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SIMULATION BASED PERFORMANCE ANALYSIS OF AN INTELLIGENT ROBOTIC SYSTEM CONTROL ARCHITECTURE

Pieter Voss
Jorge Haddock

Rensselaer Polytechnic Institute
Troy, NY 12180-3590, U.S.A.

ABSTRACT

This paper presents a discrete event simulation approach to the analysis of intelligent robotic systems. These systems require the integration and control of many diverse functions. The simulation model is constructed in SIMAN, and the performance measure is the average time required to complete a task. The model is intended to help balance system design decisions. Future work will focus on methods to use the simulation model to improve operation of the robotic system.

1 INTRODUCTION

Operations of intelligent robotic systems depends on the integration of many diverse functions. These range from low-level control activities, such as motion and vision control, to mid-level control activities, such as trajectory calculation and database management, to high-level control activities, such as task planning and sequencing of operations.

Discrete-event simulation models developed in the course of this research will assist the system designer in determining "optimal" system parameters, including the number of computers and processing speeds, robot precision, and task planning strategies. This work is an extension of an earlier Petri net-based tool developed at the Center for Intelligent Robotic Systems for Space Exploration (CIRSSE) [Robinson and Desrochers, 1990].

2 DESCRIPTION OF ROBOTIC TESTBED

This project focuses on the robotic testbed at CIRSSE. The testbed is intended to demonstrate how an intelligent robotic system can assemble a truss structure similar to that planned for the space station. Two independent Puma robots are mounted on mobile platforms. Five cameras and a programmable laser are used to determine the positions of the robots and the objects to be manipulated. Each of the robots have force and torque sensing capabilities.

The system is designed to operate autonomously. However, human operators may intervene. The testbed is equipped for telerobotic operation, where the operator may not be directly present but would monitor system operation electronically.

3 DESCRIPTION OF INITIAL SIMULATION MODEL

This model is constructed using the language SIMAN. In this model, the plan of system tasks to be accomplished is considered to be an entity. The blocks in the simulation model represent the operations performed to execute a task. Activities performed by the user, who initiates planning activities, and by the operator, who may intervene in system operation, are also considered to be entities. The actions which the user and operator perform are also represented by blocks in the simulation model. Robots, computers, and other equipment, are considered resources.

This arrangement is chosen since the activities performed by elements of the system toward completion of the overall task, rather than the detailed operation of the system components themselves, are of interest in predicting the response of the system. Since the performance measure is the system response time, only component activities which affect completion of the overall task of the system must be modeled. As additional detail is incorporated in the model or system components are changed, only the blocks describing the affected activities must be modified.

The primary measure of performance is the average response time, which is the expected time to complete a task after issuing a command. This simulation model is equivalent to the earlier Petri net model, and yields identical results when all operation times are assumed to be exponentially distributed. This model provides an initial validation of the simulation modeling approach to analysis of the robotic testbed.

4 FUTURE GOALS FOR PROJECT

The next stage in the project is to develop a more accurate model of the system. Times required to perform system functions, and factors affecting these times, will be examined in detail. The model of operator intervention will be refined and extended, possibly to include the effects of information which is available to the operator. Additional detail about equipment and software failure will be included in the model.

This refined simulation model will be used to estimate the sensitivity of system response time to design parameters, such as microprocessor speeds, and to noise variables, such as equipment failures or operator intervention. This information may be used to balance trade-offs in system design decisions.

The final stage of the project will be to develop methods to use the results of the simulation model to aid decisions required in operation of the robotic system. These decisions would likely be organization level activities, such as task sequencing, or coordination level activities, such as human intervention in robot control.

It is anticipated that decisions such as scheduling and sequencing of tasks would be conducted off-line prior to system operation. These decisions may be aided by simulating various scenarios. Simulation generators [Haddock 1988] with automated statistics processing may reduce the overhead time required to develop and analyze simulation models. Single-run optimization with perturbation methods may lead to near optimal decisions in reasonable periods of time.

Other decisions, such as whether to intervene in robot motion and rescheduling of tasks due to equipment failure, would involve decisions made on-line and would require information quickly. Perturbation analysis methods for single-run optimizations may produce sufficiently short execution times. If not simulation meta-models developed *a priori* may produce the required information quickly. Meta-models are developed based on simulation model output, and provide similar results more rapidly. Available methods include regression models, frequency-domain meta-models, rule-based meta-models [Pierreval 1992], and neural nets.

5 CONCLUSIONS

This paper presents a discrete-event simulation approach to the performance analysis of intelligent robotic systems. This work is an extension of an earlier Petri net analysis of the testbed at CIRSSE. Simulation is able to more accurately model systems more accurately than Petri net models.

The initial model described here provides results identical to the earlier Petri net analysis. The next step is to incorporate greater detail with non-exponential and history-dependent state transition times, and include external factors such as equipment failure and operator intervention. Sensitivity analysis with the model will aid system design decisions.

The final goal of the project is to develop methods to use the simulation model developed for system design to aid operation of the robotic system.

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AUTHOR BIOGRAPHIES

PIETER VOSS is an instructor and doctoral student at Rensselaer Polytechnic Institute. He holds a BSME with Honors from the University of Illinois at Urbana-Champaign in 1992. He has been a design engineer for the Aro Corporation/Ingersoll-Rand.

JORGE HADDOCK is an associate professor of Industrial Engineering and Operations Research at Rensselaer Polytechnic Institute. He holds a BSCE from the University of Puerto Rico, a MSMgtE from Rensselaer, and a PhD in Industrial Engineering from Purdue University. He has authored or co-authored over seventy technical publications and reports. Professor Haddock has also been a consultant to several companies. He received the Outstanding Young Industrial Engineer Award from IIE in 1990 and both the Martin Luther King, Jr. Faculty/Staff Award and Darrin Counseling Award at Rensselaer in 1992 and 1993, respectively.