Virtual Reality Model to Aid Case Learning

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Abstract

Virtual reality can be used to configure and build detailed models of factories that can serve as the framework for the cases derived from real-life situations. Practicing process modeling and design using a "real-world" process increases student learning. Virtual reality in the course helps to bridge the gap between industry-based projects and classroom case studies. This paper presents such a model of an aerospace lean manufacturing cell to teach activity and process modeling, analysis, and design.

Keywords: Process Design, Virtual Reality

1. Introduction

Most engineering subjects are taught by presenting theory and then presenting examples. Frequently, the examples are trivial. Senior design courses provide better student experience by interacting with industry. These real-life situations require an active learning knowledge construction approach. However, this method also has drawbacks in establishing these projects and ensuring the students have sufficient access to the required information. By utilizing a virtual model of a manufacturing line, students are able to view the process and interrogate the details. The instructor also has "complete" knowledge of the specific manufacturing environment as the instructor helped implement the virtual model. This also helps to ensure that the manufacturing line has all the desired features and allows students to review and correct errors under expert guidance.

The Industrial and Manufacturing Engineering Department at Wichita State University is developing an integrated set of virtual reality models of a manufacturing line at Boeing Wichita. This mega-case will be used throughout the curriculum to integrate the concepts across the curriculum and provide a situated learning experience for our students. This large-scale virtual reality factory modeling effort, "Innovation in Aircraft Manufacturing through System-Wide Virtual Reality Models and Curriculum Integration" has recently been funded by NSF through the Partners for Innovation program (http://www.slvr.org).

This paper describes one of the initial efforts of this project, which is to use virtual reality models to teach process modeling, analysis, and design. The paper begins with an overview of process modeling, analysis, and design. Then it presents virtual reality and case studies and discusses the pedagogical issues. Our approach is presented and then a conclusion and future plans are discussed.

2. Background

This section provides background on process design, the author-reader cycle, virtual reality, case studies, and then presents the pedagogical issues involved.

2.1 Process Modeling, Analysis, and Design

Jack Welch, former CEO of GE, is famous for stating, "Automate, emigrate, or evaporate" [1]. Due to this, many companies tried to automate everything in sight. Computer programmers attempted to automate engineering designs and processes. But the programmers had limited understanding of the processes they were trying to automate. Industry needs those who understand processes as well as Information Technology and can integrate business processes with information technology. Davenport and Short foresaw the need for a new kind of industrial engineer [2],[3]. Davenport and Short claim that industrial engineers traditionally have understood both information technology and business processes, but considered them as two separate and distinct tools. Industrial engineers are uniquely qualified to integrate the two tools into a competitive advantage. Hammer and Champy define a business process as “a set of activities that, taken together, produce a result of value to a customer” [4]. They present the history of using hierarchical management and discuss why that will not work any longer. Hammer promotes the “process-based” organization.

An "As-Is model" is a model of the current system. It demonstrates a common understanding of the current system. The resultant model is presented to a wider audience to confirm its accuracy and relevance. Upon completion of the As-Is model, subsequent models presenting the desired system, called "To-Be models," are created. Different To-Be models are generated to reflect different design scenarios. These models are then viewed together to identify good design characteristics and these evolve into an implementable, improved design. The use of virtual reality is here primarily directed at developing an ‘as-is’ model of the virtual environment.

2.2 Virtual Reality and Case Studies

If a picture is worth a thousand words, then an interactive 3D model is worth a thousand pictures [5]. Virtual reality (VR) is beginning to be widely used in fields such as entertainment, medicine, military training, and industrial design. Virtual reality models of manufacturing systems range in complexity from the level of a single process on a single machine [6], to flexible manufacturing cells [7], to virtual models of entire factories [8].

Jones et al. [9] discuss the use of virtual reality to present the results of simulations as a “super” graphical animation that will lead to an expanded role of simulation in decision-making and communication. Lefort and Kesavadas [10] have developed a fully immersive virtual factory testbed for designers to test issues such as plant layout, clusters and part flow analysis. Many researchers [11][12][13][14]) have discussed the use of large-scale simulations for studying the virtual behavior of factories. Virtual factories have also been used for simulation-based control of real factories [15], for studying the interaction between business decisions and quality [16], optimal design of large-scale automated facilities such as postal mail process facilities [17] and for optimizing the performance of flexible manufacturing systems by testing different system configurations and control policies [18].

