Abstract submission for the AR&C conference at Williamsburg, Virginia on Nov. 19-21, 1991.

Category 1: Hardware Systems: Sensors and Targets

Title: Video Guidance Sensor for Autonomous Capture

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A video-based sensor has been developed specifically for the close-ranged maneuvering required in the last phase of autonomous rendezvous and capture. The system is a combination of target and sensor, with the target being a modified version of the standard target used by the astronauts with the Remote Manipulator System (RMS). The system, as currently configured, works well for autonomous docking maneuvers from approximately forty feet in to soft-docking and capture.

The sensor was developed specifically to track and calculate its position and attitude relative to a target consisting of three retro-reflective spots, equally spaced, with the center spot being on a pole. This target configuration was chosen for its sensitivity to small amounts of relative pitch and yaw and because it could be used with a small modification to the standard RMS target already in use by NASA.

Work began on this system under the Research and Technology Objectives and Plans (RTOP) program in 1987 under an Automation and Robotics task. The system was to use a Charge Injection Device (CID) as its detector, laser diodes as illuminators, and corner-cube retro-reflectors for the target. Eventually, the Retro-reflector Field Tracker (RFT) was available for use, and it already utilized a CID sensor and laser diode illuminators. It's target was retro-reflective tape, which was even easier to use with the RMS target than corner-cubes. The sensor was used in a closed-loop mode for automatic docking at MSFC's Flight Robotics Laboratory in December of 1987. The RFT was a sensor that flew on the shuttle in the Solar Array Flight Experiment in 1984. It worked very well for automated docking, but only with an entirely black background. That would not do for a sensor that would be facing highly reflective satellites. The next step was to develop a sensor that could acquire and track a target despite reflections from other things in the background, most notably the multi-layer insulation on many spacecraft. A new sensor was built around a standard Charge-Coupled Device (CCD) camera, two different wavelengths of laser diodes, and retro-reflectors with optical narrow-band-pass filters in front of them, designed to pass one of the two laser diode wavelengths.

The current sensor works by turning on one set of laser diodes, at 830nm wavelength, and digitizing a picture of the illuminated target; then the sensor turns on the second set of laser diodes at 780nm and digitizes a second picture. Since there is a narrow-optical-bandpass filter in front of the retro-reflectors on the target, the laser light is returned by the three target spots at 830nm but not at 780nm. The second picture is then subtracted from the first picture to give a low-noise image of the target spots. From the centroids of these three spots, and the knowledge of the actual physical configuration of the reflectors, the position and attitude of the target relative to the sensor are calculated for all six-degrees-of-freedom. This information can be fed into a guidance routine to allow automatic docking/berthing or it can be put on a screen to facilitate man-controlled docking/berthing.

The system has been used for large-scale autonomous docking simulations and tests at MSFC's Flight Robotics Laboratory. It was first used to autonomously guide an Air-Bearing Vehicle (ABV) with freedom in the X, Y, and Yaw axes. The ABV, which weighs 2000kg, is powered by batteries on board and propelled by compressed air thrusters. The sensor was later integrated into the Orbital Maneuvering Vehicle (OMV) model on the Dynamic Overhead Simulator , which has six-degrees-of-freedom and a longer range of travel than the ABV. Some of the work on the OMV application involved TRW, the OMV prime contractor prior to its cancellation. Their work mostly involved automated guidance routines as well as integration of the sensor data into the OMV's guidance system.

As currently configured, the system has a maximum range of approximately 12 meters and a 30x30 degree field-of-illumination. The camera in the sensor has a field-of-view of 45x45 degrees, and the video signal from that camera is available for use in manned supervision. With the same sensor, by using a larger target and corner cube reflectors, a range of 45 meters has been tested. Various other options are available to obtain different ranges and depths of operation, including changing the lens used in the sensor, increasing the number and/or power, of the laser diodes, changing the illumination field of the laser diodes, using more than one lens or camera, or making the target larger and with more than one sub-target.

The funding for this research has been from Code RC under the Autonomous Rendezvous and Docking RTOP program. Also, one sensor was funded by the Space Station program for use in testing the SSF module berthing and evaluating the sensor as a possible aid to the actual berthing process. As of now there is no firm amount of funding for FY92 to continue research in this area.

The research and experimentation on this system has been ongoing for over four years, and the next step in the evolution of a system such as this one is a flight test or the use of this system with a real application. Further research will more closely define the parameters of operation of the system and reveal more of the possible configurations, but without an actual application, there is not a target to capture.