Multidimensional Data Visualization in iOS Using Google Cardboard

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***Abstract*—Birdboard is a virtual reality application for Android utilizing Google Cardboard that creates an interactive diorama of the environment for overhead view and exploration. Using Unity, Birdboard has now been successfully ported to iOS so that the application is available to a wider audience. Additionally, several new features such as natural background environment audio as well as improved visual assets have been added to enhance the immersive experience for the user.**

I. Introduction

Project Birdboard is our take on bird data visualization through virtual reality. The project was originally started to help with conservation and environmental issues. A user can utilize this application to view information about the various birds found in and around Columbia Missouri. This product is supposed to be an open source, under the Attribution-Noncommercial License. It's a virtual reality system that currently runs on mobile devices with the use of Google Cardboard or other similar virtual reality headsets.

How the application's software works is the system implements gyroscopes and motion sensors for tracking head, hand, and body positions when exploring certain locations for birds. The system also provides small screens for stereoscopic displays when viewing the bird data and uses lightweight and fast processors for optimal performance when utilizing the device.

As of now the application is working for both Android and iOS devices. Either portable device can be inserted into a VR headset and allows users to experience the application. The program has been modified to have the user experience an immersive forest environment while wearing the Google Cardboard or any virtual reality headset.

There are a lot of main features that are included in the Birdboard. The software has a menu screen that opens at start that gives the users different options to explore the program. From the menu screen, the user will experience most of their time in the Table View and World View that will be discussed later on the paper. The software also included an Instruction Page for users who isn't experienced with virtual reality and to give experienced users direction on how to use the program.

II. Literature Review

A. Google CardBoard Overview

Google Cardboard is a virtual reality platform that was developed by Google. It was released on June 25th, 2014 for use with compatible mobile phones. It is compatible with both iOS and Android operating systems, as long as the portable device has the capabilities to use 3-Dimensional features. It is very simple to use and inexpensive. All a user needs to do is buy or obtain a Google Cardboard virtual reality device, start the virtual reality software, input their device into Google Cardboard, and begin playing.

B. Why Google Cardboard?

For our project, Google Cardboard is used to immerse the user within a 3-Dimensional environment. Our application lets the user feel as if they are surrounded by a forest while viewing information about the birds found in the specific area they are viewing. Google Cardboard is also a perfect fit for an academic setting due to its low cost and easy to use hardware. Currently, Google Cardboard supports many applications that are also supported on its more expensive and complex counterparts, the Samsung Gear VR. In essence, anything the more expensive mobile hardware devices can do, the Google Cardboard VR can do as well.

C. Developing for Google Cardboard

Developing for Google Cardboard is relatively simple. There are various programs that can assist you with developing your application such as Unreal Engine or Unity Game Engine. For our project, we used Unity. Unity allows for an easy transition from a non VR project to a VR project by having you import the necessary packages and then adding the necessary code to your own scripts that tie to the objects in your application. Unity also allows the developer to make their application for either Android, iOS, or both by simply choosing the platform the developer wants and then running and building onto that platform. Once the developer creates their application, they can add it to the device of their choosing or they can upload it to the Google play store so that others may enjoy their application as well.

D. Google Cardboard Advantages

Google Cardboard comes with several advantages. One advantage is Google Cardboard's low cost. According to Technavio.com, Google Cardboard is one of the major reasons for growth in the virtual reality market. The device is made out of recycled paper and the lenses are made from plastic [5].

Another advantage is there are a large number of vendors producing the device. Many vendors take advantage of the low entry barriers that allow them to place their cardboard VR device on Google's website [5].

A third advantage is that it is easy to setup and use. It is one of the simplest headsets to begin using out of the box. You can buy the unassembled version and easily assemble the device in minutes. You can also purchase a premade version if you do not feel like doing the assembly yourself [5].

E. Google Cardboard Drawbacks

Although easy to use and cheap, Google Cardboard doesn't come without some downsides. One downside to using Google Cardboard is that some of its hardware versions are not comfortable. There is not a lot of padding around the outer edges that go around a user's face compared to other hardware like the Samsung VR. Another drawback is there is some performance downgrade when comparing applications across platforms [1]. Also, when using Google Cardboard, many users find themselves holding the device in place with their hands, unless they can comfortably alter the strap [1].

Another issue that can arise is that Google Cardboard is not one size fits all unfortunately. We know that phones that are 5.5 inches can fit into Google Cardboard and work properly. Due to the size of some phones, the application and hardware would not be able to work in a cohesive manner.

