



**José Castanheira**

Graduation in Computer Science

## **Representing and Indexing Archaeological Information**

Dissertation submitted in partial fulfillment  
of the requirements for the degree of

Master of Science in  
**Computer Science and Informatics Engineering**

Adviser: Armanda Rodrigues, Assistant Professor, NOVA University of Lisbon

Co-adviser: Nuno Correia, Full Professor, NOVA University of Lisbon

Examination Committee

Chairperson: João Leite

Raporteurs: Teresa Chambel  
Armanda Rodrigues



FACULDADE DE  
CIÊNCIAS E TECNOLOGIA  
UNIVERSIDADE NOVA DE LISBOA

June, 2019



## **Representing and Indexing Archaeological Information**

Copyright © José Castanheira, Faculty of Sciences and Technology, NOVA University Lisbon.

The Faculty of Sciences and Technology and the NOVA University Lisbon have the right, perpetual and without geographical boundaries, to file and publish this dissertation through printed copies reproduced on paper or on digital form, or by any other means known or that may be invented, and to disseminate through scientific repositories and admit its copying and distribution for non-commercial, educational or research purposes, as long as credit is given to the author and editor.



## ACKNOWLEDGEMENTS

I would like to thank my advisors Armanda Rodrigues and Nuno Correia for their guidance and support during the writing of this dissertation. My gratitude is also directed to Dra Inês Pinto and her colleagues for their availability and contribution, and also to everyone who devoted their time to help in the evaluation of this dissertation, which was an essential aspect to the achievement of its goals.

I am also grateful for the colleagues and friends that made me company during this process. A special thanks to the ones that took some time to help me escape some of the struggles and motivated me to do my best.

And last, to my partner who did her best to cheer me through all the hard times.



## ABSTRACT

---

The need to preserve and remember the past is a particular human trait. The richness of our cultural history is approached by a vast array of disciplines, that investigate and manage it. However, their effectiveness can be hindered by several technical issues. One of the concerns of experts in this area is the way the importance of cultural heritage is communicated in order to cultivate interest, curiosity and respect. Another concern is the lack of suitable tools that can handle the dimension and complexity of the collections with which they interact.

With the emergence of digital tools and the creation of online repositories for the collections of cultural institutions, it is possible to suggest different solutions to tackle these problems. The proposed solution aims to facilitate access and interaction with cultural information, through the implementation of an application capable of integrating multiple forms of representation of historical artifacts. The application tackles two problems that arise from distinct goals. One is the need to represent, in a single view, collections of related items from different repositories. The other is how to, effectively, communicate the information associated with an artifact and its context.

This MSc dissertation is part of a collaborative effort between NOVA LINCS researchers and several archaeological institutions of the Iberian Extremadura, aiming to develop tools that will support research and help sharing the cultural wealth of archaeological sites and artifacts from the region. In this dissertation, the developed application covers a general view of the aforementioned problems, while being flexible to the customization of the representation of cultural data. The solution was evaluated on usability and effectiveness on reaching the proposed goals, during a process that involved target audience users and experts in the area of culture and history, as well as human-computer interaction. The results provided positive conclusions.

**Keywords:** Cultural Heritage, Archaeology, Indexation, Visualization, Interaction, Multiple representations

---





## RESUMO

---

A necessidade de preservar e recordar o passado é uma característica particularmente humana. A riqueza da nossa história cultural é abordada por um conjunto vasto de disciplinas, que a investigam e gerenciam. No entanto, a sua eficácia pode sofrer devido a várias questões técnicas. Uma das preocupações de especialistas desta área é a forma como se comunica a importância da herança cultural, com o objetivo de cultivar o interesse, curiosidade e respeito. Outra preocupação é em relação às ferramentas usadas não se adequarem à dimensão e complexidade das coleções com que se pretende interagir.

Com o aparecimento de ferramentas digitais e a criação de repositórios online para coleções de instituições culturais, é possível propor diversas soluções para combater estes problemas. A solução proposta pretende facilitar o acesso e a interação com informação cultural através da criação de uma aplicação capaz de integrar diversas formas de representação de artefactos históricos. A aplicação pretende solucionar dois problemas que surgem de objetivos distintos. Um é a necessidade de representar em uma só visualização, coleções de itens de diferentes repositórios. Outro, é como comunicar eficazmente a informação de um artefacto e o seu contexto.

Esta dissertação de Mestrado insere-se num trabalho colaborativo entre a NOVA LINCS e várias instituições arqueológicas da Estremadura Ibérica, de forma a se desenvolverem ferramentas que contribuam para as investigações da área e ajudem na partilha da riqueza dos sítios e artefactos arqueológicos provenientes da região. Nesta dissertação, a aplicação desenvolvida cobre de uma maneira geral os problemas mencionados, sendo ao mesmo tempo flexível à personalização de como é representada a informação cultural. A solução foi avaliada quanto à sua usabilidade e eficácia a alcançar os objetivos propostos, durante um processo que envolveu utilizadores do público-alvo e especialistas na área da cultura e história, assim como interação pessoa-máquina. Os resultados geraram conclusões positivas.

**Palavras-chave:** Herança cultural, Arqueologia, Indexação, Visualização, Interação, Múltiplas representações

---



# CONTENTS

<b>List of Figures</b>	<b>xiii</b>
<b>1 Introduction</b>	<b>1</b>
1.1 Motivation . . . . .	2
1.2 Problem Context and Final Goals . . . . .	3
1.3 Contributions . . . . .	4
1.4 Document Structure . . . . .	4
<b>2 Background</b>	<b>5</b>
2.1 Presentation of Digital Cultural Heritage . . . . .	5
2.1.1 Cultural Heritage . . . . .	6
2.1.2 Digitization and Preservation . . . . .	8
2.1.3 Indexing and Retrieval . . . . .	9
2.1.4 Interfaces and Usability . . . . .	11
2.2 Visualization and Interaction . . . . .	13
2.2.1 2D and 3D Visualization . . . . .	13
2.2.2 Virtual and Augmented Reality . . . . .	14
2.2.3 Tangible Interfaces . . . . .	15
2.3 Spatio-Temporal Representation . . . . .	16
2.3.1 Geographical Data . . . . .	16
2.3.2 Timelines and Narratives . . . . .	17
2.4 Conclusions . . . . .	19
<b>3 Related Work</b>	<b>21</b>
3.1 Cultural Heritage Multimedia Presentation Systems . . . . .	21
3.2 Cultural Heritage Research . . . . .	22
3.2.1 Visualization and Interaction Research . . . . .	23
3.2.2 Storytelling, Geo-referencing and Semantic Mappings . . . . .	25
3.3 Integration of Georeferenced Historical Information . . . . .	28
3.4 Conclusions . . . . .	30
<b>4 Design and Implementation</b>	<b>31</b>
4.1 Design and Conception . . . . .	32

## CONTENTS

---

4.2	Development and Implementation	34
4.2.1	Technologies	34
4.2.1.1	Cesium	34
4.2.1.2	React	35
4.2.1.3	TerriaJS	35
4.2.1.4	Node.js	35
4.2.1.5	Sketchfab	36
4.2.2	Indexing and Navigation	36
4.2.2.1	Interface	36
4.2.2.2	Search Methods	38
4.2.2.3	Categorization	41
4.2.2.4	Geographical Visualization	42
4.2.2.5	Relationships	46
4.2.2.6	Object Properties	46
4.2.2.7	User Contribution	49
4.2.3	Multiple Contextual Visualizations	49
4.3	Conclusion	55
<b>5</b>	<b>Evaluation and Results</b>	<b>57</b>
5.1	Methodology	57
5.2	Results Assessment	61
5.3	Evaluation Limitations	73
5.4	Expert Evaluation	74
5.5	Proposed Changes to Improve Usability	76
5.6	Conclusion	79
<b>6</b>	<b>Conclusion and Future Work</b>	<b>81</b>
6.1	Conclusions	81
6.2	Future Work	82
	<b>Bibliography</b>	<b>85</b>
<b>A</b>	<b>Usability Test</b>	<b>89</b>
<b>B</b>	<b>Evaluation Questionnaire</b>	<b>101</b>
<b>C</b>	<b>Users Profile</b>	<b>107</b>
<b>I</b>	<b>Screenshots</b>	<b>109</b>

## LIST OF FIGURES

2.1	Examples of AR and tangible interfaces in cultural applications . . . . .	16
2.2	Combination of different layers of information and complex thematic identification and classification using GIS [15] . . . . .	18
3.1	Examples of cultural heritage multimedia presentation applications . . . . .	22
3.2	White Bastion and its virtually reconstructed 3D model [33] . . . . .	23
3.3	The architecture of the Labyrinth 3D system [7] . . . . .	27
4.1	Scheme of the designed solution . . . . .	34
4.2	First view of the web application desktop interface . . . . .	37
4.3	Interface of search methods . . . . .	40
4.4	Icons used for categorizing objects. From left to right: Images, videos, 3D models, text documents and others. . . . .	42
4.5	Use of categorization icons on the application . . . . .	43
4.6	Use of the navigation tools to create a different view of the globe. The position of the user, object icons and a cluster of objects are also present. . . . .	44
4.7	Accessing related results . . . . .	47
4.8	Showing object properties and the associated image resources in a slideshow . . . . .	48
4.9	Submission form and submitted object list . . . . .	50
4.10	Exploration window . . . . .	54
5.1	Results of the SUS questionnaire in graph form . . . . .	62
5.2	"It is easy to search for the desired objects" . . . . .	62
5.3	"It is hard to find a specific georeferenced object." . . . . .	63
5.4	"It is easy to find a specific non georeferenced object." . . . . .	64
5.5	"It is hard to manage the object search lists." . . . . .	64
5.6	"It is easy to navigate on the map." . . . . .	65
5.7	"It is hard to find related objects." . . . . .	65
5.8	"It is easy to inspect objects on the map." . . . . .	66
5.9	"It is hard to search by location." . . . . .	66
5.10	"The object categorization is useful." . . . . .	67
5.11	"The preview window is not useful." . . . . .	67
5.12	"The property window is not useful." . . . . .	68

5.13 "It is easy to navigate in the Explore window." . . . . .	69
5.14 "The Explore window is suitable for learning and exploration of the context of an object." . . . . .	69
5.15 "It is easy to submit an object." . . . . .	70
5.16 "It is hard to find a submitted object." . . . . .	70
5.17 "It is useful to submit objects to the platform." . . . . .	71
5.18 "I consider that the application is useful to generate interest and respect for history and cultural heritage." . . . . .	72
5.19 "I consider that the application is useful to raise awareness about the preservation of cultural objects and encourage the participation of users in this process." . . . . .	72
5.20 Proposed solution for usability issues. . . . .	77
C.1 Users background. . . . .	107
C.2 Users age. . . . .	108
C.3 Users gender. . . . .	108
I.1 First view of the web application . . . . .	109
I.2 Search by term interface . . . . .	110
I.3 Search by location interface . . . . .	110
I.4 Categorization icons on left panel and map . . . . .	111
I.5 Categorization icons on left panel and preview window . . . . .	111
I.6 Use of the navigation tools to create a different view of the globe. The position of the user, object icons and a cluster of objects are also present . . . . .	112
I.7 Related resources button in preview window . . . . .	113
I.8 Related results in a new list . . . . .	113
I.9 Showing object properties and the associated image resources in a slideshow . . . . .	114
I.10 Filling the submission form . . . . .	114
I.11 Submission form and submitted object list . . . . .	115
I.12 First view of the window showing a description of the archaeological site . . . . .	115
I.13 Focus on point of interest showing a video and images belonging to that part of the site . . . . .	116

## INTRODUCTION

Connecting cultural information to the public is of great importance to a collective understanding and respect for the past. Digital cultural presentation systems highly promote its preservation, knowledge and dissemination. There are multiple sources of digital cultural archives available for this process. However, to bring these collections to light and improve this process, there is a need to combine and integrate different platforms and representation technologies, in order to develop more engaging and interesting ways to communicate them. This dissertation presents the studies performed in this area and the efforts in creating a solution that provides a collection system capable of indexing multiple forms of visualization and interaction from diverse sources. The design of these solutions concerns the existence of different target users and how they can be adapted to be useful to all and accomplish the desired function and goals. The project here presented is part of a collaboration of various archaeological institutions from the region of Iberic Extremadura and FCT-NOVA. The proposed platform was created in order to promote archaeological sites and artifacts of the region and support investigations and research. The work here presented aims to study methods and structures that aid in the access, visualization and interaction of multiple representations of cultural archaeological artifacts. The developed platform aims to address numerous flaws related to the communication of cultural heritage and concerns about its preservation, management and research. This platform was designed to adapt itself to all sorts of applications and collections. In the design and development process, some expected limitations are known and discussed, as the decisions made during development depend on what goals are prioritized.

## 1.1 Motivation

Archaeology is a discipline that recovers and analyzes material culture. Studies in this area are performed by investigations happening in historical sites and laboratories [31]. These investigations are usually carried out by teams of experts from a wide range of disciplines and involve a large volume of complex data that needs to be documented, curated and managed. Archaeological findings are inserted in the much larger domain of cultural heritage, consisting of all the tangible and intangible culturally significant remains. There is an increased concern by cultural conservation institutions to promote a collective responsibility about the preservation and dissemination of our cultural past. In order to do this, a strong bonding should be formed between the general public and cultural heritage.

Nowadays, this can be accomplished with the help of digital technologies, presenting collections of cultural objects in an engaging, interesting and interactive way, when compared to traditional means. All the different kinds of visualization and interaction systems grab the attention of a larger audience and assist in the satisfaction of new-born curiosity, by providing efficient tools and attach meaning and context to user experiences. Their accessibility is also an important advantage in establishing this close link to the public and even assist specialists of the cultural disciplines with their tasks, such as research, collection management and more. These systems should not only be available at cultural institutions but also reach the user whenever possible, through common devices. These devices not only let the user consume the media but also submit input to participate in cultural heritage preservation.

Designing visualization systems implies the existence of cohesive metadata. The process of developing a system takes into account the nature of the collection and the defined objectives. To make the most out of these systems, the use of multiple representations of the same object can prove effective. However, the lack of methodologies and standards on how to handle the visualization and the metadata behind it hinders its development. Relational metadata makes the integration of objects from different collections and different types of representation possible, converging data so it can be communicated, managed and understood without difficulties, losses and mistakes.

This project aims to present a solution on how to bring more visibility to digital cultural collections, by simplifying the process of gathering and integrating cultural heritage content from different sources and, consequently, creating contextualized representation. There were efforts to design the solution to be customized to different interfaces and collections, allowing contribution by non-technical users. However, this goal could not be evaluated, so there is not guarantee of this detail being fulfilled.



## 1.2 Problem Context and Final Goals

This dissertation aims to find a solution to the problems mentioned in the motivation. Thus, next, the problems addressed in this dissertation are described in detail, in the form of research questions:

- How to exploit the cultural heritage data stored in multiple repositories to its best potential, by encouraging and facilitating its exploration and the contribution and collaboration of different types of users, in order to raise cultural awareness, knowledge and respect?
- How to integrate and add context to digital cultural heritage data from a single collection or separate sources, filling in incomplete or less noticeable information by creating relationships between objects and displaying their spatial location relative to each other or site of interest?
- How to provide efficient interfaces for interacting with different digital representations of cultural artefacts?
- How to create a versatile platform to be used by non technological experts from cultural institutions, wishing to showcase their own collections of cultural objects?

This dissertation was developed in context of a plan from the Museu Nacional de Arqueologia and Museu de Mérida<sup>1</sup> with the goals of bridging digital archaeological information to the general public. The result was a tool for searching, access and interacting with archaeological information relevant to, but not only, the region of the Iberic Extremadura. It was intended to support researchers and spread the cultural richness of the region, by promoting physical sites and artifacts. The developed platform addresses more than this region and was designed to be adapted according to the needs of each institution, who might require a global solution.

The developed solution was divided in two important parts. The one presented here focuses on the presentation and indexing structure, while the integration of different repositories and the structure for retrieving their information for the project was developed in parallel by another colleague in *Integration of Georeferenced Historical Information*. The two parts interconnect in the implementation but do not necessarily address the same goals.

---

<sup>1</sup><https://www.mecd.gob.es/mnrromano/home.html>

### 1.3 Contributions

The previously mentioned research questions cover numerous problems from the area of cultural heritage. This dissertation brings, in itself, the following contributions:

- Dissemination of cultural heritage knowledge, providing different perspectives from its contact through traditional means;
- An easily configurable digital platform for institutions that wish to showcase their cultural heritage collections.

### 1.4 Document Structure

This thesis is divided in the following chapters:

- **Introduction**  
Chapter 1 presents an overview of this thesis, following its motivation, context, goals and expected contributions.
- **Background**  
Chapter 2 provides a simple background about the context of the different parts of the thesis, consisting of a definition and presentation of cultural heritage, visualization and interaction and spatio-temporal representations. It ends with a conclusion on how these topics will be approached and narrowed-down.
- **Related Work**  
Chapter 3 shows work addressing the mentioned topics, including applications, research and solutions. It concludes with important notes for the development of the solution described next.
- **Design and Implementation**  
Chapter 4 describes the proposed solution in detail, from its design phase to implementation, with the involved technologies, a comprehensive explanation of the decisions made, problems faced and how the final platform works.
- **Evaluation and Results**  
Chapter 5 addresses the methodology used for the evaluation of the implemented solution and how competent it presented itself in regards to the proposed goals by analysis of user feedback. It finishes with a brief overview and discussion of these results.
- **Conclusion and Future Work**  
Chapter 6 concludes the thesis with a review about its outcome, presenting results and discussing limitations, and also suggestions on what could be improved or implemented in the future.

## BACKGROUND

This chapter aims to enlighten the reader on concepts about cultural heritage, digital visualization and interaction of objects and techniques for handling and representing geographical data, timelines and storytelling context. These concepts will be explained without overlapping the themes behind them, so we can think separately about the intricacies and challenges of each subject, in order for the designed solution to better overcome the struggles associated to them.

The basic layout of this chapter is divided in three sections: The entire simplified process of how archaeological digital heritage can reach our devices, from a brief explanation about cultural heritage, its documentation and retrieval to studies on the visualization by the users end (section 2.1); a section dedicated to the visualization and interaction of digital objects, in 2D and 3D, virtual and augmented reality devices and tangible interfaces, exploring their connection to the user and its benefit to the project, (section 2.2); a third section investigating the representation of the spatial and temporal properties of objects, with geographical data and timelines and narratives, (section 2.3); and lastly, the conclusion to this chapter, with a discussion on how these subjects were tied in and taken into account when developing the proposed solution in this document (section 2.4).

### 2.1 Presentation of Digital Cultural Heritage

In order to work on the domain of archaeology and its preservation and representation in digital systems, it is necessary to understand digital cultural objects. There is a laid out process that allows us to transport these information-rich objects into a digital environment and present them in our devices. A significant amount of research has been made on how to approach and describe every single task in this process. From its documentation in various forms of media, to best practices on how to present cultural objects and reach

the intended public in the most useful manner. These studies conclude on a large number of solutions, but also bring to light more questions and studies. Presented next, are the relevant concepts associated with these solutions, described very broadly. This allows us to adopt a general view of the workflow and specific techniques about this thematic and providing us with more tools to tackle the problems at hand more efficiently and autonomously. This is due that it is assumed here that the area of archaeology is unknown to most computer scientists.

### 2.1.1 Cultural Heritage

Humanity lives fascinated by its past. Human culture relies on holding on to, understanding and learning from key events in history, previous generations, distinct societies and intellectual achievements. Most of what happened before does not remain physically in the present time and what is left over time progresses toward the loss of its intrinsic cultural richness. The preservation of a collective memory is an important task to allow any advancements pertained by a civilization that wishes to prosper. A wide range of disciplines dedicate their expertise to the study and conservation of the past.

Albeit the concept of cultural heritage is considered a complex, subjective and evolutionary notion, due to the belief that culture belongs to anyone, it can broadly translate to **all the preserved inherited evidences of the past**. It consists of all the tangible and intangible legacy from previous generations, as well as natural heritage, which still delights us and can still be investigated. In a more practical examination, UNESCO<sup>1</sup> proposes on a more exhaustive categorization of what classifies as cultural heritage [22].

The existence of this definition poses a question on where all this heritage is actually preserved. This is the role of memory institutions, like museums, sites and monument records, archives, galleries and libraries. The actual definition of cultural heritage implies the existence of documentation and all the knowledge that surrounds it, along with its preservation and maintenance, as something we collectively hold value to. Citing Doerr [9], the diversity of all kinds of cultural heritage can be distributed in the following categories:

- History of arts and modern arts (graphics, painting, photography, sculpture, architecture, manuscripts, religious objects);
- Historical heirloom (treaties, letters, manuscripts, drawings, photos, films, personal objects, weapons);
- Archaeology (sherds, sculptures, tools, weapons, household items, human remains);
- Design (furniture, tableware, cars, etc.);
- Science and Technology (machinery, tools, weapons, vehicles, famous experiments, discoveries);

---

<sup>1</sup><https://ich.unesco.org/>

- Ethnology (costumes, tools, weapons, household items, religious objects, etc.);
- Immobile sites (architecture, sculpture, rock art, caves);
- Natural history collections, such as paleontology, biodiversity, mineralogy can also be considered culture, because they are involved in human activities, like research.

As we can see, the definition of cultural heritage comprises a wide range of terms, and each of these categories have their own area of study. In this dissertation, given the context defined in 1.2, the focus is on the area of archaeology as a case study. However, the presented conceptualized solution is aware of the possibilities of abstraction to adapt itself to other domains of cultural heritage. There is much value in researching and preserving cultural heritage. These topics summarize the work of professionals in the field and their goals[5]:

- To encourage cultural comprehension;
- To contribute to knowledge on all levels;
- To influence on related sciences and engineering;
- To strengthen our understanding of past arts and culture;
- To improve our perception about the intrinsic nature of the objects.

The existence of digital systems that deal with this definition of cultural heritage comes from the need to address multiple problems related to heritage in order to motivate the topics mentioned previously, complementing traditional methods. Solutions to these problems are aided by computer applications and techniques: Collection management, conservation, research and presentation [9]. Therefore, the complement of computer science knowledge to this topic can positively affect not only scientists and researchers, but the general public, helping perpetuate the indispensable value of cultural heritage in human culture.

On a lower note, the process of transposing physical heritage objects to digital information still has divergent takes and pipelines, resulting in the disparity of data. However, there are some attempts at standardizing how digital culture is handled, in order to avoid loss of information and incompatibility between archives and access systems. One example of this is the ISO 21127<sup>2</sup> standard, that establishes an ontology for the interchange of heterogeneous cultural heritage information between institutions, developed by experts from a wide range of disciplines, such as computer science, archaeology, museum documentation, history of arts, natural history, library science, physics and philosophy, from an ontology that started under the name of CIDOC Conceptual Reference Model (CRM) [9]. Another example is the open organization Dublin Core<sup>3</sup>, which aims to promote and further advance a standardized metadata usage.

---

<sup>2</sup><https://www.iso.org/standard/57832.html>

<sup>3</sup><http://dublincore.org/>

### 2.1.2 Digitization and Preservation

So that cultural heritage may exist in digital form, it must first be documented digitally. Digitization of physical cultural artifacts extends the life expectancy of the objects intrinsic information, on which research and studies can continue. Preservation is a very important factor, because of how vulnerable some artifacts are. Not only are they formed by an assortment of types of materials that decay naturally over time, but the loss of its historical value can also be caused by human intervention or natural disasters. It does not take a great effort to get part of our culture lost in time, due to the fragile nature of historical artifacts [5].

These records, due to the nature of digital data, can also reach new audiences and be accessed simultaneously, in a plethora of ways. There are many techniques that can be used to generate this digital information, depending on the type of object and on the information to extract. Some examples of successful digitization methods are laser scanning, photogrammetry, photography, video, 360° video, X-ray, 3D scans, infrared, UV and laser scans, which result in both 2D and 3D representations [5]. However, the object's relevance goes beyond its physical aspect. The documentation of an artifact is not complete just by recording its imagery, context is also needed. Registering what surrounds it helps support the overall comprehension of the artifact. Supporting descriptive metadata is also a very important part of documenting a collection, in order to support more efficient and informative browsing and retrieval.

The record of the visual aspect of an object is bounded to its characteristics at the specific time of data collection. Sometimes, this means that the unimpressive condition of the object, caused by decay, reflects on a lesser impact on the observant, as unintended. These damaged artifacts can be virtually reconstructed, so their representation better resembles its appearance at the time of creation, from small fragile objects to majestic buildings and monuments. Several studied techniques allow for this type of reconstruction, administered from people from this area of expertise, resulting mostly in 3D representations, using various information sources, for spatial and visual queues [17, 23, 32]. Some research is even directed towards the automation of this process, with the advantage of removing the barrier of knowledge about the field and tools [19]. Besides the efforts described for physical objects, there is a recent concern on preserving and documenting performing arts and oral traditions, which require digitization models that do not operate the same way as the previously discussed [9].

The process of digitization of cultural heritage does not necessarily originate from curated sources. Nowadays, technology allows the general public to contribute to its preservation, as we now have access to very powerful tools that can make the process easier and more pleasant. For instance, we can easily photograph a monument with our smartphone or even 3D scan a small artifact with more specialized devices. This whole workflow of non-experts contributing to the process of documenting cultural heritage approximate the community to heritage and encourages its preservation, resulting in more

respect towards it, as intended [5]. One example is the platform Sketchfab, described in 4.2.1.5, a community for storing and sharing 3D models, a whole section devoted to cultural heritage and history. Here we find content submitted by all kinds of users, from curated institutions to personal accounts, such as hobbyists using techniques mentioned previously.

The surfacing problems from this type of contributions, is that does not exist a single standard on how to model them. Different archives use different methods for creating cultural content. This results in a steeping disparity of data from different sources, making it difficult to retrieve and match the same object from different sources. Establishing the methods used for the documentation process would protect the integrity, fidelity and security of these records [5]. Some even advocate the use of centralized 3D repositories, with quality control defined by peer review, in order to address issues like standardization, consistency of information, transparency, accessibility and incentives for contribution [17].

### 2.1.3 Indexing and Retrieval

Following the digitization of cultural heritage pipeline, after the documentation of objects, these need to be accessed and delivered to visualization systems, after being retrieved from their respective repositories. There are multiple open repositories from well known cultural institutions (Europeana<sup>4</sup>, The British Museum<sup>5</sup>, etc. . . ). Retrieval methods, to be satisfactory, should preserve traditional browsing properties and accomplish the aimed function and user goals.

The design of the indexing and retrieval processes should follow a previously outlined objective, in order to better achieve its function. The method of data retrieval can be designed to fulfill different specific functions. We can consider the different types of end users and user knowledge and needs. For collection management needs, the users behind it are museums and archives employees that work with large amounts of data, needing relational and hierarchical context, for general perspective and handling of the collection. Relating to conservation information problems, the users need to have more expertise and the scope of the database needs to focus on specific objects that scientists need to analyze, aiming for the maintenance of these objects. For research purposes, users with other kinds of expertise on historical research need the database to include a more detailed and rich relational context, integrating data with, for instance, geographical information. For its use on presentation systems, the user is the general public, which can have close to no expertise on the matter. In this case, the priority is to make the data presented to be as accessible and engaging as possible, with context linking data to allow more superficial browsing [9].

---

<sup>4</sup><https://www.europeana.eu/portal/en>

<sup>5</sup>[http://www.britishmuseum.org/research/collection\\_online/search.aspx](http://www.britishmuseum.org/research/collection_online/search.aspx)

As all these systems with different functions share the same repositories, there is a need for a standardized relational system and data structure. However, the ideal system would abstract enough the goals of these different user bases in order to satisfy the most possible ones. As the focus of this dissertation is widespread accessibility and not so much the professional use by experts of the area of history and culture, the work will follow towards a 'experience over information' design.

This approach tries to bring information to users by enabling them to experience the cultural objects closely, resembling a traditional exploratory visit to the museum, instead of creating extra walls of information between them. This means shifting the priority of what is in contact with the users from the rich information that helps build the databases to the experience of presence of a real object. It is believed real, culture filled objects emanate a sense of materiality, authenticity, or 'aura' that is difficult to replicate in digital systems - nevertheless our goal is to approximate these feelings and provide the user with essential emotions, affections and sensations that characterize the experience of enjoying heritage [26].

This opens new forms of perceiving cultural heritage in databases, as new forms of metadata and relational schemas need to be built, creating semantics for digital cultural data that resemble our natural language. The impact of cultural information can vary for different users. Loulanski [22], discusses how the definition of cultural heritage changes, depending on the values of communities and environments and presents a list that categorizes the different types of values one can attribute to heritage: cultural values, educational and academic values, economic values, resource values, recreational values and aesthetic values.

Values are linked to perception. Someone's own perception can alter how it actually discerns the information ahead and its perception can be altered after it experiences something. This should also be a factor when it comes to shaping a cultural experience. Experiences are rather subjective and the perceptions of each individual differ. Creating an objective awareness for a cultural topic is no easy task, hindering the process of building relational schemes. The best way to overcome this is to provide enough context to recreate these topics in a broad fashion, to promote imagination, creativity and ingenuity in their presentation [14].

Back to the practical part of the process of retrieval, all this context can be built through metadata and ontologies that create semantics for handling cultural information. As this semantics get close to more human perceptions, that interconnect numerous and complex concepts, they can be harder to homogenize in order to become useful to digital systems. For instance, the content of an object is not only the properties of an object in itself, but it can also be its meaning. Color and shape are concepts easier to address by computers (automatically or not) than, for instance, the meaning, mood or the style of a painting. However, a clear grasp and wider knowledge of these concepts by a computer would allow for a more responsive system. In this way, queries could consist of more



vague and complex terms as subjective as art, bridging interpretation and data [5]. Implementing this type of semantics helps to create richer relationships between objects with complex properties, linking objects that would not have similarities if only digital extraction of characteristics were applied, like different types of objects with different functions that relate to a specific style or event. Not only do these systems need to relate objects in the same repository, but they also need to be able to create connections with external objects and other types of data, like georeferencing metadata, in the same way. This is a larger feat to accomplish, as it means a convergence of information between archives [17]. Interoperability is key in integrating different cultural heritage systems that complement each other. Sources with common interpretations can be linked, with as less descriptive data, assigned during the process of documentation, as possible. This is aided by standard ontologies, like the CIDOC CRM, using minimal description elements from metadata as vocabulary. Citing Doerr [9]: *“One source may relate Roman names to Roman inscriptions, another Roman inscriptions to stones, another stones to place of finding, and another places to coordinates.”*

### 2.1.4 Interfaces and Usability

Technology enables the dissemination of heritage, otherwise only accessible at the mentioned institutions that decide to exhibit it. There is a great concern on these institutions to make the largest possible part of their large collections public, as sometimes it is not possible to display them in its entirety, as large museums can hold millions of objects. This concern follows the right that everyone should have access to a shared global culture. It is estimated that 95% of objects in these collections are not in exhibition, mostly stored in archives hidden from the public [9].

