USER-GENERATED CONTENT-BASED EDUCATIONAL ECOSYSTEM IN THE METAVERSE

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I certify that in my opinion the thesis submitted by Qasim Ahmed Qasim QASIM titled "USER-GENERATED CONTENT-BASED EDUCATİONAL ECOSYSTEM İN THE METAVERSE" is fully adequate in scope and in quality as a thesis for the degree of master's degree

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Qasim Ahmed Qasim QASIM

ABSTRACT

Master Thesis

USER-GENERATED CONTENT-BASED EDUCATIONAL ECOSYSTEM IN THE METAVERSE

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Establishing the right environment is essential to maximizing the learning experience, and changing classroom layouts has an impact on student performance[1]. The Metaverse, which uses virtual or augmented reality, is a digital space where users can interact with a computer-generated environment and other users in real time. Metaverse also can be utilized to create immersive and engaging learning environments for students. However, current metaverse solutions are limited in terms of flexibility and customization of the environments. In other words, they lack user-generated content (UGC), which provides more flexibility by increasing the number of possible environments and layout options. Therefore, this study proposes a framework that can provide UGC by allowing users to perform real-time geometry manipulation and procedural asset placement to generate multiple types of 3D virtual environments with a high number of variations. The framework employs geometry manipulation techniques, including mesh boolean operations and vertex displacement. It also allows procedural asset placement by interacting with a dynamic set of values depending on both the base environment and individual assets, each with its own set of interactions through the created UI. The framework also allows for dynamic lighting, such as the orientation of the sun and the location of each light point, to simulate the environment for different times of day, resulting in the creation of different 3D virtual experiences. The framework also provides the ability to implement custom functions for each mesh and offers the ability to save the current state of the virtual world, allowing users to share their creations with others.

Key Word : **V**irtual Reality, Metaverse, Algorithms and Computational Theory, Unreal Engine.

Science Code : 92425, 92402

ÖZET

Yüksek Lisans Tezi

METAVERSE DE KULLANICI TARAFINDAN ÜRETİLEN İÇERİK TABANLI EĞİTİM EKOSİSTEMİ

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Doğru ortamın oluşturulması, öğrenme deneyiminin en üst düzeye çıkarılması için çok önemlidir ve sınıf düzeninin değiştirilmesi öğrenci performansı üzerinde etkilidir[1]. Sanal veya artırılmış gerçeklik kullanan Metaverse, kullanıcıların bilgisayar tarafından oluşturulan bir ortamla ve diğer kullanıcılarla gerçek zamanlı olarak etkileşime girebildiği dijital bir ortamdır. Metaverse, öğrenciler için sürükleyici ve ilgi çekici öğrenme ortamları yaratmak için de kullanılabilir. Ancak mevcut metaverse çözümleri, ortamların esnekliği ve özelleştirilmesi açısından sınırlıdır. Başka bir deyişle, olası ortamların ve düzen seçeneklerinin sayısını artırarak daha fazla esneklik sağlayan kullanıcı tarafından oluşturulan içerikten (UGC) yoksundurlar. Bu nedenle, bu çalışma, kullanıcıların çok sayıda varyasyona sahip birden fazla 3B sanal ortam türü oluşturmak için gerçek zamanlı geometri manipülasyonu ve prosedürel varlık yerleştirme gerçekleştirmelerine olanak tanıyarak UGC sağlayabilen bir çerçeve önermektedir. Çerçeve, örgü boole (boolean) işlemleri ve tepe noktası yer değiştirme dahil olmak üzere geometri manipülasyon tekniklerini kullanmaktadır. Ayrıca, her biri oluşturulan kullanıcı arayüzü aracılığıyla kendi etkileşim kümesine sahip olan hem temel ortama hem de bireysel varlıklara bağlı olarak dinamik bir değer kümesiyle etkileşime girerek prosedürel varlık yerleştirmeye olanak sağlar. Çerçeve ayrıca güneşin yönü ve her bir ışık noktasının konumu gibi dinamik aydınlatmaya izin vererek günün farklı zamanlarında ortamı simüle eder ve farklı 3B sanal deneyimlerin yaratılmasını sağlar. Çerçeve ayrıca her bir ağ için özel işlevler uygulama yeteneği sağlar ve sanal dünyanın mevcut durumunu kaydetme olanağı sunarak kullanıcıların yarattıklarını başkalarıyla paylaşmalarına olanak tanır.

Anahtar Sözcükler : Sanal Gerçeklik, Metaverse, Algoritmalar ve Hesaplama Kuramı, Unreal Engine.

Bilim Kodu : 92425, 92402

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ABBREVIATIONS

UGC : User-generated Content (Kullanıcı Tarafından Oluşturulan İçerik)
UI : User Interface (Kullanıcı Tarafından Oluşturulan İçerik)
AI : Artificial Intelligence (Yapay zeka)
NFT : Non-Fungible Tokens (Değiştirilemez Tokenlar)
3D : Three Dimensional (3 boyutlu)
UE5 : Unreal Engine 5

PART 1

INTRODUCTION

Educational technology is always moving forward and is evolving at a rapid pace, the quest for optimal learning environments has led to a mix of solutions. Traditional classroom setups are undergoing transformative changes, with educators and technologists alike seeking to leverage cutting-edge technologies to enhance the educational experience. One such new technology that holds immense promise for the future of education is the Metaverse.

The Metaverse, a digital space where users engage with computer-generated environments and each other in real-time, represents a new way to interact and participate in virtual experiences. Rooted in virtual and augmented reality, the Metaverse provides a platform for immersive learning, offering new possibilities for education. There is a significant potential for the Metaverse to revolutionize learning environments, as it can provide a dynamic educational experience that removes the limitations of traditional classrooms.

While the Metaverse presents a compelling opportunity for educational innovation, current solutions within this space face limitations, particularly in the customization and flexibility of virtual environments. A crucial element in maximizing the potential of the Metaverse for education is the integration of User-Generated Content (UGC). UGC empowers educators and learners alike to create and manipulate virtual spaces, creating a dynamic and personalized educational experience.

This study aims to address the existing gap within the Metaverse solutions by proposing a framework that enables environment customization in real-time using various methods such as geometry manipulation, boolean operations and procedural asset placement, allowing users to generate diverse and customizable 3D virtual environments. The framework aims to overcome the limitations of current Metaverse platforms by offering a high degree of flexibility in environment creation. users can engage in the creation of educational spaces tailored to their specific needs.

This study explores the technical aspects of UGC within the Metaverse and also delves into the educational implications of such an approach. By empowering users to actively participate in the creation of virtual learning environments, this study seeks to contribute to the ongoing discussion on the future of education in the digital age.

1.1. BACKGROUND AND CONTEXT

To understand the significance of UGC within the Metaverse for education, it is essential to explore the broader context of virtual learning environments and the limitations of current solutions.

1.2. PROBLEM STATEMENT

Current Metaverse solutions for education lack robust UGC features, limiting flexibility and customization. Despite theoretical discussions on UGC challenges, there is a gap in providing concrete, standardized implementations. Existing literature highlights the need for comprehensive solutions.

The absence of standardized implementations is also observed in Environment Customization, where existing methods lack a unified approach. This research identifies a crucial problem: the absence of a comprehensive and standardized framework integrating User-Generated Content, Environment Customization, and the Educational Metaverse within the Metaverse platforms.

To address this gap, our proposed framework aims to empower users to create, modify, and share virtual learning environments seamlessly. Additionally, implementing core design principles such as Modularity, Expandability, Accessibility, and Standardization for an enhanced user friendliness and adaptability.

This study seeks to contribute to educational technology by providing a solution that actively involves users in creating dynamic virtual learning environments, unlocking the full potential of the Metaverse for educational innovation.

1.3. PURPOSE OF THE STUDY

This research endeavors to address the identified limitations by proposing a framework that empowers users to create, modify, and share their virtual learning environments within the Metaverse.

1.4. SIGNIFICANCE OF THE STUDY

The findings of this study are expected to contribute to the enhancement of educational technology by introducing a novel approach to virtual learning environments through UGC in the Metaverse.

1.5. RESEARCH QUESTIONS

To guide this exploration, the study poses the following research questions:
How can a framework for UGC enhance the educational experience within the Metaverse?
What technical features should be integrated into the framework to allow for comprehensive environment customization?
What educational implications arise from the incorporation of UGC in virtual learning environments?

1.6. SCOPE AND LIMITATIONS

While the proposed framework holds great promise, it is important to acknowledge the boundaries of this study and the specific aspects it aims to address, this study is not meant to create a feature full framework but a foundation to build upon.

1.7. ORGANIZATION OF THE THESIS

This thesis is structured to provide a comprehensive examination of UGC in the Metaverse for educational purposes. The subsequent chapters delve into the existing literature, frameworks, methodology, development, discussion, and conclusion.

PART 2

LITERATURE REVIEW

The exploration of user-generated content within the Metaverse has gained traction in recent years, reflecting the evolving landscape of digital environments and their impact on various domains. This literature review delves into the existing research, methodologies, and key findings related to UGC and world generation in the Metaverse.

In navigating the literature, the conceptual framework revolves around key terms such as the "Metaverse", "user-generated content", "UGC", and "world generation" or "procedural generation". These concepts provide a foundation for understanding the diverse dimensions explored in the reviewed papers.

Organized thematically, the literature review is divided into three main sections: UGC in the Metaverse, Procedural World Generation, and the Metaverse in Education. Each section examines relevant papers, their methodologies, and key contributions.

2.1. USER-GENERATED CONTENT IN THE METAVERSE

The exploration begins with a focused search on UGC within the Metaverse. Leveraging keywords and search parameters, a total of 12 relevant papers were identified, covering surveys, case studies, and analyses of UGC in video games and the Metaverse. These papers address organizational impacts, AI-driven semantic communication, and security challenges related to UGC integration.

A synthesis of the literature reveals a predominant focus on theoretical and foundational aspects of UGC. The papers discuss challenges such as quality, privacy, security, authenticity, ownership, accessibility, and moderation. The methodologies employed are primarily survey-based, providing insights into current Metaverse projects and video games.

