Robust Single Cycle Target Approach and Instrument Deployment for Mars Rovers

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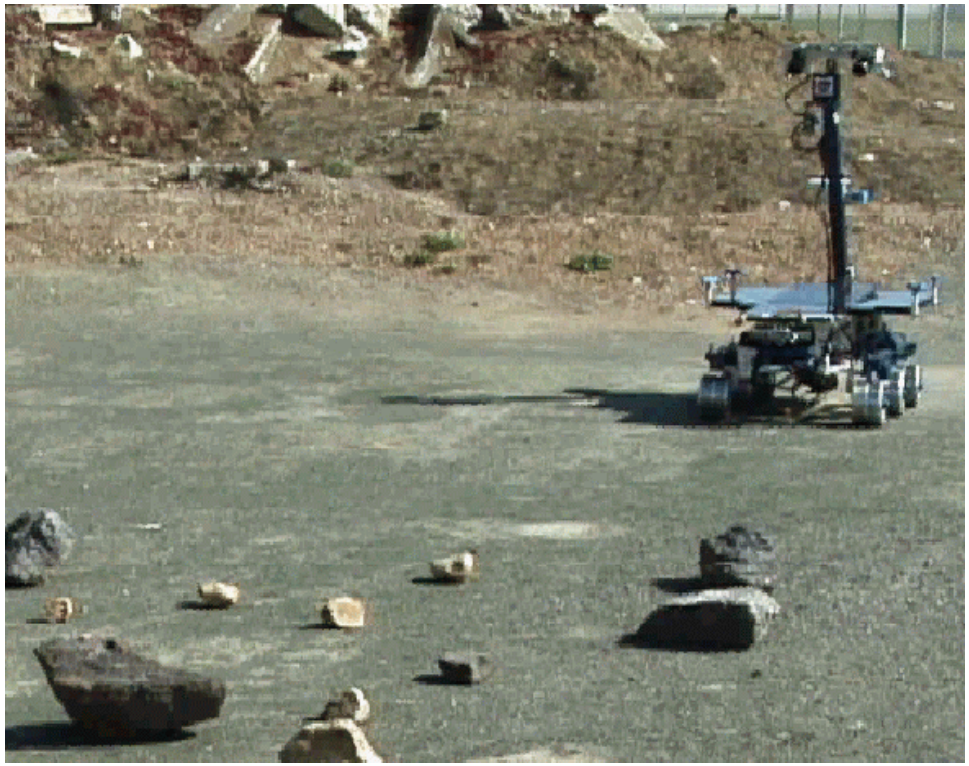
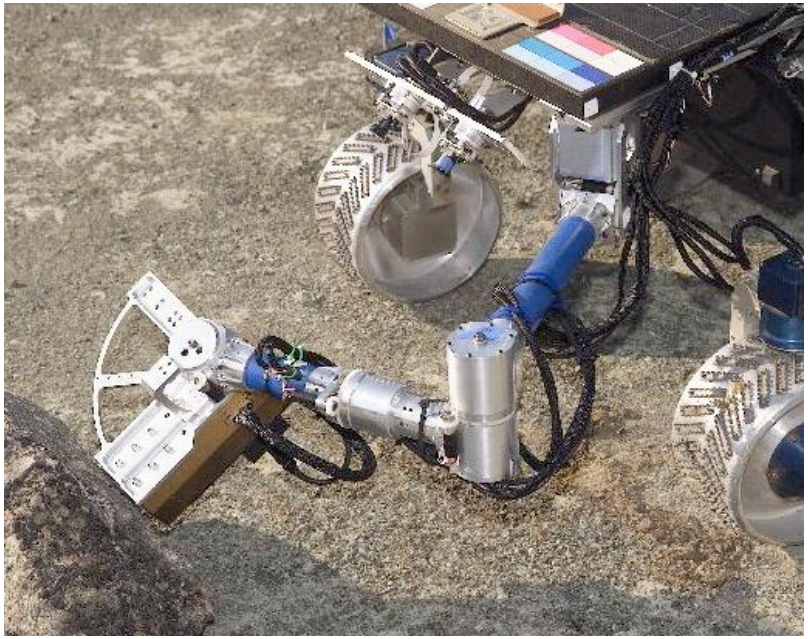
(for Liam Pedersen)
QSS Group/NASA Ames

Objectives



Get to a science target autonomously



Safely place instrument near specified location

Motivation: MSL 2009

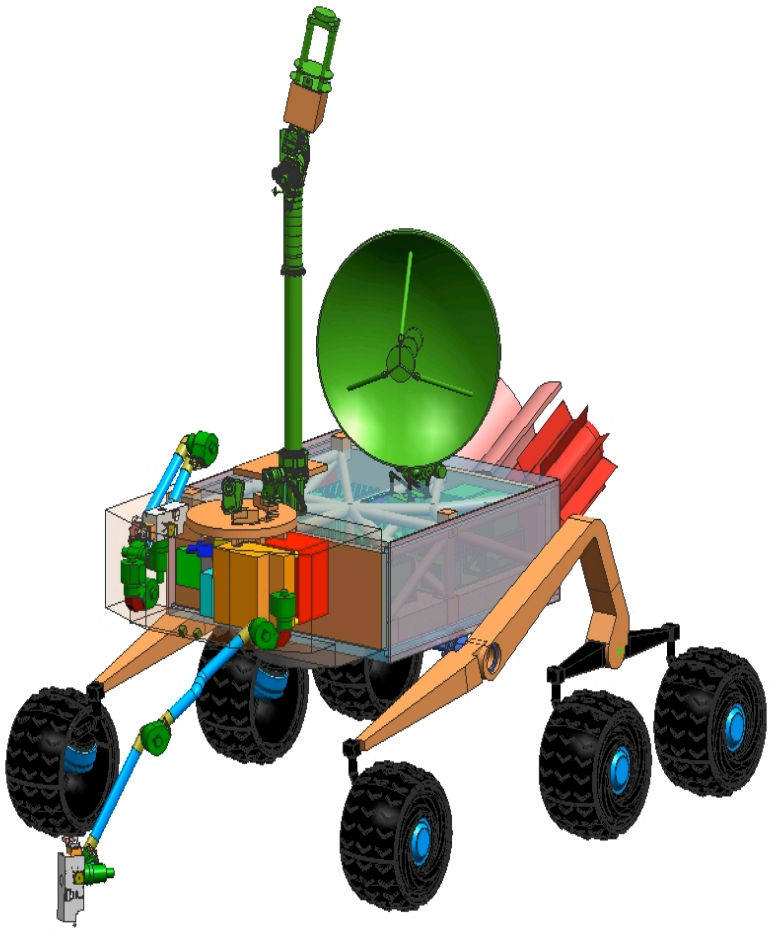
Objectives:

1 cm accuracy

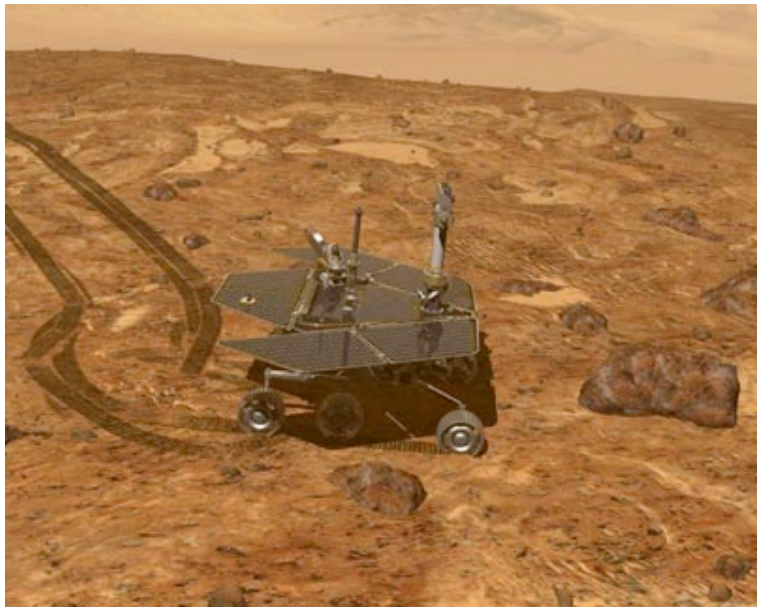
10 m approach

Multiple targets in one command cycle

No catastrophic failures



State of the art



Mars Pathfinder

MER

3+ comm cycles per placement

Part of the puzzle

- Ground tools
  - Viz
  - Contingent planner
- Onboard
  - K9 infrastructure
  - Autonomous approach and placement
  - CRL Executive
- Testing and Validation
  - Marscape
  - MSF simulation

Key components

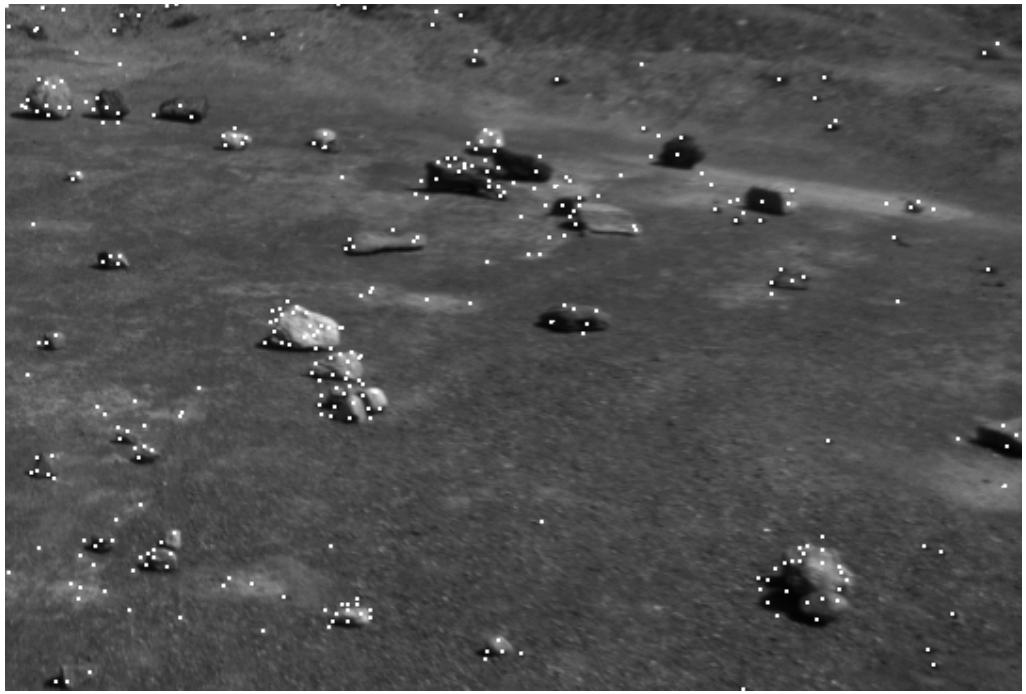
Approach

- 2D Interest points
- 3D Model registration
- Target tracking and handoff

Placement

- Target assessment
- Instrument placement

2D Interest points



"Keypoint" interest point detector

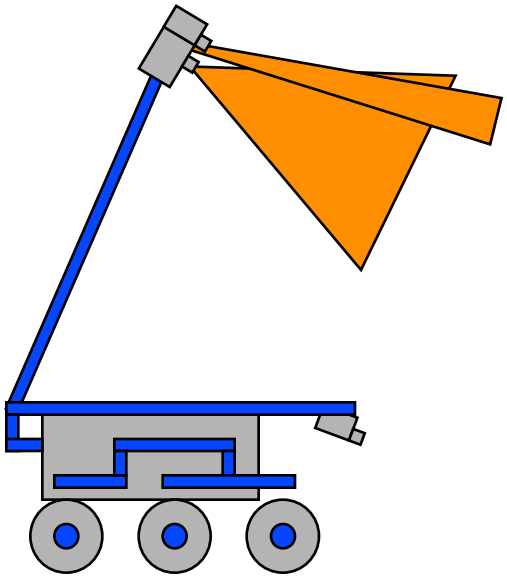
Invariant to translation, rotation, scale

