# Project Report
# for
# Non-Euclidean Game Engine

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# Abstract

Nowadays, most game engines and for this reason most of the games use Euclidean geometry as a base for their development. Euclidean games as we describe them do not bend space and time. As these games continue to get developed, non-Euclidean games also started to get popular because things you can do with non-Euclidean spaces are more mind blowing and confusing for us to perceive, therefore this creates a great field to discover both for developers and players. Our objective is to create a non-Euclidean game engine that will contain non-Euclidean features to help game developers create their own games using these features as they see fit. In this report we will detail the geometry and methods we will use.

**Keywords:** Non-Euclidean geometry, Game engine, Euclidean geometry

# 1. Introduction

Game engines are created and used to develop new games or remake existing ones; they are IDEs for games. They make complex game development processes simpler by providing tools to make normally big tasks done easily, while the game engine does all the work in the back. To put it another way, game engines are frameworks designed specifically to be used in development and creation of video games.[1] Unity, Unreal Engine, Source and many more examples can be given for game engines that are used today.

Since the creation, or even idea, of the first video game, developers have mainly used Euclidean geometry to represent their games. Because, Euclidean geometry is what we use in tasks we perform in our daily lives. From our way of perceiving the world to the way we represent the fiction world we use in our games. [2] Euclidean geometry that most games use is geometric representation of axioms and theorems on the plane and solid figures employed by the Greek mathematician Euclid.[3]

Video games always try to introduce new concepts to draw people into their game's "alternative reality".[2] As game developers were looking for these new concepts to introduce, some of them were interested in the idea of non-Euclidean geometry, which is literally any geometry that is not the same as Euclidean geometry. [4] Thus our objective is to give game developers some tools they can use to develop this type of games.

This report goes through related works that got developed before and lists software and libraries that can be used to both develop a game engine and implement non-Euclidean features.

## 1.1 Problem Statement

Game Engines don’t come packed with non-Euclidean functionalities. With this project, we aim to implement basic non-Euclidean functionality to our project and make it easy to access.

## 1.2 Background or Related Work

Not many works are done in this area, but we listed and written about them in our literature search.

## 1.3 Solution Statement

After our researches we understood that developing an addon for a popular game engine is better for accessibility. So, we choose to use Unity as our base application, which is one of the most used and most popular game engines.

## 1.4 Contribution

We researched old and upcoming non-Euclidean games and which game engines they used to choose our base application. Also, we researched how they implemented non-Euclidean functionality using these engines.

# 2. Literature Search

## 2.1 Similar and Related Works

There are many works that make use of non-Euclidean geometry. Some of them is listed in the following sections.

### 2.1.1 Hyperbolica

Hyperbolica is a game with a non-Euclidean curved space where you journey through bizarre landscapes, solve puzzles, navigate labyrinths and do much more while also being challenged to perceive the non-Euclidean space.[5] At least this is how the game developer of this game explains his work. It is a game in development but the developer of the game shares development logs in video format in his Youtube channel. [6]

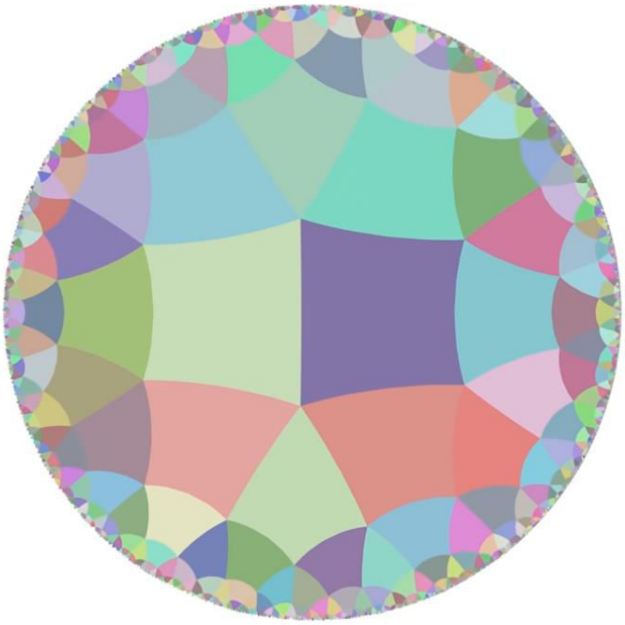

*Figure 1 - Hyperbolica's Tilemap*

The game uses Unity Game Engine and creates a hyperbolic geometry by making square per vertex number five instead of four (shown in Figure 1) and by making use of visual tricks and changes on perspective locations of game objects. It is a complex method and is detailed in a development log developer recorded and published on Youtube. [7] He also has other development log videos where he goes into detail of Non-Euclidean geometry and a video where they show a demo of their non-Euclidean game engine. [8] [9]

