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RE-IMAGINING STEREOSCOPIC PHOTOGRAPHY IN THE AGE OF VIRTUAL REALITY

Dissertation in the context of the Master in Design and Multimedia advised by Professor Jorge Carlos dos Santos Cardoso and presented to Department of Informatics Engineering / Faculty of Sciences and Technology of the University of Coimbra.

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Um grande Obrigado

Ao meu coordenador, Jorge
Pelo apoio e disponibilidade até ao fim.

Ao meu pai
pela ajuda a tornar o Spectare algo real.

À minha mãe
pela preocupação desde o início.

À Teresa
por me fazer nunca desistir, mesmo nos momentos difíceis e pelas palavras carinhosas e sinceras.

Aos bons amigos
por toda a alegria que proporcionaram.

Ao pessoal do Jardim da Manga
pelo apoio prestado durante uma semana complicada.

Ao Projeto Santa Cruz
por acreditarem no projeto e pela cooperação.

ABSTRACT

Stereoscopic photography was one of the main forms of visual communication in the second half of the 19th century, leaving even today an important impact on our visual culture(Christie, 2018).

This technology, which still exists today through small groups of enthusiasts and collectors, has adapted over time and shares its space in the tridimensional universe with the latest virtual reality. Virtually at the same time as the appearance and propagation of stereoscopic photography, in Coimbra, the Santa Cruz Monastery is handed over to the State through the extinction of all religious orders in the country, being reused for other infrastructures. Nowadays, in order to spatially restore this Monastery, the Santa Cruz CES project team super realistically modelled the space as it was in 1834. Wanting to expose their work to the public taking into account the temporal window of these events, we were challenged to create a stereoscopic viewer that was up to the Virtual Reality technology of today, but that managed to contain in it the original experience of stereoscopic photography of the 19th century. In order to respond to this challenge we propose the prototyping of a stereoscopic viewer and software that rethinks and reinterprets the original experience of viewing a stereoscopic photograph.

In this dissertation, we describe the creation and development of Spectare, a late 19th century inspired stereoscope capable of Virtual Reality and its usage in cooperation with the work made by Santa Cruz CES Project.

Keywords:

Stereoscopic Photography, Virtual Reality, Interaction Design, Cultural Heritage

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1. INTRODUCTION

When the subject of a work is separated from us by a long curtain of time, we are faced with several problems, one of which being that there are no living testimonies that can testify what they experienced in times gone by. Everything we can speculate and imagine is materialized through relics that we inherited from our ancestors, generation after generation. Among them, we find a whole range of written testimonies about a wide range of topics in books, articles and diaries. Our interpretation of the past is revealed through the analysis of these artefacts and there is an interest in digging up something that we can no longer see with our own eyes and thus disseminate knowledge that the general population does not have. To rethink the original experience of viewing stereoscopic photography we had to dig up how it started and how it evolved.

Stereoscopic photography, as its name suggests, is an aspect of conventional photography, which came to life through the fusion between the concept of stereoscopy and photography, in the fortieth decade of the 19th century. These were special photographs that needed to be seen through a special device. This action would generate a three-dimensional image, where layers can display the various details recorded when capturing the photograph (Christie, 2018). We can assume that stereoscopic photography was created in virtually the same period as conventional photography, and, in a way, became one of the most influential forms of visual culture in the entire second half of the 19th century, with millions of stereoscopic cards being produced during this period, fueled by the industrial revolution that was felt all over Europe and by the favourable opinion of Queen Victoria during the demonstration of this technology at the Great Exhibition of the Works of Industry of all Nations, in 1851.

As stated before, to explore these photographs it is necessary to have a stereoscope and since its invention, several models have been produced, each dependent on its target audience and the time when they were launched on the market. From the first Wheatstone model (fig. 1), through Brewster (fig. 2) and Holmes (fig. 3), to the ViewMasters of the 40s to the 60s of the last century (fig. 4), the devices have adapted from their vigorous rise to their sharp decline at the beginning of the last century, changing their target audience, production materials and themes of photographic content, through that time (Christie, 2018; Pellerin et al., 2017).

Fig. 1
(left)
Wheatstone stereoscope
by Charles Wheatstone

Fig. 2
(right)
Brewster stereoscope
by Mr. Elliot

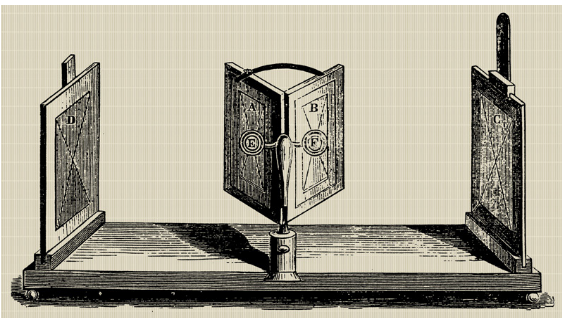

Fig. 3
(left)
Holmes Stereoscope
by Oliver Holmes

Fig. 4
(right)
View-Master
by Sawyer's

Although used mainly for a cultural and artistic perspective, being consumed by virtually all social classes, the use of stereoscopic viewers and stereoscopic photography itself had a place in other areas such as medicine (Beurde et al., 2012) or space exploration (Coates et al., 2017), thus demonstrating its versatility and the research and development opportunities it provides.

Although there has been a long period of time in which this technology has been overlooked by the majority of the population, thanks to advances in areas that encouraged more the development of conventional photography, there are still some groups of enthusiasts and academics which collect, disseminate and discuss the cultural heritage this technology left us. Whether in groups of social networks, in posts at our universities and museums or even in the form of private collectors, with some of whom we contacted during this dissertation, stereoscopic photography resists the pressure of time through exhibitions that make it known to the public today (CICANT, 2021; Sell et al., 2021). Even organizations that had already closed doors have resurrected to revive the memories that this technology left us to discover, as in the case of the London Stereoscopic Company (May, 2021).

It is through the experiences of all these people who keep this technology alive that is possible to use it in applications from other areas such as the "Looking Glass Portrait" project (Glass, 2018) which works with holograms generated through two-dimensional images in real-time, where a distant person can access our image in a three-dimensional way, or else, in the conversion of two-dimensional images into images with depth in real-time through a tool of the social network Facebook (Facebook, 2021).

Motivation

After the second half of the 20th century, through the development of electronics, Virtual Reality (VR) emerged. Even though it seemed revolutionary for those who witnessed it for the first time, they were just experiencing the use of the concept of stereoscopy in a new medium, focused on immersion and presence, achieved through the creation of super-realistic virtual environments (Machover &

Tice, 1997; Sherman & Craig, 2003; Lombard & Ditton, 1997).

Having gained increasing media attention in the last two decades, due to the ever more rapid evolution of technology, VR has become a technology increasingly accessible to the public, which also made possible the appearance of several models of viewers, which are available from its cheapest versions to the most expensive ones, depending on how capable they are. The most expensive ones are destined for projects that work with big budgets, created by electronic giants such as the HTC VIVE (fig. 5), which was used in a virtual recreation of the Titanic (LLC, 2021), or the Playstation VR (fig. 6), used to play connect to the playstation consoles .

Fig. 5
(left)
HTC Vive
by VIVE

Fig. 2
(right)
PS VR by Sony

This variety of existing VR headsets practically emulates and surpasses the range of stereoscopes that we found in the past (fig. 7, 8).

Fig. 7
(left)
Various examples of stereoscope models in an old french magazine

Fig. 8
(right)
Various examples of VR headsets


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When contacting with these VR headsets we experience the undeniable structural and conceptual proximity to that of old stereoscopes. The main difference is the exchange of a stereoscopic card with a photo for a smartphone screen, which allows the consumption of a bigger variety of media than a single photograph. As such, this dissertation results from this observation, thus wanting to explore the possibilities of reinventing and reimagining the original experience created by the use of stereoscopes in the past, trying to achieve the "awe effect" generated in people, as described by Gurevich (2013), using the current technology that makes it possible, a smartphone.

The output of what was described would be a stereoscopic device that would be able to support a smartphone to enable the viewing of VR content, with a body design influenced by older stereoscopes and that would be able to read stereoscopic cards, all in one.

Creating an artefact with the characteristics described before became our main goal, which will contribute to the development of the Santa Cruz CES project.

"The SANTA CRUZ project deals with the former monastery of Santa Cruz, one of the most important Portuguese religious houses, and its situation in 1834, the year in which the orders were extinguished and its heritage integrated into the state, sold or transferred to museums."

(*...*) *based at CES-UC and DARQ-FCTUC, aims to collect and systematize documentary and iconographic information on the architectural history of the monastery. At the same time, we intend to elaborate a 3D digital reconstruction of the monastery in 1834, including parts of the monastery's façade, the cloisters of the Gatehouse and the Manga, the dormitory, the library and the bell tower. We will also try to reconstitute the original layout of the magnificent sculpture of the "Last Supper", by Hodart, which presided over the refectory and is today on display at the Machado de Castro National Museum"* (Projeto Santa Cruz, 2021).

CES stands for Centre for Social Studies at the University of Coimbra, which is a *"scientific institution dedicated to research and advanced training in the social sciences and humanities, through an inter and transdisciplinary approach"* (Universidade de Coimbra, 2021).

Our contribution to this project, which has its objectives described above, results in the use of the device we intend to create to disseminate the work carried out by the Santa Cruz CES project team. In this way, there is a consistency between the period portrayed in the Santa Cruz project and the technology that we are recreating, which appeared in that same period. This diffusion will be possible through the use of the final product that we create in a real environment, where people can interact with it and discover more about the history of the Monastery of Santa Cruz and the work carried out by the Santa Cruz project.

Fig. 9
(left)
Igreja de Santa Cruz
by Jean Laurent
c. 1869

Fig. 10
(right)
Claustro da Manga e Torre dos sinos
by José Sartoris
c. 1880

Challenges

This dissertation, which is part of the themes of interaction design and, to a certain extent, product design, results mainly from the study of the evolution of stereoscopes, which followed the development of the first stereoscopic photograph until the virtual reality headsets of today. Also, it relies on how it is possible to create immersive environments in virtual reality through the tools we have at our disposal nowadays.

For this study to be efficient, it is necessary to collect information and testimonies from several people who are connected to this topic, from researchers to enthusiasts. Finding out what aspects most fascinate them in this area and how, from their experience, it is possible to create a viewer that perfectly fits the project's objective, is something that will shape our point of view on the subject and make us think in certain details we may miss if this contact wouldn't happen.

An inherent concern in the development of this dissertation must always be how and where this final prototype will be used, as external factors will change the final solution in terms of materials, format, interaction, which also transfigures the experience of the user. Another important concern is the decision of what type of content will be the best choice, considering that there is a wide variety of options, it can become difficult to balance the simplicity of the original experience and the possibilities of interaction of virtual reality. This balance must also focus on the connection of the material we have at our disposal with the experience we wanna build for the user.

Objectives

The main objectives of this dissertation are:

(i) To reimagine and create a stereoscopic viewer that contains in it the original experience of viewing a stereoscopic photography, adapting it also to enable the experience of content through the use of virtual reality;

(ii) As well as creating the physical prototype design, we will also create the digital interface design, which will enable the development of this whole immersive experience, being more focused on the use of more recent resources found in the virtual reality area.

(iii) Later, we will test the final product in the real world environmet in cooperation with Santa Cruz CES project, in a target audience aged 18 to 50.

Contributions

The contributions achieved with this dissertation were:

(i) The creation of a wooden stereoscopic device on which you can hold a smartphone and stereoscopic cards (fig. 139). The smartphone, by reading the cards through its camera, makes the stereoscopic content that is directly linked to each card appear on its screen. This content can be viewed through the device's lens to reveal its stereoscopic features (fig. 183 to 189);

(ii) A stereoscopic experiment with the theme "Claustro da Manga" was created in co-operation with the Santa Cruz Project and was executed in a real environment in the actual Mango Garden during a period of one week (fig. 194, 195);

(iii) One scientific publication was submitted and accepted at the ICAT-EGVE Conference;

(iv) A website has been created for Spectare — https://spectare.dei.uc.pt.

2. HISTORIC BACKGROUND

This chapter was written through the interpretation of texts and lectures by various authors of what was the history of stereoscopic photography and virtual reality. Its focus was on understanding how these technologies were born and how they evolved through time. Understanding the past would help us know better the present in order to make better choices while developing our own tool, which will work with these technologies.

Stereoscopic Photography

To understand the history of stereoscopic photography, it is necessary to understand the history of photography itself and the factors that contributed to the spread of both.

We have to put ourselves at the feet of the upper-middle class of the second half of the 19th century. Many people had to find ways to entertain themselves and learn at home, without having to go to museums or art galleries and libraries. Those options only applied to those who had all that culture close to them. For many, stereoscopic photography was a way to spent time, to gain some knowledge about the world beyond the borders of their city or country. We can imagine how we would live in an environment without light, internet or any other device that today we take for granted for the acquisition of knowledge or entertainment (Christie, 2018).

To understand how this technology appeared, we will have to go back to the end of the 18th century.

Robert Baker created the Panorama, an endless painting with strict rules to be executed and intended to give the viewer a sense of infinite spatiality, which spread through Europe. Louis Daguerre became interested in this invention and created the diorama. Both the panorama and the diorama have an enormous depth of focus, both architectural and natural. Eventually, he joined Niépce and created what today we call a daguerreotype (fig.11), considered the first photographic image, through a complex process. Fox Talbot, during the same period, started to work in photography (fig. 12), but through the negative-positive process, which was used until the revolution of digital photography, at the turn of the 21st century(Christie,2018).

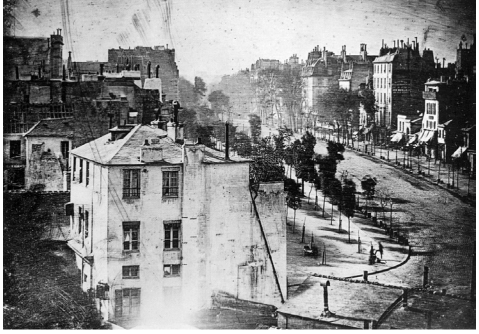


Fig. 11
(left)
Boulevard du Temple
by Daguerre
1838

Fig. 12
(right)
An oak tree in winter
by Talbot
1842

In 1838, through the study “Contribution of the physiology of vision”, a prototype with mirrors was created that studied how human vision works. The images used in this prototype were stereograms. Thus, the concept of stereoscopy was created, a way of creating depth in a two-dimensional image. A prototype of a stereoscopic viewer was quickly created, which made it possible to see a photo printed in duplicate on a card and thus see depth in an image where it did not initially exist (Christie, 2018).

In 1851, the Great Exhibition of the Works of Industry of All Nations takes place. An exhibition of England’s power to all the great nations of Europe. This was the starting point for the expansion of stereoscopic photography, mainly because of Queen Victoria’s and King’s enthusiasm for this technology. Stereoscopic photography was released around the world, although reserved for the elites given the cost of production. The stereoscopic viewer that dominated the market was the Brewster model (fig.2), created by Mr. Elliot, which was complicated to mass-produce but provided a quality experience to the viewer, guaranteeing its success. It was completely produced in wood, with a manual hole at the top to let in light, which showed ostentation and at the same time genius in execution (Christie, 2018) .

In the decades after, stereoscopic photography spread even more with the invention of the Holmes Stereoscope (fig.3), by Oliver Holmes, a more affordable option created to give a possibility to those less wealthy, to interact with this technology (Holmes, 1859). It was cheap to produce and simple to use, trading the exuberance for simplicity in the production of its materials, selling thousands of models and making stereoscopic photography known to millions around the world. It was now possible for several people to access cultures and historic events that were happening around the world, without leaving their own homes (Christie, 2018).

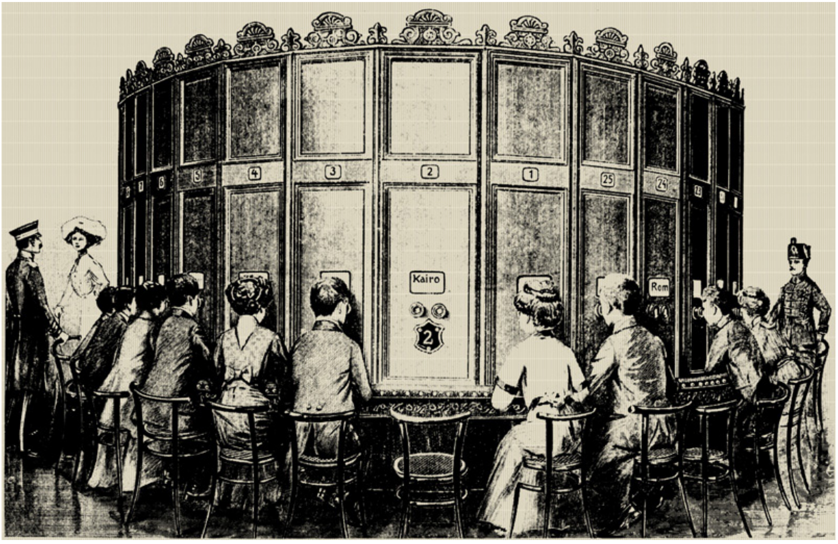
Until the end of the first Great War, mass photographs were produced, involving the most varied subjects such as astrology, war, and the cultures of the colonies or the daily life of European and North American societies, throughout its regions (Christie, 2018).

Underwood and Underwood was one of the largest producers of stereoscopic photographs and provided even greater access to the population, trying to be inventive with their publications. They also produced a stereoscopic viewfinder that was almost a copy of the Holmes Stereoscope, modifying some of the production materials (Christie, 2018).

Fig. 13
Physiography lesson by the Underwood stereograph system, high school Plainfield, N.J.
by Underwood and Underwood
c. 1860

In order to innovate the process of viewing stereoscopic photographs, which after some experiences became monotonous, Kaiserpanoramas (fig. 14) were invented. Rooms that contained several stereoscopic viewers in a circle, where a group of people could witness at the same time, each one in a different viewer, a collection of stereoscopic photographs that were would be exchanged in a certain period of time. This was a new experience for a technology already rooted in society, although being produced in small numbers, taking into account the space they occupied (Christie, 2018; Mark, 2011).

Fig. 14
Drawing of a Kaiserparonama
in Berlin
1880



The "disappearance" of stereoscopic photography seems strange considering that it was accessible to so many people in the Western world, especially in the early 20th century. It is possible to consider that most of the experiences that a significant part of the population had between the 60s of the 19th century and the first decades of the 20th century, were to review stereoscopic photographs, on cards, books, street vendors, Kaiserpanorama, etc. Most of the photographs we find today from the Victorian era are just one side of stereoscopic photographs of the time. This "disappearance" was due to the democratization of personal photography on film, through the appearance of Brownie Kodak (fig.15), a cheap camera that allowed anyone to capture personal photographs, send them for development and then keep them to themselves at a reduced cost(Christie, 2018).

Fig.15
Kodak Brownie Nº2 Model F
1924

After the great depression of the last century, many of the companies linked to stereoscopic photography had already closed, forcing the few that survived to adapt to other branch of influence, such as the branch of education or the military. This is how we see the appearance in the 1940s of the View-Master (fig. 4), a low-quality stereoscopic viewer, created in plastic, aimed mainly at children. These viewers were produced in large quantities and have been adapted over the decades in terms of how photo cards were inserted and in the shape of the viewer body. These viewers survived until the 70s of the last century and were for many people the first form of interaction with stereoscopy that they have ever had, according to a survey we conducted to collect information for this dissertation.

In 1959, Bela Julesz created a random dot stereogram, which was the first stereogram created with a computer. With that, she proved that depth perception is a neurological process. Stereogram was still the terminology used to describe two images that needed to be seen through a stereoscope. The autostereogram was created in 1979, by one of her students Christopher Tyler and consisted of a single image that didn't require the use of a special viewer to enable the stereoscopic effect (fig. 16). This concept was originally founded by Brewster but this was the first time it would be created on a computer (Tyler, 2014).

All of this advances were only possible by the study of how our vision works, the study of binocular vision (Bicas, 2004).

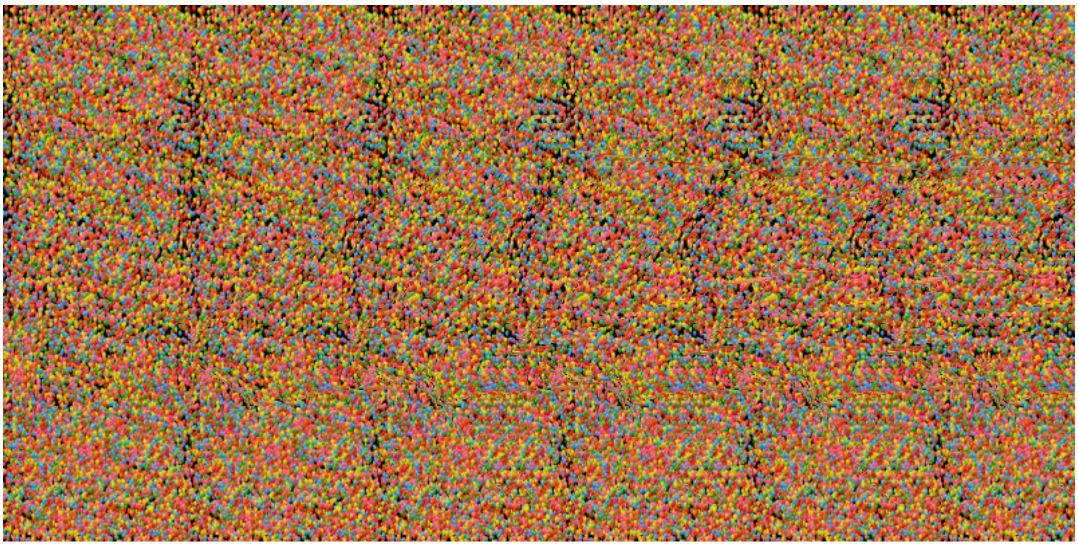


Fig. 16
Autostereogram example

We can also assume some of the reasons why this technology became not as well-known and valued as other forms of visualization, as stated by Ian Christie (2018):

(I) "Around 5-10% of the population cannot see the optical illusion that is stereoscopy, due to the distance between the eyes with which they are born, which often cause diseases such as strabismus;

(II) It is the slowest optical illusion, often making clear visualization more complicated to achieve;

(III) It requires a relaxation and training of vision to be able to perceive the illusion of stereoscopy and most people do not like to wait too long to see something happen, especially nowadays when time is increasingly valued."

In the cinematographic field, Louis Lumière, always thought that animated photography, known as film, should be produced with stereoscopic photographs, and, although the difficulty of projecting this technology, he created a machine capable of doing so.
In the 20s and 30s of the 20th century, this technology was being developed and in the 50s there was a boom of 3D movies. The glasses used were mainly of two coloured filters, one red and the other blue or green. There was a big revival of 3D movies again since the start of the new millennium with the transition to digital. It is now possible of doing this kind of movie with great quality, being Avatar an example of that (Patterson, 2009).

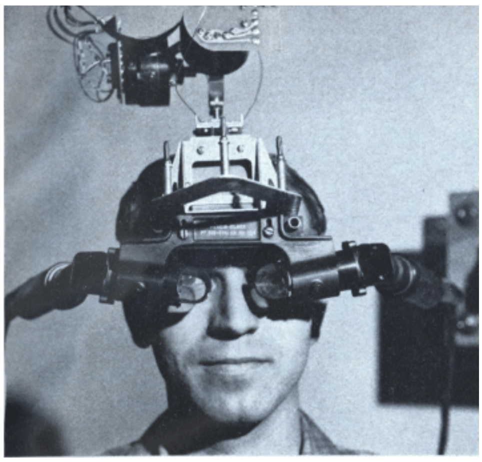
Virtual Reality

Virtual reality was born as a new way of adapting stereoscopy to a completely virtual medium, with a great focus on immersiveness and interaction, in a time where stereoscopic photography was becoming a niche technology.

The first attempt to produce a product that would allow the use of virtual reality was Sensorama, by Morton Heilig (fig.17). Started to be prototyped in the late 1950s, it was patented in 1962 and consisted of a kind of arcade machine with a stereoscopic display where it was possible to see stereoscopic images in motion. This machine would also try no enhance senses like the smell by releasing odours to the user (Sakane, 2011).

Fig. 17
(left)
Sensorama machine
by Morton Heilig
1962

Fig. 18
(right)
Sword of Damocles
by Ivan Sutherland
1966



During the rest of the 1960s, some prototypes of primitive VR displays were created that were unsuccessful, but one got some attention, the Ivan Sutherland's "Sword of Damocles" (fig. 18), which was directly connected to a computer, but became so heavy and uncomfortable that ended up not being practical (Barnard, 2019; Machover & Tice, 1997; Sherman & Craig, 2003).

By the end of the 1980s, some progress had been made and NASA created a completely virtual reality program to help training astronauts, the View project (fig. 19). This program contained hand movements through the use of gloves, which pioneered other companies to create their own prototypes from this concept, mainly the big game companies, which saw virtual reality as the future of the gaming universe (Barnard, 2019; Machover & Tice, 1997).

Fig. 19
View Project
by NASA

The first implementation of virtual reality as a form of entertainment was through the creation of "Virtuality Group Arcade Machines". These Arcade machines were open to the public in their buildings, where each person was entitled to a virtual reality helmet to interact with the machine. Some machines were connected to the others, allowing communication between them with low latency, an important factor for a good experience in the world of virtual reality (Barnard, 2019; Machover & Tice, 1997).

In the 90s, Sega prototyped a virtual reality model that was a sales fiasco, as it had several flaws in the way the user interacted with it, was quite expensive for a first-generation device and it only featured the colours red and black in all the games that had been created on purpose for this platform. After its fiasco, the world of virtual reality games was side-lined because it did not create the expected revenue.

In 2010, Google focused on VR by introducing the 3D stereoscopy mode in street view (Lardinois, 2010). In the same year, the first prototype of the Oculus Rift, capable of viewing in 90º and with a computer connection, was prototyped, allowing the processor of the computer to generate images shown in the device.

This development led to bigger spending in the improvement of virtual reality, with the creation of new platforms and displays with increasingly advanced features and the generation of realistic environments. VR has become something that is presented as the future in areas like design, games, journalism, construction, social networks and many others (Barnard, 2019; Machover & Tice, 1997; Sherman & Craig, 2003).

The development of free access platforms for the development of virtual reality environments has led to a globalization of this medium, allowing the appearance of a wide variety of displays on the market, which gives the possibility to contact with this technology and generate new content for it to an increasingly broad audience.

For enthusiasts who do not want to spend big amounts of money, there are several versions of prototyped displays with low-cost production materials such as the Google Cardboard or cheaper versions of it (fig. 20), which can be considered as the Holmes Stereoscope of the present, because it is a very inexpensive display that allows a large portion of the public an opportunity to contact with this medium.

