

Orbit determination methods for space debris

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Agenda

- 1 Introduction
- 2 The asteroid identification problem
 - Space Debris applications
- 3 Telescope Observations Campaign

Acknowledgments

The work presented in this talk is by:

- Prof. A. Milani Comparetti, Dep. of Mathematics, Univ. of Pisa
- Dr. G. Gronchi, Dep. of Mathematics, Univ. of Pisa
- Dr. G. Tommei, Dep. of Mathematics, Univ. of Pisa
- The NeoDys-AstDys team

The project

- A collaboration has been established with the Celestial mechanics Group of the Dep. of Mathematics of the Univ. of Pisa, working since many years in the field of precise orbit determination, mainly for Near Earth Asteroids.
- A contract has just been awarded

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The background

The **identification problem**:

- an object (NEA, space debris,...) passes above an observing station and is observable for some short time (a **“pass”**);
- The observations of a given object during a pass are called a **Too Short Arc (TSA)**, also called a tracklet (or uncorrelated track in the space debris context)
- Data from a TSA are believed to belong to the same object, because they can be joined by some smooth curve (in most cases, simply a straight line, or a great circle)

The background - Identification

- The data from one TSA cannot allow for the determination of an orbit. E.g., if only two angular observations are available, as in the case of a trail, there are 4 equations in 6 unknown orbital elements.
- Thus it is not possible to solve **the orbit determination problem** without solving first the **identification problem**
- We have to find two or more TSA belonging to the same physical object (**linkage**) and an orbit fitting all the observations.

The background - Identification

Complexity

This problem has a very dangerous computational complexity, increasing at least like the square of the number of TSA, thus increasing very sharply with the size of the observable population, that is with the limiting magnitude of the survey.

For the new generation asteroid survey (Pan-STARRS) **the number of asteroids detection will range between 100 000 and 1 million per night!**

The background - Identification

Warning

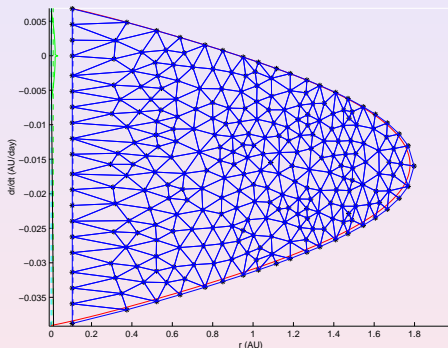
If the problem of identification is not solved, or not completely solved, then a significant fraction of the observational data remain locked in the TSA and have no practical use, apart from an approximate estimate of the population size.

Solution method

- **The Attributable** is a four dimensional quantity defined by two or more observations and synthesizing the useful information from a TSA (e.g., α , $\dot{\alpha}$, δ , $\dot{\delta}$).
- From the attributable an **Admissible Region** of orbits bound to the solar system (in the case of NEAs) is computed. The AR is a compact subset of the range, range rate half plane
- The admissible region can be sampled, e.g., by **an optimal triangulation**, generating Virtual Asteroids which can be used as alternate preliminary orbits.

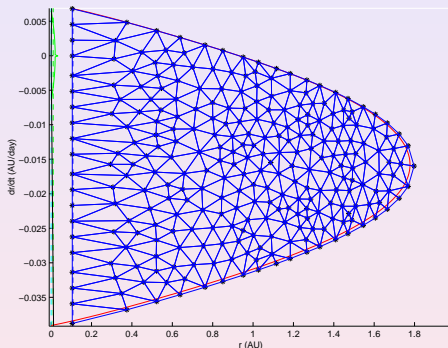
Solution method

- The admissible region can be sampled, e.g., by an **optimal triangulation**, such as the **Delaunay triangulation**.
- The triangulation generates dots in the plane that can be called **Virtual Asteroids** which can be used as alternate preliminary orbits.



Solution method

- First the **Virtual Asteroids** are propagated to the epoch of the second Too Short Arc
- Then a recursive procedure of identification and orbit determination is started.



Space debris application

- The same technique can be used for space debris.
- The definition of admissible region can be modified to contain the orbits belonging to the Earth's sphere of influence
- The theory takes essentially the same mathematical form, thus the same principles can be applied.
- A complete theory of the radar observations case would require some more significant work, but in principle is feasible.

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Planned telescope observations

A test run of observations has been planned at the **Campo Imperatore** telescope.

- 90 cm, Schmidt telescope;
- 52' × 52' Field-of-View, 2048 × 2048 pixel chip, thinned and back-illuminated, with high efficiency.
- The expected limiting magnitude for space debris is ≈ 18 , with 4 – 5 sec of exposure (for NEAs it is ≈ 20).



Planned telescope observations

- The first test run was planned for the beginning of January, but.....



Planned telescope observations

- The first test run was planned for the beginning of January, but.....
- Next try in April (waiting for the melting of the ice...)

