CPI 441 Gaming Capstone - Linear Algebra Game

Extended Abstract

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Figure 1: *Main Game Menu*

ABSTRACT

Vector Unknown is an ongoing project that has been a work in progress for several semesters. The game is a collection of several linear algebra-based puzzles, with each level focusing on a different concept. The purpose of the game is to provide college students with a more engaging way of learning linear algebra. One level deals with linear spans, two levels cover vector displacement, and the cannonball game focuses on matrix multiplication. The art style of the game is low poly and has a pirate theme. Previous semesters saw the bulk of the game's creation, so our task this semester was to improve the project and get it into a better state, both gameplay wise and behind the scenes.

1 INTRODUCTION

1.1 Project Introduction

Our sponsors for the project were Ashish Amresh, Michelle Zandieh, and PHD student Jeremy Bernier, all from ASU's math department. We established communication with them early on and were able to schedule a weekly meeting time that worked for everyone. We were very consistent with these meetings, with every member able to attend every meeting, with some absences here and there. Our sponsors wanted us to focus primarily on improving the existing project, since it is an ongoing project and not expected to be 100% completed yet. However, they did open the door for

us to make any additions that we felt would improve the game or would better teach linear algebra concepts.

1.2 Technologies Used

Unity 2019.3.1F1

The game was created in an older version of Unity, so at the beginning of the semester we updated to a newer version. Unity is a popular game engine for the creation of both 2D and 3D games. Unity is free for personal use.

Github

Github is an online repository where people can upload code projects and manage version control. We used it to obtain a copy of the original game and then created separate branches where we staged our changes. Unity has Github integration built in.

GitKraken

GitKraken is a project management tool that works in unison with Github. The tool allows teams to create and assign tasks and keep track of a project's progress.

Microsoft Visual Studio

Visual Studio is an Integrated Development Environment created by Microsoft for coding and software creation. We used it to create all of the new scripts and edit existing scripts for the game. Unity scripts use C# and comes with Visual Studio integration built in.

3DS Max

3DS Max from Autodesk is a 3D art creation tool good for creating 3D models and animations. We used it to create our new art assets for the game.

2 Game Changes

2.1 UI Overhaul

Our first major task involved overhauling the UI. The existing UI was stylized to fit the pirate theme of the game, but was not very readable. The font was a script type font and some of the sizing was either too small, or too big depending on where it was. We resized the font so it was more consistent across the game. We also changed the font type to a sans serif font so it would be readable to every possible user. Some elements were color-coded to make gameplay more intuitive, such as the matrices in the cannonball level. Redundant elements were removed. Several changes were made to the tutorial UI to make it more accessible to newcomers. New dialogue was added in the Hub World to explain the goal of the game to the player. Additionally, there were several UI-specific bugs that were persistent, and we fixed these.

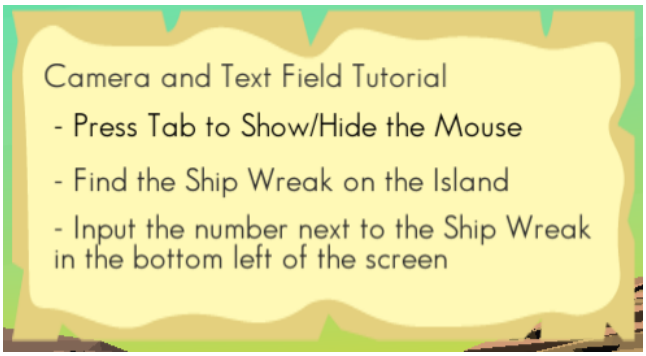

Figure 2: *New UI*

2.2 New Level

Another one of our tasks this semester was creating an entirely new level for the project. The level initially was meant to replace the existing vector displacement level, but our sponsors recommended having both levels in the game. The level functions similarly: the player reaches impassable chasms where they are to input the correct vectors in order to cross these chasms and successfully complete the level. We created a basic grapple-hook system which is how the player crosses the chasms, whereas Level 1 uses ramps and bridges. The level was built from scratch but its scripts were derived from Level 01's scripts. Within the level, there are 3 stages, with the first 2 working in 2D spaces and the third being a 3D space. A new camera system was created for this level that combines a side scrolling camera with a freely rotating camera which allows the player to both focus on the math that needs to be done, as well as look around the environment. The final addition to this level was the grid system. This system was developed specifically from feedback received from our sponsors. Early on, they felt as though it was difficult to understand the levels from a mathematical standpoint. The grid system, which can be toggled on and off, brings up a grid overlay that represents the 2D or 3D space in which players are working from. Combined with our visual vector representations, players can see exactly how they are manipulating vectors and what they need to do to reach the goal points.

