Target Tracking, Approach, and Camera Handoff for Automated Instrument Placement

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Goal

- **Target designation (from 10m)**
  - Using a mast camera panorama
  - Select a rock, outcropping, etc.

- **Approach (10m-2m)**
  - Navigate to the target, avoiding obstacles
  - Track the target from the mast cameras

- **Camera Handoff (2m)**
  - Project from mast camera to body camera

- **Instrument Placement (2m-contact)**
  - Refine the rover position so the target is in the arm workspace
  - Place the instrument on the target
Motivation

- **Mars Exploration Rover (MER) (2003)**
  - Requires at least 3 communication cycles to approach a target

- **Mars Science Laboratory (MSL) (2009/2011)**
  - Increased science return

- **Mars Sample Return (MSR) (2013/2016)**
  - Decreased time on the surface
  - Selection and investigation of multiple targets before sampling
Target Designation

- Rover panorama
- Downlink
- Target selection
  - In Maestro
- Uplink

- Maestro
  - Science analysis and activity specification tool
  - Used on MER
Navigation

- Use front and rear stereo images
- Create a cell-based traversability map
  - Consider slope, roughness, and step height
- Evaluate potential arc motions
  - Local cost based on arc traversability
  - Global cost based on D* cost from arc endpoint
Tracking

- Move
- Estimate motion
- Point camera
- Coarse match
  - Normalized cross correlation
  - On subsampled image
  - Template updated every cycle
- Fine match
  - Solve for affine parameters
  - At multiple pyramid levels
  - Template updated periodically
- Triangulate target
  - Use for pointing and error detection
Camera Handoff

• **Kinematic projection**
  – Requires well calibrated cameras and small pointing error
• **Stereo Image Based**
  – Project target template to body cameras
  – Match using correlation

View from mast camera

Mast view projected to body view

View from body camera
Results/Conclusion

• Tracking accurate to several pixels over 10m run
  – 0.25m-0.5m steps
• Handoff is currently largest source of error
• System performance is currently being evaluated and validated
• Currently working on handling approach and sampling on sloped terrain
End-to-End Video