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## **SUSTAINABLE DESIGN AND RENEWABLE ENERGY IN THE ENGINEERING CURRICULUM**

### **STRESZCZENIE**

W artykule opisano kurs projektowania oferowany w formie warsztatów na Wydziale Inżynierii Elektrycznej i Komputerowej Uniwersytetu Minnesota Duluth. Warsztaty są jednym ze sposobów, w jaki studenci ostatniego roku mogą wywiązać się z przygotowania wymaganego od nich projektu. Tematyką kursu projektowania w semestrze zimowym roku akademickiego 2010/2011 było zastosowanie logiki rozmytej do kontrolowania domu korzystającego z energii słonecznej. Przy bieżącej ocenie projektów studentów oraz przy wystawianiu ocen końcowych zastosowano zasady oparte na problemowo-projektowej metodzie nauczania. Otrzymane rezultaty wykazały wysokie efekty kształcenia.

### **ABSTRACT**

This paper describes a Design Workshop course offered at the Electrical and Computer Engineering Department (ECE) at the University of Minnesota Duluth (UMD). The workshop course is one mechanism by which students completing the ECE program at UMD can satisfy the requirement for a senior design project. The design workshop topic for the fall 2010 was the use of fuzzy logic to control comfort in solar home. The workshop is described. The project work is evaluated during the process as well as the final results using principle based on Problem Based and Project Organized Learning (PBL). The results show that the students learning outcome has been very high.

### **INTRODUCTION**

In the last several years, the topic of sustainability and renewable energy has become a very attractive to engineering students. It has been shown that students working with these problems are more motivated as they do understand that the real problem is real and therefore they show more interest in learning digital electronics, microcontrollers, and analog circuits; this is because they see an immediate application of the subjects they are learning. The UMD is located in northern Minnesota on the shore of Lake Superior. The average low temperature in January is  $-18^{\circ}\text{C}$  with an average high of  $24^{\circ}\text{C}$  in July, with extremes in the winter of  $-32^{\circ}\text{C}$  and  $+32^{\circ}\text{C}$  in the summer which has been common in recent years. With the chilly winters of northern Minnesota it can be difficult to keep comfortable in solar home. There also have to be a delicate balance between comfort and cost. So there is a need to develop a cost effective way to keep us comfortable in solar home during the winter months and reduce the energy consumption. Within this problem area each project has to delimit their scope, and has to limit the comfort to the temperature, humidity, and level of light within a room.

The design workshop topic for the fall 2010 was the use of fuzzy logic to control comfort in solar home. In this workshop, students worked in small groups and were required to design, build and program a controller with intelligent behaviors using fuzzy logic. The project work actually is carried out as projects based on Problem Based Learning (PBL) principles [1]. This pedagogical approach imply that the students within a theme choose which problem they want to investigate and solve in their projects. There might be some demands and restrictions connected to their learning goals, but apart from this it is up to the students to analyze the problem area, define the specific problem they want to solve, choose methods, implement, test and evaluate results. Furthermore students have to organize their project work in their team. The experiences with this pedagogical model are that the

students get extra motivated for learning because they choose their project, so they get ownership. We also know that students get more independent, because they have to work a lot by them self and have to make many decisions. So the students obtain specific technical knowledge according to the study program. But they also get knowledge about group work and managing a project as well as presenting a poster and a project which gives valuable competences within communication skills [2].

In this workshop no formal lectures are taught; however the students receive an intensive review covering the topics of the 68HC12 microcontroller [3], [4], sensors, and Fuzzy Logic Control [5]. Fuzzy Logic has emerged as a practical alternative that provides a convenient method to implement nonlinear controllers. Fuzzy controllers work differently than conventional controllers; expert knowledge is used instead of differential equations to describe a system. This knowledge can be expressed in a very natural way using linguistic variables, which are described by fuzzy sets. Fuzzy Logic has been used primarily on large-scale computing systems and personal computers. The introduction of Motorola's MC68HC12 microcontroller, which incorporates several Fuzzy Logic primitives in its instruction set, has made possible the implementation of fuzzy controllers in microprocessor-based systems [6], [7], [8].

### **FUZZY LOGIC ON THE S12 MICROCONTROLLER**

Three specific instructions in the instruction set of the S12 microcontroller are designed to implement fuzzy logic primitive operations. These instructions are MEM (membership), REV (rule evaluation), and WAV (weighted average). These three instructions are described briefly here.

The first step in fuzzy logic calculations involves „fuzzification,” in which the crisp input variables to the system are assigned degrees of membership in various fuzzy sets. In the S12 microcontroller, fuzzy sets are described as trapezoidal functions that identify the degree to which a particular crisp value is a member of the set. These trapezoidal functions are described in a data structure in the microcontroller memory, and that data structure is used by the MEM, membership, instruction to calculate the degree of membership in each fuzzy set for a given crisp input value. The resulting degrees of membership in each fuzzy set, or fuzzy inputs, are stored in the microcontroller memory for use in the next step of processing.

