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UNIVERSIDADE D
COIMBRA

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VIRTUAL REALITY MACHINES
THE HAAS-GALINHA PRESS

**Dissertation in the context of the master's degree in Design and
Multimedia advised by Professor Jorge Carlos dos Santos Cardoso
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Obrigado Inês,
por estares sempre presente.

Obrigado a toda a minha família,
que me apoia e motiva todos os dias.

Obrigado FAN-Farra Académica de Coimbra,
que me fizeste sentir em casa nesta cidade maravilhosa.

*“Sempre que aqui voltares e estivermos juntos
a tocar, beber, a conversar, será sempre,
ainda que por repetidas vezes,
a véspera do adeus.”*

FAN-Farra Académica de Coimbra

RESUMO

O prelo Haas-Galinha é uma prensa manual cujo fabrico remonta a meados de 1784. A sua autoria é hoje associada a Wilhelm Haas-Decker da Suíça, apesar de durante muitos anos se pensar que o Português Manoel Bernardes Galinha o teria construído.

Com o intuito de divulgar a história do prelo, que foi restaurado em 2021, a presente dissertação visa criar uma aplicação que permita explorar esta máquina, em ecrã e em contexto imersivo. Através deste projeto, o utilizador será capaz de interagir com um objeto virtual criado à semelhança do prelo Haas-Galinha, podendo aprender sobre a máquina e a sua história sem condicionar o estado de preservação da mesma.

A produção de vários artefactos, através de fotogrametria e modelação, serviu de base para os processos seguintes. Inicialmente modelado em 3D, o modelo foi então animado e adaptado a uma simulação imersiva onde o utilizador pode interagir com a máquina. Após a sua avaliação, sob a forma de testes de usabilidade, foi percebido que a presença de uma miniatura animada na simulação ajuda o utilizador a entender o seu funcionamento, agilizando a sua compreensão e interação com o sistema. Esta miniatura animada foi introduzida sem operador, havendo a possibilidade de incluir no seu lugar uma animação onde um manequim de madeira opera a máquina de uma forma simplificada. Todos os protótipos podem ser vistos como uma evolução gradual, sendo a fotogrametria o modelo mais simples de conceber e a interação em realidade virtual o mais complexo.

Esta dissertação está enquadrada na exposição do prelo Haas-Galinha que foi exposto no átrio da Biblioteca Geral da Universidade de Coimbra no ano de 2022.

Palavras-chave

Haas-Galinha; Prelo Manual; Modelação 3D; Realidade Virtual; Motor de jogos.

ABSTRACT

The Haas-Galina prelum is a hand press whose manufacture dates back to ca 1784. Its authorship is now associated to Wilhelm Haas-Decker from Switzerland, despite being thought that the Portuguese Manoel Bernardes Galinha had constructed it.

With the intent of spreading the history of the prelum, which was restored in 2021, the present dissertation aims to create an application that allows exploring this machine, on screen and in an immersive context. Through this project, the user will be capable to interact with a virtual object created similar to the Haas-Galina prelum, being able to learn about the machine and its history, without conditioning its state of preservation.

The production of various artifacts, with photogrammetry and 3D modeling, served as the base of the following processes. Initially modeled in 3D, this model was then animated and adapted to an immersive simulation where the user is able to interact with the machine. After its evaluation, through usability testing, it was understood that the presence of an animated miniature of the press helped the users to understand how it works, streamlining their comprehension and interaction with the system. This animated miniature was introduced without an operator, with the possibility of including on its place a prototype where a wooden dummy operates the machine in a simple way. Every prototype can be assessed as a gradual evolution, with photogrammetry being the easiest model to produce and the virtual reality interaction the most complex one.

This dissertation is a part of the exhibition of the Haas-Galina press which was placed in the hall of the General Library of the University of Coimbra during the year 2022.

Keywords

Haas-Galina; Hand Press; 3D Modeling; Virtual Reality; Game engine.

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I. INTRODUCTION

Forgotten on display in the entrance of the academic prison of the Joanine Library, there was an incomplete wrought iron hand press in very poor condition. The “Galinha press”, as it was known at the time, was in need of restoration and, due to its patrimonial value the neglected printing press was then reconditioned and set for display on the hall of the General Library of the University of Coimbra, which also was renewed and inaugurated in April 2022.

Its maker was thought to be Manoel Bernardes Galinha, a Portuguese locksmith from Coimbra (Carvalho, 1888) but, it is now believed that he only repaired it and rebranded it. Due to the resemblance and features, the author of the Coimbra press might be Wilhelm Haas-Decker, who improved his father’s metallic printing press in 1784 (Maia do Amaral & Oldham, 2021). The machine has been restored and is now in fairly good condition, the now renewed printing press, is the newest attraction of the library, being displayed on the hall of the General Library. With the exposition of the item, comes the need to portrait its use and information, leading to a need to showcase the mechanics of the printing press while maintaining its physical integrity.

I.1. Motivation

To expand its availability, boosting the number of visitors to the General Library and showcasing its recently renewed printing press – *Figure 1.1* – a virtual simulation poses a safe and low-cost solution, opposed to either make the machine available to visitors or replicate it for interactivity purposes. With the creation of an application, available online to every visitor, it is expected that people can experience and understand the printing press’ mechanism just like it was centuries ago, through their screens and/or virtual reality headsets. On this experience it will be possible to examine the animated machine from every angle, access historical information, and recreate the steps needed to print a page with the printing press.



Figure 1.1. The Haas/Galinha Press, also known as Coimbra Press

This project is highly focused on the creation of an application where a tridimensional model of the printing press will be available for interaction and exploration, providing information about the history of the machine, its historic value, hints for use, and animations showcasing the different movements of the parts of the machine. Using these technologies, it is intended that the users can experience how the machine was used and learn more about the printing press processes and history.

The purpose of this dissertation is to provide an application, accessible by web browser, to the General Library of the University of Coimbra, which can be used to provide a better understanding of the printing press processes of operation and history, as well as dynamize the visit to the library. Due to its patrimonial value, our main goal is to draw attention to this wrought iron hand press – the Haas/Galinha press – an object which history appear to go back to the 18th century, being one of the oldest “living” printing presses of its kind, if not the oldest, being associated to Wilhelm Haas-Decker.

It is intended that, with this project, this machine can become accessible to everyone. By showcasing the Haas/Galinha press both physically, on the hall of the General Library, and virtually, online or on application, with a tridimensional model available for examination, it is expected to arouse the public’s curiosity. Hopefully raising the number of visitors of

the General Library and sharing information about the artifact's history and usability. Although the purpose of this dissertation is set and well defined, there is concern on how the final prototype will be available and used. The content of the experience and the way the user interacts with it will be the main challenge to conquer, setting the ultimate goal on creating a simple and easy to use artifact. This all can be translated to the following chart, *Figure 1.2*, where the motives mentioned previously are displayed.

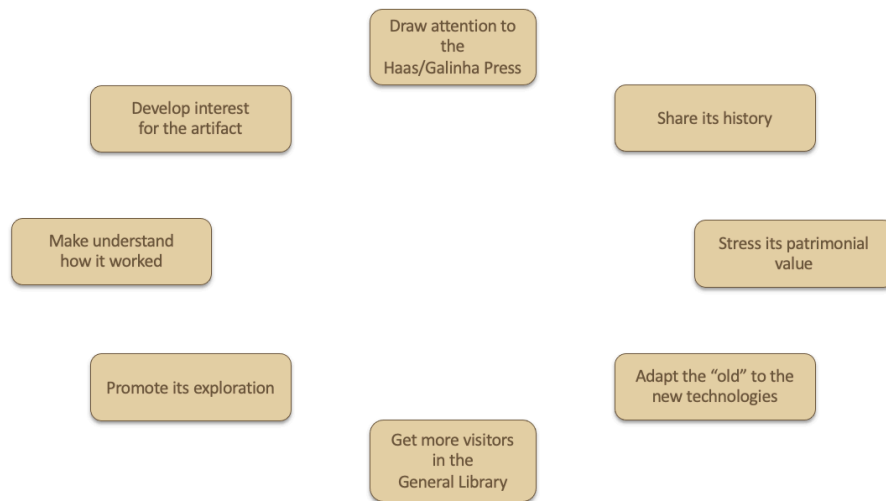


Figure 1.2. Motivation chart

1.2. Objectives

This dissertation aims for the creation of an animated tridimensional model of the printing press, accessible through an interactive visualization on desktop devices. On this application, the user will be able to trigger the whole animation, or individual segments of it, and access readable content which purpose shall be to contextualize the machine. This project is also to be adapted for an immersive environment where the Haas-Galinha press will be displayed to be virtually explored and tested.

Through screen and/or immersive environment, the user will be able to operate the machine as it was operated in the past. Accompanying the simulation, there will be information on display, enabling the viewer to learn about the artifact, its history, and use. Hints of use also will be on the application, as well as an animation featuring every step of the process of printing using the press.

The two main objectives are oriented to different audiences, as virtual reality is only available to some people and/or on a designated location, opposed to the digital visualization which will be widely accessible. Although the simulations are the main goals, the development of the animated model is the starting point for both, *Figure 1.3*.

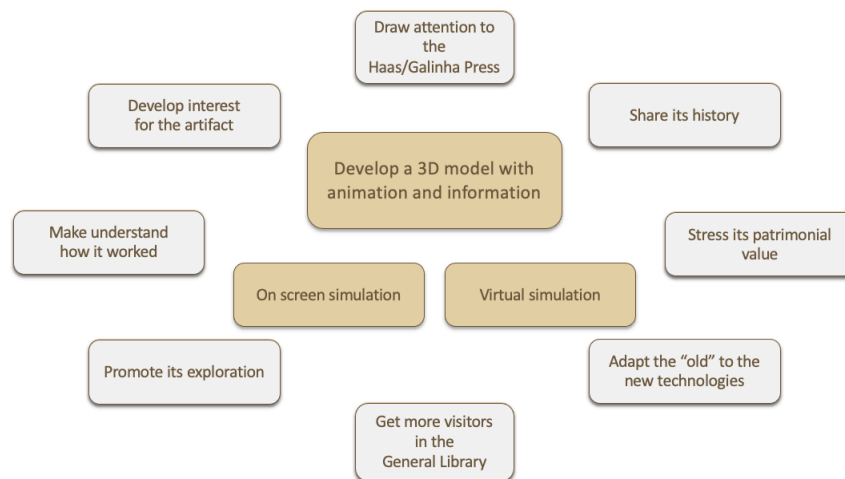


Figure 1.3. Objective chart

I.2. Document Structure

The present document is divided in six chapters which are to be read sequentially to improve the comprehension on the subject and on the project.

