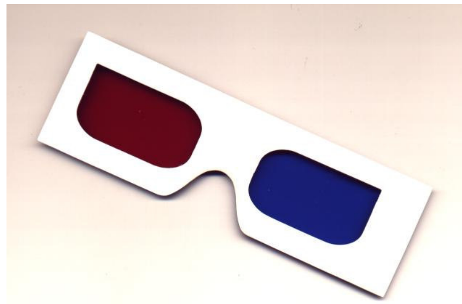
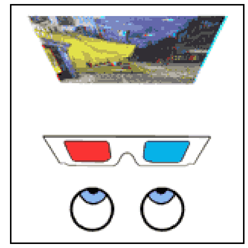
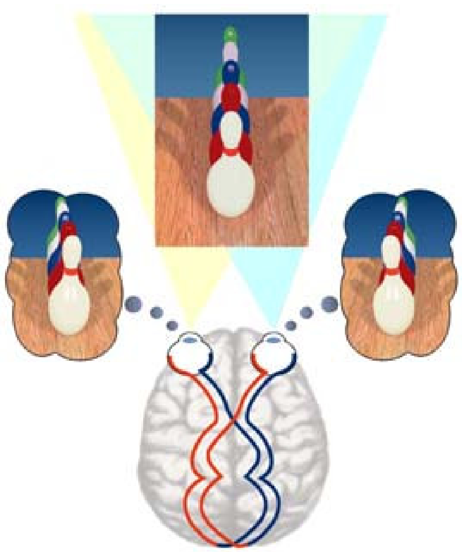




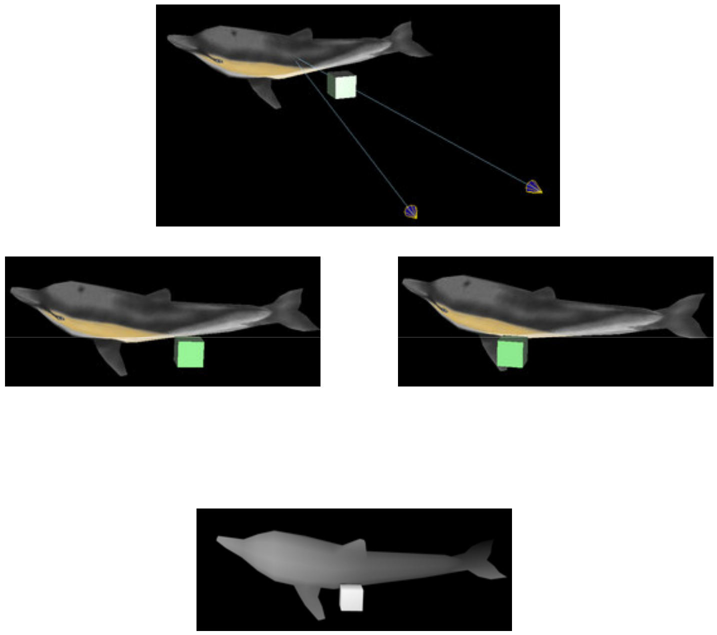
Stereo

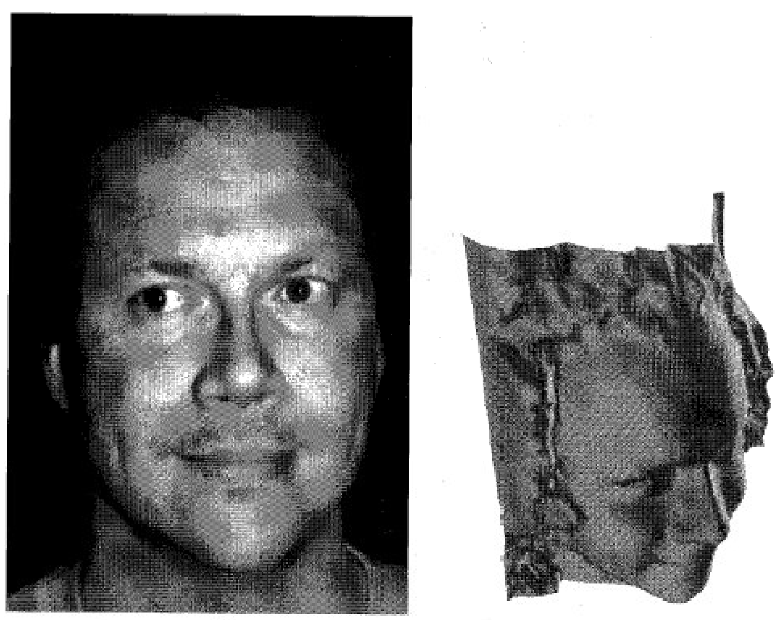
What is stereo vision?



