The Design and Implementation of Augmented Reality Learning Systems

Sejin Oh
Convergence R&D Laboratory
LG Electronics
Seoul, S. Korea
e-mail: sjin.oh@lge.com

Yungcheol Byun
Department of Computer Engineering
Jeju National University
Jeju-si, Jeju-do, S. Korea
e-mail: ycb@jejunu.ac.kr

***Abstract*—In this paper, we present an augmented reality learning system that enables users to experience an interactive flower garden with the assistance of interactive agents in the augmented picture. We develop an interactive agent that generates problem-solving peer support to a user's action. We overlay virtual flower garden over a physical book and offer a collaborative environment that allows a learner to interact with the agent. To evaluate the effectiveness of the proposed system, we implement it on a mobile device and enable users to experience the collaborative task with the animated character. Through evaluation, we found that the interactive agent could be a promising technology for motivating users to engage in learning systems.**

Keywords- Augmented reality system; interactive learning system, collaborative learning environment

I. INTRODUCTION

With the rapid increase in the importance of interaction in educational systems, subsequent demands from consumers for interactivity have been on the rise. In enhancing human learners' interactive experiences, researchers have applied animated agents into learning environments for a variety of human learning tasks [1] [2]. They enabled these animated agents to provide learners with advice in response to problem-solving activities in a believable manner. The presence of agents induces a learner's motivational role on their learning experiences [3]. There have been studies pertaining to animated agents based on augmented reality (AR). Since AR technology make users experience computer generated content embedded into real environments [4], it can allow agents to coexist with users in the same real space.

The agents in AR settings express guidance suitable for learners' problem-solving situations directly. In the *Welbo* system, an augmented agent assists users to simulate virtual furniture in a mixed reality (MR) space [5]. The AR Lego presented an animated agent to demonstrate how to assemble toy blocks [6]. These systems visualized the animated agents over real environments where the users actually exist and reduced users' perception of the spatial seam to the agents.

In this paper, we develop an augmented reality learning system that enables users to experience flower gardening with an interactive agent over a physical book. To make the agents encourage users to engage in learning experiences effectively, we design a belief, desire, intention (BDI)-based framework for interactive agents. Thus, the agents appraise a user's action and respond to the problem-solving context through nonintrusive expressions. To allow users to cooperate with the interactive agents in a real space, we overlay a virtual flower garden over a physical book by detecting and tracking the page of the book through a camera and assign collaborative works on the gardening to the learners. To show the effectiveness of the proposed system, we implemented a prototype on a mobile device and performed usability tests. Through evaluations, we observed that the interactive agents encouraged participants to engage in learning experiences.

In the remainder of this paper, we provide a detailed description of the augmented reality learning system and its implementation. We show evaluation results to verify the effectiveness of the implemented system. Finally, we conclude with some general observations about our learning system and outline directions for future research.

II. AUGMENTED REALITY LEARNING SYSTEM

We present an augmented reality learning system that provides learners with opportunities to simulate flower gardening over a physical book. To enable the learners to experience learning environment directly, we offer them with an augmented scene, consisting of simulation factors, virtual flowers through their mobile devices with a camera. We allow users to explore environmental considerations of gardening with user interface. To improve learners' engagements in gardening, we augment a picture with an interactive agent that assists users in achieving desired goals in the gardening environment. Specifically, it allows users to seamlessly interact with an interactive agent with their mobile devices. Figure 1 describes the overview of the augmented reality learning system.

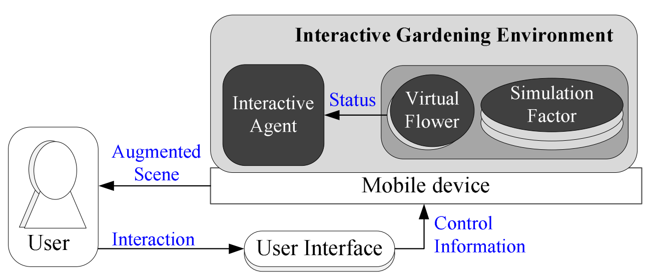


Figure 1. Overview of an augmented reality learning system.

978-0-7695-4694-0/12 $26.00 © 2012 IEEE
DOI 10.1109/ICIS.2012.106

A. An Interactive Agent

We develop an interactive agent based on the framework for designing interactive agents in interactive learning environments [7]. Thus, the agent has the ability to perceive changes by a user's actions in the learning environment. It generates peer-like responses in accordance with the agent's own beliefs, desires, and intentions [8]. Consequently, the agent generates problem-solving advice with peer support in an autonomous way. Figure 2 describes the response generation process of the interactive agent.

