ARGarden: Augmented Edutainment System with a Learning Companion*

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Abstract. Recently, many researchers have studied on agent-based edutainment systems to improve students' learning experiences. In this paper, we present ARGarden which makes users experience an interactive flower gardening with a learning companion squatting on an augmented picture. The companion perceives users' actions as well as situations in the learning environment and appraises the perceived information autonomously. Then, it presents peer support to help participants' problem-solving through anthropomorphic expressions. We developed our system on a mobile device and visualized a learning companion as an animated bluebird. We also demonstrated the implemented system at an exhibition and evaluated the effectiveness of our system through the observation of participants' responses to the demonstration. In this evaluation, we found that the bluebird as a learning companion helped users to experience how to properly grow the flower in our edutainment setting. Finally, we expect possibilities that an augmented learning companion is one of the key factors for developing effective edutainment applications.

1 Introduction

In enhancing the effectiveness of educational applications, researchers have studied how they could increase students' engagements in learning experiences. Since the pedagogical agents can provide students with advice in response to their problem-solving activities, many researchers have applied the pedagogical agents to their educational systems for improving students' abilities [1], [2], [3], [4]. Moreover, the animated pedagogical agents have persona effect which makes their presences increase students' motivation on their learning experiences [5]. Although the research on animated pedagogical agents has been progressed, they rarely presented a connection to the real environment where the users actually exist. The spatial gap between users and pedagogical agents can be one of reasons why the users lose their interests in current educational systems.

To reduce the discontinuity between users and learning environments, there have been studies on augmented reality (AR) technology based educational systems [6], [7],

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[8], [9]. Furthermore, many researchers have developed augmented pedagogical agents in their educational settings [10], [11], [12]. Since AR technology allows users to experience computer generated contents embedded into the real world [6], it can make pedagogical agents coexisted with users in the same real space. Moreover, it enables the users to interact with the agents over a physical environment. Finally, it reduces the spatial seam between the users and the agents.

The pedagogical agents in AR setting express the guidance suitable for problem-solving situations in the real space. In the *Welbo* system, an animated agent guided users who wear HMD to simulate virtual furniture in an MR space [10]. The *AR Lego* exploited the augmented agent to educate an untrained user for assembling LEGO Mindstorms robot [11]. Wagner et al. introduced *Mr. Virtuoso* as an augmented expert which taught users about art history in an educational game [12]. In these systems, it lets users perceive the reduced spatial gap to agents and receive more benefits on their learning abilities from educational systems. However, since the augmented agents only have focused on guiding users explicitly as instructors, it sometimes disturbs the users and reduces their motivation on the educational settings. To offer more effective ways to improve users' learning experiences, edutainment systems need to give them less intrusive guidance for motivating them to engage in the systems.

In this paper, we present ARGarden which provides users with flower gardening experiences with a learning companion in real space. This system supports users to explore environmental considerations that affect gardening. Thus, the users can simulate specific factors, e.g., water, fertilizer, and light, to an animated flower in the augmented scene. In addition, we visualize an interactive learning companion as an animated bluebird. The bluebird presents pedagogical strategies with peer support through anthropomorphic expressions. Furthermore, users can collaborate on a work with the bluebird in our edutainment settings. We have implemented the proposed system on a mobile device attached with a camera. Then, we demonstrated our system at an exhibition and evaluated the effectiveness of the installed system. In the demonstration, participants presented better engagement in their learning experiences by interacting with a bluebird as a learning companion. Therefore, we can see indications that the augmented learning companion in edutainment system can be one of factors for improving students' engagement in their learning experiences.

The presented ARGarden has following characteristics. It presents a learning companion that responds to the users' interaction and shows peer support for helping the users to solve the problem situation. It offers a believable situated environment in which human learners can experience environmental consideration for the flowering in the real space where the learners actually exist. Moreover, it motivates users to engage in our learning environment by making them cooperate with the learning companion. Ultimately, we expect possibilities that a learning companion can increase users' engagement in learning experiences and improve the users' learning abilities in edutainment systems.

