LEGO Mindstorms Robots as a Teaching Tool in Agricultural Education

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LEGO Mindstorms Robots as a Teaching Tool in Agricultural Education

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Abstract. *The objective of this paper is to convey the results of a first effort to use LEGO Mindstorms kits in an introductory course in Technical Systems Management (TSM), at the department of Agricultural Engineering of the University of Illinois.*

Four groups of students built Robotic Agricultural Machines using LEGO Mindstorms kits, with Robolab as the programming environment. The projects were carried out as part of TSM 221 (Technical Systems Management), an introductory course in Power and Machinery Management. This course is the student's first exposure to Agricultural Engineering after finishing their extra-departmental course load.

A survey among 14 students showed that all students were challenged by the projects and were highly satisfied with the outcomes. They all strongly agreed that the projects were effective in helping them to work in teams, apply problem-solving techniques and to boost their programming and mechanical design skills.

Keywords. LEGO, Mindstorms, Robot, Automation, Agriculture, Vehicle, Undergraduate

Introduction

Information and Automation Technology will be part of the future careers of virtually all students in Agricultural Engineering. Traditionally students are exposed to a course in a higher order computer language, which is perceived by many students as unexciting and tedious. To introduce students to automation in a far more challenging and exciting manner, LEGO Mindstorms were used in TSM 221.

The LEGO Mindstorms kits contain a programmable brick which essentially is a micro controller (Hitachi H8/300L) built in a plastic LEGO package with three connectors for actuators (motors) and three sensor inputs such as switches, optical analog sensors, angle encoders etc. The micro controller has an infrared serial link through which programs can be uploaded and executed. The brick also has buttons to start, stop, and select programs and to check the status of actuators and sensors in real time.

The Mindstorms brick can be programmed in a variety of languages. LEGO supplies its proprietary pictorial ladder-style language, there is NQC (Not Quite C), which is a C-derivative, and advanced users can even use C/C++ that runs on a dedicated operating system called BrickOS. The programming environment used in TSM221 was Robolab, a simplified version of LabView developed by National Instruments in cooperation with LEGO's educational division Dacta and Tufts University. Robolab is a pictorial programming environment, where actuators, sensors and control structures are joined together showed to be very suitable for students with no procedural language background. The reason for selecting this language was the widespread use of LabView in industry and the basic philosophy behind it. Users select components and attach modifiers to change their properties. Components are linked using a wiring tool very similar to building electrical circuits.

TSM221 is a course in Farm Power and Machinery Management. Although the text used for this course (Hunt, 2001) does not elaborate on Automation, examples were used from the book to set the stage for the problem to be solved using the LEGO robots. Variable Rate Application equipment is a essential component of the Precision Agriculture paradigm. For this reason one assignment was the development of a Variable Rate spreader that could sense soil parameters and adjust the application rate accordingly. A second group was assigned the task to develop a self-guided tractor to tow the Variable Rate spreader. Two other groups worked on harvesting optimization based on examples from Hunt's text.

The objectives of the LEGO Mindstorms projects were:

1) To introduce the concepts of Automation to undergraduate students in TSM
2) Develop communication skills among students
3) Exercise critical thinking and engineering design principles
4) Promote enthusiasm for studying engineering
5) Develop skills of graphical programming
6) Enforce precision agriculture concepts
7) Promote creativity and engaged learning
8) Experience the feeling of accomplishment by completing a group design

Description of projects

Project 1: Self guided tractor

Team 1 was given the assignment of developing an autonomous tractor that was guided by a black line, drawn on a board. The group was given this assignment to make sure group 2 (which developed a Variable Rate spreader) had a vehicle to pull their implement. Although in it self perhaps technically the least challenging project, communication between the two groups was essential for a satisfactory outcome. The principle of following the black line was implemented using two optical sensors, which detected the difference between the black line and the white background. When the sensor on the right side would detect the black line it would turn off the right side motor and steer the vehicle left, back toward the line. When a motor was turned off, the tractor would beep to indicate activity in the control loop. The challenge of the self-guided tractor was the narrow turn radius required. The group had to build the tractor extremely short and use rear wheel steering to allow for this turning radius. The weight distribution was also an issue, since the design of the Variable Rate spreader applied a significant amount of weight on the drawbar of the tractor.

