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Author: Dr. Yunhua Wu
Nanjing University of Aeronautics and Astronautics, China, yunhuawu@nuaa.edu.cn

Ms. Nan Yang
Nanjing University of Aeronautics and Astronautics, China, yangnan@nuaa.edu.cn
Mr. Wei He
China, hvv864@163.com
Mr. Zezhong Zhang
Nanjing University of Aeronautics and Astronautics, China, zezhongzhang@nuaa.edu.cn
Dr. Hua Bing
China, huabing@nuaa.edu.cn
Dr. Zhiming Chen
Nanjing University of Aeronautics and Astronautics, China, zenkichen@gmail.com
Dr. Feng Yu
Nanjing University of Aeronautics and Astronautics, China, yufeng@nuaa.edu.cn

RELATIVE STATE MEASUREMENT OF A NON-COOPERATIVE SPACECRAFT FOR FINAL APPROACHING STAGE OF ON-ORBIT SERVICING USING CONTOUR FEATURES

Abstract

On-orbit servicing including spacecraft maintenance, on orbit assembly, refueling as well as de-orbiting can reduce the cost of space missions, improve the performance of spacecraft and extend its life span, etc. The relative state between the servicing and target spacecraft is vital important for on-orbit servicing missions especially the final approaching stage, e.g., relative distance is less than 5 meters. A monocular vision system is designed for the short distance relative measurement as many methods, such as laser or microwave ranging, are no longer applicable. Different from cooperative spacecraft, the non-cooperative target does not have artificial feature markers. Therefore, contour features, including the triangle supports of solar array, docking ring and corner points of the spacecraft body, are used as the measuring target. To overcome the drawback of FOV (Field of View) limitation and imaging ambiguity of the camera, a "selfie stick" camera installation structure and a self-calibration strategy are proposed, ensuring that some of the contour features can be observed sharply before the two spacecraft come into contact. The observed features are constantly changing with the shortening of the relative distance. It is a difficulty to build a unified measurement model with different types of features, including point, line segment and circle. Therefore, dual quaternion is implemented to build the relative dynamic model and the above measurement model. With the consideration of the uncertainty of the state of the non-cooperative target, an improved strong tracking filter is designed to robustly estimate the relative distance and attitude between the servicing spacecraft and the target. Finally, 3D virtual reality software is designed to demonstrate the relative motion of final approaching stage of a typical on-orbit servicing mission, followed by a group of mathematical simulations to verify the effectiveness of the proposed strategy. The achievement of this research will provide a theoretical and technical foundation for future spacecraft on-orbit servicing missions.