MSE | MASTER OF SCIENCE IN ENGINEERING

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Haute Ecole Spécialisée de Suisse occidentale
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Bachelor of Science HES-SO in Software Development

Orientation : Développement logiciel et multimédia

ArcheoGame : A serious Game in the field of Archeology

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Abstract

This bachelor project, in collaboration with Bienne's Nouveau Musée aims to develop a small educational serious game (SG) in virtual reality oriented towards childrens and young visitors. The exhibition will feature original work from an invited painter representing a palaeolithic life scene. Visitors will be able to interact with a virtual representation of objects from this era which would be way too fragile to manipulate in real life and place them in the painting. The intent is to educate players on aforementioned objects with an entertaining experience.

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1 Introduction

1.1 Context

Bienne's Nouveau Musée (NMB) was born from the merger of Musée Schwab and Musée Neuhaus in 2012. Focused towards archeology, history and art, the museum regularly holds temporary exhibitions. One of those exhibitions, which will take place in June 2018, will features many works on the theme "Imagine the past" among which we would like to introduce a work of painter Benoît Clarys (fig. 1) which will be themed around perception. The NMB, with the partnership of the Haute-Ecole Arc, University of applied science and art of western Switzerland (HE-Arc, HES-SO) that provides the development of a virtual reality (VR) platform, will propose a stand aimed towards young visitors to explore VR potential in exhibitions. Within this VR experience, end users are able to explore, discover and interact with archaeological objects.

Figure 1: Benoît Clarys at work

1.2 Objective

The objective of this project is to develop an educational SG in VR.

As the NMB (fig. 2) exhibition features original work from invited painter Benoît Clarys representing an archaeological life scene (fig. 3), visitors will be able to interact with a virtual representation of objects from this era which would be way too fragile to manipulate in real life and match them with their representation in the painting.

The intent is to suggest potential instructions to players on aforementioned objects with an entertaining experience. End users evolve in a virtual replica of

Figure 2: NMB's infrastructure

Figure 3: The painting, by Benoît Clarys

a BNM's specific area (fig. 4) environment in which they are presented with a table on top of which five distinct ancient objects are laying. In front of them is a large painting picturing the use of these objects in a real life scenario.

The objective of the SG is to match each object by replacing them in the correct area of the picture. By doing so, objects will "fade" into the picture, revealing the original work of art. Objects will be paired with a short audio anecdote provided by the Museum.

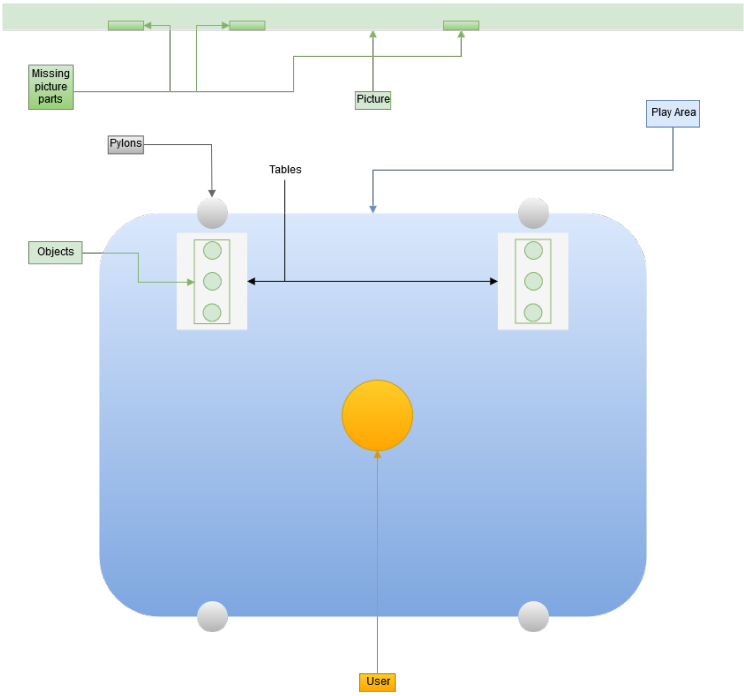

Figure 4: Overview of the game area. The objects replicas, laying on the tables, must be matched with their missing counterparts on the picture.

Figure 5: Unity's logo

1.3 Environment

The Unity game engine (fig. 5) will be used, along scripts written in C#. The VR device will be an HTC Vive. 3D models (Room, small props) will be created in Maxon Cinema 4D. As of sound, possible editing will be done in Ableton Live.

