Robot Vision Part 2: Visual Odometry

Guest Lecture by David Meger
McGill CS 417
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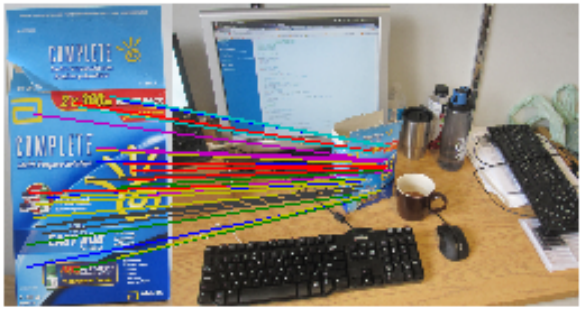
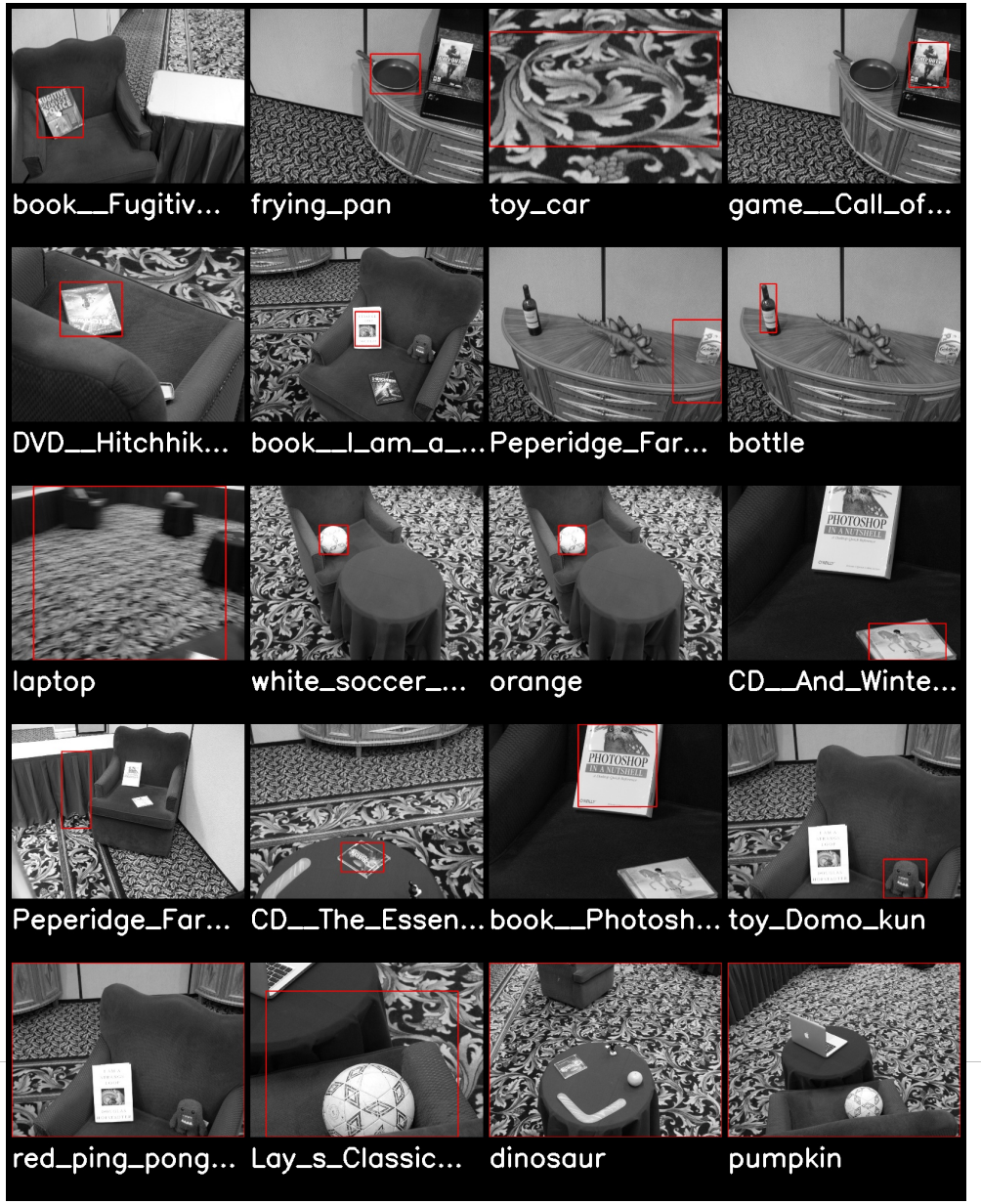
Last Time: Object Recognition

