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FASTER THAN REAL TIME ROBOT SIMULATION FOR PLAN DEVELOPMENT AND ROBOT SAFETY

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ABSTRACT

The University of Florida, under the Department of Energy University Program for Robotics for Advanced Reactors, has successfully implemented teleproprioception techniques for determining robot position and orientation in known environments with a single camera. Additionally, stereo vision has been successfully implemented to determine robot location and orientation from known position landmarks. Stereo vision has been shown to also allow registration of a robot in an unknown environment such that position and orientation can be future verified within 0.3 inches in location and 0.4 degrees in orientation.

I. INTRODUCTION

The University of Florida, in cooperation with the Universities of Texas, Tennessee, Michigan and Oak Ridge National Laboratory, is developing an advanced robotic system for the U.S. Department of Energy under the University Program for Robotics for Advanced Reactors. As part of this program, the University of Florida has been pursuing the development of a faster than real time robotic simulation program for planning and control of mobile robotic operations to ensure the efficient and safe operation of mobile robots in nuclear power plants and other hazardous environments.[1]

A Nuclear Power Plant is a highly structured and controlled facility that is ideal for representation in a computerized data base ("a priori" world model). Work[2] at Florida is currently underway to develop an intelligent database of a nuclear plant. Using a State-of-the-art graphics workstation, a 3D graphics image of the robot's environment can be generated. The use of interactive computer graphics to display the robot's environment offers several advantages to assist the operator in controlling the actions of the mobile robot. Since the images generated are clear and sharp, the operator gets a good "feel" of the environment. Objects in the environment can be displayed in various colors to provide a good contrast. The operator can easily change the location and orientation of the eye position so as to view the environment from different vantage points. Several views of the environment can be simultaneously presented to the operator using windowing techniques on the graphics workstation (Figure 1).

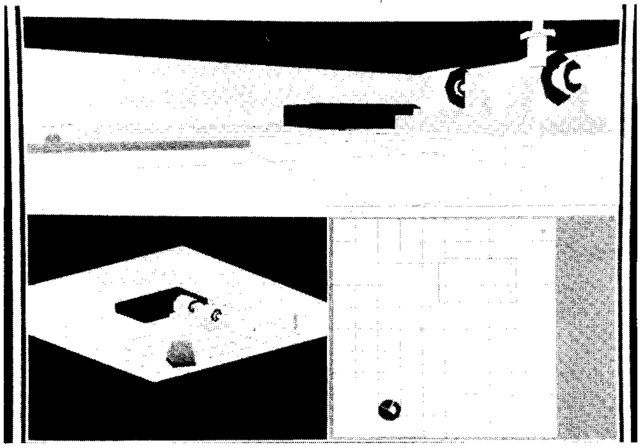

Fig. 1. Teleoperator Windowing Techniques

The "a priori" world model, combined with a reasoning module and sensory feedback can function as a knowledge based reasoning system allowing the robot to plan and aiding him to carry out operator directed actions through the position determination and verification programs. The requested actions are first previewed in the simulated model world and then, upon acceptance by the operator, the robot is activated in the real world (nuclear plant environment) to carry out the task under operator overview. The integration of sensory feedback (sensed world model) with the "a priori" world model (a process termed "teleproprioception") allows the operator to overview the compatibility between the preplanned model environment and robotic simulation and the as-encountered plant environment and actual task operation. Florida has been successful in the first part of its simulation task in demonstrating the capability to carry out the teleproprioception task with onboard robotic vision sensors and the simulated environment. Secondly, Florida has demonstrated the ability of the robot to autonomously plan its actions in the model world and then simulate its actions in the model world. Through the time acceleration concept we are able to approach real time planning during the simulation planning and control activities.

II. TELEPROPRIOCEPTION

The improved teleoperator method uses the concept of teleproprioception (Figure 2) where actual sensor feedback is compared with the model sensor information obtained from the modelled world (simulated environment). The actual sensor feedback comes from a camera mounted on the mobile robot. Both the actual and model feedback images are overlayed on top of each other. The simulated camera image is generated on the graphics workstation based on the reported position and orientation of the mobile robot, the data base of the robot's environment and the modelled camera parameters. The high resolution "estimated camera image" is connected to a low resolution NTSC format and overlayed on top of the "actual camera image." The final operation consists of matching the two superimposed images to determine true position.

