NOVA SCHOOL OF
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DEPARTMENT OF
COMPUTER SCIENCE

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Bachelor in Computer Science and Engineering

VIRTUAL RESEARCH ENVIRONMENT FOR THE ROSSIO INFRASTRUCTURE

MASTER IN COMPUTER SCIENCE

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Abstract

Intuitive workspaces are crucial to the productivity of any researcher. In the field of Humanities, researchers usually need to deal with different formats of metadata, often coming from different sources. This is a serious drawback since it makes research a lot more demanding and time consuming. Therefore, shielding the user from this layer of complexity by presenting the data in a user-friendly and accessible interface is of great relevance. Moreover, the exchange of information and resources between researchers is an important aspect regarding the evolution of their work, making it ideal to provide them with a system where they can engage in collaborative activities.

ROSSIO is an infrastructure that aims to be a meeting point where researchers have free and intuitive access to diverse digital contents in the areas of Social Sciences, Arts, and Humanities. For instance, this can be accomplished through the creation of a Virtual Research Environment (VRE). To that end, the goal of this dissertation is to develop a VRE that overcomes the mentioned challenges. Once the VRE is developed, researchers will have access to a number of functionalities that facilitate their workflow and research activities.

Keywords: Virtual Research Environment, Metadata, Collaborative Investigation, Humanities

Resumo

Um ambiente de trabalho e intuitivo é crucial para a produtividade de qualquer investigador. Na área de Humanidades, os investigadores costumam lidar com diferentes formatos de metadados, muitas vezes provenientes de diferentes fontes. Isto é um grande inconveniente, uma vez que torna a investigação muito mais exigente e demorada. Por conseguinte, proteger o utilizador desta camada de complexidade, apresentando os dados numa interface intuitiva e acessível, é bastante vantajoso. Para além disso, a troca de informações e recursos entre investigadores é um aspeto importante no que diz respeito à evolução do seu trabalho, fazendo com que seja ideal fornecer-lhes um sistema onde se possam envolver em atividades de colaboração.

O ROSSIO é uma infraestrutura que pretende ser um ponto de encontro onde os investigadores têm acesso aberto e intuitivo a diversos conteúdos digitais nas áreas das Ciências Sociais, Artes, e Humanidades, e uma das suas iniciativas é a criação de um Ambiente Virtual de Investigação (AVI). Para o efeito, o objetivo desta dissertação é desenvolver um AVI que supere os desafios mencionados. Uma vez desenvolvido o AVI, os investigadores terão acesso a uma variedade de funcionalidades que facilitam o seu fluxo de trabalho e as suas atividades de investigação.

Palavras-chave: Ambiente Virtual de Investigação, Metadados, Investigação colaborativa, Humanidades

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Introduction

A Virtual Research Environment (VRE) is a web-based working environment with the goal of serving the necessities of a specific community. These environments are the most useful for people like researchers, that can rely on VREs for researching, sharing, and working with resources, as well as collaborating, and keeping personal annotations in an easy to navigate and intuitive UI. For all these tasks to be possible, the implementation of a VRE must be user-centered, secure, and flexible, supporting different data types for all kinds of resources.

1.1 Motivation

Virtual Research Environments are challenging platforms to develop because they are the highest level of a complex architecture that relies on already existing systems and/or resources made from scratch. Managing interoperability between these resources, which may range from data sets, collections, storage facilities, and computing power to services realising specific utilities and research objects [5], is one of the big challenges of a VRE. Besides management, it is also very demanding to optimize the interaction between these components in order to develop a highly functional and consistent system. Sustainability is another major challenge faced by VRE development, and one that is very hard to overcome without the economical means, making it ideal to develop self-sustainable business models.

A functional and secure environment is key to the productivity of a researcher. A VRE provides researchers with a set of tools that combined form a help service and a workspace where they can collaboratively produce content with restricted access. Functionalities like researching digital content, visualizing and selecting metadata, putting digital resources on a favorites list, adding annotations to these resources, and collaborating with other researchers would be expected from this system. Despite the system's technological density, VREs should be developed focusing primarily on using technology to implement workflows and processes rather than having technology invading the scenario and distracting effort from its real needs [5].

1.2 Context

The project to be developed will be integrated into ROSSIO, an infrastructure that aims to be a meeting point where researchers, professors, students, and citizens have free and intuitive access to unique and diverse digital contents in the areas of Social Sciences, Arts, and Humanities in the Portuguese language. Its main goal is to aggregate, organize, enrich, and spread digital resources coming from research activities, repositories, archives, libraries, art collections, and databases from several referenced institutions. ROSSIO is composed of a consortium, coordinated by Faculdade de Ciências Sociais e Humanas da Universidade Nova de Lisboa, from which it is highlighted the Division of Libraries and Documentation, and the Investigation Unities, that counts with partners like Câmara Municipal de Lisboa, Cinemateca Portuguesa – Museu do Cinema, Direção-Geral do Livro, dos Arquivos e das Bibliotecas, Direção-Geral do Património Cultural, Fundação Calouste Gulbenkian and Teatro D. Maria II [12].

The resources provided by these partners are handled by ROSSIO's data management subsystem. This subsystem acquires and stores datasets, prepares the data for processing, manages the datasets life cycle and makes datasets available for other systems from ROSSIO's infrastructure. Its architecture is composed by several complementary applications, and the one responsible for collecting the datasets provided by external entities is the Harvesting and Ingestion Application. This application also store the datasets in the Internal Repository, indexes them in the Search Engine and publishes them on DSpace. The resources collected by this application are the ones that are meant be used and manipulated by researchers through the Virtual Research Environment.

1.3 Objectives

The goal of this project is to create a Virtual Research Environment incorporated in ROSSIO's infrastructure. In this environment, a researcher should have access to a number of functionalities that facilitate the workflow and research activities. These functionalities include researching, having a list of favorites, managing the work environment, adding annotations, writing on a text editor, and collaborating with colleagues.

Researchers will have access to advanced search on all kinds of resources of which they can take notes and organize in their workspace. Besides that, researchers will be able to organize their work by creating and managing folders that can be erased and altered by their owner. The researchers will also have the possibility of saving resources that they can later access or work on.

When organizing resources in their workspace, researchers will have the possibility of making annotations to describe their progress or personal answers about a certain item. This can also be done independently of a resource, in a space where important information, in general, can be kept and edited, with access to a text editor where they can write freely.

On top of that, a researcher will be able to collaborate with with colleagues, by sharing personal notes a favorite digital resources, and commenting on the ones that were shared with him.

1.4 Expected Contributions

With the work developed in this dissertation, the following contributions were provided:

- Creation of a Virtual Research Environment for ROSSIO;
- Design and evaluation of an intuitive UI, shielded from the system's complexity;
- Development of a helpful workspace for researchers;

1.5 Document Structure

This document is divided in six chapters:

- **Introduction** - The first chapter is composed of the Motivation for the dissertation's development, the Context of the project, the Objectives and the Expected Contributions;
- **Related Work** - Throughout this chapter, several systems will be explored. In each section, the way these systems implement or handle the challenges raised by their Architecture or Data Management will be studied. In the end of the chapter, a discussion about what can be taken from this segment will be made;
- **Specification** - This chapter has the purpose of contextualizing the developed project by explaining ROSSIO's role and requirements, and also specifying the system's functionalities.
- **Implementation** - The Implementation chapter describes the application's development course, by stating the technologies used and explaining the thought process and logic behind the evolution of its three main components: backend, frontend, and security layer.
- **Evaluation** - This chapter explains the methodology with which the application was evaluated, and presents an analysis of the obtained results, as well as the application's limitations and proposed changes.

- **Conclusions and Future Work** - The last chapter resumes the document with a conclusion, and a reflection on the future work that can be pursued concerning the developed system.

2

Related Work

In this chapter, several systems with similar goals to the developed project will be analyzed. The chapter is divided in three sections, where the first two, System Architecture and Data Management, represent either the most relevant quality of the systems that will be analyzed or a challenge that these systems are trying to overcome, and the last one is a discussion about this chapter that leads to the content of the Specification and Implementation of the VRE.

2.1 System Architecture

When developing a Virtual Research Environment, one should look for ways to promote a highly maintainable and testable application. These are qualities present on the architecture of the systems analyzed in this chapter, which were also a goal for the developed VRE. These system architectures overcome the problems of maintainability and sustainability faced by many VREs, while also improving fault isolation, preventing the whole system from being compromised by a single fault in one specific service. [15].

