Sensing Glove Study for Augmented Reality Environments [1]

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Abstract

Computer, mobile devices and the newly emerging wearable technologies motivate the researchers to create new environments. Smart glasses, which are one of the current wearable technologies, are among the developing technologies. Studies have been conducted for the usability and functionality of this technology, which is used in augmented reality environments, in education as well as many other areas. Some of these studies focus on users' control over digital objects. In this context, object control of augmented reality environments through various sensors such as RGB-D, heat or movement sensors were tried to be established in this study. The aim of the current study to develop a sensing glove which is a wearable technology for augmented reality environments. The Unity and Vuforio SDK software was integrated with Epson Moverio BT-200 and various sensors such as Accelerometer, Flex, and Force etc. that are being developed. A sensing glove was prepared for the user in the augmented reality environment. An environment including alternative, new and up-to-date applications that can be used in augmented and virtual environments was provided for developers with the new hardware and software.

Keywords: augmented and virtual realities, channels and controllers introduction, wearable technologies.

1. Introduction

Humans have used different technologies in order to facilitate or differentiate their lives and they saw and used technologies as a means to achieve their goals in general. Information and electronics come to the mind first today when talking about technology. The technology became smaller, can be moved and even worn thanks to the fact that both areas complete one another perfectly. However, the technology has not decreased the efficiency during that transformation. On the contrary, it has improved in a more functional and fast manner (Bäckman and Tenfäl, 2015).

Virtual worlds became more widespread due to the rapid development of the technologies used in information and electronics areas. Use of virtual worlds has increased dramatically especially since the 2000s. However, users' desire in recent years to move the virtual world into the real increased the interest in augmented reality (AR). The market share of AR and virtual reality (VR) is expected to reach 150 billion dollars by 2020 (DIGI-CAPITAL, 2016). AR is anticipated to have the biggest share in the distribution of the technology market with 120 billion dollars. It is predicted that this sector will consist of movies, data, entertainment, games etc. and hardware will have the biggest share (DIGI-CAPITAL, 2016).

It is hard to develop a suitable AR application and use the hardware and software systems used in applications successfully. In order to overcome these difficulties, software and hardware are constantly supplemented with development, redesign or new inventions.

Different techniques have been developed for AR and VR environments. They mainly consist of display devices (Head Mount Display (HMD), Head Up Display (HUD), Head Down Display (HHD), projectors etc.), tracking systems (position based, hardware based, gesture based, fingerprint-based position etc.), marker tracking (marker-based and markerless-based). These options may vary depending on the developers' preferences for the environment to be developed (Li et al., 2011; Mitobe et al., 2006; Nishiyama and Watanabe, 2009; Elder and Vakaloudis, 2015; Hong and Tan, 1989; Kadous, 1996). Many researchers performed markerless hand or finger movements (Wang et al., 2009; Mizuchi et al., 2010; Metcalf et al., 2013; Yang et al., 2013; Ha et al., 2014; Shim et al., 2016; Shen et al., 2011) or movement analyses of real objects (Huang et al., 2011) using deep cameras in AR environments.

Smart glasses, which are AR environment hardware, are frequently used in various studies. As smart glasses are used like traditional glasses, they have started to be defined as wearable technology. However, smart glasses are different from traditional glasses as they are equipped with camera, microphone, GPS receiver etc (Rauschnabel et al., 2015).

Wearable technology is a user interface that can be on a person's body and based on electronic design (Mann, 1997). Smart glasses are regarded as wearable technology. So the concept of "eye-wearable technology" has been added to the literature. Basically, users are provided with the opportunity to carry out some commands and transactions via an interface. Some examples include document transfer, communication, document editing (Kim and Lee, 2016), rotating the object around a specific axis, command verification and cancellation (Jimeno-Morenilla et al., 2013). The biggest disadvantage of smart glasses is users' inability to carry out touch interaction. Therefore, researchers have tried to produce solutions with different alternative hardware for users so

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that touch interaction can be performed (touch-less interaction). Such hardware include camera, glove, wristband and belt. Their usability was differentiated by supporting each of them with different sensors. Such hardware was basically used to receive individuals' actions, locations or preferences although its shape and function changed. This study aims to develop wireless sensing glove hardware in order to enhance user experience and interaction.