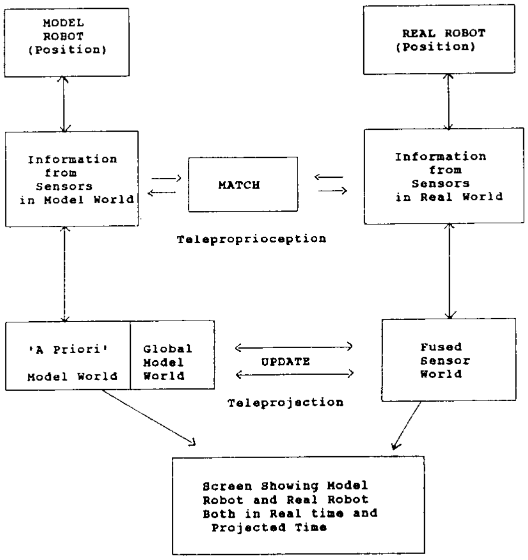

Fig. 2. Schematic of Teleprojection and Teleproprioception Concepts

If the simulated environment is correct and if the reported position and orientation of the mobile robot are also accurate, then the 'actual camera image" and the "estimated camera image" will exactly match. When the images do not match, the error in the robot's position and orientation must be evaluated from the degree of mismatch. This has currently been done manually.[3] The experimental set up used is shown in Figure 3. If a position or orientation error is identified then the position values in the robot's memory can be altered and replaced with the corrected values. A program is underway with the University of Florida and Oak Ridge National Laboratory to develop the same position monitoring system based upon a laser range finding sensor.

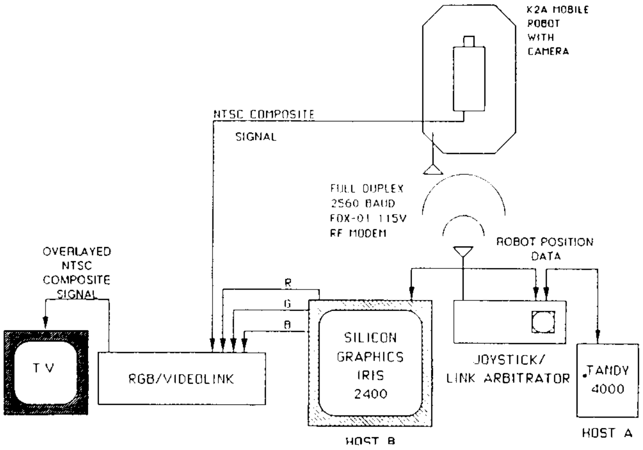

Fig. 3. Vision Overlay Experimental Setup

Where the environment may not be known, Florida is working on a separate locating system described in the next section that enables the robot to register its position and orientation for future location and orientation checks.

III. STEREO VISION FOR ROBOT LOCATION AND CONTROL

Florida has carried out work[4] to verify the accuracy of dimensional vision software using stereo image processing techniques. We have verified the feasibility of two approaches for robot location and orientations using a known landmark. First, if the position of the landmarks are known in terms of the world coordinate system, then the location and orientation of the robot can be determined. If the location and orientation of the landmarks are not known, then the robot can be defined for future time with respect to its position and orientation at the initial sighting of the landmarks. Using a two circle landmark system, the absolute error values were less than 0.3 in. in location and 0.4 degrees in orientation. This positional verification method provides a capability to quickly verify position off known landmarks or to initiate a location system based on a chosen landmark.

IV. TIME ACCELERATION CONCEPT

A time acceleration concept is being applied to the specific case of path planning for our mobile robot system. The concept is mostly directly applicable to the scenario where an operator is directly specifying the motion to be performed. The path can be either planned by the operator off-line or the operator can be inputting path data at an accelerated rate while the robot simultaneously moves in the real time domain. In the second case, the robot is effectively executing the planned motions at a much slower rate than the operator can specify them.

Two numerical values dictate the nature of the time acceleration process. These values are:

t_g = image generation rate.

S_w = time warp scale factor.

The value t_g represents the time required for the graphics system to generate a new image of the environment. Typically, for a simple scene this time would be approximately 0.2 seconds. For a complicated scene, such as that for the fully described nuclear power plant, this time value could reach as high as 20 seconds.

The value S_w represents the time warp scale factor and indicates the amount of time acceleration. When S_w equals 1, the operator is "driving" the vehicle in real time which is 1 ft per second. Images will be drawn at intervals of t_g (0.2 seconds) and thus the vehicle will be shown moving a distance of 2.4 inches per graphic frame. In order to decrease the time required for path planning, the operator can increase the value of S_w. A value of four for S_w would mean that the operator was "driving" the vehicle at a simulated maximum velocity of four feet per second.

This work augments similar research in the area of telerobotics in non-real time.[5,6]

V. CONCLUSION

The developments in the areas of time acceleration and system modeling have been integrated into demonstrations held at the Oak Ridge National Laboratories (ORNL) in December 1988 and February 1990. The developments in the areas of teleproprioception and stereo-vision location has been demonstrated in the Laboratory for Mobile Robots for Hazard Environments in May, 1990. Successful completion of the demonstration indicated the effectiveness of our approach.

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