Paper ID: 53457
oral
student

IAF ASTRODYNAMICS SYMPOSIUM (C1)
Guidance, Navigation & Control (3) (9)

Author: Mr. Kai Matsuka
California Institute of Technology, United States, kmatsuka@caltech.edu

Mr. Alexei Harvard
California Institute of Technology, United States, alexh@caltech.edu
Prof. Soon-Jo Chung
California Institute of Technology, United States, sjchung@caltech.edu

TERRAIN RELATIVE NAVIGATION WITH TIGHTLY COUPLED RANGE-VISUAL-INERTIAL ODOMETRY

Abstract

Vision-aided navigation has various applications for space exploration such as entry, descent, and landing, asteroid proximity operation, on-orbit servicing, and planetary surface and aerial exploration. A Laser Range Finder (LRF) combined with visual inertial odometry (VIO) is a popular complementary suite of sensors that is light weight, resolves depth, and arrests estimation error growth. There exists literature that proposes loose coupling approaches where the range measurement is used simply to resolve scale ambiguity. Some tight coupling approaches do not take a full advantage of the available precision of range measurement.

This paper formulates a novel sensor fusion approach that tightly couples range and vision measurements. The algorithm finds reference templates for pixels with depths obtained from lidar measurements, and matches to targets template in other frames with sub-pixel precision. By including measurement errors of matched templates with precisely known depths, the tight coupling approach resolves the scale ambiguity of monocular VIO and reduces the estimation error drift. The proposed fusion approach is independent of the number of lidar sensors and it can be applied to different types of existing standard visual inertial odometry algorithm. This algorithm only makes mild assumptions on scene geometry, hence it is useful for missions with unknown landscapes.

We also present the range-visual-inertial odometry (RVIO) algorithm, based on nonlinear batch least square using keyframes. It is implemented in a quadcopter experiment simulating a terrain relative navigation in GPS-denied environment, such as Mars Helicopter. The quadcopter platform that carries a downward facing monocular camera, IMU, and a LRF is conducted to validate and analyze the approach.