2.1.1 SnowVision Science Gateway

Developing a Virtual Research Environment with the main purpose of providing researchers with humanities content poses many challenging aspects that have to be taken into consideration, like processing data in different formats, handling constant access to the platform, and providing a secure environment. Just like VREs, Science Gateways provide access to a large range of computing and data resources, thus enabling science communities to effectively utilize them. They allow users to see and manipulate the resources without exhibiting the underlying complexity of the system.

SnowVision is a science gateway deployed on XSEDE's Jetstream academic clouding computing resource that enables individuals and institutions to upload and store sherd images, matching them to original stamped designs from which their fragments descend through machine-learning algorithms. This subsection was based on [24].

Before SnowVision was developed, there were hundreds of thousands of pottery sherds that researchers could not make sense of. In 2020, they had already digitized more than 4000 sherds and reconstructed 900 hundred designs that were added to their collection. With such increasing numbers and the fact that Science Gateways usually have a monolithic architecture, scientific packages for data capture and pipeline processing, which are usually single-threaded, can create traffic bottlenecks when processing many requests. SnowVision fights these challenges through a modular architecture:

UI Frontend service	Angular
API backend service	Java Play platform
Authentication service	Auth0
Middleware service	Apache Airavata

Table 2.1: SnowVision Architecture.

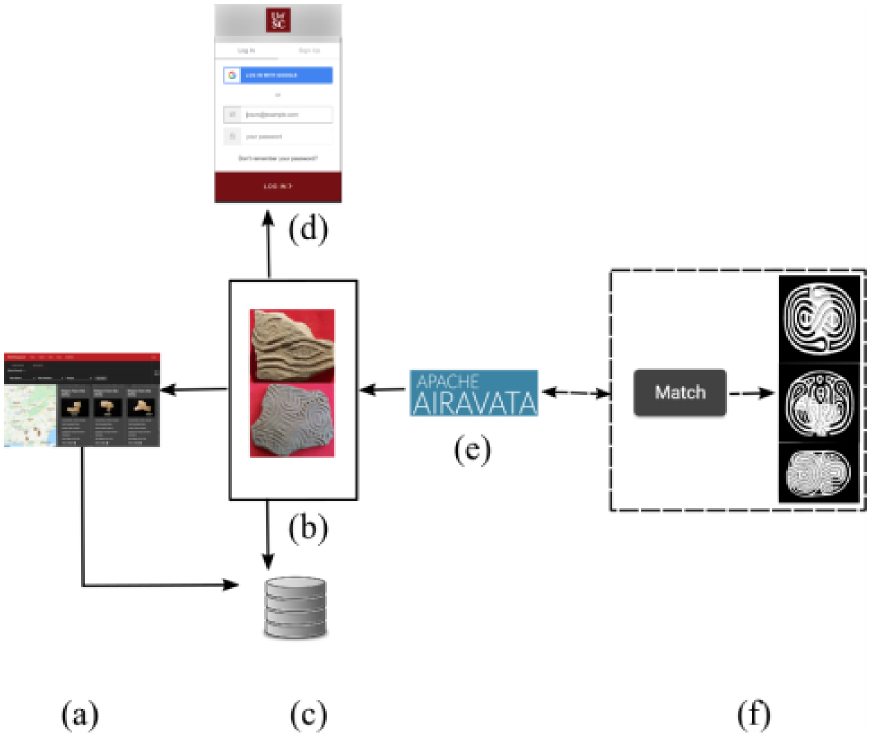

Figure 2.1: SnowVision Architecture [24].

The main qualities that can be highlighted from SnowVision's architecture are related to the type of approach that should be used when developing a VRE, and can be found on their UI Frontend and API backend services. Similarly to what would be expected from a

VRE, the SnowVision website allows users to query pottery sherds and design collections. Besides that, users can have an account on this website where they can manage their own collection of sherds, and add unidentified new ones for the matching service to connect with the corresponding designs. This UI was developed using Angular, which eliminates the need for redundant code and allows the interface to be developed separately from the backend service, avoiding that modules interfere with each other.

When it comes to the API service, Java Play Frameworks facilitates the creation of highly scalable web applications, which is considered something to look for in a VRE. The pattern used by the Play Framework handles request asynchronously using non-blocking operations, and can quickly scale a small fixed thread pool. This feature makes it possible for multiple users to make requests simultaneously and not have to wait for each others operations to complete.

2.1.2 EVI-LINHD

Entorno Virtual de Investigación del Laboratorio de Innovación en Humanidades Digitales (EVI-LINHD) is a virtual research environment developed by Laboratorio de Innovación en Humanidades Digitales devoted to Spanish speakers interested in digital scholarly edition, especially designed for non-experienced researchers and students. This subsection was based on [10].

In EVI-LINHD, users can create three types of projects:

- Digital Scholary Editions in XML-TEI with TEIscribe, which is a Web-based application implemented with Vaadin, combined with an eXistdb solution published through a TEIPublisher platform;
- Digital Libraries with Omeka;
- Plain Web sites using Wordpress.

Through the creation of a metadata profile based on Dublin Core, this Virtual Research Environment allows projects to deposit and share their metadata in a LINDAT/Common Language Resources and Technology Infrastructure (CLARIN) repository.

EVI-LINHD is hosted in an Ubuntu Linux Server with the classical LAMP configuration. **LAMP installations** (Linux + Apache + MySQL + PHP/Perl/Python) are a popular setup for Ubuntu servers, which have the advantage of being substantially flexible for different databases, web servers, and scripting languages. EVI-LINHD development was based on a model–view– controller software design pattern paradigm.

EVI-LINHD faced two major challenges in its development:

- The first one was how to let the users without technical expertise run their projects with no need to configure them. This is because depending on the project the users demands, a different deployment is made, where either a new instance is created (for Omeka or Wordpress) or a service is reused and shared (for the TEIscribe scenario). An administrator examines the users demand and with a single click deploys the project in EVI-LINHD. This is possible thanks to a set of scripts in Python that take care of the installation and configuration of every project, making it unnecessary to have any kind of interaction between the user and the administrator.

- The second challenge was to connect the authentication system of every project in a Single Sign-on process. **Single Sign-on** (SSO) occurs when a user logs in to one application and is then signed in to other applications automatically, which is possible through the use of sessions. The system handled this by providing different solutions, like JSON Web Token and cookies, and hooking them to the different software pieces.

Client side	Silex and Twig
Server side	LAMP Configuration
	Ubuntu Linux Server
	PHP, Python
	Database (eXistdb and MySQL)
Authentication	JWT, Cookies and SSO

Table 2.2: EVI-LINHD Architecture.

Lastly, EVI-LINHD interface has a minimalist design that promotes usability, accessibility, and navigability, focusing its pages only on the required elements for each functionality, avoiding the use of excess content that can draw away the user's attention. It aims to guide users to find the desired functionalities without having to speak a certain language, adapting the interface to a multilingual context.

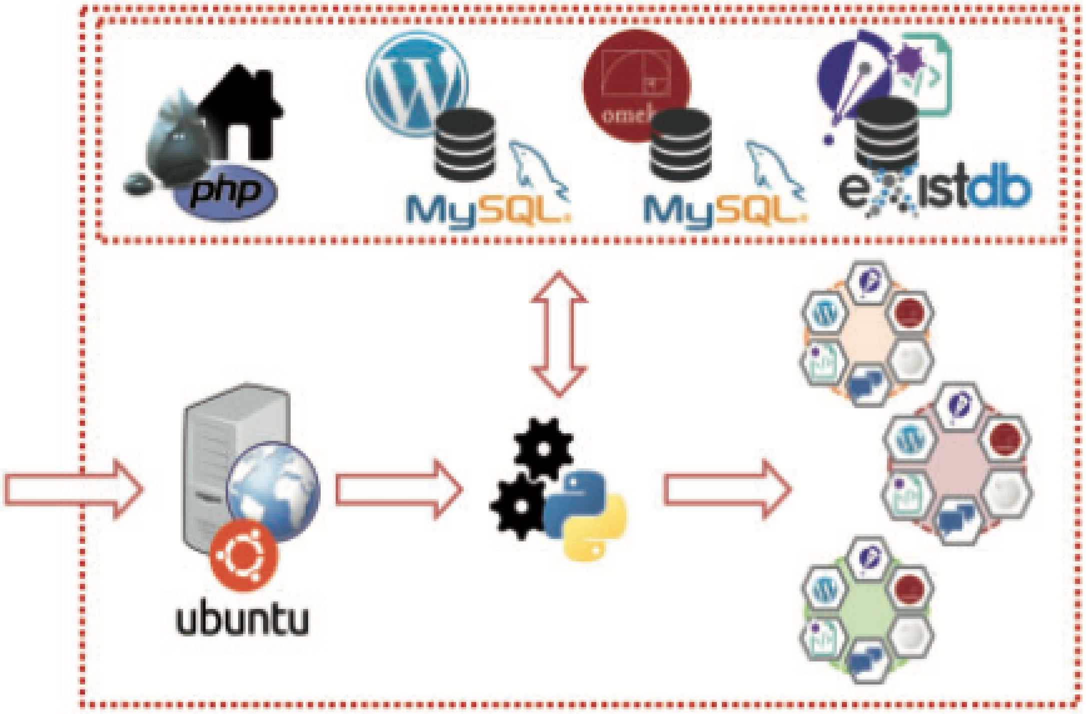

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Figure 2.2: EVI-LINHD's technological infrastructure [10].

