Johan Wittmers - 480648

Movella™

Design Aspects for Technical Demonstrations

A process of emphasizing design elements of interactive demonstrations for high-tech hardware in video games

Abstract

The following readable informs about the use case of motion capture technology developed by Movella inside a videogame development pipeline. By demonstrating the key features of the technology and the corresponding reasoning behind the design choices, this paper analyses and summarizes the necessary development steps to develop a convincing interactive product for demonstration purposes. With the support of a developed product, design thinking and testing, the areas of importance include accessibility, look and feel, feature highlights, new technologies and universal stability across hardware. These key factors of design effectively incorporate all necessary design choices within a technical demonstration and lead to a successful product.

Contents

1   Introduction

1.1   Movella

Movella (formerly known as the separate company Xsens) is an international high-tech company, which focuses on the development of motion tracking via motion sensors. Not only does Movella's team focus on the entertainment industry, which this paper partially emphasises on, but also on health, fitness, and automation and mobility. Movella has built a brand around their motion sensor soft- and hardware, creating a trustworthy and well-known brand and product. With an ever-growing market, Movella expands their customer base rapidly and requires research and investigations into fields they have not yet had the spare resources to further deploy into, which includes the integration and documentation of utilizing motion capture for game development.
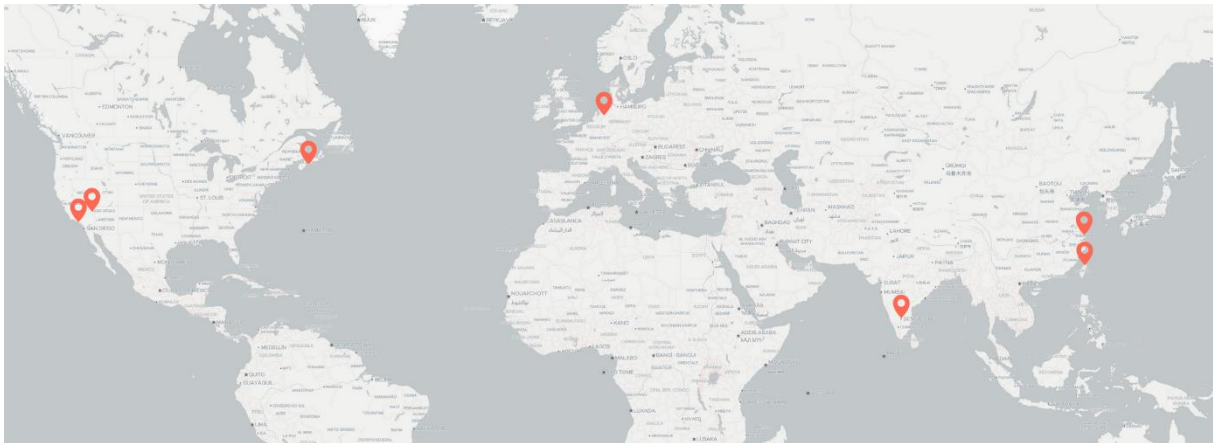
Figure 1 Movella's global network of support and developers. Locations include Canada (Halifax), USA (Los Angeles, Henderson), India (Bangalore), China (Shanghai, Taipei), Netherlands (Enschede)

Movella seeks the new possibilities provided by functionality inside the game engine Unreal Engine 5.1[1] and game development processes to further increase their expertise and provide better and precise customer support all over the globe.

1.2   Researcher

The researcher focuses on the design and development steps necessary to create motion in video games with the support of motion capture data. Additionally, as a technical artist, the interest lies with the use case for motion capture technologies outside of the cinematic industry. The integration of new technologies into a game development pipeline can provide knowledge for both the researcher and the end-users of Movella products.

These ambitions are planned out and align with the goal of the companies wishes during the graduation period. Developing solutions within the entertainment industry and specifically game development, helps provide better insights for the researcher's colleagues and therefore improve overall user experience.

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[1] *Unreal Engine 5.1 is a game engine that provides developers with pre-built tools and resources to simplify the creation of video games. It offers features for graphics rendering, audio management, and user input, allowing developers to focus on designing gameplay mechanics and creating game assets.*

1.3   The Product

The researcher collaborates with Movella to develop an interactive technical demonstration that combines their respective goals and ambitions in the gaming industry, particularly regarding motion capture technologies.

This final product includes a multipurpose playable prototype that incorporates the three features of Movella's software (Drag-and-drop, live-link, and locomotion) in an engaging and demonstrative way. Alongside the final prototype the researcher provides an analysis which highlights design choices and crucial aspects of a technical demonstration.

1.4   The Goal of Research and Product

The goal of the conducted research and the product includes the demonstration and possibilities of motion capture animations within video games and specifically Unreal Engine 5.1. However, this goal also includes the education of the employees and clients of Movella via the form of documentation and tutorials, to focus on workflows and prevention of errors during the process.
To achieve the research goal, the paper will address the question: "What design choices are necessary for a successful product?". This inquiry is pivotal as it directly relates to the product and will be the central focus of the research.

2   The Problem

Lacking documentation and features inside the MVN software (such as root motion[2] integration) creates difficulties for video game developers and animators to purely rely on motion capture animations for their characters locomotion and interaction systems without prior knowledge as animators.
The growing tooling for animations in game engines, such as the Unreal Engine 5.1. retargeting system (Epic Games, n.d.) and advanced animation blueprints (Epic Games, n.d.), provide the clients of Movella with new technology for development. However, this can lead to challenges for both clients and end-users of Movella's products during the development process. Recognizing this, Movella is committed to enhancing support to address any difficulties that may arise.
This research aims to investigate the necessary features that need to be showcased within a technical demonstration to inform the audience within the MVN entertainment market. Movella has not developed an interactive prototype that showcases their technology in the newest version of Unreal Engine and therefore wishes to dive deeper into the possibilities.
The connected prototype showcases the possibilities and translate the theoretical elements of this research paper into a practical prototype.

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[2] *Root motion refers to a technique in game animations where character movement is driven by the motion of its root position. It enhances realism by incorporating the character's entire body movement into animations, resulting in more natural and dynamic motions.*

3   Research Objectives

The goal of this research is to assess design choices for creating an immersive video game prototype using Movella's motion capture technologies. This involves integrating a live-link system through the new Live-link Plugin for Unreal Engine 5.1, developing a locomotion and movement system for the main character with the suit's assistance, and creating captivating scenes with NPC (NPCs) by exporting animations from MVN Software directly into Unreal Engine 5.1.
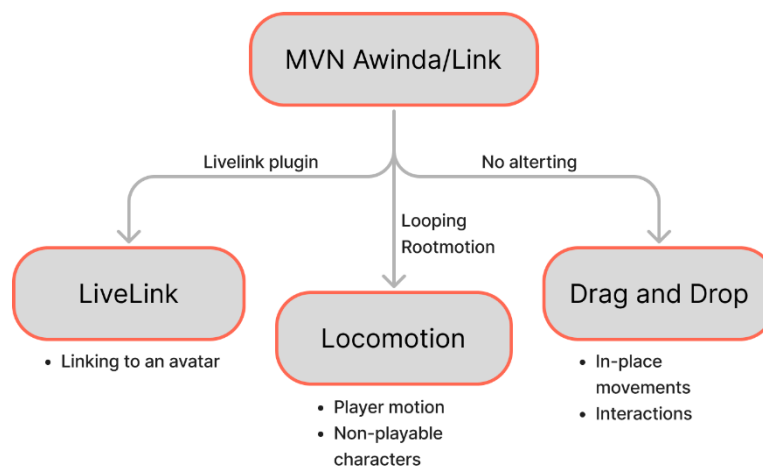
Figure 2 The use cases for MVN Awinda/Link recordings inside the product and Unreal Engine 5.1

Utilizing qualitative data from research, such as surveys in connection with playtest sessions, the researcher assures a positive development cycle during this project and its related research and an inclusion of both the client and employees at Movella, which are included in the end-user.

4　Design Methods

The process of designing an intricate technical demonstration requires the decision between two major design processes: Design thinking and the design diamond. These two methods of design underline a different approach of creating prototypes and final projects.

The design thinking method is a user-centred approach and focuses on empathizing with its end-users, defining the problems they have, ideating for solutions regarding the problems and then prototyping and testing those solutions.

In summary, the design thinking method is constructed by the following steps, where prototyping and testing may reoccur during production:

- Empathize: Collecting insights of the end-users, gathering needs and wants.
- Define: Conclude a specific problem that needs to be addressed.
- Ideate: Gather solutions for the problem the end-user's encounter.
- Prototype: Based on ideated solutions, create testable prototypes.
- Test: Gather test results of prototypes and iterate on the project.

Figure 3
The Steps of Design Thinking Visualized
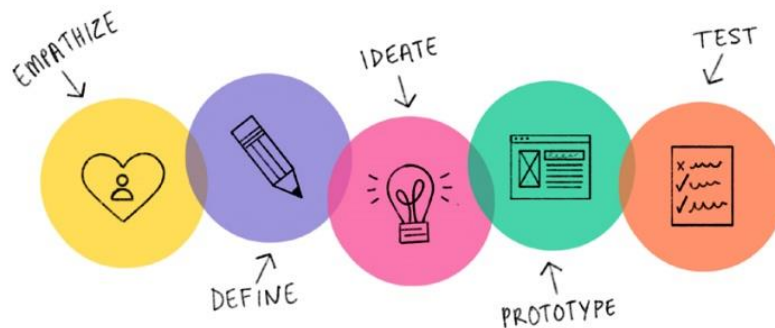
Note. By eurobit, 2023, graphic

The design diamond on the other hand, focuses on the specific problem and its possible solutions, while refining the outcome.

To summarize the workflow of the design diamond:

- Discover: Collect information regarding the problem.
- Define: Conclude a specific problem that needs to be addressed.
- Develop: Create a range of solutions for the specific problem.
- Deliver: Refine one of the developed solutions into a final deliverable.

Figure 4
The Design Diamond Method Visualized
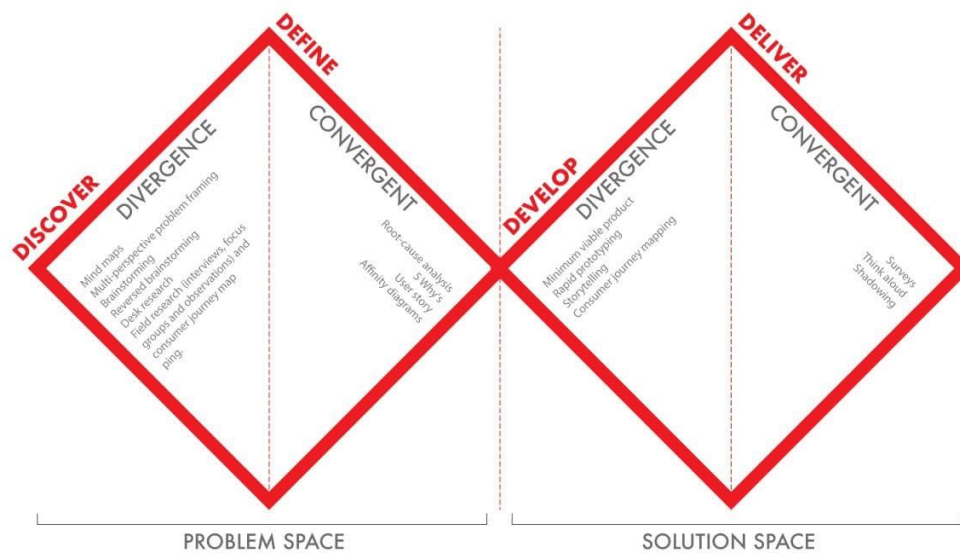
Note. By Dr. Rafiq Elmansy, graphic

4.1   Design Method Conclusion

When comparing product design methods, design thinking prioritizes user needs and involves them in the development process. In contrast, the design diamond focuses on identifying solutions for the initial problem. Design thinking generates a wide range of potential solutions for end-users, while the design diamond develops multiple solutions and implements the best one directly.

For motion capture animation research and technical demonstration, choosing the right design approach is crucial. Both methods are suitable for thorough research to address the research question. Design thinking involves end-users more in the development process, while the design diamond allows for refining a solution to a specific problem.

Design thinking is commonly used for underdeveloped problem definitions, requiring a creative approach. It is particularly beneficial for developing interactive prototypes in the gaming environment and gathering input from end-users.

In summary, the choice of design method lays the foundation for research and development processes in answering the research question. Given the focus on customer support and understanding client issues in the Movella department in Enschede, design thinking, with its emphasis on end-users' needs and expectations, is the most suitable method for both answering the research question and developing an effective prototype.

5   Empathise

5.1   The End-User

To comprehend the market, the researcher divides end-users into two groups: Internal Movella employees and external customers. External customers are crucial for company growth and funding, while the internal use case of this prototype enhances customer support and understanding by explaining processes and potentially offering additional training.

The following table below briefly demonstrates the main differences between the end-users:

Table 1
Comparison between the two end-user possibilities.

External Use (Clients)	Internal Use (Training, Workflow)
Advertising possibilities and versatility of the motion capture system. **Interactive demo** with the potential of customer engagement. - Social media **promotion** of an internal product developed by Movella itself. - Accessible **information** about the development process. - Technical **demonstration** of system integrations.	**Better understanding** of the newest possibilities within entertainment. **Replicating processes** for easier customer support. - Wiki articles for **quick recognition** of problems for Product Specialist, Marketing and Sales. **Tutorials** to provide to customers. **Bug** discovery and tracking. **Back tracking** of customer issues.

5.2   Needs and Expectations

As this project involves two defined end-users, there are two sets of needs and expectations, where the external users are in focus during the research and development.

5.2.1   External Use

The external user directly benefits from a playable and interactive demonstration. This includes better understanding and incorporation of motion capture animations into video games, resulting in an engaging and interactive experience. The prototype showcases the possibilities of the suit within a game development environment and therefore provides information regarding the process and its final integration, potentially growing an interest in the technology. The client expects this technical demonstration to thoroughly showcase the possibilities and limitations of the motion capture data and the appeal of utilizing it in their development process, as well as showcase the creation process starting from recording animations within MVN to creating locomotion inside Unreal Engine 5.1.

5.2.2   Internal Use

For an internal use case, the needs arise for further improvement regarding their understanding of game development aspects that includes motion capture animations from recordings that utilise Movella's technology. This new gained information will help the product specialists at Movella tracing the steps of the client, to reproduce errors, target the difficulties and create better documentation for end-users. The internal user expects this development process to further increase their expertise within the entertainment industry and specifically inside Unreal Engine 5.1. This knowledge includes the utilization of new technology, such as the Runtime IK Retargeting (Epic Games, n.d.) system, advanced animation blueprints for blending and the manipulation of animations.

5.3   Technological Advancements

The motion capture integration market in video games is diverse, with applications ranging from in-game motion to cinematic cutscenes. Notably, games developed by Avalanche Studios and Telltale Games have utilised motion capture (Movella, 2017a; Movella, 2017b).
This expansive market drives technological advancements in various areas. For this research, the focus is on demonstrating interactive motion in the Unreal Engine 5.1 environment. The engine's advancement is crucial to the development process and the researcher. Notable technological advancements include, but are not limited to:

- Improved IK Retargeting for faster and more natural animation transfer between characters.
- Introduction of Runtime IK Retargeting, enabling smoother virtual production and enhanced gameplay elements.
- Deformation of motion capture recordings through foot placement manipulation on surface normals using IK goals.

5.4   Case Studies

Technical demonstrations are an important aspect of developing or advertising a new feature within the soft- and hardware market. They showcase the potential of the product in a controlled environment and in some cases in fully developed prototypes.

Aspects of technical demonstrations within the PC market may include (Tropedia, 2021), but are not limited to:

- Newest hardware pushing the requirements for the game to a limit outside of the average consumers system specifications (for instance Crysis 3 from the year 2013).
- Creating an interactive application which showcases the systems capabilities and includes the peripherals of that system.
- Creating a new interactive product that showcases a new feature created by the developers.
- Showcasing the possibilities of new hardware and its integration into an existing product.

For the case of integrating a hardware into video game development, the last three elements of the qualities are relevant to the product of Movella.

Showcasing the possibilities of motion capture integration inside video games is a quality that builds the foundation of the product and connects well into the other aspects. The new features of Unreal Engine 5.1. that provide functionality for development, allow for a demonstration of possibilities.

5.4.1   Existing Technical Demonstration

Analysing and evaluating an existing technical demonstration supports both the development process and the research conducted in this paper.

One demonstration, which showcase new technologies and workflows well, include the release demonstration of the then new Unreal Engine 5[3].

The Unreal Engine 5 demonstration showcases the newly integrated features in an interactive demonstration that any end-user can experience. It displays the functionality individually and wraps up the promotion with the combination of all features in a seamless transition into gameplay. These features include:

- Nanite[4]: The interactive demonstration showcased highly detailed environments, demonstrating the ability to handle intricate geometry in real-time.
- Lumen[5]: Real-time changes in lighting were presented, highlighting dynamic global illumination that accurately simulated lighting effects.
- Virtualized Texture Streaming: A large environment with high-resolution textures was seamlessly explored without noticeable stutters.
- Enhanced Physics Simulation: Dynamic and realistic destruction effects were demonstrated, showcasing improved physics simulation.
- Niagara VFX System: Various dynamic particle effects, such as swirling dust and flowing water, demonstrated the versatility of the Niagara VFX system.
- Improved Audio System: Spatial audio and realistic sound effects created a more immersive audio experience.
- Seamless Asset Editing: Although not shown in the interactive demonstration, the improved workflow for real-time asset editing was emphasized.

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[3] *The Tech Demo video can be found at https://www.youtube.com/watch?v=d8B1LNrBpqc.*

[4] *Nanite is a new system within Unreal engine 5. It allows the import of highly detailed models with only minor loss of performance. More information can be found at https://tinyurl.com/yhu8482p*

[5] *Lumen is the new system Unreal Engine 5 has implemented as one of their new main features. Lumen allows for real time global illumination within an environment. More information can be found at https://tinyurl.com/yfeyfkbs*

While not all these features are vital for comparison to the development of this project, it is important to note that these key elements are highlighted within the demonstration.

The flow of the technical demonstration has been precisely placed into the following order:

1. **Introduction**: The demo begins with an interior environment that showcases the possibilities of Nanites and Lumen, setting the stage for the advanced and most prominent features within Unreal Engine 5.
2. **Progression**: As the demonstration progresses, the additional highlights, such as improved audio, are introduced one by one and combined with the previous elements of the demonstration.
3. **Highlights**: Periodically the demonstration pushes the user towards spectacular possibilities of the technology, such as the high detail of 3D assets in combination with light.
4. **Combined end results**: The final showcase combines all previously introduced elements of the new technology and briefly showcases the full potential of the systems all in sync with each other.
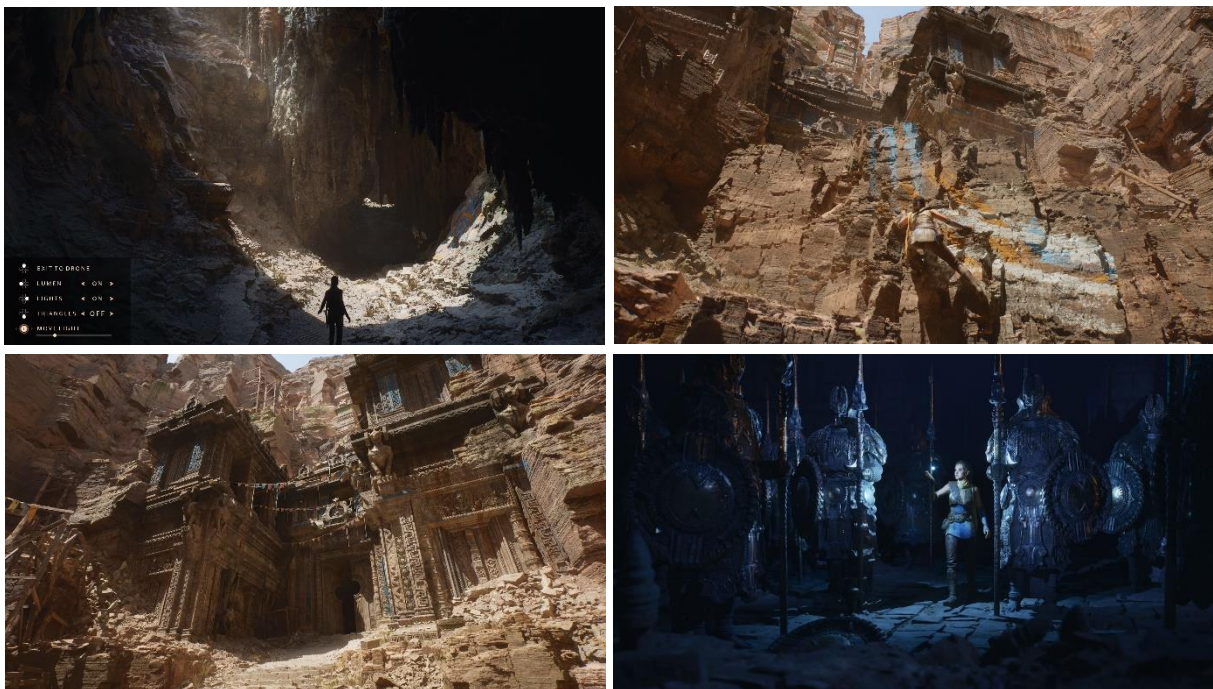
Figure 5 Images from the Unreal Engine 5.0 reveal demo. From top left to bottom right: 1. The showcase of Realtime bounce lighting; 2. The demonstration of motion warping of pre-existing animations to fit the environment; 3. The support of very detailed meshes with the support of Nanite; 4. The combination of Nanite and Lumen in real time.

5.4.2   Movella as Industry Leader

As an industry leader in motion capture technologies, Movella utilizes on-body recordings to drive avatars in their software. Being at the forefront of the industry, it is essential for Movella to develop and produce products that exemplify their leadership position and demonstrate a high level of professionalism. To accomplish this, Movella must conduct research to explore new methods and enhance the fidelity of their product's use cases. Relying solely on clients and third parties to showcase the effective utilization of their product is insufficient; Movella needs to take an active role in showcasing the full potential of their products.

