



Quarterly Progress Report

April - June 1993

A VIRTUAL ENVIRONMENT FOR MANUFACTURING SYSTEMS

ONR Grant N00014-92-J-4092

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Introduction

This is the third quarterly progress report on the project. With this report we have elected to change format somewhat to include a cumulative running total of all project progress to date. Thus, the progress toward each of the three research goals described in the original proposal is presented on a cumulative quarterly basis.

Background

The award of this grant last summer was a major factor motivating the decision of the Iowa Center for Emerging Manufacturing Technology (ICEMT) to purchase a Silicon Graphics Reality Engine workstation, the premier graphics platform for advanced visualization applications. The high level of activity generated by our URI research combined with the excitement generated by this workstation has since intensified interest in VR applications throughout the university. In support of this demand, ICEMT has recently purchased a second, more powerful, Reality Engine, a set of Crystal Eyes stereographic glasses, and a Logitech space mouse and tracking system with two sensors.

This equipment allows us to take the first step toward the development of complete VR environments for manufacturing systems. It will exploit the advanced graphics capabilities of the Reality Engine by using the computer screen as a "window" into the virtual world via the instrumented stereographic glasses. In addition, the 3D mouse will allow new levels of interaction with the virtual world. Combined with the advanced virtual environments and systems under development in this project, this research equipment will allow a user to directly control his or her interaction with a virtual model in a real-time three-dimensional environment. This capability will revolutionize our ability to evaluate and understand new and proposed manufacturing technologies and systems.

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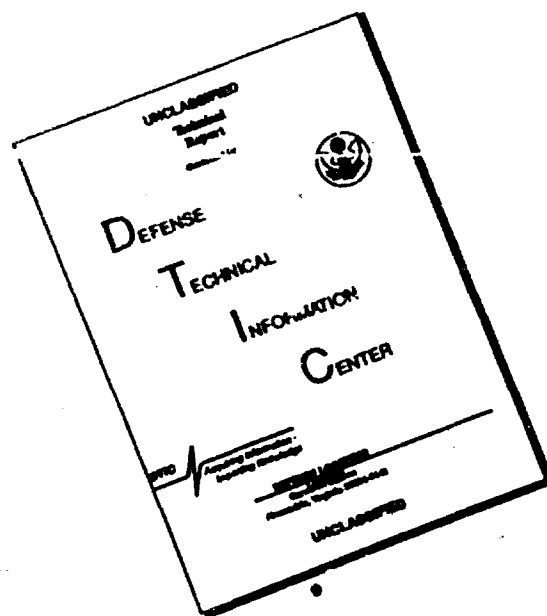
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Assembly Planning Through Visualization

Quarter 1: October-December 1992

From October to December 1992, the research on Assembly Planning Through Visualization has been focused on the development and implementation of algorithms for proposing disassembly trajectories. Three graduate students are currently involved in this research under the supervision of Dr. Lin-Lin Chen.

One of the graduate students has been working on the development of a new set of algorithms for generating potential assembly/disassembly directions for components with free-form surfaces. To generate potentially feasible disassembly directions, an $O(n^2 \alpha(n))$ time algorithm has been developed for computing the spherical convex hull of a possibly self intersecting spherical curve consisting of n algebraic curved segments, where $\alpha(n)$ is the functional inverse of Ackermann's function and is an extremely slow growing function of n .

Another graduate student has been working on the development of an interactive tool for visualizing a Bezier surface and its corresponding Gaussian Map formed by translating the unit surface normals at the points on the surface to the origin. The Gaussian Map of a surface will be the input to the previously mentioned spherical convex hull algorithm. This interactive tool allows the control points that define the surface to be interactively edited and displays the resulting Gaussian Map. Concurrently, another graduate student has implemented Woo and Dutta's algorithm for generating an assembly/disassembly plan of a two-dimensional assembly. As an initial effort, this program takes a AUTOCAD DXF file that describes an assembly as input and computes a disassembly plan.