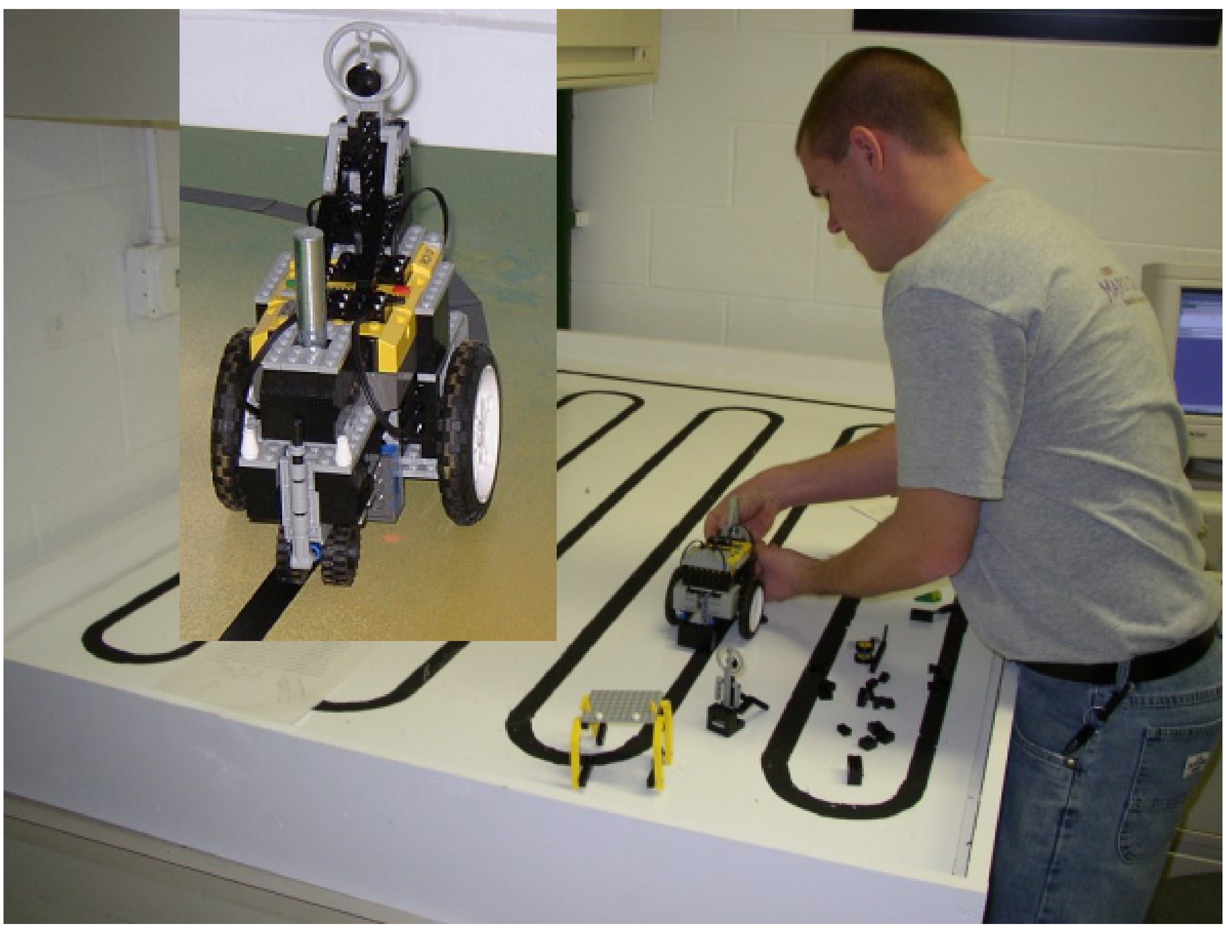


Figure 1 Group 1 working on a Self-Guided Tractor

Project 2: Variable Rate Applicator (VRA)

The variable rate applicator was assigned to promote thinking about site-specific application. The group needed to cooperate intensely with group 1, since their tractor had to pull the VRA machine. This resulted in heated discussions about the proper weight distribution, the hitch configuration and the narrow turning radius limitations.
The VRA group painted a green background with different shades of yellow, red and brown to indicate differences in soil properties. The design as shown in figure 2, is using an optical sensor that senses the different colors in the soil surface. The program completely shut off the belt and spinners when the color green (background) was sensed and turned the belt and spinners at different rates when other colors were encountered. This procedure required quite some time in calibration and it was found that the LEGO supplied optical sensor has limited capabilities in detecting different colors. The spreader mechanism was tested with soybeans; other options such as rice, grains and fertilizer were considered but were discarded because of their flow properties and chemical aggressiveness.

