Mobile Autonomous Robots Play Soccer - An Intercultural Comparison of Different Approaches Due to Different Prerequisites

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Abstract. In the effort to meet the steadily changing demands of teaching computer science and computer engineering, new methods of learning and teaching are used by which multifarious knowledge and learning techniques can be imparted, practical skills and abilities can be developed and teamwork and creativity are encouraged. A promising attempt is the use of robotic construction kits.

This paper portrays the educational environment that was used at the courses "Hamburg RoboCup: Mobile autonomous robots play soccer" at the University of Hamburg, Germany and "Advanced robotics - Soccer playing mobile autonomous robots" at the California State University of Chico, USA and compares the experiences made during both courses due to intercultural differences.

1 Introduction

For over thirty years the "Epistemology and Learning Group" of the Massachusetts Institute of Technology (MIT) did research about correlations between learning environments and learned skills. One of the results based on the research of Seymour Papert is the idea of using robotic construction kits coupled with user-friendly programming environments [1].

While the utilization of robotic construction kits at schools was analyzed in detail and appreciated [2][3], it was often depreciated as a toy and therefore considered irrelevant in the context of universities [4]. Using "real" robots at universities has the disadvantage of being very expensive so that many students often have to share a single robot. Additionally it can be difficult to motivate the students to work with "real" robots because the orientation time of a complex robot system often requires weeks or even months so the course is nearly over before the students have figured out all the possibilities of the robot. To avoid these obstacles in the courses at the University of Hamburg and the California State University of Chico we decided to use robotic construction kits which are less expensive (and therefore available in sufficient numbers), more flexible and easier to understand.

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The opportunity to offer the same course at different universities arose from the USE-ME Project. USE-ME means "US-Europe Multicultural Educational Alliance in Computer Science and Engineering", a cooperation project to promote the development of new student-centered teaching units in computer modelling and simulation with exchanges of students and instructors between European and US universities. For this reason the courses were held by the same instructors under the same circumstances at both universities which makes them easy to compare.

2 Robotic Construction Kits and Programming Environments

To understand the relevance of using robotic construction kits at universities it is important to know the elements contained and the possibilities of programming. In the following this is exemplified through the LEGO Mindstorms robotic construction kit [5].

The LEGO Mindstorms kit contains a programmable RCX-brick (Hitachi H8/3293-microcontroller with 16 KB ROM and 32KB RAM), two touch sensors, a light sensor, two motors and lots of common LEGO bricks. Also included are an infrared sender to transmit data between the RCX-brick and a personal computer, the programming environment Robotics Invention System (RIS) and a construction handbook. The RCX-brick provides three inputs for sensors, three outputs for motors or lamps, five spots for programs, a LCD-display, four control buttons, a speaker and an infrared interface. Figure 1 shows a RCX-brick with two motors, two touch sensors and a light sensor.

The RCX-brick comes with the firmware installed. The firmware is necessary to communicate with a personal computer to load programs from the computer

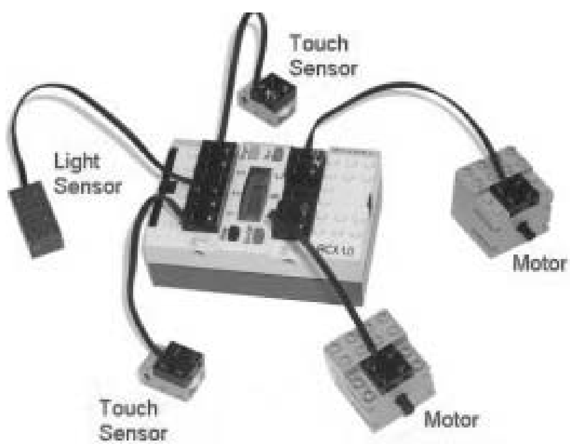

Fig. 1. RCX-brick with sensors and motors

to the robot. Five simple programs are preinstalled so the robot can be tested immediately after just short periods of configuration.

