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SIMULATION PROJECTS WITH COMPUTER SCIENCE UNDERGRADUATE STUDENTS

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ABSTRACT

We report on our recent experiences with a project-based simulation course in the third year of the Computer Science curriculum at the University of Rostock. Students developed and implemented simulation models of queuing systems in the campus canteen or traffic flow at an intersection close to the campus. We pre-structured the projects into milestones and acquired real-world data for model input or validation. Both of these aspects were evaluated positively by the participants. We also report on experiences with managing and grading students in a collaborative group project.

1 SCENARIO

In the third year of the Computer Science bachelor's program at the University of Rostock, students can choose from different software projects. During these projects, students learn about software project management and apply their skills acquired in previous courses, such as software engineering as well as algorithms and data structures. In a series of projects offered by the Modeling and Simulation group, students had the opportunity to also put the knowledge from the 4th semester course on Modeling and Simulation into practice. The fundamental idea of these projects is that the students implement a simulation model and use it to answer a research question about a real-world system. In three of the semesters, students simulated the waiting queues in the campus canteen and in the two most recent semesters they simulated the traffic at an intersection close to the campus.

The model of the campus canteen includes the customer queues at the three food counters and four cash registers. By creating the model and running simulation experiments, the students were to find ways to decrease waiting times for the customers, for example by incentivizing contactless over cash payment. The students implemented a discrete-event simulation algorithm parametrized with probability distributions for inter-arrival and service times, as presented in the textbook by Law (Law 2015, sec. 1.4). Some of the probability distributions could be estimated from a data set provided by the *Studierendenwerk* (the organization running the canteen). However, in contrast to similar simulation studies (Curin et al. 2005), we could not acquire data for all processes. Therefore, the students had to rely on their experience of visiting the canteen to estimate some of the distributions. This threatened the validity of the model as well as the conclusions from the experiments, which was acknowledged by the students when they reflected on their projects.

For the traffic model, we relied on the text book by Treiber and Kesting (2013). Here students implemented a hybrid algorithm that combines continuous and discrete-event simulation. The continuous component controlled the movement of the cars via the differential equations of the *Intelligent Driver Model*, whereas cars entering or leaving the system as well as the traffic lights switching were discrete events. The city government of Rostock provided data from automatic and manual car counting as well as information regarding the traffic light control. As a result, students were able to build a realistic model of the traffic at the intersection and run different experiments, for example to see whether the throughput of the intersection can be increased with a different traffic light pattern.

2 DIDACTICS

For both model domains, the general structure of the project was identical. First the students formed groups with three to four members. We predefined weekly or biweekly milestones with specific deliverables, for example reading and summarizing a book chapter, analyzing a data set, or adding an aspect of the model. After each milestone we scheduled a meeting with each group and gave feedback on their progress. In addition, the groups presented their work mid-semester and at the end of the semester and handed in a written final project report. After the students received their grade, they were invited to an optional informal *post-mortem* meeting, where students and instructors reflected on the project.

The students' feedback for the project in general was positive. They appreciated the pre-planned milestones with well-defined deliverables, which gave them a feeling for whether they invested enough time and work into the project. The immediate feedback for each milestone made sure that the groups were working in the right direction. Another aspect that the students evaluated positively was that they used real-world data to model real-world systems, in particular systems that they knew from everyday life.

The students also cited different areas in which they had to overcome challenges, partially by applying knowledge from previous courses. For example, the students needed their software engineering knowledge to design and implement the simulation in a way that allows working on the model logic (e.g., number of queues or traffic laws) without needing to adapt the simulation algorithm. To estimate probability distributions from data and integrate them into the simulation algorithm, the students needed to apply their knowledge from the Modeling and Simulation lecture. In addition, the groups could freely choose programming languages or libraries, but we required that they adopt a software project management tool (e.g., Apache Maven for Java projects), which was new for most groups.

Collaborative work in groups has well-known benefits for learning, but it is also known to require attention by the instructors (Oakley et al. 2004). Therefore, in the most recent semester, we adopted some of the methods suggested by Oakley et al. (2004) to improve the effectiveness of the student groups. In the beginning of the project we informed the students that they would peer-assess the members of their group at the end of the semester. Then after handing in the final report, the members of each group had to fill out a questionnaire to assess each other's "team citizenship". For each team member, we combined the results of these questionnaires with the commit log of the groups' source code repositories and their contributions in the milestone meetings and presentations to adjust the individual grades. The students reacted positively to the peer-assessment and, when discussing other methods suggested by Oakley et al. (2004) (e.g., signing a "group contract") in the *post-mortem* meeting, argued for implementing more of them.

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