Actions Requiring Stereo Vision

- Throwing, catching or hitting a ball
- Driving and parking a car
- Planning and building a three-dimensional object
- Threading a needle and sewing
- Reaching out to shake someone's hand
- Pouring into a container
- Stepping off a curb or step





(a) (b)

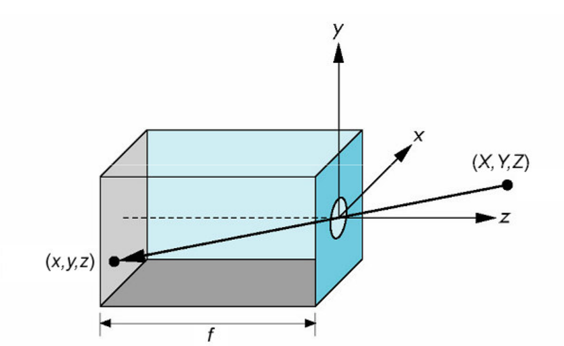
Figure 7.2 (a) One image from a stereo pair of Emanuele Trucco's face. (b) 3-D rendering of stereo reconstruction. Courtesy of the Turing Institute, Glasgow (UK).

Stereo

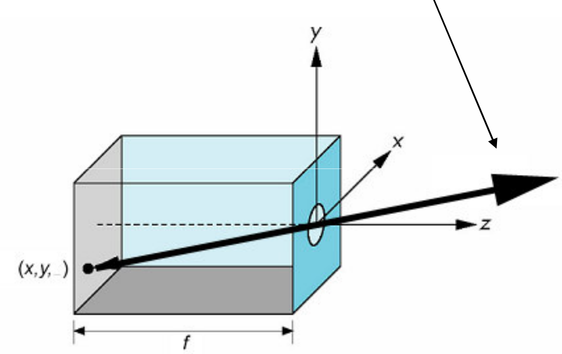
- The **perspective** transform relates a **3D world point** to its corresponding **image point**, via the **camera parameters**
- The **inverse perspective transform** will relate an image point to the world point
- It does not have a unique solution