5.5 Outlook

The increasing fidelity of tech demos, driven by complex systems and higher quality expectations, enables developers to create interactive media showcasing these complexities. To handle this complex data, a simplified solution like documentation can eliminate intermediate development steps and streamline workflows.

Incorporating motion capture into interactive tech demos presents both opportunities and challenges. Finding a more integrated approach to developing animations and motion in games, leveraging the MVN software while addressing its limitations, can generate new client interests. However, budget constraints in game development, including the cost of the motion capture suit, impact marketing, sales revenue, and opportunity costs for smaller companies.

Documenting the development process in collaboration with Movella employees provides valuable use cases and insights for efficiently overcoming common errors, equipping developers with a stronger foundation.

The tech demo also provides sales personnel with an interactive prototype which clearly demonstrates the capabilities and use cases of the MVN system within Unreal Engine 5.1. The prototype aims for a look and feel that will be relevant in the future and is scalable by future developments.

5.6 The Market for Motion Tracking

Motion capture technology is widely used in the video game industry with the support of varying hard- and software from different developers. Examples for companies that utilise motion capture animations inside video games are Avalanche Studios or Telltale Games (Movella, 2017).

Figure 6 Three different inertial full body motion capture systems. From left to right: Movella's (Xsens) Link suit, Rokoko's Smartsuit Pro II and Noraxon's Ultium Motion Straps with trackers.

5.6.1 Market Trend Relevancy for Technical Demonstration

Investigating market trend relevancy is a necessary step for the development of a technical demonstration which highlights all the outcomes a motion capture integration has to offer for video game development. Not only should the showcase highlight unique selling points, but also display the different methods that the developers can utilise the data, which include but are not limited to:

- Live-link motion capture integration into a gameplay element to showcase the Unreal Engine 5.1 Plugin provided by Movella.
- Drag-and-Drop features of direct integration of motion capture animations without altering the animation graphs to highlight ease of use.
- Motion system for the main character with looping animations with the support of motion capture animations to showcase possibilities with end-user input.
- The efficient deformation of recorded animations via math and scripts to create effective and immersive motion which are derived from motion capture.

As the market for motion capture includes many competing companies, Rokoko is one of the competitors of inertial motion capture[6] for the entertainment industry and specifically games. Rokoko is an affordable solution by an Indie development studio, which highlights their integration of motion into entertainment more dominantly and has authored papers and guides on how to work with motion capture data (David E. Lindberg). Investigating their marketing and sales techniques potentially leads to findings that support the development process of building an interactive prototype for Movella.

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[6] *Inertial motion capture utilizes wearable sensors to track and record human movement. It captures the body's motion without relying on external cameras or markers, making it a self-contained and portable solution for motion tracking in various applications.*

6   Define

6.1   Problem Definition and Statement

Investigating the relations of Movella motion capture technology and indie game developer by questioning product specialists for the MVN systems, the client base for their technology indicates a bigger interest for larger companies, as their investment risk is smaller (see Appendix

A windows build for the research related project can be found at
https://drive.google.com/drive/folders/1BXahgOcaWL_AViUuax7FTmJTxo9mMAea?usp=drive_link

Appendix A - Questions towards Product Specialist Stefan Beuker). This also supports the place Rokoko holds, as they offer a more budget-friendly alternative[7].

However, this problem is partially tackled by the more cost-effective solutions provided by Movella, such as the Awinda system and motion cloud subscription[8], reducing the investment by a larger sum. The lack of interest may directly result from the investments costs, but also, because Movella has not created an in-house developed prototype with their own assets and documentation. A developed prototype can highlight the suits capabilities inside Unreal Engine 5.1. This allows for the highlight of opportunities, development, and accuracy of the motion capture data within a game engine and potentially benefit the direct involvement of both parties (Movella and the end-user).

Additionally, an interactive prototype has the potential to deliver the use case for the motion capture data inside video games more thoroughly. The prototype has the potential to create more engagement with both the client and Movella and therefore could potentially increase interest in the product. A well-designed technical demonstration, which incorporates different elements of motion capture use, can benefit in selling the product to in-experienced clients.

6.2   Research Goals

This research aims to investigate the necessary features and design aspects that need to be implemented within a game and technical demonstration. The connected prototype showcases the possibilities and translate the theoretical elements of this research paper into a practical prototype. This includes the assessment of necessary design choices to build an engaging and demonstrative video game prototype that heavily utilises the motion capture technologies in different workflows.

By utilizing the qualitative data gathered from surveys and playtests, the researcher assures a positive development cycle during this project and its related research.

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[7] *Rokoko provides a full body motion capture system at a lower price: https://eu.store.rokoko.com/pages/full-performance-motion-capture-bundle*

[8] *Motion Cloud is a subscription based MVN license, allowing for faster computing time and an affordable alternative. More information at https://movella.my.site.com/XsensKnowledgebase/s/article/MotionCloud-FAQ?language=en_US*

6.3   Application of the Define Phase into a Prototype

Applying the empathized information from the previous chapter, the define phase further focuses on the application of this knowledge. This application of knowledge can be structured into four important points:

1. A vital point of empathy is the end-users needs and insights:
   - The end-users want a more immersive way of animation inside video games.
   - The end-users want an interactive prototype that is accessible and engaging.
   - The end-users want to control a character with the motion capture data in a live environment.
2. The goals and objectives within the development team are fundamental for success:
   - Develop an interactive prototype that showcases the capabilities of motion capture inside a video game environment.
   - Showcase three vital elements of the MVN system and its integration: Live-link, Locomotion and Drag-and-Drop integration.
   - Develop an immersive application that showcases how accessible the implementation of motion capture animations inside video games is.
   - Develop a stable, yet engaging technical demonstration that the end-user can use and experience.
3. The goals and objectives of the development team in combination with the end-users needs and insights comes with constraints and considerations:
   - The product needs to be developed within a timeframe.
   - The product needs to be compatible with a range of target platforms to ensure versatility.
   - The demonstration within the product needs to be accurate and reliable.
   - The product needs to be scalable, to ensure future iterations and extensions of the demonstration.
4. Stakeholders play a fundamental role in development as their trust lies within the products development span and directly influence the decision making. These stakeholders include:
   - Game Developers
   - Movella Product Specialists
   - Movella Sales and Marketing Employees

7   Research Question

The main research question guides the development process of the project, both prototype and research. It is fundamental for this question to incorporate the valuable assets of the development process and clearly demonstrates, with the help of sub- questions, what this paper focuses on.

"What design choices are necessary for the design of an interactable prototype that effectively highlights the integration of motion capture animations into videogame development, which also educates clients and employees at Movella?"

7.1   Sub-Questions

To engage the main question and all the aspects related to it, dividing the research into smaller segments for each individual element within the question, further supports solving the problem and build a prototype which is directly influenced by the research.

7.1.1   Movella related information

What elements of the motion capture pipeline within video games are vital for showcase?

- **Approach**: Plan to get direct information from Movella employees as to what types of motion capture integration is necessary to showcase and focus on.
- **Data Type**: Utilise qualitative data to gather input from product specialists and regional manager.
- **Data Source**: Collect primary data from colleagues at Movella.
- **Data Relevance**: The collected data fundamentally influences the technical demonstration and its interaction with the motion capture data. It also influences the design choices made during the process.

What does Movella want to achieve with this interactive demonstration?

- **Approach:** Plan to get direct information from the Movella sales and marketing team, as well as advice from product specialists and managers for product goals.
- **Data Type**: Utilise qualitative data to gather input from employees.
- **Data Source**: Collect primary data from colleagues at Movella.
- **Data Relevance**: The collected data influences the planning and approach of the design choices for this prototype. It directly supports the educational part of this research for the end-users.

7.1.2 Technical demonstration

How long and accessible should a technical demonstration be?

- **Approach:** Investigate and evaluate existing technical demonstration and conclude a fitting scope for the project.
- **Data Type**: Utilise qualitative and quantitative data to determine the length and accessibility of the product.
- **Data Source**: Investigate and evaluate existing demonstrations to determine the key factors.
- **Data Relevance**: Accessibility is one of the major design choices of technical demonstrations and heavily factor into the complexity of the game and its controls and thus influencing the design choices.

How can the technical demonstration educate clients and employees best?

- **Approach:** Determine the necessary documentation to educate end-users. Document workflows and difficulties during the design process to submit together with the prototype.
- **Data Type**: Qualitative data is utilised to gather information from end-users' opinion and product specialists experiences.
- **Data Source**: The combined experience from product specialists and marketing employees allows for the input of necessary educational information to provide.
- **Data Relevance**: Researching the method of highest educational impact is an important step to deliver the information gathered by the developing process. This ensures that the end-users get relevant and direct information from a source that immediately utilises this data.

7.1.3 Client related information

What does the end-user need to see to understand the aspects of motion capture data inside video games?

- **Approach:** Determine via an end-user surveys and experience with previous customers on what features the technical demonstration should showcase.
- **Data Type**: Qualitative data provides the best information towards the importance of motion capture implementation.
- **Data Source**: End-user surveys provides feedback during playtest sessions of the prototype that generates relevant information for evaluation and design choices.
- **Data Relevance**: In combination with the motion capture aspects that Movella wishes to showcase, the relevant features within the tech demo will cater towards the end-users as well.

How can a demonstration convince clients of the product?

- **Approach:** Determine vie an end-user survey what features the technical demonstration lacks and could improve upon.
- **Data Type**: Qualitative data provides information that can be evaluated to determine design changes within the project.
- **Data Source**: End-user surveys provide criticism and feedback during playtest sessions of the prototype that generates relevant information for evaluation and design choices.
- **Data Relevance**: Creating an engaging and interesting technical demonstration is only possible with the input from end-users and their relevant feedback, which directly influence the design choices within the prototype.

7.2   Methodology

The collected and utilised primary data shapes the research of this paper and the development of the interactive prototype. This ensures that the client and employees of Movella have an input into the development process and fundamentally help design a product that is best suitable for them. Quantitative data helps in certain areas of optimization and guidance. However, this data type gives limited information about how the design of the prototype conveys information to the client.

Secondary data, however, influences the steps the researcher takes to create a prototype that follows the guidelines of design thinking, as well as development methods that are relevant to this research and its connected prototype.

8   Ideate

With the empathizing and defining phase evaluated, the process of ideating the best options for demonstration purposes, is the next step in designing the technical demonstration. The ideation phase within design thinking involves the concept creation and weighing their potential against each other, drawing a conclusion on which solution to iterate upon with testing and evaluations.

8.1   Conceptualizing and Evaluating

Conceptualizing multiple possible design choices is fundamental to compare possible solutions and draw a conclusion on which concept has the potential for full development. Creating a successful technical demonstration includes key elements that will help guarantee the goal (Dealessandri, 2019; Karanja, 2020):

1. Look and Feel
2. Accessibility
3. Feature highlights
4. Game stability

8.1.1   Multi-Game Prototypes of three Key Genres

The first concept includes how vertical slices of three games in different genres can highlight the application of motion capture animations in various environments. This concept allows for the opportunities to further develop these prototypes to full games and bring the meaning of movement into different genres, possibly resulting in a broader audience of end-users.

Table 2
SWOT analysis of the first concept

Strengths	Weaknesses
• Detailed overview of different motion capture integration within video games. • Appeal to a broader audience.	• Direct lack of consistency due to different genres and art style. • No coherent story within the prototypes. • The playtime for the demonstrations has the potential to be too long.
Opportunities	**Threats**
• Future development opportunities to further polish the prototypes. • Diverse application for training employees and clients.	• Development of multi-game prototypes is time costly. • Multi-game prototypes include multitudes of bugs. • Lack of polish for art assets

8.1.2 Game Demonstration of Third Person Character in an Open World

The second concept is an open world exploration prototype that integrates motion capture into character locomotion, staying visible throughout the entire game in third person. This incorporates the strengths of motion capture technology to showcase all possibilities in a single, immersive world.

Table 3
SWOT analysis of the second concept

Strengths	Weaknesses
• Third person character allows the display of main character movement. • The open world aspects allow for low difficulty. • More exploration and engagement.	• The single game demonstration does not necessarily allow for the education of end-users. • Experienced end-users generate no interest in an exploration game.
Opportunities	**Threats**
• Showcasing a full main character movement throughout the entire game. • Easily distributed with no need of tutorials and explanations.	• Single-game prototype attract smaller audiences.

8.1.3 Technical World in Third Person to Showcase Technology

In this concept, the end-user can play through and is guided in a virtual museum that showcases the different applications of motion capture animations within Unreal Engine 5.1. The different approaches of capturing and integrating motion inside the engine are on display with explanations and where possible, use cases and examples.

Table 4
SWOT analysis of the third concept

Strengths	Weaknesses
• Third person character allows the display of main character movement. • More exploration and engagement. • Directly showcase the technology in a technical environment	• As a sterile technical environment, it has no necessary engagement. • Has the potential to be non-engaging and therefore not time efficient.
Opportunities	**Threats**
• Showcasing a full main character movement throughout the entire game. • Easily distributable with no need of tutorials and explanations. • Can be followed during a live demonstration of the Movella systems.	• Can only be used in connection to a live demonstration of the suit. • No interest in playing this prototype outside of purchase interests.

8.2   Concept Conclusion

The concepts presented have unique strengths, weaknesses, and associated opportunities and threats. The multi-game experience concept, offering diverse motion capture suit integration, has the potential to attract a broad audience and demonstrate various development aspects. However, given the limited project timeline and research scope, the time investment for this concept is beyond its current scope.

Both the second and third concept have the potential of delivering a product that can answer and represent the main question of this research. Both concepts cover each other's weakness and ensure a smooth gameplay involving the development process with motion capture, while also educating the end-users.

In conclusion, the second concept takes precedence, featuring an open world exploration game that excels in accessibility and showcases the three major aspects of motion capture demonstration: Live-link, main character motion, and drag-and-drop features. However, the educational component requires improvement. To address this, a separate UI element and a smaller environment are necessary to provide comprehensive client education. The detailed live-link element will be showcased in the smaller environment, while additional UI elements within the main menu will outline the development steps needed to achieve the product's goals.

9 Development

9.1 First Steps

Defined in the sub-questions and incorporated into the ideation phase of this research, the development state requires preparation. These important first steps are fundamental for the development of a successful technical demonstration (Daeleesandri, 2020, 'What's a good demo?' section).

- The choice of an art style which does not oppose Movella branding and includes an inviting and professional environment within the game.
- The choice of simple functionality to provide accessibility towards a broad audience of end-users and avoid user errors.
- The choice of level layout, environment, and motion to include the best possible approach for integrating MoCap animations into the product.
- New development processes provided by Unreal Engine 5.1 to encourage the end-users to gain new information.
- The focus on performance and fidelity of the product, to ensure a stable experience for the end-users.

The technical demonstration can take various forms, including cinematic trailers, interactive gameplay, or walkthroughs with developer commentary. Each approach has its own advantages and disadvantages. Among these options, interactive gameplay emerges as the most suitable choice for a technical demonstration. This format enables the active involvement of clients and users, allowing them to experience the product first-hand. It serves as an engaging method to showcase the capabilities of motion capture while also providing educational content and supplementary information.

9.2   Look and Feel

The scope of this project and the availability of resources during the development time required the inspiration from an existing asset package on the Epic Games marketplace. This package includes a simplistic and stylized art style which can be seen in Figure 7.

Figure 7
Image depicting the Epic Games marketplace asset 'FANTASTIC – Village' Pack'.

Note. By Tidal Flask Studios 2022, screenshot

This choice of style directly aligns with the goals of the product: An inviting and bright environment, which invites the end-user to explore the world, free of strong negative feelings.
Developing a technical demonstration and product in a small 'team' of one person, requires great planning and execution of fast prototyping.

Therefore, taking an existing art style as reference will speed up the development process greatly. In addition, the use of multipurpose textures and materials generate a consistent scene with great iteration processes.

The adaptation of the style produces an individual piece of environment, while also not generating constraints on the developer in regards of conceptualizing and time management. In Figure 8 the adaptation of style can be seen in progress.

While the style is not identical, it is unique enough to be considered a well-adapted version of the original reference.

The environment and assets include several procedural aspects, making the iteration process during testing and scalability a lot more accessible.
These include, but are not limited to:

- Procedural textures
- Procedural roads and paths
- Tooling for NPC commands
- Descriptive commenting of blueprints

Figure 8 Two early screenshots from development. The top picture showcases 8 weeks of development, the other 4 weeks.

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The final look of the environment and its characters can be found in detail in Appendix B - Development of the product in detail in the section of 'Final Look and Feel.'

Figure 10. Screenshot of the starting area of the final product version.

Figure 9 Screenshot of the marketplace within the final product version.

9.3   Accessibility

Accessibility is a key factor for distributing an interactive technical demonstrations, which the end-user can use. Accordingly, preparations and fundamentals of accessibility need to be implemented into the product, to ensure that the end-user has no complications during gameplay. These preparations include, but are not limited to:

1.   Input explanations at the start of the game. It is clear what keyboard and mouse inputs are required to play the game and the controls are intuitive. An example of this can be seen in the figure below. In addition to the visual que in the scene, a 'controls' options menu has been added to the main menu and the pause menu within the game for great accessibility.

Figure 11 Screenshot depicting the initial accessibility approach. A direct explanation of controls. The NPC in the back guides the player towards him.

2.   Game guidance during the play session is an important element to keep the end-user focused on the game flow. This accessibility aspect is a combination of world building and dialogue directions. The end-user needs to be aware of the direction of the game and the direct area they are currently in. In a direct overview, the figure below showcases the flow of the technical demonstration. The direction of the player is linear and guides the end-user through the first level.

Figure 12 Screenshot depicting the environment of the technical demonstration from above. The red lines represent the game flow and showcase the linear and direct guidance of the player.

3. The difficulty of game elements and their complexity are directly tied to the accessibility and therefore the end-user. If the product is too difficult to complete for in-experienced players, the technical demonstration can heavily influence the opinion of the product. Therefore, a shallow difficulty curve within the gameplay elements has been established. With testing and iterating this curve has been adjusted during development.
4. The dialogue within the game is guiding the player through the technical demonstration and ensures that the player is informed about the possible options within the product. The dialogue needs to be simple and explanatory for non-native English speaker.

Figure 13 The dialogue at the start of the game, explaining what this product it. All dialogue of NPCs is simple to understand and follow.

The simple controls and schematics allow for a straightforward world building and logic scripting within Unreal Engine 5.1. Accessibility has a direct, if not the biggest, influence on the development part of this process. The product needs to be accessible to a broad audience, resulting in an appealing and intuitive game experience.

9.4   Feature Highlights (MoCap Integration)

The following section explains the aspect of MoCap integration, and its influences in the development phase. To ensure an integration that can showcase the data the best way, multiple approaches are necessary (see full list of integrated animations in Appendix H - Recorded and used Motion Capture Animations).

9.4.1   Root Motion Driven Animations for Motion Capture

The first discussion point of motion driven character movement is root motion. Root motion describes the transform values of a root bone, which drives the movement of the character. For example, in an animation of a walk cycle, the root motion is the parent bone of the pelvis and drives the skeleton forwards. Alternatively, no root motion keeps the animation in place and utilised scripts to drive the skeleton instead. Both approaches of animating movement are valid and are considered in development. Below is a summary of both workflows:

Table 5

Comparison between two animations systems.

Root motion animation	No root motion animation
• **Animation** driven movement and speed. • **Interchangeable** animations with **no script** change. • **Low risk** of foot sliding and mismatches. • Opportunity for **more precise** animations. • **Less freedom** of design regarding character speed and locomotion.	• **Script** driven movement and speed. • **Interchangeable** animations with **script** change. • **Risk** of foot sliding and mismatches. • Can lead to **less precise** animations. • **More freedom** of design regarding character speeds and locomotion.

Investigating the opportunities and risks of both animation approaches and comparing these to the motion capture integration and its goal, the root motion animation workflow is superior. The integrated root motion, which directly drives the skeleton allows for a precise depiction of the realistic motion from real world captures. In addition, the root motion animations are quickly interchangeable with no changes to the scripting background, allowing for faster prototyping and iterating with a variety of recorded animations.

9.4.2   Locomotion Systems within Unreal Engine 5.1

To ensure detailed preservation and scalability, the project incorporates root motion animations, a technique supported by the locomotion system in Unreal Engine 5.1. Interchangeable animations, as discussed with developers and stakeholders, are crucial for this project's locomotion system, enabling the use of new recordings or significant changes to the main character's characteristics. The product utilizes blendspaces and blueprint logic to drive the third-person character.
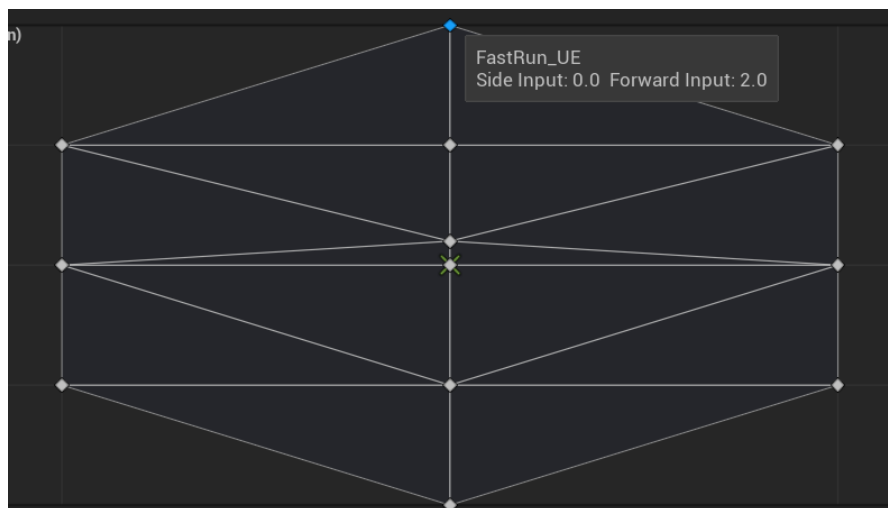

Figure 14 The blendspace utilised in this project. The dots determine the animation that is placed. Their individual placement describes their functionality within the motion.

9.4.3   Integrated MVN Features

With the focus on highlighting the possibilities of MVN hard- and software within the Unreal Engine 5 systems, the different approaches are highlighted in multiple ways. It is important for the project to contain all these elements, as the product is a means to present the vital functionality of the MVN systems inside the Unreal Engine and educate the client about these features.