While the literature contributes valuable insights into the challenges of UGC, there is a notable absence of standardized implementations or specific technical methods. The research tends to be theoretical, emphasizing the problems associated with UGC rather than proposing concrete solutions.

2.2. PROCEDURAL WORLD AND ENVIRONMENT GENERATION IN THE METAVERSE

Expanding the scope, the literature review explores papers related to "world generation," "random generation," and "procedural generation" in the Metaverse. A total of 10 relevant papers were identified, discussing tools and methods for automating content creation and generating assets in the Metaverse.

These papers delve into the applications of virtual reality, potential convergence with the Internet of Things (IoT), and the use of NFTs in the Metaverse. The methodologies discussed range from AI-driven automation to the use of game engines and 3D building tools for asset generation.

While some papers explore innovative methods and tools, there is a lack of standardized implementation across the reviewed literature. The focus remains on the potential of automation and the challenges associated with content creation rather than providing concrete, widely applicable solutions.

2.3. THE METAVERSE IN EDUCATION

Expanding the exploration to the intersection of the Metaverse and education, seven relevant papers were identified. These papers discuss the definition, framework, features, and potential applications of the Metaverse in education. Factors influencing the intention to use Metaverse education platforms are also explored.

These papers shed light on the benefits, opportunities, and challenges of integrating the Metaverse into educational settings. However, there is a notable absence of detailed discussions on UGC within the educational Metaverse context.

While the literature provides insights into the potential impact of the Metaverse on education, there is limited discussion on the role of UGC in shaping educational experiences within these digital environments.

Table 2.1. Brief summary of all the citations from the literature review.

Ref	Specific Issue	Findings	Methodology	Limitations
[1]	The specific problem addressed in the paper is the pursuit of relative equality in educational opportunities through the integration of the Metaverse in education	The paper found that combining the Metaverse with education is a feasible approach to overcome barriers and achieve greater equality in educational opportunities. Emerging technologies, such as immersive interactive technology, network computing, AI, digital twins, and Blockchain, can address challenges that are difficult to tackle in real-life classrooms. The Metaverse provides unique visualization capabilities that traditional classrooms lack	Overview of existing research, cases, and emerging technologies to support the argument of the paper	The paper mentions the need for further research to address new moral problems, such as changes in the relationship between parents and educational institutions and the safe protection of private information in the Metaverse.
[2]	Adding uniques to UGC in the metaverse	The paper presents a method called "Crypto-Dropout" that leverages crypto information to generate unique and personalized content in the metaverse	Crypto, Neural Networks	Some neural network have much higher white than other which results in unpredictable output when adding randomness

[3]	Benefits and challenges of UGC-based microverses	UGC-based microverses provide avenues for creative expression, participatory education, and skill development. However, they rely on unpaid child labor and raise concerns about addictive tendencies in children	Literature Review	Limited primary data and limited scope of analysis to Minecraft and Roblox platforms
[4]	Challenges of combining user-generated content and virtual worlds	The paper presents problems related to content quality, secondary liability, game structure, and ownership issues in virtual worlds with user-generated content	Analysis and discussion of examples and legal cases	The study relies on case studies and observations rather than empirical research, the findings may not be universally applicable to all virtual worlds and user-generated content platforms
[5]	The specific issue addressed in the paper is the impact and role of user-generated content in pervasive games	The paper discovered that user-generated content plays a significant role in enhancing player enjoyment and immersion in pervasive games. It also found that blending history and fiction in game prototypes can lead to engaging and immersive gameplay experiences	Field trials, surveys, interviews, and prototypes	The study acknowledges a few limitations in its methodology. Self-reported survey data may be subject to biases and may not fully capture the complete range of player experiences. The field trials were conducted in specific contexts which may limit the generalizability of the findings. The specific design principles and prototypes tested in the study may not represent the entire spectrum of pervasive games

[6]	The paper addresses the problem of secure semantic communication for AI-generated content in the Metaverse, focusing on preventing semantic attacks and ensuring the integrity of data in virtual transportation networks	The paper proposes a blockchain and zero-knowledge proof-based semantic defense scheme that can differentiate between adversarial semantic data and authentic data. The defense scheme can successfully identify malicious edge devices attempting to corrupt AI-generated content services	Blockchain, zero-knowledge proofs and training-based targeted semantic attack schemes	The paper acknowledges that the integration of blockchain can be resource-intensive, requiring significant computational power and storage capacity. This may lead to increased costs and slower transaction processing times. The authors suggest the need for efficient blockchain structures, consensus algorithms, and on-chain/off-chain collaboration mechanisms to improve performance and efficiency
[7]	The paper addresses the fundamentals, security, and privacy challenges in the context of the metaverse, It aims to explore the issues in security and privacy of metaverse experience	The paper discusses various aspects of the metaverse, including its architecture, enabling technologies, security threats, and privacy concerns. It reviews existing and potential solutions for addressing these challenges and highlights the importance of AI-enabled governance, decentralized governance, and digital forensics in regulating the metaverse	Surveys	The paper acknowledges several limitations, including the need for tailored security solutions for the unique characteristics of the metaverse, the interoperability challenges posed by different blockchains, the resource constraints of wearable XR devices, and the potential security risks associated with content-centric networking in the metaverse. It also emphasizes the necessity for further research from both technological and sociological perspectives
[8]	The paper aims to investigate the motives for user-generated content sharing and their impact on sharing intentions among content creators in South Korea	The paper reveals insights into the motives behind UGC sharing and their effects on sharing intentions among content creators in South Korea	Quantitative and qualitative research methods to examine the UGC sharing motives and intentions	No specified limitation

[9]	Aims to address the problem of enhancing social good within a university campus using the concept of a metaverse	The paper suggests that the implementation of a metaverse prototype on a university campus can positively impact social interactions, academic engagement, and overall campus experience	Surveys and Unity	The paper acknowledges limitations in terms of generalization due to the specific focus on a university campus and the potential challenges associated with scaling the metaverse prototype to larger settings
[10]	The paper addresses the challenges and requirements of virtual reality technology for the metaverse, like the connection of virtual and real objects, and the transmission of data	The study explores various technologies such as 3D modeling, rendering, AI algorithms for virtual characters, blockchain, digital currencies, and IoT. It also covers motion capture, XR, BCI, 5G/6G, and edge computing for immersive interactions and efficient data transmission in the metaverse	Surveys, Reviewing existing technologies and research	The need for further research to meet the demanding latency requirements of the metaverse, resource allocation challenges in dynamic computing and communication environments, user mobility management, and ensuring privacy and security in the transmission of sensitive data
[11]	The paper discusses the challenges and open issues in the convergence of Internet of Things (IoT) and Metaverse, aiming to bridge the physical and cyber worlds	The paper identifies various critical issues related to data processing, security and privacy, real-time 3D modeling, scalability, mobile user experience, interoperability of virtual platforms, and barriers in the physical world.	Literature review, Surveys	No specified limitation

[12]	The specific problem addressed in the paper is the increasing automation of game development processes and the potential implications it has for workers in the industry, as well as the stratification of tasks and values within the game development pipeline	The paper highlights how game engines, such as Unity and Unreal Engine, are being used beyond game development in industries like architecture, engineering, construction, and manufacturing. And the consolidation of market share by game engine platforms and the potential impact on cultural production and practice. It also raises concerns about the potential marginalization of certain tasks and artistic values in the game development process due to automation.	Literature, industry reports, and insights from professionals	No specified limitation
[13]	The specific issue addressed in the paper is the exploration of the metaverse as a new concept in education, aiming to overcome obstacles and limitations in current education and maximize its positive effects on future education	The paper discusses various potential applications and benefits of the metaverse in education, including personalized learning, immersive experiences, collaboration, and expanded learning opportunities. It also emphasizes the need for developing new pedagogical theories and assessment frameworks tailored to the metaverse	The paper does not explicitly state a specific methodology used. It appears to be a conceptual and theoretical analysis based on existing literature and expert opinions in the field of education and technology	The limitations of the methods and techniques used in the paper are not explicitly mentioned. However, it is acknowledged that the introduction of the metaverse in education may raise controversial issues such as security, ethics, and addiction, which require further discussion and consideration

[14]	The study aims to identify the influencing factors of usage intention for metaverse education application platforms	The paper found that social impact, community-driven and utility-driven modes, perceived ease of use, and personalized learning and social needs are significant factors influencing users willingness to use metaverse education platforms	Survey based empirical research approach, using Project Portfolio Management and Technology Acceptance Model models as the theoretical frameworks. And data collection involved a questionnaire administered to participants.	The paper acknowledges limitations such as regional and time restrictions in data collection, lack of real scenario testing, and potential variations in users' willingness to use the platform based on income and cultural differences
[15]	The specific problem addressed in the paper is the underutilization of immersive and metaverse technologies in agriculture education, including limited learning content, design elements, and implementation gaps.	The paper found that most immersive technology applications in agriculture education focus on delivering declarative knowledge, while opportunities for richer interaction and learning experiences are underutilized. Additionally, there is a significant gap between current technology implementation and the mature concept of the metaverse	Review of eight works related to immersive and metaverse technologies in agriculture education	Difficulties and costs associated with implementing various design elements in immersive education applications. Off-the-shelf solutions often lack educational content specific to agriculture, while tailored solutions are expensive and challenging to build. The paper also acknowledges the limitations of the reviewed publications, which primarily focused on augmented or virtual reality applications rather than fully embracing the metaverse concept
[16]	The specific problem addressed in the paper is how to enhance literacy education using narrative richness in the metaverse, specifically focusing on media literacy, language literacy, and sustainability literacy	The study hypothesizes that the richness of narratives in the metaverse has a positive effect on reflective learning and that has a positive effect on attitude toward learning	Metaverse Prototype, Higher education student survey,qualitative and quantitative analysis from focus groups	No specified limitation

The synthesis of the literature highlights the predominance of theoretical discussions and surveys in the exploration of UGC and world generation in the Metaverse. The identified papers contribute valuable insights into challenges, potential applications, and factors influencing user behavior. However, there remains a need for more comprehensive, standardized implementations and methodologies to address the evolving landscape of UGC and world generation within the Metaverse. The subsequent sections of this thesis will build upon this foundation, proposing a framework that addresses the identified gaps and challenges.

