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Abstract #
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Title
GNSS relative navigation for operations in cislunar space

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Abstract
In view of the upcoming Moon exploration, space agencies are developing communication and navigation systems in order to provide fundamental services to lunar transporters, orbiters, landers and rovers. One promising solution is to realize a lunar navigation satellite system similar in concept to GPS, GALILEO or GLONASS systems, but with reduced number of source satellites (down to as few as four satellites) in order to help or even substitute faint signals coming from Earth-based GNSS systems. It ahs to be remarked that, rather than a continuous global coverage, the specific goal will be to provide an acceptable performance at least in the most interesting lunar regions and in the part of the cislunar space closer to the Moon.
The simplified architecture of the lunar navigation satellite system is not purposely developed for allowing onboard orbit determination of vehicles bound to the Moon. However, it is possible to demonstrate that with the use of proper estimation algorithms, based on precise lunar orbit environment modeling, precious information can be obtained for on board navigation.
This paper shows that lunar navigation satellite systems performance could be further pushed for estimating not only the inertial position of an onboard receiver in a lunar reference frame, but also, and with a consistent accuracy, the relative position between two or more spacecraft in proximity. This could be the case of two spacecraft performing a rendez-vous, or of a lander released by an orbiter. It could be even the case of the permanent relative navigation service for a formation of satellites exploiting its mission around the Moon. In such a case, the presence of a lunar navigation satellite system could greatly help, as satellites of a formation are often mini- or even micro-satellite class, and they have strict limitations for on-board technology; this will be even more true for the case of a lunar formations. Therefore, it is meaningful to imagine that precise but power demanding technologies like laser ranging and image-based systems could be not available for relative navigation of lunar formations.
This paper mainly focus on the part of the space volume where the Moon can be considered as primary attracting body. At first, this contribution investigates the performance of a standalone lunar orbiter, and then considers the case of two or more orbiters flying in formation or two vehicles carrying on a rendez-vous manoeuvre. Nonlinear Kalman filters (in extended or unscented formulation) are employed to estimate the relative position and velocity of the spacecraft, providing a prediction in the (long) periods in which the navigation signal is not available, or insufficient number of signals is available. The performance in terms of error statistics, together with suggested guidelines for designing a reliable but computationally light estimation algorithms are the main outcomes of this research.