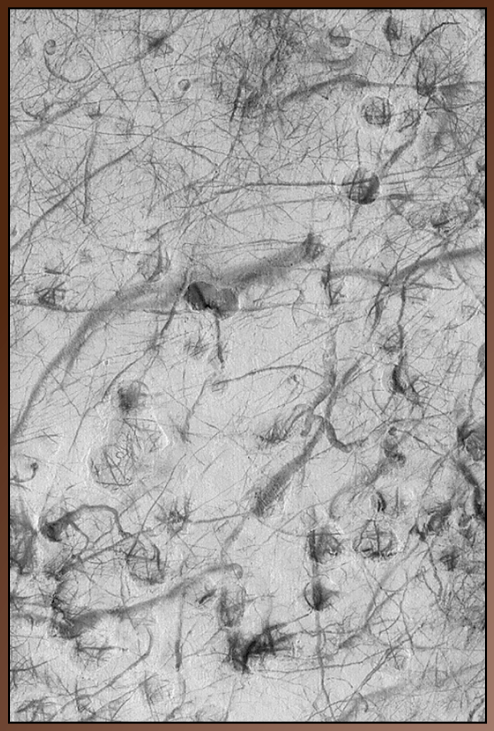
Detecting Transient Surface Features via Dynamic Landmarking



MOC E11-02045 (5/03)

AISR PI Meeting

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MOC S13-00818 (12/06)

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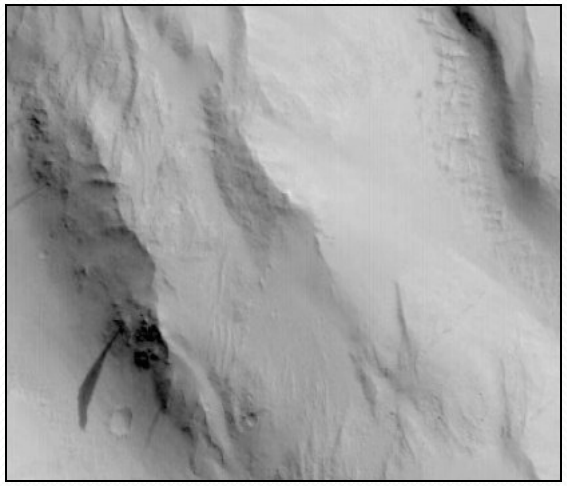
Dynamic Landmarking

- Landmarks: visually salient, sparse content representation
- Innovation
  - Generic feature detector: can discover unexpected features
  - Change detection without image registration
    - Compare landmark sets



MOC, June 2000

MOC, April 2002

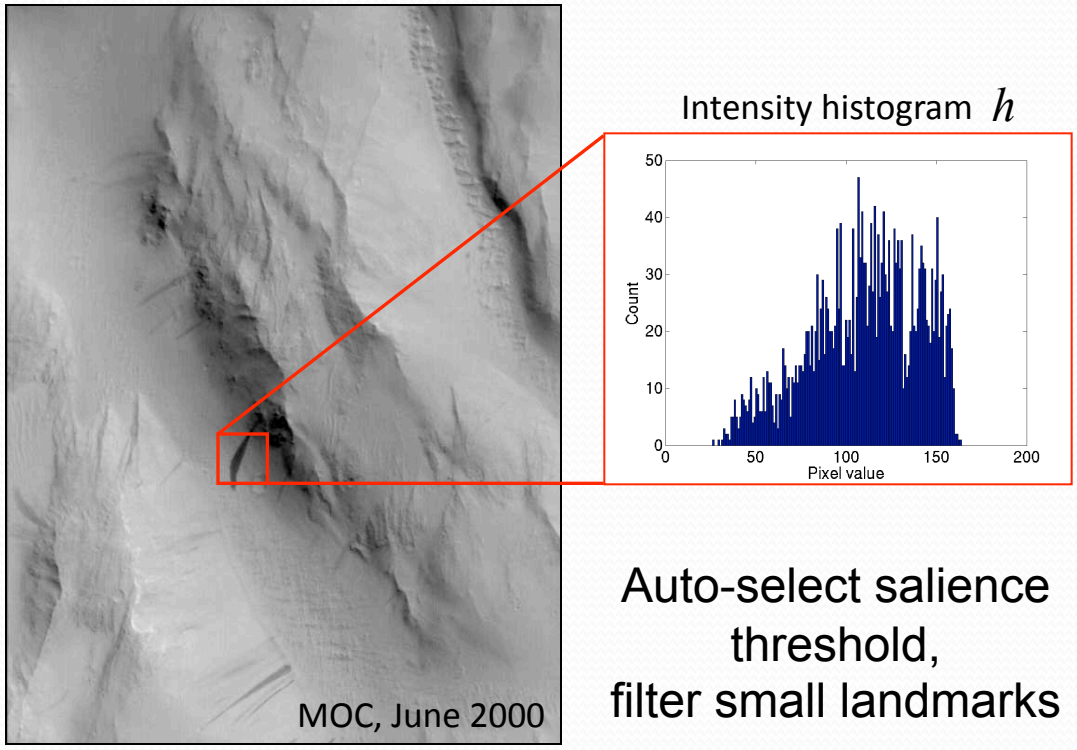
Accomplishments

- Technical
  - Landmark detection
  - Landmark classification
    - 94% accuracy (n=788)
  - Change detection
- Software
  - GUI for landmark annotation (RockIT)
  - GUI for change annotation (MatchGUI)
  - Discussions with PDS about integrating meta-data
- Science
  - Dust devils: analysis of dust lifting in Gusev using track area
  - Dark slope streaks: seasonality of formation rates
- Publications and Presentations
  - Fall AGU, Dec. '08:
    - "Automatic Landmark Identification in Mars Orbital Imagery"
  - Invited talk, LPI, May '09:
    - "Automated Surface Feature Identification in Mars Orbital Images"
  - Invited talk, Univ. of Utah, Nov. '09:
    - "Detecting Changes on Mars with Dynamic Landmarking"

Landmark Detection: Contrast-Weighted Histogram Salience

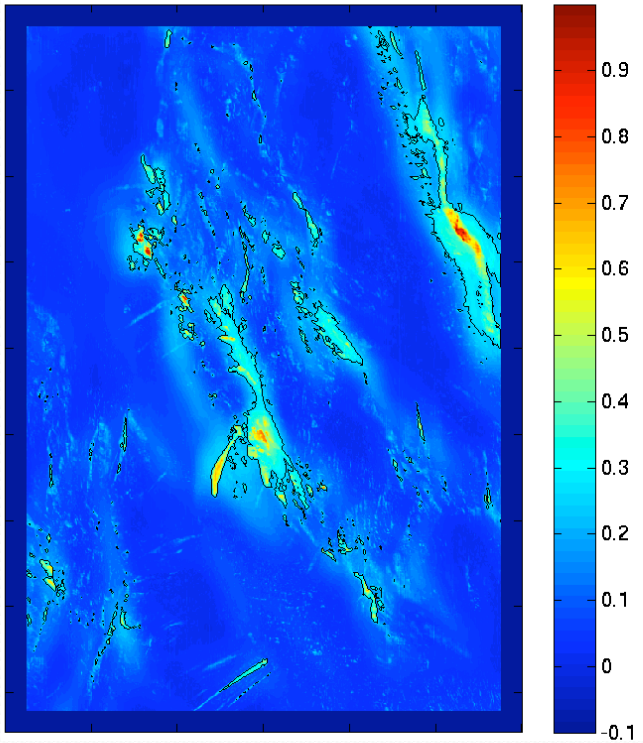
- For each pixel, compute salience with respect to window