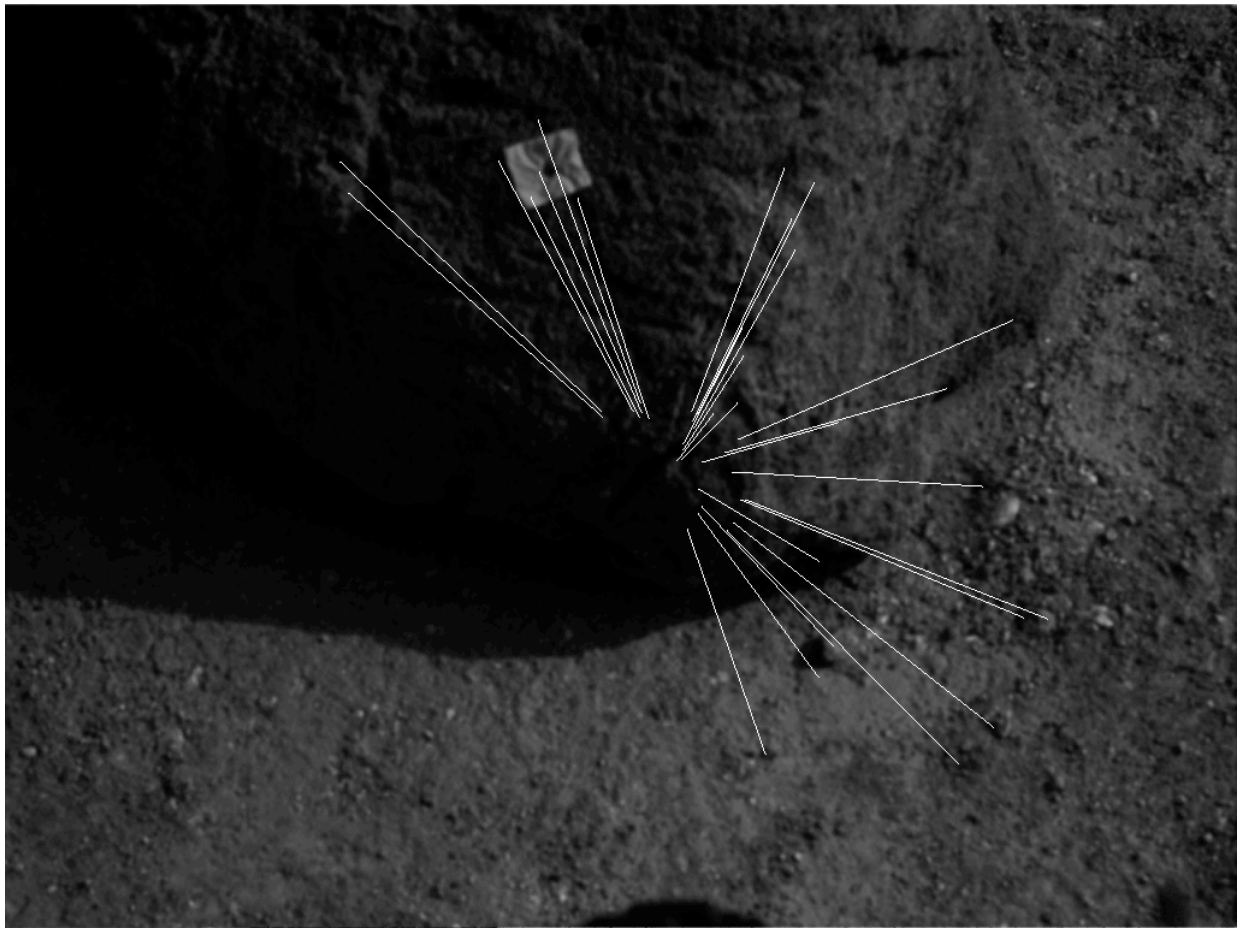
Fast global matching, no "search"

[Lowe, D. G., "Distinctive image features from scale-invariant keypoints," *International Journal of Computer Vision,* submitted June 2003.]

