Supporting K-5 Learners with Dialogue Systems

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Abstract. Interactive learning environments have been built to support various audiences from preschool to university students. However, it is not yet known how to bring the great promise of tutorial dialogue systems, which engage students in rich natural language, to bear for young learners such as those in grades K-5. This doctoral consortium paper presents our goal of developing a dialogue system in the form of an interactive spoken dialogue agent with embedded assessment to support K-5 students in learning computer science. It discusses the challenges faced so far and how we plan to solve those challenges to bring individualized dialogue systems technology to young learners.

Keywords: Spoken dialogue · Virtual agent · Assessment

1 Introduction

As technology advances, dialogue systems are becoming more versatile with respect to their functionalities. Systems such as personal assistants on mobile devices and in video games are used daily, whether the goal is to complete a practical task or to have fun. Dialogue systems have also begun to find a place in schools where they are useful to university and high school students in their studies. Researchers are realizing that intelligent systems also have the potential to help children as young as preschoolers [3]. Learning in a classroom environment can be difficult as students often struggle with grasping concepts and mastering skills. Not only would students benefit from individualized scaffolding, but by embedding assessments into our intelligent systems we can help teachers know when students need help. We propose to build a tutorial dialogue system for elementary (primary) school students learning basic computer science concepts. Through dialogue systems, we can help students make the most of their education by building tools to better support their needs. Our work will be one of the few spoken dialogue systems for K-5 (ages 5-11) students and may be the first dialogue system with embedded assessments for this age group.

2 Related Work

This section presents a literature review of intelligent systems and conversational systems that have been built for, and piloted with, children in fifth grade and below.

C. Conati et al. (Eds.): AIED 2015, LNAI 9112, pp. 873–876, 2015.
DOI: 10.1007/978-3-319-19773-9_136

Marni is an animated conversational agent that helps young elementary students learn how to read [1]. Marni has interacted with approximately 1500 kindergarten through second grade students in control and experimental group classrooms. In one study, kindergarten and first grade students had greater learning gains when interacting with Marni compared to the control condition in single-word reading and letter identification. Later, Marni was adapted into a spoken dialogue tutoring system to aid upper elementary students in learning science concepts [2]. Marni uses a strategy called *Questioning the Author*, a strategy that directs students to challenge the authors' text, which helps them better understand the content by forming counterarguments. Marni is supplemented by illustrations, as well as both non-interactive animations and interactive animations. Although the authors did not report whether there were learning gains, they reported a word error rate (WER) of 27.4%, a concept recall of 0.86, and a concept precision of 0.90, suggesting that content word recognition was very accurate. Students reported a positive experience with Marni and students in low-performing schools felt Marni was helpful.

Another spoken dialogue system is Project LISTEN's Reading Tutor [6] which, like the early version of Marni, was built to help elementary students learn how to read. In a study over seven months, one group of students between first and fourth grades spent 20-25 minutes completing sustained silent reading (SSR) while the other group read with the Reading Tutor. There were 90 students in the SSR condition and 88 in the Reading Tutor condition. Various pre- and post-tests were given to the students to measure their learning gains. The authors found higher learning gains for the students in the Reading Tutor condition in many skills including Word Identification, Reading Comprehension, and Written Spelling. There was not a case where the SSR students learned more than the Reading Tutor students.

Axelsson, et al. describe a mathematics game with a teachable agent (TA) that supports preschoolers in understanding the meaning of numbers [3]. The authors conducted a study in which some students played the game that had the TA while others played the game without it. They found that the students were engaged with the game regardless of whether the TA was present or not. This suggests that the TA does not hinder preschoolers' engagement in an educational game. In addition, the authors tested the students' "theory of mind," the understanding that each individual has a different set of knowledge, and students without a fully developed "theory of mind" successfully interacted with the TA.

Developing spoken dialogue systems for young children can be difficult for many reasons: children often mispronounce words, are more spontaneous, and may find systems frustrating when misinterpreted. The ALIZ-E project produced a spoken dialogue system for young children embodied in a Nao robot [4]. The authors ensured that the natural language interpretation was robust; they trained their acoustic model on a corpus of children's speech, developed language models to recognize predefined quiz questions and answers, and implemented a fuzzy matching technique to increase the accuracy of quiz question recognition. Their dialogue manager allows users to navigate across sub-dialogues rather than remain confined in one sub-dialogue [5]. They conducted a study of the system with 19 children between the ages of 5 and 12 interacting with the Nao in one-on-one sessions for a maximum of three hours.

The average WER was 38%; improvements in automatic speech recognition (ASR) accuracy may improve the quality of the conversations.

We plan to build upon this prior work by creating a dialogue agent to support young children learning computer science. Based on prior work, we will incorporate the following design principles into the process of building our intelligent system: it will employ language models trained on a corpus of children's speech to increase ASR accuracy and concept accuracy; it will have an expressive child's voice with varied dialogue output to increase engagement; it will use pedagogical strategies such as Questioning the Author to assess students' understanding.

3 Preliminary Results

Our ultimate goal is to develop a dialogue system that supports young students in learning essential computer science concepts. We have already collected preliminary results in developing domain content for implementation within our intelligent agent. To date we have developed new 4th and 5th grade computer science curricula.

The 5th grade class based upon our preliminary work has completed two iterations during the 2014-2015 school year. The curricula was developed based on CS Principles. During each iteration, we collected data from students after receiving consent. We interviewed the students at the beginning and end of the course and collected data including videos of class participation and screen recordings of them programming. The interviews include questions about the students' motivation for taking the class, previous experiences in computer science, current attitude toward computer science, and attitude towards the class. Finally, we collected brainstorming documents from project work such as conditional trees and storyboards.

We are analyzing the data we have collected from the first two quarters of the fifth grade class. We would like to determine how much the students learned. These findings will be used to inform the design of the intelligent agents.

One challenge we faced during the pilot of the class is properly assessing the students on their knowledge and concept understanding. Each class runs for 45 minutes and students often face difficulties completing the task within the given timeframe. Depending on the activity, the students work individually, in pairs, or in groups. Although we are able to observe the students and make subjective inferences on how well they grasp each concept, we would like a formal assessment to better pinpoint their understanding. We propose the use of embedded assessment techniques within the agent to assess students' learning.

4 Project Proposal

We propose an animated virtual agent within a spoken dialogue system as a mobile app for young students for support and assessment of computer science learning. The agent will be designed to appear similar in age to the students and will converse with the students as a peer; this interaction is more natural to children than speaking to an investigator. Our overarching research questions are as follows:

- How can we build embedded assessment to measure elementary students' comprehension of a subject using an animated virtual agent?
- Which spoken dialogue strategies can be successfully used as embedded assessment techniques to assess elementary students' knowledge?

We will begin by building a simple dialogue system that will implement a Wizard-of-Oz approach. This app will converse with the children about computer science. The system's utterances will be generated by a wizard based on the system's ASR. During the study we will record the children's speech, the ASR interpretation of the speech, and the wizard's response to the interpretations. The first iteration will allow us to refine the techniques that evaluate the students' knowledge, and understanding via embedded assessment. Techniques we will use include self-explanation, and having the student and system quiz each other. This iterative cycle of research and development is expected to yield significant insight into how very young learners reach an understanding of computer science through interaction with a virtual agent. Moreover, the research results will shed light on dialogue strategies and embedded assessment approaches for these very young learners.

Acknowledgements. This work is supported in part by the Wake County Public School System.

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