2.1.3 heipMAP

heiMAP is a Virtual Research Environment for collaborative spatiotemporal research destined for users interested in numerous disciplines within the Humanities Context, which allows them to collaborate and share data through a web platform. The main characteristic that stands out in heiMAP is its holistic approach, representing the entire scientific data life-cycle, from generation of spatiotemporal data to its publication, archiving and reuse. This subsection was based on [17].

One of heiMAP's main goals is to provide a secure and controlled environment to its user's while also allowing them to share data with each other, just like ROSSIO's VRE. In order to achieve that, heiMAP has fine-grained control of user rights based on the Content Management System (CMS). Therefore, the VRE consists an Open Source CMS for specific project management needs, custom CMS modules for individual groups and an integrated WebGIS application used to contextualize vector and raster data, especially maps. The platform intends to provide resources for users with different degrees of expertise in spatial research and GIS, as well as the possibility to export research data into desktop-base GIS programs.

The heiMAP platform is a distributed application based on the client-server model, structured around different modules and connected to external databases. heiMAP is based on Drupal CMS because allows users to publish, edit or remove data, while also providing high flexibility for customization and having a modular structure. Within heiMAP's platform data can either be managed by private or public projects. Any user can access public datasets, but in the case of private projects, there is a project manager that assigns roles and writes to specific users, making them project members and giving them access to the data related to private projects. Any content and settings related to a private project are stored in a PostgreSQL database. When it comes to the long-term archiving of data, this is assured by the pan-institutional repository heiDATA, a service developed by the Computing Center of the Heidelberg University that ensures the publication of research data by assigning a Digital Object Identifier.

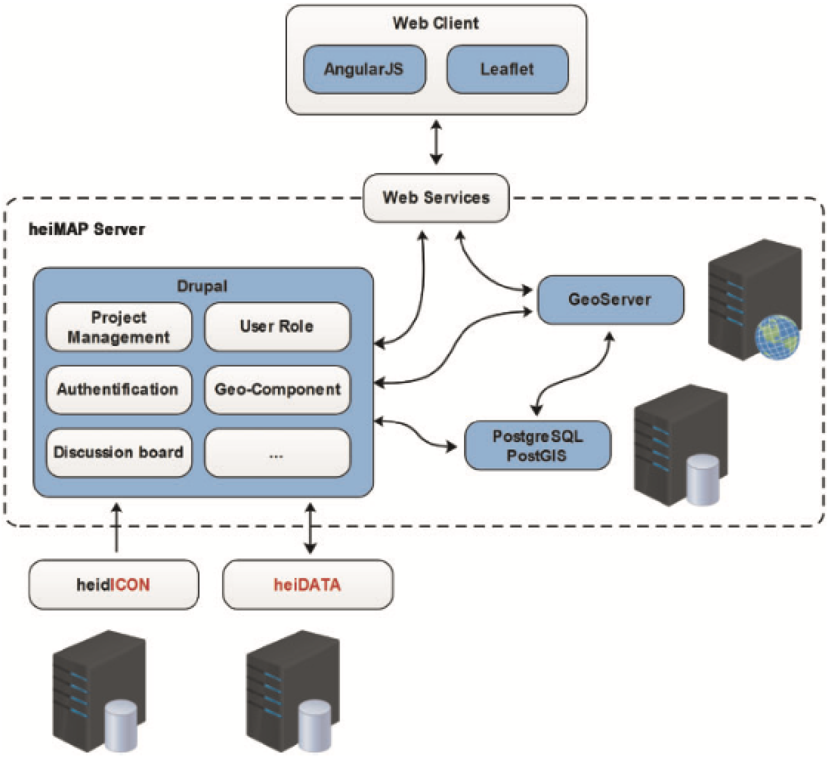


Figure 2.3: e-VRE metadata acquisition and retrieval workflow [17].

heiMAP was developed taking into account multiple challenges related to VREs for spatial Humanities, aiming to address them:

- **Collaborative research in a project-based environment** (project management) - heiMAP's main goal is to provide collaborative research, connecting scientists with each other, as well as connecting several datasets. In order to facilitate the exchange of data a shared, standardized data model is used;

- **Data sensitivity in a collaborative environment** (roles and rights management) - This challenge is solved by including user and rights management functionalities in each project that give project administrators control over their data;
- **Facing heterogeneous spatiotemporal humanities data - the data model** - As this platform intends to support a large range of spatially and temporally referenced data, to assure interoperability it was decided to base the data model on an international standard. Relying on a standardized data model makes it easier to exchange and reuse data, both within and outside the heiMAP platform;
- **Data imperfection management** - To fight the fact that spatial data in the Humanities context in not always precise, heiMAP includes a discussion board that is directly linked to the WebGIS application where users can comment and discuss on all levels of the research project. Besides that, heiMAP includes version tracking for its vector data, which is useful to see how the community reached a certain result or even when sources offer conflicting information;
- **User centric design** - HeiMAP makes itself user centric by having its WebGIS application focus on elementary vector and raster data management functionalities that cover basic requirements of spatial research, resulting in a intuitive and simple UI, rather that displaying full GIS software that can appear challenging to a most users. Besides that, heiMAP will also focus on useful functionalities in the Humanities context and support their less experienced users, like scholars, with documentation on working within a spatial context.

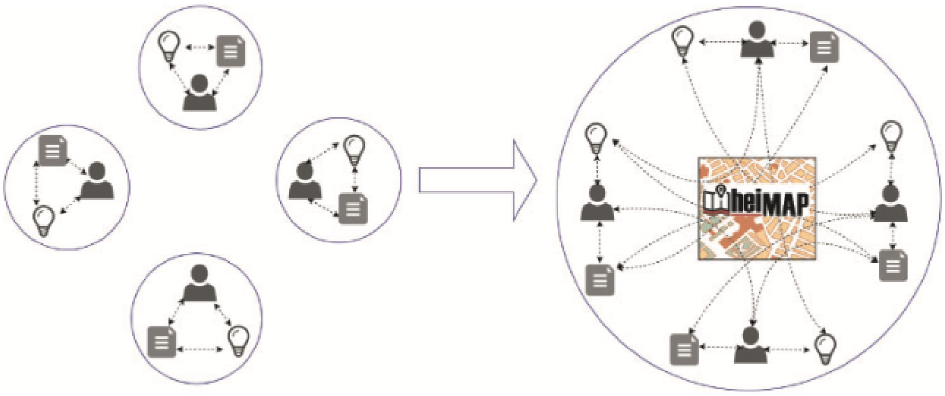


Figure 2.4: heiMAP's collaborative approach [17].

2.1.4 TextGrid

TextGrid is a Virtual Research Environment for researchers in the arts and humanities context, being developed by a research group that consists of a consortium of ten research institutions in Germany. This VRE provides tools and services for the analysis of text data, and support the curation of research data by means of grid technology. This subsection was based on [16].

The TextGrid virtual research environment is composed by two main components:

- **TextGrid Laboratory (TextGridLab)** - serves as an entry point to the virtual research environment that provides common functionalities to intensify data reusability in a sustainable environment;

- **TextGrid Repository (TextGridRep)** - long term data humanities data archive that promotes sustainability, interoperability, and durability.

The **TextGridLab** includes tools for handling metadata, search functionalities, and rights management, a workflow editor, and a set of specialized tools and services that fulfill the researcher's needs. These tools and services, which include an XML editor, a Text-Image-Link editor, a Dictionary Search Tool, a Text Publisher Web, a Note Editor, a Bibliography tool, e.g, enable collaborative research in a distributed, secure, and extensible environment. Research can work with data from their local computer or in the grid, and collaborate with each other through the platform.

The advantage of providing tools for text-based research on a system enriched with a data curation system is that users can save their data in a secure place (the grid storage). Instead of worrying about data curation, users will be able to work on top of services and guidelines for long-term accessibility and sustainability, taking into consideration that these services are continuously updated.