PART 3

METHODOLOGY

Building the metaverse is based on key principles that form the bases of the framework, each subsection of the methodology delves into the tools used and why we chose them, methods and techniques used in the development process and what they achieve.

3.1. FRAMEWORK

The base foundation of the framework revolves around three interrelated pillars: User-Generated Content, Environment Customization, and the Educational Metaverse. These pillars encapsulate the primary themes identified in the literature review and serve as the basis for understanding the main aspects of integrating UGC within digital environments.

3.1.1. User-Generated Content in the Metaverse

Drawing from the literature [2–9], the UGC pillar recognizes the multifaceted nature of content created by users within the Metaverse. Key concepts such as quality, privacy, security, authenticity, ownership, accessibility, and moderation provide a foundational understanding of the challenges and opportunities associated with UGC.

3.1.2. Environment Customization in the Metaverse

Expanding the framework to include Environment Customization [10–12], foundational concepts encompass tools, methods, and algorithms for automating the creation of Metaverse content. Concepts such as virtual reality applications, and the use of game engines form the basis for understanding the diverse approaches to content generation.

3.1.3. The Metaverse in Education

The educational Metaverse pillar incorporates concepts from papers exploring the intersection of the Metaverse and education [1,13–16]. Foundational concepts include the definition, framework, features, and potential applications of the Metaverse in educational settings. Factors influencing the intention to use Metaverse education platforms, as well as benefits, opportunities, and challenges, contribute to the conceptual foundations

3.2. SYSTEM DESIGN PRINCIPLES

framework also aims to make the process of creating and expanding user generated content easier and more accessible for developers to expand and users to create and share the work, and it attempts to achieve that by providing a baseline project with a demo and can be extended and built upon, incorporating four mains designs choices:

3.2.1. Modularity

The adoption of a modular design paradigm facilitates the customization, alteration, and expansion of the framework while mitigating compatibility issues, this solves the problem of changes breaking the framework or the creation of different users conflicting with each other [17,18].

3.2.2. Expandability

Contracting the framework in a way that allows each component to be expanded and modified individually without affecting how other systems work[18], such as the user interface scaling dynamically based on the number of current variables that are present in the system.

3.2.3. Accessibility

Ensuring accessibility within the framework is critical for a user-centric design. This involves implementing features that cater to diverse user needs, that includes having the ability to function on multiple types of platforms and input devices.

3.2.4. Standardization

The process of standardizing repetitive development segments and intricate problem-solving tasks into reusable packages affords enhanced ease of use and time efficiency for developers and creators seeking to extend the capabilities of the framework. This practice serves as a strategic approach to streamline development efforts and optimize resource utilization.

3.3. UNREAL ENGINE 5

Unreal Engine 5(UE5), developed by Epic Games, includes many features and enhancements to push the boundaries of real-time 3D graphics and virtual development. Some of its key capabilities include: Nanite Virtualized Geometry for highly detailed environments, Lumen Global Illumination for dynamic lighting, World Partition for seamless open-world development, Chaos Physics and Destruction for realistic interactions, MetaSounds for adaptive audio, and improvements in animation and rigging. It offers a user-friendly environment with advanced tools for development, with a comprehensive amount of documentation that can help developers to feather understand and expand on this framework [19].

The main features that we utilize from Unreal Engine 5 for this framework are:

3.3.1. Blueprints Visual Scripting

In Unreal Engine, Blueprints are a visual scripting system that allows developers, including those without extensive coding experience, to create mechanics, interactions, and logic. Essentially, Blueprints provide a node-based interface where users can design and implement functionality by connecting nodes that represent various actions, events, and variables.

Key aspects of Blueprints include:

1. Visual Scripting: Blueprints offer a node-based visual scripting system that represents logic through a graph-like interface. Users can create and manipulate nodes to define behavior without writing code.
2. Node Types: Blueprints consist of various node types, including events (triggers), functions (actions), variables (data storage), and control flow nodes (such as loops and conditionals). These nodes are interconnected to define the flow of a system.
3. Actor Blueprints: In Unreal Engine, actors are objects in the virtual world. Actor Blueprints allow developers to create and customize these objects, defining their behavior, appearance, and interactions through visual scripting.
4. Component System: Blueprints utilize a component-based system where different functionalities are encapsulated within components. This modular approach allows for easy reusability and organization of logic.
5. Integration with C++ Code: While Blueprints are primarily visual, developers can integrate them seamlessly with C++ code. This allows for a flexible combination of visual scripting and traditional programming for more complex game systems.
6. Rapid Prototyping: Blueprints are well-suited for rapid prototyping and iteration, enabling designers and developers to quickly experiment with and test game mechanics before implementing them in code.
7. Extensibility: Unreal Engine's Blueprints are extensible, allowing developers to create custom nodes and functionality to suit their specific needs. This flexibility makes it a powerful tool for both beginners and experienced developers.

The blueprints system in UE5 provides us with a very flexible and powerful tool to develop any type of module and expandable system that is the perfect baseline for a dynamic framework.

3.3.2. Geometry Script

Geometry Script is an official Unreal Engine plugin containing a set of Function Libraries that provide the ability to generate and edit mesh geometry via Blueprints and Python, utilizing Geometry script we can set the basis for geometry of our environment.

3.4. ENVIRONMENT LAYOUT

To create the main layout for our environment we need techniques that can create and change virtual geometry in real-time that can be scaled and expanded within our framework.

3.4.1. Mesh Boolean Operations

Boolean operations involve combining, subtracting, or intersecting geometric shapes to create more complex forms.

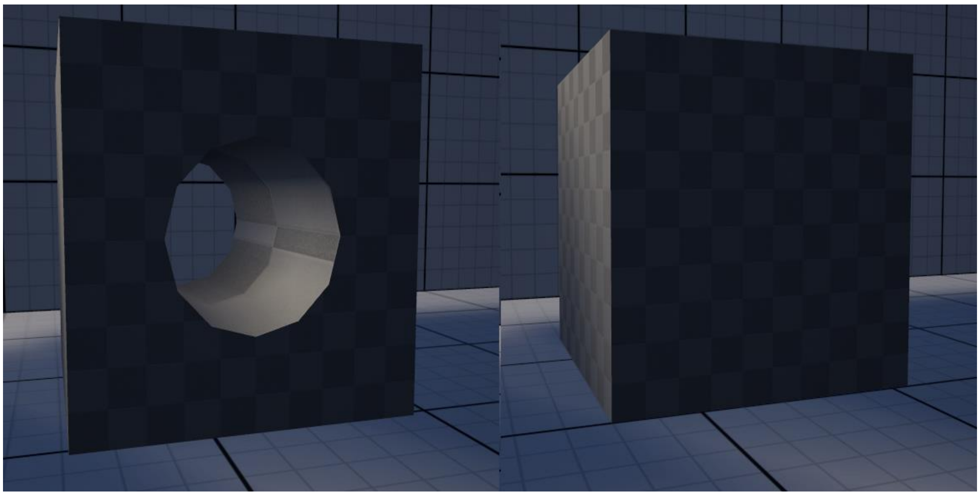

Figure 3.1. Depicting a boolean operation inside unreal engine on a cube mesh as a base and a cylinder mesh as the subtracting mesh.

This operation can be repeated and irritated upon with different sets of meshes to create unique shapes, Figure 3.1 is an example of cylinder being subtracted from a cube mesh.

3.4.2. Geometry Manipulation

This method refers to the process of modifying the shape, structure, or properties of 3D objects. it involves operations such as scaling, rotating, translating, deforming, or creating new geometry and editing vertices, edges, and faces, allowing for detailed geometry manipulation to achieve the desired shapes and forms.

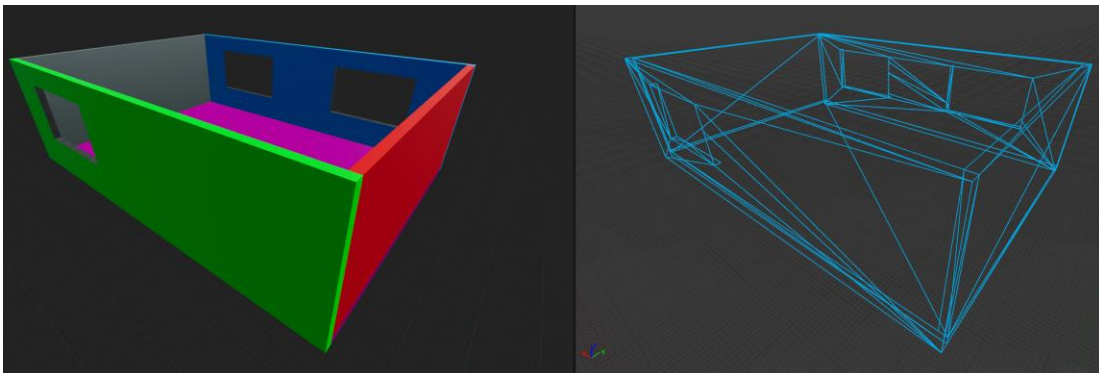

Figure 3.2. Depicting geometry manipulation inside unreal engine scaling and deforming multiple cubes to create a basic layout of a room.

In Figure 3.2 we use geometry manipulation to combine 5 cubes with different transforms and scale to create a room layout and then we can apply the mesh boolean operation to each wall in specific order and location to create a window or a door and the location of the of the operations can all be controlled dynamically through variables.

3.4.3. Algorithm Based Asset Placement

This method consists of using mathematical algorithms to create a set of rules for determining the transformations of a dynamic number of objects in 3D space.

Figure 3.3. Showcases algorithm-based asset placement inside unreal engine using a grid and a circle shape for placement.

Figure 3.3 demonstrates the use of 2 different algorithms to detriment the shape and the model of the placed asset(chair), Both algorithms use the same inputs as variables such as the grid size, space between the chairs, chair transform, center location and chair mesh model. They produce different types of output based on the algorithm used, which essentially means the end user does not have to worry about using different forms of inputs to produce the desired results.

3.4.4. Dynamic User Interface

User interface (UI) is the main method of interaction between the framework and the end user, it offers simple controls to set the input variables for the algorithms.

