Mobile Augmented Reality as Rehabilitation for Lateropulsion

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***Abstract*—Virtual reality applications have been utilized as a method of therapy for post stroke patients and this current research aims to explore the expansion of rendered environments into a real-world environment. Post-stroke patients with lateropulsion see the world skewed by differing angles. To help rehabilitate lateropulsion patients, an application was developed using the Pass-through Camera to be used with all generic Google Cardboard Headsets. In addition, the app is also cross platform working as both an iOS devices as well as Android phones. Under the guidance of a Physical Therapist, this application provides a dynamic way to adjust the patient's tilted view with varying degrees. The advent of augmented reality as a medical tool opens up a wide realm of possible rehabilitative enhancement methods that a therapist can utilize in addition to supplement traditional methods. No special training on behalf of the therapist is needed to utilize the application and therefore can be used as an additional tool to augment lateropulsion patient therapies. Currently, there are no augmented reality applications that modify the properties of the camera on a head mounted display. The augmented reality application helps treat patient symptoms thereby enhancing their quality of life through an easily accessible mobile app that any therapist can download and utilize in their therapy.**

***Index Terms*— Augmented Reality, Lateropulsion, Mobile Applications, Patient Rehabilitation, Stroke Rehabilitation, Virtual Reality**

I. Introduction

LATEROPULSION is a symptom that certain stroke survivors experience. Strokes can cause an effect called hemiparesis which is the paralysis on one side of the body. Lateropulsion is an extreme case where the patient perceives the world on a tilt both visually and proprioceptively. [13] The after effect causes the patient to push with their non-affected side into their hemiparetically affected side due to the false perception of visual cues, resulting in balance issues while both seated and standing. Virtual reality treatment has been used as a therapy tool to correct lateropulsion with the supervision of a physical therapist supplementing traditional therapy.

The current rehabilitation of lateropulsion involves a physical therapist initially educating the patient that they have a skewed natural posture. Next, the patient visually explores their surroundings in relation to their body position and re-learn movements with the therapist to reach a normalized posture. The goal is to maintain this posture while performing normal daily activities designed by the therapist. The level of lateropulsion is also determined by the therapist through various tests.[4]

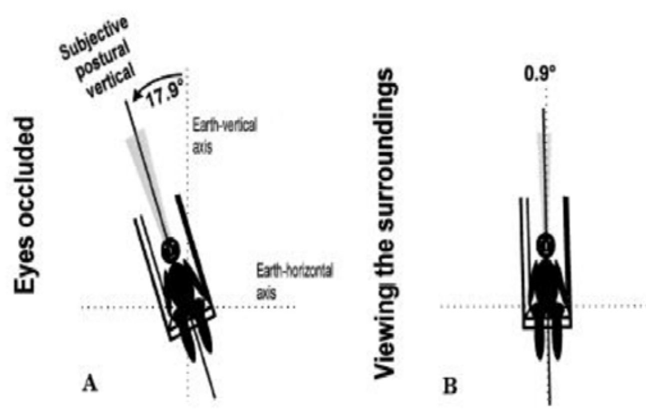

Figure 1: Image A shows how the lateropulsion patient sees the world. Image B shows how the should see normally.[13]

This study researched the possibilities of utilizing Augmented Reality in the treatment of lateropulsion to improve full body movements, using the built-in camera of a mobile device with the goal of improving a stroke victim's quality of life. Lateropulsion reduces quality of life by increasing the risk of falling and performing routine tasks safely without supervision. Current research in VR technology as a rehabilitative tool has shown promising results in treating stroke patients to some degree with motor impaired deficiencies. [14] However, this research was not entirely conclusive, thus requiring more hands-on methodologies, that identifies which types of training devices assists clinicians in treating lateropulsion. [8]

The research was conducted with collaboration between Pace University and the Burke Hospital Medical Institute, to develop a mobile application that will help the rehabilitation of lateropulsion through AR. The initial mobile hardware was provided by Samsung and included the Gear VR, Galaxy S6 phone, and Samsung tablet. The Burke Hospital Medical Research institute provided parameters for the research as well as patients to test the prototype. This paper is broken down into the following sections: *Introduction, Literary Review, Specifications, Methodology, Preliminary Findings, Results, Future Works and Conclusion.*