137 tentative matches

35 final matches



Estimated Object



Today: Visual Odometry

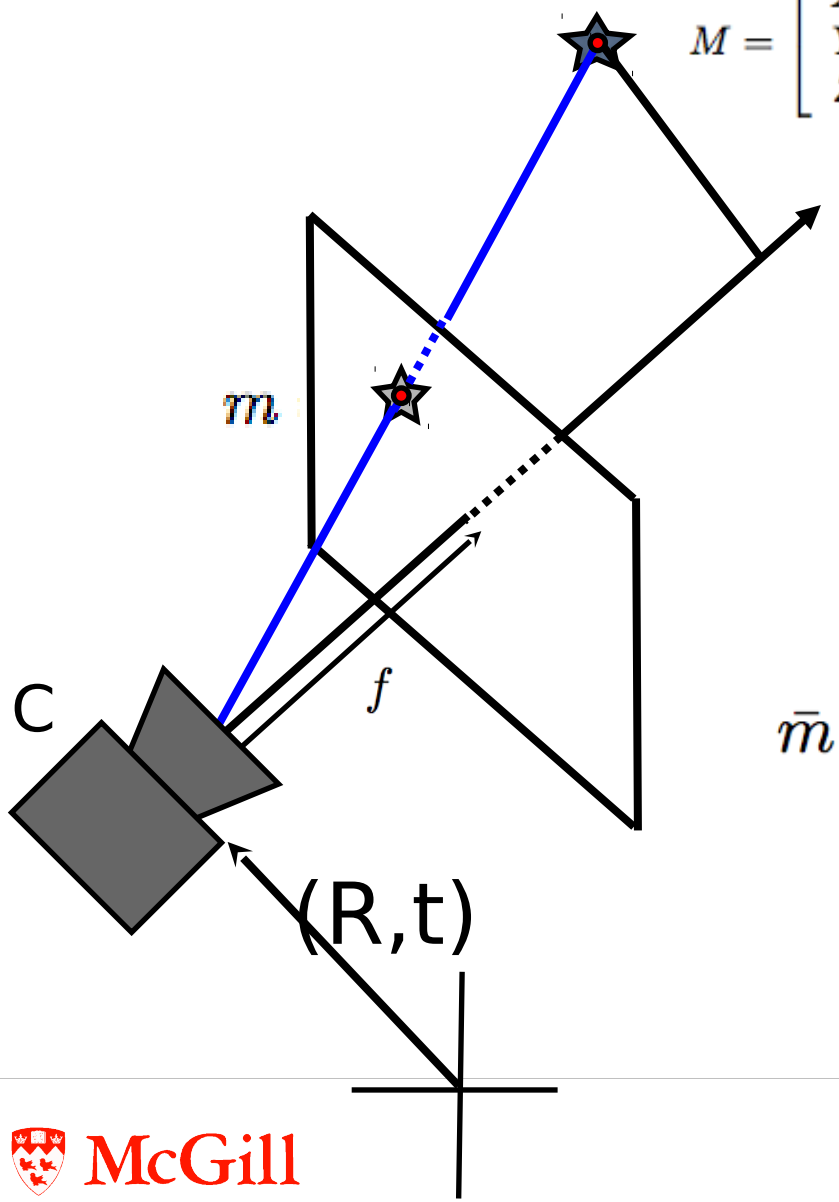
- Videos...

Visual odometry problem

- Input:
  - Images from a moving camera: Robot's-eye-video, cell phone video feed, automobile safety system feed, GoPro, tourist photos
- Output:
  - The location of the camera when each image was taken
  - (optional) information about the geometry of the world

How?