- **Drag-and-Drop**
  The feature of implementing recorded animations from MVN into the system of Unreal Engine 5 motion for in-place systems, highlights the ease of access and implementation of the animations. This is featured by the animations of the non-playable character in the background, which run on minimally altered recordings from MVN.
- **Locomotion with looping animations**
  The motion of the main character is driven by the edited recorded animations, able to loop and drive the character model with root motion integration. This workflow allows for the interchangeable approach of later development and the demonstration of work with motion capture animations. The importance of demonstrating that the recorded animations are eligible for editing in other software such as Autodesk Maya, highlights the versatility of this workflow.
- **Live-link plugin for Unreal Engine 5.1**[9]
  Live-link implementation is a vastly different approach than Drag-and-Drop and locomotion systems. It requires the use of the Unreal Engine 5 plugin provided by MVN. As this system is not able to drive a main character or provide realistic motions for non-playable character a different approach is required. This leads to the separate implementation of the live-link system in a separate environment, which showcases the live-link possibilities in detail. The image sequence demonstrates the possibilities of live-link (Figure 15**Error! Reference source not found.**). It allows the user to inspect the linked actor, including the possibilities of pausing the animation.
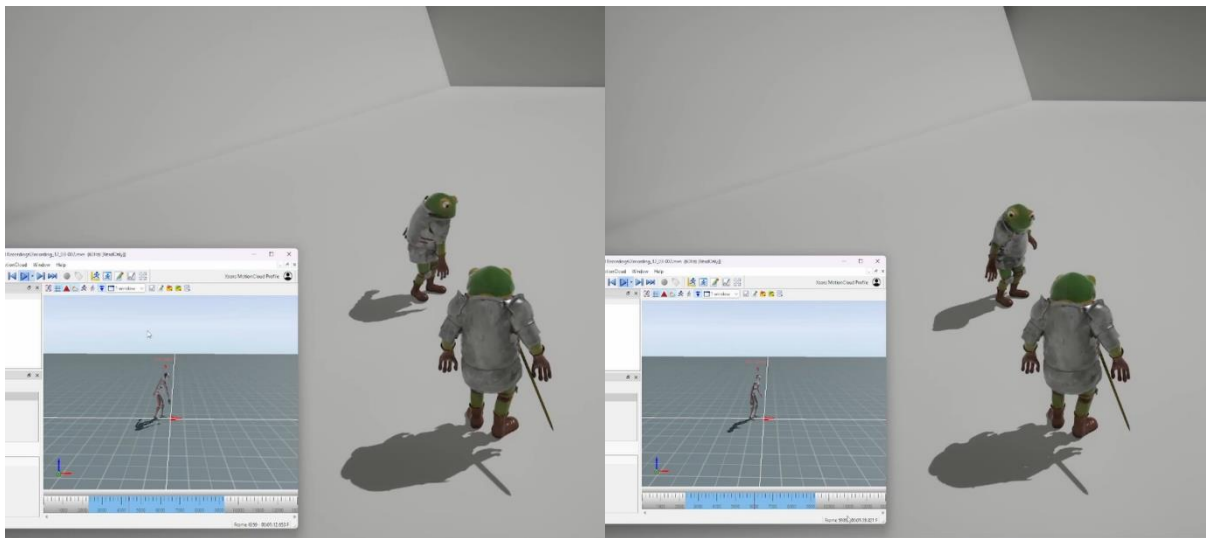

Figure 15 The MVN live-link plugin working inside Unreal Engine 5.1. This separate scene represents the live-link possibilities.

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[9] *More information about the Unreal Engine 5.1 MVN plugin can be found at*
https://www.movella.com/integrations/unreal-engine

9.4.4   Stakeholder Input

With the integration of MVN workflows inside Unreal Engine 5.1 and gathered feedback from the stakeholders, an additional menu option has been implemented to showcase how these aspects fit into the game, and how a recording session for animations with these applications can look like. Developing a complicated UI widget with tab selections and video implementation without prior experience is a challenge, as Unreal Engine 5.1 supports video implementation in an unintuitive way.
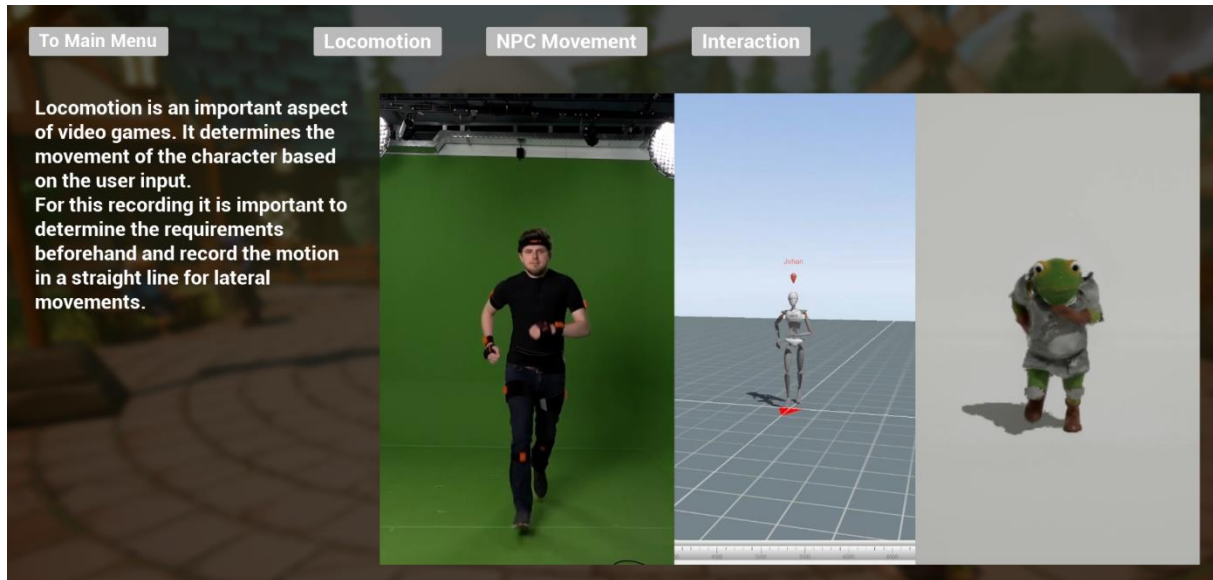

Figure 16 The 'How To' menu page. By the wishes of the stakeholders, it showcases a side-by-side video of the actor, MVN puppet, and the in-game avatar, as well as a brief explanation for all three types of motion capture integration.

In addition to the extra menu screen, the stakeholders wish to document these efforts into a useful guide. The researcher has written out a step-by-step guide for the workflow of recording inside MVN and using these animations in an Unreal Engine 5.1's locomotion system.
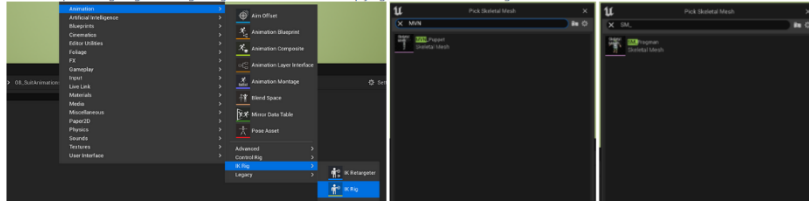

Figure 17 Three example steps from the step-by-step guide for 'From MVN to Game Locomotion'. The guide is written with a lot of visuals to support less experienced developers.

9.5   New Systems and Technologies

Working with motion capture animations creates realistic movement for characters within a game. These high-fidelity animations require implementation techniques that further improve their blending and interaction with the environment within the product to showcase their adaptability and ease of use inside a different software. This has the potential of convincing a client to utilise motion capture over keyframed animations. The possibilities within Unreal Engine 5.1 leave room for improvement regardless of the currently existing systems used for this product, creating a scalable animation base.

9.5.1   IK Foot Placement

The animations created by the motion capture systems are baked[10] onto the skeleton of the character mesh, therefore, not accounting for environmental changes in surfaces. The IK Foot placement script provides both feet with the missing information. This system allows for realistic foot placement on stairs and rotation on slopes and deforms the leg accordingly. Figure 18 showcases the IK foot placement tool in game.
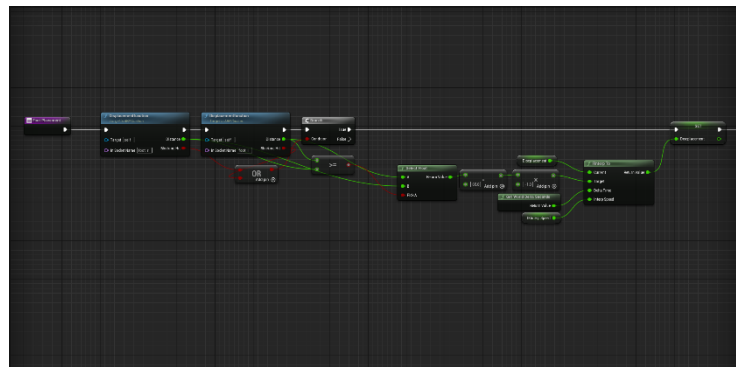
Figure 19 The start of the IK foot placement logic inside the main characters animation blueprint. More Images for this system can be found in the Appendix C - IK Foot placement and Head Rotation.

Figure 18 Test images for the IK foot placement tool, testing on slopes and steps in the game, altering the default idle animation provided by MVN recordings. Note the red line traces detecting the surface level and forwarding that information to the IK goal of the feet.

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[10] *Baked animations are converted simulated or dynamic animations into set keyframes, locking in the motion of the character for that specific file.*

9.5.2 Head Rotation

Like the IK foot placement system, the additional head rotation calculations, which follow the mouse movement of the user and set the angle of the neck joints equally, takes the static and set animations of the MVN systems and adds a responsive and realistic system for a better flow of the animations. Implementing these systems and demonstrating how they work with motion capture animations, show end-users the possibilities within Unreal Engine 5 in combination with MVN data.
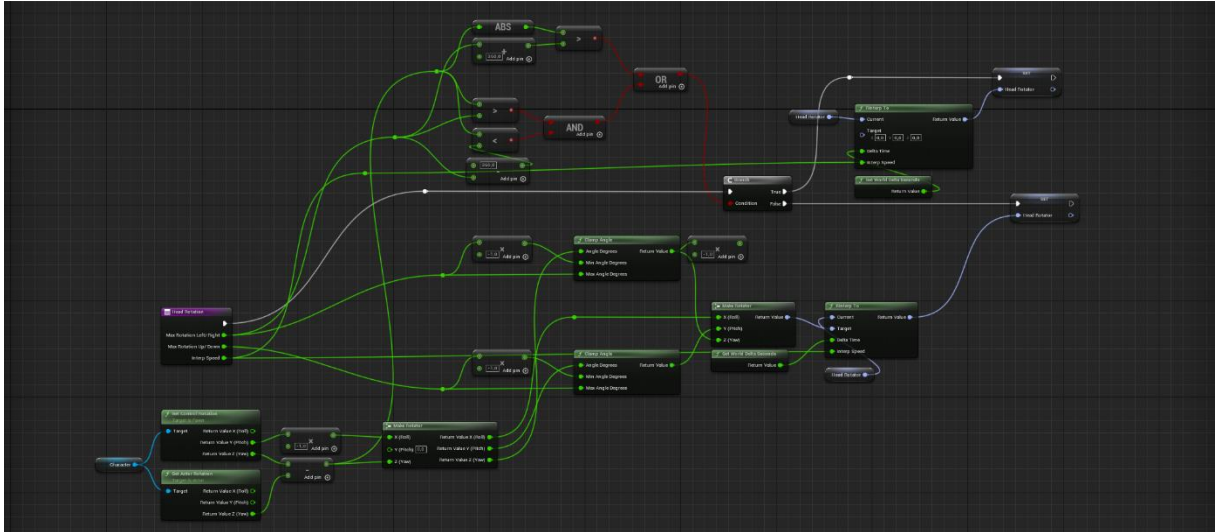
Figure 20 Showcase of the amount of maths required to set the head rotation to the precise angle of the camera. A more detailed screenshot can be found in the Appendix C - IK Foot placement and Head Rotation.

9.5.3 Advanced Animation Blueprints

With the possibility of altering the imported animations, the blending and conditioning of these animations is vital for an immersive and engaging experience, showcasing the client the opportunities. With the new Unreal Engine nodes, such as 'Layered blend per bone', 'Blend poses by bool' or 'Transform (modify) Bone' and their ease of use, the animations generated by motion capture can be blended, replaced, or modified.
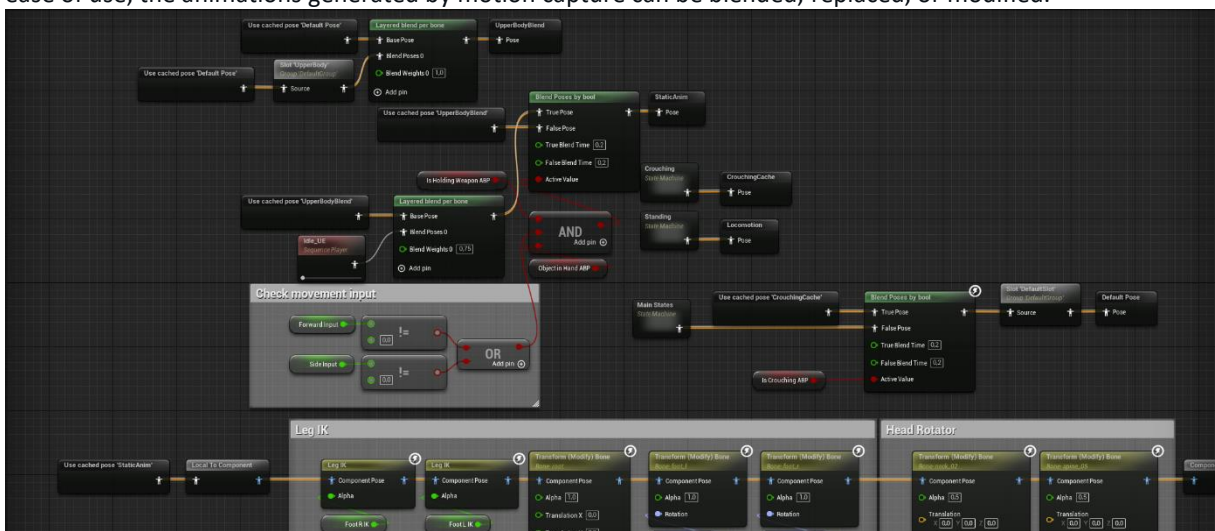
Figure 21 The main characters animation blueprint, with complex blending of bones and animations. A challenging aspect of development.

9.6   Performance

9.6.1   Stress Test and Scene Budget

In order to develop a performant product that ensures smooth and stable performance, a stress test is to determine the limits of the system on set specifications. The tables below showcase the stress tests conducted prior to development, to establish the maximum polycount possible, without loss of performance. These numbers are prior to any optimization methods and heavy systems, such as Lumen, activated.

Asset Count	Triangle Count	Performance	Frame rate	Nanites	Asset Count	Triangle Count	Performance	Frame rate	Nanites
1	960	No change	60	No	1	17.272	No change	60	N/A
10	9.600	No Change	60	No	10	172.720	Frame drop	55	N/A
100	96.000	No Change	60	No	20	345.440	Frame drop	50	N/A
1000	960.000	No Change	60	No	40	690.880	Frame drop	35	N/A
1500	1.440.000	Frame drop	35	No	80	1.381.760	Frame drop	28	N/A
3000	2.880.000	Frame drop	30	No	160	2.763.520	Frame drop	20	N/A
3000	2.880.000	Frame drop	40	Yes	320	5.527.040	Frame drop	11	N/A
6000	5.760.000	Frame drop	30	Yes	640	11.054.080	Frame drop	5	N/A

Figure 23 Stress test table for calculating the scene budget. On the left the test with a static sphere. On the right the test with the main character model. The system specifications for the hardware can be seen in Appendix D - System
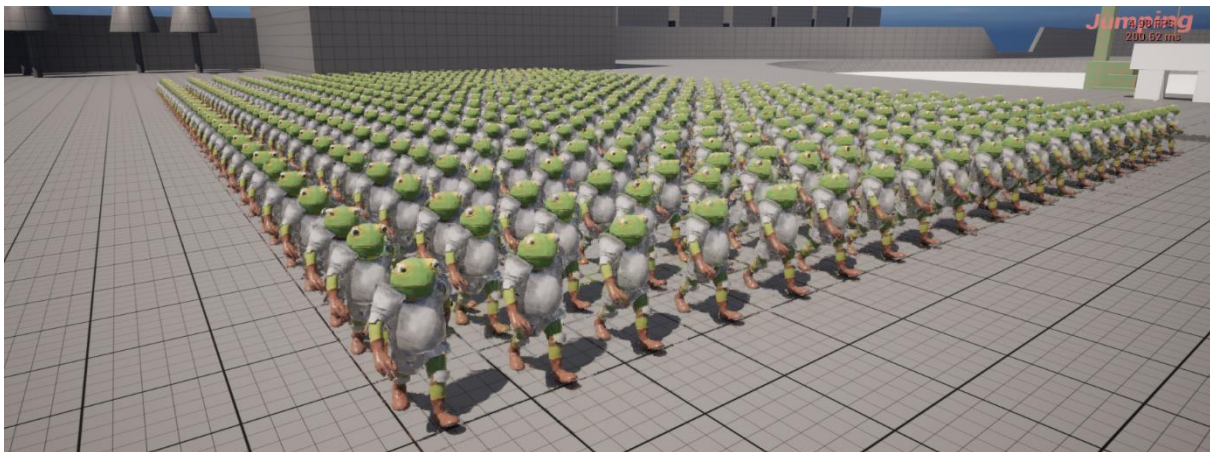
Figure 22 The test session with the main character model, prior to development of the scene. This is an estimate 640 moving models, which resulted in an average 5 frames per second.

Based on the findings of the stress test, without extra optimization methods and an outdated system, a scene budget of between one and two million **rendered** polys is handled well by Unreal Engine 5 inside the editor.

9.6.1   Optimization methods

Occlusion and Distance Culling
Culling is a major aspect of optimizing a game for a broad audience. This method stops rendering objects that are not in the view of the player and transfers those saved resources into other aspects of the product.

Batch Rendering
Bath rendering refers to the grouping of 3D assets within a scene. This method reduces the draw calls[11] within the environment and ensures smooth gameplay.

Limiting Polycounts
Limiting the polycounts of environmental assets allows for faster rendering times of 3D objects within the product.
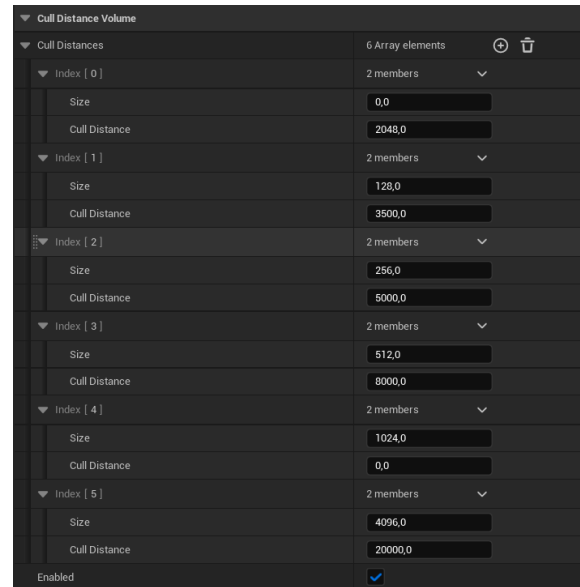
Figure 24 The dynamic settings of distance culling within the Cull Distance volume in the scene.

9.7   Development Summary

During the development phase, significant attention was given to various aspects to ensure a successful outcome. The look and feel of the project were carefully curated to align with the desired aesthetic and convey the intended atmosphere. Accessibility considerations were integrated to ensure a broader user base could engage with the product effectively. Key features were highlighted to showcase the unique capabilities and functionalities. New systems were implemented to enhance the overall experience and provide innovative interactions. Additionally, performance optimization was prioritized to deliver a smooth and seamless user experience. This comprehensive development approach includes aesthetics, usability, innovation, and technical efficiency.

A detailed overview with images of development steps and implemented systems can be seen in Appendix B - Development of the product in detail.

Additionally, a short promotional video[12], which showcases the final design of the product, and its creation has been produced.

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[11] *Draw calls refer to the amount of assets rendered on the screen. Each instance of an object and its material (textures) requires its own draw call. Minimizing the amount improves performance and computing time.*

[12] *The promotional video can be found at https://youtu.be/KjL6oOfswDk*

10 Planning, Testing, and Iterating

10.1 Defining the Test Objective

The interactive prototype and technical demonstration aim to deliver an experience that highlights the different methods of integrating motion capture data into a game. The game's objective includes the exploration of the world and executing small puzzles and interactions with the environment for more engagement.

10.2 Test Requirements and Conditions

Setting predefined test requirements and conditions is important for receiving test data that can be properly analysed and evaluated into test results that directly benefit the product. Therefore, the following rules apply:

- The developer/researcher explains the prototype's goal and its relevance to the research and end goal.
- The developer/researcher outlines any control schemes not currently implemented in the prototype.
- The developer/researcher intervenes during gameplay only for significant errors, such as the test-user getting stuck or encountering game-breaking bugs.
- The developer/researcher acts as an observer, noting down errors not covered in the survey during gameplay.
- The test-user provides feedback by openly discussing concerns, suggestions, and other aspects of the prototype during gameplay.
- The test-user completes a five-minute survey provided by the researcher.
- The test-user utilizes their own computer for testing.

10.3 Developing and Prioritizing Test Scenarios

A list of test scenarios and questions further helps creating a successful test environment. The focus in the first test round is look and feel, accessibility and error reports. This may include:

- Is the game accessible for a broad audience?
- Are there any major difficulties within the game that the test-user is struggling with?
- Is the world guiding intuitive and straight forward?
- How fitting is the motion capture animation in the game world?
- Do the motion capture animation blend well together?
- Does the game bring any errors that could alter the game flow or block it completely?