II. Literary Review

Virtual reality as an instrument for therapy has been met with generally positive results. The lowering barrier to entry for the technology has catalyzed it into being a viable and useful tool for therapists. Patients are restricted to small living areas in a hospital which prohibits large scale solutions. As an iteration of virtual reality, mobile augmented reality works well in areas with space limitations, meaning that in-hospital patients will be able to benefit from therapy in their current space. A review in June 2016 found that chronic stroke victims who received virtual reality treatment along with standard methods produced positive effects in balance.[8]

A confined environment provides patients with safe and familiar areas to explore their functional capabilities without interferences from their physical or cognitive limitations. A key factor in treating lateropulsion is to use visual feedback to retrain a patient into a correct posture. This is currently done through mirrors and other horizontally and vertically aligned structures in a therapy room along with emerging technological advances. It has been found that a computer-generated interactive visual feedback training program is more effective than traditional mirror visual therapy. To take this further, virtual reality therapy applications have been produced to much success that provide the patient with simulated environments.

The drawback to simulated environments is that it can cause motion sickness in certain individuals. An augmented reality application has not yet been made as a therapy method. Augmented reality is best described as rendered objects or effects being placed in real world environments and viewed through a phone or tablet. To do this correctly, computer vision software is used to detect and measure the environments using the phone's native capabilities.

III. Specifications

Pace University, Burke Hospital Medical Research Institute, and Samsung collaborated to produce an augmented reality rehabilitation environment which will integrate traditional therapy with rendered environments to aid in therapy.

Pace University researched the development of an augmented reality application along with relevant rendered experiences for patients. Burke hospital provided the research, medical expertise, and testing with patients. Samsung provided a Samsung branded smartphone, Gear VR Headsets, and tablet. Additional android devices and Google cardboard headsets were also used once limitations were found in the Samsung Oculus framework.

Figure 2: Generic Google Cardboard headset

The research built upon previous research on virtual reality applications in relation to lateropulsion therapy. A previous Pace project had the patient interact in a rendered environment whilst encouraging movement by creating obstacles. The augmented reality research will leverage the findings to allow the patient to view a real-time environment rather than a computer simulated one. It will provided the patient with a more grounded visualization of the degree of their condition. Motion sickness is an issue for many people and is triggered by a variety of individual factors.

Currently virtual reality applications have been produced with a varying degree of success in patient rehabilitation.

IV. Methodology

To provide custom parameters based on a specific patient's level of lateropulsion, an interface will be designed to allow the therapist to adjust the skew of the pass-through camera accordingly. The therapist will also be provided with premade targets which will trigger different activities for patient rehabilitation. The current research is divided into the following sections:

A. A method to adjust the angle of the pass-through camera

B. Programs and implementation

C. Research an appropriate SDK that will enable target detection with the aforementioned camera.

D. Creation of responsive scenes that target different symptoms of lateropulsion.

E. Testing tools

F. Testing

A. Method to adjust the angle of the pass-through camera

Currently there are only post-rendering solutions on the app markets to adjust the angle of an image. The goal of this area of research will be to either A) create a custom camera app that allows for manual adjustment or B) research if the Unity Development Platform can provide a solution to adjust the camera within the app. The goal is to provide the patient with a real-time detection and correction of their specific degree of lateropulsion. The first approach will be to develop a custom native android camera that will allow for the adjustment of the horizon to match the patient's degree of lateropulsion. [2] The second approach is to work with Unity's provided camera, setting a variable that can be adjusted through the user interface prior to placing the phone into the Gear VR. [1]

B. Programs and implementation

The preferred approach will be to use the Unity Developer Environment to create all the necessary components. Unity has been chosen because of its learning curve and readily available documentation, development tools, and ease to build rapid prototypes. Unity can be programmed in both C# and java-script of which the C# scripting approach will be used. Unity is platform agnostic, allowing for further expansion of the application into different mobile or virtual reality platforms with minimal effort which will allow the app to be potentially expanded to other mobile devices as hardware capabilities expand. Two versions of Unity will be used to for testing which are version 5.4.3f1 and beta version 5.6.011b. The beta version was added after the first prototype programs because of its native inclusion of mobile virtual reality features which will can be explored for in the scope of this research.

The proliferation of devices capable to run these environments will be taken into consideration and development research and documentation will aim to simplify the adaptation of the application for different hardware platforms.

