Stereo Vision – A simple system

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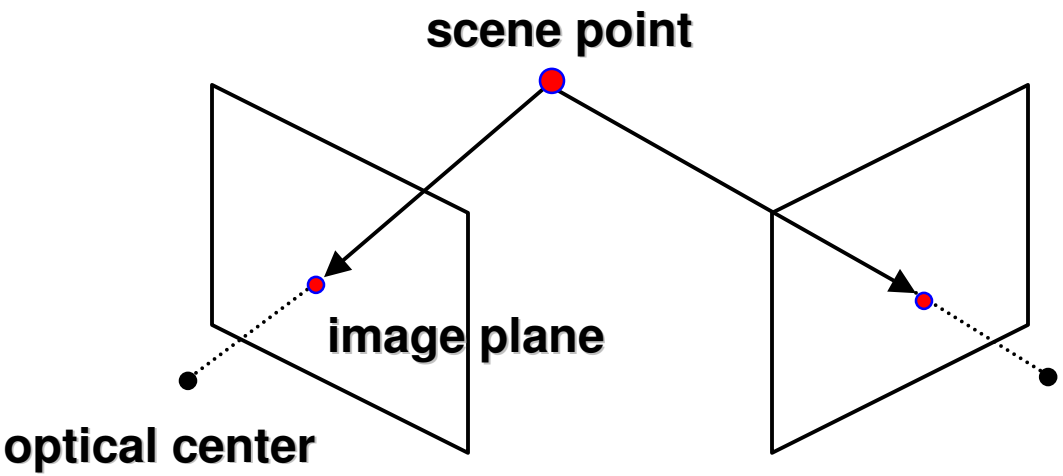
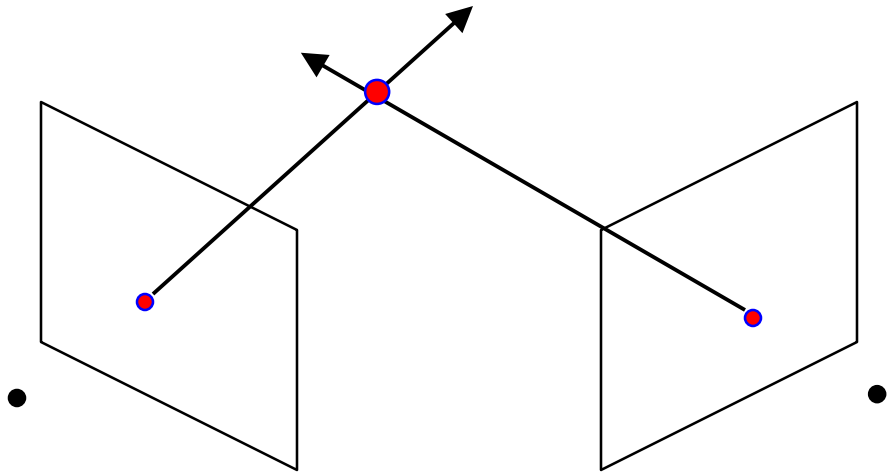
Stereo

- Stereo
  - Ability to infer information on the 3-D structure and distance of a scene from two or more images taken from different viewpoints
  - Humans use only two eyes/images (try thumb trick)
- Two important problems in stereo
  - Correspondence and reconstruction
- Correspondence
  - What parts of left and right images are parts of same object?
- Reconstruction
  - Given correspondences in left and right images, and possibly information on stereo geometry, compute the 3D location and structure of the observed objects