The later test phases focus on the motion capture data, the integration of the data into a game and the influence it has on the world within the game. This may include:

- Are there motion capture animations that were not fitting into the environment of the game?
- Were some motion capture animations snapping and unnatural?
- Are the motion capture animations helpful in delivering a believable and alive world?

10.4 Developing Test Cases

The approach of testing with end-users can be structured in a step-by-step list:

1. Build a relatively stable and structured build of the game, which the end-user can easily start and interact with on their own machine.
2. Create a survey that covers all testing aspects, such as accessibility, look and feel, and errors.
3. Seek out test-users for the prototype and give access to both the prototype and survey.
4. Give basic instructions on what to do:
    a. The researcher provides basic information on common errors that would break the flow of the game entirely, to prevent major loss of test results and feedback.
    b. Open the game and play the prototype as long as the tester needs to.
    c. Tell the tester to think aloud what they are trying to do.
    d. Inform the tester that the survey takes around 5 minutes and greatly improves the development process.
    e. Ask for any remarks from the tester, which might not have been covered in the survey.
5. Compile and evaluate test results in an Excel Sheet to further improve development.

10.5 Defining Test Metrics

The survey handed out during testing covers all aspects necessary to develop the prototype further. However, this survey provides both quantitative data and qualitative data. A scale rating for difficulty, intuitiveness and look and feel can give structured data that is rapidly compliable and comparable. Qualitative data, however, provides suggestions and subjective opinions, which provides feedback on the end-user requirements.
The focus within the first testing round relies on three major aspects: Accessibility, MoCap integration and Look and Feel. These three aspects all cover the necessary design choices needed to create a product that highlights the aspects of development with such technology.

10.6 Analysing first Test Results

With a completed first testing period, the researcher can evaluate the responses and compile the feedback into usable data. This data is separated in the major aspects of the development process:

The feedback received regarding the accessibility is focused on the fact that the interaction with the jumping across the lake is deemed too difficult, this can be seen in Figure 25.

The general feedback regarding the difficulty spike of the jumping puzzle could generate a bad impression of the technical demonstration. This is a major element of the product that needs to be addressed and iterated upon multiple times.

In correlation to the difficulty rating, the number of hours the tester spends playing video games varies greatly, which indicates that the difficulty of this game element is unfairly balanced. Figure 26 breaks down the gaming hours spend per tester.

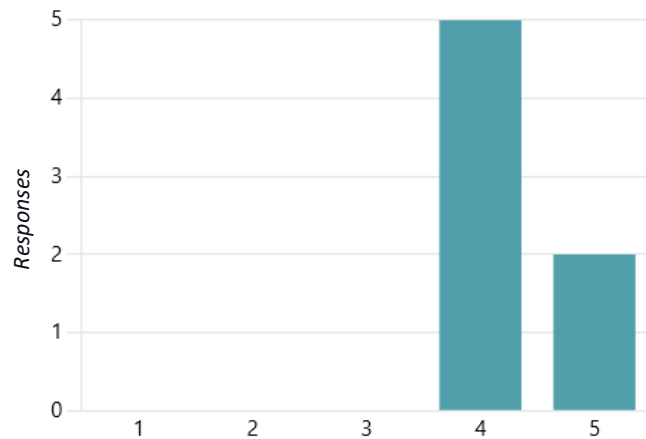*Figure 25 Visualisation of the expressed difficulty rating of the game mechanic 'Jumping Puzzle'. (1 – easy, 5 – hard)*

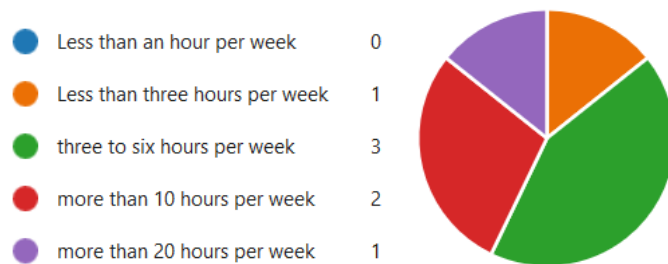|	
🔵 Less than an hour per week	0
🟠 Less than three hours per week	1
🟢 three to six hours per week	3
🔴 more than 10 hours per week	2
🟣 more than 20 hours per week	1

Figure 26 Breakdown of hours spent playing video games each week.

Text responses for the question of challenging and inaccessible content generates answers that support this claim in more detail. It becomes clear that the difficulty is from the jumping functionality, as well the placement of the jumpable platforms. Survey question one relates to these findings (Appendix E - Test survey from the first play-test session).

The guidance of the player throughout the level received positive input as can be seen in the responses of survey question two (Appendix E - Test survey from the first play-test session). This indicates that the general approach of the end-user within the game is straight forward, and the player does not get lost. However, a brief story and introduction could benefit the integration of guidance even more.

The test survey includes the option to deliver feedback (survey questions 11 and 15) regarding the implementation of additional content and features, including motion capture animation and art assets. This section of the survey is an important step to determine the lack of features which correlates to the engagement spikes during gameplay or negative feedback regarding look and feel. The suggestions provided by test-users are compiled in Table 6.

Table 6
Compiled feedback gathered for the motion capture implementation and look and feel of the scene.

Motion Capture Implementation	Look and Feel of the Scene
- Additional interaction with the environment and NPC. - Additional player animation feedback on slopes and stairs. - More non-playable character animations. - More engaging animations with context of gameplay interaction.	- Additional types of buildings and structures. - Additional types of flora and fauna. - A separate area for a cave or a mine for variety. - More generic non-playable character models. - Creating a visual destination for the end.

The gathered feedback regarding additional features and assets highlights the lack of interaction between the main character, environment, and NPC. While the look and feel receives positive feedback, the goal of this technical demonstration is the highlight of motion capture, an aspect the test users criticize.

10.6.1 Bugs and Errors

The first test phase indicates that the build created for this stage of development includes several major and minor bugs and errors that can prevent the player from finishing the game. The developer anticipated this behaviour and implemented a reset switch prior to shipping the build for testing.
This implementation prevented the testers from being skewed on focusing on the fact of impossible elements of the product, resulting in better responses.
Differentiating between game-breaking bugs, which include errors that completely halt the further progress of the player during gameplay, and minor bugs, which include less impactful issues with the build, such as wrong collisions or NPC getting stuck.

Below is a list of errors experienced during the gameplay sessions, compiled into priority:

Table 7
Compiled task priority based on the feedback of end-users.

High priority	Low priority
• Colliding with NPC creates unwanted physics interaction. • Locked camera during the chest opening sequence, preventing the observation experience, and disabling all input. • Dialogue system stops functioning when leaving the dialogue trigger area too early. • A lack of game guidance regarding main menu, quit button and options. • During the live-link demonstration view, the input is not disabled, resulting in unwanted behaviour.	• Collision problems with buildings and fences. • The user interface widget for playtime does not work during gameplay. • Smaller art assets are overlapping and create flickering effects during gameplay. • Some NPCs get stuck on terrain and other characters.

10.6.2 Test Conclusion

The mid-development build lacks features and contains game-breaking bugs, hindering smooth gameplay for testers. However, the test results also indicate that the product's development is promising for motion capture demonstrations in video games. This positive outcome will guide further development processes and enhance player engagement in the product, as the baseline of development has been established.

The test aspects of accessibility, motion capture animations and bugs give great insights into the necessary design aspects for technical demonstrations. Breaking down the design choices into their fundamental categories for testing, supports the claim that an interactive technical demonstration must be engaging, accessible, approachable, and entertaining, to create a smooth experience for the user.

10.7 Iterating and Refining First Results

Based on the test results and the drawn conclusion, the iteration and refining chapter includes a compilation of features that are implemented in the next build. These added features include, but are not limited to:

- Additional accessibility of menus, control elements and instructions for the user, as the test results indicated a lack of UI and UX.
- Improvement of performance and stability of the build, to further improve the playability in all systems.
- Look and feel have been improved to enhance the visual representation of assets, animations, and scenery, to further develop an inviting and engaging world.
- With the addition of a second area and map, the engagement of the user while playing the product has been greatly improved.
- The implementation of live-link and additional interaction using motion capture has elevated the product's demonstration purposes.
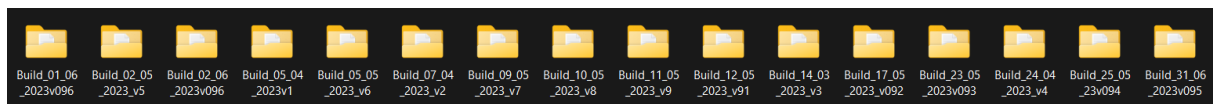
Figure 27 Visualisation of the amount of test builds that have been developed and tested individually by the developer between test sessions.

An extensive list of changes made based after the first testing round can be found in Appendix F - Compiled list of all added features after the first test.

11 Final Test

11.1 Test Requirements and Conditions

As this test will be conducted similarly to the first one, test requirements, conditions, scenarios, cases, and metrics remain the same as the first test.

11.2 Analysing Final Test Results

With the implementation of new features, bug fixes and new assets within the scene, the final test revolves around elements that would benefit the product beyond the initial scope, as well as immediate smaller adjustments to give the user a better experience, while keeping the time constraints of the project in focus.

11.2.1 Accessbility, Game Flow, Performance and Stability

The most important aspect of the product is the accessibility and its game flow through the world, as this drives the user to play the game. The addition of NPC giving clear explanations throughout gameplay and the addition of an 'objectives' user interface greatly benefits the game flow of the product. Figure 29 demonstrates the transparency of the game objectives and Figure 28 showcases the successful implementation of direction from the NPC.

Figure 28 Visualisation if the non-playable characters were helpful indicators for objectives and guidance.

Figure 29 Visualisation of the transparency of objectives within the game (1 – very unclear: 5 – very clear).

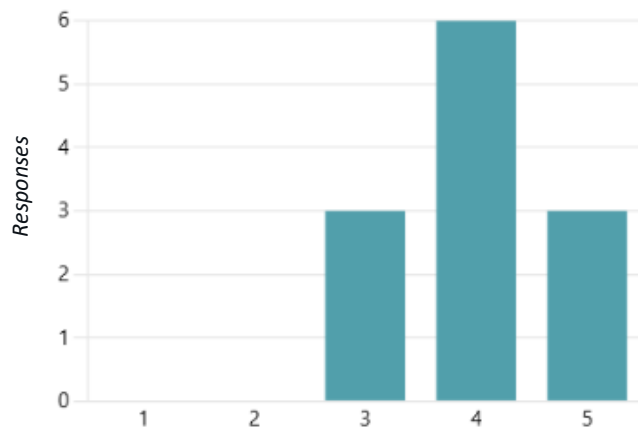While the accessibility regarding menus and non-gameplay related elements was not tested in the survey, but documented through observation from the researcher, it can be concluded that the addition of a main, pause, options, and controls menu greatly benefited towards the positive experience for the end-user.

The overall performance and optimization methods implemented during development, resulted in a smooth (between 40 and 60 frames per second) experience on all machines of test-users (Figure 31), if the game was not running smooth, the newly implemented options menu to lower graphical requirements greatly helped improve this aspect (Figure 30).
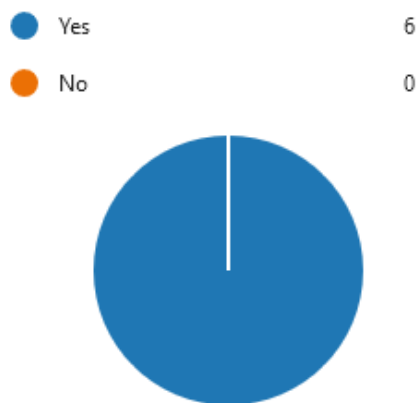
Figure 30 Indication for users that experienced stutters throughout gameplay, and if lowering the graphics settings helped improve performance.
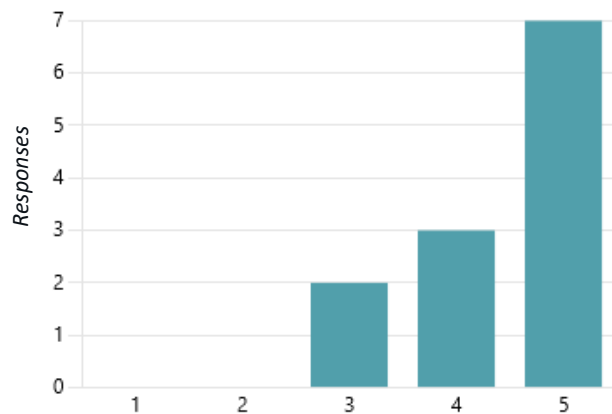
Figure 31 Visualisation of feedback for a smooth gaming experience (1 - very stuttering: 5 - very smooth)

The final testing phase revealed a significant reduction in the number of errors and bugs encountered during the gameplay. Initially, the average number of errors per test-user was found to be between 3 and 4 (Appendix G - Test survey from the final play-test session , survey question 6: 'Did you encounter any errors while playing, if so, how many?'). However, because of the developer's efforts, the average number of errors has now decreased to **just one per test-user** on average (Appendix G - Test survey from the final play-test session, survey question 9: 'Did you encounter any errors while playing, if so how many?).

This noteworthy improvement in stability demonstrates the commitment to enhancing the quality of the interactive technical demonstration. It has resulted in an almost bug-free experience for users, exceeding the expectations set prior to development. The notable decrease in errors indicates the effectiveness of the development processes and emphasizes the progress made towards creating a software product that is stable and reliable.

11.2.2 Motion Capture Integration

With the integration of motion capture animations as feature highlight within this technical demonstration, the first test indicated a lack of visible animations and therefore a missing and vital element for the product. This gathered feedback led to the better implementation of motion capture animations for both the main character and the NPCs.

The survey also indicates that the scalibility of this project can be taken even further, with wishes of additional animations for combat or interaction with NPCs and objects (Appendix G - Test survey from the final play-test session , survey question 13: 'Are there animations you would have liked to see be implemented and highlighted more?')
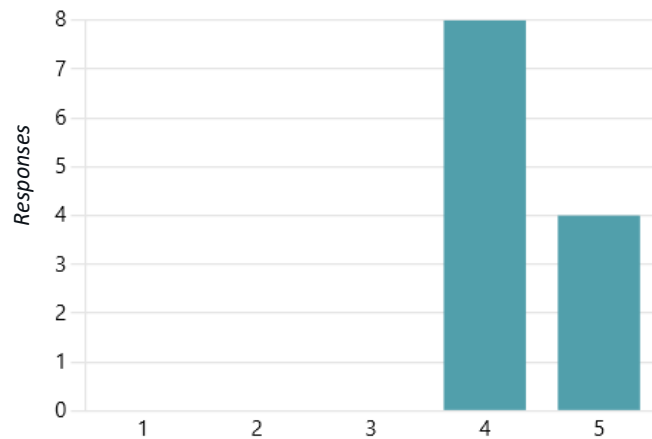
Figure 32 Visualisation of feedback for immersion and livelihood regarding the animations and benefits of motion capture (1 – not beneficial at all: 5 – very beneficial.

11.2.3 Look and Feel

As the look and feel has not changed by a large degree, the positive outcome of this testing phase becomes quite clear. The end-users had no criticism for the art style and setup of the scenes, compared to the first testing phase, in which some users indicated a lack of consistency.

Yes	10
No	0
Maybe	2
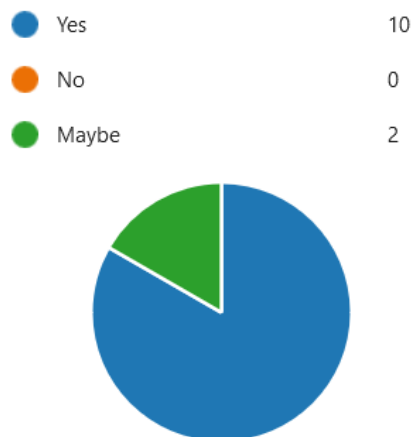
Figure 34 Indication if the end-user perceived the environment and the scene as 'alive'.
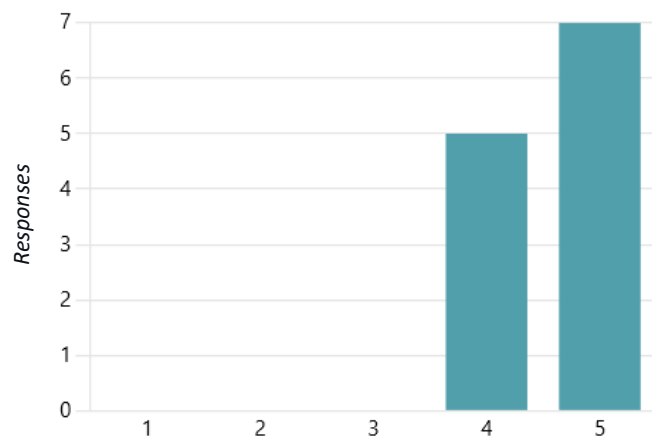
Figure 33 Visualisation of the immersion and of the environment within the game (1 – not immersive and engaging at all: 5 – very immersive and engaging).

The addition of additional non player character models and the introduction of 'bump-text'[13] greatly supported the existing immersion within the game.

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[13] 'bump-test' refers to the user interface, which gets introduced when the player and non-playable characters collision overlap. Example for this 'bump-test' include 'Good morning!' or 'This box is very heavy!'

11.2.4 Test Conclusion

The final build addressed the shortcomings of the mid-development version by resolving game-breaking bugs, enhancing accessibility through improved menus and instructions, showcasing more motion capture animations, and exploring new technologies such as interactive head rotations and IK foot placements. This product effectively promotes and demonstrates the possibilities of Movella's motion capture technologies. Feedback from the initial testing phase highlighted accessibility issues due to missing elements like menus and objectives. These concerns were successfully addressed in the final build, resulting in improved usability and positive testing outcomes.

The conclusive testing phase demonstrated the success of both theoretical research and its practical implementation. To further enhance the product, it is recommended to incorporate additional third-party hardware and software, as this would enhance its versatility and user-friendliness.

12 Internal Testing with Stakeholders

During the company-wide Sales and Marketing event in Enschede, product specialists from around the world took part in a meeting to experience and interact with the developed product.
The goal of this testing phase is the direct involvement of the stakeholders, as their expertise and interest are fundamental to the development of the product and give great insight.

The stakeholders took great interest in the product and provided valuable feedback from the point of view of the internal end-users. The demonstration and explanation delivered by the researcher helped convey the product in a positive light, and feedback has been documented during the session. Additional information regarding this test session can be found in Appendix I – Internal Testing Details.

13 Recommendations

Based on the scope of the project and the time constraint of five to six months, including holidays, the final product could scale further after the deadline. This scalability is an included factor during the development phase of the product and will allow for other employees at Movella to pick up the project and continue the work on it.

Additional features that would benefit this project could include, but are not limited to:

- Implementing Metagloves[14], developed in cooperation with Manus, enhances the demonstration capabilities by introducing third-party hardware and software. Finger and hand animations contribute to more immersive animations and world building.
- Implementing HTC Vive optical trackers[15] provides flexibility and more accurate motion capture data for multi actor recordings and interactions with objects.
- Incorporating multi-actor streaming in the live-link elements showcases another capability of MVN.
- Creating additional levels and gameplay elements extends the longevity and excitement of the end-user experience.
- Adding appropriate audio for interactions, ambient sounds, and other sound effects greatly enhances the feel of the demonstrations, as these elements are fundamental for immersion.
- Improving the implementation of motion capture animations within the game world, leveraging Unreal Engine 5's new technologies such as dynamic animation events, and motion warping[16] for a more immersive experience.

14 Conclusion

The process of development and the feedback gathered during iterations, indicates that the production of technical demonstrations focuses on four specifics:

1. *Key feature of technological highlights*
2. *Accessibility*
3. *Look and Feel*
4. *Stability*

It is recommended that these four key factors of design in developing an interactive technical demonstration are considered throughout the process. Each factor includes the necessary precautions for delivering a successful product:

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[14] Find additional information on the Metagloves developed by Manus at https://www.manus-meta.com/products/xsens-metagloves

[15] Find additional information on the HTC Vive developed by HTC and Valve Corporation and its use for MVN at https://base.xsens.com/s/article/HTC-Vive-Setup-Guide?language=en_US

[16] Find additional information regarding motion warping inside Unreal Engine 5 at https://docs.unrealengine.com/5.0/en-US/motion-warping-in-unreal-engine/

Key Feature of Technological Highlights

To ensure a smooth development process, the team should identify key features to highlight. During the interactive technical demonstration, it's important to avoid overwhelming users with multiple aspects simultaneously. Clear functionality can be achieved through in-game guidance or a brief introduction beforehand. This enhances the user experience and effectively communicates the product's intended functionality.

Accessibility

An interactive technical demonstration has the unique ability to be utilized by anyone. Therefore, it is crucial to ensure accessibility for a broader user base, expanding the reach and potentially attracting more customers. This can be accomplished by adjusting the game difficulty, incorporating a settings menu to accommodate various system specifications, and implementing other strategies to enhance accessibility.

Look and Feel

The aesthetics and overall experience of the interactive prototype are greatly influenced by the company and its target user base. In general, the design choices should align with the company's values and goals, aiming for a suitable art style. However, opting for a vibrant and colourful environment can attract a wider audience and create a positive impression.

Moreover, maintaining player engagement throughout the experience is crucial. Without engagement, there is a risk of losing interest and potentially causing frustration. To address this, it is important to incorporate simple gameplay features and points of interest, allowing for various user interactions. These elements will foster player engagement and leave a lasting positive impression.

Stability

Ensuring a smooth user experience in an interactive technical demonstration is vital, as game-breaking errors can hinder users from enjoying the game. When users encounter bugs or errors that prevent them from fully experiencing the interactive demo, it can leave a negative impression of the company and its product. Therefore, it is crucial to prioritize product polish and, in case errors do occur, provide viable workarounds to mitigate any potential disruptions.

In conclusion, the development process and feedback received during iterations underscore the importance of considering the four factors in the design of interactive technical demonstrations. These factors include highlighting key technological features, ensuring accessibility, creating an appealing look and feel, and prioritizing stability. By incorporating these factors throughout the development process, precautions can be taken to deliver a successful product. This includes providing clear functionality, accommodating a broad user base, creating engaging gameplay features, and addressing potential errors to maintain a smooth user experience. By adhering to these recommendations, companies can optimize the impact of their interactive technical demonstrations and leave a positive impression on users.

