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UNIVERSITY AND INDUSTRY COOPERATION IN THE DEVELOPMENT OF A CURRICULUM FOR INTEGRATED MANUFACTURING SYSTEMS ENGINEERING

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Abstract

This paper describes the Computer Integrated Manufacturing (CIMS) Program at the Georgia Institute of Technology, which was established with the help of a grant from the IBM Corporation. The Program began its third year recently, and involves a cooperative effort within Georgia Tech among eight Schools, with strong support and interaction with over a dozen industries. The Program is one approach to the problem of educating graduate students in industrially related inter-disciplinary topics of major importance.

Introduction

The past decade in the United States has seen a major change in the industrial sector. The need for improved productivity and lowered cost of production and improving quality has caused industry to identify the need for new methods of production.

The initial steps taken to develop these new methods were based on the traditional methods of economic analysis and resulted in certain high payback operations being automated first. This has resulted in the factory becoming a collection of "islands of automation". The next step on the continuum of improvement is the integration of these islands into a cohesive manufacturing system. This will be done by enhancing the level of systemization in the factory. The computer will play a major role in this improvement. It will be used not only to improve a particular process step by mechanization but to provide the integrative "glue" of communication between related steps in the process.

High tech tools for manufacturing such as CAD and robotics can be used to enhance the individual manufacturing steps. Communications tools such as local area networks and complex wideband nets are also being used to enhance the manufacturing process. As these tools mature the next problem facing American industry is the lack of people trained in the use of the tools.

Industry and Universities recognized this problem. In searching for a solution they discovered that an engineer involved in manufacturing required an inter-disciplinary education. The problems facing today's engineers are not neatly divided into catagories such as electrical, mechanical or industrial. This has resulted in universities offering a larger selection of interdepartmental programs.

A second area that required improvement was obtaining the involvement of the top students and faculty in the problems facing manufacturing. At present there is little in the way of a rigorous theoretical basis for manufacturing. This makes it difficult to meet the traditional goals of extending the theoretical basis of research. This suggests that the proper approach to provide this motivation is to develop a strong background in a basic engineering discipline followed by an interdisciplinary masters program in manufacturing systems. This should lead to an extension of the traditional theories from the base disciplines into the new problems discovered in manufacturing. This provides the optimal utilization of academia in generating "science" and industry reducing it to "engineering".

When graduates from these programs reach the work force, industry will have a cadre of personnel with a depth of knowledge in a particular engineering discipline but with a broader than normal appreciation for the other engineering disciplines and management techniques.

The IBM Initiative

In September 1982 IBM announced a $50 million program of cash and equipment grants to universities. These grants were to help them teach the most up to date and cost effective design and manufacturing concepts and techniques. Concepts such as robotics, resource planning, and CAD/CAE required more attention in engineering curricula than they were getting at that time. IBM recognized that need and wanted to participate in the required cooperative effort and to encourage others to become a part of it.

In November 1982 over 150 universities responded to IBM's announcement with preliminary proposals. These proposals were for planning grants to develop a more detailed proposal. Although these initial proposals were short, it was obvious that some of the best people in academia recognized the problem as a pressing one and wanted to cooperate with industry in its solution.

IBM awarded planning grants to approximately 50 universities in December 1982 to develop final proposals for curriculum development. These proposals described the universities plans and qualifications. They were received by IBM in the beginning of April 1983.

As a result of a comprehensive review of these proposals by the IBM management team, grants of approximately $2 million each were awarded to Georgia Institute of Technology, Lehigh University, Rensselaer Polytechnic Institute, Stanford University, and the University of Wisconsin at Madison.

Although only five schools received grants, over 50 schools have continued their efforts to develop curricula in manufacturing systems engineering.

The remainder of this paper will describe the implementation of the program as it was done at Georgia Tech.