The Robotic Invention System (RIS) is a graphic-based programming environment that works with blocks. Every programming instruction is represented by one block. The blocks are joined by "Drag and Drop" in form of a chain while programming and executed in this order when the program is running. To include sensor-data of the robot, parallel chains of blocks can be used.

Besides the software RIS that comes with the LEGO Mindstorms construction kit and that is directed to children and teenagers without programming skills, several other possibilities to program on an advanced level have been developed by active LEGO online-groups. Most of this software can be downloaded as freeware.

Some examples of programming environments used during the courses in Hamburg and Chico are:

- ROBOLAB: works with a kind of advanced flowcharts, based on LabVIEW, was developed especially for use in schools
- RCX Command Center: with the programming language Not Quite C (NQC), a language similar to C, programs can be written text-based
- LEGO Java Operating System (lejOS): an implementation of a Java Virtual Machine (JVM)

Other programming environments can be found in [6][7][8][9].

3 General Structure of the Course

The overall goal of the courses was to build teams of soccer playing robots according to the rules of the RoboCup Junior league. Two teams, consisting of two robots each, play against each other on a field measuring 122 cm by 183 cm with a wall around it to keep the ball and the robots from falling of. The game lasts for two 10-minute halves with a 5-minute break in between. For more details see [10][11][12].

In Hamburg prerequisites were made by offering the course as a seminar only open to advanced students with intermediate diploma in computer science. Ten students were participating. In Chico a quite similar restriction was made by offering the course in the advanced level. Among the fifteen students participating one lacked the official qualifications but was still admitted and had no problems following the course.

Both courses where held with a quite similar structure. During the first sessions the students got a brief introduction on the general topic of robotics. They also got some first hands on experience with the LEGO Mindstorms kit. The students were then grouped into teams: Each team was given two LEGO Mindstorms kits and they should come up with a soccer-team at the end of the course.

Additional they had to choose one out of a list of relevant special interest topics, work it out and present it to the other students. Afterwards they served as specialists for this topic and answered students questions on their topic for the remaining time of the course.

One example of such a special interest topic is modelling a robot with fuzzy logic. Fuzzy behavior of the robots recognized by the students can be precisely expressed with fuzzy logic. While students work with the robots they find out that the robots do not move on a straight line although both motors run with the same performance. In this situation fuzzy logic can be very helpful to solve the problem. The students learn by means of linguistic variables of the mobile robot to determine the membership function of the linguistic variables and to draw up rules to describe the dynamic behavior of the soccer-playing robots.

Some contests where held during the course to test the performance of ideas and solutions on their real world behavior. Several problems crop up during these contests: the robots could not find the ball, the robots aimed at the wrong goal or had no orientation at all, the robots fell apart when they touched the wall or other robots, etc. Most of the students were stimulated by these problems to extend their work on the project. Finally a tournament was held at the end of the course. Figure 2 shows one of the LEGO Mindstorms robots build by the students.

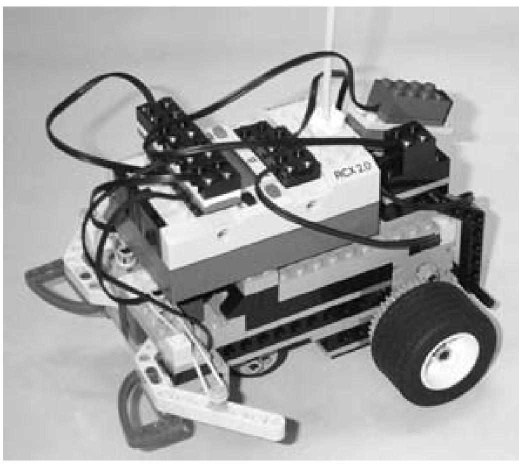

Fig. 2. Soccer playing LEGO Mindstorms robot

To evaluate students opinions about robotic construction kits being utilized in university education several questionnaires were given to the students during and at the end of the courses. These questionnaires also served to find out about the students understanding and interest for robotics in general and their willingness to learn with interactive elements.