### 2.1.2 Antichamber

Game devs describe this work as being a mind-bending psychological exploration game in a Escher-like world where hallways wrap around upon each other, spaces reconfigure themselves and accomplishing what you think is impossible, maybe is the only way forward.[10] This game uses Unreal Engine 3 as their game engine. Antichamber uses many camera tricks and uses perspective manipulation to make some mind-blowing puzzles to solve. The game makes use of something called a stencil buffer which is an extra data buffer found on modern graphics hardware.[11] There are videos that go into detail about how Antichamber makes use of it. [12]

### 2.1.3 Superliminal

Superliminal is a puzzle game based on the perspective and optical illusions. What you do with an object in the game may cause unexpected results. Players need to change their perspective and think outside the box to solve puzzles and progress through the game. Game scales objects you interact with according to angular diameter and lets you solve puzzles by scaling objects to different sizes.

## 2.2 Software and Libraries

Many different software and libraries can be used to make a non-Euclidean game engine possible. We listed the primary options in the following sections.

### 2.2.1 Unity

Unity is the world's leading application for creating and developing real-time 3D content, which may be a game or an animation. It also provides a wide range of tools to make these content and lets users publish them to a wide range of devices. [14] Thus unity is one of the best game engines to make a game project in and Unity uses C# as its scripting language which is a common and easy to use programming language. It does not provide tools for making a game in non-Euclidean geometry and our task will be enhancing it with prefabs, scripts and even add-ons if needed to make a game engine for non-Euclidean projects using tricks on perception.

### 2.2.2 OpenGL

OpenGL is one of the first frameworks that come into mind for developing graphic applications. Since its first release in 1992, it has become the industry's most widely used and supported 2D and 3D graphics application programming interface. [15] OpenGL let us write a game engine from scratch giving us the ability to make non-Euclidean rendering the default option however it lacks the uncountable number of tools (i.e. objects, materials, collisions which will be needed to implemented from scratch) Unity provides us with, in exchange for more customization.

## 2.3 Conclusion

Using non-Euclidean geometry is a new concept that game developers make use of to expand concepts of game development. In our report we analyzed games done in non-Euclidean geometry and features they used to provide us with ways we can implement in our engine. Report also goes through software and libraries one can use to code a non-Euclidean game engine.

# 3. Software Requirements Specification

## 3.1 Introduction

### 3.1.1 Purpose

The purpose of this document is to explain the Non-Euclidean game engine. The goal of this game engine is to create games by using non-Euclidean geometric elements by going beyond the boundaries of current reality. This document contains detailed information about the project's requirements, reflecting the defined restrictions and recommended software functionality.

### 3.1.2 Scope of project

Most games today are made with game engines created based on known physics rules. For this reason, games are designed and created in accordance with Euclidean geometry. Whenever we want to make a project that is not suitable for Euclidean geometry, we have to design the mechanics of this game from the beginning. The main purpose of our project is to design a game engine ready to be used in the creation of games based on non-Euclidean geometry mechanics.

Most mechanics available are actually about smoothly moving the player from one location to another, directing the player to another location as opposed to the one they think they will reach, or altering the surrounding items or some material about the user indiscriminately during this smooth teleport to create an illusion.

While working on this project, it will be more beneficial for us to use the Unity Game Engine and C# language, which we are familiar with in this sector, and we think that it can be more efficient while getting help about the problems we face in the rest of the project.

## 3.2 Overall Description

### 3.2.1 Product Perspective

Non-Euclidean Game Engine is for game developers who are making games about Non-Euclidean geometry. These games generally use portals and camera tricks to change perspective. Game engine has 2 parts which are portals and camera tricks.