The **TextGridRep** is a grid-based repository infrastructure that ensures sustainability, interoperability, and long-term access by providing a repository infrastructure based on grid technology.

Through role-based access control, implemented on the rights management module, researchers are able to choose who they share their work with. This is handled by the middleware, which consists of several components for handling files in the data grid, rights management, metadata in an XML database, and relations in a Resource Description Framework (RDF) triple store. Due to its modular structure it is easy to integrate external web services. Its layered structure also allows access to the services via other GUIs beyond the Eclipse-based TextGridLab software provided by TextGrid.

2.2 Metadata Management

Handling different formats of metadata is a big part of developing a Virtual Research Environment. Data in the Humanities is often heterogeneous and imperfect, which makes

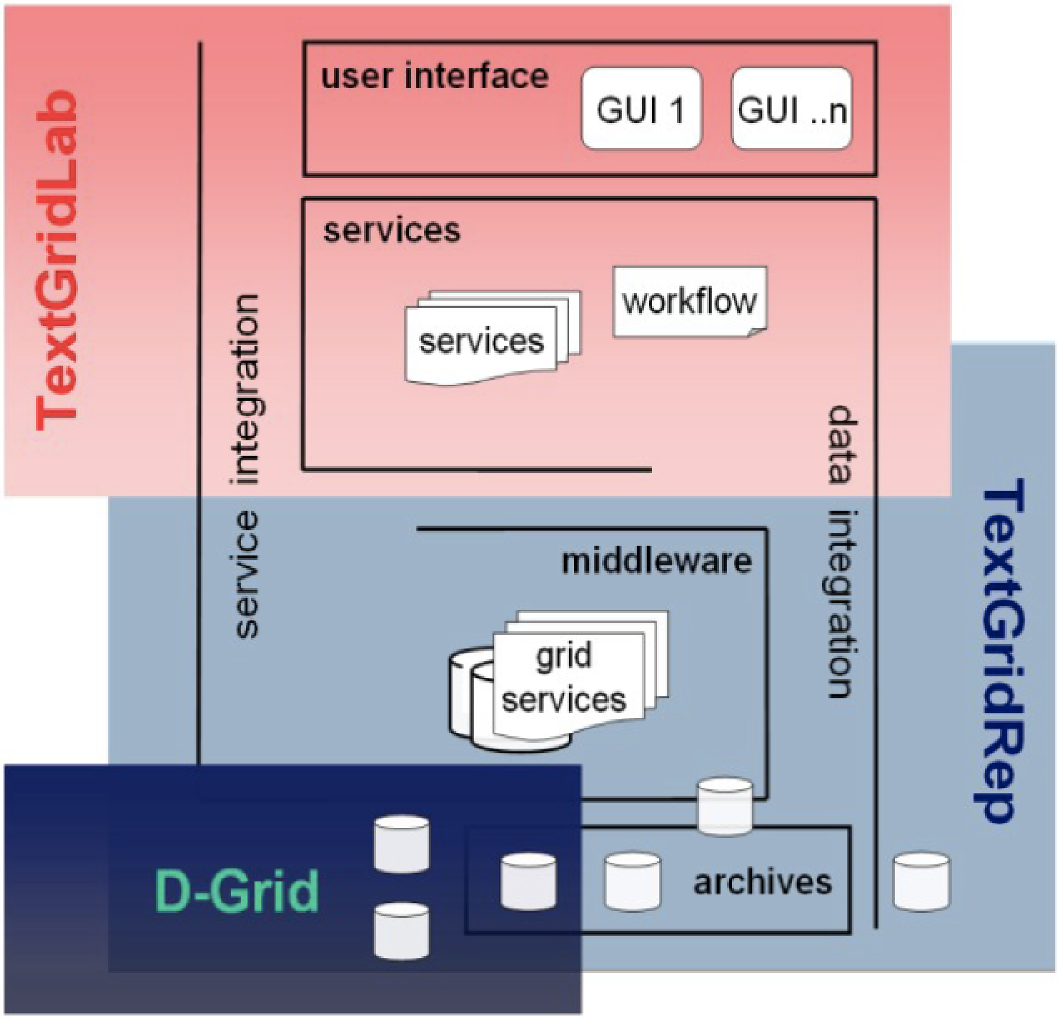


Figure 2.5: TextGrid Infrastructure [16].

organizing metadata a critical task when trying to develop a VRE. In this section, it will be discussed how a VRE4EIC e-VRE NESTOR handle metadata.

2.2.1 VRE4EIC e-VRE metadata service

In the previous section, the e-VRE reference architecture used to develop the VRE4EIC Metadata Portal was described, as well as how it manages the descriptions provided by other Research Infrastructures (RI). In this section, it will be analyzed how the VRE4EIC e-VRE metadata service describes these resources and how it addresses the challenges of cross-RI search. This subsection was based on [14].

As it was mentioned before, this system uses a centralized approach, in which it aggregates data within a single VRE catalogue, after harvesting it from multiple RIs. Searching for a resources in the VRE4EIC portal is done through a composition of queries based on the context of the research data and several filters.

In order to build the VRE catalogue based on heterogeneously data sources, metadata harvested from external sources is converted to CERIF RDF using the X3ML mapping framework. This process is composed by five steps:

- Fetching sample metadata and the corresponding metadata schemes;
- Defining mappings that dictate the transformation of the selected RDF and XML based schemas to CERIF;
- Retrieving metadata in its native format;
- Using the mappings to transform the retrieved data into CERIF format;
- Ingesting the transformed data into the CERIF metadata VRE catalogue.

Once ingested, these data become available to authenticated users of the metadata portal.

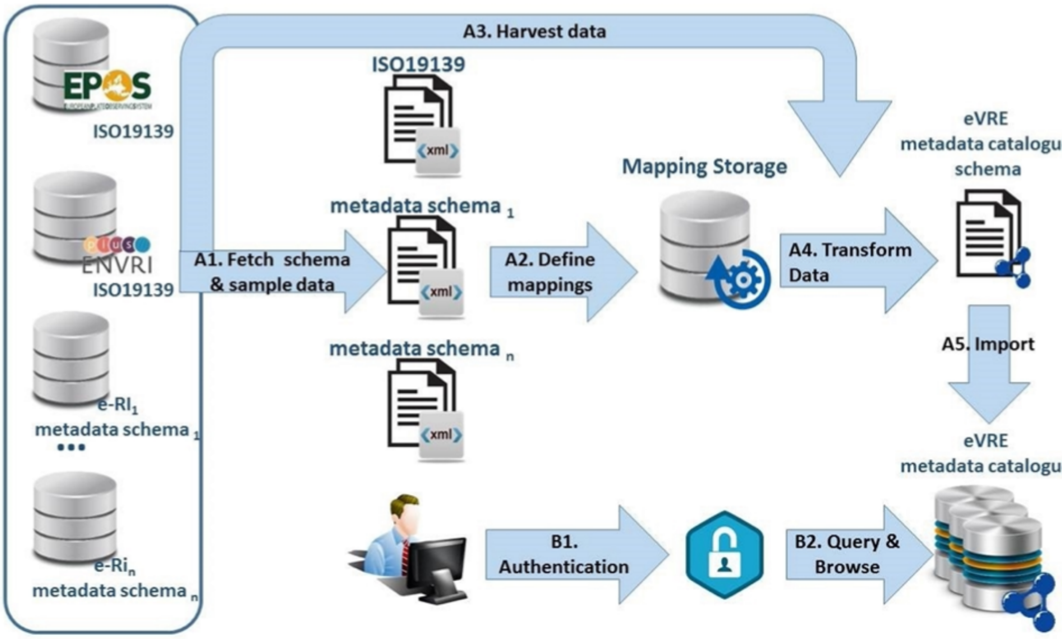


Figure 2.6: e-VRE metadata acquisition and retrieval workflow [14].

2.2.2 NESTOR

Archives are one of the main cultural institutions comprised in Digital Libraries, representing the paths of activities of a physical or legal person along their business. Archives main characteristic is their hierarchical structure, which is used to retain the context of the archival data. This is reflected digitally through the Encoded Archival Description (EAD) in XML format, originated from the traditional hierarchical structure of paper-based archival description - *finding aid*, which plays a major role in managing, finding and accessing archival data. This subsection was based on the work developed on [7].

In the last 10 years, the priorities of Digital Libraries shifted to usability, interoperability and findability of resources thanks to the amount of users accessing these resources. This makes finding aids a worse option since users with navigational interaction patterns need to browse the whole archival hierarchy to understand the archival data. Two common interaction patterns [8] are top-down, where users "start at the highest level, gain background and context, and work down to the most specific level of detail", and bottom-up, where users “start at the most detailed level seeking specific information, and then move back to the higher levels” [7].

