Project Description

A. Goals and Objectives

The overall goal of the project is the development of an undergraduate comprehensive course in robotics that encompasses the various fields of engineering which are integral to robotic systems: Computer Science (CS), Electrical and Computer Engineering (ECE), Mechanical Engineering (ME), and Industrial Engineering (IE). The pedagogical goals of the course include:

1) To provide a hands-on experience in practical robotics
2) To learn about integrated system design
3) To learn to interact with people in different disciplines in a cross-functional team
4) To learn about group dynamics and teamwork

The project will adapt exemplary materials and methods mainly from the General Robotics course at Carnegie Mellon University (CMU) but will also rely on materials recently developed from other courses that include hands-on robotics projects. A major goal of the project is to adapt the materials in a way that the course can be taught at undergraduate institutions that do not offer a degree in robotics, an active robotics research center, or even the full range of engineering expertise that is represented in such a comprehensive course.

Another major goal of this project is to develop materials that provide an understanding of team development and group dynamics. Generally, students are given group experiences, but are not given any guidance on group interaction, conflict resolution, and teamwork. Furthermore, the complexity of today's integrated systems requires cross-functional team development; so students need to learn to speak with people from other disciplines. As part of this goal, a team assessment method will be developed that specifically addresses cross-functional aspects.

B. Detailed Project Plan

Hands-on robotics projects have become useful educational tools across a variety of subjects. Robots are complex integrated systems comprised of interdependent electrical, mechanical, and computational components. Because of their multidisciplinary nature, the study of robotics in the classroom has become a valuable tool for the practical, hands-on application of concepts in various engineering and science topics [1, 2, 3, 4, 5, 6, 7, 8]. They afford a view of information processing from the microprocessor level up through the application software and are a perfect illustration of the connection between mechanical, electrical, and computing components. Furthermore, robots are a physical embodiment of computational processes. The connection of the physical actions to the more abstract computation creates effective feedback for learning [9, 10, 11]. In addition to being an educational tool, robotics is becoming an important area with the increasing number of successful consumer robots. While these successes are mainly in the area of entertainment robots, such as Sony's AIBO and Mattel's Furby, a few personal productivity robots have recently hit the market, such as lawn mowers, tennis ball retrievers, and vacuum cleaners [12].

However, the multidisciplinary nature of robots that make them effective teaching tools has also relegated their study to larger universities with research groups whose members have the full range of requisite knowledge to engineer such complex systems. Pre-constructed robots are available, but their steep prices make them cost prohibitive to the more modest budgets of smaller educational institutions. With the recent commercialization of inexpensive computational components, robot platforms have become affordable to these programs [13].

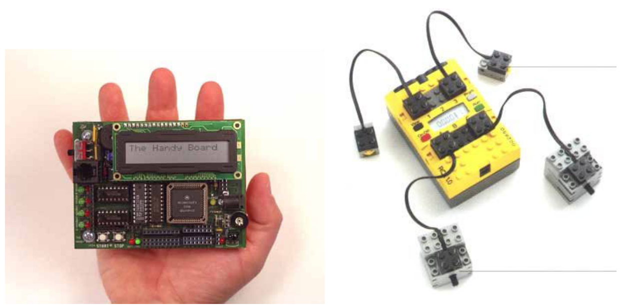

Figure 1: The Handy Board Computer and the Lego Mindstorm RCX

More importantly, the new robot platforms have made the area of robotics accessible by removing the need to have an extensive background in electrical engineering, mechanical engineering, and computer science simultaneously. Platforms such as the Handy Board and the LEGO RCX (See Figure 1) [13] have managed to allow educators to cross the *threshold of indignation*, which is "the maximal behavioral component that we are willing to make to get a task done" [14]. If end users perceive that their efforts must go beyond this point, a new tool will not succeed in the consumer market, no matter how good or interesting the manufacturer believes it to be. These robot platforms provide users with simple techniques for connecting sensors and motors, as well as straightforward methods for programming the controllers that manage those components in a variety of programming languages [7, 8, 15, 16]. From the mechanical engineering perspective, robot bodies can be constructed from the simple building blocks of standard and specialized LEGO parts, which include gears, axles, and hinges.

