The Use of an Electronic Voting System in a Formal Methods Course

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Abstract. We describe the design of a discussion-based tutorial within an honours “Modelling Reactive Systems” course facilitated with an electronic voting system. The approach combats confidence and breadth issues, and we report on its effectiveness.

1 Introduction

In industry, formal methods are traditionally viewed as obscure, unscalable and lacking in sufficient tool support [4]. In the lecture theatre too, formal methods can seem too mathematical [8] and of little practical use in the development of complex systems [7].

In order to gain any insight into the benefits of formal methods, it is important that students are allowed to develop confidence with a specific formal notation, and use it to solve a wide range of problems [7]. This is usually achieved via practical lab sessions in which students are encouraged to complete a set of problems for practice and assessment, typically using only one formalism, due to the limited time available. We have observed that, with such a restriction, students are unlikely to reflect upon their practical experience and relate it to the other formalisms introduced in the course only theoretically.

In this paper we describe how we have developed a single teaching tutorial, making use of an electronic voting system (EVS), to complement an existing model checking course. The tutorial is designed specifically to consider the problem described above incorporating small group teaching techniques, such as buzz groups and brainstorming [2], along with the use of an EVS.

The authors are both lecturers in Computing Science at Glasgow University. Quintin Cutts’ recent research focuses on the use of an EVS within the context of higher education, and computing science education in particular [6, 10]. His focus is on engaging the students with the material either by problem solving or by reflecting deeply on their own understanding or misconceptions.

Alice Miller’s research is in the area of formal methods. Specifically her interests are in the use of advanced mathematical techniques, like induction and symmetry reduction, for model checking [11, 3]. She is director of the “Modelling Reactive systems course” discussed in this paper.
2 Modelling Reactive Systems Course (MRS4)

"Modelling Reactive Systems" (MRS4) is a fourth year honours course provided by the department of Computing Science at Glasgow University [5], which has now been running for 5 years. Designed to introduce and explore a variety of formal process description and analysis techniques used in the design of reactive systems, the course consists of 20 hours of lectures and 8 of lab sessions. It is divided into two parts. The first part of the course contains an introduction to reactive systems and basic (graphical) modelling formalisms, and focuses largely on the use of the model checker SPIN [9]. The second part (consisting of 6 lectures) is concerned with tools designed for real time systems development (e.g. SDL 2000). This paper relates to the first part of the course. There are, on average, 35 students in the class, with a wide range of ability. The mathematics in the course is kept to a minimum, although some students still struggle with some of the more theoretical concepts – the definition of Büchi automata etc. This is, of course, a well known phenomenon with formal methods courses [8]. Since the students perceive the course to be difficult, they choose not to participate when prompted for a response by the lecturer, in case they get an answer wrong. In addition, the mathematical nature of the course leads the students to assume that every problem has a right or wrong answer, although in many cases (for example, the most appropriate formalism to use in a particular situation) there is more than one possible solution.

Because of the steep learning curve and lack of time available, in the labs the students only gain experience from one formalism (SPIN). There is no scope within these sessions for wider discussion of the issues involved and to generalise experience across the breadth of the subject.

3 Electronic Voting System (EVS)

A typical EVS consists of a set of keypads, one per student, and a receiver connected to a PC. Multiple choice questions can be presented verbally, on the board, by overhead projector (OHP), or using a PC; students then submit their answer using the keypad. Finally, a bar chart showing the collated responses is displayed by the PC at the front of the class. The lecturer can then use the answers, and the increased knowledge about the students’ level of understanding provided by the answers, to guide class-wide or buzz group discussions designed to encourage the students to explore the topics more deeply. Students typically report the anonymity of answering and their increased attentiveness to the subject matter at hand as the key benefits of the system; lecturers the feedback on student understanding, which they use to guide their ongoing course delivery.

4 Using EVS in MRS4

In order to address the problems posed by strict lecture plus lab teaching methods described above, we introduced a tutorial session to the course which exploited the EVS.
4.1 Objectives

The major objectives here are:

1. to encourage participation in lab sessions prior to the tutorial
2. to affect self-learning via reading of a prescribed text
3. to promote reflection, an appreciation that issues are not always black and white, and a deeper knowledge of formal methods.

4.2 Methods

The task took the form of a set of 8 multiple choice questions (see below for a set of sample questions). The first 5 questions were assessed (in total they contributed up to 2% of the final mark for this course). The reason for making these questions assessed was to encourage the students to prepare for, and turn up to the session. The percentage was kept small, as it was based on only 1 of 28 teaching hours related to the course. The remaining questions were designed to promote debate within the class. The structure of the questions (and the mark obtainable) was discussed with the class prior to the session.

In order to achieve objective (1) above, the first three questions were based on issues that arose from discussions in the lab sessions related to the example sheets. In order to achieve objective (2), questions 3 – 5 were based on the prescribed text, namely “The Great Debates”, a discussion of some of the deeper questions relating to formal verification (see [9]). Finally, to achieve objective (3), some more open-ended questions were provided. We will discuss how these questions were used below.