Stereo

All solutions along the ray are valid



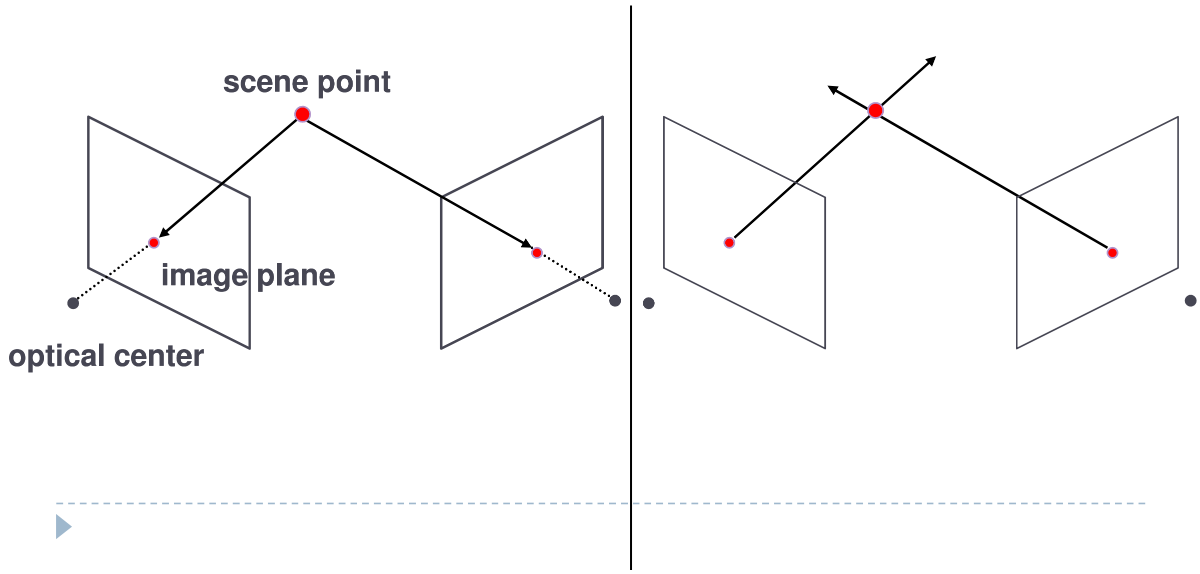
Perspective Transform



Inverse Perspective Transform

Stereo

- What if we have two cameras

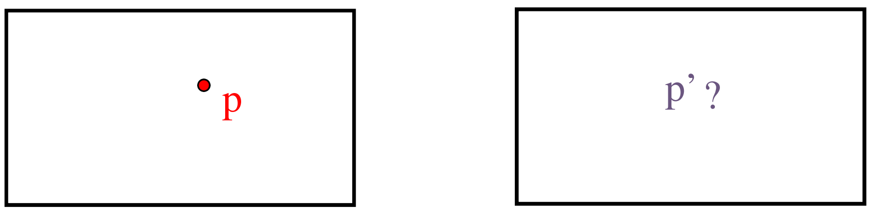


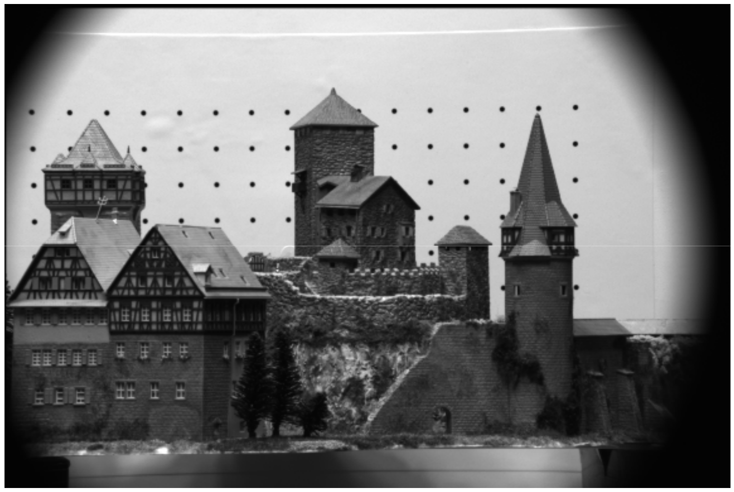
Stereo

- Basic Principle is **triangulation**
- 3D coordinates are computed from intersection of two rays
- Requires
  - Camera Calibration [Why?]
  - Point Correspondence [Why?]

Stereo

- Point Correspondence:
- Given a point in left image, find the **corresponding point** in the right image