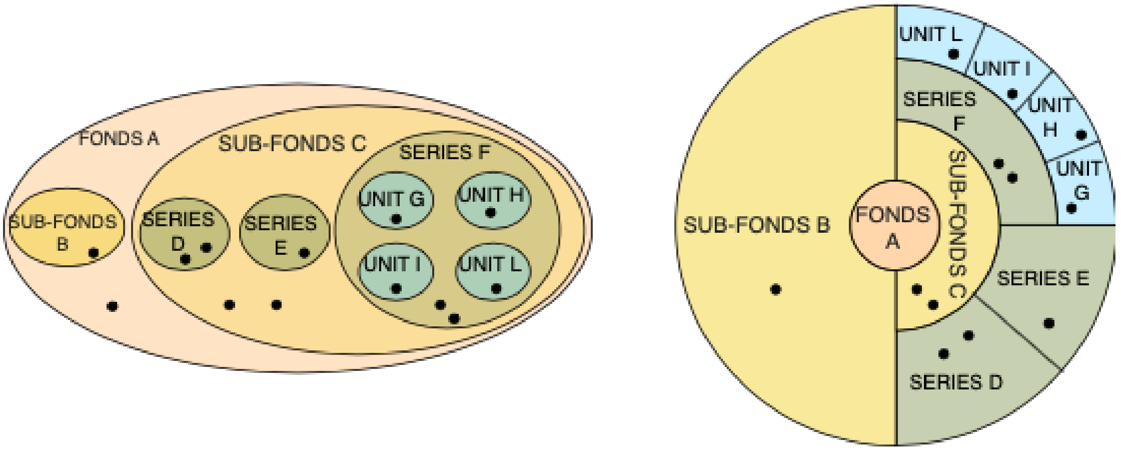
This way, EAD, which is an XML description of the whole archive that reflects its structure, relationships, and context, limits users access to archival data because a lot of operations are slow or inefficient, like quickly accessing a specific item; allowing users to reconstruct the context of an item without having to browse its entire archival hierarchy; or being presented with only a selected item instead of the whole archive to which the item belongs to. Besides that, these limitations also affect the interoperability of archives in a distributed environment, since it is not possible to exchange only a subset of records instead of a whole archive. Lastly, EAD provides archivists with many degrees of freedom in tagging practice exacerbating the differences in how XML elements are used and nested one inside the other, which makes it difficult to know how institutions will use their elements and to define general rules to access EAD elements.

EAD’s main problems:

1. Supporting user-oriented information access;
2. Supporting flexible control access policies;
3. Enabling interoperability between digital archives in distributed environments.

NEsted SeTs for Object hieRarchies (NESTOR) focuses on overcoming the previously mentioned limits by defining an alternative way to represent hierarchical data. It expresses relations between objects through the inclusion property between sets. The NESTOR model by two data models: The Nested Set Model (NS-M) and the Inverse Set Data Model (INS-M). Figure 2.7 show they are related to the archival three.

For NS-M and INS-M data models, each set corresponds to an archival division. The innermost sets are the leaves of the hierarchy and the archival records are represented as elements belonging to the sets. The difference between them is that NS-M adopts a bottom-up approach, where it is possible to create supersets by climbing up the hierarchy,



(a) Euler-Venn representation of the NS-M

(b) DocBall representation of the INS-M

Figure 2.7: NESTOR's data models [7].

while INS-M adopts a top-down approach where the supersets are created by climbing down the hierarchy. Moreover, with the NS-M, an archive is modeled as a collection of subsets where there is a set which contains all the subsets of the archive and where two subsets at the same level cannot have common elements, thus their intersection is empty. In the case of INS-M, an archive is modeled as a collection of sets where there exists an archival division shared by all other divisions. Each of the data models is useful for specific use cases.

The NS-M adopts a bottom-up approach where each set corresponds to an archival division, the innermost sets are the leaves of the hierarchy, and it is possible to create supersets by climbing up the hierarchy.

The INS-M adopts a top-down approach where each set corresponds to an archival division, the innermost sets are the leaves of the hierarchy, and it is possible to create supersets by climbing down the hierarchy. With the INS-M an archive is modeled as a collection of sets where there exists an archival division shared by all other divisions.

The reason why NESTOR surpasses EAD is because it offers users the possibility of selecting and managing archive records independently from other records. Not only can users access and relate records freely, but they are also shielded from the complexity of the archive structure. NESTOR can be instantiated by three data structures, Direct Data Structure (DDS), Inverse Data Structure (IDS) and Hybrid Data Structure (HDS), built around the constraints of NS-M, INS-M, and a mixture of NS-M and INS-M, respectively. The structures are each composed by 3 dictionaries that contain the materialization of the sets, the direct subsets of each set and all the supersets of each set.

2.2.3 The Importance of Interoperability: DPLA

Interoperability plays an essential role in any large-scale project that relies on metadata provided by numerous sources, as it is the ability of multiple systems to exchange data with minimal loss of content and functionality. In this subsection, it will be discussed how the Digital Public Library of America, an infrastructure that has similarities with the one that is being built for ROSSIO, deals with the elementary complexity and interoperability of its system. DPLA provides an interface where numerous digital contents, coming from other libraries and institutions, can be searched. This subsection was based on the work developed on [19].

Building DPLA was not a simple task because it required that each participating institution satisfied a given set of requirements, as well as a determined level of consistency in the underlying metadata. The institutions benefit from this because, although DPLA saves some metadata and full-text to promote retrieval, users have to navigate to the institution's website to access the digital object itself. Still, when providing the resources, metadata must be prepared for the system to ingest it taking interoperability into consideration.

DPLA manages metadata by aggregating content from Content hubs and Service hubs. Content hubs are large institutions, while Service hubs can be a union of smaller institutions, usually geographically organized. The sum of all DPLA hubs, both Content and Service, results in more than 1000 partner institutions and over 11 million digital items. These numbers are only possible thanks to interoperability. The DPLA interface allows users to research specific content, both filtered geographically or organized chronologically. However, for this to be possible, DPLA has to carry out several enhancements to text strings in metadata related to digital object's location, as well as to data-related information, before ingesting the metadata. Also, for the metadata to be ingested in the first place, institutions must make their metadata interoperable by aligning it with DPLA standards.

DPLA uses a MAP to support interoperability, which is an application profile or a set of metadata elements taken from multiple schemas, available through their namespaces on the Web, for a particular local use. Not only does DPLA's MAP describe content, but also the relationships between different elements in an item's metadata record.

2.3 Discussion

Each of the previous sections describes systems focused on implementing or overcoming the challenges of achiving the desired features of a VRE. In this section, the benefits that have been taken from analyzing those systems will be discussed, as well as how they would be integrated into the project to be developed.

One of the project's main goals is to promote the durability and scalability of the system. Through the analysis made of SnowVision, EVI-LINHD, and heiMAP, it was possible to conclude that choosing the system's architecture is a critical step to reach this goal. Not only did this analysis show that the use of widely popular technologies is a benefit when trying to achieve durability, but also that the independent implementation of each component will make further development of the system a simple task.

Metadata is the core element of a VRE, making its mapping and manipulation a vital step in building one. By studying VRE4EIC e-VRE metadata service and NESTOR, it was possible to understand how the way metadata is mapped and organized is impactful in a project, not only by relieving the load of the system, but also by facilitating users' research. Besides that, interoperability is key for any large-scale project, as is the case of DPLA. For DPLA, the collaboration between different sources is the base concept of their work, and without interoperability that would not be possible. The same happens with ROSSIO, where most of the metadata is provided by partners.

While developing a VRE for the ROSSIO infrastructure all of these aspects and features were taken into consideration, specially when it came to the choices that were made concerning the technological stack. All the challenges presented by the previous systems were acknowledged while implementing the system's functionalities, in the sense of working towards a highly functional environment.

3

Specification

This chapter is meant to thoroughly describe the features of the Virtual Research Environment developed throughout the course of this dissertation, as well as ROSSIO's role in the development. As mentioned previously, this VRE is meant to be integrated into the ROSSIO platform. In this regard, most of the features were specified and designed in collaboration with the ROSSIO research team.

Some of the features that were initially planned to be a part of the VRE are not fully developed and integrated into the application, due to delays in ROSSIO's project. This will also be further explained and analyzed in this chapter.

3.1 VRE Web Application Features

The Virtual Research Environment for the ROSSIO platform is a brand new application that will soon be a part of its website. This application is a work environment for researchers in the Humanities area, and its main objective is to facilitate access to many digital resources in a single website while also providing an area where they can organize and work on those same resources. To reach this goal, the current functional version of the developed web application is composed of six main components, each composed of several features. These six components match the main frontend pages, accessible through the navigation bar, that are presented in the Design section of the specification.