### 3.2.2 Development Methodology

For developing the project, we meet twice a week in the beginning and end of the week and we divide project parts among project members.

### 3.2.3 User Characteristics

#### 3.2.3.1 Game Developer

User could be anybody but preferably a game designer or game developer.
User must be able to read and understand English language due to engine being English
Users must have knowledge of game making or game developing and read the guide provided beforehand.

## 3.3 Requirements Specification

### 3.3.1 External Interface Requirements

#### 3.3.1.1 User Interfaces

User interfaces will be integrated to Unity as an add-on and will use Unity's own tab system.

#### 3.3.1.2 Hardware Interfaces

There are no external hardware interfaces.

#### 3.3.1.3 Software Interfaces

Product requires Unity 2019.1 to work.

#### 3.3.1.4 Communications Interfaces

There are no external communications interface requirements.

### 3.3.2 Functional Requirements

#### 3.3.2.1 Create_Portal Function

Create Portal function will be used to create a portal in the game world when the user activates it from the add-on menu.

Process:

1. Game Developer clicks the appropriate button.
2. A pre-made portal is put into the world.
3. Optionally, Game Developer can set;
4. its width and height,
5. where the user will be teleported with coordinates,
6. a connected portal, where users will be teleported.

### 3.3.2.2 Create_NonEuclidean_Area Function

Create Non-Euclidean Area function will be used to put a non-Euclidean area attribute to the selected GameObject when the user activates it from the add-on menu.

Process:

1. Game Developer will select a GameObject, that they pre-made,
2. Game Developer will click the appropriate button,
3. Non-Euclidean Area attribute will be put into the selected GameObject.
4. After this, Game Developer can set and change;
5. its type and status.

### 3.3.2.3 Teleport_Object Function

Objects in the game world will be teleported when they collapse with the Portal object.

Process:

1. Object collapses with the portal
2. If portal has a connected portal, object is teleported to that portal,
3. if portal doesn't have a connected portal but has coordinates for teleportation, object is teleported to that coordinates,
4. if the portal doesn't have both, the object doesn't get teleported.

### 3.3.2.4 Warp_Objects Function

Objects in the Non-Euclidean Area will be warped differently depending on the type of the Non-Euclidean Area, if the Non-Euclidean Area is turned on.

Process:

1. Game Developer needs to define an object as a player and/or camera.
2. If Player/Camera is collapsing with the Non-Euclidean Area;
3. System will check if the Non-Euclidean Area is turned on,
4. If it is turned on, objects will be warped according to type of the non-euclidean area,
5. if it is turned off or a player/camera is not identified, nothing will happen.
6. When the Player/Camera leaves the Non-Euclidean Area, the area will return to normal.

### 3.3.2.5 Change_Camera Function

Game Developers may want to use their own camera to change perception of the Non-Euclidean Area so depending on the type of the Non-Euclidean Area, the system will change the camera defined to the one the user wants.

Process:

1. Game Developer needs to define an object as a player and/or camera.
2. Game Developer needs to define a camera that will be changed with the current one.
3. When Player/Camera collapses with the Non-Euclidean Area, the camera will be changed with the one the Game Developer has chosen.
4. When Player/Camera leaves the Non-Euclidean Area, the camera will be changed with the default one.

#### 3.3.2.6 Basic Game Engine Functions

Other than our project's functionality, a basic game also needs to contain some functionality. These are;

- Gravity,
- Object Collision,
- Character movement,
- Character-Object Interaction and many more individual functionalities based on the needs of the game Game Developer plans to develop.

### 3.3.3 Performance Requirement

Performance is highly relevant to the project the user is working on, scaling with its size. But as a minimum, Unity 2019.1 requires:

- Windows 7, 8, 10, 64-bit operating system,
- graphics card with DX10+ capabilities,
- and an appropriate amount of space in the disk.

### 3.3.4 Design Constraints

Software will be designed as a general non-Euclidean add-on to help developers build non-Euclidean game projects. As the plot or gameplay of their project may require specific elements that we can't predict, this project will only cover common elements that can be used in a variety of non-Euclidean game projects.