With the development of inexpensive and accessible platforms, robotics projects provide an opportunity to directly interact with technology, as well as an opportunity to design and implement the various concepts that they embrace. Seymour Papert termed this style of learning "constructionism" [17]. This approach to teaching creates an active learning environment in which students can explore a significant design area, make hypotheses about how things work, and conduct experiments to validate their assumptions [9, 10, 17, 18].

Without formal guidance, however, students in a particular discipline could be overwhelmed by designs that prove to be impractical from the perspective of other disciplines. Some courses overcome this problem by providing the students with those elements of the project that are not in the designated area of study, e.g., giving computer science students a specific mechanical platform and/or sensor configuration [6]. Other courses use a structured exercise approach, in which students are given a number of exercises to familiarize them with the relevant concepts of other disciplines [5]. For this approach to be effective, instructors need to have sufficient background knowledge to formulate effective learning exercises, e.g., an understanding of mechanical gears and structures, electronic sensor limitations, as well as basic algorithmic design and multitasking.

To address this need for cross-disciplinary knowledge, we formed a Multidisciplinary Project Action Group (MPAG), which includes faculty members from Computer Science, Electrical & Computer Engineering, Industrial Engineering, and Mechanical Engineering. The MPAG provides a basis for sharing expertise across the disciplines [19, 20] (See www.siue.edu/robotics for more information). The group's main goal is to share expertise for the express purpose of using inexpensive robotics platforms for teaching engineering and computer science concepts. Consequently, students in mechanical engineering can learn enough about structured programming principles, behavior-based robotic control, and multitasking to successfully implement a control program. Conversely, computer science students can learn enough about sensor processing, gearing, and transformation power to successfully design a physical robot structure. The framework for sharing this expertise includes exercise design discussions, the hiring of student assistants between the areas, demonstrations, and guest lecturing.

Members of the group create project modules that encompass concepts to be mastered in structured exercises for courses in their respective areas. These modules provide a basis of concepts and technical vocabulary for design discussions between the members. Through these discussions, the technical concepts of one discipline are translated into materials and exercises at a level that students in a complementary discipline can understand.

Area	Course	Concepts Emphasized	Concepts Shared
Computer Science	Artificial Intelligence (CS 438)	Embedded agents, deliberative/ reactive robot control, planning, multitasking	Subsumption architecture, search strategies, multitasking
Mechanical Engineering	Robotics Mechatronics (ME 458)	Sensor processing, logic circuits, real-time processing, actuators, analog/digital conversion, electro-mechanical system integration	Differential motion, gearing, translation motion
Industrial Engineering	Engineering Problem Solving (IE 106)	Problem formulation, structural design, algorithmic design, search strategies, gearing, drive train	Problem analysis and definition, integrated system design
Electrical & Computer Engineering	Senior Project (ECE 491)	Signal processing, robotic system design, and project management, analog/digital conversion	Sensor characteristics, robotic system integration, robot navigation strategies

Table 1: A sample of concepts emphasized and shared

Prior to this effort, individual members of the MPAG felt that they did not possess the necessary expertise to assign robotics exercises in their courses. The group was formed in Fall 1999. Beginning with the Artificial Intelligence course in Spring 2000, robotics projects have been included in every MPAG member's area of study (See Table 1) [19, 20].

While the MPAG approach has been successful for introducing hands-on robotics projects in individual courses, it lacks three important educational goals. The first is the design and development of an integrated system. While the students in one area get a sense of how issues in the other disciplines might affect the design, they do not get a true experience of how to design a complex system of interdependent components from the different disciplines.

The second educational goal is learning to work in cross-functional teams. A high degree of cooperation is needed among cross-functional team members for a project to be successful [21]. The amount and type of communication, the amount and type of conflict, team cohesion and work processes appear to be the key areas for influencing cooperation and performance in cross-functional teams [21, 22, 23]. The curriculum in any specific area of study tends to narrowly focus students on that area, whereas real-world complex systems integrate electrical, mechanical, and computing components. The development of these systems has shifted from designing individual components in isolation to working in cross-functional teams that encompass the variety of expertise needed to design the entire system [24, 25, 26]. This means that students must learn the team building and communication skill to work with others outside of their own discipline. The Accreditation Board for Engineering Technology (ABET) recognizes the importance of this ability in the Criteria for Accrediting Engineering Programs: “Engineering programs must demonstrate that their graduates have an ability to function on multi-disciplinary teams” [27]. While the MPAG approach has provided for team projects in individual courses, the teams consist only of students in each course’s specific major. A true cross-functional experience will have teams consisting of students in CS, ECE, ME, and IE.

