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Research Paper

TARogic: Tangible augmented reality game

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Abstract

Augmented Reality (AR) has been around for the past decade. It has been applied in many fields and one of the common fields is in education. In this paper, we have make use of Tangible Augmented Reality technology in creating an interactive game called TARogic that teaches students on the basic of programming logics. Tangible Augmented Reality is a combination of Augmented Reality (AR) technology and Tangible User Interface (TUI), which uses real environment objects to interact with the Augmented Reality (AR) environment. In this project, we have created a hardware console that uses USB drive as a tangible element to interact with the game. The USB drive is plug on to the console (Arduino module) to transfer the information of the game input to a smartphone via Bluetooth. The output is displayed on the smartphone in the form of Augmented Reality (AR) game objects and environment. By qualitative user evaluation of two groups of participants, 10 for each groups, 60% of the participants were positive with the overall learning experience using TARogic.

Keywords: *Augmented Reality; Interactive Educational game; Tangible Augmented Reality; Tangible User Interface.*

1. Introduction

Augmented Reality (AR) technology is the environment that combines both real and virtual information. It superimposes the virtual objects or a particular 3-dimension (3D) objects into a real environment [1]. AR enables human to experience the simulation of virtual objects in real world. It has been implemented in medical, industrial design, entertainment, education and other areas [2]. AR technology is commonly used in education. In a particular paper, AR technology is used to help medical students to understand and memorize the 3D anatomy structure of a human [3]. AR technology is also useful to help students to visualize abstract objects that cannot be seen in real life. For example, a group of students in University of Texas at San Antonio has developed an AR application for solar energy education. With the application, students can learn about the science behind architectural design and how passive solar energy design impacts internal temperature and energy usage efficiency [4].

In relation to the usefulness of AR, a study was conducted by students from University Technology PETRONAS for investigating the usefulness of AR in learning. The data was collected from a group of people that includes diploma students, undergraduate, postgraduate, high school teachers and working adults. Result shows that 27 out of 33 people have agreed that AR is useful in the daily learning process. In addition, AR can also enhance the learning experience for students [5].

There are two approaches for displaying AR virtual objects on a real environment. The two approaches are marker-based AR and markerless AR. In a marker-based AR application, a marker is needed to determine the position and orientation of the AR virtual object. Simple AR markers can consist of one or more basic shapes made up of black squares against a white background [7]. Commonly, the marker is represented in a circular 2-dimensional bar-coded fiducial system. The fiducial design allows having thousands of different codes, thus enabling uninterrupted tracking [6]. A camera is used with AR software to detect AR markers as the location for placing the virtual objects. As the result of that, 3D virtual objects, image or video can be placed on the scene at the exact location of the marker [7].

Markerless Augmented Reality (MAR) is the using of AR technology without using a fiducial marker. In MAR approach, any part of the real environment can be used as a marker to place the virtual objects. However, the device which is used to display the virtual objects needs to extract the surroundings or environments characteristic information. This method is known as monocular MAR [8]. There are two types of monocular MAR; the model based and Structure from Motion (SfM). In model based technique, knowledge about the scene needs to be obtained first before tracking occurs. The information is stored in a 3D model that is used for estimating camera pose. Whereas, in SfM based technique, camera movement throughout the frames is estimated without any previous knowledge about the scene [9].

In the last decade, people uses keyboard and the mouse as the user interface input for a computer. Those keyboard and mouse are one of the earliest example of tangible user interface. Tangible User Interface (TUI) uses real environment objects as the interface input to a computer [10]. With the growth of interactive technology, keyboard and mouse can be replaced with more intuitive physical objects to interface with the computer. For example, the use of 3D-printed geometric objects as TUI for teaching and reinforcing tactual shape perception; spatial awareness sub-concepts in small-scale space for visually impaired children [11]. There is a TUI application that teaches young blind children to recognize Braille letter. It uses NFC-tag embedded blocks with embossed Braille letters and speech interface for interacting with the application [12]. By having TUI, it does provide an intuitive manipulation of digital data. However, it has limited support for viewing 3D virtual objects. Whereas, AR interface provides an excellent interface for viewing virtual objects but limited support for tangible interaction [13].

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Having a combined system of AR technology and TUI, Tangible Augmented Reality uses the display capability of AR technology with the tangible interaction of TUI. This paper focuses on using the visual benefits of AR for 3D object manipulations and the interaction benefits of TUI for tangible interaction in creating the Tangible Augmented Reality game, TARogic to teach basic programming logics.

2. Game design

2.1. Game concept

TARogic is tiled-based educational game which requires player to input their commands using Universal Serial Bus (USB) drive to enable the character to perform in-game actions. Simple in-game actions such as move forward, turn left, turn right, pick up and recycle. The game concept is designed to help students to learn the basic of programming logics and the execution of logics. Firstly, player is required to understand the objective of the game level by viewing the game level in AR mode. After that, player will need to plan for possible in-game actions on the level. Player needs to assign in-game actions/commands via USB drive. Once done, they can start the game. The game will execute all commands and translate to character actions. Output of the game will be represented in AR view.



