Using Bayesian Optimization to Find Asteroids' Pole Directions

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Finding the Rotation State

- Pole direction: What part of the sky does the rotation axis point toward?
  - Defined by **ecliptic longitude** ($\lambda$) and **latitude** ($\beta$)
- Need to know that to do shape modeling properly
Old-Fashioned Grid Search

Choose all test points before starting each set of models.

But usually, run multiple sets.

Bayesian Optimization on a Plane

Test on (162421) 2000 ET70 (Raïssi et al. 2016)
Bayesian Optimization on a Plane

We want to measure distance on a sphere

Test on (162421) 2000 ET70 (Raissi et al. 2016)
Bayesian Optimization in spherical coordinates first considered by Carr, Garnett, and Lo (2016)

Test on (162421) 2000 ET70 with Spearmint (Snoek et al., 2012)

Bayesian optimization in spherical coordinates first considered by Carr, Garnett, and Lo (2016)
Old-Fashioned Grid Search

Test on 1981 Midas
Bayesian Optimization on a Sphere

Test on 1981 Midas with Spearmint
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Backup slides
Future Work

- Experiment with initialization settings and convergence criteria
- Use latest version of Spearmint
- Test more asteroids
- Write up paper
- Publish code and documentation
- Apply Bayesian optimization to other problems, such as thermal modeling
Bayesian Optimization (1D example)

Function for which we want to find the minimum

Expected improvement

From Adams 2014
Bayesian Optimization (1D example)

From Adams 2014
Bayesian Optimization

From Adams 2014
Bayesian Optimization

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Bayesian Optimization

From Adams 2014
Bayesian Optimization

From Adams 2014
Gaussian Processes

- GP is defined by its mean and covariance:

\[ f(x) \sim \mathcal{GP} (\mu(x), K(x, x')) \]

- **Mean function**
- **Covariance function**

Example covariance: Squared exponential

\[
k_{SE}(x_1, x_2) = h^2 \exp \left[ - \frac{(x_1 - x_2)^2}{2\lambda^2} \right]
\]
Gaussian Processes

- Prior (before observations):

From Roberts et al. 2012
Gaussian Processes

• After three observations:

From Roberts et al. 2012
Bayesian Optimization

Finding a minimum automatically, without human oversight

Red curve: Acquisition function

1D example; from Adam Cobb using GPyOpt