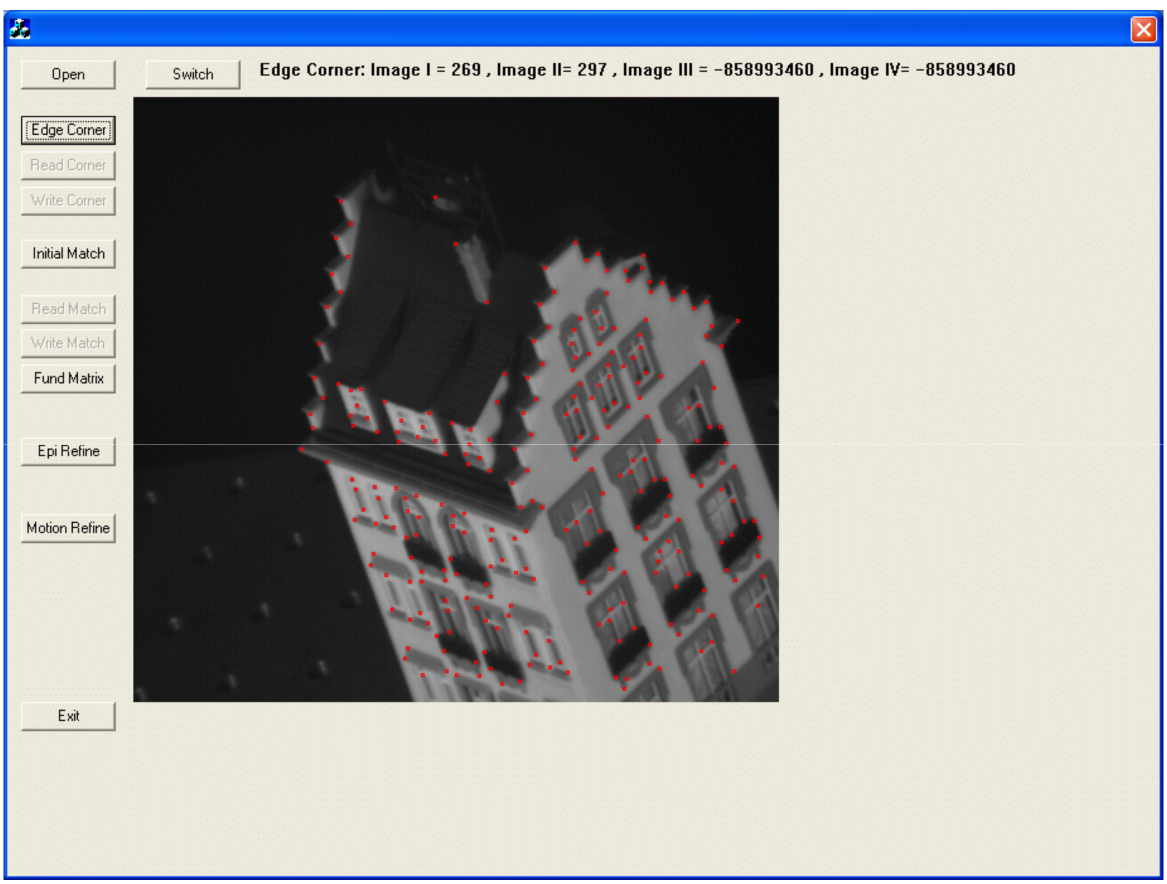


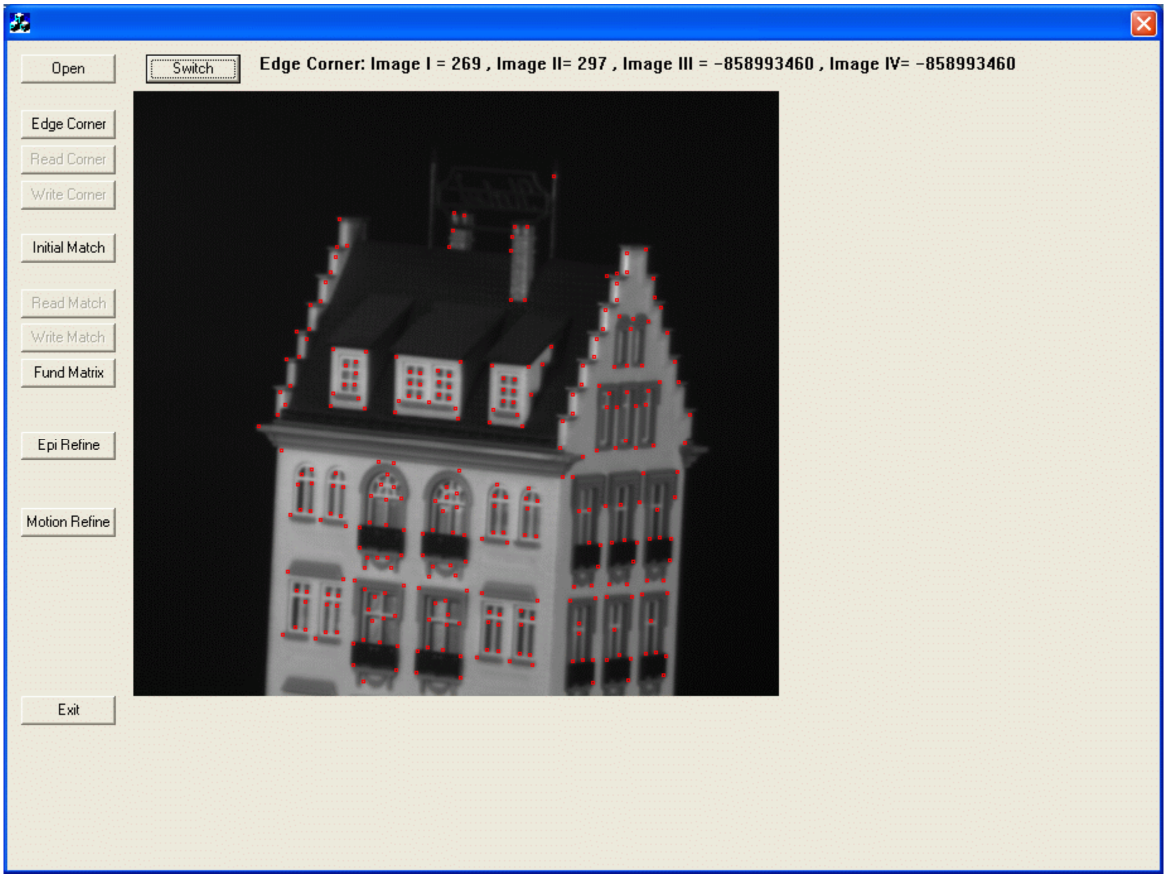
Solving for Depth Using Stereo

- Requires solving two problems
  - The Correspondence Problem
    - Which parts of the left and the right images are projections of the same scene element
  - The Reconstruction Problem
    - Given a number of corresponding parts of the left and the right image, and possibly camera calibration information, what can we say about the 3D location and structure of the observed objects?

