Development Methods for a Social Conversational Agent in a Virtual Learning Environment with an Educational Math Game

Annika Silvervarg
Department of Computer and Information Science
Linköping University
annika.silvervarg@liu.se

Abstract: We are developing a virtual learning environment, which includes a math game with a teachable agent, the embodiment of the agent, and a social conversation with the agent. In this work we are using various methods for design and system development, with a focus on iterative methods, and high involvement of the user in the process. In this paper we discuss the motivation for and the applications of these methods in the development of the social conversation with the agent.

Introduction

A common approach to computer-based learning environments today is the inclusion of virtual characters. Various pedagogical gains have been claimed: increased motivation, increased sense of ease and comfort, stimulation of learning behaviors, improved information and communication processes, forming personal relationships in learning, and gains in terms of memory, understanding and problem solving skills. However, the evidence of these claims is ambiguous depending on the particular methods and settings used (Gulz 2004). We are interested in conducting further studies into several of these aspects, both on short term and on long term, in ecological valid environments. We are therefore developing a learning environment that can be used as a platform for studying how various visual aspects (e.g. gender, age, personality traits) and communicative aspects (e.g. linguistic style, vocabulary, choice of conversation topic(s)) of virtual characters influence factors such as learner motivation, attitudes, self-efficacy and overall learning quality, as well as how the communication with the agent and the experience of using the learning environment is affected.

Architecture

The overall architecture for the system includes three main modules: a math game with a teachable agent, the embodiment of the agent, and social conversation with the agent (Fig 1).

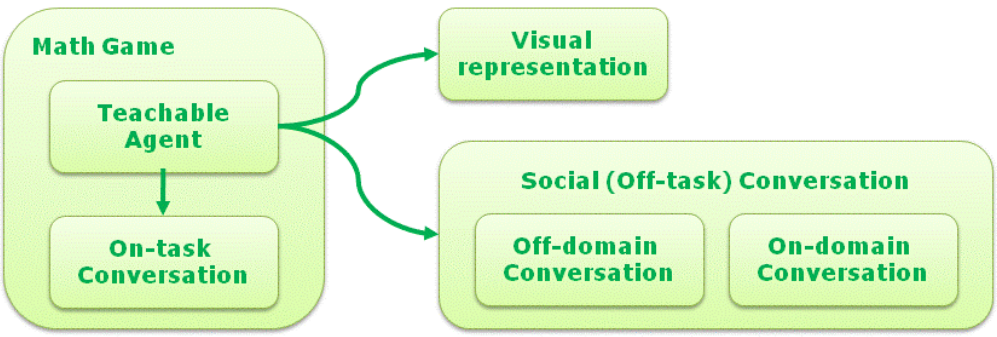

Figure 1: The architecture for the learning environment including a Math game with a teachable agent, a visual representation of the agent, and social conversation with the agent

Math Game with a Teachable Agent

The learning environment is based on an educational math game (Fig 2) developed by Lena Pareto and Daniel Schwartz (Pareto 2004). A crucial part of the environment is a pedagogical agent, or more specifically a teachable agent that is taught by the students (Biswas et al. 2001). While the student is playing the game, the agent can "learn" the rules of the game in two ways, by observing the student's moves and through an *on-task dialogue* (Fig 3), where the agent poses multiple-choice questions about how the game is played. For the present project, the intended users are 12-14-year-old students, and the teachable agent will be designed as having the same age or slightly younger. A teachable agent is independent and can act on its own, yet is dependent on the student to learn rules and strategies. Thus, in a sense the agent will reflect the student's knowledge. Chase et al. (in press) have shown that students make greater effort to learn for their teachable agent than they do for themselves.