C. Research an appropriate SDK *that will enable target detection with the aforementioned camera*

There are various off the shelf SDK's (Software Development Kits) that provide marker detection using a camera. These SDK's generally work by specifying targets and when detected by the camera they trigger pre-rendered scenes. Research includes the accuracy of the software, the time it takes to detect a target, and the level of sophistication a target must have to be unique. The SDK's that will be explored are Vuforia, OpenCV, Wikitude and the Kudan SDK. Google Cardboard SDK will be looked upon to leverage the expansion of the application to possibly run on devices beyond GearVR[19]. However, this will be provisional and later determined after intensive testing of the SDKs has been completed. Each one has its strengths and weakness which will be explored and documented. The cost of implementation will also be taken into consideration. What will also be accounted is the facility to use provided code into our specific use case.

D. Creation of responsive scenes that target different symptoms of lateropulsion.

Previous research will be used to determine effective rendered environments that best aided in detection rehabilitation. Each unique target will present the patient with different situations which will consider full body movement and function to encourage incremental rehabilitation of the present symptoms. The goal is to provide a gamified framework in which different activities can be produced and implemented with ease. By adapting existing gamified environments, the research and development will be able to focus on the normalization of the camera mechanics.

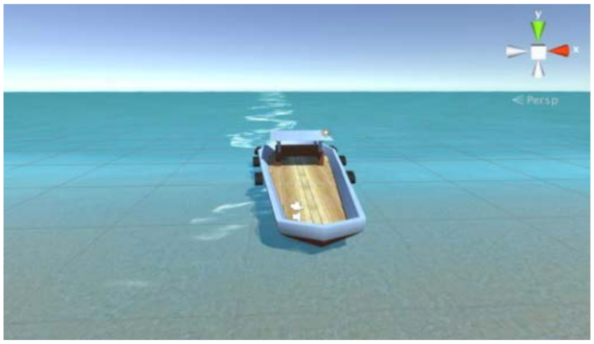

Figure 3: The above figure shows work of past research using virtual reality to help with Lateropulsion[20]

E. Testing tools

To test the prototype builds on the Gear VR, the team used a tool called sideload VR which allows for allocation of a Gear VR signature file so that the apk will execute in the Gear VR seamlessly. At first Unity version 5.6.1f was used with a consistent build apk to mitigate as many factors as possible. The initial tests were all run off of a Mac with the latest OS at the time of testing. Android build was selected, virtual reality capabilities were chosen, and multithreaded processing as per documentation. Further along Google cardboard headsets and different android devices were also included to better represent the availability of current hardware and their capabilities. It is to be noted that a cardboard viewer is not limited to just a cardboard viewer but also branded versions by various companies.

G. Testing

The testing was done in spaces with limited variables. A collaborative room in the Pace library proved ideal because of its constant arrangement of furniture and its constant specification. The room was also small, close to what a hospital space may provide. For each of the apk's that was produced, there was a standard procedure to measure the effectiveness of the pass-through camera rendering. There was a target that each member attempted to reach, followed by comments on what was perceived to be distorted and improved upon and considerations and feedback from each tester. Each researcher tried on the same headset and gave their perspective of how successful the build was. This allowed builds to be evaluated fairly and without prejudice. Different visual perspectives were necessary in this research because everyone has different vision and balance. This type of testing while not all inclusive of all possibilities included people with very different degrees of vision impairments which provided a good sample. The headsets were also calibrated to each tester's pupillary distance, head size, and focus. Those who wore glasses kept them on within the headset.

Since the headsets are designed to show as close to real rendering as possible, the user will still see a distorted image even if the phone or device is physically close.

Once the provided prototype was ready, testing also involved standing, looking up, down, and some locomotion in order to gauge any peculiarities in perspective.

Figure 4: This is from the research and development of this paper, using AR for the treatment of Lateropulsion

V. Results

The research team has explored various SDKs with varying degrees of success. The Wikitude, Kudan, and OpenCv SDKs have proved to be cumbersome when paired with the Gear VR. Of the three, Wikitude proved the most successful and by presenting a pass-through image, but only in full screen without the right and left eye division, even with the appropriate android virtual reality settings. The other SDKs were only able to produce blank screens. The hypothesis is that the Gear VR software compensates for the changes made to the stereoscopic views produced by each SDK.