Following fuzzification, the fuzzy inputs are combined using a list of „rules” for producing fuzzy outputs of the system. The rules each say „If A and B and C and... then output is XX.” The „and” operator is implemented on the fuzzy input variables using a „minimum” operation, and the results of various rules are combined using a „maximum” operation, producing a set of fuzzy output variables that record the degree to which the variables belong to certain classes of output. The instruction in the S12 instruction set that accomplishes this operation is REV, rule evaluation. There is another instruction REVW, or weighted rule evaluation, that can be used instead for the situation where some rules are weighted differently than others in producing the fuzzy outputs. The result of this core processing is a collection of fuzzy output variables, again stored in the microcontroller memory.

The final step of processing involves „defuzzification” in which the fuzzy output variables are converted to crisp outputs that can then be used in the system under study. This process involves calculating a weighted average of the possible values of the crisp outputs, using the fuzzy output values as weights in the calculation. The WAV, weighted average, instruction in the S12 instruction set implements this process, completing the fuzzy logic calculations. WAV produces crisp output values that can then be displayed or used in the rest of the system

These instructions, MEM, REV (or REVW), and WAV, form the heart of the fuzzy logic processing capabilities of the S12 microcontroller. They are included as primitive operations in the microcontroller's instruction set. They ease the process of designing fuzzy logic applications by implementing the core parts of the processing in a compact and easily used package.

In the next sections the objectives, description, and organization of the workshop are described. Results of the student projects are shown, and conclusions and further perspectives are presented.

**OBJECTIVES**

In order to include several of the ABET EC2008 a-k criteria [9], the objectives established for the Design Workshop are:

- Expose students to team-based design and experience team learning,
- Expose students to engineering problems with realistic constraints, and use their creativity, knowledge, and skills acquired in previous courses to solve the problems,
- Exercise their oral and written communication skills, and improve them by presenting written reports and oral presentations during the semester,
- Expose students to the knowledge of contemporary issues, and made them realize the need to engage in life-long learning,
- Since no formal lectures are given, the students exercise their own self-learning and research skills.

**WORKSHOP DESCRIPTION**

The Design Workshop course is offered each year and the topic of the course varies depending on the expertise of the instructor(s) teaching the course. Usually a team of two faculty members teaches this course, and the main role of the instructors is to guide and advise the students in order that they can develop a real engineering project. In order to make the Design Workshop more interesting for the students, during the last years we have selected topics in areas that are not typical or that are not usually covered in normal courses. For example in the past four years the topics were: Intelligent Toys, Fuzzy Mobile Robots, and Intelligent Mobile Robots. In 2010 Sustainable Design and Intelligent Controller was the topic. So one of the challenges for the students was to understand the concept of comfort in connection with in-door climate.

Merriam-Webster defines comfort as „a feeling of relief and encouragement” and „a satisfying and enjoyable experience.” Seeing as those definitions are quite broad we must narrow down the definition to suit people’s needs. For the project we also have to limit the comfort to the temperature, humidity, and level of light within a room. For people being comfortable means that the room has at an ideal temperature, an acceptable level of humidity, and the amount of light in the room is neither too bright nor too dark. Keeping a perfect level of comfort can be a difficult task. Because the difference between the outdoor and indoor temperatures can be so vast, it can be tough to compensate for disturbances such as doors and windows opening. Also, since cold air doesn’t hold water as well as warm air does, your cabin would become dry during the winter which could lead to health issues as well as household damage. Another factor in all this is the sun. Since no formal lectures are taught in this workshop, an intensive review, covering important material related to the specific topic, is given at the beginning of the semester. In particular for the robotics, and intelligent systems topics, the reviewed material includes: the MC68HC12 architecture and assembly language, introduction to robotics, sensors for robotic applications, motors and drivers, and fuzzy logic. Several papers and references are given, and students are encouraged to read the material, analyze the complicated problem area, and define the final problem statement they want to solve which means that students are exercising their self-learning skills. Furthermore students have to consider their own detailed project plan according to the overall plan for the workshop. It is important to have in mind that since this is a capstone design, students should be able to apply the knowledge and skills that they have learned in previous courses to solve problems that will emerge during the development of the project. This means that the students have to show ability to use, combine and generalize previous gained knowledge in a new situation.

**WORKSHOP ORGANIZATION**

In the workshop, teams of two students are formed. Each team is encouraged to develop ideas of their own and present a proposal for their project. All the proposed projects should fit

into the selected topic, and should be reviewed and approved by the instructors. The students have fifteen weeks to do all the work, from the definition to the development and completion of the project. To secure that the proposed projects are developed on the specified time, the activities are planned as follows:

- Weeks 1-3. Intensive review covering key topics for the projects. Typically the themes have been: The 68HC12 microcontroller, its architecture and assembly language. Principles of mobile robots. Sensors for robotic applications. Principles of fuzzy logic. Literature review.
- Week 4. Definition and specification of the proposed projects. Each team works on a formal written proposal for their project.
- Week 5. Students present the written reports and oral presentations of the project proposals.
- Week 6-7. Students work in the simulation part of their projects. They use *Mathematica* and its Fuzzy Logic Package.
- Week 8. Midterm written reports and oral presentations. Students present the results of the simulations. A formal oral presentation is required, and each student in the team has to participate.
- Weeks 9-14. Implementation of the systems. Students build their intelligent systems, using the 68HC12 microcontroller. Circuits and interfaces are designed and built to connect different sensors and actuators to the 68HC12.
- Week 15. Final written reports, poster, oral presentations, and demonstrations of the working systems.