The final educational goal is a complete survey of the study of robotics. The MPAG approach has allowed us to introduce concepts from the different disciplines into each other’s courses, but understandably each course still emphasizes concepts in its own specific area. So, a course in ME emphasizes dynamics and kinematics, while the course in CS emphasizes computational architecture. Students do not get exposure to the full breadth of robotics.

To meet these educational goals, a new course in General Robotics will be developed by building on the framework of the MPAG [19, 20]. The course will be cross-listed for credit to students in CS, ECE, ME, and IE. The specific pedagogical goals of the course are:

1) To provide a hands-on experience to practical robotics
2) To learn about integrated system design
3) To learn to interact with people in different disciplines in a cross-functional team
4) To learn about group dynamics and teamwork

The course we propose adapts curriculum and material from CMU’s General Robotics Course [21, 25], from Swarthmore University’s and Bryn Mawr College’s Robot Building Laboratory Project (NSF CCLI Grant #9651472) [5], from Drexel University’s Research and Education Tools for Low-Cost Robots (NSF CISE Grant #9986105) [30, 31], and from Southern Illinois University Edwardsville’s Laboratory Experience for Teaching Participatory Design (NSF CCLI Grant #9981088) [32]. See Table 5 for a more complete listing of material.

Table 2 is a sample schedule for the proposed course. The topic list is adapted from CMU’s General Robotics course, which is a comprehensive robotics course (See Table 3) [21, 25]. The CMU course provides an integrated systems approach to robotics with a cross-functional team experience. Similar to the CMU course, the proposed course is targeted to senior, junior, and advanced sophomore computer science and engineering students. While the list of topics is similar, the order of the topics differs. The proposed course (Table 2) follows the Swarthmore/Bryn Mawr model in presenting intelligent robot control starting with Reactive Control Architectures (Week 2) followed by Deliberative Control Architectures (Week 9). Topics follow an order that would allow the students to perform labs and create projects to implement these control architectures.

Week	Lecture Topic	Lab Activity
1	Introduction to Robotics	Introduction to LEGO Robot Building Kits:
2 & 3	Introduction to Artificial Intelligence, Robot Control Architectures, and Behavior Based Robotics	Design and implementation of subsumption architecture, multitask programming, and methods for embedded systems programming
4	Group Dynamics, Teamwork, and leadership. Problem analysis & definition, and Integrated systems design	Ice breaking and team building exercises
5 & 6	Sensors and signal processing: analog to digital conversion, interpretation of analog signals	Implementing and programming sensors: light, touch, infra-red
7	Mechanisms & Mobile Robot Platforms	PID Feedback control, translation and rotation, differential gearing, drive trains, degrees of freedom
8	Robotic Vision	Blob detection, contrast, and thresholding
9 & 10	Delibrative Control & Robot Navigation	Dead reckoning methods, path planning,
11	Team Project Preparation	Team Project Workshop
12 & 13	Forward and Inverse Kinematics	Mathematics of planning motion for robotic arms
14	Multi-robot coordination	Robot communication
15	Team Project Demonstration	

Table 2: A sample schedule for the proposed General Robotics course

The philosophy of the labs in the CMU course is to provide hands-on design experiences that complement the lecture material. In this way, it produces a type of “directed constructionism” learning experience where students are asked to explore related topics in a specific order [10, 24]. We intend to maintain this same philosophy. The laboratory components of the course will mainly utilize the LEGO Building Block platform for the mechanical aspects of the robot and the Handy Board 6811-based microcontroller for the computational aspects (as do all three of the robotics courses from which we are adapting material). The accessories, tools, and material developed for the Handy Board are extensive and will be useful in creating sophisticated assignments to challenge the students. For example, Drexel University’s Research and Education Tools for Low-Cost Robots includes software tools for displaying the result of a certainty grid for navigation, tools for using the Handy Board’s speaker for debugging, and tools for doing inter-robot infrared communication [30, 31]. A color camera developed at CMU, called the CMUcam Kit, is available for the Handy Board [33]. All three programs we are adapting from have an extensive set of tested labs that include sensor building, image processing, subsumption architecture, wave-front motion planning, and graph traversal.