The first chapter is Introduction, the current chapter.

Historic Background is the second chapter. This section features a short introduction to the history of the General Library of the University of Coimbra, dividing in subcategories the history of printing presses, and with substantial detail and insight on the history of the Haas-Galinha press.

The third chapter is the State of the Art, which is a study and reflection on related projects and expositions.

On Methodology, the fourth chapter, the approach on the project is presented, defining the target audience and the plan of work.

On the fifth chapter, which is Prototype, the experiments made are documented as well as the different prototypes are displayed and explained.

The evaluation of the project is described on chapter six Validation.

And the final chapter, the seventh, is the Conclusion of the project, where the assessments are made: challenges, focus points, and final considerations.

I.2. Project Links

- Youtube simulation test video: <https://youtu.be/ZCevlPwbQ9M>
- Sketchfab animated model: <https://skfb.ly/oxBZI>
- Sketchfab animated model with operator: <https://skfb.ly/oKQEZ>
- Project folder:
<https://mega.nz/folder/yjgDUbbS#2x0CjvmnJLCec13oz9ER8w>

2. HISTORIC BACKGROUND

The General Library of the University of Coimbra is the students' main central library in the city. Established during the 16th century, the General Library preceded the definite transfer of the University from Lisbon to Coimbra, in 1537, being known that there already were the Library of Study – *Livraria do Estudo* – which was regulated by diverse status, set in 1591, 1597, and 1643 (Nogueira, 2009). During the reign of D. João V of Portugal, the construction of a building for the library was ordered by the king with the intent of both serving the University and its students and exalt the Portuguese monarch. The Joanine Library – *Biblioteca Joanina*, *Figure 2.2.* – was finished in 1728 but it was only until 1750 that it started receiving the first books. In the 20th century the old Faculty of Letters was adapted to serve as a new library – The New Building, *Figure 2.1.* – which started working in 1932 as the General Library.



Figure 2.1. The "New Building" of the General Library

On both these libraries, the number of books and items which are unavailable for the visitors are considerable and, to counteract this unavoidable phenomenon, the University has implemented throughout the few past years some exhibitions and installations, with technology as key resource, with the goal set to improve the experience and attract more visitors as it is the case of the permanent exhibit “*Segredos da Luz e Matéria*” (Monteiro, 2019). There was created a Virtual Reality experience to visit the Joanine Library, currently available on its website. With these innovations, the next step would be to expand the new technologies to other locations and items, providing a virtual interaction to the visitors that is physically unavailable due to its patrimonial and historic value.



Figure 2.2. Inside the Joanine Library

2.1. A brief history of printing presses

The making of an imprint – transferring a mark by pressure – is as old as mankind. (Moran, 1978)

Going back at least to 175 AD, reproducing by impression or stamping one surface with another – printing – has been in Man’s life for a long time. This practice is attributed to the Chinese, who also invented/discovered paper some decades before. Many tried to produce an efficient method to reproduce text, but the unrestrained number of characters was a considerable limitation. “*The method of production of the fifteenth-century European book was basically not much different from that which had been carried out in the Orient for some hundreds of years. Typographic printing, of the other hand, with its special characteristics, can be truly said to be a European invention.*” (Moran, 1978). During the 15th century, Johannes Gutenberg (ca. 1400-1468) develops the first mass printing method, using the same typesetting methods developed by Bi Sheng (畢昇 ca. 972–1051). Despite its limitations in the Chinese language, typesetting with a 24 words alphabet was considerably an easy task for mass-reproduction of books, the first being the Holy Bible by Gutenberg.

Being used for over a century, woodcut printing was mainly used for printing on cloth. In the beginning of the 15th century paper starts to be used for this purpose. The relief printing technique, which consisted in pressing a carved and inked wood block to a surface posed as an opportunity to make books more time-efficient, accessible and cheaper, in some cases these imprints would be made in reused pages. The

palimpsests were essentially old and expendable handwritten books that were too expensive to maintain, these books' text was scraped and/or washed away to be reused. With the use of UV light, some texts were recovered from these pages, some containing substantial historic value, these being an important source for ancient texts.

In ca. 1436 the first movable metal type wooden press is finished and in 1455, Gutenberg prints between 160 and 185 copies of the 42-line bible, a bible with 42 rows of text per column, widely known today as the Gutenberg Bible, shown in *Figure 2.3*. Only fifty copies of the bible resisted time, with the majority of them being incomplete (Kramer, 2017). Throughout the 15th century, printing evolved at a constant pace and, in ca. 1499, the *Aldine Press*, founded in Venice in 1494 by Aldus Manutius and Francesco Griffio, produces the first portable book, the *octavo*, a book format that could be read without lecterns or stands, this format being of common use until today. The Italic type is also attributed to the *Aldine Press*, as this company was the first to present the type format in their books.



Figure 2.3. Gutenberg Bible at the Library of the Congress

2.2. The Haas-Galinha Press

Prelo é, Galinha o fez? (Maia do Amaral, 2021)

Stored in the archives of the General Library of the University of Coimbra there is a manual press, which was on the entrance of the academic prison of the Joane Library until 2009, *Figure 2.4.*, that may be traceable to a swiss printer maker named Wilhelm Haas-Decker (Maia do Amaral, 2009). Originally, though, its authorship has been attributed to Manoel Bernardes Galinha since its supposed manufacture in ca. 1845 (Carvalho, 1888). It is known that Manuel Caetano da Silva, a printer from Miranda

do Corvo who supposedly ordered the printing press from Manoel Bernardes Galinha, took advantage of the presence of the known locksmith in his town to request the build of the small lithograph press.” (Carvalho, 1868, p. 417). Being well known for his work, in 1843 Manoel Bernardes Galinha, who had made several repairs to his town’s bell tower’s clock, met Manuel Caetano da Silva, who commissioned the printing press (Pimenta, 1955). According to Joaquim Martins de Carvalho (1822-1898), who wrote about the prelum at hand on a brief note for the journal “*O Conimbricense*”, it was known to have been constructed by the skillful Manoel Bernardes Galinha with its purpose being the printing of this journal.



Figure 2.4. Entrance to the Academic Prison of the Joanine Library



Figure 2.5. Press's plate made by Galinha

“Joaquim Martins de Carvalho was the first historian of the press in Coimbra, having written 115 articles on the subject in O Conimbricense, as well as entirely devoting the second part of his Apontamentos (1868) to it subject. The persistence of his interest on printing is attested by the large number of annotations, additions and corrections he made in his copy of the “Apontamentos” (today kept in the Reserved Books section of the BGUC), which M. Lopes de Almeida published in full (Carvalho, 1966).” (Maia do Amaral & Oldham, 2021).

On his publication, which is a relevant source on the history of the prelum, which he names “”, Carvalho dates its usage on the paper until 1850, the year it was introduced in the printing of the “*Observador*”. In 1866 the prelum was bought by Francisco dos Santos e Silva, who then sold it to the General Library of the University of Coimbra to be used to print book catalogs. The Haas/Galinha press also served the Botanic Garden, printing the garden plants labels, being this its last known use (Carvalho, 1888).

In 2009, Maia do Amaral wrote about the press with the purpose of drawing attention to the object, which needed maintenance and restauration. At that time, the sole information about the object was the one provided by Joaquim Martins de Carvalho. Based solely on the information available, the press seemed to represent a great interest in the academic panorama and was needing some attention. This prelum appeared to be similar to an iron press invented by Wilhelm Haas in 1772 – the first to use iron for the frame – with the Coimbra press having many key features of the earlier Haas press, the form of the frame and the dimensions of the platen and bed, as well as the materials of the latter (Maia do Amaral & Oldham, 2021).

The Haas-Galinha press is a wooden base prelum, with a wrought iron frame and compound lever system with fixed stop to prevent over-stressing the materials. Its bed harks back to the wooden-press era, being moved on rails with a stone for the hard surface onto which the type was placed, as they were for 400 years (Maia do Amaral & Oldham, 2021). The lever impression mechanism is easily associated to the Stanhope press, with the Coimbra press having the same features as the earliest known cast iron press, although its wrought iron provided much more durability and robustness, opposed to the Stanhopes. The T-shape wooden base which the Coimbra press has, is also a feature on both the early Stanhopes and the Haas presses. Although the similarities are considerable, they were repeatedly redesigned to sustain more stress and when the first Stanhopes were introduced in France, these presses no longer resembled either the Coimbra press or the Haas ones. This evolution may hint a different origin for the Coimbra press, as when it was supposedly made in 1845, the “canon” was considerably different, leading to a number of hypothesis, arguably the most plausible being that the Portuguese Manoel Bernardes Galinha did not construct the press, but was hired to repair it, placing his cast brass identification plate to state he had done his work on the 60-year-old machine, *Figure 2.5*. Other hints of his

repairs are the few hex nuts on the press, which were only invented during the 19th century, and his initials – MG – that are struct in one hand crank, which was probably remade by Galinha in 1845, *Figure 2.6*.



Figure 2.6. Manoel Galinha's monogram retrieved from a hand crank (Photo BGUC)

The following schematics, *Figure 2.7.*, were taken from a reproduction of Haas's 1790 pamphlet, this document help understanding how the frames of the presses work, while serving as a precious guide to help develop models of the different parts.

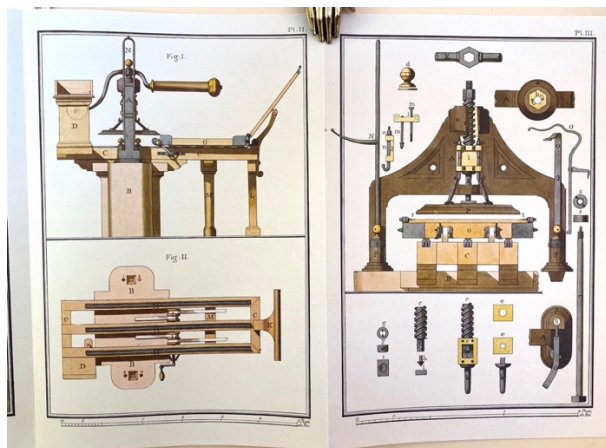


Figure 2.7. Schematics of the Haas press from the 1955 reproduction of the 1790 pamphlet.