1.4 State of the Art

1.4.1 VR

Virtual reality (VR) is a computer-generated scenario simulating experiences through senses and perception. VR has been here for a long time and saw experimentations in the 60's [1]. Since computers performances skyrocketed lately (mostly led by the video game industry), people have been able to explore more and more realistic imaginary landscapes and worlds through 3D visuals projected on a two-dimensional plane. People naturally wanted to grasp and feel said worlds through more interaction and immersion.

Since VR has been tricky to commercially exploit (we can think of Nintendo's 1995 Virtual Boy [2]) because of expensive devices and end users non-optimal experience. Early products were also technically lacking and expensive for their era, like the Forte Technologies, Inc.'s VFX1 [3] which provided a field of View (FOV) limited to 45 degrees and poor resolution (but already included head tracking through the use of internal sensors).

In 2012, Oculus VR successfully raised US$2.5 million through a Kickstarter campaign [4] for the Oculus Rift [5], an affordable VR head mounted display (HMD). Oculus VR also got purchased by Facebook [39], Inc two years later [6] and started a commercial race towards commercially exploitable HMDs, notable opponents being HTC's & Valve's *HTC Vive* and Sony's *PlayStation VR*. Google and Samsung proposed cheaper alternatives using end users smartphones, with the *Google Cardboard* [7] and the *Samsung Gear VR* [8].

1.4.2 HTC Vive

The chosen device for this project is the HTC Vice [9] (fig. 6). The Vive comes with several advantages over other head mounted devices (HMDs), the main one being the ability to walk around (reducing motion sickness for most people). A task performed by a human with the Vive is done with better accuracy most of the time [10] and its overall quality of experience is considered a bit superior. As its two sensors track both the headset and the controllers (in opposition to the Oculus Rift, which has one tracker for controllers and one tracker for the headset), the Vive is also less prone to line of sight (LOS) obstruction.

However, the HTC Vive has some disadvantages : it was shown to use a reference plane that is tilted away from the true ground plane, causing incorrect roll and pitch. Changes of height measurements across the tracking space may occur [11].

It may come to the fact that the tilt of reference plane changes each time the headset loses and regains tracking. This is not an isolated case, as the results can be replicated with a second Vive system and same problems were reported on online community like www.reddit.com/r/Vive [11].

As this project aimed for a near perfect tracking in the first place, this could be a big issue as tracking losses can't be avoided in a museum environment. Tests in the real room will reveal this.

Figure 6: The Vive HMD (model credits : Eternal Realm)

1.4.3 Motion Sickness

Generally, motion sickness is induced by a disparity between the informations about acceleration coming from the vestibular system (inner ear) and visual information coming from the eyes [12]. This is well illustrated when people travel by car or plane : being subject to accelerations while observing the vehicle interior creates a discrepancy, resulting in people feeling sick.

The fact people experimenting VR content can be subject to said motion sickness is one of the biggest challenge to overcome when developing VR content. Two big families of solutions are explorable to solve this issue :

The first is to alleviate sensibility of the vestibular canal by taking standard medicine (Dramamine [13], VIRMO [14]). While being a viable option, it is a temporary one that can induce potential side effects.

The second can be divided into three sub-categories that do not make use of any drugs:

- Information can be injected at a corresponding timing with visuals organs. A low latency between head movement and visual feedback (20 ms) can mitigate a lot of motion sickness. Latency should ultimately reduce to 0ms.

- Information can be injected with corresponding timing with vestibular system (GSV, Galvanic Vestibular Stimulation) [15] [16] [17]

- Avoid sudden camera movement and overall drastic changes in visual information.

A handful of web articles describe good practices when developing VR content [18] :

- Use slow motion movement, avoid sharp camera movements, avoid motion blur
- When a user is seated, the use of a cabin/capsule (e.g. putting the player in a car model) can mitigate motion sickness
- Teleportation is currently the best method of movement, as there is no interpolation between two locations
- *ingame* Partial or full refusal body visualization (e.g. seeing your hands and/or body model)

1.4.4 Exhibition and VR

Qualifying both the HTC Vive and the Oculus Rift as "commodity HMDs" by the above-mentioned QoE Assessment [10] is pretty accurate : virtual reality in exhibition and art performances, while having being explored thorough the last years, is now more accessible than never before. *"Scientists, artists, technologists, and Human Co mputer Interaction (HCI) experts now have an opportunity to develop novel interaction techniques and strategies, and new forms of expression, expressivity, and narrative approaches. In turn, these technologies can provide an integrative, dynamic, interactive platform for the experience, entertainment and learning."* [19]

The idea of a empty museum has already been explored several times [20] [21], where an empty space is used as a walkable surface : the exhibition is 100% virtual and experienced through HMDs. The idea of a digital museum also saw tentatives in the Second Life online game [22]. Research on user feedback and painting enhancement [23] showed that such techniques can improve user implication : Younger, technology enthusiasts user groups, who are often less interested in traditional art such as paintings, gave very positive feedback. This is also the case for people that consider themselves less skillful with new technology [24].

