N91-20643

IVA THE ROBOT: DESIGN GUIDELINES AND LESSONS LEARNED FROM THE FIRST SPACE STATION LABORATORY MANIPULATION SYSTEM

Carl R. Konkel
Allen K. Powers
J. Russell Dewitt

Teledyne Brown Engineering
300 Sparkman Drive
Huntsville, Alabama 35807

ABSTRACT

The first interactive Space Station Freedom (SSF) laboratory robot exhibit has been installed at the Space and Rocket Center in Huntsville, Alabama and has been running daily since March. IVA the Robot is mounted in a full scale United States Laboratory (USL) mockup to educate the public on possible automation and robotic applications aboard the SSF. Responding to audio and video instructions at the Command Console, exhibit patrons may prompt IVA to perform a housekeeping task or give a speaking tour of the module. Other exemplary space station tasks are simulated and the public can even challenge IVA to a game of tic-tac-toe.

In anticipation of such a system being built for the Space Station, a discussion is provided of the approach taken, along with suggestions for applicability to the Space Station environment.

INTRODUCTION

Teledyne Brown Engineering is pursuing an IR&D effort in robotics and automation in support of the NASA Space Station Freedom. This effort was initiated by user requirements which underscore the need for enhanced levels of automation and machine intelligence to reduce crew workloads. SSF phase B studies have shown available crew time as one of the most limited consumables and an obvious solution would be to automate those repetitive tasks which lend themselves to automation. This would allow the crew to perform the more sophisticated duties which require human dexterity and interaction. A prototype of an IntraVehicular Activities (IVA) robot for a conceptual Laboratory Manipulator System has been assembled as IVA the Robot (Figure 1) within a Space Station Freedom mockup at the Space and Rocket Center in Huntsville, Alabama.

IVA THE ROBOT

The Space and Rocket Center is a functional museum which presents a unique history of America's adventures in space as well as conceptual models of what may be expected in future space efforts. The intent of a Laboratory Manipulator System within the Space Station mockup is to display realistic space robotic applications to a public which expects C3PO and R2D2 capabilities from robotic systems. Following is a discussion of original design requirements and the approach taken to fulfill those specifications.

Design Requirements: The original IVA the Robot Exhibit specification detailed the location, weight, dimensions, configuration and appearance of the Laboratory Manipulator System. IVA was to be located on a six-foot track suspended from the laboratory module and be able to reach three racks of equipment. Standard Space Station tasks such as picking up a cylindrical sample and placing it in a materials processing furnace, or opening a door to remove a piece of equipment were specified. Among the more specific capabilities was the definition of a "wipe-down" task in which the robot would open a storage door, remove a sponge, proceed to clean a wall, and replace the sponge. Another unique task, included for both entertainment value as well as dexterity demonstration reasons was a Tic-Tac-Toe game played between the robot and an observer. Figure 2 is a block diagram of IVA's major elements and their interfaces.
All of the required tasks are initiated from the Control Console by the user. Based on user inputs from a joystick or pushbuttons, IVA will perform the following tasks:

1) Housekeeping. This task has already been defined for the SSF habitable modules and crew members were the first to suggest a "cleaning robot" to do it. IVA removes a sponge from a storage compartment, wipes down the walls and replaces the sponge in the compartment. Concurrently, a voice system is used to explain what IVA is doing and why it is necessary.

2) Furnace sample changeout. In an effort to demonstrate the usefulness of a robot for experiment manipulation, a task to changeout samples in a materials processing furnace was defined. First, IVA opens a storage door within which samples are stored. Then IVA proceeds to the furnace where the "heated" sample is removed and placed in an empty storage bin. A "fresh" sample is selected from the storage bin and placed into the furnace and all doors are closed. Sensors are located in the furnace compartment and in the storage bin to sense the location of all samples. Intelligence is programmed into IVA so that samples are not placed into an occupied slot. Again, IVA speaks to the exhibit user and explains the process.

3) Tours of the Space Station and module. There are two tours which have IVA speaking to the public explaining the Space Station, the Laboratory Module, and IVA's purpose. During the discussion, IVA guides the user by pointing and motioning to the various items of interest.