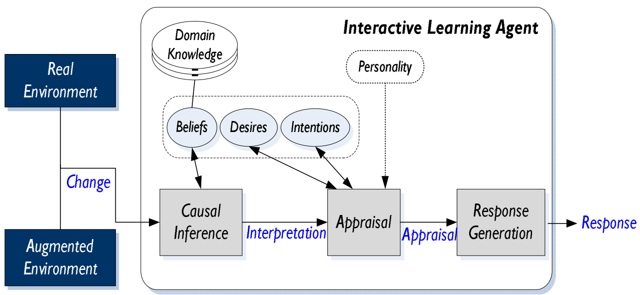


Figure 2. Response generation process of the interactive agent.

We have developed an explanatory process that allows an agent to explain a situation in its internal state [9]. In this process, we model the three explanatory variables, personalization, permanence, and pervasiveness, potentially affecting the explanatory style. We adjust the degree of the variables in accordance with personality factors. In this way, the agent attributes responsibility for the occurrence of an event, and blames or gives credit for the circumstance in different ways. As the agent has inclination for evaluating the persistence of a situation, it can assign different degrees of controllability and changeability of appraisals to the outcome. The agent can also adjust the extent of influence of previous circumstances by the degree of pervasiveness. Therefore, the same situation can be evaluated differently according to an interactive agent's personality.

Our agent presents pedagogical strategies through less intrusive responses. Since an agent can foster enthusiasm in a learner by conveying an emotional state [3], we allow the agent to generate its emotional state according to problem-solving situation. Based on the *Ortony*, *Clore*, and *Collins* Model [9], the interactive agent generates appropriate emotional responses to appraisal results. Here, we examine simple examples of mapping from situations and emotions. Since our agent has the desired goal, "*I will engage my learning colleague (human learner)*", the agent would become distressed when the learner appears bored with the task at hand. Additionally, if the agent has the principle, "*I should make the learner cautious when it is appropriate to do so*", the agent can express different responses to the circumstance according to the agent's explanatory tendencies. That is, a pessimistic agent respects a learner when he/she is cautious during an appropriate situation, and reproaches itself when the learner is not. However, an optimistic agent shows opposite responses to these same situations.

B. Interactive Gardening Environment

We offer an interactive learning environment that enables users to experience gardening in a natural manner. To support users in simulating environmental considerations when gardening, we provide a user interface that enables users to choose specific factors such as water, light, and fertilizer that they can apply to a virtual flower in the augmented environment. We also provide users with a simple interaction metaphor for applying the selected factor to the virtual flower. Then, according to the user's request, the status of the augmented flower is changed in real time. Thus, participants not only experience gardening, but also learn about the influences of a specific environmental factor on the flower.

We allow a user to collaborate with an interactive agent by assigning collaborative problems pertaining to flower gardening. To achieve assigned tasks, the user tries to select an appropriate simulation factor and apply it to an augmented flower. Since the interactive agent coexists in the user's learning environment, it expresses problem-solving peer support in real time. Moreover, it offers pedagogical guidelines to assist the user in solving the problem. Thus, the user can learn how to cooperate to achieve collaborative results.

C. Working Scenario

In this environment, a learner may have the mission *help-to-bloom* to achieve the goal *blooming-is-helped*; there are two possible solutions: *apply-water* and *apply-fertilizer*. *Apply-water* consists of the primitive tasks; *select-water* and *sprinkle-water*, and *apply-fertilizer* is composed of *select-fertilizer* and *sprinkle-fertilizer*. *Sprinkle-water* and *sprinkle-fertilizer* have the effect *blooming-is-helped* which is a desired goal for both the agent and the participant. However, *sprinkle-fertilizer* has an undesirable side effect for flower gardening, which is *root-becomes-weak*.

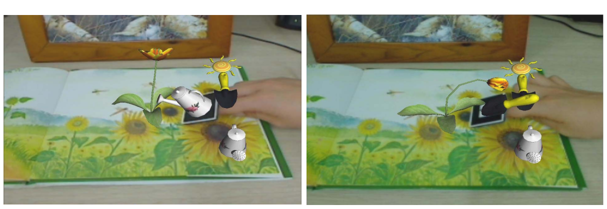
Let us imagine that a learner interacts with an optimistic agent. In this case, the learner chooses the method *apply-fertilizer* and performs the subtasks *select-fertilizer* and *sprinkle-fertilizer*. As a result, the undesirable outcome *root-becomes-weak* occurs. First, the interactive agent knows that the participant is the causal agent for this effect. The agent also infers that the participant has foreknowledge about the possible effects of the action and intended to achieve the consequence. Then, the agent externalizes an undesirable state and assigns the responsibility to the participant as the causal agent for the outcome. Moreover, the agent regards *root-becomes-weak* as unstable, and attributes high controllability and high changeability to the state. Finally, the agent reproaches the participant for being blameworthy for the undesirable state *root-becomes-weak.*