As far as digital archeology is concerned, a complete methodology for digital exhibitions has been proposed by the University of Calabria [25], detailing how techniques such as photogrammetry can be used to create photorealistic 3D models of buildings and small objects of different materials, including wood, stone, marble, pottery and metals. This won't likely be exploited though, as this task is outsourced to an external team.

1.4.5 Location

As the exhibition feature original work from an invited painter representing an archaeological life scene, visitors will be able to interact with a virtual representation of objects from this era which would be way too fragile to manipulate in real life and replace them in a painting. Said objects all come from the Neolithic site of Sutz-Lattrigen, Rütte (situated on the shore of Lake Biel), which is listed in the UNESCO world heritage list. [30] [31]

1.5 Requirements

The requirements were decided in accord to school professors and NMB's curator and were as follows :

1.5.1 Primary

- Customization of input high resolution objects meshes from 3D artist
- Low resolution realistic objects as well as respective picture representations input
- 3D model of the room (realistic render type, best effort)
- Objects interactions :
  - Grabbing the object
  - Throwing the object on the painting (Matching mechanic)
- Audio :
  - Audio anecdotes
  - Game FX
- Reset mechanic
- Game mechanic
- Scoring and user interface (UI)
- Tuning of game parameters
- Indoor testing and setup

1.5.2 Secondary

- Advanced game mechanics
- Advanced scoring and UI
- Advanced sound and music FX
- Object breaking / respawning

The "advanced" term can concern unexpected changes in design due to constraints or limitations.

The next section will detail the initial design decisions taken during the analysis phase.

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2 Analysis

The NMB initially wanted an VR installation for kids. As this project is their first experience with VR, the requirements and specifications were discussed with HE-Arc professors and assistants.

2.1 Engine

The choice of engine fell on the Unity game engine (and its C# scripting system (fig. 5). Unity is well suited for quick prototyping as well as larger scope projects, due to it's rendering capacities and integrated physics engine.

2.2 Art style

At first, the museum thought of a cartoon type of render (cell shading). This type of render works well in Unity (which supports such shaders) and reduce drastically the need for detailed models with high polygon count. On the other hand, cell shading can throw non-initiated people off as the replication of the room could be misperceived. In addition of this, the museum had access to external photogrammetry teams which could scan the artefacts to produce high fidelity models and textures. Thus, the decision of art style was taken on a realistic type of render.

2.3 Constraints

As this project will be displayed in a real museum, constraints played a big part in this project and encouraged many design decisions. It is impossible to predict all kind of visitor behaviors, so the goal was to minimize potential issues in the program design.

2.4 Motion sickness

As discussed in the state of the art, motion sickness in VR can be a big issue when dealing with a lot of different types of profiles. Some people may be more subject to it and we wanted to avoid nauseas. In accord with that and While respecting good practices, a particular attention should be accorded to performances as frame drops may also cause motion sickness. Things such as high lightning count, high polygons count and post processing must be avoided. The fact the player isn't supposed (and doesn't have the ability) to move freely in the room helps as movement isn't a concern. To avoid high polygons count models (Fig. 7), the museum specifically asked the photogrammetry team to provide low polygons models (Fig. 8) of the artifacts, while having high resolution scans for the normal and color maps. Despite a fairly low poly count, the objects stay well recognizables and the framerate stays constant.

Figure 7: High polygon count model

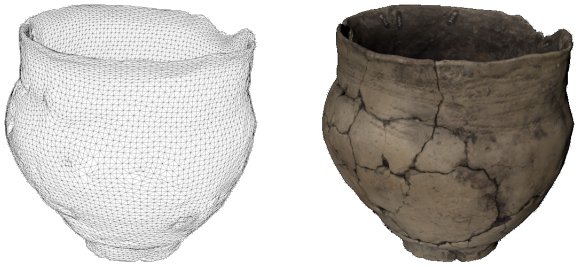

Figure 8: Low polygon count model with HD texture, drastically improving performances

2.4.1 Physical constraints

Aside from motion sickness, the physical setup of the room came with its lot of issues. Initially, the installation should have taken place between the picture and the two pylons (Fig. 9), with the player evolving in the small space in-between. After visiting the room, it became sure the location wasn't appropriate as people could fit in but could be harmed by the pylons if left unchecked. Furthermore, the illustration could be damaged by potential sudden movements. Thus, the

Figure 9: The place the installation will take place (left side of the picture). The illustration and the metal pylons can be noticed.

decision was taken to move the play area further from the illustration (to the right of the picture, behind the pylons).