A case study is typically defined as “A problem statement suitable for use by students and set in narrative form. The narrative should provide information that will lead more to a discussion of a problem than to its solution” [19]. The use of cases studies in managerial and business science is pervasive and well documented [19]. The use of case studies in engineering education has just begun to become a useful tool for teaching subjects such as engineering ethics and economics. Recently Raju and Sankar [20] reported on their funded research investigating “Teaching real-world issues through case studies.” Their study developed a single case study that was utilized in a single course to impart “cross-disciplinary education (finance, marketing, communication) in the engineering classroom.” Raju and Sankar developed their case study according to the traditional business definition highlighting the technical aspects of the problem. Their approach to the development of the case study was good and will be utilized in part by this research team.

3. Pedagogical Issues

Situated learning places the learner in the center of the instructional process. It differs from other processes by: 1) content, emphasizing higher-order thinking processes, 2) context, placing the learner in the social, technological and political environment of application, 3) community, providing the setting for social interaction and dialogue, and 4) participation, requiring the engagement of others to develop meaningful systems [21].

In an effort to summarize the research relevant to the design of a situated learning experience, Jan Herrington and Ron Oliver [22] have reviewed and organized much of the research to date. The researchers conclude, “situated learning is an effective instructional paradigm for advanced knowledge.” Table 1 presents the critical elements required for an effective situated learning experience and the realization of these characteristics in the VR process design application.

Table 1: Critical characteristics of situated learning experience in VR for process design.

	Characteristics of Situated Learning [22]	VR Process Design
1	Provide *authentic contexts* that reflect the way the knowledge will be used in real life.	VR model of an existing complex production process that is undergoing continuous improvement.
2	Provide authentic activities.	Documenting the existing process, designing an improved process, and assessing impact are essential activities of practicing professionals.
3	Provide access to expert performances and the modeling of performances.	Models developed by practicing professionals are part of documentation
4	Provide multiple roles and perspectives.	The VR model allows for a variety of team defined roles and perspectives.
5	Support collaborative construction of knowledge.	Individuals *and* teams must interact with the VR model to develop the proposed design.
6	Promote reflection to enable abstractions to be formed.	The nature of the modeling process requires that the level of model abstraction be continually addressed.
7	Promote articulation to enable tacit knowledge to be made explicit.	The product of the process design is an artifact that can be examined.
8	Provide coaching and scaffolding by the instructor at critical times.	Process modeling and design can be performed in stages with feedback provided by the developer of the VR model.
9	Provide authentic assessment of learning within tasks.	At each step of the process design, student products can be compared with those developed by practicing professionals.

4. Approach

A Quest discrete-event simulation model was developed of an actual Boeing manufacturing line. A VRML model was generated from this and placed on the web. Students are able to examine the process though viewing the virtual reality model. Additional annotations are available through web queries of the model. Students can develop the "As-Is" model from this information. Student models are examined to ensure that the process models were developed properly. Students then develop an improved design. Selected designs are implemented in Quest and the resultant VRML model is generated. A class session then can be used to discuss the advantages and disadvantages of each design.

The purpose of this project was to provide a student experience in capturing existing domain knowledge. SADT (Structured Analysis and Design Technique) [23], the forerunner of IDEF, has developed a structured modeling process for the capture of domain knowledge. Knowledge is initially captured through interviews with various sources. These sources include people, documents, and observation of the existing system. For this project, the two primary sources of information are: the factory in a virtual model and a series of video interviews of various factory personnel. The students must determine the appropriate scope of the model which is commonly referred to as 'bounding the model.' It is easy to continually add to the model leading to 'analysis paralysis,' where the model is never completed. The model must also have only one viewpoint. The students can understand the problem by investigating all the models including a video interview that is placed on the web. From this information, the diagrams are composed and supporting text is added. All of this information forms a 'kit'. These kits are composed of a kit cover page, diagrams, text to support the diagrams, and a glossary. A kit is typically one level of diagrams in the hierarchy with the previous level diagram included to provide context. The author/reader review cycle is used to verify IDEF 'kits'. These kits are typically sent to the system experts who comment on the kits. For this project, a graduate assistant and the instructor commented on the kits. The project team receives these comments and makes the required corrections. The experts verify the corrections. This iterative review process continues until each kit is complete. Student kits typically will take about three iterations to complete. The cycle for each review of a kit is usually about a week. The next kit is then created and the review cycle begins for that kit. The kits are created and reviewed in a top-down manner until sufficient detail is captured.