$$S(p) = \sum_{i=0}^{255} h(i)|p - i|$$



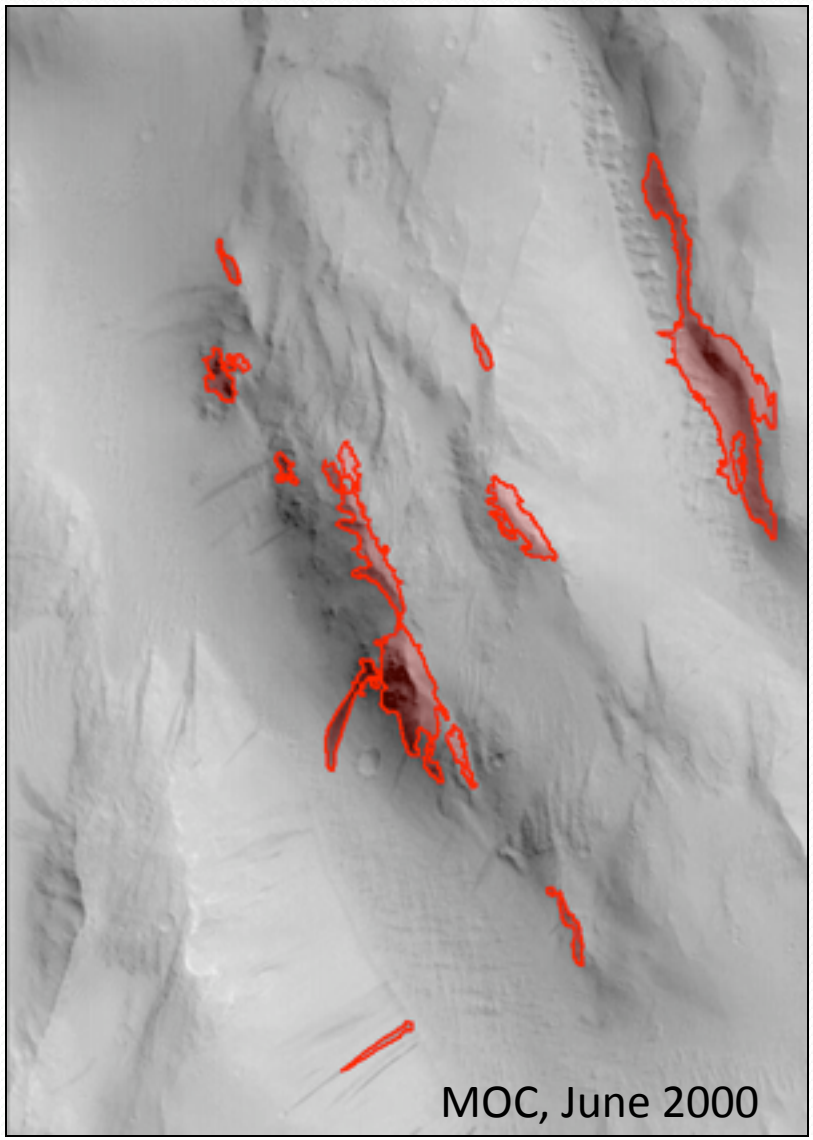
Auto-select salience threshold, filter small landmarks

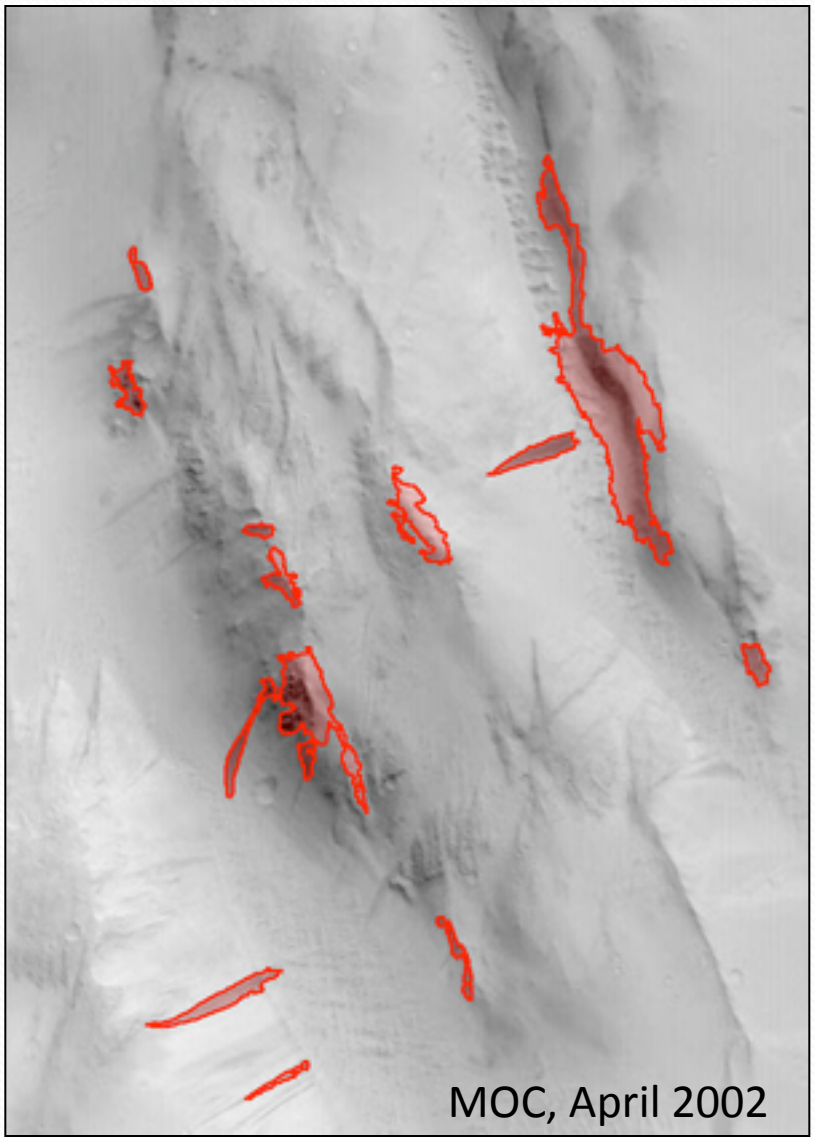
Salience Map (win=50x50)