The following list will present a description of each component. The order of the components in this list differs from the order in which they appear on the application so that the specification is easier to understand.

- **Simple and Advanced Search** - The simple and advanced search component is meant to give users the possibility to search for every kind of resource made available by ROSSIO. As mentioned previously, this resources are gathered from multiple collaborators in order to make searching an undemanding activity for researchers. Users can either do a simple or advanced search in the platform. Simple search is made through a word or phrase, and can include the selection of a specific resource provider. Advanced search allows users to search with greater detail through the inclusion of filters for person, places, time and topics.

- **Favorite Resources** - After searching for resources, users can add them to their Favorite Resources. Once they do this, the resources will be kept in a list that they can consult later. These resources can be seen with more detail and personalized with topics added by the user. Besides that, a favorite resource can be organized in folders and shared with other researchers through their email.
- **Notes** - The notes are a space where researchers have access to a text editor to write down their thoughts or even develop some work. These, just like the favorite resources, can also be organized in folders and shared with other researchers. The notes can also be edited and deleted whenever the researcher desires.
- **Dashboard** - The dashboard is a place where users have access to all the information about their last access to the platform as well as ROSSIO's latest updates. This component is also the place where users can edit their account details, like name and username, and add personal topics to their account that characterize their area of activity.
- **Folders** - The folders component is where users can create, edit and erase their folders. Besides that, this is another place where they consult their favorite resources and work notes through their respective folders, where all the resources are kept according to the user's previous choice.
- **Collaborative Research** - The collaborative research shows users a list of resources and notes that were shared with them. Users can open each resource and note to see the details, and can also make an annotation for the researcher that shared that resource with them. An annotation is a simple comment to let the researcher know their thoughts about the work they are developing. This is a first approach to collaboration in this platform.

3.2 ROSSIO Infrastructure Role

ROSSIO had a major role in the development of the Virtual Research Environment Application, with contributions like the specification of its features, discussed in the previous subsection, standardization and handling of digital resources, and design of the web pages.

3.2.1 Digital Resources API

ROSSIO's research team is developing an API that retrieves the data provided by the several project partners in an organized and easy to manipulate format. The API has not come to its final state, and for that reason was not used in the developed VRE. That is also the reason why functionalities like simple and advanced search, are not implemented in the backend component of the VRE, something that will be discussed with greater detail in the Implementation chapter. Even so, the digital resources format and data is already defined, as well as the types of resources that will be presented by the platform. The platform will make available approximately 5.000.000 resources, with the following formats:

- Image
- Video
- Pdf
- Txt
- Mp4

Every resource will be presented with the following metadata, focusing on the most important information for the final user:

- **Title** - Name for which the resource is formally known.
- **Creator** - Entity responsible for the creation of the resource.
- **Subject** - Several topics and keywords that describe the intellectual content of the resource.
- **Description** - General information about the resource, usually presented in the form of free text.
- **Publisher** - Entity, person or organizations that made the resource available.
- **Date** - Date associated with an event in the life cycle of a resource, which is frequently its creation or the date in which it was made available.
- **Type** - The type of scientific resource of which the resource is a manifestation. Describes the type of intellectual content the resource refers to.
- **Format** - Physical manifestation of the digital resource.
- **Identifier** - Unique reference to the resource in a determined context.
- **Source** - Reference to the original resource that the current resource is based on.
- **Language** - Language of the resource.
- **Relation** - Reference to a related resource.

- **Coverage** - Extent or scope of the resource's content. Can include elements like spacial location.
- **Rights** - Information about the rights of the resource.
- **Audience** - The type of entity the resource is useful to.

3.2.2 Design

The design of the VRE web application was another feature that counted with ROSSIO's team contribution. More specifically, with the contribution of the team's web designer. Almost all of the application's mockups were developed by the web designer and shared with the team through Adobe XD. These mockups were approved by ROSSIO's consortium and therefore were the ones used as a base for the development of the application's frontend.

Although the mockups were developed by the designer, every decision taken in relation to the design took into account and received input from all team members. Not only was this input verbal, but also in the form of hand-drawn sketches with examples of an elementary structure to the pages. All of the application's mockups can be found in appendix A of this dissertation. In the following example a hand-drawn sketch is presented, followed by the mockup page, and the real application page it turned into.

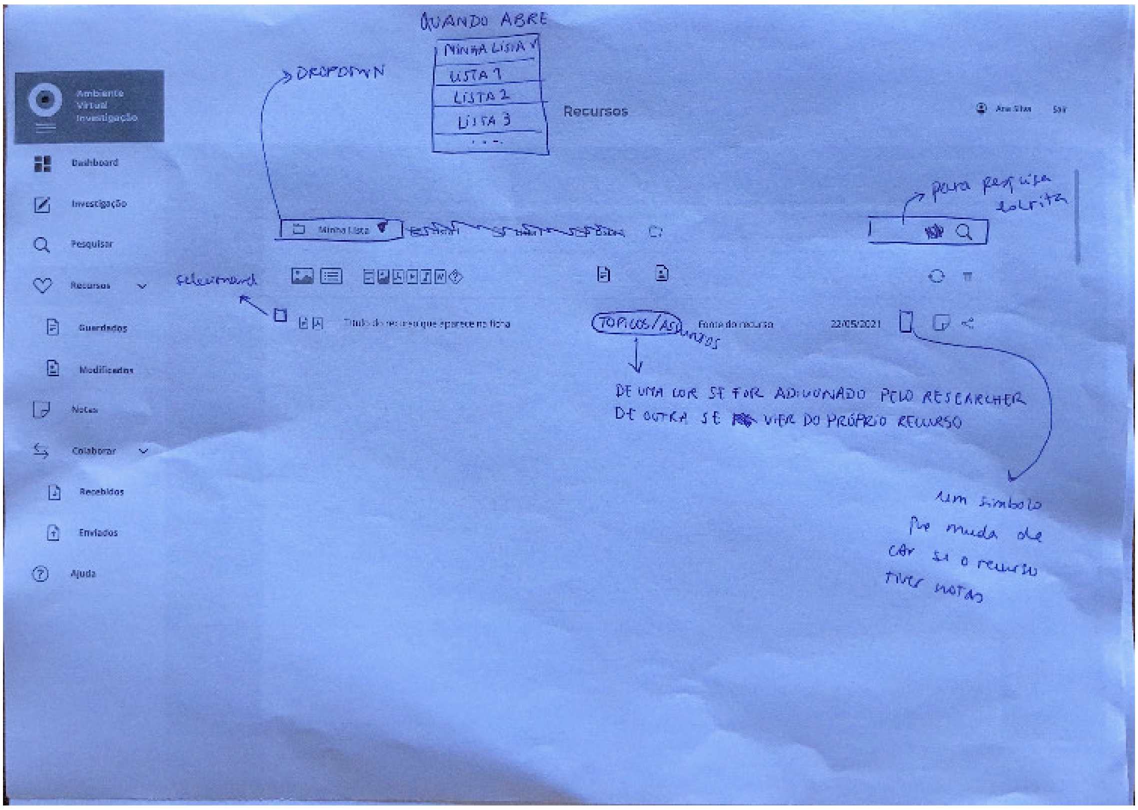
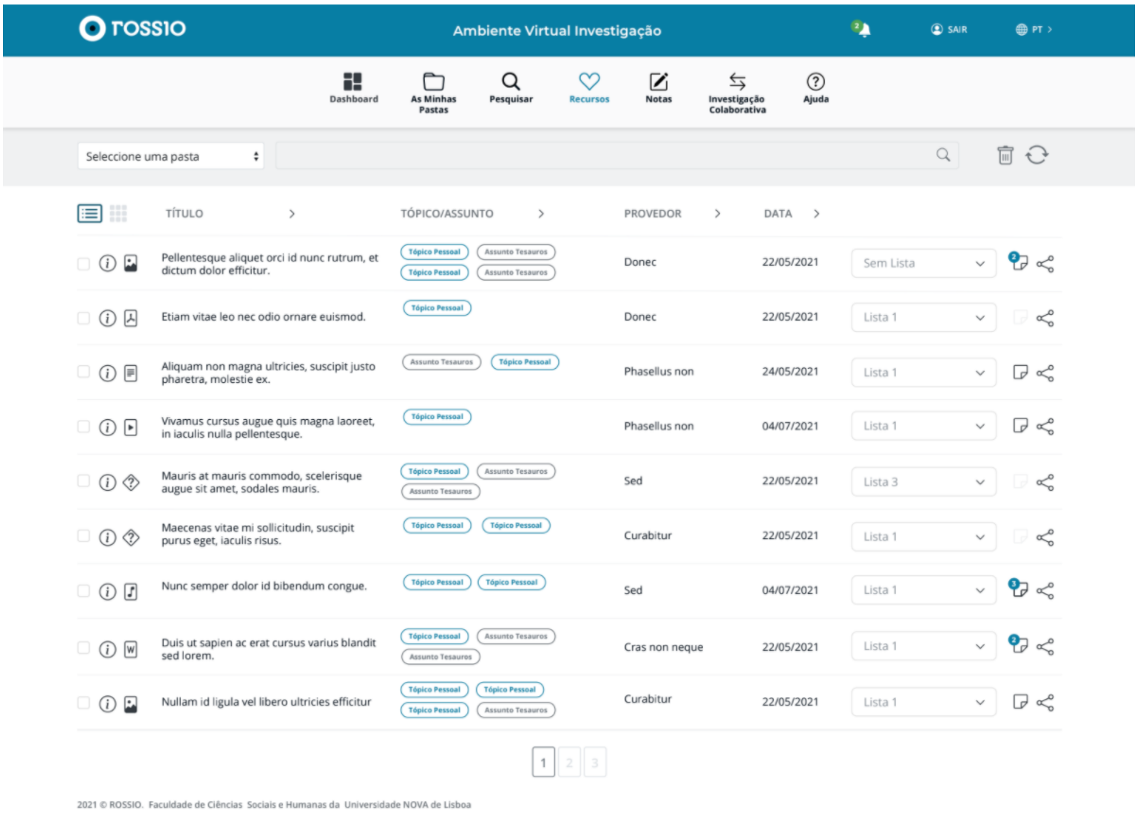