F. Other Google Cardboard Initiatives

Due to its wide availability and low cost, many developers looking to develop an AR application can utilize Google Cardboard to begin their endeavors. For our project, the original project gives conservation information on various birds found in a part of Missouri. Research shows that VR technology can help with conservation of wildlife and even languages.

A study from Stanford's Virtual Human Interaction Lab, shows that virtual immersion can influence attitudes and behaviors in the physical world. Using immersion, users can embody the experience by seeing, hearing, and feeling cues linked to the experiences they get in 3D immersion. Being immersed creates a sensation of the user actually feeling like they are physically in the 3D environment [3].

Studies explored the effect of a user's immersive experience on pro-environmental attitude and behavior by having users cut down redwood trees as a result of not using recycled paper products. The researchers also put focus on investigating each individual's' capacity to feel like they are perceiving their experience as real. The research concluded that users exhibited pro-environment behavior although their self-reports contradicted a pro-environment stance [3].

Over the past 15 years, these researchers from Australian universities have been taking recordings of languages from the Pacific islands and digitising them and putting them into an accessible database of endangered languages. There are upwards of 850 different languages that have been recorded and stored by the researchers [2].

Dr. Nick Thieberger, Dr. Rachel Hendry, and Dr. Andrew Burrell took the media files and turned them into a virtual reality experience. The application allows a user to travel over the Pacific Islands and view various points that emerge from different islands as white beams. When a user selects a beam, they are able to hear language spoken at this particular point on that island [2].

The current application is only on display in select museums in Australia but the team is actively working towards a mobile phone version so that they can utilize Google Cardboard. The team hopes to use Google Cardboard to bring the experience to remote communities. The team is hoping that VR technology like Google Cardboard, will help them record and save languages that are at risk of extinction [2].

Both examples of conservation can help boost the efficacy of an application like Project Birdboard. Due to more and more industrialization across the globe, the future of conservation could be dependent on technology like Google Cardboard and 3D immersion. This technology can give users a first hand experience on the importance of conserving our wildlife, cultures, and planet as a whole by immersing them to give them a personal experience that can actually change how they perceive the real world.

G. Future of Google Cardboard

While Google Cardboard and mainstream virtual reality is relatively new, companies are always hard at work developing newer technologies to improve user experiences. Google already has another product called Google Daydream that uses cell phones in the way Google Cardboard does. As long as portable devices continue to advance in power, Google Cardboard will be able to weather the storm of advancing VR technology.

III. Proposed Solution

With Unity's asset library, we can add to the immersive aspect of the application. Unity also allowed for us to transition the application to iOS by creating a build through Unity's build and run settings.

A. Adding Immersion

We were able to add forestry to the Table view seen and to the World view scene with the help of Unity's built in assets. Unity has a landscape painter option that lets developers pick the type of tree they want to use in their forest and then add several treas at once. This helps keep the application free of excess information due to the actual data size of each tree. In the Bird data view scene, we added a body of water, by utilizing Unity's terrain builder, as well as the tree assets. No extra coding was needed to add to the environment.

We also added sound to the Table View and to the Bird Data View. Unity allowed us to add audio to the scene by placing an object into the scene and adding a MP3 clip to that object. The sound was attached to both the Table View and to the Bird Data View. At the moment, the user only needs to choose to view those two scenes in order to begin hearing the audio. Currently, there is not a way to turn off the audio within the application but the user can adjust the media volume on their mobile device.

B. Porting to iOS

We solved the requirement of porting Project Birdboard to iOS by utilizing Unity's built in function that allows a developer to build and run their application across various devices. All a user needs to do is go to File > Build Settings then choose the platform for their application to run on and

Unity will create the necessary packaging for that device to run the application. Unity also allows for automatically putting the application onto a particular connected device as long as the device is in developer mode and the user checks Autoconnect Profiler and Development Build; this is usually used for debugging purposes.

By Unity building all of the needed files for the application when building on IOS, the project didn't need modification in regards to IOS specific code. Although, the project did run into issues while porting to IOS, these issues were solved by removing outdated dependencies such as Gaze Click and updating the Google VR library. This may change in the future as google continues the development of the Google VR library. As google aims for better support of the Google Pixel VR device with Android we believe that Google may focus on Android support or may even drop support for IOS altogether as it seems that the current market for VR on IOS has not changed dramatically since Google Cardboard was introduced. The tendency for the mobile VR market to lean in Android's favor may be due to heavily supported VR devices such as Google's Pixel phones and Samsung's GearVR. Apple has yet to make an attempt at native support for the iPhone although that may change in the future.