Landmark Detection Results

Landmark Detection Results





Landmark Detection: Dust Devil Tracks

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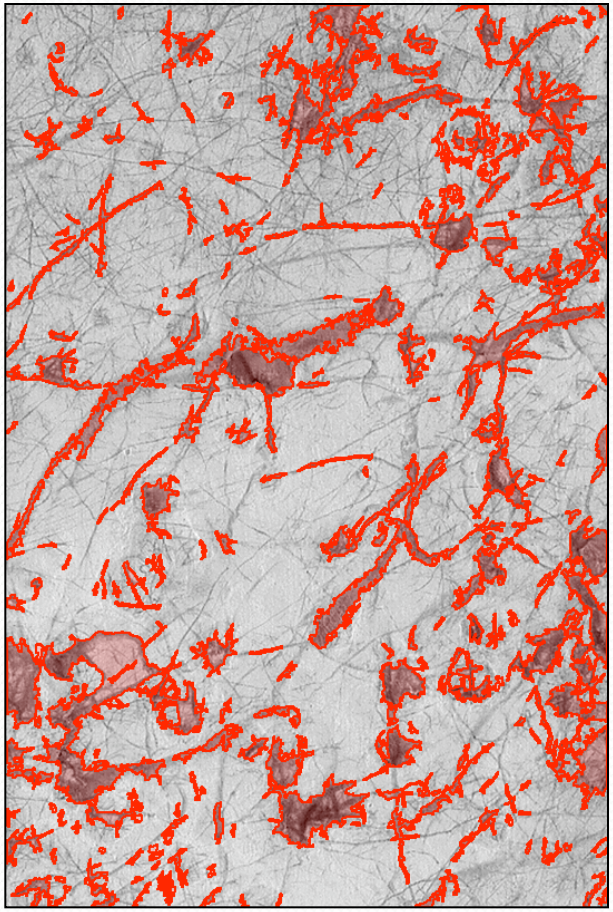
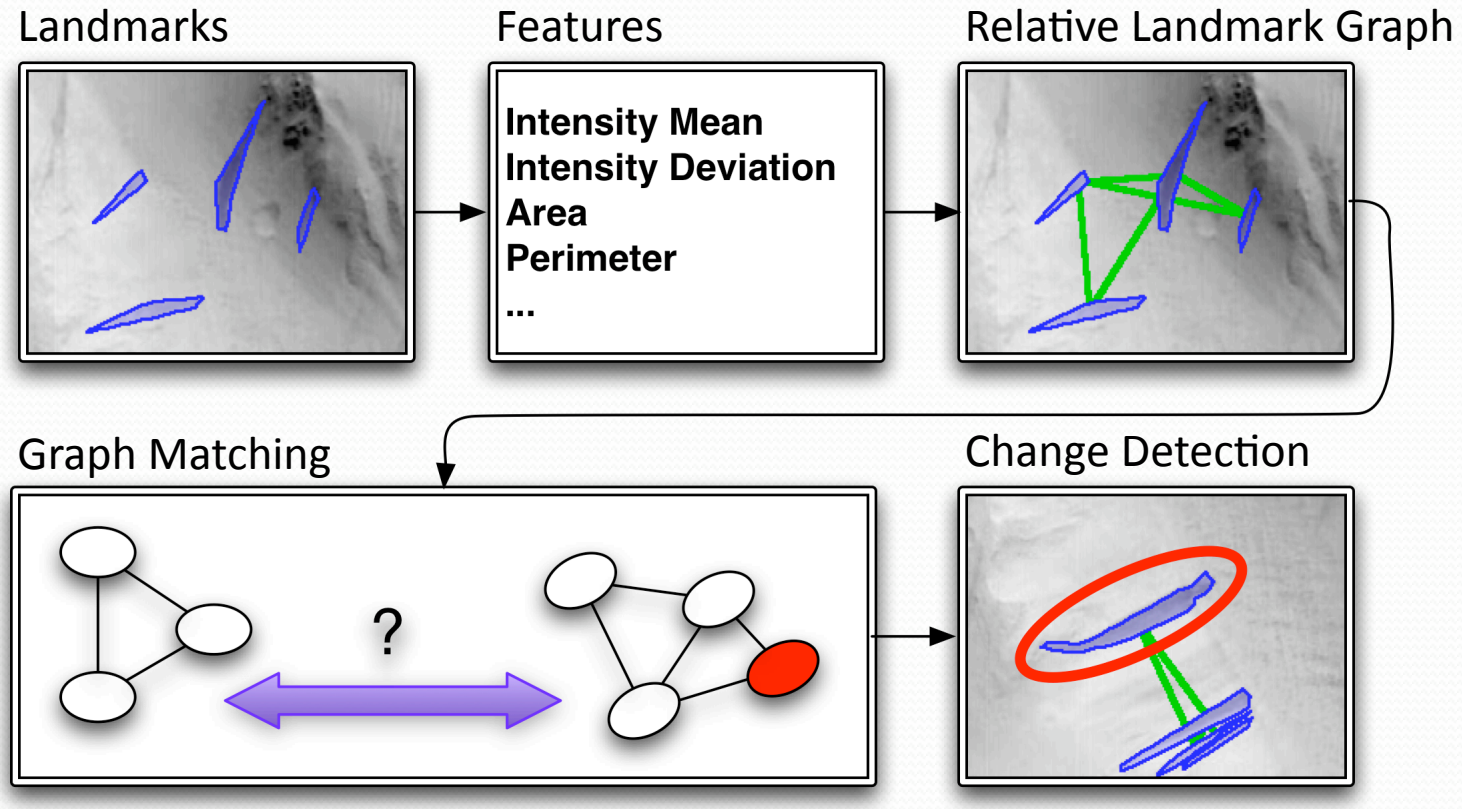
Window size = 250