This decision comes with three following consequences :

- The player is unable to put the object directly in the picture, as the room setup stays the same in the game (the player will be placed to a certain distance from the picture). A projection system is needed.
- The pylons can still be an issue. Modeling them *ingame* can be a solution by visually warning the end users.
- A table was supposed to be present both in real life and in game to serve as a receptacle for the objects. If moved around, this table would break the scenography.

Further testing in the museum revealed other issues which will discussed in the realization section.

2.4.2 Other constraints

As the installation is supposed to run for extended periods of time, some mechanics are needed to ensure the program requires as little maintenance as possible, as well as being as easy to understand as possible. Initial considerations included the following mechanics :

- Detection of the headset status : if it isn't worn anymore, the game should reset to prevent people leaving in the middle of the experience, leaving the game in an incomplete state

- Items, when wrongly placed, have to reappear on their starting location
- Items, when dropped on the ground or placed out of reach of the player should as well reappear on their starting location

This sums up the constraints which were initially discussed in the analysis phase. As the build was regularly tested at the NMB, other issues appeared and will be described later, in the realization phase.

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3 Conception

3.1 VR implementation

Valve's Steam VR plugin, available on the asset store, provides us with ways to quickly build VR projects. Its main component, the camera rig, can be incorporated in an unity scene to quickly access the Vive's tracking properties. Both controllers and HMD are symbolized by GameObjects (Unity's base class and main components container) and can be interacted with like every object in the scene. In that way, we do not need to handle "by hand" the basic behavior of the Vive, which would have led to a serious loss of time. In itself, the HMD behaves like a camera. By simply putting the camera rig in a scene, the basic setup is done and the scene can be viewed through the (physical) HMD by just walking and looking around. Physical height of the user is respected.

Basic classes are available for object interaction, such as the Throwable class that is used by all our artifacts *ingame* representations and represents an item that can be held and thrown. When attached or detached from a hand (a controller), a list of callbacks are invoked. Those callbacks *can* be registered in the Unity Editor directly, but were directly implemented in the Throwable default behavior to avoid breaking scene when swapping Prefabs (Unity prefabricated items system).

3.2 Unity structure

All the nonphysical or visual only items (Room model, details, floor) are contained in a scene GameObject. Managers, such as the ScoreManager, the AudioManager and the GameManager are children of a 'utility' empty GameObject. The PlayArea contains all gameplay elements, ranging from the camera rig to the interactable objects.

3.3 Mechanics

3.3.1 Matching mechanic

The matching mechanic is used to determine if an item is dropped on goal. Two key classes are used : the KeyObject and Goal classes. The Goal class symbolizes a missing part of the painting and is attached to a GameObject containting a sprite renderer with its alpha set to 0 , making it non visible. Goals also contains two public audio clips used for audio description playback and a collider for collision detection. In addition of this, each goals possess a private boolean 'completed' variable : when completed, this variable becomes true. If all goals are completed, the end of game occurs. The KeyObject class symbolizes the artifacts that needs to be matched with their painting counterparts. KeyObject scripts are attached to GameObjects and require a Rigidbody component (Unity class used to manage rigid, physical elements) in order to work properly. Goals and KeyObjects both have an identification number used to check if the two items match.

The detection occurs when a item is detached from hand : the Throwable class has been altered to call the KeyObject TryGoal() method. Initially, this method used both the KeyObject and Goal colliders to detect collisions. It was later changed to use a raytracing system which will be described in section 3.3.3.

3.3.2 Scoring

Figure 10: *ingame* Score UI display

In order to add a competitive aspect to the SG, a leaderboard is present at the end of the game. A serializable Score class is used to store data such as the number of consecutive good placement of objects, errors made and time spent. A number of points is computed in function of those values. Those values are visually presented to the user *ingame* as a spatialized (physically present as an in game element) UI at the right of the painting (fig. 10). The ScoreManager stores a list of Score objects. This list is deserialized from a binary file at each loading of the game. When a player finishes the game, a random name is generated from a combination of an animal and a color and stored in the 'name' field of the Score object. The current Score object is then added to the Score list. Finally, the list is written to the disk. After each actualization, the list is sorted again with an enumerator (implementing the IEnumerator standard C# interface) using the total points value.

The leaderboard (fig. 11) is then displayed in front of the player for a brief period of time.