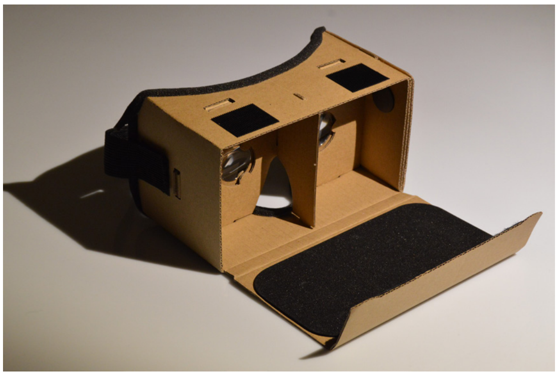


Fig. 20
(left)
Cheap Version of Google Cardboard

Fig. 21
(right)
VR Fold

We can also find accessible models (fig. 21) which are simpler in terms of shape and uses other materials. There are also cheap variants of more expensive displays that as not as resistant or feature-heavy as their more expensive siblings.

In the list of more advanced models, we find displays from Sony, Oculus, HTC, Google, Microsoft and Samsung. Each of these displays has different characteristics and are meant for different platforms, but all of them seek to boost the capabilities of virtual reality and the environments generated, as this technology is expanding bigger very fast.

3. STATE OF THE ART

This chapter was written with the main goal of deepening our knowledge and explore other projects developed in the area of study of this dissertation.

By the end of this chapter, we should have all the knowledge needed to apply in our practical project. It also becomes possible for us to understand if our project will be relevant or not, according to other examples we find.

It was necessary to study various kinds of stereoscopic devices, to understand their features and particularities; how other projects with similar goals were prototyped and used; and what prototyping materials and techniques would we have at our disposal for the prototypes we were about to start doing.

3.1. RELATED PROJECTS

Projects developed in the area of stereoscopic photography nowadays are scarce, taking into account the transition that has been made to virtual reality. However, some people try to keep this technology alive, through, for example, exhibitions (Cipriano, 2015) or book launches with stereoscopic material. On the other hand, when looking for projects that use virtual reality, we are overwhelmed by the number of areas that use this technology to produce content.

From the visualization of 3D construction projects to the world of games, virtual reality has been explored in a multidisciplinary way. However, these are not the type of project that is linked to the project we are developing as they do not try to create a bridge between stereoscopic photography and virtual reality. The projects that we will describe were particularly chosen because of the way their creators used stereoscopic photography, especially in projects where the theme is cultural heritage and what reasons made them chose that over choosing to do something easier.

OWL Virtual Reality Kit
(London Stereoscopic Company, 2021)

Being a stereoscopic viewer that is linked to several works by the London Stereoscopic Company (May, 2021), the OWL VR Kit (fig. 22) has been produced to be used in projects that involve stereoscopy, by the London Stereoscopic Company.

The London Stereoscopic Company is interested in reviving the stereoscopic heritage through the creation of exhibitions and literary works that present stereoscopy photography to the public that already knows this technology and for those who don't.

The work of this organization is interesting to my research since the stereoscopic content of their books is as it was originally, that is, the photographs are the dimensions of the photographs that were on the stereocards about one hundred and fifty years ago. With the creation of these stereoscopic contents, it is also necessary to create a stereoscopic device that would allow the consumption of the content. Thus the OWL was born, a versatile and easy to assemble stereoscopic viewer, which is perfect for viewing stereoscopic photographs in books. However, nowadays there is stereoscopic content on various platforms to which we have unlimited and free access and this viewer gives the user the possibility to consume these contents in the object that most people own, a smartphone. Leaning the smartphone against a removable backplate that gives stability allows a very interesting versatility, both for consuming old stereoscopic photographs and for viewing virtual environments. This reinterpretation of the concept of viewing 19th century stereoscopic photography for today's technology in a device that is easy to assemble and use and allows all you can do in a smartphone makes it a major source of inspiration for our project.

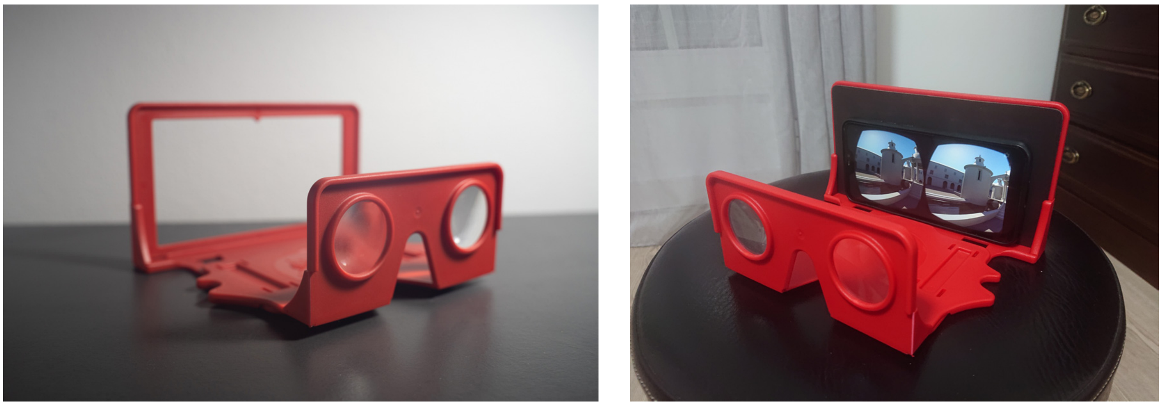


Fig. 22
OWL VR Kit with and without a smartphone

The London Stereoscopic Company has also created a "lite" version (fig. 23) of this same viewer, which consists of a plastic plate with two lenses, thought to be on used with one hand and the stereoscopic content in the other. However, this viewer is not so interesting from the construction point of view because it does not resemble the viewers of the past, neither makes the process of seeing the intended stereoscopic effect as smooth as its larger version.

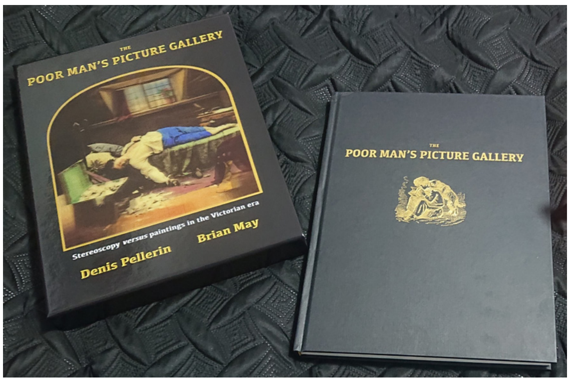


Fig. 23
(left)
OWL VR Lite

Fig. 24
(right)
Poor Man's Picture Gallery
by London Stereoscopic Company

Sheffield General Cemetery
(Ciolfi et al., 2013)

This project, created by a team of volunteers who is responsible for the supervision and maintenance of the centenary cemetery in Sheffield, has several interesting aspects in its composition, starting with the fact that it is maintained over time by a team of volunteers, who try to create ways of drawing people's attention to details of the space around them, which often go unnoticed. Being a historical site that has served the local population for more than a century, it keeps several secrets and to discover them, this team prepares several interventions on the site, such as the following one, which is particularly interesting to us given its link to our project.

In order to draw people's attention, this team developed a prototype they called "Binoculars", which is an augmented reality display inspired by the 19th century stereoscopes, powered by the smartphone that each user has. This display can be transported during the visit around the cemetery or be fixed on the floor. To recognize the environment, the software was started by reading a marker and then creating an overlay over the natural image that the user had in its front.

They adopted a highly influenced design on the Brewster Lenticular Stereoscope and complete wooden construction, to achieve a longer resistance to weather and a greater connection to the natural environment surrounding the device location.

This display prototype easily demonstrates how to apply technology from the past to the present. This team was particularly inspired by the historical load of the site and what technologies existed at the time it was built. Other details that the team was considerate of, like which materials to use and the design of the display, were thought to achieve a sense of enthrallment with the environment in question, which is something we will have to work on as well.

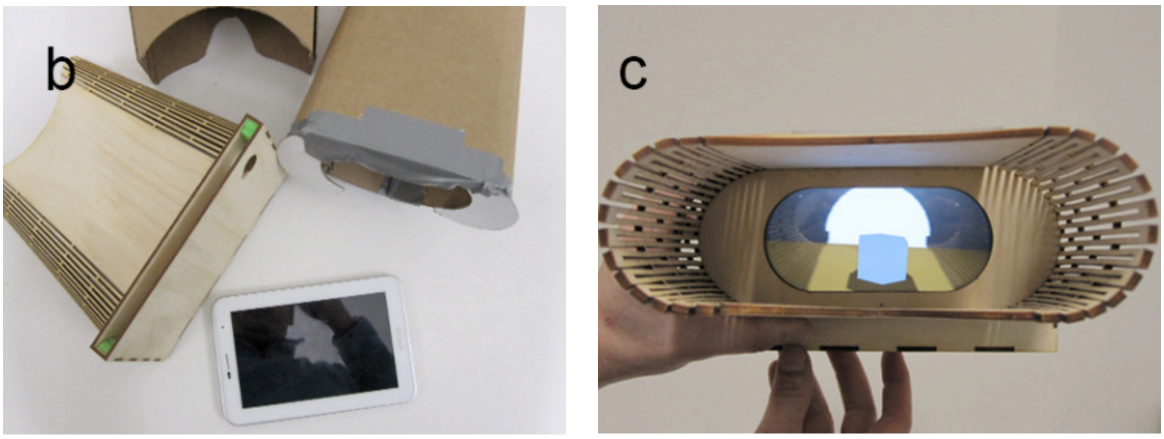


Fig.25
Binoculars device by Sheffield Hallam University

Daydream by Yifeng & Gong Yan and *Poor Man's Picture Gallery* by The London Stereoscopic Company
(May, 2021; Yi Feng, 2008)

Daydream is a book with unique characteristics, which makes it almost impossible to obtain or find. It is a fantasy book, with stereoscopic pop-up technology, that you can only see through the mirror that each image contains in front of you. It is a three-dimensional experience, both physically and visually. It took about a year and a half to produce the technology that adapts the animated images to the stereoscopy, necessary to achieve the three-dimensionality of the drawn image. In this case, the "viewer" is the mirror that we use to achieve the experience of three-dimensionality and depth. What is interesting about this book is that they had to think of a new way to show two-dimensional content, in a three-dimensional way, through a rethink on how to use stereoscopy for a new experience.

In the book *Poor Man's Picture Gallery* (fig. 24), I wanted to focus solely on its cover, because even though the interior has stereoscopic photographs, it is the cover of the book where it is shown a new way of rethinking stereoscopic photography. There, we find only one image, which shows depth without needing a special viewer. To create this effect, the two parts of stereoscopic photography were superimposed in a certain way, in several layers, giving the impression of seeing a three-dimensional photograph. When seen from different angles, we can see depth in the image.

Fig. 26
Back and inside views of *Daydream* book
by Art Book Collection

Making virtual reconstructions part of the visit: An exploratory study (Petrelli, 2019)

This article describes the process of introducing environments generated in virtual reality in historical museum exhibitions and the reason for the need or interest in doing so. The examples described in it have several points in common with the Santa Cruz CES project, as they have also created a virtual architectural environment to help visitors understand what a certain place looked like decades or hundreds of years ago, exactly the purpose of the Santa Cruz CES project. In the examples, during a visit to the Dr Jenner's House Museum and the Trajan Museum, it was necessary to create virtual architectural environments that would help the perception of the objects displayed in these same museums and to be able to view these environments, a stereoscopic device was necessary.

Taking into account the cultural load that a museum of Trajan represents, the viewer that they created was mainly influenced by the Brewster model, both in materials and in form, being created through 8 reused pieces, earning the nickname "Steampunk viewer". This model was chosen instead of Google Cardboard, as both allow the same level of interaction and the prototype viewer was more interesting, both culturally and appealingly, being something that many people had never seen before in their lives.

A very important factor in these projects is the interest spawned in the exhibition's visitors. When we generate content that we want to show, we should always think about the best way to attract people's attention and, taking into account the "awe effect" (Gurevich, 2013) that stereoscopy creates, it is important to use its strengths in our work, as it was done by the Museum of Trajan's team.

Fig. 27
Steampunk device
by Nick Dulake

3.2. STUDY ON EXISTING MODERN VIEWERS

This subsection is intended for an evaluation of the current viewers that exist on the market, which we chose because they are the most suitable for collecting important characteristics for the development of a good stereoscopic device. For its success, it is necessary to know the examples of existing products and test them as much as possible, trying to understand their strengths, as well as to not replicate their weaknesses.

This assessment stems mainly from our personal experience with all the viewers that will be described below.

OWL VR Kit

As already mentioned, this viewer (fig. 22) was created by the London Stereoscopic Company. It contains several interesting features that make it a unique device. In addition to being able to be coupled with a smartphone, which enhances the user's approach to virtual reality, this viewer was built with an opening at one of its ends, designed to observe stereoscopic photographs on stereoscopic cards or books, especially those published by this same company, demonstrating the care in enabling the stereoscopic viewing experience as it was originally.

It is completely made of good quality plastic including its lenses, making it incredibly light. However, transporting it can become complicated because of its size, both assembled and disassembled. Its lenses are large at an angle and in diameter — about 3.5 centimetres — which enhances the viewing quality on the different content platforms, which are of different sizes. These are the best lenses I've tested of all the viewers I've used, thanks to their size.

Its structure is inspired by the Brewster model (fig. 2), but it is so simplified that it allows us to easily understand what is around us and at the same time being properly focused on the immersion that virtual reality requires.

This structure is adjustable to the extent between the lenses and the other end of the structure, which allows the user's vision to adapt in order to get the best possible visual experience. The OWL VR Lite (fig.19) has the upper hand in terms of ease of movement because it is so small and simple, but its handling makes the experience less immersive and rewarding than its bigger sibling.

Google Cardboard

This model from Google has gained so much recognition that there are even cheaper unbranded copies of it (fig. 20). This recognition was thanks to its aggressive price in the market, made possible by its construction with cheap materials and a simplistic design. It is possible to compare it to the Holmes Stereoscope, which had these same characteristics and enabled access to stereoscopic content to a more generalized audience, as the Cardboard does nowadays.

The design of this device is a simplified version of headsets dedicated to virtual reality, like the Oculus Quest (Oculus, 2021), and, to some extent to the Brewster Stereoscope (fig. 2). It uses cheap materials in its construction, and the whole body is made of thick cardboard, except the lenses, lowering its cost of production and sale to very low values. Being made of a material that easily breaks down, this device is not prepared for very intensive handling and to hold on very long.

One of the problems regarding this type of viewer is having the lenses — that are not adjustable — so close to the smartphone screen, making the stereoscopic effect difficult for some people and create headaches in long-term use, especially in cheaper models that have even lower quality lenses.

When compared to the OWL, while viewing a film with stereoscopic properties, the Cardboard allows greater immersion, given the fact that it is completely closed, forcing the user to focus completely on the content in front of his eyes. However, the OWL allows for higher quality viewing thanks to its big lenses, without putting so much pressure and weight on the user's body, even both of them being light as they are.

VR Fold

This device (fig. 21) has several features that make it an important example for this study. Like the OWL, its entire structure is made of resistant plastic, including the lenses, which are the weak point of this viewer due to its low optical quality.

Taking into account mobility, this viewer is the best example among all the others, as it was designed so that it can be folded, compacting its total volume a lot, which allows its movement to wherever the user wants without taking up much space. Completely unfolded, it allows a level of immersion between the two examples presented above, thanks to the two side plastic plates, perpendicular to the lenses.

One of its most important features to take into account is the possibility to adjust the distance between your lenses, as different people have different widths between the eyes. Another equally important feature is the possibility to adjust the distance between the lens and the smartphone screen, just as the OWL viewer allows.

However, there is a negative point to underline. As the smartphone is coupled by a piece that has a fixed size and this device has the peculiarity of being used with the opening of that piece facing the floor, if the smartphone is narrow it will end up slipping and falling, causing the experience to be lost. Even turning the viewer upside down, it is impossible to attach the smartphone, forcing the use of a cover to increase its thickness. That is a point to take into account when prototyping, especially not to harm expensive equipment.

3.3. PROTOTYPING MATERIALS AND TECHNIQUES

This subsection on which prototyping materials and techniques are appropriate for the project we are developing was written through the interpretation of various articles and thesis that I leave here referenced in other not to refer to it at all following paragraphs

(Martins, 2010; Palhais, 2015; Santos et al., 2018).

When creating prototypes of whatever object or program, one must always know what materials are appropriate for each type of project and each phase of prototyping.

In this subsection, we will focus mainly on the types of materials and techniques that we think are the most suitable for the project we are developing. Having this knowledge allows us to think in advance about what materials we should use for what phase of prototyping and what techniques we may need during this process.

3.3.1. MATERIALS

Paper/Cardboard

Being the most widely available material on the market that allows for various types of prototyping, it should be the material chosen mainly for low-quality prototyping such as drawings, two-dimensional cuts and wireframes. It is a very easy material to work with, as it allows you to make folds, cuts and even three-dimensional models with little effort and in a short period of time. If more firmness is required for low and medium level prototyping, it is possible to use cardboard, given its thickness above 0.5mm.

As it is reusable material, it makes perfect sense to be used in the first prototyping phases, in which several modifications are made to the models in short periods of time.

Polymers (plastics)

There are several categories of plastics, but for this project, the category that interests us the most is thermoplastics.

When heated, they become a viscous substance that can be injected into a mould, thus creating the complex shapes we want. It is material accessible on a large scale and cheap to produce. However, it is a highly polluting material that should be used only in the final stages of prototyping, or even in the final product, in order to reduce the carbon footprint to a minimum level.

Polystyrene (Styrofoam)

Polystyrene foam, or Styrofoam, is the ideal material for the transition between the use of paper and the use of final material, such as plastic or wood. It is an easy material to handle, although it is not possible to fold it. However, as it is easy to shape with cut, it is possible to create three-dimensional models in accuracy and thus discover the problems of this prototype before moving on to the final prototyping phase.

Wood

It is a resistant and waterproof material, of low cost, perfect for prototypes in final prototyping phases or even for use in finished products. Wood is one of the most abundant products in nature and is renewable, making it the most suitable material for several different uses, existing in various thicknesses and prepared for laser cutting if necessary, taking into account that manual handling of wood is an overall difficult process but may be necessary.

Glass

Being a material that not everyone can handle, glass has to be used with caution, being mainly focused on finished products. In order to produce glass objects, it's important to study which design is the best and forwarding it to a specialist in working with this material.

In this project, glass could be a viable option for the construction of the stereoscopic device lenses in detriment to plastic ones, if there's a need for more quality of visualization than plastic allows.

Ceramics

An extremely resistible material that can resist the test of time against corrosion and deterioration and is easy to shape the way we want, is a good contender for a transition between a paper prototype and a possible final material. Its biggest disadvantage is that it takes some time to harden, but after that, it becomes sturdy and can hold for long periods of time untouched. It's not the perfect material for a final prototype, because it needs a lot of after-work to make its original raw look disappear.

Metals

There are two kinds of metals, ferrous and non-ferrous. All of the types that are included in these two lists are classified as final products since they are incredibly hard to work with and resistant to the environment. Even if it is a material for prototyping, it takes time and not everybody can shape metal easily the way they want, so expensive professional work is needed to be accounted for when using the material. However, as a finishing material, it provides a lot of exclusive bonuses to the prototype, like the professional feeling, the sturdiness and the resistance.

3.3.2. TECHNIQUES/TECHNOLOGIES

CNC Technology

"*CNC technology is a subtractive methodology, devastating a block of material to obtain the final shape, as opposed to the addition of material in most rapid prototyping technologies*" (Palhais, 2015).

Since this technology takes some time from the beginning to the end of its process, even for cutting simple forms, its cost is relatively high and it is recommended to be used mainly in the final prototyping phases, with more robust materials that emulate the appearance of the final product well to reduce the cost. However, it is a technology that is found in several places, which makes its use more appealing since it is not as exclusive as other technologies.

Stereolithography (SLA)

Stereolithography is a very common quick prototyping method, used very heavily in industry. It's a fairly simple process, related to 3D printing and it involves a resinous solution that is solidified in layers through a path created by a laser that reads a CAD program. After all of this process, there's a need for cleaning the result and it has to go to a UV furnace, where it gets its structural resistance. Due to all of the complexities of this process, the final product that results from it is very detailed and represents fairly well the 3D model that served as its model, showing easily where the prototyping problems are and where it is needed to act quickly in the next iteration.

Selective Laser Sintering (SLS)

It's a very close process to SLA, mentioned before, but it differs in the way that can work with a bigger variety of materials like metals, plastics and ceramics, thus enabling a much bigger variety of prototypes being formed in it. Using a method of layering enables the use of different materials in the same prototype, like metal and ceramics connected in a final object with no need for changing machines in the process.

Its process time is relatively smaller when compared with other techniques, but it does require some post cleaning due to the rough finish that the object has when comes directly from the SLS machine. Another important factor is the cost of some of the materials that it uses, being that it can become really expensive in big objects.

3D Printing

It is a relatively recent technology and is still in constant development, being increasingly accessible to the general public. However, its access is still limited in many parts of this country.

Its process consists of the successive addition of layers of material on a powder base, which is then glued with a binder material and is oriented by a model in CAD. It's a technology that uses mostly plastic, but in some cases, it can use metal or ceramics, depending on the machine, since this technology grew so fast and a lot of different models emerged, each one with different possibilities for materials.

The final parts from this process are fragile, making them not ideal for final products, but for intermediate prototyping phases.

Fused Deposition Modelling

One of the most used methods in the current industry, its process consists of an "*extrusion head made of a thermoplastic material that controls the part three-dimensionally on a base*" (Palhais, 2015).

However, it's not just plastic that can be used in it, because, as prices of the machinery have been going down, new models appeared and new material can be used, like acrylonitrile butadiene styrene – ABS – certain ceramics and even foods, like chocolate.

Good for building complex objects linked together with plastic, it implies being more suitable for high-fidelity prototypes. Its extended production time also encourages this type of prototyping in the final stages of the project, since even after the printing is done, it is needed to take some time to clean the object and leave it as was primarily intended.

4. WORK PLAN

In the first stages of creating a project, there is a need to create a work plan. This is a way of planning what tasks are we doing during all of the duration of the project, the time we estimate they will take and what do these tasks really mean for the project development.

This planning saves time in the long run and makes us decide early in the process in what way are we gonna work, even if the methodologies change in the midlle of the project for some reason.

4.1. TASK IDENTIFICATION

Since the beginning of the project, it was discussed what would be the best way to fulfil the project's goals through an order of execution of outlined tasks, even if these had certain time freedom to be implemented. Five main tasks were outlined, each of which is later divided into phases, necessary for a completed project.

The tasks are as follows:

(i) Dissertation writing;
(ii) Research;
(iii) Collection of Experiences;
(iv) Prototyping;
(v) Testing.

September – September

Dissertation Writing

This task concerns the complete writing of the document taking into account all the information collected in other tasks, being divided into two periods of time, which concerns the two mandatory deliveries of this dissertation.

September – August

Research

This task is divided in three smaller tasks: Historic background, State of Art and Contact with Coordinator and Santa Cruz Project Contributors. The State of Art phase is divided into Related projects, Study of modern viewers and Prototyping materials and techniques.

Research – Historic background

September – January

This task consists in the collection of important moments in the history of stereoscopic photography and virtual reality, from books, articles and lectures from various reliable sources.

Research – State of Art

September – January

The state of the art consists of a review of projects with similar objectives to this dissertation, a qualitative assessment of stereoscopic devices that were created over time tested by me and a study of materials to be used in the future prototyping of the viewer that I will have to elaborate.

Research – Contact with Coordinator and Santa Cruz Project Contributors

September – September

In order to understand the intentions of the contributors of the Santa Cruz CES project and also to create bonds to work together, it is necessary to have contact sessions with them throughout the development of the project. Also, this task regards all of the contact session between student and coordinator.

Collection of Experiences

November – December

This task is divided in two smaller tasks: Surveys and Interviews and it consists in the act of collecting experiences of using stereoscopic viewers and stereoscopic photographs by conducting and analysing surveys and interviews.

Collection of Experiences – Surveys

November – February

The survey phase was designed to obtain accurate data on people who have some kind of experience with stereoscopic photography, especially in groups of enthusiasts with whom we could not have contact personally.

Collection of Experiences – Interviews

November – December

The interview phase, which was interspersed with the survey phase, was designed to obtain data and expertise on stereoscopic photography directly from people who are influential in the area, mainly researchers and collectors.

February – August

Prototyping

This task is divided in two smaller tasks: The prototyping of the stereoscopic device and the prototyping of the Software.

February – August

Prototyping of the stereoscopic device

This task was scheduled mainly for the second phase of the dissertation development, the first phase being the collection of information for good prototyping. The purpose of this task was to phase the implementation of the prototype according to the project's objectives, improving the prototype at each iteration, ending up with a finalized viewer at the final delivery.

January – August

Prototyping of the Software

This task has been thought to be implemented at the same time as the prototyping of the stereoscopic device, since the two work together. It is also a task dependent on material provided by the Santa Cruz CES project. The intention of the task was to create an algorithm that could read images through the camera of a smartphone and connect us to a virtual environment.

Also, the design of the cards that keep the images needed to be read, is considered part of this task.

February – August

Testing

This task is linked to the various iterations of the prototyping phase of the stereoscopic device and is decisive for recognizing which points it would be necessary to improve in this prototype, to create a finalized version corresponding to the objectives of the project.

Also included in this task was the idealization of a real use case for the implementation of the entire project created, thus enhancing a testing phase in a real space.

4.2. METHODOLOGY

To ensure progressive development of the practical component of this project, we adopted a "Define, Prototype, Evaluate" model, created by Alice Agogino (fig. 28). This model idealizes the accomplishment of a cycling method of reviewing the task you did before if any of the output come wrong (Dubberly, 2005).

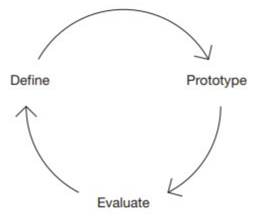


Fig. 28
Define, Prototype, Evaluate Model
by Alice Agogino

As an example, if the test output of the prototype comes with negative points, there's a need of reviewing the prototype again.

The *Define* step concerns all of the preliminary work that has been done to ensure that the prototyping task goes according to the concept and objectives of the project, like all of the research effort implemented to have enough information about the experience of using stereoscopes and what characteristics made them stand out above others. The *Prototype* step concerns all of the prototyping steps there are in the project, going through the material to material, always trying to fix all of the weak points that were spotted in the *Evaluate* step.

Every aspect of the prototype has to be tested and make sure that it goes with the final objective of the project. After one cycle, we start the process again with a review of what went wrong, evaluate according to the information that was gathered before prototyping, and then start iterating again until there's a final solution.

Gantt Diagram

The Gantt diagram is a tool where all of the dissertation tasks are broken down by how much time they will take to be completed. We present two diagrams, one made during the first delivery of the dissertation and other in the final one.