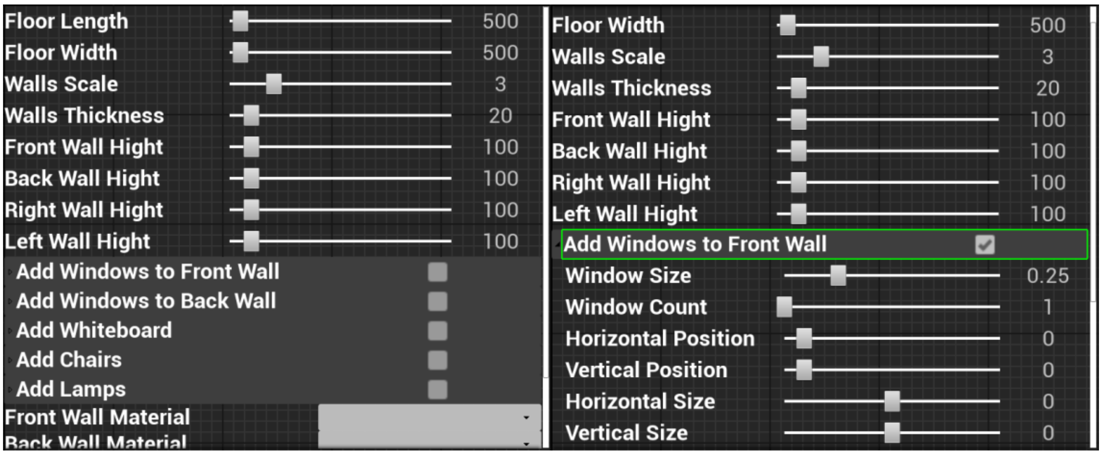

Figure 3.4. Displays a dynamic UI built based on the current components active in the framework and accessible to the user.

Figure 3.4 displays the use of a dynamic and context-based UI to provide the user with only the information that they can control based on the current context and it directly communicates with the underlying systems and algorithms to produce the desired results in real time, the values displayed is determined by the current active systems in the framework.

3.4.5. Dynamic Lighting

Realistic lighting is crucial to create an immersive user experience and leveraging UE5 powerful dynamic lighting and rendering systems help to create a more realistic environment, by using lumen as the main rendering engine in unreal we can create realistic bounce light and global illumination, and a directional light linked to atmospheric sky system to recreate a more realistic dynamically look during any time of the day as shown in Figure 3.5.

Figure 3.5. Showcases the real time dynamic lighting system during different times of the day based on the rotation of an object in the world.

Using lumen does come at some performance cost mainly on the GPU of the selected system and in order to make it more accessible for more platforms lumen can be dynamically turned on and off based on the user preference.

3.4.6. Algorithm Based Safeguards

These methods utilized the use of dynamic algorithms to place safeguards around the rage of accessible variables, avoiding mistake is object placement and transforms, and providing a smoother transition between two states as depicted in Figure 3.6.

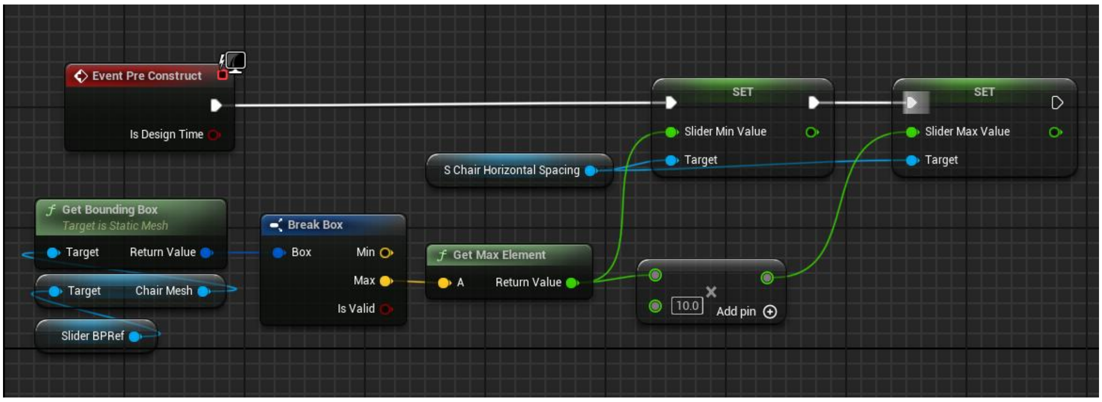

Figure 3.6. Showcases the use of safeguards in the UI element to prevent objects from overlapping.

PART 4

DEVELOPMENT

In this section of the paper the main goal is to provide a detailed description of the technical aspects of frameworks, how different system connect together and how they can be expanded and scaled at each section.

4.1. BASE MESH WITH GEOMETRY SCRIPT

We start by defining some of the base variables in the Geometry Script blueprint that will act as out input, not all the variables here need to be inputs some of them hold temporary values, but the input variables need to have the "instance editable" and "expose on spawn" ticked in the details panel as shown in Figure 4.1.

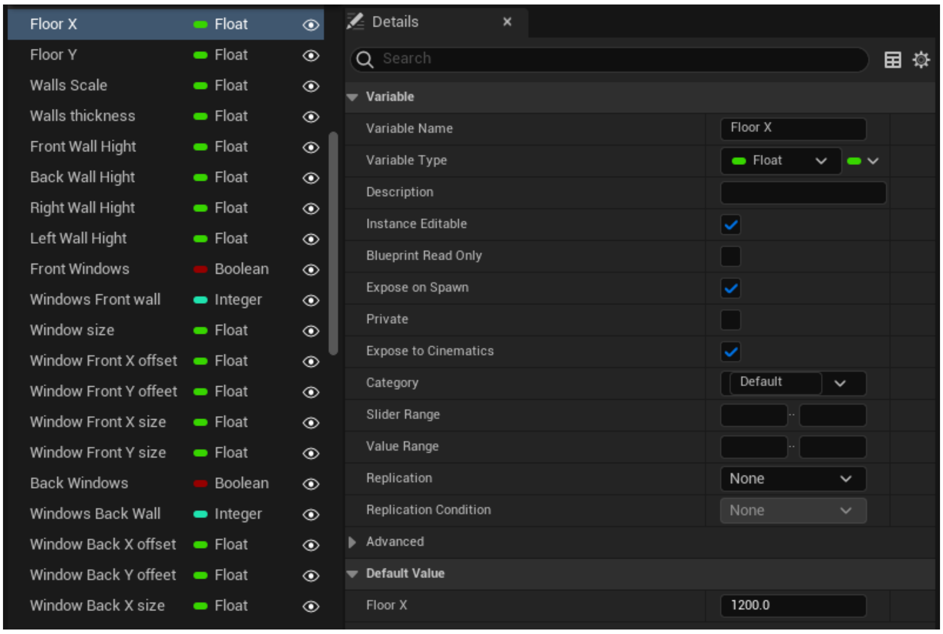

Figure 4.1. Variables set up inside Geometry Script.

The main event in geometry script is the “on rebuild generated mesh” event as shown in Figure 4.2 it runs every time there is a change in the any of the variables, but it comes with the limitation of being in editor only, it's an easy way to test and prototype but in a later stage we will be switching to a blueprint interface system to eliminate performance problems for a real time system.

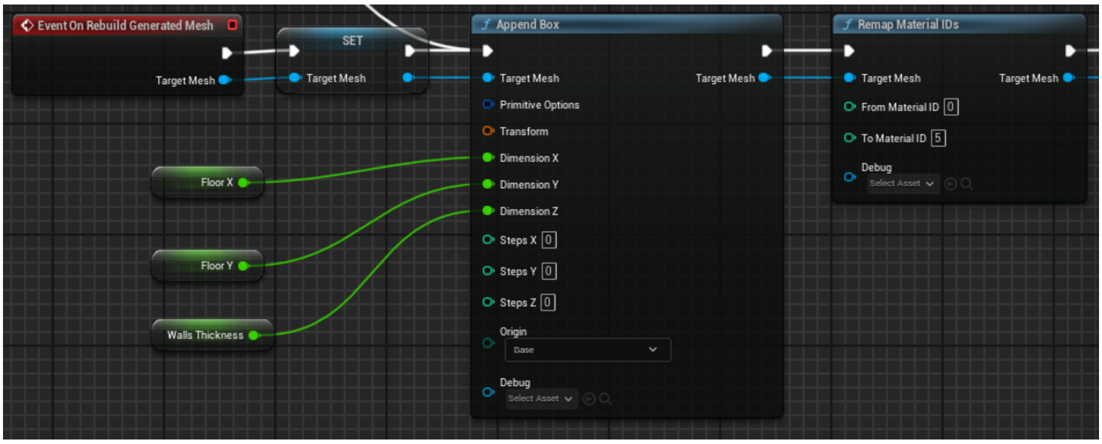

Figure 4.2. Geometry Script flow.

An Append Box function shown in Figure 4.3 is used to create the floor based on the input variables and then it gets sent to a material remap function to change the default material ID, this workflow is used to create the other walls, floors and ceilings.

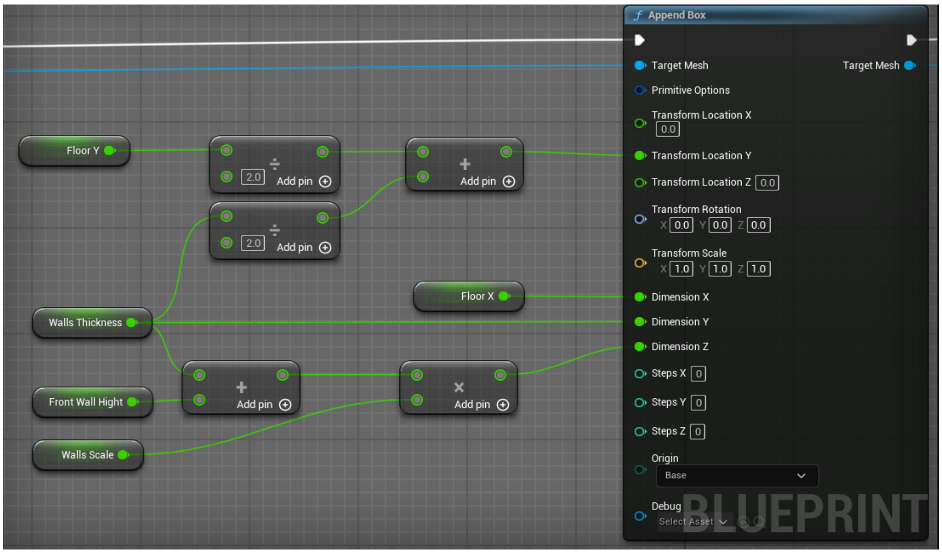

Figure 4.3. Front wall example.