Change Detection: Landmark Graph Matching



Julian Panetta, summer internship, 2009

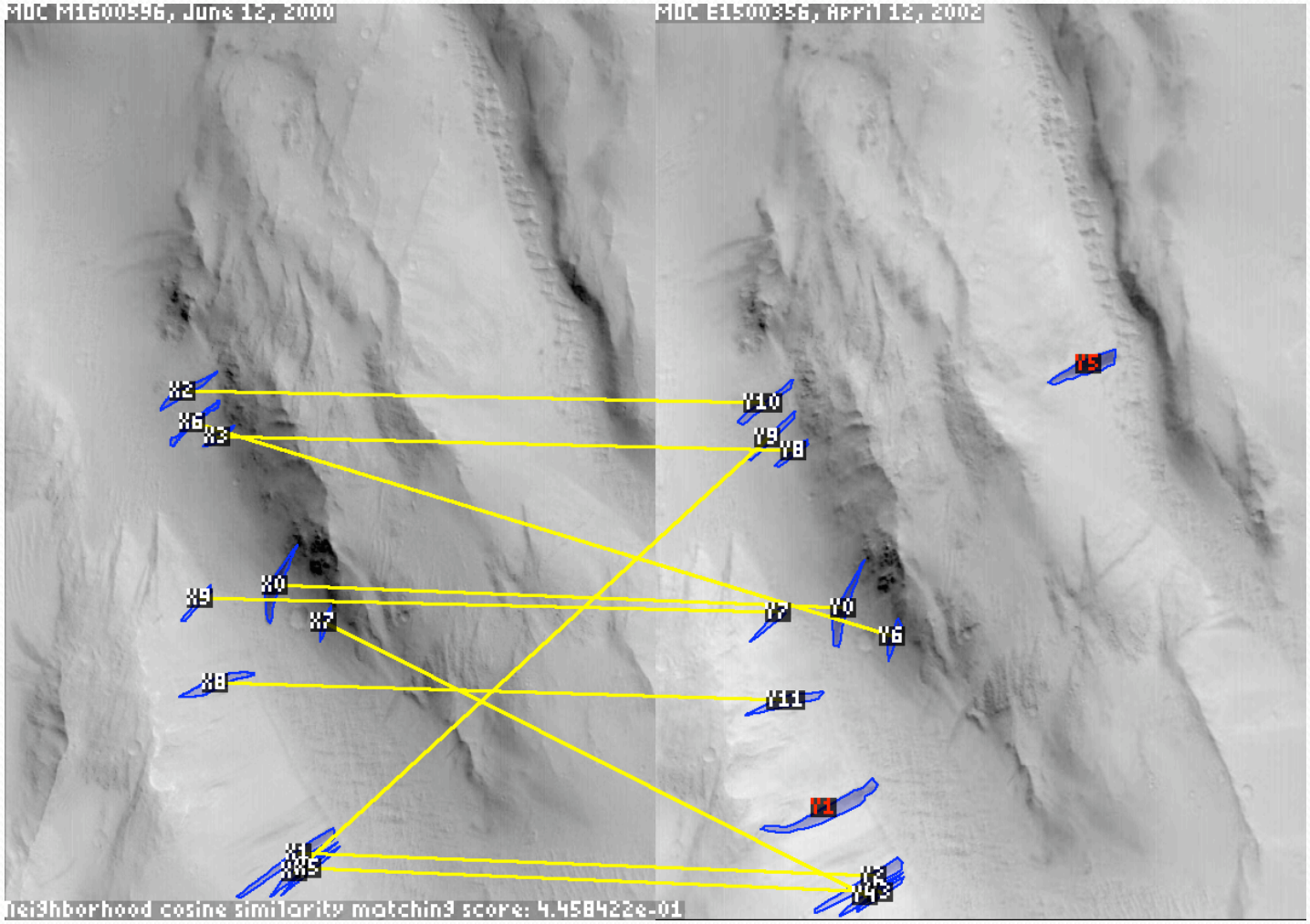
Landmark Matching

- Hungarian/Kuhn-Munkres algorithm: $O(n^3)$
  - Finds best assignment (matching), using landmark similarity

$$Similarity(L_1, L_2) = \frac{F(L_1) \cdot F(L_2)}{\|F(L_1)\| \|F(L_2)\|}$$

  - Features do not include absolute x,y position
    - Translation invariance

Changes in Manual Landmarks (k=0)



Matching

New

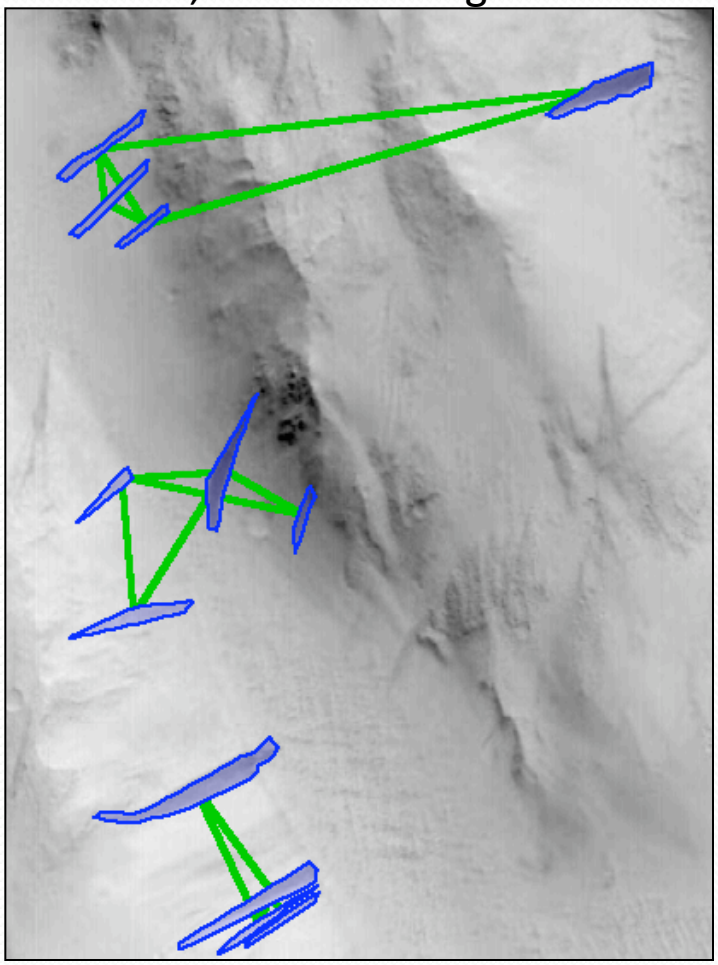
7/10 correct matches

2/2 correct changes

Relative Landmark Graph

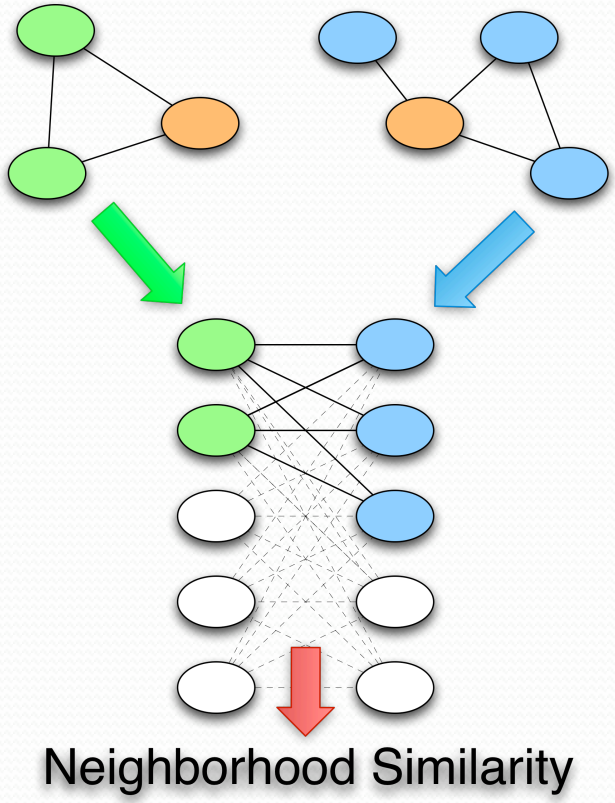
- Invariance to camera orientation
- Nodes: landmarks + features
  - Intensity, area, perimeter, ellipse fit, etc.
- Edges: k-nearest neighbors
  - Using Euclidean distance
  - Choice of k?