While no modifications to IOS specific code needs to be modified at the moment, it is always a possibility that this will change in the future. If IOS code modifications the future teams will need a student who is efficient in the Objective-C and Swift programming languages as well as core knowledge of the Cocoa concepts. These changes will need to take place on an Apple computer as the development platform for IOS/OS applications, Xcode, is only supported on Apple made computers.

C. Data Point Selection Refactor

The final modification that was made to an application was a code refactor involving the way that the application loads the wiki data to be shown to the user after selecting a point on the table view. This part of the application needed to be refactored in order to become scalable for future teams.

Before the refactor when a user selects a point on the table view the application loaded the worldview scene which was a larger version of the map in the table view. This then grabs the information from a point on the map based on name of the selected point on the table view scene. Data is not loaded from a file or database directly but from the points in the world view scene. This created some issues when we wanted to change the world view scene with a table view scene. The application needed a better way to inject data between scenes.

The refactor work laid down the foundation for future scaling of the application. This was done by sending the needed information for loading a wiki page to the forest scene from the table view. In Unity all objects are deleted upon transition from the current scene to another scene. A persistent object was needed to inject the data between scenes, a data point manager class. Using the singleton pattern with C# we were able to reach this objective.

IV. Results/Performance Evaluation

Since little to no new code was added to implement the required features. Our testing procedures involved running the application on the mobile devices to check for compliance between our added features and the specific mobile device, such as Android or iOS.

A. Testing Added Features on Android

To test the added features on Android was our first objective since the application was originally developed for Android. We also did this in case we ran into issues in the future with iOS. This made sure that the application would at least be fully functional on its original platform.

We utilized a Samsung S7 Edge mobile device to place the application on so that we could test the added features. The added features work completely on Android devices. Some minimal loading times were added between the scenes that had added features such as tree, sound, and other terrain assets.

B. Testing Original Features on iOS

In order to test the original program on iOS we created an iOS build with the help of Unity's build and run settings. With the application on the iPhone, we went through each scene to test the functionality of the application. The original program works the same on iOS as it does on Android.

C. Testing Added Features on iOS

In order to test the added features on iOS we created an iOS build with the help of Unity. With the application on the iPhone, we went through each scene to test the functionality of the application's added assets like a MP3 sound clip for each scene and added tree assets to give the feeling of immersion. Most of the added features work on the iOS build. We will discuss what issues arose later in this section.

D. Results

Our results were mostly favorable. The application is fully functional on Android devices and does work on iOS devices with a few hitches that do not remove from the intended requirements such as immersion. Due to the simplicity of the tree assets, there is a noticeable difference between them and paid for assets when it comes to the realistic feel of the application but due to budget constraints, only the free assets were implemented in the final version.

On each device, there was a minimal addition to load times while transitioning between the Menu View and the Table View as well as transitioning between the Table View and the Bird Data View. These additions to the loading time are contributed to the addition of the landscape assets and audio asset. These increases in load times were expected.

a. Issues with Original Features (Gaze Click)

Originally, the application implemented Gaze Click in order to let the user select from the different options and to select data points. Due to Gaze Click being a paid asset, our team decided to remove it due to limited funds and possible issues with it working on iOS. The user can now use either the touch feature or their device's click feature in order to choose an option.

b. Issues with Implemented Bird Data View Solution

After adding a new scene to the program to take over the original Data point view, we ran into issues with certain points not being able to be selected on an iOS device. Another small issue is that the Next and Previous options cannot be selected on iOS devices. This issue does not interfere with the user being able to go back and forth between the Bird Data scene and the Table scene. We believe that for this issue to be resolved, Google must update their Google Cardboard software.

V. Conclusion and Future Work

Substantial improvements have been made to Birdboard both quantitatively and qualitatively and it will prove to be a unique and powerful immersive experience for future users as well current users. By porting the application successfully to both iOS and Android, a much larger user base will be able to enjoy and learn from the application.

A key component of current progress has hinged on the notion of "immersion". The vision for Birdboard is to not be purely an informational transaction but an embodiment experience. The improvements made to Birdboard are consistent with and make significant progress towards this vision. To exemplify this notion of immersion ambient background audio was added to aid in creating a realistic scene for the user. This audio consists of unsynchronized natural sound that you would expect from a wilderness experience, and when looped allows for the constant background noise that adds an exciting element of realism. Additionally, by adding a diverse range of tree assets and other natural characteristics the environment will seem much more expansive for the user and will reflect the variety that one would expect.

As exciting as recent improvements have been, the direction of future work holds many more interesting and creative possibilities. Birdboard and its goal of immersion are open-ended allowing for a large number of additions and improvements. As such it will not be possible to explore all further directions, but a few will be discussed to aid in its development and hopefully prevent getting lost in how impressively open-ended the project can be.