15 Self-Reflection

A brief self-reflection on the research process and development of the product will lead to personal improvements and showcase the accomplishments of the student:

Research related reflection:

1. Strong points of the student:
    - The early switch from a comparison focused thesis to a design choice evaluation, has greatly benefited the overall process of the student.
    - Based on the research question, the product, and its connection towards Movella all involved parties benefited of the knowledge gain.
2. Improvement points for the student:
    - Gathering more sources regarding interactive technical demonstrations could be beneficial for a better drawn conclusion.

Product related reflection:

1. Strong points of the student:
    - The solo development of an interactive demonstration resulted in significant knowledge gain. Building a game from start to finish including scripting, animation, rigging, asset creation, gameplay elements, and world design, proved to be one of the best ways to gather knowledge. More information regarding the development process can be seen in Appendix B - Development of the product in detail.
    - During the development of the project the time management and scheduling of vital milestones have been set precisely, which resulted in no required crunch/over time during the entire development phase.
    - Contacting end-users, Movella employees, and testers is an important aspect of research and development has been utilised to a great extent during the development of this project. The results gathered from feedback and impressions greatly helped shape the project.
2. Improvement points for the student:
    - The limitations of a solo development cycle include the unfinished aspects of the game in certain aspects. The limited amount of time of the project created rushed assets that could not be iterated upon further.
    - The variety of features and feedback gathered for the implementation of additional features within the project resulted in a broad task division throughout the weeks. The goal would be to finish an element of development, thoroughly test it and then create a new element. This ensured a smoother development cycle and reduced time spent on error fixing.

Positioning and looking ahead.

As for the professional outlook and job opportunities gathered from this project, it is a difficult decision to make. What is set is the goal to work in the creative and entertainment industry, if this necessarily includes the section of video games is debatable, as the market is difficult to get into as a junior and the work environment can be over-demanding and unfair within video game development studios.

As for now, the job position at Movella is not what is desired after spending months of work on a game. This became clear during the difficult decision of taking the role of Product Specialist at Movella. In the end, the decision has been made against said position, as the heart lies within video games and the work in a game company with experienced professionals is what is best for the student.

The best fitting roles within the professional field might include 3D environmental artist, rigger, technical animator, game element/tooling scripter, optimization control, or even a leading position.

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17 List of Figures

Figure 1: Eurobit (2023). The Steps of Design Thinking Visualized [graphic]. https://www.eurib.net/design-thinking/

Figure 2: Dr. Rafiq Elmansy (n.d.). The Design Diamond Method Visualized [graphics]. https://www.designorate.com/the-double-diamond-design-thinking-process-and-how-to-use-it/

Figure 3: Tidal Flask Studios (2022, September 19). FANTASTIC - Village Pack [screenshot]. https://www.unrealengine.com/marketplace/en-US/product/fantastic-village-pack

Appendix

A windows build for the research related project can be found at
https://drive.google.com/drive/folders/1BXahgOcaWL_AViUuax7FTmJTxo9mMAea?usp=drive_link

18 Appendix A - Questions towards Product Specialist Stefan Beuker

Question: Do you, as a product specialist think that the use of MVN systems is more used in indie development studios or larger companies, like Ubisoft? Could you briefly elaborate on this?
Answer:
'Currently big for big part, bigger studios use our system. Throughout the years due to high price and strategy, we focused more on the big fish. Now since we slowly were able to lower the prices throughout the years, you see more and more mid and small studios adopt our systems. This is the market we try to focus on now, since pretty much all of the big boys have our products.'

Question: With the amount of experience, you have gathered throughout the years, what are possible reasons people would not use MVN systems, but rather opt for Rokoko or other alternatives?
Answer:
'In the beginning, people went for Rokoko due to price. This for the most part is out of the way, now the reason is I guess their marketing machine. You see that they have a great marketing machine which helps them out with their sales. However, the amount we lose to Rokoko is not high, simply because we tell prospects to test both products. They will see the difference hands-on.'

19 Appendix B - Development of the product in detail

During the development of the product, the student has gathered great insight into multiple disciplines within the industry. This chapter within the appendices showcases some of the work and knowledge that has been gathered throughout the process. As 3D artist, who focuses on environmental and technical art, some of these processes had to be acquired with no prior knowledge. These include, but were not limited to:

1. Visual scripting within Unreal Engine 5.1.
2. Detailed and procedural texturing within Substance Designer
3. Level design for a linear, but open environment
4. Puzzle and gameplay design for engaging content
5. AI scripting and creation for interactive design
6. Runtime Virtual Texture implementation for fast changes and prototyping
7. UI design and functionality scripting for smooth operating menus
8. The learning curve of recording, editing, and implementing motion capture animations recorded with the support of MVN Awinda and Link
9. Advanced asset creation with vertex painting and shader/material manipulation
10. The creation of shaders for water surfaces

Final Look and Feel

A small promotional video rendered and edited by the developer can be found at
https://youtu.be/KjL6oOfswDk

Below are screen captures from the final scene. As this game incorporates a lot of animation, playing the game or watching the video is better suited.
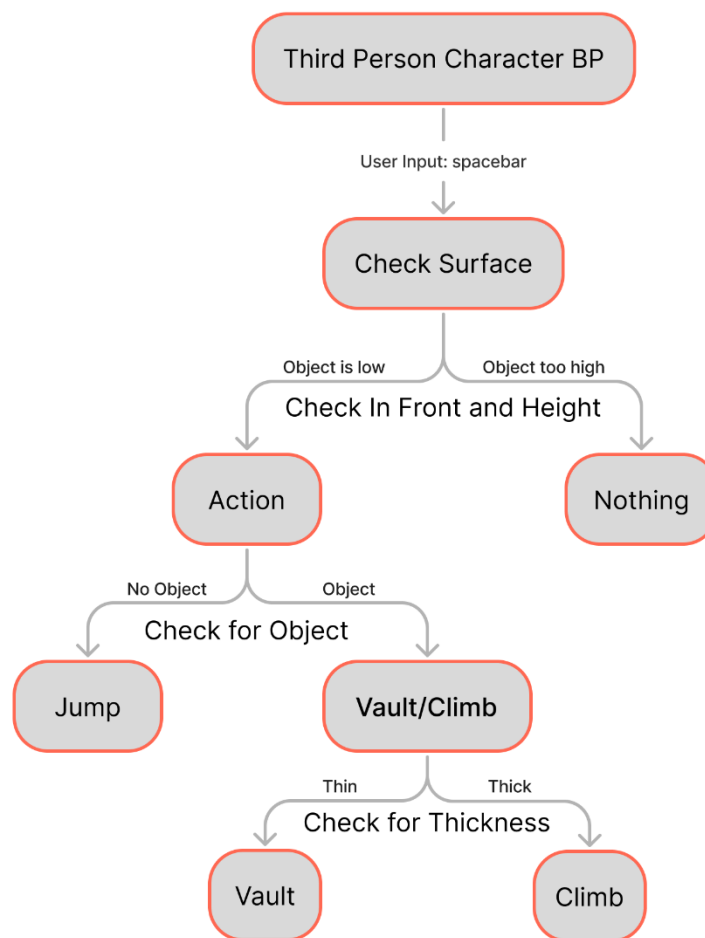
(Visual) Scripting

Based on the experience of the developer the visual scripting in this project is more advanced than anything the researcher has done before. From creating animation blueprint logic based on player input, to AI movement with destination points. The following list covers some blueprints worth mentioning and their difficulties and how these difficulties help developer a better understanding of Unreal Engine 5.1.

Blueprint for vertical movement

```
                    Third Person Character BP
                              |
                    User Input: spacebar
                              ↓
                        Check Surface
                        /           \
              Object is low        Object too high
          Check In Front and Height
              /                            \
          Action                         Nothing
          /      \
    No Object    Object
      Check for Object
      /              \
   Jump           Vault/Climb
                   /        \
                 Thin      Thick
               Check for Thickness
               /              \
            Vault            Climb
```

This graph describes the logic for the character movement regarding jumping, vaulting and climbing. On user input it sends out several line traces that check the existence, distance, and height of an object, and based upon the gathered information proceeds with the next action.

This blueprint enhances the understanding for logic conclusions based on line traces. The complex surface checking and actions based on the solutions resulted in a better understanding of blueprints and their flow together with the environment.

Blueprint for interaction

```
                          ┌──────────────────────────┐
                          │ Third Person Character BP │
                          └──────────────────────────┘
                                      │
                               User Input: 'e'
                                      ↓
                          ┌──────────────────────┐
                          │   Check for Collision │
                          └──────────────────────┘
                        Overlap              No overlap
                           Check for overlap
                           ↓                        ↓
                    ┌──────────┐            ┌──────────┐
                    │  Action  │            │ Nothing  │
                    └──────────┘            └──────────┘
                   │            │
        ┌──────────────┐   ┌──────────────────────┐
        │ NPC Dialogue │   │ Interaction Enumerator │
        └──────────────┘   └──────────────────────┘
            │                      │
       User input: 'e'      Cast to: Interaction BP
            ↓                      ↓
   ┌──────────────────┐    ┌──────────────┐
   │ NPC Dialogue End │    │ Enumerator: n │
   └──────────────────┘    └──────────────┘
                          n      n+1  n+2    n+3
                          ↓       ↓    ↓      ↓
                   ┌─────────┐ ┌─────────┐ ┌─────────┐ ┌─────────┐
                   │ Action 1│ │ Action 2│ │ Action 3│ │ Action 4│
                   └─────────┘ └─────────┘ └─────────┘ └─────────┘
```
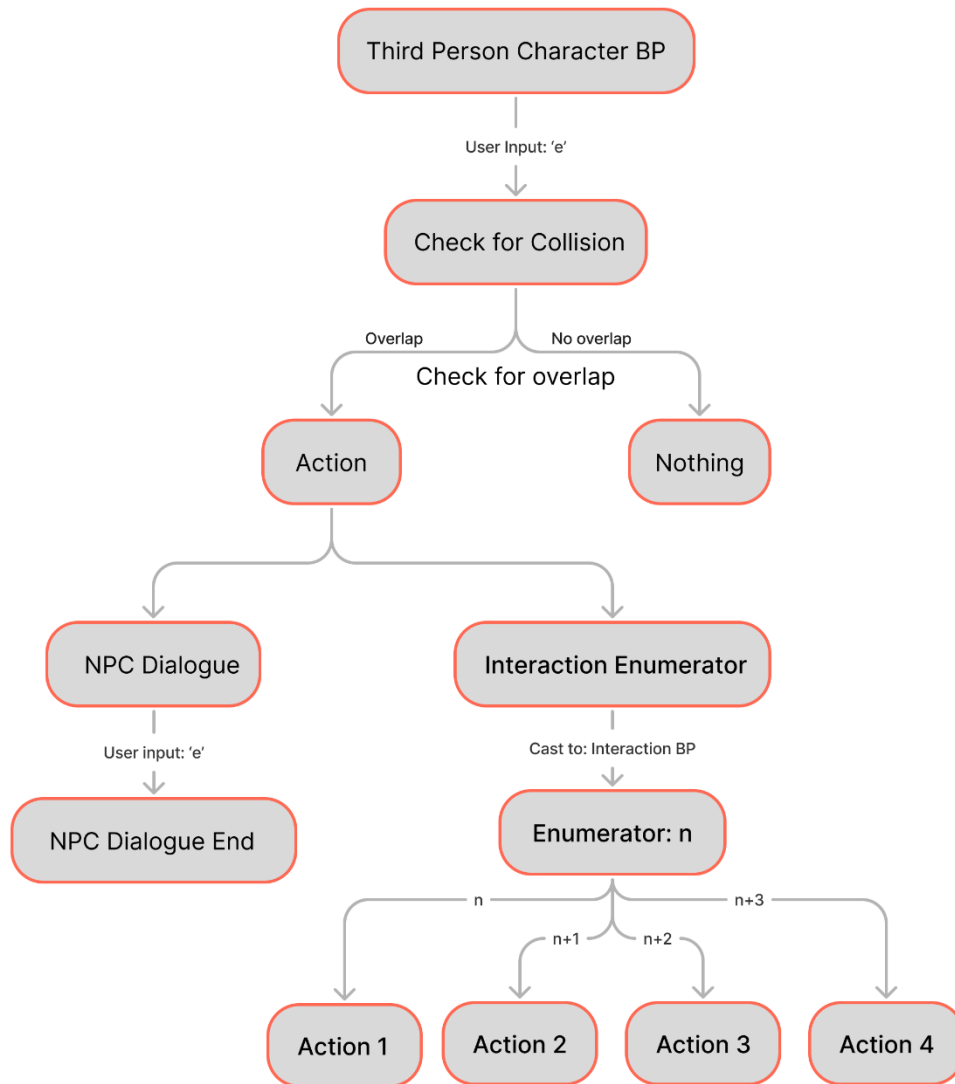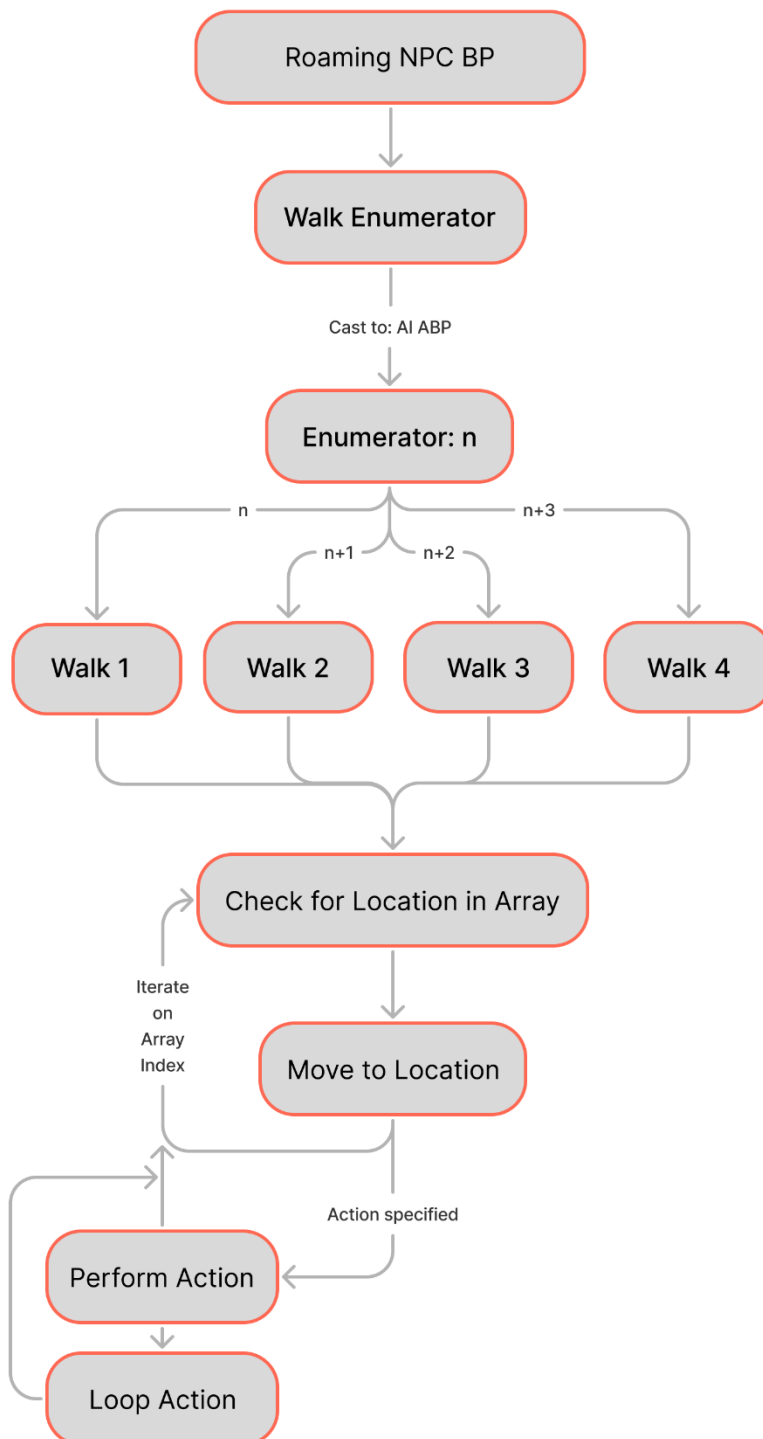
This graph describes the interaction logic within the third person character blueprint. It checks for a collision overlap and decides the action based on the output, it then proceeds to gather information from the other blueprint to take an action.
This blueprint generates overlapping events based on pre-set collisions. It supports the better understanding of Unreal Engine 5's system of variable and script interactions, as these elements are connected to multiple different blueprints.

Blueprint for throwable objects
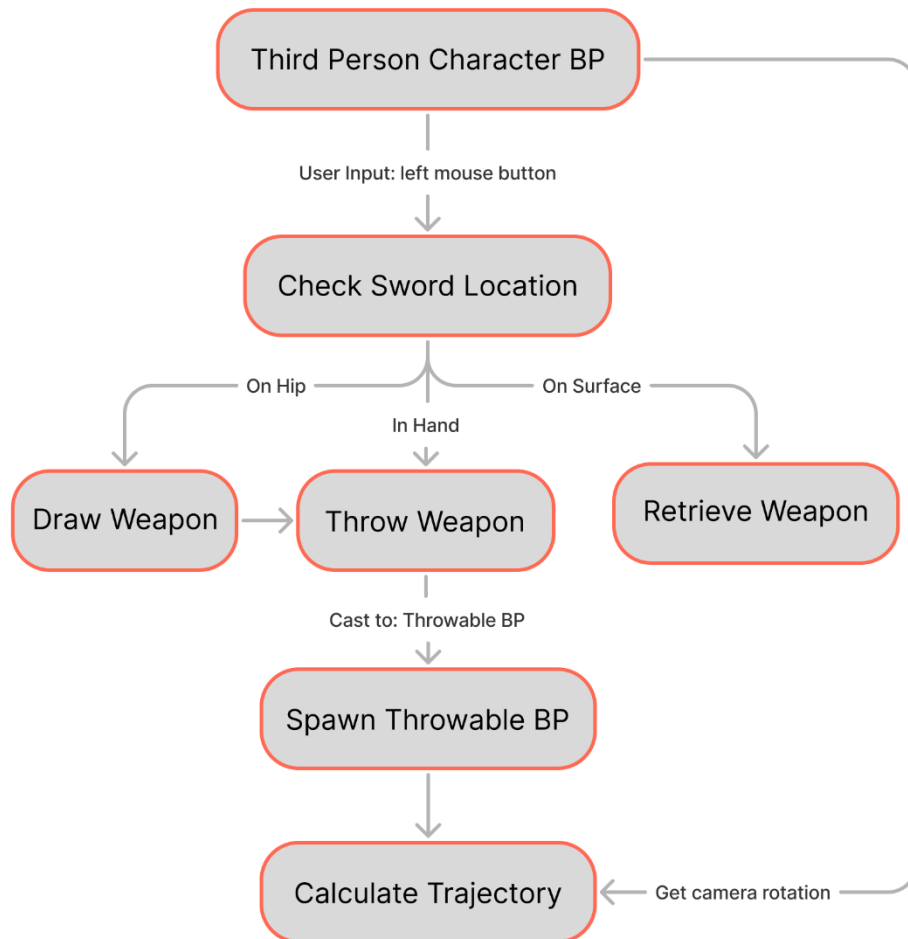
This graph shows the flow of the throwable object the character can use to hit targets and solve puzzles. It checks if the object is in the hand, on the hip or already thrown and decides the next action based on the information gathered.

Spawning objects based on a different blueprints position attribute (in this keys the hand bone (socket)), is an important feature to learn inside a game engine, as this can greatly enhance the experience of the user. This blueprint also calculates trajectory and physics based on the camera rotation, an element that the developer has not done before.

```
                        ┌─────────────────────┐
                        │   Roaming NPC BP    │
                        └─────────────────────┘
                                  │
                                  ▼
                        ┌─────────────────────┐
                        │   Walk Enumerator   │
                        └─────────────────────┘
                                  │
                             Cast to: AI ABP
                                  │
                                  ▼
                        ┌─────────────────────┐
                        │    Enumerator: n    │
                        └─────────────────────┘
```

n   n+3

n+1   n+2

| Walk 1 | Walk 2 | Walk 3 | Walk 4 |

Check for Location in Array

Iterate on Array Index

Move to Location

Action specified

Perform Action

Loop Action

This graph explains the cycle the non-playable character goes through to move around the scene. The blueprint allows for the change of walk animations, depending on the set input in the editable variable. From there on it sets the animation and checks the specified locations in the world via iterating over an array.

This more complex AI system allowed for the experimentation of arrays, enumerators, and AI tooling. This blueprint spawns moving NPC in the scene, that have a range of editable variables that help fast prototyping and iterating of the AI placement. The editable variables in the screenshots below, showcase the ease of use of the blueprin within the scene, as a lot of these elements can be altered to generate various scenarios.