III. Implementation

We developed an augmented reality learning system on an ultra mobile personal computer (UMPC) containing a camera. As shown in Figure 3, we allowed users to explore an interactive flower garden over a physical book that describes contents related to gardening. To augment the interactive gardening environment on the book, we exploited *BazAR*, an open library based on computer vision technology for feature point detection and matching, to track pages of the book [10]. Then, each page was overlaid with the virtual gardening environment, composed of a virtual animated flower and selected environmental factors such as water, light, and fertilizer. In this scenario, we visualized the interactive agent as an animated character and enabled users to interact with the character. In this way, the character assisted users to solve problems through anthropomorphic expressions, i.e., animated movements, texts, and sound effects.

Figure 3. The implemented augmented reality learning system over a physical book.

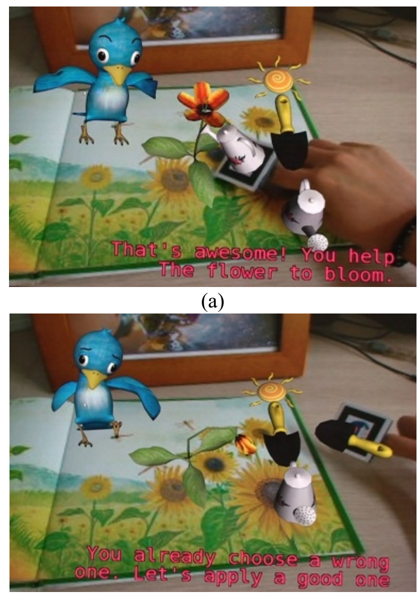
We provided a user interface to enable users to simulate environmental considerations in a garden. In prototype, users could see the virtual gardening environment using their mobile devices. To allow users to select a specific factor affecting the growth of the flower, we designed a ring-type controller attaching a fiducial marker, which was exploited using *ARToolkit* [11]. Thus, the users could choose a factor and apply it to the augmented flower with the controller. When a user approached the controller located near a 3D computer graphics model augmented over a page of a book, as shown in Figure 4, the 3D model was transmitted and overlaid on the controller, thereby allowing the user to know which factor was selected. In addition, we allowed users to apply the selected factor to the augmented flower through simple actions. Then, according to the applied factor, the augmented flower showed several changes through animation sequences of 3D models, such as growing up, withering, and waving. Hence, participants not only experienced gardening, but also learned the effect of different factors on the flower.



(a) (b)

Figure 4. Applying a selected factor to a flower: (a) Watering and (b) Fertilizing the flower.

Since the interactive agent is represented as the animated agent, the agent customizes dynamic gestures and verbal responses suitable for a user's problem-solving situations. The agent appraises the user's selection to assist the user in solving the situation. Then, it presents its own comments or advice related to the situation. For example, when a user selected an improper factor for the flower, an interactive agent recommends the user to select another factor. However, if the user ignores the comment and applied the incorrect factor to the flower, the agent appears afraid because the goal of making the flower bloom would not be achieved. At this time, the agent shows corresponding visual expressions and displays texts indicating a *fear* state, instead of giving explicit commands like an instructor. Figure 5 describes examples of the agent's expressions in both positive and negative circumstances.



(a)

(b)

Figure 5. Examples of the implemented agent's expressions: (a) A positive response to the user's appropriate action and (b) A negative response when the user chooses an improper factor for flowering.

IV. EVALUATION

To verify the effectiveness of the proposed learning system, we evaluated our implemented system through usability tests. In these evaluations, there were 15 participants of which 9 were male and 6 were female, none of which had prior experience with this learning system. Since the major participants of this exhibition were children aged 8 to 13, we could evaluate children's responses to our system. We assigned the task *help-to-bloom* and offered a collaborative environment by making the implemented agent respond like a companion. In order to verify the effects of existence and interactivity of the agent, we compared our system with the case without animated agent.

After finishing the experiment, the participants filled out a questionnaire indicating their satisfaction regarding experimental conditions. Participants were asked to indicate on a 5-point *Likert* scale (from 1=strongly dissatisfaction to 5=strongly satisfaction), to describe how much they were satisfied with the conditions.

In this analysis, we found that most participants preferred the existence of an animated agent and engaged the interactive agent in their learning environments. Figure 6 shows the average satisfaction of the learning environments with and without an animated agent, respectively. Thus, we could confirm that participants favored the learning condition with an interactive agent.