### 3.3.5 Software System Attributes

#### 3.3.5.1 Portability

Non-Euclidean Game Engine is an add-on for Unity thus it can be installed to any Unity instance in any computer with ease.

#### 3.3.5.2 Performance

Performance scales with the needs of the user, the base add-on only requires Unity's system requirements to work.

#### 3.3.5.3 Usability

Add-on will have an understandable and easy to use interface.

#### 3.3.5.4 Availability

Add-on will work on Unity 2019+ and all operating systems that Unity 2019+ works on.

# 4. Software Design Description

## 4.1 Introduction

Software Design Description, is a document to detail implementation and design of the project in question and detailing it with visuals.

### 4.1.1 Purpose

Purpose of this document is to present the design and implementation of the Non-Euclidean Game Engine. Non-Euclidean game engine is a tool to help developers develop Non-Euclidean games.

### 4.1.2 Scope

This document details this project's design. It will have two major features. One of them is the customizable portal which can be used by user to perform tasks that will make the player feel like they are in a Non-Euclidean environment and second one is a Non-Euclidean Area which will warp objects and other props to make it look like a Non-Euclidean space.

### 4.1.3 Definitions, Acronyms, Abbreviations

Non-Euclidean: Elements that deny Euclidean Geometry principles Portal: A gate for changing position in space-time plane Unity: A modern game engine with its own editor. GameObject: Main object class for game objects in Unity. Camera: Camera class for game camera in Unity.

## 4.2 Architecture Approach

### 4.2.1 Design Approach

We will use the spiral development approach because we will work in an area we are not very accustomed to and by using this methodology we can add in new features and take out or change features that can't be implemented in the way we planned beforehand.

### 4.2.2 Software to Use

This project will be an add-on to Unity Game Engine and will work hand to hand with it. Code part will be written in C++ and C#. To write our code in, we will use different text editors and IDEs that will not be a part of our final product.