Default	
State	Box
Anim to Play	0 Array elements
Repeats	0
Destinations	4 Array elements
Index [0]	InnerMarket3
Index [1]	InnerMarket4
Index [2]	InnerMarket
Index [3]	InnerMarket2
Has Object in Hand	☑
One Handed	☐
Object Roll Edit	90,0
Object Pitch Edit	0,0
Object Yaw Edit	0,0
Bump Text	7 Array elements
Index [0]	Mhm.
Index [1]	Yes?
Index [2]	Hello!
Index [3]	Good Morning!
Index [4]	Who needs THIS many fish?
Index [5]	These fish are freshly caught!
Index [6]	Hope I don't trip

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Given the interconnected nature of multiple blueprints and their role in creating new game elements, setting up UI elements, implementing death sequences, and forming the foundation for puzzle solving, individually listing each blueprint and its associated logic would result in unnecessary page length. To provide a comprehensive overview, a screenshot displaying all the blueprints within the game is presented below.
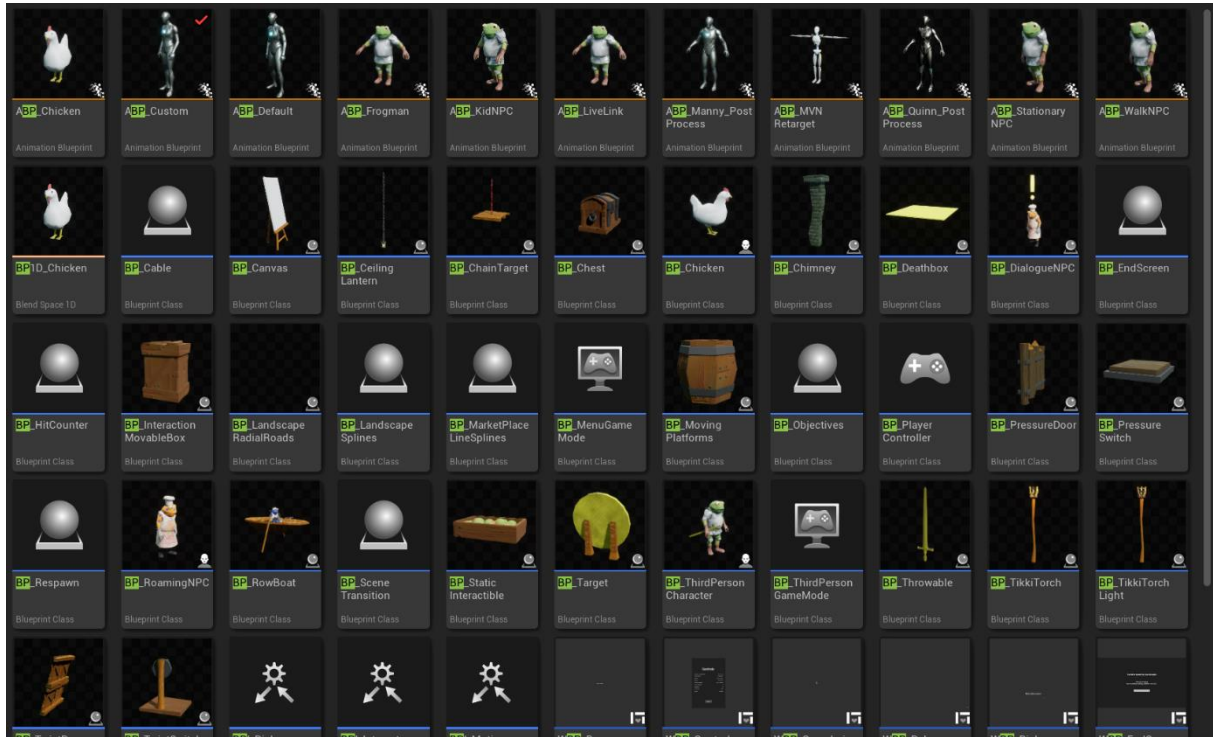
Block out and Level Design

With the importance of conceptualizing and starting with a good foundation, a first blockout and level design is a vital aspect of a successful product. Below is an image of the very first iteration of the environment inside Maya and below that a version in Unreal Engine 5.0.
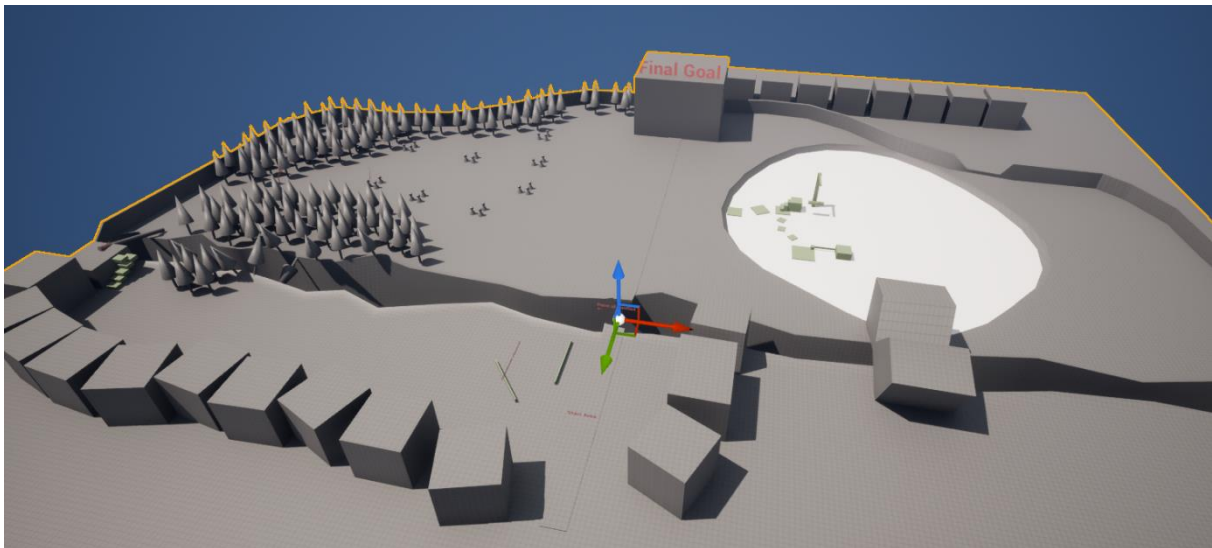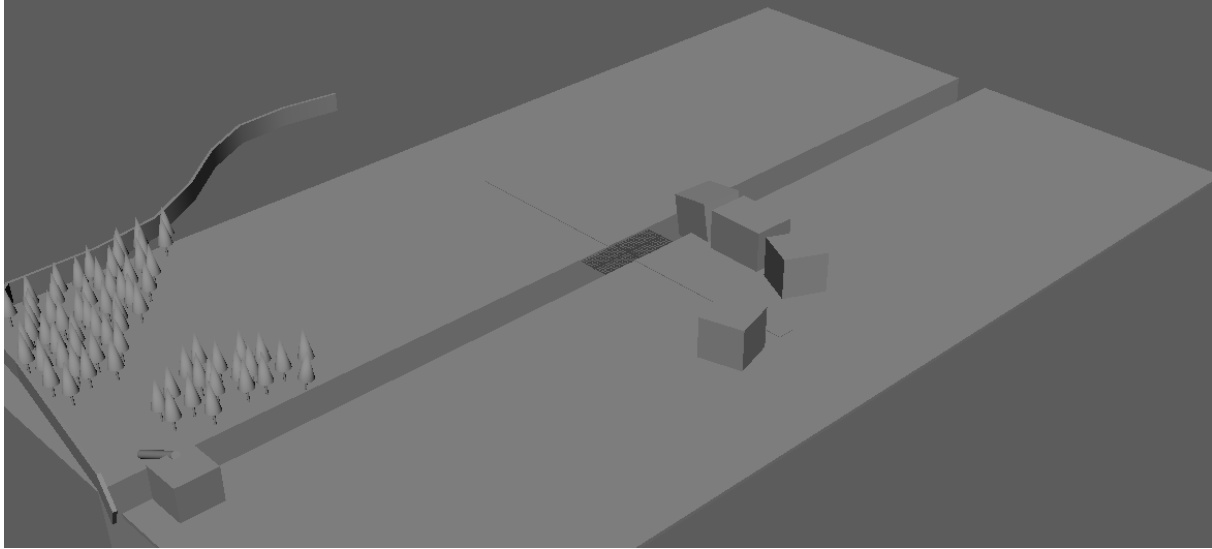
During the initial stages of development, the concept of incorporating a forest, houses, and a lake was present. However, as the project scope became clearer, a significant shift occurred in the layout of the environment. To effectively accommodate the creation of custom-made assets and avoid potential production issues, it was determined that a smaller, more confined environment would be more suitable than the initially envisioned large blockout.

The final layout of the game represents these changes:

In the interactive demonstration, the game flow follows a linear path with a predefined set of actions. However, the user is granted the freedom to deviate from the designated path and explore various interactions scattered throughout the map. The primary objective of this game is to encourage exploration and discovery of motion capture integration in an engaging and immersive manner.

Substance Designer Materials and Textures

As a 3D environmental artist and a focus on technical art as well as scripting and rigging, the experience within Adobe Substance Designer was limited before the project. However, the need for professional and seamless textures presented itself during the development of the project. The researcher built custom procedural textures fitting for the scene and overcame great difficulties during the creation. The following images showcase the complexity of the materials.
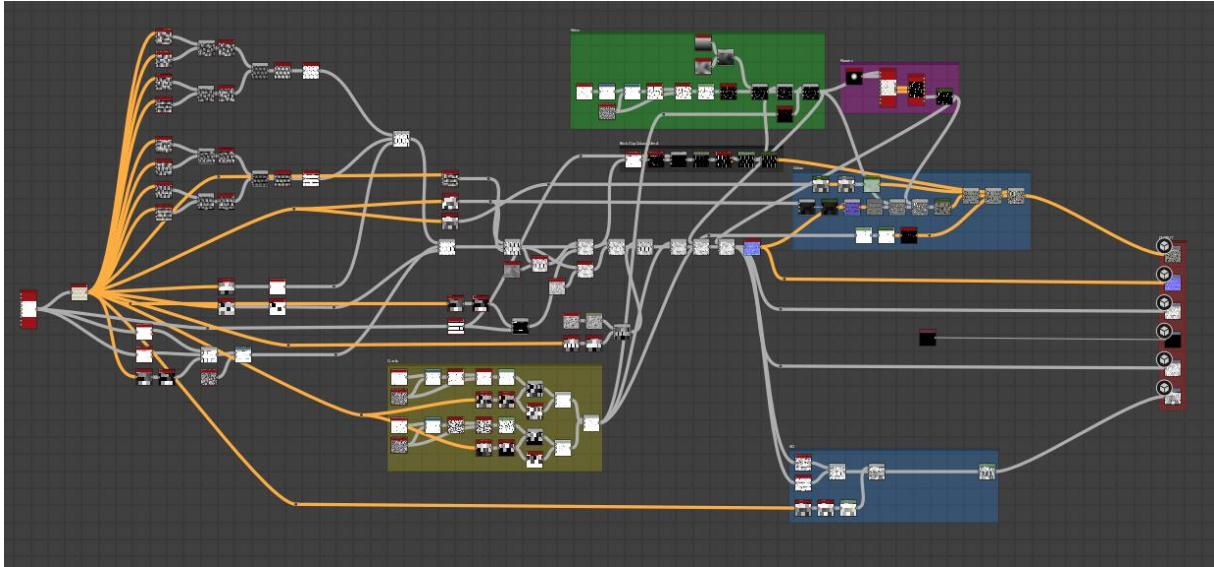
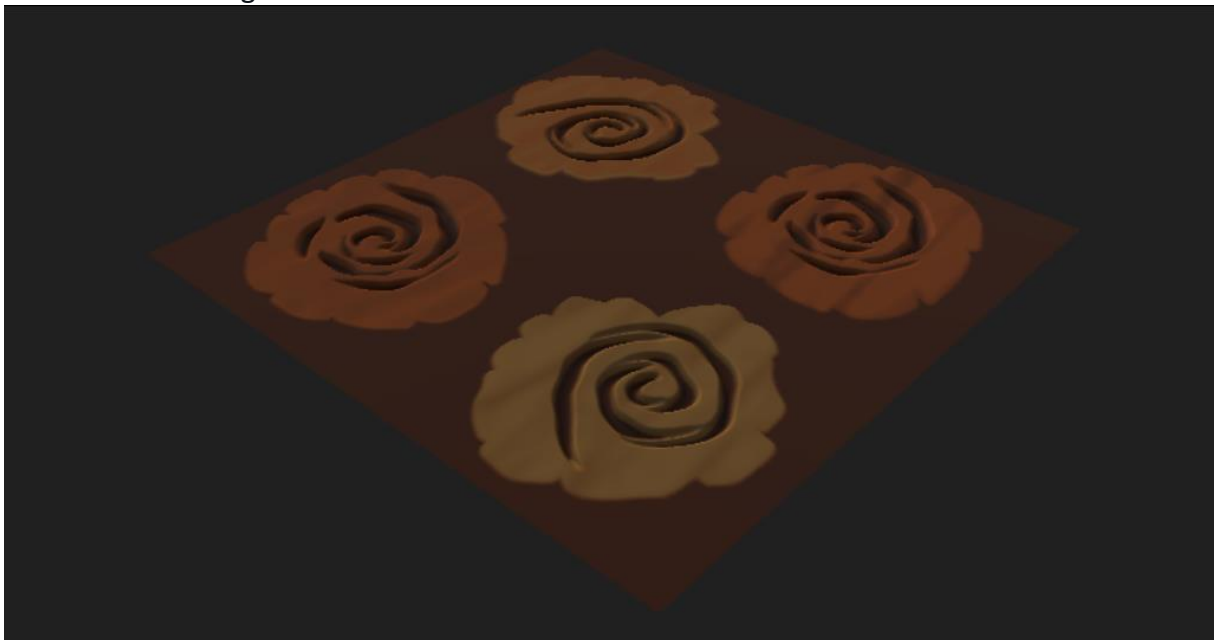Bricks wall for houses and towers. Covered with plants and flowers.
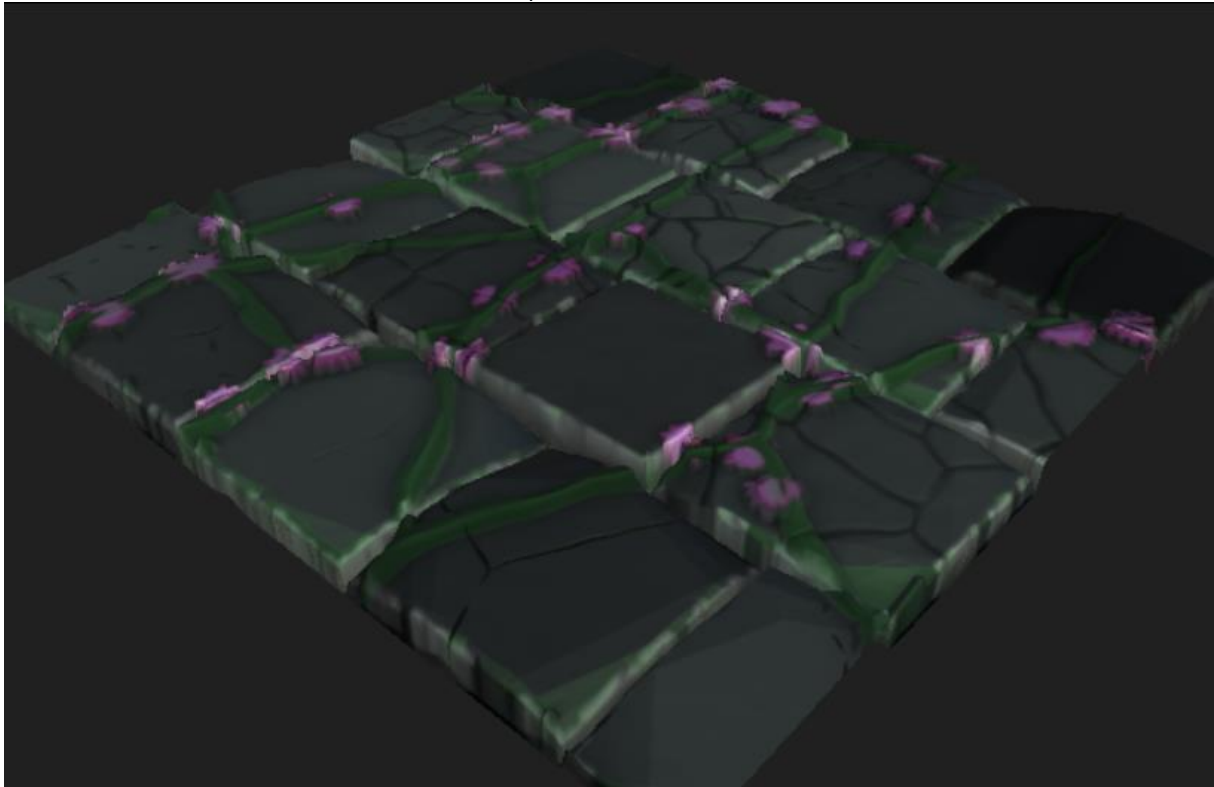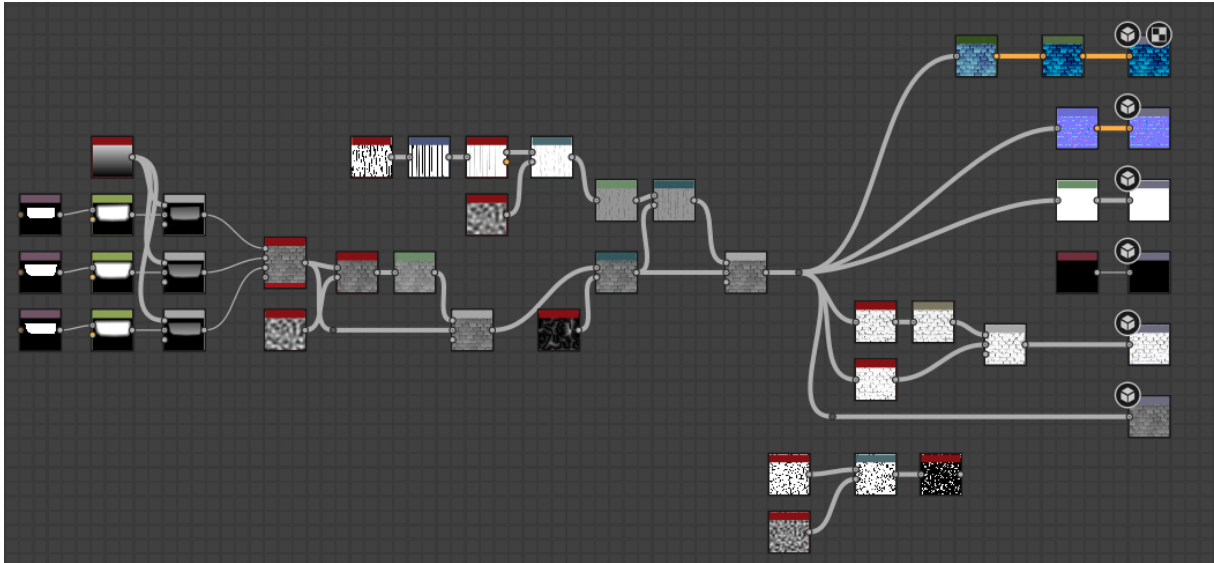
Rooftiles for houses and windmills.
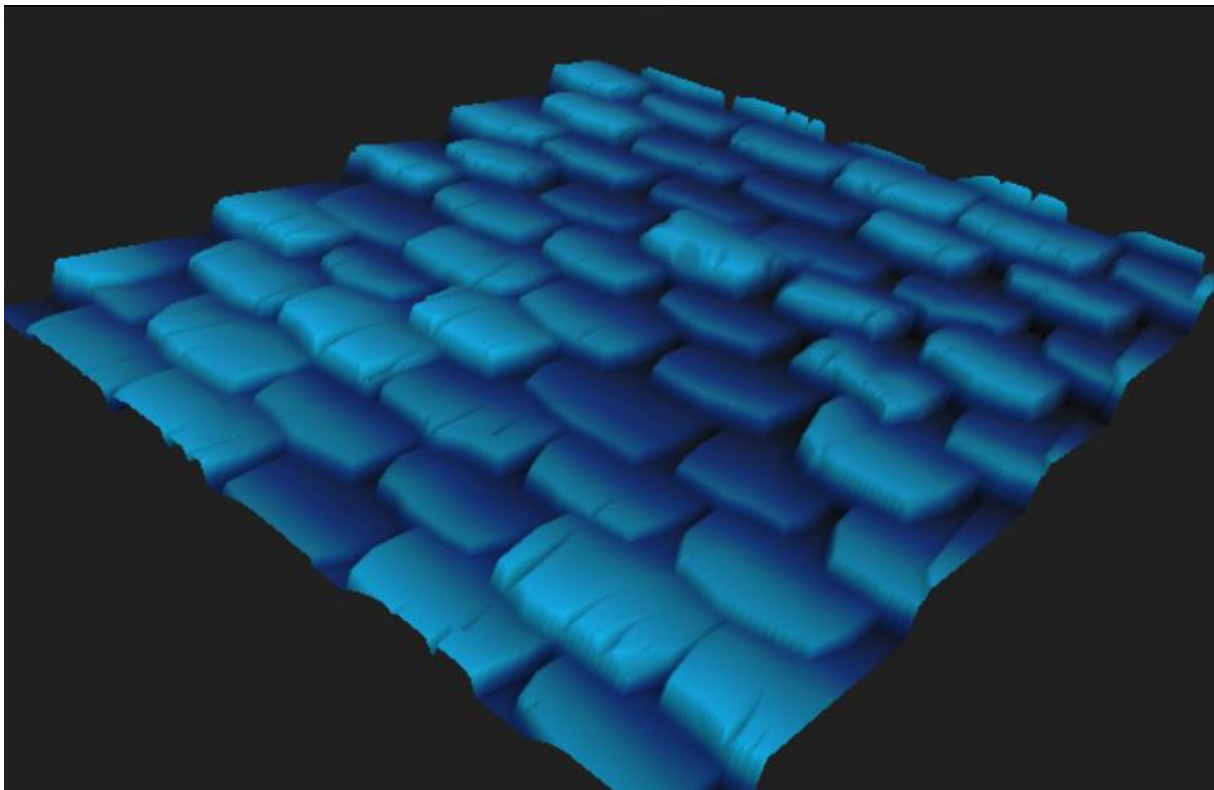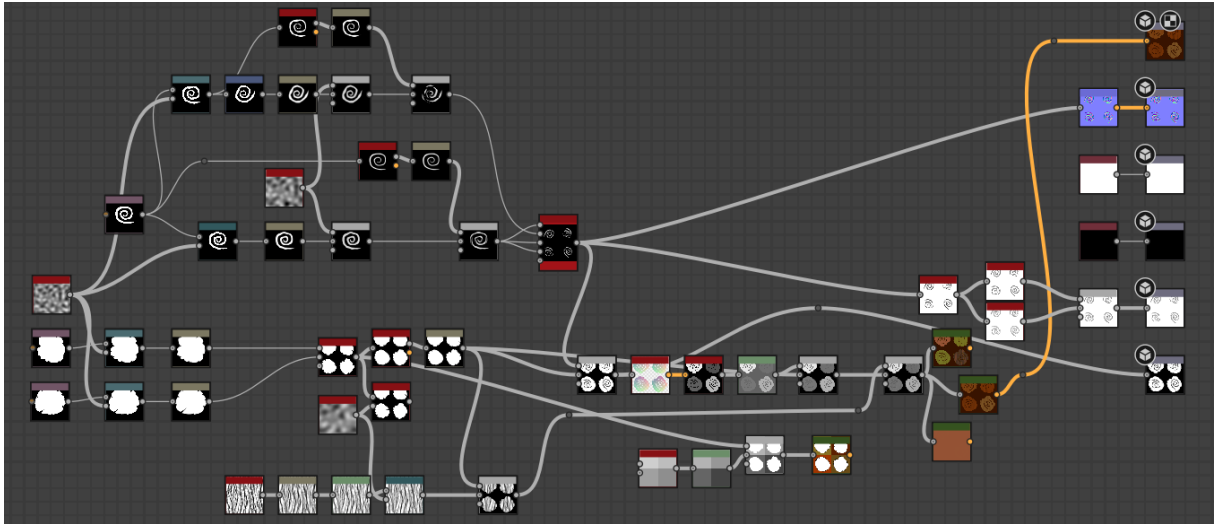
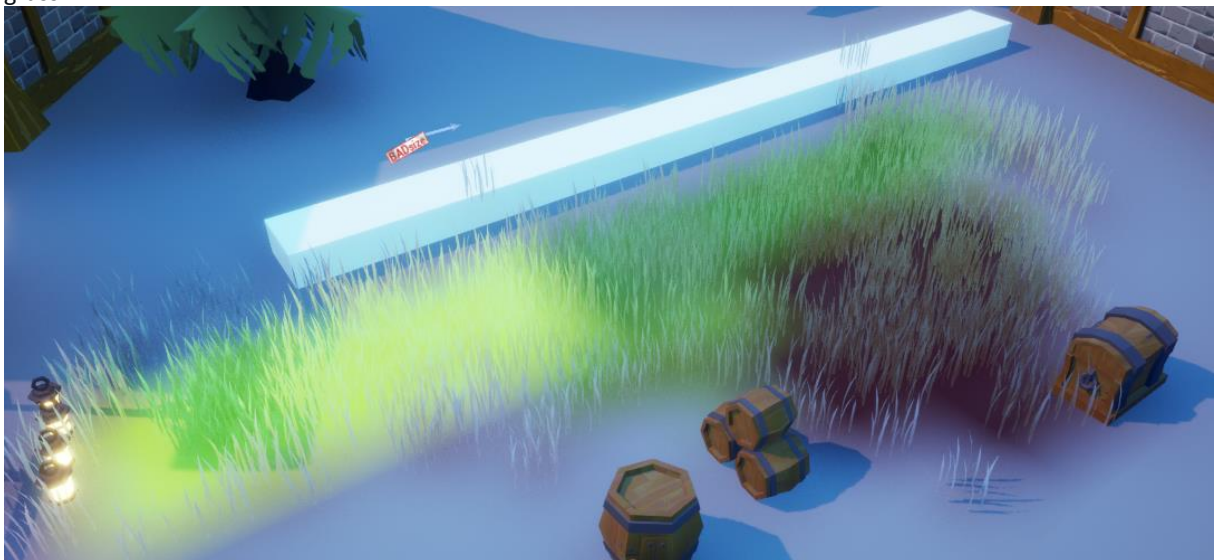Cross section of logs and beams for construction elements.