4 Experiences During the Courses in Hamburg (Germany) and Chico (USA)

As shown in Figure 3 neither the students in Hamburg nor those in Chico had any experience with LEGO Mindstorms. Only one student in Hamburg had no experience with LEGO. The experience of the other students resulted in short time for building the robots, very fast adaptation whenever a hardware problem occurred and some rebuilding of the robots to adjust it to specific problems rather than solving them with the software. In Chico a majority of the students had no experience with LEGO at all. This was caused by a great number of students coming from India and China (the same number as students stated to have no experience with LEGO) where LEGO is not as widely spread as a kids toy as it is in Europe and the USA. As a result the robots built in Chico were closer to those shown in the LEGO construction handbook and underwent fewer changes during the course. Adaptations were made in the software rather then changing any hardware.

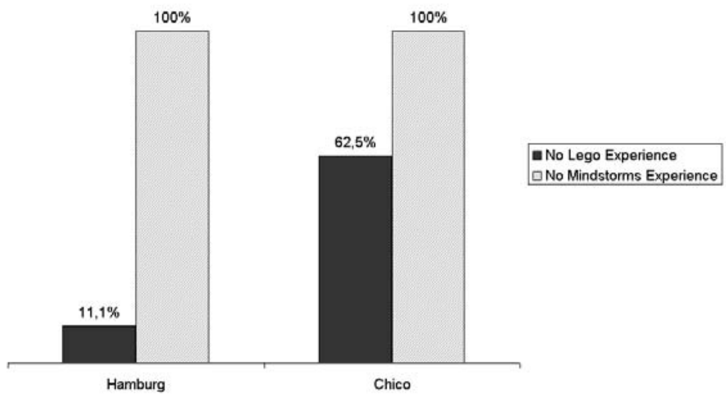

Fig. 3. "Do you have any experience with LEGO or LEGO Mindstorms?"

Interesting results also came from the questions "Was the class as you expected?". Overall students expectations were met total or at least party. But there are interesting differences in the details. The first questionnaire was answered shortly after the presentation of the special topics and before most work was done on the LEGO Mindstorms. The second questionnaire was answered at the very end of the course. While total agreement fell from first to second questionnaire in Hamburg it rose in Chico. This indicates that students in Hamburg rather expect theoretical work than hands on experience in courses while students in Chico seem to have expected less theory and more practical work. This is shown in Figure 4.

A very encouraging result came from the question: "Would you take the class another time?" In Hamburg and Chico all students stated they would do so on

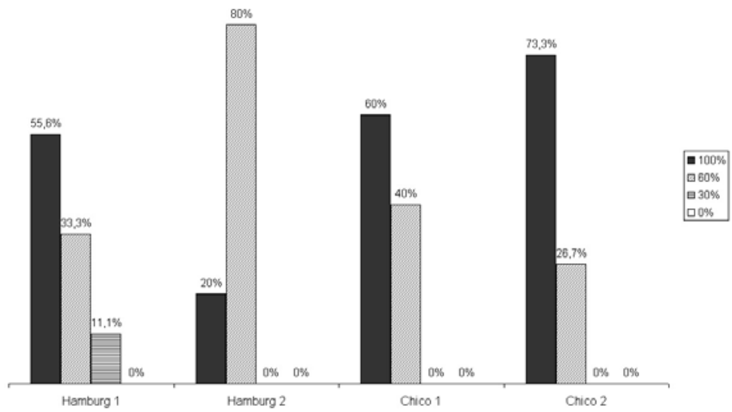

Fig. 4. "Is/Was the course as you expected?"