A. Bird Calls

There are still many avenues to add to Birdboard's distinct immersive environment through a variety of physical assets ranging from rocks, trees, streams, brush, bushes, paths, or perhaps even insects. A more directly beneficial addition would be including audio for the specific bird calls that the user can interact with and learn about. This not only adds to the feel of the environment but also communicates further specific information in a fun and interactive manner.

B. Actual Physical Location

Additional realism can be obtained by modeling the virtual environment off of the actual physical region in Missouri that Birdboards use was originally intended. By giving the user specific and recognizable landmarks and physical characteristics they can feel both excitement and familiarity with Birdboard from its first use.

Unity allows for 3D representations of actual land formations by using other software like Max, Maya, Blender, Cinema 4D, Modo, Lightwave and Cheetah3D. Advantages of using one of these is that updates made to the original model are automatically imported into Unity [4].

C. Google Maps

Furthermore, Birdboard could be tied in with Google Maps to add an additional element geographic realism, allowing users to develop an experience integrated with that of other users by labeling, tagging, or otherwise documenting locations (and/or birds) in ways that allow interaction between uses and across the user base.

D. Adding a Social Aspect

In recent years, the collective shared experiences of many video games has become their primary selling point to the extent that many games specialize solely in this experience. Users love to interact in a virtual environment with others benefitting from others interaction as well as other users benefitting from their interaction. Tapping into this social aspect of the virtual world could take advantage of an already massive and accelerating trend. When one user can tag specific virtual elements positive feedback loops are created that facilitate further interaction and draw the attention of other users.

Implementing a social dimension to Birdboard can have a massive impact, the positive consequences of which cannot be understated. Further, due to its informational and educational role Birdboard could prove to be groundbreaking by blazing a trail for future educational and informational experiences to be shared experiences amongst others in an exciting environment.

E. Billboard Addition to Table View

Currently locations to view are chosen looking down on a table view of the map so that users have to disengage from their environment in order to change locations. By changing

the map into a billboard style element in the environment the users can have a fun and immersive way to change locations as well as view their current location in relation to the overall setting without having to detach from the enjoyment of the surroundings.

This also aids the user's view of the map by allowing them to view it in its entirety due to the increased distance. As of now, the table view can feel cramped and must be rotated by the user selecting one of the colored dots around the periphery of the circular table on which the map lays. The continual and repeated downward directional movement for selecting locations can grow to feel repetitive and mildly claustrophobic while, again, the billboard styled map allows the user to maintain their expansive view with drastically less head movement required.

F. Player Movement

Lastly, the majority of current virtual reality applications allow the user to move around within their environment. The more advanced VR hardware has movement pads located on them but the more simplistic devices such as Google Cardboard, have simple ways of clicking the screen. There are currently Bluetooth remotes that would give the player the ability to move around in their environment.

Some applications also give the user the ability to move to specified marks within the application. A user chooses a point and then the application moves them to that point. This could be implemented in Birdboard by letting the user transport between bird data points in the world scene instead of the user having to go back to the table view in order to choose another point. With the addition of a 3D rendering of the actual location, a user would be able to view the rest of the map while traveling from point to point.

By including this simple addition the user experience can become more flexible, smooth, and streamlined in its approach. The user would no longer have a break in the environment by relocating but could follow a smooth transition which further allows for and even encourages exploring. This exploratory nature is much more consistent with the vision for Birdboard by fostering a curiosity which can quickly be rewarded by the user taking the next logical step.

Simple movement such as this is also very natural and its absence is felt most notably by the user because it is predominantly one of the first interactions that a curious user will try. Fostering this nature of curiosity and exploration will serve Birdboard well by including instinctual human actions into its design. The user should not feel hindered or restrained in his or her use of the application so allowing the user freedom should be one of the top priorities.

G. Final Remarks

Conservation of wildlife and forestry has become a major issue in the world today. Project Birdboard's future could be shaped to become a major player in the fight against diminishing habitats across Missouri and the entirety of the earth eventually. Adding the future features we mentioned as well as having a version of Birdboard ready for every piece of VR hardware, could really help set Birdboard up for success.

Birdboard has proven to be a fun and informative application that shows enormous potential for both its specific use and for paving the way for future applications. The recent additions of a diverse range of physical assets, natural background audio, error handling, and streamlined processes have all made substantial contributions in furthering Bird Board's user experience and it has an exciting future ahead of it.

By implementing some of the previously suggested changes Birdboard can be a groundbreaking application that blazes a trail for how we learn, interact, and view our environment. This project has a history of nursing healthy am ambitions whose potential is now paying off in a beautiful and creative endeavor.

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