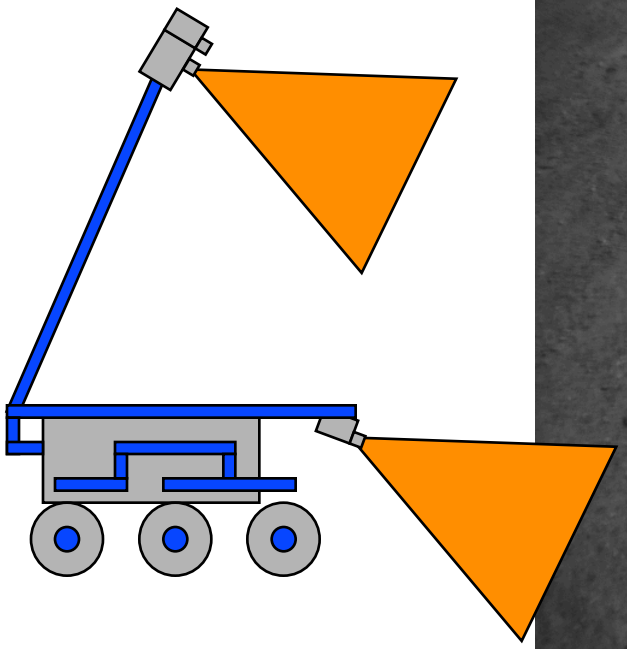
Keypoint tracking

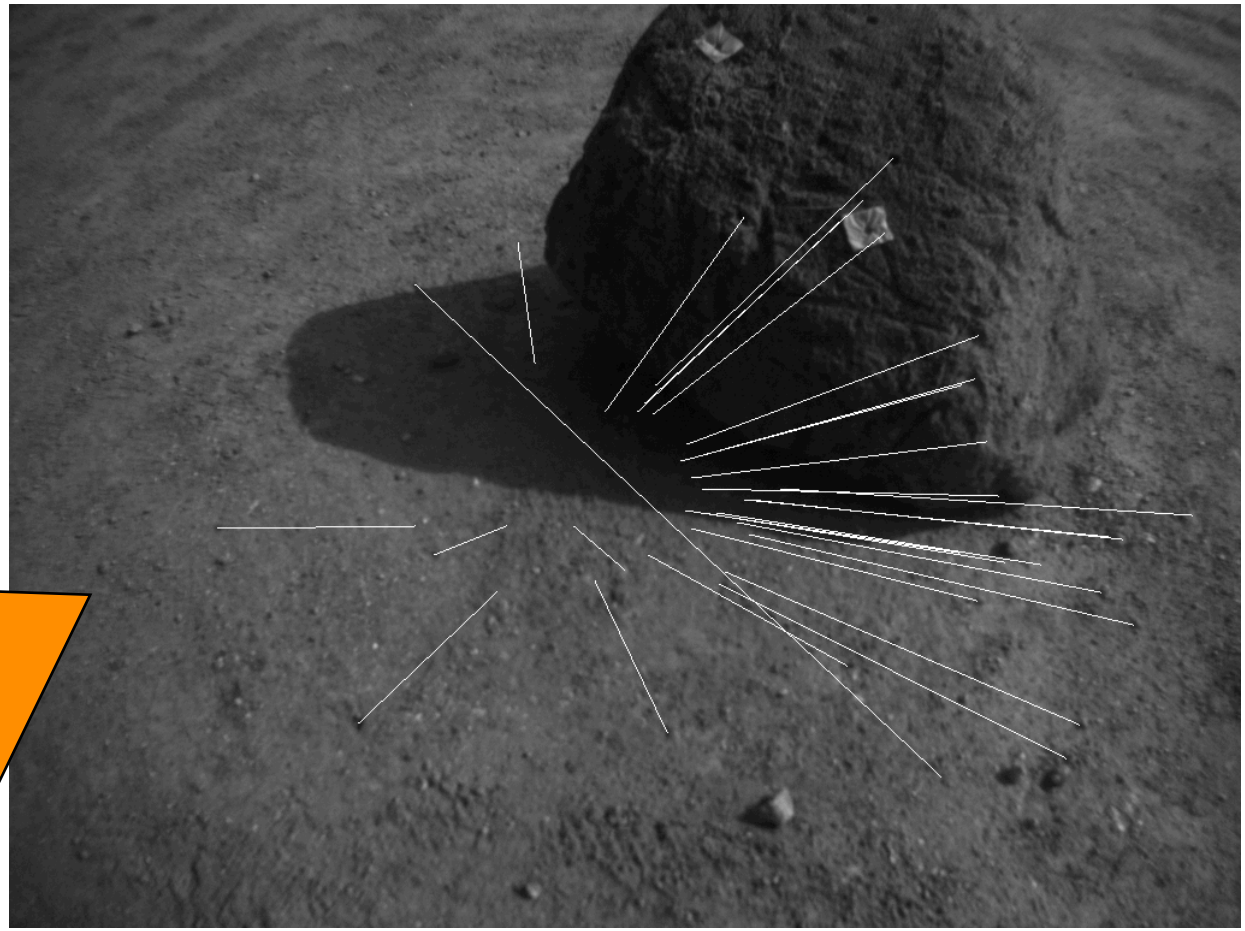
Keypoint Matching



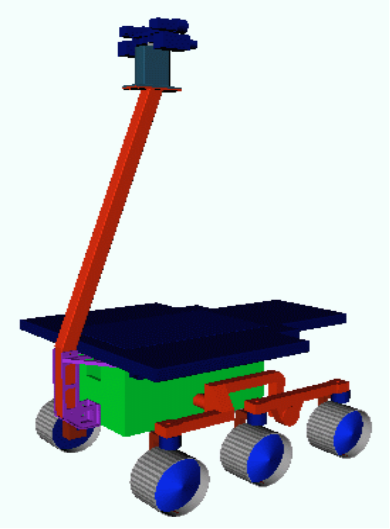


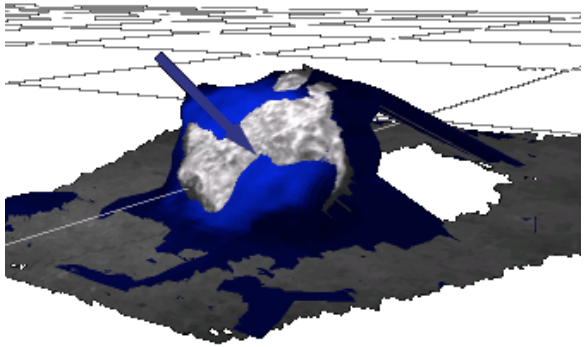
Keypoint Matching





3D Model registration





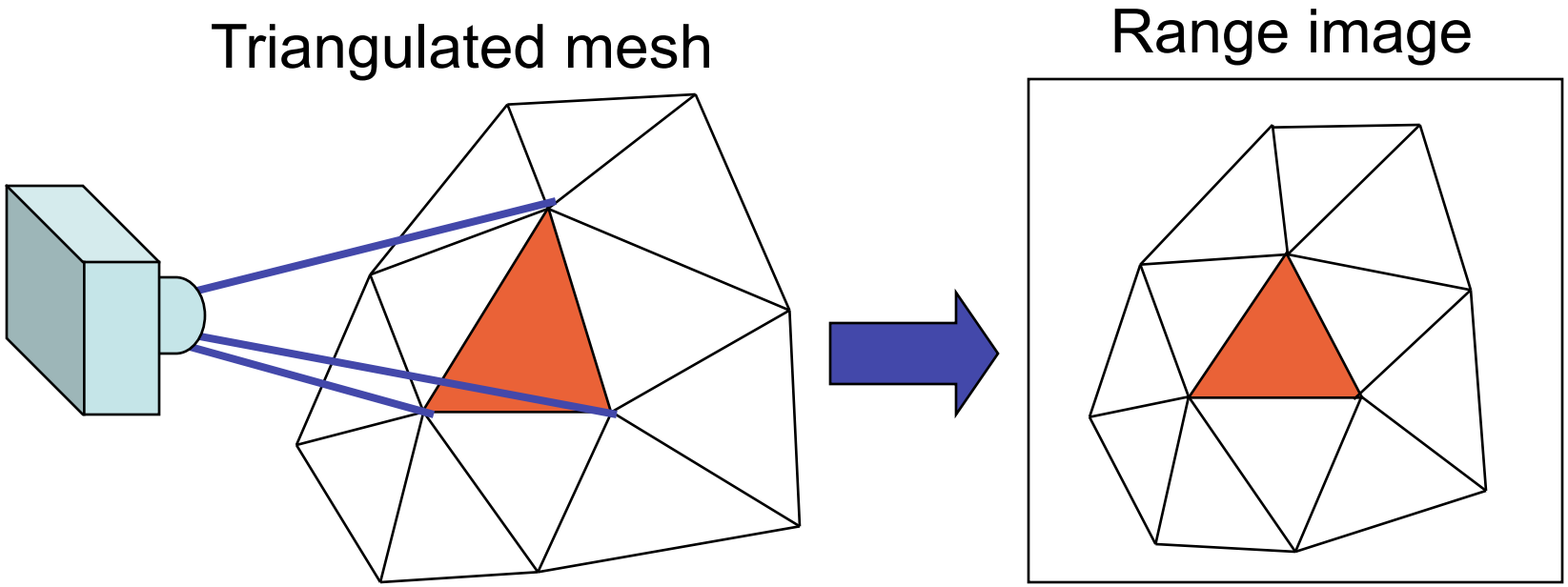
Approximate pose of rover known

Build and register 3D models of features

- Range image matching
- Coarse to fine approach

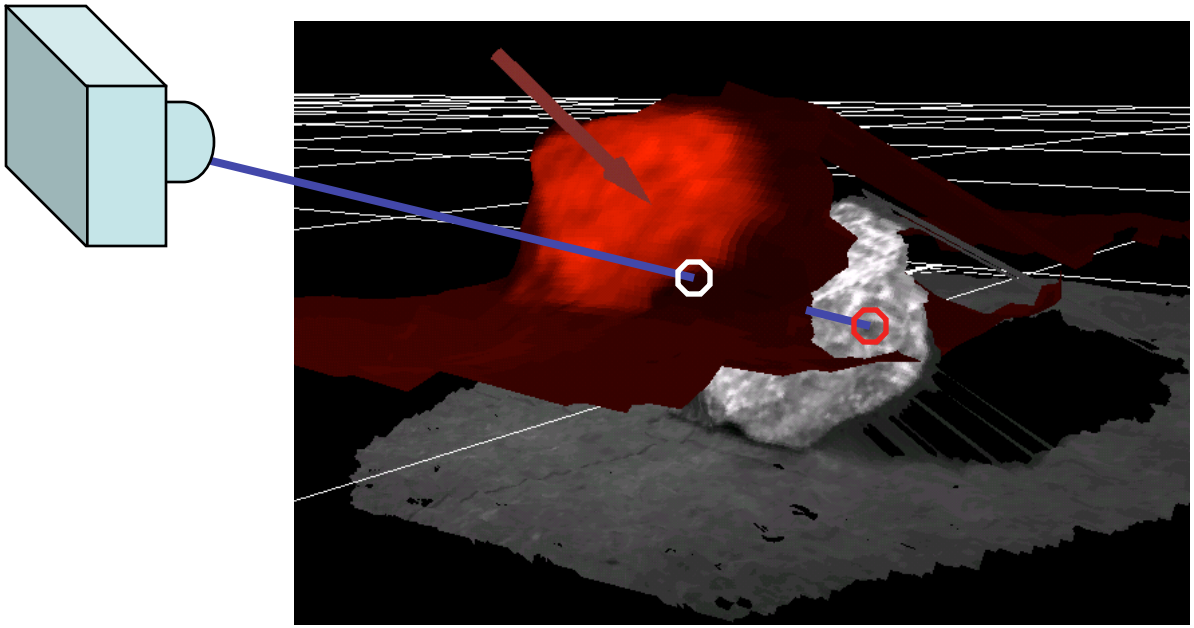
Used for navigation and handoff

Rendering



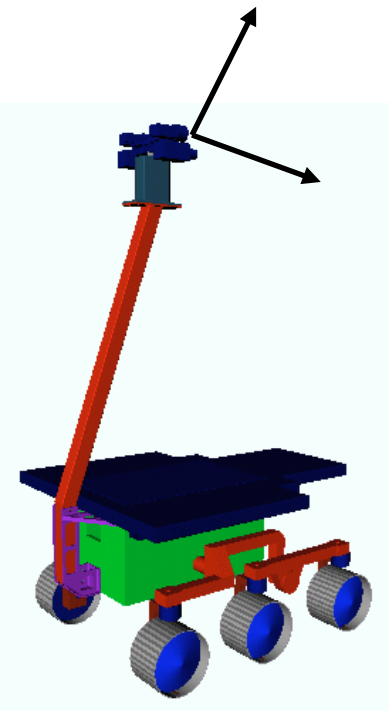
Project mesh vertices
Rasterize facets
O(N) algorithm

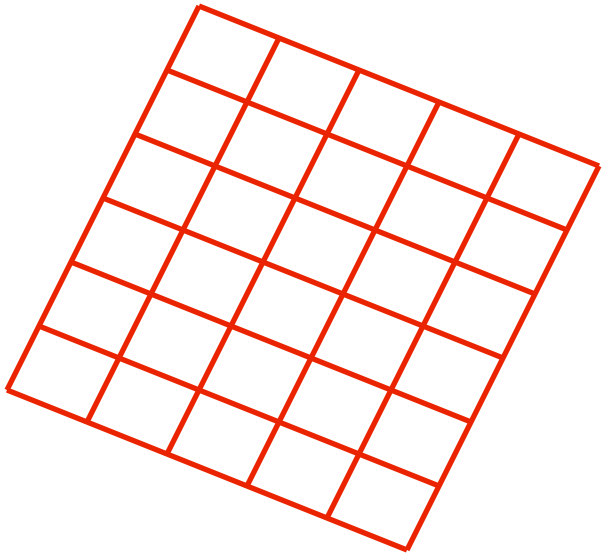
Correspondence



Handled by rendering
Correspondences and depth error in O(N)
No nearest neighbor search