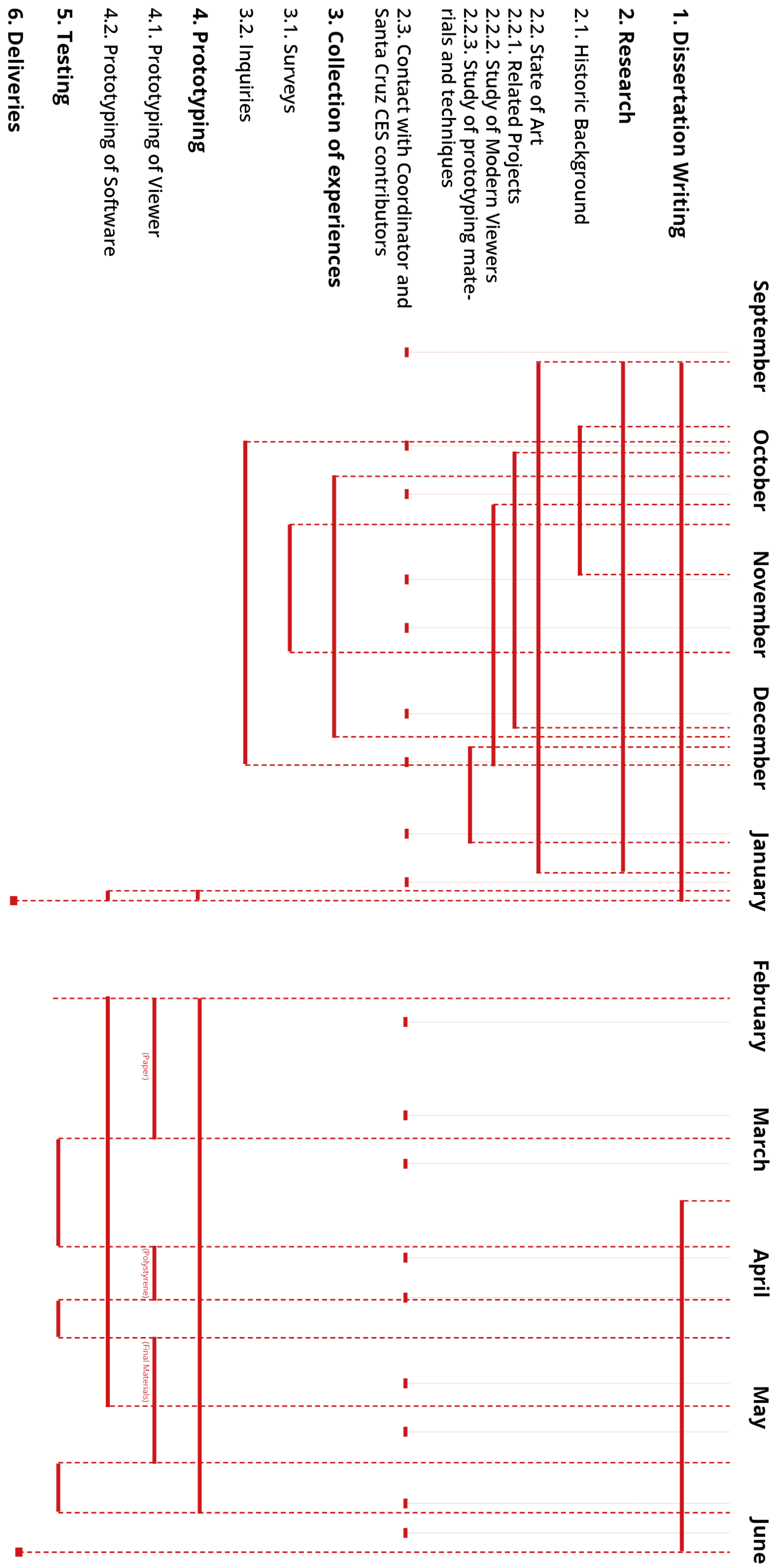


Fig. 29
First Dissertation delivery
Gantt diagram

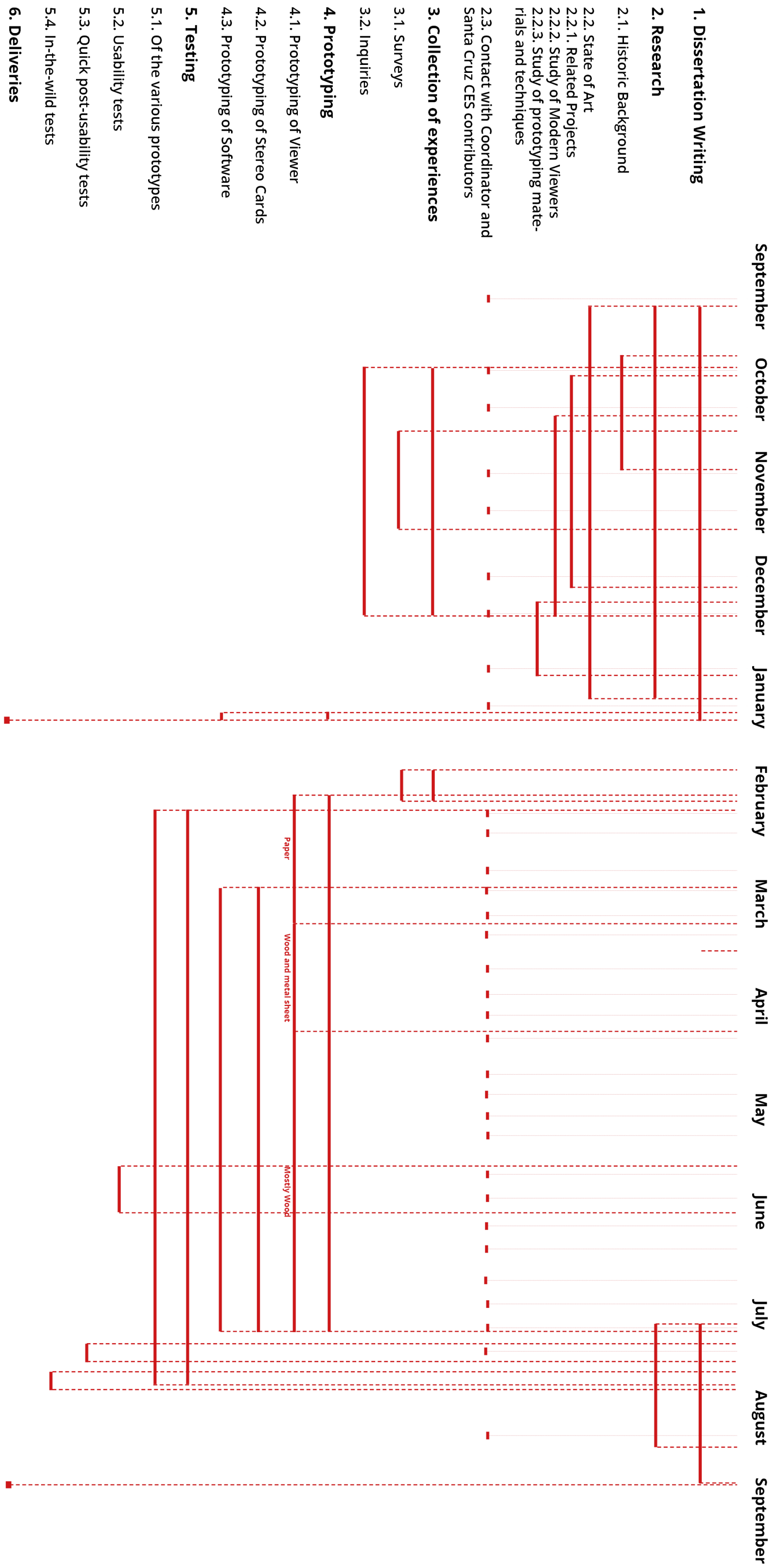


Fig. 30
Final Gantt diagram

As it can be seen by comparing both diagrams, we miscalculated the time that some tasks would take during the first dissertation delivery.

There was no certainty about the time interval between February and September. Although we knew we would prototype a device and test it in a real environment, we had no idea exactly how long each task required to do so would take. We assumed that all of the objectives of this dissertation would be completed by June and we could deliver it by then. However, by trying to make a better device, we had to postpone the delivery to September.

Prototyping the software was an unexpected barrier as well as we faced some difficulties adapting the number of functions needed for the experience to be as we aimed to.

The realization of the final experience in coordination with the Santa Cruz project was very late as well since it was made after the usability tests and we had no thought date to do them in the first place.

This discrepancy in the diagrams was due mostly to some time mismanagement and difficulties on the prototyping process

5. SPECTARE

Spectare was the name chosen to represent the three constituent parts that resulted from the work done in this dissertation: the design of the stereoscopic device, the design of the virtual interface made to run on a smartphone and the design of the stereoscopic cards needed to use in the virtual interface. All of these constituent parts are necessary for the experience created in this project, as they all work together, performing the function for which they were created.

Each of the parts were developed through iterations that increased their complexity in order to serve the task they had to perform, being tested several times and thus improved with each iteration. All parts were designed to have characteristics that would always hark back to the original experience of viewing stereoscopic photographs and that together would demonstrate a cohesive, simplified design adapted to each experience in which they would be put to use.

Once all the parts were finalized, we tested Spectare throught an experiment where we could collect data to be able to pinpoint potential problems with the design and improve the user experience in a next iteration.

In this chapter, we will describe all of the prototyping processes of Spectare, from the paper prototypes to the final evaluation, where we can see all of the advances made and the problems we faced to be able to create a final object capable of fulfilling the objectives of this dissertation.

5.1. VISUALIZATION EXPERIENCE

Throughout the first months of writing this dissertation, we agreed that it would be important to collect information in order to create an idea of what was the original experience of visualizing stereoscopic photographs, based on the testimony of people who have a lot of experience in the matter. Two tactics were devised: collecting, through surveys, testimonies from people in groups dedicated to stereoscopic photography on the social network Facebook (Bolch et al., 2021; Sell et al., 2021) and conducting interviews with individuals of relevance to this topic, such as researchers and private collectors. This section is dedicated to the subsequent analysis of the data collected.

Surveys

These surveys were intended to gather information from a wide group of people that has or has had some kind of interaction with stereoscopic photography. Since it is difficult to find groups online that focus completely on stereoscopic photography, there were just two groups from Facebook that seemed the most indicated to get information from. Both of these groups had around 2000 members in each of them and after we got permission to do the survey, we had 34 people answering them. Bearing in mind that these surveys were made for people with different backgrounds, we had to adapt the questions so that they were simple and universal, allowing open answers. The questions chosen were the following:

(i) What was the first time you contacted with stereoscopy or 3D?
(ii) Why do you like Stereoscopy or 3D?
(iii) Do you understand completely how stereoscopy works?
(iv) Have you ever used stereoscope and stereoscopic photos as they were used in Victorian times? If yes, what are the physical aspects that you liked the most when you were having that experience? What did you like the most about using a stereoscope?
(v) What model of stereoscope do you like using the most and why?
(vi) What experiences with 3D content do you consume nowadays?
(vii) If there's anything you feel you want to share with me about the theme, share it here, please.

Some of the collected answers inspired further research which is described in other chapters of this document, like the State of the Art, and made us understand the situation of stereoscopic photography today. Some of the responses were too vague and didn't allow getting much information from them. However, there were some situations where it was possible to understand why stereoscopic photography was so important to some of the participants. After having gathered a lot of information about the topic prior to these surveys, some of the results were somehow expected. For example, 68% of the participants answered that the first form of interaction with stereoscopic photography was through the use of the ViewMaster. This was understandable since View-Masters were some of the most produced and distributed types of viewer in the last century and introduced stereoscopy to a large part of the population alive today. About 60% of the participants also answered that what most fascinates them about this technology was the sense of reality generated that conventional photography fails to give, further highlighting the need to give importance to stereoscopic photography and the experience it enables. Nearly all of the participants fully understood the concept of stereoscopy, which was to be expected, given that daily publications of stereoscopic content are made in these groups.

It was also possible to determine that two stereoscope models were more frequently used than all the others: the OWL VR Kit (fig.18) and the View-Master (fig.4). The OWL is mainly used for viewing stereoscopic cards and stereoscopic photographs in books. The View-Master is one of the most affordable viewers on the market, allowing photographs to be cheap and thus becoming an option for many people who do not want to spend a lot of money on this technology. Another important result is that only around 30% of the participants have ever used a Victorian era stereoscope, which means that most of the surveyed people still only had the experience of using mainly modern stereoscopic viewers. This shows that they do not perceive the type of experience that people had in the 19th century, making our understanding of what was the original experience harder to achieve.

When reviewing the answers, it was possible to collect phrases that described the feeling of interacting with stereoscopic photography, such as:

"Looking through a stereoscope you get a sense of participation in the picture and it is like time travel revisiting places in the past".

"I like the restitution of reality through the stereoscopic image where everything seems real".

"I love the effect of stereophotography. Even in black and white, the images seem to come closer to capturing reality".

Not being satisfied with the collected data and having received feedback about how it might not be enough to build a good concept of what the original experience of viewing stereoscopic photography would stand for, we decided to make a second try of this online survey, by focusing on questions we didn't asked in the first one. We did it on the same Facebook groups and tried to clarify for those who had already done surveys earlier that they could fill this one as well since it had different questions. All answers were open-ended to allow participants to write as much as they wanted.

We also got demographic information, something we forgot in the first survey.

The new questions were the following:

(i) Regarding the emotional side of the experience of viewing a stereoscopic photograph, how would you describe the emotions it arouses? What stereoscopic viewer models do you associate with these emotions?
(ii) In technical / physical terms, what aspects do you think to make your experience possible? (age of the stereoscope, materials of which it is made, its most relevant physical aspects, the sound it produces, its form factor, etc.)
(iii) How would you imagine a digital stereoscopic viewer (to which it would possible to attach a smartphone), that would be used in the context of today? What physical aspects and which aspects of software / interaction with photography are the most relevant to you?

We got 11 answered surveys in total.

The average age of the group was 61 years old. The youngest age was 45, which shows that the majority of members of this groups are mostly older adults. Most of them worked or still work in the arts area like filmmaking and the engineering area.

Most answers were very small and didn't answer specifically to what we asked, which yet again made it difficult to try to create a concept out of it. Most people classified the emotions they associated with this experience as amazement, fascination and pleasure. The experience of watching a photograph is as it was the first time doing it, the fascination never fades. One answer we thought was very interesting was:

"There is something fascinating about the way time is 'frozen' in a stereoscopic photograph. The perceptual immersion in a stereograph invites narrative exploration in a way that two dimensional photographs do not. I find myself connecting in a more emotionally involved way with people and animals in stereographs; this is because they seem more naturally 'alive' to my imagination in 3D. I think about their lives beyond the captured moment. My mind spends more time imagining connections between objects in the frame too. For example, I will see a cup on a table and think about who held that cup, how heavy it might feel in my hand and where it might have ended up - the object has an imagined 'life' for me. But when I'm decoding a 2D image my mind simply registers 'a cup' if it notices it at all."

As for the second question, 60% of the participants stated that what is important is not the device you use but the content itself. Since the content was interesting, it didn't matter what kind of technicality the device they used has. The lenses were a point of focus for them, as they ensure a good visualization quality which is the most important factor.

For the third question, the OWL was suggested three times as an incredible stereoscopic device that is capable of VR, is very practical and has good dimensions, as we had already thought. Other devices were suggested as well but they were not of much interest for our goals.

Interviews

When the research of stereoscopic photography started, we began collecting names of people who were influential in this area, through the investigation of lectures, books and projects. Before starting the surveys, we had already started to make contact with several of these people, so that they could hopefully share their expertise on the subject with us. The people who gave the possibility to be interviewed were the following:

(i) Victor Flores, professor at Universidade Lusófona, director of Stereo Visual Culture and researcher;

(ii) Dennis Pellerin, researcher and artistic curator at The London Stereoscopic Company;

(iii) Alexandre Ramires, private collector, researcher and contributor to the Santa Cruz CES project.

These interviews were very informal and two of them were by video call, due to the pandemic situation we were living in. It was established at the beginning of the interviews that we'd try to do most of the questions present in the surveys, but that was a complicated task to achieve since the subject changes so quickly in informal conversations. All of the interviews took different directions, some more technical than others, but they all started by letting us know what their first experiences with stereoscopy were and why they remained fascinated with it until today. We obtained the same answers from two of the interviewed people as what was their first contact with stereoscopic photography, which was by using a simple plastic stereoscopic device that would be found in cereal boxes. Also, they shared what was the state of this technology in Portugal, because even if it isn't well known by most of our population, there are big collections of stereoscopic photographs that are kept closed and aren't shared with the general public, since there's no cultural and monetary incentive for that. This hiding of content was responsible for not allowing a big part of the population to discover and understand more of this niche medium.

The information we highlighted from these interviews was the technical tips that were shared with us so that the development of the stereoscopic viewer we were about to do was as successful as it could be. For example, that almost a tenth of the population is unable to witness the stereoscopic effect; that the lenses must be large at an angular level and must have more than five centimetres of the perimeter, to maximize the quality of the visualization and not to tire the human eye; and, that being able to manipulate the inter-lenticular distance is important to increase the number of people who can see the stereoscopic effect.

We felt that the information we collected, especially from the surveys, was not the most suitable to build a solid idea of what really was the original experience of watching stereoscopic photography. However, we had to start creating prototypes to advance quickly into our goals and we came up with a concept based on data collected: as most people have never used a Victorian-era stereoscope, there is not a lot of people that really know what that experience is. As such, the stereoscopic viewer we were about to prototype should be greatly inspired in Victorian-era stereoscopes, so that when people would test use our device, they would be able to be as close as possible as if they were using an old stereoscope, recreating a somehow similar experience to the original. Recommendations of other devices like the OWL should be taken into account for the necessity of how practical and light our prototype should be. All of the tips we received from the interviews would be used as physical requirements for the final prototype and the device design would have to ensure the easy use of a smartphone as the mediator between the stereocards and the interface. The stereocards were an essential part of the experience as stated by one of the interviewed participants because they had the content itself and the content is the main driver for those who like the experience of stereoscopic photography. The rethinking of the experience would be present mainly in the interface, through the use of tools provided by VR that would enable the use of even more interesting content.

5.2. CONCEPT

Although an idea of what a concept for the project would be was born soon after we had finished analysing the data from the interviews and surveys, the final concept was only completed when the final experiment was prepared in collaboration with the Santa Cruz CES Project.

This concept was based from the beginning on emulating the original experience of viewing stereoscopic photographs through a stereoscopic viewer with a design highly influenced in stereoscopes from the second half of the 19th century, mainly the Holmes Stereoscope (fig. 3), already mentioned above, taking into account how popular it was in the past, and that could incorporate in its body a current smartphone. To create a more realistic experience, prototypes were made in various materials, but always with the idea of creating a final display composed almost entirely of the material used in 19th century stereoscopes, wood. The device body design should transmit an idea of it being crafted by a human, with visible construction imperfections and a finishing resembling something made in the mid decades of the 19th century.

As well as the device, it was also important to create stereoscopic cards similar to those of the past as similar as possible to the original ones. However, as these cards only had the functional purpose of being read by the smartphone, thus giving the trigger to demonstrate stereoscopic content, they were later rethought to contain within them information about the project and also about the experiences they would be used in. A few different designs were also created that could be used in different circumstances depending on their purpose, for example, a stereoscopic card that could be sold and used as a postcard for tourism (fig.174).

The rethinking of the original experience was mainly in the way of viewing the content, which was now through the smartphone screen. The smartphone functions as the link between the reading of the cards and the viewing of content on its screen, which has the advantage of being able to use content that virtual reality makes possible, such as video, 360º images and the use of sound.

To easily demonstrate the project to those who wanted to know it, a website was also created where there is a video explaining what Spectare is and where you can access the experiences created for using it — https://spectare.dei.uc.pt.

5.3. VISUAL IDENTITY

For aesthetic and functional reasons, the colours used in the project were black and white. Choosing these two colours it was possible to have great contrast, necessary for the easy reading of barcode markers. Thus we also achieved a strong historical connection to the theme of the project, taking into account that old photographs were in shades between black and white, when they were not painted by hand after the moment of capture.

As for the typography used, the project logo (fig. 31) was created with the Newsreader font, designed by Production Type, for running text the Georgia font was used, designed by Matthew Carter, and for titles and subtitles the Roboto Slab font was used, designed by Christian Robertson.

Fig. 31
Spectare Logo

Spectare

The logo is completely typographic and uses the colours used in the rest of the project, to increase contrast and work on different backgrounds, only changing the filling of the letters from black to white if necessary. It was designed with this font to represent something that would be manually written and crafted, just like the concept of the project. The name Spectare means “to watch” in Latin, which made sense for us to use since it was deeply connected with the theme of the dissertation.

5.4. PHYSICAL MODEL

As mentioned before, the concept for designing the stereoscopic device since the first prototype was to be highly influenced by stereoscope designs from the past, with the particularity of having to be able to support a current smartphone.

For this achievement, it was necessary to understand the physical particularities of various stereoscopic devices from the past and the present. The process of prototyping this device went through several phases, each one more complex than its previous.

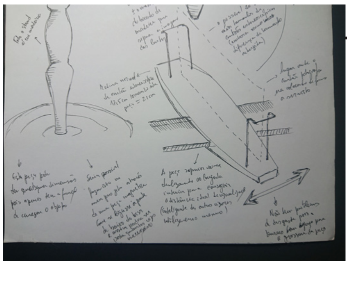
In the first stages of prototyping, we took into account prerequisites chosen through the analysis of data from interviews and surveys, which were very important to be able to provide the best possible experience, including the possibility of being able to modify the distance between the lenses of the device, enabling the maximum number of people to be able to perceive the stereoscopic effect; the possibility of adapting the distance at which the smartphone is from the display lenses, which allows the focus of the content present on the screen of smartphones with different dimensions; it would have to be simple and intuitive to use and being able to support a current smartphone, as already mentioned.

We will describe the various stages of prototyping our device went through, what challenges we faced and the choices we made during these stages.

Paper Drawings

The first phase of prototyping the stereoscopic device was to draw on paper several constituent parts of different stereoscopic devices we had access to. We draw important details and measures of those devices to use in paper prototypes, whice were intended to be done after this phase. The drawings were of old and recent stereoscopic viewers. The recent viewers should be simple and contain in themselves an interesting way to support a smartphone.

The biggest inspiration within the stereoscopes of the past was the Holmes Stereoscope (fig. 3), already mentioned before and the biggest inspiration of the present was the VR Fold (fig. 21), particularly for a body part it has that makes it possible to hold a smartphone, even if it is face down without any protection, and also to change the distance the lenses are from the smartphone, to focus the content present on the smartphone screen.



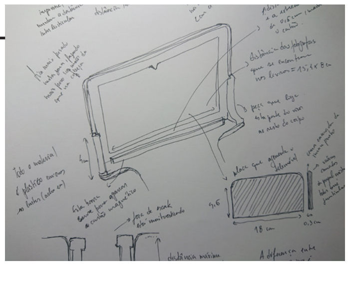


Fig. 32 & 33
Detail drawings

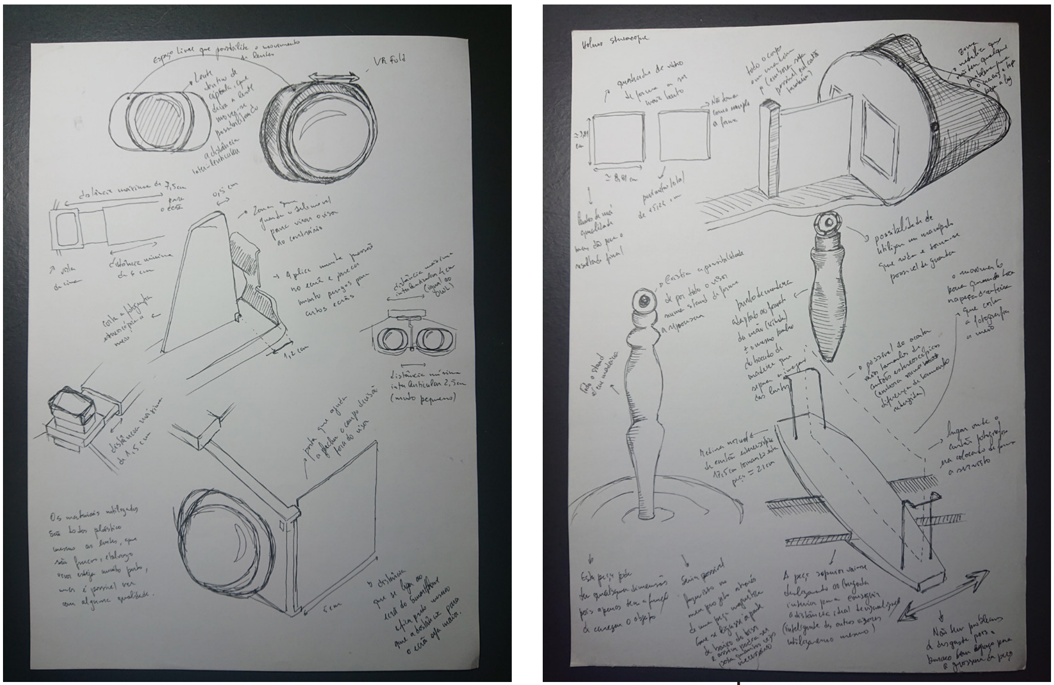


Fig. 34 & 35 Drawings of VR Fold and Holmes Stereoscope characteristics

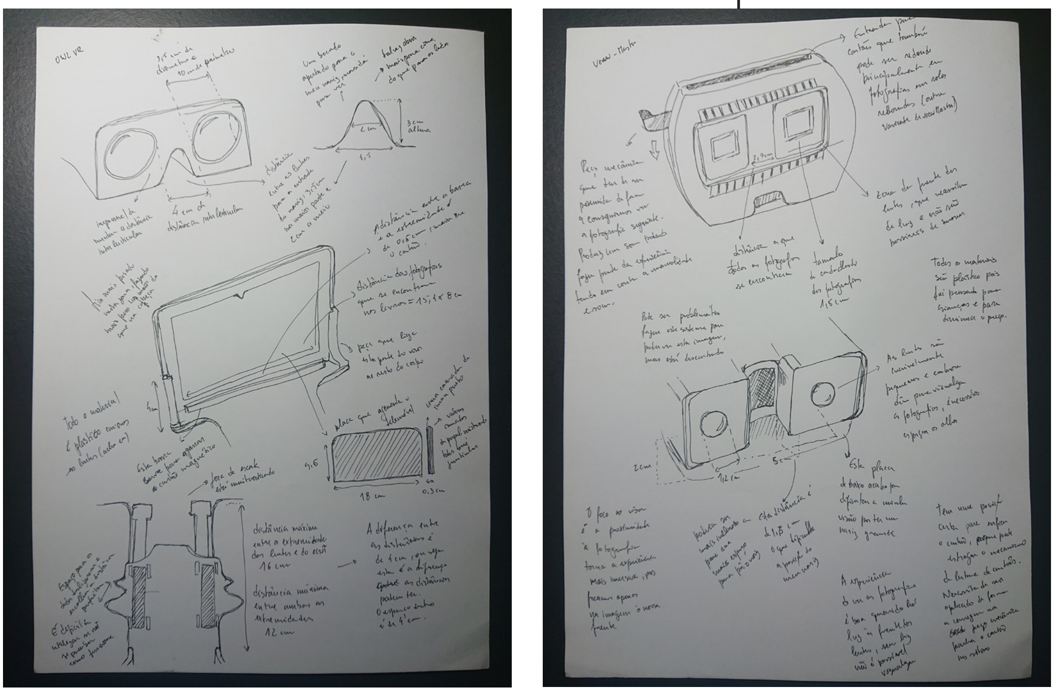
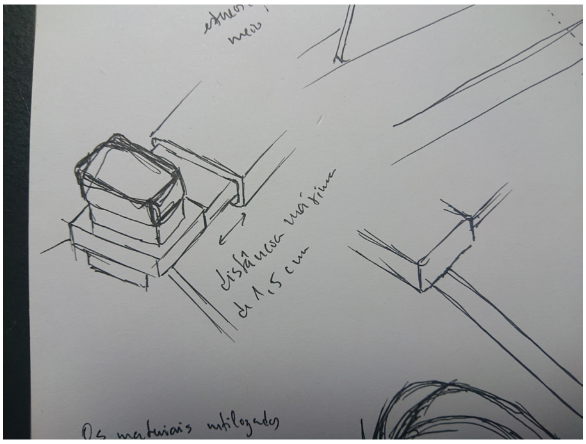
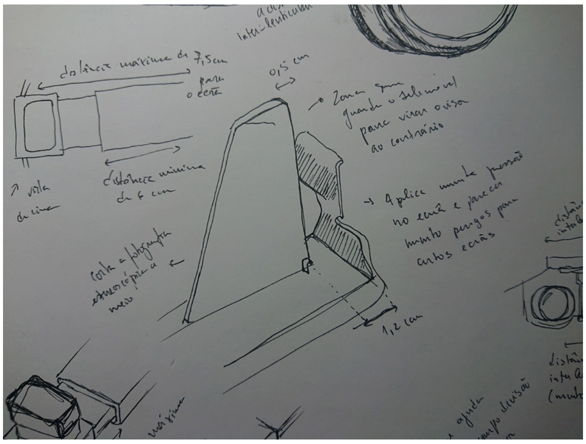


Fig. 36 & 37 Drawings of OWL VR and View-Master characteristics

The purpose of these designs was not to have a high level of realism, but to point out important details such as measurements taken from various devices and to explore various physical shapes that could be used in prototypes.