4.2. BOOLEAN OPERATIONS

In order to apply a boolean operation we need two meshes a base mesh and a tool mesh, our base mesh input is the mesh generated from the previous box appends, the tool mesh will be generated temporarily using an “Allocate compute mesh” function and then once are done with the tool mesh we use the “Release all compute meshes” functions to dispose of the temporary meshes from memory.

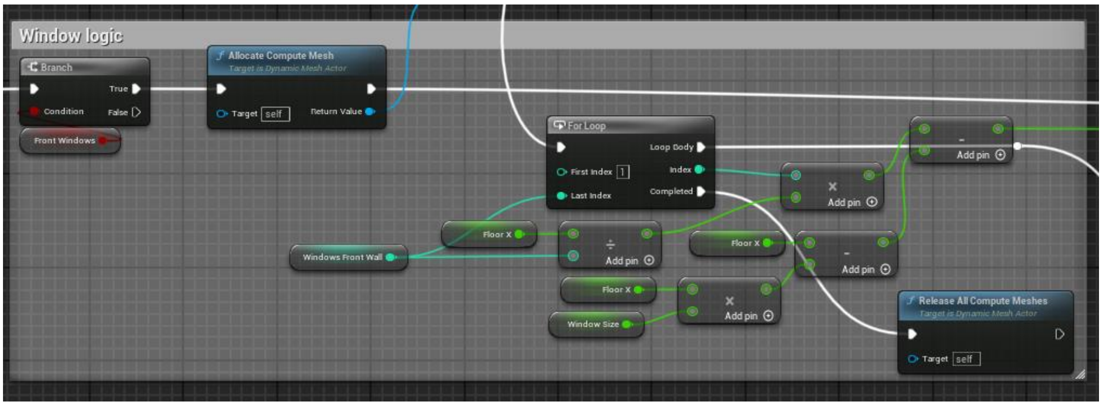

Figure 4.4. Tool Mesh logic.

Figure 4.4 is the first part for determining the size and 3D coordinates of our tool mesh the loop runs based on the desired number of window variable, then we run the output to with more math nodes to dynamically determine the correct location and size of the mesh in 3D space based on the number of windows as shown in Figure 4.5

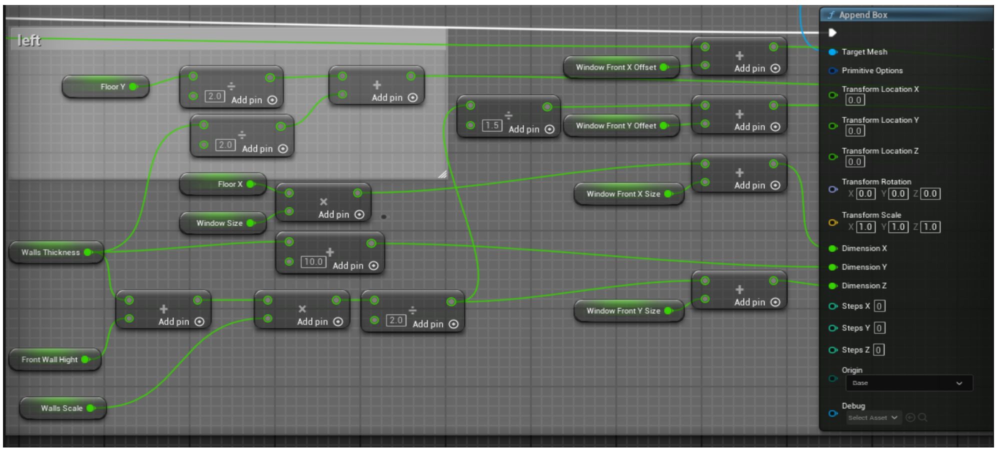

Figure 4.5. Dynamic tool mesh transforms based on a mathematical formula.

Finally we use the “Apply Mesh Boolean” function with operation type set to “subtract” to create our windows based on the number of loops as shown in Figure 4.6

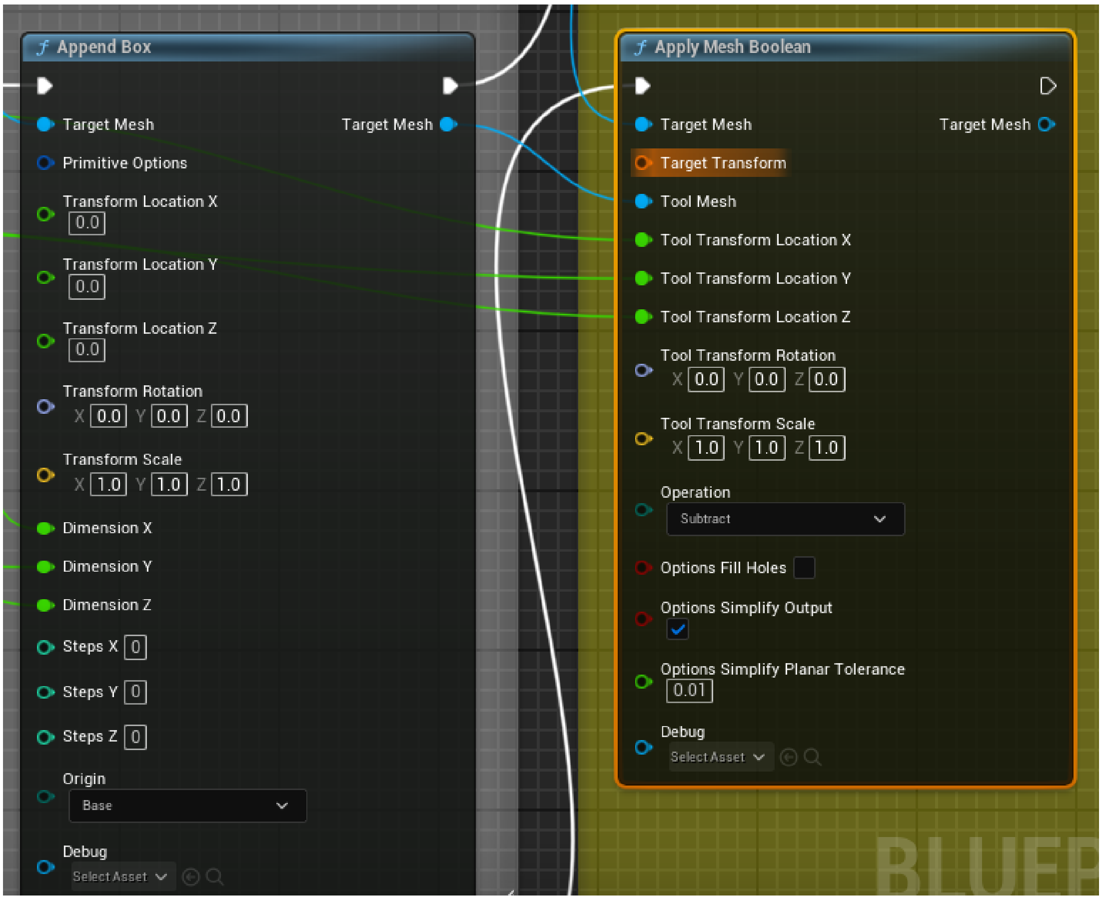

Figure 4.6. Applying the boolean operations.

4.3. ALGORITHM BASED ASSET PLACEMENT

Figure 4.7 shows the grid base approach uses two nested loops utilizing a mathematical algorithm to determine the size, space in between and transforms of the asset locations.

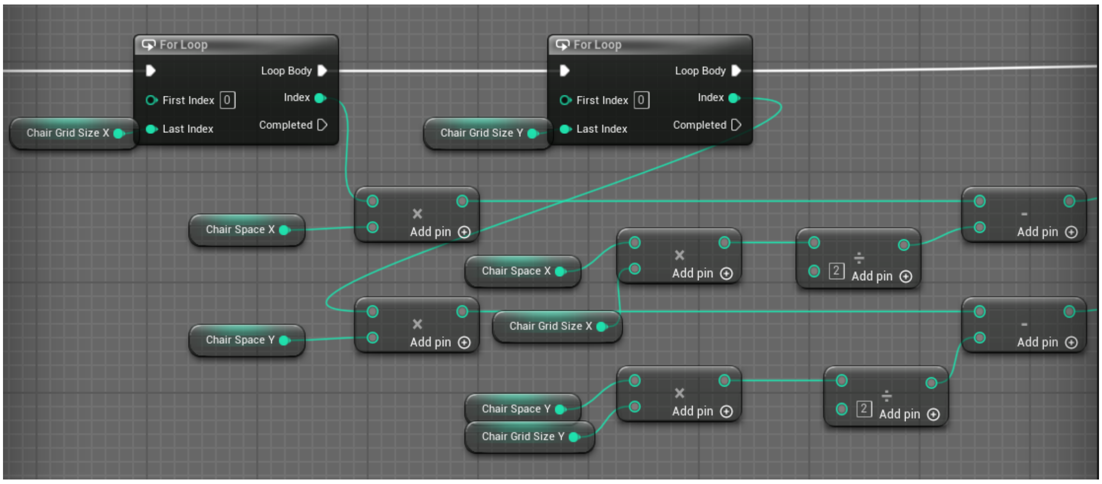

Figure 4.7. Gird base placement algorithm.