Coarse match



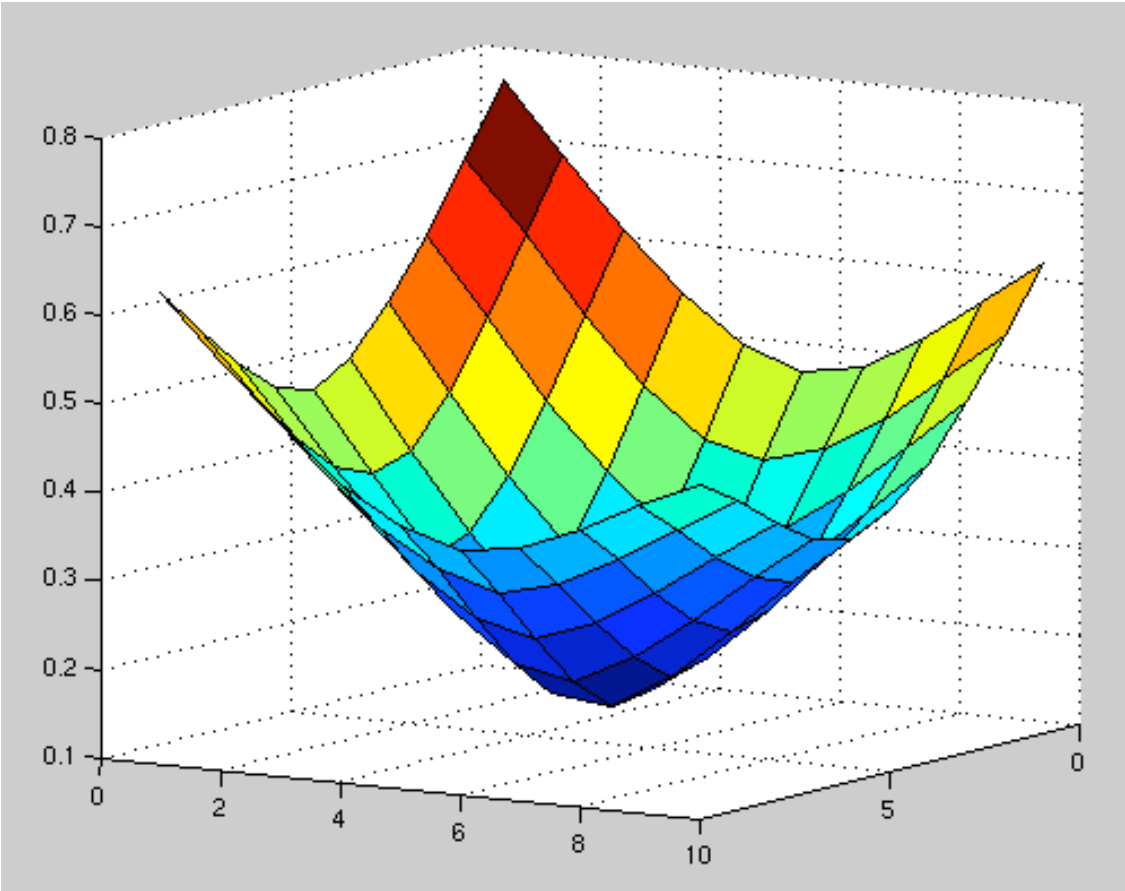


Approximate camera pose defines plane

Correlate range images

Discrete search in 2 DOF

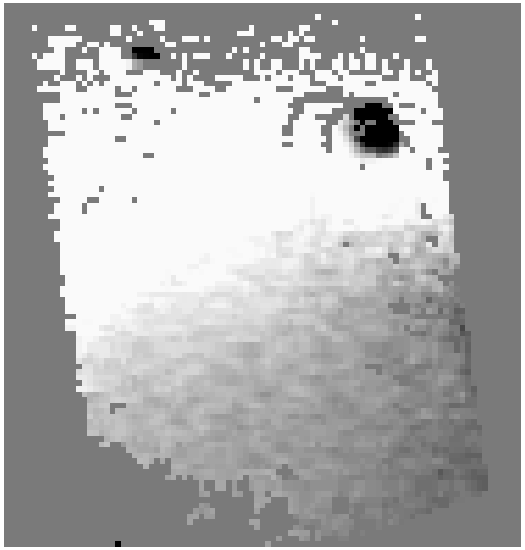
Coarse match



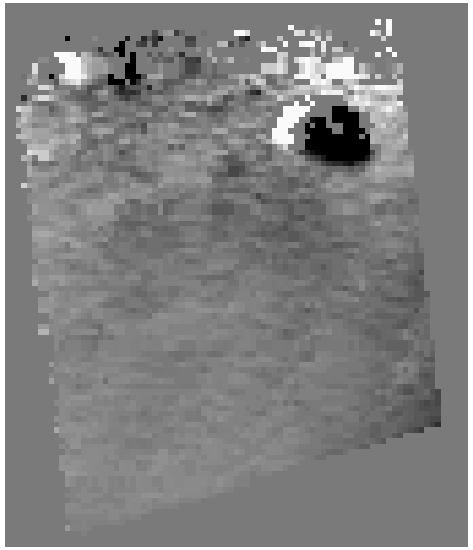
Minimum taken as coarse match

Fine match

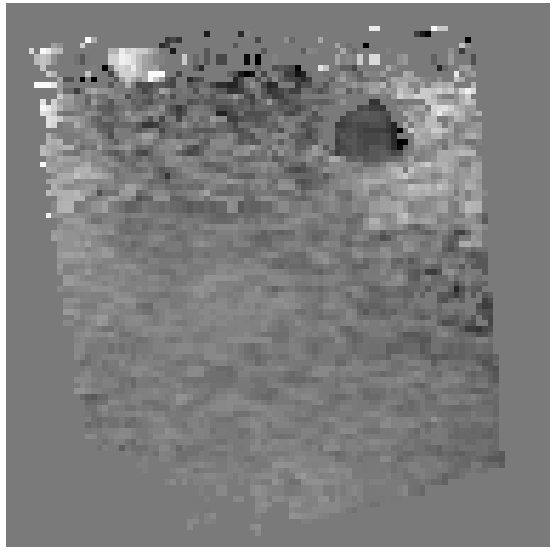
Directly minimize difference between range images