3.3.3 Ease of use

As discussed in sections 2.4.1 and 2.4.2, the installation is intended to welcome a large panel of visitors, with varying level of skills about VR and games in general. Various systems ensure the good flow of the game :

- When an item falls to the ground, it is automatically replaced to its starting position on the tables with its velocity and angular speed set to 0.

Figure 11: The leaderboard, displayed *ingame*

This avoid the loss of KeyObjects and potential softlock (state where the game cannot be completed) of the SG

- The tables have a Rigidbody component, but their rotation is restricted on all three axis to avoid their possible fall, which would result in items continuously falling to the ground and respawning (making them nearly uncatchable)
- As the play area as been moved away, the artifacts don't require anymore to be physically put into the picture. Instead of this, the objects will emit a visual line between their location and their projection on the painting. This allow visitors to simply walk in front of the painting horizontally and putting it on the right spot
- When the projection of an item hits the box collider of a goal, the area is highlighted with particles, indicating a possible spot
- The HMD transform position is monitored and the scene loaded if it stayed static for a few seconds. This prevents a potential user to be bothered by the game being left in the middle of the experience

The next section will describe the realization process, as well as encountered issues.

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4 Realization

4.1 Room model

Figure 12: Plans of the room

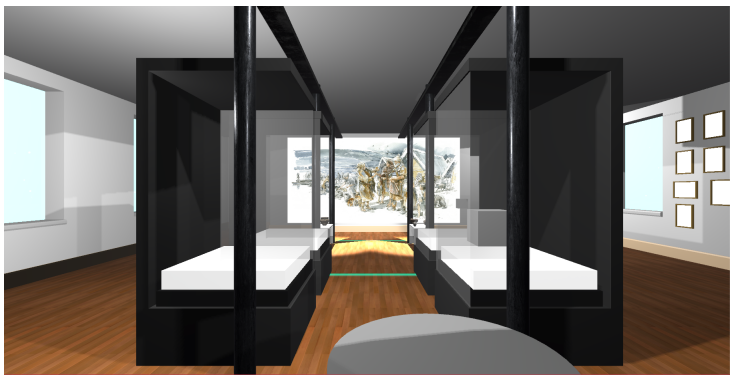

Figure 13: The museum model, main room

As the 3d model of the room is supposed to be as close as possible to the real museum room, the modeling process took a long time. Plans of the museum (fig. 12) have been used to respect the room scale by being placed in the background of a Cinema4D (Maxon's 3D modeling software) top view window. By using traditional polygonal modeling techniques such as extrusion and bridging, an accurate representation of the museum can be obtained. After this process, a first visit of the empty room was necessary to adjust its model overall design. Things like the showcases were modeled at this point.

After a few months in the project, the exhibition was installed and further photographs were taken to adjust furnitures layout and notable elements, like the paintings on the walls.

Figure 14: The museum model, from the other room POV

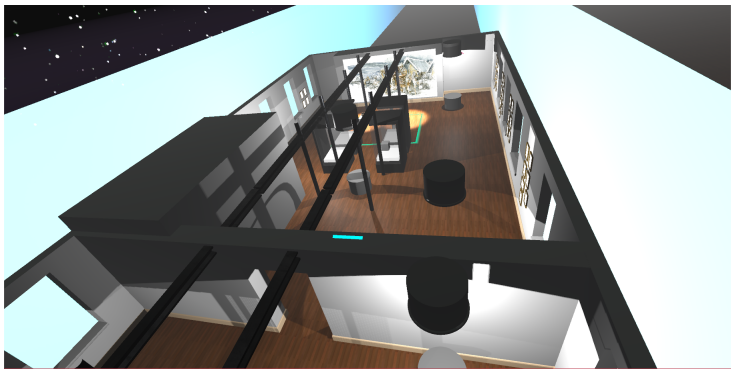

Figure 15: The museum model, overview

4.1.1 Textures

For the most part, simple materials (Unity basic shader) without textures were used to reduce the quantity of textures needed. Objects that will be close to the user, like pylons or artifacts (Section 4.3), were UV unwrapped and textured in Substance Painter to obtain a more realistic render. Unity supports transparent materials for the showcases glass and windows.

4.2 Image processing

In order to add difficulty to the game, the objects representation in the painting need to be erased in the picture sprite (Unity name for pictures used in game). The picture was then processed in Photoshop, by erasing (best effort) the objects in the picture. The originals were kept in layers in order to create the apparition effect (alpha interpolation).

