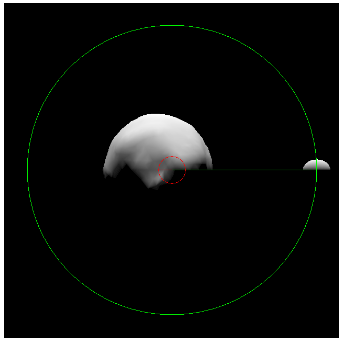
Determining the mass of Didymos' secondary by visual imaging

B. Grieger (Aurora Technology B. V. for ESA/ESAC)   M. Küppers (ESA/ESAC)

The wobble



A critical requirement for the Asteroid Impact Mission (AIM) is the determination of the mass of the secondary with an accuracy of 10 %. Here, we study the possibility to measure the primary's wobble by visible imaging. The wobble radius, which is expected to be about 10 m, is exaggerated 10 times in the illustration.

Assumed spacecraft trajectory

The assumed trajectory is linear with the distance varying between 10 and 7.07 km.

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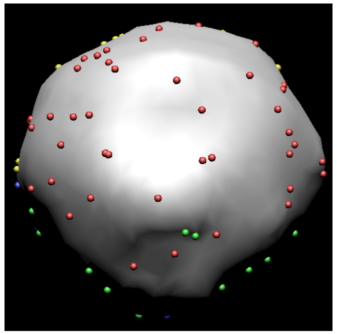
Randomly distributed landmarks



- ● visible and illuminated
- ● visible but not illuminated
- ● not visible but illuminated
- ● neither visible nor illuminated

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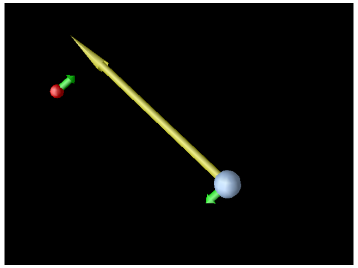
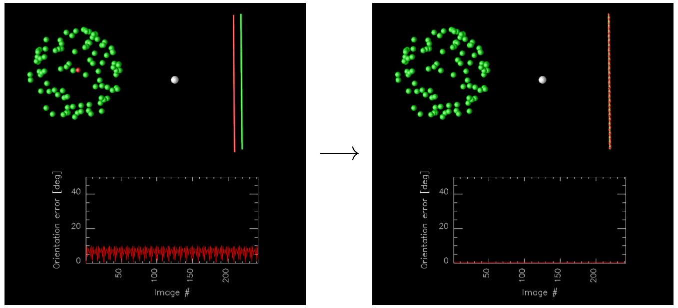
The retrieval algorithm

The simulated measurements are inertially referenced directions (yellow arrow) from the spacecraft (gray sphere) to the landmarks (red sphere).



We minimize the misfit by repeatedly looping through all time points and all landmarks and pulling them towards each other, perpendicular to the viewing direction. Cf. the panel to the right for asteroid orientations.

Optimization: initial to final state



Top left: True (green) and reconstructed (red) landmark positions in the body fixed frame. Note that initially all reconstructed position are at the origin (thus only one is visible) and finally they are overlaid by the true positions (thus none is visible). Top right: True (green) and reconstructed (red) trajectory relative to Didymos (white sphere). The final reconstructed trajectory comprises the wobble visible as coil. Bottom: Angular difference between reconstructed and true orientation of Didymos.

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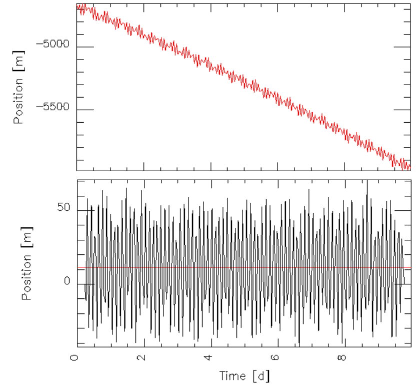
Reconstruction of asteroid orientations

1. Collect the desired shifts for all landmarks.
2. Fit a rigid rotation to all shifts (employing SVD).
3. Add that rotation to the current asteroid orientation.
4. Subtract the effect of that rotation from the landmark shifts.

Extraction of the wobble



The reconstructed trajectory (top, only x) comprises two wobbles: one from the gravity pull of the secondary (this is the one we are after) and another one because of the unknown center of mass of the primary. We extract the former by smoothing the trajectory with the secondary's orbital period and subtracting that from the original, and then projecting the result onto the known wobble direction (bottom). The mean (straight red line) is the estimated wobble radius.

Example scenario

Inputs	
Dist.[km]	7.07
# images	242
# landmarks	100
Dir.err.[″]	60.00
Wobble [m]	10.88

Results	
Residuals [m]	2.19
LM error [m]	1.83
Orient.err.[°]	0.38
SC error [m]	14.11
Wobble err.[%]:	3.52

Supplementary website

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