Implementing a Flexible Assembly Cell (FAC) - Phase II

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Abstract

The paper describes the second phase of the development of a Flexible Assembly Cell (FAC) in the CIM Lab at GMI. The funding for the cell was obtained under the auspices of the NSF ILI program and matched by GMI and industry. In the first phase equipment was acquired and installed. In addition experiments were outlined. Initial planning evaluations were also conducted. This paper describes the second phase which deals with the integration of the cell into the overall CIM facility. Three student research projects were conducted using the FAC environment and this led to the implementation and integration of the hardware in the cell. The cell was also used for several term projects in undergraduate courses in CIM and Robotics. This paper describes the synthesis between the objectives of the cell and undergraduate education at GMI. The paper examines the effectiveness of the learning experiences that were conceived in Phase I of the project. The results of the implementation evaluation - an activity under Phase II that was conducted to assess the effectiveness of the project - are presented and discussed

Introduction

This paper is the second one in a series of three describing the development, implementation, integration, and evaluation of a Flexible Assembly Cell (FAC) in the Computer Integrated Manufacturing (CIM) laboratory at GMI. The first year of the project saw the acquisition and installation of the majority of the capital equipment for the cell. Over the same period of time the author was able to attend several training sessions to gain proficiency in the operation and maintenance of the equipment. Several experiments were developed and a planning evaluation was conducted internally. Over the second year of the project the cell was further developed and integrated into the CIM environment at GMI.

FAC Implementation and Integration

The implementation of FAC was an effort that featured the active participation of the author, a senior laboratory technician, several students working under the College Work Study program, a group of students taking a course in Robotics, and three students working on independent research projects for college credit. A Gantt Chart was developed at the onset of the project and was used to guide the project through various stages of implementation. Milestones were identified and tasks associated with each milestone were elaborated upon in the implementation plan. Precedence relationships between various tasks were identified, resources were allocated, and a Critical Path was identified. The participation of several is described in the following paragraphs. The work was supervised by the author over a nine-month period.

Adept One Flexible Assembly Cell Design

In Winter 1995, Kimberlee Holtz - a Senior in the Manufacturing Systems Engineering program enrolled in an independent study to conduct research on the design of the cell. Using skills acquired in courses in Production Systems Design and Computer Integrated Manufacturing and following the 6-stage design process outlined by Shigley, she designed and specified the hardware in the cell. This included the robot stand, the assembly and inspection station, the docking station for the Automated Guided Vehicle, the plumbing for electrical, computer, and pneumatic connections, and an initial design for the hand exchanger for the robot. Extensive reach studies were conducted and multiple design alternatives were examined before a final design was recommended. This project was executed over a three-month period and culminated with extensive documentation on AutoCAD R 12 and a comprehensive Bill of Materials.

Development of the Hand Exchanger

In the Spring of 1995 the author taught a senior-level elective course on Robotics. The term project for the course was the design and implementation of hand exchangers for flexible machining and assembly cells in the CIM Laboratory. One group of students elected to work with a GMF M-100 robot servicing a machining cell with two CNC machines. The other group of students elected to work on the implementation of the hand exchanger for the Adept One FAC. Using the design work done by Holtz in the preceding term the student teams proceeded to build a wooden prototype. At this stage minor modifications were made by both student teams to the hand exchangers. The hand exchanger in its final form was manufactured using Aluminum plates and threaded fasteners and incorporates nesting/aligning features for each of the three end effectors and DFMA principles in its overall design. The hand exchanger was instrumented by the group and quasi-intelligent robot programs were developed to track and exchange grippers based on the assembly task being undertaken by the robot. This project was executed over a three-month period and culminated in a fully-functional hand exchanger featuring two instrumented precision mechanical grippers and an instrumented vacuum gripper.

Interfacing The Adept One Robot and CIManager Software

In Winter 1995 Michael Johnson - a Senior in Manufacturing Systems Engineering enrolled in an independent study to conduct research on the supervisory control of the Adept One robot using a personal computer and the integration of the FAC into the CIM environment at GMI. The software chosen for supervisory control was CIManager. CIManager by Cimulus, Inc. is a Microsoft Windows-based application enabler that permits integration of a variety of devices distributed across a site. CIManager provides the tools necessary to specify system control logic, develop device drivers, and create graphical displays of system information. The research done by Johnson addressed the technical and practical aspects of the serial interface between a personal computer running CIManager and the Adept One robot running the V+ operating system. Multiple design alternatives were specified and evaluated by Johnson for the development of this Adept One/CIManager interface. This project was executed over a four-month period and resulted in the development of two separate programs - the Serial Interface Monitor (SIM) on the Adept robot and the ADEPT 1 driver under CIManager. The two systems are connected using a specially fabricated serial cable. The SIM, written in V+, is a command parser that resides on the serial port of the Adept waiting for commands. It parses these commands and calls subprograms to execute the various implemented functions. The ADEPT1 driver, written in LDL (Logical Driver Language under CIManager) provides commands to CIManager which sends the appropriate sequences to SIM to perform specific tasks such as initializing the robot, loading specific programs and executing them, aborting programs, and powering down the robot. Using the two programs tests were successfully conducted to assure the operational status of the cell.