**It is important to emphasize that during all the semester, students and instructors meet once a week. Students talk about their progress, and problems that they are having in the projects, and the instructors give suggestions.**

#### **HARDWARE DESCRIPTION**

For the actual implementation of the projects, each team is giving an evaluation board based on the Motorola MC68HC12 microcontroller. The boards that we have been using include the Motorola M68EVB912B3 evaluation board, the NMT MRK board and the Wytex MC9S12 MiniDRAGON+ Development Board.

#### **Projects Description**

By controlling the temperature, humidity, and light levels of a room at the same time, it would be possible to produce a room that is comfortable no matter the time of day or outdoor weather conditions. The system would utilize three different sensors. One sensor would monitor the current temperature, one would monitor the humidity level, and the other would monitor the amount of light in the room. All of these sensors would feed into a controller (shown in Fig.1), and the inputs would be put through a set of rules. Once the rules of the system are put into place the system can control each aspect based off the other aspects. An example of these rules would be: if the temperature and humidity are ideal but the light level is too high, then we would need the window to tint enough to lower the level of light and have the heater increase its output to compensate for the loss in heat from the extra sunlight. If the temperature is too low and the humidity is too high we would need both to balance out in order to maintain an ideal level of comfort. By having a controller do this we would allow the user to enjoy themselves without having to constantly monitor and change the settings in their cabin. Since the controller would employ fuzzy logic, the response of the system would be optimal and accurate. Also, the system would also be efficient which would save energy and money.

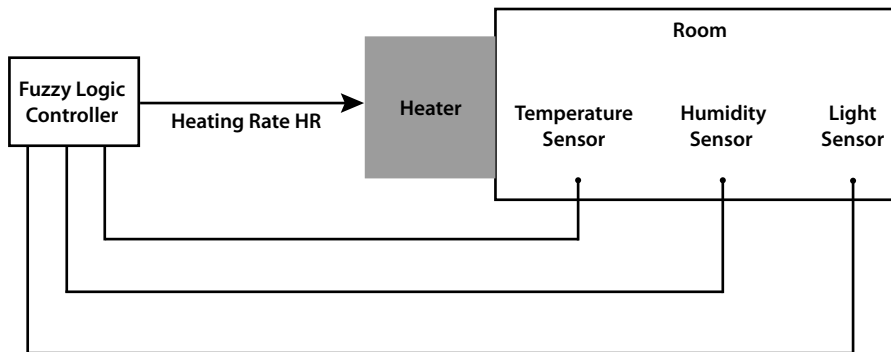


Fig.1 Block Diagram of the System

### EVALUATION OF THE PROJECTS

Upon completion of this course the student should be able to:

- Complete a design project that is interdisciplinary in nature, integrating the knowledge obtained in previous ECE classes.
- Accurate communicate his/her project results, both in written report format and in oral presentation format.
- Understand how teams work and how to interact in a team setting. (Understand what it is like to work in industry).
- Appreciate the role of engineering in society, and ethical issues.

The projects are evaluated in several stages, in a gradual and continuous way. In the weekly meetings each team presents the evolution of their projects and receives orientation of the instructors. The objectives of these weekly meetings are also to have a close observation of the teams' progress and assure that each team member contributes to the teamwork. For the final grade, all the members of each team obtained the same grade. 35% of the final grade is assigned during week nine, when students present a written report and oral presentation of the results of their simulations. Another 35% of the final grade is assigned to the students during week fifteen when they demonstrate that their project is working in accordance to the specifications. The last 30% of the final grade is assigned based on the final oral presentation, taking into account the quality and clarity of the presentation, and the completeness of the final written report and quality of the poster.

### CONCLUSIONS

During the four years that we have been offering the Design Workshop course on intelligent systems we have found that students get more motivated in learning fuzzy logic theory and microcontroller programming by applying them to the design and implementation so students can real problems being solved. From the oral presentations, written reports, posters, and demonstration of the projects, we can say that the students gain an excellent understanding in both disciplines: microcontrollers and fuzzy logic control. The organization of the activities kept the students working in the projects during the whole semester, and as a result, most of the projects were able to meet the original goals. Students were exposed to team learning experiences, and team-based design, managing a project and had the opportunity to exercise and improve their written and oral communication skills. Future improvements to the Design Workshop course will in addition to the existing workshop have the following aspects: Multidisciplinary teams including students from different engineering disciplines (electrical, mechanical, industrial) and computer science. Also, student should address as part of their final reports any environmental, ethical, and economical issues that are affected by their projects. Furthermore the project work will be evaluated using principle based on Problem Based and Project Organized Learning (PBL) with concrete goals and criteria.

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