This paper is organized as follows. Section 2 introduces our augmented edutainment system. Section 3 describes detailed explanation of components in the implemented results. Then, section 4 shows the observation of users' responses to demonstration at an exhibition. Section 5 presents some general observations and remarks in our system and directions for future research.

2 ARGarden: Augmented Edutainment System

We have developed ARGarden that allows users to experience the flower gardening with a learning companion. In our system, users can see an augmented scene, which is consisted of simulated factors, a virtual flower and an animated learning companion, through their mobile devices. In addition, it enables users to explore environmental considerations that govern gardening and to interact with an augmented learning companion in the learning environment. The companion perceives users' interaction and changes of the augmented gardening environment, and then assists the users to solve the problem-solving situation. Fig.1 shows the overview of ARGarden.

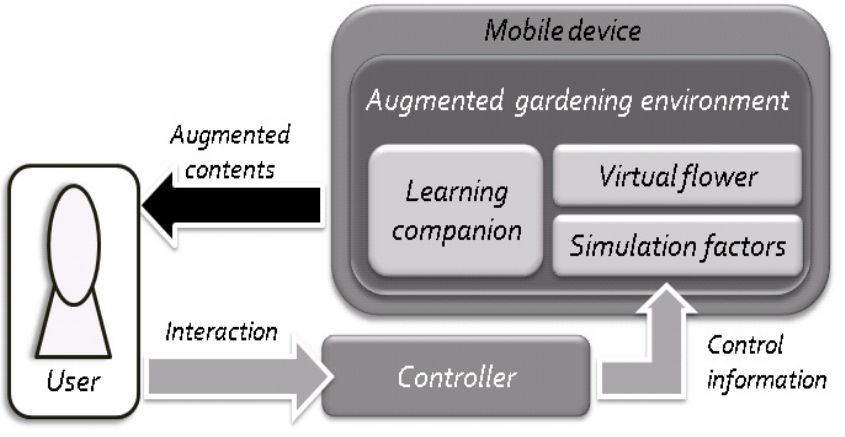


Fig. 1. The proposed ARGarden

2.1 Interactive Gardening Environment

We design an interactive learning environment which allows users to experience the gardening in real space. To support users to simulate environmental considerations on gardening, we offer a user interface for enabling the users to choose a specific factor, e.g., water, light, and fertilizer, which they can apply to a virtual flower in an augmented environment. We also provide users with the interaction metaphor for applying the selected factor to the virtual flower. According to users' simulation, the status of an augmented flower is changed. Therefore, participants can not only experience the gardening, but also learn influences of a specific environmental factor on the flower gardening.

We let users collaborate with an augmented learning companion by assigning collaborative working problems on the flower gardening to the users. In achieving the assigned work, users try to select a simulation factor and apply it to an augmented flower. In addition, the learning companion expresses peer support to the users' interaction by offering pedagogical comments to assist the users to solve the problem. Therefore, users can learn how to cooperate with their companions to achieve the desirable results.

2.2 A Learning Companion

Our learning companion generates autonomous behaviors to provide learners with problem-solving advice with peer support. The companion has the capability to perceive learners' action and changes generated from the augmented learning environment. In addition, it appraises the perceived information according to its own internal state, e.g., belief, desire, and intention [13]. Then, it generates responses suitable for problem-solving contexts [14]. Fig. 2 describes the response generation process of the learning companion.

