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Optimizing initial asteroid orbit determination of Gaia with normal point calculation

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Part of the work of the Data Processing and Analysis Consortium (DPAC) of ESA's Gaia mission involves producing accurate astrometry of known asteroids as well as discovery of new asteroids in the Solar system (Mignard et al. 2007, Tanga et al. 2016).

A basic unit of Gaia asteroid observations is called a transit, which comprises several positions of a moving target during the passage of the appropriate part of the sky by Gaia. Each transit comprises 4-10 observations. Transits are then bundled together to comprise a set of observations. From these observations, a swarm of possible orbits is calculated by an orbital inversion method called random-walk statistical ranging (Muinonen et al. 2016). The short-term processing of asteroid observations is dedicated to unknown objects. Orbits unmatched with known asteroids are then propagated for follow-up observations by ground-based observatories.

With the evolving of the short-term processing of the astrometry of Gaia, there has been an understanding that there is room for improvement in orbit calculation. A deeper understanding and use of various engineering data of the Gaia spacecraft (different attitudes) has yielded the necessity to split the observational errors into a systematic and random part. Previously, each point within the transit was treated as an independent observation. With the introduction of separate error sources this is no longer the case, since the systematic part of the error is common to all points within the transit. The uncertainties caused by the fluctuations of Gaia's attitude are a dominant factor in the systematic error. The fact that the time scale of fluctuations are of the same order as the duration of the transit make the systematic error a dominant factor.

Simple addition of systematic and random errors into combined covariance matrices may lead to near-singular matrices. We therefore propose an approach of collapsing all the points within a transit into a single normal point, calculated by the linear least-squares method at the mid-epoch of each transit. The random error of a normal point, calculated as the mean of all random errors within the transit, is then added with the systematic error for the entire transit. As a result, we expect to decrease the prediction area for follow-up observations for the majority of targets.

Gaia asteroid observations are comprised of several consequent short single observational arcs with varying systematic errors between each arc. The proposed method is particularly suitable for such cases. We anticipate that this method may be found helpful also for other asteroid surveys with cadences and error variabilities similar to Gaia.

References

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