Week	Lecture and Lab Topics
1 & 2	Introduction to Robotics, C Programming, Computer Vision & Vision Programming
3	Vision Problems, Introduction to the Handy Board, LEGO Controls and the Art of LEGO
4 & 5	Motion Planning: Road Maps, Graph Search, Cell Decomposition, Configuration Space
5 & 6	Embedded Systems Programming, Degrees of Freedom, Mobile Platforms
7 & 8	Sensors and Sensor Planning, Urban Search & Rescue Project Assigned (USAR)
9 & 10	Matrix Transformations, Evaluate Design Proposals for USAR, Evaluate Prototypes for USAR
11	USAR Preparation and Competition
12, 13, & 14	Forward and Inverse Kinematics, Non-Holonomic Path Planning
15	Final Review

Table 3: Schedule of Fall 2002 General Robotics Course at CMU (www.generalrobotics.org)

The list of topics for the proposed course (Table 2) meets the goal of providing a comprehensive robotics course by covering topics from the different disciplines and hands-on experiences of practical robotics (Goal 1). Because the course does include topics from the different disciplines and a larger team robotics project, it meets the goal of learning about integrated system design (Goals 2). This allows students to experience how components of different areas interface. The material on group dynamics and the team robotics project provide the basis for learning and experiencing cross-functional teamwork (Goals 3 & 4).

In adapting the course, a major change will be the way the course is taught. CMU is a Ph.D. granting institution with an active robotics research center [29], whereas, Southern Illinois University Edwardsville (SIUE) is primarily a 4-year undergraduate institution. While the SIUE School of Engineering has the range of expertise to teach the topics in the robotics course, it does not have an extensive research faculty in the area of robotics. CMU has robotics researchers who are familiar with the various areas expertise and are experienced with their integration, but at SIUE, the course would need to be co-taught by 3 or 4 faculty members. This would be logistically and economically infeasible.

Instead of a co-teaching approach to the course, the members of the MPAG will work together to develop the course material so that it could be taught by one or two of the members. This will require developing extensive course notes and instructor manuals for each of the topic areas. For example, the sections on sensors and signal processing will need sufficient explanation of the material for a CS faculty member to be able to present material that is central to ECE such as inputting raw signals and measuring resistance. It will also need to have sufficient tips and pointers to allow the CS faculty member to conduct a lab that includes wiring and soldering. Martin [34] is an example of such an approach to teaching robotic topics. In addition, graduate assistants will be hired from areas that complement the faculty member's area of expertise to help with less known material, and faculty members from complementary areas of expertise will be available to answer student's questions. A goal of this project is that the resulting course materials can be used by schools of similar size to offer a comparable integrated, multidisciplinary course in robotics with a cross-functional team experiences. Table 4 presents the project timeline. The responsibility for teaching the course will be rotated through members of each of the disciplines to keep the material in each area fresh.

Summer 2003	Fall 2003	Spring 2004	Summer 2004	Fall 2004	Spring 2005
MPAG members to co-develop lecture and exercise materials. Order equipment for labs.	Continue course material development. Work with graduate assistants, to set-up lab equipment, test lab exercises, and develop robot environment for team project	Offer the course for the first time. Members of the MPAG will teach subjects in their own area for this time as a means of honing the material. Collect data for course & project evaluation.	Revamp course material based on assessment. Continue to develop notes and instructor's manuals.	Second offering of course. Course taught by a single faculty member of the MPAG with graduate assistants from complementary areas. Collect data for project evaluation.	Perform assessment. Revamp course material as needed. Prepare publications and material for dissemination.

Table 4: Time Line

C. Meeting the Criteria of the CCLI-A&I Program

As stated in the program solicitation, outcomes expected for CCLI-A&I projects (Type I) include all of the following:

- **Adaptation and implementation of exemplary practices and/or materials for course, curriculum, or laboratory improvements in innovative ways**

The proposal is adapting successful material from CMU's General Robotics course. This course has been noted as being the first of its kind comprehensive course in robotics [24, 28]. The proposal also adapts material from Swarthmore and Bryn Mawr's Robot Building Laboratory Project [5] and Drexel University's Research and Education Tools for Low-Cost Robots [30, 31].