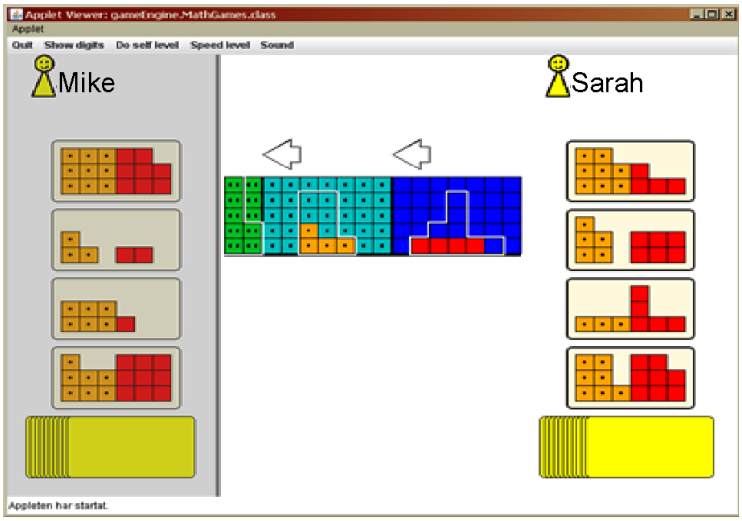

Figure 2: The initial Math game developed by Lena Pareto and Daniel Schwartz

Embodiment of the Agent

The current game version employs a very rudimentary image of the teachable agent (over left and right corner in Fig 2); an important extension is therefore the inclusion of a more elaborate visual representation of the agent (Fig 3). It has been suggested that the contextual relevance and aesthetics of the agent's visual representation is essential, since it influences the user's expectations of the agent's abilities (see Gulz & Haake 2006 and Veletsianos 2007), something we are planning to further investigate. Another important aspect of the visual representation is how it can evoke empathy through facial characteristics such as smiles, eye-contact, positive demeanor, and an expressive face which shows emotions and states such as thinking or reflecting (Cooper et al. 1999). The agent will therefore have some simple animations for these.

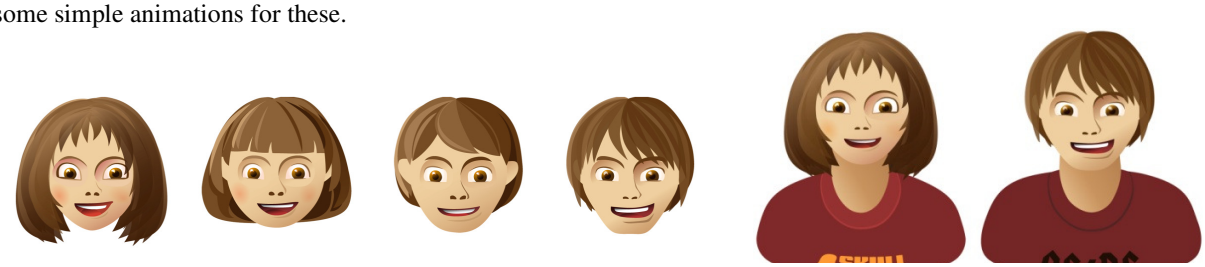

Figure 3: Examples of visual representation of the teachable agent. To the left the initial pictures used during focus group discussions, to the right the modified versions that also include simple animations used in the first prototype.

Social Conversation with the Agent

Another novel part of the learning environment is a module for freer conversation between the student and the agent. The student will be able to write freely, in contrast to the multiple-choice format in the on-task dialogue, and also bring up basically any topic (Fig 4). We call this the *off-task* conversation. In turn, the off-task conversation can be distinguished into *on-domain* conversation, referring to freer conversation related to school, math, the math game, etc., and *off-domain* conversation, referring to freer conversation related to any other topics. Bickmore and Cassell (1999) argue that small talk and conversational storytelling fills an important role in interactions, e.g. in developing a relationship and establishing trust or the expertise of the agent. From a pedagogical perspective, the purpose of the more social conversation is to enrich the game and its motivational qualities for the age group in question. Another purpose is to explore whether such a conversational module can enable additional pedagogical interventions, such as supporting students math self efficacy and change negative attitudes toward math in general. For an extended discussion on the motivation of off-task conversation see Gulz et al (2010).