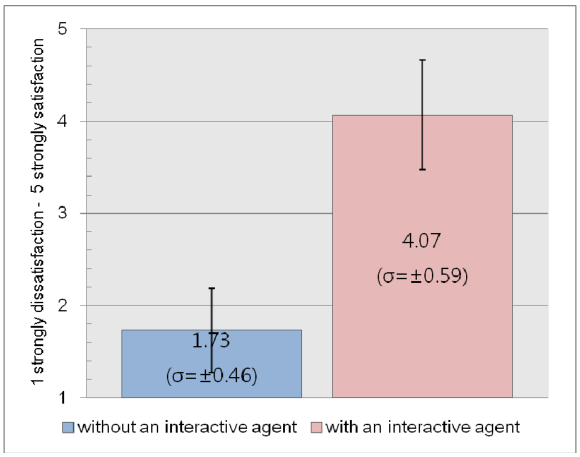


Figure 6. Satisfaction of learning environments with and without an interactive agent.

The main focus of these evaluations has been to explore the effects of a companion-like agent on users' enjoyment and engagement in a learning task. To this end, when the users were asked their opinions of the different conditions, we could observe that they enjoyed the existence of an animated agent and more actively engaged in the interaction with the agent. Thus, we found that our interactive agent's responses were enjoyed by the participants during their interactions. We also observed that the participants felt the agent's responses were helpful in achieving a collaborative task. Even though the current agent's responses were insufficient to provide participants with a companion-like impression, participants expressed generally positive views regarding their interactions with the agent, and enjoyed the helpfulness of the peer support offered.

However, subjective results in the responses to educational gains of the implemented agent showed significant differences across participants. Therefore, we should customize the agent's responses suitable for individual differences through personalization. Nevertheless, we anticipate that an interactive agent could motivate human learners to more actively engage in their learning experiences and achieve their learning potential in augmented reality learning systems.

V. Conclusions and Future Work

In this paper, we described an augmented reality learning system that enabled users to experience an interactive flower garden with the assistance of an interactive agent. To support interactive experiences, the agent perceived the users' actions and then responded like a companion through nonintrusive expressions. By observing learners' responses to our implemented system, we found that interactive agents increased participants' interest and motivated them to engage in the learning environment.

However, the implemented system has limitations. There is insufficient commentary for users to fully feel the peer support to social events. Therefore, we need to customize the agent's responses with respect to individual differences to offer more effective support in learning environments. Furthermore, we plan to evaluate how much an interactive agent affects users' learning experiences in more complex tasks.

References

[1] W. Johnson, J. Rickel, and J. Lester, "Animated pedagogical agents: face-to-face interaction in interactive learning environments," International Journal of Artificial Intelligence in Education, Vol.11, pp. 47–78, 2000.

[2] E. Sklar and D. Richards, "The use of agents in human learning systems," Proc. of 5th International Joint Conference on Autonomous Agents and Multiagent Systems, pp.767-774, 2006.

[3] J. Lester, B. Stone, and G. D. Stelling, "Lifelike pedagogical agents for mixed-initiative problem solving in constructivist learning environments," User modeling and user adapted interaction, Vol. 9, no. 1, pp. 1-44. 1999.

[4] R. Azuma, Y. Baillot, R. Behringer, S. Feiner, S. Julier, and B. MacIntyre, "Recent advances in augmented reality," IEEE Computer Graphics and Applications, vol. 21, Issue 6, pp.34-47, 2001.

[5] M. Anabuki, H. Kakuta, H. Yamamoto, and H. Tamura, "Welbo: an embodied conversational agent living in mixed reality space," Proc. of the SIGCHI Conference on human factors in computing systems pp.10-11, 2000.

[6] I. Barakonyi, T. Psik, and D. Schmalstieg, "Agents that talk and hit back: animated agents in augmented reality," Proc. of IEEE and ACM International Symposium on Mixed and Augmented Reality, pp. 141-150, 2004.

[7] S. Oh, J. Gratch, and W. Woo, "Explanatory style for socially interactive agents," Proc. of 2nd International Conference on Affective Computing and Intelligent Interaction, vol.4738, pp.534-545, 2007.

[8] M. E. Bratman, Intentions, Plans, and Practical Reason. Harvard University Press, Cambridge, 1987.

[9] A. Ortony, G. L. Clore, and A. Collins, The cognitive structure of emotion, Cambridge, UK Cambridge University Press, 1988.

[10] V. Lepetit and P. Fua, "Keypoint recognition using randomized trees," IEEE Trans. Pattern Analysis and Machine Intelligence, vol. 28, no. 9, pp. 1465-1479, Sep. 2006.

[11] http://www.hitl.washington.edu/artoolkit/