Implementation of Machine Vision Hardware and Software

In Spring 1995 Joel Bollinger - a Senior in Manufacturing Systems Engineering enrolled in an independent study to study machine vision using the AGS-GV vision system available in the FAC, two cameras, and a Dolan-Jenner lighting system. Bollinger's work addressed the development of the inspection station, the evaluation and implementation of the initial work done by Holtz for hardware implementation, the implementation of lighting solutions in the cell, the development of simple inspection routines for sample objects presented to the robot, and the development of vision guided assembly sequences. The three-month study culminated in the development of programs for the inspection and sortation of various objects using user-developed algorithms and the functions provided by the system.

Role of the College Work Study (CWS) Students in FAC Implementation

Over the last eighteen months several CWS students have participated in various capacities in the implementation of FAC. These include the implementation of the Programmable Logic Controller (PLC), the fabrication of hardware needed in the cell, the layout and hookups in the cell, testing of installed hardware, and project management. Undergraduate students working about 8 hours/week on average have contributed significantly to the advancement of the project.

The Application of FAC to Education and Outreach at GMI

FAC was used in the Spring and Summer terms of 1995 by the author in courses on Robotics and Computer Integrated Manufacturing. The first phase of the project saw the development of experiments pertaining to Robot Programming, Programmable Logic Controllers, Machine Vision, FAC System Integration and Control, and the Integration of FAC with Manufacturing Management Software.

In Spring 1995 the students enrolled in the Robotics course worked on the Robot Programming and Machine Vision aspects of FAC. In addition the equipment was used for the implementation of the term project. In Spring 1995 the students enrolled in the CIM course worked on FAC Systems Integration and Control and Programmable Logic Controllers in addition to the Robot Programming and Machine Vision aspects of the cell. The cell was also used for implementing solutions in automated assembly for three term projects involving the design and manufacture of various products.

The experiment involving the interfacing of FAC with manufacturing management software has been delayed until Summer 1996 due to problems associated with the database server used for the Fourth Shift (MRP) software. This is to be rectified in Winter 1996. The cell was used by the author to demonstrate vision-guided assembly to a group of young women attending a pre-college program in engineering. The cell has been used for several demonstrations to diverse audiences over the course of the year.

Effectiveness of the Learning Experiences Conceived Under Phase I

Objectives of the cell and its effectiveness vis-à-vis undergraduate education at GMI were first examined in Phase I of the project. At that time it was stated that "FAC seeks to challenge students by providing them an automated, instrumented, vision-assisted, quasi-intelligent, integrated assembly environment. The environment has been designed to provide students the opportunity to explore the above-mentioned facets through structured experiments, open-ended projects, and ample opportunities for further exploration and research". The experiments that were developed over Phase I and implemented over Phase II have proven to be more than adequate in providing the target audience with strong coverage of subject material with closed and open-ended experiments and projects. Favorable student evaluations regarding experiences

with FAC and the strong and continued interest from students in participating in the project are further evidence of the learning experience that FAC will provide when the implementation is completed.

Project Evaluation

The Gantt Chart developed at the onset of the project was an effective tool in monitoring the progress of the project and keeping the team on track. Despite the apparently sequential nature of the project, usage of the Critical Path and Resource Leveling helped the implementation team work on several projects in parallel to accelerate the process of implementation. At several stages along the past year Formative Evaluations were conducted to solicit information that could be used to improve the project. These were done internally through faculty, technicians, and students at GMI. The suggestions and insights that were gleaned through this process were very valuable in the development of the cell. The process of Formative Evaluation included Implementation Evaluations to determine if the project was proceeding as planned and Progress Evaluations to assess and ensure the timely completion of the project.

Conclusion

The final stage of the project will be completed in the next four months and will be comprised of the continued application of the cell to the MSE program, the completion of the integrated operation of FAC with the manufacturing management software, post implementation reviews, and the summative evaluation to assess the effectiveness of the project. The FAC project has done much to rectify GMI's deficiencies in the area of flexible automated assembly by introducing our students to the field in a structured, integrated, and modular manner.

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Biography

Dr. Winston Erevelles is an Assistant Professor of Manufacturing Systems Engineering at GMI Engineering & Management Institute. His teaching and research interests are in the areas of CIM, Robotics, and Manufacturing Systems. He has a B.S. in Electrical Engineering from Bangalore University, India, and M.S. and Ph.D. degrees in Engineering Management from the University of Missouri-Rolls. He has worked as a Service Engineer and Plant Manager at Mykron Engineers, India. He is an active member of SME, ASEE, and AAAI