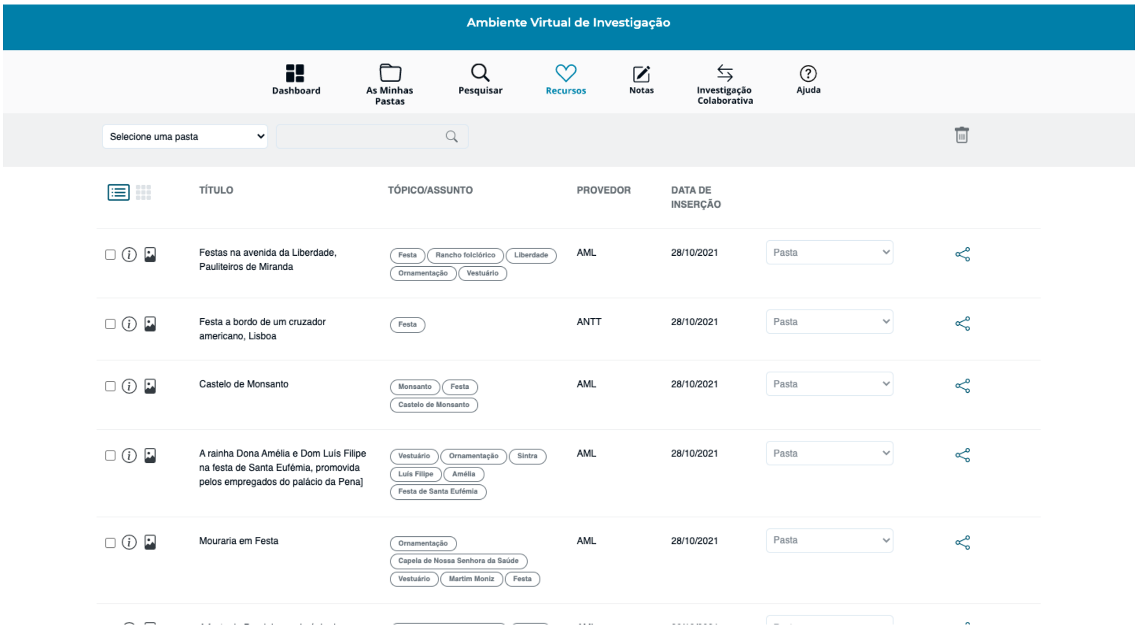
Figure 3.1: Hand-drawn sketch of the Resources page.



TÍTULO	TÓPICO/ASSUNTO	PROVEDOR	DATA	
Pellentesque aliquet orci id nunc rutrum, et dictum dolor efficitur.	Tópico Pessoal Assunto Tesauros Tópico Pessoal Assunto Tesauros	Donec	22/05/2021	Sem Lista
Etiam vitae leo nec odio ornare euismod.	Tópico Pessoal	Donec	22/05/2021	Lista 1
Aliquam non magna ultricies, suscipit justo pharetra, molestie ex.	Assunto Tesauros Tópico Pessoal	Phasellus non	24/05/2021	Lista 1
Vivamus cursus augue quis magna laoreet, in iaculis nulla pellentesque.	Tópico Pessoal	Phasellus non	04/07/2021	Lista 1
Mauris at mauris commodo, scelerisque augue sit amet, sodales mauris.	Tópico Pessoal Assunto Tesauros Assunto Tesauros	Sed	22/05/2021	Lista 3
Maecenas vitae mi sollicitudin, suscipit purus eget, iaculis risus.	Tópico Pessoal Tópico Pessoal	Curabitur	22/05/2021	Lista 1
Nunc semper dolor id bibendum congue.	Tópico Pessoal Tópico Pessoal	Sed	04/07/2021	Lista 1
Duis ut sapien ac erat cursus varius blandit sed lorem.	Tópico Pessoal Assunto Tesauros Assunto Tesauros	Cras non neque	22/05/2021	Lista 1
Nullam id ligula vel libero ultricies efficitur	Tópico Pessoal Tópico Pessoal Tópico Pessoal Assunto Tesauros	Curabitur	22/05/2021	Lista 1

2021 © ROSSIO. Faculdade de Ciências Sociais e Humanas da Universidade NOVA de Lisboa

Figure 3.2: Design mockup of Resources page.



TÍTULO	TÓPICO/ASSUNTO	PROVEDOR	DATA DE INSERÇÃO	
Festas na avenida da Liberdade, Pauliteiros de Miranda	Festa Rancho folclórico Liberdade Ornamentação Vestuário	AML	28/10/2021	Pasta
Festa a bordo de um cruzador americano, Lisboa	Festa	ANTT	28/10/2021	Pasta
Castelo de Monsanto	Monsanto Festa Castelo de Monsanto	AML	28/10/2021	Pasta
A rainha Dona Amélia e Dom Luís Filipe na festa de Santa Eufémia, promovida pelos empregados do palácio da Pena]	Vestuário Ornamentação Sintra Luís Filipe Amélia Festa de Santa Eufémia	AML	28/10/2021	Pasta
Mouraria em Festa	Ornamentação Capela de Nossa Senhora da Saúde Vestuário Martim Moniz Festa	AML	28/10/2021	Pasta

Figure 3.3: Final frontend Resources page.

4

Implementation

In this chapter, a detailed description of the Virtual Research Environment implementation will be presented. Like the implementation of the practical solution, this chapter is divided into three sections, corresponding to the VRE's development stages. The first stage was the backend development, which was divided and organized according to the system's entities. Following was the frontend development, where a more technical overview of the presentation layer is stated, alongside the UI screens. Finally, the last section will comprise the development of the security layer, where further details on the authentication and authorization mechanisms will be explained.

4.1 Backend Component

This section will go through all the phases of the backend development, starting with the technology used to implement this component, followed with a decomposed explanation of all the backend components, which consist of: Entity-Relationship model and Repositories, Services and Controllers and a general explanation of the system's most intricate functions.

4.1.1 Technology and Language

The technology and language used to develop the backend component Virtual Research Environment will be detailed below, accompanied by a brief explanation of its purpose.

- **Spring** - Framework that provides a comprehensive programming and configuration model and infrastructural support at the application level for modern Java-based enterprise applications - on any kind of deployment platform [20].

- **Kotlin** - Kotlin is a modern but already mature, concise and safe programming language that is interoperable with Java and other languages, and provides many ways to reuse code between multiple platforms for productive programming[9].

4.1.2 Entity-Relationship model and Repositories

After defining the system's features, and deciding on the adequate technology to implement them, the first step involved in developing the backend component of the VRE web application was to create its Entity-Relationship model.