Figure 4: Examples of designs for the new interface of the learning environment. On the left is the game with the agent engaging in on-task conversation. On the right has the agent initiated off-task conversation.

Methods for Development of the Social Conversational Module

The development of the conversational module and its integration in the learning environment is inspired by Design-based research, which stresses the combination of theory development with research in authentic and naturalistic environments, and the sharing of knowledge amongst practitioners and researchers (The Design-Based Research Collective 2003). Development and research takes place through continuous cycles of design, enactment, analysis and redesign. In this case it means that theories about conversational virtual characters in pedagogical settings are used as a foundation for design and development of the conversational module. The learning environment is then deployed and tested in a natural setting, i.e. a school or home environment for the intended age group, and analysis of the outcome is then to be used to refine theories and redesign the module.

One of the crucial challenges when designing a conversational pedagogical agent is to establish its credibility and trustworthiness. The agent must meet the user's expectations, and answer questions promptly and adequately (Doering et al. 2008). This is related to the implementation of adequate domain and task knowledge but also adequate linguistic models, i.e. the agent need to be able to successfully interpret the user utterances and respond with appropriate content and language use. To meet this challenge we utilise a number of methods which involve end-users, i.e. students, in the design process, including short iterations of design-testing-redesign. A school class of 20 students 13-14 years old is taking active part in the design and development of the off-task conversation.

User involvement can be done on different levels, ranging from end-users acting as testers who provide feed-back to the developer about the finished product, to students as active partners throughout the development process (Nesset & Large 2004). We are combining two approaches. The 20 students in the participating school class acts as native

informants (Scaife & Rogers 1998) who take part in the design process and contribute during functionality specification, design, and evaluation of lo-fi and hi-fi prototypes. A larger group of 40 students will acts as testers during the iterative development of the module. They will have the opportunity to interact with hi-fi prototypes and the interaction will be logged and analyzed. Interviews and questionnaires will be used to gather qualitative data.

Design Decisions Based on Theories of Pedagogical Aspects

Initially, some design decisions for the conversational module were made on basis of pedagogical aspects related to the goal of the learning environment. For example, a starting point for the design of the conversational agent is that users should like to interact with it and find it enjoyable, thus improving the overall experience of using the learning environment. But we would also like the agent to control the conversation so as to maintain a balance between on-domain and off-domain conversation. There are two reasons for this; one is to avoid the problem of users becoming so immersed in off-domain conversation that they lose focus on the learning task (Veletsianos & Miller, 2008), the other is that we want to be able to try out some pedagogical interventions through the on-domain conversation content.

In order to explore possible pedagogical interventions, we decided to design the agent such that the agent attends school and have the same subjects as the user. Since the whole learning environment builds on the idea that the TA wants to learn to play the game, it follows naturally that it should be interested in mathematics. However, its specific attitudes to and knowledge of mathematics are less obvious and were an open issue in the design.

Furthermore, we have explored several aspects which define the social role and status of the agent, for example, the relationship between agent and user, the age of the agent, and its personal qualities. However, results from previous studies are too ambiguous to serve as an empirical basis for any definite design decisions in these respects, why we turned to our focus groups of actual users for better answers.

Focus Group Discussions

The selected school class was introduced to the project and played the current version of the game for 30 minutes. Half of that time, the agent was present in the game and posed on-task questions. The class was then divided into four focus groups of 4-5 students each. The assigned themes of discussion in the groups were: the agent's personal qualities and interests, topics for conversation with the agent, and the agent's visual appearance. On basis of the results from discussions, a number of design decisions could be made, most of which were consistent with previous design decisions based on theories related to pedagogical issues. For example, we concluded the agent be a fictive character which is human-like in appearance and personal interests, that it has a family and friends, goes to school, is an average student, is intelligent but not a genius.

