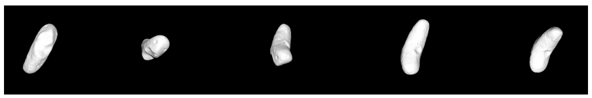
Autonomous Navigation at Primitive Bodies Using Optical Measurements

Principal Investigator: Shyamkumar Bhaskaran (392); Co-Investigators: Brandon Jones (University of Texas at Austin), Ryan Russell (University of Texas at Austin), Enrico Zucchelli (University of Texas at Austin)

Program: FY21 SURP **Strategic Focus Area: GNC and Mission Design**

Objectives

The primary technical objective of this work is to develop an approach to relative-state estimation using optical navigation and a Gaussian process for the body's shape.



Background

The current state-of-the-art technology for navigation and mapping is stereophotoclinometry, requiring:

- a large ground team,
- radiometric and optical data,
- substantial computational power

Exploit silhouettes for onboard navigation and mapping

- can achieve sub-pixel accuracy, and are easy to extract.
- cannot provide the exact shape of the body, but only the visual hull [1].

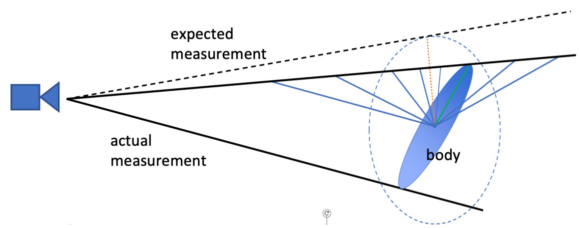
Silhouette extraction

Approach

- Primitive body treated as a single target; solve an Extended Target Tracking (ETT) problem [2].
- A two-dimensional GP [3,4] is used to represent the shape of the body.
- An EKF is used to simultaneously estimate relative position and velocity of the target, its spin axis and rate, and its shape.
- Shadows removed by taking the Sun angle into account.

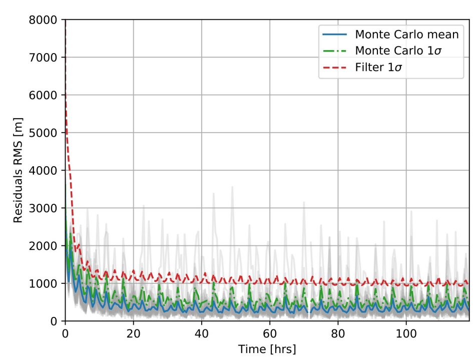
Mission Scenario
Approach to 433 Eros (34 x 11 x 11 km)
11 days of simulation
One update every 30 min
Start: 1000 km, no rel velocity, sun angle 0 deg
3 maneuvers

State	Initial 1 σ
Position	17 km
Velocity	8 cm/s
Spin rate	6 deg/hr
Spin axis	7.5 deg

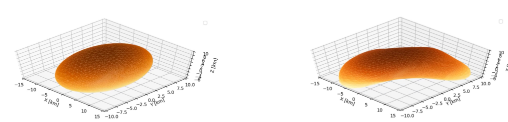


Results

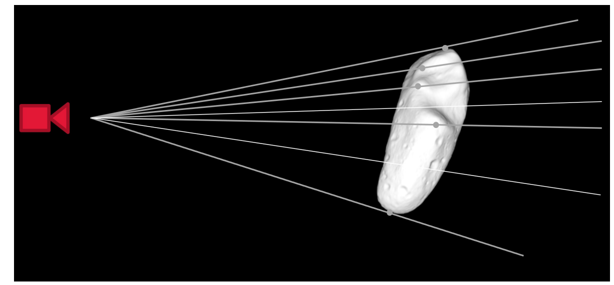
- We apply this filter to the approach phase to 433 Eros.
- Tested for 50 Monte Carlo runs (see plots).
- The estimated relative position is accurate for the angular direction, but the three maneuvers are not sufficient for the filter to converge in the depth direction.

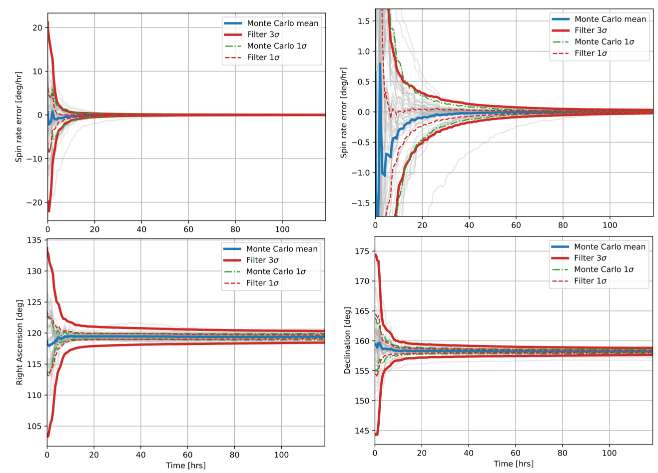


Residuals in the shape estimate



Shape estimate after 1 measurement (left) and after 50 measurements (right)





Spin-rate (top left), spin-rate zoom (top right), right ascension (bottom left) and declination (bottom right)

Future Work

- Make the filter more robust in estimating depth.
- Further analyze convergence regions

Significance/Benefits to JPL and NASA

- Current SOA for shape modeling is Stereo-Photoclinometry, a powerful but very operator intensive method, that requires radiometric data.
- Future missions to small bodies that rely on autonomy need robust methods that are implementable onboard to accomplish shape modeling
- We demonstrate that the shape can be reconstructed from a silhouette from early approach images of an asteroid

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

PI/Task Mgr Contact
Email: Shyamkumar.Bhaskaran@jpl.nasa.gov

Clearance Number:
RPC/JPL Task Number: SP21018