National Aeronautics and Space Administration

SMALL BODY SHAPE ESTIMATION VIA EXTENDED TARGET TRACKING

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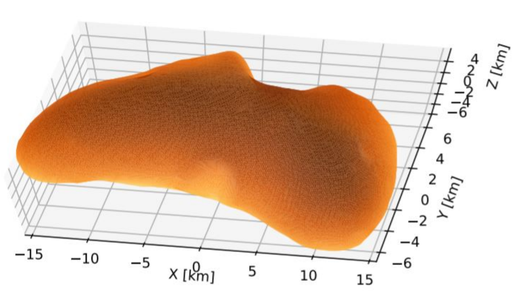
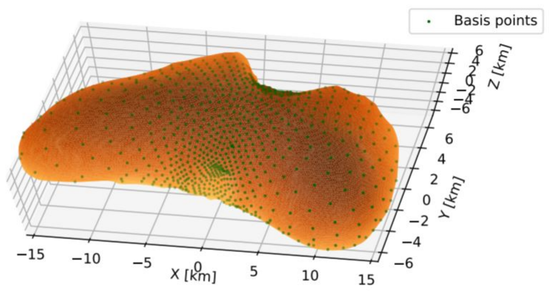
Program: SURP

Project Objective:

The objective is to demonstrate the use of Gaussian Processes and Extended Target Tracking to reconstruct shape and pose of a small celestial body.



(a) Truth



(b) GP

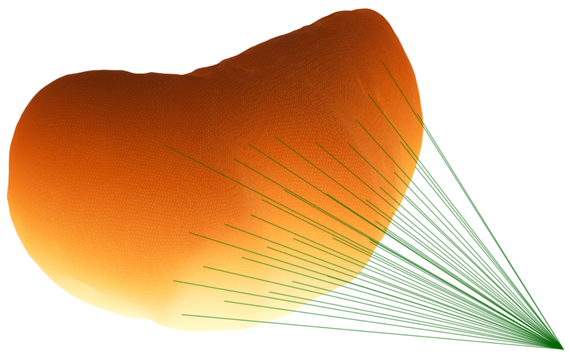
FY18/19 Results:

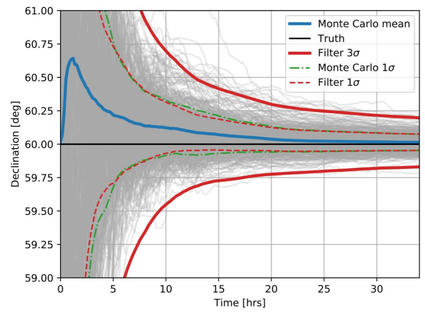
- We used Extended Target Tracking and Gaussian Processes to estimate shape and pose of a small body, with known (with some noise) S/C position and attitude
- A Gaussian Process provides a continuous parameterization of the shape and of the corresponding uncertainty
- We use LIDAR as proof of concept, and then synthetic optical cameras (using silhouette data), on Eros

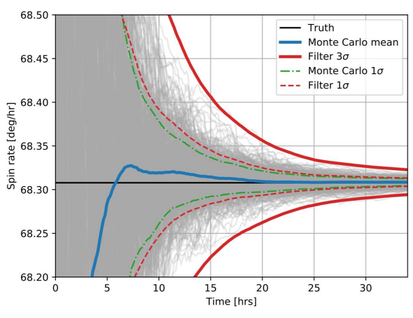
- LIDAR:
  - 500 runs, convergence with standard deviation initial uncertainty of 15% spin rate, 20 deg orientation, 500 m in asteroid center position, 100 m in S/C position estimate
  - Average error of 100 m (about 1%)

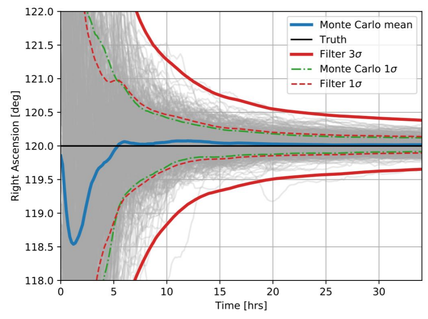
- Silhouette:
  - 25 runs, convergence with standard deviation initial uncertainty of 5% spin rate, 5 deg orientation, 250 m in asteroid center position, 100 m in S/C position estimate.
  - Average error of about 600 m