Regarding personal qualities, the focus groups confirmed that the agent should be friendly, curious, eager to learn and like school; this has also been suggested by previous experiences and studies. However, it was added that the agent should not be too polite, but express some 'attitude'. This is an example of how a particular user group can differ from general design guidelines, and thus highlights the importance of involving target user groups in the design.

In the initial discussions to this project, we listed what we thought to be relevant personal interests and possible topics for off-task conversation, based on our knowledge of the target user groups. Some of these were confirmed in the focus groups, for example friends and school, but there were also some presumed topics which were not mentioned, such as film and travelling. The focus groups also quite consistently proposed topics that we had not previously considered: sports, music, and computer games. Again, it confirmed the importance of user involvement in the design process.

Corpus Studies

To capture the expected content in terms of topics of off-task conversation and linguistic expression of user utterances, we have and will continue to collect and study corpora of both human-human written conversation, and human-agent conversations.

Based on the design decisions and results from focus groups discussion a sketch of the agent's persona was written. This sketch was intentionally unspecific and reflected the limitations of the personal qualities and interests brought up

in the focus groups. For example, the agent were not said to do specific sports after school, but that it likes gym class; that it likes to listen to music and watch music programs on TV in its spare time, but not anything about favorite artists and songs. This persona sketch then formed the basis for a role play, in which students simulated off-task conversations in the game. 3 students played the part of the agent, and 4 students played the role of the user. The persona had the same content but the agents had different gender, names and pictures. Agent players were asked to act in accordance with the persona, and in case dialogue topics occurred outside its known scope (for example about pets), they were asked to improvise.

The resulting 12 dialogues were analysed according to topics, linguistic style and dialogue phenomenon. For example a number of new topics emerged that had not been brought up in the focus groups, eg literature and film, where the agent lived. The linguistic style of utterances could be charcterised as grammatical, short sentences, with sparse use of smiles and "chat-expressions". The dialogue mostly consisted of unconnected question and answer pairs, but some instances of connected dialogue with 3-4 turns. The initiative was evenly distributed between user and system. There were frequent use of elliptic expressions but not anaphora. The topics and dialogue phenomenon were than classified as high priority to be included in prototype 1, low priority to be included in later versions of the prototype, or not desirable to implement.

Persona Workshop

After the role play, the participants were asked to form 3 pairs and rewrite the persona, with more details added to it. They were provided with some leading questions for help, for instance, as to "music", they were asked to fill in information on the agent's preferences, when and how it listens to music, etc. One standard persona for the conversational agent has been constructed by merging common features from these three descriptions, with the goal that it appeals to a broad group of users.

Iterative Development and Testing of Protoypes

Based on the developed persona and the analysis of the corpus, a high fidelity prototype of the game that include off-task conversation and a new visual appearance of the agent has been implemented. Both the informants and other student groups, a total of 38 students, have used the prototype and had the interaction logged. Two questionnaires were distributed, one to gather data about the experience of using the learning environment, and one relating to the personality of the agent. The first questionnaire is partially based on Hone and Graham's (2000) tool SASSI (Subjective Assessment of Speech System Interfaces). The second questionnaire is a Swedish translation and adaptation of the TIPI test, a 10-item measure of the Big Five (or Five-Factor Model) dimensions (Gosling, 2003). Based on the analysis of the collected data students from the participating class will be invited to partake in further focus group discussions that will focus on the personality of the agent persona, and the relation to the experience of talking to the agent. Analysis of these discussions, as well as analysis of the logged interactions, will go into the development of a second prototype. This will be tested in a similar manner before the final system is implemented.

Summary

In the heart of the architecture for our learning environment is a teachable agent. We are extending the learning environment with a visual representation of the agent and a conversational module for off-task dialogue. We use various methods for design and system development, with a focus on iterative methods, and high involvement of the user in the process. The aim is to produce a high-quality learning environment, which can be used in further investigations, but also to evaluate the applicability of the different methods, tools, and techniques used for technical development. So far the inclusion of users in the design process has been very fruitful and given valuable input and we anticipate that participation of user in the future testing and redesign of the prototype will be even more valuable.