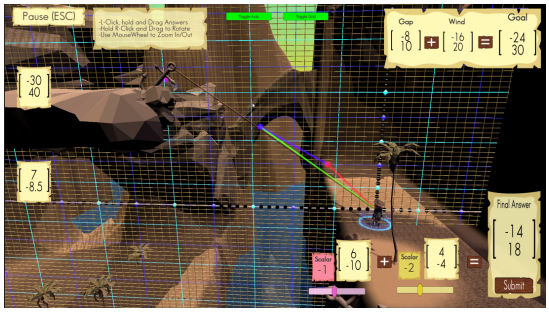

Figure 3: *New level, Level 04*

2.3 Hub World Structure

Our other major new addition to the game was breaking up its linear structure and creating a hub world. Having a hub world gives players the option of selecting a specific level they want to play, and by extension selecting what linear algebra concept they want to cover. Previously, players could only progress level-by-level and could not progress to other levels until successful completion of the current level. If they wanted to select a specific level, they had to keep playing until they reached it. Players select levels by passing through portals, with each portal leading to a different level. We also added some story elements to this change as well. The player is a pirate stranded on the hub world, which is an island. Completing levels gives them pieces to repair a damaged ship off the coast. Once all levels are successfully completed and all ship pieces collected, the player can board the ship and escape the island. The player's progress is shown to them using the ship model. The ship's condition varies based on the level of completion, with it being battered and broken with no levels completed and slowly improving in appearance as levels are completed. When all levels are completed the ship model is complete and in good sailing condition.

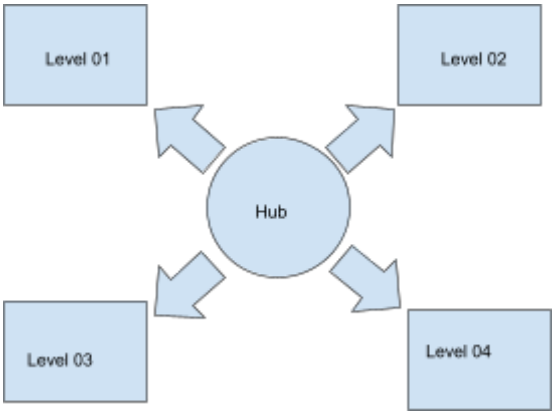

Figure 4: *Hub World Structure*

2.4 Level 03 Upgrade

Our final major change to the game was for Level 03, which is a linear span game. The game was finished but had several major issues. The goal of the level was not very clear to the player mainly due to the camera's placement. We moved the camera from behind the player to a more overhead position, which allows the player to more clearly see the puzzles. We also added a minimap in the corner that displays the vector span so it is visible at all times. Players can also view the span by simply tilting the camera upwards. Additionally, some of the math was incorrect. We changed the way players input vectors. Originally, players would select from a handful of vectors. This required a lot of guessing and trial-and-error if appropriate math knowledge was below par. We updated this so that one of the correct vectors is given to the player, and they select the second vector needed to complete the rotation.

Figure 5: *Level 03 after improvements*

2.5 Minor Changes

In addition to these major changes, we also made minor changes and fixes to the existing levels and some additional quality of life changes. We fixed numerous bugs and issues that were persistent on each level. Collision in particular was problematic in some areas, causing the player to get stuck in the air. Player movement was also improved to make traversal more enjoyable. We also created a new stage for Level 02 so players can continue practicing with the level's math concept and take on more challenging versions of it. We also did a host of general bug fixes and usability fixes to make both playing the game and further development on it more manageable. Additionally, we made several QOL improvements. One such fix was adding in keyboard controls for camera movement to support laptop

users, as well as improving the game's tutorial to better instruct non-gamers in how to play the game.

3 Results & Feedback

3.1 Results

Our work this semester was inline with what our sponsors wanted from us. We improved and added to the existing game while retaining the core of what was given to us. We greatly enhanced the games that were already playable, and added a new game that will allow for further exploration of linear algebra concepts. Our QOL changes have made the project more accessible and will help it resonate with a large audience. The project works as well on laptop as it does with a keyboard and mouse. The additions we made to the tutorial will allow users with little to no gaming experience to better understand how to play the games.

3.2 Feedback

Our sponsors are thrilled with the work we did on the project this semester. We had 3 sponsors, each with different levels of gaming experience so we got a really good sampling of how the project will be received. Michelle has almost no gaming experience and had trouble with the game's basic functionalities at the beginning of the semester, but was able to understand how to play at the end of the semester because of our additions like the enhanced tutorial. Jeremy and Ashish both have more experience playing games so gameplay was more intuitive for them from the start. All 3 of them really liked our additions and fixes, as well as the new level we produced. They felt as though it blended in seamlessly with the existing games and will be beneficial to the project going forward.

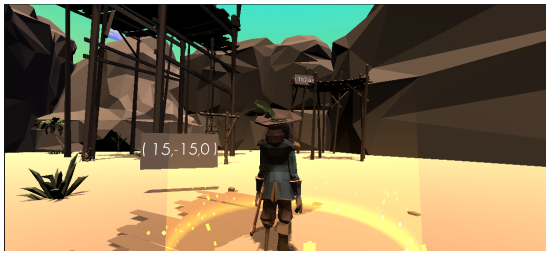

Figure 6: *Level 01.*

Figure 7: *Level 02*

4 CONCLUSION

In conclusion this was a very productive and ultimately successful semester. We were able to make consistent progress and accomplish our goal, which was to deliver the game in a better state than what it was at the beginning of the semester. We made several QOL changes that improved what was already there. We have left the project in a good state for the next group that works on it so they can continue and hopefully finish the game. Our new major additions enhance the overall product and will help facilitate Ashish and Michelle's goal of providing students with an entertaining and engaging way to learn linear algebra.

5 ACKNOWLEDGMENTS

This project was made under the supervision of Ashish Amresh, Michelle Zandieh, Jeremy Bernier, and Yoshihiro Kobayashi, in association with Arizona State University, with funding for the project provided by the National Science Foundation.

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