Abstract
Project DUKE explores the design and development of a virtual reality based first-person shooter (FPS) game using gesture-based technologies. By integrating Oculus Rift, Microsoft Kinect and Leap Motion technologies, we attempt to foster natural in-game hand presence while maintaining foot- and torso-based navigation. We demonstrate in this exploratory work, a fully immersive prototype that enables a full-body FPS gaming experience involving interactions for complete navigation, combat and viewing control.

Author Keywords
Immersive Gameplay; Virtual Reality; Gestures Recognition; First-Person-Shooter

ACM Classification Keywords

Introduction
Recently, with the major leap in immersive technology and improved hardware capabilities, Virtual Reality (VR) and new gesture technologies have gained substantial interest in the area of video game and simulation. There are many devices in the market that are able to support a greatly enhanced virtual reality experience.
experience with applications ranging from virtual "walkthroughs" to gesture-based games and assistive technology. Oculus Rift [1], Kinect 2 [2] and Leap Motion [3] are among some of the more well-known technologies used for creating immersive experiences.

Virtual Reality (VR) refers to a collection of technologies and techniques developed to integrate both user and computational systems, with the main objective to provide user with the experience of living inside a 3D virtual environment in real time using advanced interfaces [4]. VR applications are classified based on the way user interacts with the virtual environment. There are two types of VR: Immersive VR (IVR) and Non-Immersive VR (NIVR). The objective of IVR is to immerse the user inside the software’s environment, giving him the feeling of a complete isolation from the real-world. In contrast, NIVR does not require total isolation of the user [4]. A well-known example of IVR is CAVE or Cave Automatic Virtual Environment, an immersive virtual reality environment that uses projectors to direct visuals onto the walls of a room-sized cube [5]. In order to set up CAVE, an enormous amount of resources including costly equipment and physical space, is required.

The term First-Person Shooter (FPS) refers to a specific genre of computer game that is played from the first-person perspective, with shooting as the main action mechanics of the game [6]. Some of the well-known methods to control a FPS game are through the use of keyboard and mouse, or game controller [7, 8]. Recently, Epic Games created an advanced VR experience game titled "Bullet Train" that uses a pair of tracked controllers (Oculus Touch) for in-game interactions [9]. This pair of tracked controllers is able to provide the player with the feeling of natural in-game "hand presence" — the ability to immerse the player by allowing them to visualize and move their virtual hands and fingers inside the VR world using the controller.

Related work
In recent years, researchers have been working on integrating multiple input devices to accomplish IVR. This is intended to provide better user control and immersion, giving an edge over existing single-input games or applications. The KOS VR game [10] developed by Andong National University is controlled with a combination of the Kinect, Oculus Rift and a smartphone. Kinect is used for skeletal tracking, Oculus Rift for rendering stereo images and smartphone for capturing input instructions. Hand presence is still lacking in the KOS VR game as primary it uses smartphone to perform typical gestures such as touch, swipe and drag. Similarly, another work [11] pairs the Oculus Rift with the Wiimote controller to attain better motion control. However, in order to immerse the user with an actual hand presence experience, the user needs to have full control over their five fingers independently, allowing them to interact with 3D objects freely in the virtual environment.

Leap Motion provides a way to immerse fine motor gestures. In a walk-through VR application developed by Khundam [12], Oculus Rift and Leap Motion are combined to enable first person movement control in an immersive environment. Users can perform forward, backward, step left and right, stop and speed control using hand gesture interactions. Another interesting VR game, "Diplopia" [13] also utilized Oculus Rift with Leap Motion controller to help people with amblyopia (lazy
eye syndrome) regain normal vision. Nevertheless, movements from other body parts (legs, torso) are equally essential in creating an immersive experience for users by allowing them to physically move around in the virtual environment.

In our exploratory work, we ask the following questions: How can we provide full-body interactions to enhance the player’s experience in a first-person shooter game without using physical controllers? Can current gesture-based technologies be integrated to achieve better immersion in VR-based games? To answer these questions, we have developed DUKE, an experimental VR-based FPS game that relies on the use of gesture-based technologies to provide full-body interactions. The purpose of this project is to create an advanced VR experience demo where player can move freely in the VR environment and perform shooting actions without using any physical game controller while having a natural in-game "hand presence". Our main contribution lies in the creation of a VR based FPS game prototype powered by gesture-based technologies that enable full-body interactions with the VR world.