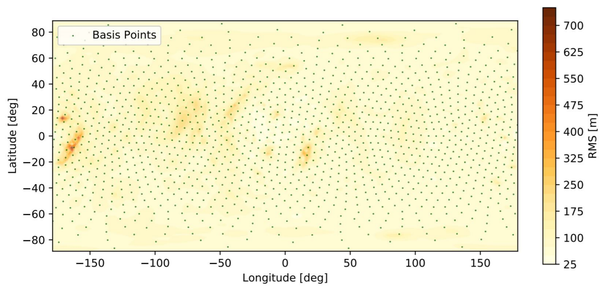
Lidar Approach



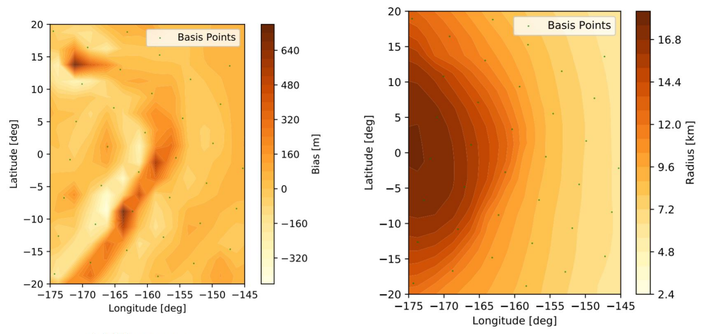






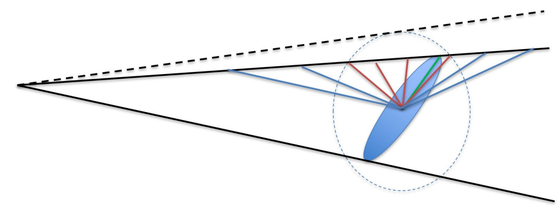


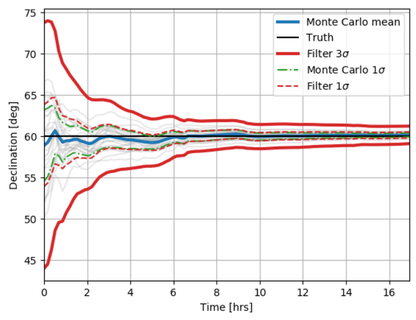
(a) Mean error

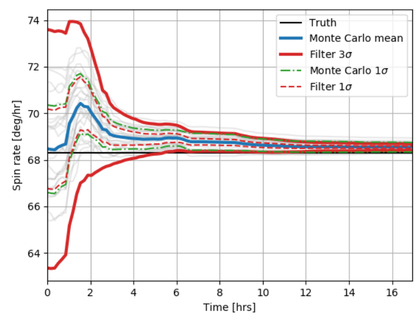


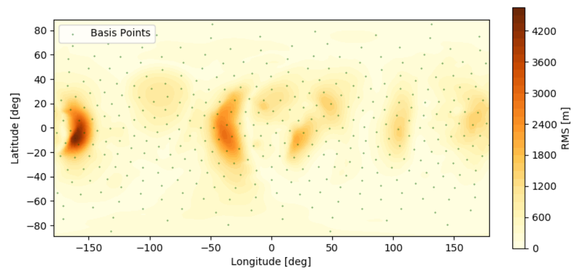
(b) True asteroid radius

Silhouette Approach









Benefits to NASA and JPL (or significance of results):

- Current SOA for shape modeling is Stereo-Photoclinometry, a powerful but very operator intensive method for creating shape models.
- Future missions to small bodies that rely on autonomy need robust methods that are implementable onboard to accomplish shape modeling.
- Extended Target Tracking methods described here show promise in initial tests to perform shape modeling with in situ data.
  - Lidar data shows good ability to compute continuous surface representation of small body with simultaneous estimation of spacecraft pose.
  - Preliminary results show promise for silhouette approach, which is preferred for long distance initial surveys of small body before initiating proximity operations.

Publications:

•"Shape and Pose estimation of a Small Body via Extended Target Tracking", Enrico M. Zucchelli, Brandon A. Jones, Ryan P. Russell, 2019 AAS/AIAA Astrodynamics Specialist Conference, Portland, ME

•"Autonomous Optical Estimation of Spin and Shape of a Small Body via Gaussian Processes", Enrico M. Zucchelli, Brandon A. Jones, Ryan P. Russell, Shyamkumar Bhaskaran, 2019, 2nd RPI Space Imaging Workshop, Saratoga Springs, NY.

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