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VISUALIZATION METHODS FOR VIABILITY STUDIES OF INSPECTION MODULES FOR THE SPACE SHUTTLE

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Introduction

An effective simulation of an object, process, or task must be similar to that object, process, or task. A simulation could consist of a physical device, a set of mathematical equations, a computer program, a person, or some combination of these. There are many reasons for the use of simulators. Although some of the reasons are unique to a specific situation, there are many general reasons and purposes for using simulators. Some are listed but not limited to (1) Safety, (2) Scarce resources, (3) Teaching/education, (4) Additional capabilities, (5) Flexibility and (6) Cost.

Robot simulators are in use for all of these reasons. Virtual environments such as simulators will eliminate physical contact with humans and hence will increase the safety of work environment. Corporations with limited funding and resources may utilize simulators to accomplish their goals while saving manpower and money. A computer simulation is safer than working with a real robot. Robots are typically a scarce resource. Schools typically don't have a large number of robots, if any. Factories don't want the robots not performing useful work unless absolutely necessary. Robot simulators are useful in teaching robotics. A simulator gives a student hands-on experience, if only with a simulator.

The simulator is more flexible. A user can quickly change the robot configuration, workcell, or even replace the robot with a different one altogether. In order to be useful, a robot simulator must create a model that accurately performs like the real robot.

A powerful simulator is usually thought of as a combination of a CAD package with simulation capabilities. Computer Aided Design (CAD) techniques are used extensively by engineers in virtually all areas of engineering. Parts are designed interactively aided by the graphical display of both wireframe and more realistic shaded renderings. Once a part's dimensions have been specified to the CAD package, designers can view the part from any direction to examine how it will look and perform in relation to other parts. If changes are deemed necessary, the designer can easily make the changes and view the results graphically. However, a complex process of moving parts intended for operation in a complex environment can only be fully understood through the process of animated graphical simulation.

A CAD package with simulation capabilities allows the designer to develop geometrical models of the process being designed, as well as the environment in which the process will be used, and then test the process in graphical animation much as the actual physical system would be "run". By being able to operate the system of moving and stationary parts, the designer is able to see in simulation how the system will perform under a wide variety of conditions. If, for example, undesired collisions occur between parts of the system, design changes can be easily made without the expense or potential danger of testing the physical system.

The simulation component of CAD also opens the door to users of the equipment as well as the equipment designers. For example, a robotics workcell designed for assembling parts by arc welding [1] may be simulated and the motion sequences required for the welding operation tested in simulation prior to actually performing the operation. Unanticipated collisions between the welding robot and the parts being joined or other parts of the workcell can be detected, and the system can be reprogrammed to provide collision-free motion. Thus, simulation adds a new

dimension to CAD by extending its usefulness from design to the manufacturing process, i.e., Computer Aided Manufacturing (CAM).

Historical Background of Robosim

ROBOSIM is a graphical simulation system used for three-dimensional geometrical modeling of robot manipulators and various objects in their workspace, and for the simulation of action sequences performed by the manipulators. ROBOSIM was originally conceived and developed between 1985-88 by NASA-MSFC and Vanderbilt University as a means of rapid prototyping of robotics systems [2]. This early version of the simulation system was written in FORTRAN and was developed for DEC VAX mainframe computers with TEKTRONIX 4014 terminals and also Evans & Sutherland graphics terminals. Robots and other objects in the simulated environment were specified through a program that the user wrote. After a robot had been designed, the user could solve the inverse kinematics problem for a set of points and store the results in a file. This file could then be read back in and used to display the robot at the stored points. This early version of ROBOSIM could only display wire frame models and was basically a robot modeling tool. It also did not contain collision detection capabilities, and it did not possess any advanced features of artificial intelligence-based collision avoidance or path planning capabilities. Despite these shortcomings, ROBOSIM was used at the MSFC in a number of space related activities including: development of off-line welding programs for robots used in fabricating the Space Shuttle Main Engine (SSME), integration of a vision sensor into a robotics workcell used for Solid Rocket Booster (SRB) refurbishment, and planning of a robot mechanism to be mounted on the Orbital Maneuvering Vehicle (OMV) [3].

In the early 1990s Springfield abandoned completely the basic architecture of the earlier versions of ROBOSIM and compatibility with earlier versions to create the current version called ROBOSIM II, [4]. The underlying architecture of the software was redesigned to integrate the desirable features of the earlier versions of ROBOSIM into a common package. The new architecture designed by Springfield provided for an open platform upon which additional features can be more easily added.

The objectives of current effort is two fold: First to utilize the ROBOSIM II simulation environment in the development of an additional module (Boom) for the space shuttle as means of inspection, and second to incorporate the ROBOSIM II into the engineering curriculum at Alabama A&U University.