References

Bickmore, T & Cassell, J. (1999) Small Talk and Conversational Storytelling In Embodied Interface Agents, In *Proceedings of the AAAI Fall Symposium on Narrative Intelligence*.

Biswas, G., Katzlberger, T., Brandford, J., Schwartz D., & TAG-V. (2001). Extending intelligent learning environments with teachable agents to enhance learning. In J.D. Moore, C.L. Redfield, and W.L. Johnson (Eds.) *Artificial Intelligence in Education*, pp. 389–397. Amsterdam: IOS Press.

Chase, C., Chin, D. B., Oppezzo, M., & Schwartz, D. L. (in press). Teachable agents and the protégé effect: Increasing the effort towards learning. Journal of Science Education and Technology.

Cooper, B., Brna, P. & Martins, A. (2000) Effective Affective in Intelligent Systems - Building on Evidence of Empathy in Teaching and Learning. In A.M. Paiva (Ed) *Affective Interactions, LNAI 1814*, pp. 21-34

Danielsson, K. & Wiberg, C. (2006) Participatory Design of learning media: designing educational computer games with and for teenagers, in *ITSE special issue: Computer Game-based Learning*, Vol. 3, Issue 4, p.275-291, November 2006.

Doering, A., Veletsianos, G., & Yerasimou, T. (2008). Conversational Agents and their Longitudinal Affordances on Communication and Interaction. *Journal of Interactive Learning Research, 19*(2), 251-270

Gosling, S. D., Rentfrow, P. J., & Swann, W. B., Jr. (2003). A Very Brief Measure of the Big Five Personality Domains. *Journal of Research in Personality, 37, 504-528.*

Gulz, A. (2004). Benefits of virtual characters in computer based learning environments: claims and evidence. *International Journal of Artificial Intelligence in Education*, 14, 313-334.

Gulz, A. & Haake, M. (2006). Design of animated pedagogical agents – a look at their look. *International Journal of Human-Computer Studies*, 64(4), 281-394.

Gulz, A, Silvervarg, A & Sjödén, B (2010) Designfor off-task interaction – Rethinking pedagogy in technology enhanced learning *Proceedings of the The 10th IEEE International Conference on Advanced Learning Technologies*

Hone, K.S. & Graham, R. (2000) Towards a tool for the subjective assessment of speech system interfaces (SASSI). Natural Language Engineering, 6(3/4), 287-305

Nesset, V. & Large, A. (2004). Children in the information technology design process: A review of theories and their applications. *Library and Information Science Research*. 26(2): 140-161.

Pareto, L. (2004). The Squares Family: A Game and Story based Microworld for Understanding Arithmetic Concepts designed to attract girls. In *World Conference on Educational Multimedia, Hypermedia and Telecommunications*, Vol. 2004, Issue 1, 2004, pp. 1567-1574.

Scaife, M. and Rogers, Y. (1998) Kids as informants: telling us what we didn't know or confirming what we knew already? In A. Druin (ed.) *The Design of Children's Technology: How We Design, What We Design, and Why*. Morgan Kaufman.

The Design-Based Research Collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher, 32*(1), 5-8.

Veletsianos, G. (2007). Cognitive and Affective Benefits of an Animated Pedagogical Agent: Considering Contextual Relevance and Aesthetics. *Journal of Educational Computing Research, 36*(4), 373-377

Veletsianos, G., & Miller, C. (2008). Conversing with Pedagogical Agents: A Phenomenological Exploration of Interacting with Digital Entities. *British Journal of Educational Technology, 39*(6), 969-9

Acknowledgements

Many thanks to Agneta Gulz, Björn Sjödén and other project members who have participated in the work on the agent persona and for valuable comments and discussion on the methods and material used. A special thanks also to the participating students and their teacher Hanna Olsson at Nyhemskolan in Katrineholm. Thanks to the KK foundation for their financial support.