Systems that enable the visualization and representation of these objects are a great help at this dissemination. Presentation systems can be used in various ways, from a system designed by the institutions to be used locally, to guide the visitor through a more detailed or personalized experience, to an universal application that allows the user to explore the entire collection from the comfort of his home. In order to provide the most pleasant, informative and authentic experience to the user, theory on designing interfaces to these systems is needed. Interface design theory collects information from a wide range of fields like visual communication design, literary studies, digital humanities, and computer science. To build and refine these theories, the basic strategy consists in the creation of prototypes and the evaluation of its interaction with the intended user of the system [35]. The discussion in this section includes the experience the user has when interacting with the application and how it can quickly and efficiently find the object it wants or satisfy its goals, and briefly how the intended objects can be displayed.

Relating to how these physical objects can be presented digitally, recent investigations have been trying to find a structure to categorize the different types of cultural

heritage visualization. S. Rizvic *et al.* [32] propose, after research and evaluation, a definition that divides different types of cultural heritage visualization in eight categories, based on predefined parameters that are important when designing these presentation systems. For clarification, these parameters are: Background of the project, context of the project, schedule, people involved, objectives and goals for the project, application field, application/preservation format, possible areas of application, type of 3D visualization method, technical system/aspects, methodology and steps in the working process, results and type of cultural heritage. These categories range from unedited pictures and film to building information models (BIM) [32]. To simply elucidate on BMI, it consists on a high-fidelity digital representation of an environment, building or structure, containing all the necessary data and resources to reliably inform on its characteristics during all its life-cycle [21]. This type of categorization helps to identify the importance that each form of visualization can have on the overall usability of the system. These forms of visualization and their part in presentation systems will be discussed in detail in 2.2.

Relating to user interfaces, we can explore the process of their design by backtracking from end user satisfaction. An efficient system should allow any user goals to be accomplished easily, quickly and in a pleasant way. As cultural collections can have a large dimension, these systems should show this scale, as to avoid having objects lost and hidden within. However, this should be accomplished without scaring or making the user feel unwelcome. Whitelaw [40] advises to stay away from the use of search boxes that receive a single text query, to allow for the use of generous interfaces. These types of interfaces are described as providing the most freedom as possible, so the user can build its own path in the navigation, providing a comfortable feel on its most basic human behaviours when browsing large collections. By focusing on these behaviours and providing the necessary tools for these (scanning, glimpsing, selecting or sampling, and evaluating) the system favours pleasant browsing to objective searching, alphabetical lists or sets of thumbnails. However, this type of browsing can only be as free as the relationships between the objects, defined in the documentation (2.1.2) and retrieval (2.1.3) sections, allow [40].

*Imagine yourself outside an art gallery in a far-off city, with a collection you don't know well. You enter the building to find a small, drab lobby with an attendant at a desk. The attendant asks you to enter your query on a small slip of paper. Not knowing the collection, and not seeking anything in particular, you write down something arbitrary, and pass it over. The attendant disappears for a moment before returning with a line of artworks sitting on trolleys. These are paraded, ten at a time, through the lobby. You can submit another query at any time, calling forth more trolleys, but there seems to be no way to explore the gallery beyond this small lobby. [40]*

Using presentation systems opens up a lot of opportunities to stimulate the perception

of the collection through auditory, visual and haptic sensory enhancements creating overall richer experiences. Regarding systems present at institutions that are coupled with the exhibition, its design should help to augment the authentic experience, instead of serving as distraction from the real perception of cultural heritage [36]. Designing these experiences implies different concerns. Petrelli *et al.* [26] describe some common flaws of these systems and advantages of the physical experience, focusing on preserving and enhancing the experience through them, by adopting a "object over information" approach. This concludes on three vital pillars: tangible interaction, do-it-yourself and personalization [26]. These concepts, even though they were formed for these specific types of systems with support from their physical locations and collections, can be interesting to take into account in other types of systems.

## 2.2 Visualization and Interaction

On the process of interacting with cultural heritage objects and spaces through digital means, it mostly stands for using our vision to look at a representation of them through our screens and using parts of our body to control whatever device we are using for input. There are multiple visualization and interaction schemes, each having their own dimension, complexity and impact on a user's perception of the displayed object, which is desired to be as faithful as if said object was in the presence of the user. Relevant forms of visualization and interaction for this project are described below, along with discussion on their technical approach, their advantages and shortcomings for different user goals and needs and how they can enrich the overall user experience in the context of its inclusion in the proposed interface, specified in 2.1.

### 2.2.1 2D and 3D Visualization

Visual objects can be categorized as how complex in dimension the information that constitutes the image is, forming two-dimensional (2D) or three-dimensional (3D) content. It is important to distinguish how the object is represented from the information that builds the said object. As almost every output devices, like computer monitors and printers, process two-dimensional grids of dots (called pixels), the end result of the object representation has to fit in this 2D space, in a process called rasterization. However, the object itself can be defined by a richer configuration, for instance, scalable vector graphics defined by floating point values in the digital space coordinates [16]. Examples of this are computer generated graphics, like vector graphics and 3D models. Generally, photographs and video are captured in 2D, so all of the information for this type of media is part of a pixel grid called bitmap.

Due to the visual nature of archaeological objects, its most beneficial representation method are 3D models. However, this representation can be aided by photographs and videos. 3D models allow a 360° perspective of a textured geometry model, with possible

manipulation of all components. This geometry model is lit by an illumination technique that calculates the amount of light that reaches all points of the object from a light source, creating highlights and shadows taking into consideration the material of the object. These calculations are based on where the projection camera is pointing and set. This camera maps the 3D scene to a 2D plane, creating the view from the scene. As we are dealing with informative objects, detailed measurements to build these geometric structures are needed, which can be obtained by using specialized devices. Other types of techniques extract or depict the material of the object and texture it around the shape of the model [16]. This can better represent all intricacies of a complete object in a more practical representation and even allow for reconstruction or enhancing [32], thus bringing the object to life. 2D representations like photographs and video are usually followed by a specific mood that comes from the exact conditions of the moment of capture, like the lightning and ambience, camera position or the physical condition of the object [5]. These two types of objects may fit different goals in perception.

The great advantage of using 3D models is how close it gets to a real representation of the object and how it allows its manipulation. This type of representation can be used with different input devices for its full potential. The creation of this type of content still requires specialized equipment and staff. However, advances on technology bring new techniques to quicken this process and produce higher quality representations, and also allow for less specialized contributors [5]. 2D content production on the other hand, is largely accessible.

### **2.2.2 Virtual and Augmented Reality**

Virtual reality consists on a user interface that involves the user in a real-time simulated environment that connects with the user sensory abilities [4]. In summary, it puts the user in a virtual world that he can interact with through basic human tasks. In relation to cultural heritage, the use of virtual reality systems allows the recreation of environments like monuments, that may be currently in bad conditions and are recreated in their original appearance, that lets the user navigate in, creating an intimate experience. These virtual objects are represented by 3D models and interaction with them depends on the device used, the most complex of interaction systems allowing for closer interaction. These devices normally constitute head gears with screens and controllers that attach to parts of the body . The advantages of their use in this field have been proven. Its accessibility is being expanded, from high-end devices that incorporate real-life spatial movements to cardboard devices that a user can attach to a personal smartphone. As for technical implementation, advanced technical skills or equipment are still required and it constitutes a complex and heavy system, specially in representing cultural heritage objects and environments, that should be recreated as realistically as possible in order to maintain their presence. In terms of usability, this is also important, as it is the focus of the real human experience, enriched by providing as much context and freedom, with

high-fidelity representations and avoiding obstructive gear [34]. Virtual reality enabling devices can be present at cultural institutions to enhance learning, but not only. Some of these devices are nowadays accessible to a larger audience, with these virtual worlds and objects easily reaching more public.

Augmented reality consists of another type of interface, that instead of creating a virtual new world, enhances the real world with virtual objects, providing additional information from its environment [4]. It uses a camera spatial position and orientation to recreate, in real time, the existence and pose of the virtual object and layer it on the real world camera view. This type of tracking can be aided by picture processing in identifying real world objects and shapes [3]. This makes augmented reality more accessible than virtual reality, due to it only needing more commonly available devices. This accessibility makes it for a popular system to be in contact with the general public, generating more interest in cultural heritage [8].

Virtual reality and augmented reality can create a very personal feeling on the interaction with digital objects, generating a digital immersive environment that fades the bridges between the user and the device . These technologies can be used both in the physical institutions or anywhere else, due to the dissemination of additionally complex devices, providing a very rich and authentic experience, when interacting with cultural heritage, to take into account.

### 2.2.3 Tangible Interfaces

Tangible interfaces include all kinds of physical objects that act as devices for the connection between human and digital actions. These graspable devices make use of our innate spatial behaviours in physical space to create more natural inputs for navigation and manipulation of virtual objects. These types of devices are built with strong sensors for spatial recognition and refined human interaction, in order to maintain the very important real-time unification of digital and real space, keeping a tight relationship between input and output. This characteristic is necessary for a standard experience with these devices. For the sake of improving the quality of tangible user interfaces, they should be designed, as much as possible, taking the final task they support into account. This link makes the interaction more convenient as it allows the user to perform familiar actions [37].

The use of tangible interfaces brings accessibility based on a more hands-on approach, making it very popular with younger audiences. However, its more specialized use may be too restricted to cultural institutions or exhibitions. It constitutes a very interesting learning tool, as it can provide a more enhanced experience of the task presented by combining other types of digital information, forming a multimedia representation with physical engagement [29]. In terms of cultural heritage, this type of interfaces should be used only if they add to the experience, bringing to light more context to concepts that are desired to learn. For instance, an incomplete archaeological object can be physically

recreated through a rough shaped tangible artifact that communicates with a 3D model. The type of interaction can be divided as internal or external, as if the technology is embedded in the object or surrounds it. One of the challenges when designing meaningful tangible experiences comes from the balance on which the devices should be specialized to the task or the representation of the intended objects [26].

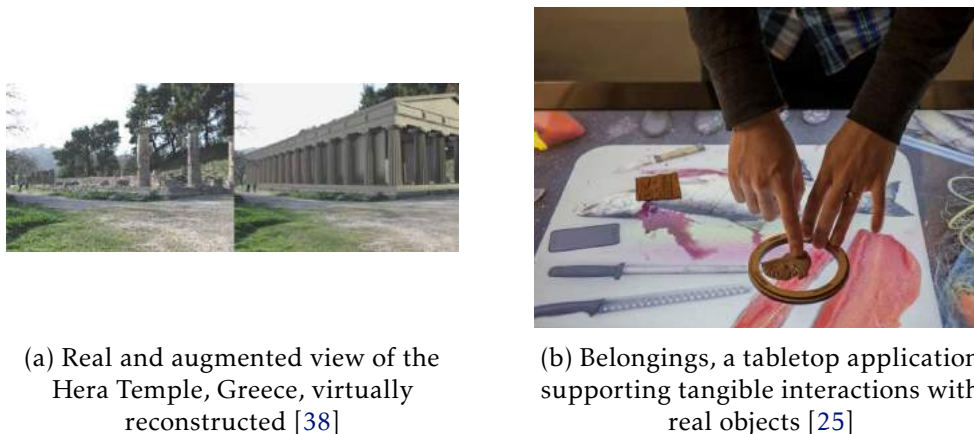


Figure 2.1: Examples of AR and tangible interfaces in cultural applications

## 2.3 Spatio-Temporal Representation

There is more to an object than its appearance. In order to fulfill the users goals and to allow a more efficient and pleasant browsing through digital heritage collections, as described in 2.1, every object needs context. This context of the representation can be given by time or location bounding, whether it is defined in a global view of the world or in relationships to other objects. This allows us to build timelines and maps based on the geographic footprint, which are useful to our needs and rich representations of a whole collection. Below, we describe how we can approach these representations, both technically and conceptually, and then relate them to interfaces and usability.

### 2.3.1 Geographical Data

Providing a location context of digital cultural objects can be an important aid in learning and researching. The location associated with an object can range in detail from a relative location to a an absolute location. It can be the spatial location intra-site compared to a global geographic one. For instance, the location assigned to the object can be of two types: the exact location of the finding of the object in an archaeological site or the presumed location of its origin. This type of data is also decided based on the specifications of the system and what is known about the cultural objects of the collection intended to present. Any of these specifications are significant, for different goals. One example is their use for virtual reality navigation on a digitally recreated site. Another example is their use

for viewing a global map displaying objects georeferenced to their finding location and their assumed area of creation, at the same time for comparison.

Georeferencing is simply associating an object to a geographic location in physical space. The presentation of multiple georeferenced objects placed on geographical references in the form of maps or aerial photos can form a simplification of the real world coordinate system. This allows for the measure of realistic distances and areas concerning the objects, providing spatial awareness of their position. A geographic coordinate is defined by a pairing of latitude and longitude, and this is enough to pinpoint an object in a 2D map. Nowadays, location devices are common, so the creation of this type of data is accessible [13].

Geographical Information Systems (GIS) are more complex spatial and geographical systems. GIS refers to database systems that handle spatio-temporal data in a very complete way, capable of receiving input from various sources, store, retrieve, manipulate, analyze, model and report data. As GIS handle representations of real world locations and dates/times of occurrence, they constitute a very reliable and informative source for research and analysis. These representations offer very detailed visualizations of the geographical and temporal data stored and different visualizations can also be layered so spatial and temporal patterns and processes can be recognized and conclusions can be drawn [28].

As archaeological data benefits largely from its time related and geospatial representations, its a perfect fit for it to be handled by GIS. Many solutions in GIS related to archaeology have been created in order to solve some of its major problems, like maintenance costs, integration of different program components and accessibility of contribution [30]. A case study from Greece (figure 2.2) proves the advantages of the integration of GIS systems with a 3D model of an archaeological site, providing a very rich spatial and temporal intra-site representation in a unified system [15].

### 2.3.2 Timelines and Narratives

Every action happens in a designated point of a perpetual moving timeline. Contemplating the temporal context of an object can provide us with a deeper insight. In presentation systems, the presence of a timeline, with objects that have associated dates of creation in points in time, can provide us with a chronological path or convey a sense of temporal scale. As for archaeological objects, determining the exact age is insubstantial. In the process of absolute dating, the date of creation can be attributed to a range of timestamps. In the process of relative dating the date of creation is created in context to other objects, by defining an order of events with estimated measures of time between them. This type of information can be easily represented and stored with the data, at the moment of documentation.

However, in the perspective of a user navigating a collection, following the chronological order of a collection, or a subset of it, is not really desired, in terms of engagement

to the general public. This is another type of time-bounding, one that relates to the experience and the direction a user takes, in opposition to the time-bounding of the objects. Leading the attention of a user, and building an information-filled path of interaction, following context and a common thread, can be achieved with the use of narratives. Narratives allow for an enjoyable journey to the destination of the defined goal. Narratives are paths that guide the user through a story. This story can be subjective or objective, linear or non-linear. The basis of visual storytelling consists on capturing and connecting interesting content with deeper meaning in order to tell a story [12].

As for the stories we try to tell to users of digital heritage presentation systems, their narratives can constitute their personalized path of navigation. The goal is to give this path a deeper meaning. In practical terms, as the focus of these systems consists on visualization, the main challenge can be on providing this meaning and context through visual characteristics. This can be simply the intrinsic story of the object and how we

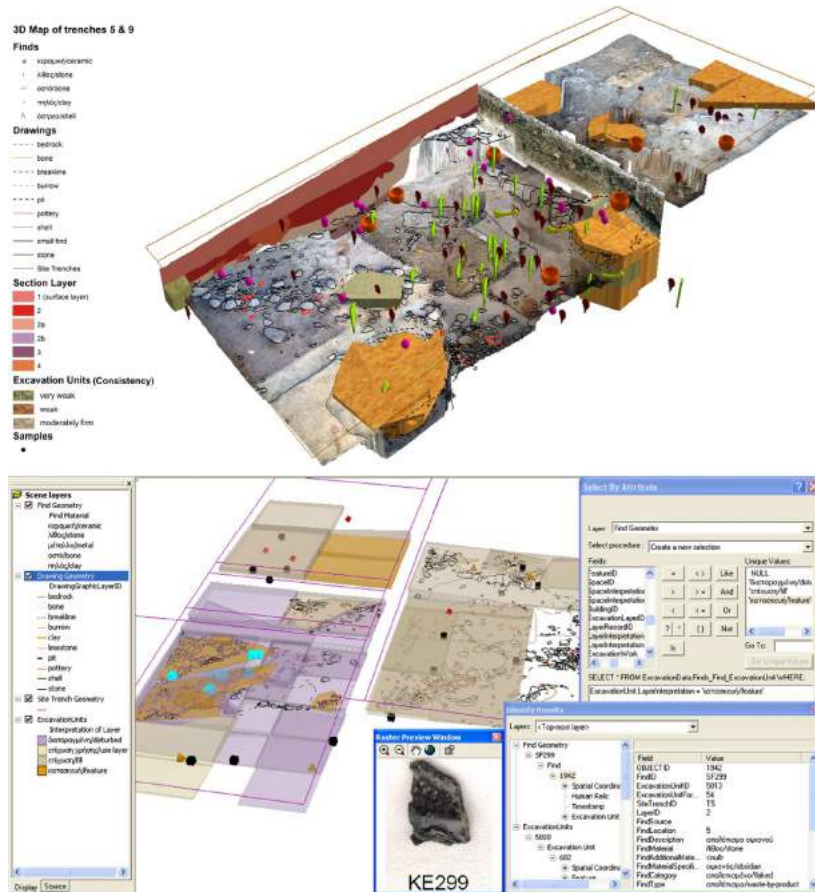


Figure 2.2: Combination of different layers of information and complex thematic identification and classification using GIS [15]



project its importance and on the act of beholding. However, a more stylized and creative story can be used, through unique relationships between objects and video or narration that go along with the object description.

This communication through stories is a very natural human concept that stays relevant to this day. It has the advantage of turning any heavy or tedious subject engaging and interesting, by approaching the end user intimately, through the use of an emotional link. Storytelling methods and tools have evolved and, nowadays, we have access to the unique characteristics of digital storytelling [32]. Digital devices allow for an interactive and immersive experience in presenting a story. These types of interactive experiences are increasingly disseminated and are not only present at the institution that owns the collection. The intimate nature of these devices compared to traditional storytelling attracts new audiences and retains interest. The combination of other popular visualization methods like virtual reality and augmented reality provides an even more attractive experience [39]. Some recent studies defined frameworks that abstract the creation of stories from a cultural heritage database using the objects metadata, like spatial and geographical information, facilitating the construction of an efficient storytelling platform [2, 11]. The existence of a story editor gives the opportunity to a larger audience of sharing their stories to the platform [39].

## 2.4 Conclusions

All these concepts can now come together to create solutions to the problems presented in chapter 1. We have seen how they can contribute to create an integrated representation system that enforces efficient learning and research, motivate the interest of the general public, bridge cultural heritage to a larger audience and allow participation and contribution from different areas. However, to successfully accomplish these goals, there needs to be a very defined approach and clearly identified obstacles.

Some of these obstacles have been established as areas in need of development. These are: the design of successful advanced multimedia user interfaces, display and delivery technologies, 3D issues, presentation and exploration of multiple multimedia representations, and the visualization and summarization of cultural heritage collections as well as aggregation and relationship between different collection resources [5]. This project aims to focus on multiple forms of representation, advanced multipurpose interfaces and the convergence and interoperability of resources from different collections. The workflow for digital cultural heritage presentation is established by well defined and highly specialized areas. However, the information shared by these areas should overlap. The focus of this dissertation is on overcoming visualization and indexing challenges, but with a clear understanding of other areas. In terms of computer science, this research draws concepts and precedents from across various fields like information retrieval, human-computer interaction, information visualization, artificial intelligence and digital humanities [5, 40]. It should be considered that the solutions to these challenges are assigned to a specific

context, like the institution it belongs, the type of collection it holds, the target audience and function.

The study present in this chapter helps to narrow down the conceptualization of a solution that works in favor of the goals presented. For the solution presented in this dissertation some decisions had to be made in order to develop a coherent and focused solution. The existence of a defined problem context guides these decisions. The implementation works with all the types of cultural heritage objects presented in this chapter in 2.1.1, as most digital repositories are prepared to store any defined type. The target audience is non-experts, as the goal is to disseminate knowledge about cultural heritage and history, so the solution does not need to focus on appealing and serving the purposes of experts the area. As for types of visualization and interaction, the solution is limited to the ones provided by most of the digital repositories, because one of the objectives of the proposed solution from the start would be to connect different repositories using the integration platform, described more deeply in 3.3. These types are limited to 2D images, 3D models, videos and text, created by any process of documentation and digitization, as long as the end result of the files provided fit these categories. About the representation of data, the most interesting aspect, considered as the basis of representation for the cultural objects was their spatial location, as a large percentage of objects provided by the repositories are georeferenced.

Due to the decisions made in light of the context of the problem, time constraints and limitations on technology, some of the themes mentioned in this chapter were not explored in the implementation of the solution. These themes are virtual and augmented reality, tangible interfaces, timelines and narratives. However, they serve the purpose of enlightening the reader on what kind of approaches exist for dealing with cultural heritage and how to fulfill the main goal presented by this thesis. This adds dimension to the problem at hand, providing a significant help during the conceptualizing process of this solution and has become an important feature to be implemented in future work.

## RELATED WORK

In this chapter, some examples of related work are demonstrated and discussed. These are projects that connect the subjects previously mentioned in chapter 2, with their respective goals, motivations and context, allowing a more practical approach to these concepts. Evaluating similar projects will help identify what was already established, proven and tested, shaping the path of this dissertation in a more informed manner. We analyse some end user examples, evaluating their effectiveness on the proposed goals of this dissertation (section 3.1). Research has also been taken into account as to identify the efforts in conquering these challenges (section 3.2). In this section, some case studies and their conclusions are presented. Conclusions about this overview complete the chapter, relating the work presented here with the one developed (section 3.4).

### 3.1 Cultural Heritage Multimedia Presentation Systems

Related work to the context of the previously discussed background will be analyzed in this section. These practical solutions of the previously addressed background concepts help visualize and feel how cultural heritage can be communicated. A brief description of each of these projects will be given, taking into account the intended objective, its context and design decisions. All concepts shown in chapter 2 will be exemplified by at least one project, providing a glimpse at their viable applications.

**Cyark**<sup>1</sup> (subfigure 3.1a) is a 3D online library referencing cultural heritage sites around the world, in order to make them accessible and preserve their integrity and knowledge. The 3D models are documented through the use of 3D laser scanners. There are different projects for different objects and monuments, presented through a mosaic

---

<sup>1</sup><http://cyark.org>

interface with distinct query options, for instance, a timeline or drop-down menus for varied categories like cultures, country and themes. Inside each project, a very detailed documentation is provided, along with a 3D model, detailed descriptions enriched with stories and legends, a media gallery and its location on a satellite view of the world map. Although the completeness of the information is indisputable, the way to access it does not feel natural and intuitive. The navigation between projects is not inviting giving how each different project is separated in pages filled with information, albeit structured in an appealing way.

**3D Monuments**<sup>2</sup> (subfigure 3.1b) is a web application that presents 3D models of monuments on a world map. It connects the locations of monuments in the web map application built with Google Maps API<sup>3</sup> to a visualization of their 3D models stored in the Sketchfab<sup>4</sup> platform. However, these connections form a list of scarce entries.

**Hiroshima Archive**<sup>5</sup> (subfigure 3.1c) is a web application that integrates geographic mapping to different kinds of multimedia contents about the events related to the Hiroshima atomic bomb. Using Google Earth, it displays a map of that time period filled with photographs and videos grouped into category surrounding a reproduction of the explosion's epicenter. People directly or indirectly affected by the bombing can submit their own stories and content to be displayed on a location of the map. This application creates a visual representation of the impact of this historical event on the lives of many, exalting its importance.



Figure 3.1: Examples of cultural heritage multimedia presentation applications

## 3.2 Cultural Heritage Research

In this section some case studies from different authors presenting research methods, evaluations and conclusions will be discussed. These projects provide a deeper insight into the practical approach for this project, informing of previous struggles, as well as

<sup>2</sup><http://3d-mon.com/>

<sup>3</sup><https://maps.google.com>

<sup>4</sup><https://sketchfab.com>

<sup>5</sup>[http://hiroshima.mapping.jp/index\\_en.html](http://hiroshima.mapping.jp/index_en.html)

decisions and technologies for its design and implementation. They are divided in visualization theories and the handling of metadata, but involve all the concepts discussed in chapter 2.

### 3.2.1 Visualization and Interaction Research

S. Rizvic *et al.* [33] overcome the need of representing the original appearance of cultural heritage with the design of an efficient workflow making use of advanced 3D technologies. The authors discuss benefits and limitations from their evaluation of all parts of the process used in a case study. The case study consists on the visualization and multimedia presentation of a fortification known as "White Bastion", an important and imposing historical site in the surroundings of the city of Sarajevo, Bosnia and Herzegovina. The digitization of this building will allow the representation of its appearance through the ages, using digital 3D techniques for the reconstruction of its remains, dating from the 18<sup>th</sup> century. The documentation needed for the reconstruction included drawings and blueprints of the archaeological remains, help from historians and archaeologists working on the site and consultation of available literature from historical sources. Six different building shapes were then considered to be presented in the timeline of the interactive application, as result of interior and exterior changes to the building during its existence. The building was modeled and textured using 3D modeling software, after the creation of a terrain with precise realistic measures using a GIS application called Global Mapper, for spatial awareness. The model was then exported and used in Unity Web Player for presentation in web, after unsuccessful attempts with 3D Heritage Online Presenter (3DHOP) and XML based X3D files with HTML5, due to the scale and complexity of the model. Storytelling is planned for this project, with interactive stories told by 3D models, as a way to reveal interesting insights, like objects and characters, about the building history across the different time periods, through virtual exploration.



(a) White Bastion fortress



(b) Exterior of the 3D model

Figure 3.2: White Bastion and its virtually reconstructed 3D model [33]

In a different article [32], S. Rizvic *et al.* establishes a plan to define general practices,

methods and strategies for the visualization of cultural heritage, based on research conducted by a working group of "Colour and Space in Cultural Heritage"(COSCH)<sup>6</sup>. The main purpose of the work is to further automation and consistent standards in the process of handling cultural heritage visualization and advance its dissemination to the general public. By investigating a wide variety of different projects from London and Sarajevo, the authors identified a common workflow and categories for different types of visualization. This common workflow can be useful when there is a necessity to abstract the different processes required to reach the goal of visualization. The definition of a process as an input-output scheme is possible when finding similarities between the case studies. The four main phases identified were preparation, collection, processing and finishing. This framework is characterized by three milestones. These milestones feed their output as input to the next: defining the project preconditions, process the data collection and producing the digital dataset needed for the final presentation. However, these can be as flexible as the purpose of the project requires.

The authors also define how user evaluation is important in experimental design, in order to develop engaging user interaction and communication. This was accomplished by conducting interviews on users about their satisfaction when interacting with a digital application recreating an archaeological site in Sarajevo. This way, design decisions are affected by contribution. For instance, it was evaluated how immerse the users felt with an interactive storytelling and how interesting it felt in comparison to a linear one. In conclusion, the article ends with guidelines and recommendations taken from their research for digital visualization:

- it should be based on accurate measurements or consultation of precise documentation;
- it includes comprehensive metadata, whether sourced from the collection or extracted independently;
- it displays the visualization including all scientific data and historical sources used to create it for consultation;
- it incorporates extensive technical metadata about all details and conditions on how the object was recorded;
- it includes comprehensive paradata (information about all the technical and subjective design decisions);
- it is scalable, viable and reusable.

---

<sup>6</sup><http://www.cosch.info>

### 3.2.2 Storytelling, Geo-referencing and Semantic Mappings

D. Pletinckx *et al.* [27] present a prototype of a cultural presentation application and discuss the results of its implementation. This application is part of a project called Ename 974, whose objective is to highlight the archaeological, historical and cultural assets of a small, rural village called Ename, in Brussels. The system also seeks to be cost efficient and sustainable to reflect the local identity of the village and be easily integrated in tourism. To achieve this, the application resorts to the use of interactive storytelling. The inhabitants of the village had influential decision on the way these stories are presented, giving new life to the village cultural and social scene and making the system feel authentic with their identity.

The system focus on readability, by letting the user explore the village virtually and physically and create connections. The user has the freedom to explore a variety of themes, like history, landscape, art, archaeology and nature. It also gives the user the liberty to explore the points of interest in the desired order. An object is given significance and meaning when placed in a wider context. "*An old house becomes the home of an important family with clear links to the national political, cultural, and historical scene.*" All of these features allow a visitor to build a personalized story. This is compared to a real life visit to a place of interest, where a visitor navigates as it most desires. However, for a storytelling system like this to be captivating, there is a concern on the balance of personalized storytelling, versus the creation of a coherent and appealing story.

To attain this balance, the interactive storytelling system is built in what are called "nuggets". These are units of information containing written text, spoken text, a timeline, multiple images, animated images, video sequences or interactive panoramas or objects. Each nugget shows information about a heritage asset from a particular perspective or theme. Their interconnection allows the visitor to follow interactive stories that follow one or multiple themes. Its navigation is divided on spatial or thematic storylines. This type of system allows for a very accessible method of content contribution, as it uses a simple form-based interface that can be used by non-technical users from different cultural areas.

In the end, these systems proved to be feasible and cost-efficient. This makes them a good presentation system to be used by small local communities with modest means. Its effectiveness is enhanced by the close link to the local identity in its development and contribution.

E. Gadolou *et al.* [11] suggest a methodology to be used in cultural heritage management that is based on the connection of storytelling and geographical information technologies. Their case study is a project that aims to enrich the archives of the museum containing information about the Georgios Averof battleship, a famous Greek warship, through the use of storytelling technologies. Consequently, strengthening the presentation, maintenance and the significance of the archives, by building links of knowledge. The paper explores various forms of multimedia digital storytelling.

This long term process of digitally empowering a cultural collection was developed with well defined objectives that relate to the strengths of the archive. This defined even the documentation process of the project, ranging from scans of historical photographs of the ship and extraction of their metadata to building a spatial database of the ship decks with accurate measures. The necessity to integrate all this data to satisfy the previously defined objectives led to the creation of a methodology explaining the process from documentation to presentation model. By following this methodology, the archive evolves to being built on a semantic model that allows, through a graph of relations between objects, the creation of non-linear stories consisting of beginnings, middles and ends, with different types of content in between.