Pinhole Camera Model



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

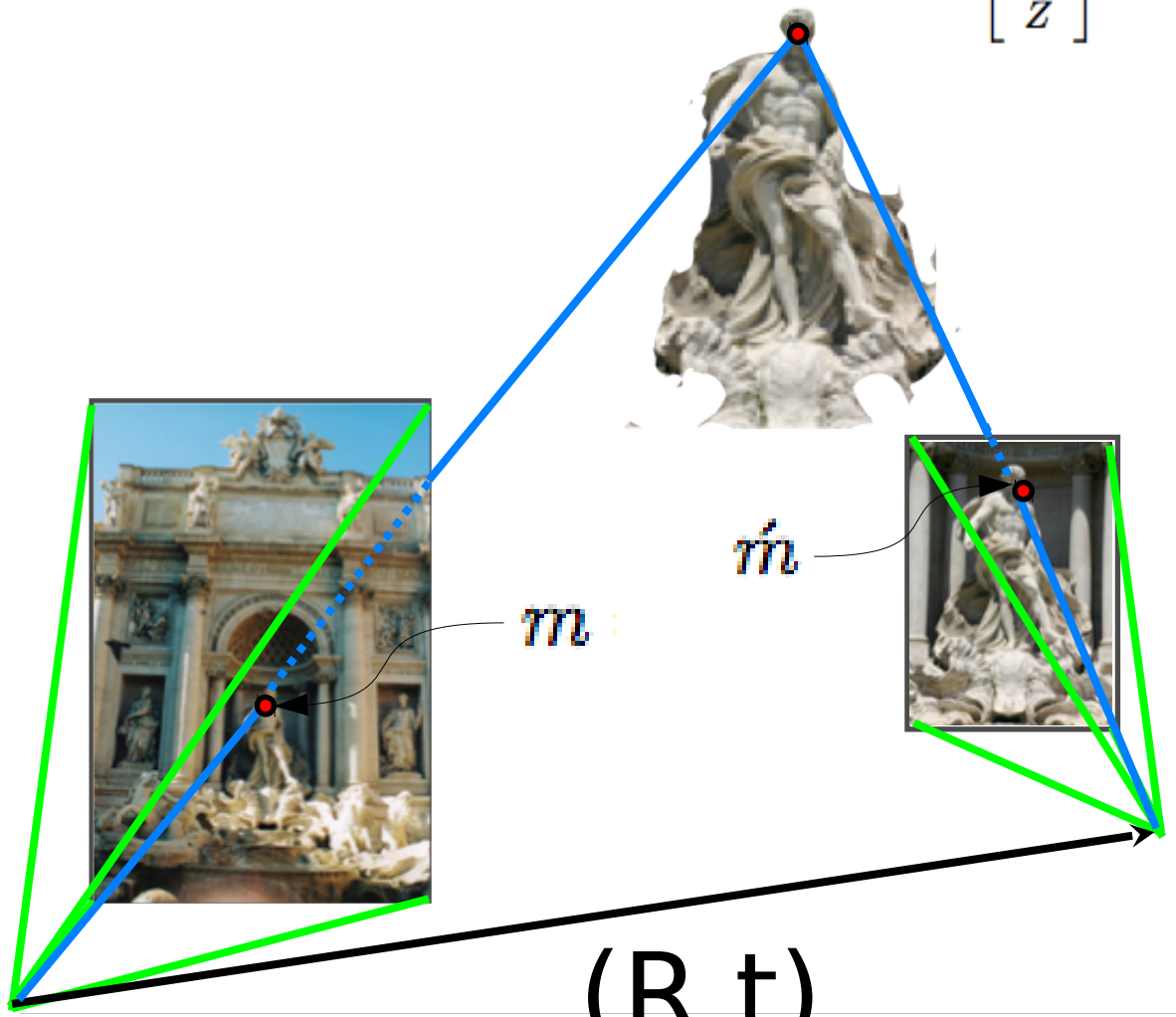
$$y = \frac{f}{Z}Y$$

$$m = \begin{bmatrix} f & 0 & 0 \\ 0 & f & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

$$\begin{aligned} \bar{m} &= \begin{bmatrix} f/s_x & 0 & o_x \\ 0 & f/s_y & o_y \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \\ &= KM \end{aligned}$$