Vuforia presented the best results initially. Vuforia was able to build on the emulator perfectly and presented the desired stereoscopic rendition. Through further development, it was discovered that the modifications on the tilt would not translate correctly to any of the aforementioned devices through an apk build. Through research of the documentation and professional and enthusiast forums, it was found to be a common occurrence without a solution as of now.

Regarding the prototypes produced with the first, the lag was not significant and the video feed displayed in real-time, giving a fluid experience. However, the image itself was magnified, making the field of view smaller and objects present closer to the viewer by around a foot on average. We determined the magnification by each attempting to touch a target and stop at the point where we perceived the target to be in reach.

In Unity, we placed a rendered cube in the scene to establish a constant. This increased the risk of motion sickness and disorientation significantly, since what was displayed was a real world environment. The fulcrum of the augmented reality camera has to be more fully explored through documentation and researched to determine if it can be modified for the specific goal.

The second prototype repositioned the augmented reality camera in scene to compensate the magnification which modified the cube but not the rendered feed, which indicated that a change did occur. The background plane on which the video texture was being reproduced on was then repositioned. The results were nearly identical except that that cube maintained its size. To test tilting the plane, the axis of the camera was modified first on the x axis and then on the y axis which again only repositioned the cube accordingly. Modifying this certain property within the Vuforia SDK has not been possible due to their black box model of producing the image. Two conclusions can be made from these experiments. One is that the Gear VR is itself propriety code which compensates tilting in order to reduce injury and liability to Samsung. The second is that Vuforia's propriety code does not allow a developer to edit the properties of the rendered stereoscopic camera.

Given the prior limitations, development and research then turned to using generic cardboard viewers and android devices to eliminate proprietary code as factors. Google's cardboard SDK allows for unrestrained development and facilitated prototyping by opening up any capable android device, thus not limiting research into only Samsung products.

Figure 4:Input field for therapist to enter the number of degrees to compensate.

Utilizing Unity's webcam texture within the cardboard SDK, we were able to dynamically modify the user's visual environment. The WebCamTexture leverages a device's native camera in order to display live video feed as a material/texture to be rendered on any Unity GameObject attached. This was only known method to get a live-stream rendition of the camera feed to display within a real-world environment. It also enabled the ability to dynamically tilt the augmented reality scene intuitively.

Unity itself abstracts away many of the complexities for development which well into research became an issue. While it facilitates the development of pre-rendered content such as virtual reality application and games it is dependent on third party resources and paid assets to access hardware level functions such as the camera. A good familiarity with Android application development was needed in order to make sure the manifests were properly set to give access to the camera functions in addition to resolving merge conflicts.

Figure 5: Testing of the stable application with measurements of cpu resources on the top right.

Google cardboard SDK 1.40 released April 17th coupled with Unity version 2017.1.0b.1 released April 11th has resolved all of the previous issues. The prototype application is now a beta version for both Apple 7 phones and Android phones with cardboard capabilities. Prior builds had functioning elements with each build fixing an element while breaking another. An example was how one build would crash after a certain amount of time, while another would crash when inputting a new tilt. The new SDK stabilized the issues while at the same time allowing the tilting to occur. What was surprising is that the new SDK also translated to iOS devices relatively smoothly. The one issue we found that natively the pass-through camera would flip vertically, creating a disorienting mirror effect. This can be rectified by changing the code for the iOS version.

VI. Comparisons

This research focuses on how the Google Cardboard platform handles the pass-through camera. The result allowing the therapist to run on any Android phone and possibly iPhone device, since this approach is less intensive on the hardware. Augmented reality provided the patient with a more familiar environment as opposed to a more unrealistically fabricated Virtual environment. It also allowed the therapist to use techniques already being utilized. The application served as an extension to the rehabilitative process.

There are hardware alternatives that provide augmented reality experiences. The Microsoft Hololens is the most recognized one, with the Meta 2 in development, the Epson Moverio, and the google tango project which has only recently been released commercially. While these are all head mounted displays(except for the tango) they do not allow for tilting as desired due to their physical design. It is notable however that Vuforia is popular on each platform to generate and trigger content for an augmented reality experience.

The Hololens and the tango project are notable for their use of infrared cameras to create point clouds that the respected devices can use to detect real surfaces. An example is how two horizontal surfaces such as a tabletop and a floor can be distinguished and their distance measured to provide more realistic avatar interactions. They are also able to mark the spaces along with GPS input to track the location of placed objects. Both have limitations regarding lighting and reflective surfaces which interfere with the IR sensors which prevent the correct rendering and tracking of content. Although released they also have significant individual application crashes due to the ongoing development of both the hardware and software.

