Universität Rostock

Traditio et Innovatio

Simulation Projects with Computer Science Undergraduate Students

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Abstract

We ran five courses with 3rd-year Computer Science students. 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 from their everyday life. Three courses dealt with the queues in the campus canteen and two courses dealt with the traffic flow at an intersection close to the campus. The students worked in small groups to implement the simulator, visualize the results, prepare the input data, and run simulation experiments.

Context

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 us (the Modeling and Simulation group), students had the opportunity to also put the knowledge from the obligatory 4th semester course on Modeling and Simulation into practice.

Temporal structure

The project is structured into predefined biweekly milestones with associated deliverables. Immediately after each milestone, the groups meet with an instructor and receive feedback on their results and progress. At the end of the semester, the students present their work and hand in a project report. After they receive their grade, the students are invited to an optional informal *post-mortem* meeting, where students and instructors reflect on the project. An example sequence of milestones for a traffic simulation project is shown on the right.

Available Data

The projects are tightly linked to real-world data. For simulating the queues in the campus canteen, the *Studierendenwerk* (the organization running the canteen) provided a data set sourced from cash register protocols. For the traffic simulation, the city government of Rostock provided data from automatic and manual vehicle counting (including source-destination counts) as well as information regarding the traffic light control.

Managing and Grading Groups

We adopted some of the methods suggested by Oakley et al. [1] 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.

Lessons Learned and Feedback from Course Participants

- Use the milestones to define a gradual increase of complexity. Check and correct the students' understanding in the milestone meetings.
- Define concrete deliverables for each milestone. For example, instead of asking students to implement a simulator, ask for a video showing the simulator at work.
- Acknowledge that students often dislike group work. Make an effort to teach and incentivize effective teamwork [1]. In our experience, students appreciate it. Be prepared to handle dysfunctional groups, too.
- Let the students run simulations of systems they are familiar with. They will be able to take the role of the domain expert and, for example, spot errors in the simulation (face validation). Reach out to organizations that can provide data sets.

References and Acknowledgements

[1] Oakley, B.; Felder, R. M.; Brent, R. & Elhajj, I. "Turning student groups into effective teams". Journal of student centered learning, 2004, 2, 9-34

[2] Treiber, M. & Kesting, A. Traffic Flow Dynamics. Springer Berlin Heidelberg, 2013

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Example Milestones for a Traffic Simulation Project

Milestone 1: Basics

Students read and summarize some textbook [2] chapters to learn about salient terminology and concepts. In particular, the students become familiar with the *Intelligent Driver Model*, which allows a continuous simulation of vehicle movement. The groups also discuss their preferences regarding programming languages and experiment with version control via Git.

Deliverable:
- Written report/literature review

Example meeting topic:
- Continuous and hybrid simulation

Milestone 2: Simple Traffic Simulation

Students implement a first simple simulator with vehicle movement according to the *Intelligent Driver Model*, for example with cars driving in a circle. They also implement a visualization of the simulation. As a preparation for the next milestone, students read and summarize a paper about random arrival processes in discrete-event simulation.

Deliverables:
- Video recording of a visualized simulation run
- Written report on stochastic arrival processes

Example meeting topics:
- Choice of numeric integrator
- Data structure for vehicle positions
- Transformation of vehicle positions to coordinates in the visualization

Milestone 3: Integrating Data

The students adapt their simulation to the layout of the actual intersection (based on map data made available). They also extend their continuous simulator to a hybrid one by adding discrete events for vehicles arriving and traffic lights switching. Data for both aspects is made available. In addition, rules for right of way must be integrated into the simulator.

Deliverables:
- Video recording of a visualized simulation run of the intersection
- Table of estimated parameter values

Example meeting topics:
- Implementation of random arrivals
- What happens if arriving vehicles do not fit on the road?

Milestone 4: Preparing Experiments

The students add the recording of output data to their simulator. They also adapt their software to allow batched simulation runs without visualization. In addition, they use more fine-grained data to distinguish different types of vehicles in their simulation.

Deliverable:
- Video recording of a visualized simulation run of the intersection with different vehicle types

Example meeting topics:
- Visual representation of vehicle types
- Choice of recorded outputs

Milestone 5: Running Experiments

The students formulate a research question and according hypotheses. They plan and conduct simulation experiments to check the hypotheses. For example, research questions can involve optimizing the traffic light programming, what-if scenarios (e.g., with a lane blocked by an accident), or determining the maximum throughput of the intersection.

Deliverable:
- Experimentation protocol

Example meeting topic:
- Choice of replication number

Final Presentation and Report

The students present their results in a short talk and assemble a project report based on the deliverables for the individual milestones.

Deliverables:
- Final report
- Software including usage instructions
- Peer assessment

Example *post-mortem* meeting topics:
- Are you satisfied with your results?
- What would you do differently if you could start from scratch?

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