Quarter 2: January-March 1993

Three graduate students, Shiang-Fong Chen, Fay Gau, and Mei-Chu Cheng, have been working on this research project under the guidance of Dr. Lin-Lin Chen.

Shiang-Fong Chen, an MS student, has been working on automated generation of disassembly/assembly plans for two-dimensional assemblies. She has implemented an algorithm for generating disassembly plans by utilizing information that can be obtained from mating faces of components. The output of her program is a disassembly sequence and feasible directions for disassembling the components. This information is then fed into an animation program to simulate the disassembly process on an SGI workstation. She is currently extending her work to finding directions for separating two components which do not have mating faces.

Fay Gau, also an MS student, started in January to work on computing a representation of all directions in which a given surface is completely visible. Computation of these directions are critical in disassembly/assembly planning since they are the directions along which two components can separate without global interference. She has identified characteristics of the directions across which the a surface changes from completely visible to partially visible or to not visible. She has also implemented a graphical interface on an SGI workstation for displaying these directions as points, arcs, and regions on a unit sphere. A technical paper describing this algorithm is in preparation.

Mei-Chu Cheng, a Ph.D. student, has been developing and implementing an algorithm for identifying pocket (or cavity) features on a component. When separating a target component from another component, if the target component lies inside a pocket of the other component, then only the surfaces in the pocket might obstruct the disassembly of the target component. Therefore, by

identifying and concentrating on the pocket that contains the target component, the number of surfaces need to be tested for global interference can be greatly reduced.

Quarter 3: April-June 1993

From April to June, two graduate students, Shiang-Fong Chen and Mei-Chu Cheng, have been supported by the grant and working under the guidance of Professor Lin-Lin Chen.

Shiang Fong Chen is continuing her research on automated generation of assembly/disassembly sequences for two-dimensional assemblies. During the last three months, she has implemented an algorithm for generating feasible directions that can be used for separating two components, which may not have any mating face. In computing these feasible directions, the algorithm takes into account all possible global interference, and generates a set of directions in which one component can be separated from the other component and translated to infinity. She has already implemented an algorithm that generates potential disassembly directions by using only the information from mating faces of the components. These two algorithm will be the basis of the software for automated generation of SEQUENTIAL assembly/disassembly plans. These plans are sequential because the components are removed one at a time. However, there are assemblies where some components need to be removed simultaneously. Shiang-Fong Chen is currently developing an efficient algorithm to generate assembly/disassembly plans for such type of assemblies.

Mei-Chu Cheng has finished the implementation of an algorithm for identifying pocket features on a polyhedral component. This algorithm is useful in reducing the number of faces that need to be tested for global interference.

Off-line Programming and Visualization of Robots

Quarter 1: October-December 1992

Darren Knapp, an outstanding Masters student, has been hired to head up the off-line programming efforts. Mr. Knapp's research will be supervised by Professor Martin Vanderploeg. Initial efforts are evaluating the current off-line programming software and designing the structure for the next generation of software. The objectives of this new software are to enable modular installation of many robot types and other assembly equipment, and to facilitate high speed graphics that are available using the Silicon Graphics Reality Engine in the Visualization laboratory. In addition, the user interface is being redesigned to accommodate interactive off-line programming of cooperating robots.

Quarter 2: January-March 1993

Two graduate students, Darren Knapp (an MS student) and Jim Troy (a Ph.D. candidate) are supported by the grant and are conducting research under the guidance of Professor Martin Vanderploeg. Development of the next generation of off-line programming software is underway. This software will enable programming of cooperative robots and machine tools. The software is being written to operate in the SGI Performer environment to facilitate VR applications.

Solid models of the manufacturing workcell at the Iowa Center for Emerging Manufacturing Technology have been developed to provide a virtual environment for evaluating off-line programming applications. Jim Troy and Jawad Mokhtar have written software to convert solid models generated in IDEAS and AutoCAD into the proper format for IRIS Performer. This will enable the use of existing models of the workcell's machines to be used directly in VR applications.