Georgia Tech's Response to IBM's Initiative

The response at Georgia Tech to IBM's request for proposals in the manufacturing system area was, like that at many universities, one of extreme interest. Initial meetings concerning a response brought together groups from across the campus that saw relevance in what they were doing to the problems of manufacturing. Of course, turf issues surfaced in the ensuing discussions, but most of this energy was usefully directed toward contributing to a successful proposal. The substantial support by an internationally successful company was effective in convincing many academicians that the problems of manufacturing were more than the simple lack of attention in relatively mundane matters. Once "out of the closet" the interest in manufacturing could be respectably pursued.

An initial grant was received to prepare the full proposal. This was used to support faculty time, travel to industrial and academic institutions and to conduct literature surveys. The material was collected from across campus by a small writing team. The outline and many drafts were reviewed by a group of administrators of the interested academic units all the way up to the president. The commitment of these administrator's was impressive, most helpful and out of proportion to the funds at stake. It seems that the type of funds, namely largely unrestricted and available for education related purposes, and the large effort from all academic institutions across the country, resulted in a high priority for this proposal. Georgia Tech proposed a program in Computer Integrated Manufacturing Systems (CIMS).

What is CIMS and Why

CIMS is an innovative option in graduate education which blends instruction, laboratory and research experience, and industry interaction into tailored, challenging programs. Eight schools (departments) at Georgia Tech cooperate in this effort to fill the indispensable needs in manufacturing -- for technical depth tempered with broad comprehension of several disciplines and for the management perspective required for applying technical solutions effectively.

The details of the CIMS program are included in the section on curriculum. This section will focus more on the reasons that lead to the details of the curriculum.

The name Computer Integrated Manufacturing Systems was chosen over others after consideration because it emphasized our desire to keep the program technologically based, building on Georgia Tech's strengths. It also carried to the potential student the message that manufacturing was a segment of industry with an exciting technical future, and worthy of their consideration. Education in CIMS is itself an integration of many disciplines into a coordinated whole. The Georgia Tech CIMS Program retains the technical strengths, student appeal, and national recognition of existing disciplines and degrees, but integrates them through a Multidisciplinary Program administered in the College of Engineering. Both the School of Information and Computer Science and the College of Management are participants outside of the College of Engineering, but the other six units are "Schools" in engineering disciplines. The resulting Master's degrees are distinguished with an accompanying certificate in CIMS. The Certificate requirements insure competence in CIMS (breadth) while the degree insures technical competence in a recognized discipline (depth). Georgia Tech had previous experience in multidisciplinary programs through The Material Handling Research Center, The Microelectronics Research Center, The Georgia Mining and Mineral Institute, and other certificate programs on a smaller scale.

The CIMS Program

The program establishes a balance between specialization and generalization and includes

a. The physical and informational processes and equipment of CIMS, their interfaces to a manufacturing and design data base, and

b. The management of projects to implement and operate a computer integrated manufacturing system.

The subject is too broad for any one student to master in total. Students from different disciplines work together on problem where a common understanding is needed. They become accustomed to working with a variety of specialists in the core courses, in the CIMS electives, and in the CIMS project course.

The program is not specific to any industry, although some of the elective courses are specific to a particular group of industries. The large size of the engineering and computer science programs at Georgia Tech enables and encourages this breadth. The CIMS Program seeks industrial input to courses, research and design projects, and program direction. It also depends on continued financial support from firms in addition to IBM. This will be further described in the section on Industry Interaction.

A realistic understanding of engineering requires responsibility for some aspect of an "open ended" technical problem. This requirement can be met in the following ways:

a. Appropriate industrial experience (regular or graduate co-op);
b. Thesis work related to CIMS;
c. Special research problem (independent project) or design of CIMS;
d. Documented research related to CIMS not culminating in a thesis or special problem;
e. Project course in CIMS (a team project).

All CIMS graduates must appreciate the role of research in advancing technology for manufacturing. Those oriented to research acquire this appreciation through participation. Others acquire it also through research seminars, speakers, and the advanced components of courses. Support for research and teaching assistants is provided through the CIMS program for both Master's and Ph.D. students.