Correspondence Problem

- Simple Approach
  - Find Corners in both images
  - Evaluate some similarity measure between each pair of corners to find corresponding pairs

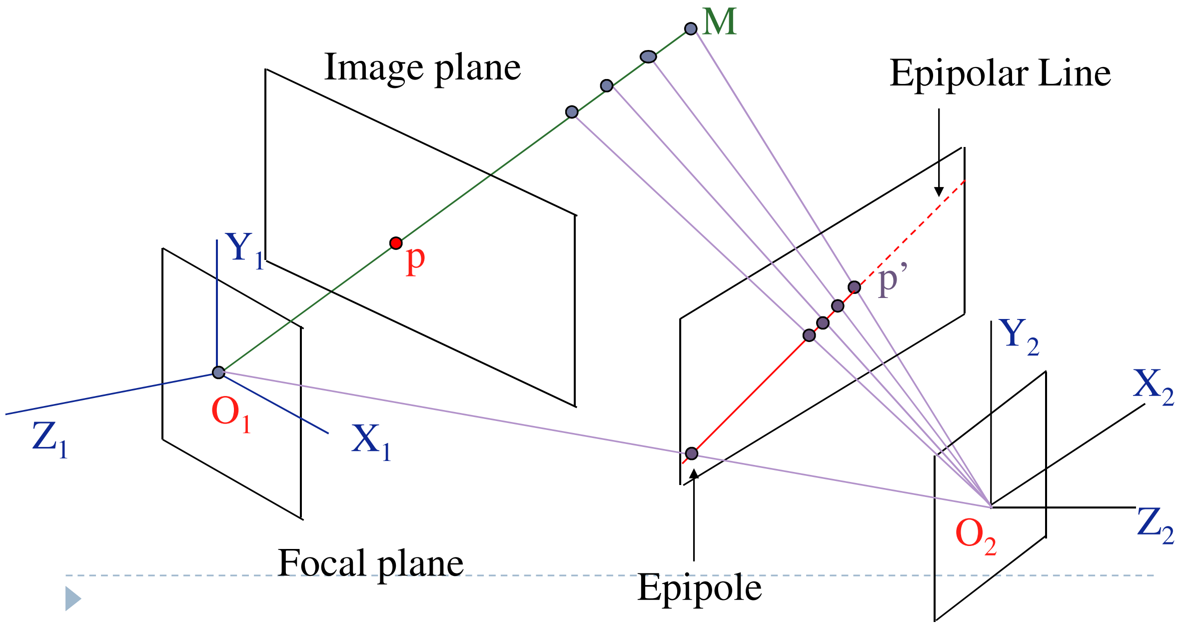




Stereo – Epipolar Constraint

- We do not have to search for the corresponding point all over in the image
- The **Epipolar Constraint** states that the corresponding point must lie on the **epipolar line**

Epipolar Constraint



Epipolar Plane

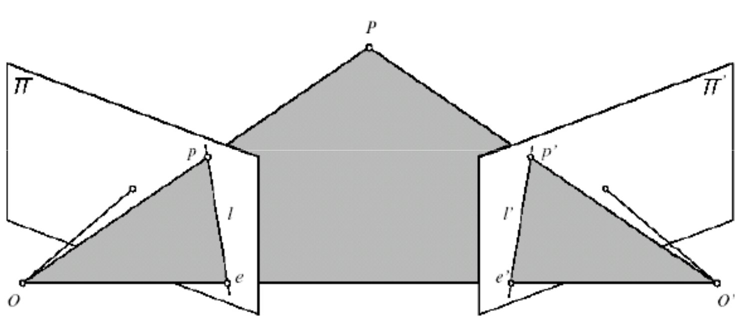
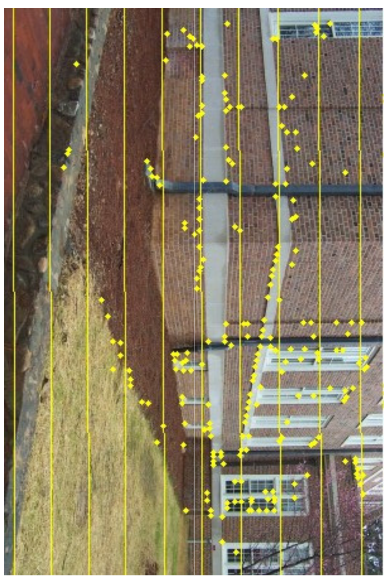
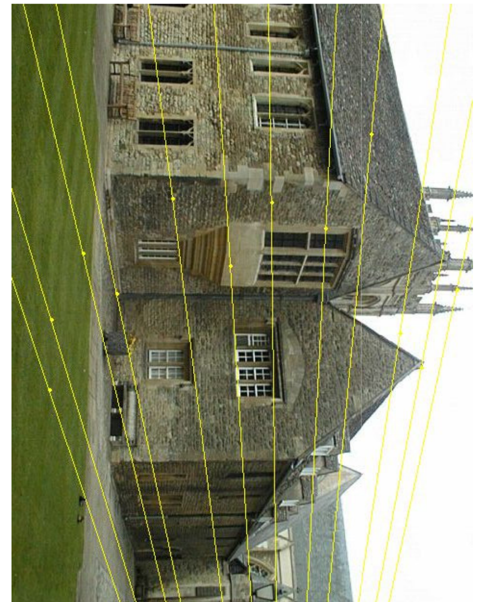
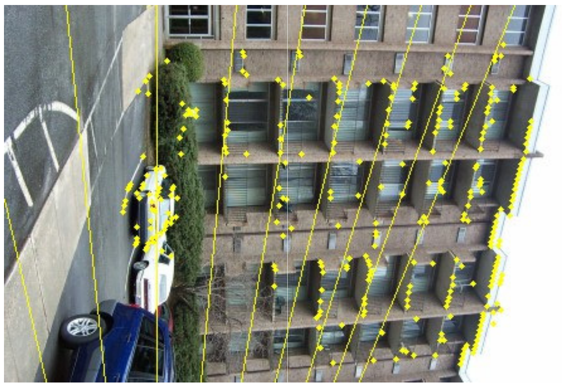