Although most of the designs focused on the shape and measurements of the "head" of the device, several other details were studied such as measurement of the lenses; shape of the lenses; the distance between lenses; the difference in distance between lenses when it was possible to adjust it; measurements of the various bodies of the viewfinders such as the size of the cut for inserting the nose, ways of fitting body parts; mechanisms for moving the stereoscopic content away and their measurements and parts that helped to block out outside light.





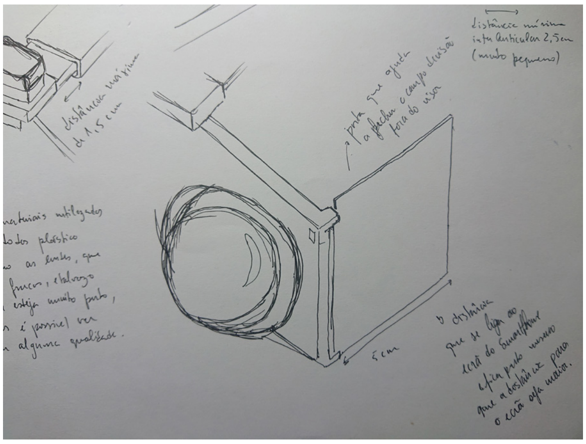
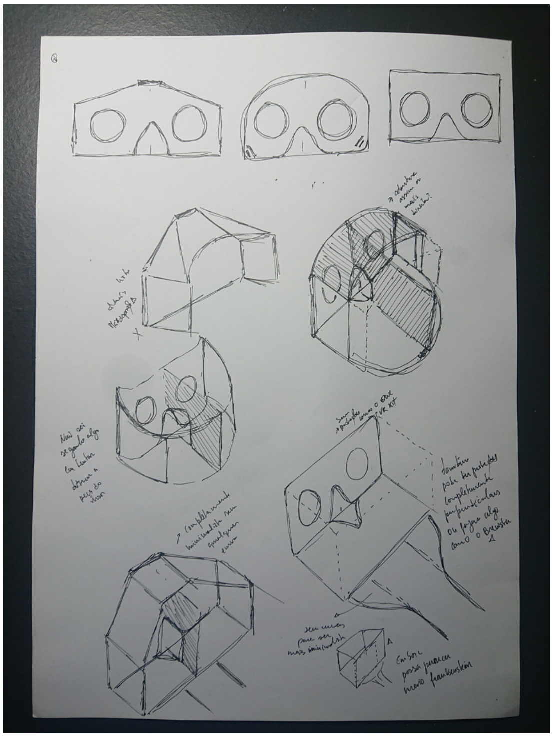
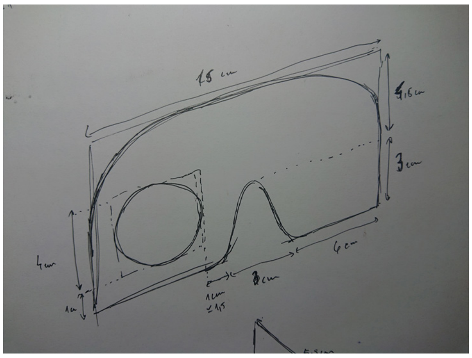


Fig. 38, 39 & 40
Detail drawings

We also started drawing possible designs for prototypes we could build from all of the data we gathered in all the drawings. These ones focused especially in what was about to be the head of the device.





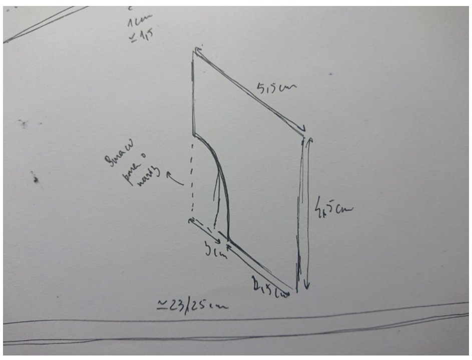


Fig. 41
(left)
Drawing of possible device head designs

Fig. 42 & 43
(right)
Detail drawings of device head parts

Paper Models

The first task when transitioning from drawings to three-dimensional paper models was to create several quick models, where it was possible to explore several physical forms without thinking about their construction complexity, through the data collected in the previous drawings.

The whole body of the display was to be modelled, not just the part where the smartphone was inserted, to already have an idea of which design worked best according to the requirements, even if this phase was open to any kind of design. Several ways of trying to incorporate the smartphone into these primitive models were explored, this being one of the most important factors in choosing that specific design to be used in the next prototyping phase.

During this phase 4 different designs were tried: based on the Holmes Stereoscope (fig. 44, 45); based on the Brewster Stereoscope (fig. 46 to 48); based on the OWL VR (fig. 49, 50) and another based on the Brewster Stereoscope (fig. 51 to 53).

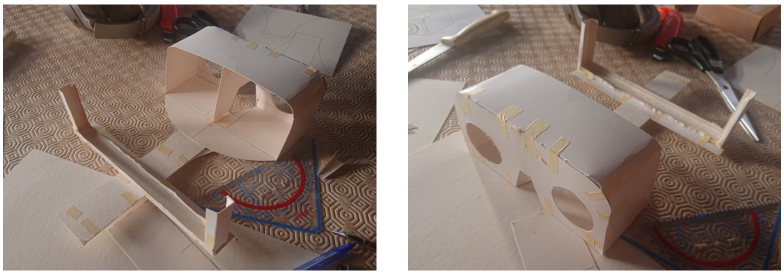


Fig. 44 & 45
First paper model design

Fig. 46, 47 & 48
Second paper model design

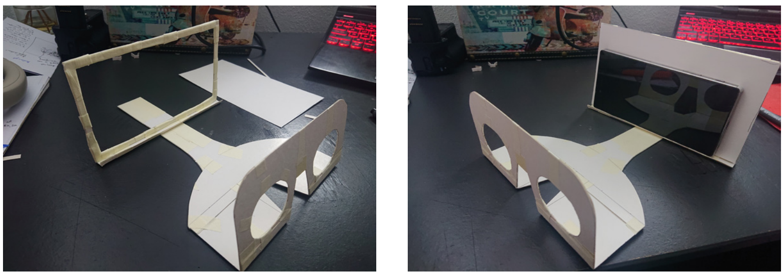


Fig. 49 & 50
Third paper model design

Fig. 51, 52 & 53
Fourth paper model design

At this stage, the functional side of the various models already had an important role to play in order to be chosen to evolve to more concerned and thorough prototyping. All the models already had in mind aspects such as the necessary measure for the insertion of the lenses and their movement (fig.48), or the necessary measures to be able to encapsulate a current smartphone screen. To this end, tests were always made with smartphones of different screen sizes, from 5.8 inches to 6.7 inches (fig. 53 to 55), which we had at our disposal during this phase.

Fig. 54 & 55
Detail of smartphone enclosure in different paper models

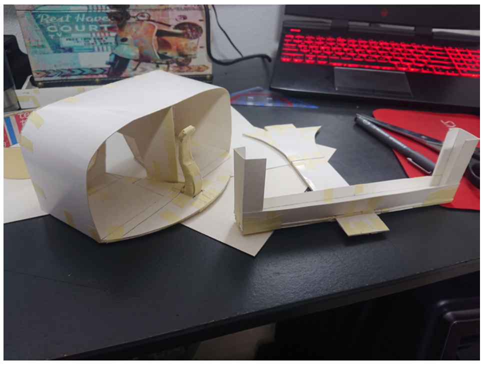
Two of these designs (fig. 45, 49) also included a component to view stereoscopic photographs that were printed in books similar to the OWL VR (fig. 24), as all the features our display could have were not yet decided and this particular feature looked interesting.

Later on, this feature was discarded as the lenses that were going to be used in the viewer did not allow to execute it since they were made to focus in short distances on contents much smaller than stereoscopic photography in a stereocard.

Of all the designs, only one was chosen to be worked on from this stage to final prototyping. The chosen design was the one that most closely resembled the Holmes Stereoscope (fig. 44, 45), as it had a body that was easy to grip with just one hand, leaving the other free to do other actions. It was modelled to create a light-free space inside its 'head' where the smartphone was held, which improved the visibility of the content on the smartphone screen and it contained in its body a cardholder that could easily hold the cards needed to give the trigger on the smartphone, that allowed the content to be shown to the viewer. The only drawback compared to other designs such as those inspired by the Brewster Stereoscope (fig. 46) was that the smartphone support mechanism was not as secure and required a lot of work to be functional. This model was a very interesting design as well, but it would have to be held with two hands and we were more interested in the one-handed use.

Therefore, the smartphone support part became a high priority already in the next phase. Inspired by the data collected about the VR Fold (fig. 21) we designed a smartphone support piece the would be locked in the device body. This piece was made of paper as well but in its core had moulded thin metal sheet (fig. 58).

Fig. 56 & 57
First model redesign



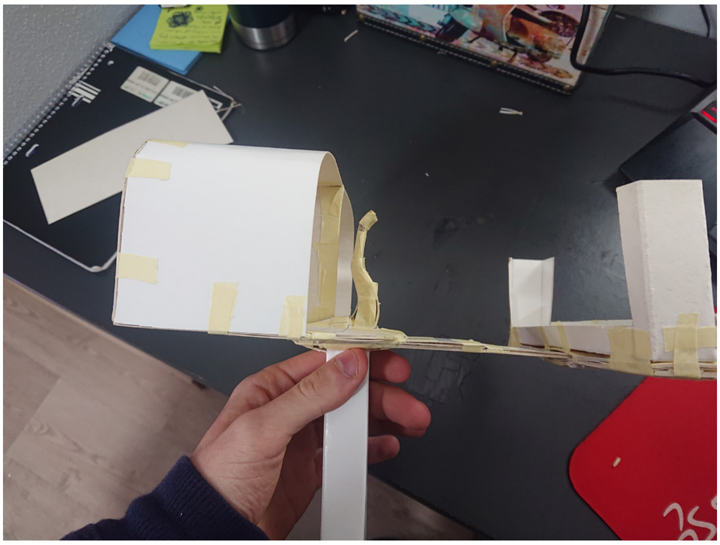


Fig. 58
Detail of new smartphone support piece

This design (fig. 58) also included an adjustable handle to be able to hold the display (fig. 59, 60) that replaced its earlier boxy design. Eventually it had to be rethought at a later prototyping stage due to its production complexity.

Fig. 59 & 60
New handle design prototype

The main problem we encountered while testing this prototype was that the smartphone support piece wasn't completely flat at the smartphone insertion area, which caused the smartphone to slip and not be secure.

The next phase was to create an improved version of the chosen design that could have more robustness and proportions closer to those that would be used in the final model, continuing to use paper as modelling material.

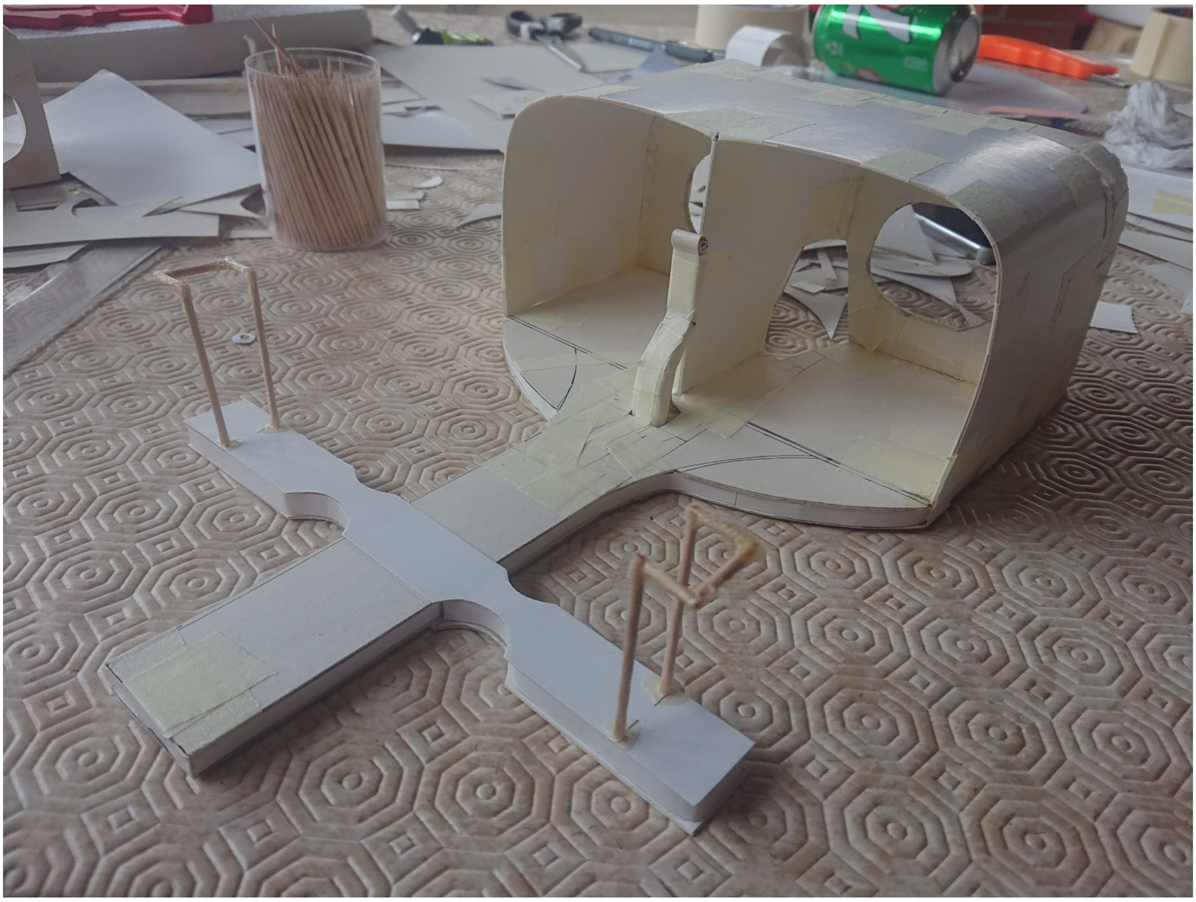


Fig. 61
Finished model of first design with stronger structure and enhanced smartphone support mechanism

It was necessary to understand beforehand how the various pieces would have to be put together to simulate the assembly into final materials, which we already anticipated would be mainly wood and possibly some kind of metal or plastic. All these pieces were reinforced with several layers of paper cut-outs, and to make sure the structure could hold up with a smartphone, it was necessary to fill the base of the model with glued cuts in geometric patterns similar to those created by bees in their hives (fig. 64), reducing the fragility of this piece, which held up most of the weight of the whole prototype and smartphone. In this base was also incorporated the smartphone support piece, which already allowed to support the test smartphones, but had the big problem of letting it slide to the sides since it was composed of paper. This piece also still did not allow any movement to adapt the distance in between the smartphone and the lens, which would be addressed later.

A piece was also added attached to the head of the prototype (fig. 67), in order to decrease the amount of light the device received on its lenses through their peripheral vision. This made it easier to focus on the content we were seeing through the lenses.

Another piece that that was greatly developed in this phase was the cardholder (fig. 70). Inspired by cardholders from the past, this piece was modelled already with volume, so that it could be inserted in the prototype base and thus be possible to move it, increasing and decreasing its distance to the prototype head. It was modelled with measures that made possible the insertion of a standard-sized stereoscopic card from the 19th century, in this case, emulated with a print of a stereoscopic photograph on paper (fig. 72). Glued wooden sticks were used to hold the card, half the height of the stereoscopic card, which would be made of metal in the final model. To improve the user interaction with this piece, four half-circles were cut, two by two, on each side of the cardholder, near the hole where the display base penetrates the cardholder and that allows the user to use the 4 fingers of one of the hands to slide this piece more easily through the prototype body. This idea was inspired by a similar mechanism in the OWL VR Kit.

Fig. 62, 63,64, 65, 66, 67, 68 & 69 (left to right, top to down)

Paper prototype construction process

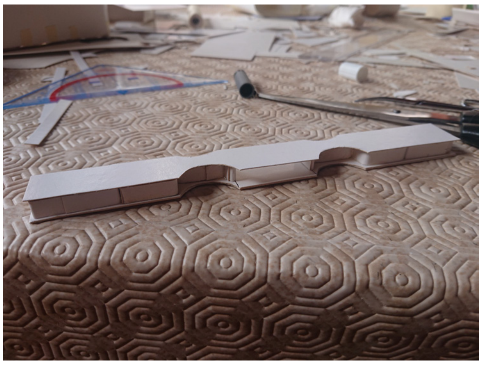
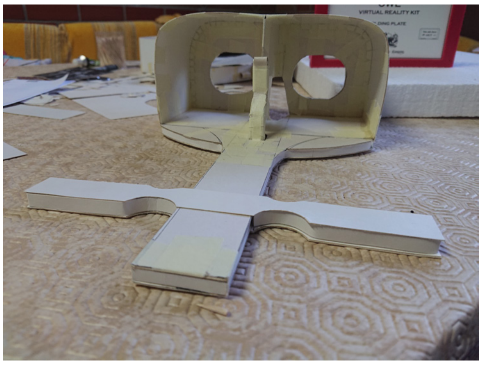



Fig. 70 & 71
Paper prototype construction process continuation

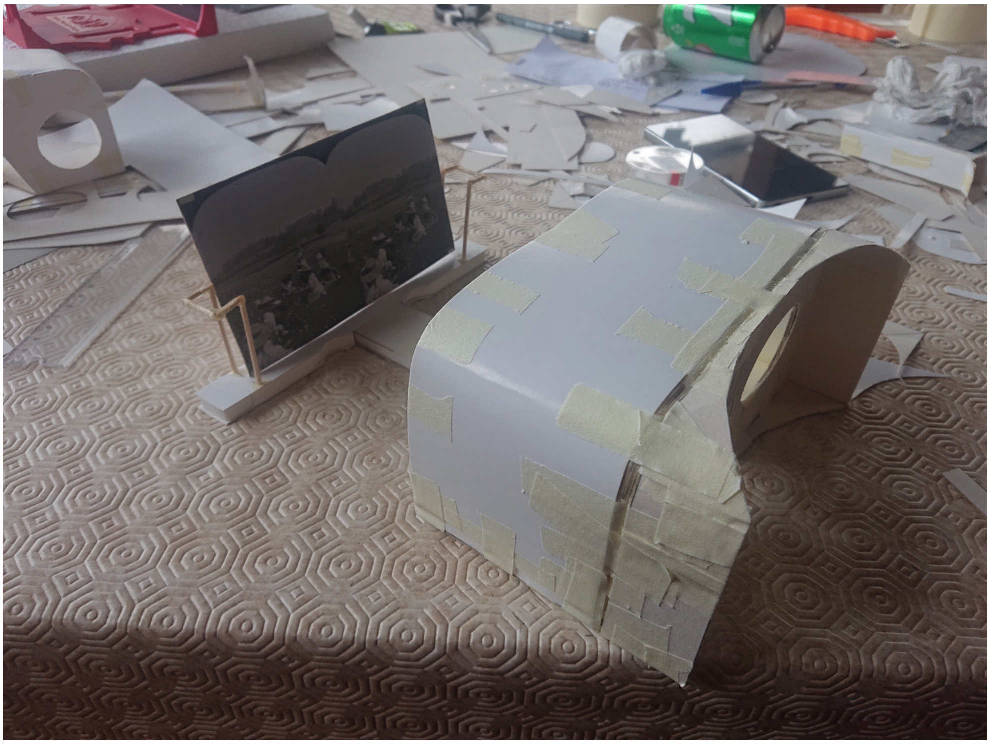


Fig. 72
Testing of stereocard in the new cardholder

This model used the same handle as the previous model, as this component had not yet been rethought and had been made so as to be removable from the model, in order to make it possible to modify other parts of the model easily without damaging the handle.

A custom base was also created to hold the display (fig. 74).However, it wasn't possible to pass this paper model to a wooden model because we didn't have the necessary time and it wasn't a priority.


Fig. 73
(left)
Custom base holding the new prototype model

Fig. 74
(right)
Custom paper base

Overall, this model was 20% larger in dimensions than the previous model and weighed 11.3 grams more, fully weighing 83.4 grams (fig. 75).

Fig. 75
Both paper prototypes side-by-side for size comparison

However, the latter model had a big issue. Depending on the size of the smartphone we used to test, the darkness effect generated inside the display head was less effective when the smartphone was small. Furthermore, if it was narrower than the other smartphones, it tended to slip sideways and end up falling through to one side of the mask.

The solution found to this problem was to increase the size of the prototype head by 1 cm in length and 1 cm in height, in order to be able to fit inside the head the whole body of the smartphone (fig. 76, 77). To make sure that any smartphone could be inserted into this new head, it was necessary to know the measurements of a smartphone with a 6.9 inch diameter screen, the largest smartphone measurement today, and to test it inside the mask opening.

For this test, a prototype was created with a new head only, where there was also a new, tougher and tighter smartphone support piece. However, it was quickly apparent that all the body measurements would increase, as the base measurements were directly proportional to any difference in the head measurements, which ended up increasing the measurements of the whole body.

Fig. 76 & 77
New head prototype with bigger dimensions that was capable of holding all the existing smartphones

Regardless, a new problem appeared and another continued to exist. As the smartphone support piece was fixed inside the prototype head, it became incredibly difficult to insert the smartphone into the prototype head without ruining the holder or damaging the smartphone. The solution was to create an opening at the top of the mask with the necessary measurement to safely insert the smartphone. However, this solution was not practical when moving towards materials such as wood and there was a need to rethink this piece without having to redo all of the design.

In addition, one of the prerequisites had not yet been realised. It was not yet possible to change the distance between the lens of the display and the smartphone.

To solve the problems raised above, it was necessary to think about how it would be possible to be able to create movement within the display head without drastically increasing the difficulty of production and use.

The solution found was, once again, by prototyping a paper head, focused mainly on the creation of a new smartphone support mechanism, capable of supporting the smartphone and at the same time being able to be moved near and far from the prototype lenses. Furthermore, it solved the problem of inserting the smartphone into the display head, as the mechanism extended completely until it was outside the head, so there was no risk of damaging the smartphone in the process. This mechanism used a smartphone support identical to the one used in previous models, but this time it was a single piece, inserted into a cavity created at the base of the display and which was attached to its top, giving it the possibility of becoming mobile (fig. 83, 84).

This new design increased the difficulty of prototyping in materials such as wood, but that was a risk we committed to.

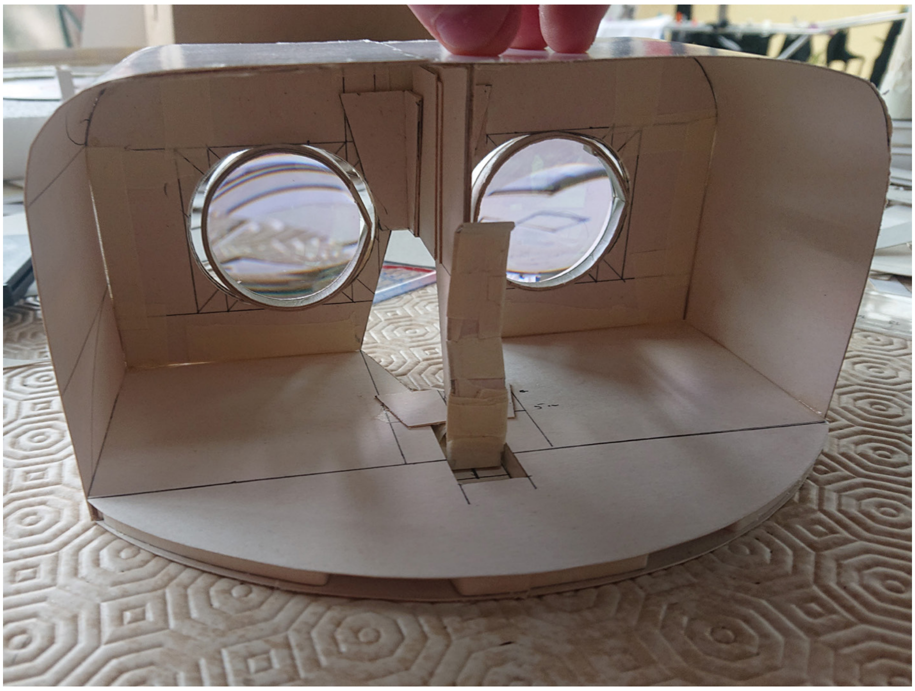


Fig. 78
New head prototype with redesigned smartphone support mechanism

Fig. 79, 80, 81 & 82
(left to right,
top to down)
Process of prototyping
new head with better
smartphone support
mechanism

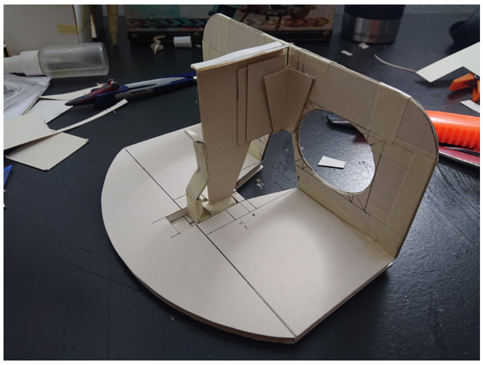
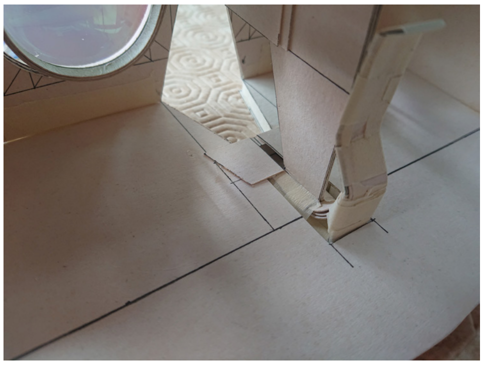



Fig. 83 & 84
New smartphone
support mechanism

This prototype was already capable of reproducing stereoscopy when using a smartphone screen, since it already had enclosured VR styled lenses (fig. 85).

