Design of an Interactive Table for Mixed-Reality Learning Environments

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Abstract. This paper presents a prototype of a low-cost Mixed Reality Interactive Table (MRIT) which is equipped with a Web camera, a projector, animal-appearance robots, gloves with accelerator sensors, and a computer. The motivation of the development of the MRIT is to provide a low-cost learning environment where students can learn effectively when they play an educational software game on the interactive table via embodied interactions. We hope the MRIT can be a good entry point for studying how educational software games incorporated with an interactive table and embodied interactions are able to promote students' interest and improve students' engagement.

Keywords: embodied interaction, mixed reality, digital game-based learning.

1 Introduction

The concept of learning may have many different implications for children. Serious learning in schools certainly may not interest most children. In fact, play is our brain's favorite way of learning things [1]. Many psychologists also have the same observation that games are an important means through which children learn to understand their world [2]. Without any doubt, enjoyment and fun play an important role in the learning process. More and more researchers seek ways to promote students' motivation and engagement while they learn.

In the twenty-first century, various new technology tools for education are rapidly emerging. Since video and computer or digital games interest children, digital games may play an important role in helping children in learning materials that are not intrinsically interesting but which have to be learned. If approaches or learning tools really interest children then they will not have short attraction span for learning. More and more research projects try to develop software games for education to increase children's motivation and engagement [3]-[5]. Prensky provides many important and practical ideas of the application of digital game-based learning and a good overview of the trend of digital game-based learning in his book [6]. He suggested five levels- "How," "What," "Why," "Where," and "When/Where" in which learning happens in digital games. In addition, he also suggested that computer games can be classified into 8 "genres": action, adventure, fighting, puzzle, role playing, simulations, sports,

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and strategy. Furthermore, he made a comprehensive linkage between types of learning and possible game styles. For example, mnemonics and games show competitions are suitable for learning some kinds of facts such as laws, policies, etc. They involve in the learning activities such as questions, memorization, association, and drill. Greenfield has extensively studied the effects of video games on players' minds [7]. One of her findings is that video game skills can transfer to and lead to greater comprehension of scientific simulations.

Although education software games are sprouting now, are they really educational or just not-very-educational games? Many researches have been conducted for evaluating the education software's effectiveness [8]-[9]. Some researchers claimed that usability is an important factor that affects the educational effectiveness [10]-[14]. Virou and Katsionis conducted an evaluation on the usability and likeability of virtual reality games for education [15]. Their evaluation results revealed many important issues about further research on virtual reality educational games.

Embodied interaction (i.e., using the physical world as a medium for interacting with digital technology) is an active and attracting area of Human-Computer Interaction [16]. If users can use their whole bodies instead of just fingers to interact with games then the games will become more appealing. Romero et al. proposed that embodied interaction may have the potential to advance educational technology in many ways [17]. They claimed that embodied interaction have a positive effect on skills such as problem solving, narrative and literacy. Antie claimed that tying hands to a mouse and keyboard may limit children's cognitive performance and inhibit developing mental skills [18]. She found that new gaming platforms such as Nintendo Wii console with embodied interaction may offer opportunities to support the tight coupling of physical action with mental operations required for learning.

In this paper, we present a low-cost Mixed Reality Interactive Table (MRIT) and show how we use it to construct a learning environment where students can play an educational software game on the interactive table via embodied interactions. In 1994, Milgram and Kishino defined Mixed Reality (MR) environments as those in real world and virtual world objects are presented together on a single display [19]. Mixed reality technologies have been proven valuable in many applications (e.g., simulation based learning, interactive product content management, medical visualization, in arts and entertainment industries, etc). A good review of MR techniques for developing computer supported collaborative work interfaces can be found in [20]. Our mixed reality learning environment refers to a new environment where physical (i.e., animal-shaped robots) and digital objects (i.e., objects in an educational software game) co-exist and interact in real time.