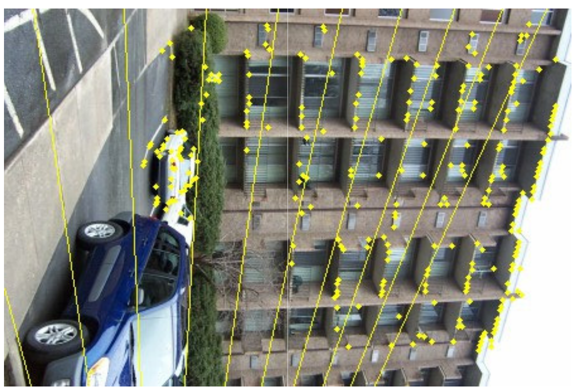
FIGURE 11.1: Epipolar geometry: the point P, the optical centers O and O' of the two cameras, and the two images p and p' of P all lie in the same plane.

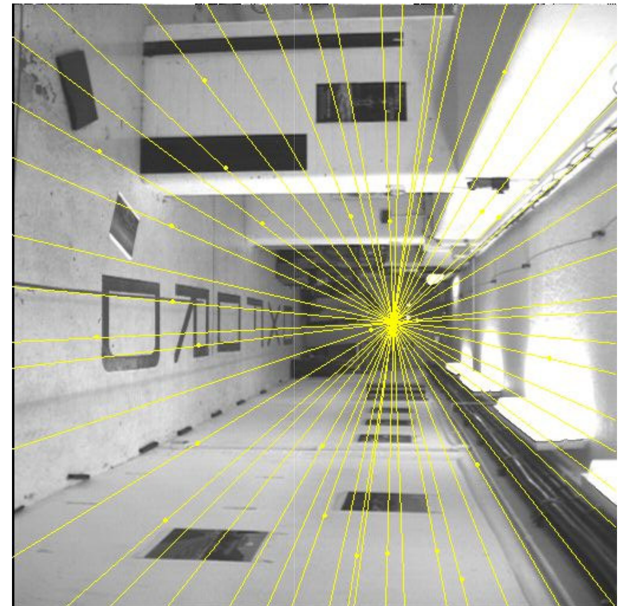
The Epipolar plane is found by the fitting a plane to points *O*, *O′* and *p*. The intersection of the image plane and the epipolar line gives the epipolar line