Quarter 3: April-June 1993

This effort is continuing and is now being extended into virtual environment technology. The software is first being modified to work in conjunction with the "Crystal Eyes" hardware. This will enable enhanced off-line capability by bringing 3D perception into the process. This should reduce the number of viewpoint changes and increase the overall efficiency of the off-line process.

Simulation and Verification of Material Removal Processes*Quarter 1: October-December 1992*

A dixel-based representation of workpiece, part, and milling tool has been developed to facilitate real-time visual simulation and dimensional verification of five-axis NC milling processes. Mr. Yunching Huang, a Ph.D. candidate under the guidance of Professor James Oliver, is the primary researcher on this portion of the project. Preliminary results are very encouraging; the method is robust and computationally efficient. A technical paper describing this technique is currently in preparation, and we are investigating the possibility of a patent application. A video tape demonstrating a preliminary implementation of the method will be presented at the ONR Manufacturing Workshop on January 12-14, 1993.

A related research project, funded by NSF, has produced some unexpected results which will soon be incorporated within this project. Mr. Nirmal Nair, an MS student, has been working to develop a sheet metal formability constraint for use in a synthesis algorithm for sculptured surface models. A spin-off from this work is a linear-time algorithm for constant area mapping of non-developable surfaces onto a plane. We are confident that this method can be employed to provide accurate analytical assessment of forming processes, and provide the basis for visual simulation and verification tool for sheet metal forming. Mr. Nair will finish his MS in May of 1993, and will be offered an assistantship on this grant to pursue his doctoral research on virtual environments for forming processes.

Quarter 2: January-March 1993

The grant is currently supporting the research of Yunching Huang, a Ph.D. student working under the guidance of Professor James Oliver. Progress is continuing on the dixel-based NC simulation and dimensional verification algorithm. Several new example applications have been demonstrated, and research toward automated correction of five-axis tool paths is underway. This work is aimed at incorporating the tool chuck and holder mechanism into the verification algorithm. Spatial "sensors" on these parts will interact with the dixel representation of the milling environment to indicate interference. Necessary corrective actions are calculated from the degree of interference encountered. An abstract for a technical paper describing the dixel-based NC simulation and verification technique has been accepted for the SIAM conference on Mathematical Methods for CAD/CAM. The university research foundation will soon apply for a patent on this technology.

Mr. Nirmal Nair, an MS student funded on another grant, will defend his thesis in April. His work on an interactive manufacturability assessment tool for press formed surfaces has recently been enhanced to incorporate an efficient assessment of forming strains (in addition to its current capability in blank development). A paper describing his work has been accepted for the 1993 ASME Design Automation Conference. In May, Mr. Nair will join this project pursue his doctoral research on virtual environments for forming processes.

Quarter 3: April-June 1993

On May 26th, Jim Oliver presented the paper "Five-Axis NC Milling Simulation and Dimensional Verification via Dixel Representation" at the 1993 SIAM MCAD Conference in Ann Arbor, Michigan. The paper is co-authored by Yunching Huang a Ph.D. student supported by this grant; it represents the first public disclosure of research results directly attributable to this grant. The paper was also recently submitted to the journal *CAD* for a special issue on NC machining and cutter path generation. On May 27-29 Professor Oliver attended an ONR sponsored workshop on virtual environments held in Raleigh, NC.

Also in May, Mr. Nirmal Nair began his doctoral research under URI support. Mr. Nair had recently completed his Master's degree on under Dr. Oliver's supervision. His work on an interactive manufacturability assessment tool for press formed surfaces was indirectly supported by the URI grant, and his doctoral research will focus on virtual environments for forming processes.

In June the Iowa State University Research Foundation filed two patent applications on technology supported by the URI grant. The first, "Five-Axis NC Milling Simulation and Dimensional Verification via Dixel Representation" attributed to James Oliver and Yunching Huang acknowledges sole support from the URI grant, while the second, "An Area Preserving Transformation System for Press Forming Blank Development," by James Oliver and Nirmal Nair, acknowledges partial Navy support.