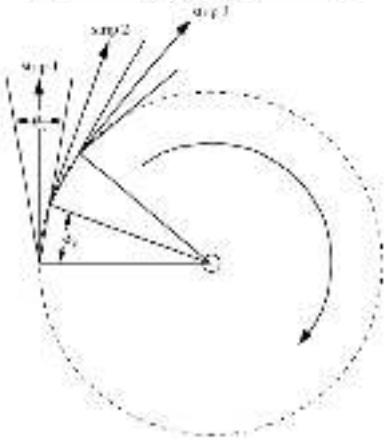


Toe-in cameras (above) vs parallel cameras (below)

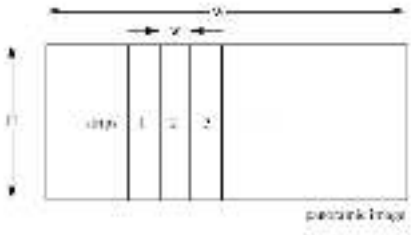


Advanced topic: Stereoscopic panoramic pairs





- Two cameras rotating about their common center.
- Ideally capture as slit cameras.
- Alternatively stitch the two sets of images to form the two panoramic images.
- Care needs to be taken over exposure and lighting.
- Obviously issues of movement in the scene.



Examples from Hampi, Antarctica, and Boolardy.

Place Hampi

Peter Morse

Peter Morse

Final notes

- Parallax is not the only source of depth perception. Perspective plays a larger role for distant objects, there is also lighting/shadow cues, and for dynamic objects (eg: sports) there are motion cues.
- Needless to say, the quality of the final result depends on the care taken when capturing the photos. In particular
  - parallel and aligned cameras, rotational and offset errors can often be corrected, zoom differences between cameras is much more problematic.
  - if using two cameras then identical settings are important especially with regard to settings that affect colour, brightness, and contrast.
- There has been no discussion of the projection technology but they are not all equal. If stereo content that is "easy on the eyes" is created then it has more success of being acceptable on a variety of different projection systems.
- Stereoscopic filming is a natural extension of the above except that the post processing is more involved. An issue with stereo filming and photography is that when using dual cameras, it is usually difficult to achieve the eye separation required to mimic human eye separation. I will soon have a number of different camera racks available, suited to single or dual cameras with a range of separations, tripod mounts, leveling bubbles.