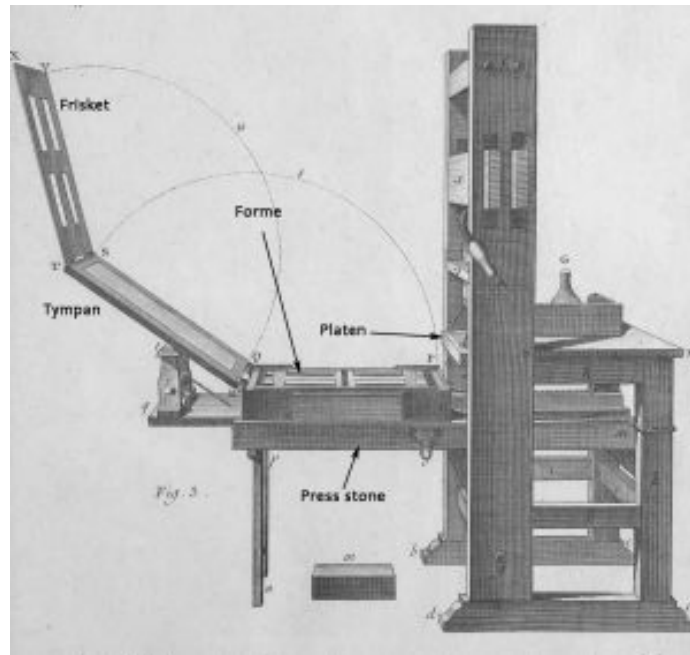


Figure 2.8. Public domain image made available by Smithsonian Libraries

Figure 2.8. features a diagram with the different jargon names of the wooden press's parts: frisket, tympan, forme, press stone and platen. Although they are not present on the diagram, we can also consider the movable bed, composed by the forme, the tympan, and the frisket; the rounce, the handle by which the bed of the press is runned under and out of the platen; and finally the handle bar which presses down the platen and the bed on to the press stone, consequentially making the imprint on the paper.

In April 2022, the General Library of the University of Coimbra had its hall renewed and inaugurated with the Haas-Galinha Press on display. For Amílcar Falcão, Dean of the University of Coimbra, this artifact assured a completely different dignity to the entrance of the library, being a place of great importance both on cultural and scientific point of view. On this hall, a booth was also installed to give continuity to an academic tradition “*Questões Disputadas*”, a fun public debate of rhetorical questions.

3. STATE OF THE ART

Through the study of the history of printing presses, and the one at hand in more detail, it is possible to identify mannerisms and hints of use which will be of great importance while creating the tridimensional model. The related projects will also serve as example to follow and learn from, not only on the subject of the present dissertation, but also on how 3D modeling and virtual/augmented reality was implemented to transmit information to its user.

3.1. Related projects

The Uncommon Press



Figure 3.1. Screenshot of the model published by arboo in 2018 (<https://sketchfab.com/arboo>)

This model which was published by the user *Arboo* on the *sketchfab* platform, *Figure 3.1.*, showcases a printing press which could be the one at hand. The movements, the interactions, and the accessories – the ink balls and the paper – pose as a goal for this project, missing only the complexity of the textures. The animation is composed by seven steps, scenes, the first being the coloring of the type, forme, with the ink balls, these ink balls return to their designed stands in the second step and, at the same time, a sheet of paper is fixed on the tympan. On the third scene, the frisket closes on the tympan, and then on the carriage, which then is activated by the rounce in the step four. The imprint is made in the fifth step with the bar being turned and the platen being pressed on to the back

of the tympan. The following step is a reversed 4th step, the rounce rolls back and the carriage accompanies the movement, leading to the final step, the seventh, which also is a reversed animation, this time being a reversed scene three – first the tympan opens from the carriage, and then the frisket opens from the tympan, revealing a printed document. Every key element of the hand press model is marked with a numbered button that, when clicked, shows information about the part to the user, due to its educational and historic value, this feature is one to mimic and implement, as it may be of interest having information available directly in the model.



Figure 3.2. The completed press, named the Uncommon Press, at the Cary Graphic Arts Collection at RIT (Gottlieb, 2017)

The Uncommon Press, *Figure 3.2*, is wooden hand press created for the Cary Graphic Arts Collection in 2016, by Seth Gottlieb, Randall Paulhamus, Daniel Krull, Veronica Hebbard, Ferris Nicolais, and Professor John Kaemmerlen. The fully working printing press was created respecting the basis of Phillip Gaskell’s 1970 “*A Census of Wooden Presses*” and was based on the Smithsonian Libraries’ “Fig.3”, *Figure 2.8*. The model, which resulted from the cooperation between the Cary Collection with the RIT’s College of Engineering and the Museum Studies Program, is currently available for examination and manipulation on the reading room outside of the Cary Collection.

Index - Máquina de Nairne

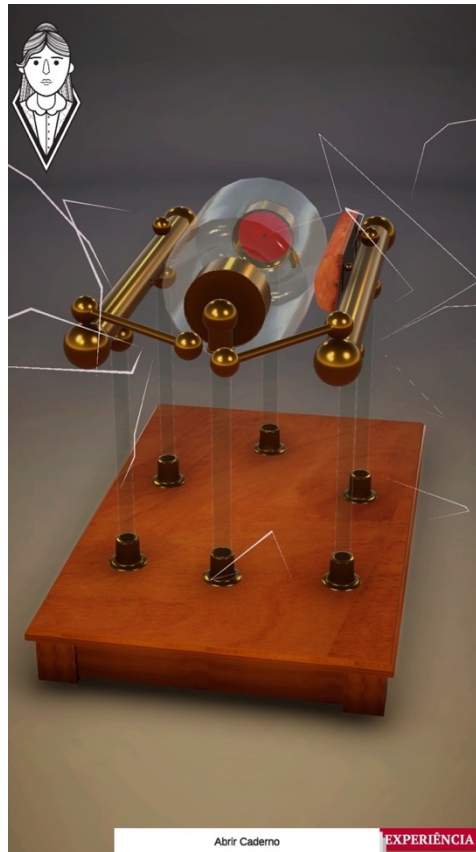


Figure 3.3. Model of the Nairne Electrical Machine made by André Monteiro

Monteiro's project is closely related to the present dissertation, the context of use may differ but, the motivation sums up being the same: to increase the number of visitors, while providing a new experience. This master's degree thesis explores the interaction through an application which reads markers via phone camera and opens the respective models. The project is focused on the Nairne Machine, which model is displayed in *Figure 3.3*. The modeling and animation pose a great feature on this work, as the application revolves around the inspection and interaction with the model.

Although this dissertation main attraction is the tridimensional model of the machine, it is important to refer the whole design of the project and the attention to detail while making it. The interface on this project is its strongest feature, in my opinion, as all the experience has something new to show, whether it is the introduction to the application, the scan of the markers, *Figure 3.4.*, or the interaction with the machine.

This project portrays a great experience to the visitors of the Physics Museum, being a great example on how the whole interface can directly influence the experience. Instead of having just the model for examination, Monteiro presented a game of discovery with a guide hinting the way to play it. The idea of the card with the marker to explore the machine in

augmented reality will possibly one interface to explore on the Haas/Galinha press project, this option is not discarded.

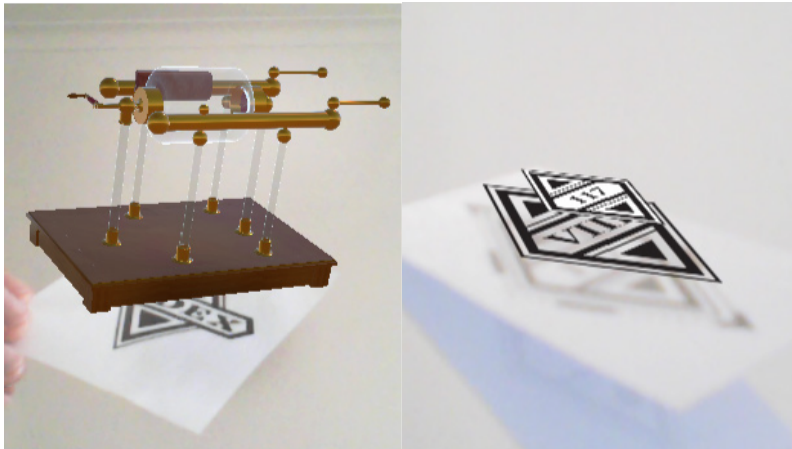


Figure 3.4. Augmented Reality using markers

Mona Lisa: Beyond the Glass

This is an application which showcases the famous Leonardo Davinci’s painting “La Gioconda”. Available for Android and IOS devices, on this experience the user is taken on a virtual tour of the museum. Although the Louvre Museum has a much more complete museum virtual tour, on the “Mona Lisa: Beyond the Glass” it is possible to hear the narrator talking about the painting and, explore the painting on a tridimensional plan. For this effect, it was done a 3D model of the whole Mona Lisa, the woman and the landscape. While the narrator is speaking it is possible to analyze all scenarios and in the end of the narrative, the user is invited to board a flying machine from the Davinci’s journals and fly over the landscape of the mentioned painting. This machine is also fully animated and is the model which the user can inspect with more detail as they are placed inside the machine for the flight, as seen in *Figure 3.6*.



Figure 3.6. Flying machine designed from Davinci’s drawings

This experience lacks free mobility, as screen users are restricted to stay on one location. This ends up not being relevant as there are no interactive elements on the experience. On the website of the museum is possible to see a video with the programmers talking about the project and how they overcame some of their challenges, the way the background was replicated and expanded, and of course, how the most famous smile was modeled.

The animation is key, as all information is presented by a voice-off. Being a possible way to provide information to the user of this dissertation's project.

The contextualization of the main 3D artifact, here being the Mona Lisa, on a virtual scenario is the main source of the idea of producing a tridimensional model of the General Library's hall or a room environment, so the printing press can be placed on a virtual place, opposed to being floating on the void.

Reflecting on the projects

Due to the nature of this dissertation, it is clear that the first project was the best example on what the final prototype should be, although the machine is different, its purpose and operation was and is the same. Although the model is very well designed and developed, the lack of a surrounding environment is an issue that can be pinned to the platform where it is displayed, but it is indeed something that some might find strange. On the Monteiro's project, the texturing of the model is very good, but also lacks an environment. The concept behind this project is very different than the current dissertation, but the idea of a game with sequential operations is something that makes sense to adapt to it, while adding the main feature of the last artifact mentioned, the explorable environment.

