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# A Navigation and Control System for an Autonomous Rescue Vehicle in the Space Station Environment

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## Abstract

A navigation and control system was designed and implemented for an orbital autonomous rescue vehicle envisioned to retrieve astronauts or equipment in the case that they become disengaged from the space station. The rescue vehicle, termed the Extra-Vehicular Activity Retriever (EVAR), has an on-board inertial measurement unit and GPS receivers for self state estimation, a laser range imager (LRI) and cameras for object state estimation, and a data link for reception of space station state information. The states of the retriever and objects (obstacles and the target object) are estimated by inertial state propagation which is corrected via measurements from the GPS, the LRI system, or the camera system. Kalman filters are utilized to perform sensor fusion and estimate the state propagation errors.

Control actuation is performed by a Manned Maneuvering Unit (MMU). Phase plane control techniques are used to control the rotational and translational state of the retriever. The translational controller provides station-keeping or motion along either Clohessy-Wiltshire trajectories or straight line trajectories in the LVLH frame of any sufficiently observed object or of the space station.

The software has been used to successfully control a prototype EVAR on an air bearing floor facility, and a simulated EVAR operating in a simulated orbital environment. The design of the navigation system and the control system are presented. Also discussed are the hardware systems and the overall software architecture.

## Background

There exists during EVA operations the potential for an EVA crewperson or piece of equipment to separate from the Space Station. It was determined that a significant probability would exist for the loss of a crewperson(s) if a retrieval by a crewperson were attempted. The EVA Retriever is conceived as an autonomous vehicle which could perform the retrieval task, avoiding risk to a crewperson. The EVAR incorporates various capabilities including task scheduling, world modeling, path planning, and image processing. A navigation and control system capable of performing the necessary maneuvers is required.

## Current Status

The core of the navigation and control system has been designed, implemented, and tested. Further development will be towards more sophisticated measurement noise models (utilized by the Kalman filters) for phenomena such as range effects on the LRI accuracy and unmeasured plume impingements effects, namely on the target object. Additional development will be towards reducing propellent consumption by performing simultaneous translational and rotational accelerations when feasible.

## Test Experience

The software has been used to successfully control a prototype EVAR on an air bearing floor facility (at Johnson Space Center, Houston). The software has also been used to successfully control a simulated EVAR operating in a simulated orbital environment including modeled sensor errors and plume impingement effects.

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