R. Damiano *et al.* [6, 7] work focus on enriching the relations between cultural objects and increasing interoperability by developing contextual ontologies. These ontologies are used to provide descriptive and clearer backgrounds when focusing on a single cultural object associated with different types of media, making them self-explanatory with the help of context and narratives. The explored ontologies and subsequent narratives are inserted in a 3D virtual environment application called Labyrinth 3D. This system creates a virtual maze that serves as the interface for exploring collections through different narrative archetypes. Archetypes follow classic storytelling concepts that gather related stories, locations, characters and objects that share a symbolic meaning. This allows the existence of an abstracted ontology layer that reasons about the relations of the metadata of cultural objects from different sources, creating pleasant and coherent stories that fit in these archetypes. This way it is possible to build a personalized path of exploration between seemingly unrelated cultural objects, by revealing their intrinsic connections.

The ontology is built with classes categorizing the different objects and it also extends the CIDOC-CRM ontology. The CIDOC-CRM ontology helps to link the objects to its artistic creation. This visualization framework of semantic metadata focuses on creating an environment that intuitively describes the narrative context of the system, like the graph-nature of the labyrinth and how it relates to the connections between objects, and displays interactive objects. The user is invited to get loose himself in his own exploration of these personalized narratives.

N. Adabala *et al.* [2] provide a framework to address the challenges of interconnecting different forms of representation of cultural heritage in order to create a coherent story. The framework is also evaluated from a user study accomplished in two historical sites in South India. The solution focuses on the automatic creation of engaging narratives, with both passive or active user interactions. The importance of the choice of digital representation used for the right topic is underlined. Also, the context in the relationships of objects in creating a self-explanatory cultural domain.

The framework presented serves two functions, to allow anyone to create a culturally relevant interactive narrative through the context of the objects and to enable the user to choose their depth in the exploration of the narratives it follows. The architecture of this framework then follows these core aspects:



- **Data abstraction:** Defining a small, but effective, set of generalized data types by categorizing and abstracting cultural content, enabling its combination to form rich interactive narratives;
- **Process abstraction:** Creating a uniform interface that connects with different representation technologies in categories, in order to form an adaptable composition of visualization schemes;
- **Process-process interaction:** Enable the composition of all the interface elements to provide a comprehensive integrated experience that promotes interactive exploration through cultural heritage collections;

The evaluated users demonstrated a strong preference to these types of interactive cultural heritage representation over traditional ones. The use of this unified framework presents an extensible and adaptive platform for multiple representations of cultural heritage systems.

S. Kulasekaran *et al.* [18] work consists on developing a collection architecture based on metadata, for integrating a large variety of archaeological archives. This collection architecture allows data and metadata to be curated and managed when moving across multi-component systems and adapting methods during the life-cycles of each collection. This brings advantages in terms of accessibility, by enabling multiple diverse users to perform the necessary tasks of documentation and analysis in a seamless and concurrent way, and also in terms of preservation, by providing a fail-safe environment in case any stage of the process fails.

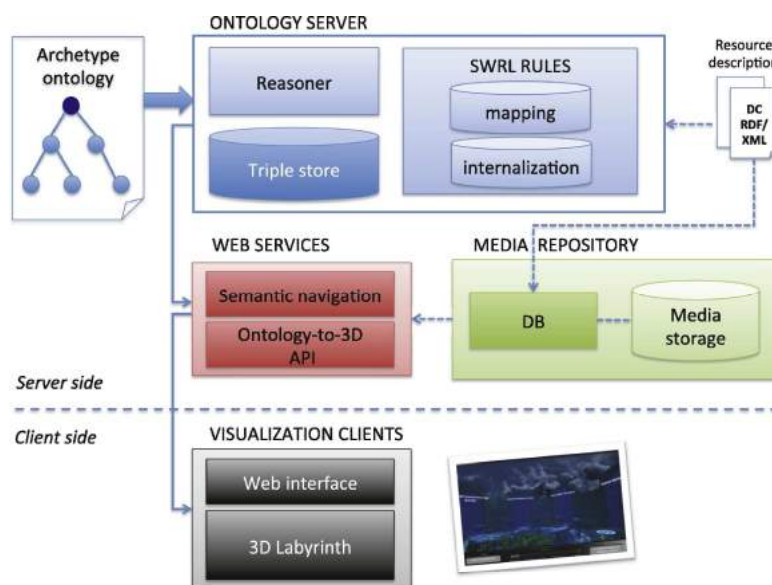


Figure 3.3: The architecture of the Labyrinth 3D system [7]

The project focuses on archaeology as a way to demonstrate the effectiveness of the architecture. Archaeology requires investigations comprising a large number of complex documentation and the participation of specialists from a wide range of areas in field-work and research, so coordination between these resources is essential. The architecture is built around a record-keeping system for metadata collection, extracted automatically where possible. The framework used to design the system is based on the records management big bucket theory, where data is grouped on different tiers. The tier below groups data according to the basic research phases of any type of investigation. These phases are field, study and publication, allowing the passage of data through these phases. This system focuses on the source of the collected data. Lower tiers inside these phases group data according to specific categories. The architecture uses different systems to archive and present this data and making sure the syncing of information happens smoothly, with the help of user input. All the different schemes are tied together in a normalized way with the help of the Dublin Core schema, generalizing the relationships between objects. This decision was made to help mapping to a semantically rich ontology like CIDOC-CRM in the future.

### **3.3 Integration of Georeferenced Historical Information**

As mentioned in 1.2, this dissertation is part of a project involving two dissertations. The dissertation developed in parallel to the one presented in this document complements it by solving the issue of bringing together different digital repositories and combining cultural heritage data for more efficient exploration. The project developed by Fonseca [10] consists of a platform that accesses data from various types of cultural heritage repositories through an uniform access, bypassing the need to know different data access methods and formats associated with each repository. This project seeks to simplify the process of searching for this type of data, querying multiple repositories and converting the results into a common format. In the process, it also combines similar data and detects relationships between results, allowing a contextualized search and unifying related data from different sources (for example, various types of testimonies related to the same artifacts and available from different sources). This dissertation, from now on referred to as interaction platform, benefits from the project presented by Fonseca, from now on referred to as integration platform. Both projects, however, can operate independently. The integration platform helps to provide richer data from diverse sources to use in the interaction platform, with the same effort as it would access only one repository. And the integration platform benefits from a more accessible and natural way to interact with the data it uses and retrieves, by showcasing results in the interaction platform, adding value to this information.

The integration platform consists of an intermediate access layer between different repositories and end user applications and interfaces. All the communication between the applications and the repositories through the platform needs to be unified, from how

the data is returned to the search methods used by the applications. These parameters can change from one repository API to another. This presents in itself an abstract way of communication between user and data. The integration platform is, in this way, also independent from the solution presented in this thesis and vice-versa.

The integration platform works by defining an internal model of properties for the received results. This internal model is structured in a way that all object properties can be composed in this unique format. This structure was defined using Dublin Core, CIDOC CRM (mentioned in 2.1.1) and studying some of the most notable cultural heritage repositories. What this means, for instance, is if in one repository the objects have a property *Author* and another property *Type*, but in another repository the objects have a property *Creator*, but no property similar to *Type*, then, in the internal model of the platform, all objects have a property *Creator* and *Type*. The object from the first repository would have the value of property *Author* stored in the property *Creator* of the integrated platform and the value of property *Type* value in the property *Type* of the internal model. The object from the second repository would have the value of property *Creator* stored in the property *Creator* of the integrated platform and no value in the property *Type* of the internal model. Like this, the communication between client and platform happens by using this unifying model. The communication between platform and repositories is possible due to these conversions, making every result from different sources the same in structure in the eyes of the platform.

One of the disadvantages of this method is that all of the data becomes homogeneous, with some objects losing some of its more detailed information that can not be unified. Another one is that objects with less complete properties suffer from lack of information and become more disconnected from the data as a whole. Either way, a single search returns a far more complete result, bringing to life more incomplete repositories.

The repositories that are connected to the platform as of the time of its use are Europeana, Fitzwilliam Museum, Geodata of Lisbon City Hall about Religious Houses and DigitalNZ. It is also made possible to integrate new repositories to the platform without applying changes to it. This will prove useful when customizing the application, as we will see later, as specified in our goals.

To use the integration platform, a REST request must be constructed. The platform has two types of search methods: query terms and location. In the search by terms, the search is based on a string, returning objects containing the string. In the geographic search, the search is made using coordinates, returning results inside a spatial bounding box. The platform also allows to personalize the returned results, like deactivating the use of relationships between objects, the combination of objects or the extra properties, which is all the data which cannot be converted to the unified model. It is also possible to return the data of a specific object, using an identifier assigned by the platform. The request then returns all the possible results, given the maximum number of results allowed by each repository, in a JSON file. This file holds an array of results, each with all the properties stored in keys. The structure is documented, so that a simple JSON parser can explore its

data in a comprehensible way.

### 3.4 Conclusions

By analyzing the projects mentioned in this chapter, it's possible to better understand the solutions available to address the challenge at hand. Not only by focusing on the technical part of this dissertation but also on how it is possible to create a significant connection with the end user, an essential key to bridge the public to cultural heritage as a whole. These presentation systems work in diverse contexts and tackle different objectives, allowing us to understand how the design of each system is influenced by where it's inserted, being molded by the institution, the collection, the location and the public. However, presentation is only possible with a clear understanding of the available metadata and how it is integrated. The mentioned abstraction systems for the automatic extraction and indexation of metadata facilitate the construction of compelling cultural presentation systems. Adaptability is crucial when developing an abstract layer that supports multiple representations. The use of already available standards and methodologies can shape the design of these types of architectures, enabling good practices and convergent methods. This brings advantages to effective preservation, understanding and presentation of cultural heritage.

In the context of this dissertation, the study of these types of projects helped on the design stage, as it's possible to get a clear understanding of what succeeded and the gaps behind these solutions. Having these concepts present at the design stage clearly defined objectives for the proposed solution. These will be discussed in 4.2. It was important to find a good balance between the goals proposed in the beginning. Given the information provided in this chapter, the main objectives in designing the solution could be summarized to connecting users to the data provided by the different repositories in a useful and appealing style, and allowing this data to be visualized in the way it would be more interesting and engaging. Having defined these objectives for design and implementation, some of the concepts had to be partially left behind, like the emphasis on relationships between objects and consequently, the emergence of narratives. Nonetheless, the importance of these concepts should be noted and discussed in the future.

## DESIGN AND IMPLEMENTATION

In this chapter, all the parts of development of a proposed solution for the problem and goals presented in 1 will be documented and explained, having in context the information presented in 2 and the inspiration from the various projects from 3.

The first section describes all the decisions made during the design phase of the project, how they contribute to the goals presented and some background behind the development (section 4.1).

Next is the implementation phase, with first being discussed the technologies chosen to be used in development and their part in the project (section 4.2.1). The development phase is divided in two major parts, covering two different obstacles. In *Indexing and Navigation* the decisions behind the implementation of the presentation and visualization of cultural objects are explained (section 4.2.2). The other part of development is *Multiple Contextual Visualizations*, where the problem of multiple visualizations given a certain context of an object is described (section 4.2.3).

Lastly, this chapter is concluded with a brief overview and reflection of every section, covering the use of the proposed solution by expert agents, where it can be personalized for other similar purposes and contexts (section 4.3).

## 4.1 Design and Conception

In order to find the most efficient solution for the project, the problems to be addressed needed to be outlined and clearly defined. By simplifying and combining the goals of this thesis mentioned in 1, it was decided that we would face two, non overlapping, main obstacles. These obstacles fall under the main theme of connecting people to culture and history. Simply put, one is facilitating the exploration of all the preserved digital objects distributed in diverse repositories, the other is how to give context to these objects to make them more interesting and appealing to the end user. The first emerged from the use of the integration platform and ways to present a large amount of historical and cultural data, in the most accessible way possible [10]. The last obstacle was detected from the problem of using that same information for more detailed, contextual learning, which was simply not possible due to the amount of information and lack of data informing its relationships. In short, this decision had its roots in the problem of the dimension of the data, and at what level we would decide to present this information to the end user. Instead of focusing at a more abstract or detailed level, both options were considered and implemented with various degrees of success. It was also decided that the solutions for each problem would be independent from each other, but would be presented combined in this project as a unified proof of concept. The reason for this decision was based on the fact that, given how distinct the functionalities goals were, the task of presenting a completely functional application for both goals would prove to be a difficult task for the time restraints and struggles with the technology that were faced. On the other hand, presenting two distinct applications would not fully display the potential of each functionality as much as the combination of the two. From early on it was decided that the solution would be a web application, working for both desktop and mobile. This goes in favour of the goals of the dissertation, of creating a history and culture software that can be of easy access, in order to reach the largest audience possible. TerriaJS, one of the technologies described in 4.2.1, proved to be an added value in light of the early design decisions for this application. The developed web application is built on top of TerriaJS, that in itself is built with parts of other relevant technologies which made sense given our proposal, like Cesium and React. The selection of technologies and the design of the platform were studied back and fourth, given limitations and shortcomings, leading to some sacrifices in terms of planned features.

As discussed in 1.2 and 3.3, this solution is benefiting from parallel work that retrieves data integrated from different well known repositories from cultural and historical institutions, with added context and relationships. In an earlier prototype for this project, the loaded data originated from Europeana. With the same amount of work, it was possible to configure it to work for the integration platform developed in [10].

Given the potential of using the integration platform to include richer data in the project being developed in the context of this dissertation, it was important to give the information a thoughtful representation. As a large part of the data from the repositories

is georeferenced, it was decided that the information would be represented in a map, when possible. This decision was supported by the fact that in today's devices, exploring and navigating a virtual map is a natural action to most users, adding a sense of presence to the displayed information. Also, large quantities of information could be conveyed just by looking at a single screen, from the number of objects placed in the map to their location. However, another large part of the data is not georeferenced, with other methods being needed to properly represent them and allow their exploration. Other techniques to enrich the information given by the placement of data on a map were settled, like visual categorization through symbols, coloring and clustering, as it will be described further in 4.2.2.4 and 4.2.2.3. To manage all the information during an user session, an interface based on layers and lists was considered. This would help the user structure its searches, as well as explore all the retrieved objects, even the ones with no georeference. An initial design for the solution, involving all the desired discussed features for the interface, was prepared.

As for the problem of creating context for cultural data from different sources in a appealing way, the solution was presenting this data preserved in various interesting formats and combining the visualizations of these objects in an accessible interface. This decision was inspired by the studied applications in chapter 3, as interacting with multiple formats of visualization provides a dimensional factor to the objects. For convenience purposes, the data for this part of the solution is also provided by the same repositories through an intermediary platform for unique access proceedings, but, unfortunately, not all objects available are of the same type. Also, there is not a sufficient amount and not flexible enough data to create full contextual representations, consisting of an interesting amount of relationships, of every object. The application must thus allow the manual filling of information. It is also interesting to let the user manipulate different representations in an integrated fashion, to better gather information about the object in question. This contextual view would be accessible when choosing an object during navigation, allowing the two parts of the project to be connected in a natural way.

Gathered these design decisions and the study of the used technologies, an architectural scheme was defined as seen in figure 4.1. This figure represents an abstract scheme of the architectural interactions in the application and of the features it will focus on. Technologies are also referenced and will be described in section 4.2.1. The user interacts with the application developed in the context of this dissertation, which consists of an interface built in TerriaJS that represents cultural heritage objects. The basis of this interface is the geospatial map, but the objects can also be accessed through a complete list, including non georeferenced objects. By inspecting an individual object, the user can see a preview of its properties. It can go deeper in a window and inspect all of the properties of a given object, or explore its spatial and cultural context with the help of Sketchfab and Youtube viewers. All this information is obtained from the integration platform that, in itself, queries all of the available repositories. Information about cultural objects not present in the application can also be provided by the users, by filling a form with the

information, parsed in the format used by the application to manage objects.

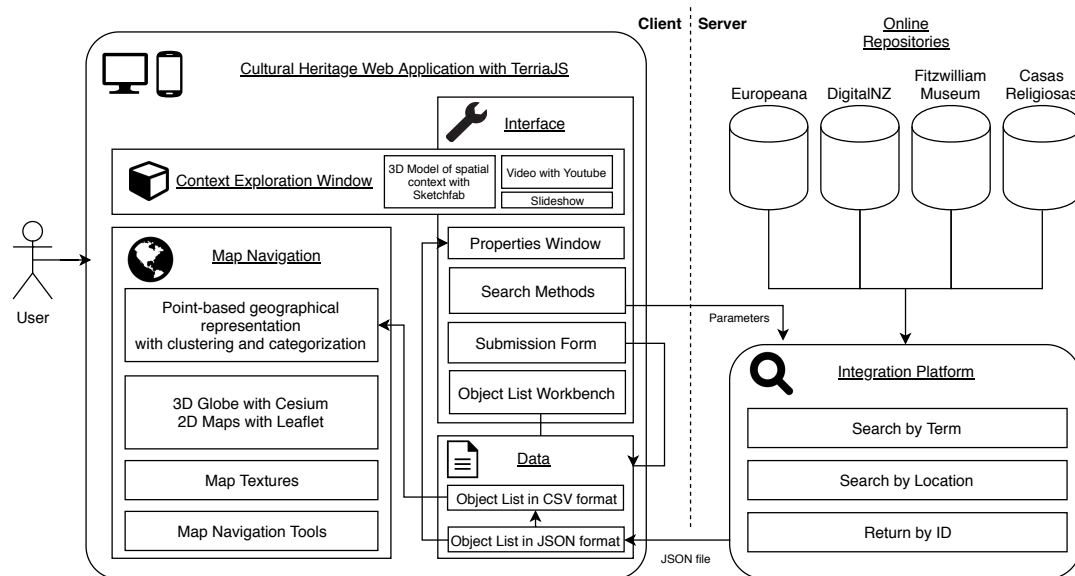


Figure 4.1: Scheme of the designed solution

## 4.2 Development and Implementation

The following sections cover all the aspects of the implementation of the desired application found in the design phase. Every implemented features is described in detail.

### 4.2.1 Technologies

The following technologies were examined as suitable for the development of the project, according to the design phase. Some decisions were made in light of the studied features, how to connect the technologies and what goals were prioritized. In this section they are introduced, alongside the most useful features for this project and their role in the development is lightly discussed.

#### 4.2.1.1 Cesium

**Cesium**<sup>1</sup> is an open-source JavaScript library to visualize 3D globes and maps on the web. This library provides easy to use geospatial 3D mapping representation tools, allowing customized visualizations of georeferenced objects and points of interest. Some of the most interesting features for this project include the rendering of the globe with dynamic layer imagery from multiple sources, drawing and styling different types of geometry, layering primitives, individual object and terrain picking, 3D robust camera navigation, clustering and a timeline widget for controlling simulation time. Hence, Cesium proves

<sup>1</sup><https://cesiumjs.org>



to be an excellent starting point to allow the user to explore georeferenced cultural objects in a more appropriate environment.

### 4.2.1.2 React

**React**<sup>2</sup> is a Javascript library for building responsive user interfaces. Paired with the usual web technologies it allows for interactive interfaces that display content almost instantly, offering a powerful sense of control to the user. The component-based system lets each component of visualization connect to the system individually and be noticed when the data they manipulate is changed, alerting a new state and letting each designed view to be efficiently updated and rendered. As this project requires real-time user interaction in a browser, React is a good fit and very practical. It is also easy to adapt to work alongside with **Cesium**, serving to build an user interface to help with the remaining features, non-geographical, of the project. The next described technology couples these two libraries in a very efficient and practical manner.

### 4.2.1.3 TerriaJS

**TerriaJS**<sup>3</sup> is an open-source library for geospatial visualisation, offering an efficient way of publishing spatial data on the web and explore it. Its user interface is built with **React** and uses **Cesium** and **WebGL** for rendering the 3D globe and maps, aswell as **Leaflet** for the 2D maps when Cesium is not available. It runs browser-side using Javascript. The most useful features for this dissertation are the management of layers of data, multiple file type support, animated time dimensions, spatial tools and its tested, intuitive and responsive user interface. TerriaJS offers a good starting point for the development of the project, handling various types of data, its geospatial visualization and most user interface basic features. To work with TerriaJS, it is required to have the following components: **npm**, a JavaScript package manager with reusable code used by TerriaJS, a BASH command shell, in this case the one used was **Git Bash**, and **Node.js**, which will be described below.

### 4.2.1.4 Node.js

**Node.js**<sup>4</sup> is an open-source asynchronous event driven JavaScript run-time environment. It was designed to build scalable network applications by executing JavaScript code also outside of a browser, as command line tools or server-side scripting. This unification of web application development around a single programming language for server and client side scripts and its asynchronous event-driven architecture, allows for the optimization of real-time web applications with many input/output operations. For this project, Node.js is used for building and running the **TerriaJS** application.

---

<sup>2</sup><https://reactjs.org>

<sup>3</sup><https://terria.io>

<sup>4</sup><https://nodejs.org>

#### 4.2.1.5 Sketchfab

**Sketchfab**<sup>5</sup> is a platform that allows users to easily publish, share and visualize their 3D models. The 3D viewer is powerful, with multiple configurations and features and offers pleasant controls for interacting with 3D models and also AR and VR content. The platform provides an API for using and building applications on top of the viewer or accessing the community models. One of the downsides is that the viewer only works with content submitted by registered users to the platform. However, a large number of institutions and professional users are present at the community, offering high quality 3D models created with techniques mentioned in 2.2.1 , preserving their historical and educational purposes, in a section of the platform properly called *Cultural Heritage & Story*. The features offered by the viewer and its API include camera animation, events, but more importantly, it supports the use of annotations, a way to place descriptions and points of view over the 3D model, giving complementary information to an object without leaving the viewer. Sketchfab is used to visualize the 3D models offered by the cultural repositories in this platform. The submission of content to the platform is also explored during development.

#### 4.2.2 Indexing and Navigation

This section focuses on the problem of representing cultural heritage objects returned from the integration platform, as mentioned in 4.1. All the screens depicted in this section were captured in the desktop version of the web application. Presented next are detailed explanations about all the small blocks of what consists the proposed solution for this problem in the developed application.

##### 4.2.2.1 Interface

TerriaJS is equipped with an interface designed and tested by experts in the field of user experience. The default TerriaJS interface is used for the most part, except in implemented features, where it had to be adapted, as well as slight changes to colors, sizes and fonts. The interface described in this subsection refers to all the visual and interactive elements surrounding the map in use. Figure 4.2 depicts the first view of the web application when it is initialized.

The initial interface is divided in three different parts.

**Top buttons:** General map related buttons, share button and about button. Low priority buttons for rare use operations;

**Right panel:** Where the map navigation and interaction tools are located. Also, a button for accessing the object submission form was added here, as it will be detailed in section 4.2.2.7.

---

<sup>5</sup><https://sketchfab.com>

**Left panel:** A large panel where the data represented in the map is managed. It contains the search methods for assigning data to the map and the workbench. This panel can be minimized by the small tab on the top.

This division of the different interface areas was kept intact from TerriaJS. Some alterations to the interface were implemented whenever needed, in order to prepare the application to better perform its function. These alterations will be described in the respective section of the implemented feature. TerriaJS is ready with different built-in features. The following list aims to clarify some of the terms used in the subsequent sections, related to the interface of TerriaJS and its alterations during the development of this solution.

**Workbench:** Area of the left panel below the search inputs, where general information and actions about each object list are found. It includes a button to remove all object lists.

**Object List:** Group of objects derived from an action. A list is represented as a layer in the workbench. It contains a list with all the objects from that collection, separated by categories and an icon referencing if the object is georeferenced or not. The layer

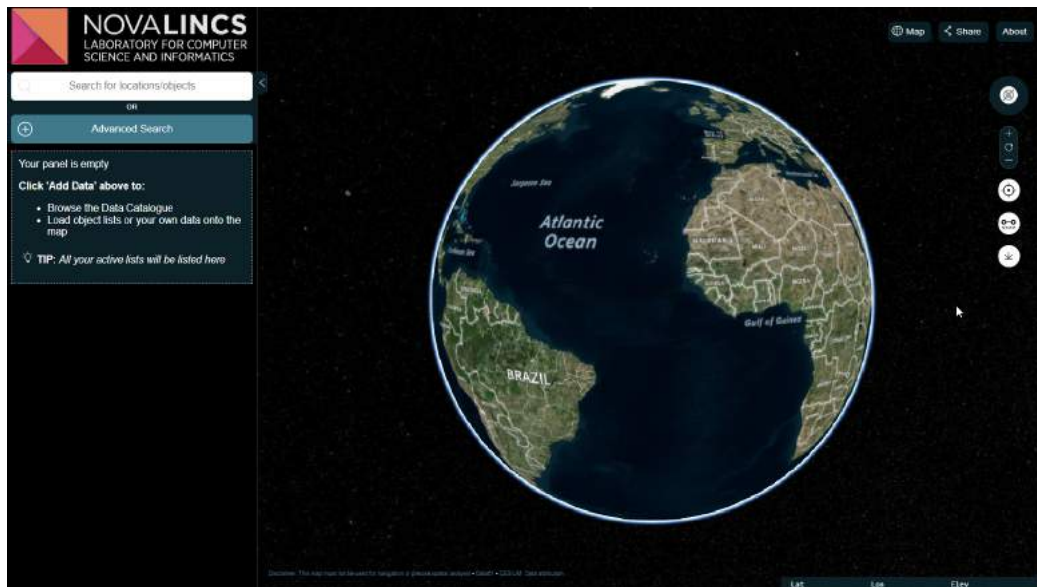


Figure 4.2: First view of the web application desktop interface

can perform actions such as delete, display information about how it was created and zoom to the collection extension on the map.

**Catalogue Window:** A catalogue in TerriaJS refers to an item that is used to place data on the map. Catalogues can be a file of data in any TerriaJS supported file format, a group of other catalogues or a function that returns catalogues through requests with defined parameters. In this application, only catalogue functions are used, tweaked to return data in the format defined for this project and process it. These catalogue functions are referred as the search methods defined in 4.2.2.2, and this is the only use for catalogues in the application.

**Preview Window:** The preview window in the application is accessed when an object on the map is selected. TerriaJS calls this window *Feature Information*, because it displays the information contained by the selected features, in a list of tabs. A feature in TerriaJS is any element on the map with information associated to it. For this application, features can only represent digital cultural objects, with information formatted in the same way, and using the same template for the previewing of its data.

**Property Window:** An object can contain information beyond the one displayed in the preview. In order to allow the user to explore all of the information of an object, the property window displays all of its properties and values. This window is accessed by clicking in the *Discover More* button located in the preview window of the selected object. Its located in the *Information* tab, the default when opening the window.

**Exploration Window:** The exploration window function is to allow the user to explore an object context through diverse media. This window is located in the same window as the property window, but in the *Explore* tab.

#### 4.2.2.2 Search Methods

To present the digital information contained in the online repositories, we must first retrieve it. These repositories hold millions of entries for cultural and historical objects. It is a challenging task to try to present all this information in a single view or screen, as it would be too demanding for the end user to navigate and orient himself. Therefore, the retrieval of information is a result of a personalized search. The integration platform that communicates with the application, offers searching services for the repositories through REST and SOAP formats, retrieving files in JSON or XML format, respectively [10]. The interaction application uses REST requests and manipulates the information obtained in JSON format.

The integration platform API allows a certain customization of the search request. REST requests are made by accessing an HTTP address built with parameters specified by

the user of the API. There are two types of search methods possible with the API: Search by term, or search by geographic region (bounding box). It also allows the listing of all the repositories connected to the platform and their identifier for internal use. Besides the arguments used to customizing the search functions of each repository, the integration platform also allows customization on the way the platform manages the results after they are retrieved. These other arguments can be applied to all types of search:

- If the platform combines similar objects into one single object;
- If the platform detects relationships between objects and returns data that holds that information;
- If it returns extra-properties, which cannot be matched to the internal model of the integration platform;
- What repository to apply the search, if we want to limit our search to a specific repository.

The search by term method allows the retrieval of results containing the term defined by the user. All repositories connected to the platform allow this type of search. The integration platform processes the results provided by each repository and returns them. Thus, by using the integration platform, the search by term, inside each repository, works as it would if we were to request the same search individually. Each repository may use different techniques when executing this search.

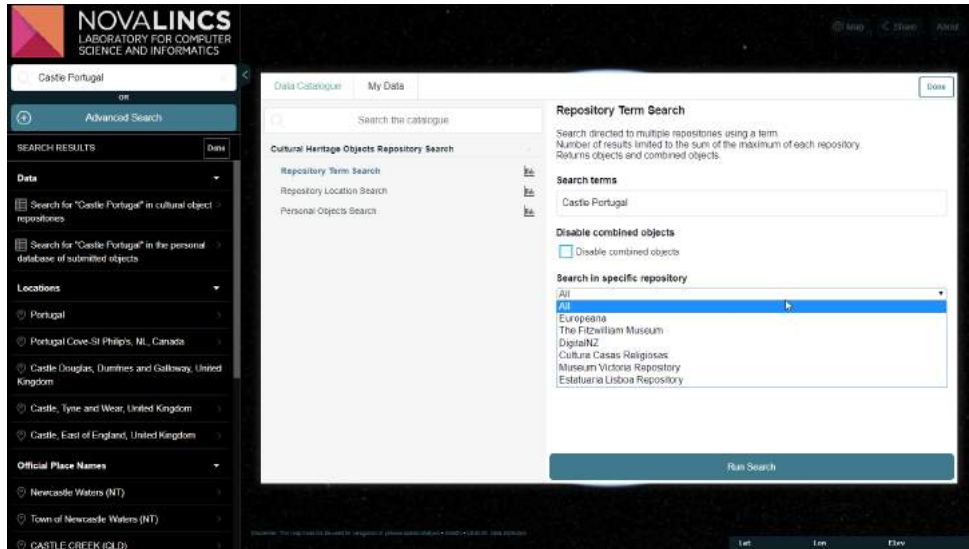
The search by geographic region method allows the retrieval of georeferenced results inside a geometric spatial boundary defined by the user. This geographical boundary is a bounding box defined by four coordinates. As not every repository allows this type of search, its a very specific method that only affects georeferenced objects.

Apart from the integration platform, it is also possible to search by term in the collection of user submitted objects. The process for submitting objects is described in [4.2.2.7](#). This search method allows the representation of all the submitted objects in the application or filtered by term.