4. METHODOLOGY

In order to produce a good quality artifact, experimentation is key. Through various experiments, one is able to understand which are the strong features of a project and which are not. For this project's implementation developing prototypes will alternate with periods of testing and documentation. This methodology aims for a better comprehension on if the user understands of the application, what they expect from it, and of course, what is to maintain, improve, and/or remove. If a test of a prototype reveals negative points, this prototype will not be tested again (Taipina, 2021).

The steps will involve creating a model from scratch, with all parts disconnected and independent from each so they can be then animated.

4.1. Task Identification

4.1.1. Research and writing

The first stage of this dissertation is reserved for researching and writing. Due to its importance, it is believed that the main focus of this step should be studying the subject and documenting findings. The definition of the objectives is also of great importance as it helps defining which technologies must be engaged. To help contextualize these objectives some related projects were reviewed and from these examples, our goals were set.

4.1.2. Photogrammetry

Starting with the gather of photographic material of the printing press and with the technology of photogrammetry, a first tridimensional model will be made, providing a first 3D view of the printing press serving both as a reference for how the model should look like, and perhaps source of some of the textures featured in the final render of the model. The product of this stage will be used as reference for the manual 3D modeling of the press, as it an easy way to access the machine without having to go to its location.

4.1.3. 3D Modeling

Having a first 3D static model of the press, the next step to take is modeling every part of the press separately. By having these parts independent from each, with the respective sizes and measurements, it is intended to create a model, similar to the real object, ready to be showcased and explored.

4.1.4. Animation

With the manual 3D model made, animating the moving parts of the press will be the fourth task. During this step, the animation of the parts will be of importance not only for the animation but also for the future manipulation of the press, as the movements will be defined throughout

this stage. By the end of this part of the project, it is expected to have an animated 3D model of the prelum. These animations will then be exported to video and shared, with the approval and consent of the General Library.

4.1.5. Virtual Manipulation

With the animated model of the Coimbra press rendered, its manipulation, the next step to be taken, will be proceeded in various stages. On a desktop, the user will be able to explore the model from every angle and control its animation with dedicated buttons which will be available on their screens. Closing this process, it is expected to provide to the user a fully interactable simulation of the machine. Using the movements created for the animation, the handles of the machine will be available for manipulation, generating the movements of the bed and the frame when activated.

4.1.6. Testing the Desktop Simulation

With the creation of an interactive artifact, comes the need for feedback. This process will preferentially take place online, and the user will be invited to answer a quick survey about their thoughts and opinions on the simulation.

4.1.7. Writing the Dissertation

The last stage of this dissertation is writing. Although this process is regarded as a continuous one, it will surely be the last to be finished.

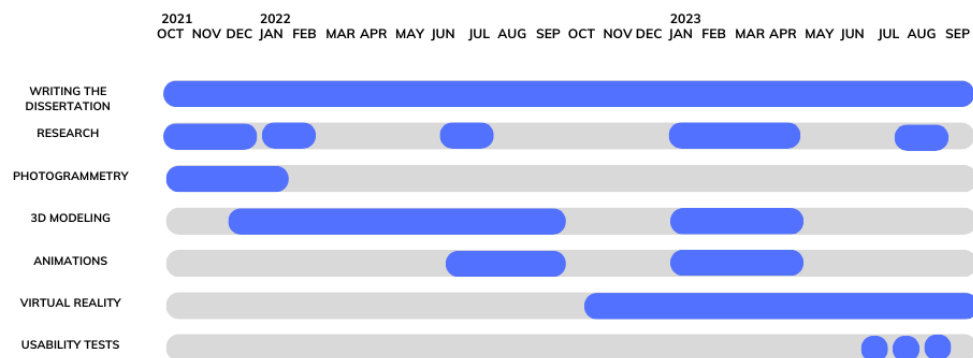


Figure 4.1. Gantt chart with the different tasks and timelines

5. PROTOTYPE

Entering the prototyping stage, photogrammetry was considered to be a great tool to produce the first tridimensional model, which could become the base example for the 3D modeled one. With the program *Metashape by Agisoft*, the first experiments were disastrous, although some results ended up being quite satisfactory. Due to the complex mechanism of rendering models from photos, photogrammetry can be in a way a whole process made from a few smaller but sequential processes that transform the photos in points, the points in meshes, and then the meshes in models. The photogrammetry models produced were used merely to help constructing the 3D model, serving as a tridimensional guide just like photos are commonly used to model real objects.

During the 3D modeling, *Blender* was the selected platform as it is somehow easy to use due to a previous contact with the program. This process was as slow and tedious as one can imagine, being a super detailed artifact with so many small pieces and parts. In contrast, animating the model was the contrary. Since animation is not only mechanical movements set and defined by the armatures and constraints, the realistic feel is a matter of the utmost importance. In order to attain this goal, the trial and error is the way to go, and it surely ended up giving some interesting results.

Wrapping up this dissertation, the adaptation of the whole project to Virtual Reality ended up being the one true challenge. Not only the textures behaved differently in the different platforms, but also the initial idea of interacting with the model had to be left behind. With the *Unity* game engine, it was possible to produce a clear and realistic virtual simulation of the Haas-Galinha press operation movements, which can be inspected from all angles. In addition to this project, the animated model was uploaded to the *Sketchfab* platform where it can be accessed with every device and seen on screen, in virtual reality, and augmented reality.

5.1. Stage One – Photogrammetry



Figure 5.1. Textured model generated with photogrammetry on Agisoft Metashape

During this stage of work, there were made several experiments in order to deeper understand the technology which is photogrammetry. Due to inexperience, the first test was a failure as there was not enough photographic material, the one that existed was not captured in the right settings, and the details of the press were not photographed in close up. This resulted on a render without any detail and filled with noise and interferences from items in the background and lighting issues.

After a second round of photographing, with the settings described on the following paragraph, where every angle of the press was covered, the result was somehow similar, as the *Metashape* settings were the same used on the first try. After some more research on the program, and a lot of experiments, the results were as good as it could get, with the materials at hand. As it is addressed next, there were variables like light that compromised the render of the model, creating some grain and noise around the less exposed areas. Although some of these imperfections were taken off manually, there was detail that could not be recovered. The model described throughout this section is still to be finished.

For this model, there were taken 173 sequential photographs of the model taken in low ISO and high aperture and exposure with low shutter speed for extended exposure time. The Point Cloud alignment, *Figure 5.2.*, of the photos was done sequentially with Key Point limit set at 50.000 and

Tie Point limit at 20.000. For the Dense Cloud, *Figure 5.3.*, the quality was set to medium and the Depth filter to mild due to the level of detail on foreground. For the build of the Mesh, *Figure 5.4.*, both the quality and the face count were set to medium. Finally, the Texture was generated as a diffuse map with generic mapping with mosaic blending. The texture count was ratioed on 16.000 to 1, and both hole filling and ghost filter were set as active.

These settings were the ones which worked best, with the only trouble being the natural light that entered through a window on one side of the press. This sided illumination led to a blur on the model which could not be resolved. This issue led to the removal of the wooden tympan and frisket of the mesh, as it was too much blurred.

Although this technology, photogrammetry, was experimented on the object throughout the first stage, the technology will be applied on the background of the application, presenting a good and reliable help on contextualizing the printing press on a real environment: The General Library's hall. Assessing the experiences made with the press, the windows of the hall will certainly pose a challenge on this stage.

This experiment led to the main conclusion that harsh edges and slim details are difficult for the program to identify. A more capable computer which can handle more polygon faces should be able to process these, but it is likely the model will still be “damaged” somewhere due to the lighting issues presented in all the experiments made.

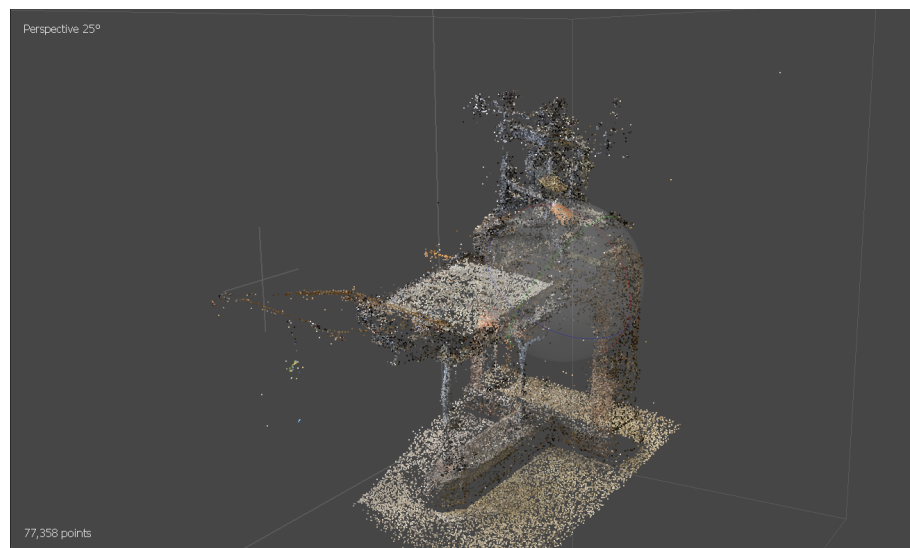


Figure 5.2. Point Cloud, a set of data points in space

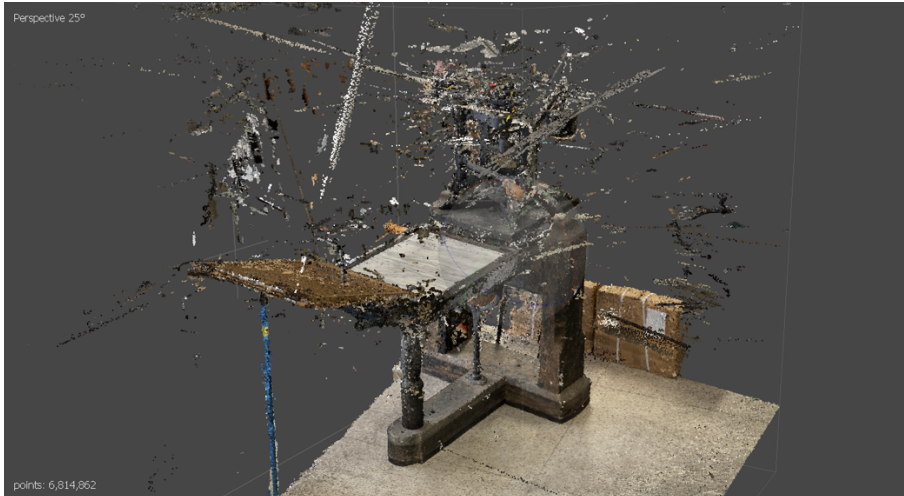


Figure 5.3. Dense Cloud, a more complex form of a point cloud



Figure 5.4. Mesh model shaded with texture

The main purpose of this stage was to produce a first artifact with a tool which was first seen as an easy source of content. The models acquired through this process ended up not having the intended and much needed quality due to the factors mentioned above. Although these are to be used as reference on the processing of modeling the hand press, the experience and knowledge gained while using the *Agisoft Metashape* might be of use when creating an environment to place the printing press model.