RLG, 2 nearest neighbors

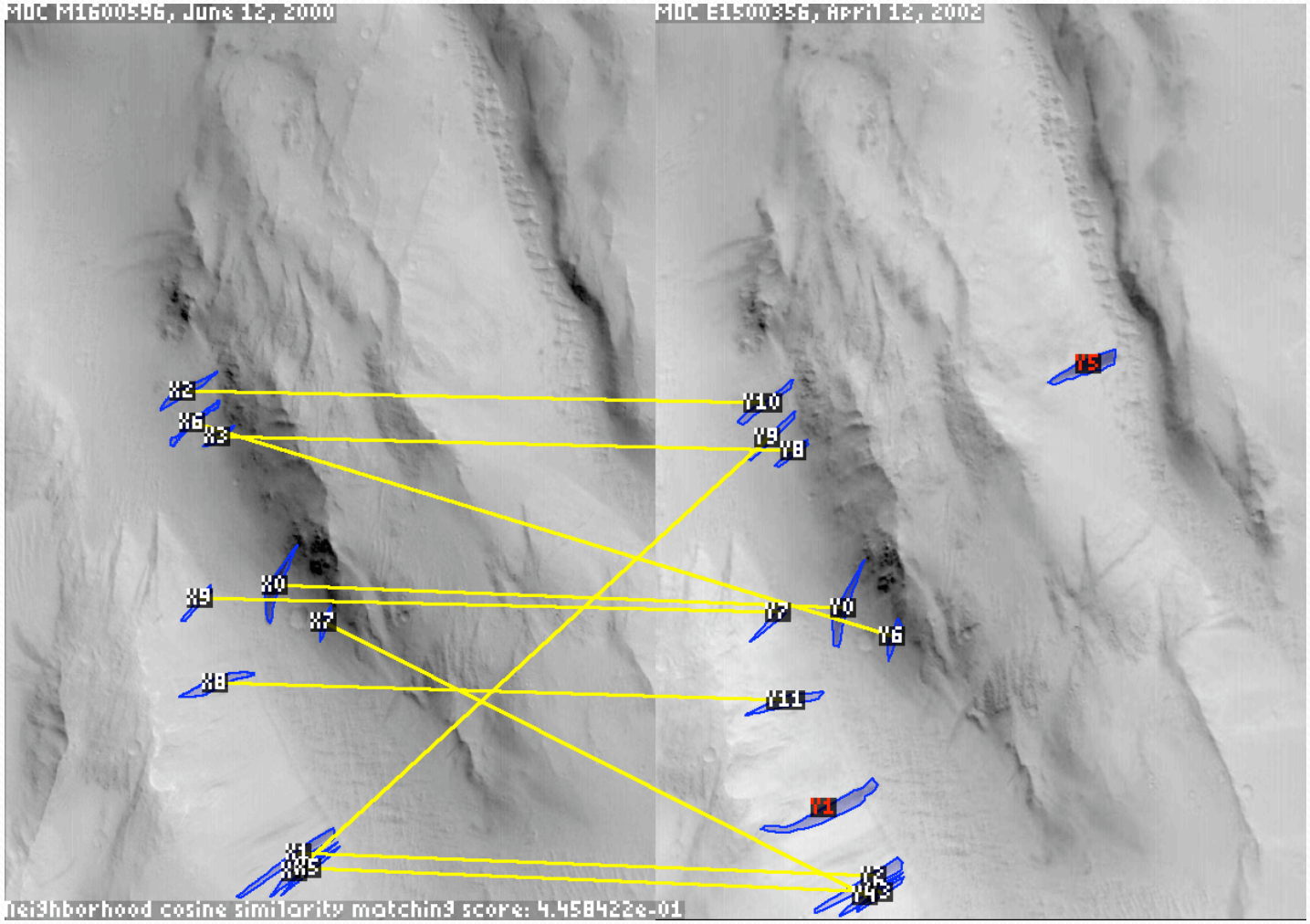


RLG Graph Matching

- Regular matching ignores connectivity
- Solution: augment similarity with neighborhood similarity
  - Average to get match score



Changes in Manual Landmarks (k=0)



RLG Edges

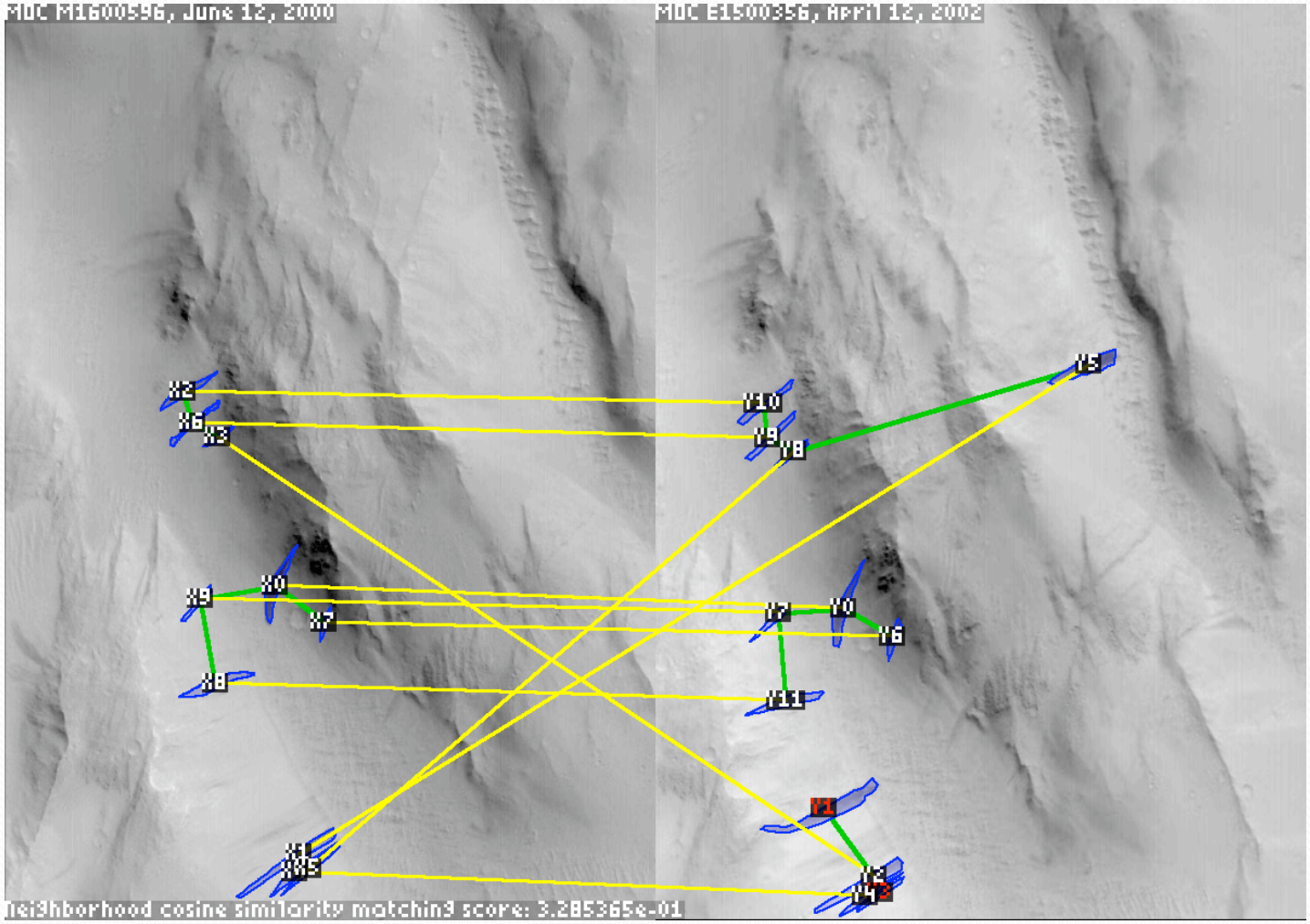
Matching

New

7/10 correct matches

2/2 correct changes

Changes in Manual Landmarks (k=1)