**The multiple choice questions** We give samples from the set of questions only, due to lack of space.

1. In SPIN, what can be passed as parameters to processes?
   (a) global variables and constants
   (b) constants and channel names
   (c) channel names and global variables

2. One of the following statements about the temporal logics CTL and LTL is true. Which is it?
   (a) CTL is much more expressive
   (b) the expressiveness of the two logics do not overlap
   (c) LTL is more suitable for “on the fly” verification

3. What do you think of the statement “SPIN allows us to accurately model synchronous communication”?
   (a) the statement is true
   (b) the statement is false
   (c) The statement is not exactly true, but it is close enough.
7. Some real world examples of protocols (e.g. IEEE 802.11, FireWire, bluetooth device discovery) include some notion of randomness and probability. However Gerard Holzmann does not believe that the addition of probabilities to SPIN is necessary. Do you
(a) agree
(b) disagree
(c) neither agree nor disagree (i.e. you have a better solution.)

8. What do you think is the most important thing that is lacking in SPIN?
(a) a reliable, informative type-checker
(b) the ability to model real time
(c) something else (that you can describe)

**Responses and Discussion** Using EVS the students became increasingly confident in choosing their response and became far more engaged in this session than in other classes. (Until this session there had been almost no student participation in whole group sessions.)

Question 1 (and two further questions based on lecture/lab material): Over 80% of students answered these questions correctly (b for question 1). This was gratifying as it showed that discussions within lectures arising from problems in the labs had brought the relevant issues home. Answering these initial questions correctly also encouraged the students to be bold in answering the subsequent questions.

Question 4. 75% of students got this right (c). This demonstrated that they had read and understood the text. As this was the only exposure to CTL model checking that the students had on the course, their success was surprising.

Question 6. This prompted a lively discussion lasting several minutes. Most students went for (c), (which is the answer suggested in the prescribed text). Students were split into buzz groups and asked to come up with examples of synchronous/asynchronous systems. Some good examples arose (email, slot machine, cash machine, ADSL, token ring). The class discovered that it is generally very difficult to decide which systems are synchronous (in terms of communication) and which are not – it depends very much on the actual implementation. Some students expressed surprise (and, in some cases, relief) that an issue such as this was not completely black and white.

Question 7. The responses were approximately half (a) and half (b). The students were asked to discuss the problem for 5 minutes within buzz groups and then two students were selected, one to advocate (a) and one to advocate (b) (each justifying their answer). The main argument for (a) was that one can use non-determinism instead of probabilistic choice to some extent (when considering discrete time probabilistic systems, this point was perhaps too sophisticated for the class). The main argument for (b) was that we can only allow for a limited number of choices using non-determinism. The issues that arose in the discussion
were; probability is not suitable for adding to SPIN, but there are other more suitable tools: probabilistic model checkers like PRISM for example; and that probability is a very important aspect of some protocols.

Question 8. Almost all of the students went for (c). This led to some very lively and noisy debate. The students had strong opinions on this issue as they had spent several hours in the lab working with SPIN, and were keen to express their opinions on its perceived shortcomings. We did not attempt to divide the class into small groups in this case as time was running short. Students were invited to volunteer their suggestions to the rest of the class. There followed enthusiastic criticism of the error messages given by SPIN, the poor editor etc.

4.3 Outcomes

- Reassurance that students had read and understood material that could then comfortably be referred to later in the course. The first 3 (of the original 8) questions probed their understanding of the course material, and the remaining questions their ability to self-teach. They could not have understood the later questions if they had not read the text provided.
- Noticeable increase in confidence with students volunteering to answer questions within the class in subsequent lectures. Previous to the EVS session there had been no response from most students to questions asked in the class. After the session there were responses to questions, interruptions from the class and (well-meaning) contradictions from other students.
- The use of EVS was very popular with the students as a means to communicate anonymously. A typical comment in the course feedback was: "we enjoyed the session with the handsets more than we thought we would. It was good to argue with each other and made a change from lectures which can be rather boring".
  EVS was also invaluable for providing an immediate summary of responses, enabling further discussion.
- The debate-style questions prompted a great deal of discussion and gave rise to unexpected responses with a high degree of ingenuity. An observer (a lecturer from the Electronic Engineering department at the University of Glasgow) commented thus:
  "The groups behaved like groups in a pub quiz. Correct answers even caused cheering and strengthened the spirit of the group ... Besides the fun aspect the students found it much easier to speak to the whole class after having discussed the issues with their peers – possibly because they had the approval from their peer group."

Note that the major benefit of using EVS was that students had the means to anonymously express their doubts and opinions. This could, to some extent, be achieved by other means, e.g. via a Moodle forum [1]. However, we believe that the immediate feedback, within a controlled environment could not have been reproduced in that context. We also point out that our outcomes are based on our
observations rather than from the result of a rigorously controlled experiment. We had no control group, like that used in [12] for example. However, we could compare the behaviour of students before and after the intervention, and with students taking the course in previous years.

5 Conclusion

We have identified two major problems with the traditional lecture plus lab teaching of Formal Methods, namely low class participation in discussions, and lack of breadth in acquired learning. We have implemented a tutorial session using EVS which has provided an environment in which these problems have successfully been addressed. We are planning to extend the concept to a greater number of sessions in the next academic year.

References

5. University of Glasgow Computing Science. Modelling reactive systems course description:
   http://www.dcs.gla.ac.uk/courses/teaching/level4/modules/MRS4.html/.  