**Game Concept**

DUKE is an Immersive Virtual Reality First-Person Shooter (IVR FPS) Game implemented with Unity3D 5, interfacing with three immersive technologies: Microsoft Kinect 2, Leap Motion Orion and Oculus Rift. The player takes up the role of a protagonist, a member of an elite organization called DUKE that does time travel. Their purpose is to remove anomalies that cause chaos in that particular time dimension. The player needs to close all the dimensional portals to prevent the spawning of enemies. The game is science-fiction themed; with three level settings depicting past, present and future. Each level requires player to find the source of the disturbance and eliminate it. When engaging the enemies, combat can be performed through movements of player’s left/right hands and fingers. Player has the ability to switch weapon type between melee and range modes. In melee mode, the player can swing their arm to mimic slashing action. Whereas in the range mode, player can move their fingers to mimic the action of pulling the trigger. Larger navigational movements involving moving forward/backwards can be easily done by physically moving their body and legs. A summary of these interactions are illustrated in Figure 2 with in-game screen captures shown in Figure 3.

![Figure 2: Full-body interaction technique using Oculus Rift, Leap Motion and Kinect 2](image-url)
Implementation

DUKE was developed using the Unity engine version 5.3.5, supplemented by Microsoft Kinect 2 SDK, Leap Motion Orion and Oculus SDK v1.4.0 through various programming interface (APIs). Other third-party APIs supported by Unity were also used to control the audio, video data streams and skeletal tracking of the player.

Our implementation enables the detection of full body gestures from head, body, right and left hands including index fingers to both legs; thus allowing the player to perform natural gestures and movements. The animation captured via Leap Motion sensor for each hand is mapped (using the skeleton mapper from Leap Motion Orion SDK) to allow the translation of the player’s physical hand and finger movements into on-screen graphical display of the avatar hand. These mapped movements are also interpreted as game combat instructions. The Kinect sensor captures the orientation of the player’s spines to determine the left and right strafing direction of the avatar. It also captures the position of both legs and determines the avatar’s movements in the game. Lastly, the Oculus Rift tracks the player’s head orientation and renders stereo screens to create a virtual reality image.

Game Interactions

In DUKE, we have categorized game actions into 3 categories; Viewing, Navigation and Combat (Menu,
Melee & Range), each controlled by a different sensor device (as shown in Figure 2).

- **Viewing**: Player can turn his/her head around freely to view the 3D virtual environment in the game.
- **Navigation**: Player can control the directions of the avatar by moving the body to the left or to the right. In order to move forward, player has to position his/her left leg in front of the right leg. To move backward, player has to position his/her left leg to the back of the right leg. Both legs at the same depth position indicates stop movement.
- **Combat Menu**: When looking at the left hand, the weapon menu will appear. Player can then use his/her right index finger to touch on the button to activate the melee or range weapon.
- **Combat Melee**: When the melee weapon is activated, player can swing his/her right hand to perform a slashing action.
- **Combat Range**: When the range weapon is activated, player can pull his/her trigger (index) finger on the right hand to mimic a gunshot action.

A tutorial level was created to allow the player to learn and familiarize with the interactions within the virtual world. During the game, visual (avatar hand movements) and audio effects were also invoked when the player performs an action. Except for the requirement to remember some less-natural movements for e.g. moving forward and backward without walking, the rest of the gestures are more intuitive as they mimics real physical actions.

**Preliminary Deployment**

DUKE is an exploratory project to introduce an advance virtual reality experience by capturing full-body movements of the player using a slew of devices such as Oculus Rift, Microsoft Kinect 2 and Leap Motion. This integration enables the player to have full movement control and interaction in the virtual world. The game was tested with people who have a strong interest in playing FPS games, and have played them often. The game was tested with 10 participants ranging from 18 to 40 years old. All participants were given only 10 minutes to play with an option to extend the playing time. Through our qualitative survey and interviews, we found that 90% of the participants expressed a strong preference towards our design and implementation of the Viewing actions, 50% of them liked the Navigation actions while 60% of them are favorable towards the Combat actions. However, there were some criticisms and suggestions for future improvement work. One major concern is that the Navigation actions are less intuitive for some of the participants when they have to move their right foot instead of left foot to the front in order to move forward. This can be addressed by allowing dominant leg preferences \[14\]. Overall, all participants felt immersed with the shooting action in the game. Participants were able to complete the game with minimal or no assistance.

**Conclusion and Future Work**

In this paper, we have described DUKE, a FPS game prototype that introduces full-body interactions to promote advance virtual reality experience. This idea presents a new way of enhancing immersion in virtual reality through the integration of several state-of-the-art gesture-based technologies. From the initial feedback received from the participants, we have
identified several directions for future work. One is to implement more natural combat gestures such as punching, grabbing and throwing objects in the game to further enhance interactivity. Besides addressing the dominant leg issue, the Navigation actions can be improved to capture and translate more natural body rotation and leg gestures into in-game movements.

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References