4) Manual Mode. To give the public a direct feel of operating a robot, IVA responds to various joystick and push button inputs which give the user direct control of the robot. Precautions are programmed so that IVA can't collide with anything or damage laboratory components.

5) Tic-tac-toe. One of IVA's more ambitious programming tasks, tic-tac-toe demonstrates IVA's flexibility and dexterity in a fun way to exhibit patrons. The game is controlled by the user at the console monitor and the game pieces are physically moved by IVA. This is the most popular task and IVA isn't easy to beat. On the average against a good player, IVA will win 20% of the time, tie 60% of the time and lose the rest. As with all tasks, IVA uses the voice system to explain the game and how to operate the controls.

IVA is powered up around the clock and runs in three basic modes. The first mode includes all the interactive actions described above, where IVA interacts directly with the public. Another mode is the non-interactive mode in which IVA will run different tasks from those discussed above until someone approaches the command console. There is a pressure mat in front of the command console so that IVA knows when someone is at the controls. The last mode is a "sleep" mode where IVA will park and go into a dormant state when the museum is closed for the night.

An integrated system, IVA is built mostly from off the shelf components. The brains of the system is an IBM PC/AT using the GWBASIC and Quick Basic programming languages. The PC reads inputs from exhibit patrons at the command console and converts those inputs to directives to the robot arm and exhibit peripherals. The PC also schedules events like the parking of the robot at night, occasional recalibrations and keeps records of all tasks performed by IVA. Given a quantitative record of activity, the exhibit may later be streamlined according to usage. Having a written record also helps the troubleshooter to pinpoint problems by showing which routine was executing and when a problem occurred. The voice capabilities are provided with a COVOX VOICEMASTER system. This speech system digitizes a spoken message and allows the ability to prompt IVA's speech within the control program. The robot arm is a Canadian-made CRS M1 six axis arm mounted on a six foot track bolted to the mockup ceiling. Programs which move the robot gripper to teach points are written in the CRS particular language and are prompted in response to signals from the PC. Lastly, a control/SVC panel was built to house the OPTO22 I/O boards. This panel distributes signals between the robot and the PC, the robot and the exhibit, and the PC and the exhibit.

IVA has demonstrated the ability of a single 6 axis track-mounted robot to successfully service three racks within the Space Station exhibit. But before any robotic system will be implemented within Space Station Freedom, crew and lab safety issues must be addressed and solved. Regardless of obvious workload benefits from a robotic system, there must be complete assurance that no detriment to the crew or lab hardware can occur at the hands of that system. The logistics of being a museum exhibit precludes exhibit patrons from any direct physical harm from IVA. The complete safety system is a "deadman" switch located in the access door to IVA's module, so entering the workspace powers down the robot. Certainly, this isn't possible in a Space Station environment where it is conceivable that man and robot may directly interact, therefore demanding the demonstration of harmonious interaction between the two.

Lessons Learned. Tho onboard IVA robot element of the system has been working successfully on a daily 12-hour basis. Minor problems such as workspace incompatibilities with the original teach points and robot voice coordination were anticipated and solved early. Unanticipated problems included intermittent failure of flexible cable wires exhibiting symptoms analogous to "software" errors, and early saturation of I/O signals.

CONCLUSION

The IVA the Robot exhibit was developed with the anticipation of the implementation of robotic systems within Space Station Freedom. The exhibit has been operational since March, 1990 and IVA services three racks of mock equipment. Extension of an IVA-type robot to SSF could free astronauts from repetitive tasks for better usage of their time. Such a system may be directly voice controlled by an astronaut or possibly even remotely controlled by a ground station operator. In an effort to alleviate astronaut workload, it is believed that while classical robotic techniques are readily applicable to specific tasks, the major area of concern is to crew and laboratory safety.

ACKNOWLEDGEMENTS

The authors wish to recognize Mike Cobb, the electronics techician for this project. With a keen insight of electronic troubleshooting, Mike considerably shortened the Lessons Learned portion of this paper, saving valuable time and a portion of the authors' sanity.

