Lecture 10: 2D Transformation & Alignment

COMP 590/776: Computer Vision
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Course Website: Scan Me!
Today’s class

• Fitting with outliers – RANSAC
• Warping
• Blending
• HW3 Motivation
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• Fitting with outliers – RANSAC
  • Warping
  • Blending
  • HW3 Motivation
Outliers
Matching features

What do we do about the “bad” matches?
Robustness

• Let’s consider the problem of linear regression

Problem: Fit a line to these datapoints

Least squares fit

• How can we fix this?
Idea

• Given a hypothesized line
• Count the number of points that “agree” with the line
  • “Agree” = within a small distance of the line
  • I.e., the inliers to that line

• For all possible lines, select the one with the largest number of inliers
Counting inliers
Counting inliers

Inliers: 3
Counting inliers

Inliers: 20
Translations
RAndom SAmple Consensus

Select *one* match at random, count *inliers*
Random Sample Consensus

Select another match at random, count inliers
RAAndom SAAmple Consensus

Output the translation with the highest number of inliers
Final step: least squares fit

Find average translation vector over all inliers
RANSAC

• Idea:
  • All the inliers will agree with each other on the translation vector; the (hopefully small) number of outliers will (hopefully) disagree with each other
    • RANSAC only has guarantees if there are < 50% outliers
  • “All good matches are alike; every bad match is bad in its own way.”
    – Tolstoy via Alyosha Efros
RANSAC

• General version:
  1. Randomly choose $s$ samples
     • Typically $s =$ minimum sample size that lets you fit a model
  2. Fit a model (e.g., line) to those samples
  3. Count the number of inliers that approximately fit the model
  4. Repeat $N$ times
  5. Choose the model that has the largest set of inliers
RANSAC for estimating homography

- RANSAC loop:
  1. Select four feature pairs (at random)
  2. Compute homography $H$ (exact)
  3. Compute inliers where $\text{dist}(p'_i, Hp_i) < \varepsilon$
  4. Keep largest set of inliers
  5. Re-compute least-squares $H$ estimate on all of the inliers
How many rounds?

• If we have to choose $s$ samples each time
  • with an outlier ratio $e$
  • and we want the right answer with probability $p$

\[
N \geq \frac{\log(1 - p)}{\log(1 - (1 - e)^s)}
\]

<table>
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<tr>
<th>$s$</th>
<th>5%</th>
<th>10%</th>
<th>20%</th>
<th>25%</th>
<th>30%</th>
<th>40%</th>
<th>50%</th>
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<td>3</td>
<td>5</td>
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<td>9</td>
<td>26</td>
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<td>272</td>
<td>1177</td>
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</table>

$p = 0.99$
How big is $s$?

- For alignment, depends on the motion model
  - Here, each sample is a correspondence (pair of matching points)

<table>
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<tr>
<th>Name</th>
<th>Matrix</th>
<th># D.O.F.</th>
<th>Preserves:</th>
<th>Icon</th>
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<tbody>
<tr>
<td>translation</td>
<td>$\begin{bmatrix} I &amp; t \end{bmatrix}_{2\times3}$</td>
<td>2</td>
<td>orientation + ⋅⋅⋅</td>
<td></td>
</tr>
<tr>
<td>rigid (Euclidean)</td>
<td>$\begin{bmatrix} R &amp; t \end{bmatrix}_{2\times3}$</td>
<td>3</td>
<td>lengths + ⋅⋅⋅</td>
<td></td>
</tr>
<tr>
<td>similarity</td>
<td>$\begin{bmatrix} sR &amp; t \end{bmatrix}_{2\times3}$</td>
<td>4</td>
<td>angles + ⋅⋅⋅</td>
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<tr>
<td>affine</td>
<td>$\begin{bmatrix} A \end{bmatrix}_{2\times3}$</td>
<td>6</td>
<td>parallelism + ⋅⋅⋅</td>
<td></td>
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<tr>
<td>projective</td>
<td>$\begin{bmatrix} \tilde{H} \end{bmatrix}_{3\times3}$</td>
<td>8</td>
<td>straight lines</td>
<td></td>
</tr>
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</table>
RANSAC pros and cons

• Pros
  • Simple and general
  • Applicable to many different problems
  • Often works well in practice

• Cons
  • Parameters to tune
  • Sometimes too many iterations are required
  • Can fail for extremely low inlier ratios
  • We can often do better than brute-force sampling
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Implementing image warping

- Given a coordinate xform $(x', y') = T(x, y)$ and a source image $f(x, y)$, how do we compute a transformed image $g(x', y') = f(T(x, y))$?
Forward Warping

• Send each pixel \((x, y)\) to its corresponding location \((x', y') = T(x, y)\) in \(g(x', y')\)

• What if pixel lands “between” two pixels?
Forward Warping

• Send each pixel \((x,y)\) to its corresponding location \((x',y') = T(x,y)\) in \(g(x',y')\)

  • What if pixel lands “between” two pixels?
  • Answer: add “contribution” to several pixels, normalize later (splatting)
  • Can still result in holes
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Blending

• We’ve aligned the images – now what?
Blending

• Want to seamlessly blend them together
Image Blending
Feathering
Effect of window size
Effect of window size
Good window size

“Optimal” window: smooth but not ghosted
  • Doesn’t always work...
Pyramid blending

Create a Laplacian pyramid, blend each level

Band-pass filtering in spatial domain

Gaussian Pyramid (low-pass images)

Laplacian Pyramid (sub-band images)
Pyramid Blending

Left pyramid

blend

Right pyramid
The diagram illustrates the concept of laplacian levels in the context of pyramids. Each level represents a different scale in the pyramid structure, with levels 4, 2, and 0 shown respectively. The left pyramid is labeled as (a), (b), and (c) for levels 4, 2, and 0 respectively. The right pyramid is labeled as (d), (e), and (f) for the same levels. The blended pyramid, which is a combination of both left and right pyramids, is labeled as (g), (h), and (i) for levels 4, 2, and 0 respectively.
Poisson Image Editing

For more info: Perez et al, SIGGRAPH 2003
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Fun with homographies

Original image

St. Petersburg
photo by A. Tikhonov

Virtual camera rotations
Analysing patterns and shapes

What is the shape of the b/w floor pattern?

The floor (enlarged)

Automatically rectified floor

Slide from Criminisi
Analysing patterns and shapes

From Martin Kemp *The Science of Art* (manual reconstruction)

2 patterns have been discovered!
Analysing patterns and shapes

What is the (complicated) shape of the floor pattern?

*St. Lucy Altarpiece, D. Veneziano*
Slide from Criminisi

Automatically rectified floor
Analysing patterns and shapes

From Martin Kemp, *The Science of Art* 
(*manual reconstruction*)
Some panorama examples

“Before SIGGRAPH Deadline” Photo credit: Doug Zongker
Some panorama examples

• Every image on Google Streetview
Slide Credits

• CS5670, Introduction to Computer Vision, Cornell Tech, by Noah Snavely.

• CS 194-26/294-26: Intro to Computer Vision and Computational Photography, UC Berkeley, by Alyosha Efros.