Fig. 85
Test of new head prototype
with a stereoscopic photograph
in smartphone screen

Lens testing in paper prototypes

Once all the prerequisites had been achieved, the highest priority was to test lenses on the models created to see if it was possible to move on to prototyping in more resistant and durable materials.

To do these tests, it was necessary to take lenses from current VR headsets we had available. These lenses allowed focusing over a large field of view and were about 4.3 cm in diameter (fig. 87). However, they were specialised only for viewing stereoscopic content on smartphone screens at a 4.5 cm distance, unlike existing lenses on older displays.

Fig. 86
Lenses taken from VR headsets and the paper cases we buit for them, as well as wood casing prototypes

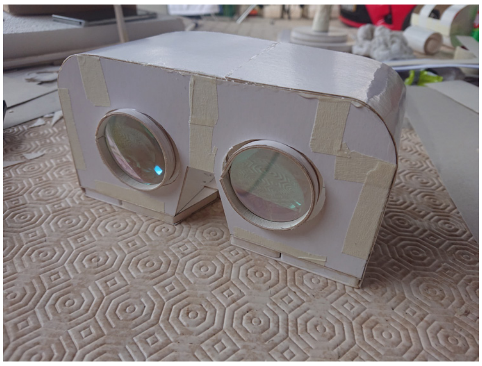


Fig. 87
(left)
Vr glass lenses

Fig. 88
(right)
Paper prototype with functional paper lens mechanism

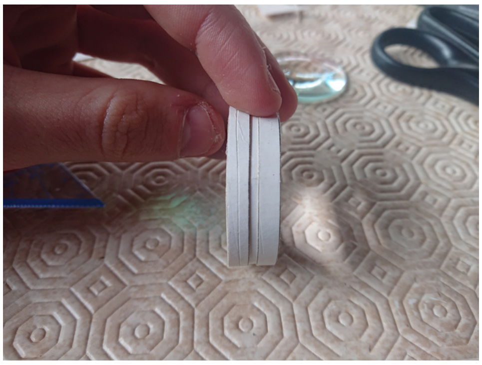


Fig. 89
(left)
Front view of lens paper casing

Fig. 90
(right)
Side view of lens paper casing

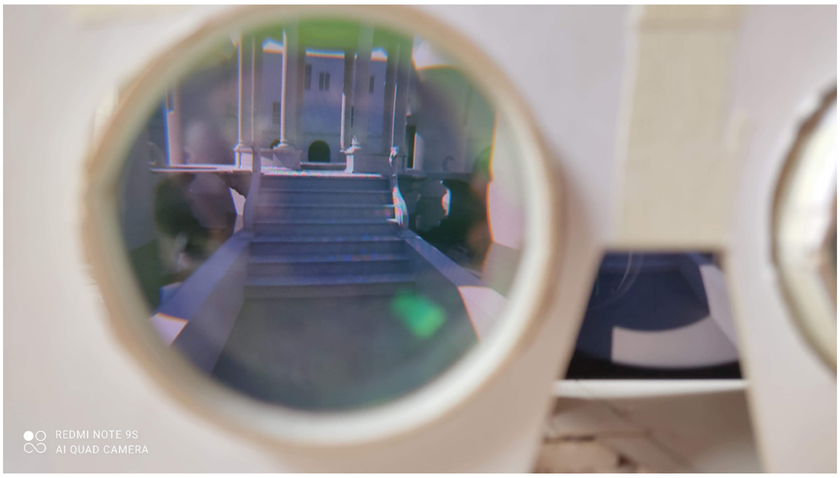
The first step for this phase was to figure out how to fit the lenses into the head of the device we had just modelled. This model already had holes in its head big enough to insert this type of lens but the fitting method had not yet been thought of.

The solution found, on paper, was to create a casing for the lens that contained a groove all around it on the outside and inside. In this way, it was possible to fit the lens into the casing, close it and then insert the assembly into the hole in the viewfinder (fig. 88). We then managed to complete the last prerequisite, which was to be able to modify the distance between lenses, even if it had to be manual, which, in this project is always interesting to enrich the final experience.

This solution seemed the easiest to prototype, even in stronger materials.

To test the result, we created a small A-Frame test program with a 360º stereoscopic image of the Manga Cloister and the goal was to perceive the three-dimensionality of the image, having the smartphone inside the model already with the lenses inserted (fig. 82). This test was a success, which allowed us to move on to the next phase, prototyping in more resistant materials.

Fig. 91
Stereoscopic image seen through lens from paper prototype



Wood and Sheet metal prototype

Once the test with the lenses on the paper model was completed, the phase of testing on wood began. The first test of this phase was to create a wooden casing that could encapsulate and protect the lenses.

The procedure was similar to that used in the paper tests. Two doughnut-shaped pieces of wood were cut and then we sanded the inside of one side of each piece, creating a space to house the lens, that was once again taken from a VR headest. Once the space was big enough to house the lens, they were placed in that space and the second piece was glued to the first, finalising the enclosure (fig. 94).

The last step was to cut a groove all the way around the housing, as in the paper model, so that it could be inserted into the display mask and be moveable (fig. 95).

Fig. 92
(left)
Doughnut-shaped pieces of wood after sanding

Fig. 93
(right)
Lens wood casing before being glued

Fig. 94
(left)
Lens wood casing after being glued

Fig. 95
(right)
Cutting a grove in lens wood casing

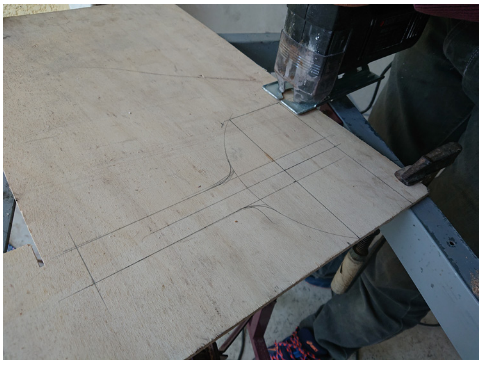
To be able to use the lenses, it was necessary to rethink the mechanism in which they would be inserted because in wood it was impossible to replicate the latest one, as we noticed when finishing the lens casings. Therefore, as we had already thought about how the body would be divided and assembled, we rethought the piece of the "face" of the device, adding a piece of sheet metal in its rear side, so as not to be perceptible for the users, that had a cut in the area where the lenses were inserted, thus providing the possibility of adjusting the distance between lenses (fig. 97). We also had to redo the holes for the lenses in the wooden face piece, to be able to insert in it the whole diameter of the lens housing, something that had not been thought necessary at the beginning of this phase. Once the face piece was finished glueing, we tested the lenses with a stereoscopic image on a smartphone screen at the right distance to make sure we could see the stereoscopic effect.

Fig. 96
(left)
Cutting holes in the face piece to insert lenses

Fig. 97
(right)
Glued metal sheet in the face piece with lenses already inserted

The base of the display (fig. 99), the head of the handle and all the parts needed to form the cardholder (fig. 102, 103) were cut from pieces of wood and sanded until they were ready to be used. For the handle (fig. 100) a file handle was used, which made simpler and cheaper this part of the prototyping process, besides saving many hours needed to create an identical piece.

Fig. 98 & 99
Prototype wood base



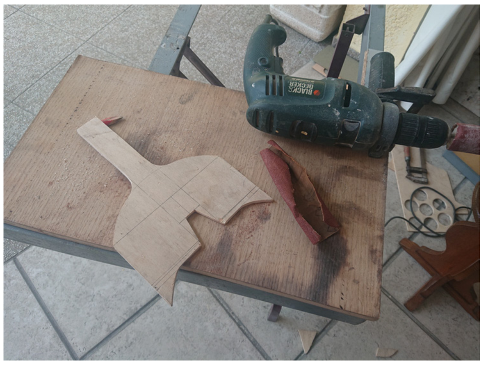


Fig. 100
(left)
Prototype wood handle. The top piece was made by us and the bottom one was bought

Fig. 101
(right)
Cardholder wood pieces

Fig. 102 & 103
Wood cardholder

As for the smartphone support system(fig. 104, 105), it was impossible to replicate the one made out of paper in wood, due to the difference in the characteristics of these materials, which also made it necessary to rethink the structure of this piece and how it would be inserted in the prototype base. The solution chosen was to make this piece through sheet metal. It was necessary to cut out the two different parts of the support, with the measurements already collected in the design phase, and fuse them to have enough resistance to hold a smartphone. A hole was cut in the base that was deep enough to fit the piece of sheet metal, the length of this hole being longer than the piece, giving it room to be moved in or out of the prototype head. Two more pieces of sheet metal were also needed to attach the smartphone support piece to the prototype base.

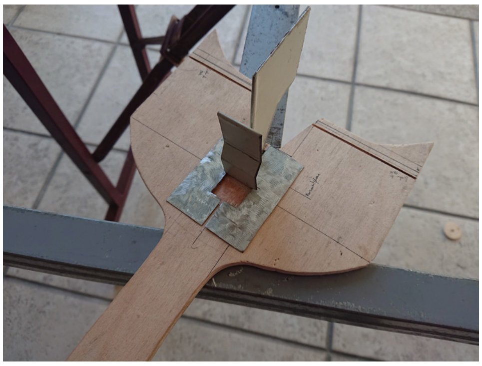
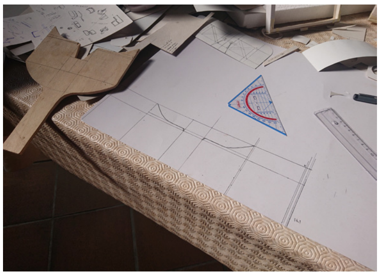



Fig. 104 & 105
New smarthone support mechanism made with sheet metal

The top of the head was made in sheet metal since the difficulty of making it in wood could greatly delay the prototyping process. It was necessary to create a small mould in wood with the measurements of the face piece, where a sheet metal plate was moulded (fig. 108).

All the sheet metal parts were painted white so that there would be less contrast with the natural colour of the wood.



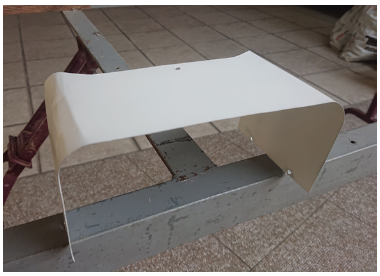
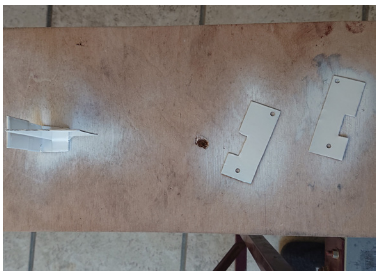





Fig. 106, 107 & 108
(left to right)
Top head sheet metal piece building process

Fig. 109, 110 & 111
(left to right)
Painting of all sheet metal components

With all these pieces completed, they were all glued, starting with the base and the facing piece, then joining the complete handle to the base and, finally, the sheet metal top, which was screwed on in the areas of greatest tension, to ensure more rigidity throughout the device.

For the cardholder, two pieces of wood were glued, where a rectangular hole had already been drilled with the necessary measurements to pass the arm of the base, which had the functions of allowing the movement of this piece and serving as a place to house it. It was necessary to open holes where two pieces of thin moulded metal were inserted to be able to support the cards and a hole in the base of the cardholder, to insert a thread, also prototyped by us, which had the purpose of tightening the cardholder to the display base arm, making the cardholder not fall when sliding when the device is turned to the ground. This piece was thought of at this stage, as the cardholder fell to the ground several times while we were building and perfecting it.

Fig. 112, 113, 114, 115, 116 & 117 (left to right, top to bottom) Prototype assembly process



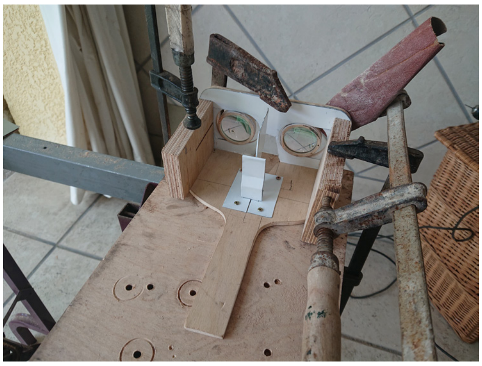
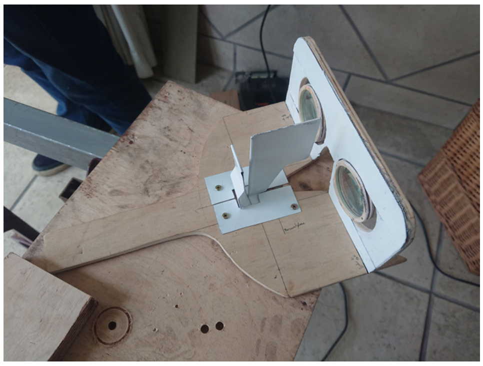
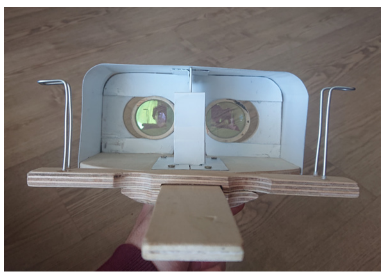



Fig. 118, 119 & 120 (left to right) Finished wood and sheet metal prototype





It should be noted that the choice of materials was restricted to the materials we had at home, as were all the gluing and cutting techniques, as we were going through a period of isolation, caused by Covid-19.

With the display fully assembled, we tested the smartphone support mechanism and the position of the lenses. The smartphone holder was too tight and had to be opened as it damaged the screen of the test smartphone. The lenses were working perfectly, which meant that the goal of creating a stereoscopic display capable of supporting a personal smartphone and providing the viewing of any kind of stereoscopic content, as intended, had been achieved. At this point, all the prerequisites for the display had been achieved and we had created a fully funtional device.

Final Spectare Model

After having tested several old stereoscopic photographs and 360º images on the wood and sheet metal prototype, we felt that it was not able to provide the tactile experience that an old stereoscopic viewer was capable of. This was due to the aesthetics of this prototype, which was a kind of "Frankenstein's monster" made of many different types of materials and colours.

At this stage, we had already decided that we would delay the delivery of the project, which allowed refining the body of the prototype in terms of materials. This refinement focused mainly on modifying two parts of the display: the use of wood instead of sheet metal to build the top of the display and a new mechanism for the lenses. Naturally, this new prototyping phase raised problems such as increasing the difficulty of construction and the cost of production. However, at this stage, it was already possible to have access to woodcutting and thinning machines, which allowed us to shorten the production time.

To facilitate the whole process, we tried not to change any of the measures used in the previous model. This new prototype would be built from scratch, without the need to recycle parts from the old model, which remains intact.

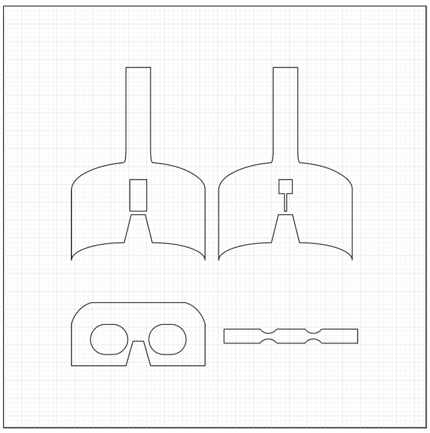


Fig. 121
Wireframe of pieces of wood to be cut in CNC machine

The base of this new prototype also had to be rethought so that it was only necessary to use sheet metal to produce the smartphone carrier part, which was now to be attached inside the base, that would be completely made of wood. The support piece could not be built in wood as it was impossible to mould it in the same way as metal. The solution found for the base was to cut out two pieces, each with different cuts, which, when glued together, allowed the smartphone support piece, which had been inserted between the two base pieces, to move without being able to free itself.

The new face had a much more complicated solution to achieve. Since we wanted to try not to use sheet metal to rotate and hold the lenses, several proposals were discussed on how to do it with wood only. The solution chosen was the one we thought could not fail, even if it was complicated to achieve. It was necessary to cut 3 faces of equal length and width, but of different thicknesses. Inside the two pieces that had the greatest thickness, it was necessary to sand the wood, in the opening for the lenses, at an angle of approximately 60º in the area where the lens case would be fixed. It had to be tested several times to make sure the sanded area was deep enough, which required a lot of time and focus because if we sank the wood too deep, it would allow the lenses to move inside the face by themselves, which required redoing the whole piece again. Between these two thicker pieces, a thinner piece was placed with the holes for the lenses, large enough to fit the entire diameter of the lens casings, with the function of creating more space so as not to damage the casings while they were being moved (fig. 126 to 128). Extra care was needed when glueing all the pieces together, to make sure that the casings did not stick to the wood around them, thus damaging the whole face and lens.

Fig. 122
Drawing of new lens mechanism

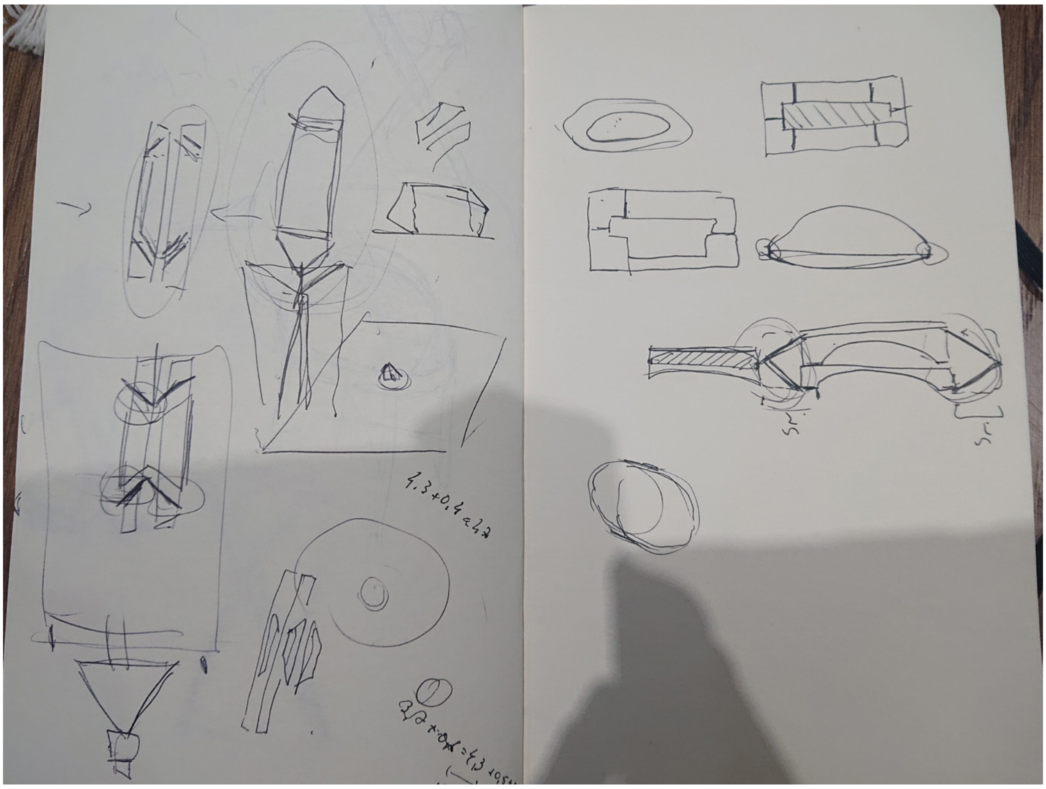




Fig. 123
(left)
Wood cuts for new lens casing

Fig. 124
(middle)
Sanding of wood cuts for new lens casing

Fig. 125
(right)
Glueing of wood cuts for new lens casing

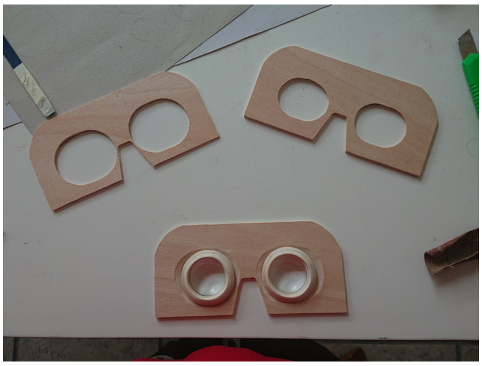
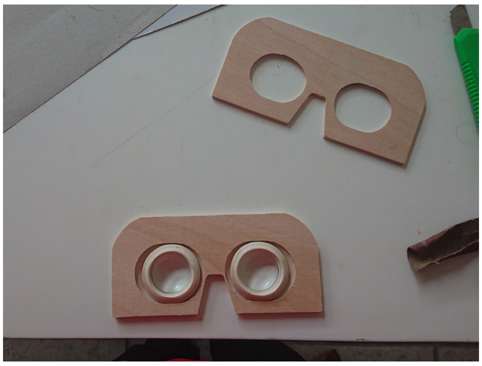




Fig. 126, 127 & 128
The various steps of glueing the face pieces with the new lens mechanism

For this new face piece, the used lenses were only 3.7cm in diameter, as they were cheaper and easier to find available for sale. To encapsulate the lenses, it was also necessary to rethink the casings we would create, as the previous design would not work on this model.

For each lens, two donut shaped pieces of wood were cut out, which had to be sanded on the inside and this time on the outside as well, in order to create a final piece that could be rotated by hand inside the face of the stereoscopic device (fig.123 to 125). Both wooden pieces were glued with the lens inside and sanded again if necessary (fig.126 to 128).

The most complicated part of this prototyping phase was undoubtedly the creation of the top piece of the device completely in wood.

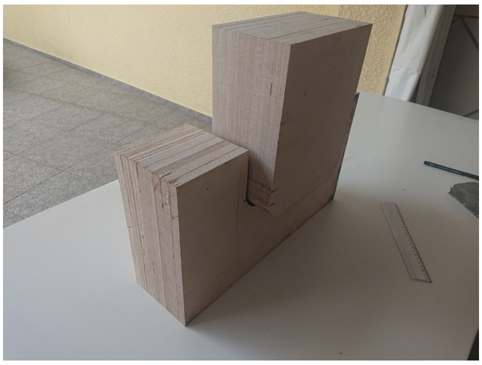
This piece became particularly complicated to make because it had to be curved. The goal was to recreate the top of the previous prototype, but, for that, it was necessary to mould wood, which was difficult and time consuming to achieve, besides having to be made with 1mm wood sheets, something that is not easy to find for sale, besides being expensive. It was necessary to create a custom mould with the exact measurements for the execution of this piece exactly like the one created with metal sheets (fig.129).

To mould the wood, 7 stacked wood sheets had to be glued together and placed inside the mould to dry for a minimum of 24 hours.

Due to the difficulty in getting the angle of each of the sheets right when glueing, the first attempt was a failure, which required creating a new top piece. Once the second top had dried, it was necessary to cut it to the exact measurements. A shape was also deburred in the upper area of the top piece to facilitate the positioning of the user's head (fig. 132), just like the top piece made of sheet metal.

Fig. 129
(left)
Wood mould built for the device top piece

Fig. 130
(right)
Wood mould in use (7 wood sheets are being compressed inside the two parts of the mould for 24 hours)



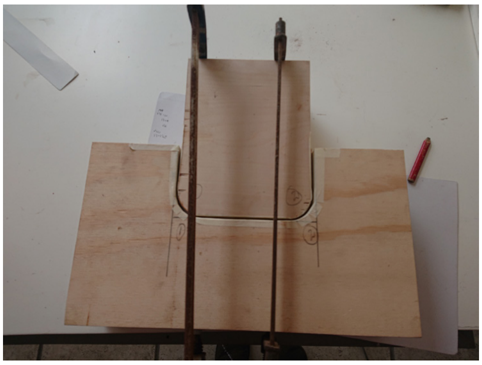
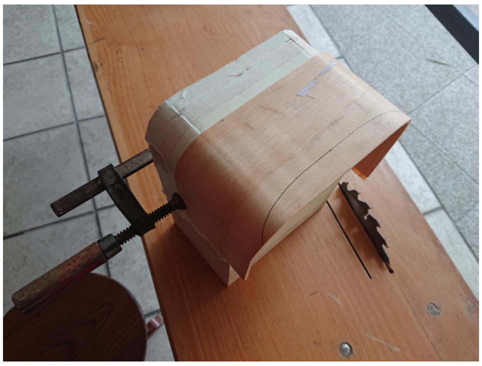


Fig. 131
(left)
Wood top piece drying in one of the mould pieces

Fig. 132
(right)
Wood top piece ready to be cut and sanded



Once all the pieces were ready (fig. 133), they were glued in the order used in the previous prototype, a process that takes approximately 24 hours. To finish, the entire prototype was lightly sanded and painted, using a dark paint to recreate the Victorian aesthetic and to protect the wood from the elements of nature (fig. 134).

Fig. 133
(left)
All of the new prototype pieces

Fig. 134
(right)
Painting of new prototype pieces

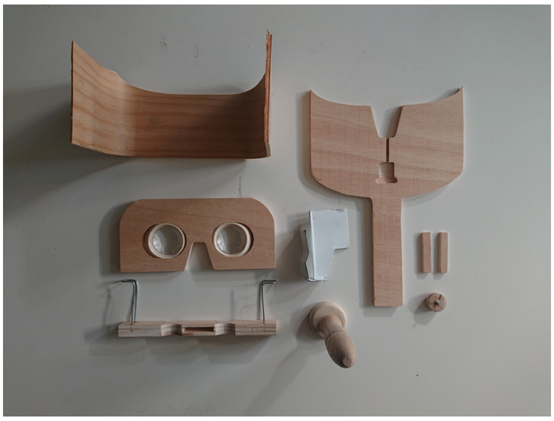


Fig. 135 & 136
Painted and assembled new prototype

This new model had the particularity of not hurting the user's face when being used, as it had no sharp surface that would allow this, unlike the previous model.

At this point, we thought we had completed the prototype until we tested it. Thanks to the change in lens size, the distance between them was too big, which did not allow us to see the stereoscopic effect in the images we tested. This meant that it was necessary to redo the entire face of the device to make it functional, which took us about a week.

It was necessary to cut, sand and re-glue all the pieces that made up the face of the device, already with the correct measurements between lenses. To achieve this, it was necessary to reduce the space where the nose is placed, thanks to the size that the lens casings occupied inside the face of the device.

It was possible to dismantle the whole prototype with caution, so as not to break any of the constituent parts, because the glue was not yet completely dry, which allowed us to reuse all the other parts that were well built. We didn't paint the face piece for for aesthetic reasons.

Once the face was complete, we glued all the parts of the display together and the final prototype was finally completed, mostly made of wood and fully functional, able to ensure all the prerequisites chosen at the beginning of the prototyping.

Fig. 137
Front view of Spectare device

Fig. 138 & 139
Different views of Spectare device

Fig. 140
Individual handling Spectare device

Fig.141
Individual handling Spectare device

This model weighs 360 grams in total, just 280 grams more than the paper model and it takes at least 4 days to fully assemble..

With the conclusion of this prototype, we felt it was necessary to create a complete experience, which included the stereoscopic display, stereoscopic cards and online software, to test it on people who had not had contact with the project, in order to understand what bugs still needed to be fixed in the display.

Spectare simplified model

Through the feedback gathered from the tests that were made with the complex wooden model, we realized that there were some aspects in which it needed small improvements to provide a better user experience.

We also realized that it would be interesting to have more than one device available for the final experience of the project, made in cooperation with the Santa Cruz project, which made it necessary to build more devices.

However, it wasn't necessary to produce new devices as complex as the previous one, since none of the users that tested the device needed to use one of the features that made it complex, the possibility of modifying the distance between lenses.

Therefore, it was decided that the new displays would have fixed lenses, 6 cm apart from their centres. In this way, it was only necessary to cut out a single piece for the face of the display and glue the new casings onto it, casings which also became easier to produce (fig. 146).

Spongy fabric has also been added to the smartphone support mechanism, in order to better hold users' smartphones and protect their screens, especially those without a screen protector (fig. 160).

The cardholder has been redesigned to make it more robust. Its construction required the cutting of more parts that were also simplified. In the hole where the display base arm is inserted, two small tailor-made pieces were added to prevent the cardholder from turning sideways when the users interacted with the device, something that happened a lot during the tests and that made it harder for the smartphone to read the card (fig. 153).

All these changes had no impact on the production cost or weight of the device, but made it more robust and safer to use.

A total of 5 new displays were produced, two of which were used in the Claustro da Manga experience and the others are kept for possible new experiences in the future.

We had the ideia that all of the produced devices should have some kind of identification. Our choices were the Spectare and Santa Cruz projet, since they always supported us and we would use the devices as a way of showing the work of that project. As soon as we had green light from them, we printed both logos in the base of all of the devices (fig. 154).

Fig. 142
(left)
Cut wireframe with new designed pieces

Fig. 143
(right)
All the pieces cut in CNC machine

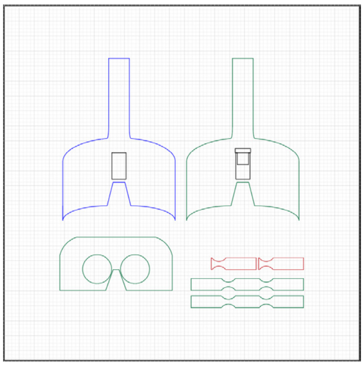


Fig. 144
(left)
Prototype component: handle

Fig. 145
(right)
Prototype component: smartphone support piece

Fig. 146
(left)
Prototype component: new lens casings

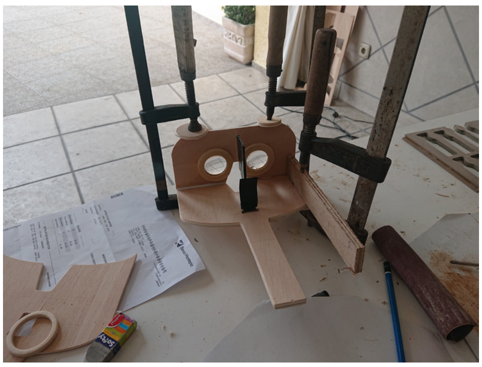
Fig. 147
(right)
Prototype component: wooden tops

Fig. 148
(left)
New lens mechanism

Fig. 149
(right)
Base glueing

Fig. 150
(left)
Face and base bleuing

Fig. 151
(right)
Almost finished model



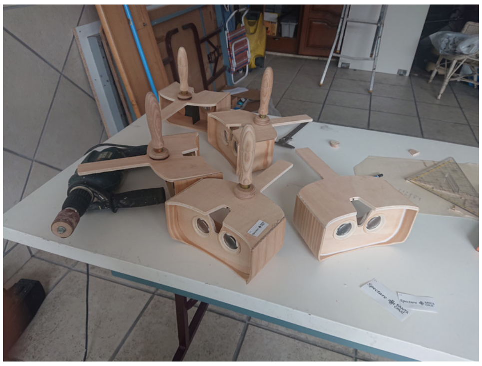



Fig. 152
(left)
Testing of logo printing size in finished models

Fig. 153
(right)
New cardholder design

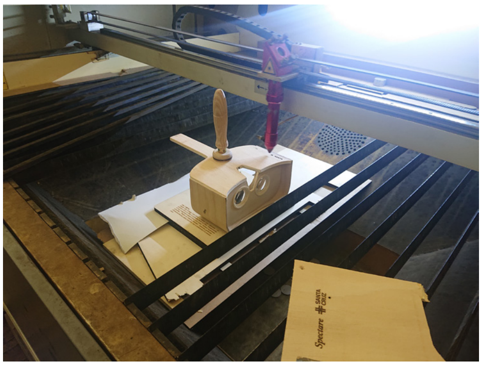



Fig. 154
(left)
Logo printing process

Fig. 155
(right)
Finished models




Fig. 156 & 157
(top)
Different views of Spectare Simplified model

Fig. 158 & 159
(bottom)
Spectare Simplified and complex models side-by-side in different views

Fig. 160
Spectare simplified model

(with focus on the enhanced smartphone support mechanism

5.5. STEREOCARDS

In this project, the stereoscopic cards had the very important role of not only providing an experience closer to the original one of seeing a stereoscopic photograph but also of being the link between the content outside and inside the smartphone screen. The concept was always to get the smartphone to read the card and that action would trigger stereoscopic content to appear on the smartphone's screen.

These cards don't need to use stereoscopic photographs, as the lenses of the device we built can only be used for viewing on smartphone screens at small distances. However, to replicate the original experience as closely as possible, we have taken inspiration from the way these cards were constructed in the past and tried to replicate that construction in a way that is appropriate for this project. Most of the photographs used in many of the cards we will demonstrate are not stereoscopic, due to the limited amount of stereoscopic photographs available from the eras and locations we worked with.

We will therefore demonstrate how these cards varied throughout the prototyping process.

Early stereocard prototypes

In the initial prototyping phase there was still no idea of what the cards that the smartphone would read would look like. At this point, the goal was to get the software, through the smartphone's camera, to be able to read Barcode markers (fig. 161). These markers are part of a collection created by Nicolo Carpignoli, which can be read with the help of the AR.Js library, and thus give the trigger to make some kind of content appear on the smartphone or computer screen.

Fig. 161
(left)
Barcode marker example

Fig. 162
(right)
Screenshot of smartphone reading barcode marker and displaying a 3d model

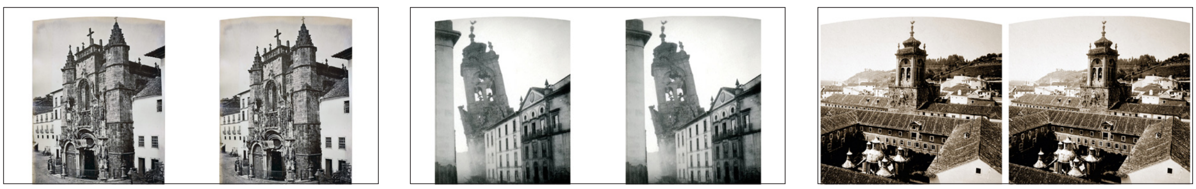
The first approach in this implementation was to try to display content — in this case a model of a dinosaur — as soon as the smartphone could find the marker, as a way of testing the marker tracking capabilities (fig. 162).

Once we had achieved this objective, the next step was to be able to use images chosen by us to use as triggers, or in other words Natural Feature Tracking (NFT). The way NFT works is by reading and converting an image we chose into a format that AR.js would be able to read, using that image as if it was a marker. By reading the NFT it was possible of tracking the image chosen in the first place. It was not possible to use any image, as there is a classification system that says whether images are legible or illegible to be used for tracking depending on their readability.

At this stage, we already had the concept formed of creating cards similar to those used during the second half of the 19th century (fig. 13), so we collected several variants of these cards and started developing designs that used old images from Coimbra that the software could easily recognise.

The design that seemed most natural, inspired by the photographic references collected, was to position two images together in the centre of a 17x8 cm card, enclosed by a frame with a round top. The images were used with the two original proportions to be read more easily, which made all the cards look different and there was no hegemony between them (fig. 163).

Fig. 163
Initial stereocard design



This design worked, but it was far from professional and interesting. While we were improving it, we ran performance tests on the interface that was using them and realised that NFTs were overloading the software, leaving the framerate on smartphones very low, which made us chose to use Barcode markers over NFTs. However, the design that was being created looked interesting and so it was decided to try and merge it with Barcode Markers.

Evaluation Test stereocards

Once we started testing card designs with images and barcodes together, the need arose to complete an interface to do Spectare usability testing and this card would be used in it. Since it would be interesting for users to evaluate the card's design, we chose to collect more information on stereoscopic cards and try to create a functional and interesting final design for the test.

While searching we found information about the anatomy of the stereoscopic cards commonly used in conjunction with the Holmes Stereoscope (Lee, 2021). As this stereoscope was one of the biggest influences for this whole project, we decided to rely on this information to create our own cards.

In the design that was being developed, the main focus was on how to combine the use of photos and barcode markers. We did several tests to understand the minimum size the barcode marker needed to be in order to have no reading loss from a smartphone camera. The size that had the best space/functionality ratio was 1.1 cm per side, which became the size for all barcode markers to be used from that point on.

Another functional option also adopted was the use of several identical markers in several places on the same card, thus decreasing the possibility of smartphone reading loss and allowing smartphones with different camera positions to read barcode markers more easily.

From the information gathered (Lee, 2021), the first design change was to adapt the standard size of the card to 18 cm long by 9 cm wide. The frame surrounding the images was also updated so that the images are no more than 8 cm high and a bottom bar was added so the image doesn't reach the bottom of the card. As for the measurement between the two images, it was not increased as we liked the aesthetic effect that already existed, plus there are several stereoscopic photographs with both pictures touching in the middle of the card. The free space on each side was used to place two barcode markers, the name of the project and the title of the card, numbered by its viewing position in the experiment. In most old stereoscopic photographs this space was blank, but we thought it would be better to use it to contain useful information. There were various variations of what information was used in this space while experimenting with what options were possible for a final design (fig.164).

The photographs used in these stereocards are not stereoscopic photographs, they are duplicated and moved slightly, in order to emulate the layout of an old stereoscopic photograph since there were few available stereoscopic images.

Fig. 164
Variations of the front side of stereocards design, with different typography, spacing, number and size of barcode markers and content location

The backside of the card had not been explored much yet, as it did not have crucial information for the functioning of the interface. The solution for it was to use it to place information about the project and the content that the user would experience with it, in case they were interested in reading more about both. Taking into account the interest in testing the project with people who were not Portuguese, there was an incentive to write all the content used in Portuguese and English, a choice that was made for all the content used in the Usability test contents.

A QR code and the link to the website where the interface was stored was also inserted in this backside, so that people could use it if they only had that card at some point and wanted to access it.

All the measurements used on the front of the card were also used on the back, to unify the design and not create redundancies. The headings are in the corners of the card, written vertically and are relative to the body of text closest to them. Between the texts, there is a line that cuts through the content relating to both titles. The colours used, as in the rest of the whole project, were black and white.

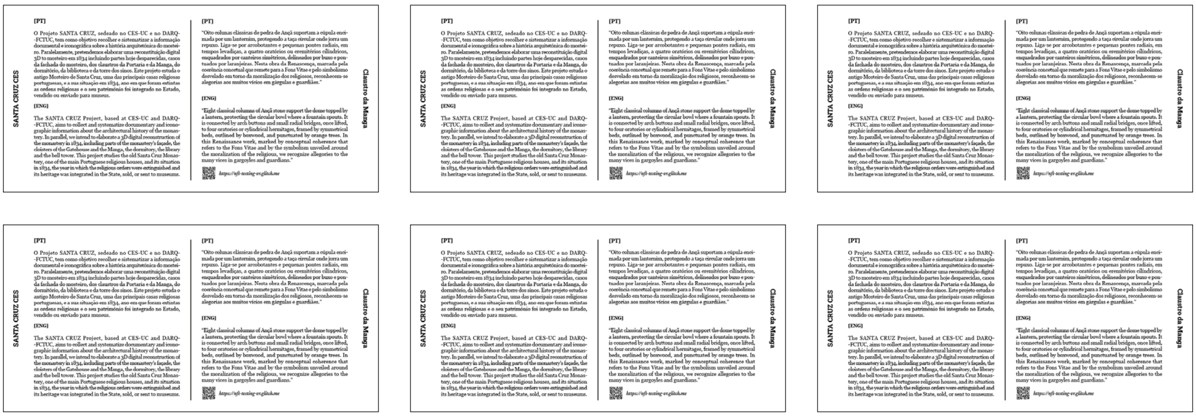
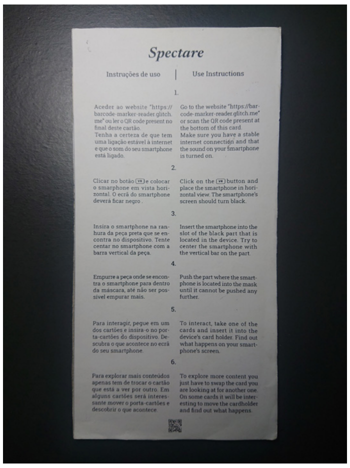


Fig. 165
Variations of the back side of stereocards design, with different typography, spacing and content location

For the instructions, a typographic-only card was created, which described all the steps for using the device, which we had already thought of redoing for the next experiment (fig. 166) with the inclusion of pictograms.

For this experiment, the theme chosen was the city of Coimbra and therefore all the photographs used were from different areas of the city, collected from several online collections.



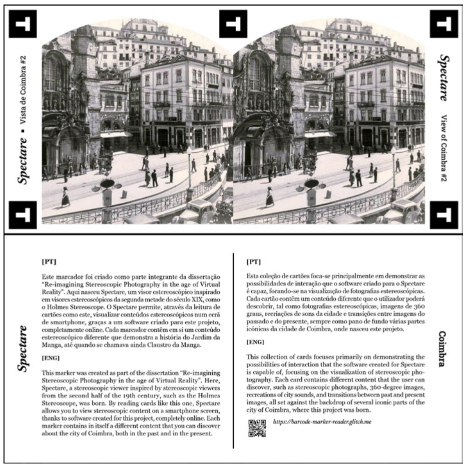


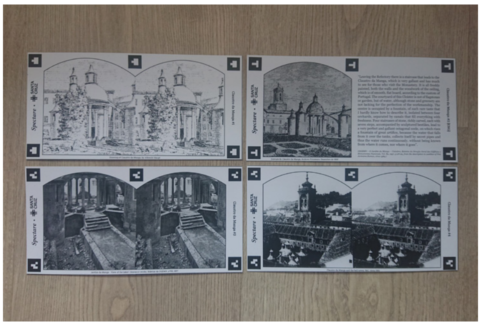
Fig. 166
(left)
Instructions Card

Fig. 167
(left)
Final stereocard design

Claustro da Manga stereocards

During the usability tests, we were not able to get any constructive comments regarding the stereocards. On the other hand, for the instructions, we received several comments recommending the use of images or figures, as it is easier to understand than the exclusive use of typography, something that we had already intended to do. This interface was different from the previous one as it was completely formed through the material provided by the Santa Cruz CES project and focused on a unique area of the Santa Cruz Monastery, the Claustro da Manga, which was one of the areas of the monastery that had undergone the most changes since 1834.

The whole design of the card changed. On the front side, the images were framed in black, because it was sometimes difficult to see where the boundaries of certain images were, due to the quality of those images. Besides that, the whole card got a black border to increase the contrast in the space near the Barcode markers, something that we found out at printing that is not a good practice because the lines can get badly cut and the border doesn't look perfect (fig. 169). The Santa Cruz project logo was added and both logos were strictly on the left side of the card. The right side was reserved for the title of the experience and the number of the card we are looking at. In the area below the images was added the legend of the image.



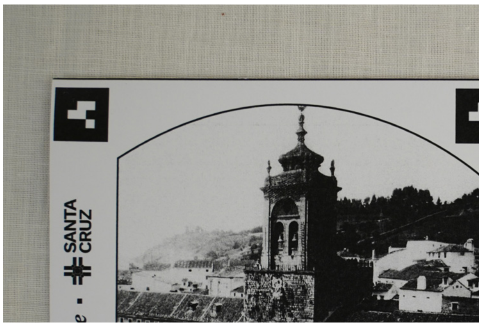
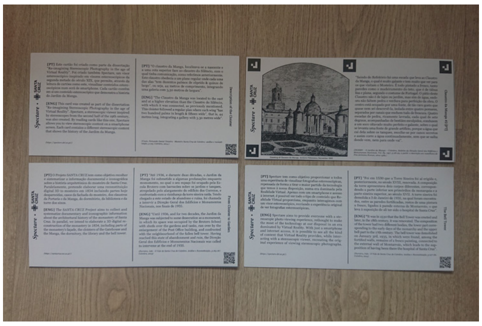


Fig. 168
(left)
New sterecard front side design

Fig. 169
(right)
Detail of printing and cutting problems



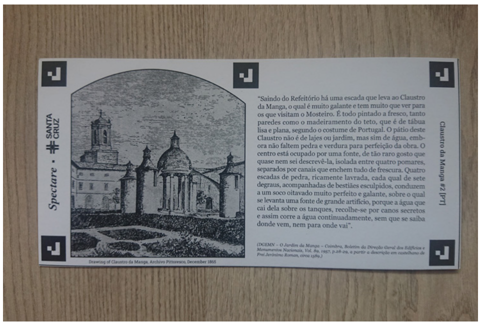


Fig. 170
(left)
New sterecard back side design

Fig. 171
(right)
Second stereocard from Claustro da Manga Experience

On the back side, the logos were also left and on the right side, we have the title of the text it is associated with, which describes the image we see on the front side of the card. All the texts have been shortened and the font size increased for better readability. Each of the texts on the left side of the card is an explanation of either Spectare or the Santa Cruz project, with a link at the end for anyone interested in finding out more information. On the right side, there are texts taken from historical documents describing the Cloister or parts of the Cloister, also with a caption at the end to reference the author. In case the user has access to only one of the cards, we placed the QR code that leads directly to the interface in the bottom right corner, exactly where there is a barcode marker, on the front side of the card.

This final design symbolizes exactly the concept thought for the project, the junction of important characteristics existing in the cards from the past, in an updated and simple layout.

There was however a card that had some characteristics that made it different from the others and that made other different design proposals appear. Being this an experience thought for the use of regular visitors of the place and for tourists passing by, all the contents needed to be in Portuguese and English. In this card, the idea was to use the recitation of a text taken from an old bibliographic source in Portuguese and also translated into English.

For this reason, it was necessary to use two different barcode markers, each one linked to a recitation in a certain language. To have different barcode markers, it was not possible to use the design that the other cards had. One of the design options was to turn one of the images upsides down and swap the barcode markers on that side of the card, so that when you rotate the card the smartphone reads the different barcode markers (fig. 172). Another option was a design of a card that would have a wheel on its back with several different barcode markers and which, when rotated, would cause one marker at a time to appear in an open hole on the front of the card (fig. 173). Because of their complexity, both designs were discarded.

Fig. 172 & 173 (left to right) Discarded design options for second stereocard

The design chosen for this card was a third option where the front side of the card was only Portuguese and the back side was only English. Most of the components stayed in the same position as the other cards. However, only half of the picture appeared on each side, having accompanying it an excerpt of the text that is recited on the interface when it reads the right barcode marker. This was the option that seemed the simplest to the user that did not stand apart from the design that all the cards had together (fig. 171).

Another idea that came up for a card design that would aim to monetise this project in some way was to create a card that you could buy and send to other people, like a postcard. This concept was only tested digitally (fig. 174) and ended up not being used in any real-life situation.

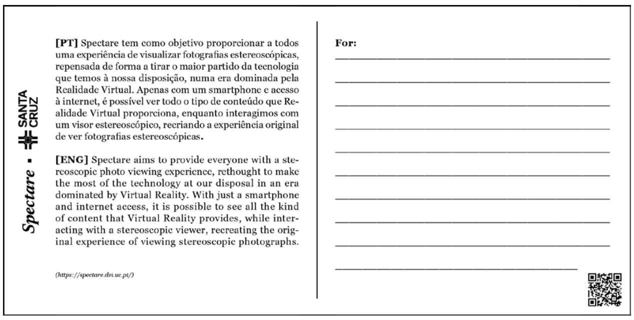


Fig.174 Back side of postcard like stereocard design

The instructions card (fig. 175) was the one that suffered the most changes. To follow the concept of the other cards, one side of the card was all written in English and the other in Portuguese. The number of steps was reduced to a minimum, as well as the amount of text used, thus giving priority to the use of pictograms created by us, that easily portrayed which actions were necessary for how to use the device and access the interface. All pictograms were black and white and their cut-out style, inspired by instruction manuals from large furniture companies, was on par with those used in the animations of the interface, so as to unify the design of the whole project. The QR to access the website was moved to the top right corner, in order to give more space to the pictograms. As in the other cards, a black frame was added around the whole card.

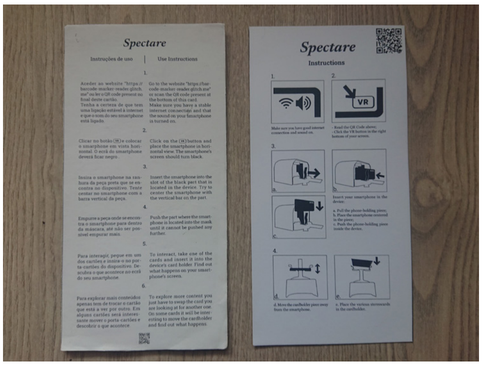


Fig. 175
(left)
New instructions card design

Fig. 176
(right)
Comparison of old and new instruction card designs

5.6. SOFTWARE

During the first stages of the stereoscopic viewer prototyping, we agreed upon starting to prototype the software that was needed to work in coordination with the stereoscopic device prototype. This choice was made to understand what technologies we would have to use and present what was possible to do in the very first stage of prototyping. There would be a continuation of improvement of this software and a start of the stereoscopic device prototyping and testing, alongside the testing of the software in the device itself, when that would become possible.

To start prototyping the interface, there was a need to understand the tools that were going to be used for it, which led to a need for research. A choice was made when we knew exactly what we wanted to do and what were the best tools to do it.

This interface allowed for creativity since there were no virtual environments in the 19th century, so we were able to try different ideas that could or could not make it into the final experience.

Programming tools

The first step to start this task is choosing the tools we will use to aid us in programming it. First of all, the software should be available to everyone who has a smartphone, so it should run on an online webpage, supporting HTML, CSS, and JavaScript, which

are programming languages. In order to create a virtual world online, in this case, there's no need for modeling software because all of the models were provided by the Santa Cruz CES Project. The only needed tool is to run those models in the programming languages that we're chosen, and, for this matter, there's a tool called A-Frame (Supermedium, 2021). However, there's still a need for a stereoscopic view enabler on the web, and for that exists the tool called Aframe-stereo-component (Miro, 2018), that works in coordination with A-Frame.
In the meantime, before the use of the tools presented above, there's a need for the tool that starts all of this process, a tool that allows a smartphone camera to read a marker that can be an image or a QR code alike marker, recognize it and show the content linked to it. This tool is AR.js (Etienne & Carpignoli, 2021).
In order to understand better these tools, I will follow explaining them in detail:

A-frame

"A-Frame is a web framework for building virtual reality (VR) experiences. A-Frame is based on top of HTML, making it simple to get started. But A-Frame is not just a 3D scene graph or a markup language; the core is a powerful entity-component framework that provides a declarative, extensible, and composable structure to three.js" (Supermedium, 2021).
As stated, A-Frame can be used simply on HTML with certain tags and lets us create a complete world in virtual reality that we can manage as we want. Also, it can be online as quickly as we want. It is possible to use models created in other platforms directly in the code and animate them if wanted. When our world is created, we can see it in our computer screen, or, the way that is important for us, see it in our smartphone screen with a VR headset or a stereoscopic viewer of any kind.

A-frame-stereo-component

This component (Miro, 2018), was created to be used alongside A-frame, by Oscar Marin Miro and adds to A-frame two new components for stereoscopy: "Stereocam" and "Stereo". "Stereocam" is a way of telling the A-frame camera - that is used by the user to see the contents that we created - on which eye of the stereoscopic view it should render. It knows if we are watching in a monoscopic display, or, if it finds a stereo display active, it should only display the eye that was defined in the code. "Stereo" is a way of telling A-frame which projection of the object in the scene is displayed in the left or right eye. This enables the use of stereoscopic video as well if desired.

AR.js

“AR.js is a lightweight library for Augmented Reality on the Web, coming with features like Image Tracking, Location-based AR and Marker tracking” (Etienne & Carpignoli, 2021). This library, in the case of this project, is only used for its ability of marker tracking. These markers are simple high contrast symbols that, by being read through the camera of a smartphone, should trigger an event that is coded. In some cases, if we want a personalized marker with an image, it can track it as well, enabling that image marker to be unique and only show the information that is attached to it, but, we need to create it first according to some rules.

Proxemics

"A Proxemic Interactions component for A-Frame" (Cardoso, 2021). This component, created to work in coordination with A-Frame, is able to calculate how far away a certain object is from the camera that is being used when we run a software with A-Frame, whether from a smartphone or a computer. This distance calculation is important when we want to modify something within our virtual world, depending on the distance being sent by the camera reading.

Early software prototypes

The first prototypes we created were focused on understanding the technology we had adopted. We experimented with using several different contents like a 360º image provided by the Santa Cruz project or a stereoscopic photograph taken from the internet, testing which contents could we use with these tools.

Another important focus at this stage was to prototype a program that could read images using the AR.Js tool. However, before we could read images, we started by reading pre-made patterns called Barcode Markers.

These markers (fig. 161) come in various sizes and are characterised by their high contrast, like the QR codes, making them need good lighting to be read. To understand whether or not the smartphone was reading the marker, we used a three-dimensional model of a dinosaur taken from the internet, which should appear whenever the card was being read (fig. 162).

There was the possibility for us to use custom Barcode Markers by using an image inside the marker, something we never tested for possible use as the existing Barcode Markers were simple and reliable in their use.

The next step was to test new stereoscopic content as photographs using the A-Frame-Stereo-Component tool, but this time by reading NFTs. NFT, by transforming an image into data that has to be loaded into the program we are creating in A-Frame, makes the program heavier compared to another program reading barcode markers, which downgrades the framerate of the interface.

During this phase, we programmed a virtual experience to explore all the contents that it was possible to use in a final interface. We tested the use of stereoscopic photographs, conventional photographs, 360º images, 360º videos and sound.

Tools with the potential to be used in experiments were also explored, such as having the camera on while the smartphone is not reading any cards, allowing the user to see beyond the device, or having a text block that always moves to the centre of the user's vision, no matter how much they move their head.

The path so far predicted that the experiment we were going to set up to do testing with people outside the project would use reading NFT and most of the stereoscopic content already tested by us. However, during one of our tests, we noticed that the framerate while viewing some of this content through reading an Nft was very low, often reaching 1 frame per second. With this framerate, it was impossible to have a pleasant and enriching viewing experience. We decided it was important to do performance tests on all the content that had been implemented, reading Barcode markers and also NFTs. The tests were done on several different smartphones we had at our disposal, both Android and IOS.

According to the results, the problem was how heavy it became for the A-Frame to read the NFT, especially having several in a single experience, while the Barcode Markers did not create any slowness in reading them. We also noticed that the performance difference in demonstrating stereoscopic and non-stereoscopic content was minimal on almost all smartphones.

From this collected data we decided that all virtual experiences that to be created would have to use Barcode Makers reading, which ultimately influenced the design of the stereoscopic cards we were designing, and when it was possible, use non-stereoscopic images to save on the data traffic that was needed to load the interface.

Usability tests interface

Once the prototype of the Spectare device (fig. 139) was finished, it was necessary to test it with a large number of people who had never had contact with it. This opportunity created the need to have a virtual stereoscopic interface that could be used together with the device and the customised stereoscopic cards.

The theme chosen for this experience was the city of Coimbra.

We chose 4 different contents linked to 4 different photographs of Coimbra, used in 4 stereocards. These contents were meant to show the different content possibilities that Spectare was able to demonstrate, focused on stereoscopic photographs, and understand people's reaction to these contents.

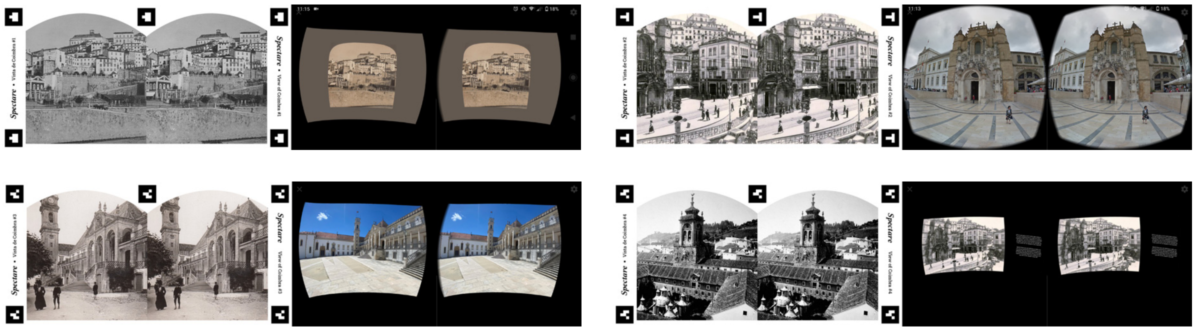


Fig. 177, 178, 179 & 180
(left to right, top to bottom)
Usability tests stereocards
(left) and their related contents
(right)

The first card contained a stereoscopic photograph of the entire city in the early 20th century (fig. 177). The second card contained a current 360º image of 8 de Maio Square (fig. 178). The third card contained two photographs of the university in the 1940s and today (fig. 179). The fourth card contained a photograph also of 8 de Maio square in the 50s of the last century, accompanied by a descriptive text and a soundscape created by us, which imagined the sound generated in that part of the city at the time the image was captured (fig. 180).

The second card had the particularity of containing two photographs, as we found interesting the idea of experimenting with demonstrating different contents depending on the distance the marker was from the smartphone camera. This idea came from the potentiality that the arm of the stereoscopic device, where the card holder was located, had. During much of the prototyping process this piece had no functional purpose, only aesthetic. However, the act of changing the position of the cardholder was part of the original stereoscopic photograph viewing experience and transposing that movement into this project seemed interesting. To do this, it was necessary to use the Proxemics tool (Cardoso, 2021), which was incorporated into the software in order to read the distance the Barcode marker was from the smartphone camera. If the distance was less than a certain value, the first image appeared in the experiment. If the distance was bigger, that image would disappear and the other would appear(fig. 181). In this way we were able to give a functional purpose to this movement and created the interaction that users found most interesting during usability testing.

Apart from the photographs that appeared in a fixed place in the interface, no other content or animation was added to this it, forcing the user to focus on the content that appeared from each of the cards.

Fig. 181
Different views of third
card content using
Proxemics

Claustro da Manga Interface

The Claustro da Manga interface was the last interface developed in this project. The goal was to create an interface with material provided by the Santa Cruz CES project focused on the former Claustro da Manga, now converted into the Manga Garden. We focused on this space of the Santa Cruz Monastery due to the various modifications it has undergone since the year 1834, the year in which the Santa Cruz project was based to digitally reconstruct the complete Monastery.

In this prototyping phase there was the intention to create a more elaborate and enriching interface than the one created before, because we already had all the feedback collected during the usability tests and we knew what we had to improve and add. This interface was to be part of an experiment conducted on the terrace of the Mango Restaurant, located in the Mango Garden, with the purpose of evaluating Spectare's performance in a non-controlled in-the-wild environment.

Fig. 182
Terrace of Mango Garden Restaurant

This interface also used 4 cards, each with a different content.

The first card contained a 360º image of the Mango Cloister modelled three-dimensionally, from the same point of view as to where the users were standing, so they could easily find the differences between the past and the present (fig. 183).

The second card contained a 360º image of the three-dimensionally modelled Manga Cloister, but from a different position than the previous content, making it easier to see the whole Cloister and the Bell Tower (fig. 184). Depending on which side of the card we chose, we heard a recitation of a 16th century text describing this Cloister, either in Portuguese or in English.

The third card contained two photographs of the Cloister, one from a period when the Cloister was clearly in a process of degradation and the other from the period when the Cloister was transformed into a Garden, as it is today (fig. 185). To view the different photographs the Proxemics component was used once again.

The fourth card contained three 360º images of the whole Monastery from an elevated point of view, centred from the

Mango Cloister (fig. 186). All the images were entirely the same, what changed was the material used to fill the three-dimensional model of the Monastery, thus demonstrating the stages that the Santa Cruz Project went through to get the final model. One image showed the wireframes of the model, another showed the monastery with a final texture and the final image showed the model with the final textures. If the smartphone was close to the smartphone, the image with wireframes would appear. Changing the distance to an intermediate value would switch to the image with glass textures. If the distance was increased, the model with final textures would appear, thus creating a timeline of the more distant the card is, the more developed the model is, a concept created through the feedback collected in the usability tests (fig. 188, 189).

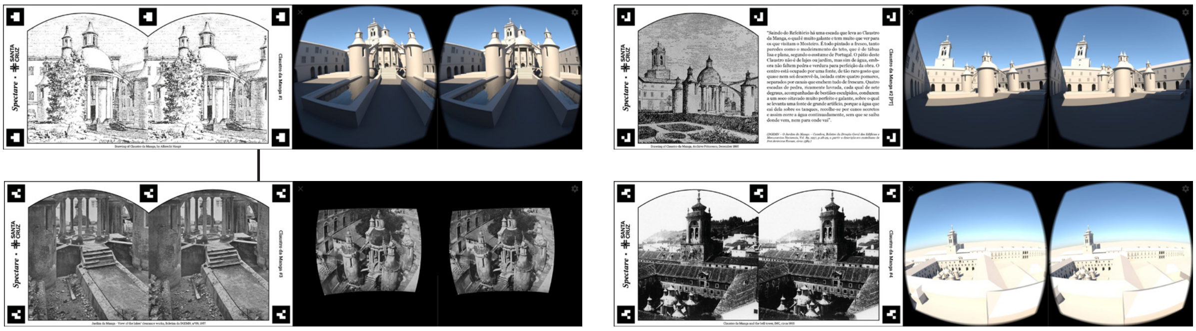


Fig. 183, 184, 185 & 186 (left to right, top to bottom) Claustro da Manga stereocards (left) and their related contents (right)

In addition to the contents of each of the cards, there were several additions to the interface to make it more complete.

As soon as the user connected to the interface, they entered a completely black environment and were greeted with images of the Project logo, the Santa Cruz project logo and the name of the Experience (fig. 187). These images were animated so that they would appear and disappear after a period of time chosen by us. Then an animated gif appeared, with a design identical to the one used in the instruction card, which warned the user that he had to insert a card in the cardholder. Each time the user inserted one of the first two cards, a timed animation appeared, warning the user to rotate the display and head to fully explore the content they were being exposed to. In the third and fourth cards, the animation that appeared warned the user about the possibility of moving the cardholder, since most people didn't know they could change the content they were viewing that way, information collected in the usability tests.

In the third card, because they were images that didn't occupy the whole field of vision, animations were added in all the environments around the user, warning in which direction was the content of that card. The decision to fix these images that occupied small fields of vision in a fixed point was made thanks to the lenses that the stereoscopic displays used for this experiment had. Thanks to their low quality, these lenses can only focus on a small central point, which makes it not easy to see all the details of photographs without having to move the viewfinder. For that reason, we fixed the images, forcing users to explore the images by moving their heads more.

All the animations in this interface were white over the black background, to be easily visible and to be in accordance with the colours chosen for the concept of the project.

This interface was only able to be used in Android devices, since IOS was not able to run the A-frame version we needed.

Fig. 187
Claustro da Manga experience introductory panels

Fig. 188
Different views of third card content using Proxemics

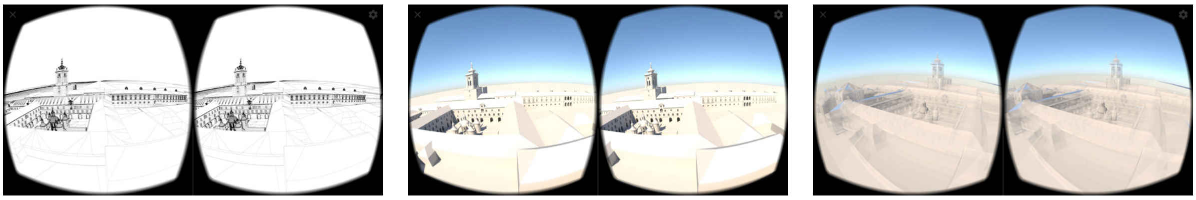


Fig. 189
Different views of fourth card content using Proxemics

6. EVALUATION

Evaluations are an integral part of the prototyping process. Whenever we go through a prototyping process in which we are trying to create a product, physical or virtual, it is important to test it to be able to understand and correct what errors it contains. These tests should be done mainly with people who are not directly connected to the project, as they tend to have a more open and broad vision of the product, which increases the number of suggestions and comments that can help in the success of the product. This is not to say that the creators of the product are not constantly testing to modify details during the prototyping phase, but an outside view can increase the chances of success and the quality of the prototype in the iteration made after testing.

In addition to all the internal testing of Spectare, we subjected this project to three phases of testing, the first with usability testing, the second with testing by some of the users of the previous test with a better interface and new simpler devices, and the third phase of in-the-wild testing.

6.1. USABILITY TESTS

Procedure

In order to be able to find faults and problems that existed in the final Spectare device, the stereocards and the software created until that moment, we performed a usability evaluation. For this evaluation, we used the System Usability Scale (SUS) (Brooke, 1996), a variation of the Microsoft Desirability Toolkit and the NASA Task Load Index (NASA TLX) (G. Hart & E. Staveland, 1988). The SUS was used to get a general idea of usability of the device . The Microsoft Desirability Toolkit (Barnum & Palmer, 2010) was used to express the user experience by choosing 5 words from a 25 word list we adapted from the original one. The NASA TLX was used to understand if the manipulation of the device has led to any discomfort to the user.

For the execution of these tests we used the final Spectare Model (fig. 139) and the Usabiliy Tests experience (fig. 177 to 180).

Each test had an average duration of 30 minutes.

The tests unraveled in the following steps:

(i) A small period of time would be given for the participant to handle the device and the stereocards while trying to better understand both;

(ii) We would explain what did the test required the participant to do, what was the project about, a little background on stereoscopy and stereoscopic photography, and how the test was going to be done;

(iii) The participant would fill a demographic questionnaire, as well as sign an informed consent;

(iv) The device and an instructions paper would be given to the participant and they should use its smartphone to enter the website, in order to read all stereocards, one by one, in a specific order;

(v) After having experienced all of the stereocards contents, the participant would fill another questionnaire that included the SUS, Microsoft Desirability Toolkit, and the NASA Task Load Index, to evaluate the experience;

(vi) After completing the questionnaire, we did a short interview with the participant where he/she was free to express what they liked most about this experience and what suggestions he/she had for improving the design of the device, the cards and the virtual interface.

The fourth step described before was divided into four tasks which were meticulously observed and notes were taken for further analysis. The tasks were:

T1 — Load the software (web page) in their smartphone by reading the QR code or the link from the instructions card;

T2 — Insert the smartphone in the Spectare device, making sure that is perfectly centered, in a way that the message that appears on the smartphone screen would be readable;

T3 — Insert a stereocard into the cardholder of the device and view the content linked to each card (four different cards in total);

T4 — After reading all the cards, remove the smartphone from the device and pack it as it was originally.

We were always taking notes regarding the participant's behavior, what strategy would they use to get to the goal of the task, what would they struggle with within the experience and all of the errors that would show up. We rated the participants' task completion using the following score values:

— 0%: fails to complete the task correctly, gives up, or succeeds only with assistance from moderator;

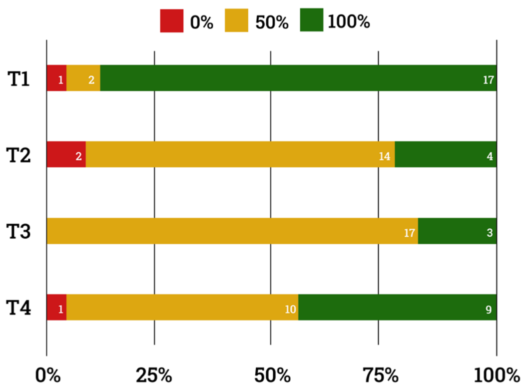
— 50%: succeeds, but in a roundabout way, making mistakes, needing to backtrack.

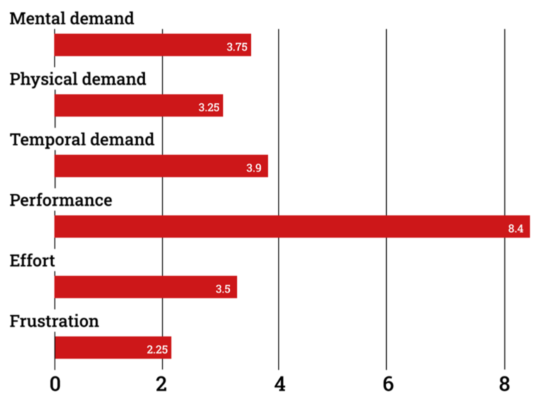
— 100%: succeeds quickly, following the route the designer intended.

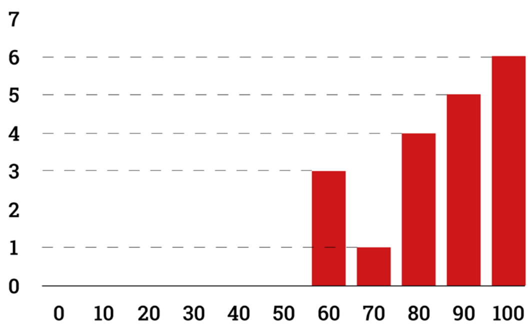
We recruited 20 participants through direct contact/social media/departmental mailing list. The ages were between 16 and 30 years old, with an average of 22 years old. Eleven participants had never used a smartphone enclosure to experience VR. Of the nine that had, five were interested in VR experiences and VR in general. Half of the participants were involved in the design and technology areas, while the rest were involved in areas like psychology, law, and history. This ensured a good balance between people with different interests and mimicked a public that would use this device in a real case environment.

In most cases, the participants were tested in their own house, in a place where an internet connection and a good source of light were secured. One participant was tested in a room of the Computer Engineering Department with all of the aforementioned factors.

Results







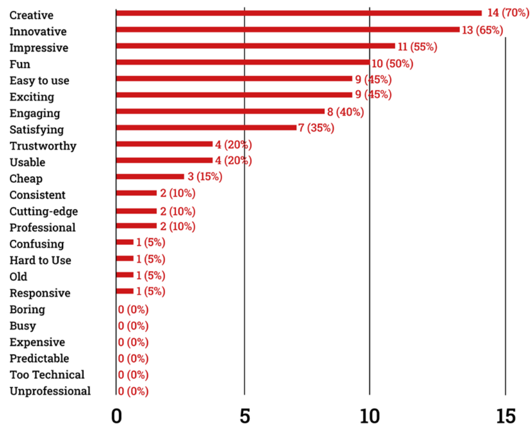


Fig. 190
(left, top)
Task completion rates chart

Fig. 191
(right, top)
SUS results chart

Fig. 192
(left, bottom)
NASA TLX results chart

Fig. 193
(right, bottom)
Miscrosoft Product Reaction Cards results chart

Regarding task completion rates (fig. 190):

— Task 1 was successfully executed by most participants, except for three participants in which the software did not run (1), or on which it ran but did not enter VR mode (2). This task completion average rate was 90% and its mode was 100%;

— Task 2 was a bit more difficult for participants and the great majority (14) forced the smartphone into the device without first pulling out the metallic clip. One participant gave up trying to insert the smartphone. This task completion average rate was 55% and its mode was 50%.

— Regarding Task 3, all participants were successfully able to insert the stereocard and view the associated contents. We rated most (17) as 50% because participants did not understand the interaction where they could move the stereocard along the arm to change the content, or because they did not understand they were viewing a 360° photo and could thus rotate their heads around.

Task 3 completion average rate was 57.5% and its mode was 50%.

— In Task 4, one participant gave up trying to remove the smartphone (the same that gave up in trying to put it inside), and ten participants pulled the smartphone out without first pulling the smartphone support piece, leaving this task completion average rate at 70% and its mode at 50%.

The general average rate for all the tasks completion rates combined was 68.13% and the general mode was 75%.

Regarding the results of the SUS (fig. 191):

— In a scale from 0 to 100, the general average score was 79.5, which is classified as an above average score (68 being already an above average result (Brooke, 2013);

— The lowest individual score was 55 and the highest was 100;

— The question with the worst results was " I think that I would need the support of a technical person to be able to use this device."

Regarding the results of the Microsoft Desirability Toolkit (fig. 193):

— The four most often chosen words were Creative (70%), Innovative (65%), Impressive (55%), and Fun (50%). Cutting-edge and Easy-to-use share the fifth place with 45% each.

— The six least often chosen words were Boring, Busy, Expensive, Unprofessional, Predictable and Too technical, all sharing the same 0%.

— Words like Old, Hard to Use, Responsive and Confusing were also chosen in low percentages (5%).

— Words with bad connotations were chosen the least in number, even though there was a balance between words with a good and bad connotation in the list.

Regarding the results of the NASA TLX (fig. 192), on a 10 point (1 to 10) scale:

— Participants' average response for how successful they considered their use of the device was 8.4 (in this item, the bigger the number the better). The minimum value was 2 and the maximum was 10. The mode was 9.

— As for mental, physical and temporal demands, effort required and frustration, their average answers fall below 3.9, far from the 5.5 midpoint (in these items, lower is better).

— Mental demand average score was 3.75. The minimum score was 1 and the maximum was 9. The mode was 1.

— Physical demand average score was 3.25. The minimum score was 1 and the maximum was 8. The mode was 1.

— Temporal demand average score was 3.9. The minimum score was 1 and the maximum was 10. The mode was 3.

— Effort required average score was 3.5. The minimum score was 1 and the maximum was 8. The mode was 1.

— Frustration average score was 2.25. The minimum score was 1 and the maximum was 9. The mode was 1.

Observation and comments

For all the IOS users, it was not possible to run the software on their smartphones, so they all used our personal smartphone. For android users, only 4 were able to use their personal smartphones for the test, forcing us to make our smartphone available to everyone else as well. In all the tests where participants successfully used their personal smartphones there was a large amount of time spent at the beginning for the smartphone to download google services that are required to view in VR. This process is required on all smartphones that had never been used for VR before and makes the experience complicated and time-consuming at the very beginning.

For 3 of the participants, it was unclear which side of the display they should put their face on, as they tried to put their face on the cardholder;

For 5 of the participants it was not clear where they should place the stereocards and after an explanation, 2 of them placed them in the opposite direction;

Two participants tried to see the stereoscopic picture of the card through the lens of the device;

It was not clear to 90% of the participants how to use the smartphone support piece, with them trying to insert the smartphone into the device without pulling the piece out of the device head or inserting the smartphone with the screen facing the wrong way, thus potentially damaging the smartphone and the device. Removing the smartphone from the device was also one of the biggest problems we observed, with participants either not pulling the part out of the device head to remove the smartphone safely or not being able to move the smartphone support piece with fear of breaking it, even though it is made of sheet metal.

After having the smartphone ready, 6 of the participants tried to put the stereocard into the cardholder with the device on their face, thus not being able to see what they were doing. All of them had to move the device away from their faces to be able to put the cards in the cardholder.

Four participants went about stacking the cards in the cardholder, while all the others went about putting in and taking out the cards without stacking.

Half of the participants didn't realise they could detach the cardholder. Only 2 participants out of the 20 were able to move it as intended by us, with all the others trying to pull the cardholder from one side only, which caused it to turn and lock.

All participants who had never had contact with VR did not realise that they could turn their heads to modify their field of view.

All participants liked the use of sounds in the virtual interface, but in environments with sound distractions, it became impossible to discern the sounds without using headphones.

Six of the participants with no VR experience showed reactions of surprise when seeing content such as 360º images.

About 85% of the participants did not realise that they could move the cardholder to change content as they did not try to move it. On the fourth card, 7 of these participants thought that the features present on the cards were cumulative, which made them try to move the cardholder when it was not necessary.

Three participants who were familiar with virtual reality tried to move themselves back and forth, thinking they would also move within the contents of the experience.

One participant completely gave up trying to insert his smartphone into the device because he did not want to read the instructions. After we helped him he eventually saw the various contents, but again refused to remove the smartphone from the device at the end of the experiment. During the experiment, he showed no interest in trying out the cardholder or exploring the stereoscopic content in time.

Another participant gave up trying to use his smartphone in the experiment for fear of damaging it. During the experiment, he encountered several errors and rushed the experiment to try to finish the test as quickly as possible.

One participant tried to grab the head of the device with both hands as if it were an actual VR headset. When it was necessary to interact with the cards, he opted to grab the device in a generic way.

In two of the tests done in natural light, because it was late afternoon, there were tracking issues that made the experience difficult for participants. In contrast, in 6 of the tests done in completely artificial light, there were no tracking issues at all.

In two tests, the software had to be restarted because it was not running for the first time on the participants' personal smartphones.

In three tests the software presented bugs in which the stereoscopic content was not fixed in the place it was supposed to be and did not function correctly.

Participants who already had experience in the virtual reality field had less exaggerated reactions when viewing the different contents and were easier to point out errors or suggest possible changes that would improve the design.

None of the participants tried to change the distance between lenses, as all were able to see the stereoscopic effect with the standard measurement.

Regarding participants suggestions:

Six participants suggested that it was important to put some kind of protective material on the smartphone support part, to feel more confident and carefree using the device.

Three participants suggested redesigning the instruction card into something more intuitive, for example using pictures. One of these participants even suggested that the instructions could be a recorded sound, so as not to force you to read.

Three participants suggested using headphones and another participant suggested punching holes in the face of the head of the device to let the sound flow more easily in front of the participants.

One participant suggested that it would be important to have some kind of guiding information within the interface and that when there were movements required for interaction, that they should be suggested in it.

One participant suggested creating packs of stereoscopic cards that could then be collected, with each pack having a theme and that people could purchase if they had an individual Spectare to use them with.

Two participants suggested using more sounds in the experience, especially in 360º images, to increase immersion.

Two participants suggested that the device should encapsulate more of the participant's head in order to cut down on light input.

One participant commented that the smartphone support piece was poorly designed and did not present a good way to put on and take off the smartphone, but did not present an idea on how to devise a new design for that piece.

One participant found the order of the photographs contained in marker 3 (fig. 176) strange, so he suggested that they should be swapped in order, with the older photograph being linked to the longest distance from the cardholder to the smartphone, creating an idea of temporality in the movement of the cardholder.

Discussion

Although we encountered several problems while running this evaluation, the results were satisfactory and encouraging. The vast majority of participants embraced Spectare with enthusiasm and showed interest in using it and giving their feedback on it. With the exception of two participants, all were able to use the device without any major problems and enjoyed the experience. The participants who had no experience in the VR area showed expressions of surprise and glimpses more often, but those who already had were the ones who showed the most genuine interest in understanding how the whole project worked and a realistic appreciation of all the work that was needed to get to the point where the project was. It was also those participants who made the most suggestions on how they would improve Spectare, as they had already been looking in more detail at how it worked.

The highest pressure point in this evaluation was the smartphone support piece. Being an unfamiliar piece to all of the participants, it didn't show ease of use. To begin with, it was not protected with any kind of sponge or fabric, which immediately worried the participants. Furthermore, it was not perceptible that this piece could be moved, which led to many of the problems described above that put this piece and potentially the smartphones used in the evaluation at risk. This piece was the cause of the values for tasks 2 and 3 being so low, and the number of participants responding that they would need the help of someone connected to the project to help them use the device. Problems such as not knowing how to stick the smartphone in the piece, not being able to move the piece into the head of the device or get it out, undermined the experience for many people, which then weighed on the evaluations and demonstrated the need to rethink the whole smartphone support mechanism. Often, these problems stemmed from participants not being interested in reading the instructions carefully or trying to rush through the experience to get the test over as quickly as possible, but these factors will always exist in any test that is done and need to be taken into consideration.

Another physical part of the model that should be reviewed was the cardholder. Because it was a new piece for most of the participants, it was not noticeable to many how it was used, which led to the need to restore this piece because it was damaged during a test. The lack of time to study the piece and perceive it, caused most participants tograb it from the side, the most natural way for them. However, because of the size of the hole inside the cardholder, it allowed the piece to rotate and get stuck, not letting it to move, thus ruining the experience. This led to the complete redesign of this piece in the next iteration.

Overall, the physical problems encountered failed to dethrone the novelty that the experiment meant to the participants, which was demonstrated in the NASA TLX results, where all the values linked to the handling of the piece were below the average value, which is satisfactory in this test. The highest value achieved in this test was linked to how successful they were in using the device, and the vast majority were able to use it satisfactorily, which we think is a good result.

There is one value in NASA TLX modes that stands out from all the others, and that is linked to temporal demand, which was strange for us because most participants did not spend much time testing the various contents. Only a small minority took the time to look at everything around them and explore the various details of each image. It is possible that they found the tests too long, but in the area of stereoscopy, time is something necessary to understand what we are experiencing and no participant complained about this factor.

The stereoscopic cards were virtually not discussed with the exception of the instruction card. All comments were the same and demonstrated ideas that we had already thought of to apply in the next iteration, like the inclusion of images.

The virtual interface showed that it still needed to be more professional and complete, besides having all its errors corrected. Although at this stage it was not yet a major concern to demonstrate a finished interface but to show that several different contents could be used in this kind of experience, it was clear that it was necessary to improve it to provide a better final experience to the viewer. The use of more sound content and 360º images was highly recommended, for increasing the immersion and the interest of the participant in these contents, something that we decided to adopt for the next phase of prototyping the interface.

Even with the problems encountered, these did not stop the participants from enjoying the content they had the opportunity to watch, which can be seen in the words most chosen by them to describe the experience as Creative, Impressive or Fun. Furthermore, most of the derogatory words on the list were the least chosen, demonstrating that most of the tests were good experiences.

The worst scores in this evaluation on both SUS and NASA TLX were given by the two participants who gave up trying to have the experiment by themselves, which shows that for some participants it is extremely difficult to use this device and that we cannot have the thought that experiments will always go well, no matter how different the participants are.

We rate Spectare's performance in this evaluation as successful, but with major problems that could not be left for the next experience.

6.2. SECOND USABILITY TESTS

In the final phase of this project, the goal was to have Spectare, including the new simplified devices (fig. 160), the new stereoscopic card design (fig. 168) and a new interface (fig. 183 to 189), ready to be tested in an in-the-wild context. However, we were able to have all the parts described above completed before testing began, which made it possible to run a second test on a small group of people who had already taken part in the Usability Tests. This new test was intended to gather feedback on the new experience from people who had the opportunity to have tested the previous one as well, in a very informal way.

Procedure

For this tests, no questionnaires were filled out. Seven of the twenty participants who took part in the previous test were contacted, through direct contact.

The participants would have to test the device, the interface and the cards as in the previous test, but there was no order of actions, giving them the freedom to act as they wished. The only command given was to view the cards in their numerical order while testing them on the device.

While the participants were doing the test, we wrote down actions that we found interesting. At the end of the test we interviewed the participants about the modifications applied to each of the integral parts of the project and also noted down comments they made.
The smartphone used in all the tests was our personal one, so as not to disturb the flow of the experiment, as we had little time for such a large number of tests.

Observation, comments and discussion

Overall, all participants liked this new experience more than the previous one.

It was interesting to note that, even after having already tested the project once, all participants had difficulties interacting with the smartphone support piece. The only change to the piece that had been made was indeed the application of a black spongy material that protected and gripped the smartphone, but we thought that in a second use most people would already have less difficulty interacting with it. However, it was impossible to modify it without deconstructing the whole display design, something that at this stage was impossible to do.

Another part of the device that had been problematic in the previous test, the cardholder, did not show any problem in these tests, thanks to its new design, appreciated by all test participants. Comments on it were focused on the ease of sliding that the new design provided, even though it was tighter than the previous one.

All participants were able to use the device without any problems, even one of those who had given up in the previous test, thanks to the experience he had gained previously, which made him able to enjoy this new experience, especially for its historical value.

As for the new design of the cards, everyone thought it was well done, especially on the new instruction card. Thanks to the use of pictograms used to imitate the actions, it was much more understandable which actions the participants should do.

The new interface, which was the part of the experience that was most different from the last tests, also received favourable reviews. No errors were found during testing and all content seemed well chosen according to the theme, for most participants. Half of them were not interested in the historical theme the experience was connected with but agreed with the idea that it is interesting to demonstrate the past of a place that looks completely different today, through a device that was influenced in the historic period that the content of the interface is in.

No participant suggested that anything had to be changed or improved in this experience and everyone found it more interesting than the previous one, due to the stereoscopic and sound content that was used in it.

The results taken from this test were very positive from our point of view. On one hand, they didn't present any major issues, which made us go into the In-the-wild tests with confidence that this was a quality project, and on the other hand, it made us realise that even having used the device before, there are always mistakes that participants make during new tests, which reminds us that design is never completely finished and that there are always edges that can be perfected for a better final experience. We felt that all participants enjoyed this new final design of all the integral parts of the project, even if they were not interested in the theme it presents and had a more enriching experience during this second test.

The only problem pointed out that we knew it was not possible to solve in the state the project was in was the fact that all participants had difficulties using the smartphone support piece, something that we know decreased the quality of the experience but that we didn't have time to be able to solve as it would involve modifying the design of the whole display.

6.3. IN-THE-WILD TESTS

These "In the Wild" tests were the accomplishment of all the work done up to this point.

They provided the possibility to test Spectare's purpose with a real audience while giving different people a different view on the historical past of the place we were in, the Jardim da Manga.

It was the perfect occasion in demonstrating whether our proposal of each person using their personal smartphone to access cultural and historical heritage by viewing stereoscopic content on a device inspired by the Victorian era, was good or not.

In collaboration with the Santa Cruz CES project, which provided 360º images and sound recreations of the old Cloister and the entire Santa Cruz Monastery, we were able to adapt our interface and four stereocards to demonstrate the history of the place over the last two centuries and the work that the Santa Cruz CES project had to digitally reconstruct the entire Monastery as it was in 1834. This also gave us a chance to test Spectare in a real non-controlled environment, unlike previous tests.

From each In-the-wild test it became clearer whether this kind of environment was conducive to the use of Spectare or not, what the reasons for this were and what possible alternatives existed.

Procedure

Initially, the idea we had conceived for these tests was first to get permission from the owners of the restaurant that is currently in Jardim da Manga, to have access to their space, so that we could leave two devices, two packs of stereocards and a poster with an advertising nature, in a safe but visible place within the vicinity of the restaurant. This way, the people who frequent the place could pass by the devices and interact with them without any kind of action needed from us. As soon as we got the permission to do so, the weather was clear and sunny, so we could place the devices on the terrace of the restaurant, near the entrance door and at the same time near the fountain in the centre of the garden, which is now the tourist attraction of the place.

We had not chosen a concrete age group for the tests, as anyone could be part of them, but the ages we expected to be the most recurrent were between 16 and 50, considering the greater ease of access and use of smartphones and the internet that this age group has.

In addition to tourists passing through the area, the restaurant's regular customers were also invited to to interact with the project.

To publicize this event, we put up posters at the main entrances of the garden and the restaurant workers encouraged the customers having lunch there to go and have an experience of the place that they had never had before.

However, it was quickly apparent that this strategy was not working. Many people went to the restaurant for lunch and looked at the devices but showed no interest in trying them out. Tourists visiting the garden often did not even notice the devices and quickly left.

The new strategy we adopted was that from 11:30 am until 5 pm, we were always by the devices asking various people if they wanted to have a different experience once they had finished their lunch or if they showed any interest by looking at the devices. Participants were free to ask questions and make comments during the test and we used this time to note interesting reactions, emotions and gestures that we thought were important to keep. If participants showed some willingness at the end of the test, we asked them quick questions about what they thought of the experience they just had and collected some demographic data. The smartphone to be used in the tests was that of each participant, except for the iPhone users, who had to use our personal smartphone.

Fig. 194
In-the-Wild tests location and configuration

Fig. 195
In-the-wild test participant

Results

Over a period of 4 days, we were able to do a total of 8 tests. Of all the tests, only 2 were individual. All the others were done in groups of 2 to 5 people. The ages we were able to record fluctuated between 7 and 90. Most of the participants were people who had lunch in the restaurant and took the test after lunch was over. Only 1 test was done by people who were visiting the place for tourism purposes. In 3 of the tests, the participants were foreigners.

Out of 13 occasions where possible participants showed interest by looking at the devices, only 1 of them turned out to be a test, after being invited by us.

None of the tests was done with the participants' personal smartphones. In one of the tests, one of the two participants tried to use her smartphone but could not enter VR mode.

In all the tests, we were the ones who had to access the website and place the smartphone in the correct position inside the stereoscopic device, either because the participants didn't want to have that work and would give up if we didn't do it, or because the participants were in a hurry and forced us to rush that part of the test.

Observation, comments and discussion

The execution of these tests was a real-life demonstration of how difficult and frustrating it can be to test a project in a real-life environment. All the expectations we had for the execution of these tests did not predict what happened. In a way, this helped us to understand what points of the project still needed rethinking and what would be the best use case for a project like this.

As mentioned earlier, initial expectations were that people would take interest in the device at hand and try to use it spontaneously, without any action on our part. Our mission would be to try to write down as many reactions and emotions as we could and, at the end, try to collect even more information about the participant who had just tested Spectare by trying to contact him/her.

However, this scenario was quickly recast due to the complete disinterest of the people visiting the site. Not a single person approached the devices and tried to at least read the instructions to use it. This was one of the consequences of our choices. To make sure that the devices were kept safe, we decided to place them near the restaurant, where there is a constant flow of people. This way we decreased the potential for theft but increased the potential for the devices to go unnoticed by all the people visiting the fountain in the centre of the Jardim da Manga.

In order to gather people to do tests, we had to constantly stand near the devices and try to recruit those who seemed to be interested by the way they looked at the devices. In most cases, the customers ended up leaving the restaurant without contacting us, thus ending the possibility of carrying out a test. Only one test was made by a participant who accepted the suggestion of one of the restaurant's employees. We also tried to invite several people who were only using the restaurant terrace to rest, but we only collected negative responses.

Another difficulty with these tests was trying to collect data about the participants at the end of each test. Most of them argued that they were not available to do so and in most cases, we could only find out their name, age and whether they had already had an experience of viewing stereoscopic photographs or virtual reality.

Even so, we managed to do 8 tests in total. We were lucky that the participants had a wide range of different ages. On the same day, we tested both a 7 year-old child and a 90 year-old lady, which allowed us to gather information about the different ways different age groups interact with Spectare.

For the children — 7 to 12 y.o. — who took the tests, it made no sense what they saw in front of them. Whenever we asked them if they knew what they were looking at that moment, they couldn't make the connection with the location they were in. We had to explain to them the various contents they were seeing and explain them how to use and hold the device. However, they learned quickly and started asking for more content for them to watch.

For this age group the mere opportunity to try something new increases their interest in doing so exponentially, which led to energetic reactions, without them realising that they were learning and having fun at the same time.

The reactions to seeing the virtual interface were mostly fascination and admiration. It was normal for them not to want to let their relatives also interact with the device, so that they could have as much time as possible with it and explore every bit of the stereoscopic content they saw in front of them, always with a smile on their face.

This age group was also marked by the number of times they let the devices fall to the ground, which also demonstrated the extra care needed to safeguard the physical integrity of the devices, however robust they may be. Only one of the children grabbed the device as they were supposed to. The others chose to grab it with one hand on either side of the device or just put their face in it with an adult holding it.

For the only teenager — 13 to 18 y.o. — who took part in the tests, using the devices was the best part of the whole experience, as she had never come into contact with virtual reality before. The awe when putting the first stereoscopic card into the device and an image appeared was huge, which led to the comment, " *Wow, how crazy is that*! *This is amazing*!".

It didn't take long before she asked how the device worked and tried all the cards twice each. Another comment was that she had had "*a lot of fun using this device with the cards*".

There were no problems handling the device and it was easy for the participant to swap the various cards. However, because she was not always looking at the content, she did not realize that she could move the cardholder to see new content. Once we explained that she had this option, she showed even more enthusiasm to interact with the experience, which made us realize the potential of using this project in the area of teaching younger age groups.

The adult age group (19 to 65 y.o.) was the most present in numbers in these tests. However, it seemed sensible to split this group into two because of the differences between generations and between the data collected.

For those aged between 19 and 45, these tests were mostly an experience that revealed a great interest mainly in the way the device works and not so much in the content presented. Being an age group more accustomed to the existence of virtual reality in various media, they did not find the contents that were presented strange, but they did find the device's design strange. As they were used to the design of current VR headsets, they did not initially understand the why of that body design. Once we clarified their doubts, they took as little time as possible to explore the various contents of the experience. Some of their comments described the feeling of lack of immersion and presence in the virtual environment, due to the lack of sound and movement.

Even so, the predominant emotion expressed was curiosity, while at the same time they displayed a calmness that hid their haste.

A comment made on the device was that it was incredibly well constructed in accordance to represent stereoscopes of the past and that it would pass as one if the participant did not know that we were the ones who prototyped it.

There was no odd behaviour in terms of handling and all participants used the device as expected, although they did not take the time to explore its features in most cases.

For the 41 to 65 age group, which were in greater numbers than the previous one, the factors of interest in the project were reversed.

These participants showed much more interest in the stereoscopic content, spending more time understanding the details of each image they saw, forgetting the interest in the way the device worked.

They showed more often joy, enthusiasm and fascination. As soon as they saw the first image to appear they grew a smile and one commented: "*Wow, what a show*".

Many of them didn't know that they could rotate their body to change their field of view, so we had to suggest to them that this movement was possible and necessary. However, they showed great ease in handling the device, especially when trying to understand how the cardholder worked.

Many of these participants showed interest in reading all the information that the stereocards contained, as they wanted to know more about the history of the place, which led them to ask us about it.

At the end of one of the tests we managed to talk for a while with a participant and he commented that there was great difficulty in using the device in the initial moments, when you have to enter the website and place the smartphone on the device, without the help of a person who knows how to do it, which reinforces a weakness of the device found in the usability tests, especially in the question that was linked to the need for technical support for the use of the device.

For the highest age group (65+ y.o.) these tests were the most difficult to manage to perform.

Starting with the complete resistance of having to interact with the device to get it working properly, they made us to have everything ready so that they only had to do the fewest tasks necessary.

They also encouraged us to explain in advance what actions were needed to interact with the device and to explain to them everything that happened in real-time.

As the tests ran, these participants showed joy at first, but the emotion expressed most prominently was confusion. One of the participants did not understand why we were creating this project as we were standing exactly in the place he was looking at the device and was not paying attention to our explanations.

Once the tests were over, the main comments we received were that it was a funny experience, but that the technology was too complicated for them to understand and use.

The movement restrictions and the lack of sight and hearing were the main factors for the experiences not being more rewarding. We always had to explain to them which movements they should make with each card they exchanged and none of them showed any intention of exploring the features of the device without being told to do so. Although it was expected, they all showed some fear of holding the device, afraid that they might drop it and damage it.

The participant who had the worst experience made no effort to be able to see the stereoscopic effect as he was regularly closing his left eye, even when we warned him that this would miss the essence of the experience.

Most of these participants gave positive evaluations to the project for having made it possible to find out about the history of the place they have known all their lives. *"It was as if it was real and we were inside it"*.

In conclusion, these tests showed that the use case initially thought is not the most appropriate for the use of Spectare. This fact is mainly due to the choice of the scenario used in these tests. Taking into account that we were on a restaurant terrace, the main audience that could appear came intending to have lunch and not to enjoy a stereoscopic experience. Most of the participants we met were not open to experiment and learn something new. Even if they often stared at the devices, they never tried to take the time to interact with them and find out why they were there in the first place.

The use of the personal smartphone is also a point that we did not think posed as many problems as it did, as most of the participants were reluctant when we mentioned that the experiment would use their personal smartphone and most of them asked not to have to do so.

The uncontrolled environment surrounding the test site also caused difficulties, due to constant background noise and sunlight appearing and disappearing as clouds passed.

In addition to all these problems, it was shocking for us to realise that a large number of participants did not find the content we provided interesting, none of whom had the opportunity to see it before and would probably never see it again.

However, these tests made us realise the real potential of Spectare, especially for the younger population. Through the children's reactions we collected, it was easy to see that Spectare can be used as a fun and interesting learning tool, especially for cultural heritage topics. With some adaptations, Spectare could be present in schools, providing children with current and past stereoscopic content through a different experience in the classroom or at home.

Another possible use of Spectare is in museums and historical sites, where a controlled environment exists and where it is possible to maximise the use of all the features of the device to present historical content in a different way than usual. For example, it would be possible to use Spectare in an exhibition dedicated to the medieval period in Portugal. In the centre of the room, we would find the device and several stereoscopic cards and we could use it to see the recreation of the period through several photographs or videos created for that.

Our final evaluation of the tests turned out to be satisfactory, even with all the adversities encountered. Most of the reactions regarding the use of Spectare were of joy, admiration, curiosity and fun. We were able to understand the problems of the device and what implementations of it would have more potential than the one tested. The image we keep at the end of these tests is of one of the participants who had a smile on his face from the beginning to the end of the experience, showing the the joy the Spectare can provide for those who find it interesting.

7. CONCLUSION

We have designed and implemented the Spectare device inspired by stereoscopes from the past, like the Holmes stereoscope, for experiencing digital content through a smartphone device. The goal was to recreate the original viewing experience of stereoscopic photography and develop a device that "fits" into the experience of exploring 19th century cultural heritage. This device updates the original experience, allowing users to see stereoscopic images but also 360º images or videos and hear their associated soundscapes.

For that, we needed to understand the history of stereoscopy, stereoscopic photography and virtual reality. Also, we had to understand clearly what really was the original experience of watching stereoscopic photography, by contacting individuals that had the opportunity of experiencing it widely. Also, as we were going to prototype a stereoscopic device, we needed to know more about the materials and techniques we could use for it. There was also a need to explore projects with similar goals to ours and understand their design choices and what purpose did they serve.

With all of this information gathered, we started building a concept that would reconcile an old stereoscope body inspired design with a way of using a smartphone to access a software interface built with current VR capable tools. As part of the new experience, that software would have to be able to read images present in stereocards created by us.

Our prototyping approach was to start prototyping the device, which implied being the most difficult to get right and build, and as soon as we had it working, we would start prototyping the stereocards and the interface, in order to be able to test them all together. These were usability tests and told us exactly what aspects of the project we needed to rework. Even though we had already achieved the goal of building a stereoscopic viewer capable of support a smartphone early in the prototyping phase with a wood and sheet metal build, we wanted it to feel more organic and true to the concept of building it like an old stereoscope, so we decided that the amount of work needed to build it all in wood was worth our time, and this would be the design that was actually going to be used for testing.

The results of the tests were mostly good and showed us that our project achieved its initial goals, with minor issues that could be fixed.

Then came the time to adapt all of the Spectare to be used in a real-life environment, using stereoscopic content provided by the Santa Cruz CES project, which was the plan since the beginning of this project. The place chosen was the Jardim da Manga and the contents used showed the past of this place with the work that the Santa Cruz CES project had to be able to digitally rebuild all of the Santa Cruz Monastery as it was in 1834. The participants had the opportunity of watching images depicting this place in this period of history in a device that kept the experience of that time but was prepared to work with nowadays technology.

We believe we achieved all of the goals proposed at the beginning of this dissertation. We managed to build a completely functional wood stereoscopic device that was able to support a smartphone that would read a stereocard and show an online interface with stereoscopic contents in it. Also all of these pieces together were able to deliver an experience close to the original and at the same time rethink the contents shown in it. We managed to achieve the goal of disseminating the work made by the Santa Cruz CES project as intended as well.

However, we also found some problems we cannot dismiss if there is to be a continuation of development in the future. The smartphone support mechanism is still flawed and to be rethought requires that all of the device design may need to be changed. Also, it's quite expensive to produce these devices and, if there was a need to mass-produce them, there would be a need to make a major redesign of the device. The interface could also be perfected in terms of animations and interaction controls. As for the use of it in real-life contexts, the environment chosen for the Claustro da Manga experience was a flawed one. The environments where Spectare would be more suited would possibly be as a tool for educational learning in schools or as a way of demonstrating stereoscopic contents in museums, expositions and touristic places, as long as they are controlled.

As for the future, there is a possibility of making the Claustro da Manga experience again, as a way of promoting the work made by the Santa Cruz CES project, although there might be a need to change some of the choices made in the first time. We also think that continuing to update and perfect Spectare could be a way of having an opportunity for using it in new places, where it makes sense to use it.

In order to disseminate the work carried out in this dissertation, two articles were written. The first article *Re-imagining Stereoscopic Photography in the Age of Virtual Reality* (Taipina & Cardoso, 2021a) was written in the context of the 18th EAI International Conference on Mobile and Ubiquitous Systems: Computing, Networking and Services and is still waiting to be accepted. The second article *The Spectare device for experiencing stereoscopic photographs* (Taipina & Cardoso, 2021b) was written in the context of the International Conference on Artificial Reality and Telexistence Eurographics Symposium on Virtual Environments(2021) and is going to be presented in September of 2021, in the Poster category.

8. ANNEXES

The Spectare device for experiencing stereoscopic photographs – *Poster*

International Conference on Artificial Reality and Telexistence
Eurographics Symposium on Virtual Environments (2021)
J. Maiero, M. Weier, and D. Zielasko (Editors)

The Spectare device for experiencing stereoscopic photographs

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Abstract

Stereoscopic photography was one of the main forms of visual communication in the second half of the 19th century, leaving even today an important impact on our visual culture. In this work, we have re-imagined the classical stereoscope in order to take advantage of smartphone-VR technological capabilities, while still trying to maintain a viewing experience close to the original. This poster describes the design and operation of the Spectare device for experiencing stereoscopic photographs.

CCS Concepts

• ***Human-centered computing*** → ***Virtual reality; Displays and imagers;***

1. Introduction

Stereoscopic photography was invented virtually at the same time as conventional photography and, in fact, became one of the most influential forms of visual culture in the entire second half of the 19th century [Gre18]. Viewing these photographs requires a stereoscope and perhaps the most well-known model is the Holmes stereoscope (Fig. 1a). Our motivation is to create a viewing experience for Cultural Heritage (CH) content that resembles the original viewing experience of stereoscopes, with current smartphone-based VR technology. By recreating aspects of the original stereoscope usage experience to view digital Virtual Environments (VEs) we hope to provide a more engaging and memorable CH experience. We have developed the Spectare device, which keeps essential elements of the stereoscope such as the physical action of placing/removing the stereo cards, adjusting their position on the arm of the device, and the physical act of bringing the device close to the eyes. The experienced content, however, is not limited to stereo photographs and can include any digital VE. It should be stressed out that, although Spectare is similar to a Google Cardboard, it provides a very different user experience. On the one hand, the experience is very similar to the one provided by a Holmes stereoscope, which was what we were trying to emulate. On the other hand, it effectively constitutes a tangible interface where the physical stereocards represent digital content and a simple way to interact with that content. This poster describes the design concept, and implementation details of the Spectare device for CH exploration.

2. Related Work

Custom Virtual Reality (VR) viewers inspired by stereoscopes have been applied to CH fruition in previous studies. Petrelli [Pet19] developed the "Steampunk viewer" – a device similar to the Brewster stereoscope – in the context of a visit to the Dr. Jenner's House Museum and the Trajan Museum. Content is triggered by Bluetooth beacons spread throughout the museum. In Spectare, we wanted a deeper connection to the original experience of using a stereoscope: the content displayed is associated with a "stereo card" that users manually place in the device. Ciolfi et al. [CPG*13] developed "Binoculars", an augmented reality display with a form factor that resembles binoculars. The device allows users to insert a smartphone that displays augmented reality information during visits to the Sheffield General Cemetery. The device itself is simply an enclosure for the smartphone, providing a different way to hold the smartphone as if one is looking through binoculars. It shares the purpose of the "Spectare" device: to enhance the user's experience by providing a custom tangible device that fits better into a given context.

3. Design of Spectare

The main goal of the Spectare device is to recreate, and re-imagine, the experience of viewing stereoscopic photo cards using a smartphone-based viewer. Operating the device is reminiscent of the form and operation of a late 19th-century stereoscope. However, it allows viewing richer digital content such as 360º images, audio, or even 3D models.

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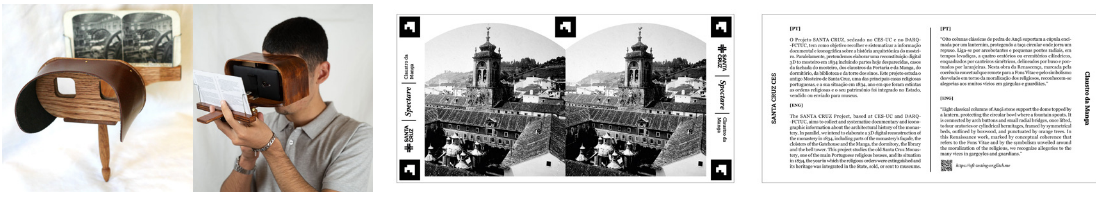

(a) (b) (c)

Figure 1: a) Holmes stereoscope (photo by Davepape on en.wikipedia); b) Spectare device; c) Stereo card.

3.1. Prototyping and Physical Construction

Several prototypes were created before the final physical construction solution was reached.

Some of these prototypes were made to test specific elements of the device such as the lenses' adjustment and smartphone locking system. Initial prototypes were made using paper (Fig. 2a), but

(a) (b) (c)

Figure 2: a) Cardboard prototype; b) Final lens mechanism; c) Smartphone gripping mechanism.

with an internal structure similar to a honeycomb to provide rigidity. These allowed to test: the overall size of the face, the size of the aperture for the nose, the distance between the holes for the lenses, the size of the posterior arm that holds the stereo cards, the sizing of the case for holding the smartphone. Other prototypes were built to test specific mechanisms such as the distance adjustment between the lenses (Fig. 2b). Still other prototypes were made to test the smartphone clip mechanism (Fig. 2c). The final device is made almost entirely of wood (Fig. 1b).

4. Experiencing Coimbra Demo

We designed a stereocard with five barcodes to support a variety of smartphones with different camera placements (Fig. 1c). The software that runs on the smartphone is a web page implemented using the A-Frame VR framework (https://aframe.io). This allows users to simply load a web page in their smartphone's browser (or scan a QR code available in the back of the stereo cards) and then place the smartphone inside the Spectare device to start the experience. Although there is no limitation to the type of content that can be displayed, we are currently focusing on experiences that display stereo or mono photographs or digital images, 360º photos or videos, soundscapes. We have also implemented the possibility of calculating the distance between the smartphone and the stereo card and use this as an additional degree of freedom. We have developed a demonstration, based on locations in Coimbra, Portugal. The experience uses four cards. The first card displays a stereo photo of the historic center of Coimbra, from start of the

(a) (b) (c) (d)

Figure 3: Contents of the demonstration Spectare experience. a) Stereoscopic photo of the historic center of Coimbra; b) Praça 8 de Maio in 360°; c) University Palace; d) Soundscape.

20th century. The second card displays a current 360º photo of the "Praça 8 de Maio", where the town hall is located. The third card displays a photograph of the University Palace, now occupied by the Rectory. In this card, moving the card holder to the front or to the back of the arm will display a photo from the early 20th century or a contemporary photo of the University Palace. The fourth card will display a recreated soundscape of the "Praça 8 de Maio" in the 1950s as well as an accompanying photo from the same time.

5. Conclusions and Future Work

We have designed and implemented the Spectare device inspired by the Holmes stereoscope for experiencing digital content through a smartphone device. The goal is to recreate the original viewing experience and develop a device that "fits" into the experience of exploring 19th-century cultural heritage. This device updates the original experience, allowing users to see stereoscopic images but also 360° images or videos and hear the associated soundscapes. We are currently conceiving a tour of the digital reconstruction of the Monastery of Santa Cruz in Coimbra as it was in 1834 using the Spectare device.

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