For the circle-based algorithm we create a 2D circle made out of polygons, and the number of polygons is set to the number of desired assets, the location of the polygons determines where to place the asset then we run each location by a “find look at rotation” with the target location being the center of the circle to control the rotations of the assets as shown in Figure 4.8

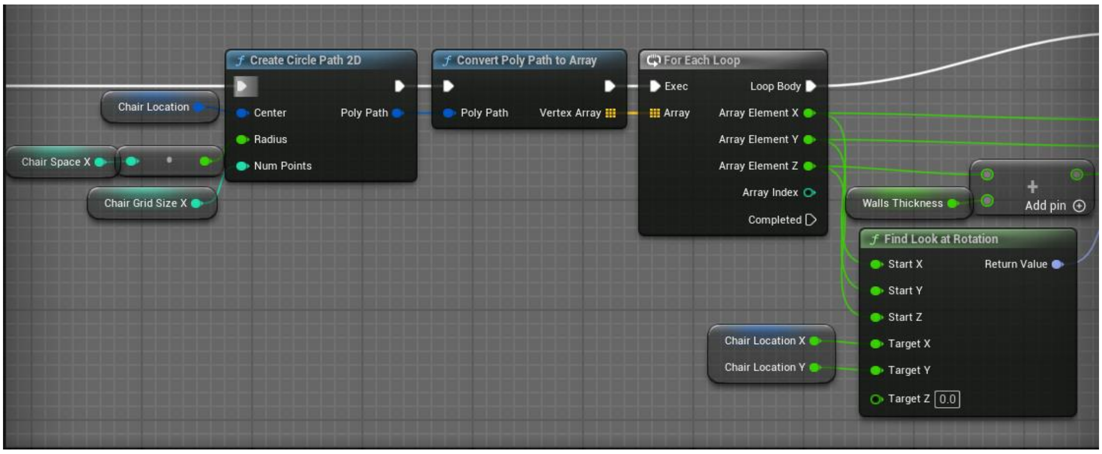

Figure 4.8. Circle based placement algorithm.

Both algorithms provide an array of locations as an output, using the same set of nodes and functions we can dynamically add any type of asset into those locations as shown in Figure 4.9

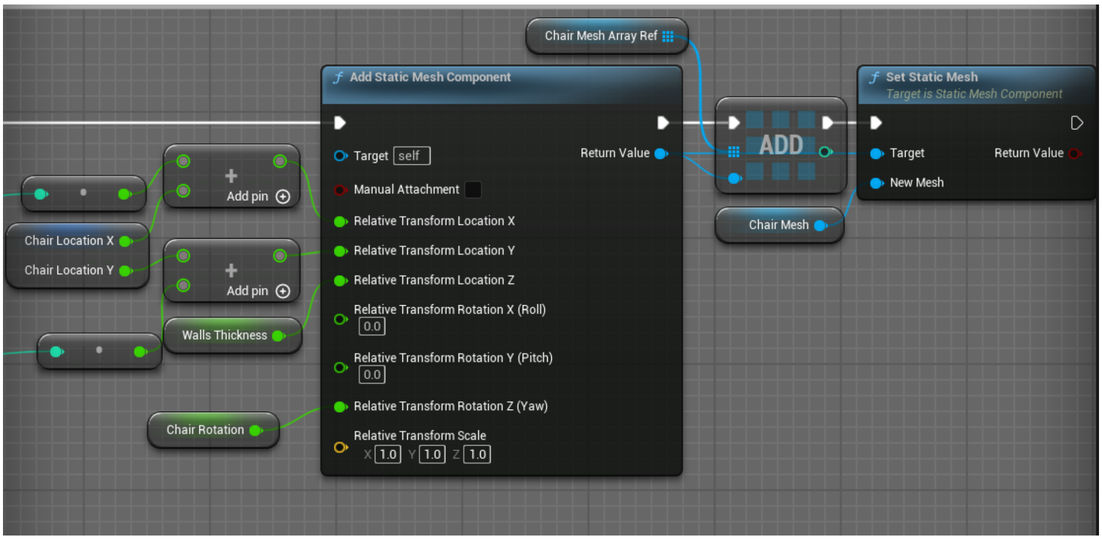

Figure 4.9. Asset placement using the output from the algorithms.

4.4. PACKAGING SYSTEM INTO REUSABLE FUNCTIONS

Understanding the inner workings of complex systems can be daunting for developers to expand on and that is why converting large portions of framework into reusable packaged functions can help immensely with readability and ease of use.

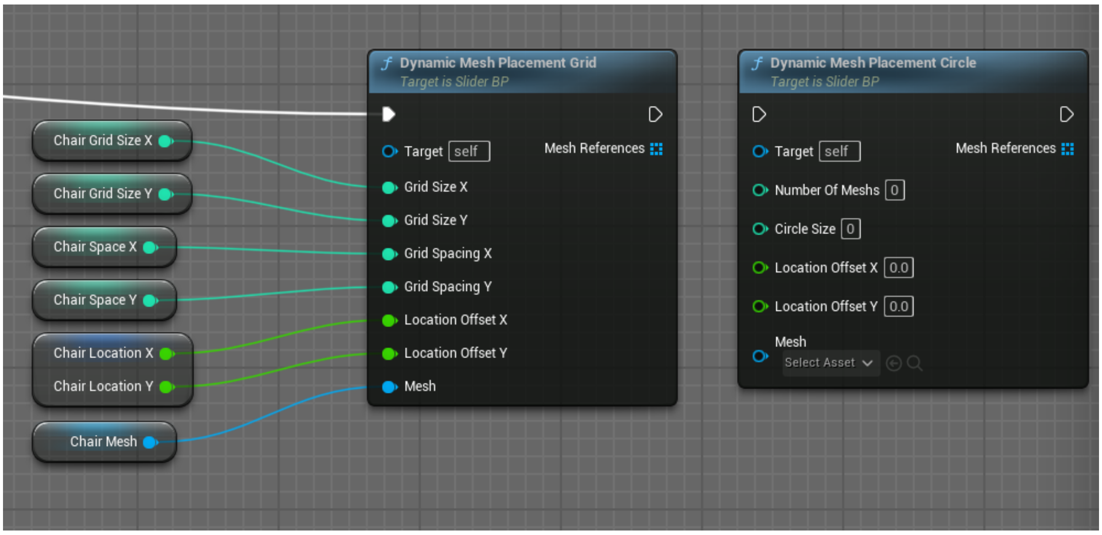

Figure 4.10. Packaged functions for Grid and Circle placement algorithms.

Figure 4.10 displayed packaged functions for both Circle and Grid based asset placement algorithms. These functions can be called from any part of the system to place assets, accommodating various inputs and outputs. This design promotes system upgrades and adaptability, allowing developers to extend the framework without delving into its internal complexities. It mitigates conflicts among different systems developed by various contributors.

4.5. BLUEPRINT INTERFACES FOR MODULAR DESIGN

Utilizing the blueprints interface system in UE5 allowed us to apply modular design principles to the framework, we start by creating the Blueprint Interfaces node and applying it to the Geometry Script node, this allows us to create custom events and call them dynamically from other systems without the need for them to be tightly integrated.

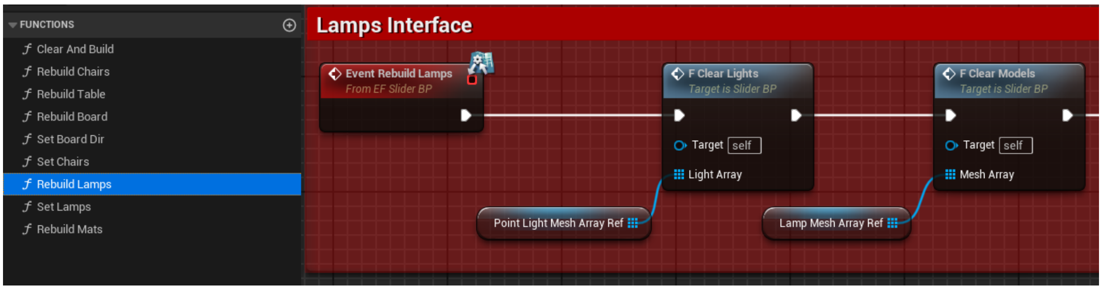

Figure 4.11. Blueprint Interfaces events.

Figure 4.11 displays the setup for a custom Blueprint Interfaces event called “Rebuild Lamps” that executes two packed functions that clear both lights and lamp meshes, and this event can be called with anywhere of the project.

4.6. DYNAMIC USER INTERFACE

The main UI consists of smaller elements as shown in Figure 4.12 elements can be dynamically added based on the context of existing systems.

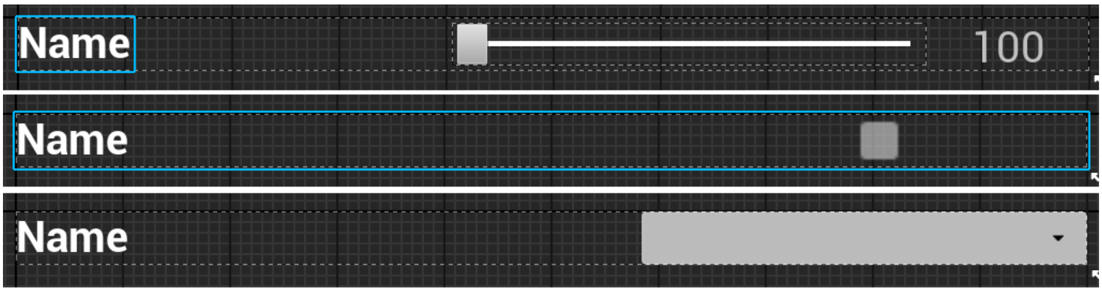

Figure 4.12. Each row in this figure is a different UI element that can be dynamically added in real time.

Figure 4.13 displays how each element can be connected to a Blueprint interface event to dynamically create interaction between systems in real time.

