U. S. AUTOMATED RENDEZVOUS AND CAPTURE CAPABILITIES REVIEW

REMOTE UMBILICAL SYSTEM ABSTRACT

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Technical details to be discussed:

This document will describe the technology developed at Kennedy Space Center (KSC) to demonstrate automatic tracking, docking and mating of umbilical systems. Specifically the use of a real time six degree of freedom (6DOF) target tracking vision system, (developed by Adaptive Automation, Inc. under contract to KSC), will be discussed in detail. The paper will also describe the use of mechanical compliance in the docking, mating and tracking - after- mating operations.

The vision system computes six coordinates that define the position and orientation of a three dimensional target using data from a single CCD camera. The camera is mounted on a 6DOF robot arm. After target coordinates are computed, they are transmitted to a supervisory computer which controls the robot motion in real time. Details of the image processing algorithms, image processing hardware, and target configuration used in the vision system are discussed in the paper.

The motion of the space vehicle relative to the service structure after mating led us to the development of a compliant system that allows enough displacement of the target relative to the camera so that tracking after mating may continue. This reduces internal stresses between flight and ground hardware.

Origins and Evolution of KSC tracking, mating and docking capabilities:

Umbilical systems are used in the space industry to supply fuel, power and life support systems to space vehicles during ground servicing operations. They safe space vehicles that use liquid propellants in the event of an abort. In 1983 KSC began to investigate the possibility of automating umbilical mating operations mainly because it is desirable to disconnect prior to launch to insure there will be no disconnect problems. However in the case of an abort it is necessary to immediately reconnect to safe the vehicle by downloading the propellants. Other disadvantages of current umbilicals are the dangerous and time consuming nature of the operation. Existing dangers include exposure of personnel to hazardous environment and the use of pyrotechnics to separate the T-0 umbilicals from the vehicle during lift-off. The goal was to develop an automatic system to successfully mate ground and flight side umbilical plates. Some of the constraints were:

1. Space vehicles on launch pads move relative to service structure due to wind, solar and thrust factors.
2. Cleaning and verification of fluid lines must be automated.
3. Mating is required in all weather and light conditions.

From 1983 to 1985, KSC detailed the requirements of a vision system and a 6DOF robot working together to follow a target moving in two dimensional space. ASEA Robotics and Adaptive Automation worked together to deliver the system. Testing revealed that much mechanical compliance was necessary with the system for the mating operation to work. Between 1985 and 1987 KSC decided to develop a 6DOF vision/force tracking capability to minimize mechanical compliance requirements. Adaptive Automation developed a 6DOF vision tracking system which is not manipulator dependent. This means that the algorithms can be used by robots other than the ASEA IRB-90 for which it was developed.

Today KSC has captured the technology that allows us to track, dock and mate a 200# ground umbilical plate to a flight plate moving at 3 in/sec. This was done combining the 6DOF vision system with mechanical compliance.

Level of maturity:

The 6DOF vision tracking technology is operational and a video tape with a demo is available for review.

System testing:

Testing has been done to quantify the system performance using an ASEA IRB-90 robot and a 200# payload on the arm. Results of tracking errors vs tracking speeds will be presented. Testing has also been conducted to quantify speed of data transfer between the vision system, the supervisory computer, and the robot controller. Results will also be discussed in the paper.

Fund sources:

The development of this technology was financed by the following groups: ETB, Code R, Advance Development and Shuttle production.

Current Funding Estimates:

Implementation of this technology for the Space Transportation System is not financially attractive. Therefore KSC has decided to stop further work on this project until an economically feasible application emerges. This could be the automation of umbilical systems for future space vehicles or the automation of tracking, docking, and mating operations required in space. Current funding levels will allow some further testing to be conducted to draw important conclusions which could be used at a later time.