The Boeing line is modeled using the Quest discrete-event simulation software. Quest has all the typical simulation features and also allows control over the animation of the simulation displayed. This control aids in providing realism to the model. It is important not only that the model represents a real-world manufacturing environment, but that it also "feels" real. As quoted by Gobbetti and Scateni [24] in 1965, Sutherland stated that the real challenge of VR is that, "the screen is a window through which one sees a virtual world. The challenge is to make that world look real, act real, sound real, feel real." We are approaching this in phases by making the factory seem as close to real as possible. Figure 2 shows the model in the simulation tool, Quest. Figure 3 shows the same model but from the browser using the Cortona VRML viewer add-in. In the browser the user can start the simulation and view the animation in progress. The students can actually see the inventory stack up in front of a bottleneck machine or slow worker; then they can see the inventory being used as additional workers or machines are added. The distance moved by the workers becomes more apparent.

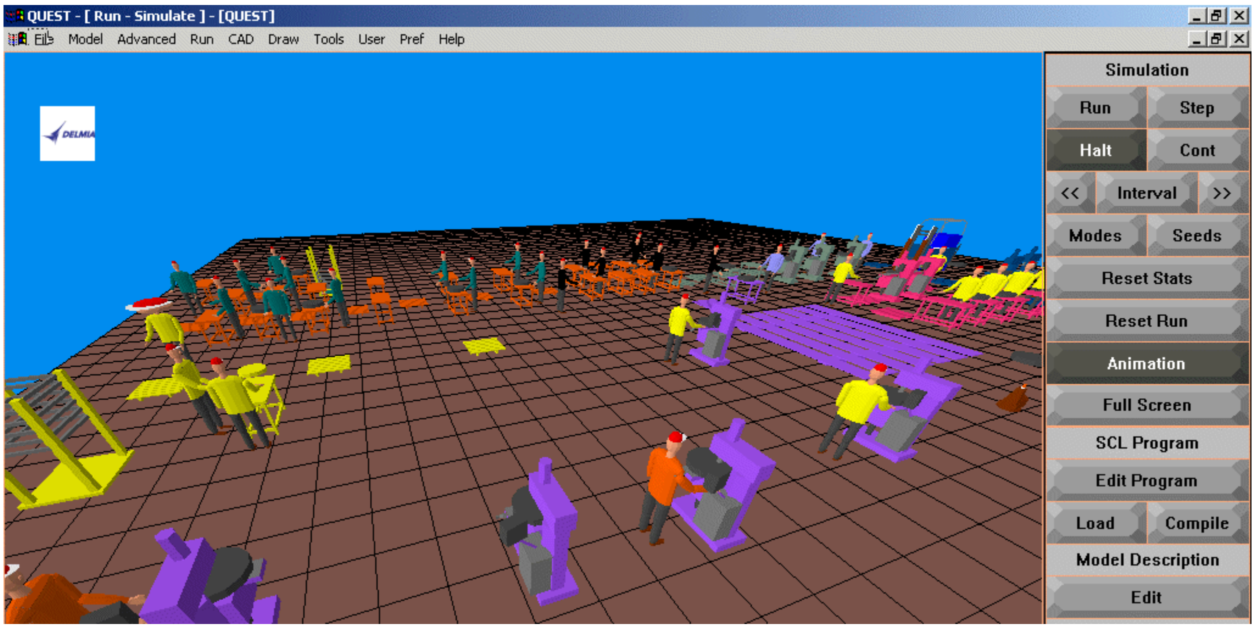

Figure 1. Quest Discrete Event Simulation Model of Line

The students can investigate the model and develop an IDEF3 (process description capture method) model which describes the process. The students can document the steps and determine the times and resources required for each step in the process.

5. Conclusion and Future Directions

This paper discussed integrating virtual reality with real-world case studies to teach process modeling, analysis, and design. Practicing process modeling and design using a "real-world" process increases student learning. By being able to see the results of their improved designs in the Quest environment, students recognize the disadvantages of different designs as well as the advantages. This type of virtual reality in the course helps to bridge the gap between industry-based projects and classroom case studies.