The Curriculum

Requirements and Options. The CIMS Certificate is awarded as an enhancement to a degree offered through an existing degree program to students who have satisfied the requirements and appropriately submitted documentation to that effect. Certificate requirements are intended to insure that the holder has an appropriate set of skills.

These requirements include:

a. Receipt of a graduate degree from a participating School.
b. Six hours of CIMS core courses.

c. Approved electives.
d. A Seminar course in CIMS.
e. Project experience, either a Special Project, a Thesis, Graduate Research, or other relevant experience on or off campus.

The CIMS curriculum is individually tailored, in conjunction with an advisor's approval, by the student's selection of electives and project experience. CIMS Electives consist of Tailored Electives and General Electives and can be selected from four CIMS areas.

The areas are:

a. Processes and Design for Manufacture.
b. Computer and Communications Hardware and Software.
c. Systems Dynamics, Measurement, and Control.
d. Management of Industrial Systems.

Students electing the non-thesis option must complete 24 quarter hours of CIMS Electives with at least three hours in each CIMS area. At least four courses must be CIMS Tailored Electives.

Students electing the thesis option must receive credit for 18 quarter hours of CIMS Electives with at least three hours in each CIMS area, of which at least three courses must be CIMS Tailored Electives.

CIMS Core Courses. These introductory core courses take students with diverse backgrounds and introduce them to the broad aspects of the factory of today and tomorrow. The first of two planned core coursesCIMS I, was developed and taught Winter and Fall Quarters of 1984. In the core courses, the processing and flow of materials and information is treated in a unified way. Few, if any students have backgrounds in all the concepts presented, but most know from their undergraduate work, some concepts very well. The courses are organized to capitalize on this feature using student-project teams consisting of a mix of disciplines. Each student brings to the team an area of special competence. Personal communication with other technically trained people about a specialty is required on a job in a multidisciplinary activity such as manufacturing.

The courses are supplemented by tutorials that allow the topics to be covered in more depth than otherwise possible. Distinguished speakers from industry are invited to supplement the team of faculty lecturers.

CIMS I. An introductory course at the graduate level in manufacturing systems, CIMS I, is team-taught by a number of faculty who are experts in their topical areas. The course is designed to familiarize students with manufacturing issues and the need for improved productivity. The multidisciplinary nature of manufacturing is emphasized by individual and group assignments. The manufacturing topics introduced are categorized into four major course segments.

These are: processes, equipment, their capabilities and functions, factory integration and the flow of material and information, product and factory design, and factory control.

CIMS II. The second of the core courses, it was developed and taught during the Winter Quarter of 1985. This course is designed to look specifically at the technologies for integrated manufacturing, including CAD, electronic communications, designing for manufacturability, robotics and factory control techniques. It consists of readings from the current literature, followed by student presentations and discussions. An essential outcome of this course, is the generation of an up-to-date data base on the current literature on CIMS related technologies. The content of this course is dynamic as we try to track the forefront of the current literature.

CIMS Tailored Courses. A Tailored Course serves several purposes in a multidisciplinary program such as CIMS. It brings together students from many disciplines to contribute to class discussion and projects from several perspectives. It orients material to the problem area at hand, namely manufacturing systems. Finally, it packages material for students with backgrounds untraditional to the subject, thus, presenting important prerequisite material at an accelerated pace. Several courses have been and continue to be developed in each of the CIMS areas.