The rest of this paper is organized as follows. In Section 2, we introduce the MRIT. Finally, Section 3 concludes the paper.

2 The MRIT

The MRIT is equipped with a Web camera, a projector, animal-appearance robots, gloves with accelerometers, and a computer as shown in Fig. 1. The proposed MRIT creates an MR environment where digital and physical objects are aligned together and interact in real time. A crucial problem of the MR environment is how to track the positions of the physical objects (i.e., the robots in our case) in order to accurately align them to digital objects in a game scene. Motivated by the low-cost multi-point interactive whiteboards using the Wiimote [21], we solve the problem with the use of a low-cost Web camera of which len is covered by a film to filter out visible light, robots with three infrared LEDs on their tops, and a tracking algorithm which can track many sources simultaneously. A calibration procedure has to be executed before we can correctly track the positions and orientations of the robots and then align them to the virtual game scene. The calibration procedure involves the following two steps. First of all, we sequentially place a small box with an LED on its top at the four corners of the image projected on the table. Then we adopt an affine transformation based on these four known corners' coordinates to implement the geometric transformation. Fig. 2 shows an example of the 12 sources of infrared light on the image acquired by the camera and how these 12 sources are clustered into 4 groups corresponding to 4 robots. Each robot is with three LEDs so that these three light sources can be used to calculate the position and orientation of the robot. After we have located the positions and orientation of the robots from the image acquired from the Web camera, we align them to the virtual game scene.

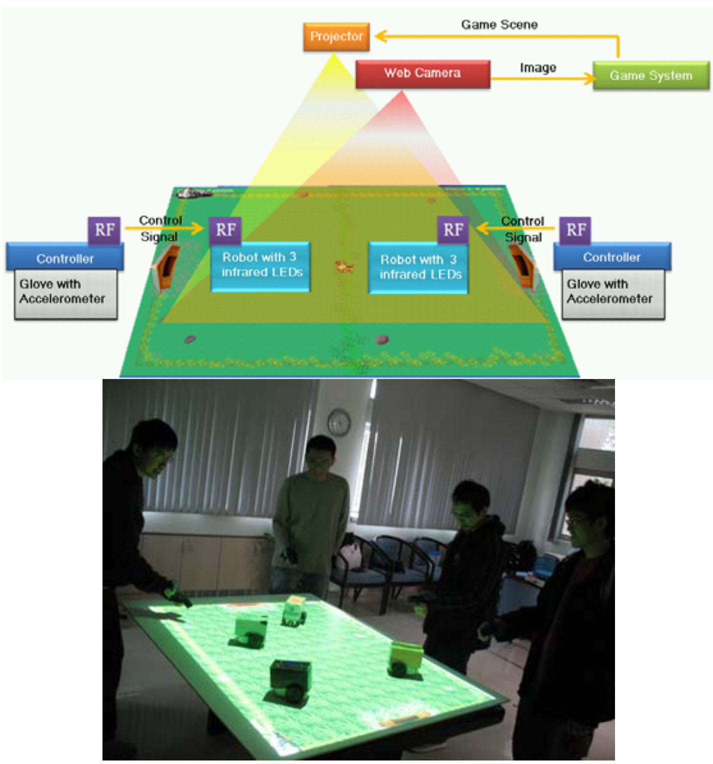

Fig. 1. The MRIT and its scene of the learning environment

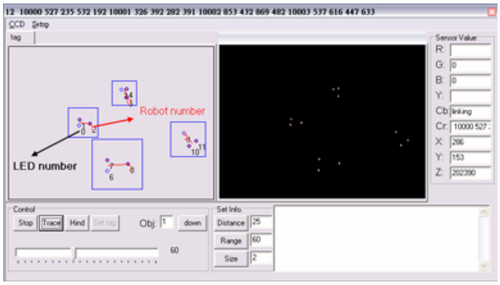

Fig. 2. An example of 12 sources of infrared light on the image acquired by the camera