Similar studies conducted in this area focused on control of location and movements of digital images in virtual environment by the glove with detect hand and finger movements through sensors. Also feedback was given to the relevant user with digital objects by applying vibration and pressure (Zhao et al., 2016). The common goal of the studies is to use real, physical objects and tools (Seo and Lee, 2013; Ben-Tzvi and Ma, 2012). In this way real-time tracking and computation can be performed ideally (Nee et al., 2012). As a result, environments developed according to the view of a physical world may look like tangible interfaces (Brancati et al., 2010). Application trends of tangible AR interaction can be classified as paddle-based (Nogueira et al., 2010), glove-based (Mistry and Maes, 2009) and direct hand-based. Users are provided with actions such as pointing, grabbing, and selecting etc. in glove-based AR interactions.

Jimeno et al. (2013) developed a system based on 3D gloves for establishing interaction with virtual footwear models. This system enables a hypothetical customer to check the goodness of a virtual footwear model from an aesthetic perspective in real time. Ben-Tzvi and Ma (2012) performed a study on design, application and experimental validation of a new robotic haptic exoskeleton device which was aimed at measuring and assisting the user's hand motion while remaining portable and lightweight. The device comprises a five-finger mechanism that is operated with miniature DC motors via cables routed antagonistically at each finger acting as both active and passive force actuators. It is possible to wirelessly link the glove to a computer in order to display and record the hand status by means of 3D Graphical User Interface (GUI) in real-time. Mistry and Maes (2009) came up with a wearable gestural interface and called it Sixth Sense. No hardware input device is used in the user interface of Sixth Sense. The user gets only the system's visual feedback. Finger movements are interpreted into gestures through movement analyses performed with the system. These gestures function as an interaction device for the projected interface. Asai and Hirakawa (2015) made use of Finger and Camera Motion in order to increase the interaction between the user and digital object. Lv et al. (2015) analyzed not only hand locations but also the locations of hands and feet with respect to one another and transformed these locations into a command. Examination of studies revealed implementations performed with one or more cameras of different types, computer-vision based techniques and markerless motion capture based methods (Mann, 1997; Lee and Hollerer, 2007; Kim and Lee, 2016).

In the light of these studies, it is seen that wearable technologies are developed with constant trials especially for AR and it is thought that this study can contribute to the literature as similar studies are required for this development.

2. Method

In this study hand and finger movements with sensors using the sensing gloves developed for the study were analyzed and attempted to measure the locations. The system was prepared for AR and VR environment developers with wireless communication, flexible wires, force and flex sensors in a lightweight and independent manner.

In this context, the study was conducted in three stages. The first stage was preliminary preparation in which feasibility works were carried out and the literature related to wearable technologies was reviewed. In the light of related literature, an environment was created with wearable technologies. The second stage was the development stage. The smart glasses which are among the wearable technologies, were supported with a glove and new environments were created. The relevant digital objects were visualized and an application was developed in order to try the AR environment prepared by the researcher. Expert opinions were obtained about the environment in the final conclusion stage. Two experts were interviewed during the study. The experts work at the Department of Education Sciences in the same university as the researcher. They achieved their doctorate degrees in the field of technology integration in education. They are currently teaching instructional technologies and material development courses at undergraduate level.

2.1. Hardware and Software Sections

Epson Moverio BT-200 smart glasses were selected for the project. The glove and smart glasses were merged into single software and offered to the user. The glove was developed so that the user could control the AR environment. Finger positions of the user as well as the roll and pitch movements of the hand were analyzed with Accelerometer ADXL335, flex and force sensors. Wireless communication was established between the glove and the smart glasses through Lilypad microcontroller and Bluetooth Mate Gold which are parts of the glove located 100 ms away from one another. The force and flex sensors used on the glove were connected directly to the Lilyaped microcontroller with 16-Channel Analog/Digital Multiplexer.

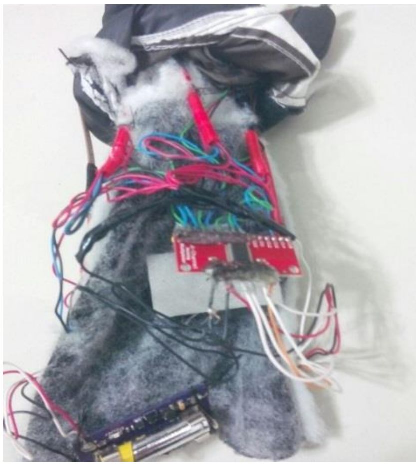

Figure 1: Parts of the glove [Upper part of the glove (16-Channel Analog/Digital Multiplexer and AAA battery unit)]

Figure 2: Parts of the glove [Lower part of the glove (Lilyaped, ADXL335, Flex and force sensors)]

Arduino IDE, which is a code editor and compiler written in Java programming language, was used to operate the sensors and control the microcontroller in the project. Unity software was preferred to perform the smart glasses application while Vuforia SDK was preferred for the AR application.