Figure 16: Close up of the painting, with and without the objects

4.3 Artifacts models

Figure 17: The mapple wooden cup model

Figure 18: The ceramic container model

As we work with fragile ancient items and due to their value, an external, professional team was required to produce 3D reproductions from them. The NMB archaeological team used photogrammetry to obtain accurate meshes and textures, while asked to keep geometry complexity low. Scanned objects, all coming from the Sutz-Lattrigen, Rütte (Biel's lake) archaeological site, include :

Figure 19: The flint dagger model

- A mapple wooden cup (fig. 17)
- A ceramic container (fig. 18)
- A performed serpentine axe (fig. 22)
- An oak stilts (fig. 20)
- A flint dagger (fig. 19)
- Copper pearls (fig. 21)

Figure 20: The oak stilt

Other items, such as charred cereals and apples and a shoe in free linden, were left out because organic items are hard to manipulate and would have been damaged by photogrammetry.

4.4 Encountered issues

4.4.1 Unity rendering depth with VR

When using VR, Unity's engine tends render items with a wrong z-buffer. This is especially true for close items : The picture is constituted from a big sprite

Figure 21: A copper pearl

Figure 22: The performed serpentine axe

(the painting with missing objects) as well as smaller sprite (the missing objects) that are positioned with a very small offset (.01f) from the picture. Depending on the angle and HMD position, those sprites tends to be rendered after the big picture, leading to invisible or misplaced sprite. The solution to solve this issue is to use sorting layers feature from unity, which offer a manual control over the z-buffer. The UI is rendered first (to avoid the raytracer line renderer being rendered under the painting). Then, the missing parts are rendered before the painting itself. This fix is quick to implement but have to be considered the whole time afterwards.

4.4.2 Valve SDK standard behavior

Another issue was encountered when implementing the object respawn mechanic : When spawning back on the tables, the objects conserved a small velocity and tended to fall on the ground. Setting their Rigidbody to kinematic (a state where a Rigidbody isn't affected by other colliders) didn't help. After multiples attemps, an inspection of the Throwable class showed that when detached from a hand, the Throwable :

1. Invokes the registered callbacks

2. Calculates its new velocity according to the hand parameter

3. Sets itself to non kinematic again (picking up an item makes it kinematic)

Because of this execution order, a thrown Throwable cannot have a null velocity if held by a moving hand. A modification of the of the KeyObject.TryGoal() and Throwable.OnDetachedFromHand() methods has been done : the method now returns an ObjectState enum, telling if the item has simply been dropped or if a goal was tried : in the first case case, it adopts the standard Throwable behavior. In the second, it reappears on the table without estimating its new velocity.

4.4.3 Multiple languages

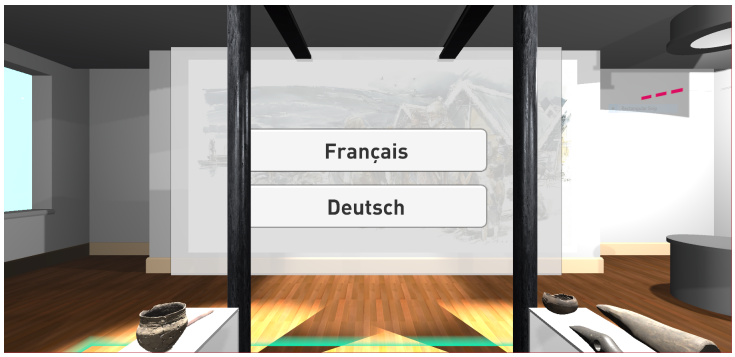

Figure 23: Language selection UI element

Being located in biel, the NMB naturally hosts bilingual exhibitions (german and french). As it was unsure audio anecdotes were to be included, the development began without planning the inclusion of a second language. To correct this, a language selection UI (fig. **??**) has been added. Refactoring the GameManager, ScoreManager and AudioManager was needed in order to include an CurrentLanguage enum. This enum is used it to determine whether audio anecdote clip has to be played when an item is successfully deposed on a missing part of the painting. The leaderboard and score UI both have their text localized as well.

4.4.4 Shadow dithering

Unity's standard shader, when set to transparent, produces odd shadow dithering (fig. 24), 25). A quick fix to this is to make objects using transparency (such as the showcases glass one) ignore lightning by using culling masks. In this way, windows appear unlit but dithering disappear. A custom shader could have be written to repair this, but was not due to time limitation.