Figure 2 Group 2 working on a Variable Rate Applicator

Project 3: Optimization of turning an offset harvester through 90 degrees

The two remaining teams Group 3 and 4, were assigned the task of demonstrating the problem of cornering during harvesting operations. Hunt's text illustrates the problem of backing up over crop while harvesting with an offset towed harvester. The graphs that show the path of the extreme parts of the machine in the text are hard to understand and replicate. To illustrate this problem, it was proposed to use a model tractor to mimic the cornering process and automatically draw the graphs. This was perceived as not challenging enough and the group decided to try to steer the tractor differently so no crop would be left standing after the turn. Although it is questionable whether this is possible at all, the group struggled with it and came to the conclusion that it was not possible by time-based steering without position feedback. Group 3, which had one member from the department of Industrial Design, spent much time on making the tractor resemble their favorite brand and model.

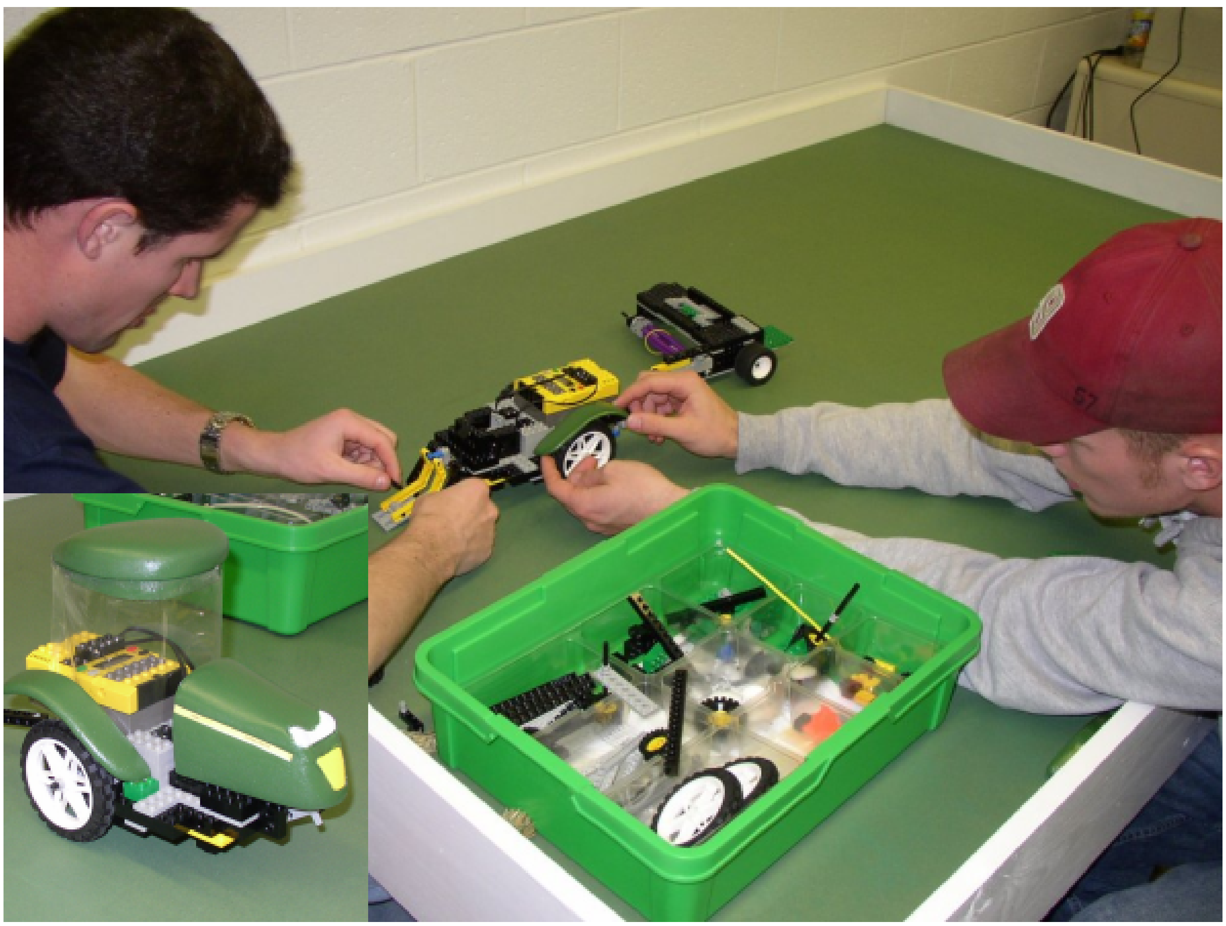


Figure 3 Group 3 developing an optimized system to steer an offset harvester through a 90 degree corner without leaving any crop standing

Project 4: Automated farm concept

Group 4 initially was assigned a project to illustrate the 270-degree turn that a self-propelled harvester employs. This again, was not perceived as challenging enough, so the group elaborated and developed the concept of a self-propelled autonomous machine that leaves the shed, enters the field, performs a harvesting operation using several 270 degree turns, and returns to the shed. This goal was not met completely, because of the lack of position feedback even after experimentation with different wheels and tracks.