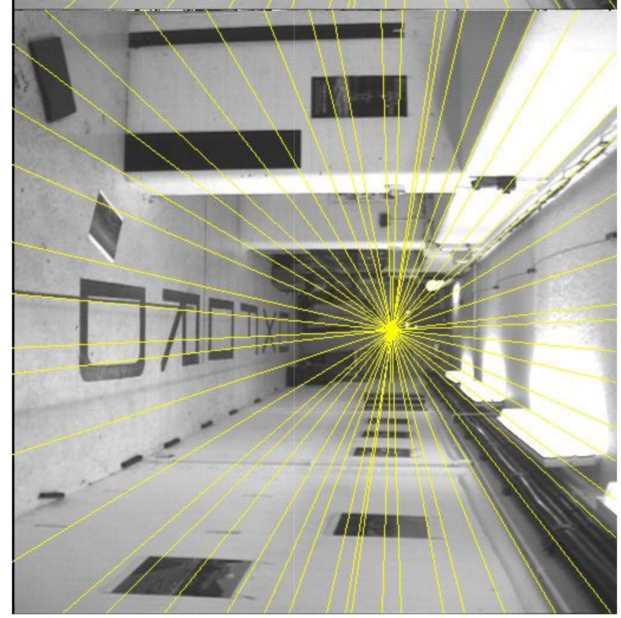




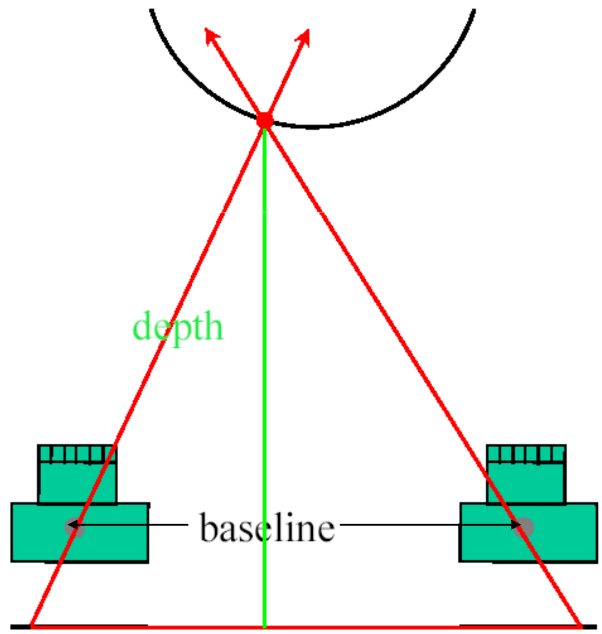




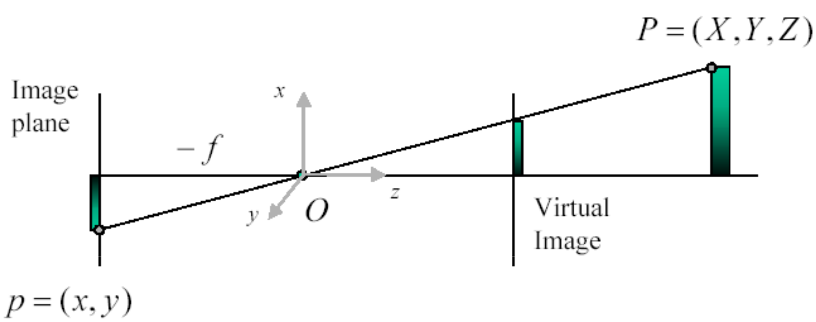




Shape from Stereo: Simple Formulation

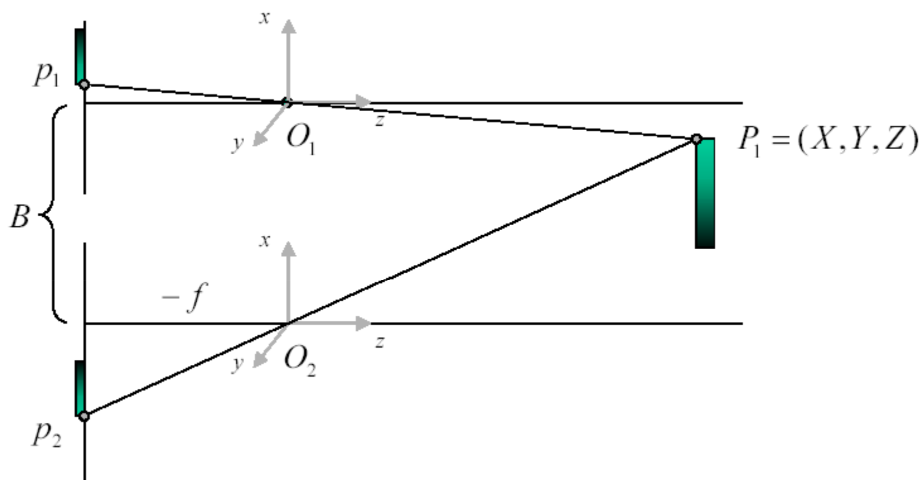


Pinhole Camera Model



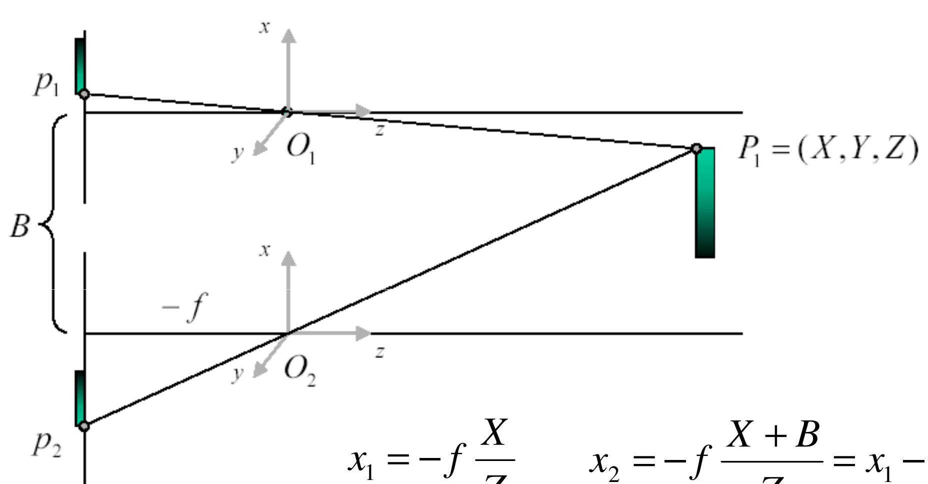
$$x=-f\frac{X}{Z}$$

Basic Stereo Derivations



Derive expression for Z as a function of x_1, x_2, f and B

Basic Stereo Derivations



$$x_1 = -f\,\frac{X}{Z} \qquad x_2 = -f\,\frac{X+B}{Z} = x_1 - f\,\frac{B}{Z}$$

$$Z = \frac{fB}{x_1 - x_2}$$

Basic Stereo Derivations

Define the disparity: $d = x_1 - x_2$

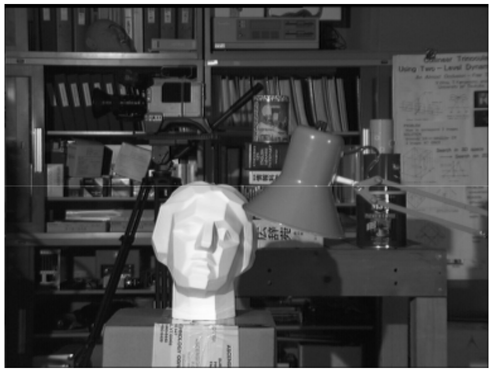
$$Z = \frac{fB}{d}$$