## 4.2.3 Class Diagram

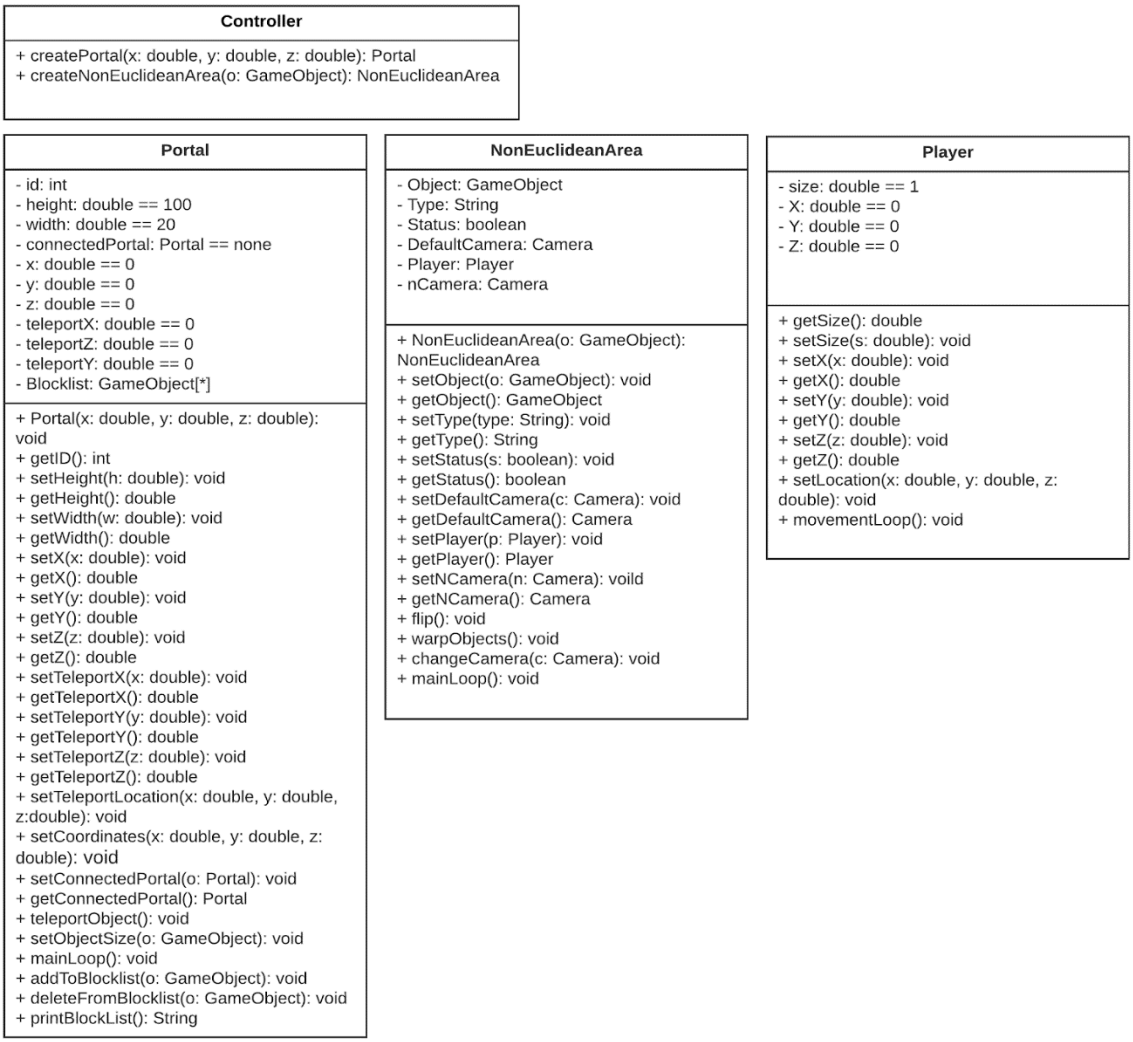


*Figure-1: Class Diagram*

## 4.2.3.1 Class Diagram Description

### 4.2.3.1.1 Controller

Controller will be interacted by the addon interface to create objects.
**Functions:**

- **createPortal:** createPortal function will be used by the addon interface to create a portal by calling the overloaded constructor of Portal class, which will require x, y, z coordinates.
- **createNonEuclideanArea:** This function will be used by the addon interface to create a Non-Euclidean Area by calling overloaded constructor of the NonEuclideanArea class, which requires a GameObject to put NonEuclideanArea attribute on.

#### 4.2.3.1.2 Portal

Portal will have another portal that it is connected to or coordinates of a point to teleport a player it collapsed with. If both attributes are filled, the connected portal will have the priority.
**Functions:**

- **Set/Get Methods:** Set/Get methods are default set/get methods for private variables which will be used by Unity's "Inspector" interface to change attributes of the object.
- **setTeleportLocation:** This function is for changing the teleport location of the portal and for ease of use to not set each coordinate one by one.
- **setCoordinates:** This function is for changing coordinates of the portal by inputting all values in once and to not set each of them one by one.
- **teleportObject:** This function is called when an object collapses with the portal and will check if the Portal in question has a Connected Portal or a Teleport Location saved as a variable. If it has both of them Connected Portal will be prioritized.
- **setObjectSize:** Multiply object's size attribute depending on the difference between connected portals.
- **mainLoop:** Loop to check if Portal collapses with a GameObject that is not in the Blocklist and call appropriate functions.
- **addToBlocklist:** Blocklist is for objects that Game Developer doesn't want to teleport and with this function Game Developer can add objects to Blocklist.
- **deleteFromBlocklist:** For deleting objects from blocklist.
- **printBlocklist:** Prints an organized list of items in the Blocklist.

#### 4.2.3.1.3 Non-Euclidean Area

Non-Euclidean Area will be an attribute that can be mounted on to GameObjects, if the GameObject has this attribute. When a player is collapsing with this area by being in it, depending on the type of the area, the player camera will be changed by another camera that has different attributes as to perception or game objects will be warped (also depends on the type of the area).
**Functions:**

- **Set/Get Methods:** Set/Get methods are default set/get methods for private variables which will be used by Unity's "Inspector" interface to change attributes of the object.
- **warpObjects:** Warps objects in the Non-Euclidean Area depending on the Type attribute.
- **changeCamera:** Changes Default Camera with inputted Camera.
- **mainLoop:** Loop to check if an object collapses with the Non-Euclidean area and calls appropriate functions depending on the situation.