Epipolar Geometry

$$M = \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$



$$m \cdot (t \times R\acute{m}) = 0$$

$$m^T [T_\times] R\acute{m} = 0$$

$$m^T E\acute{m} = 0$$

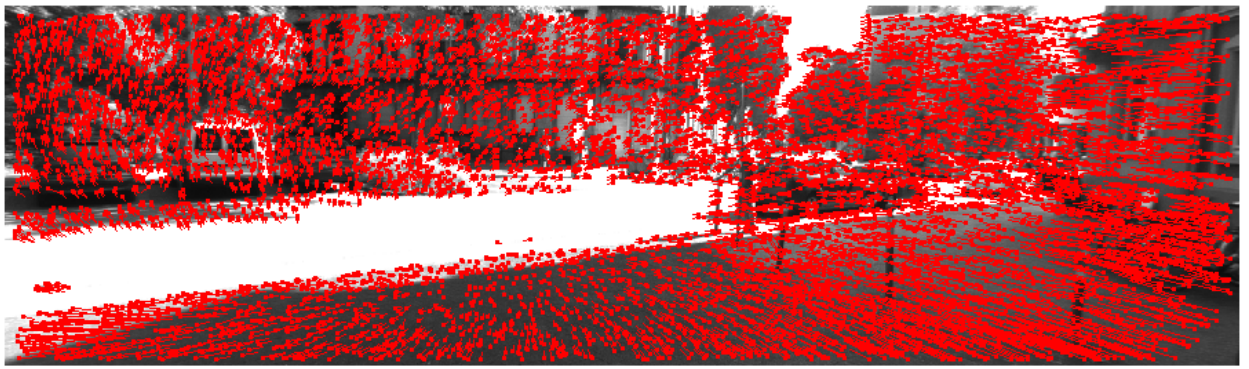
Solving for E from images

- E holds the geometric information that we require for our visual odometry solution
- m'Em=0 for all corresponding points
- Each pair of points constrains possible values for E
- Constructing a linear system from 5 or more matches allows solving for E
- How can we find good matches?

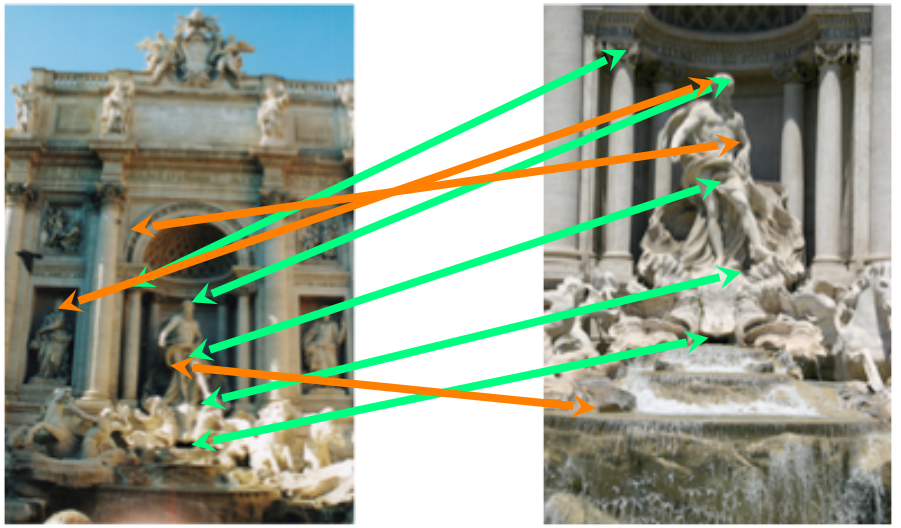
Several ways to find candidate matches

- Interest point matching in every image
- Use temporal consistency between frames in video:
  - Find longer feature tracks
  - Simpler processing to find the “flow”

