

Loop Closure Verification via MVG

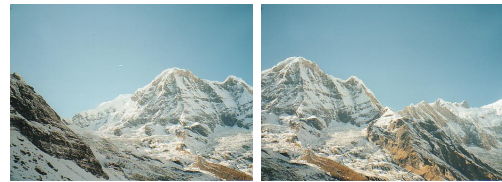
CMPUT 631
Mobile Robot Navigation
Fall 2019

Background

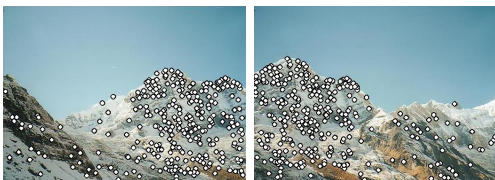
- BoW-based loop closure detection provides top-ranked map images, efficiently
- Each candidate match needs to be verified before being accepted as a loop closure.

Applications of Keypoint Matching

- Computer Vision
 - **Structure from motion**
 - Object detection and tracking
 - Image registration
 - ...
- Robotics
 - **Loop closure verification**
 - Visual odometry
 - ...



Source: L. Lazebnik



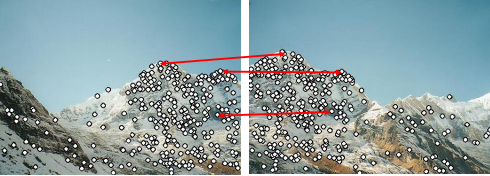
- Extract keypoints

Source: L. Lazebnik



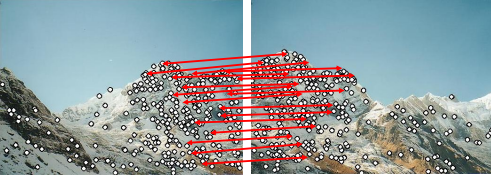
- Extract keypoints
- Compute *putative matches*

Source: L. Lazebnik



- Extract keypoints
- Compute *putative matches*
- Loop (a.k.a. RANSAC):
 - *Hypothesize* transformation T (small group of putative matches that are related by T)

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- Extract keypoints
- Compute *putative matches*
- Loop (a.k.a. RANSAC):
 - *Hypothesize* transformation T (small group of putative matches that are related by T)
 - *Verify* transformation (search for other matches consistent with T)

Source: L. Lazebnik

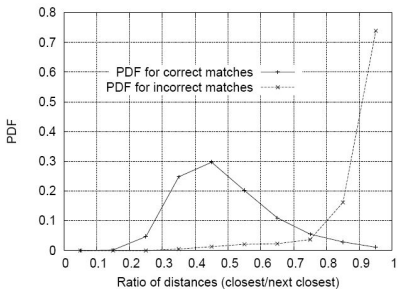
Keypoint detectors and descriptors

<ul style="list-style-type: none"> • Detectors <ul style="list-style-type: none"> • Harris • SIFT • SURF • MSER • BRIEF • FAST • 	<ul style="list-style-type: none"> • Descriptors <ul style="list-style-type: none"> • Raw image patch • SIFT descriptor • BRISK • ORB • Moments • Shape context • Spin images • PCA-SIFT •
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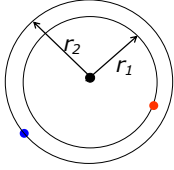
Matching SIFT Descriptors

- Nearest neighbor (Euclidean distance)
- Threshold ratio of nearest to 2nd nearest descriptor



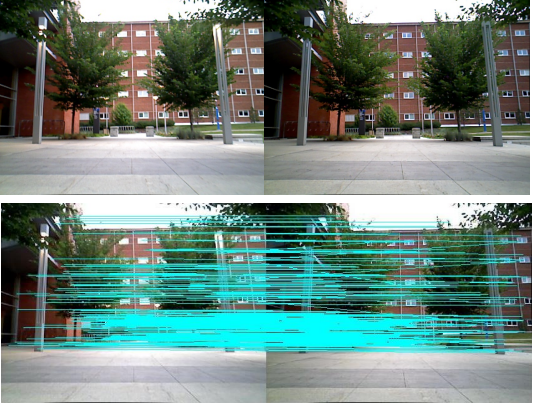
Lowe IJCV 2004

- : Keypoint in Image 1
- : Its nearest neighbor in Image 2
- : 2nd nearest neighbor in Image 2



For a match to be accepted, $r_1/r_2 \leq DR$, $0 \leq DR \leq 1$

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Left: 3363 keypoints. Right: 3339 keypoints. Matches found: 206. DR = 0.6

Verification of putative matches

Recall the epipolar constraint between matched feature points:

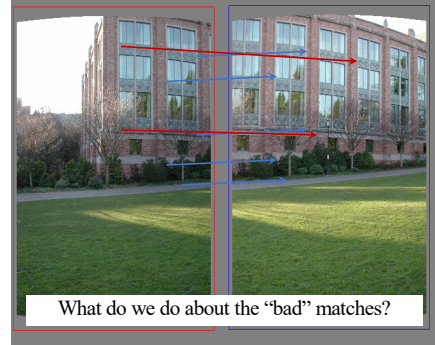
$$\Rightarrow p_2^T E p_1 = 0$$

where p_i are in some "spherical coordinates" for simplicity of derivation. There is an equivalent constraint:

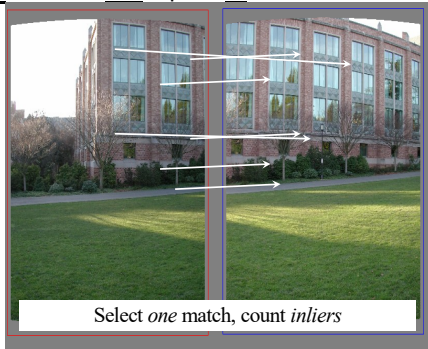
$$p_2^T F p_1 = 0$$

where p_i are matched feature points in their "homogeneous coordinates" (3-vectors for 2D image points).

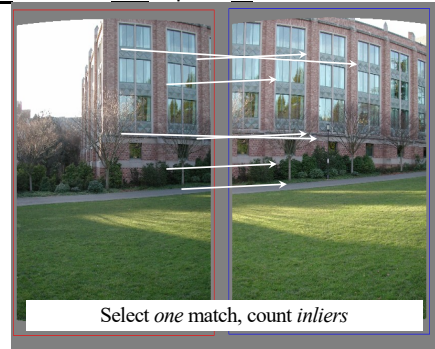
Verification of putative matches



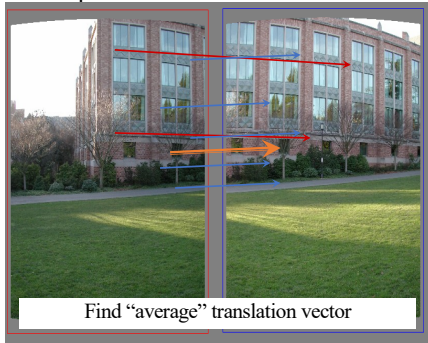
RANdom SAmples Consensus



RANdom SAmples Consensus



Least squares fit to find F



RANSAC for identifying inlier matches

RANSAC loop:

1. Select at least eight (8) feature pairs (at random)
2. Compute the fundamental matrix F (exact)
3. Compute *inliers* where $p_2^T F p_1 < \epsilon$
4. Keep largest set of inliers
5. Loop closure is verified if the # of inliers exceeds a threshold.