#### 4.2.3.1.4 Player

Player object will be a controllable object that can be moved by the player.
**Functions:**

- **Set/Get Methods:** Set/Get methods are default set/get methods for private variables which will be used by Unity's "Inspector" interface to change attributes of the object.
- **setLocation:** Sets user location for ease of use to not input each coordinate one by one.
- **movementLoop:** Moves users depending on the key pressed while in the game playing environment.

### 4.2.4 Unity Functionality

Unity supplies us with a lot of functionality that will be used in games Game Developers want to develop. And provide means to implement Basic Game Functionality mentioned in Software Specification Requirements. Unity does this by providing pre-made collision detectors implemented into the editor and/or pre-made scripts that can be found on the Unity Store. Since these can be provided by other means and our project's main focus is to help Game Developers with Non-Euclidean functionality, we will not implement these into our addon.

## 4.3 Flowchart

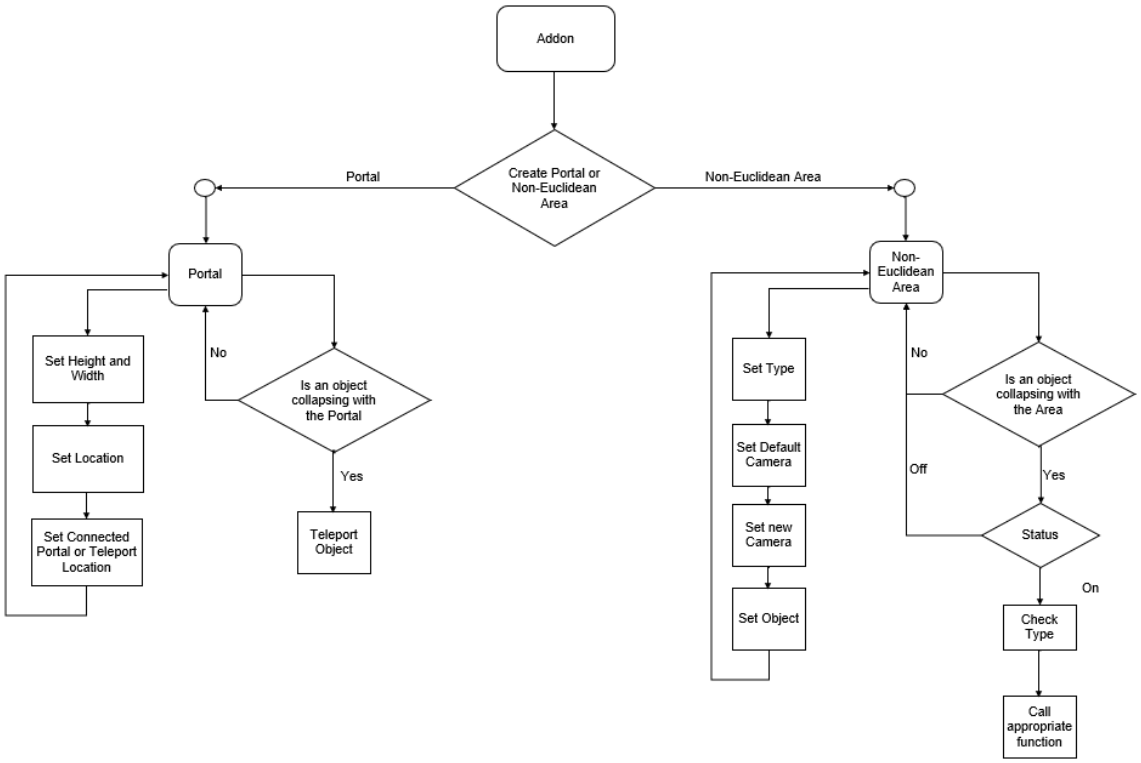


*Figure-2: Flowchart*

Figure-2 shows add-on's flowchart of operations and how it should work.

## 4.4 Add-on Interface

Non-Euclidean Game Engine addon will have its own interface docked into the Unity application and will have 2 buttons that will be used to create a portal and create a Non-Euclidean Area. Clicking either one will spawn its respective object in the game world. After that, created objects will be controllable and modifiable by Unity's own user interface.

# Acknowledgement

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