5.2. Stage Two – 3D Modelling

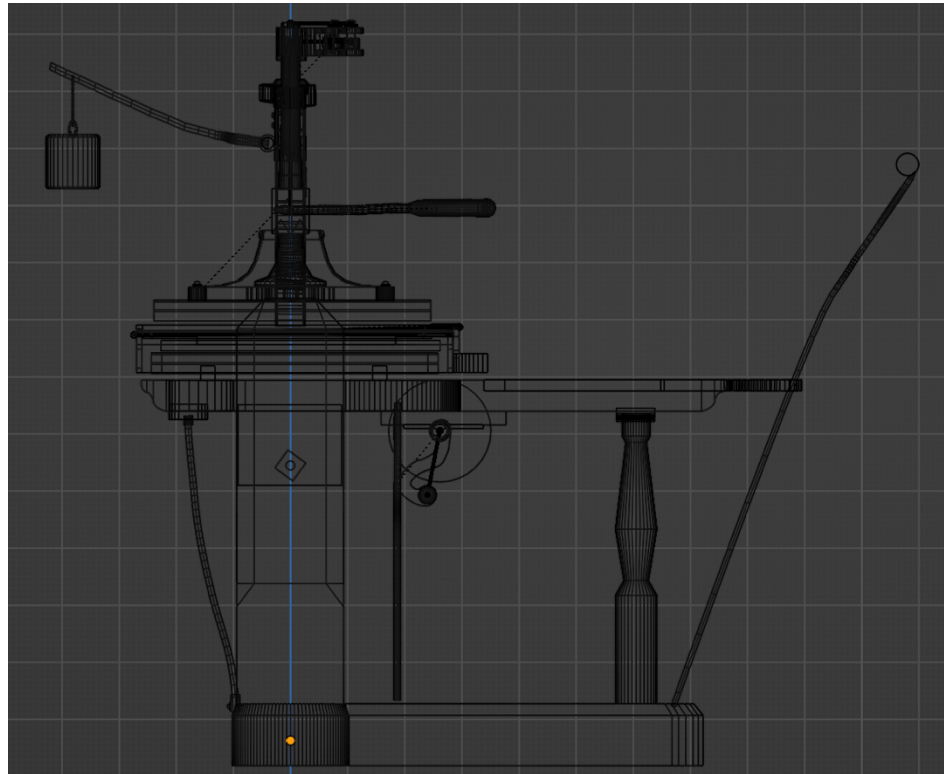


Figure 5.4. Wireframe of the 3D model

The modelling process went through two different tasks, the first being the creation of simple geometric figures with the size of the different parts of the press, and the second focused on deforming and adjusting them to respect the machine's measures and features. Although these tasks are separately mentioned, these processes were done almost simultaneously so that no part or feature was left forgotten, due to the complexity of the machine, *Figure 5.4*. Although most of the main features were reproduced, many details were left behind in order to make the project easier and faster to render and display.

The program Blender was the selected as it is free to use, has a good easy to understand modelling process, having a whole lot of documentation to help reaching the main goals of the current dissertation, and is also very reliable for texturing and animating the model.

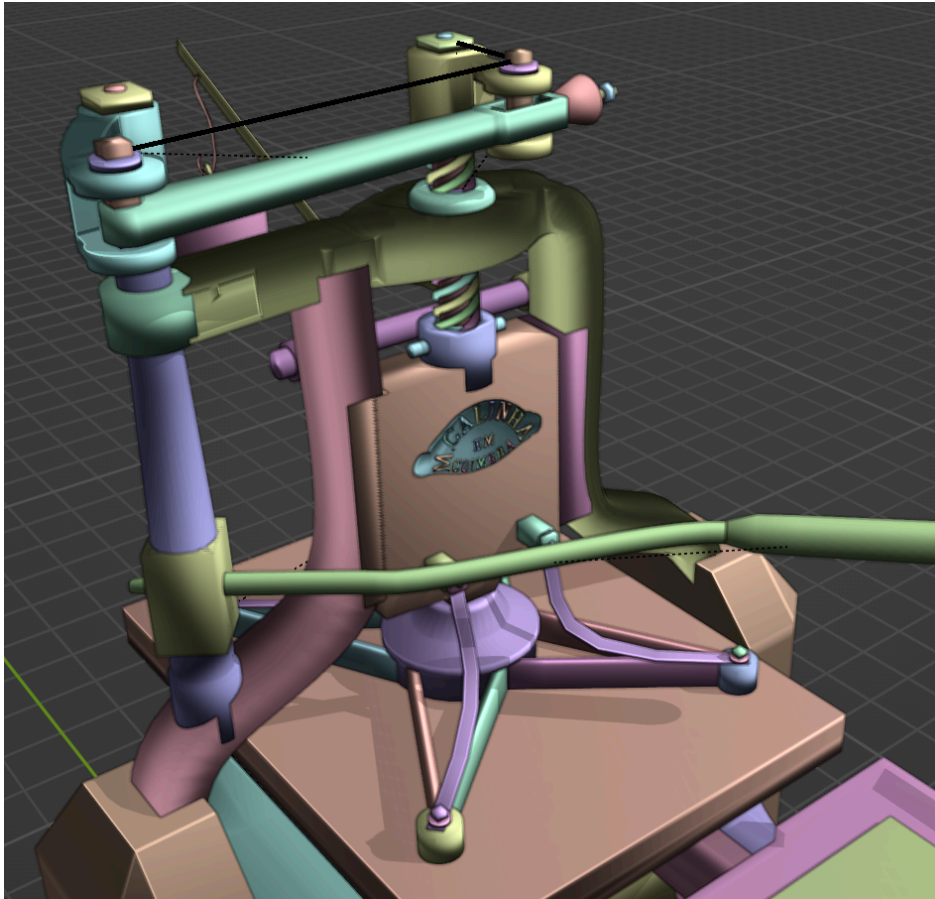


Figure 5.5. Top part of the model with randomized colors

During the first task, the modelling was as forward and simple as it can get: simple geometric shapes done by extruding mainly faces, resizing whole parts, and also rotating others. Although Blender offers the local view feature, which is very useful when trying to model or adjust some components, randomizing colors helped keeping track of the different parts of the model, *Figure 5.5*. Some parts like the base of the press were created from cubes and extruded into the desired shape, *Figure 5.6*, while the top parts depended on *Boolean* operations, as they were made from different shapes that were merged into one.

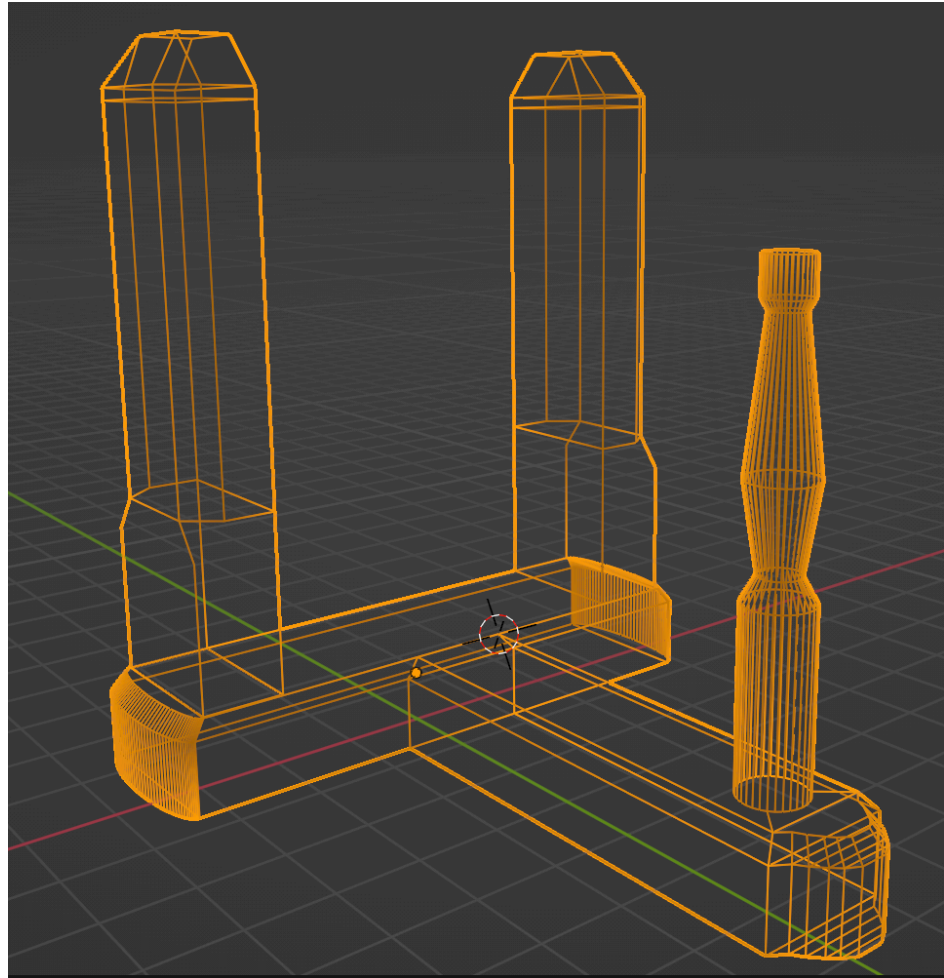


Figure 5.6. Wireframe of the base of the press

The product of this task served as the base of the whole modelling process, as almost every piece was made from these simple shapes. Due to the nature of some other part like the signature plate on the front, *Figure 5.6*, some shapes had to be design point by point by extruding every vertex, creating the desired shape on a plane, and then filling it and extruding it into the part, *Figure 5.7*. Although this process was more focused on forming and deforming a shape, it will be accounted as 'stage one' in this dissertation, as they were tweaked during the final adjustments.