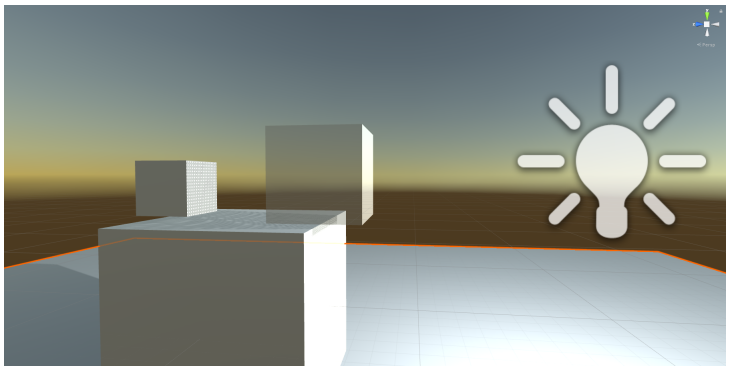

Figure 24: dithering rendering bug

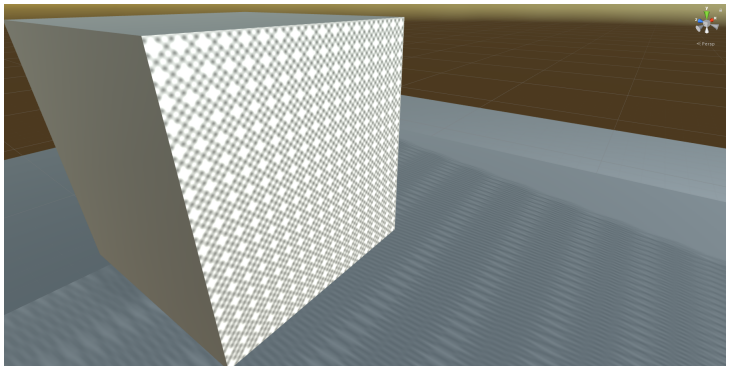

Figure 25: Close up of the dithering rendering bug

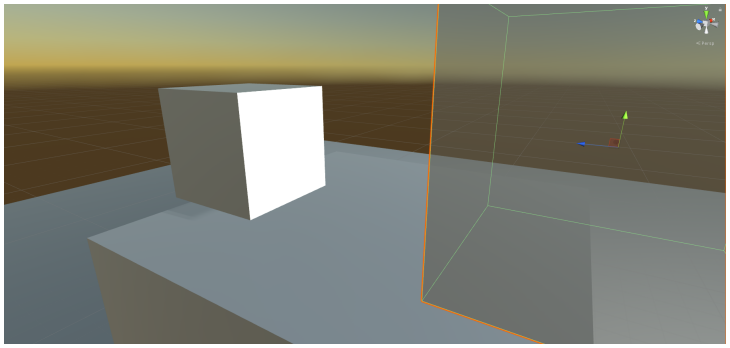

Figure 26: Dithering bug solved

Figure 27: *Backlit* effect, rendering

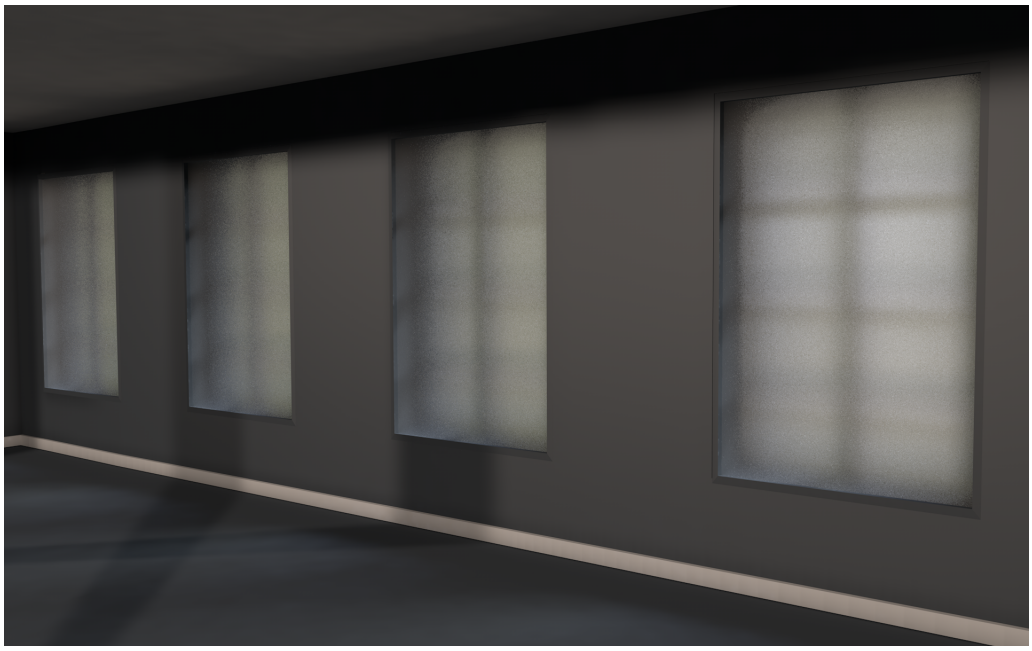

Figure 28: *Backlit* effect, rendered

4.5 Backlit effect

The real museum's windows are covered by rice paper. This effect was possible to obtain in rendering software like Cinema4D (fig. 28), but the rendering (fig.

