Report Research Activity

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This report summarises the activities carried out by the research fellow during the first six months of activity, from November 25th 2019 to May 25th 2020.

The research activity is supervised by Prof. Giovanni F. Gronchi and Phd Giulio Baù and it is related to techniques for Initial Orbit Determination (IOD) of space objects from observations. In particular it is focused computation of several asteroid orbits with the observations of the Isolated Tracklet File (ITF) available at the Minor Planet Center and the application of the IOD to asteroids and space debris.

This activity belongs to the European project Stardust-R and it is founded by an MSCA-ITN-ETN - European Training Networks (see `http://www.stardust-network.eu/` for more information).

Developments and work in progress:

During the first months of the project, we have mainly followed the work presented in the research papers of Orbit Determination with the two-body integrals I, II, III ([4] [5] [6]) and the book by A. Milani and G. F. Gronchi [3]. In particular, our work was focused on the use of the polynomial method (see [6]) with the aim of identify whether if two tracklets belong to the same observation and to construct a preliminary orbit (link2 problem) and similarly on the use of the method introduced in [7] with the aim of identify whether if three tracklets belong to the same observation and to construct a preliminary orbit (link3 problem).

To this purpose we have made use of the software Orbfit (`http://adams.dm.unipi.it/orbfit/`), introducing improvements in the implementation of said methods. In addition, thanks to the datasets provided by Robert Jedicke, these methods have been tested and analysed in various controlled conditions. For these datasets, we have found quite good results in terms of the total number of real identifications obtained.

Nevertheless, three problematics have been detected, in which we have already started to work on:

1. For big datasets, the total number of comparisons that are needed to be made with link2 or link3 is extremely big/huge. In order to fix this, the role of different (already) known filters have been analysed to avoid such a big number of comparisons. Some alternatives for these filters are also being studied.

2. The number of false positives, that is the number of cases for which link2 and link3 methods construct a preliminary orbit for tracklets that does not belong to the same object, is high. In order to reduce this number, some behaviour of some indicators are being analysed.

3. In some cases, we can achieve to construct a preliminary orbit for two tracklets that belong to the same object. When this is the situation, it has been seen that some solutions can be recovered by relaxing the tolerance for the solutions corresponding to the nine degree polynomial in link2.

With the aim of solving these problematics, besides of the previously mentioned techniques, we have also used, started to use and thought about using some works and tools, already existing, like Maruskin distance [8] for the orbital distance computation, the method epsilon GCD to have further information about the polynomial roots ([1] [2]) and the ML techniques, specially for problems 1) and 2).

Finally, we have begun the first tests with the ITF database. To do this we have had to analyse this database and manage with some problems that we found on it.

Activities:

I have attended to the following schools and workshops:

- Stardust-R Opening Training School, University of Strathclyde, Glasgow, 2-7 December 2019;
- I-CELMECH Training School, Università degli Studi di Milano, Milano, 3-7 February 2020;
- Stardust-R Training School II, Politecnico di Milano, Milano, 10-13 February 2020;
- Stardust-R Local Training Workshop I, organised by the Universidad Politécnica de Madrid and Deimos, 18-21 May 2020.

I have attended to the following course:

- Determinazione Orbitale, by Professor G. F. Gronchi;

References

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[3] Milani, A., Gronchi, G.F.: *The Theory of Orbit Determination.* Cambridge University Press, Cambridge (2010)

[4] Gronchi, G.F., Dimare, L., Milani, A.: *Orbit determination with the two-body integrals.* Cel. Mech. Dyn. Astron. 107(3), 299–318 (2010)

[5] Gronchi, G.F., Farnocchia, D., Dimare, L.: *Orbit determination with the two-body integrals. II.* Cel. Mech. Dyn. Astron. 110(3), 257–270 (2011)

[6] Gronchi, G.F., Baù G., Marò S.: *Orbit determination with the two-body integrals. III.* Cel. Mech. Dyn. Astron. 123, 105–122 (2015)

[7] Gronchi, G.F., Baù G., Milani A.: *Keplerian integrals, elimination theory and identification of very short arcs in a large database of optical observations.* Cel. Mech. Dyn. Astron. 127, 211–232 (2017)

[8] Maruskin J.M.: *Distance in the space of energetically bounded Keplerian orbits* Cel. Mech. Dyn. Astron. 108(3), 265-274 (2010)

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05/06/2020