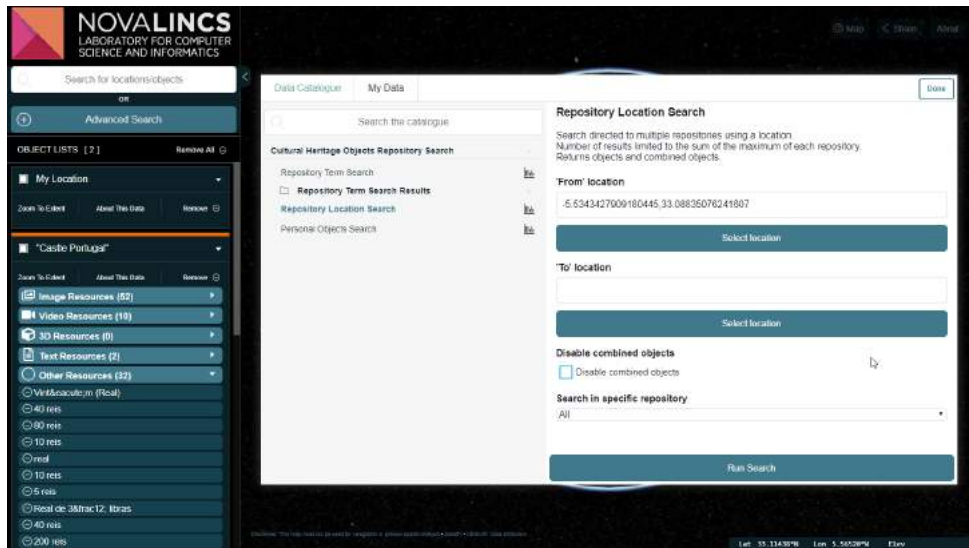
In our web application, these search methods are accessed through the left panel. There is a search bar on the top left part of the interface. This search bar is a default of TerriaJS. After typing something in this search bar, the left panel changes and presents various search options for the user. TerriaJS allows searching for locations, addresses and official place names. This feature was kept in order to present more options for navigating the map. Added to the search bar list was the ability to navigate to the search by term and search the personal submitted objects method, using the term inserted in the initial search bar. By selecting these methods, the catalogue window opens with the selected search method and the input box filled.

The catalogue window, where more options for the search are presented, can also be accessed through the button beneath the initial search bar. Here in this window on the left

## CHAPTER 4. DESIGN AND IMPLEMENTATION



(a) Search by term interface



(b) Search by geographic region interface

Figure 4.3: Interface of search methods

side, are presented buttons to access the search methods. In the right side, the inputs for personalizing the selected search method are shown. For the search by term method, an input box for the desired term is presented. For the search by geographic region method, four buttons are presented, allowing the user to select the coordinates for the boundary box on the map. Both of these methods also include a checkbox for specifying if the results are to be returned combined and an input list for choosing the target repositories for the search. In the personal submitted objects search, only an input textbox for the term is provided, as this search is not connected to the integration platform. TerriaJS includes a wide array of options to handle data. To implement these search methods, new classes were created extending the Catalog Function interface. Catalog Functions is an interface for TerriaJS that manages types of data. In this case, acts as a service that requests data through the use of parameters and returns a result. This request queries an URL that returns a JSON file in the format used by TerriaJS to store a catalog. However, as the integration platform returns a JSON file with a very specific format, these new classes had to be tweaked in order to parse this information. Instead of attributing the JSON file directly to the catalog, the result from the request is parsed to a CSV format that is fed directly to TerriaJS map functions. For the input view, the parameters necessary to the URL request were added to a JSON file in TerriaJS that handles the presentation of Catalog Functions. When the user clicks the submit button after personalizing a search, a new list of objects is added to the workbench. This list presents a loading icon until all the objects returned from the search are loaded, formatted and added to the map. Every list receives a random color, shown at the top of the list, generated by the search inputs. A list shows all the objects in that collection, separated by categories. To easily distinguish if an object is georeferenced or not, an icon is placed next to the title of the object. For georeferenced objects, this icon is a geographical pin and for the others it is a stop sign, symbolizing information that does not exist. Georeferenced objects can be accessed through the map and the list, while non georeferenced objects can only be accessed through the list. The workbench view had to be completely reworked, in order to support these visual changes necessary for the goal of this application. TerriaJS original workbench view is directed towards data analysis, featuring a color legend of the variables of the points or areas displayed on the map. This shift in objective required the workbench to focus on displaying large quantities of interesting individual information, that we named objects, that could not be aggregated the same way as data in graphs.

### 4.2.2.3 Categorization

In order to facilitate the comprehension of the types of objects presented by the application, it was decided there should be a visual aid to distinguish them. It was decided that the most important property to communicate to the user was the type of digital resource associated to the object. For all objects, the types can be narrowed to 5 categories, allowing the types to be represented by icons. These categories are: **image**, **video**, **3D model**,

**text and other.** This property is given by analysing the data in a property of the internal model of the integration platform, that is stored in the CSV file of the object list. This property, referred as "*type*", is provided by the source repository. It contains a description of the type of object, however, this description cannot be constructed into a predefined list of types. To bypass this problem, the final category is calculated in a process that matches its data to one of the categories and assigns it to the object. This process consists of finding synonyms of the predefined types. If any synonyms of the predefined types are found, it labels the object as part of that category. If they are not found, it is labeled as "*other*". Icons can thus be attributed whenever a representation of an object is needed. They are used in the workbench list category divisions, the preview list and in the map on their location. An icon with two photographs is used for the image category. A movie projector is used for the video category. A cube drawn in perspective is used for the 3D model category. A document sheet is used for the text category. Objects in the "*other*" category are represented by a simple circle. These categories are sufficiently abstract to enable focus on the type of digital file of the resource. Objects in the image category can be a photograph or a painting. Videos can show a documentary or a simple animation. 3D models refer to any type of model independently of the method of creation. Thus, this categorization allows the platform to know what file type to handle when showing the resource of the object. These resources are shown in the property window. For images, a slideshow is created by all the image links contained in the data. For video, whenever possible, a Youtube player is embedded playing the selected video. For 3D models, a Sketchfab viewer is embedded with the selected 3D model.



Figure 4.4: Icons used for categorizing objects. From left to right: Images, videos, 3D models, text documents and others.

#### 4.2.2.4 Geographical Visualization

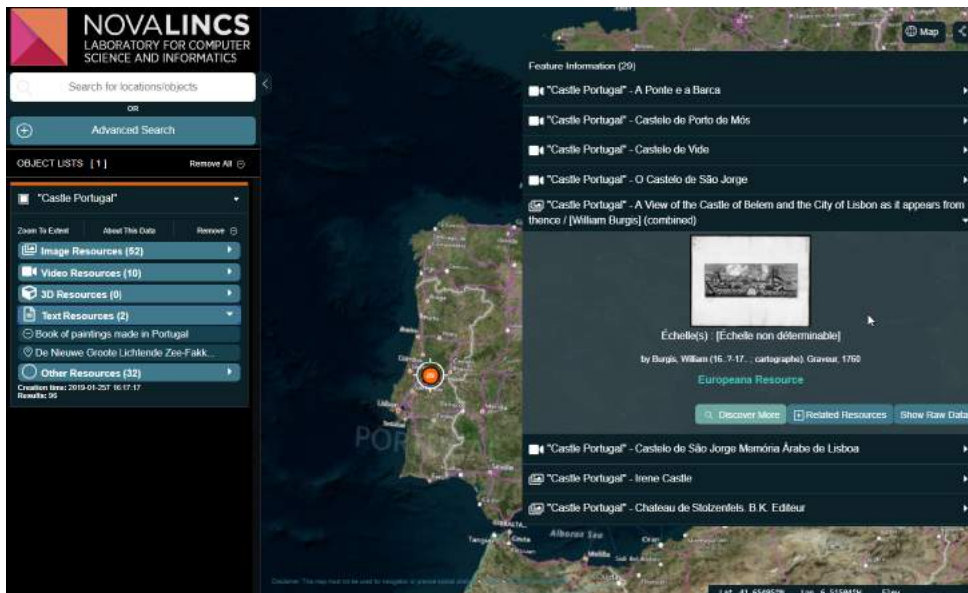
The Cesium globe and Leaflet maps are the basis of geographic navigation and exploration of objects. The tools to navigate these maps are provided by Cesium and TerriaJS. These tools are located in the right side panel. The mouse is also used to interact with the map. With these tools it is possible to zoom, tilt and rotate the map. On the top buttons there is



## 4.2. DEVELOPMENT AND IMPLEMENTATION



(a) Categorization icons on left panel and map



(b) Categorization icons on left panel and preview window

Figure 4.5: Use of categorization icons on the application

also a **Map** button, allowing the user to change the texture of the map or globe. A user can choose between 3D terrain, 3D smooth, using Cesium, or 2D, using Leaflet. The textures available come from different providers, changing the appearance of the terrain, from drawn maps to satellite images and labeled or unlabeled regions. The right panel tools also include a button to create a point in the map with the current geographic location of the user of the application, a ruler that can measure distances between two or more points in the map and the upload button, as it will be explained in 4.2.2.7.

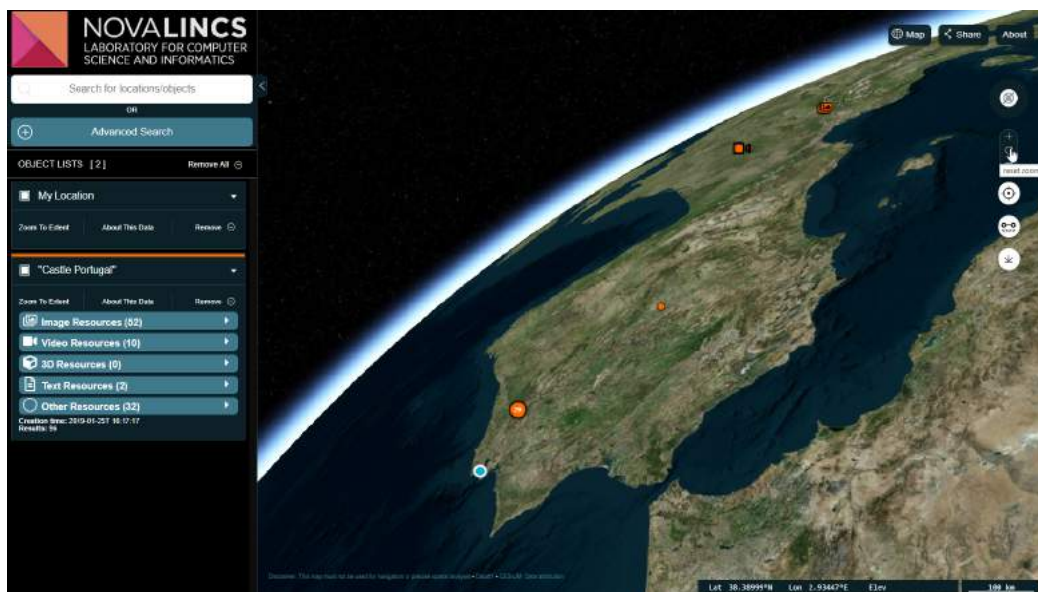


Figure 4.6: Use of the navigation tools to create a different view of the globe. The position of the user, object icons and a cluster of objects are also present.

TerriaJS handles the map representation of different geographical information file formats. It also supports graphical representation of non geographical information, but that feature is not necessary for this project. The ability to support this was maintained in case a user wants to combine visualizing its data while using the platform. This can be helpful to aggregate additional related information. A user can try this by simply dragging a supported file to the application window or accessing the catalogue window and selecting a file. TerriaJS supports the representation of imagery data and tabular data. Imagery data refers to information built with images combined to be layered on top of a map or globe, for example, from satellite views. Tabular data is information stored in tables, in this case, containing data used to build regions or points, as well as other type

of data associated to it. For our application, we only need to present points in the map, referring to each individual object returned from the repositories. We will assume every object only has one location, given by the coordinates, latitude and longitude. This is not always the case when inspecting the information returned from the repositories, as most objects contain more than one location. However, there is no logical way to extract some sense on why they have this information, as it could depend on the entity that uploaded it or the rules of the repository of its origin. For instance, some locations could represent the place where the object was found or created, and others the place where it was stored or preserved. Some examples were examined, but failing to find a coherent use for all the locations of each object meant that, for simplifying reasons, only the first location of an object was used to reference it on the map.

For handling the representation of the objects on the map, it was decided to use the CSV (comma-separated values) format. After requesting objects through a search, some of the values from the returned JSON file are stored in a newly created internal CSV file to be handled by TerriaJS. The properties of these values are the title, description, creator, date, type of resource, latitude, longitude, preview image, repository of origin and link to its repository page. They are only used to represent the objects on the map and creating a preview window with introductory information. These properties were chosen as being the most generic for a preview of an object. However, a large quantity of them do not contain information for all these properties. Each object occupies only a line in the CSV file, which is a file containing tabular data, and each property is a column. The JSON file is kept to store all the other, more detailed, information. For instance, it is used to create the property window.

The preview window is accessed when the user clicks on an object on the map or on the object list. Using the object list affects the view of the map. For non georeferenced objects, the preview window appears after the map focuses on the extension of the collection in which the selected object is contained. For georeferenced objects, the preview window appears after the map zooms on the location of the object. The preview window is a small window with a tab showing some of the information of the selected object stored in the CSV file for that list, formatted for improved readability. When multiple objects are selected on the map, through the mouse region where the user clicked, the preview window shows multiple tabs for all the selected objects. These tabs have an icon on the left side next to its title, indicating the category of the object, and a strip of color on top, indicating the list where they belong.

When two or more objects in the map are seen on top of each other, depending on the level of detail of the map view, their representation changes to a different icon, a big circle with the number of all the aggregated items inside. This process is called clustering and it is supported by Cesium. It uses parameters like the minimum distance between objects and other aesthetic parameters. When this circle is clicked, it selects all the objects inside the cluster and previews them in the preview window. This way, when the level of detail of the map shows two icons very close to each other, they do not create visual noise

with overlapping icons and the system informs the user on how many objects are located in that cluster area. Objects from the same list, resulting from a single search, usually contain similar objects placed close to each other, so this was considered to be a useful feature to implement.

#### 4.2.2.5 Relationships

The integration platform supports the creation of relationships between objects. These relationships are stored in a property of the JSON file returned after a search, for each object, in the case the object contains them [10]. Relationships are defined by connections between objects. The values stored in an object, for relationships, are the identifiers of all the related objects to the one in question, grouped in an array. To allow navigation between related objects, it was necessary to perform another request with the identifiers, in order to obtain the data of all the related objects. It was decided that these objects would be presented in a new list, created by a new request, after selecting to explore the related objects of the object in question.

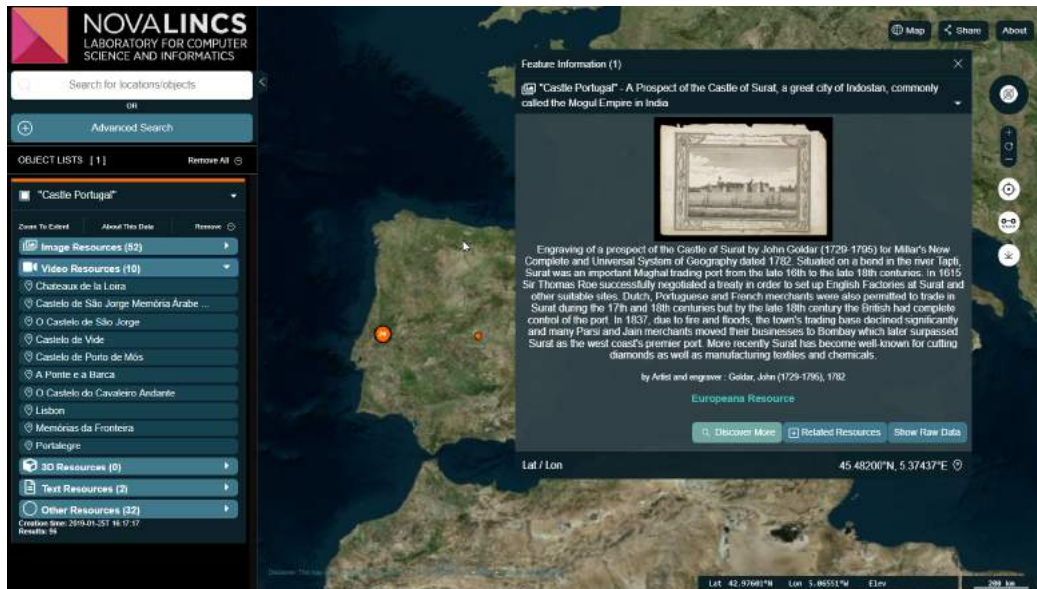
The relationships feature is accessed through the preview window. In the tab of the desired object, if it contains relationships, then a button with the text *"Related Resources"*, with an icon of a plus sign, shows up in the bottom right area. By clicking this button, a new list is loaded, with the name *"Related to..."* followed by the name of the requested object. This list is created in the same way as the Catalog Functions for the search methods, where a request is sent to the integration platform and it waits for an answer. After loading the result, the user can inspect the newly obtained related objects apart from the previous list, in the same fashion as any other object list in the workbench.

#### 4.2.2.6 Object Properties

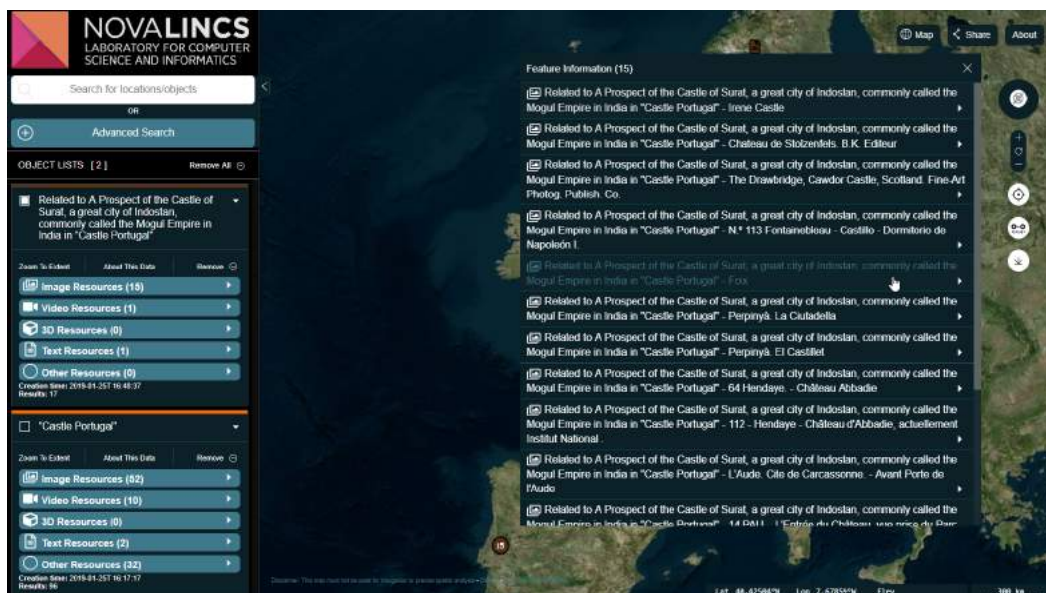
Every object contains more information than the one presented in the preview window and which is stored in the CSV file. To give the chance for the user to explore all the information returned by the JSON file, a new type of window was designed. This information is more detailed and specific to the type of object, as opposed to the generic information conveyed by the preview window. The property window is accessed through the preview window, by a button with the text *"Discover More"* with the icon of a magnifier.

The property window lies inside the exploration window. This is a white window covering the map area. This window contains two tabs, where the properties for the object are found in the *Information* tab, with an icon for a sheet of paper. Here, all the properties of the object provided by the JSON file and part of the internal model for the integration platform are presented in a descriptive way. All the properties that exist for the selected object are listed on the left side, except for the repository of origin and the link for the object page on the repository site, which are converted to a button on the top right corner. The titles of the properties, when listed from their denomination on the internal model

## 4.2. DEVELOPMENT AND IMPLEMENTATION



(a) Related resources button in preview window



(b) Related results in a new list

Figure 4.7: Accessing related results

of the integration platform, are converted to a more user-friendly title (for instance, *dc-subject* is converted to *Subject*). On the right side of the window is presented the media resource associated to the object, using the specified method of visualization, the title of the object and below is the value of the selected property. A user selects a property by clicking on it from the list on the left side, and this action changes the information below the title of the object to the value of the selected property. If that property holds more than one value, all values are presented in a bullet list. In this way, the user can inspect the data behind an object with more detail, even if there is no coherent representation for it, as the values of these properties are dependent of the logic used by the provider that submitted the object to the repository.

As to display the resource associated to the object, the method used is as described in 4.2.2.3. The type of resource is extracted from the *dctype* property, while the resources are extracted from the *resources* property, always an array containing the preview image in the first slot and a link to the other resources in the next slots. A simple slideshow is provided when the type of the resource is an image, showing all the images contained by the resource property. A Youtube player with the selected video is shown when the resource type is video. A Sketchfab viewer is shown when the resource type is a 3D model.

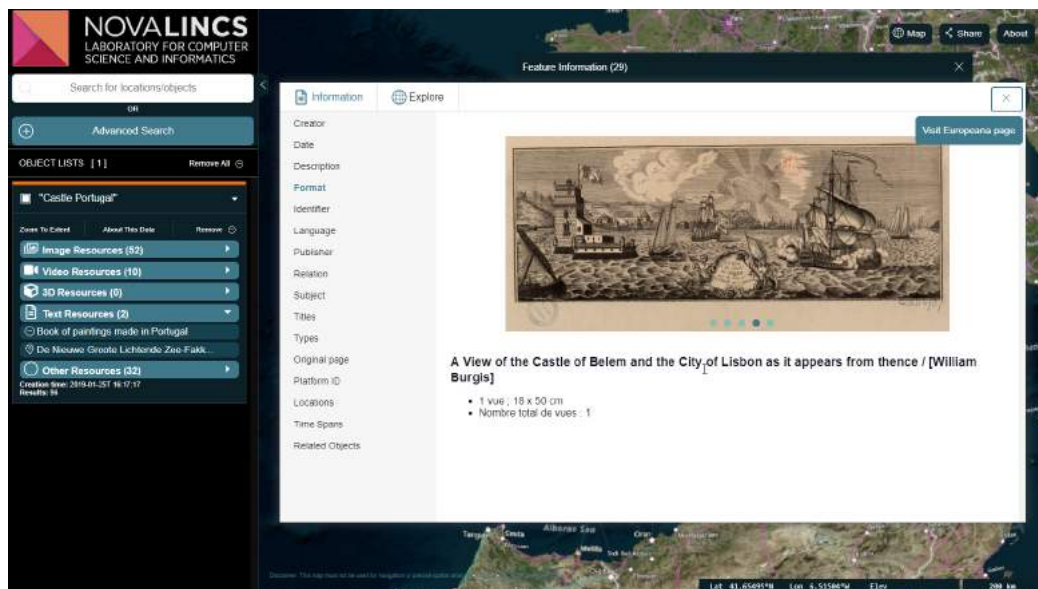


Figure 4.8: Showing object properties and the associated image resources in a slideshow

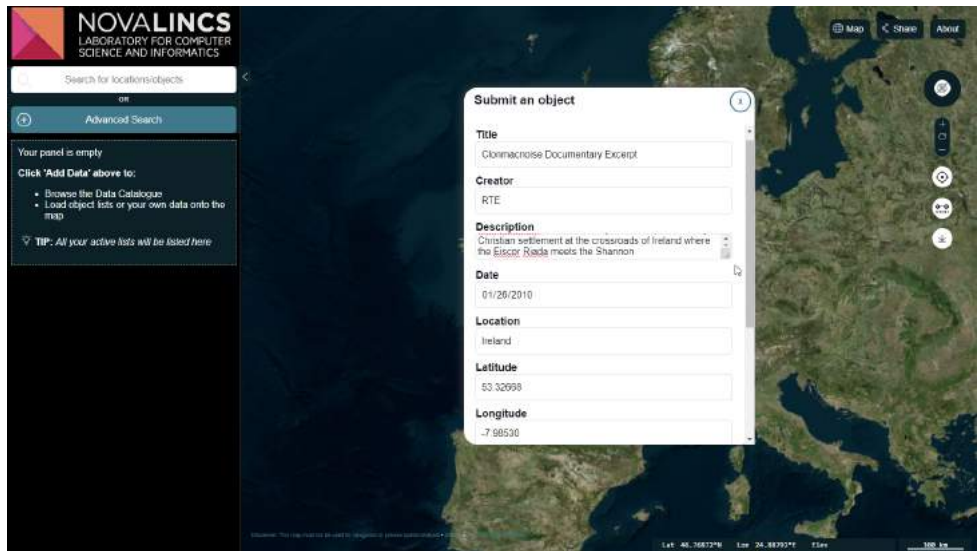
#### 4.2.2.7 User Contribution

As to allow users to take part in the preservation of history and culture, a user contribution method was designed. The last button on the right panel of buttons, accessible whenever the user is navigating the map, opens a submission window with a form where users can fill with information about the item they want to add to the application. For now, this form is a proof of concept of how user contribution would be handled in this project, as the submitted objects are not preserved between sessions or sent to an online repository for objects of this kind. The button for accessing the form for submitting an object was added to the right side panel as this operation also implies the use of the map. The form presents fields for all the properties used in the preview window, using the most suitable input type: title, creator, description, date, location, longitude, latitude, image preview, type of resource and link to the resource. The repository of origin and link to repository page, properties still necessary to be used in the CSV file to represent objects in the map, are filled in with a placeholder value, indicating that this is an user submitted object. The longitude and latitude input fields are filled in with the coordinates of the last selected position on the map, as to allow more precise geographical referencing and intuitive use.

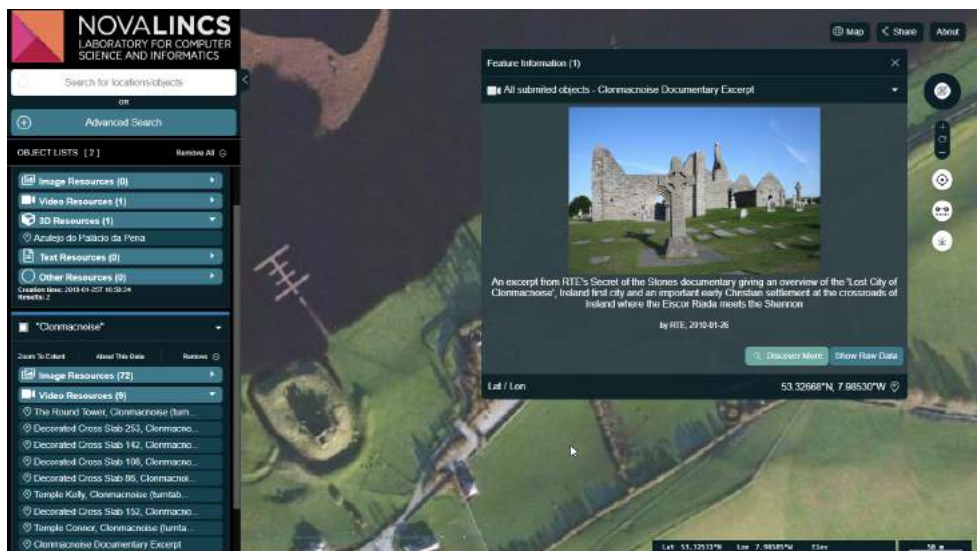
When a user finishes filling in the form and submits, a success window is presented. The object information is then added to an internal JSON file formatted in the same way as the ones returned by the integration platform. To access the submitted object, an user can use the search method for the collection of submitted objects or by using a search by term using a term that is contained in the properties of the submitted object of choice. By leaving the term blank in the search method for the collection of submitted objects, the entire collection is returned. On the contrary, by using a term, the search only returns the submitted objects with properties containing the term. As for the search by term method, after receiving a response from the integration platform, the application also searches on the submitted objects collection, adding the result to the newly created list. In this way, user submitted objects and repository objects are presented the same way seamlessly. Submitted objects function exactly the same as repository objects, for the preview and property window and their representation on the map.

#### 4.2.3 Multiple Contextual Visualizations

This part of the implementation aims to provide a solution to the problem of visualization of multiple types of media originated from different digital repositories in a single interface. This solution is presented in the form of a window, part of the indexing and navigation solution. This solution was designed in a way that, by accessing the property window and clicking the *Explore* tab, the user can visualize different types of resources in multiple formats, relating to the same selected object, combined in a single interactive interface. However, the implementation of this solution could not be adapted to every possible object, as it was desired. This setback happens as there is not enough data in



(a) Filling the submission form



(b) Returning a list with all the submitted objects

Figure 4.9: Submission form and submitted object list



the repositories to dynamically generate these windows, by relating different entry formats of the same object. Between repositories this information is non-existent. To work towards a solution for this problem, the explore window is designed to be constructed with a simple JSON file, receiving the URLs of all the objects with their identifier on the integration platform. This way, the media displayed here can originate from any of the available repositories and can be arranged together by browsing the application and using the identifiers of the objects needed for this visualization. This solution was designed to, not only show multiple visualizations of the selected object, but to cover information from what surrounds it, providing information on the contextualization of an object. This information is the site or monument of origin and other objects from that same location.

The exploration window consists of multiple sections. In the right column, a Sketchfab viewer is provided, containing a 3D model depiction of the spatial location of the origin of an hypothetical selected object. This could be an archaeological site or a monument. The 3D model is filled with annotations, working as points of interest. Annotations are a tool provided by Sketchfab to add information to specific parts of the model, working as notes that contain a camera position, a title and a description. By clicking in an annotation, the camera zooms to the point of interest and a description connected to the position of the annotation appears. This tool was adapted to store information about a certain object located at that point in the location. By clicking in an annotation in the 3D viewer, Sketchfab communicates with the application and the left column changes from a rich description of the site or monument seen in the viewer to a detailed view of the object associated to the selected point of interest. This detailed view consists of a Youtube video on the top and a slideshow of images on the bottom. The video and images displayed in this window are resources originated from the repositories that work with the integration platform, through the platform identifiers. This window allows the user to explore and navigate the desired location and select cultural objects that are part of it, and learn more about them, through multiple forms of visualization. For instance, this solution could be adapted to present information about a certain archaeological site. In the 3D viewer, a model of the site could be seen, created through photogrammetry. Each annotation then holds information about certain archaeological objects discovered in those exact locations. Then, through the integration platform, media resources could be associated to each specific point of interest, like a video with information about the discovery of the object and a slideshow with photos of the archaeological object and its details. The annotations are also configured sequentially, so a virtual tour through the site could be arranged.

To achieve this, an abstract structure was designed. Using React, the various components for each media format were built. These components are viewers for image slideshows, Youtube and Sketchfab, configured to receive and output data to the explore window. They receive, as parameters, the URL of the desired resource or resources to present. When initiating the explore window component, a request to the integration platform is made to collect the image and videos URL's. All the information relating to

the URL's used by these components (Image resources URL's, Youtube URL's and Sketchfab URL's) is extracted from the object data returned from the integration platform, after requesting it from the identifier present in an external file. The format of this external file is shown in label 4.1. This file is, for the moment, a temporary solution for this use case, as it will be explained next. The JSON file contains the title of the site in context, a description, the identifier for the Sketchfab model and an array containing the object identifiers for images and videos. The explore window in itself manages the resources to present, based on the number of the annotation selected in the Sketchfab viewer, which relates directly to the order of the resource in the array. The Sketchfab component is tasked with a listener available in the Sketchfab Viewer API, which, whenever the user clicks on one annotation, triggers a function that changes the variable used by the explore window component.