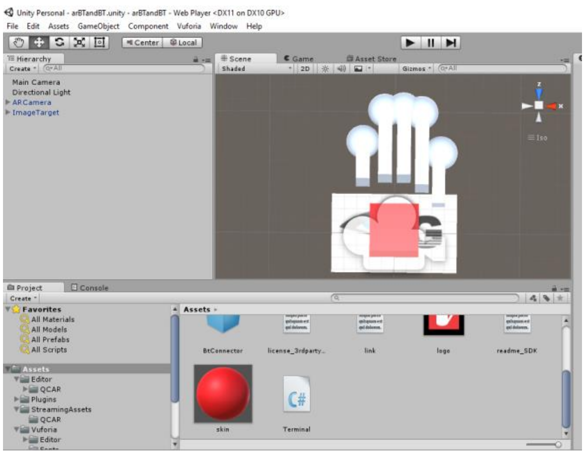

Figure 3: Unity software interface

The data obtained wirelessly from the glove was analysed and the digital objects in Unity were visualized based on calculations. Five white rectangles, five globes, and one cube represent the individual's fingers, fingertips and the hand location respectively. A rotation between 0 and 90 degrees is performed when the fingers move. The more the individual shrinks his/her fingers, the bigger the degree becomes and the rectangles move downwards. The white globes were associated with force-sensitive sensors. The colour of the globe changes as the force increases. The red cube was coded with ADXL335 on the glove. The cube rotates around the same axis as the hand (roll and pitch) simultaneously.

3. Discussion and Conclusion

The experts who were interviewed were asked to respond two open ended questions. The first question was about their opinions about the hardware; as can be seen in Table 1, the participants used the hardware produced using the designed environment and stated that they found the hardware interesting and intriguing. It was possible to use the environment with both AR and VR technologies in the interviews made with the experts. The study revealed that the hardware used in the study could be used in a desired manner and the instant reactions of the device were fast in the experiments. Another reference sensor is needed for a better analysis of hand movements. Furthermore, the skeletal structure of the hand needs to be improved. In this way, it may be possible to calculate the location and movement direction of the hand with reference to the body in addition to rotating it only around the axis.

Table 1.

The opinions about the hardware

Strengths	Weaknesses
➢ Interesting and intriguing ➢ Possible to use the environment with both AR and VR technologies ➢ The instant reactions of the device were fast in the experiments	➢ Needed for a better analysis of hand movements ➢ The skeletal structure of the hand needs to be improved

The second question was about the aspects that are needed to be improved if the faculty members were to use the glove in their areas. The participants stated that the AR application content could be improved depending on the scenario. They also stated that efficient AR applications could be performed with the glove for students in cooperation with experts from different areas.

As can be seen in Table 2 they also said the glove was suitable mainly for in-class activities and accelerometer and digital Gyro sensors could be used at the same time for more efficient movement analyses. However, they added that it should be supported with compass and GPS modules if it were to be used for out-class activities.

Table 2.

The aspects that are needed to be improved

In-class activity	Out-class activity
➢ Accelerometer and digital Gyro sensors could be used at the same time for more efficient movement analyses	➢ Should be supported with compass and GPS modules

Analysis of the literature revealed that hand or finger movements performed with the glove designed in this area were performed specifically from an angle that can be captured by the camera. This brings some limitations for the user. Therefore, sensors were used on the glove developed for the study. In this way, the user was allowed to perform hand or finger movements without any limitations. Enriching the glove with force and flex sensors made it possible to realize more controls. The glove, which was developed in a different manner compared to other gloves developed in this area, could be used to control the objects outside the camera angle in AR applications.

4. Recommendations

As a result, a glove on which two different sensors can be used was designed. Finger movements, roll and pitch can be controlled wirelessly with this glove. However, it was determined that the glove should be technically improved. The interviews revealed that if the AR environment is supported with suitable scenarios, it could be more interesting and a more efficient work can be performed for the user by developing a different interface in each case.

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