This use of virtual reality was one of the first applications at Wichita State University and is only the beginning of a suite of models aimed at increasing student understanding of Industrial and Manufacturing Engineering concepts. A possibility exists to integrate the virtual reality models and the videos either through links or by allowing students to interrogate a "virtual employee" using an expert system.

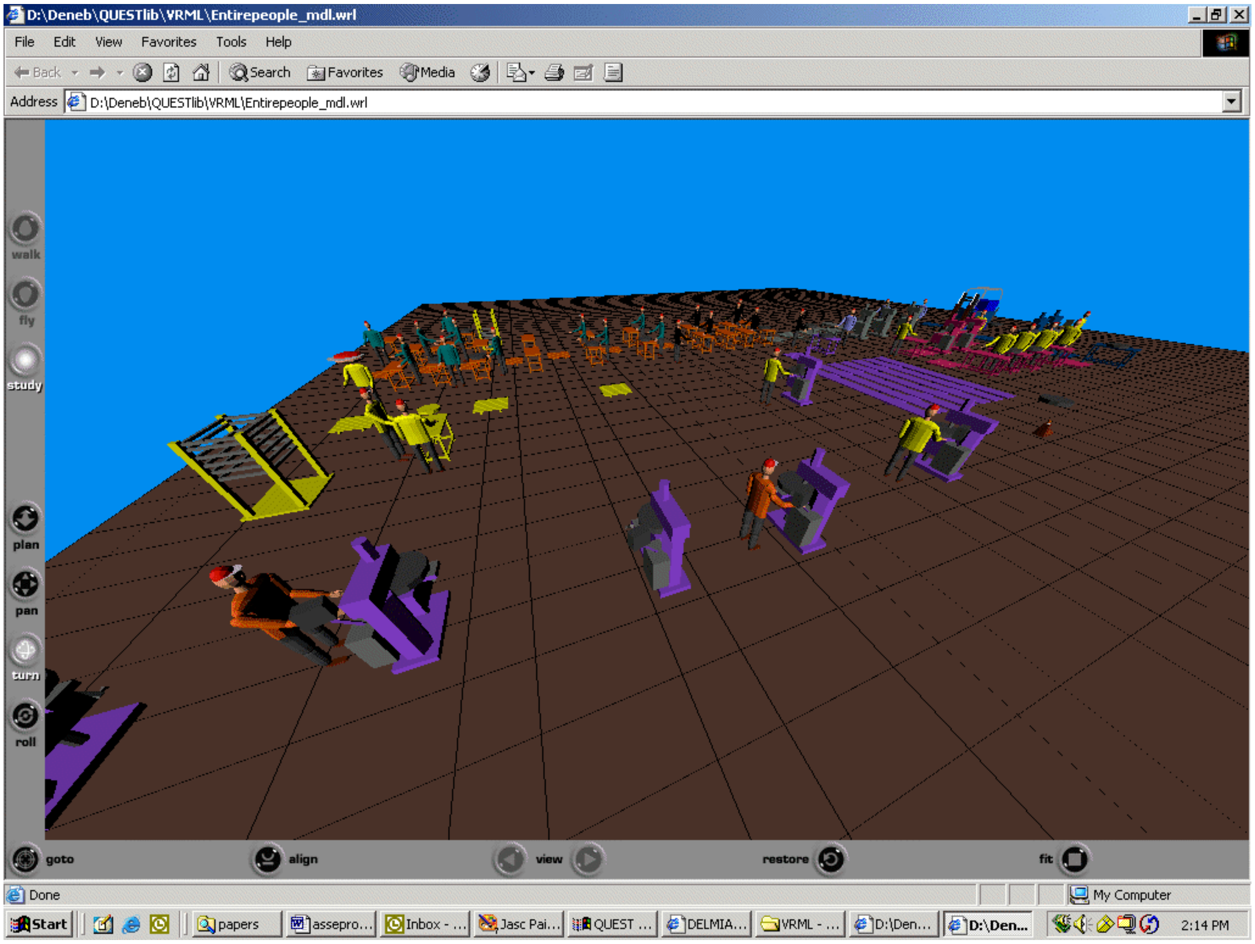

Figure 2. Model Viewed in Browser

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