SCALE: Student Centered Adaptive Learning Engine

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Abstract. We present a new ITS system called SCALE (Student Centered Adaptive Learning Engine), which is focused on improving learning outcomes by using data collected from existing and emerging educational technology systems combined with machine learning techniques to automatically generate adaptive capabilities. This allows for the creation of intelligent tutoring systems in a less costly fashion in terms of time and effort. SCALE uses data logs collected from an existing educational technology system to create the initial adaptivity and then improves over time as additional data is added or with the help of human input. This paper describes two main adaptive capabilities of problem selection and hint generation.

In this research, we present a system called SCALE (Student Centered Adaptive Learning Engine), which has been designed to greatly reduce the high cost of adaptive learning by implementing methods of deriving intelligent tutoring capabilities from collected student data. A key differentiator of SCALE from existing intelligent tutoring systems is that it improves over time with additional data and/or with the help of human input. SCALE employs a 'human-centered, data driven' approach to discover or improve the underlying models that drive learning. Unlike a pure machine learning solution, SCALE is able to report to the developers exactly why the system behaves as it does and allows for human input to maximize improvements through refinement over time. By using existing large datasets previously collected from existing educational technologies, we have tested and validated the techniques used in the system.

While intelligent tutoring systems have delivered significantly better results compared to non-adaptive software, their use has been limited due to the difficulty and cost of creating the adaptive content. Most tutors rely on "student models" that are time consuming to create and require experts to understand the subject material and comprehend the underlying processes used to provide help and feedback. We streamline this work by building initial models using data collected from students solving problems with the intent to enhance the development of ITSs. Previous work in the automatic discovery of student models [4] and automated hint generation [1,5] lay the foundation of the system. SCALE features functionality that includes generating student models that build and organize themselves and improve over time as more data is collected, and dynamically selecting the students' next problems to maximize student learning and minimize time needed to master a set of skills. SCALE also pro-

vides hints and feedback on multi-step problems, and utilizes a "feedback loop" to provide continuous improvement of the features over time as more data is collected.

The Knowledge Tracing and problem selection mechanisms use past research on knowledge component (KC) modeling like that used in DataShop [3]. The hint and feedback mechanism utilize past research with the Hint Factory [1], which is a novel method of automatically generating context specific, just-in-time (JIT) hints for students solving multi-step problems [1]. The method is designed to be as specific as possible, derived on-demand, and directed to the student's problem-solving goal, to provide the right type of help at the right time.

We have demonstrated the ability to use data collected from educational technologies to automatically generate adaptive capabilities. The main contribution of this work is to demonstrate the design of the SCALE system to provide problem selection and knowledge tracing, as well as providing just in time hints and feedback. While previous efforts have demonstrated these abilities individually, SCALE represents the first complete commercial viable solution for a complete ITS generated with data.

In the future, SCALE will provide tools that let instructors and developers explore the data using meaningful visualizations that will provide insights into student learning that builds off additional previous research in improving student models [2]. Often this means identifying areas where the existing models seem to contradict the data collected. Built around the concept of curating data, these tools can also prompt developers, educators, and users of the educational software for more human input in order to improve the underlying models that the system generates.

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