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Optimization of space orbits design for Earth orbiting missions

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ABSTRACT

In Earth orbiting space missions, the orbit selection dictates the mission parameters like the ground resolution, the area coverage, and the frequency of coverage parameters. To achieve desired mission parameters, usually Earth regions of interest are identified and the spacecraft is maneuvered continuously to visit only these regions. This method is expensive, it requires a propulsion system onboard the spacecraft, working throughout the mission lifetime. It also requires a longer time to cover all the regions of interest, due to the very weak thrust forces compared to that of the Earth's gravitational field. This paper presents a methodology to design natural orbits, in which the regions of interest are visited without the use of propulsion systems, depending only on the gravitational forces. The problem is formulated as an optimization problem. A genetic algorithm along with a second order gradient method is implemented for optimization. The design process takes into consideration the gravitational second zonal harmonic, and hence allows for the design of repeated Sun-synchronous orbits. The field of view of the payload is also taken into consideration in the optimization process. Numerical results are presented that demonstrates the efficiency of the proposed method.

1. Introduction

In Newtonian mechanics, the natural motion of a spacecraft around the Earth is described by a second order vectorial differential equation, assuming that the spacecraft is attracted only by the Earth, and assuming that the Earth is a perfect sphere [1]. The solution to these differential equations is either a circular, elliptic, parabolic, or a hyperbolic trajectory [2]. The type of the trajectory is determined depending on how we initially place the spacecraft in orbit. The Earth is always at the focus of this conic trajectory. Regardless of the type of the trajectory, it is always possible to describe the orbit of the spacecraft using five parameters [3]. Another parameter is needed to determine the position of the spacecraft on the orbit. A fundamental task in the design process of any space mission is to design the orbit(s) of the spacecraft. Designing an orbit means, then, finding the values for the five orbital elements such that the mission objectives are best achieved [4].

A wide range of applications require that a spacecraft passes over a given number of ground sites. Examples for this type of missions include remote sensing [5], disaster monitoring [6], urban planning [7], natural resources, and ground surveillance missions [8]. In this type of applications, the spacecraft is usually equipped with sensor(s) to take measurements for the ground sites of interest. The spacecraft does not have to visit (pass over) each site exactly; but rather a ground site is considered "visited" if the field of view (FOV) of the sensor covers that ground site, at some point in time [9]. As can be seen from Fig. 1, the orbit selection dictates the coverage area on Earth surface.

For spacecraft at high altitudes, the coverage area is bigger than that of a spacecraft in a low altitude orbit. On

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