Fig. 1: TARogic: Tile-based educational game

The objective of this game is to recycle waste by picking up 3D objects such as paper, can or bottle and place it in the correct recycle bin. Player needs to execute the correct command in order to move the character to the correct tile; picking up the waste and recycling it (Figure 1). On top of that, player needs to complete the objective within a given amount of steps in order to proceed to the next level. Each command costs a step in the game. Currently, there are only three levels in the game. Each level presents the player a problem and player needs to solve the problem using a set of commands. In order to input a command, player inserts the USB drive with the command into the USB port on the console. During execution, player can view the sequence of the command being compiled from the first to the last USB port in the AR view. This teaches player the basic of programming logics which the code is executed from top to bottom.

2.2. Tangible user interface

This game requires hardware console as shown in Figure 2 for execution. The detail design of the hardware console will be discussed later on topic 3. The hardware served as a TUI input for the player to interact with the character in the game. It has three buttons that function as user interaction between the player and the game. The three buttons are:

- Scan button: This button triggers the scanning function. After player inserts the USB drive/s to the USB port/s, the player presses this button to scan the commands.
- Reset button: This button is to restart the current game level.
- Menu button: This button is to go back to the main menu of the game.

The actions of the character are triggered though the commands stored in the USB drives. Each USB drive stores only one command. There are five types of commands as below



Fig. 2: Hardware console, marker and storybook

- moveForward(): moving the character one tile forward.
- turnLeft(): rotating the character 90 degree to the left.
- turnRight(): rotating the character 90 degree to the right.
- pickUp(): enabling the character to pick up the waste (paper, can or bottle) at the current tile.
- recycle(): recycling the waste if the character is in front of the recycle bin at the current tile.

2.3. Tangible augmented reality

To start with the game, player places the interactive storybook on top of the console as shown in Figure 3 and 4. The interactive storybook consists of AR markers, story and instructions to guide the player to play the game. The left side of the storybook shows the story and instructions while the right side of the storybook shows the AR marker. When player puts on the Head-Mounted Display (HMD) that is equipped with the smartphone and the game, the HMD will scan the marker and display the AR user interface shown in Figure 3.

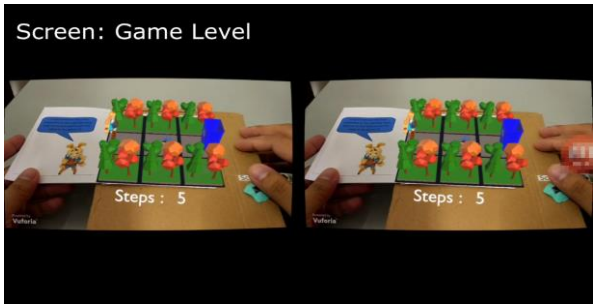


Fig. 3: Head-Mounted Display and Augmented Reality

As player follows through the storybook, the player reads the instructions which tells him/her what is needed on the game level. Once the player understands the question, player needs to figure out the correct actions for the in-game character to move to the right tile, collect the waste and recycling it. The player has to choose the correct USB drive/command to be inserted into the USB port as shown in Figure 4. The maximum USB port provided by the console is four. The player can choose four moveForward() commands to move the character four tiles ahead. After inserting the USB drives, the player presses the “Scan” button. The console then collects the commands from the USB drives and send it to the HMD via Bluetooth. All incoming commands will be interpreted and executed one by one in the HMD. The result will be displayed in AR view (Figure 5).

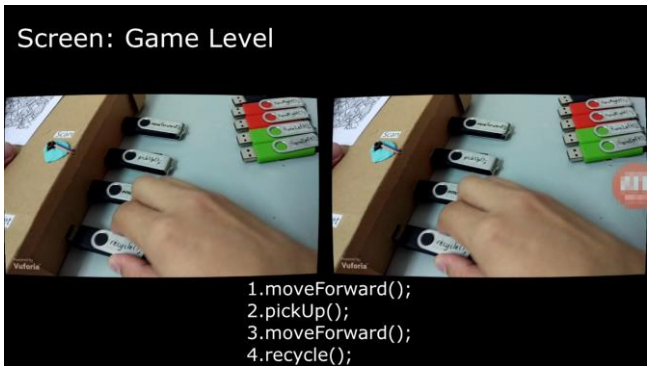


Fig. 4: Tangible Augmented Reality interaction

2.4. Implementation tools

This project is divided into the hardware and the software module. The hardware module of this project consists of the following:

- Arduino Uno R3 board
- 4 boards of USB read or write module (CH376U)
- 3 buttons for game interaction (scan instruction button, reset game button, main menu button)
- Bluetooth module(HC-05)
- 10 USB drives for storing commands
- Power bank (Xiaomi 10400mAh power bank)
- Smartphone (Redmi Note 4)
- Head-mounted display (VR Box Gen II)

The software module consists of the game and the console system. The game is developed on Unity3D with Vuforia plugin. The tile-based system, game mechanics and character actions were developed on Unity3D. Whereas, the Vuforia plugin in Unity3D is to create and detect AR markers. The assets in the game can be downloaded from Unity assets store, while only small amount of simple assets were created using Blender3D. We use Arduino IDE software to program the hardware system. The hardware system manages the interface between the modules from triggering of buttons, scanning of commands to Bluetooth connection.

