Witness Feedback for Introductory CS Theory Assignments

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ABSTRACT

Computing theory analyzes abstract computational models to rigorously study the computational difficulty of various problems. Introductory computing theory can be challenging for undergraduate students, and the overarching goal of our research is to help students learn these computational models. The most common pedagogical tool for interacting with these models is the Java Formal Languages and Automata Package (JFLAP). We developed a JFLAP server extension, which accepts homework submissions from students, evaluates the submission as correct or incorrect, and provides a witness string when the submission is incorrect. Our extension currently provides witness feedback for deterministic finite automata, nondeterministic finite automata, regular expressions, context-free grammars, and pushdown automata.

In Fall 2019, we ran a preliminary investigation on two synchronized sections (Control and Study) of the required undergraduate course Introduction to Computer Science Theory. The Study section ($n = 29$) used our extension for five targeted homework questions, and the Control section ($n = 35$) submitted these problems using traditional means. The Study section strongly outperformed the Control section with respect to the percent of perfect homework grades for the targeted homework questions. Our most interesting result was student persistence: with only the short witness string as feedback, students voluntarily persisted in submitting attempts until correct.

1 BACKGROUND AND RELATED WORK

We developed the Didactic And Visual Interface for Development (DAVID) extension to JFLAP [2]. The DAVID extension sends "Intro to CS Theory" homework submissions from students to a feedback server. For incorrect submissions, the server provides immediate feedback to the student via a *witness string*, a string on which the submission fails. We found that with only witness string feedback, students would persist in submitting attempts until correct.

We mention that Automata Tutor is an alternative feedback tool for computing theory. Version 2 provides a graphical user interface similar to JFLAP with additional features including automated grading. Presented in May 2020, Version 3 [1] has many added features, including those that we implemented on top of JFLAP.

SIGCSE '21, March 13–20, 2021, Virtual Event, USA

ACM ISBN 978-1-4503-8062-1/21/03.
https://doi.org/10.1145/3408877.3439585

2 RESULTS

On the five targeted homework questions where the Study section used the DAVID extension, the Study section's average grade was always higher than the Control section's average grade (Figure 1). We used ANOVA with a threshold of $p < 0.050$ to compare the grade differences between the sections. On three of the five homework questions (DFA, RegEx, and PDA), the Study section's higher score was statistically significant ($p = 0.001$, $p = 0.030$, and $p = 0.000$, respectively). For the other two questions (NFA and CFG), there was no statistically significant difference between the sections.

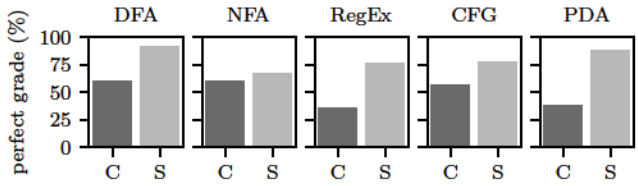

Figure 1: Percentage of students who earned a perfect grade from an experienced professor. "C" is Control; "S" is Study.

3 DISCUSSION AND FUTURE WORK

We have three results.[1] First, students knew they would get partial credit for incorrect solutions, yet students persisted until getting a correct answer from the extension. This behavioral phenomenon is *voluntary persistence*. Second, feedback of a single, short witness string requires the student to actively learn in order to solve the question. Third, we propose an alternative to partial credit: targeted yet succinct feedback that explains what went wrong in combination with unlimited resubmissions. We are most excited about student voluntary persistence. In our full investigation, we will test two new hypotheses: (1) witness feedback is the appropriate type of feedback, and (2) partial credit is not needed.

ACKNOWLEDGMENTS

We thank the SIGCSE 2021 anonymous referees for helpful comments. We thank Aaron Deever and his students for participating. We thank our advisory board: Douglas Baldwin, Joan Lucas, and Susan Rodger. Research supported in part by NSF grant DUE-1819546.

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[2] S. H. Rodger and T. W. Finley. 2006. *JFLAP: An Interactive Formal Languages and Automata Package.* Jones and Bartlett.

[1] We discuss these results in our tech report at https://arxiv.org/abs/2012.01546