In addition to the lab materials and the tools, we will also adapt Swarthmore's approach of using research grade robots to demonstrate advance concepts such as laser navigation and localization. We will also adapt methods of team process and design called "working-on-the-wall" from SIUE's Laboratory Experience for Teaching Participatory Design [32]. For an overview of material see Table 5.

Material Being Adapted	Notes
Curriculum – CMU's General Robotics Course, Swarthmore & Bryn Mawr's AI Robotics Course	To provide a comprehensive study on autonomous robotics we intend to include material on reactive and deliberative robot control architectures. Swarthmore and Bryn Mawr's material are a part of a course on Artificial Intelligence that includes these topics.
Lecture Material From CMU: Robot Vision, Motion Planning, Mobility, and Kinematics Lecture Material From Swarthmore/Bryn Mawr: Robot Control Architectures	The lecture material from these projects will provide a guide and basis for the adaptation to material for the proposed course. Similar to the Swarthmore Course, we will use a Pioneer Robot purchased from a state grant to demonstrate some advanced concepts such as gradient navigation and Markov localization.
Lab Material From CMU: Mobile base control, sensors & obstacle avoidance, motion planning (wavefront algorithms), vision. Lab Material From Swarthmore/Bryn Mawr: sensor building	In addition to using material from these labs, new labs material will be developed for teamwork and integrated system design, as well as labs that take advantage of the CMUcams.
Tools From Drexel: • Sonal: software for debugging Handy Board programs • Retina: real-time display of Handy Board sensor values • Robot Communication Protocol • IR-Talk: Libraries for IR communication between Handy Boards • Certainty Grid Display • Handy Board Sonar Wiring Tools From CMU: CMUcam	A variety of other tools are readily available from other Universities using the Handy Board Platform.
Material on Team Design From SIUE	Methods of team process for design that improves team communication and productivity.

Table 5: Material being adapted from other programs.

The proposal endeavors to adapt this material with two innovations. The first is to include material specifically on teamwork and integrated system design. Engineering students are frequently asked to participate in team efforts but are not adequately prepared to do so. The second innovation is the way the course is taught. Because we do not have specific faculty in robotics but do have the engineering expertise among the faculty members, the material must be developed with sufficient detail for each section so that any one of the members may teach the course. This material will make offering a course accessible to other undergraduate institutions that do not have active robotics researchers or possibly the full range of engineering expertise.

- **An evaluation that informs the institution and others of the effectiveness of the implemented materials and practices and also informs development of the project**

The evaluation plan includes the development of team assessment methods that includes the assessment of cross-functional teams (See Section F). These methods will be useful to programs seeking ABET accreditation to help provide evidence that their students have some experience of functioning in multi-disciplinary teams. As such, the assessment tools will be made available for others to use. Furthermore, the course material on teamwork and group dynamics will be evaluated for it effectiveness to enhance the team experience. This material will also be made available.

- **Efforts to build on the project and to broaden its impact at the institution, within the discipline or across disciplines**

Prior to 1999, School of Engineering at SIUE was spread throughout the campus, which limited the amount of collaboration between departments. With the completion of a new Engineering Building, the School is now under a single roof. The Robotics MPAG has provided a means for faculty in the diverse areas in the School of Engineering to work together to help introduce new material in each other's courses. The current proposal continues the effort to foster interaction by collaborating on a single course in robotics. It is our expectation that this tighter interaction will broaden out to collaborative research projects. Furthermore, specific components of this project are expected to have a direct impact on programs throughout the School, specifically the methods for teaching and assessing teamwork. Each program has a senior project as a capstone experience. All the programs involved use a team project format, but none teach teamwork or group dynamics. The course material on teamwork and the methods of assessment will be valuable contributions across the School of Engineering.

- **Effective dissemination of project results to the broader community**

Upon successful completion of the project, the results and materials will be presented at appropriate conferences and workshops as noted in Section G (Dissemination of Results).