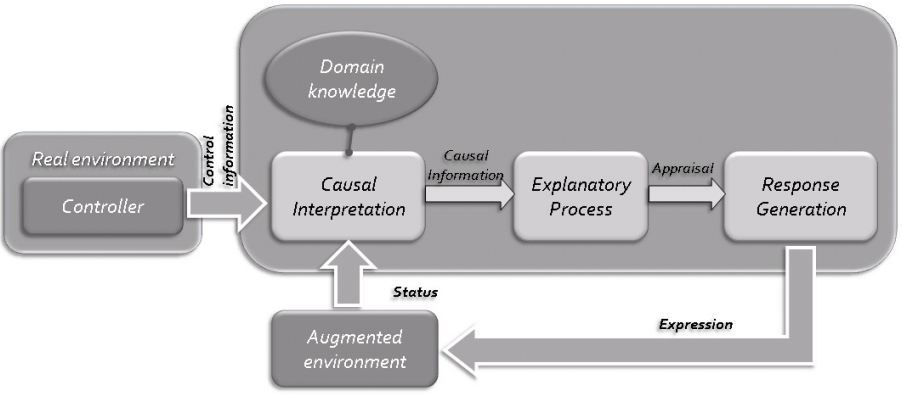


Fig. 2. The response generation process of the learning companion

A learning companion appraises the problem circumstance through the causal interpretation based on its domain knowledge. The knowledge contains the companion's mental state concerning actions and states [15]. Each state can be assigned a numerical value in the interval [-100, 100] denoting the companion's utility, which implies how much the state contributes to achieve the goal. Thus, a state associated with a positive value of utility is desirable for helping the companion to accomplish its intended goal. In addition, the relationship between actions and states is represented by causal establishment or threat relation, i.e. the effect of action can establish or threaten the goals. A plan to achieve the intended goal is composed of a set of actions, states and their relationships. Moreover, each state is appraised in accordance with computational appraisal theory, in terms of appraisal variables: relevance, likelihood, controllability, changeability, and can result in an emotional response [16].

To increase users' engagement with the learning companion, we allow the companion to show less intrusive responses than an instructor. Thus, the companion appraises the users' selection based on the status of the simulated environment. Then, it generates its own emotional state about the situation and presents the state for motivating the users to achieve desirable results. Therefore, the companion sympathizes with the users' actions in edutainment settings instead of explicit advice for problem-solving contexts. Ultimately, we expect that this kind of the learning companion can contribute to participants' better leaning experiences in edutainment systems.

3 Implementation

We have developed the proposed ARGarden on an ultra mobile personal computer (UMPC) attached with a camera. In Fig. 3, we made users experience the implemented system over a physical book which describes contents related to gardening. To overlay the interactive gardening environment on the book, we attached fiducial markers, which are exploited to ARToolkit [17], to pages of the book. Then, we augmented an animated flower and simulated factors, such as water, light, and fertilizer. Users could also interact with an animated bluebird as a learning companion. The bluebird assisted the users to solve the problem in a gardening environment through animated movements, texts, and sound effects. Fig. 4 shows the implemented results of our augmented gardening environment.

Fig. 3. The implemented ARGarden

Fig. 4. Interactive gardening environment augmented over a physical book

In our system, we attached several fiducial makers to pages of the book. As shown in Fig. 5 (a) each marker indicates its function through an understandable picture. For example, if an object is the controller for adjusting the amount of water, a marker contains a sprinkler. Moreover, as shown in Fig. 5 (b), users can see augmented 3D CG models indicating specified simulated factors, such as water, light, and fertilizer, through their devices.

(a) (b)

Fig. 5. (a) Fiducial markers over pages of a book (b) Augmented models over the markers

3.1 Interaction Metaphor

We offered a simple interaction metaphor which enables users to experience our ARGarden in a natural manner. To allow users to select a specific factor which users want to simulate to the flowering, we designed a ring-type controller attached with a fiducial marker. Thus, the users could choose and apply the factor to the augmented flower with the controller. When they approached the controller to a marker attached to pages of a book, the 3D model overlaid on the fiducial marker was transmitted and augmented over the controller. Fig. 6 shows the interaction metaphor for the selection. In addition, we allowed users to apply the selected factor to the augmented flower through simple actions. Fig. 7 describes examples of the interaction metaphor. According to an applied factor, the augmented flower showed several changes represented by animation sequences of 3D models, such as growing up, withering, and waving. Therefore, participants could experience the gardening and learn the effects of the factors on the flower gardening.