Figure 5.7. Signature plate while modeling the letters



Figure 5.8. Signature plate in 3D

Wrapping it up, the most challenging parts were modelled with the help of *Bezier curves*. For these special parts a path with the form of the part was created as if it was its skeleton, and then was wrapped with the *Bevel* feature, creating a continuous path following the curve and consequently creating the shape, *Figure 5.9*. Although this process is faster to produce a curved shape like the frame, this was one of the most challenging tasks during the modelling stage.

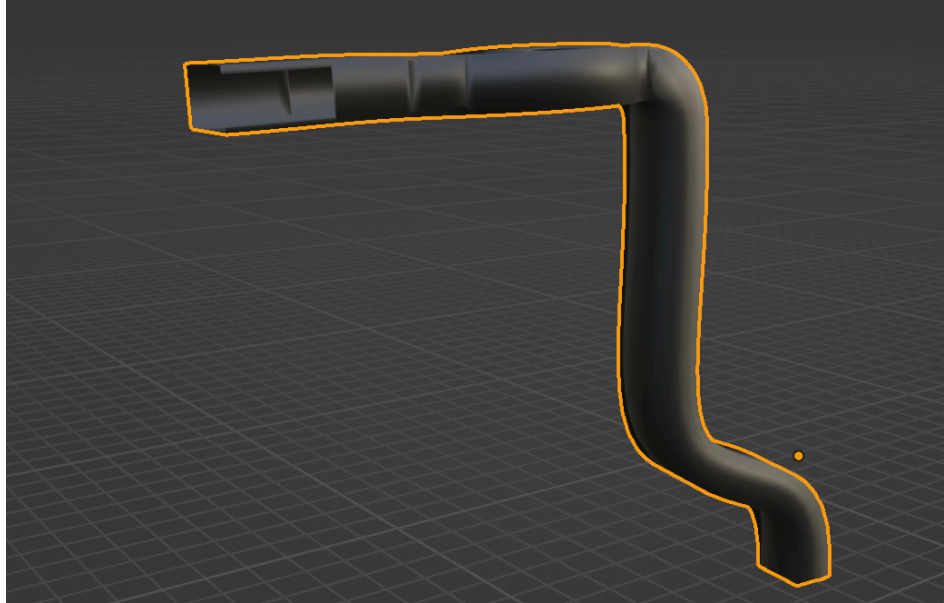


Figure 5.9. Curved shape of the top part

Closing this stage, it was noticed that not every object was properly reviewed, with some having a number of *ngons*, polygons with more than five vertices, edges or sides. This became a rather tricky process, since the solution was to manually create the desired shapes connecting different vertices and edges to avoid the more complex shapes. With this process some issues related to the rendering of the textures were fixed, although some flickering remained.

The final artifact resembles the Haas-Galinha press only to an extent, as the press renewal was finished and some of its new features were not included on this dissertation, *Figure 5.10*. These missing features do not affect the function of the machine nor are key components.



Figure 5.10. Textured 3D Model

5.3. Stage Three – Animation

The main base for the animation of the machine was the use of Armatures, it is very easy to understand the concept of these, as they are the skeleton of the model. By having a full 3D model of the Haas-Galinha Press setting up its bones was an easy task, even though there were some movements which depended on more than one points. On *Figure 5.11* there are two fixed axes, this feature became the biggest challenge of this stage. First the lever has to turn on the main axis, then the top part moves back the bar, this bar maintains its alignment, pulling back the other side, activating the second fixed axis. Due to the armature's movements being sequential and consequential, the main challenge was to hold both fixed axis on their places, as well as the machine's parts. The timeline, *Figure 5.12*, was set on a scene which runs on loop, having 4 actions that are then reversed: closing the top frame, closing the bottom frame, turning the bottom handle, and pulling the top handle. The top handle is only activated once, in the middle of the animation, the following animation are the inversion of the previous mentioned.

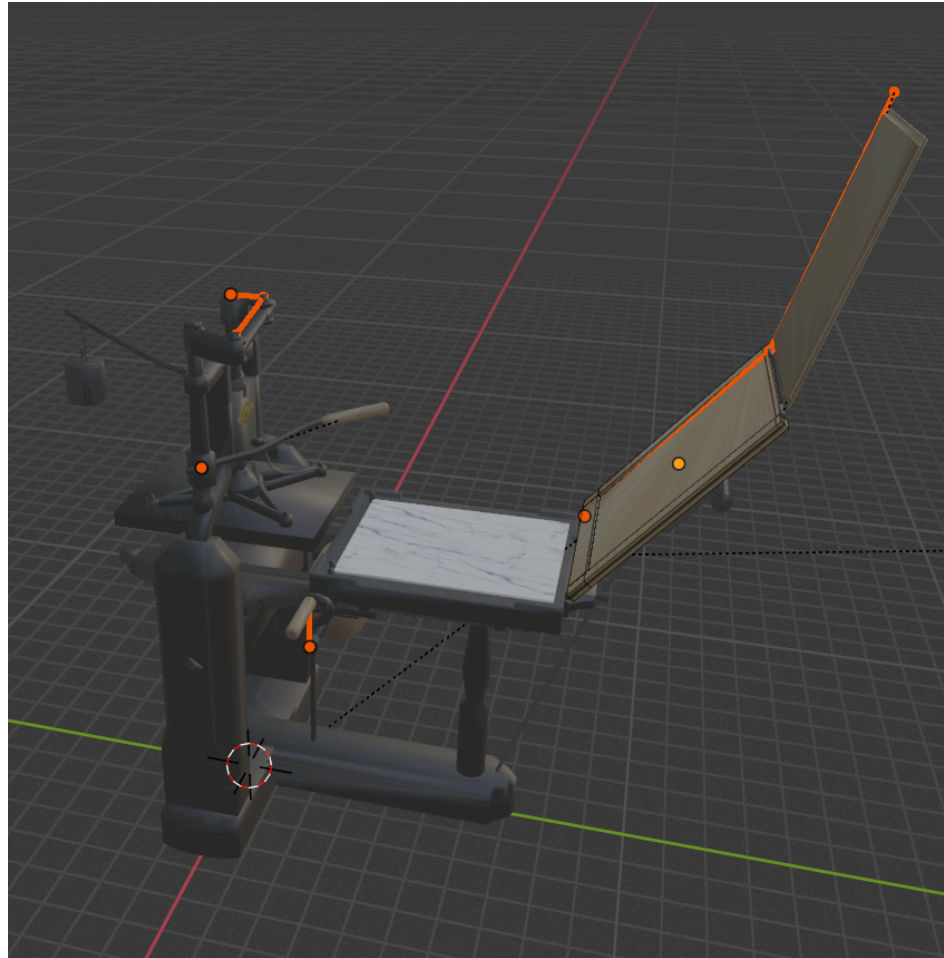


Figure 5.11. Highlighted armatures with axis that define the movement

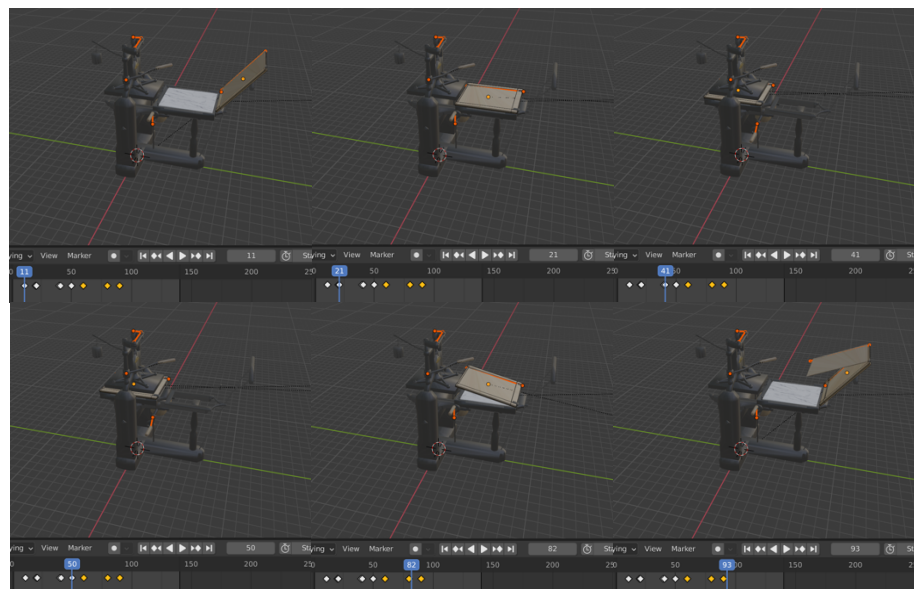


Figure 5.12. 3D Model's timeline

Thanks to the animated model, it was possible to adjust it to introduce a dummy operator, for this effect it was used the “Roblox RTHRO Dummy” modeled by the *Sketchfab* user *InterrMyl*. Since the model was already fully rigged the main tasks on this task was to reproduce the movement a human would do while operating the machine. Since the dummy had no textures, the wood textures of the hand press were applied to the dummy, *Figure 5.13*.



Figure 5.13. The Haas-Galinha Press with a dummy operator

5.4. Stage Four – VR & AR

The adaptation of the model to a virtual environment went through a number of processes of trial and error. The first test involved the *Sketchfab* platform due to its ability to display the animated model on the platform, on screen and on Augmented Reality. This platform also showcases a Virtual Reality display, relying on smartphone headsets to produce the tridimensional effect. This platform helped understanding how the model can be seen through a VR headset, since dimensions are very important while producing an artifact of this kind. As it can be seen in *Figure 5.14*, the size of the 3D model does not relate to its real dimensions, leaving the impression that the Haas-Galinha Press is less than half its size. This issue was also verified while using Unity to showcase the model, but it was easily reviewed and resolved. It is also important to mention that *Sketchfab* altered severely the textures uploaded to the model, losing a considered amount of detail and accuracy, especially on brightness and contrast.



