I. Relative Motion and Dynamics

- Hill’s Frame: centered about the Target spacecraft

II. Orbital and Lab Frame Scaling

- Length scaling parameter $r$ and time scaling parameter $\kappa$
- Lab distance is scaled by a factor of $1/r$
- Lab velocity is scaled by $\kappa/r$

III. Guidance and Control

- Vicon Motion Capture System: External position tracking system for omni-directional robots.
- Laboratory equipped with 17 cameras
- Tracking to 1 mm of precision
- Visualization Software: Model ground-based motion of robots as spacecraft in the orbital frame.
  - MATLAB modeling capabilities

Experimental Setup

- Omni-Directional Robots (x4): Low-cost robots featuring an in-house, U of Michigan open-source platforms for hardware and software, with applications for education and research.
  - Holonomic motion control and odometry with IMU and wheel encoders. Kiwi drive with 3 degrees of freedom.
  - WP4: high level control with open-source architecture
  - Raspberry Pi Pico: embedded processing
  - Position tracking capabilities via its own odometry or using an external system
- Vicon Motion Capture System: External position tracking system for omni-directional robots.
- Laboratory equipped with 17 cameras
- Tracking to 1 mm of precision
- Visualization Software: Model ground-based motion of robots as spacecraft in the orbital frame.
  - MATLAB modeling capabilities

Hardware and Software

- Systems Architecture

Methods

I. Relative Motion and Dynamics

- Hill’s Frame: centered about the Target spacecraft
- Clohessy-Wiltshire equations of motion (eq. 1)

$$\begin{align*}
\dot{x} - 3n^2x - 2ny & = \frac{\lambda}{m_d} \\
\dot{y} + 2nx & = \frac{\lambda}{m_d} \\
\dot{z} + n^2z & = \frac{F}{m_d}
\end{align*}$$

II. Orbital and Lab Frame Scaling

- Length scaling parameter $r$ and time scaling parameter $\kappa$
- Lab distance is scaled by a factor of $1/r$
- Lab velocity is scaled by $\kappa/r$

Future Work

Future steps will include continuing to investigate and implement an orbital scale visualization via MATLAB as well as a human factors component to this testbed. Testing will also begin including rendezvous with two moving omni-directional robots as opposed to one moving and one stationary, as well as verification of a Learning Reference Governor.

References

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https://doi.org/10.2514/6.2022-2514