Stereo



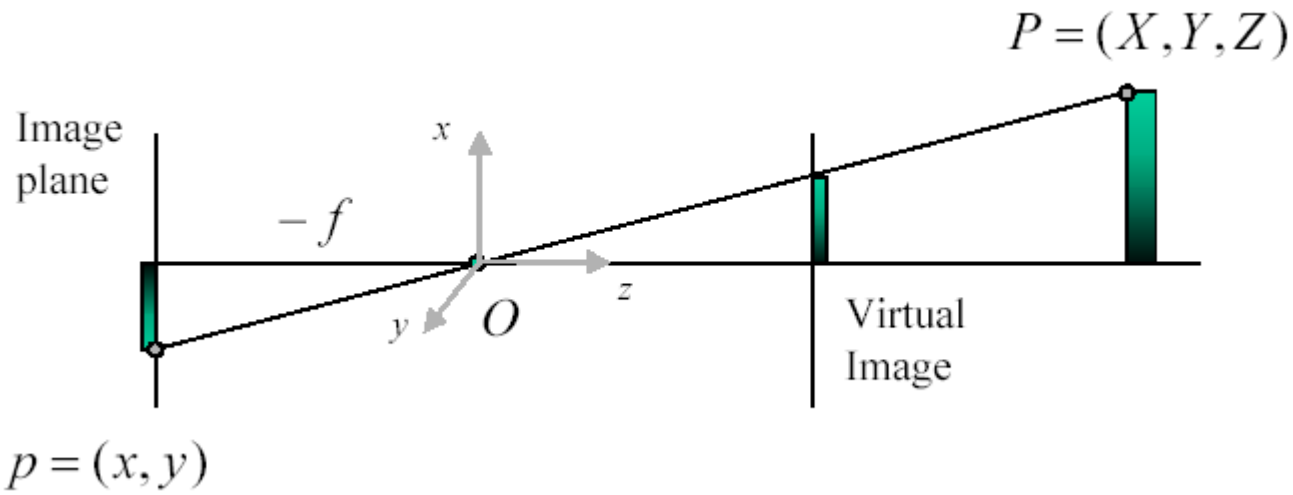
Stereo



Basic Principle: Triangulation

- Gives reconstruction as intersection of two rays
- Requires
  - Camera calibration
  - Point correspondence