Figure 5.14. 3D Model on the Sketchfab's Augmented Reality

On the other hand, Unity's sharpness showed to also be an issue. Comparing the texture mapping applied by the three platforms mentioned it can be assessed that not only the level of detail shifts, but also the color saturation, with the same textures applied none of the models rendered ended up being similar in terms of color.

The 3D Model was imported to the Unity Engine and configured to operate in Virtual Reality, *Figure 5.15*. This was possible with the use of the *XR Interaction Toolkit*, a preset of operations based on the movements of the user's headset and handset, with the *XR Device Simulator* and the *HMD Mock*, a simulator which displays a Virtual Reality operational point of view preview of the artifact on the screen, *Figure 5.16*. The *HMD Mock* was the *Unity's* main feature during the most of this stage. This script provided an easy and affordable alternative to the use of a VR Headset during the first builds. Although the simulator limits the usage and interaction it displays the fully rendered and operational project.



Figure 5.15. The Haas-Galinha Press on Unity Engine

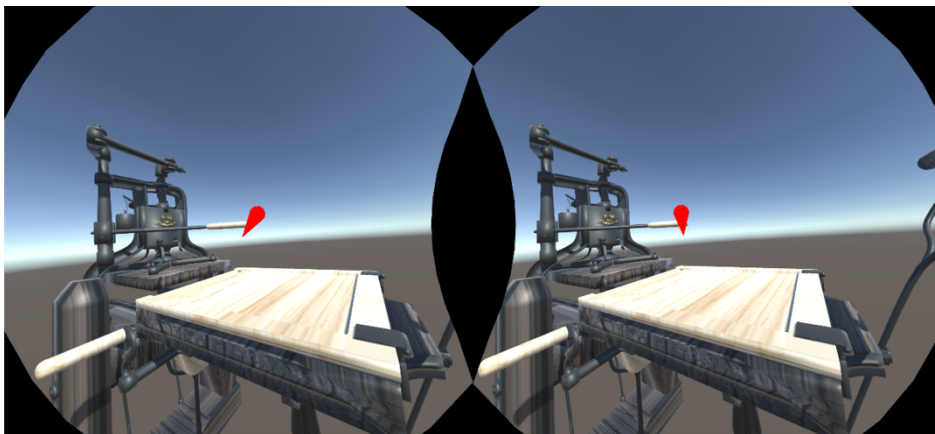


Figure 5.16. Virtual Reality with HMD Mock on Unity Engine

The whole build of the project was developed over the *Unity VR Core* template as it already provides both player view with rotation and locomotion, and usable controls with displayable affordances for every button, *Figure 5.17*, this information help mainly with locomotion as it supports teleporting and virtual movement, although it is included in the project, the main and most intuitive way to move is to move in real life. With the *HTC Vive* supporting both horizontal and vertical movement, the inspection of the model is realistic to some extent. The user can bend and peak from every angle, giving a pleasant experience even if the controls are not used, with a static model.

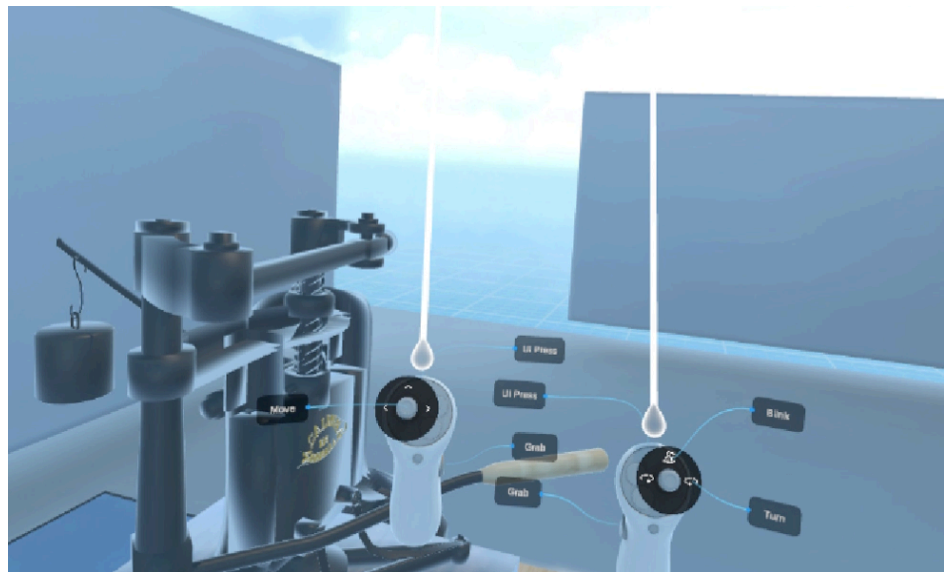


Figure 5.17. Unity VR Core Controls with affordances

The model was exported in *Blender* with the FBX extension, *Autodesk Filmbox Technology*, and imported as a *Prefab*, a type of game object, to Unity to be unpacked to be used not as a whole object but as a set of smaller objects, with this method it is possible to add different components to the objects. For this project there were four key components:

- *Rigidbody* – this component serves as a base of the object, allowing the object to react to real-time physics such as gravity, mass, drag, and momentum.
- *Collider* – both the *Box Collider* and the Mesh Collider provided a very useful collision detection, preventing some overlapping objects from going through each other.
- *Joint* – the Haas-Galinha Press uses mainly the *Hinge Joint*, *Figure 5.18*, component on most interactable pieces with the exception being the plate of the press, where a *Configurable Joint* was used in order to move it though a single axis on a drawer-like motion. The handles and the frames use the first due to their fixed door-like angular movement.

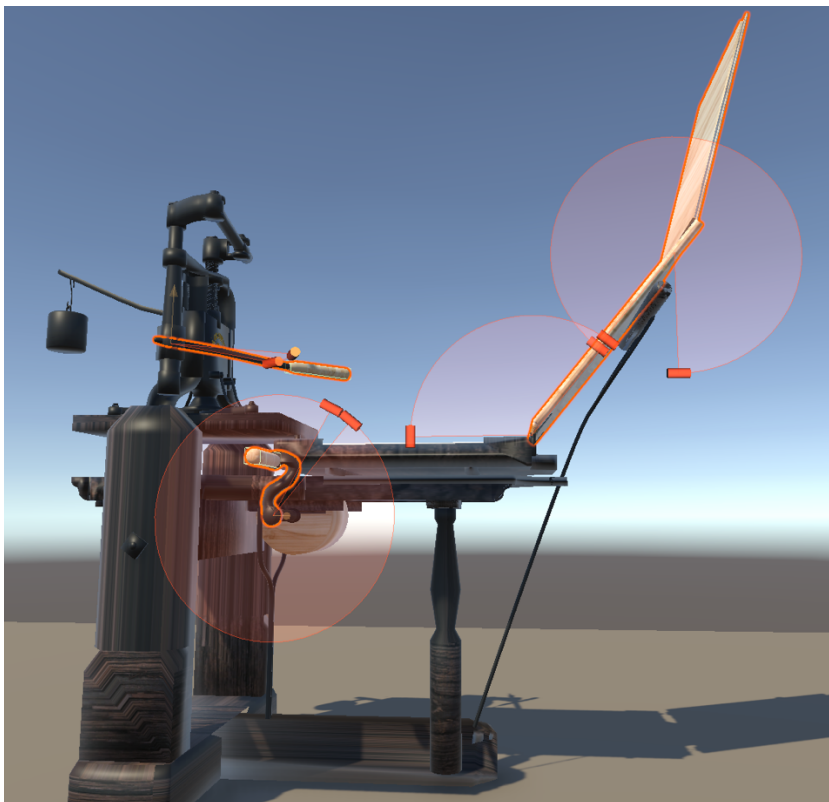


Figure 5.18. Hinge Joint system axis and limits

Although the configurable joint of the plate was able to lock the object to a single axis, an *Empty* was added to the build as parent of the plate, frisket and tympan. With this game object the three pieces of the machine became connected not only to each, but to a parent object which was then animated, *Figure 5.19*.



Figure 5.19. 3D model with activated handle and plate base

- *XR Grab Interactable* – last but not least, this component was by far the most important as it is the one that makes the objects available for interaction. The *XR Grab Interactable* is a component from the *XR Interaction Toolkit*, a component-based interaction system framework for VR and AR. This component can work on the object or through another, the wooden handles were used as colliders for the metal bars which they are connected to, *Figure 5.20*.



Figure 5.20. Haas-Galinha Press 3D model in VR,
grabbing the wooden handle

The final touch was figuring how to move the plate, the first thought was to link the joint values of the plate to the side handle to move them accordingly, however the game engine allows only to read this value and without the writing property, the initial idea crashed. The alternative was to use a hidden collider, *Figure 5.20*, to detect and trigger the animation

with the activation of the handle, in short whenever the handle would enter the assigned space, the animation would run and revert to its initial position when the handle returned to its original state. For this simple operation, the previously mentioned *Empty* was the key object as it already controlled all the parts needed. There were assigned animations with the four different states of the plate: opened, closing, closed, and opening. These different animations were set to be sequential but were limited by a bool condition parameter, a true or false variable, which determined if the animation could move to the next one. With the script programmed to detect if the hidden collider was triggered by the handle, this variable was able to be altered according to the state of the handle.

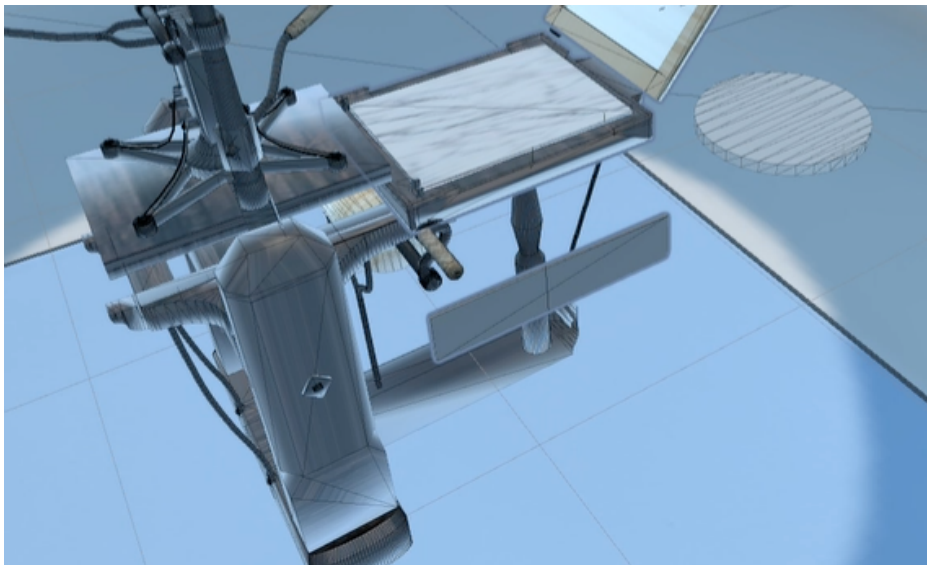


Figure 5.21. Highlighted trigger collider

Although there were more components involved on this project, these provided the basic interaction with the model using the control scripts from the VR core template. With the preconfigured XR Origin, a group of scripted objects with the user's interactable elements, camera and hands, both the locomotion and the interaction with the environment was a solved task, although there was needed a considerable amount of effort to understand which of the scripts were useful and which were not.

