Thursday, Oct 16

Today
- Pset1 examples
- Midterm solutions
- Homography recap, computing mosaics

Weak perspective
- Approximation: treat magnification as constant
- Assumes scene depth $<<$ average distance to camera

World points:
- Write matrix equation that relates world point $(X,Y,Z)$ to its image point according to weak perspective.

Which is more suited for weak perspective projection model?

Color matching experiment 2

Slide credit: W. Freeman

Color matching experiment 2

Slide credit: W. Freeman
We say a “negative” amount of $p_2$ was needed to make the match, because we added it to the test color’s side.

The primary color amounts needed for a match:

$$a = \begin{bmatrix} 1 & 0 \\ -1 & 0 \end{bmatrix}, \quad b = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}, \quad c = \begin{bmatrix} -1 & 0 \\ 0 & 1 \end{bmatrix}$$

[5, 12, 5, 9, 8, 9, 5, 5, 12, 12, 5, ?]

K-means

- Suppose we are using k-means clustering to group pixels in a (tiny) image based on their intensity. The image’s intensities are: 5, 10, 3, 20, 9, 0. We pick the initial centers randomly to be 0 and 9, and set the number of clusters $k=2$.

- Cluster membership?

- New cluster centers?
• Affinity score that will discourage intervening contours between pixels.

Hough transform for circles

• Circle: center \((a, b)\) and radius \(r\)

\[
(x - a)^2 + (y - b)^2 = r^2
\]

• For an unknown radius \(r\), known gradient direction

Midterm

• Average overall: 83.8 (+/- 17.5)
• Undergrad average: 79 (+/- 18)
• Grad average: 97 (+/- 6)
• Question 5 treated as extra credit (8 pts possible)

- 100+ = A+, 95:99 = A, 90:94 = A-
- 85:89 = B+, 80:84 = B, 75:79 = B-
- 70:74 = C+, 65:69 = C, 60:64 = C-
- 50:60 = D

Mosaics: main steps

• Collect correspondences (manually)
• Solve for homography matrix \(H\)

- Warp content from one image frame to the other to combine: say \(\text{im1}\) into \(\text{im2}\) reference frame

- Overlay \(\text{im2}\) content onto the warped \(\text{im1}\) content.
• `ginput` to collect clicked points

• What kinds of images to choose as input?

Homography

\[
\begin{pmatrix}
    x' \\
    y'
\end{pmatrix}
= \begin{pmatrix}
    w \\
    y \\
    x
\end{pmatrix} H 
\]

To apply a given homography \( H \)

- Compute \( p' = Hp \) (regular matrix multiply)
- Convert \( p' \) from homogeneous to image coordinates

Solving for homographies

\[
\begin{bmatrix}
    w' \\
    y' \\
    x'
\end{bmatrix} = \begin{bmatrix}
    a & b & c & x \\
    d & e & f & y \\
    g & h & i & 1
\end{bmatrix} \begin{bmatrix}
    w \\
    y \\
    x
\end{bmatrix}
\]

Can set scale factor \( i = 1 \). So, there are 8 unknowns.

Set up a system of linear equations:

\[ Ah = b \]

Need at least 8 eqs, but the more the better.

Solve for \( h \). If overconstrained, solve using least-squares:

\[ h = \text{inv}(A')'A'b \]

Mosaics: main steps

• Collect correspondences (manually)
• Solve for homography matrix \( H \)
- Least squares solution
• Warp content from one image frame to the other to combine: say im1 into im2 reference frame
  - Determine bounds of the new combined image
  - Where will the corners of im1 fall in im2’s coordinate frame?
  - We will attempt to lookup colors for any of these positions we can get from im1::meshgrid
  - Compute coordinates in im2’s reference frame (via homography) for all points in that range: \( H^{-1} \)
  - Lookup all colors for all these positions from im1
  - Inverse warp: interp2 (watch for nans::isnan)
• Overlay im2 content onto the warped im1 content.
- Careful about new bounds of the output image: minx, miny
Mosaics: main steps

- Collect correspondences (manually)
- Solve for homography matrix $H$
  - Least squares solution
- Warp content from one image frame to the other to combine: say $im1$ into $im2$ reference frame
  - Determine bounds of the new combined image
    - Where will the corners of $im1$ fall in $im2$'s coordinate frame?
      - We will attempt to lookup colors for any of these positions we can get from $im1$.meshgrid
  - Compute coordinates in $im1$'s reference frame (via homography) for all points in that range: $H^T$
  - Lookup all colors for all these positions from $im1$
    - Inverse warp:$interp2$ (watch for $nans$.isnan)
- Overlay $im2$ content onto the warped $im1$ content.
  - Careful about new bounds of the output image: minx, miny

---

Mosaics: main steps

- Collect correspondences (manually)
- Solve for homography matrix $H$
  - Least squares solution
- Warp content from one image frame to the other to combine: say $im1$ into $im2$ reference frame
  - Determine bounds of the new combined image
    - Where will the corners of $im1$ fall in $im2$’s coordinate frame?
      - We will attempt to lookup colors for any of these positions we can get from $im1$.meshgrid
  - Compute coordinates in $im1$’s reference frame (via homography) for all points in that range: $H^T$
  - Lookup all colors for all these positions from $im1$
    - Inverse warp: $interp2$ (watch for $nans$.isnan)
- Overlay $im2$ content onto the warped $im1$ content.
  - Careful about new bounds of the output image: minx, miny

Use $interp2$ to ask for the colors (possibly interpolated) from $im1$ at all the positions needed in $im2$’s reference frame.
RANSAC for estimating homography

RANSAC loop:
1. Select four feature pairs (at random)
2. Compute homography \( H \) (exact)
3. Compute inliers where \( \text{SSD} (p_1, Hp_2) < \epsilon \)
4. Keep largest set of inliers
5. Re-compute least-squares \( H \) estimate on all of the inliers

Sanity checks

- Click on corresponding points, solve for \( H \), then check that when you plot the transformed points from one image in the other, they land on the right features
- Do the same, but with the corners of one image.

Misc matlab (from pset)

- Watch for index conventions: ginput gives back \((x,y)\), while matrices are indexed in \(y,x\) order
- uint8's vs. doubles; give interp2 a matrix of doubles

Possible interface

Main script

\[ H = \text{computeH(pts1, pts2)} \]

\[ \begin{bmatrix} \text{im1warped}, \text{minx}, \text{miny} \end{bmatrix} = \text{warpImage(im1, H, im2h, im2w)} \]

For Tuesday:
- Read F&P 10.1.1-10.1.2, F&P 11.1-11.3
- [T&V Chapter 7]