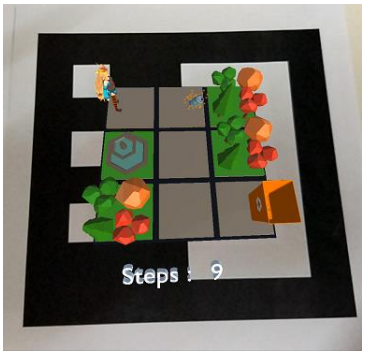


Fig. 5: Augmented Reality view of TARogic

3. Console design

In this project, we have created a Tangible Augmented Reality game that uses hardware console for tangible interaction and HMD for AR viewing. With the use of Arduino Uno board, USB read or write module (CH376U) and Bluetooth module (HC-05), we are able to produce a functional TUI for the game. The AR viewing experience is further enhanced with use of HMD (VR Box Gen II) with a smartphone (Figure 6). Player can view the game in AR via HMD and perform game input using USB drive via the console. Below are the steps on how the console operates:

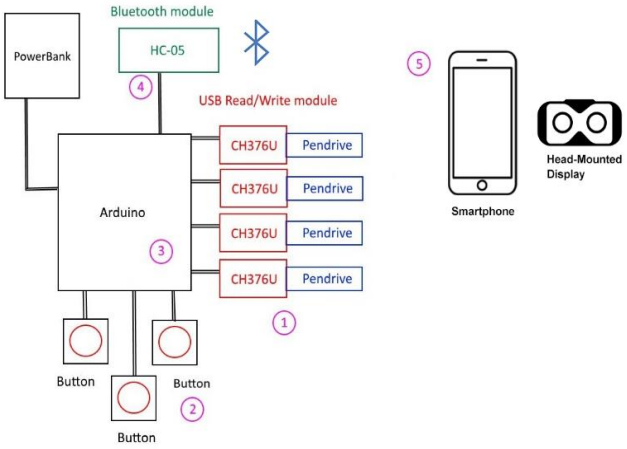


Fig. 6: Console design with the hardware modules

Step 1: Player inserts the USB drives into the USB ports that are consist of the USB Read or Write module (CH376U). We have allocated four CH376U module for the console. At the end of the session, if the in-game character has not recycle the waste completely or it runs out of steps, then the player has to repeat step 1 to 5 again. At the end of each session player needs to remove all the USB drives.
Step 2: Once the USB drives are inserted in the USB ports, player can press the "Scan" button.
Step 3: When the "Scan" button is pressed, the Arduino board will collect the commands from the USB drives. The commands will be captured sequentially from the first USB port until the last USB port. Then the commands will be processed into a single message.
Step 4: After the commands have been processed into a single message, the message is sent to the smartphone via the Bluetooth module (HC-05).
Step 5: The smartphone that runs the game is inserted to the HMD. The smartphone received the message from the console via Bluetooth connection. The game interprets the incoming message and breaks the message into multiple commands. Each command is executed one by one sequentially.

4. User evaluation

This project was targeted to teach students on the basic understanding of programming logics. Therefore, we have engaged university students for the testing. We have selected a group of 10 students ranging from 18 to 20 years old to test on the prototype. Basically we have conducted guided testing where students were properly guided to test the TARogic game. All participants were given 15 minutes for the testing. After the test, they were given questionnaires to score on the TUI, AR and overall learning experience of TARogic. On separate occasions, we have also engaged 10 representatives from Ministry of Education (MOE) to test the game. At the end of the testing, the participants were interviewed. In summary, below are the responses from the student participants through questionnaires:

- 60% of the participants scored highly on the project, they are interested on the overall learning experience of the Tangible

Augmented Reality game. Participants understand the purpose of using the correct commands to clear the level. The usage of the commands helps participants to learn the basic logic of programming.

- 30% of the participants scored averagely on the project as they think the game requires a lot of time to complete the level. It also requires a lot of steps for completing each level.
- 10% of the participant dislike the game as they have motion sickness when they put on the HMD.

Here are the responses from the Ministry of Education (MOE) representatives through interviews:

- 60% of the participants are interested in the learning of experience of the Tangible Augmented Reality game. Participants can relate the usage of commands in the understanding of basic programming logic. MOHE representatives have suggested to include more levels in the future work so that more fundamentals of programming logics can be covered in the game.
- 30% of the participants took a longer time to complete the game.
- 10% of the participants cannot play the game as they have motion sickness.

5. Conclusion

In conclusion, TARogic is a new AR game that supports tangible game inputs. Player puts on the HMD to experience AR environment and interacts with the AR environment using TUI in the form of console (USB drives and buttons). This form of visual and interaction experience was well received from the 60% of the participants. In the future, we look forward to implement this project in Raspberry Pi as it can support multiple USB hubs. With the use of multiple USB hubs, it enables the console to capture more commands. Therefore, we can introduce more complex commands in the game level.

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