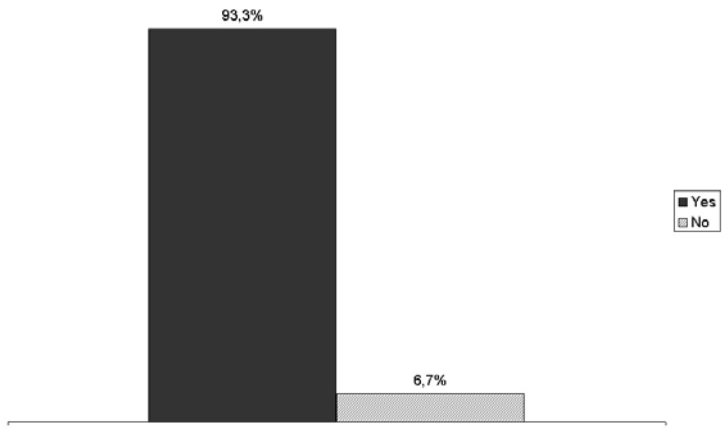

Fig. 5. "Would you like to do more research in robotics?"

both questionnaires. In Chico a large majority would also like to make some more research in robotics (Figure 5), unfortunately this question was not on the Hamburg questionnaire but since a lot of students continued in the field of robotics it seems to would have been quite similar.

Some students in Chico later stated that an introduction to LEGO at the beginning of the course would have been very helpful. This was not given by the instructors because of the assumption it would be irrelevant based on the experience made in Hamburg. If this course should be taught in an "unknown" environment again, the instructors will make this their first question (since experience with LEGO Mindstorms should not be a prerequisite) and adjust the beginning of the course according to the answer.

5 Conclusion

Although the students in Hamburg and Chico had quite different prerequisites they all reached the overall goal of the course to come up with a team of soccer-playing LEGO Mindstorms robots. But according to their different prerequisites they took different approaches and learned different new skills during the course.

As expected those students not familiar with LEGO had built their own robots but still were not as creative with the hardware as those that had played with LEGO since early childhood. But they still started to change the given designs from the handbook to more suitable designs for soccer playing robots.

Those students who tried to solve most problems by changing the hardware learned that this was not always possible and that the software also had to been taken in account. In fact, most problems where solved by a nice piece of software because the hardware of a LEGO Mindstorms robotic construction kit is too simple to solve such complex problems like playing soccer without sufficient use of proper software (meaning more than a few simple "if X then Y else Z" statements).

Regarding the different prerequisites in learning-skills of the students it can be said that most students adopted those skills they lacked before. The ones who had not presented a scientific topic before had to learn gathering information and presenting it in a decent way. Those not used to actively forming a course had to give up their inertness and communicate, on the one hand with other students to build decent robots and programs on the other hand with the instructors to come up with good presentations for the special interest topics.

6 Future Perspectives

The experiences made during the first Hamburg course and the course in Chico already lead to some consequences. Points criticized during the first Hamburg course were tried to avoid in future courses (some self fulfilling like eliminating the waiting time for delivery of hardware). Students taking the course a second time rose the overall performance of the robots because they told the new students which ideas had already proven to be good or bad so the same mistakes were not made again. One problem persisting was the very limited hardware performance of the LEGO Mindstorms robot construction kit. Some students programs were too big for the memory of the RCX-brick or too complex for the Hitachi H8/3293-microcontroller of the RCX-brick to run in decent time. To be able to run even more complex programs there was a need for more powerful hardware. Hence the idea of a continuing course using more complex hardware arose. Since most students focused on building good programs while simply assuming sound working hardware a new approach was made by using SONY AIBO ERS-210A robots. Since the Sony Fourlegged League in Robocup prohibits any changes in hardware this league automatically focuses on the software. So this league meets exactly the demands of students which have participated in the LEGO Mindstorms course and wanted to continue on a higher level of programming robots. Some of the students changing from the LEGO Mindstorms course to the Sony Fourlegged League participate at RoboCup 2004 in Lisbon as "Hamburg Dog Bots".

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