Problem Based Learning of Object-Oriented Programming with LEGO Mindstorms NXT and LeJOS

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Abstract Problem based learning has proved to be a powerful educational approach to successful and effective teaching. Experiences worldwide have shown the attraction of robotics and the improved motivation of students dealing with robots. Problem based learning (PBL) as well as robotics are usually applied when dealing with smaller groups of students. However, in the first year of study student numbers of more than 1000 are a common phenomenon for lectures in mechanical engineering. This paper introduces a setup for teaching object-oriented programming based on programming LEGO Mindstorms NXT robots for large scaled groups. The huge number of students – up to 1500 students per year – to be dealt with presents a special challenge, due to resource limitations as well as technical aspects. We therefore present a problem based learning approach based on a fixed robot setup with pre-build robot models.

Key words: Education in Mechanical Engineering, Blended Learning, LEGO Mindstorms NXT, LeJOS

1 Introduction

1.1 Overview

The Institute of Information Management in Mechanical Engineering (IMA) of the RWTH Aachen University lectures Computer Science on Mechanical Engineering [HGS09]. This lecture is currently being refactored from a general approach covering a broad range of computer science related topics to a new approach concentrating on software engineering. This renovation also affects the affiliated labo-
ratory. Here, the students are meant to gather first experience in the fundamentals of object-oriented programming. Student evaluations have shown a demand for more self-contained programming as well as “hands-on” tasks. Therefore, the new laboratory aims on palpable tasks the students can carry out completely on their own.

Previous smaller laboratories and experiences worldwide have shown the attraction of robotics and the improved motivation of students dealing with robots [HHJ10, HJNP09]. Therefore, the laboratory is based on programming LEGO Mindstorms NXT robots which has proven to be a suitable teaching instrument [Kla02] with Java using the LeJOS platform [Sol01]. The laboratory is attended by up to 1500 students each year. The students come from different programs: Approximately 80% of the students study Mechanical Engineering in the second semester, 15% study industrial engineering and management in their fourth semester. The remainder is distributed over different smaller programs.

2 Organizational and Technical Challenges

Experiences from smaller robot courses as well as the student laboratory Roboscope [HHJP10] have shown the optimal size for a team working together on one robot and one workstation is two students. This limitation does not necessarily apply to other robot courses focussing on a construction of a robot. However, the focus of this laboratory is the programming of the robot. Two students can sit together at one workstation and work on the same problem using the technique of pair programming [CW00]. For more than two students this technique is not applicable simply due to limitations in access to the workstation. Therefore, since these additional students would have to work at another workstation, the given task would have to be separable in distinct and comparable subtasks to avoid the risk of unequal workloads or even complete exclusion of single students.

The laboratory takes place in the so called ARPA (see Fig. 1), which is the largest computer pool of the RWTH Aachen University equipped with approximately 200 workstations.

These limitations in space restrict the maximal number of students that can attend the laboratory in parallel to 200 students which then work with 100 Mindstorms NXT robots. Due to increased motivation, it would be desirable to have each team construct its own robot. However, this would result in a demand for 750 robot construction kits, since the robots cannot be dismounted and reassembled in each lesson. Therefore the laboratory is based on a standardized and preassembled robot model depicted in Fig. 2. This allows several student teams to work with the same robot in consecutive courses and improves the comparability of the student’s achievements.

The decision to work with the stationary model of a robot arm is also motivated by another technical issue: To allow students to debug their code, there must be ways to read the programs output during execution. For a mobile robot one must rely on a Bluetooth connection between PC and robot. However, with 100 Mindstorms which have to connect to 100 PCs in close vicinity to each other and a probably huge number of other Bluetooth devices as mobiles, the bandwidth of the connec-