137 tentative matches

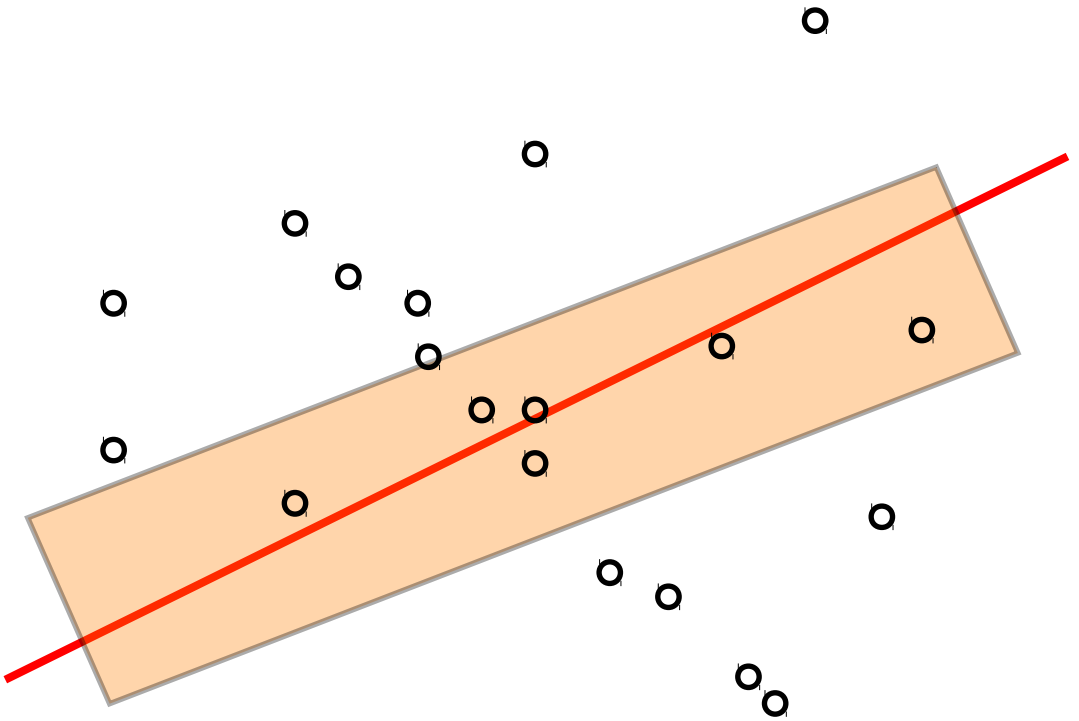


RANSAC

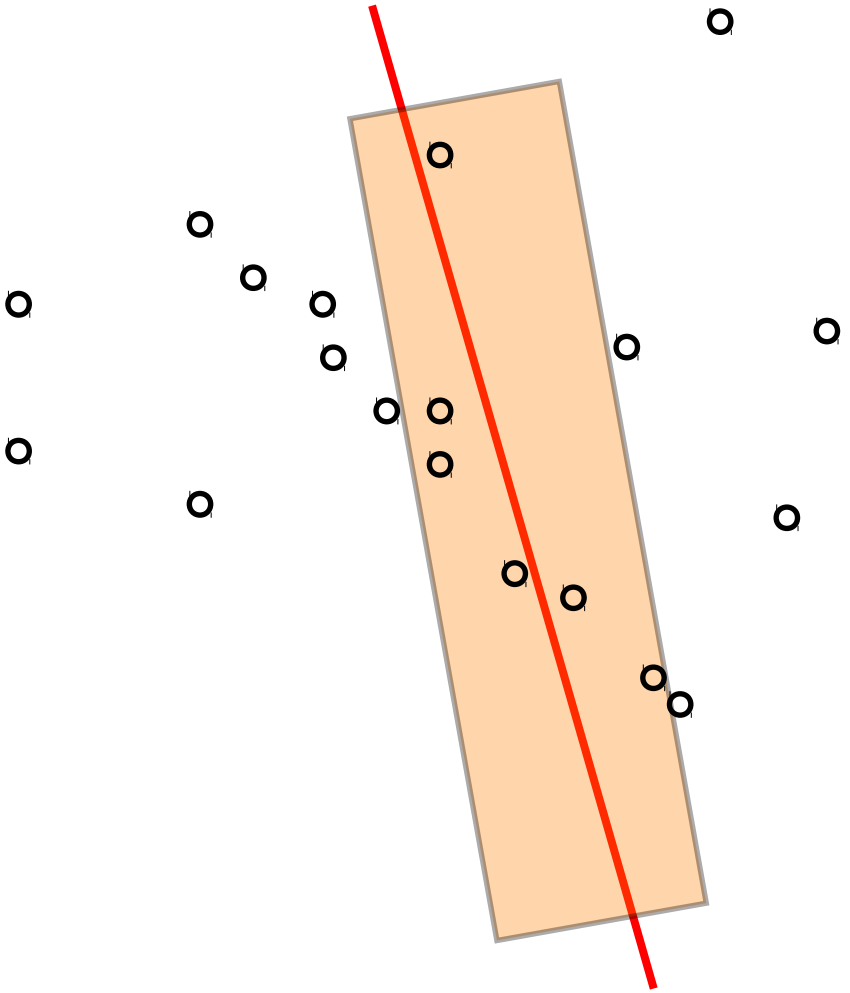


- Repeat:
  - pick K matches
  - solve for E
  - find # inliers
  - If #inliers > threshold, break
- Output E as odometry estimate

