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Title

Non-Cooperative Target Pose Estimation Based on Dynamic Region-Aware Convolution Neural Network.

Authors

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Abstract

An important technology for current on-orbit servicing and debris removal missions is the capacity to precisely determine and track the pose (i.e., the relative position and attitude) of a noncooperative client spacecraft with minimal equipment. The production of the approach trajectory and control update in real-time depends critically on the execution of on-board posture estimation. Because small spacecraft like CubeSats have low power and bulk constraints, using a single monocular camera to do pose estimation is particularly appealing. Many space missions are deployed or planed in this area [1,2]. Earlier methods of monocular-based pose estimation utilize image processing approaches to find pertinent features in a 2D image, which are then compared with features of a known 3D model of the client spacecraft to derive attitude and position data. Due to the poor signal-to-noise ratio, harsh lighting conditions, and changeable Earth background in space videos, these methods are known to be less resilient. Moreover, the 3D model of the noncooperative space target pose estimation tasks are difficult to obtain in practice, leading to the obstacle of many popular pose estimation algorithms. The objective of this work is to estimate the non-cooperative targets pose efficiently and precisely, in order to enable autonomous machines to substitute the present manual modeling-based estimation and reduce the estimation error. We propose a deep learning-based pose estimation pipeline integrating with three parts. A dynamic region-aware convolution block is firstly proposed to extract the image features from RGB images. Then a multi-granularity self-attention module is designed to integrate the target features in different layers. Finally, a novel rotation loss is proposed to solve the attitude ambiguity problem of the symmetrical target. Nine different type of non-cooperative targets are designed to generate the non-cooperate target datasets, including Asteroid, Aura, Cubesat, Dawn, Hubble, Jason, Deep Impact, Cloudsat, and Acrimat. The mission satellite (chase) is considered to be in a circular monitoring trajectory about the target. The camera configuration from the chaser, the orbit lighting condition, and the target rotation rate are adjusted and tested to verify the robustness of the proposed method. Multiple experiments have been applied and the proposed algorithms have been tested under different lighting condition, different rotation rate, different image resolution and unseen targets. The matching results from various experiments have shown its the robustness and transferring ability.

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