Initial error

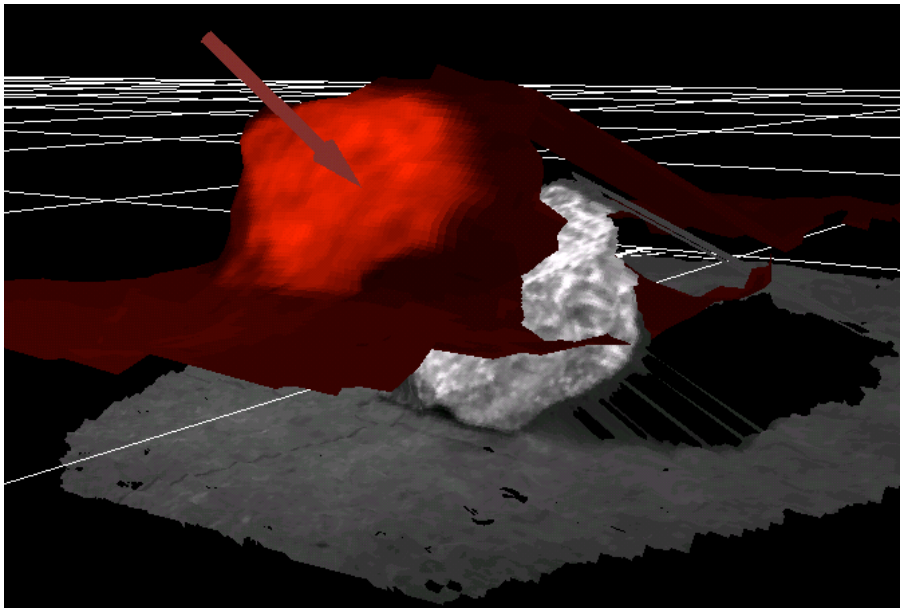


L_2 norm

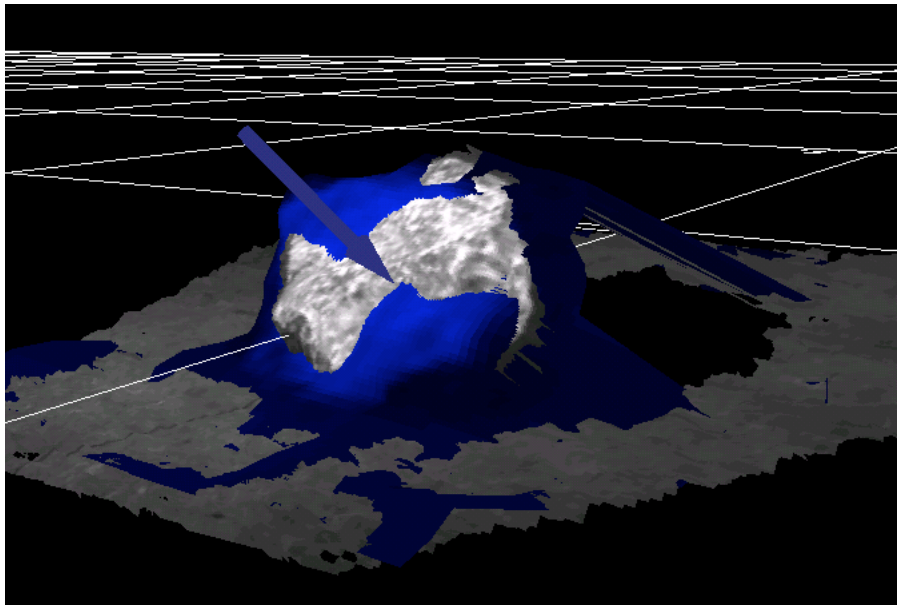


Huber norm

Result

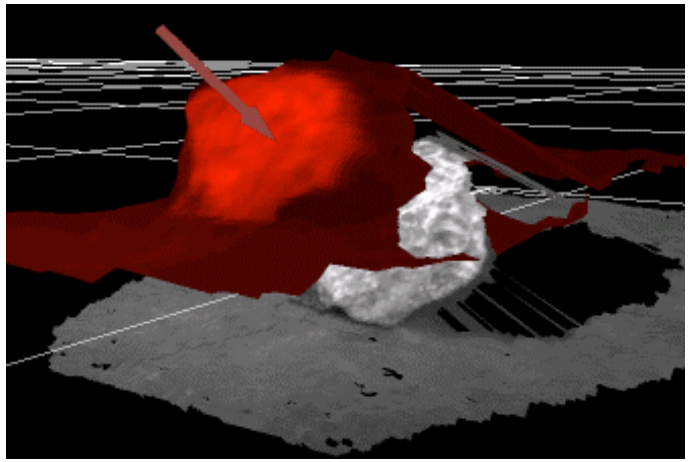


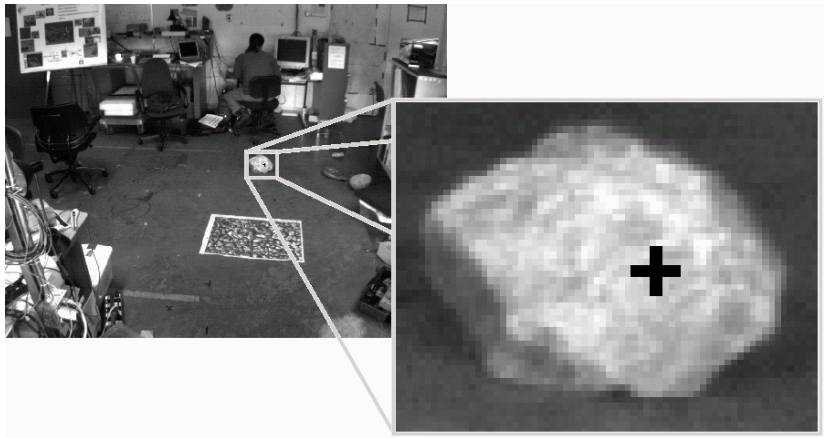
Before registration

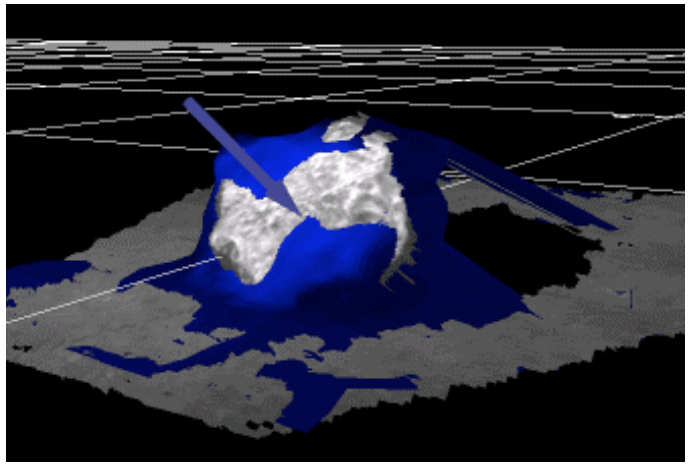


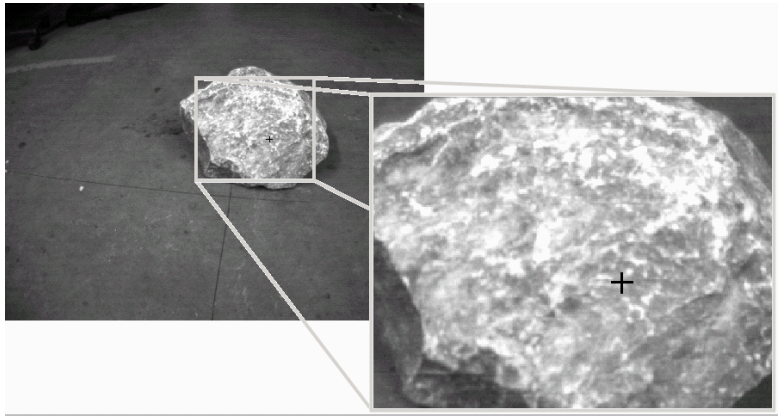
After registration

Result









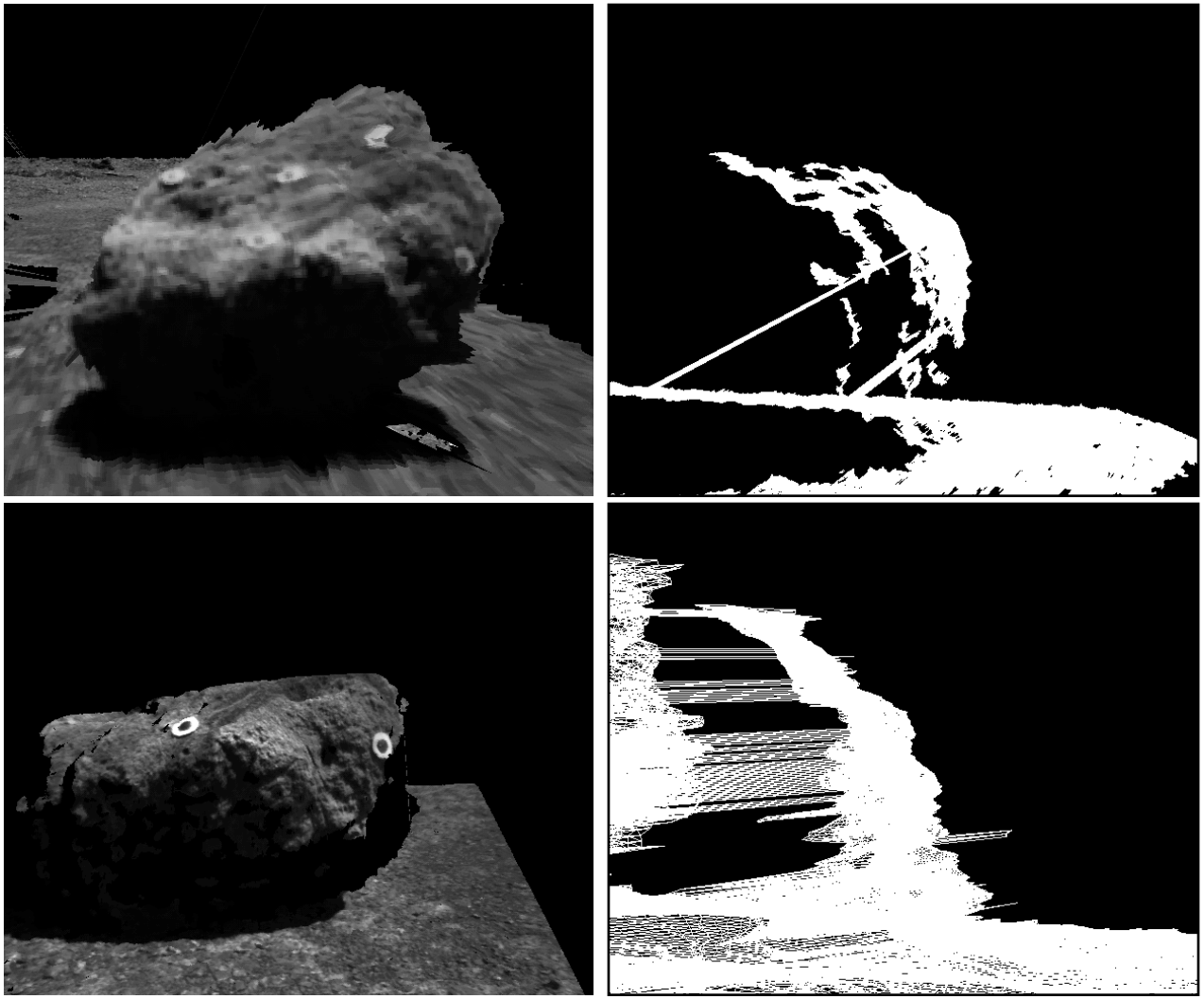
Navigation: 100% success in 10 trials

Computation: Registration is faster than stereo

Local target assessment

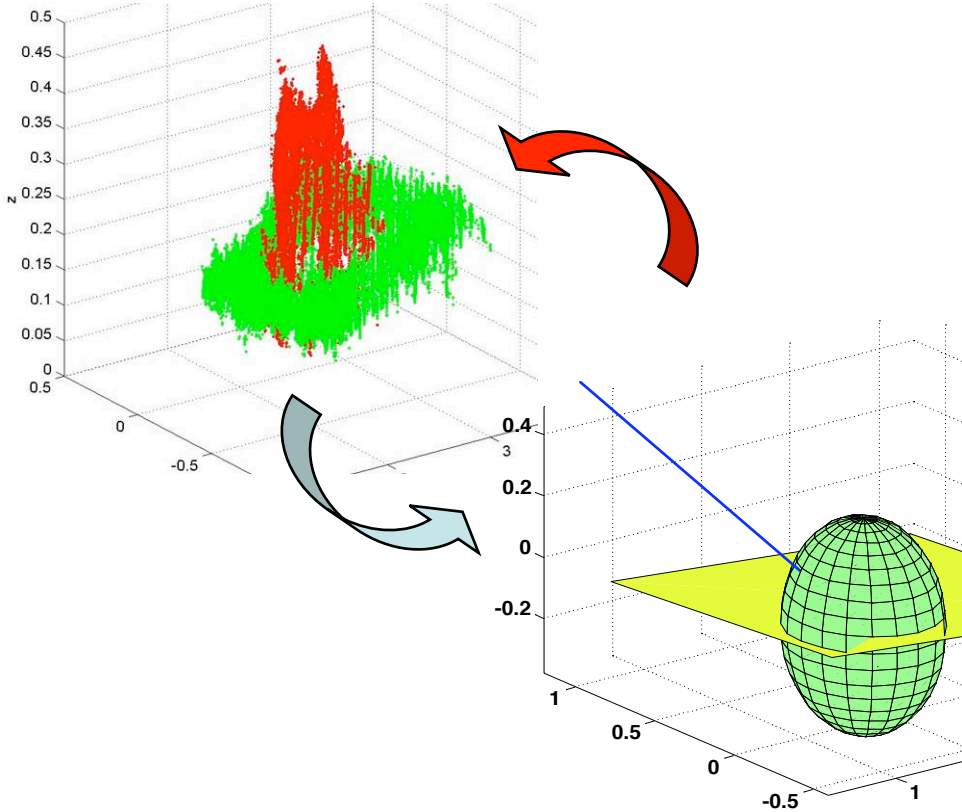
Science Camera (11 m)

Hazard Camera (1 m)



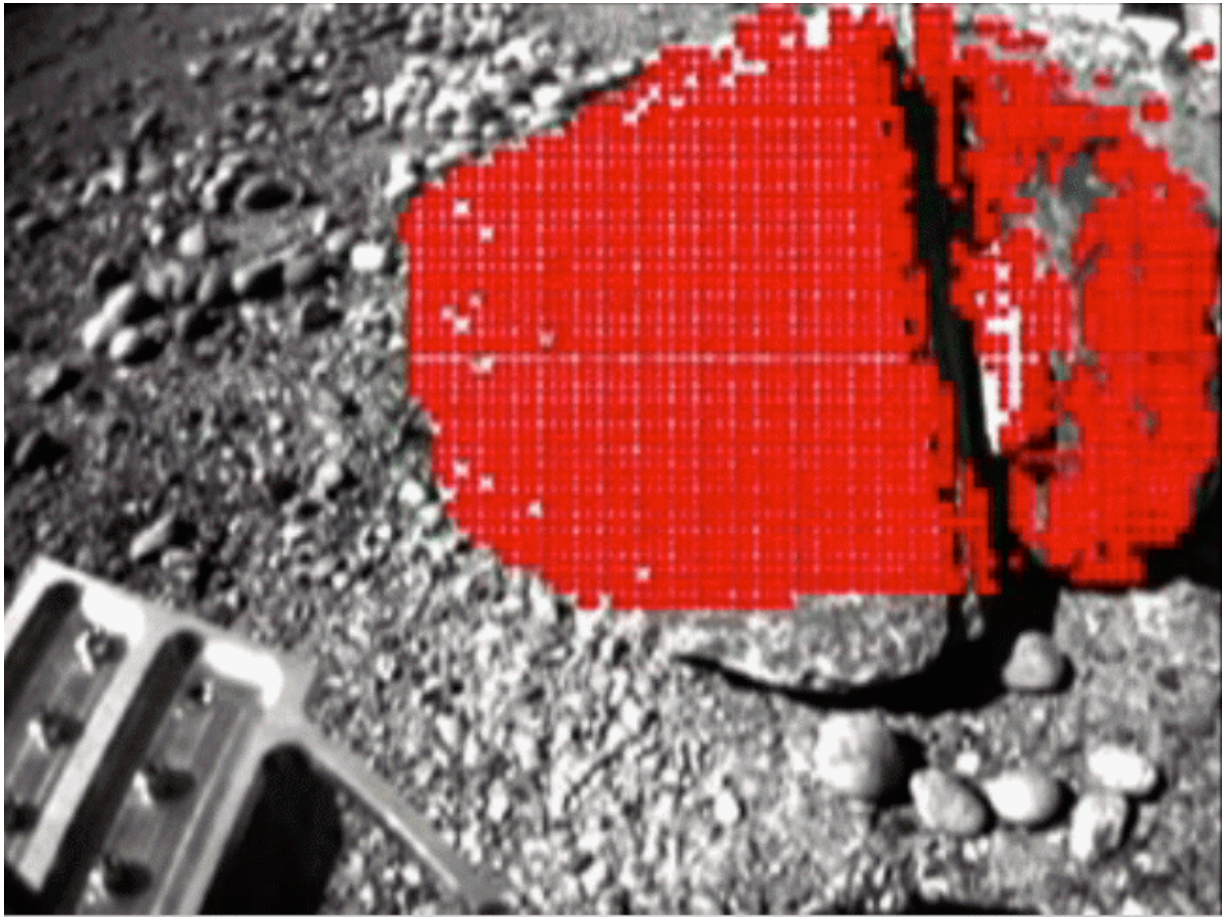
Segmentation

Two model classes
Rock: hemisphere
Ground: plane
Initialize parameters
Assign classes given parameters
Update parameters given classes
Iterate to convergence