27) takes huge amounts of time (about 10 minutes for this example. Unity cannot process such effect in real time, and internal illumination (fig. 29) was used instead to get an acceptable render.

Figure 29: Actual windows in game, using internal illumination

4.6 Respect of specifications

The specifications have been well respected except for the two following details :

- Low polygon meshes modeling and modification has been handled by an external team
- Object breaking was not implemented because of the low count but complex meshes. This is doable but time consuming, as meshes needs to be "cut" into multiples meshes. Each pieces need also to be textured which would have implied a lot of image processing. The use of photogrammetry would have induce odd and unrealistic results, as we cannot break the real artifacts in order to scan them

The next section will break down how tests were done in this project, as well as discuss possible changes for the future of the project.

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5 Tests

5.1 Tests in the development phase

The most part of tests took part in the development phase, using a computer equipped with VR capacities and plugged to an HTC Vive. A debug mode, absent from the development build, has been used to trigger things like GameState changes by using simple key inputs. A simple Rigidbody character controller (from the Unity Standard Assets [35]) can also be useful to walk around in the scene without any HMD and test scene rendering. Unity also supports objects modifications at runtime, allowing tests without HMD.

5.2 Test on location

A main test has taken place in the exhibition room in NMB. The idea was to tests potential areas for the installation (areas needs to be large, at least 1,5x2.0m) as well as making few user tests with NMB's curator and two employees. Only three objects were implemented at the time, but the game was easy enough to understand once basic controls were explained. All three users successfully completed the game under two minutes. A particularity to note is that all three users, who were not accommodated to VR experiences, experienced fear to walk towards the painting. This fact strengthened the projection approach described in section 3.3.3.

5.3 Gamification & Serious Games Symposium 2018 (GSGS) booth

The project was part of a submission to the GSGS [36] which took place on July 5 & 6 2018 in the city of Neuchâtel, Switzerland. A demonstration of the prototype was available for the visitors to try and provided insights about possible improvements for the future :

- The large majority of test subjects tried to aim for the missing painting parts instead of using the projection system
- Some users suggested *ingame* text, displaying the spoken text as an overlay
- The audio anecdotes volume was too low for a half of the test subjects
- Audio anecdotes were not audible enough due to the success sound, played on top of the beginning of the audio clips

5.4 Performances

On the development computer and with a very basic scene, performances were solid (90+ frames per seconds (FPS)) at the beginning of the project. As large textures, objects and lightning were added, the FPS count dropped to 60 FPS. However, it must be noted that the development computer had far lower VR

capacities than the computer which will run the experiment (144% lower according to UserBenchmark [37]). Testing the software on the GSGS computer (equipped with the same GPU used in the museum) showed smooth and regular performances (90+ FPS).

The last section will discuss the outcome of this project and the importance of serious games in the learning process.

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6 Conclusion

This project is still on development as it will be installed on the first September 2018. Feedback discussed in section 5.3 will be used to improve the project before the release date.

Main changes planned include :

- Use the controller as a pointing device as most people find this scheme of control more instinctive
- Display hovering text as an UI element during the audio anecdotes playback
- Sound balance, delay the audio anecdotes after the success sound

Calibration is an important part of the installation and will require one to two days on location. The room model has to be accurate and the physical objects in the room (tables, pylons) need to be at the exact same location in the 3d replica. If this objective is neglected, users may try to lean on the tables and fall or hurt themselves with the pylons. First calibration sessions will take place in the middle of the month of August.

This project was a great human experience. It offered rich collaborations with a wide panel of people and skills, including :

- The Nouveau Musée de Bienne
- Benoît Clarys
- The HE-Arc, SO
- The Biel archaeological service

It also helped creating synergies and develop new skills for each participants. On the possibilities of VR in performances and museum, one can assume that the possibilities are near endless and only limited by designers imagination, as well as human and financial resources. The skill required to interact and use efficiently VR devices and installations will only grow with time and quickly stop to be an handicap for designers and end users.

Through the process of VR and SG, we seek to offer a new intellectual and sensorial experience. We seek to find ways to improve education and cultural heritage.

However, a few questions are left open : are those new mediums of communication capable of transmitting knowledge ? Does the experience develop a deeper understanding of the environment it took place in ? Is there any place left for imagination and interpretation ?

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