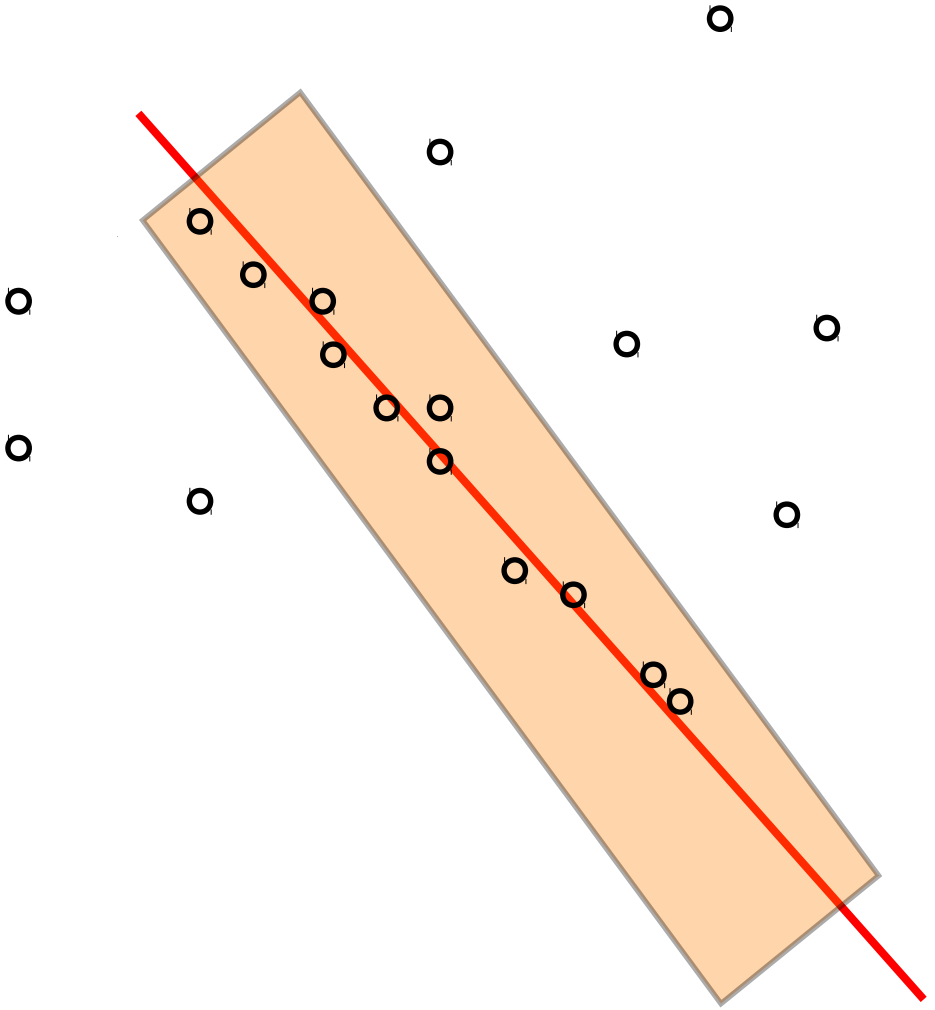
RANSAC



RANSAC



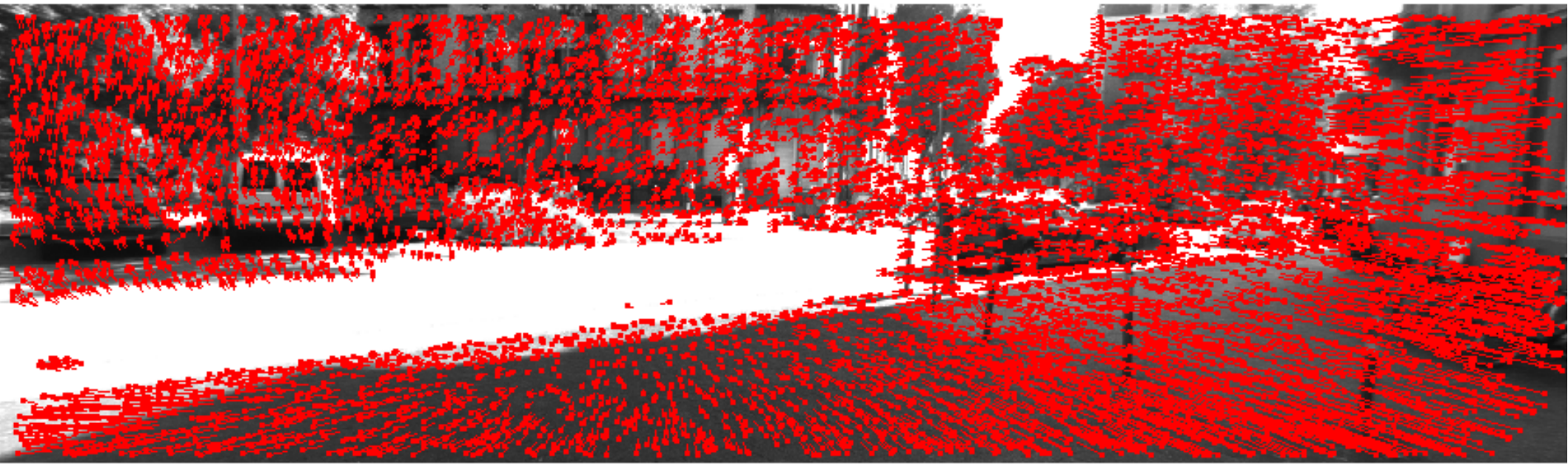
RANSAC



Optical Flow

Optical Flow

Optical Flow



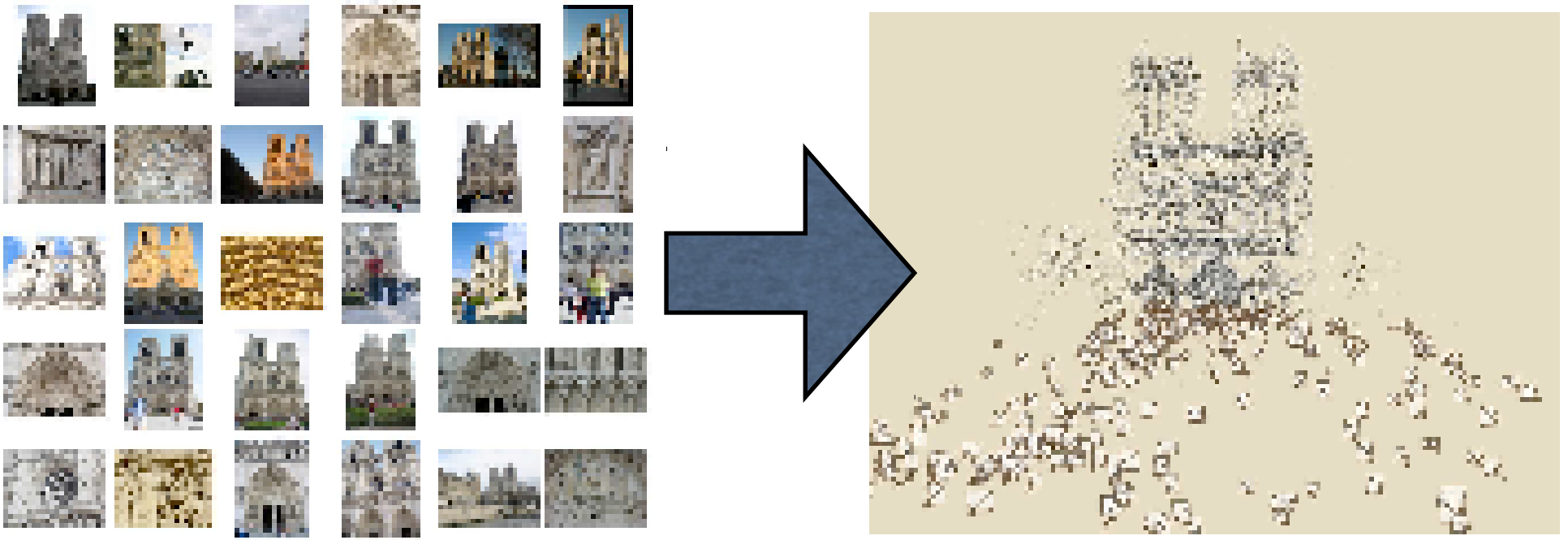
Putting it together: Visual Odometry Solution

- Running libviso2 example code...

Visual Odometry on real robots

- Camera is usually not the only sensor:
  - Combine visual odometry with compass, accelerometer, gyroscope to get intial guesses at motion
- Maps help things stay consistent over long periods:
  - Can save key-frame images, perhaps tagged with GPS coordinates and match to those sporadically

Related Problem: Bundle Adjustment



Questions