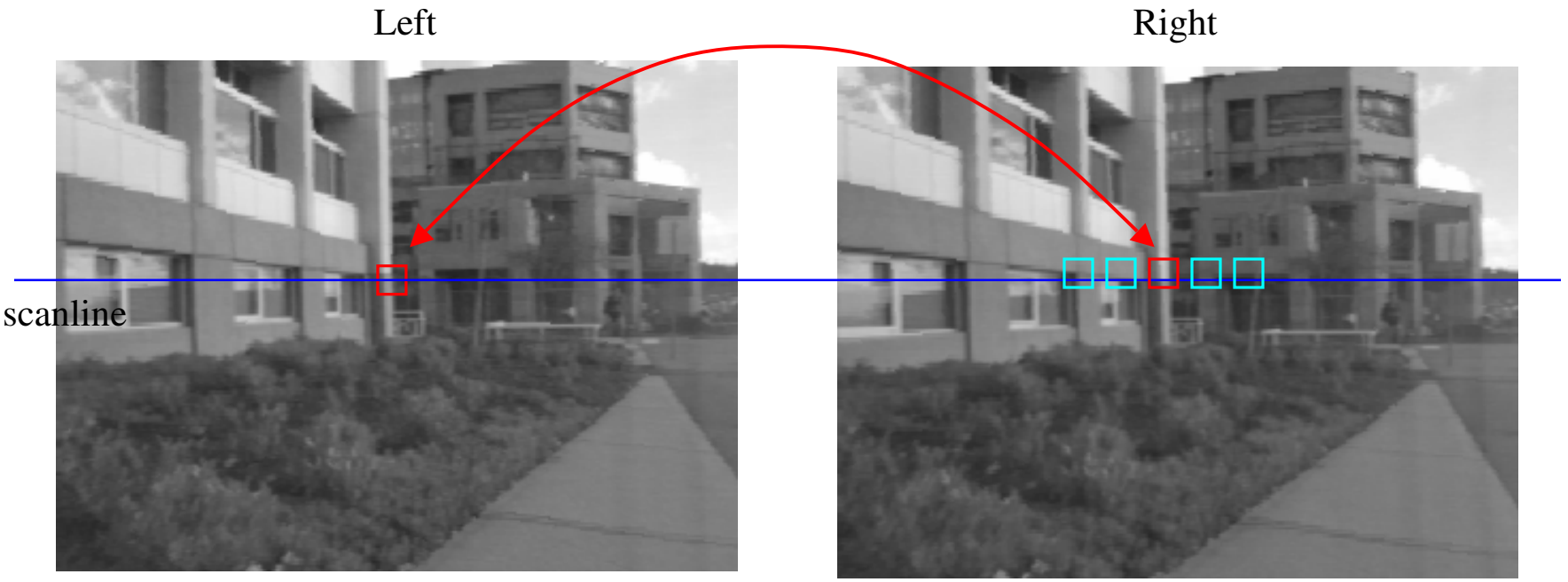
Pinhole Camera Model



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

Simple Stereo System

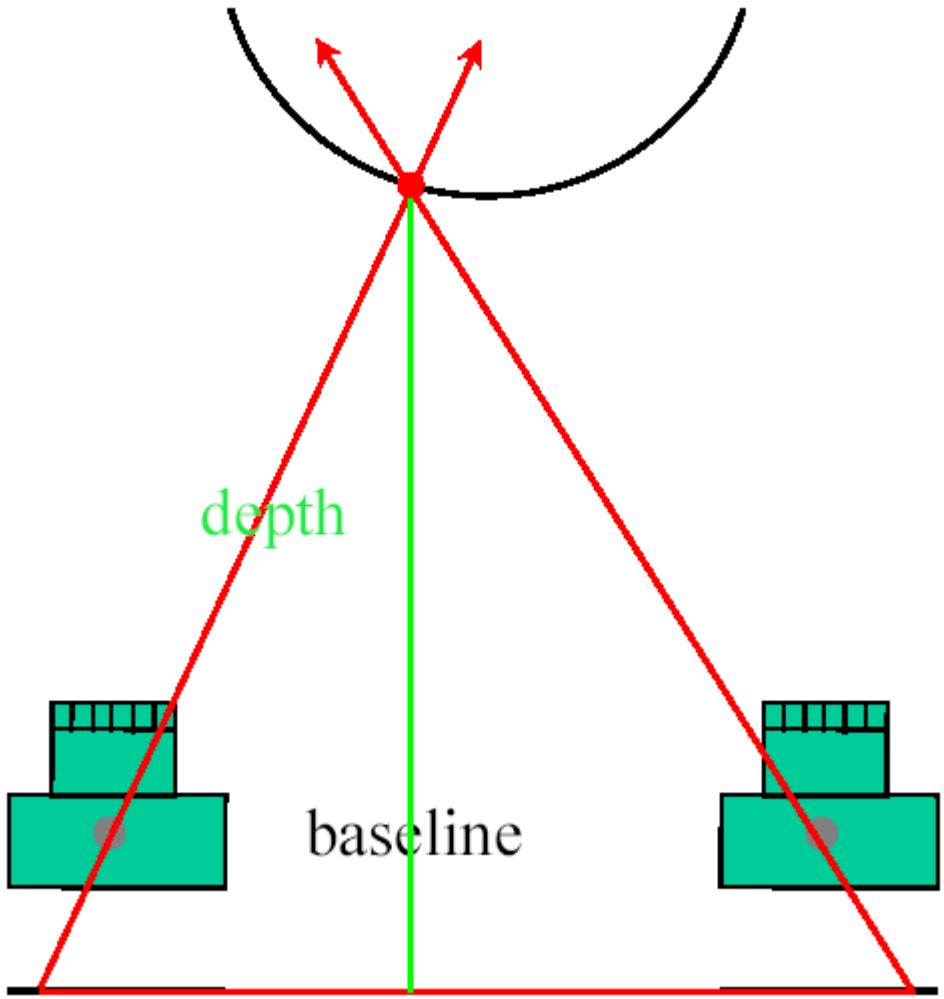
- Left and right image planes are coplanar
  - Represented by I_L and I_R
- So this means that all matching features are on the same horizontal line
  - So we can think of this as a 2D situation