D. Results from Prior NSF Support

Jerry B. Weinberg has worked on the project: "Human-Computer Interaction Software Design Curriculum Using Participatory Design Methods" (CCLI – EMD Grant #9981088). The project developed course materials and a lab setting to support Participatory Design Methods in undergraduate HCI classes. The course teaches ethnographic methods to collect data for user modeling. Students practice these methods by participating in a semester-long team design project. Similar to the way psychology courses use students in introductory classes for experiments in upper division courses, students in the HCI class employ students in the introductory programming class as potential users of their software project. A lab has been created to support user-interaction activities such as interviewing, paper prototype testing, and software usability testing. The lab also supports a team approach to modeling and design called "working-on-the-wall". A longitudinal study of the students taking the course during the first two offerings reveals a positive and lasting effect on the way students approach software design in subsequent team projects, specifically, keeping the user's conceptual task in the forefront and including the user as part of the design process. The results have been published in 2002 ACM SIGCSE conference, 2002 ASEE conference, and the Journal of Computer Science Education. Invited presentations of the project have been given at GatewayCHI, the St. Louis Chapter of the ACM SIGCHI, and ACM SIGCSE 2001 Conference. Further information can be found at www.cs.siue.edu/hci . The project award amount: $79, 987; the project duration 7/2000 – 7/2002.

E. Experience and Capability of the Principal Investigators

Jerry B. Weinberg is an Associate Professor in the CS Department. He received a B.S. degree in Nursing from Indiana State University (1984), a B.S. degree in Computer Science from The University of South Carolina (1988), and his Ph.D. in Computer Science from Vanderbilt University (1996). Dr. Weinberg teaches courses and conducts research in AI and HCI. In 1999, Dr. Weinberg formed the Robotics MPAG that has introduced robotics projects in engineering courses and outreach programs. He has introduced intelligent robotics and behavior-based robotics in the AI course. He has also coached student teams for the robot competitions at the IEEE Region 5 Conference. Dr. Weinberg has co-chaired a session on Robots and Education at the IEEE System, Man, and Cybernetics 2000 Conference. Dr. Weinberg will coordinate the collaborative effort and help to develop the CS components of the course.

George L. Engel is a Professor of the ECE Department. His interests include electronics, VLSI design, computer system design, automated design, and fabrication tools. Dr. Engel received his D.Sc. in Electrical Engineering from Washington University (1990). He teaches courses on micro-controllers and engineering design. Dr. Engel has held outreach programs for minority high school students and the Girl Scouts that used robotics projects to introduce technology. He has also coached student teams for the robot competitions at the IEEE Region 5 Conference and the Fire Fighting Robot Competition at Trinity College. Dr. Engel will help to develop the sensor and signal processing components of the course.

Keqin Gu is a Professor and the Graduate Program Director of Mechanical Engineering. He teaches and conducts research in the general areas of dynamic systems, control, and robotics. He is an Associate Editor of *IEEE Transactions on Automatic Control*. Dr. Gu received his Ph.D. in Mechanical Engineering from the Georgia Institute of Technology (1988). He offers courses in Robotics and Mechatronics. Dr. Gu will help to develop the mechanical components of the course.

S. Cem Karacal is an Associate Professor of Industrial Engineering. His main research and teaching interest areas are simulation modeling, quality control, and operations research. Before joining SIUE, he worked at the Rochester Institute of Technology as a faculty member and served as the Computer Integrated Manufacturing System project coordinator for RIT's integrated circuit factory. Dr. Karacal received his Ph.D. in Industrial Engineering from Oklahoma State University (1991). He has designed multi-robot-integrated systems, taught engineering problem solving & design, and developed freshman-engineering projects. Dr. Karacal will help to develop the problem solving & design and the team project components of the course.

Ai-Ping Hu is an Assistant Professor of Mechanical Engineering. His main research interests are nonlinear control and mechatronics. He received his Ph.D. in Mechanical Engineering at the Georgia Institute of Technology in 2000. Prior to joining the faculty at SIUE, he worked at CAMotion, Inc., a robotics company in Atlanta, GA devoted to incorporating advanced control algorithms into commercial robots. Dr. Hu will contribute to the mechanical aspects of the proposed course, including development of laboratory materials and assignments.