Figure 4 Group 4 working on an automated farming concept

Assessment of LEGO projects effectiveness

The project was carried out in the fall of 2002. Towards the end of the projects, an informal evaluation showed that the far majority of the students found the projects worthwhile. In the survey there were 7 questions with responses from 'Strongly Agree', 'Agree', 'No Opinion', 'Disagree' and 'Strongly Disagree'. An additional four questions requested a written response. The survey was completed by 13 out of 14 enrolled students.

Table 1. List of questions in student survey

1. The LEGO projects were effective in helping me understand and apply problem-solving techniques.
2. I thought that building our LEGO robots provided an effective way to learn to work in a team
3. As a result of this project, I was able to meet and get to know other students
4. I developed skills such as programming and mechanical design that I did not have before the project
5. I spent more time on this project than I could really afford
6. My enthusiasm to study technical systems management has increased due to the LEGO projects
7. I found LEGO projects to be satisfying and challenging

Figure 5 shows the results of the survey. Questions 1 and 2 clearly indicate that the LEGO projects were perceived to be effective in practice problem solving techniques and teamwork.

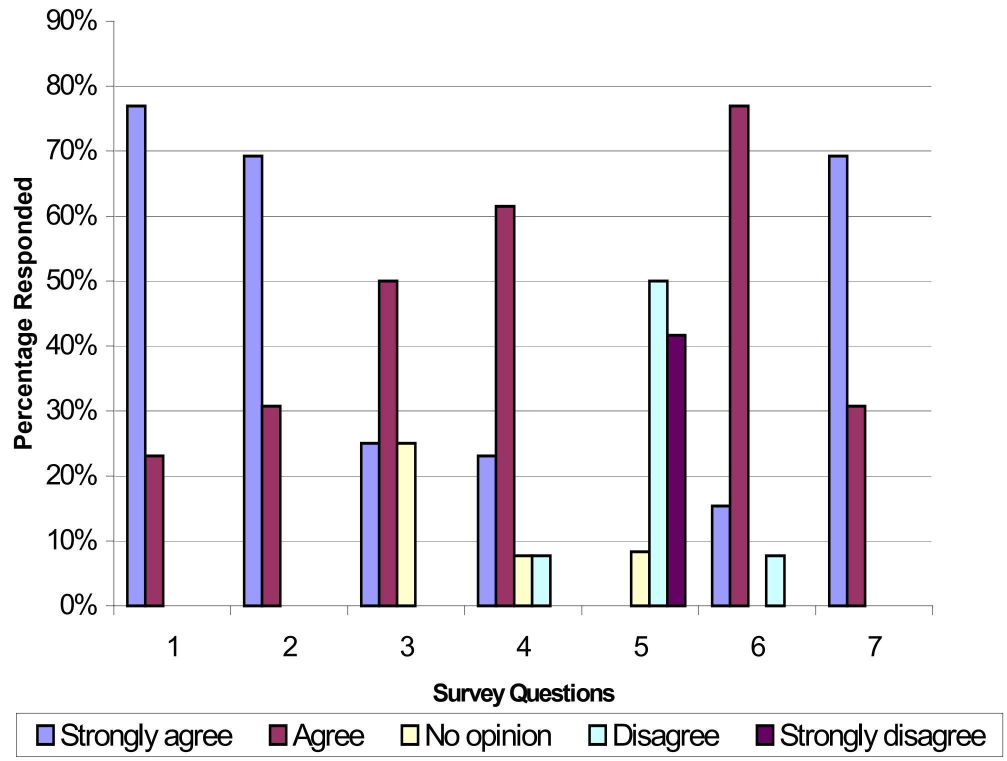
Question 3 shows that some students met and interacted with other students more pronounced because of the projects.