(a) (b)

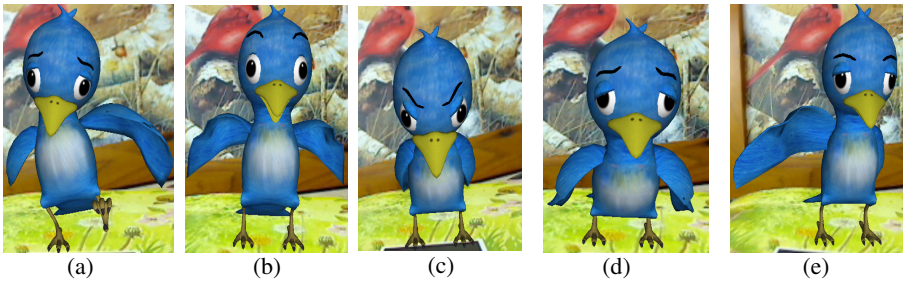
Fig. 6. The interaction for selection (a) Initial state (b) Selecting a watering factor

(a) (b)

Fig. 7. The interaction for applying the selected factor (a) Sprinkling water (b) Shining the light

3.2 A Learning Companion's Expression

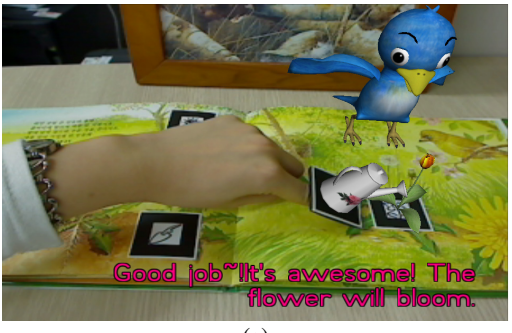
In the implemented ARGarden, we visualized a learning companion as an animated bluebird. Then, we made the bluebird present anthropomorphic visual and verbal responses autonomously. It showed visual expressions by changing animation sequences. Especially, the bluebird had capabilities to express the internal state, e.g., emotion, desire, through animated movements. Fig. 8 shows examples of the visual expressions reflecting the bluebird's states. In addition, to engage users' interests in the interaction with our bluebird, we displayed texts as bluebird's verbal actions. We also generated sound effect suitable for the verbal responses to the users' interaction.



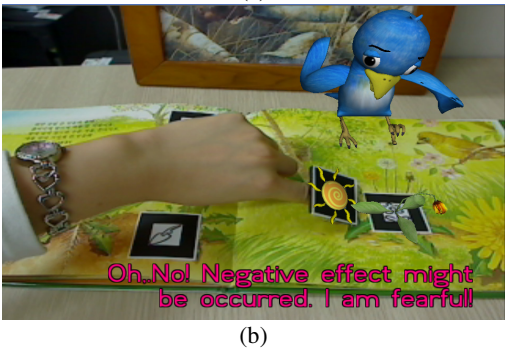
(a) (b) (c) (d) (e)

Fig. 8. Visual expressions (a) Fear (b) Joy (c) Anger (d) Tiredness (e) Encouragement

We customized the implemented bluebird's dynamic gestures and verbal responses suitable for a user's problem-solving situations as a learning companion. The implemented bluebird appraised the user's selection for assisting the user to solve the situation. Then, it presented its own comments or advice on the situation. For example, when a user selected an improper factor for the flowering, the bluebird recommended the user to select other factors. However, if the user ignored the bluebird's comment and applied the incorrect factor to the flower, the bluebird became fearful because they could not achieve the goal of flower gardening. Then, the bluebird showed corresponding visual expression and displayed texts indicating "fear" state, instead of explicit guidance like an instructor. Fig. 9 describes examples of the bluebird's expressions in a positive/negative circumstance.