The Research

While the CIMS Program was established as an educational one, it is none the less a graduate program, with primary emphasis on the Master's level. As a graduate program with a requirement of a thesis or a project, its research component is of significant importance. The research undertaken by the students and faculty involved in the program is on topics that are of long range relevance to modern manufacturing systems, and motivated by problems of interest to the industrial firms that are supporting the CIMS effort. These projects are not aimed at solving the current problems that a particular industry is having. Its primary aim is to advance the frontiers of knowledge in a complex interdisciplinary area, and impart innovative problem solving expertise to the CIMS students. While the research projects originate in the particular schools (departments) involved in the CIMS Program, they are coordinated and integrated by the program to provide a multidisciplinary environment for the projects, and to tackle real manufacturing problems that cannot be solved along disciplinary lines. The projects also require teams of students with a variety of expertise, such as computers, communications, controls, processes, material handling, management, software, and hardware.

The research topics are organized into four major areas:

a. Manufacturing systems planning and design. This area includes projects that cover the overall planning aspects of manufacturing systems ranging from a simple robotic work cell, to material handling, and on to economic and management considerations.

b. CAD interface to production. This topic includes CAD approaches to process and part design, as well as cell and machine programming using CAD data bases.

c. Manufacturing control systems. This topic covers the most wide ranging projects as it incorporates all levels of control systems, from the local machine and cell control, to the global control of a manufacturing system. Projects include several aspects of control of large scale systems, involving hierarchical, distributed, and decentralized control and takes into consideration the man-machine aspects of flexible automation and the information flow and network control in a manufacturing environment.

d. Hardware design. This topic includes projects dealing with the placement and design of sensors and actuators for manufacturing systems. It covers projects dealing with sensor integration, smart end-effectors, and the use of lightweight arms for robotic manipulators.

The topics thus cover as many of the basic elements essential to integrated manufacturing systems as can be undertaken by the faculty of a single institution. A central focus for the research areas is the theme of flexible automation. Most of the projects are carried out at laboratories affiliated with the Program, and located at individual schools, but are accessible to all the CIMS students. These laboratories are:

a. Flexible Automation
b. Control and Automation
c. Man-Machine Systems
d. Material Handling
e. Computers in Manufacturing
f. Communications Networks
g. CAE/CAD

Most of these laboratories are not exclusive CIMS laboratories, but they all carry out research projects that are CIMS related, and can use and provide access to CIMS students. The availability of eager and bright graduate students to work on meaningful projects, make the affiliation with the CIMS Program very attractive to the laboratories.

ndustry Interaction

IBM provided the initial funding that accelerated the establishment of the CIMS Program. However, in order to build a self sustaining program, industry support was solicited during the first year of operation. The solicitation generated strong support from industry, which led to the creation of a CIMS Industrial Advisory Board (IAB) that is composed of representatives of sponsoring industries. To date the following companies are members of the IAB: ALCOA, Babcock & Wilcox, Coca Cola, FMC, Hayes Microcomputer Products, IBM, Lockheed-Georgia, Motorola, NCR, Northern Telecom, United Technologies, and Whirlpool.

Although financial support is required, the primary function of the IAB is to provide valuable interaction with the faculty and students in the CIMS program. The industry interaction is invaluable in generating meaningful topics for research and education. In particular the IAB is involved in developing industry's role in curriculum enhancement, personnel exchange, and research. This role is advisory in nature as the member companies recognize that the educational expertise resides in academia.

In the curriculum area the IAB helps contribute case studies, projects, CIMS seminar speakers, and educational modules. Participation in this manner provides the university with a view of some "real" problems. Even though the problems must be scaled down significantly for classroom use it is helpful to know that they represent a real problem that either has been solved or still needs to be solved. This helps in the evaluation of the content and relevance of the CIMS program.

In the research area the IAB's role is to provide topics for CIMS projects, assist in carrying out of projects when co-op students are involved, and review research proposals for CIMS projects. As a by-product, individual industries may support specific projects on a private basis between the industry and the faculty involved.

In the personnel exchange area the IAB can work in two ways. They can enhance such efforts as recruiting of CIMS graduates, providing assignments for graduate co-ops, summer students or faculty sabbaticals.