Simulation Results

The Use of ROBOSIM II was demonstrated in a class project in the academic year 2003-2004 in EE490 Fundamentals of Robotics in AAMU within the school of engineering and technology. The class was taught by Dr. Ken Fernandez of NASA- MSFC. As part of the class project students were presented with a real world scenario of designing and simulation of boom for the shuttle. The project was presented in the following manner:

Shuttle Columbia Accident Investigation Board: Recommendation 3.4-3 Provide a capability to obtain and Downlink high-resolution images of the underside of the Orbiter Wing leading edge and forward section of both wings' Thermal Protection System.

> ***NASA's Implementation Plan for Space Shuttle Return to Flight and Beyond Response to 3.4-3: "…sensors will be mounted on the end of a 50 foot extension boom which will be carried in the Shuttle payload bay and grappled by the Shuttle's robotic arm."***

Class Project Objective were set as follows: To Apply Computer Simulation Techniques to the Preliminary Concept Verification of the Inspection Boom Planned by NASA in Response to the CAIB Recommendations. In the first trial the design specifications were given as: (1) Boom Length 50 ft, (2) RMS Docking Adapter Fwd, (3) Camera Mounted Aft, (4) Video Linked via RF, (5) Controls via RF link, (6) Boom/RMS Interface Passive, (7) Boom Power Self-Contained, (8) Comm. Via Std. Shuttle Sys.

Verification of the Design Model
<u>Stowage Verification</u>:
   Check for interference with cargo bay and other elements
<u>Deployment Verification</u>:
   Ability for Remote Manipulator System to Grasp Boom
   Remove Boom from Stowage Position
   Position for examination of wing sections
<u>Functional</u>:
   Ability of boom mounted cameras to view all critical areas
<u>Re-Stowage Verification</u>:
   Ability to remove boom from wing area and place in cargo bay
   Ability to re-position in stowage area
   Ability for Remote Manipulator to release and be stored

Figure 1 depicts the shuttle manipulator and the inspection boom. Figure 2. depicts the front view of the system in which collision detection and relative clearance distance between the shuttle and the arm maybe investigated.
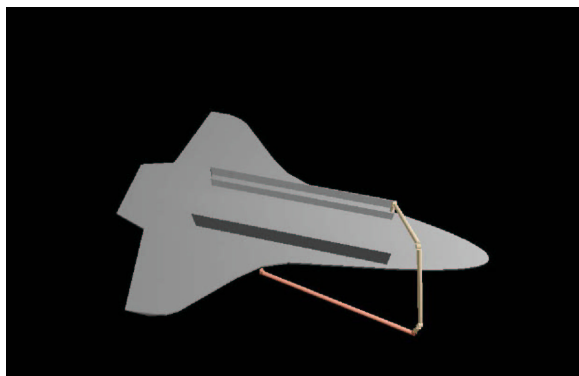

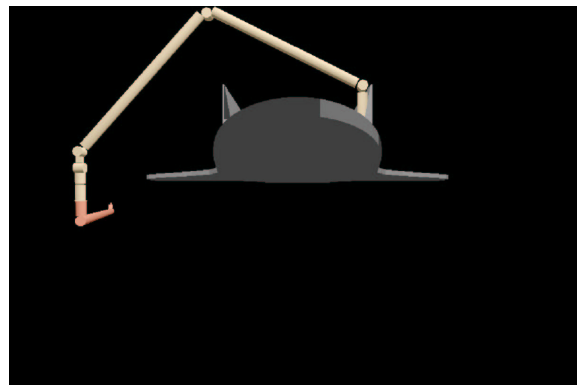Figure 1. Demonstration of ROBOSIM II Kinematic manipulator Models of the Shuttle, RMS and the boom.

Figure 2. Front view of the shuttle with the Inspection Boom

Resources

Recommended hardware for the Windows version is a 486 CPU, or higher, with 16 Mbytes of RAM. The speed of animation will depend on the processor speed. For best performance, a Pentium processor with processing speed of at least 1.2 GHz is recommended. A graphical accelerator is also recommended. Software requirements include Microsoft Windows 2000.

Conclusion

ROBOSIM II is considered to be a valuable research tool. With a little investment in time and manpower many of the hidden costs involved in the design process maybe eliminated and the safety featured of the design maybe investigated. Those features of this simulation tool are demonstrated in the class project for EE490- Fundamentals of Robotics. In that it was shown that an inspection boom maybe safely installed on board of the shuttle. Future courses that will utilize the ROBOSIM II in AAMU are ME 320- Kinematics and Dynamics of Machines and ME 432-Design for Manufacture and Reliability.

Acknowledgements:

References

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