Figure 1. IVA the Robot

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

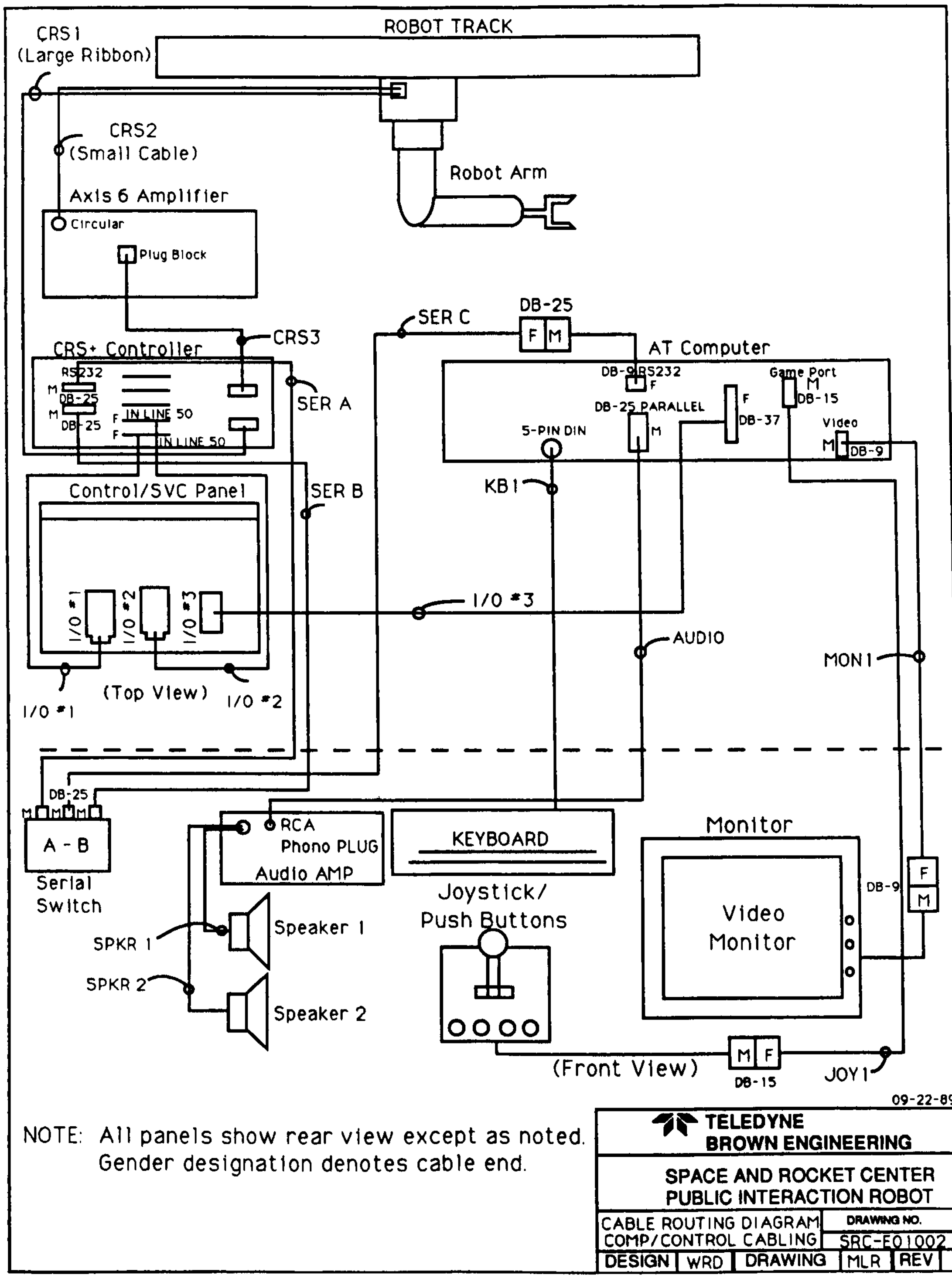

Figure 2. Exhibit elements and interfaces