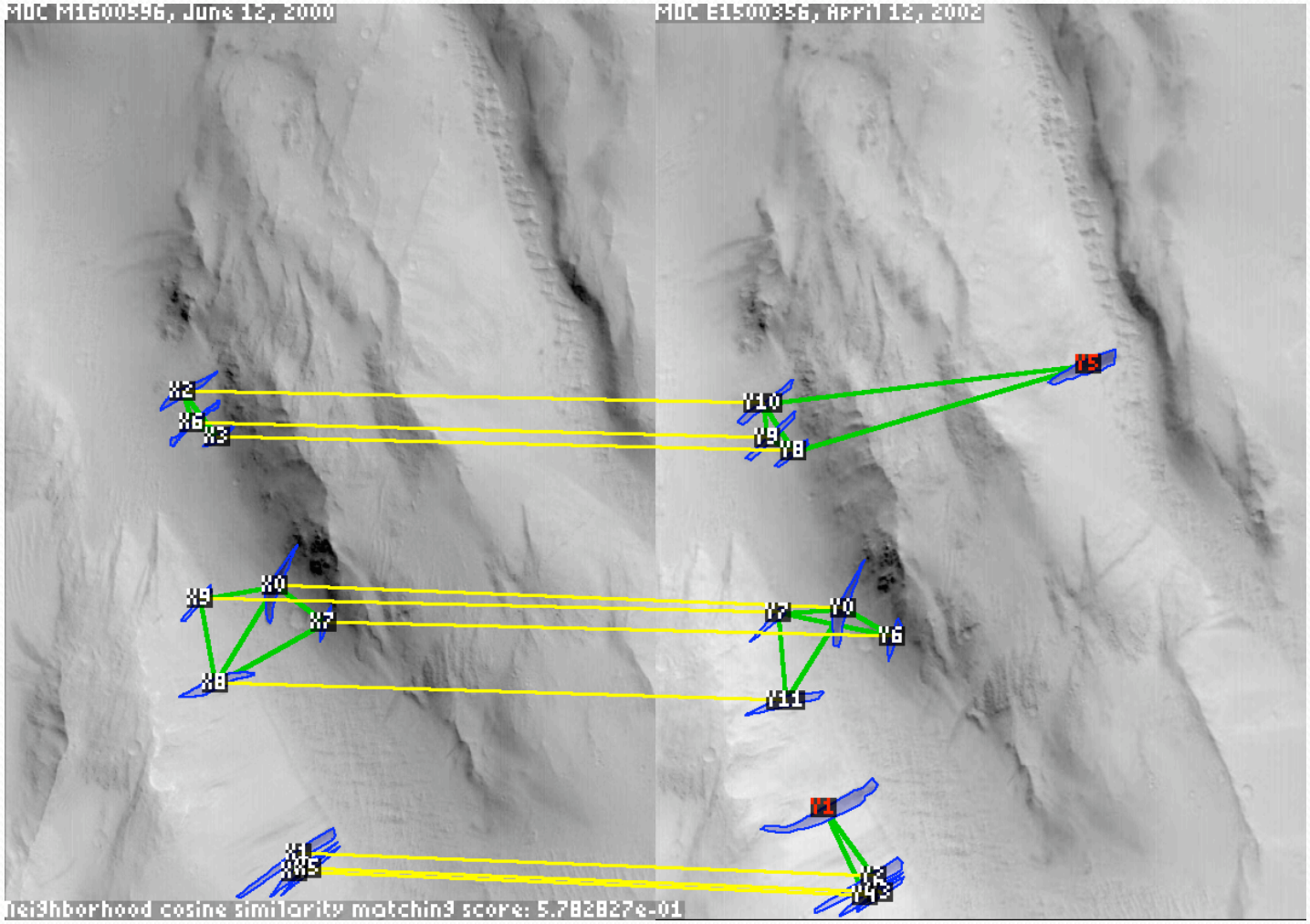


RLG Edges
Matching
New

7/10 correct matches

1/2 correct changes

Changes in Manual Landmarks (k=2)