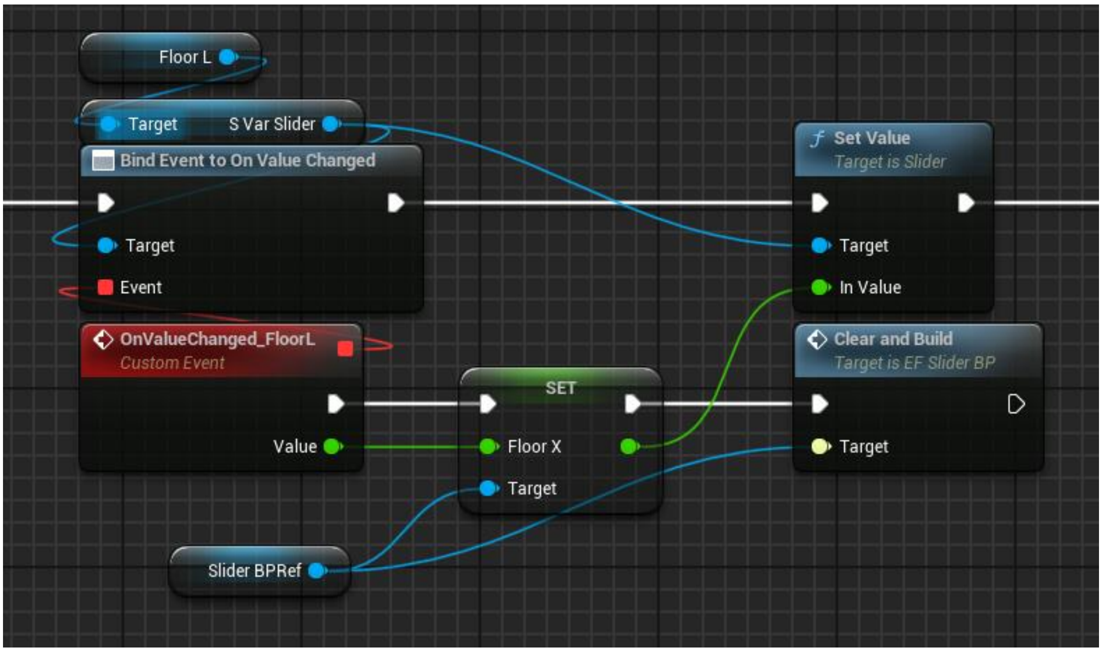

Figure 4.13. Connecting a Floor UI element to a Blueprint interface event.

4.7. MODULAR INPUT HANDLING

“Enhanced input” is the new input handling method in UE5 and it allowed for a dynamic method of interaction between system and any type of input, we starts by creating an “input action” with a set number of behaviors as demonstrated in Figure 4.14

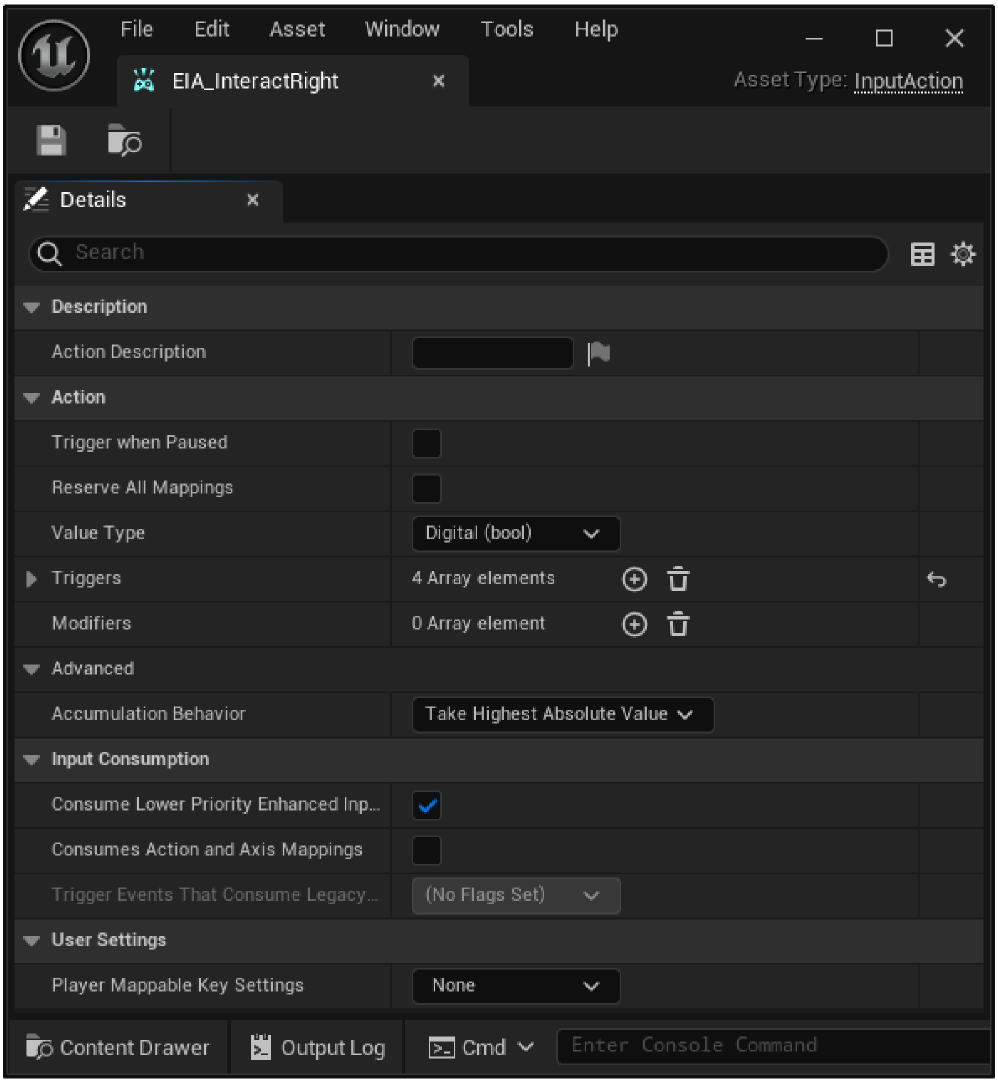

Figure 4.14. An example of enhanced input action for the right trigger.

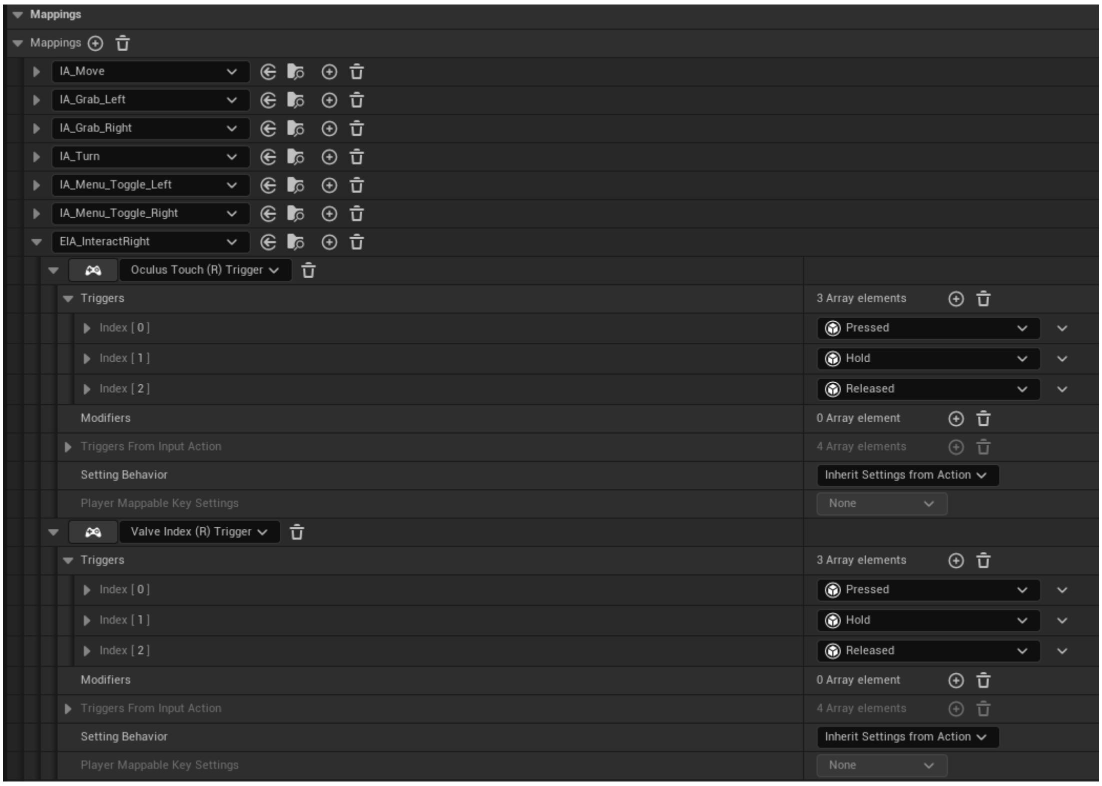

Figure 4.15. Example of mapping the input action.

Input actions then can be mapped into any number of input devices such as the oculus touch and valve index triggers as shown in Figure 4.15.

4.8. STANDALONE SYSTEM

This type of system works independently from others system and only requires interaction form the input devices, an example of this is the whiteboard system shown in Figure 4.16 and found in the project demo it allowed the user to choose between multiple types of brushes and draw or write on the whiteboard, the whiteboard was built using the base blueprint system utilizing a dynamic material with a render target as the base texture and switching between multiple secondary textures as the pen material.

Figure 4.16. Example of a standalone whiteboard system.

These systems can be built separately and integrated into the main framework.

4.9. CREATING THE DYNAMIC LIGHTING SYSTEM

To utilize lumen in UE5, the project settings need to be changed, in the rendering tap the following values need to be set,
Dynamic global illumination: to “Lumen”
Reflection Method: to “Lumen”
Shadow Map Method: to “Virtual Shadow Maps”
From the light tab we need to add a directional light to act as the main sunlight, and a sky light.
From the visual effects tab, we need to add a sky atmosphere, this setup allowed for a dynamic lighting system based on the rotation of the directional light in 3D space, utilizing a basic blueprints system we can link the rotation of the directional light to an object or a user input controlling the object as shown in Figure 4.17.