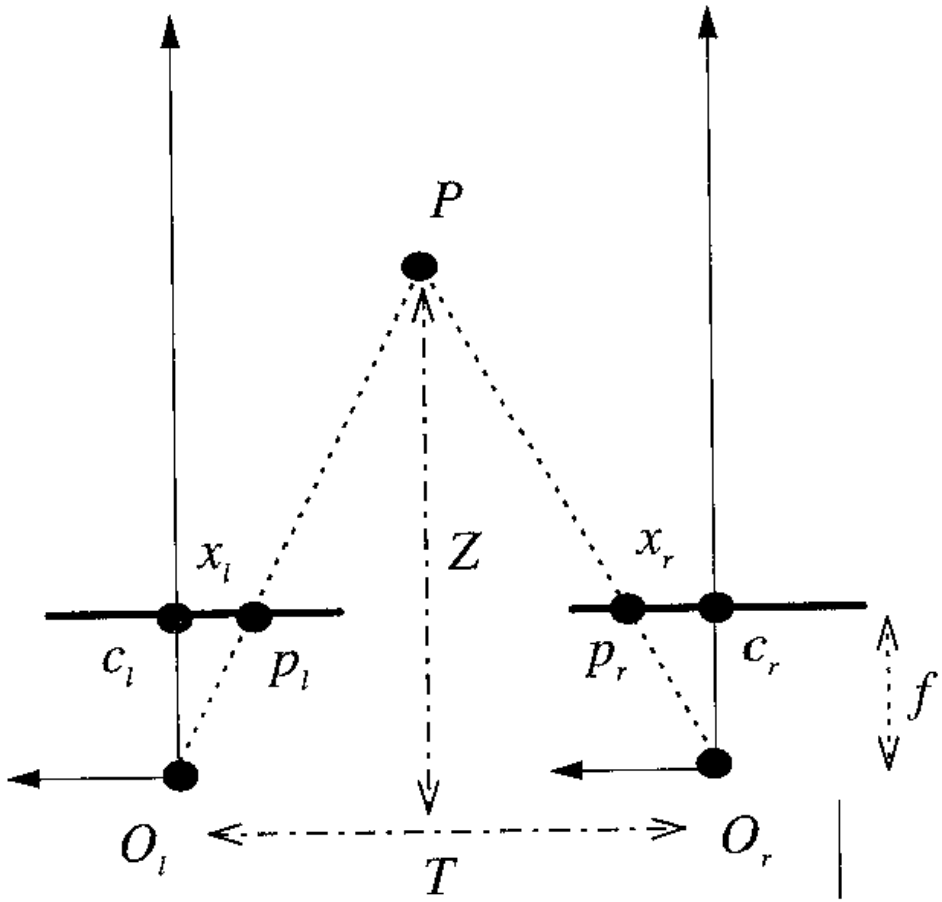
Simple Stereo System (2D)

- Distance between centers of projection is called the baseline T
- Centers of projection of cameras C_L and C_R
- Point P in 3D space projects to P_L and P_R
- X_L and X_R are co-ordinates of P_L and P_R with respect to principal points C_L and C_R
- Z is the difference between point P and the baseline
  - Z is called the depth

