More Single View Geometry

Cyclops Odilon Redon 1904

CS194: Image Manipulation & Computational Photography
Alexei Efros, UC Berkeley, Fall 2016
Quiz: which is 1, 2, 3-point perspective

Image A

Image B

Image C
How can we model more complex scene?

1. Find world coordinates \((X,Y,Z)\) for a few points
2. Connect the points with planes to model geometry
   - Texture map the planes
Finding world coordinates \((X,Y,Z)\)

1. Define the ground plane \((Z=0)\)
2. Compute points \((X,Y,0)\) on that plane
3. Compute the heights \(Z\) of all other points
Measurements on planes

Approach: unwarp, then measure
What kind of warp is this?
Unwarp ground plane

Our old friend – the homography

Need 4 reference points with world coordinates

\[ p = (x,y) \]
\[ p' = (X,Y,0) \]
Finding world coordinates \((X,Y,Z)\)

1. Define the ground plane \((Z=0)\)
2. Compute points \((X,Y,0)\) on that plane
3. Compute the heights \(Z\) of all other points
Comparing heights
Perspective cues
Perspective cues
Comparing heights
Computing vanishing points (from lines)

Intersect $p_1q_1$ with $p_2q_2$

$$v = (p_1 \times q_1) \times (p_2 \times q_2)$$

Least squares version

- Better to use more than two lines and compute the “closest” point of intersection
- See notes by Bob Collins for one good way of doing this:
Vanishing point

Vanishing line

Vertical vanishing point (at infinity)

Vanishing point

Vanishing point
Measuring height

vanishing line (horizon)

\[ v \approx (b \times b_0) \times (v_x \times v_y) \]

\[ t \approx (v \times t_0) \times (r \times b) \]
Measuring height

vanishing line (horizon)

What if the point on the ground plane $b_0$ is not known?
- Here the guy is standing on the box
- Use one side of the box to help find $b_0$ as shown above
Measuring heights of people

Here we go!

185.3 cm

reference
Assessing geometric accuracy

Are the heights of the 2 groups of people consistent with each other?

*Flagellation*, Piero della Francesca

Estimated relative heights
Assessing geometric accuracy

*The Marriage of the Virgin*, Raphael

Estimated relative heights
Complete approach

- Load in an image
- Click on lines parallel to X axis
  - repeat for Y, Z axes
- Compute vanishing points
- Specify 3D and 2D positions of 4 points on reference plane
- Compute homography H
- Specify a reference height
- Compute 3D positions of several points
- Create a 3D model from these points
- Extract texture maps
  - Cut out objects
  - Fill in holes
- Output a VRML model
Interactive silhouette cut-out
Occlusion filling

Geometric filling by exploiting:
- symmetries
- repeated regular patterns

Texture synthesis
- repeated stochastic patterns
Complete 3D reconstruction

- Planar measurements
- Height measurements
- Automatic vanishing point/line computation
- Interactive segmentation
- Occlusion filling
- Object placement in 3D model

Single View algorithms

Single image → Single View algorithms → 3D model
A virtual museum @ Microsoft

The Virtual Museum

A. Criminisi @
Microsoft, 2002

Thanks

A. Criminisi    http://research.microsoft.com/~antcrim/