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EFFICIENT SEARCH OF OPTIMAL FLOWER CONSTELLATIONS

Abstract

In a recent paper, we claimed that a reasonable slotting system for Low Earth Space (LEO) space can be obtained from a series of concentric Flower Constellations (FCs) with circular orbits, but orbit inclination and number of satellites varying between layers. The main constraint imposed to these FCs is that their dynamics must guarantee that no collisions can occur (i.e. the satellites are always separated by a given minimum distance) at any instant of time. Instead of using distances, we use angles between satellites, which are altitude-independent.

A FC is defined by three integer parameters: the number of orbits $N_o \geq 1$, the number of satellites per orbit $N_{so} \geq 1$, and a configuration number $0 \leq N_c < N_o$. It also requires the orbital elements of a reference satellite. In our case, we are interested in FCs with circular orbits, so only the orbit radius a and inclination i matter. Since we have also agreed on using the separation angle α_{min} instead of the actual distance between satellites, the parameter a plays no role. The only continuous paramenter of interest is the orbit inclination $i \in [0, \pi]$.

We propose to build a database of all possible FCs with up to a given number of satellites k, discretizing the inclination in l possible values. The number of such FCs is about $k^2 \cdot l$, each corresponding to a row in the database. The columns correspond to the parameters that define the FC and its corresponding α_{min}. For $k = 10^4$ and $l = 180$, this gives about 828 gigabytes.

Computing the value of α_{min} for a given FC is not an easy task. Our main result shows that it is possible to avoid propagating the position of satellites, and reduces the number of pairs of satellites that have to be checked to only $N_{sat}/2$. The total amount of computation is $C/2 \cdot k^3 \cdot l$, where C is the number of operations in certain closed formula. We have implemented this technique in OpenCL, and a preliminary result (on a laptop) shows that for $k = 2500$ and $l = 1$, the database can be computed in 2 minutes, which would scale to $2 \cdot 4^3 \cdot 180$ minutes (16 days) for the 828 gigabytes database corresponding to $k = 10^4$ and $l = 180$.

Our final result shows that FCs with even values for both N_o and the quantity $N_{so} + N_c$, accounting for 25% of the search space, always have self-collisions and can therefore be removed from the database. This further reduces the computation timeby a factor of 0.75.