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# Autonomous Prealignment Of A Docking Mechanism

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**Abstract:**

Proposed future space exploration, such as lunar and martian expeditions, will require autonomous docking of space vehicles. One proposed candidate method of autonomous docking utilizes a actively controlled parallel manipulator. Operation of the proposed docking manipulator can be segmented into four (4) successive events: Prealignment, Capture/Latching, Attenuation, and Structural Rigidization. This paper discusses the development and testing of a digitally controlled, six-degree-of-freedom (6-DOF), parallel manipulator for the prealignment segment of a docking spacecraft.

The manipulator, generically called a Stewart Platform, incorporates eight (8) electromechanical linear actuators operating in tandem to maneuver a mechanical docking interface in 3-dimensional space. The system is controlled by a central master controller overseeing eight digital servo controllers, one dedicated to the positioning of each actuator. A machine vision system is used to provide real-time position and orientation commands to the master controller. An optical target on a passive docking interface is sensed by the vision system via a CCD camera attached to the Stewart Platform. The vision system tracks the relative position and orientation between the target and the CCD camera providing 3-dimensional target position and orientation information to the master controller.

The master controller computes the desired Stewart platform position and orientation minimizing the misalignment between the passive and the active, i.e., Stewart platform, docking interfaces. It then converts the desired platform position and orientation into position commands for each of the eight linear actuators controlled by individual low level digital servo control circuit boards.

The system has been implemented on two prototypes. One prototype is a small-scale version used to develop the vision, control, and kinematic software, as well as low level servo control circuit boards. On this system a robotic arm is used to maneuver the passive

interface while the docking manipulator responds to its movements. The second prototype is used as a full-scale demonstration system. A docking facility located within the Structures and Mechanics Division at NASA, Johnson Space Center provides motion simulation of the passive interface for this prototype.

Several tests were preformed on the demonstration system. The passive docking interface was cyclically rotated and translated to assess the tracking capability of the docking system. Tests designed to simulate typical vehicle approach/closing conditions were also conducted.

Results from the testing were favorable. System resolution and response were well within acceptable ranges. Key to successful system operation was the calibration of the vision system. Vision system difficulties were experienced with regard to lighting. Although calibration corrected for most of these problems, the robustness of the vision algorithm was of concern. Hardware performance also lacked the desired response. However, this problem was beyond our control since the Stewart platform used in the demonstration prototype was unalterable, and had been developed for a previous unrelated program.

Several worthwhile observations can be made about the design and development process of this project. During the development of the system, cycle update time, which includes processing video signals, computing docking kinematics, error checking, communications, and servo control, was dramatically reduced. The rapid loop rate achieved resulted from algorithm optimization (to be presented in a complete paper), and provided good system response and stability.

Additional conclusions can be drawn from more of a management philosophical viewpoint. Throughout the project efforts were made to utilize existing and/or off-the-shelf hardware. As such, minimal development time and costs were realized. Concurrent engineering techniques were also employed, further reducing development time. Finally, the small-scale prototype built to test software and control system proved to be invaluable as a cost saver.

Future work is to include the study of the remaining three phases of docking, i.e., capture/latching, attenuation, and structural rigidization. In addition, alternate vision algorithms which are less sensitive to lighting variation are to be investigated. A change in the control architecture is being initiated also.