Simple Stereo System

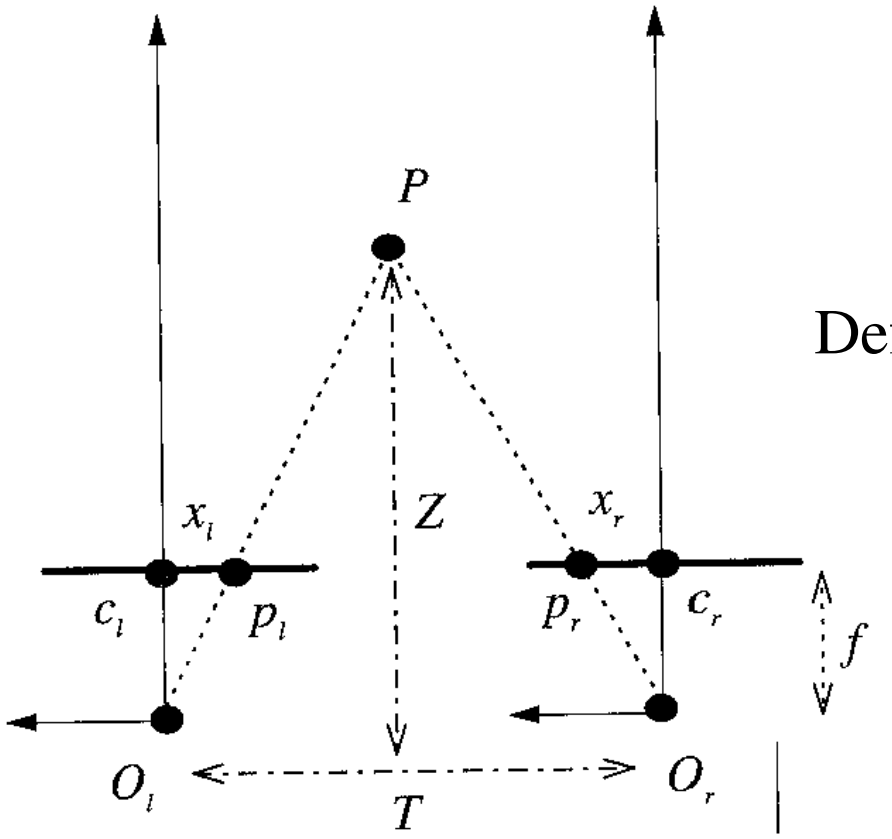


Basic Stereo Derivations



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

Basic Stereo Derivations



Similar triangles
(P_L,P,P_R) and (O_L,P,O_R)