Early Development of Assets

The following section showcases early development assets and tests inside Unreal Engine 5.1.

Above: scaling and building tests

Below: virtual runtime texture testing, gathering RGBa values from the landscape and using it as input for the grass.

Above: Testing the implementation of smaller assets such as crates, fences, and lanterns.
Below: Lighting test, a brighter and more vibrant environment is needed.

Above: Texture blending of static assets with the landscape below. While working great on surfaces that are less than 90° from the landscape, it does not work on greater than 90° angles.
Below: Early iteration of the marketplace area, notice the area tags and blockout in the background, the structure of the environment and layout has changed based on feedback from users.
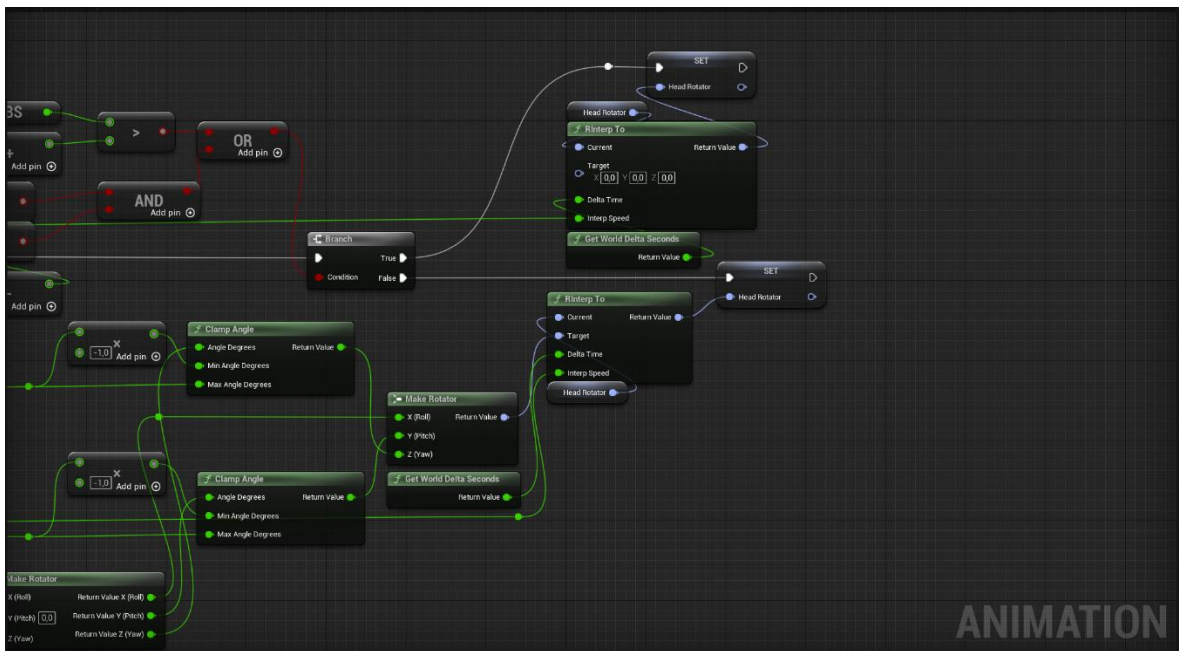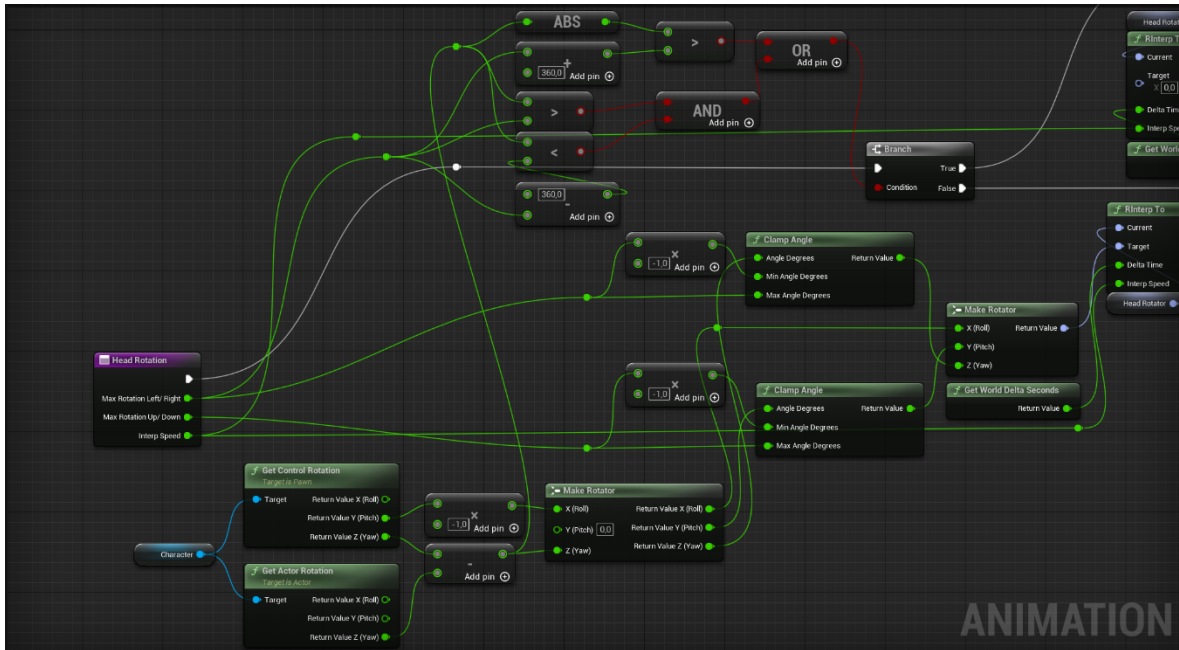
20 Appendix C - IK Foot placement and Head Rotation

Math and logic required for the IK foot placement inside the animation blueprint of the main character.
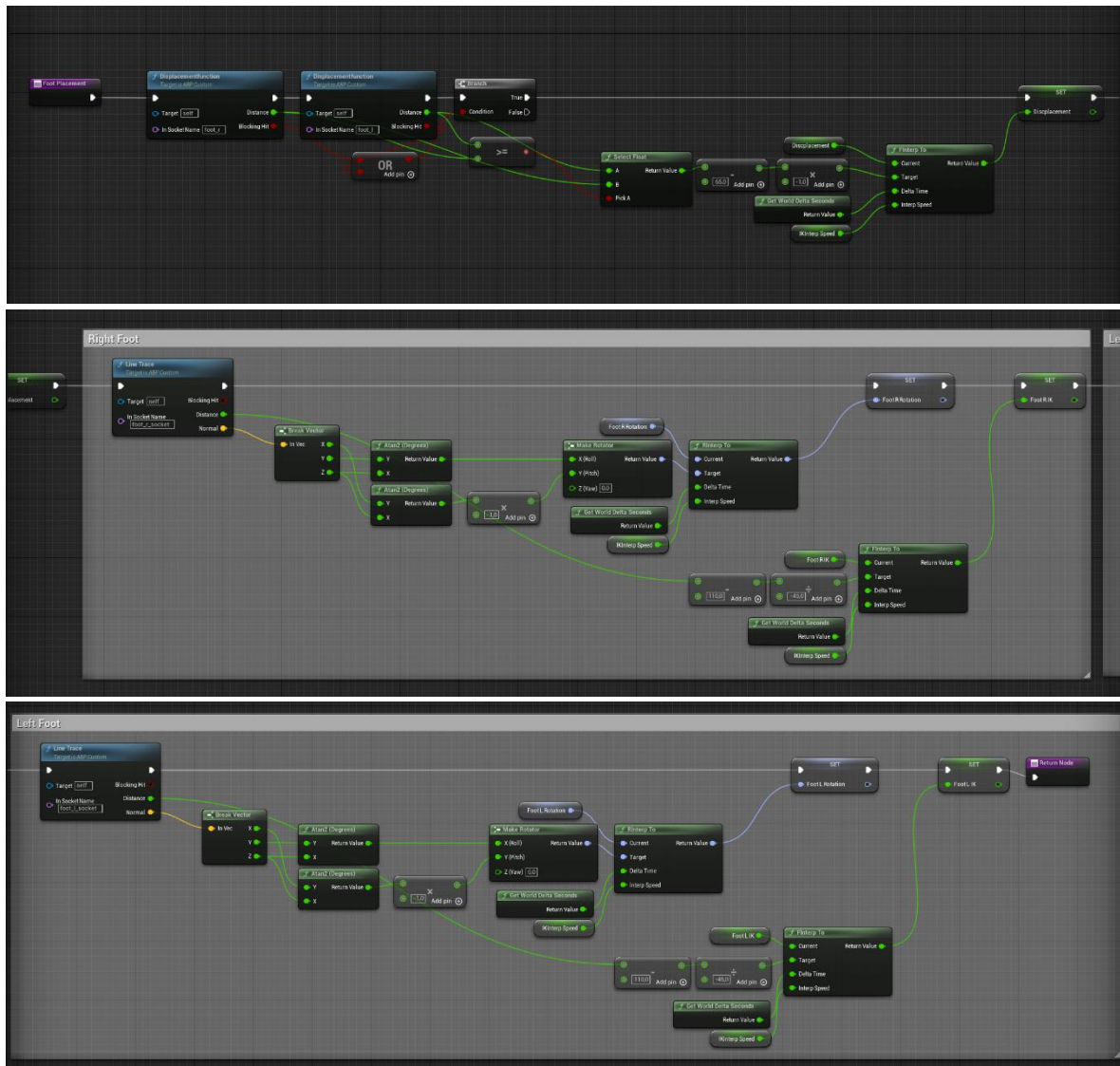
Math and logic required for the head rotation inside the animation blueprint of the main character.

21 Appendix D - System specifications of the testing hardware

Alienware M15
OS: Windows 10 64-bit
Processor: Intel Core i7-8750H CPU @ 2.20GHz
Memory: 16GB RAM
Graphics: NVIDIA GeForce RTX2070 with Max-Q Design
DirectX: Version 11
Storage: 237GB SSD (OS Drive)

Release date of the hardware: 2018

22 Appendix E - Test survey from the first play-test session

Testing period: 09.04.23 to 16.03.23
Product version: v0.1

Survey question 1: Were there any specific aspects of the prototype that were particularly challenging or inaccesible to you?

1. FPS was quite low for my end (average 15-20)
2. Jumping on the lily pads seems a bit difficult, the character **colliders with the lilypad's collider**.
3. Jumping is **hard/doesn't feel responsive enough**, but once I figured out that sprinting + jumping makes the jump bigger it gets a lot easier.
4. The jumping from lily pad to lily pad was difficult, but you already knew that.
5. The leaf jumping across the lake was **very frustrating**.
6. Lily pad jumping was very difficult.
7. Jumping across the lake was rather difficult.

Survey question 2: Did you encounter any barriers to understanding the game's story or objectives? FPS was quite low for my end (average 15-20)

1. Not exactly as long as the intention of the prototype is to test and accimulate the user with the environment (Theres no visible story perse but theres proper level design structure (training area where user tests controls followed by a "next level" where the user can die etc)
2. Objectives are clear and easily understandable with the provided guidance.
3. Nope
4. Nope it was pretty straightforward
5. No, the objective was rather clear.
6. The objective is clear.
7. The object of exploration was quite clear. The NPC helped out alot!
8. Not really, its quite straight forward and fun to play
9. The signs made the objectives and controls quite easy to understand

Survey question 3: On a scale of one to five, one being very easy and five being very challenging, do you think the difficulty of the jumping puzzle across the lake is appropriate?

4.11
Average Rating
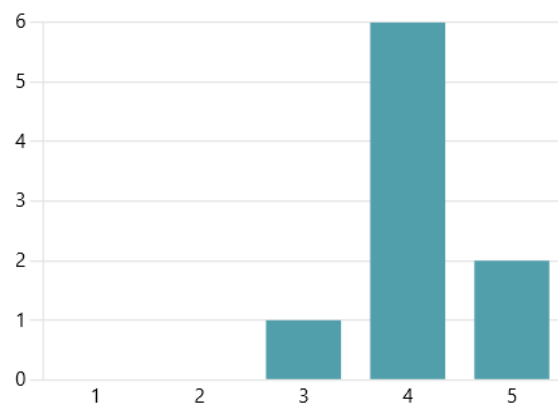
Legend: X Axis represents the subjective difficulty, Y Axis the number of responses.

Survey question 4: How much experience with video games do you have?

🔵 Less than an hour per week	1
🟠 Less than three hours per week	1
🟢 three to six hours per week	3
🔴 more than 10 hours per week	3
🟣 more than 20 hours per week	1

Survey question 5: On a scale of one to five, one being very intuitive and five being unintuitive, how did you experience the controls of the main character?

2.22
Average Rating
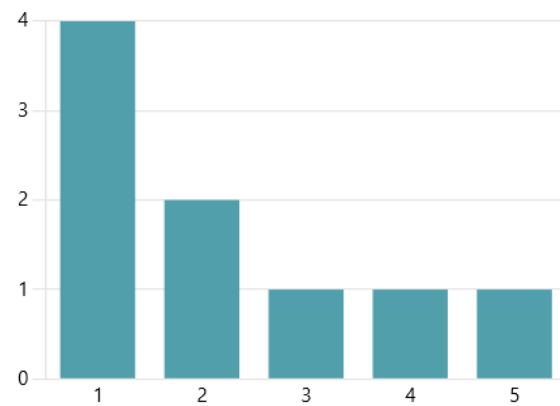
Legend: X Axis represents the scale of intuition, Y Axis the number of responses.

Survey question 6: Did you encounter any errors while playing, if so how many?

|	
🔵 None	0
🟠 One to two errors	3
🟢 three to six errors	6
🔴 six or more errors	0

Survey question 7: If you encountered errors while playing, could you list them?

1. Colission issues in a few areas, climbing moves the character to the front, npc interactions, lilly pads area was a bit off, fences have no collissions, tower cannot be climped from the other side
2. collision with NPCs makes them flow; Locked camera while looting the chest (not really an error) and facing the opposite direction, jumping over the lake; Collision of the fallen building, which the player needs to progress for the lake level, is a bit high; Bug when dying in the lake if pressed 'Tab';
3. Falling through the world/jumping off the map - once when pressing E on the chest, the main character started running and wouldn't stop. The camera and movement were locked and I had to reset the game
4. The meat cutlets hanging in the little vendor's stall spawned twice and were clipping over each other. The NPCs without dialogue got catapulted around whenever I ran into them. The chest opening animation looked real cute, but it wasn't sinced up with the character movement and I wish I could've rotated my camera while opening the chest.
5. Flying NPCs when you run into them, top left corner of the UI has some weird dots?, the collision of the tower you need to cross is wrong.
6. Character kept moving when opening the chest. Dialogue system stopped working.
7. Bouncing NPC when you collide with them (could be a cool feature?), the chest interaction locked my keyboard and mouse, I was flying above the tilted tower. Sometimes I was touching the water in the lake, but didnt die
8. One of the npcs was jumping weirdly when my character touched them
9. The chest animation problem and also the interactions with the NPCs were sometimes a bit buggy

Survey question 8: Were there any aspects of the prototype that you particularly enjoyed?

1. I liked the assets and the art style of the prototype. I also liked the theme and universe of the prototype
2. The environment is pleasant to look at, the animations (walk, sprint, pickup, and somewhat jump) are good. The navigation throughout the level is good (especially with the provided text), the '!' mark above NPCs help additionally.
3. The graphics! And frog people! Animations were really nice as well.
4. I really liked the NPCs chilling in the village and how they moved. There's lots of cute details and I like the cozy atmosphere. Also the frog wishing me safe travels across the pond made me smile
5. The environment looks very consistent! I like the frog people.
6. The NPCs.
7. The art style is adorable! I loved the idea of a town just consisting of frogs.
8. I liked the theme of the game and the character designs
9. Playing as a frog was interesting at least. Exploring the market area was fun

Survey question 9: Is the number of NPC conveying the implementation of MoCap into a video game?

● Yes	3	
● No	0	
● Maybe	6	
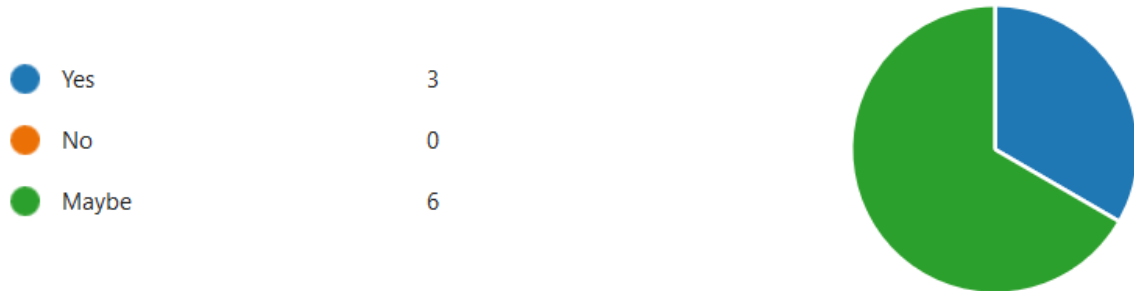
Survey question 10: On a scale of one to five, one being very natural and five very unnatural, do the animations of all characters within the world seem natural?

3.11
Average Rating
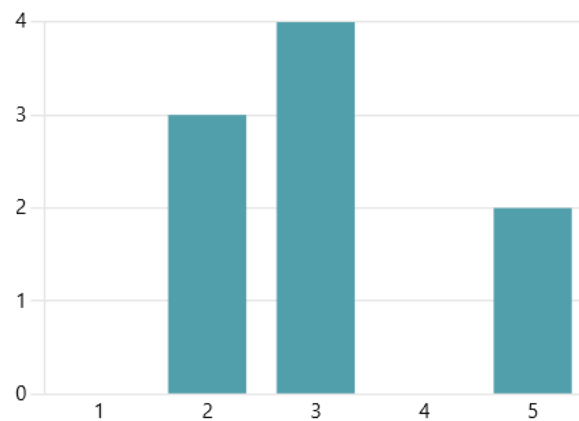
Legend: X Axis represents the natural feeling of the character movement, Y Axis the number of responses.

Survey question 11: Is there something you would like to see implemented involving Mocap animations, such as additional interaction with the environment?

1. Make this optional Woodcutting And painter doing artsy stuff
2. Interaction with the NPCs, maybe a talking animation. Attack animation?
3. Difference in animation when walking up/down a slope vs walking on flat ground.
4. I mean more is always more, right? If it was up to me I'd play games just to watch the NPCs go about their day. The frogs could go swimming in the pond, sunbathe, pick flowers, read books, so many things!
5. More environment interactions! All the NPCs have the same look and feel, they could use some personality!
6. Interaction with NPCs. More variety in NPC movement.
7. The player should have some more interactions with the NPCs.
8. Someone waving from a building window maybe would be fun
9. If you had someone in the water swimming Kids playing in the fountain?

