VERAM: Virtual Environments for Education, Robotics, Automation and Manufacturing

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Abstract: The objective of this research is to explore virtual environments in education, robotics automation and manufacturing (VERAM). The grant provides funding for the purchase of equipment necessary for research into the development of virtual environments for manufacturing applications. In specific, the research investigates the applicability of agent based design techniques in simulating assembly operations within an interactive virtual environment.

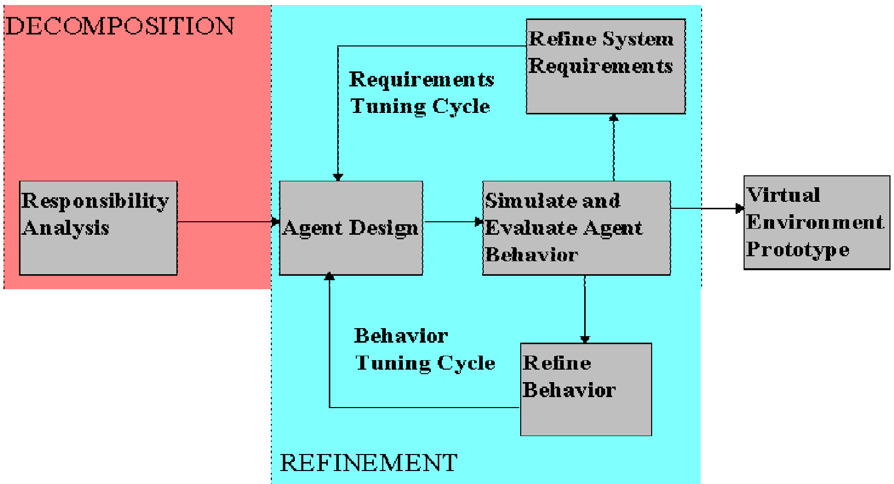
Introduction: Advances in virtual reality (VR) have made it feasible to directly utilize VR for the modeling and realization of virtual manufacturing environments. The use of virtual reality in simulating manufacturing environments give designers the opportunity to play a pro-active role in identifying flaws and optimizing the design. Current techniques do not allow the designer to be progressively involved in the design process. Often, the designer is limited to the initial specification stages and her/his experience is not exploited throughout the design process. This approach offers the following advantages.

i. Evaluate the feasibility of the floor layout for maximum efficiency.

ii. Understand and refine the job flow in an automated manufacturing environment.

iii. Use interactive simulation techniques to speedup the development of automated manufacturing systems.

iv. Evaluate the interaction between the various subsystems in the environment as well as design efficient human-interface components for the realization of the actual factory floor.

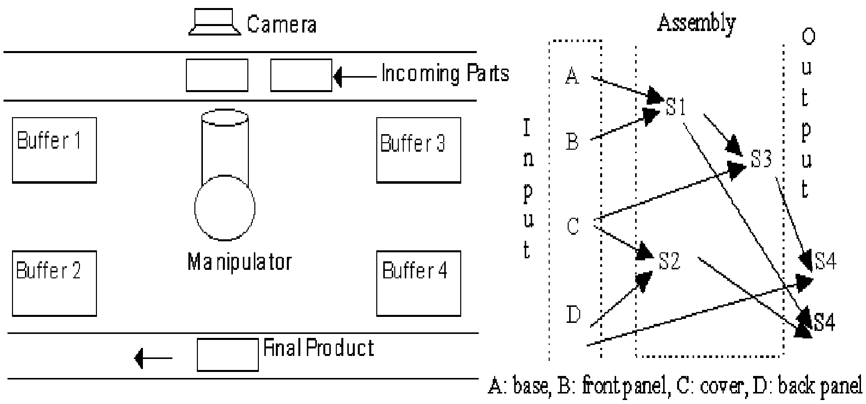


The VE (Virtual Environment) prototyping model shown in Figure 1 was used to develop the application within DIVE, a VR tool developed at the Swedish Institute of Computer Science. The VE development cycle consists of four distinct stages: Responsibility Analysis, Agent Design, Evaluation and Refinement. The refinement of overall system behaviors leads to the behavior tuning phase that results in a possible redesign for agents and the refinement of individual agent behaviors leads to the behavior tuning phase.

