Catmai

CATALOGUE BUILD-UP AND MAINTENANCE SOFTWARE

GMV's ***Catmai*** COTS software is a software application for the build-up and maintenance of resident space objects (RSO) catalogues. These catalogues of objects (and their associated information, like ephemeris, state vectors or manoeuvres) are stored in a relational database (for instance, GMV's ***Orca*** COTS software). It is capable of correlating and processing measurements from all types of SST sensors, for maintaining and building-up a catalogue of objects and their orbital information.

Catmai is able to manage at all levels of the processing survey and tracking data from the following types of sensors:

- Monostatic survey radar (like Spanish S3TSR radar)
- Bi-static survey radar (like French GRAVES radar)
- Tracking radars (like German TIRA radar)
- Ground-based optical telescopes (like ISON network and EU SST network)
- Ground-based satellite laser ranging stations (like GRAZ and ROA SLR stations)
- Space-based telescopes
- GEO ranging stations (like satellite operators stations)
- Passive ranging stations (like GMV's ***Focusear***)

Catmai cataloguing chain performs the build-up and maintenance of the catalogue of RSOs as shown in the figure below. When a new track arrives to the system, it first goes through **track correlation**, where the potential correlation of the new track against the existing catalogue objects is analysed. If this first correlation succeeds, then the new track belongs to an already catalogued object and therefore the corresponding orbit information is updated via orbit determination (OD) methods. However, if this first correlation fails then the track may belong to a potential new or manoeuvred object, meaning that it may correspond to one of the following sources, presented in order of decreasing frequency:

- **Operational satellites manoeuvres**: there are more than 900 operational satellites only in GEO, each of which perform orbit correction manoeuvres every week or two weeks. The number of satellites in LEO orbit is seven times bigger, most of which perform manoeuvres even more frequently than those in GEO orbit.
- **Satellites launches**: in the last few years, the number of launches has increased exponentially, growing up to more than 2000 spacecrafts launched in 2022.
- **Break-up events**: less than 10 break-up events happen per year.

The next step, corresponding to the most frequent source of potential new objects, is **manoeuvre detection and estimation** at observation level. In the event that a track is correlated to an existing object for which a manoeuvre is detected as part of the correlation, then the track does not belong to a new object. Instead the orbit information is updated at the same time as the manoeuvre is estimated. If no manoeuvres are detected, then the track goes through **track-association** with other uncorrelated tracks to check if they belong to the same new object. Should not the track be associated, it is not discarded but stored for future track association. The track association process is needed as the orbit that can be generated from a single track does not have enough accuracy to ensure proper correlation of future tracks, and thus it is necessary to associate the tracks in first place.

In the case of a potential new object detection, i.e. track associated with previous uncorrelated tracks, two additional checks are performed before adding the new object to the catalogue.

- **Duplicated object identification**, to avoid adding duplicated objects to the catalogue, via orbit-to-orbit correlation.
- **Manoeuvre detection and estimation on the orbit space**, via orbit correlation.

Apart from the processing of new tracks obtained from the sensor network, external catalogues, such as Space-Track's public TLE and/or SP catalogues, are used to identify the objects of the catalogue (e.g. assignment of NORAD Id) as part of an orbit-to-orbit **catalogues cross-correlation**.

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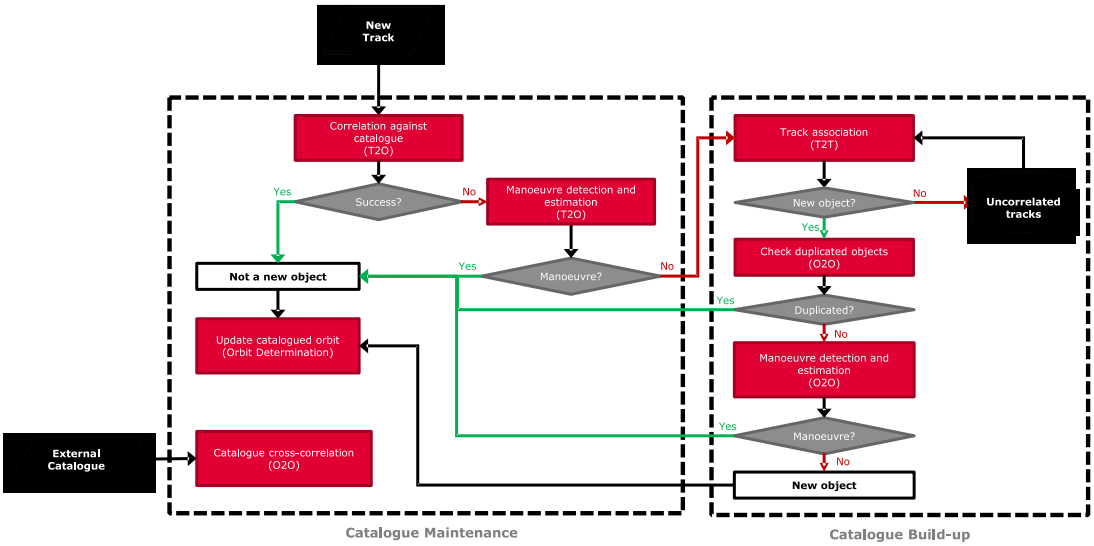

Figure 1: *catmai* cataloguing chain

The **track association** process performed by ***Catmai*** relies on the observations residuals to solve the data association problem. It consists of a **multi-step sequential filter** that uses initial orbit determination (IOD) and OD methods to evaluate associations of a certain number of tracks. Since there is no previous knowledge on the object orbit to which the measurements correspond, there is a huge number of possible combinations, growing with the number of tracks to the second power. That is why ***Catmai*** implements multiple complexity reduction techniques and filtering algorithms.

The **orbit correlation** process performed by ***Catmai*** consists on processing and storing the correlation information of all objects of the considered catalogues. This **history of the correlation** information is stored so that it is used for as much as need ensuring that two objects that used to correlate keep on correlating even if there is a manoeuvre not detected in one of the orbits. By including the result of previous cross-correlations, the stability of the correlation is improved and it is easier to correlate the orbit of a manoeuvring object when it has not been considered in one of the two catalogues. As an additional benefit of using the history of the correlation information, the solution of the correlation matrix is stabilised, preventing spurious correlations with different objects.

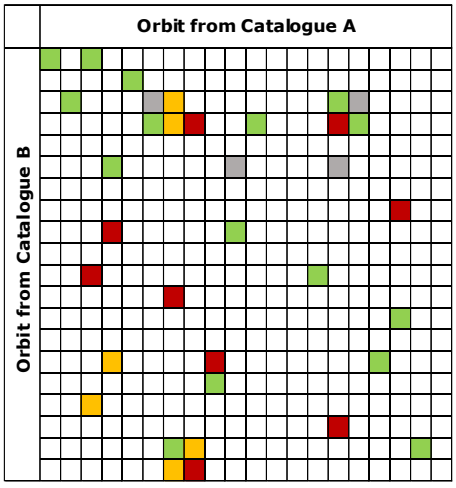

Figure 2: Orbit correlation process correlation matrix