博士学位论文摘要选登

利用星敏感器的卫星及星座自主定轨方法研究与应用

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卫星自主定轨是卫星自主导航中的关键技术，其概念是指卫星在不借助地面站系统测控情况下直接在星上实现轨道参数的自主确定，实时确定卫星飞行的位置和速度.

国际上已提出了诸如利用星敏感器测量、地球磁强计测量、利用掩星时刻测量以及近年来非常热门的利用 X-ray 脉冲星信号相位测量等多种算法来实现卫星自主导航. 其中利用星敏感器测量的自主导航方法具有成本低、研制周期短、可观测条件强以及观测设备技术成熟等优点，其可行性和经济效益比较突出，是一种非常值得采用的自主导航方法. 国内外对星敏感器自主导航的研究，基本还是原理方法的论述以及简单仿真验证研究.

本论文对卫星利用星敏感器的自主导航算法进行了研究，通过建立逼真的卫星运行平台，充分考虑卫星姿态、载荷布局、真实星空背景等因素，开展卫星利用星敏感器自主导航算法研究，并将此方法推广到卫星星座自主导航以及天基空间监测等应用方向.

论文的第 1 章和第 2 章分别介绍了卫星自主定轨常用到的一些时间和参考系，分析了当前几种典型的自主导航方法 (GPS/TDRSS 、磁强计和脉冲星) 的定轨和观测原理以及它们的优点和不足. 第 3 章则对单颗卫星利用星敏感器和红外地平仪的自主导航方法做了专门论述，基于卫星姿态运动仿真、星敏感器的恒星背景测量和红外地平仪的对地观测，开展自主导航算法研究，论证方法的可行性、导航精度以及主要的影响因素. 通过仿真低轨卫星和亚同步轨道卫星利用星敏感器自主定轨，得到了它们的定轨精度：低轨卫星定轨精度几百米，亚同步轨道卫星接近 10 km 左右，定轨精度主要受红外地平仪的系统误差影响. 同时分析了利用双探头敏感器自主定轨的精度情况，并由测量方程的特点合理地提出了一种有利于提高自主定轨精度的星敏感器和初装方式；在对亚同步轨道卫星的仿真计算中提出了一种较好的资料采样率. 仿真计算的结果论证了利用星敏感器自主定轨普遍适用于各种轨道高度的地球卫星. 对于低轨卫星、中高轨卫星都具有良好的定轨精度和收敛情况. 第 4 章则将星敏感器自主定轨算法推广到了小卫星星座的导航应用当中；通过融合星间链路的高精度测距资料和星敏感器资料，得到的定轨精度和星座的构型精度也高于预期. 相比较单星情况，位置确定精度能够提高将近一倍.

第 5 章则是针对天基卫星监测开展了两项相关预研究：一是解决了利用测向资料初轨确定收敛到观测平台自身轨道的问题，并由此形成了一种利用星间测向数据的初轨确定方法；另一项是提出了一种基于自主导航天基平台的卫星监测模型，联合星敏感器导航资料和星间测向资料确定天基平台和跟踪目标的轨道参数，通过比对国外现有的实测研究结果，初步论证了初轨确定方法和利用星敏感器自主导航天基监测模型的可行性. 本章的研究结论对于最新提出的 “空间态势感知” 的概念以及我国的空间安全建设具有参考意义.

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The Study and Applications of Satellite and Satellite Constellation Autonomous Orbit Determination Using Star Sensor

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Autonomous satellite orbit determination is a key technique in autonomous satellite navigation. Many kinds of technologies have been proposed to realize the autonomous satellite navigation, such as the star sensor, the Earth magnetometer, the occultation time survey, and the phase measurement of X-ray pulsar signals.

This dissertation studies a method of autonomous satellite orbit determination using star sensor. Moreover, the method is extended to the autonomous navigation of satellite constellation and the space-based surveillance.

In chapters 1 and 2, some usual time and reference systems are introduced. Then the principles of several typical autonomous navigation methods, and their merits and shortcomings are analyzed. In chapter 3, the autonomous satellite orbit determination using star sensor and infrared Earth sensor (IRES) is specifically studied, which is based on the status movement simulation, the stellar background observation from star sensor, and the Earth center direction survey from IRES. By simulating the low Earth orbit satellites and pseudo Geostationary Earth orbit (PGEO) satellites, the precision of position and speed with autonomous orbit determination using star sensor is obtained. Besides, the autonomous orbit determination using star sensor with double detectors is studied. According to the observation equation's characters, an optimized type of star sensor and IRES initial assembly model is proposed. In the study of the PGEO autonomous orbit determination, an efficient sampling frequency of measurements is promoted. The simulation results confirm that the autonomous satellite orbit determination using star sensor is feasible for satellites with all kinds of altitudes. In chapter 4, the method of autonomous satellite orbit determination using star sensor is extended to the autonomous navigation of mini-satellite constellation. Combining with the high-accuracy inter satellite links data, the precision of the determined orbit and constellation configuration is higher than that ever expected.

In chapter 5, two related pre-project researches are developed with respect to the space-based satellite surveillance. One solves the un-convergence question in the preliminary orbit determination and finds an advantageous preliminary orbit determination using inter satellite angle measurement. In the other pre-project research, a creative space-based satellite surveillance model is proposed, which is based on the autonomous surveillance platform navigation. Using the star sensor's navigation data associated with the inter satellite angle measurement, the orbit parameters of the tracking space objects and the surveillance platform are determined. Compared to the available experiment results overseas, the preliminary orbit determination method and the autonomous navigation surveillance platform model are found to be feasible. The research will significantly contribute to the new conception of "space awareness", as well as our country's space security construction.