Survey question 12: What, in your opinion, is the best looking animation of this iteration of the technical prototype?

1. The fisherman
2. Walking , Sprinting and Looting animations
3. Running
4. The character movement while opening the chest was banger. Also the crouching looks very convincing and I liked the fishing animations :)
5. The fishing looks cool!
6. The NPC talking during the dialogue
7. The jogging from the main characters looks so fun!
8. I liked the animations of the children
9. The NPC giving info about the poison lake was the best in my opinion

Survey question 13: How fitting into the scene do you believe that the main character and the NPC are, from one being very fitting to five being not fitting at all?

2.33
Average Rating
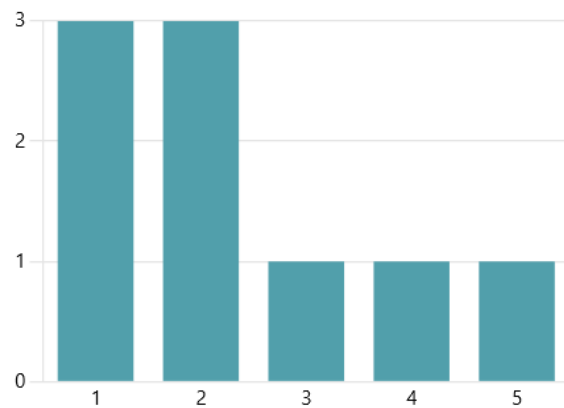
Legend: X Axis represents how the characters fit into the environment, Y Axis the number of responses.

Survey question 14: Does the world where the prototype takes place, feel alive?

● Yes	7
● No	0
● Maybe	2

Survey question 15: If you could add more elements to the world, such as nature elements, architecture, or others, what would you like to see?

1. Perhaps a different kind of building, some individual assets like a cart with wood
2. a huge castle and a cave
3. More types of buildings, more types of plants.
4. I think the overall look would benefit from more stylization consistency, since some parts like the frog anatomy and the MCs armor look relatively realistic in their art style, while the surrounding and architecture, items etc. look more strongly stylized. Other than that idk, maybe some birds? More foliage? Idk I think it's cute. But maybe the location where the demo ends could be more extravagant so you have a visual destination to approach.
5. More tree varieties! Also maybe some animals, like chickens? Some more houses would be cool as well.
6. More flora and fauna.
7. Animals! Of any kind! Maybe some castle in the background.
8. Some more particles in the air? A butterfly or some leaves on the ground
9. A mine on the edge of the village should be a nice addition to the scene

23 Appendix F - Compiled list of all added features after the first test

Category	Fix/Feature
Bug	Colliding with an NPC created unwanted physics interaction. This interaction is fixed by altering the collision aspect of the main character from 'physics actor' to 'custom'.
Bug	The locked camera during the interaction process has been resolved by altering the animation mode from 'additive' to 'no addition', resulting in the wanted behaviour and playing the animation in place.
Bug	The lack of menu and quit options during gameplay resulted in a negative experience for the player. This issue has been resolved by adding a main and pause menu, as well as basic functionality during these menus that allow for quitting the application.
Bug	During the live-link mode, the input of both keyboard and mouse has now been disabled and prevents unwanted behaviour.
Bug	The errors with collision of player and the lily pads in the jumping puzzle has been resolved. This results in the player model not getting stuck anymore and the general experience improving.
Bug	It is no longer possible to enter live-link map and mode when no MVN animation is connected.
Bug	The collisions with houses and structures are redefined and creates the wanted behaviour.
Bug	The UI has been redefined with more features, such as an objective for better player direction. This directly fixed the bug of broken widgets on the screen.
Bug	All art assets placed within the scene have been reiterated to ensure no overlaps and light issues.
Bug	NPC no longer get stuck on their path to complete a task, the pathing and interaction processes have been redefined and tested.
Motion Capture	It is now possible for the main character to interact with pre-defined objects. This interaction method allows for quick interchangeable iteration in the later processes.
Motion Capture	The NPC now have more animations and interactions with each other and the environment. The transition between their animations is clearer.
Motion Capture	The main character now changes walk animation on slopes and stairs. The legs and feet detect surfaces and bend in a natural way during gameplay.
Motion Capture	The jumping mechanic of the main character has been redefined and tested. It now runs smoother and more predictable, resulting in a better gameplay experience.
Motion Capture	The main character's locomotion now blends better between animations during rapid movement.

Motion Capture	The main character can now push predefined crates and interact with lever to solve puzzles.
Motion Capture	The main character can now throw their weapon at targets and retrieve it.
Motion Capture	Added more than 30 captured animations for NPC and the main character.
Motion Capture	The main menu now incorporates a direct link to the base.xsens.com website to give information.
Motion Capture	The main menu now incorporates a How-to page, that explains the different methods of motion capture required for the product, with a side-by-side view video of actor, MVN and Unreal Engine 5.
Accessibility	It is now possible to pause the game.
Accessibility	The dialogue of NPC has been made clearer with instructions.
Accessibility	An additional user interface widget that indicates the current objective has been added for a better gameplay experience.
Accessibility	The addition of main, pause and options menu allows for a better gameplay flow and experience of opening and closing the game.
Accessibility	A new options menu allows for the configuration of resolution, shadow, texture quality, Anti-Aliasing settings, and mouse sensitivity, resulting in better performance on lower end computers.
Accessibility	The difficulty of the jumping puzzle across the lake has been adjusted and tested. This results in the puzzle being more accessible and easier to complete.
Look and feel	Added a third section to the world. 'The mine town' will feature an additional puzzle and more non-playable character interactions.
Look and feel	Added a new map after the mine town, where the main character solves puzzles and finishes the game.
Look and feel	NPC now talk to the player when bumped into.
Look and feel	Added basic background audio to the scene for better immersion.
Look and feel	Added additional structures and houses to the world.
Look and feel	Added chickens to the scene with AI behaviour. The chickens interact with the player during gameplay and allow for a better engagement.
Look and feel	Added new models for the non-playable character, resulting in less repetition and fast iteration processes.
Look and feel	Added stairs and slopes into the scene.
Look and feel	Changed the look and feel of art assets throughout the scene to create a more consistent art style.
Look and feel	Added more plants to the scene, including bushes and flowers

| Gameplay	Added a section for throwing weapons at targets. The player can throw their main hand weapon at predefined targets, allowing for a more engaging gameplay experience.
Gameplay	When the main character hits targets with their sword, the score rises.
Gameplay	The main character can now push boxes onto pressure plates, solving small puzzles in the third section of the game.
Gameplay	The main character can now interact with switches to open gates in the third section of the game.
Gameplay	The main character can now throw their weapon at chains inside the cave to solve puzzles.

24 Appendix G - Test survey from the final play-test session

Testing period: 29.05.23 to 02.06.23
Product version: v0.97

Survey question 1: Were the objectives within the prototype clear to you? (1 – very unclrear; 5 – very clear)?

4.00
Average Rating
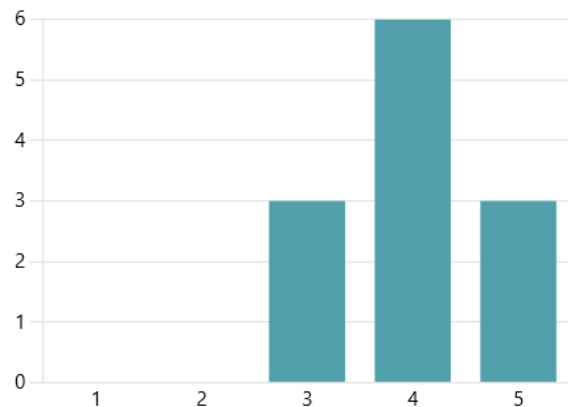
Legend: X Axis represents the transparency of the objective, Y Axis the number of responses.

Survey question 2: If the objectives were unclear, did the occasional guidance of the non playable characters help?

Yes   12
No   0
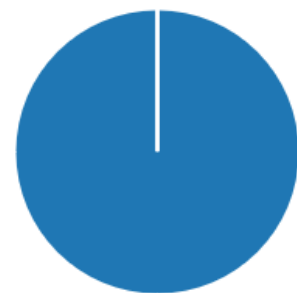
Survey question 3: Were there any objectives within the game that either positively or negatively stood out?

1. The chicken chasing had no end to it, you just kinda leave
2. Throwing the sword to get a score was fun!
3. The mine was a bit hard to navigate
4. The cave is a bit confusing at times
5. Finding the pickaxe was a fun section
6. jumping across the lake with the guidance of the npcs was fun
7. I was a bit lost at the start, but the NPC guided me a bit.
8. chasing the chickens has no goals?
9. The start was a bit unclear where to go and the mine was also difficult to navigate.
10. cave wasnt clear
11. As this game focuses on exploration, sometimes the objective was not as clear as hoped

Survey question 4: How would you rate the overall difficulty of the game (1 – very difficulty; 5 – very heasy)?

4.17
Average Rating
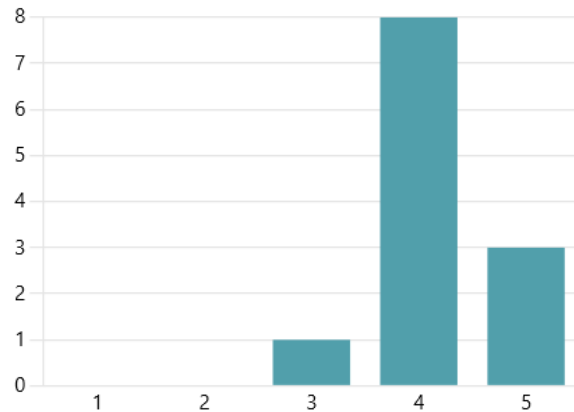
Legend: X Axis represents the subjective difficulty, Y Axis the number of responses.

Survey question 5: If you encountered very difficult areas, please provide a description:

1. liliypad jumping is tricky cuz you get stuck on the edges sometimes and also it's weird that you need to release shift before hitting the spacebar, also the sword never hits exactly where I aim it. The mine was very dark
2. Barrel jumping can be quite difficult sometimes.
3. Sometimes I got stuck on lillypads with my feet
4. I got frustrated with the jumping
5. jumping can be difficult sometimes
6. The sword flying through the air does not always hit exactly where I aim.
7. Hitting the targets with the sword sometimes misses, even though im on the target with the aiming guide
8. Jumping is sometimes acting a bit weird and the mine was super dark for some reason
9. Jumping is difficult with the barrels in the mine

Survey question 6: In your experience, was the performance of the game smooth (1 – Very Rough; 5 – Very Smooth), meaning the frames per second were between 40 and 60 fps?
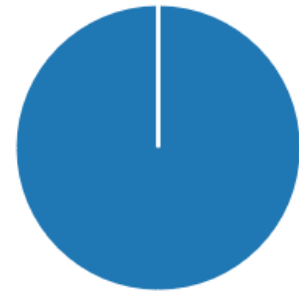
4.42
Average Rating
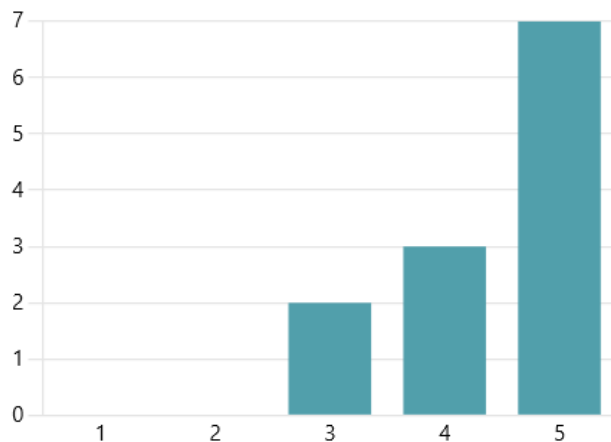
Legend: X Axis represents the perceived performance of the game, Y Axis the number of responses.

Survey question 7: If the performance was not optimal, did changing the graphics settings in the menu improve it?

● Yes	6
● No	0

Survey question 8: Were there any areas where the performance was particularly smooth or rough?

1. The marketplace was giving me some minor lag.
2. No, it all ran fine.
3. the places with many npcs and objects were laggy
4. the cave ran very smooth
5. anywhere where there are not many objects runs perfect, the dense market caused some problems
6. the cave was not laggy at all

Survey question 9: Did you encounter any errors while playing, if so how many?

|	
● One error	7
● Two to four errors	2
● Four to six errors	0
● Six or more errors	0

Survey question 10: If you did encounter bugs and errors, briefly describe them:

1. no checkpoint during the mine barrel jump section, pushing crates only sometimes triggers pushing animation, villagers got stuck at the marketplace
2. The camera moves abruptly when climbing sometimes.
3. When moving the camera and holding 'w' while interacting with elements, turns the character in a funny way.
4. sometimes the arm does not move when equipping the weapon. I saw that the confetti when hitting a target appears twice sometimes.
5. sometimes npcs get stuck into each other
6. sometimes during the target practice, the confetti appears twice?
7. Sometimes I was able to throw my sword twice
8. flickering of the character when climbing over logs
9. The barrels in the cave popup after sinking down?

Survey question 11: Do the motion capture animations within the game (both player model and non playable characters) benefit the game in terms of immersion and livelihood (1 - not beneficial at all: 5 - very beneficial)?
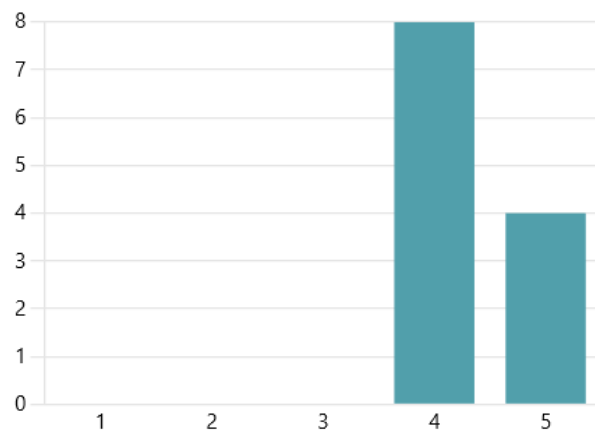
4.33
Average Rating
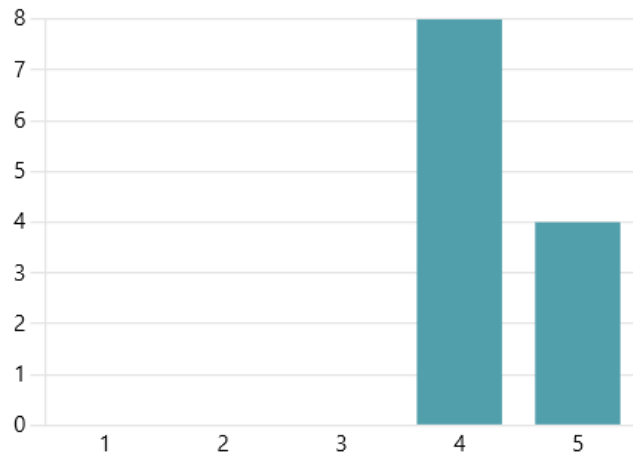
Legend: X Axis represents the perceived immersion and livelihood of integrated animations, Y Axis the number of responses.

Survey question 12: Do the animations of the main character flow well into each other and provide the player with a smooth gameplay experience (1 - very choppy and bad flow; 5 - very smooth blending and good flow)

4.33
Average Rating

Legend: X Axis represents the perceived flow of integrated animations, Y Axis the number of responses.

Survey question 13: Are there animations you would have liked to see be implemented and highlighted more?

1. idk maybe an idle animation
2. The npcs could have done more in the scene!
3. The main character could have interacted with more world objects.
4. A way of showcasing combat would have been nice to see
5. combat animations, game animations like climbing a wall or gathering materials
6. maybe a crafting station could be cool
7. An interaction with animals would have been nice to see, or fighting.
8. Yes, some additional interaction with NPCs could be nice
9. Combat, or at least some fighting against dummies. A bit more action-driven animations.
10. Combat and fighting

Survey question 14: What, in your opinion, is the best looking animation within the game?

1. the fisherman
2. The talking of npcs with each other.
3. The fisherman!
4. the kid being scolded
5. the miners mining away stone!
6. the npc that is sawing the logs before the mine, that looked really good
7. The NPCs talking
8. The sawing before the mine
9. The vaulting over objects, really cool how it detects that.
10. The fisherman
11. the marketplace overall

Survey question 15: Does the environment and the characters within the game build an immersive and engaging environment (1 - not immersive and engaging at all: 5 - very immersive and engaging)
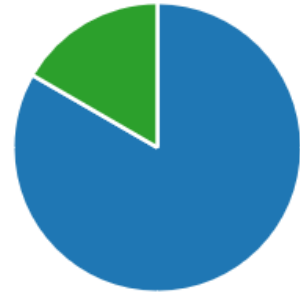
4.58
Average Rating
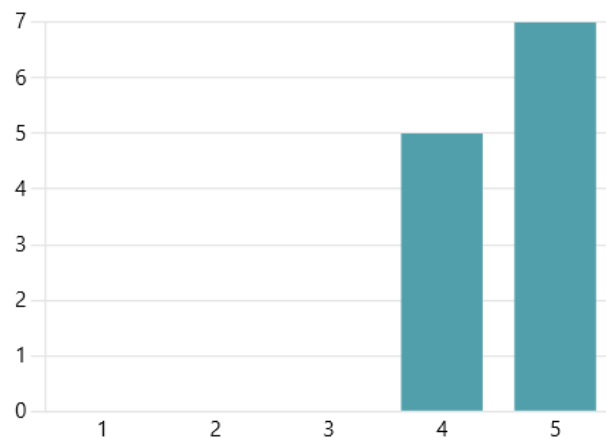
Legend: X Axis represents the perceived immersion of the environment, Y Axis the number of responses.

Survey question 16: Does the world where this game takes place, feel alive?

● Yes	10
● No	0
● Maybe	2

Survey question 17: What, in your opinion, is the best looking animation within the game?
1. more animals? maybe some birds
2. A bit more audio than background music and ambient noises would greatly benefit this.
3. Audio.
4. more audio and vfx
5. sound effects could greatly improve the scenes
6. More animals
7. Some more audio and music differences with events would help make it even better
8. Animals and audio
9. I would add some more audio and animal noises

Survey question 18: If you have any suggestions for environmental, visual or other improvements, feel free to briefly list them below.
1. The game could use more audio cues. I think more different NPCs would be interesting to see.
2. Maybe you could add more npcs and enemies around the world
3. Add more npcs including enemies to slay!!
4. Audio and animals would be cool
5. Some more audio could be interesting to listen to.
6. I would add more audio cues, but also a bit more complex area after the mine
7. I would add some more animals that roam the world, maybe cats, dogs or fish in the lake
8. Maybe some differentkind of trees would help

25 Appendix H - Recorded and used Motion Capture Animations

The product utilises over 50 animations recorded with the support of the MVN Awinda.

Animation	Context
Jog Forward	The main characters movement forwards. Sets position of the character based on root motion.
Jog Backward	The main characters movement backwards. Sets position of the character based on root motion.
Jog Sideways	The main characters movement sideways. Sets position of the character based on root motion.
Jump	The main characters vertical movement. Sets position of the character based on root motion.
Idle (5)	NPC (3) and main character (2) idle animations.
Crouch Idle	The main characters idle animation while crouching.
Crouch forward	The main characters crouched movement forwards. Sets position of the character based on root motion.
Walk Forward	NPC and main characters walking forwards. Sets position of the character based on root motion.
Throw Sword	The main character's ability to throw an object.
Catch Sword	The main character's ability to catch an object.
Inspect	The main character's ability to inspect an object.
Pickup (2)	NPC and main characters animation to pickup an object while standing or kneeling.
Interact – Turning	Main characters motion while interacting with a game mechanic.
Interact – Juggling	Main characters motion while interacting with a juggling location.
Feed Chicken	NPC motion to feed the chicken with seeds.
Talk (5)	NPC motion for dialogue and interaction.
Fish	NPC motion for fishing near water.
Play Flute	NPC motion for playing the flute.
Wave (3)	NPC motion for guiding the main character.
Chop Wood (3)	NPC motion for chopping and cutting wood.
Saw	NPC motion for sawing wood.
Mine	NPC motion for mining rocks and ore.
Carry Object	NPC motion for carrying boxes with 2 hands. Sets position of the character based on root motion.
Push Object	Main character movement for pushing an object. Sets position of the character based on root motion.
Scolding	NPC motion for scolding a child
Ashamed Child	NPC motion for acting ashamed.
Leaning	NPC motion for leaning on a bar tabe.

26 Appendix I – Internal Testing Details

During the sales and marketing week at the Movella office in Enschede, product specialists and marketing employees expressed their opinions during a playtest session. This play session was guided by the researcher and a variety of stakeholders had the opportunity to experience the product.
The latter expressed questions regarding the implementation of MVN products. These questions included, but were not limited to:

- Does the IK foot placement and head rotation work during the live-link session?
- Does the live-link controller control the main character in any way?
- How and where did you record all the animations for the game?
- Does your prototype include documentation on how to achieve this?
- Is this product scalable for the future?

Gameplay related questions included:

- Is there a way to win the mini-game where you hit the targets?
- Why is the water in the mine not killing me, the water before was killing me?
- Why is the light so dark inside the mine?

Positive expressions during the play session included:

- The game and everything in it look great and usable in future demos.
- The animations of all characters within the game look great
- The option of live-link in a separate area and the How-To menu tie well into a full deliverable.
- The world feels alive and driven with motion, exactly what Movella strives for
- The future development looks promising.

During the play session with stakeholders, it became apparent that the product in its current state has delivered a solid implementation of motion capture highlighting, engagement of end-users, and educational material for employees and clients.
Based on the feedback gathered during the playtest sessions, changes have been made to the product that are in line with the criticism and more in vision with the stakeholders wishes.
These changes include:

- The How-To menu is restructured and now showcases a side-by-side view of actor, MVN mannequin, and in-game avatar, showcasing the accuracy of the soft- and hardware.
- An implementation of the score system within the game has been created. It is now possible to track the players score when hitting targets, resulting in more enjoyment.
- The collision with water inside the mine has been fixed and now eliminates the player, resulting in consistent game elements.
- The light in the mine has been changed to be way brighter, making it easier to see on all screens and real-life environments.