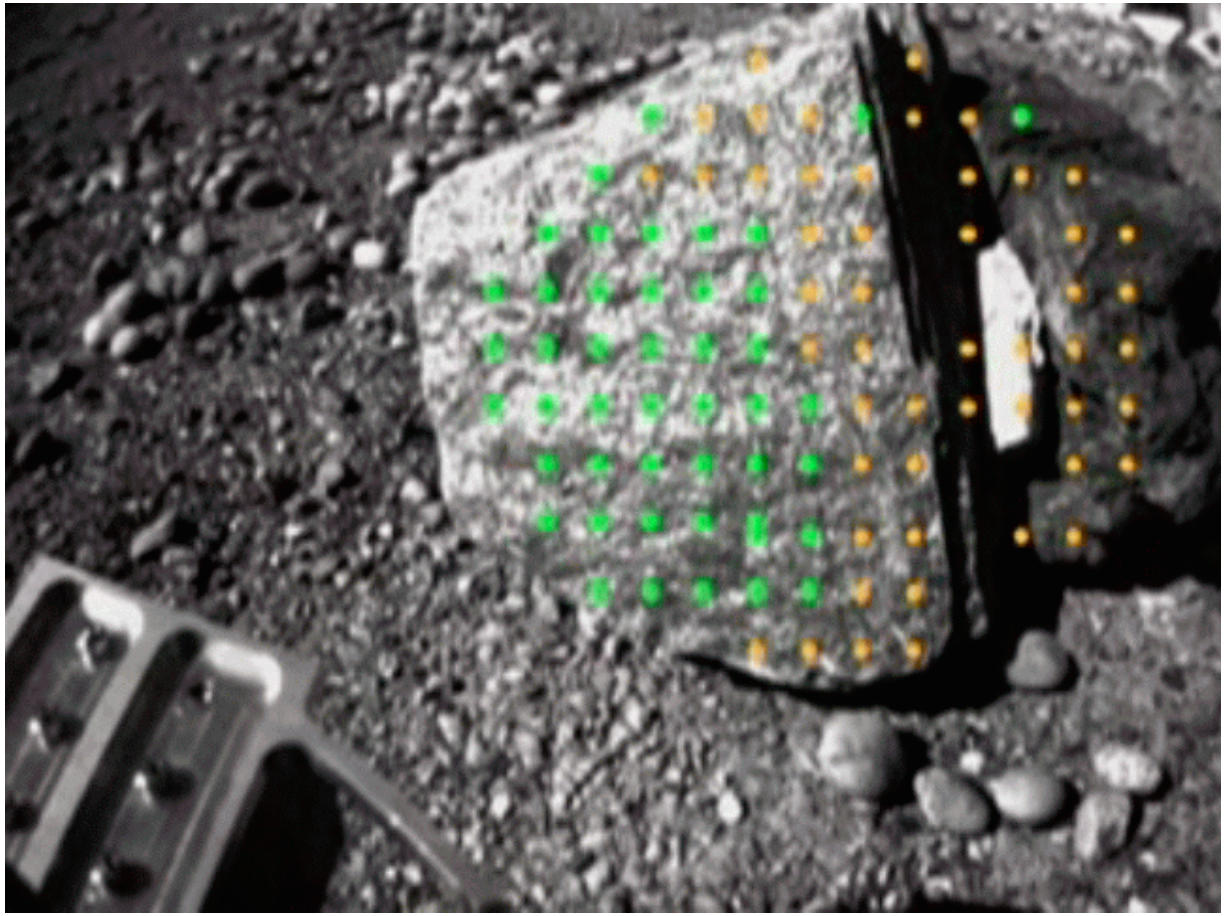


3D model

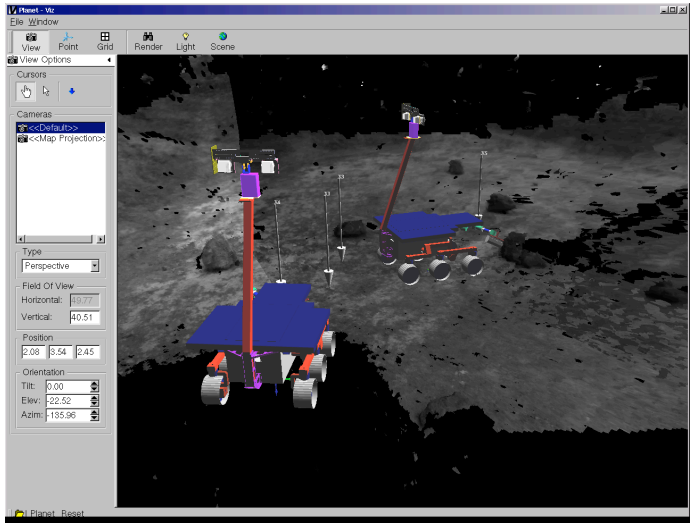
Segmentation



Identify “safe” region

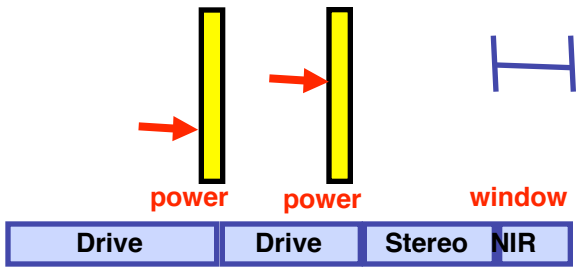


Cycle overview

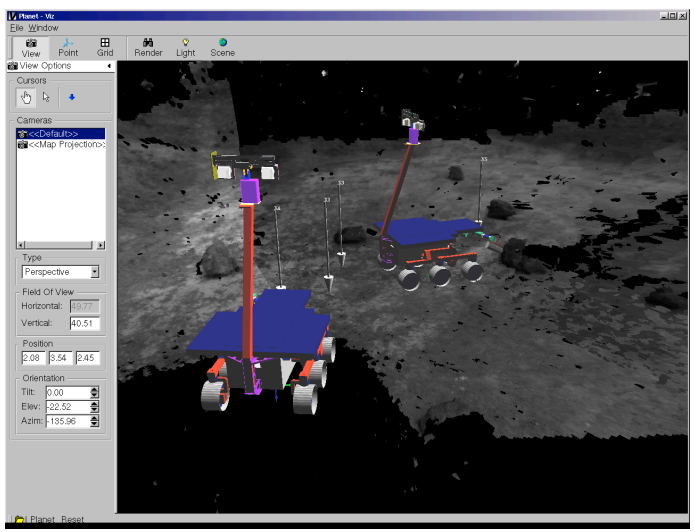


Feature selection

Cycle overview

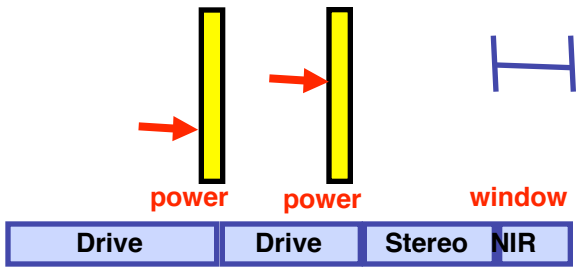


Contingent planner

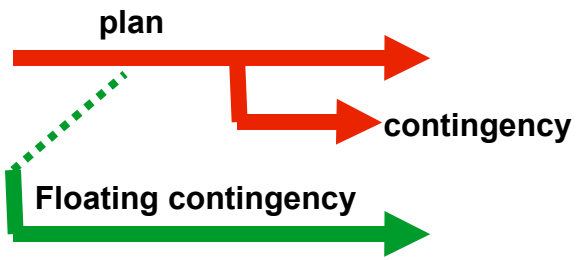


Feature selection

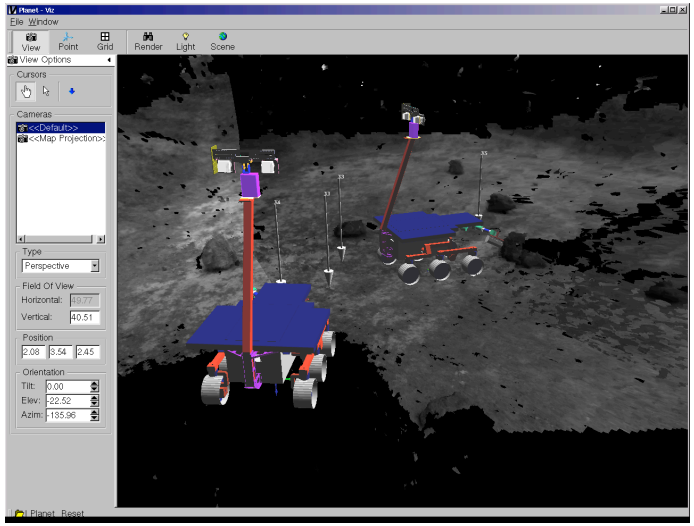
Cycle overview



Contingent planner

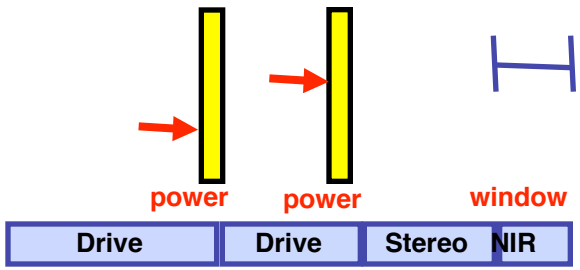


CRL Executive

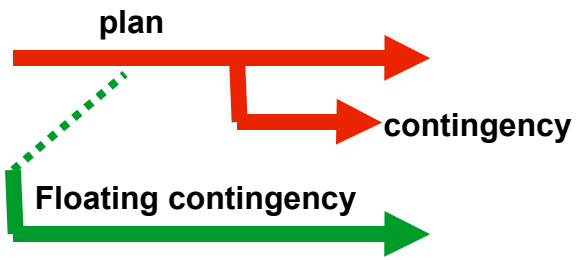


Feature selection

Cycle overview



Contingent planner



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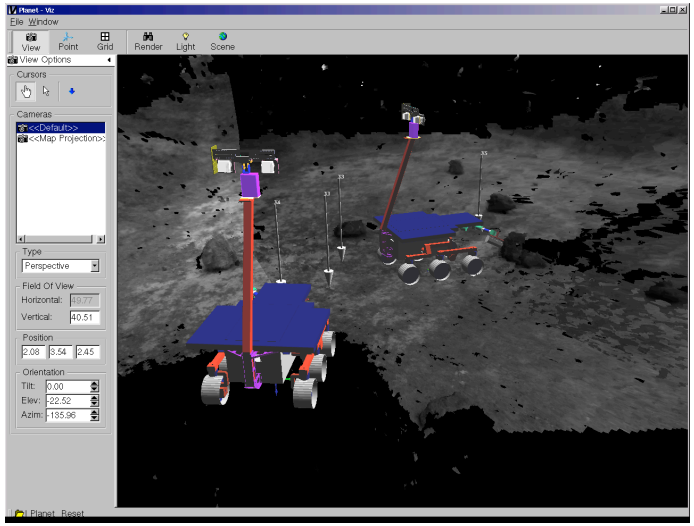
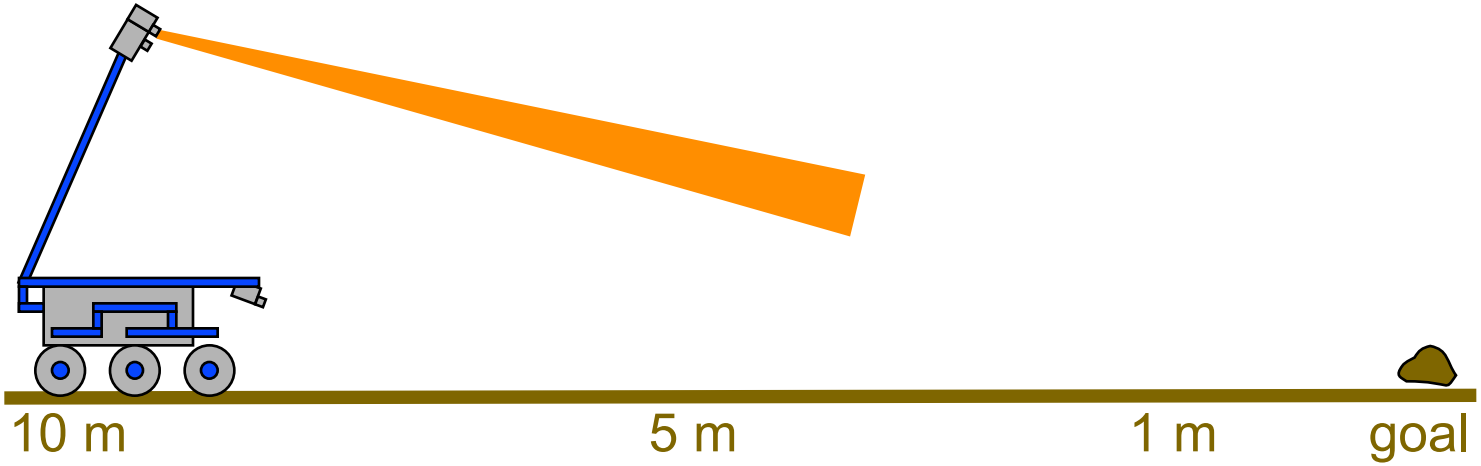