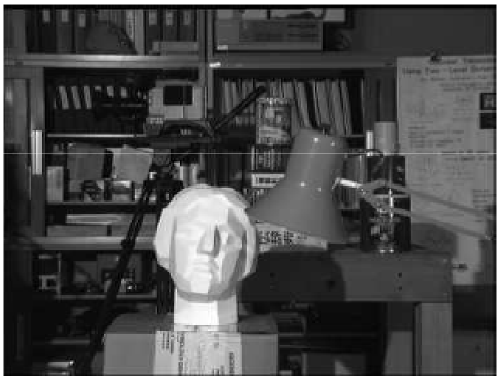
Conclusion: Distance is inversely proportional to disparity

Basic Idea of Stereo Algorithms

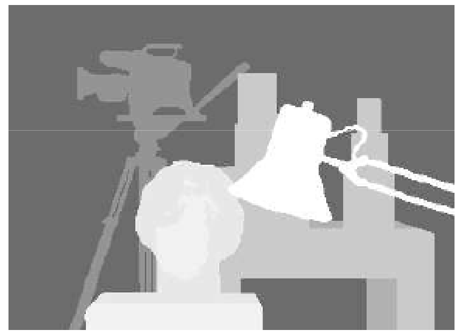
- Align epipolar lines along scan-lines
- For every feature point, search along corresponding scanline for similar image content

Stereo Results





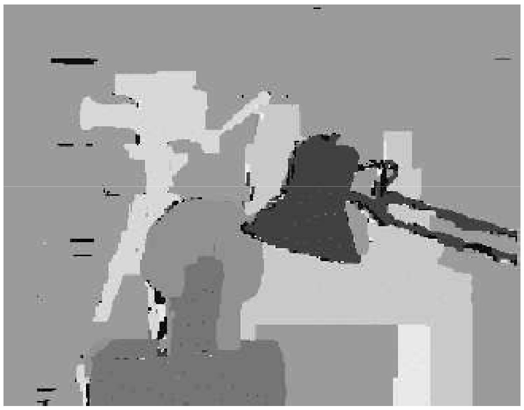
Scene



Ground truth

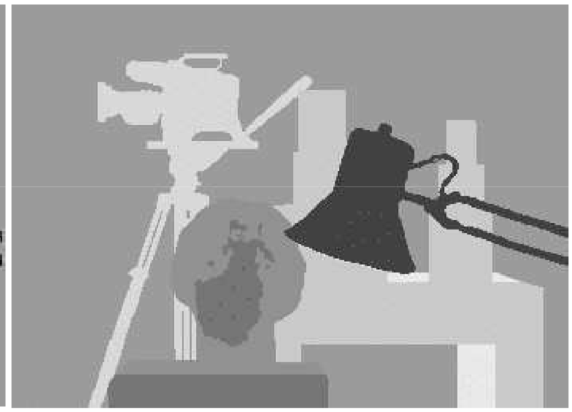
Window-based matching
(best window size)

Ground truth



State of the art method

Boykov et al., Fast Approximate Energy Minimization via Graph Cuts, International Conference on Computer Vision, September 1999.



Ground truth