Listing 4.1: Format of JSON file used to build the Explore Window

```
1 {
2   "title": "Newgrange",
3   "description": "Newgrange, the best known Irish passage tomb,
4     is surrounded by a kerb of 97 stones, (...) and three small
5     passage-tombs are in close proximity to it.",
6   "modelId": "https://sketchfab.com/models/555575
7     d8442342d4bd2f5f79c89b8a40",
8   "videoIds": [
9     "http://.../rest/getResult?id=1/2048705/object_HA_2139",
10    "http://.../rest/getResult?id=1/2048705/object_HA_1790",
11    "http://.../rest/getResult?id=1/2048705/object_HA_2156",
12    "http://.../rest/getResult?id=1/2048705/object_HA_1979",
13    "http://.../rest/getResult?id=1/2048705/object_HA_2158"
14  ],
15  "images": [
16    "http://.../rest/getResult?id=1/2048705/object_HA_1502",
17    "http://.../rest/getResult?id=1/2048705/object_HA_1539",
18    "http://.../rest/getResult?id=1/2048705/object_HA_1476",
19    "http://.../rest/getResult?id=1/2048705/object_HA_1609",
20    "http://.../rest/getResult?id=1/2048705/object_HA_1735"
21  ]
22 }
```

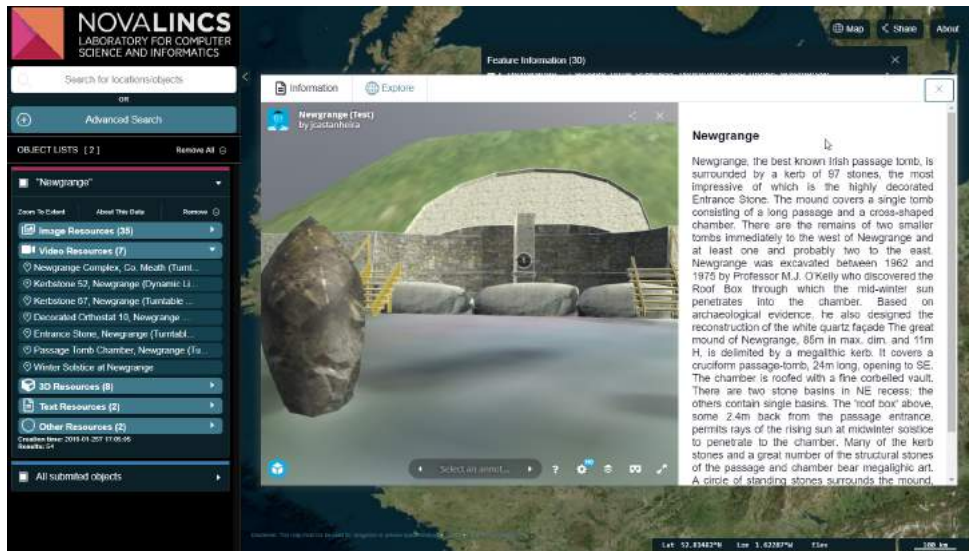
As mentioned previously, not all objects have enough information in the repositories to generate a rich exploration window. It was necessary to find an example where this solution could demonstrate its full potential during development, so it was decided that the Irish prehistoric monument Newgrange would be used as an use case. This decision

was made because of the richness of the objects related to this site, where each object was stored in multiple formats. This was due to a program focusing on Irish archaeology that aimed to enrich Europeana repositories with 3D models more accessible to the end users, using Sketchfab, along with more complete image and video records of these resources. With this, we were able to fulfill all the aspects of the proposed implementation.

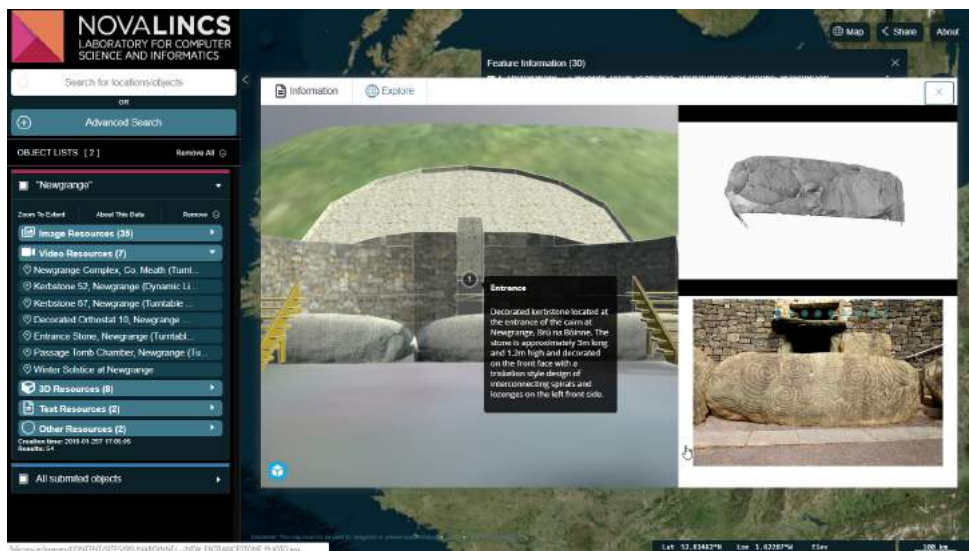
To compile all the information needed for this use case, a list was created in the application with the term *Newgrange*. Zooming on the archaeological site on the map, it was visible that there were a viable quantity of objects georeferenced to the actual place they belong on the site. These represented the kerbstones, long and narrow decorated blocks that adorn the tomb, and the inside of the passage, with resources in 3D model, video and image format. The videos contained a turntable or a dynamic light animation of the 3D models. The objects chosen to create the slideshow were combined objects with image resources, that gathered images not only from the details of the kerbstones but landscape photographs of the site. To use these objects in our use case, it was necessary to extract the identifier of these objects used in the integration platform. For that effect, it was necessary to navigate to the property window of each object and copy the respective URL. Then, they are provided to the JSON file in charge of presenting the exploration window, as we are creating a view with the content of this file. These URLs must be placed in sequence inside the array, as its order corresponds to the same order of the annotations of the model. As for the 3D model, it is extracted directly from a Sketchfab link, so there is no need to go through the platform. This was decided as there are no 3D models in the repositories with the intended annotations, and only the user who uploaded the model can add them. So in order to do this, a free to use 3D model of the Newgrange site was downloaded and uploaded to Sketchfab. Annotations were added with their relative location matching the locations of the objects to the site, as seen in the map of the application, and descriptions from the repositories were used as the descriptions for each annotation. The zoom and camera position associated to each annotation was chosen to effectively focus on the object in question. In the end, it was simply necessary to add the Sketchfab model URL to the JSON file and the connection to all these resources is made. When compiling the window, multiple calls to the integration platform are made to return the information of each object, process it and build the view using each respective resources and format.

For future work, an intermediary platform to generate stronger relationships between multiple representations of the same object should be tackled, in order to dynamically generate an exploration window for all objects with enough information about these contexts. For more precise control over what is displayed in this window and for what objects it should associate with, a graphical interface to edit the JSON file in control of this window would be more interesting to users in charge of managing a smaller collection of historical and cultural objects.

## CHAPTER 4. DESIGN AND IMPLEMENTATION



(a) First view of the window showing a description of the archaeological site



(b) Focus on point of interest showing a video and images belonging to that part of the site

Figure 4.10: Exploration window

### 4.3 Conclusion

Throughout this chapter, all available features provided by the developed solution were presented. This solution was a product of decisions taken in account by the studies of the background concepts in chapter 2 and the inspiration and reflection of existing programs and proposals presented in chapter 3, among other conditions, like time restraints, available technology and limitations with the repositories data and their completeness and interoperability. Priorities had to be assigned to the discussed concepts, despite their apparent interesting contribution, in order to better achieve the final goals proposed in chapter 1. This resulted in some concepts being implemented, while others were merely touched or even not considered.

Overall, the implemented application presented is satisfactory in what it tried to achieve differently from the mentioned solutions in chapter 3. It presents a higher level of abstraction, covering most types of cultural heritage objects from a variety of digital repositories, working as an aggregator with particular exploration focused on geographical navigation. However, it also proposes a singular view for exploring a single object context utilizing multiple formats of the same object. It is necessary to consider that these solutions are a proof of concept. Assuming that it was necessary to adapt this solution to a finished product, a compromise would have to be made. Either the solution would serve as the general platform for exploring cultural heritage objects from all kinds of sources in a superficial way or be customized to work for a single collection where data is specifically tailored for the platform, building storylines and providing complete data in a unified format and covering different formats in the documentation of the object. For the first example, a dynamic exploration window would have to be considered, albeit it would imply less interesting visualizations of most objects. For the second example, the map and navigation would have to be limited to the collection context, possibly swapping the property window for a more elegant solution designed for the collection data format, while the exploration window could be individually prepared for each group of objects from corresponding backgrounds.

Another type of customization could be achieved without much expertise. TerraJS allows the personalizing of the aesthetic and basic functions of the application just by altering JSON files. The integration platform can be customised if there is a need to add more digital repositories to work with its internal model. In the end, its potential use comes to the determined objective and scope of the desired application.



## EVALUATION AND RESULTS

The present chapter will evaluate the performance of the proposed solution given the stipulated goals, by collecting feedback from real users after being exposed to the application and given concrete tasks. It starts with a description of the methodology used to evaluate the implemented solution (section 5.1). Next, the obtained results are presented in the chosen format and briefly discussed (section 5.2). Next, some limitations of the adopted methodology are discussed, in order to evaluate the consistency of the results (section 5.3). In the next section, some feedback from experts that participated in the evaluation is examined in more detail (section 5.4). Applying the feedback collected, in the following section are proposed some solutions to improve the usability of the application (section 5.5). Lastly, the chapter finishes with some noticeable conclusions inferred from the previous section, establishing a connection to the next chapter, where general conclusions will be drawn (section 5.6).

### 5.1 Methodology

The process of evaluation of the implemented solution consisted in gathering user feedback from their experience with the application. This feedback examined how much the application, as a solution for the problem to be addressed, helped achieve the presented goals of this dissertation and its utility in performing so, as well as its user friendly capacity. This was achieved by comparing it against a standard, as it is a quality that is desired to easily communicate the intended goals of the application. In short, the evaluation measures two fields, usability and the utility and effectiveness of the application. The first considers if the application is easy to use and the users understand its features. The second evaluates how effective the application is in expressing the value of historical and cultural artifacts and raising awareness, as expressed in the first chapter. A form

was designed in order to accomplish this objective and generate valuable feedback. The structure of this form was conceived given the evaluation goals. Usability tests relate to accessibility, key in achieving the goal for dissemination and awareness for cultural heritage. As specific parts of the application are evaluated, the success of the proposed goal, of the dissertation, of encouraging and facilitating exploration, contribution and collaboration can be measured. For instance, measuring the utility of each feature and if its desired use is accomplished when non experts are interacting with the application. Experts working in cultural heritage institutions provide valuable feedback when showing interest for the application. The form presented allows this fields to be validated.

Users were given a form that included a series of tasks they needed to perform within the application, a standard usability questionnaire and a list of specific questions about the application, inquiring the users about the features they interacted with and overall appreciation in relation to the explained goals of the dissertation. During the evaluation moment, a brief description of the application features and goals were communicated beforehand to the users. This description aimed to build basic motivation and interest, as most of the users that participated in this process were not familiar with the history and cultural concepts present in this application, even if the application is designed towards all audiences. In the beginning, the users had to fill personal information (age, gender, professional/educational background) for statistical purposes only, as the results are anonymously stored. After this, the tasks section is introduced, where the users simultaneously fill the form answers to questions and interact with the application by following instructions.

The tasks section is divided in four parts, each one related to a group of features in the application with similar goals and use. By order, these parts present tasks related to the map and interface, object properties, multiple visualizations and context, and content submission. These tasks cover all important actions the user should be aware of when using the application to its full extent. The tasks are described as a goal to achieve at the current step of the test, with minimal help on where the features needed to complete it are located, and on how they work. At the end of the task, there is a question, which can be answered by perceiving information presented in the application screen, after completing the preceding task. To obtain this information, it is required to comprehend the interface of the application and the logic behind the features, which were used during the task. For instance, one of the tasks asks the participant what is the category of a certain object in the map. The answer can be deducted by realizing that the icon of the spatial representation of the object is the same as the one displayed near the categories tabs for 'Text' objects. This is information that is not descriptive and should be evaluated by new users. Between each part of the tasks section, a small introduction to the group of features important to the following tasks, along with a contextual screenshot is presented. In the map and interface part, the tasks focus on navigating the interface sections and the map. Testers are asked to search for objects with specific parameters, manage object lists, locate and select them on the map and workbench, and understand their categorization. In the



object properties part, the tester is asked to explore the objects property window and visualize their resources, extracting the needed information. In multiple visualizations and context, the tasks lead the user to find context of a selected object in the explore window. Here the tester is required to understand how Sketchfab annotations work, how to interact with the 3D model and visualize the displayed videos and slideshows. At last, in the object submission part, the tasks require the user to submit its own objects to the application, using the object submission form and connected features.

In the following section, the System Usability Scale (SUS) is used, as the standard for evaluating usability. SUS is a solid, dependable, low-cost tool for measuring the usability of a variety of products and services, including hardware, software, websites and applications. This standard is reliable even on small sample sizes, which is the case. This industry standard can easily, validly and effectively differentiate an usable product from an unusable one. The small size of the SUS questionnaire is also a an incentive for fair and motivated answers. SUS consists of the following ten statements, each having a five-point scale that ranges from Strongly disagree (the lowest value) to Strongly agree (the highest value):

- I think that I would like to use this system frequently.
- I found the system unnecessarily complex.
- I thought the system was easy to use.
- I think that I would need the support of a technical person to be able to use this.
- I found the various functions in this system were well integrated. system.
- I thought there was too much inconsistency in this system.
- I would imagine that most people would learn to use this system very quickly.
- I found the system very cumbersome to use.
- I felt very confident using the system.
- I needed to learn a lot of things before I could get going with this system.

In order to calculate a result in SUS, the score contributions from each item, ranging from 0 to 4 must be summed. The odd-numbered items, the ones worded positively, have a score contribution equal to the scale position minus 1. The even-numbered items, the ones worded negatively, have a score contribution of 5 minus the scale position. Next, it is necessary to multiply the sum of those contributions by 2.5 in order to obtain the overall value of the test, which ranges from 0 to 100. Despite its range, this value should not be considered as a percentage. A score above 68 is considered to be above average, while anything below 68 is considered below average and therefore presents usability issues [1]. Besides evaluating usability, SUS can also prove effective to derive another component,

learnability. To calculate the usability component, the sum of the contributions of the items 1, 2, 3, 5, 6, 7, 8, and 9 has to be multiplied by 3.125. The learnability component is calculated by multiplying the sum of the contributions of the items 4 and 10 by 12.5 [20]. These standards were used after collecting the answers to the test. As all participants were native Portuguese speakers, the test was translated from English to Portuguese using a proven, despite slightly flawed convention [24].

To be able to extract specific feedback from the users about the effectiveness of the presented solution, custom questions had to be formulated. This section contains a questionnaire about specific features and an overall evaluation. The specific questions are divided in the same number of groups as the tasks, inquiring the users about their experience with each feature. These questions inquire about the accessibility of the feature and its usefulness, and are formulated in the same scale as SUS. For an overall qualitative evaluation, the tester is asked if the application fulfills the intended goals in the same scale as SUS, followed by a binary question about its accessibility and two long answer questions about the faced difficulties and overall suggestions.

In the end, a question about the more specific background of the user is made. This allows the form to continue if the user's profile is connected to the history and cultural area. If that is the case, a new section is presented, otherwise the form is completed and submitted. This section allows domain experts to provide detailed information about their experience, relating it to their expertise. Here, some long answer questions are made about the potential relationship of the application with their work, its usefulness and experience with similar applications.

Twelve participants were submitted to this evaluation methodology. This number was decided given the goals of this evaluation. A small number of participants would be sufficient to find the most problematic parts of usability. The majority of the participants have a computer science background, with one participant having experience and technical background in interface design, providing more insightful feedback on usability. Two participants had a background in history and culture, more specifically, archaeology, contributed to this evaluation. These participants are responsible for investigating and managing the archaeological site of Troia Ruins <sup>1</sup>. The feedback of these experts was fundamental for the evaluation. The evaluation form presented to the participants was written in the Portuguese language. The form used in the evaluation can be found in the appendix of this dissertation, translated to the English language (appendix B, A. The user profile questionnaire is also available (appendix C).

---

<sup>1</sup><http://www.troiaresort.pt/ruinas-romanas-de-troia/>

## 5.2 Results Assessment

In this section, the processed results gathered from the evaluation test are presented. Figure 5.1 shows, in tabular form, the results collected from the twelve participants, for the SUS Score, Usability Score and Learnability Score, calculated by the formulas mentioned in the 5.1. Also shown is the mean, max value and min value of the results. By considering the mean for the SUS score, we can infer the obtained values are slightly below the above average threshold, meaning the evaluated system has usability issues. The SUS questionnaire also performed quite poorly in some participants answers, as the minimal score obtained is far below the threshold. Both evaluated dimensions extracted from the SUS questionnaire present ambiguous and disperse results.

User	SUS Score	Usability Score	Learnability Score
1	55	59.375	37.5
2	72.5	71.875	75
3	65	65.625	62.5
4	40	46.875	12.5
5	70	71.875	62.5
6	40	43.75	25
7	37.5	40.625	25
8	65	65.625	62.5
9	62.5	65.625	50
10	67.5	68.75	62.5
11	42.5	46.875	25
12	70	78.125	37.5
<i>Mean</i>	63.75	65.625	43.75
<i>Max</i>	72.5	78.125	75
<i>Min</i>	37.5	40.625	12.5

Table 5.1: Results of the SUS questionnaire

In figure 5.1, we can see a graph plot for the shown results, for a better visualization. It is noticeable that the majority of the results place quite below the desired threshold. Only three users (25% of participants) placed their results above the threshold, with only one having an above average score for all dimensions. From the graph we can infer that the learnability dimension of the questionnaire is the most lacking, while the usability dimension is far above from the learnability results. This correlates with most of the participants suggestions, in that the application would be easy to use and practical for long time users, but had a steep learning curve for beginners. One of the most requested features was a beginner tutorial or a manual.

Next, we evaluated each specific part of the application, focusing on each individual feature and how it performs. For the interface and map questions, in figure 5.2, half the participants rated the search methods for objects above average, despite most of the

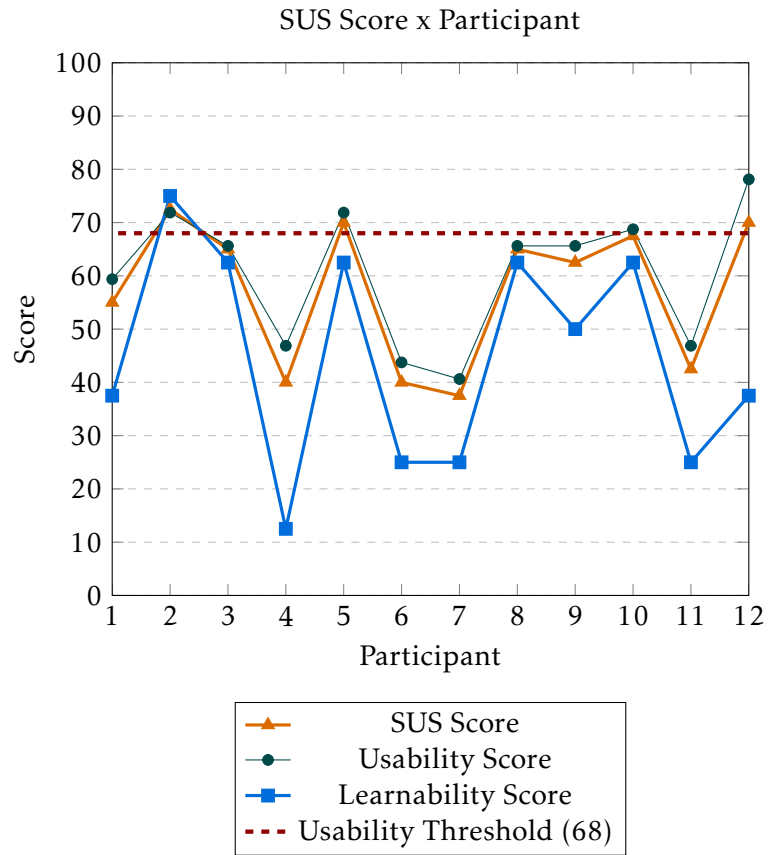


Figure 5.1: Results of the SUS questionnaire in graph form

participants clearly showing some difficult in finding the search input and searching with the requested parameters, which should be the most necessary feature. This feature was the most problematic and requires a redesign.

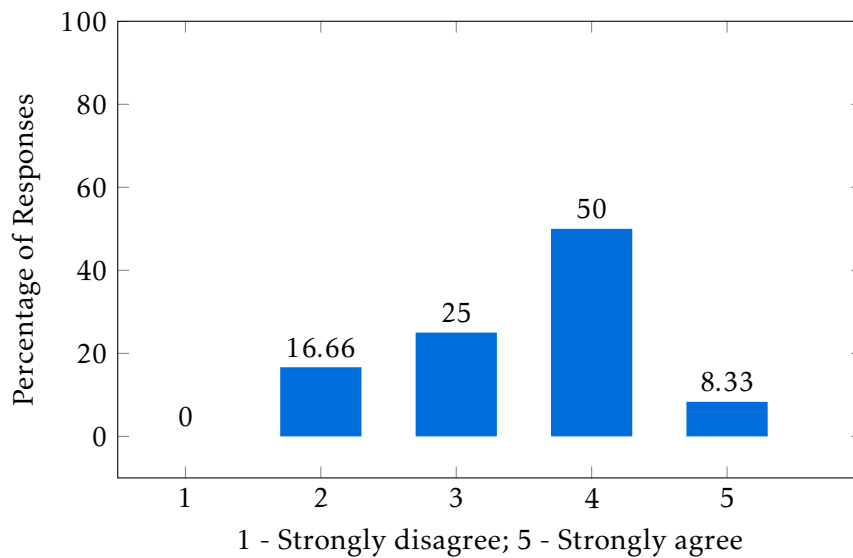


Figure 5.2: "It is easy to search for the desired objects"

In figure 5.3, which asked if the participants had any trouble finding a specific georeferenced object, formed very dispersed results. This might be due to how some participants were more comfortable navigating a 3D virtual globe than others, leading them to finding the desired points on the map faster. However, some of the participants did not look for the object through the map and used the object list instead. This might be a beginner's mistake, but it was not clear to them that the objects with associated geolocation were represented on the map, even with instructions in the task telling them where it was located.

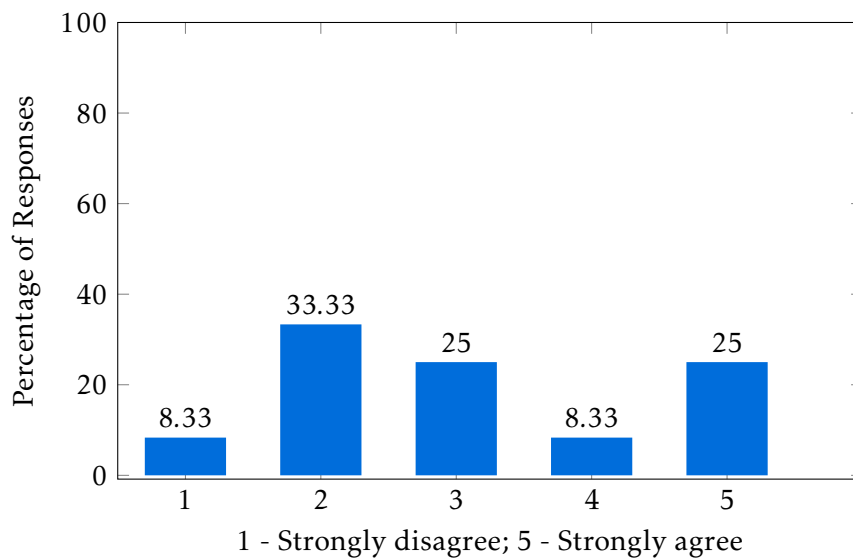


Figure 5.3: "It is hard to find a specific georeferenced object."

In figure 5.4, we see the results gathered from the participants answers on finding non georeferenced objects. The results were majorly negative, as it was visible participants did struggle with finding an object on the workbench lists, suggesting sorting the objects in any kind of order or including a search input for every object list. One positive aspect of this feature was how most participants quickly discovered the function of the icons on the left of the objects, specifying if an object was georeferenced or not.

In figure 5.5 are the answers on how hard it is to manage the object search lists in the workbench. The answers are evenly distributed, possibly meaning it was a feature the participants did not really considered until asked for. Some participants had trouble finding the remove button or hiding the visibility of the search lists. It was also unclear to some that the colors on top of the tab of the object list corresponded to the color of the object icons in the map.

In figure 5.6, we can see most participants were comfortable navigating the map. However, some users had trouble finding georeferenced objects in the map, which could mean they did not associate navigating in the map to finding an object placed in the map or the representation of objects in the map could have some issues.

In figure 4.7, the majority of participants answered that they had no trouble finding

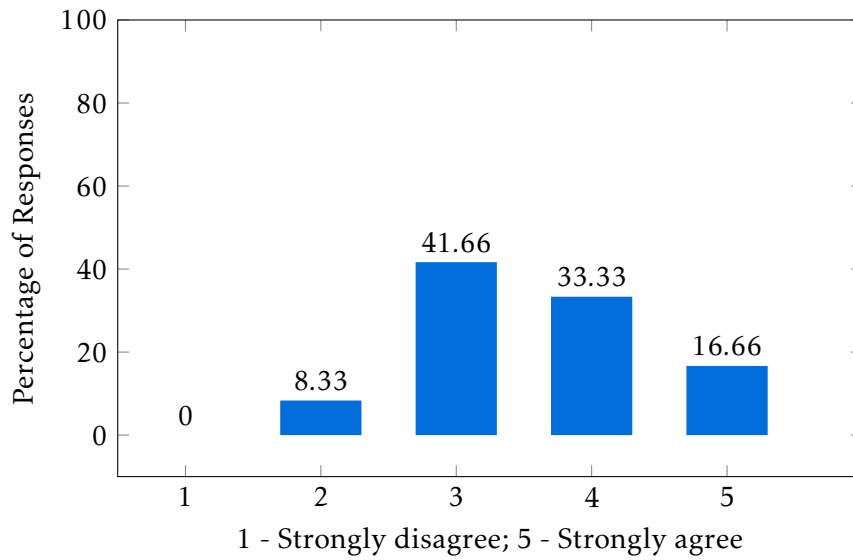


Figure 5.4: "It is easy to find a specific non georeferenced object."

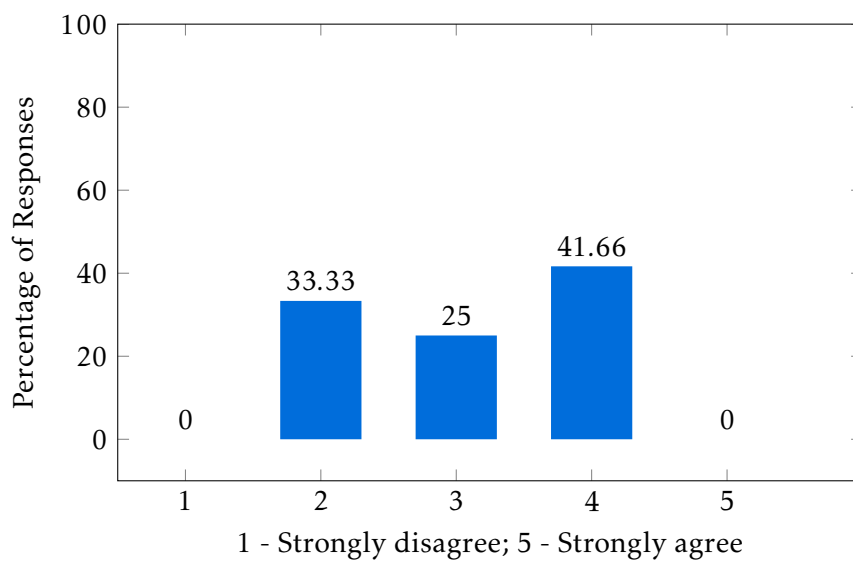


Figure 5.5: "It is hard to manage the object search lists."

related objects. However, most participants did take some time rationalizing this feature and locating the related objects button inside the preview window.

In figure 5.8, an overwhelming number of users answered positively that it is easy to inspect objects on the map. This might suggest that the representation of objects in the map is not an issue, as debated in the previous questions.

In figure 5.9, most answers about the location search are positive, even though in the evaluation environment this feature took a good amount of time to comprehend and execute.

In figure 5.10, the majority of participants answered positively on the usefulness of the object categorization. Despite some lower answers, no participant suggested a different

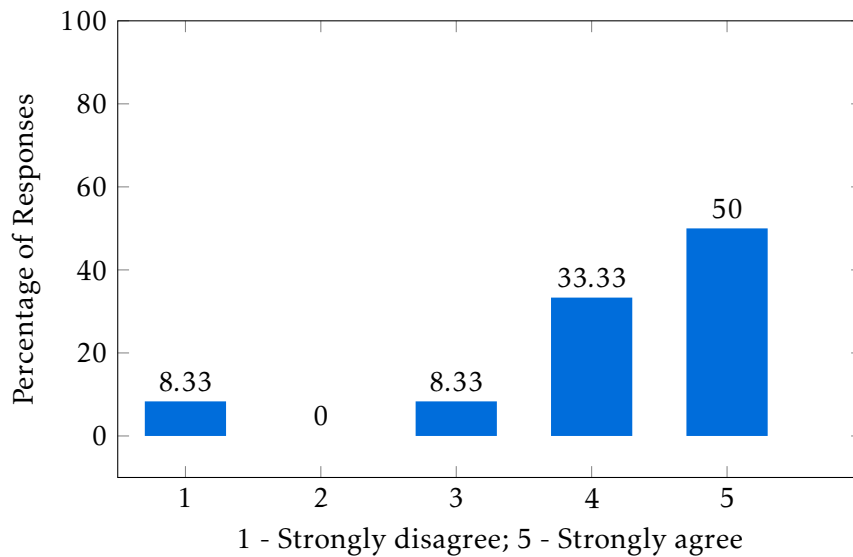


Figure 5.6: "It is easy to navigate on the map."

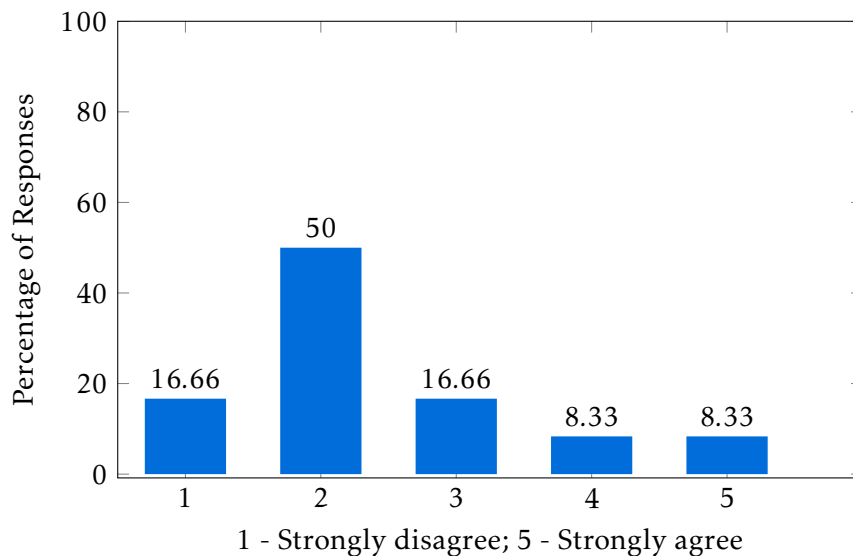


Figure 5.7: "It is hard to find related objects."

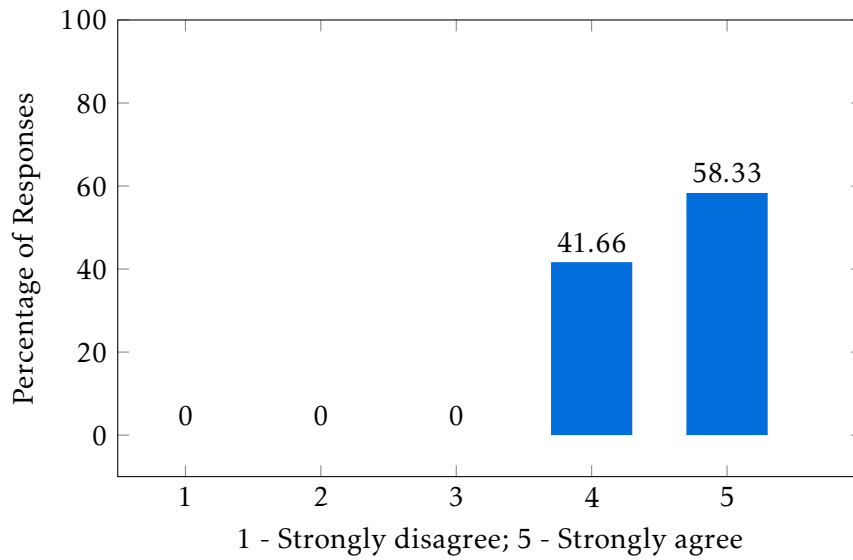


Figure 5.8: "It is easy to inspect objects on the map."

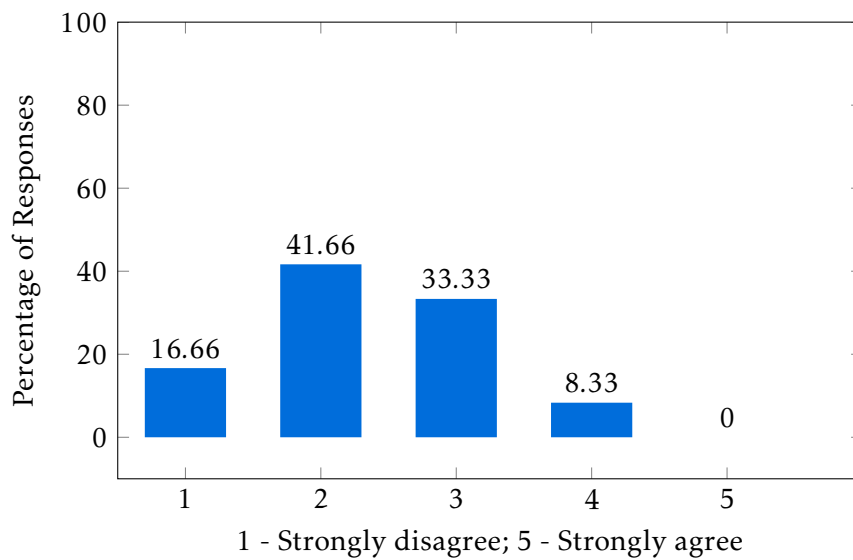


Figure 5.9: "It is hard to search by location."



method for categorization or mentioned any problem with it.

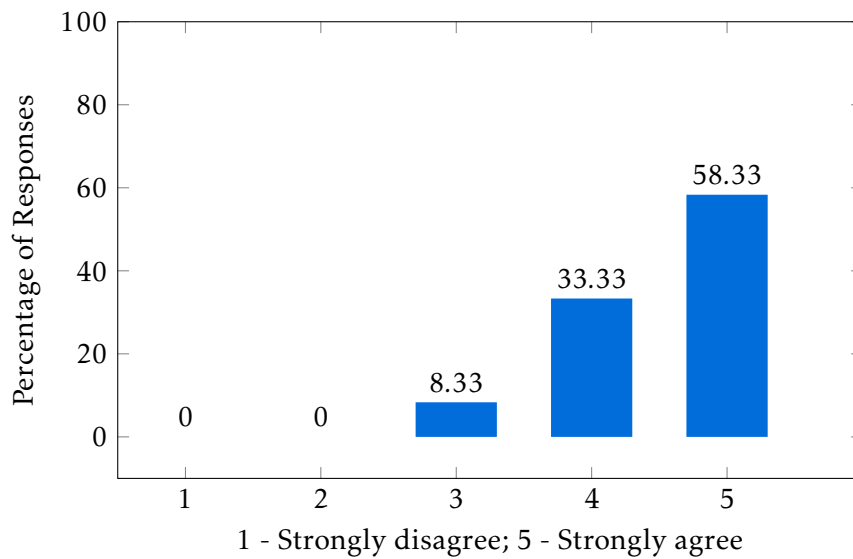


Figure 5.10: "The object categorization is useful."

In figure 5.11, the answers about the usefulness of the preview window are shown. Most participants rated the preview window as useful. However, one participant rated it as not useful at all. Some of the participants commented on how redundant it is that the same information appears in both the preview window and property window and some were confused by what window was designed to display the object information.

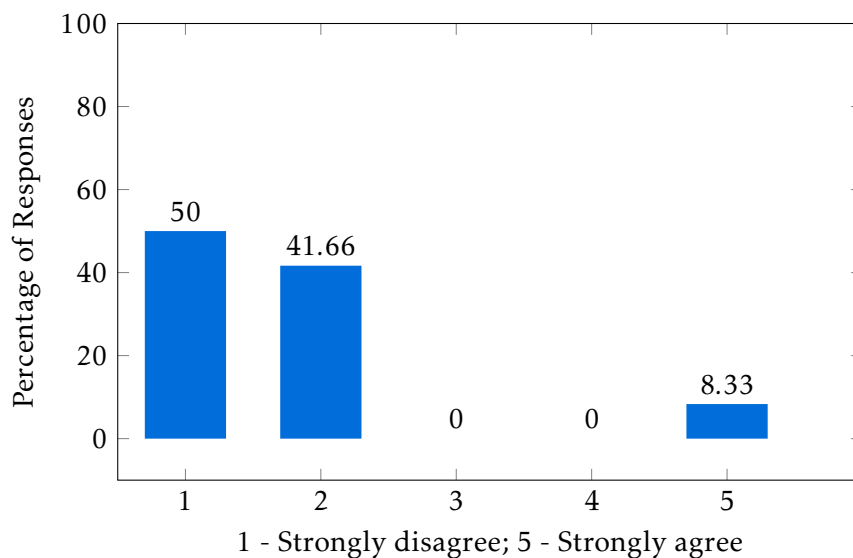


Figure 5.11: "The preview window is not useful."

As for the only question about the property window, in figure 5.12, are the answers about its usefulness. Surprisingly, all participants agreed to some degree that the property window is not useful. This might show that two windows for displaying information

might be unnecessary, even though they were designed to present information with different levels of depth. Another deduction is that the participants felt this window to be overwhelming, given the amount of properties displayed for each object, proving difficult to piece together the displayed information to the object in question.

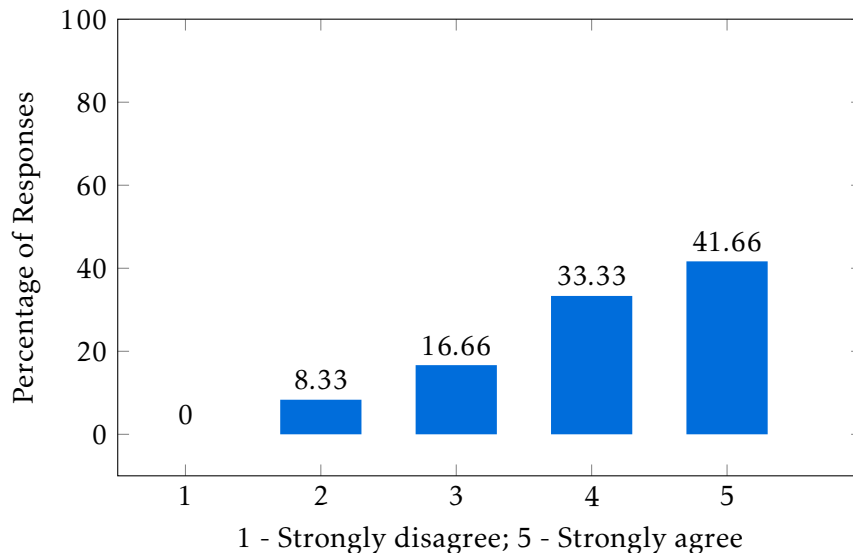


Figure 5.12: "The property window is not useful."

In the part about the exploration of context window, we have two questions. In figure 5.13 are the participants answers about the navigation on the Explore window. Some mixed opinions occur, but slightly more positive than negative. One can suppose this might be due to the inexperience with navigating a 3D viewer with a mouse, but, there is no backup evidence on this, except for the unrecorded large amount of time spent during this phase of the evaluation. Next, in figure 5.14, it is questioned if the Explore window really accomplishes its desired objective, that is, if it is suitable for learning and explore the context of an object. The majority (75% of participants) agreed, which can lead to finding improvements in this area in the future.

As for the part about submitting objects to the platform, in figure 5.15, participants rated how easy it was for them to submit an object. The majority answered positively, although not strongly. Some participants had trouble finding this feature during evaluation. The next logical step is finding the submitted object, so, in figure 5.16, participants answered precisely that. Despite the positive answers, some participants pointed out that finding an object they just submitted should not require more than a click after the submission form, if one desires to quickly check the quality of the format of information submitted. Also, some had trouble understanding that submitted objects could be returned by a term search using a term contained by the object. And finally, in figure 5.17 the vast majority of participants strongly agreed that submitting objects to the platform is useful, proving this feature is popular and a success that helps to better achieve our goals.

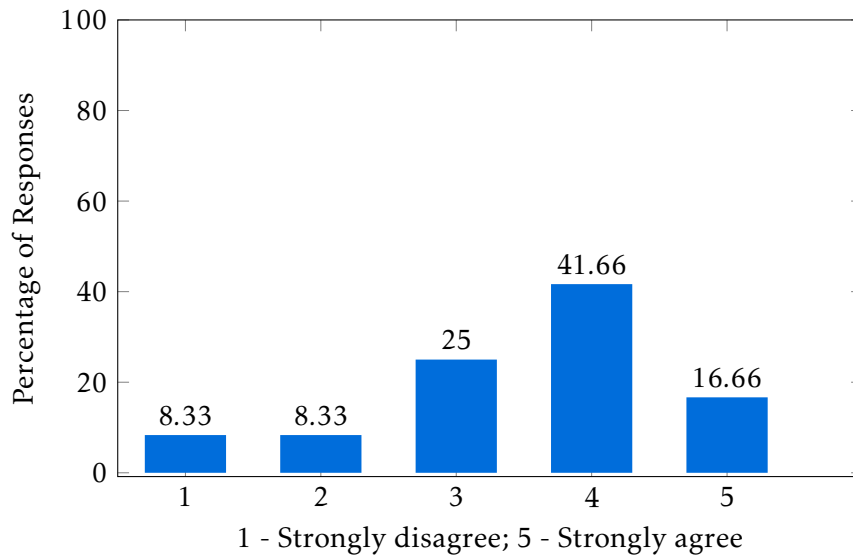


Figure 5.13: "It is easy to navigate in the Explore window."

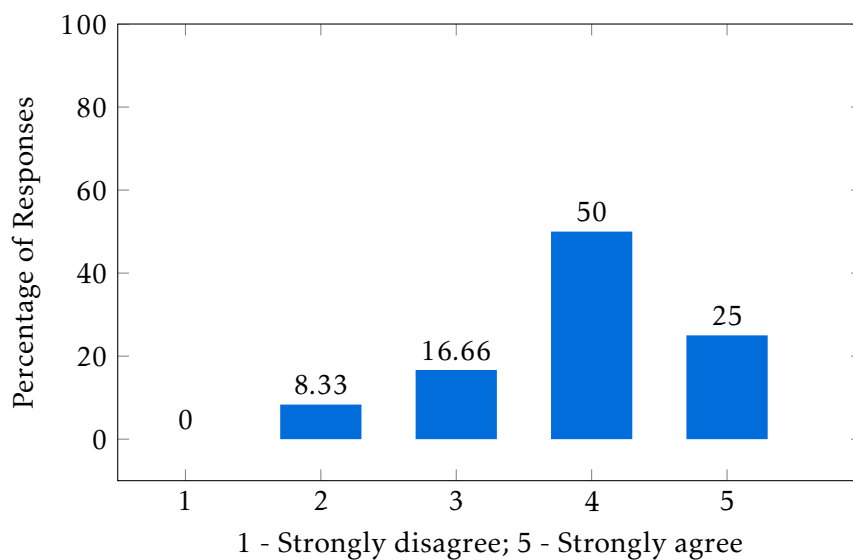


Figure 5.14: "The Explore window is suitable for learning and exploration of the context of an object."

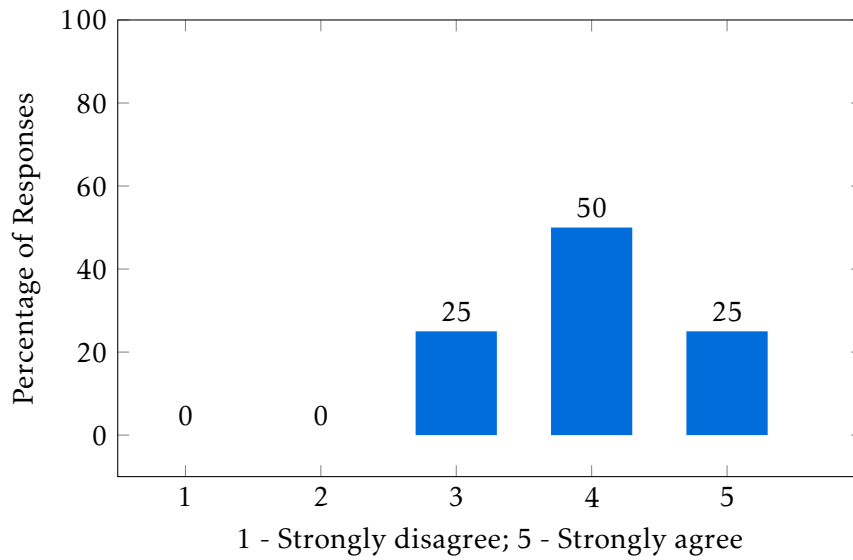


Figure 5.15: "It is easy to submit an object."

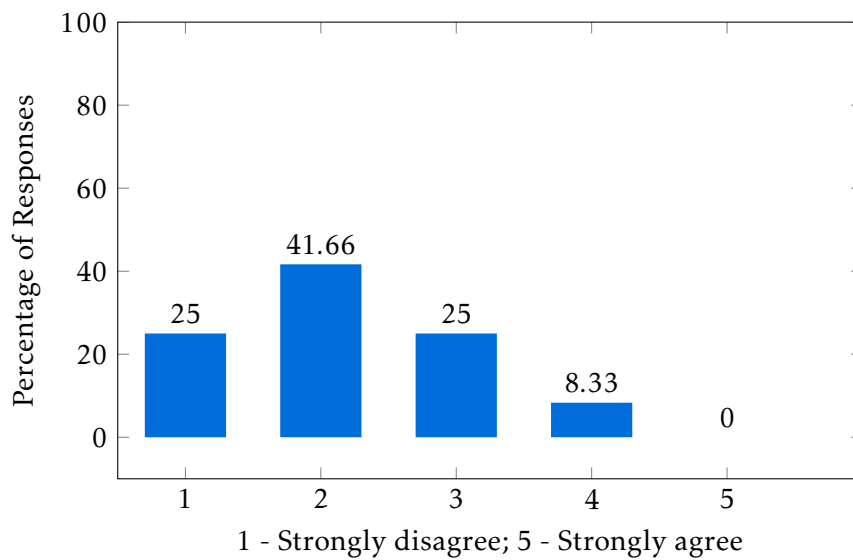


Figure 5.16: "It is hard to find a submitted object."

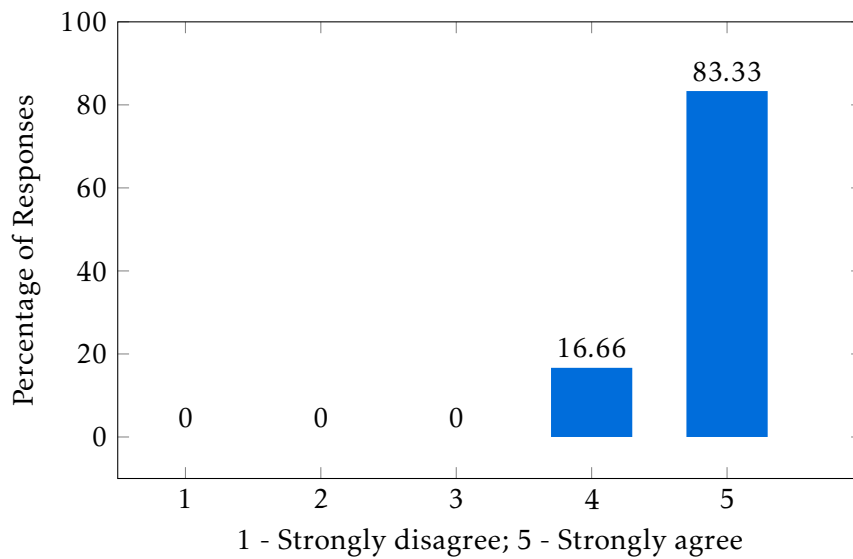


Figure 5.17: "It is useful to submit objects to the platform."

For the final general questions, testers were led to evaluate the performance of the presented solution against the initial proposed goals, explained to them in short, simple sentences. In figure 5.18, the participants are asked if they agree that the application is useful to generate interest and respect for history and cultural heritage. The majority of participants (83.33%) strongly agreed to this affirmation. It should be noted that most of the participants (83.33%) have no background in this area, making it valuable feedback on the path to accomplishing the proposed goals. In figure 5.19, participants are asked if the application might help to raise awareness about the preservation of culture and history by encouraging participation. The general response was positive, although some participants expressed their concern about the process of submitting objects, for instance, if it would involve any curatorship and if objects submitted by non experts would be available for everyone.

Overall, the general evaluation for the implemented features and the validity of the solution in response to the proposed goals was positive. Some conclusions can be made given this feedback, which will be discussed in the next sections.

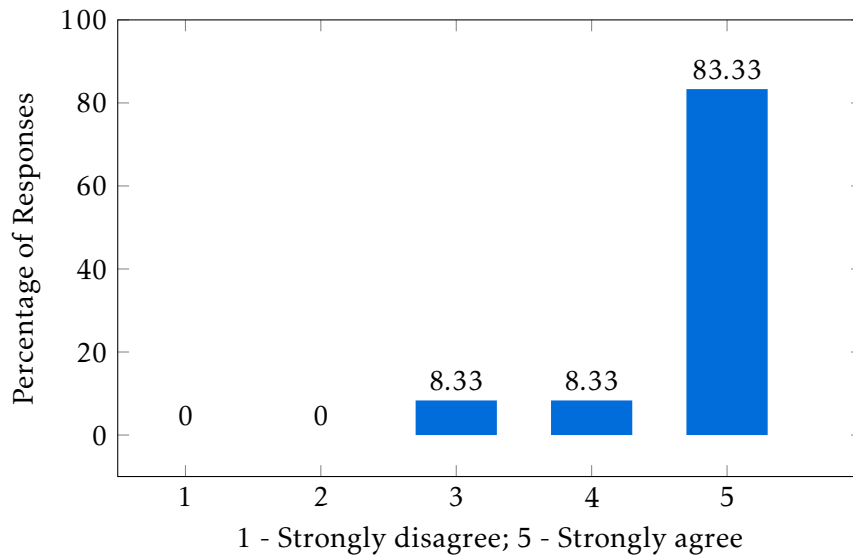


Figure 5.18: "I consider that the application is useful to generate interest and respect for history and cultural heritage."

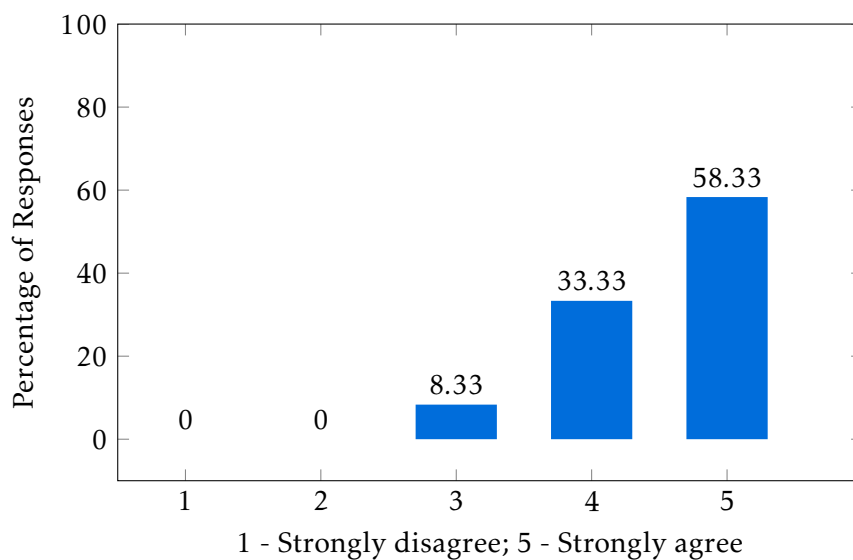


Figure 5.19: "I consider that the application is useful to raise awareness about the preservation of cultural objects and encourage the participation of users in this process."

### 5.3 Evaluation Limitations

In this section, some limitations to the methodology adopted to evaluate the solution are mentioned. Even though the results are considered final, they should not be accounted as a definitive answer on the quality of the implemented work, as the chosen methodology is merely a convention. In this case, the objective of this evaluation was to verify if the developed application was easy to use and learn, and if it contributed to reaching the defined goals at the start of this dissertation. The performed evaluation reflected this, but it should not be considered the optimal way to evaluate these dimensions. The number of participants involved in the evaluation might be considered too small. 12 participants is a very small sample to obtain reliable conclusions, as well to form trustworthy statistics. The participants profile is also a limitation. 66% of participants had a background in Computer Science, the majority of these in the area of interfaces, which means they are more at ease with navigating computer applications than the other participants and future users of this application, skewing the results on usability to perform better than it should. On the other hand, these participants generated useful and educated feedback for the evaluation on usability. As for the evaluation on the accomplishment of the desired goals, the lack of participants from technical background in history and culture resulted in poor conclusions on this area. More diverse experts would be needed, as both participants with background in cultural and history studied archaeology and worked in the same institution. Feedback from experts belonging to other institutions would provide different points of views, given the application could suit better some types of objects and areas of study. The questions aimed at experts also relied on this diversity, questioning about their work. Despite this flaws, their input was very positive. They demonstrated a genuine interest in the application and were interested to see developments in the future and how it could relate to their archaeological site. On another perspective, participants that did not had this background could answer more genuinely to the questions on generating motivation for this area and raising awareness in preservation, as this questions affected them and their views on the subject. One considered reason for the poor results was the lack of feedback during development. The usability suffered from the lack of external input during the implementation of the application. An iterative model during the development would benefit the final product, acting on the suggestions and complaints of early testers.

## 5.4 Expert Evaluation

This evaluation involved participants with backgrounds in two important areas for this dissertation. In order to benefit the conclusions, the collected feedback from the participants with background in history and usability, is detailed in this section, as their opinion can be considered relevant to the goals of the evaluation. Their evaluation consisted of the same process for the other participants, as analysed in section 5.2, however, this section explores other parts of the evaluation directed to them, as well as verbal feedback.

Two of the participants in this evaluation have a background in archaeology, so, in the end of the form described in section 5.1 and analysed in section 5.2, they were presented with questions about their work that would help understand their point of view from the experience. These questions aim to connect their expertise to the goals defined by this dissertation. Even though they are not the intended users, the application could reveal useful or interesting to their profession. The questions are the following:

**Do you commonly use informatic applications in your workspace? If your answer is Yes, list them.**

One participant answered that they worked with Amphorae ex Hispania<sup>2</sup>, a digital catalog of amphoras ( historical tall jars or jugs with handles and a thin neck, commonly originated from the Greek or Roman empire ). This catalog is accessed through a web application. The other participant had no noting applications to mention.

**Do you consider that the applications you use satisfy the necessary goals for you work to be practiced the best way it can? Explain your goals and flaws you have to mention.**

The participant that answered their workspace application identified it as satisfiable for their work.

**For the application you just used, do you consider that the navigation using the map and side menu are useful?**

Both participants answered positively.

**For the application you just used, do you consider that the categorization and the chosen icons for each type of object make sense?**

Both participants answered positively, which clear the doubts during the design phase about what categories to use. One participant mentioned the importance of a legend in the manual.

**For the application you just used, do you consider that the available information for each object is presented usefully?**

Both participants answered positively.

---

<sup>2</sup><http://amphorae.icac.cat/>



**For the application you just used, do you consider that the visualization in the Explore window is enough to provide context to an object?**

Both participants answered positively and were quite satisfied by this feature.

**Do you consider this application might be useful to raise awareness and motivate other for your work/education area?**

Both participants answered positively, which demonstrates their trust in the application.

**Do you consider this application might be useful for your work/education area?**

Both participants answered positively, with some comments about connecting the platform to repositories from their area of study. The repositories mentioned were Portal do Arqueólogo<sup>3</sup> and Portugal Romano.

These answers, albeit scarce, demonstrate how the application performs with users from cultural heritage knowledge. The participants found the visualization of multiple representations of an object and its context fascinating, which notes this feature as something to be explored upon. The goal of representing cultural heritage in an engaging and motivating way can be considered successful in these terms.

As for the usability expert participant, individually examining the score giving during the SUS questionnaire, the overall score was 70, with a score on usability of 71.875 and a score on learnability of 62.5. The overall score is above the usability threshold. However, the worst score is on learnability, a field that, during this evaluation, is consistently rated poorly. On the final questions of the form about the usefulness and learnability of features, the most problematic features mentioned by this participant were the search features and finding desired objects and submitted objects. During the evaluation moment, some verbal feedback was collected for improvements on usability, mentioning lack of visual hierarchy and actions that required a larger number of clicks than what a regular user would intuitively estimate. More specifically, in the next list are described the mentioned problems.

- The initial search to present information confuses users by being hidden in an extra window.
- Objects in the workbench were not ordered nor a search function was available.
- Some icons were misplaced and did not communicate their function effectively.
- Colors for the object lists were not contrasting enough.
- Location search should give more feedback to the user action, for instance, drawing the rectangle the user is selecting on the map.

---

<sup>3</sup><http://arqueologia.patrimoniocultural.pt/>

- Combined objects checkbox was written in a double negative.
- Properties in the property window should be called attributes.
- The process of submit an object in a location should be initiated inside the form.
- A submitted object should be made available after submission.

These identified problems, as well as other suggestions by other participants, will be discussed in the next section, where solutions will be discussed.

## 5.5 Proposed Changes to Improve Usability

Given the feedback of the participants collected during the evaluation, some major flaws and shortcomings in the application can be quickly identified. The cause of these problems can be pinpointed to the fact that the development did not benefit from concurrent feedback, building upon malformed decision. After the evaluation period, it is interesting to discuss these limitations and how to overcome them in future work. This section analyses most complaints on usability and suggests improvements that could help improve the overall usability score.

To help the reader visualize the suggested improvements, a mockup was conceived. In figure 5.20, it is shown the changes to be applied to the initial interface and map, where most improvements were suggested. This mockup was edited digitally on a graphical software, so none of these changes were applied to the working application.

One major complaint during the evaluation was that the search methods were not clear and accessible. Most participants were confused by the input form at the top and expected the repository search to happen on the left panel instead of the search window. As the functionality of searching for objects should be a priority, it should not take more than two clicks to perform, as bringing discernible data to the application view as soon as possible is an important feedback factor, to keep the user interested during its experience. To correct this issue, the search features were aggregated in a single panel in the left panel. With this panel, the user can search by term and location, by selecting the specific tab. When in the term tab, a text input appears. When searching by location, a single button is shown, that, when clicked, allows the user to form a rectangle on the map to create the desired geographical box to apply the search. The repository and combined object parameters are common for both types of search, so their inputs are kept the same. Instead of separating the personal objects search, the collection of submitted objects is treated like a repository. It is then available in the drop down repository input, so the parameter can be applied to both term and location search. By adopting this representation for the search feature, all functionality is kept intact while the number of steps to perform it are lower and the visual space occupied is smaller and better harnessed. Users can now immediately find the starting point and main objective of the application, that is, exploring cultural objects.

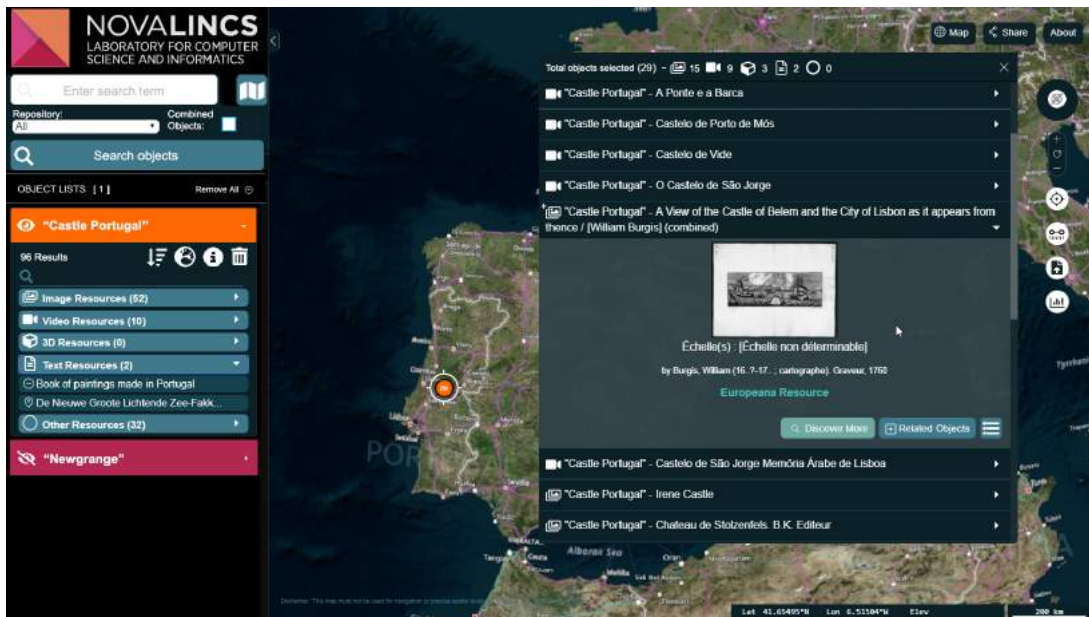


Figure 5.20: Proposed solution for usability issues.

1. Condensed search filters and more intuitive search bar.
2. Informative icons on preview window.
3. Colors of lists more prominent.
4. Icons for list functions.
5. Search bar in lists.

As for the workbench, object lists have been majorly redefined. The color associated to each object list is now more visible, as it is now the color of the tab. The visibility icon is altered to an eye to better represent visibility, as participants during evaluation had trouble understanding the request for disabling visibility of an object list. The total number of results contained by the list is given more priority, with a larger font and next to the title of the object list. Instead of representing object list actions as text, they were altered to be represented as descriptive icons. This helps reduce the amount of text available in an object list. These actions are, in order from left to right: sort, represented by an arrow pointing down in an ordered list; zoom to the extent of the object list, represented by a globe; information, represented by the info icon; and remove, represented by a trash can, the most common icon used for this kind of action. The sort action is not currently implemented in the version of the application used during the evaluation. When searching for a specific object on a list, participants had trouble locating the requested object. In

an answer to this problem, a sort button is considered, as well as search input for finding using terms. The sort button would work as a drop down, presenting a list of parameters, that would be used to specify the type of sorting applied to the list. The parameters considered, as for suggestion of the participants, were alphabetical order and georeferencing. The search input would filter objects by the title given the submitted term.

In the map, the right side buttons were updated, including a new one to host the graphic feature, where users can upload their own geographical data file and visualize it in the map. The submission button icon was also changed to better represent the upload of content to the platform, as some participants complaint about the use of a down arrow, usually connected to download features.

As for the preview window, some information was redefined, like the title of the preview window, featuring information about the amount of objects selected and its categories. Combined objects also have a plus icon so they are more easily identifiable. The show raw data button was replaced by a smaller icon, as it is not necessarily an user friendly feature, but instead, for users who need the information in its original format.

Other suggestions given by the participants for other features will not be presented were not added to the mockup, but they are worth mentioning. For the property window, participants said the list of properties presented were too many and suggested a filter input. Nonetheless, the property window was a feature that appeared out of necessity of inspecting all the information of an object so, in the future, it would need to be completely redesigned for its new use. Some participants also had trouble locating the explore window, so a better solution for the tabs presented in the property window would be needed.

The submission form also had a large number of reported problems. For starters, the month input was hard to use. Defining an object location also required too many steps, and it involved closing the submission form and re-opening. Even if the data filled in was persistent, this decision was taken by the participant with some confused and frustrating reactions. This problem could be fixed by including a location auto-fill in the location inputs, searching for known locations and providing the corresponding coordinates to the latitude and longitude fields. Also, these fields should have an attached button that briefly transports the user to the map and lets the user select the geographical point, for more detailed localization. Adding to this, a button for quickly filling the coordinates from the present location of the user, as it was mentioned by participants that adding objects to the current location was an interesting feature and should be made more prominent. Most participants also expected to be able to examine the newly submitted object after submission, something that is only currently possible by searching for a coincident term or in the personal objects search. To provide this, after submission, an object list with a single object should appear, showing the details filled in by the user. Finally, one participant suggested that the submitted objects should be available to be manipulated after submission, using the edit and delete operations. These actions should be made available in the property window. Currently, there are no registered users, meaning there

are no owners of the submitted content, so these actions should be planned according to these changes.

## **5.6 Conclusion**

To conclude this chapter, it can be considered that the main goal of the evaluation has been achieved, despite the setbacks caused by the inherent limitations of the evaluation environment. The results obtained through the validation against a standard led to the conclusion that the user interface of the application needs improvement and should be rethought. These changes can be informed by the rich feedback gathered from the participants, through observation and measurement of their behaviour or by direct communication of their troubles and suggestions. As for the solution value in the fields of culture and history, it can be noted that the more accessible the application, the larger the impact on the users and its value for the area. Unfortunately, it was not possible to evaluate and gather feedback midway during development in order to iterate from the eventual suggestions and reaching better final results. A more diverse profile of participants would improve future evaluations, as one problem with the accomplished one is the lack of experts from the area of culture and history, resulting in the conclusions coming short on the accomplishment of the proposed goals. However, most participants that had backgrounds in unrelated areas revealed they gained interest in the area of culture and history, proving that the application can be successful in generating awareness and motivation, one of the initial goals of this dissertation.



## CONCLUSION AND FUTURE WORK

In this last chapter, this dissertation is summarised by reviewing what was achieved throughout the chapters. The first section focuses on the outcomes of this dissertation, analysing general conclusions (section 6.1). The last section discusses the direction of further developments, giving suggestions to improve the developed application (section 6.2).

### 6.1 Conclusions

This dissertation followed the development of a web application that allows the exploration of cultural heritage objects stored in various digital repositories and their visualization using multiple formats. This solution aimed to solve the problem of integration of cultural heritage data in a context of visualization and interaction, and find an effective way to communicate and teach cultural heritage. The context of this dissertation was proposed by archaeological institutions that wanted to achieve a closer connection between people and cultural heritage, promoting awareness and respect for history and its preservation.

The design of the presented solution was informed by a research on different techniques for handling and presenting cultural heritage. The state of the art covered concepts of cultural heritage, visualization and interaction and spatio-temporal representation. Related work to the dissertation was also analysed, providing examples of how some of the problems of design and implementation would be solved.

The implemented application consists of multiple features for exploring, visualize and preserve representations of cultural heritage artifacts, and is intended for all audiences. It was designed to contain learning components and make cultural heritage accessible and interesting. Users can explore objects presented in a globe or map, or browse a

complete list of results in a list. These objects originate from different sources and as its properties are converted to an internal model. Most of the original information carried by the object from its repository can be examined. An object context can be analyzed by piecing together information from related objects and the explore window, comprising multiple formats of visualization of its place of origin. It is also possible for users to submit their objects in the categories available in the application model, in order to promote preservation of cultural heritage.

The web application was evaluated by twelve participants, with two having a background in archaeology and one expert in usability. Despite the low number of participants, the evaluation generated important conclusions about the developed application and the effectiveness of the solution when assessed on the intended goals. The expert input was specifically significant as no other agents involved in the development and evaluation of the dissertation had prior knowledge on the area. In the end, it is possible to identify the shortcomings of the designed implementation and, with the help of user feedback, trace a path on further solutions for those problems. Despite the overall conclusion on usability not being satisfactory, the concept of the application and its features can be considered a success.

Summing up, despite the encountered setbacks, the goals of the dissertation were met, if considered what was learned during the evaluation phase. The application was well received by all participants during evaluation and the features were marked as useful. New features and changes were suggested. Its effectiveness on meeting the requirements for the proposed goals was verified by experts and non experts. In the end, the application can be contemplated as effective in cultural heritage learning, respect and its awareness in preservation. On the technical side, the integration of information and its communication regarding cultural heritage, as well as the customization of the application by other entities, is working as intended. Future work would considerably improve the effectiveness of the solution, even if the results right now can be regarded as positive.

## 6.2 Future Work

In a future iteration of the development of the created application, some changes noted by the evaluation participants should be applied. Also, some technologies and concepts should be adapted to the solution, improving the effectiveness on how cultural heritage is communicated, using proven techniques and concepts seen in Background and Related Work (chapter 2, 3).

Usability issues were covered in section 5.5, and should be addressed first. After that, another evaluation may take place to discover new issues and compare its results with the previous one. Various iterations should be executed as needed, whenever there are relevant usability issues. Along with the improvements in each iteration, the addition of new features should also be considered.



Some interesting features to complement the proposed solution can be derived from the state of the art and related works. The information provided by timelines would be engaging to discover, delivering to the user a sense of temporal presence and placement of the objects. Objects could be found by their date property and a temporal path could be traced between related and contextual objects, uncovering a new dimension to explore. However, to be able to execute this correctly, the information provided by the repositories should be clear enough to present intelligible data. A date property, if not labelled correctly, can cause uncertainty to what it represents. For instance, the date could mean the date of creation of an object or the date of its discovery. Not matching the properties to what they represent can risk the validity of creating informative guiding lines between objects.

The correct use of the temporal properties of objects could be also used to build narratives and provide a direction of navigation to an inexperienced or aimless user. An interface for manually building custom narratives would also be a solution for the lack of interoperability between repositories. This interface could gather a list of object links available through the integration platform, and place them in order. Then, using a stimulating representation in the map, like connecting lines and camera movements, a narrative could be built to guide the user through a predefined storyline. Connecting these features to the explore window would result in a richer experience. Taken as a whole, narratives would improve and facilitate the discovery of artifacts and their context, as opposed to the current solution that relies only on the ability and the goals of the user using the application, as the relationship options are very limited. Relationships between objects could be improved with the use of more effective solutions. Related work for structuring and categorising cultural heritage objects should be investigated and deepened, in order to find a scalable solution to build and present richer information to the user.

Another improvement to the application would be the way the user interacts with the objects. Some concepts were explored that involved immersive technology. Exploring concepts like virtual reality, augmented reality and tangible interfaces in future implementations would benefit the final application and approximate the user to the richness of cultural heritage.

One needed feature for institutions that wish to use and customize the application to their own collection and entity would be the ability to manually create contextual windows. The explore window is an interesting concept if applied dynamically, but for smaller collections of data, a crafted experience would harness better results. In this way, an interface for building the context behind objects would be a must have tool for future implementations. This interface could allow a curated user from an institution to manually select videos, slideshows and 3D models and assemble a customized experience as it should be possible to see in a physical collection.

Overall, the conceived application can take many paths for future improvements, depending on the goals defined for its intended experience. The implemented application

was designed to pursue two distinct functions, so a middle ground was found. However, it can be used as starting point for the development of a more effective and cohesive experience.

## BIBLIOGRAPHY

- [1] J. M. Aaron Bangor Philip Kortum. “Determining what individual SUS scores mean: adding an adjective rating scale.” In: *Journal of Usability Studies* 4.3. Illinois, USA: Usability Professionals’ Association, 2009, 114–123.
- [2] N. Adabala, N. Datha, J. Joy, C. Kulkarni, A. Manchepalli, A. Sankar, and R. Walton. “An Interactive Multimedia Framework for Digital Heritage Narratives.” In: *Proceedings of the 18th ACM International Conference on Multimedia*. New York, USA: ACM, 2010, pp. 1445–1448.
- [3] T. P. C. Barfield Woodrow. *Fundamentals of wearable computers and augmented reality*. New Jersey, USA: CRC Press, 2001, pp. 78 –79.
- [4] G. C. Burdea and P. Coiffet. “Virtual Reality Technology.” In: *Presence: Teleoperators & Virtual Environments* (2003), pp. 663–664.
- [5] C.-c. Chen, H. D. Wactlar, J. Z. Wang, and K. Kiernan. “Digital imagery for significant cultural and historical materials.” In: *International Journal on Digital Libraries* 5.4 (2005), pp. 275–286.
- [6] R. Damiano, A. Lieto, and V. Lombardo. “Ontology-Based Visualisation of Cultural Heritage.” In: *2014 Eighth International Conference on Complex, Intelligent and Software Intensive Systems*. Birmingham: IEEE, 2014, pp. 558–563.
- [7] R. Damiano, V. Lombardo, A. Lieto, and D. Borra. “Exploring cultural heritage repositories with creative intelligence. The Labyrinth 3D system.” In: *Entertainment Computing* 16 (2016), pp. 41 –52.
- [8] M. C. tom Dieck and T. H. Jung. “Value of augmented reality at cultural heritage sites: A stakeholder approach.” In: *Journal of Destination Marketing & Management* 6.2 (2017). Special edition on Digital Destinations, pp. 110 –117.
- [9] M. Doerr. “Ontologies for Cultural Heritage.” In: *Handbook on Ontologies*. Ed. by S. Staab and R. Studer. Berlin, Heidelberg: Springer Berlin Heidelberg, 2009, pp. 463–486.
- [10] R. Fonseca. “Integration of Georeferenced Historical Information.” Master’s thesis. Almada, Portugal: FCT NOVA, 2018.

## BIBLIOGRAPHY

---

- [11] E. Gadolou, H. Papadaki, E. Stefanakis, G. Kritikos, Y. Cao, A. Hannemann, R. Klamma, and D. Kovachev. "Storytelling, Spatial Standards and Cultural Heritage Management." In: (2010), pp. 1–9.
- [12] S. Gitner. *Multimedia storytelling for digital communicators in a multiplatform world*. Routledge, 2015, p. 406.
- [13] A. Hackeloeer, K. Klasing, J. M. Krisp, and L. Meng. "Georeferencing: a review of methods and applications." In: *Annals of GIS* 20.1 (2014), pp. 61–69.
- [14] D. Harvey. "Culture, Heritage and Representation: Perspectives on Visuality and the Past." In: 37 (2012), 169–170.
- [15] M. Katsianis, S. Tshipidis, K. Kotsakis, and A. Kousoulakou. "A 3D digital workflow for archaeological intra-site research using GIS." In: *Journal of Archaeological Science* 35.3 (2008), pp. 655–667.
- [16] F. Klawonn. "Introduction to Computer Graphics - Using Java 2D and 3D." In: *Undergraduate Topics in Computer Science*. 2008.
- [17] D. Koller, B. Frischer, and G. Humphreys. "Research Challenges for Digital Archives of 3D Cultural Heritage Models." In: *J. Comput. Cult. Herit.* 2.3 (2010), 7:1–7:17.
- [18] S. Kulasekaran, J. Trelogan, M. Esteva, and M. Johnson. "Metadata Integration for an Archaeology Collection Architecture." In: *Proceedings of the 2014 International Conference on Dublin Core and Metadata Applications*. DCMI'14. Austin, Texas: Dublin Core Metadata Initiative, 2014, pp. 53–63.
- [19] G. Kyriakaki, A. Doulamis, N. Doulamis, M. Ioannides, K. Makantasis, E. Protopadakis, A. Hadjiprocopis, K. Wenzel, D. Fritsch, M. Klein, and G. Weinlinger. "4D Reconstruction of Tangible Cultural Heritage Objects from Web-Retrieved Images." In: 3 (June 2014).
- [20] J. Lewis and J. Sauro. "The Factor Structure of the System Usability Scale." In: vol. 5619. July 2009, pp. 94–103.
- [21] S. Logothetis, A. Delinasiou, and E. Stylianidis. "Building information modelling for cultural heritage: a review." In: *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences* 2.5 (2015), p. 177.
- [22] T. Loulanski. "Revising the Concept for Cultural Heritage: The Argument for a Functional Approach." In: *International Journal of Cultural Property* 13.2 (2006), 207–233.
- [23] L. D. Luca, C. Busayarat, C. Stefani, P. Véron, and M. Florenzano. "A semantic-based platform for the digital analysis of architectural heritage." In: *Computers & Graphics* 35.2 (2011). Virtual Reality in Brazil Visual Computing in Biology and Medicine Semantic 3D media and content Cultural Heritage, pp. 227–241.

- [24] A. I. Martins, A. F. Rosa, A. Queirós, A. Silva, and N. P. Rocha. “European Portuguese Validation of the System Usability Scale (SUS).” In: *Procedia Computer Science* 67 (2015). Proceedings of the 6th International Conference on Software Development and Technologies for Enhancing Accessibility and Fighting Info-exclusion, pp. 293–300.
- [25] R. Muntean, K. Hennessy, A. Antle, S. Rowley, J. Wilson, B. Matkin, R. Eckersley, P. Tan, and R. Wakkary. “Belongings: a tangible interface for intangible cultural heritage.” In: *Proceedings of the Conference on Electronic Visualisation and the Arts*. BCS Learning & Development Ltd. 2015, pp. 360–366.
- [26] D. Petrelli, L. Ciolfi, D. van Dijk, E. Hornecker, E. Not, and A. Schmidt. “Integrating Material and Digital: A New Way for Cultural Heritage.” In: *interactions* 20.4 (2013), pp. 58–63.
- [27] D. Pletinckx, L. De Jaegher, T. Helsen, I. Langen, N. A. Silberman, M.-C. Van der Donckt, and J. Stobbe. “Telling the Local Story: An Interactive Cultural Presentation System for Community and Regional Settings.” In: *VAST*. Brussels, Belgium, 2004, pp. 233–239.
- [28] Prathibha.B.S. “Geographic information systems as an integrating technology: context, concepts, and definitions.” In: (1996), pp. 3204–3207.
- [29] S. Price. “A Representation Approach to Conceptualizing Tangible Learning Environments.” In: *Proceedings of the 2Nd International Conference on Tangible and Embedded Interaction*. TEI '08. New York, USA: ACM, 2008, pp. 151–158.
- [30] T. Prinz, S. Walter, A. Wiegardt, T. Karberg, and T. Schreiber. “GeoArchaeology Web 2.0: Geospatial Information Services Facilitate New Concepts of Web-Based Data Visualization Strategies in Archaeology—Two Case Studies from Surveys in Sudan (Wadi) and Turkey (Doliche).” In: 02 (2014), pp. 91–106.
- [31] . B.-P. Renfrew C. *Archaeology. Theories, Methods, And Practice*. London: Thames & Hudson, 1991.
- [32] S. Rizvic and D. Tsiafak. *Visualization of Cultural Heritage Objects and its Dissemination*. Xanthi, Greece, 2016.
- [33] S. Rizvic, V. Okanovic, and A. Sadzak. “Visualization and multimedia presentation of cultural heritage.” In: *2015 38th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO)*. Opatija, Croatia: IEEE, 2015, pp. 348–351.
- [34] M. Roussou. “Virtual heritage: from the research lab to the broad public.” In: *Bar International Series* 1075 (2002), pp. 93–100.
- [35] S. Ruecker, M. Radzikowska, and S. Sinclair. *Visual interface design for digital cultural heritage: A guide to rich-prospect browsing*. Surrey, England: Ashgate Publishing, Ltd., 2011, p. 197.

## BIBLIOGRAPHY

---

- [36] M.-M. Schaper, M. Santos, L. Malinverni, J. Z. Berro, and N. Pares. “Learning about the past through situatedness, embodied exploration and digital augmentation of cultural heritage sites.” In: *International Journal of Human-Computer Studies* (2018), pp. 36–50.
- [37] E. Sharlin, B. Watson, Y. Kitamura, F. Kishino, and Y. Itoh. “On tangible user interfaces, humans and spatiality.” In: *Personal and Ubiquitous Computing* 8.5 (2004), pp. 338–346.
- [38] D. Stricker, A. Pagani, and M. Zoellner. “In-situ visualization for cultural heritage sites using novel augmented reality technologies.” In: *Virtual Archaeology Review* 1.2 (2010), pp. 37–41.
- [39] S. Valtolina. “A Storytelling-Driven Framework for Cultural Heritage Dissemination.” In: *Data Science and Engineering* 1.2 (2016), pp. 114–123.
- [40] M. Whitelaw. “Generous Interfaces for Digital Cultural Collections.” In: *DHQ: Digital Humanities Quarterly* 9.1 (2015).



## USABILITY TEST

### Representing and Indexing Archaeological Information

This test aims to evaluate a web application for the exploration and visualization of digital representations of historical and cultural objects originated from various online repositories. To do this, you must carefully read the tasks presented and execute them in the application as you see fit. Whenever possible explain your reasoning out loud. At the end of each task you will have to answer a question about the state of the application after your intervention. When in doubt, at any time during the test, please explain your thought process. This test is meant to evaluate the program and not your reasoning, so do not feel pressured and take your time. It is advisable to freely explore the tool as long as it does not interfere with the order in which the tasks are presented (the screen that is displayed at the end of each task is the result of the actions of the tool itself). In the end, you will need to fill out a questionnaire to assess your experience of using the application. This questionnaire is anonymous, so personal information will only be used for statistical data. Your opinions are important, we thank you for being as sincere as possible, in order to properly evaluate the work done.

**\*Obrigatório**

#### Application View

Educational Area \*

A sua resposta

Age \*

A sua resposta

Gender

Male

Female

SEGUINTE

Página 1 de 22


Nunca envie palavras-passe através dos Formulários do Google.

## Representing and Indexing Archaeological Information

### Map and Interface

This section of the evaluation will focus on the exploration of digital representations of real objects (with historical, archaeological or cultural value), map navigation and interface usability. Access to digital objects is provided through various research methods. Objects are cataloged visually by type (image, 3D model, video or text). When accessing an object, the user is first presented with a preview window with some predefined properties of the object and an image if that information exists in the original repositories. Combined objects refer to objects with different identities in their original repositories that are aggregated through similarities and represented in a single object. Clustered objects refer to the representation of several objects on the map at a single point when they overlap.

#### Map and Interface View



The screenshot shows the NOVALINCS interface. On the left, there is a list of objects under the heading 'OBJECT LIST (1)'. The selected object is 'Castro Prêgo' with a 'View' button. The main area displays a globe with several orange location markers. The interface includes navigation controls like 'Map', 'Zoom', and 'Reset'.

ANTERIOR SEGUINTE

Página 2 de 22



Representing and Indexing  
Archaeological Information

\*Obrigatório

Map and Interface - Task 1

Search by the term "Castle Portugal", with disabled combined objects and in all available repositories.

How many results are returned by the search? \*

ANTERIOR SEGUINTE  Página 3 de 22

Nunca envie palavras-passe através dos Formulários do Google.

Representing and Indexing  
Archaeological Information

\*Obrigatório

Map and Interface - Task 2

Navigate to the preview of the object named "A Prospect of the Castle of Surat, a great city of Indostan, commonly called the Mogul Empire in India" (an Image resource), placed in France.

Who is the author of this object? \*

ANTERIOR SEGUINTE  Página 4 de 22

Nunca envie palavras-passe através dos Formulários do Google.

Representing and Indexing  
Archaeological Information

\*Obrigatório

Map and Interface - Task 3

Find the objects related to the one analysed in the previous task (2). Disable the visibility of the results returned by the search made in the first task (1).

In what category is the object placed in Norway part of? \*

Text

ANTERIOR SEGUINTE

Página 5 de 22

Nunca envie palavras-passe através dos Formulários do Google.

Representing and Indexing  
Archaeological Information

\*Obrigatório

Map and Interface - Task 4

View the returned objects at the desired pace. After answering the question, remove the list added in task (3).

How many objects are located in Portugal? \*

15

ANTERIOR SEGUINTE

Página 6 de 22

Nunca envie palavras-passe através dos Formulários do Google.

Representing and Indexing  
Archaeological Information

\*Obrigatório

Map and Interface - Task 5

Enable the visibility of the list created in task (1). Apply a zoom in the map to the extent of the list. Select all objects placed in Portugal.

How many objects in the 'Video' category are placed in Portugal?  
\*

9

ANTERIOR SEGUINTE

Página 7 de 22

Nunca envie palavras-passe através dos Formulários do Google.

Representing and Indexing  
Archaeological Information

Map and Interface - Task 6

Search by location, using two coordinates that form a rectangle that fit the area of Lisbon, with the specific repository "Cultura Casas Religiosas", with disabled combined objects.

ANTERIOR SEGUINTE

Página 8 de 22

Nunca envie palavras-passe através dos Formulários do Google.

Este formulário foi criado dentro de Faculdade de Ciências e Tecnologia da UNL. [Denunciar abuso](#) - [Termos de Utilização](#)

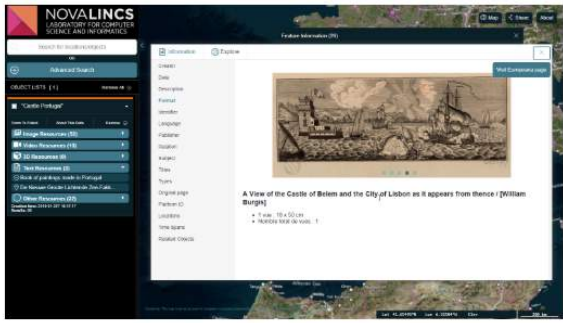
Google Formulários

## Representing and Indexing Archaeological Information

### Object Properties

This section of the evaluation will focus on exploring the properties of an object, cataloged by their respective repositories. Each object has a set of properties, with varying degrees of completeness. For example, while an object may contain information about its author and location, some objects may not have it. The properties window is intended to expose all object properties to the user.

#### Property Window



ANTERIOR   SEGUINTE   Página 9 de 22

Nunca envie palavras-passe através dos Formulários do Google.

## Representing and Indexing Archaeological Information

\*Obrigatório

### Object Properties - Task 7

**Search by the term "Newgrange", with combined objects enabled and in all available repositories.**

How many results are part of the '3D Model' category? \*

8

ANTERIOR   SEGUINTE   Página 10 de 22

Nunca envie palavras-passe através dos Formulários do Google.

Representing and Indexing  
Archaeological Information

\*Obrigatório

Object Properties - Task 8

Select the non georeferenced object from the 'Image' category with the name "New Grange (combined)". Explore the properties of the selected object.

What is the value of the 'Subject' property of the selected object? \*

Architecture Ireland

ANTERIOR SEGUINTE

Página 11 de 22

Nunca envie palavras-passe através dos Formulários do Google.

Representing and Indexing  
Archaeological Information

\*Obrigatório

Object Properties - Task 9

Select the georeferenced object from the '3D Model' category, com o nome "Kerbstone 52, Newgrange (3D Model)". Explore the properties of the selected object. Visualize and interact with the presented 3D model.

What repository does the selected object belong to? \*

Europeana

ANTERIOR SEGUINTE

Página 12 de 22

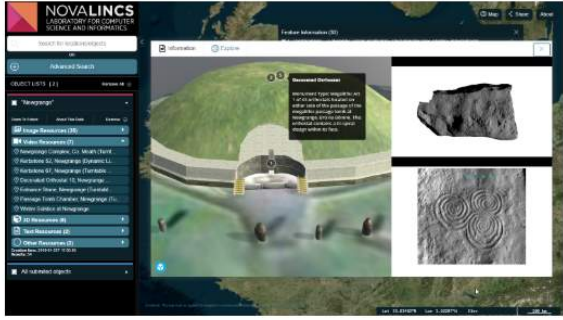
Nunca envie palavras-passe através dos Formulários do Google.

## Representing and Indexing Archaeological Information

### Multiple Visualizations and Context

This section of the evaluation will focus on exploring the spatial and relational context of an object through the Explore window, where you can view multiple representations of an object in various formats. The navigation in this window is based on a 3D model of an archaeological site, with several points of interest highlighted, associated to the place where the object in question and others related are located.

#### Explore Window



ANTERIOR   SEGUINTE   Página 13 de 22

Nunca envie palavras-passe através dos Formulários do Google.

## Representing and Indexing Archaeological Information

\*Obrigatório

### Multiple Visualizations and Context - Task 10

Explore the context window of the selected object. Explore the 3D model.

How many points of interest exist in the 3D model? \*

5

ANTERIOR   SEGUINTE   Página 14 de 22

Nunca envie palavras-passe através dos Formulários do Google.

Representing and Indexing  
Archaeological Information

\*Obrigatório

Multiple Visualizations and Context - Task 11

Course through all the points of interest related to the 3D model, viewing the multiple forms of representation of each object associated to them.

What is the name of the video associated to the last point of interest? \*

Dynamic Lighting of Decorated Kerbstor

ANTERIOR SEGUINTE

Página 15 de 22

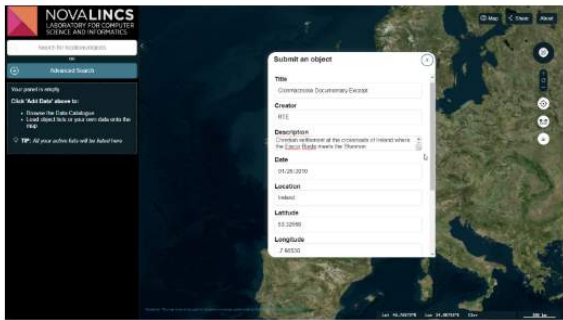
Nunca envie palavras-passe através dos Formulários do Google.

Representing and Indexing  
Archaeological Information

Content Submission

This section of the evaluation will focus on the submission of personal content generated by the users of the platform, through a form present in the application. This functionality was designed to foster interest and collaborative participation in historical and cultural preservation. In the form you can fill several fields with the properties of the object that are visible in the preview window and associate it with one of the categories, providing its resource in the desired format.

Submission Form



ANTERIOR SEGUINTE

Página 16 de 22

Nunca envie palavras-passe através dos Formulários do Google.

## Representing and Indexing Archaeological Information

\*Obrigatório

### Content Submission - Task 12

Submit to the platform an object with the following properties:

- Title: Clonmacnoise Documentary Excerpt
- Creator: RTE
- Description: An excerpt from RTE's Secret of the Stones documentary giving an overview of the 'Lost City of Clonmacnoise', Ireland first city and an important early Christian settlement at the crossroads of Ireland where the Eiscor Riada meets the Shannon.
- Date: 26-11-2010
- Location: Ireland
- Latitude: 53.32668 ( important )
- Longitude: -7.98530 ( important )
- Preview image: <https://bit.ly/2SANCj7>
- Type of resource: Video
- Resource: <https://youtu.be/lcpwqUcGFx8>

Search by repository the term "Clonmacnoise". Find the submitted object and visualize it.

What is the name of the river closest to the submitted object? \*

Shannon

ANTERIOR SEGUINTE

Página 17 de 22

\*Obrigatório

### Content Submission - Task 13

Submit to the platform an object with the following properties:

- Title: Sintra Documentary
- Creator: RTP2
- Description: Documentário sobre Sintra 'A Terra e a Gente' - apresentado por José Hermano Saraiva Emitido pela RTP 2 em 17-07-2010
- Date: 17-07-2010
- Location: Sintra
- Latitude: Your location ( Use the proper feature )
- Longitude: Your location ( Use the proper feature )
- Preview image: <https://bit.ly/2UdnkuY>
- Type of resource: Video
- Resource: <https://youtu.be/8-LpRxFFLAc>

Next, search by personal objects all of the submitted objects. View the submitted video.

What is the length of the video associated to the submitted object? \*

24:58

ANTERIOR SEGUINTE

Página 18 de 22

Nunca envie palavras-passe através dos Formulários do Google.



## Representing and Indexing Archaeological Information

\*Obrigatório

### Content Submission - Task 14

Submit to the platform an object with the following properties:

- Title: Azulejo do Palácio da Pena
- Creator: Carlos Faustino
- Description: Sintra's National Palace Tiles @ the historical centre of Sintra, Portugal
- Date: 09-01-2017
- Location: Sintra
- Latitude: Estrada da Pena,2710 Sintra, Portugal ( Use the proper feature )
- Longitude: Estrada da Pena,2710 Sintra, Portugal ( Use the proper feature )
- Preview image: <https://bit.ly/2ECZFyN>
- Type of resource: 3D Model
- Resource: <https://skfb.ly/6sHwO>

Next, search by personal objects, with the term 'Sintra'.  
Interact with the submitted 3D model.

How many column tiles does the 3D model have? \*

5

ANTERIOR SEGUINTE

Página 19 de 22



## EVALUATION QUESTIONNAIRE

### Representing and Indexing Archaeological Information

**System Usability Scale (SUS)**

Please check the box that represents your immediate response to each statement. Don't think too long about each statement. Make sure you respond to every statement. If you don't know how to respond, simply check box '3'.

**I think that I would like to use this system frequently.**

	1	2	3	4	5	
Strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly agree

**I found the system unnecessarily complex.**

	1	2	3	4	5	
Strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly agree

**I thought the system was easy to use.**

	1	2	3	4	5	
Strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly agree

**I think that I would need the support of a technical person to be able to use this system.**

	1	2	3	4	5	
Strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly agree

## APPENDIX B. EVALUATION QUESTIONNAIRE

I found the various functions in this system were well integrated.

1 2 3 4 5

Strongly disagree      Strongly agree

I thought there was too much inconsistency in this system.

1 2 3 4 5

Strongly disagree      Strongly agree

I would imagine that most people would learn to use this system very quickly.

1 2 3 4 5

Strongly disagree      Strongly agree

I found the system very cumbersome to use.

1 2 3 4 5

Strongly disagree      Strongly agree

I felt very confident using the system.

1 2 3 4 5

Strongly disagree      Strongly agree

I needed to learn a lot of things before I could get going with this system.

1 2 3 4 5

Strongly disagree      Strongly agree

### Representing and Indexing Archaeological Information

\*Obrigatório

#### Evaluation

This section aims to evaluate the application according to the tasks performed. Read the statements carefully.

#### Map and Interface

It is easy to search for the desired objects

1 2 3 4 5

Strongly disagree      Strongly agree

It is hard to find a specific georeferenced object.

1 2 3 4 5

Strongly disagree      Strongly agree

It is easy to find a specific non georeferenced object.

1 2 3 4 5

Strongly disagree      Strongly agree

It is hard to manage the object search lists.

1 2 3 4 5

Strongly disagree      Strongly agree

It is easy to navigate on the map.

1 2 3 4 5

Strongly disagree      Strongly agree

It is hard to find related objects.

1 2 3 4 5

Strongly disagree      Strongly agree

It is easy to inspect objects on the map.

1 2 3 4 5

Strongly disagree      Strongly agree

It is hard to search by location.

1 2 3 4 5

Strongly disagree      Strongly agree

The object categorization is useful.

1 2 3 4 5

Strongly disagree      Strongly agree

The preview window is not useful.

1 2 3 4 5

Strongly disagree      Strongly agree

**Property Window**

The property window is not useful.

1 2 3 4 5

Strongly disagree      Strongly agree

**Multiple Visualizations and Context**

It is easy to navigate in the Explore window.

1 2 3 4 5

Strongly disagree      Strongly agree

The Explore window is suitable for learning and exploration of the context of an object.

1 2 3 4 5

Strongly disagree      Strongly agree

**Content Submission**

It is easy to submit an object.

1 2 3 4 5

Strongly disagree      Strongly agree

It is hard to find a submitted object.

1 2 3 4 5

Strongly disagree      Strongly agree

## APPENDIX B. EVALUATION QUESTIONNAIRE

It is useful to submit objects to the platform.

1 2 3 4 5

Strongly disagree      Strongly agree

**Overall Evaluation**

The final goals for this dissertation project are:

- Promote the interest and respect for history and cultural heritage, sharing in an accessible way digital representations of historical/archaeological/cultural objects present in online repositories.
- Raise awareness on non expert users of the cultural area about the historical and knowledge importance of cultural objects, in order to promote the participation in their preservations and documentation.

Relatively to the mentioned goals, evaluate the application, given your recent experience:

I consider that the application is useful to generate interest and respect for history and cultural heritage.

1 2 3 4 5

Strongly disagree      Strongly agree

I consider that the application is useful to raise awareness about the preservation of cultural objects and encourage the participation of users in this process.

1 2 3 4 5

Strongly disagree      Strongly agree

Did you feel any difficulty using the application. \*

Yes

No

I consider that the application is useful to raise awareness about the preservation of cultural objects and encourage the participation of users in this process.

1 2 3 4 5

Strongly disagree      Strongly agree

Did you feel any difficulty using the application. \*

Yes

No

If you answered Yes to the above question, explain the encountered difficulties.

A sua resposta

Suggestions for improving the application.

A sua resposta

What is your education/professional area of expertise? \*

Computer Science

History and Culture

Other

ANTERIOR SEGUINTE

Página 21 de 22

Nunca envie palavras-passe através dos Formulários do Google.

\*Obrigatório

### Cultural and Historic Questions

Do you commonly use informatic applications in your workspace? If your answer is Yes, list them. \*

A sua resposta

Do you consider that the applications you use satisfy the necessary goals for you work to be practiced the best way it can? Explain your goals and flaws you have to mention. \*

A sua resposta

For the application you just used, do you consider that the navigation using the map and side menu are usefull? \*

A sua resposta

For the application you just used, do you consider that the categorization and the chosen icons for each type of object make sense? \*

A sua resposta

For the application you just used, do you consider that the available information for each object is presented usefully? \*

A sua resposta

For the application you just used, do you consider that the visualization in the Explore window is enough to provide context to an object? \*

A sua resposta

Do you consider this application might be useful to raise awareness and motivate other for your work/education area? \*

A sua resposta

Do you consider this application might be useful for your work/education area? \*

A sua resposta

Página 22 de 22

ANTERIOR

SUBMETER

Nunca envie palavras-passe através dos Formulários do Google.





## USERS PROFILE

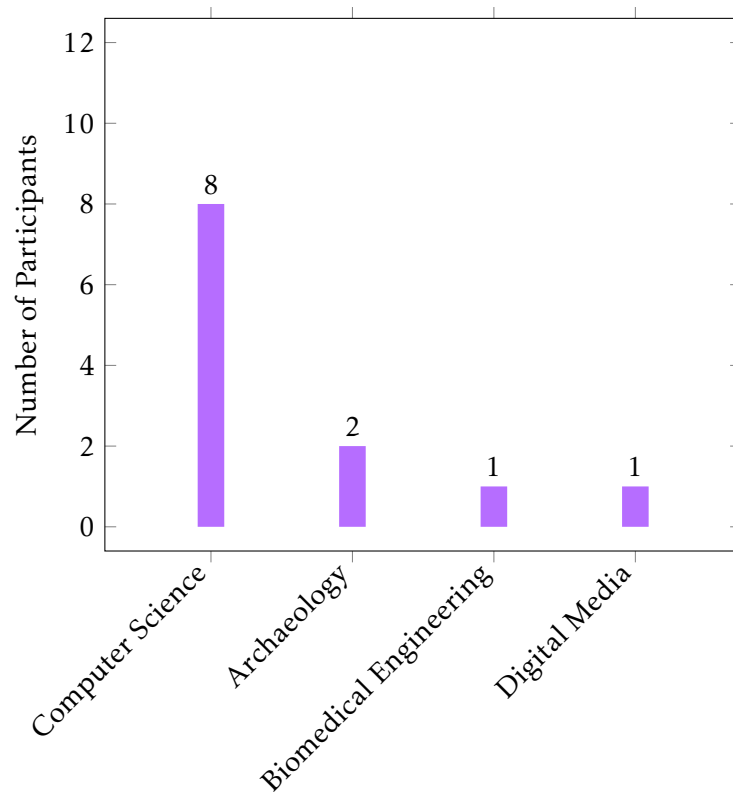


Figure C.1: Users background.

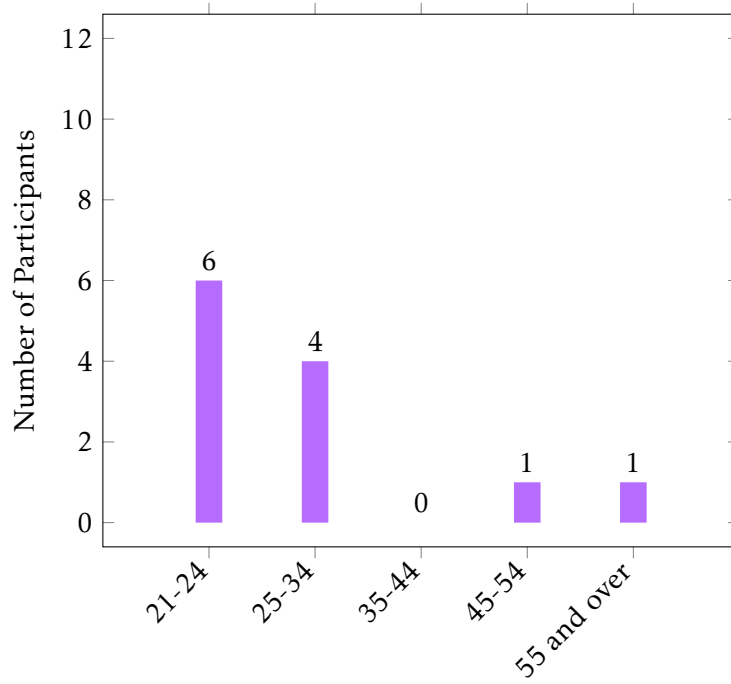


Figure C.2: Users age.

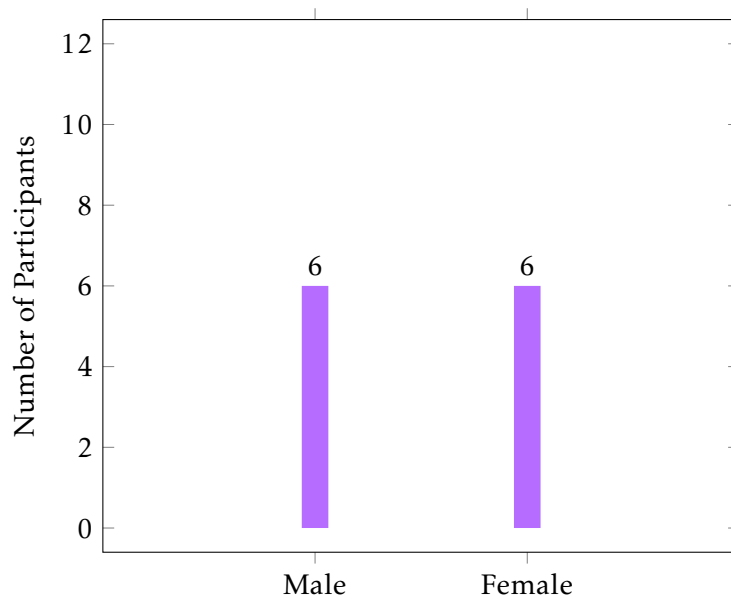


Figure C.3: Users gender.

ANNEX I

SCREENSHOTS

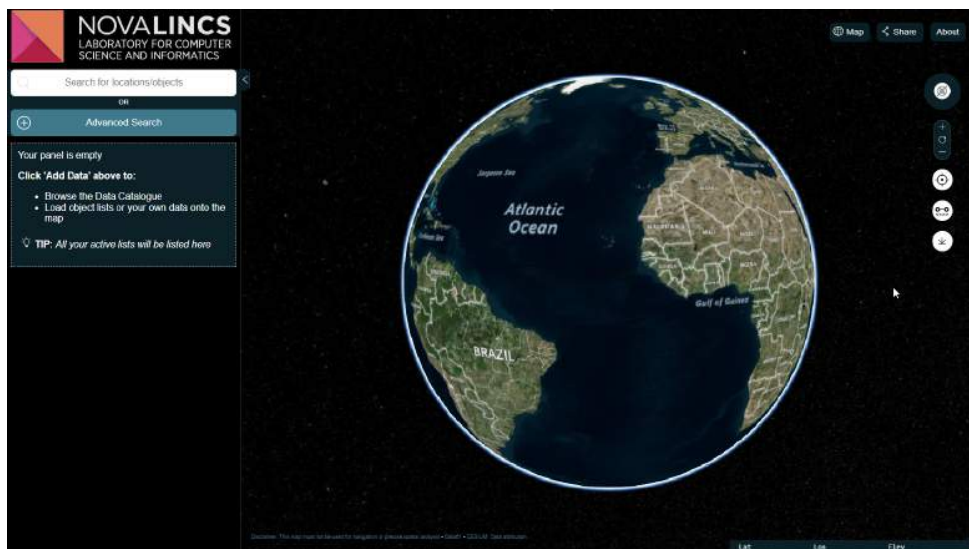


Figure I.1: First view of the web application

## ANNEX I. SCREENSHOTS

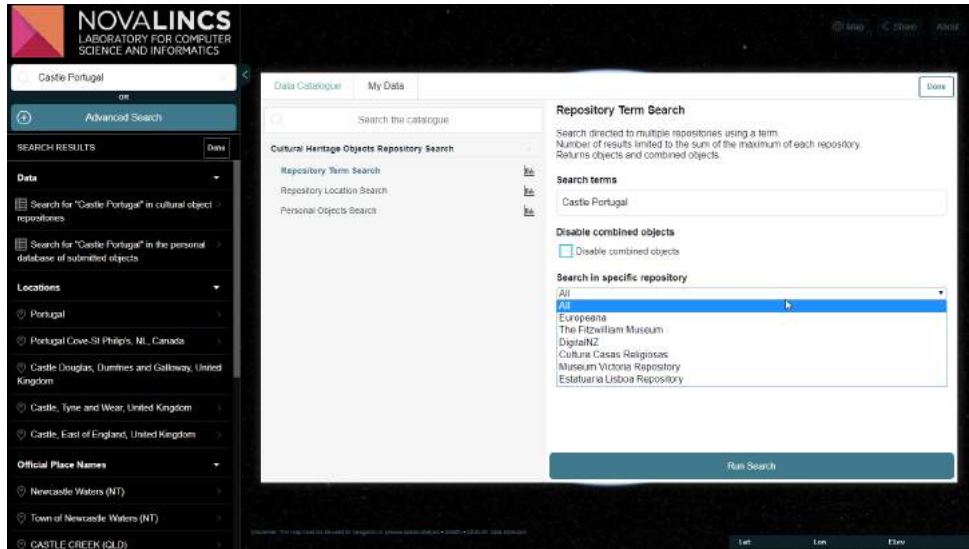


Figure I.2: Search by term interface

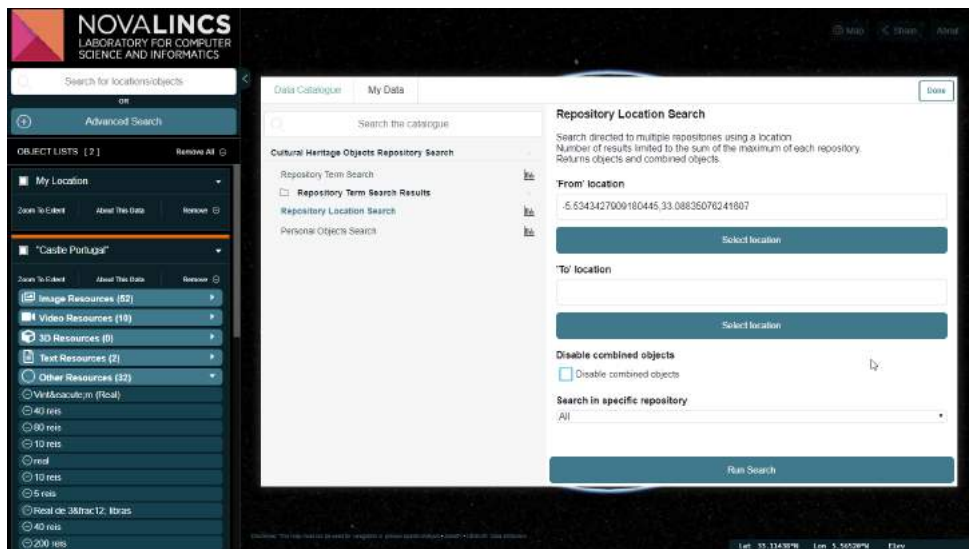


Figure I.3: Search by location interface



Figure I.4: Categorization icons on left panel and map

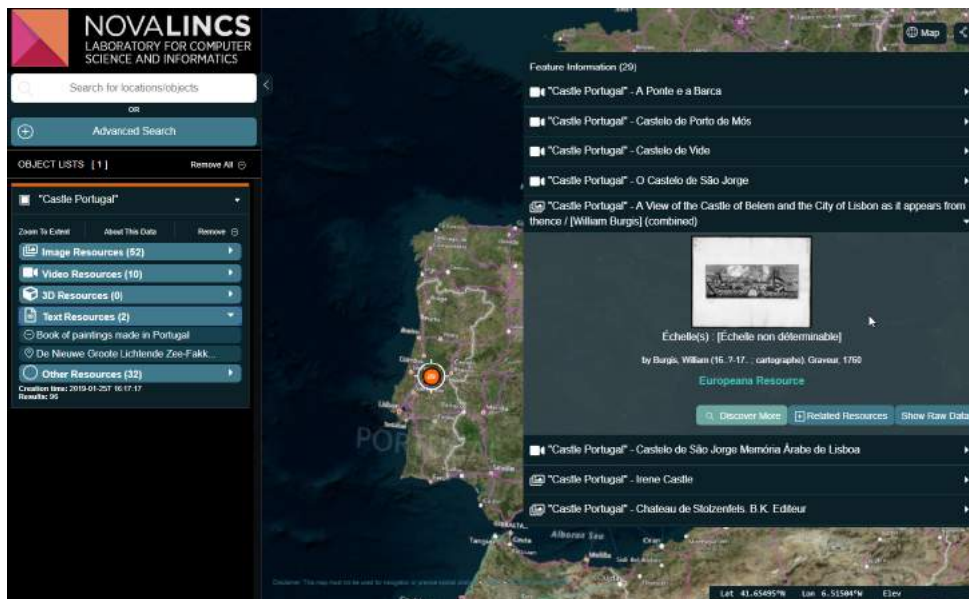


Figure I.5: Categorization icons on left panel and preview window



Figure I.6: Use of the navigation tools to create a different view of the globe. The position of the user, object icons and a cluster of objects are also present

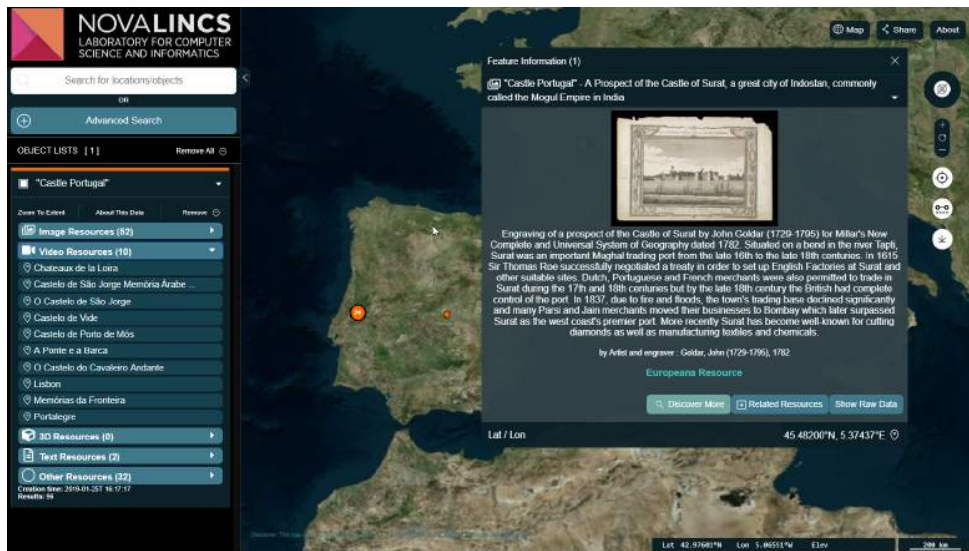


Figure I.7: Related resources button in preview window

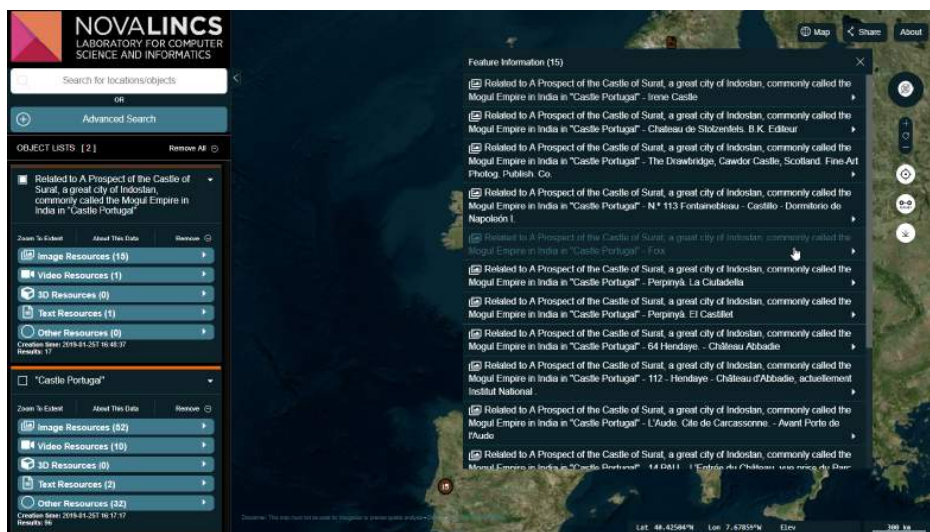


Figure I.8: Related results in a new list

## ANNEX I. SCREENSHOTS

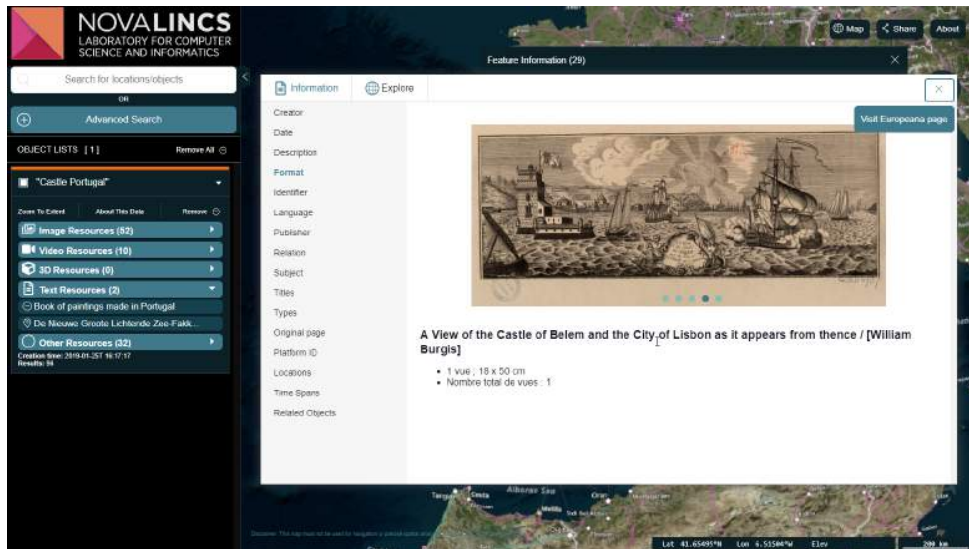


Figure I.9: Showing object properties and the associated image resources in a slideshow

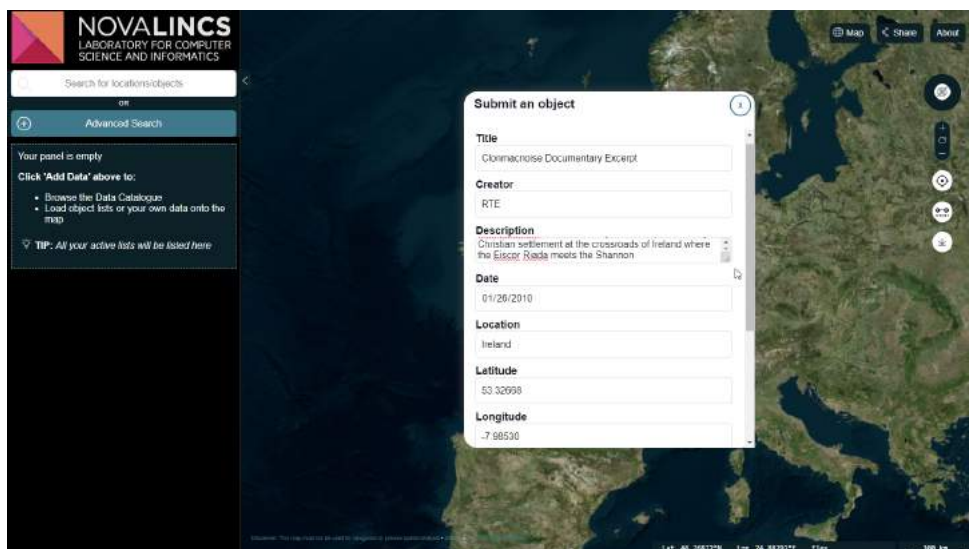


Figure I.10: Filling the submission form



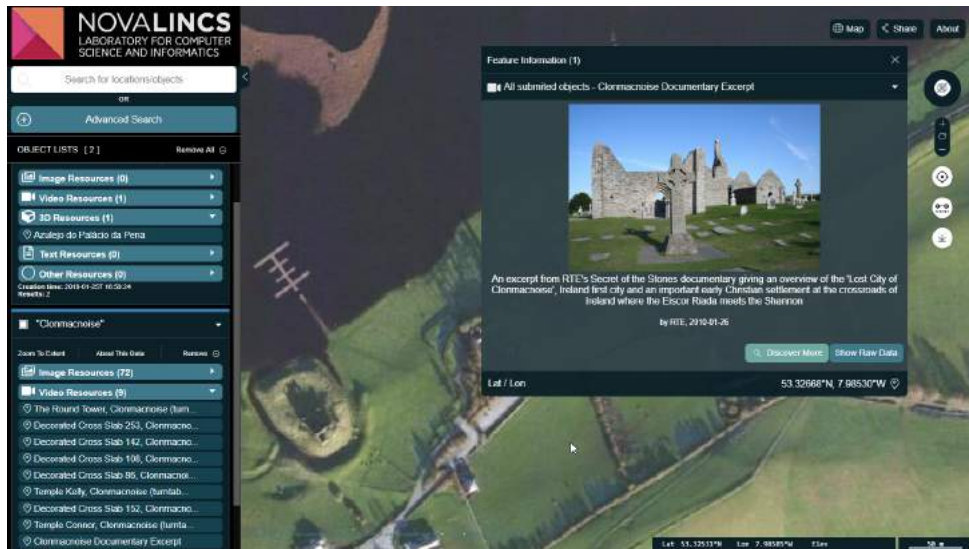


Figure I.11: Submission form and submitted object list

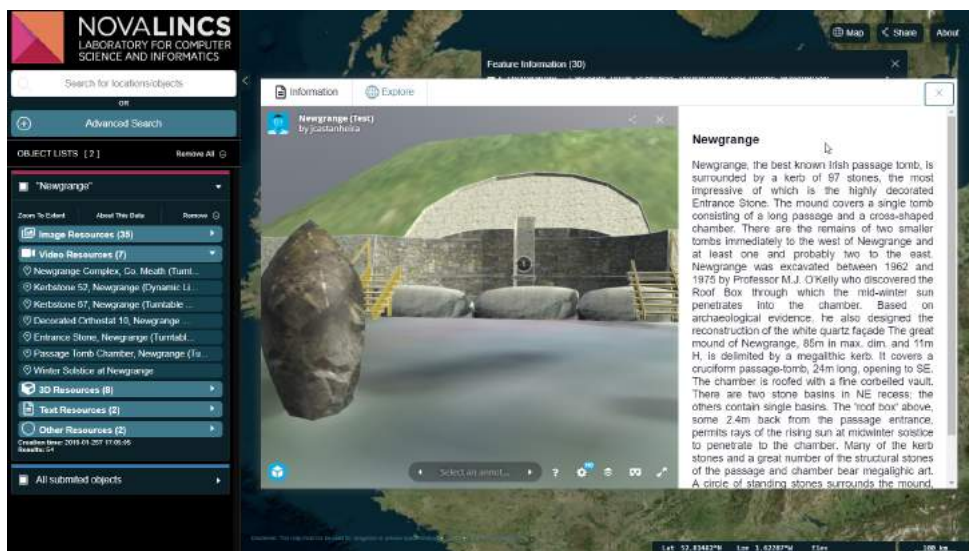


Figure I.12: First view of the window showing a description of the archaeological site

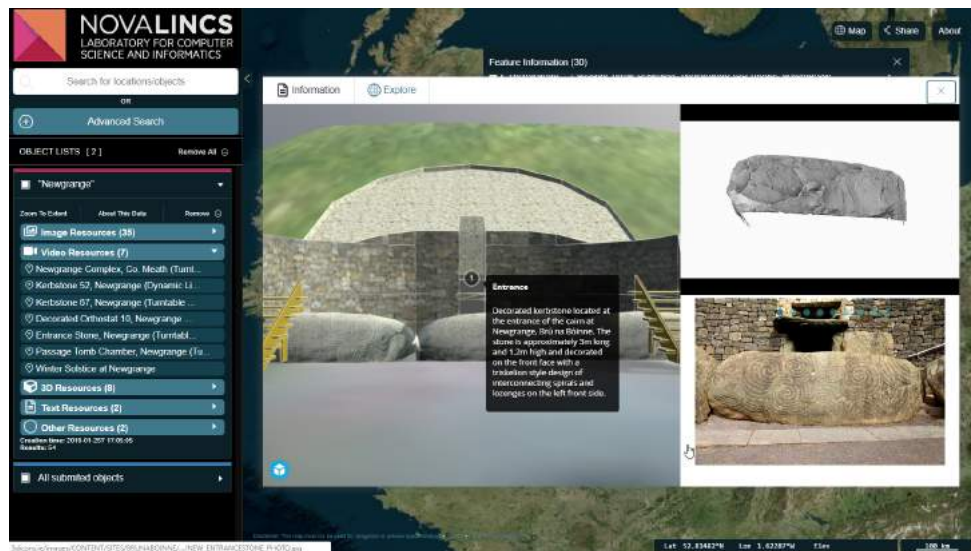


Figure I.13: Focus on point of interest showing a video and images belonging to that part of the site