The role of the MRIT is to support a new teaching paradigm. Teachers can use an authoring tool (shown in Fig. 3) to edit their learning materials into quizzes. In our present software game (shown in Fig. 4), a digital dice will be tossed to decide the number ofsteps which a targeted player has to take to go to the destination where a quiz will pop-out. Then the targeted player wearing a glove with an accelerometer has to use his or her body gestures (shown in Fig. 5) to manipulate the animal-appearance robots (shown in Fig. 6) to move to the destination in time to win the chance of answering the pop-out quiz shown on the game scene. If the player answers the quiz correctly then he or she wins a score. Sometimes, a player can have a chance of winning a bonus score if he or she can manipulate a robot to kick a digital ball into the goal on the digital soccer field. The introduction of such a soccer game into the software game is to educate the players to cooperate with each other to achieve respective goals because the players will be automatically and randomly grouped into two teams during the soccer game. Finally, a statistic record shows the competition scores at the end of the game.

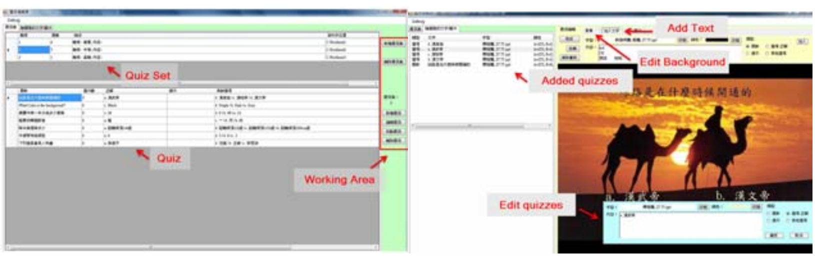

Fig. 3. The authoring tool for teachers to edit quizzes and add background images

Fig. 4. The game scenes

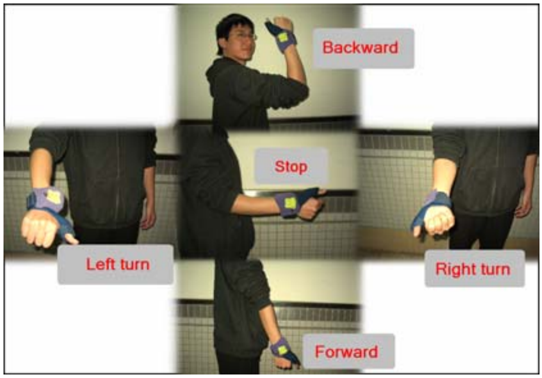

Fig. 5. The embodied interaction gestures for controlling the robots

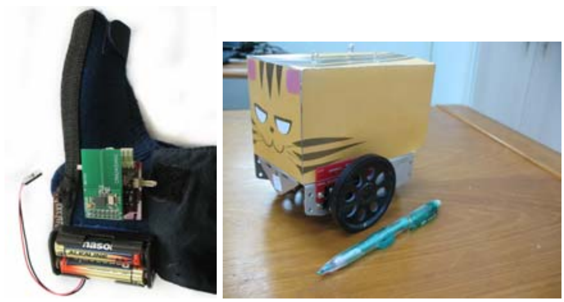

Fig. 6. The glove with an accelerometer and an animal-appearance robot

3 Conclusions

This paper reports our efforts to develop a low-cost Mixed Reality Interactive Table (MRIT). We use it to construct an MR learning environment where students can play an educational software game on the interactive table via embodied interaction gestures. The goal of the MRIT incorporated with appropriate MR educational games is to explore the possibility of applying a low-cost education tool for learning some materials which are intrinsically boring but have to be learned. Responses from many high school students who have participated in our demonstrations show that the MRIT are very interesting and promising. In the near future, we will conduct field experiments to fully evaluate the educational effect and the usability of the proposed MRIT in order to explore the possibility of using the MRIT as a new educational tool to e promote students' interest and improve students' engagement for learning.

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