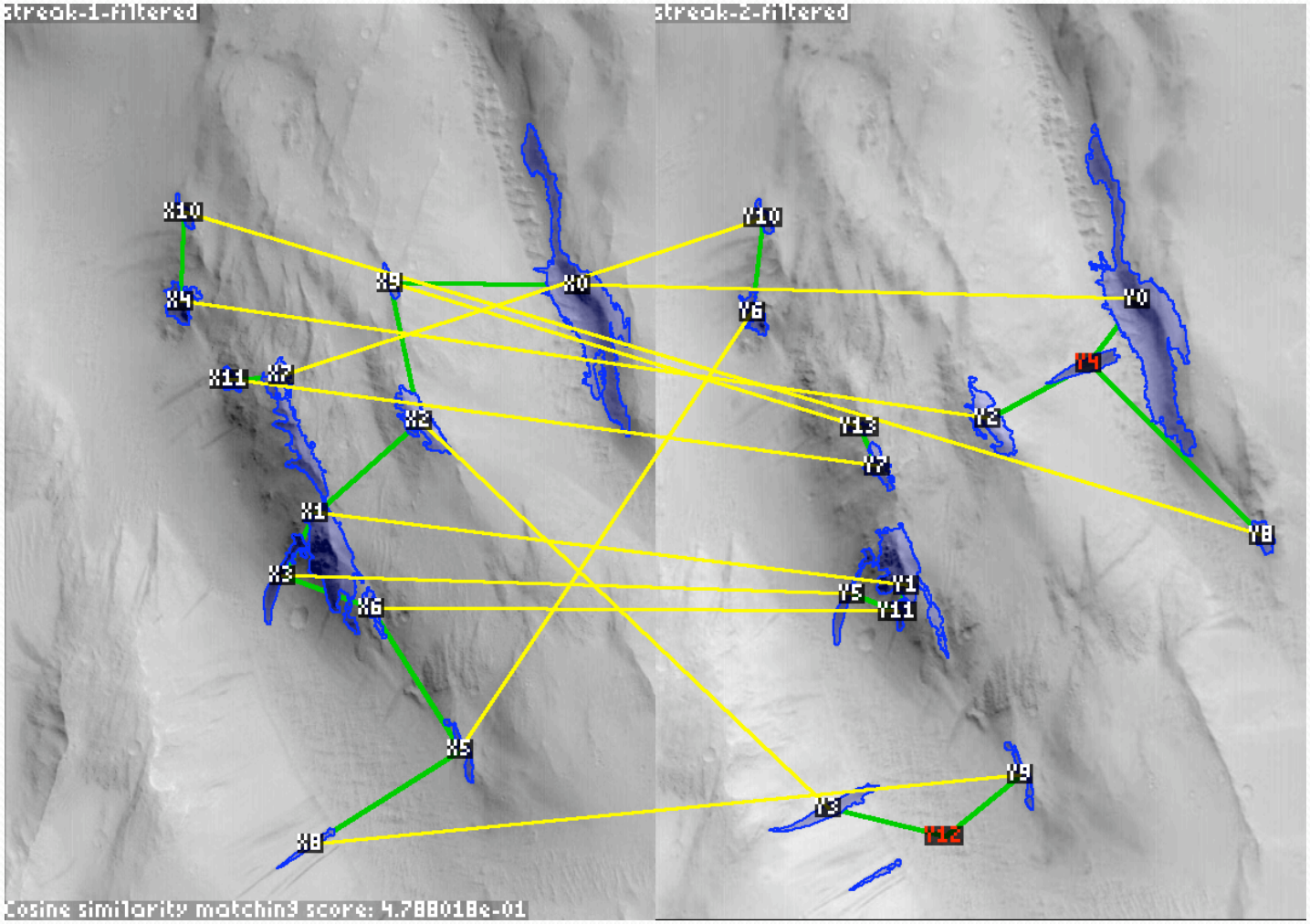


RLG Edges
Matching
New

10/10 correct matches

2/2 correct changes

Changes in Detected Landmarks



RLG Edges

Matching

New

3/12 correct matches

1/2 correct changes

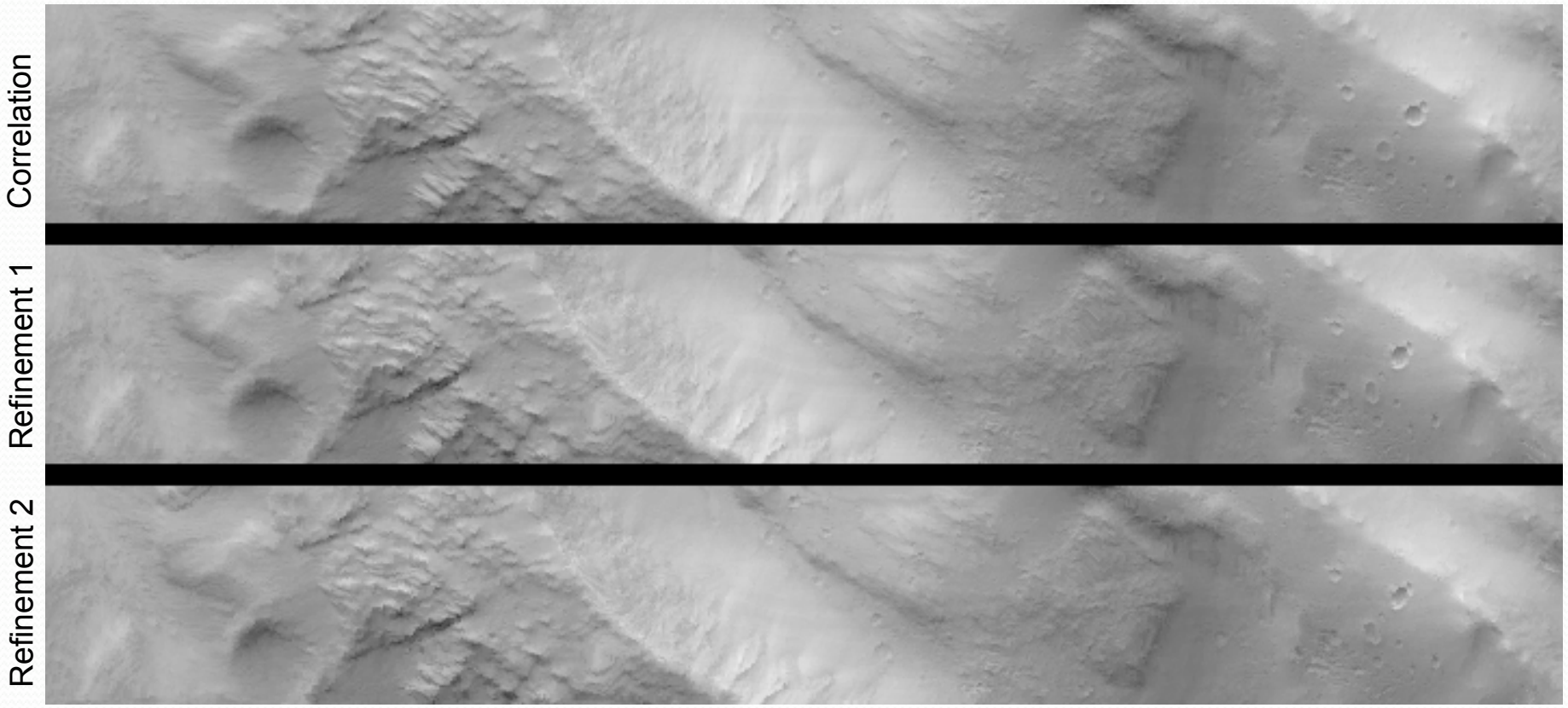
Affine Transformation Needed

- Mars and landmarks form a rigid surface
  - Landmarks cannot arbitrarily move around
    - In contrast to, say, boats on water
  - Affine: permit only rotation, translation, scaling, shear
- New approach *(in progress)*
  - Use initial matching as a starting point
  - RANSAC: repeatedly pick 3 matched pairs, estimate affine transformation, compute match error, pick best
    - Match error: sum of distances from landmarks to closest match, after transform is applied
  - Assign match using transform
    - Can detect both new and vanished!