Question 4 shows that the far majority developed skills that they did not have before the projects.

Question 5 shows that almost all students disagreed in spending too much time in the projects.

All students agreed that they found the projects satisfying and challenging and also that their enthusiasm for studying TSM had increased, as can be seen from questions 6 and 7.

Another lesson learned from the projects is to allow more freedom in the problem descriptions. The overall opinion was that the projects were too strict, the students felt limited in what they could do. In hindsight, it might have been better to limit the scope of application to 'Futuristic Farming', rather than having the projects clearly defined.



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5. I spent more time on this project than I could really afford
6. My enthusiasm to study technical systems management has increased due to the LEGO projects
7. I found LEGO projects to be satisfying and challenging

Figure 5, Student evaluation summary of LEGO projects

Some other notable comments:

“I was extremely satisfied and pleased with this project and the outcome. This was the first project in a long time that I was thoroughly enthusiastic about working on. It was stimulating, challenging, and fun. I did not ever mind staying late in the lab playing with it.”

“I’m very pleased with the project. It combined mechanical and computer aspects. It gave us experience working with a team. I also think our project turned out well.”

“I think the guidelines for the projects should be broadened so that students can be more creative in coming up with new techniques or ideas that could actually be used in real life. By broadening the guidelines, it will allow for more students creativity but will also require more professor monitoring to ensure that students are actually doing something on their project.”

“Try some different things with the projects. Different combinations, different programs, or different equipment. Using the camera with the projects could be interesting too.”

Future plans

The guidance of a robot showed problematic when no guidelines are provided on the board. Team 4, which built a demonstration of an automated farm, had major problems with reproducibility of the programmed robot trajectories that changed depending on the battery charge level and changes in the board-track friction. In future generations, a location feedback will be used in the form of a camera. The camera will be able to track the vehicle and downlink steering correction information to the vehicle through the infrared link. A drawback of this infrared link is the requirement of a direct line of sight. A much better system would contain an omni-directional radio control system, although this method requires some kind of vehicle separation through addressing.

In the future, the LEGO vehicles will be complemented with CAN bus communication. This will allow students to expand the possibilities of the LEGO bricks and also to program CAN systems using BASIC, C or assembly. CAN nodes can be constructed using very small components such as an 8-pin PIC12C67X micro controller combined with a 18-pin AN2551 Transceiver chip (Microchip, http://www.microchip.com, Document AN215). Microchip also has RF chips available such as the rfPIC12F675 that allow short-range wireless communication between micro-controllers.

Conclusions

LEGO Mindstorms kits were used as a tool to introduce automation concepts at the undergraduate level in Technical Systems Management (TSM) 221. Robolab, a programming environment similar to LabView, was used as the programming tool. Four robotic machines were developed to emphasize the merit of using Automation Technology in Precision Agriculture.

Two groups worked in a self-guided tractor, combined with a Variable Rate Applicator. The third group developed an optimized system for 90-degree turns during harvesting with an off-set harvester. The fourth group developed a self-propelled machine that left the farmstead, carried out harvesting tasks in the field and returned to the farmstead without human intervention.

The first introduction of automation at the undergraduate level was very well received. The conclusions of a survey were that the students felt they gained valuable experience in problem solving and team work. The students felt that the projects were too limiting, they expressed the need for more freedom to be creative and exploring.

References

Hunt, D. 2001. Farm Power and Machinery Management, 10th Edition. Publ. Iowa University Press, Ames, IA, US