VR may be used in both spatial and logical reasoning. The application of VR to spatial reasoning capabilities is well justified, especially in case of domains that exhibit the following characteristics: *(i)* hazards to human health, *(ii)* space / undersea exploration, and, *(iii)* understanding multi-dimensional problems such as atomic and molecular structures, etc. The application of virtual reality to logical reasoning issues in manufacturing is an evolving area of research and it is presently very controversial with respect to its net worth to any organization. It is envisioned that future manufacturing applications in spite of greater and wider automation, will keep the human element in the loop, wherein they will be required to have both critical decision making skills and keen physiological reflexes (aural and visual observation skills). In such a case, it becomes imperative that the right person be assigned to the right group of automated resources on the manufacturing floor to maximize efficiency and minimize safety-related risks. Such a match often involves not only the technical skill of the human in question but will also involve a physiological assessment of the human so that the human can rightly "fit" into the working environment. An immersive virtual environment from this perspective will be worthwhile in training new employees in interacting with the virtual shop floor resources (current examples in this regard include flight simulators). It can be used to study employee reflexes to frequently occurring shop floor situations or exceptional situations (failures, etc.) that are rare in occurrence and thereby help in the placement (or job rotation) of these employees in appropriate environments. Results obtained from such an exercise may also help to develop better human computer interfacing techniques based on advances in multi-media (for example: the three mile island nuclear disaster was blamed on bad human interface aspects). Results from implementing such virtual environments can be used to judge non-logical issues such as fatigue and efficiency of employees over time to shop floor situations thereby becoming an important issue in making the shop floor safer for our work force.

If successful, the results from this research may also be used successfully in studying multi-media enhanced instructional schemes. Although it has been consistently said that multi-media enhanced instructional schemes are very effective in student education, research into the effect of these techniques with respect to learning theories, strategies, visual and aural metaphors, and the effects of collaborated vs. situated learning mechanisms is nascent. The possible advantages of virtual reality in shop-floor simulation may actually be more easily tested in virtual reality applications specifically built for instructional purposes. Virtual reality in instruction may provide major insights into issues such as: focusing student attention, improving memory retention, interleaving visual and aural interfaces to maximize the learning process and improving interaction mechanisms, etc. Thus the proposed work may also contribute in understanding the possible limitations of multi-media techniques in instruction.

The Virtual Assembly Implementation: The DIVE environment was used to study the example assembly process shown in Figure 2a. Figure 2b details the model various assembly alternatives. The assembly consists of four unique parts, which arrive, in random order. The robot has to discern which part has arrived, then determines if the other part necessary for assembly is already buffered. If the necessary parts are buffered, the robot then combines the parts in the desired order. However, if the parts are not available, the robot buffers the current part and waits for the arrival of another part. Once the robot has assembled a subassembly it then checks for the corresponding subassembly to complete the final product. If the corresponding subassembly is not present, the robot buffers the subassembly and waits for another part. Upon completion of the final product, the product is deposited and sent down the output conveyor and the whole process then begins again.



a. Workstation Configuration   b. Possible Subassemblies: S1, S2, S3

Using traditional hierarchical control strategies, control intelligence in the VE will be centralized within the VM (Virtual Manufacturing) control box, while the components in the manufacturing system floor act as "dumb" agents. Using an agent based design technique, this intelligence is distributed across the shop-floor resources. Agent-based design techniques make it easier to encapsulate control intelligence into appropriate shop-floor components. In [1], the identification and handling of user-defined, move and pickup failures, integrated into the VE, are presented. It is also shown that it is possible to easily modify such a control algorithm to handle disassembly operations.

Conclusions: The initial work had implemented the above failure incorporated assembly process in DIVE. This implementation has been reported in [1]. Future research work will have two thrusts: *(i)* Implement a more complex, real-world example in a heterogeneous distributed platform *(ii)* Establish preliminary guidelines and metrics for assessing employee skills using such an environment and apply this for the example. Currently, the PI is approaching industrial contacts to find a suitable real-world application to apply this technique.

In addition, the equipment purchased from this grant is being used to develop the following:

1. Web-based Tutorials: A web-based tutorial for Discrete structures with interactive practical exercises and self-help quizzes (currently located at http://www.csc.tntch.edu/~srini/DM). Work on this front is aimed at developing better techniques and structure for interactive learning.
2. Distributed Java Based Simulation: A distributed, agent-based simulation environment in Java for studying frequency interference issues in mobile radar units. Current work on this front is focussed on implementing a negotiation-based strategy for conflict resolution of interfering frequencies.

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References

1. Yi Yan, S. Ramaswamy, "Interactive Modeling and Simulation of Virtual Manufacturing Assemblies: An Agent-Based Approach", *Accepted to the Special Issue on "Computer Integrated Manufacturing Systems: Recent Developments and Applications" Journal of Intelligent Manufacturing, December 1998, To appear.*