More Single View Geometry

...with a lot of slides stolen from Steve Seitz

CS194: Image Manipulation, Comp. Vision, and Comp. Photo
Alexei Efros, UC Berkeley, Spring 2020
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

Vanishing Point
Measuring height
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

Vertical vanishing point (at infinity)

Vanishing line

Vanishing point

Vanishing point
Measuring height

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

\[ v_z \]

\[ v \times t_0 \times (r \times b) \]

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

-9.0% 
-4.5%
+0.3%
+2.8%
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 image → Single View algorithms → 3D model