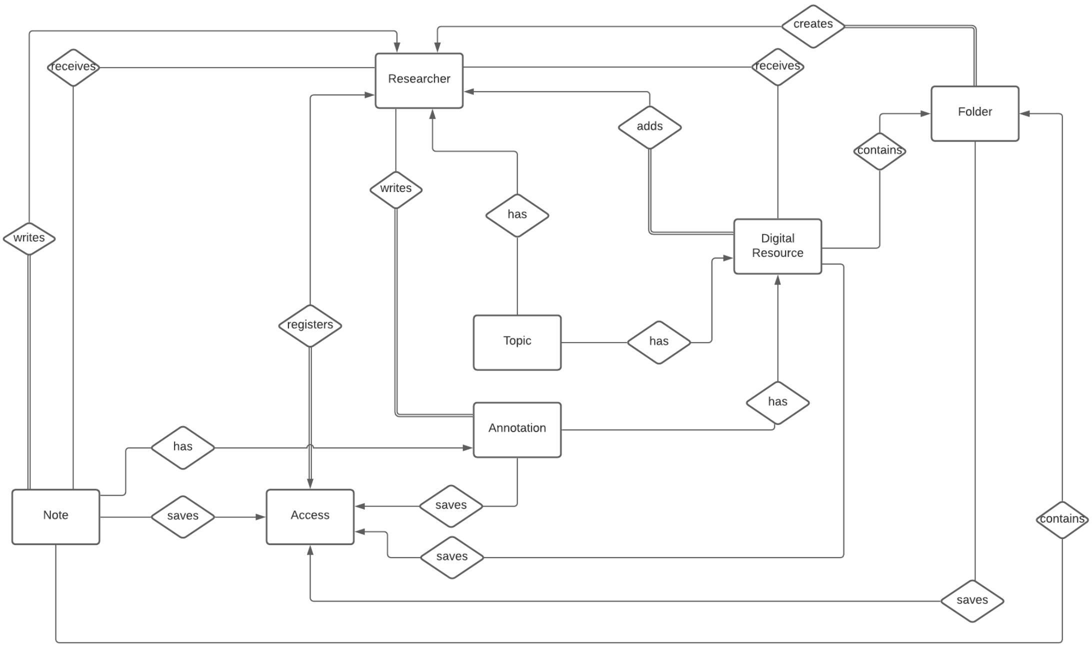


Figure 4.1: VRE ER model.

Once the system's features were specified, it was decided that each main component would be represented by an entity, leading to the 7 entities that can be observed in the ER model. Along with defining the entities, their attributes and the relationships between them were also determined. These relationships represent how the database tables for each entity relate to each other, and can be of three types: One to One, One to Many, Many to Many. **One to One** is when a record on table A is related to a single record in table B. **One to Many** is when a record in table A is related to many records in table B. **Many to Many** is when multiple records in table A are related to multiple records in table B. In the concrete case of the VRE, these are the specific relationships and attributes:

- **Researcher**
  The researcher is the main entity of the VRE and has a relationship to every other entity. Its attributes represent the personal data of a registered user of the application.

  Attributes:
  id, email, name, username

Relationships:
Researcher-Access: One to One, representing the researcher's access to the platform.
Researcher-Digital Resource: One to Many, representing the digital resources that are added by the researcher to his list of favorite resources.
Researcher-Folders: One to Many, representing the folders created by the researcher.
Researcher-Topics: One to Many, representing the personal topics added by the researcher to his profile.
Researcher-Notes: One to Many, representing the notes written by the researcher.
Researcher-Annotations: One to Many, representing the annotations added by the researcher to resources that were shared with him.
Researcher-Digital Resource: Many to Many: representing the digital resources that were shared with the researcher, that might also have been shared with other researchers.
Researcher-Notes: Many to Many: representing the digital resources that were shared with the researcher, that might also have been shared with other researchers.

- **Access**
  An access is meant to be created when a researcher is registered in the platform. It keeps the date of the researchers last access and the details the researcher's activity in his last session. Every time a researcher logins into the application this details are listed in the homepage of the application, and then erased to register the new date and new details of the current session. All of the functions related to an access were developed, but since the registration and authentication on the platform were never implemented, the process of creating and updating and access to be empty are not a part of application.

  Attributes:
  id, date

  Relationships:
  Access-Researcher: One to One, representing the researcher to who the access and its respective information belong to.
  Access-Digital Resource: Digital resources that were added by the access's owner(the researcher) during one session in the platform.
  Access-Folder: Folders that were added by the access's owner during one session in the platform.
  Access-Annotation: Annotations that were added by the access's owner during

one session in the platform.
Access-Note: Notes that were added by the access's owner during one session in the platform.

- **Digital Resource**
  The digital resources saved in the virtual research environment were initially meant to save the id of the digital resource in ROSSIO's digital resources API, the id to identify the resource added by the researcher as a favorite, a list of annotations and a list of topics. The reason why the second id was necessary is the fact that the same resource added by different researchers could not be identified with the same id, since they can be personalized with topics and annotations. Nonetheless, its still necessary to save the first id to retrieve the Digital Resource metadata.
  Considering that was not possible to integrate the digital resources API in this phase of the development, and that the project ended up using mockup data, it was necessary to change this entity to have more attributes and only the second id. Therefore, the attributes for this phase were chose accordingly to the mockup data that was provided.

  Attributes:
  id, modified, title, description, author, date, subject, archive, image, reference, conditions

  Relationships:
  Digital Resource-Annotation: One to Many, representing the annotations that are made by several researcher to a digital resource shared with them by a specific researcher.
  Digital Resource-Topic: One to Many, representing the topics added by a researcher to a digital resource from his list of favorite resources.
  Digital Resource-Researcher: Many to One, representing the digital resources that a researcher added to his list of favorites.
  Digital Resource-Folder: Many to One, representing the digital resources added to a folder.
  Digital Resource-Access: Many to One, representing the digital resources registered in an access.
  Digital Resource-Researcher: Many to Many: representing the digital resources that can be shared with several researchers.

- **Folder**
  The folders in the VRE are associated with a single researcher and can save both digital resources and notes. When creating a folder, a researcher can attribute a name of his choice to it.

Attributes:
id, name

Relationships:
Folder-Digital Resource: One to Many, representing the digital resources that can be saved in a folder.
Folder-Note: One to Many, representing the notes that are saved in a folder.
Folder-Access: Many to One, representing the folders registered in an access.
Folder-Researcher: Many to One, representing the folders created by a researcher.

- **Annotation**
Annotations are comments added by authorized researchers on digital resources or notes shared with them by other researchers, therefore they save the text of the comment made and the name of the author/researcher that commented.

  Attributes:
  id, text, author

  Relationships:
  Annotation-Researcher: Many to One, representing the annotation made by a researcher in other researchers' resources.
  Annotation-Digital Resource: Many to One, representing the annotations added by several researchers to a digital resource.
  Annotation-Note: Many to One, representing the annotation added by several researchers to a note.
  Annotation-Access: Many to One, representing the annotations registered in an access.

- **Note**
The notes are personal texts written by a researcher, that consist of a title and a body, and that can be added to folders and shared with other researchers.

  Attributes:
  id, title, text

  Relationships:
  Note-Annotation: One to Many, representing the annotations that are made by several researcher to a note shared with them by a specific researcher.
  Note-Researcher: Many to One, representing the notes written by a researcher.
  Note-Folder: Many to One, representing the notes that are saved in a folder.
  Note-Access: Many to One, representing the notes registered in an access.
  Note-Researcher: Many to Many: representing the several notes that can be

shared with several researchers.

- **Topic**
  The topics are a simple subject that is added by a researcher to his profile or favorite resources. The reason why an entity was created for the topics is scalability. It is predictable that the topics have a more complex structure in the future, incorporating more attributes. This way, the system is already prepared for that situation, and will be easier to change in the future.

  Attributes:
  id, subject

  Relationships:
  Topic-Researcher: Many to One, representing the topics added by a researcher to his account.
  Topic-Digital Resource: Many to One: representing the topics added by a researcher to one of his favorite resources.

4.1.3 Services and Controllers

Once the entities required to implement VRE were determined, it was necessary to create the layer responsible for accommodating the business requirements, as well as maintaining the application's logic - the **Service** layer. In order to do so, **Data Access Objects** (DAOs) were introduced as a representation of the different entities designed in the persistence layer. The DAO pattern is a well-known structural pattern responsible for isolating the application/business layer from the persistence layer through an abstract API [21]. With this strategy, each entity on the persistence layer is mapped to a DAO, therefore, the persistence layer is completely decoupled from the domain model. Since there are 7 entities in the Entity-Relationship model addressed earlier in this section, there are also 7 DAOs: ResearcherDAO, AccessDAO, DigitalResourceDAO, FolderDAO, AnnotationDAO, NoteDAO, and TopicDAO. Every service of the application performs CRUD (Create, Read, