Event-based Structure-from-Orbit

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Introduction

- **Space is a domain abundant with naturally spinning objects**, such as satellites and space debris (Fig. 1). Extracting the shape and motion parameters of such spinning objects in space can **facilitate vision-based spacecraft navigation and debris removal [1, 2]**.
- We formulate the task of ***event-based Structure-from-Orbit (eSfO)***, which entails the reconstruction of an object undergoing a spinning (circular) motion while being observed by a static event camera, and jointly estimating the motion of the object. Successfully achieving this task would enable us to **survey an object and characterise its motion**.

Aims

- Develop a method that can **estimate the sparse structure and motion parameters** of a spinning object observed by a static event camera.
- Development of a monocular **event-based feature detection and tracking** method that can handle the spinning motion.
- Production of a monocular event-based **dataset and benchmark** for the *eSfO* problem.

Methods

- The developed event corner clustering-based **feature detection and tracking method**, Event Tracking by Clustering (ETC), is designed to handle the unique feature tracking challenge posed by the circular motion. Its design also enables the tracker to **operate under high-speed motion and challenging lighting conditions**.
- Our Structure-from-Orbit (SfO) formulation enables **joint optimisation of the sparse structure and motion parameters** from the feature tracks.

Fig. 1: Astroscale's ADRAS-J spacecraft in orbit around some debris.[3]

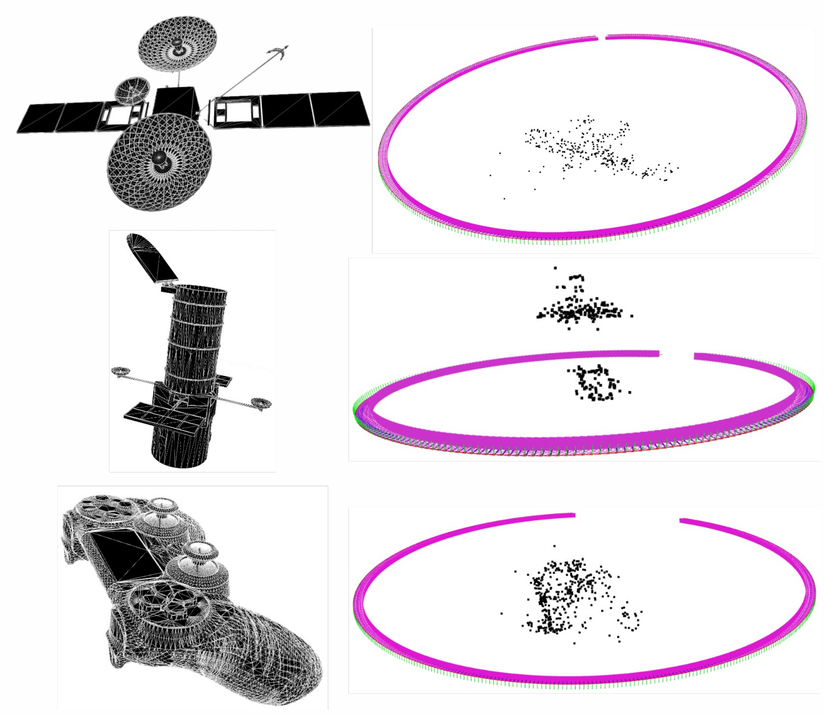
Results

- Through extensive experiments, we have demonstrated that the motion parameters (rotation rate and projection of the axis of rotation) and sparse reconstruction **are reliably recovered by the *eSfO* pipeline**.
- Unlike current state-of-the-art event-based feature trackers, our tracker **can operate under both general 6-DoF motion and circular motion**.
- Sample reconstructions are depicted below on the right.

SOHO Satellite

Hubble Telescope

DualShock 4 Controller



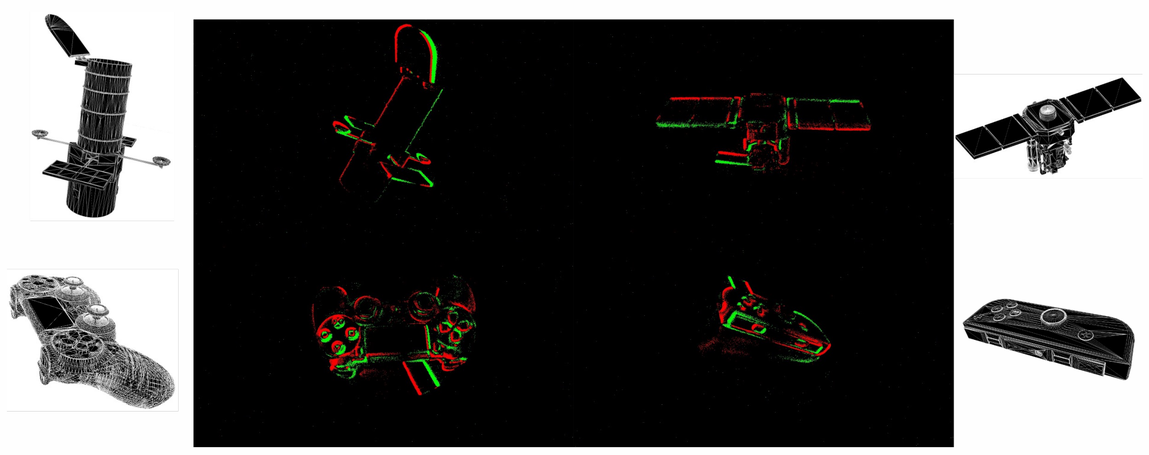


Fig. 2: Sample event frames from our TOPSPIN dataset.

References

[1] Brent E. Tweddle, et al. Factor graph modelling of rigid-body dynamics for localization, mapping, and parameter estimation of a spinning object in space. Journal of Field Robotics.

[2] Mehregan Dor, et al. Visual SLAM for asteroid relative navigation.

[3] A. Howlett, “Astroscale’s adras-J continues to make history: Successfully demonstrates fly-around observations of Space Debris,” Astroscale.

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