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# SATELLITE SYSTEM SIMULATION AND VISUALIZATION

A Thesis Submitted to the Department of Scientific Computing, Faculty of Computer and Information Sciences, Ain Shams University, in the Partial Fulfillment of the Requirements for the Master Degree of Computer and Information Sciences

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# Abstract

Problem solving process in computational science usually includes modeling, simulation and visualization. Traditionally, these components are manipulated using disparate packages, resulting in wasted time and a cognitive disconnect between the effects of model changes on simulation results. A much more efficient system is one which integrates modeling, simulation, and visualization in a single unified framework.

In this thesis we will introduce such a system: the Satellite Motion Simulation and Visualization Software System, *SatVis*. SatVis is a software system that uses simulation as a powerful tool for letting us visualize satellite motion in space and allowing us to both quantify and observe its behavior in order to study and compare alternative designs or to troubleshoot existing systems.

The presented algorithms are based on fundamentals of astrodynamics including Kepler's equation, laws of planetary motion, and Newton's laws of motion, as well as the concepts of linear algebra and 3D graphics. Those algorithms are then used for implementing the proposed software system.

The proposed software is capable of placing a satellite in its orbit, computing its position as a function of time, as well as determining the portions of the earth surface covered by the satellite during its continuous motion around the earth. The coverage of the satellite is computed from two different points of view. The first is the *Ground Track*, which focuses on the path formed on earth surface due to the satellite motion. The second is the *Footprint*, which is concerned with the instantaneous area of coverage at a certain time. Finally, the system can produce a set of

reports including position coordinates of the satellite during a specific time period as well as a statistics report about the periods at which the satellite would pass over a target location on earth.

In order to validate the performance of the developed system, six case studies were selected to represent the basic types of satellite orbits. These include: Circular orbit, sun-synchronous orbit, elliptic low earth orbit, geostationary orbit, polar orbit and the famous Russian Molniya orbit. The results produced by the developed system were validated by comparison against those of the Satellite Tool Kit (*STK*).

For each case study we present a detailed description of the orbital elements, orbit 3D visualization, satellite ground track visualization, and satellite footprint visualization. The computed satellite positions are compared with the positions computed by the *STK* in two different coordinate systems: Earth Fixed Centered (EFC) coordinate system and Latitude-Longitude coordinate system. Generally, we found that the maximum relative error between the computed satellite positions using *SatVis* and that provided by the *STK* was ($5x10^{-6}$). That is, the results obtained from the implemented software agree with those of the *STK* by 99.9% approximately.

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# 1

# Introduction


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