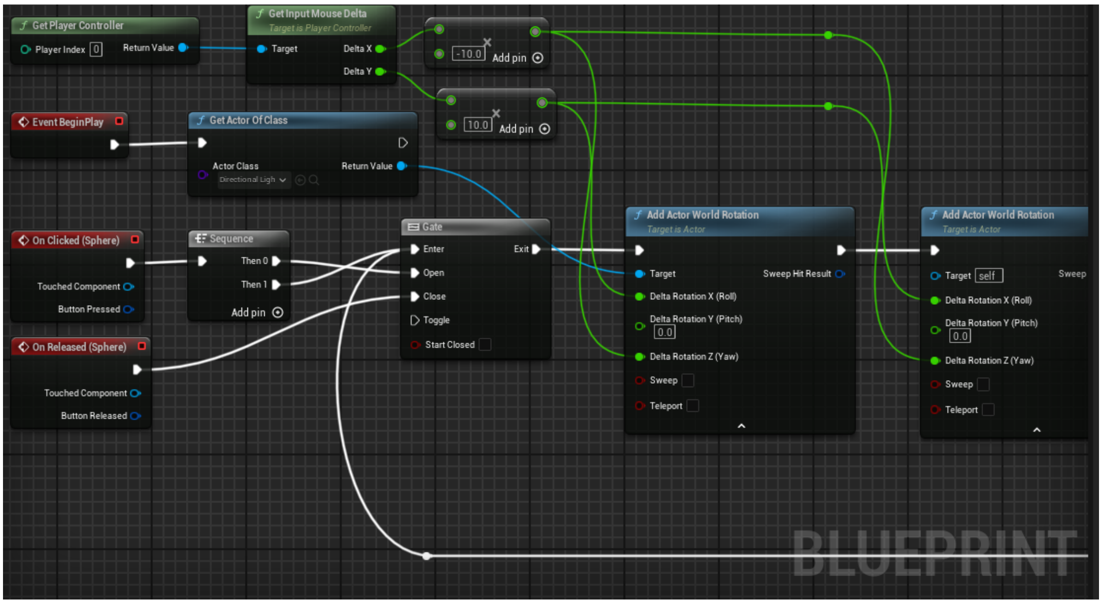

Figure 4.17. Using a blueprint system to control the location of the sun in the sky.

4.10. SCALABLE SYSTEMS FOR ACCESSIBILITY

System such as the dynamic lighting and lumen can come and a cost in performance on older devices, having the ability to change the cost heavy system to a downgraded version that can achieve similar results is crucial for accessibility, all the lighting systems and object used in the previous section can still work with no lumen but produce less accurate result, giving the end user a choice between quality and performance can be done by using a combination of blueprints and console commands to change performance heavy variables on the fly.

PART 5

DISCUSSION AND CONCLUSION

5.1. DISCUSSION

Testing the Framework:

Utilizing all the different variables, the final framework offers a notable variation in environment creation compared to other metaverses. It encourages creative and unique approaches in setting up the environment as shown in Figure 5.1

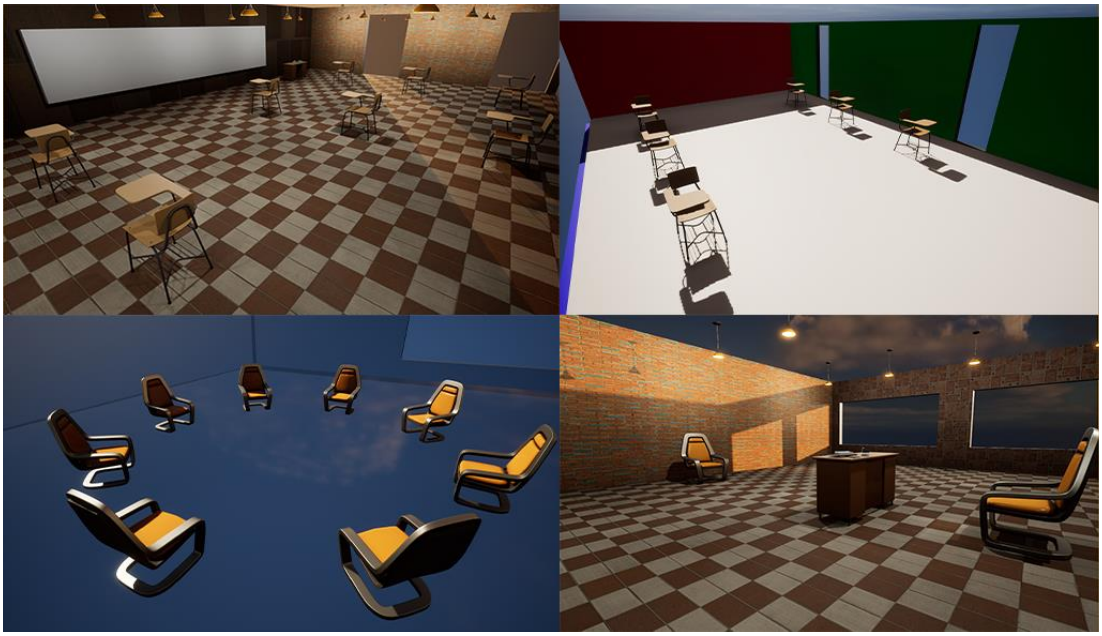

Figure 5.1. Base framework variation.

Technical Development and Integration:

The development section intricately details the framework's technical aspects, revealing its architecture, scalability features, and accessibility considerations. From foundational mesh creation to Boolean Operations, Algorithm-Based Asset Placement, and modular input handling, each element contributes to a flexible and user-friendly framework. The emphasis on packaging complex systems into reusable functions and employing Blueprint interfaces signifies a commitment to modularity and ease of use.

Modular Design Principles and User Interaction:
The integration of Blueprint interfaces exemplifies a modular design approach, facilitating dynamic interactions between components. The dynamic user interface adapts to contextual needs, enhancing real-time user interactions. The framework's modular input handling, showcased through enhanced input actions, positions it as a forward-looking system capable of seamless integration with various input devices.

Scalability, Accessibility, and Standalone Systems:
Scalability is addressed through the dynamic lighting system, enabling users to toggle performance-heavy features dynamically. The inclusion of standalone systems showcases modularity and the ability to integrate independent features. The emphasis on accessibility options aligns with a user-centric design.

5.2. LIMITATIONS:

While the framework provides a robust foundation, it currently exhibits constraints in available options. The modular design, though user-friendly, may pose a learning curve for developers unfamiliar with Blueprint interfaces and UE5.

5.3. FUTURE DIRECTIONS:

The discussion synthesizes the foundation of a practical framework design, and strategic implementation choices. Highlighting the framework's modularity, flexibility, and user interaction, continuous iterations guided by user feedback and technological advancements. Future directions include exploring emerging technologies, refining algorithms, and expanding educational applications. The Metaverse journey into the digital frontier remains guided by principles of user collaboration, accessibility, and innovation.

5.4. CONCLUSION

The exploration of user-generated content in the Metaverse, as presented in the literature review, has been pivotal in shaping the theoretical foundation and subsequent development of the proposed framework.

Bridging the gap between theoretical concepts and practical implementation, the framework draws inspiration from the literature review, incorporating key elements such as content quality, privacy, security, accessibility, and educational applications.

Designed with modularity, expandability, accessibility, and standardization in mind, the framework aims to empower developers and users alike. By providing a baseline project with a flexible demo, it facilitates seamless creation, expansion, and sharing of user-generated content within the Metaverse.

Incorporating key design principles, such as modularity, ensures that changes and expansions can be made without jeopardizing the overall integrity of the framework. The emphasis on expandability allows each component to evolve independently, promoting scalability and adaptability. Accessibility remains at the forefront, ensuring compatibility across various platforms and input devices. The practice of standardization optimizes resource utilization, enhancing efficiency for developers and creators seeking to extend the capabilities of the framework.

The synthesis of theoretical foundations, practical framework design, and strategic implementation choices forms a comprehensive approach to UGC in the Metaverse. The framework's modularity and flexibility empower users and developers to contribute to the ever-expanding digital landscape.

As we move forward, continuous iterations based on user feedback and technological advancements will refine and enhance the framework. Future directions include exploring the potential integration of emerging technologies, refining algorithmic foundations, and expanding educational applications within the Metaverse. The journey into the digital frontier continues, guided by the principles of user collaboration, accessibility, and innovation.

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CURRICULUM VITAE

SKILLS

During his time of working and studying for his bachelor’s degree Qasim Has learned many skills and programs such as:

- Visual Basic, MATLAB, C++, HTML, Python
- Flutter, Firebase, MariaDB
- WordPress, Elementor, Divi
- 3ds Max, Blender, Zbrush, AutoCAD, Photoshop
- Unreal engine 4 and 5
- Stable diffusion, ComfyUI

And many more graphics and 3D design programs:
Redshift, Vray, Nuke, Premiere, Maya, Substance Painter, Substance Designer, Megascans, Marvelous Designer, World Machine, Syntheyes, 3DEqualizer, Davinci resolve.

WORK EXPERIENCE.

NORTON / IT
From March 2014 to april 2015
Qasim has worked as the head of IT for the country wide ISP company Norton in Iraq

Blue Print / Graphic Designer
From june 2016 to May 2017
He also worked as a graphic designer for the digital art and print company Blue and managed their website.

Utrakci group / Developer and Designer

From november 2017 to july 2020

Worked as the main web developer for utrakci.com where he developed and designed many portfolios and E-commerces websites for clients. As well as developing a cross platform social network app for Andrios and IOS.

Freelancer

From 2012 –

He has made many designs, renders and 3D models as a freelancer and sold them on online markets such as:

www.turbosquid.com

Qasim also have made several apps for client's and data managing software for departments in the Iraqi government and individuals

Baggix / Game Developer

From 2021 –

Qasim is currently working as the lead technical developer under Baggix on two unnamed projects using unreal engine 5 and 4.

First project is an open world adventure game made for the PC platform.

Second project is a puzzle solving game made for the mobile platform.

EDUCATION

Al-Qalam University / Computer Engineering

2014- 2018

Qasim graduated with a bachelor's degree from Al-Qalam University and got the highest score for his graduation project which was a photo editing program made with Visual Basic.

Karabuk University / Computer Engineering

Qasim is currently studying for master's degree in computer engineering at Karabuk University

LANGUAGES

Qasim speaks three languages fluently:

- Arabic
- English
- Turkmeny and some Turkish