$$\frac{T + x_l - x_r}{Z - f} = \frac{T}{Z}$$

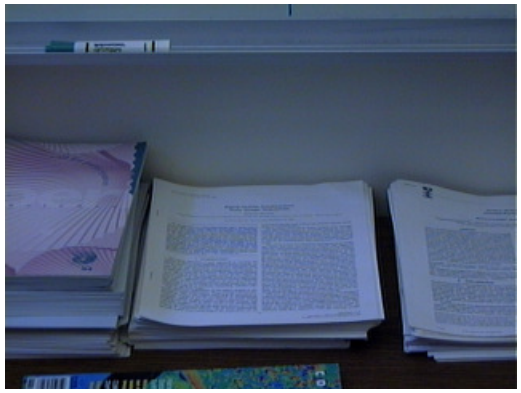
Define the disparity: $d = x_1 - x_2$

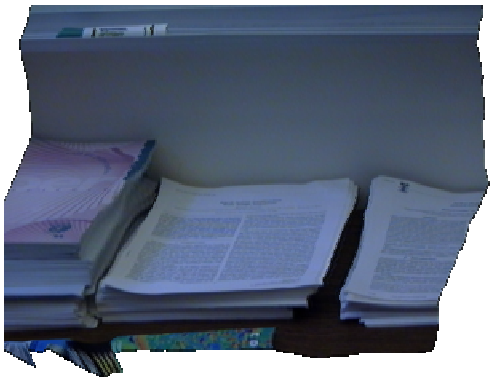
$$Z = f\frac{T}{d}$$

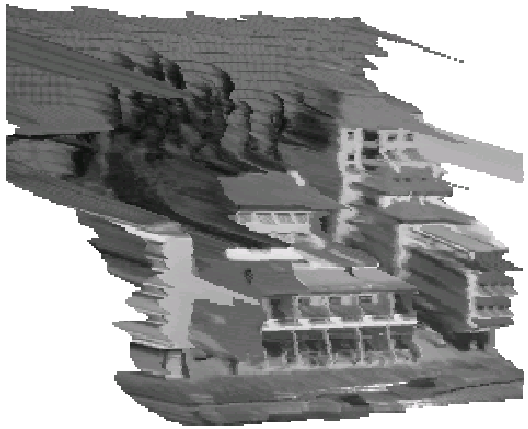
Disparity Map

- $D = ||x_1 - x_2||$ measures the distance between corresponding points in two images
  - Normally disparity is stated as number of pixels
  - Clearly a particular simple stereo configuration has a maximum and minimum possible disparity
- Depth is inversely proportional to disparity
- If we compute the disparity for the entire images then we have a disparity map
- Display it as an image
  - Bright points have highest disparity (closest)
  - Dark points have lowest disparity (farthest)
- Disparity map is a 3D image

Disparity Map

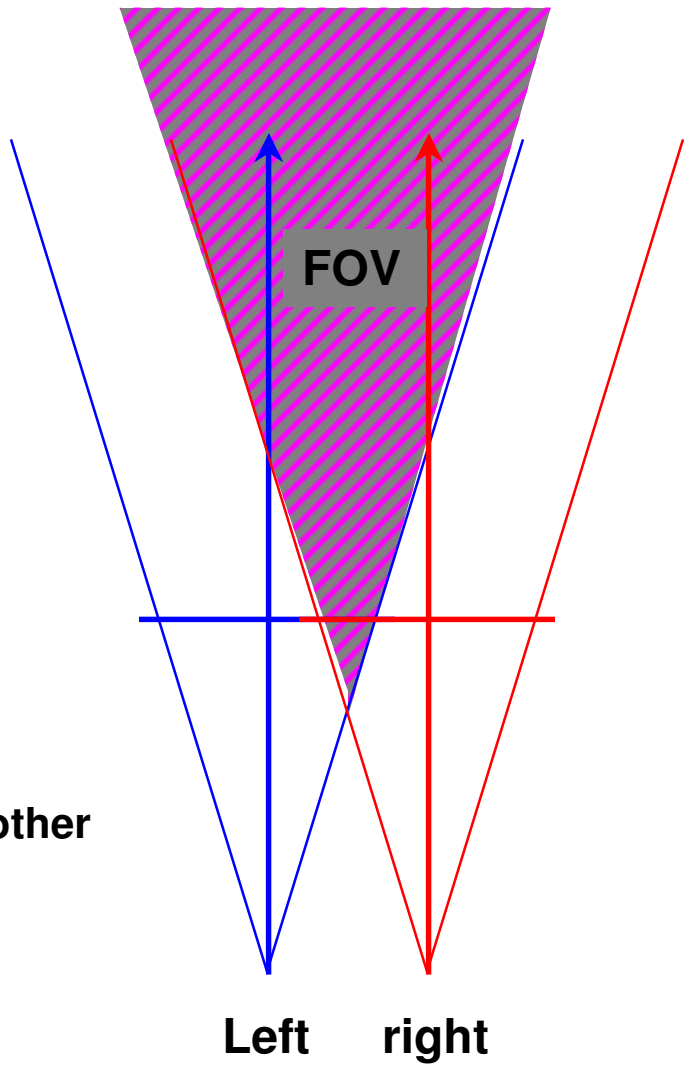




Characteristics of Simple Stereo

- FOV is field of view of cameras
  - Overlap of the two cameras
- Baseline is a system parameter
  - It is also a tradeoff
- If B is the Baseline
  - Depth Error $\propto$ 1/B
- PROS of Longer baseline
  - **better depth estimation**
- CONS
  - **smaller common FOV**
  - **Correspondence harder due to increased chance of occlusion**
  - **Occlusion means that a feature is visible in one image but not in another because something occludes it**



Real-Time Stereo Systems

- There are a number of systems that can compute disparity maps
- In practice systems only work if there is texture in the regions that must be matched
- Often such systems return sparse depth
  - A few thousand images in regions where there is texture
  - Do some interpolation when there is no texture
- Point Grey research makes such a camera
  - A successful Canadian company
- Produces a variety of stereo cameras

BumblelBee

Example image from BumbleBee