Another personnel exchange that might be of interest to an IAB company is the opportunity to participate in the Industrial Fellows program. In this program a professional employee from one of the member companies can accept an assignment on the university campus for a period of time. These assignments can be deigned to allow the employee to continue his education, teach, or do research. One might consider this a form of sabbatical for industry.

Present Status

Georgia Tech was committed to establishing a program in Computer Integrated Manufacturing and had invested a year in this planning phase. The announcement of support in July of 1983 by the IBM Corporation accelerated these plans dramatically. To initiate the CIMS program in September of 1983, students were recruited from those already planning to attend Tech in CIMS related areas. Forty students responded for the first year's program. The qualifications of these students were high, consistent with Georgia Tech's admission standards. This group consisted of the following[1]:

Thirty-seven were men and three were women.
Thirty were U.S. citizens.
One-half the group had a year or more previous industrial experience.
Six were supported by the CIMS Program as Graduate Research Assistants.

They sought degrees in six Schools listed:

Aerospace Engineering - one.
Chemical Engineering - two.
Electrical Engineering - four.
Information Computer Science - two.
Industrial Systems Engineering - eleven.
Mechanical Engineering - twenty.

Despite the time limitations for recruiting, enrollment response during the first year was excellent. This was attributed to the recruiting efforts of the participating schools, word-of-mouth, and CIMS program literature, that was available for distribution in January of 1984.

By the start of the 1984-85 academic year, the CIMS program had received 320 responses, representing 52 schools from 14 countries. Due to this favorable response, it is expected that future CIMS recruiting efforts will be sufficient to attain a goal of 100 enrolled students. Fall Quarter 1984 enrollment in the CIMS program was at 75 percent of this goal. When peak enrollment is reached, CIMS students will be given preferential registration status for enrollment in CIMS program courses over non-designated CIMS students. Preliminary figures indicate that students interest continues to be strong into the 1985-86 academic year, with an acceptance by more than twenty-two CIMS Graduate Research Assistants including at least three Ph.D. students.

The distribution of these awards is almost equal in E.E., M.E. and I.E. with lesser numbers in the other represented disciplines. The students participating overall have come from all the eight disciplines, but in the past over half have been in Mechanical Engineering. The distribution is beginning to become more balanced as is indicated by the award of Graduate Research Assistantships. The potential for increased numbers of students still exists in Management and Computer Science.

By the end of the Summer, 1985 Quarter over 50 CIMS Certificates had been awarded. In addition to those students receiving the certificate, a number of students benifited from the CIMS created courses and laboratories. This is because the certificate requirements are substantial in hours (2/3 of the minimum for a Master's Degree) and in performance (no B's are accepted in the 30 credit hours of the certificate). About 120 students have taken the CIMS I course, for example.

One interesting statistic on the students completing all the requirements to date is that over 90% have had prior industrial experience, as opposed to about 50% of those taking the introductory CIMS I course. A formal survey of the CIMS graduates is planned, but at this time only general observations on employment of the graduates can be made. Corporate laboratcturing R&D and individual
plants have both hired these students. A few of the graduates have taken non-manufacturing jobs, but this is the exception. Most have gone to major corporations.

CIMS students are now beginning to take the Graduate Co-Op option in significant numbers. At least five students were on work assignment in the Summer '85 quarter. This is far below the number we would like to see, but the interest of both the companies and the students is on the rise.

Summary

The CIMS Program is in its beginning stages, and is just one of the approaches that are used to create such programs in an academic institution. The experience at Georgia Tech indicates the problems and opportunities of such a program. The opportunities are great, because of the importance of the manufacturing area to the nation and the economy. The problems stem from the need for academic institutions to learn to operate across disciplines, which the manufacturing area demands. The mechanisms set in place at Georgia Tech contribute to the elimination of the barriers among schools or colleges. The CIMS umbrella helped many faculty and students to work together without regards to administrative or disciplinary boundaries. The end result is the engagement by faculty in meaningful research projects, and the education of students who are broad in outlook without sacrificing their deep base in a traditional engineering discipline.

References

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