Feature selection

Approach and placement

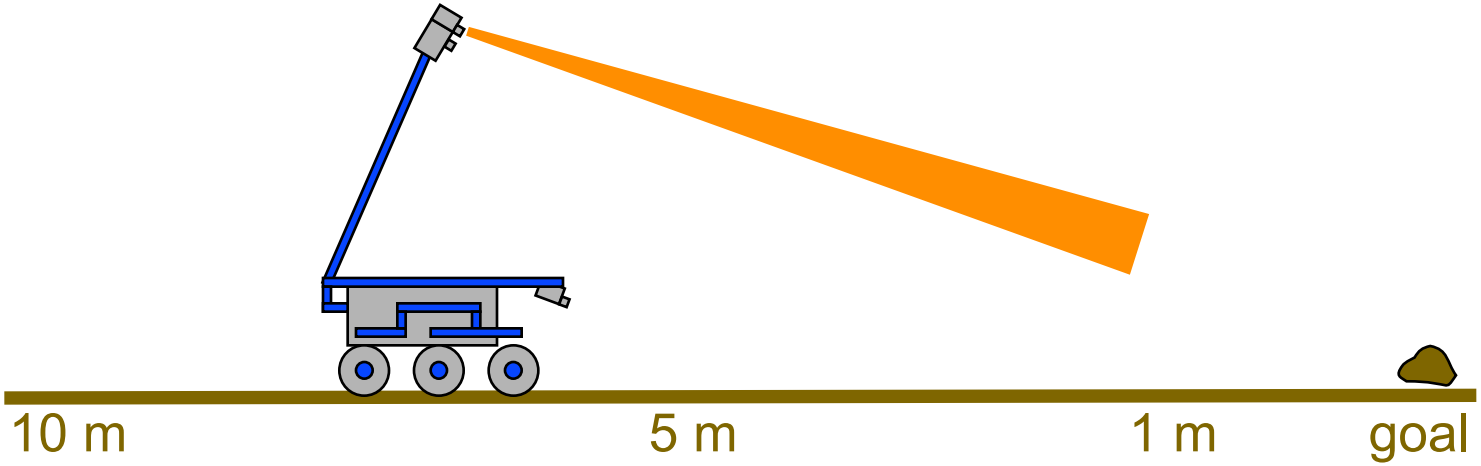
Target Approach



Startup

Get target model and goal point
Point scicams
Build and register model
Recover target location (scicam)

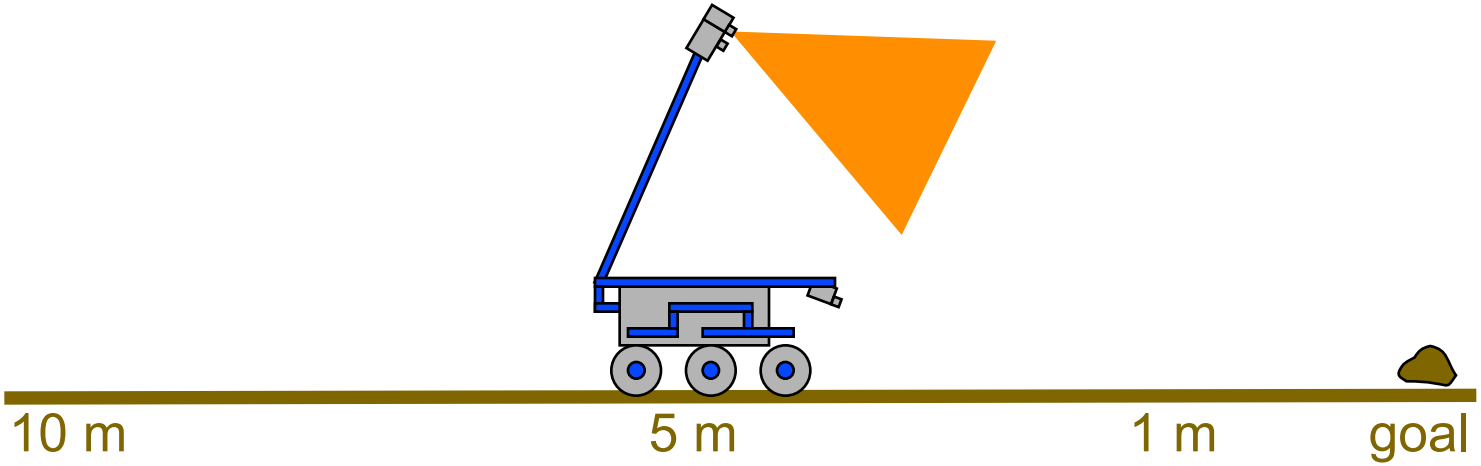
Target Approach



Scicam Tracking

Point scicams
Build and register model
Recover target location (scicam)

Target Approach

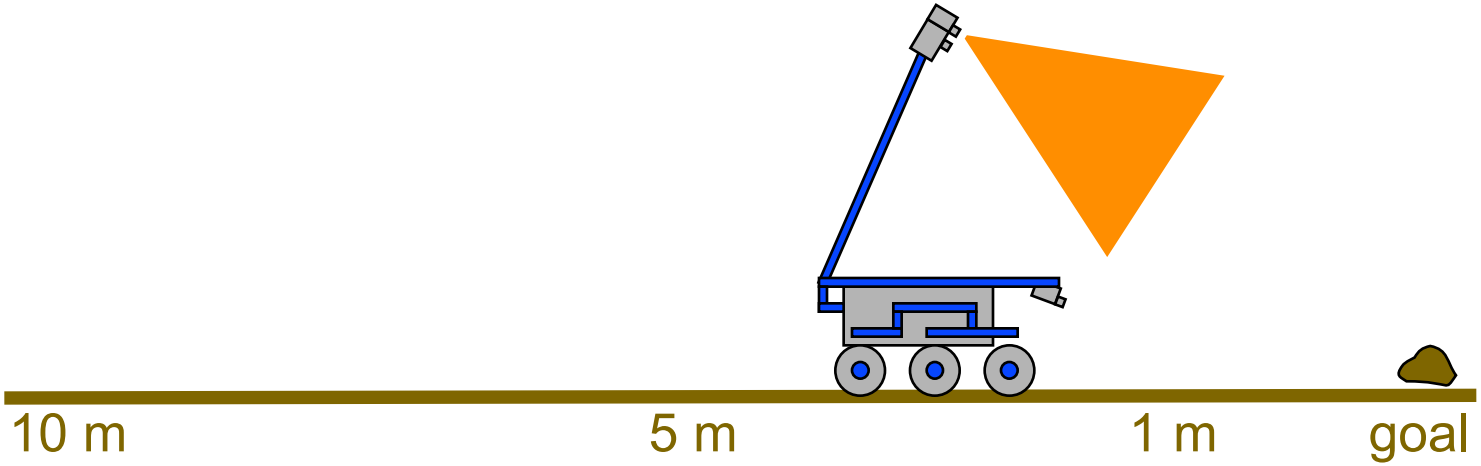


Scicam-Navcam Handoff

Point scicams to target
Build and register model
Recover target location (scicam)

Point navcams to target
Build and register model
Recover target location (navcam)

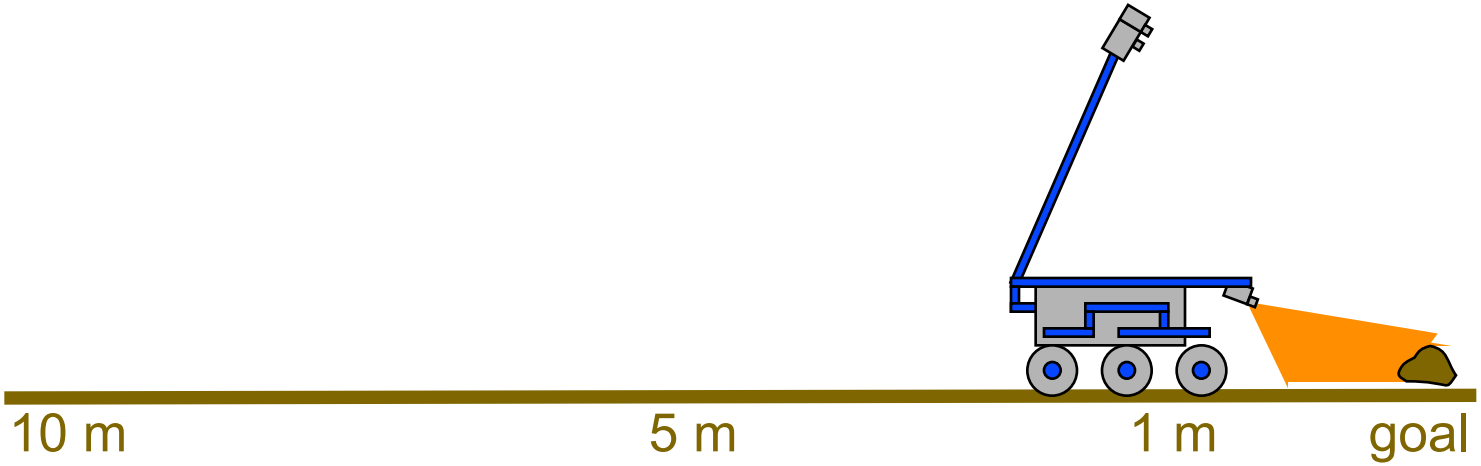
Target Approach



Navcam Tracking

Point navcams to target
Build and register model
Recover target location (navcam)

Target Approach

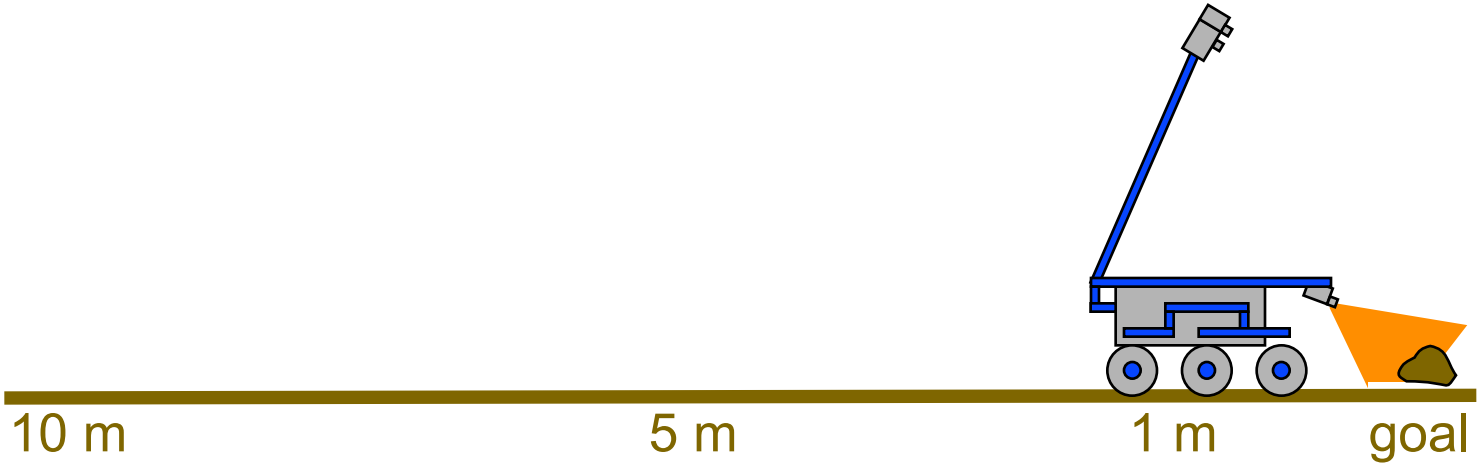


Navcam-Hazcam Handoff

Point navcams
Build and register model
Recover target location (navcam)

Acquire hazcam images
Build and register model
Recover target location (hazcam)