Change Detection: Image Registration and Differencing

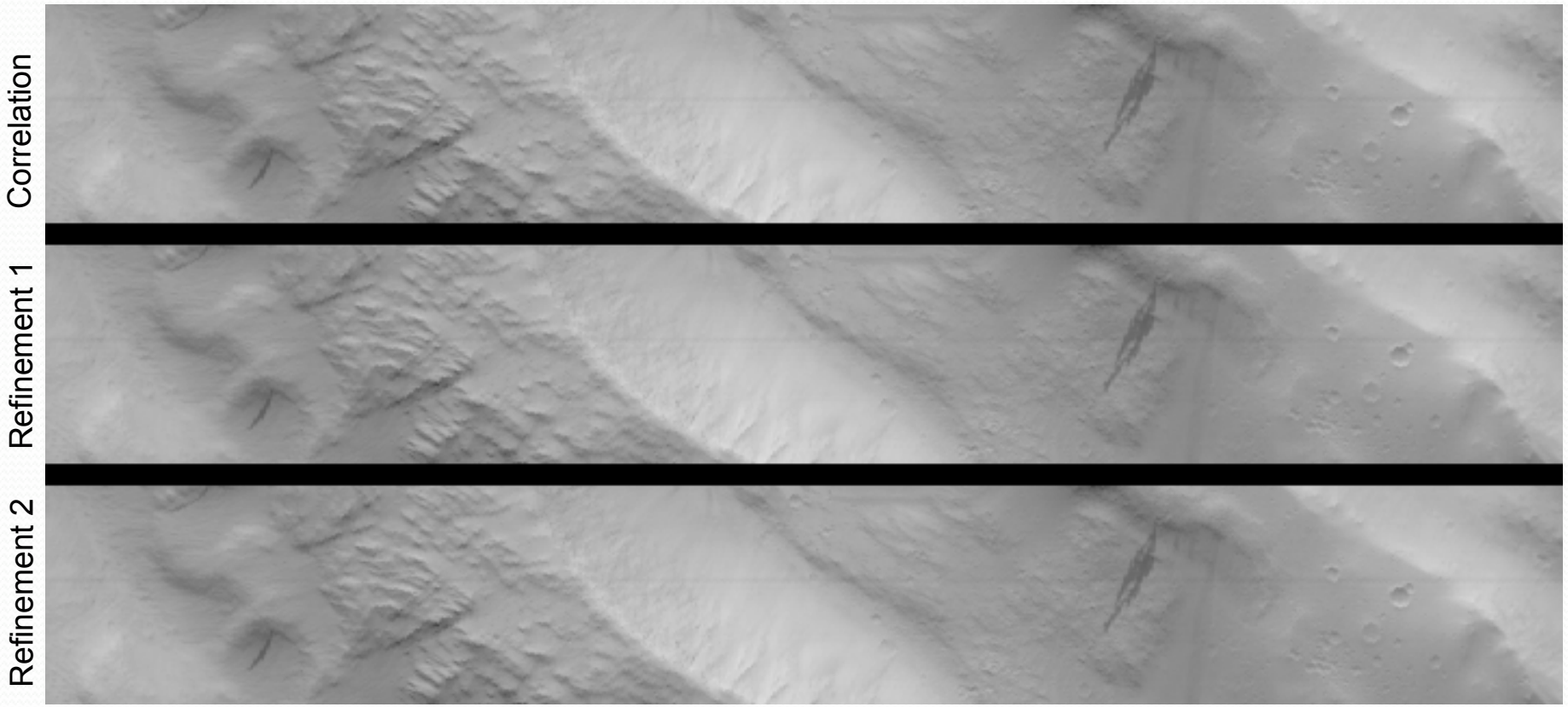
- Challenge: registration
  - Many sources of local registration errors
  - This is the headache landmarks hope to avoid
- Approach
  - Noise suppression: spectral analysis in Fourier domain
  - Correlation for coarse alignment (scale and rotation)
  - Multi-pass correlation refinement
    - Use sparse points to create Delaunay triangulation
    - Local non-linear warping within triangles to improve match

Change Detection:
Image Registration and Differencing



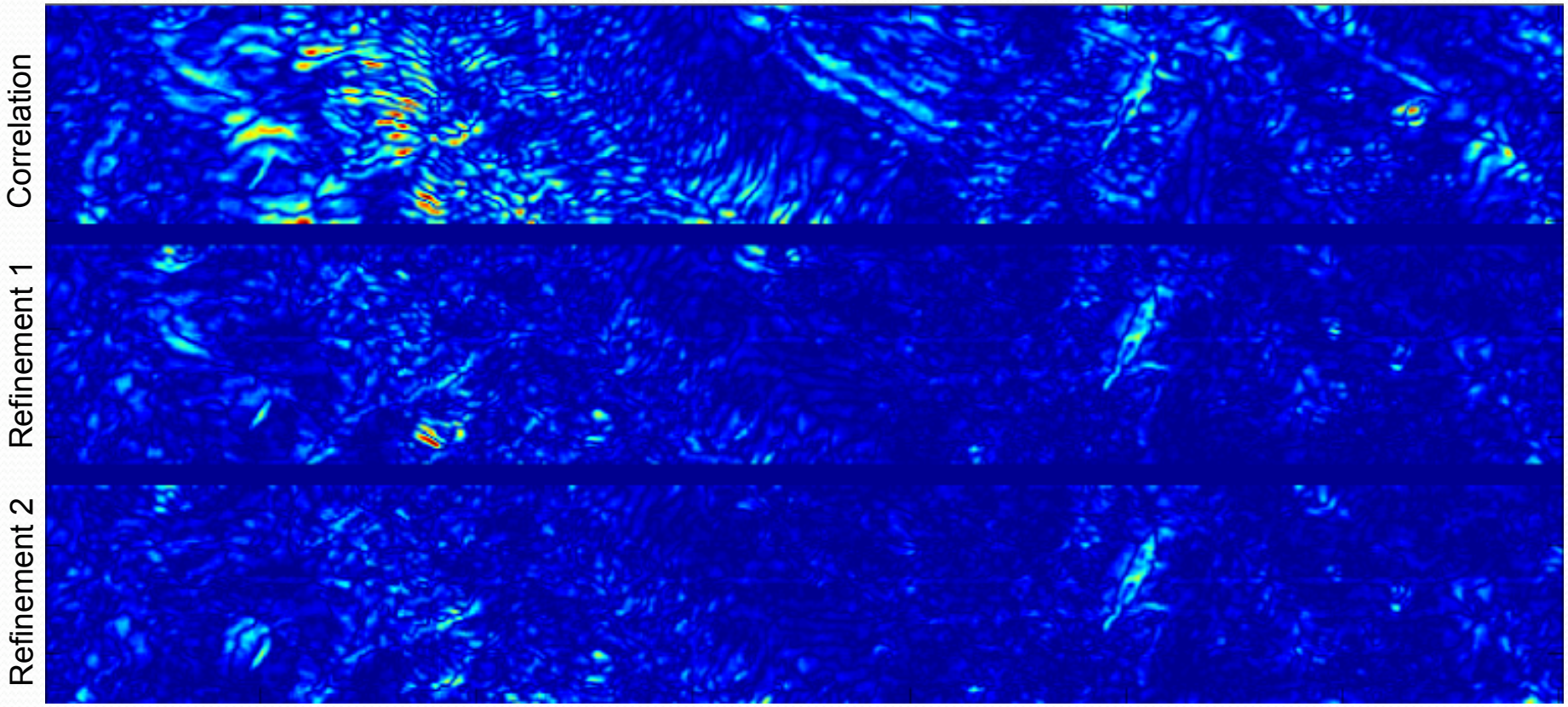
MOC M03-06336, 8/99

Change Detection:
Image Registration and Differencing



MOC E03-02374, 4/01

Change Detection: Image Registration and Differencing



To interpret changes, can perform landmarking on difference image.

Summary and Year 3 Plans

- Landmarks: obtain image content, change detection
- Continue PDS discussions for landmark integration
- Change detection
  - Finish RANSAC/affine implementation for robust matching
  - Change detection across instruments, e.g. MOC/THEMIS
- Science goals
  - Analyze other features: fresh impact craters, wind streaks
- Publication plans: Computers & Geosciences, AGU, LPSC
- More info: http://landmarks.jpl.nasa.gov/
  - kiri.wagstaff@jpl.nasa.gov

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