The key component of the XR Origin is the camera, as it serves as the main pointer, tracking the position and rotation of the user's field of view inside the simulation, this provides an easy locomotion system whereas the user can simply move in real life to move inside the virtual reality world. Although the intended locomotion system is the previously mentioned, the movement and rotation controlled on click, with the hand controllers was also included to able the user to explore the environment on a static place, being also accessible to people with motor impairment, teleportation was also included as it is the fastest way to go from one point to another instantly, serving the same purpose as the other locomotion methods.

For the environment, simplicity was the goal in order to keep the build as light as possible while providing a comfortable room to operate the machine. This configuration was chosen because it contrasts with the old technology of the machine, being an impossible construction. The goal was to make this experience as if it was a time capsule where the old machine can be operated, *Figure 5.22*.

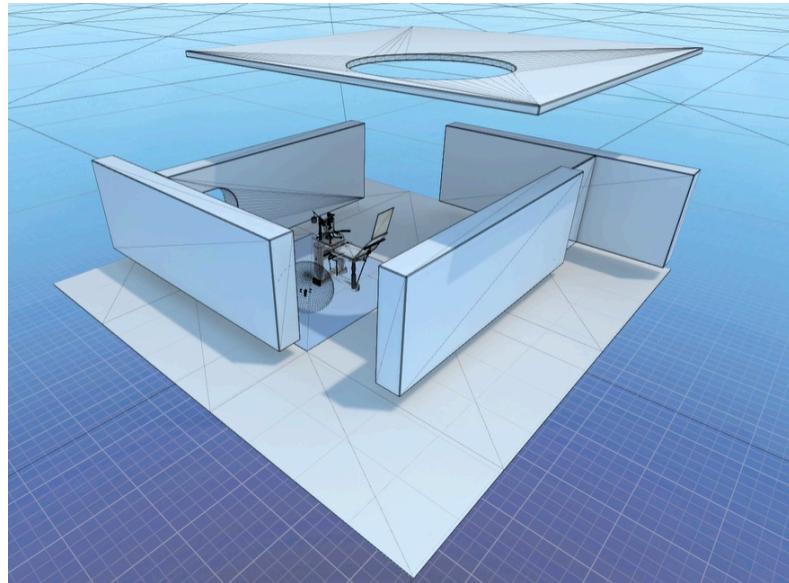


Figure 5.22. Overview of the environment of the simulation

In order to provide a guide to the users inside of the simulation it was introduced an animated miniature of the model. This animation, *Figure 5.23*, is available inside of the build and runs the animation on loop right when the program loads, and can be placed wherever the user wants, by having no physics the model can even be left floating next to the main hand press.

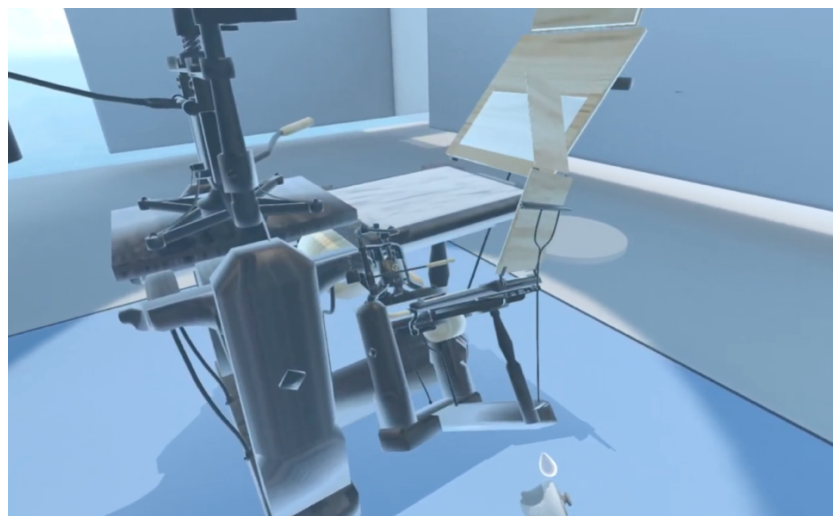


Figure 5.23. Animated miniature inside of the simulation

6. EVALUATION

Throughout Stage Four, the simulation was designed and developed according to the model studied, with the project at its close the Haas-Galinha press was fully renewed, and although the simulation still portrays the machine, there are some aspects that may currently differ, these changes were pointed out by Dr. Maia do Amaral, who classified this dissertation as interesting and curious.

During this last stage, some colleagues were invited to experiment and try the virtual reality simulation and although the initial tests revealed a fair amount of issues, they were reviewed and corrected for the final prototype. One issue that could not be resolved was motion sickness from the virtual reality headset, as almost every tester mentioned having some.

The following chart, *Figure 6.1*, is an evaluation of the different actions of the model. The different actions are:

- Locomotion: the way the user can move inside the simulation (by teleportation/blink, joystick, or physical movement);
- Action 1: closing the top frame;
- Action 2: closing the bottom frame;
- Action 3: turning the bottom handle;
- Action 4: pulling the top handle;
- Backsteps: redoing the previous steps in order to return the machine to its initial state.

	Locomotion	Action 1	Action 2	Action 3	Action 4	Backsteps
Tester 1	5	2	4	3	3	4
Tester 2	5	3	4	5	1	5
Tester 3	5	2	5	3	3	5

Figure 6.1. First test round (1 is very bad, 3 is neutral, and 5 is very good)

The first issue during these tests was that users had no information on how the machine worked and where they should start, *Figure 6.1*. The top frame was generally the first interactable grabbed on every test, but the tendency was to try to move the bottom frame while holding the first. Part of issue was fixed by introducing an animated miniature of the model inside the simulation, right next to the player spawn, this helped the users to understand the sequence of the operations but the alterations on the frames' colliders had the most effect on the experience, as the colliders were overlapping each other when the frames were closed and the users were not able to accurately select the frame they wanted. Although the first action was the hardest to figure in the beginning of the test, the second was the easiest as it is a continuation of the first.

Action 3 was perceived by all testers but the first kept activating it out of the sequence, this was also fixed with the miniature. The final action was mentioned as a filler, as the program does not have a reaction to the action, leading to some confusion on what the lever was activating. In general, the backsteps were fast and accurate since every user had the information needed to reset the machine to its initial state.

	Miniature	Action 1	Action 2	Action 3	Action 4	Backsteps
Tester 2	5	5	5	5	3	5
Tester 4	4	4	4	5	2	5
Tester 5	4	3	3	3	3	4

Figure 6.2. Second test round

The second test round, *Figure 6.2*, went smoothly than the first due to the introduction of the animated miniature on the build. One of the testers was present in the first test round and finished the simulation with ease. Both the other users had similar results but mentioned some confusion about the last action, the top lever, due to the lack of visual effect. The lack of collision of the main body of the press was revealed as a fragility by one of the testers who got one of the plates trapped inside of the machine.

For the final test round, it was discussed that an initial briefing would eliminate some of the issues found on these tests.

	Miniature	Action 1	Action 2	Action 3	Action 4	Backsteps
Tester 6	5	5	5	5	4	5
Tester 7	5	4	4	4	4	4

Figure 6.3. Third test round

In the beginning of this test round, *Figure 6.3*, both testers were shown a video, *Figure 6.4*, where the simulation is operated and were explained the different actions of the machine. This led to a faster and easier experience for the testers. The colliders of the press body were corrected so the plates could not enter not go through the object. The last tester was not able to finish the simulation due to motion sickness.



Figure 6.4. Video of the simulation (<https://youtu.be/ZCevIPwbQ9M>)

Regarding the animated model, *Figure 6.5*, the general assessment was that the animation was smooth, and the information was clean and easy to understand. The issues with this model presented on the platform *Sketchfab* was that the animation was all on one scene and the textures were rendered in a different way, appearing to be different from those used on *Blender* and *Unity*. On this platform it was also developed an animated model with a dummy operating it, which also revealed to be a good guide for the users of the simulation.



Figure 6.5. Animated model on Sketchfab (<https://skfb.ly/oxBZI>)

7. CONCLUSION AND REFLECTION

Assessing the progress of this dissertation, it is strongly believed that a better planification of tasks would have translated in a better time management. Time was indeed the ultimate challenge of this project due, having some difficulty handling the whole process. Tracing an assertive and realistic plan of work for the second part of the project was a priority, due to the number of prototypes produced.

Photogrammetry was a good technology, after producing a static prototype of the printing press, the results showed it can be of use on the background of the application, thus creating a realistic environment onto which the tridimensional model of the press would be placed. This idea was left behind in order to keep the build as light as it could be. During the whole process, the model was continuously updated and tweaked as I kept finding more and more errors and overlapping faces on it. Animating the model was the best part of the project as it was the point where the project started to gain its shape, with the animated model, the base for the interactive simulation was done.

If the animated model was the best part of the project, the interactive simulation was the most rewarding. This project was started without the knowledge if it could be finished, and to be fair it was always something to be concerned with as there were many occasions where the solution never seemed to be found. Looking back, this journey was rich in knowledge, not only about 3D modeling and Unity games, but also perseverance and resilience.

In hindsight, a simpler project as it was hard to keep focus and progress continuously due to the complexity of the platforms, and also my nonexistent knowledge on them. Although the current dissertation was not my main choice, I am very glad I took upon this challenge, otherwise I probably would have never learned how Blender and Unity work, even though I am still a beginner on these programs. The history of the Haas-Galinha press is also something very interesting, which had me thinking on how many artifacts with substantial patrimonial and historical value are currently laying around without people knowing what they truly are and mean to the world.

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