AprilTag Applications to Autonomous Spacecraft Docking

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Spacecraft Docking Applications

The spaceflight industry has expanded rapidly in recent years. As spaceflight missions increase in frequency, it is of increasing importance to **improve the efficiency and reliability of spacecraft maneuvers**.

The Nonlinear Dynamics and Control Laboratory has partnered with Blue Origin to develop a control system which will use **fiducial markers** in localization, guidance, and navigation for **autonomous spacecraft docking**. This will help streamline many common mission profiles, including:

- Personnel Transport
- Supply Exchange
- Refueling
- Repair & Maintenance
- Debris Removal

Past Work: Fiducial Markers

AprilTag is a type of fiducial marker, a specific collection of **2D barcodes**. When placed on a known object, observation of the markers can be used to calculate **relative distance and orientation** of the object.

AprilTag accuracies were tested with several variables to predict spacecraft applicability:

- Surface curvature
- Distance from camera
- Tag size
- Orientation relative to camera
- Shadow obfuscation

Testbed & Robot Operating System (ROS)

ROS: Background

The control system will be **bench-tested** using 6DOF robotic manipulator arms to carry camera-equipped spacecraft models through **simulated orbital trajectories**.

ROS, or Robot Operating System, is an open-source collection of software libraries which is being used to program the robotic arms.

ROS: Physical System

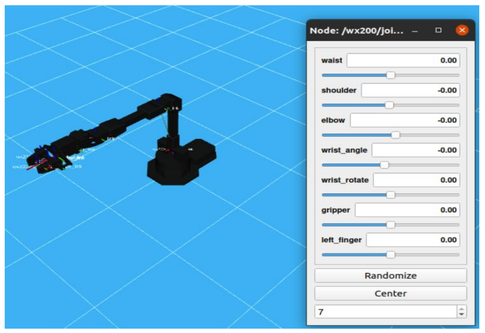
The objective is to set up a **pair of robotic manipulators** that can carry a camera (observer) and a spacecraft model with AprilTags attached (target). The trajectory of the observer could then be controlled through a **feedback loop** using data from the AprilTag-camera system.

Over the last year, the adaptation of existing single-arm configurations to a dual-arm configuration has been under development:

- Adaptation of existing Xacro/UDRF models for dual-arm
- Adaptation of launch files for dual-arm
- Visualization of the dual-arm system in RViz

ROS: Simulation

- Before running physical tests, planned trajectories will be demonstrated in **virtual simulations**
- This will help **prevent unwanted collisions** during testing
- Motion planning tools interface with the ROS simulation platform, Gazebo



Future Work

Next Steps for Robot Programming

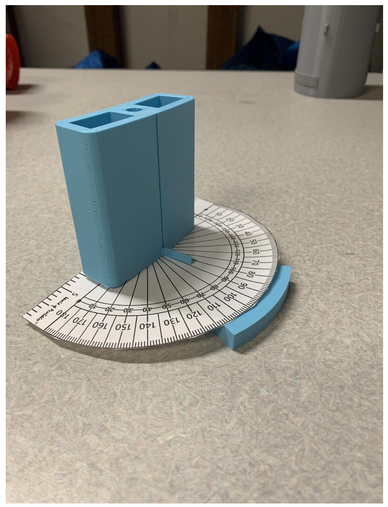
Future research and testing are underway in these areas:

- Development of the Gazebo model
- Development of the inverse kinematics model (MoveIt)
- Implementation of a feedback loop into robotic controls

Improving AprilTag Characterization

The preliminary study of AprilTag accuracy should be expanded on to achieve a more thorough understanding of their potential performance at scale.

- Determine reasonable **tag size to distance** ratios from desired mission capabilities
- Determine reasonable **tag size to curvature** ratios based on modern spacecraft fleets
- Collect significant data within these regimes
- Establish general rules of **AprilTag placement on a spacecraft** to guarantee accurate motion tracking from any angle



References and Acknowledgments

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