(a)



(b)

Fig. 9. The bluebird's expressions (a) A positive response (b) A negative response

4 Evaluation

To review users' response to the implemented ARGarden, we demonstrated our system at iDAT (Interactive Digital Art and Technology) 2007 [18]. In this demonstration, participants experienced the interactive gardening environment. Then, we observed participants' responses to the installed system. We could know that a learning companion made better participants' engagements in the installed learning environments. Finally, we found possibilities that an interactive learning companion in augmented educational setting could improve students' learning experiences in educational system.

4.1 Demonstration

In this exhibition, we allowed participants to experience ARGarden through a mobile device and to interact with other participants. Thus, a user could see the virtual gardening environment over the book and experience the flower gardening with his or her hands. Other participants could see the interactive gardening environment through large LCD monitor at the same time. Fig. 10 shows the setup of our system at the exhibition.

Since major participants of the exhibition were children, aged 8 to 13, we could collect and evaluate children's responses about our system. In this demonstration, we assigned a simple task, *help-to-blooming*, to them and offered collaboration condition by making the implemented bluebird present its movements and sound effects like a

Fig. 10. The setup of our system at iDAT

companion. While using our system, we noted their impression for indicating how they felt our bluebird's responses, and how engaged they were in the interaction with the bluebird as a learning companion.

Fig. 11. Participants to ARGarden at the exhibition

4.2 Observation

In these considerations, we observed children's impression of learning experiences in our system. At first, they actually liked to use ring-type controller and to see changes of 3D models over the controller by approaching it to markers on the book. Since they tried to change a 3D model on the controller repeatedly, we found that they had interests in the offered interaction metaphor. However, we also found inconveniences of current metaphor. Some children could not perceive the depth information when they saw the augmented scene with a mobile device. Since it was difficult for some of them to select a factor and to apply it to the augmented flower, we need to add more cues, such as the shadow of 3D model, for offering depth information.

Especially, we found how participants felt about our bluebird in our installation. Most children presented positive responses to the bluebird's expression according to their interaction. They tried to talk with the bluebird and to touch the animated bluebird with their own hands directly. In addition, we found their interesting responses to the bluebird. That is, they really liked the bluebird's positive responses, such as expression of

joy and encouragement. Contrarily, they hated the bluebird's negative responses, e.g. anger and sad. When they experienced the negative responses, they tried to find the solution for changing the bluebird's response toward positive expressions. However, some children complained that why the bluebird did not make an eye contact with them like their friends. In addition, some of them could not understand the bluebird's response to their interaction. Thus, we need the bluebird to provide more customized peer support and more companion-like responses with participants about problem-solving situation. Even if current bluebird responses are limited to offer fully friend-like impression to participants, we could see that most children showed curiosity to an augmented bluebird, and expressed joyful engagement to experiences, especially the interaction with the bluebird, in our edutainment setting.

5 Conclusion and Future Work

In this paper, we described ARGarden which allowed users to experience an interactive flower gardening with a bluebird, a learning companion. The proposed system augmented a picture with the animated bluebird to provide interactive edutainment experiences with users. The bluebird could perceive the users' actions as well as the status of the learning environment. It also could appraise the information to provide participants with problem-solving advice. Moreover, the bluebird presented less intrusive responses than an instructor through anthropomorphic expressions. Furthermore, we exhibited the implemented system and evaluated its effectiveness through observation of participants' responses to our system at the exhibition. Furthermore, we found indications that the augmented learning companion in augmented edutainment system has possibilities to motivate participants' engagement in their learning experiences.

Current implemented system has limitations as revealed from comments of participants' responses to our exhibition. At first, it was insufficient to allow participants to understand a bluebird's explanations about social events. Therefore, we plan to specify and design the bluebird's more detailed guidance for improving the participants' understanding of the bluebird's explanation in edutainment setting. We also need to improve the bluebird's expressiveness to offer peer support as a companion than an instructor. Moreover, we plan to evaluate the effectiveness of a learning companion through usability tests on our edutainment system.

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