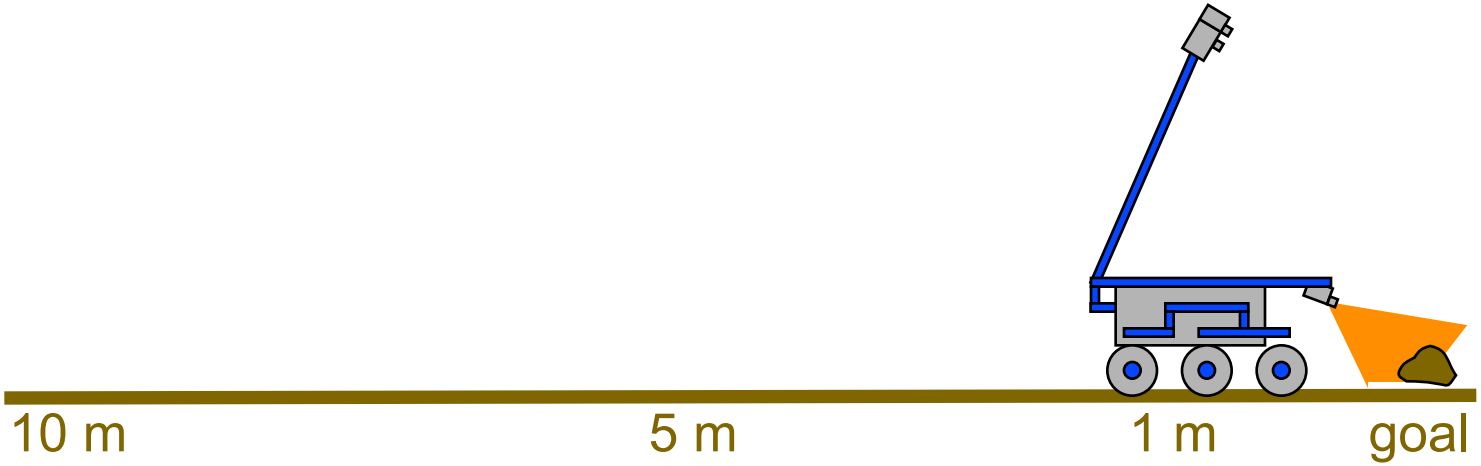
Target Approach



Hazcam Tracking

Acquire hazcam images
Build and register model
Recover target location (hazcam)

Placement



Placement
Build 3D model (hazcam)
Register model
Find goal point
Find closest safe point
Plan arm motion
Place instrument

Integrated Demonstration October 2003

3D interface for target selection

Planning for contingencies; flexible execution

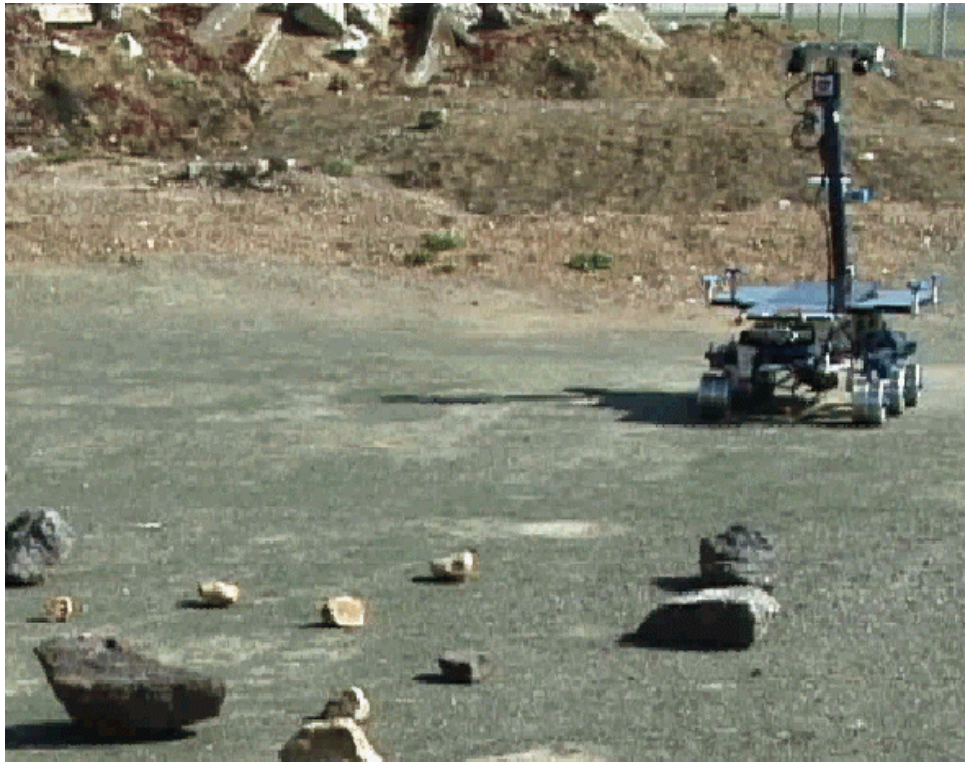
Opportunistic science

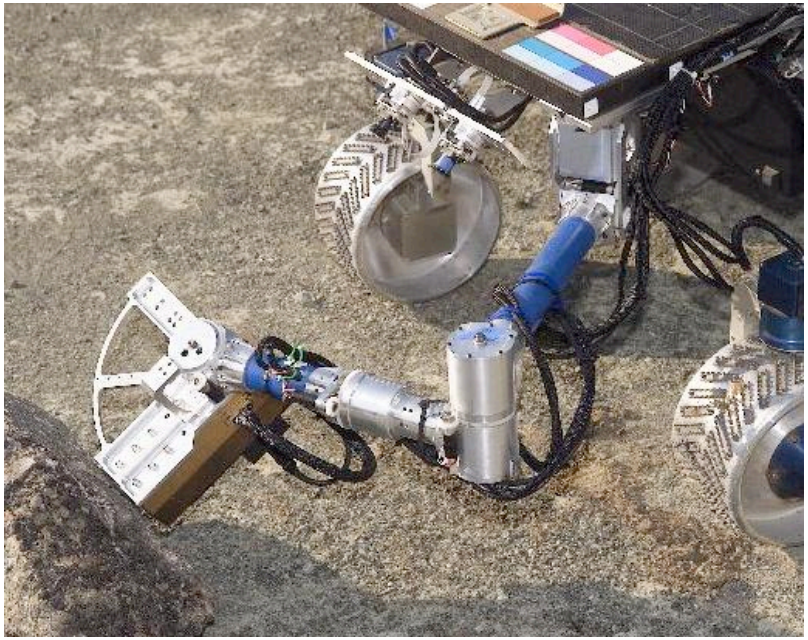
Tracking of multiple targets

Approach and placement up to 6m distant

Movie

Key contributions





Navigation
- Track multiple targets w/ stereo
- 10m
- < 1cm drift

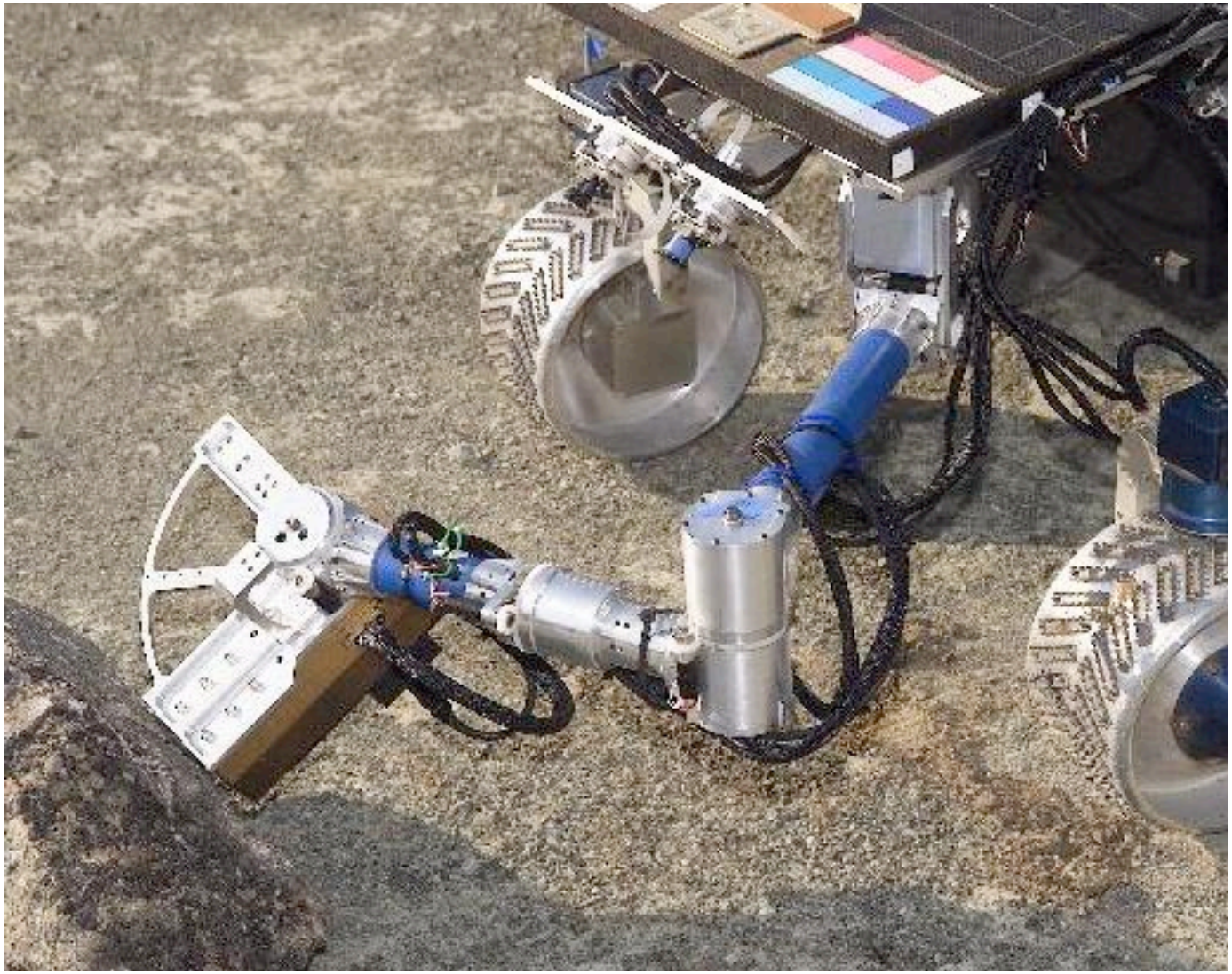
⇨

Hand-off
target between cameras

⇨

Placement
Find suitable location
Place instrument

Acknowledgements

- Single Cycle Instrument Placement:
  - Liam Pedersen
  - Randy Sargent
  - Matt Deans
  - Issa Nesnas (JPL)
- K9 Infrastructure:
  - Maria Bualat
  - Anne Wright
  - Clay Kunz
  - Eric Park
  - Susan Lee
  - Linda Kobayashi
  - Hoang Vu
- Viz:
  - Larry Edwards
  - Dave Lees
  - Judd Bowman
- CRL Exec:
  - Rich Washington
  - Howard Cannon
- Contingent Planner:
  - Dave E. Smith
  - Sailesh Ramakrishnan
  - Nicolas Meuleau
  - Tania Bedrax-Weiss
  - Conor McGann
- ARA
  - James Crawford
  - Nicola Muscettola
- IS Program
  - Bob Morris
  - Butler Hine
- Mars Technology Program
  - Rich Volpe

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