There are popular applications that use augmented reality to an extent such as snapchat with its filters. This represents a basic and intuitive use case that has become popular. Snapcaht uses propriety computer vision algorithms to track faces accurately across platforms. Pokemon Go is notable with how it was able to present augmented reality to the masses in a gamified fashion. The limitation of Pokemon go is that the augmented characters are just superimposed on the screen without regard to the physical environment around it. The game does not use computer vision which leads to characters appearing in physically impossible areas. This is an inherent obstacle with current smartphones as IR sensors are needed to produce special recognition.

This research has focused on achieving a real-time correction through tilting for laterolpulsion. It has not been burdened by special cues as of yet.

VII. Future Works

The team has researched and successfully provided a tool the physical therapist can use to tilt the real-world environment for the patient. Future projects can further engage the patient through gamification of an Augmented Reality world. Certain precautions should be taken when adding virtual elements to avoid processing lag within the device attributing to motion sickness in the patient. As is the case in technology, as further iterations of the hardware are produced, the more capabilities they will have while also eliminating current limitations.

Although the initial goal was to fully utilize Vuforia, or another of the computer vision software, it was not possible during the time period of the research. As certain tools have been updated, there is confidence that the application that was developed will be able to easily be integrated with one of the computer vision SDKs. The process would include further development in the UI and creating a prefab of the scripting and assets used. This would allow the research content to be exported to any other project that would like to utilize the tilting feature that has been developed.

The development process was also prolonged thus encumbered the further testing with stroke patients with lateropulsion. This will be an important step to generate feedback in comfort, possible motion sickness issues, or any other unforeseen circumstances that we are unable to detect due to our lack of first-hand experience with laterolpulsion.

VIII. Conclusion

Currently propriety hardware and software limitations prevent the execution of the application as intended. The Gear VR and Vuforia was a failure due to the closed source nature of both parties. Constant updates to the SDK and parameters also hindered progress as documentation was available for previous versions that were no longer offered.

One limitation of the application is in the design of phones themselves. The rear cameras are always positioned close to the top of the phone for their normal use cases. When tilted horizontally, the camera is either too far on the right or the left leading to a corresponding shift in perspective. The shift is not large enough to disorient the user and through testing we found that our perspective adjusts thus negating this factor.

The Gear virtual reality does have native access to the pass-through but only as a small rectangle on the bottom right side with the purpose of serving as a guide rather than as a full solution. This feature is also inaccessible through Unity as it is built into the Oculus software. The software also compensated for any change in the tilt.

With other android devices and the google cardboard SDK, tilting was able to be produced by including the values within the build. Limitation in knowledge on Unity UI development hindered further exploration into low level manipulation of the camera. As the field is rapidly expanding, developer tools have continuously been updated and generated which has aided in progress. In a way, it has also deterred from a deeper understanding of the hardware functions themselves as time has not permitted a complete evaluation of the expanding documentation.

A recent development has fixed many of the bugs that were present in the development builds. This was possible due to both improvements in the Google Cardboard SDK and also tweaks made in the latest beta version of Unity. Many of the previous versions have been focused on specific features such as oculus inclusion and recently native Google Daydream inclusion.

As of this time, Augmented reality has only seen real success certain advertising and games. All augmented reality applications keep default camera properties to keep users from injury. It is not a limitation, more of a safety feature that has to be overridden on a low-level basis.

Also, to take into consideration is the recent announcement that Facebook will provide a significant push into the development of augmented reality application. They aim to create an ecosystem and will encourage developers in creating applications. This is significant specifically to this research given that Facebook is one of the developers of the Oculus software and hardware. Facebook also has a partnership with Unity to publish apps to its store quickly.

This shows the importance and potential augmented reality has as a whole. In regards to other fields, augmented reality has proven to be one of the best training tools for the construction industry. Microsoft has also touted its Hololens development kit as a we initial limitations proved futile, while further research vastly opened the application to be used across multiple android and apple devices. The interface is also straightforward and intuitive without cumbersome menu options. The culmination of knowledge in app development with the integration of newer hardware capabilities has been able to provide a tool that will aid in treating lateropulsion along with traditional therapy

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