Scott R. Smith is a Professor in the ECE Department. His interests include computer architecture and design, multimedia applications, biomedical engineering, computer based education systems, and consumer electronics. Dr. Smith received his Ph.D. in Electrical Engineering from the University of Illinois at Urbana-Champaign (1991). Dr. Smith will help to develop the micro control components of the course.

William W. White is an Associate Professor in Computer Science. He received his Ph.D. at Ohio State University (1989) and has performed R&D in computer graphics and networking with positions at IBM, Los Alamos National Laboratory, Argonne National Laboratory, Walt Disney Feature Animation, and the University of North Dakota. Dr. White has attended the Robot Building Lab at AAAI and is working on methods for cross-functional team assessment. Dr. White will help to develop the team assessment methods.

Xudong William Yu is an Associate Professor in the CS Department. He received his Ph.D. in Computer Science from Vanderbilt University (1992). His research interests include model-based reasoning and diagnosis, hybrid systems for diagnosis, knowledge-based systems, and modeling and analysis of complex systems. Dr. Yu will help in developing the AI material of the course.

F. Evaluation Plan

The evaluation will focus on the three main educational goals of the project: 1) provide a comprehensive robotics course for students in the different disciplines, 2) create a cross-functional team experience, and 3) develop course material that can be taught by an individual faculty member in one discipline. The cross-disciplinary robotics course affords a unique opportunity to gauge how well team members need to grasp each other's areas on such projects, as well as how successful the course is in achieving that understanding. The assessment mechanisms to be used include:

- After presenting the basic robotics concepts of a certain discipline, the students would be tested on those concepts. Presumably, individuals from the discipline in question will have less difficulty with these questions, and their scores may be used as a gauge for how well the students from the other disciplines grasped the material.
- After the initial robotic project design, teams will be given in-class presentations in which their design decisions will be explained. By having each student explain the rationale for design decisions that involve the disciplines of the other team members (e.g., the ME student explains the algorithmic design of the robot's control program, and the CS student explains the structural design of the physical platform), an assessment can be made of how well each team member grasps the additional engineering and scientific principles being applied.

- Each project will conclude with a written summary that stresses the interaction between the disciplinary concepts that were applied to the project's development. Written by the entire team, the summary may be used to determine the extent to which the team integrated each discipline into the project, as well as the degree to which that integration was understood by the team.

Previous efforts to implement multidisciplinary curricular components have been widespread, and efforts to assess their success have varied widely. Rover and Fisher [35] relied on journals for individual self-assessment and project presentations for team assessment. King, et al. [36], utilized student evaluation forms as well as evaluations by independent faculty teams. Aldridge and Lewis [37] had students provide feedback to their project teammates. Fruchter and Emery [38] designed a metric by which cross-disciplinary comprehension could be progressively gauged. While this project will build on these efforts, we also intend to experiment with several innovative techniques for evaluating multidisciplinary teamwork and communication. Prominent among these will be the development of exams to determine how extensively students from one discipline must comprehend the fundamental concepts of another discipline and how successful they are at accomplishing that feat.

The first offering of the course will be taught as a team effort. Individual instructors will provide material in their discipline. This will provide the MPAG members an opportunity to hone the material before completing the extensive supplementary instructor material. One or two individuals will teach the second offering of the course. A comparison of the above assessment between the two offerings will provide an evaluation of how well the MPAG was able to craft the course material so that it could be taught in departments that do not have the same faculty resources or MPAG framework. During this second offering, careful monitoring will take place to insure that instructors and students do not obtain extensive assistance from the other MPAG faculty that would negate the comparison of the two semesters.

G. Dissemination of Results

The emphasis on multidisciplinary teamwork, the particular interest that is currently being displayed in robotics, and the focus on academic assessment in engineering disciplines should generate great interest in the results of this project. Appropriate forums for the dissemination of results include:

- ASEE's Journal of Engineering Education
- ACM's SIGCSE Technical Symposium on Computer Science Education
- ASEE/IEEE Frontiers in Education Conference
- Rose-Hulman Symposium on Best Assessment Processes in Engineering Education

In addition, the material will be made available on the Web at www.cs.siue.edu/robotics and by request on electronic media. Announcements of the results will be posted to Robotics and Education discussion forms such as www.lugnet.com/robotics.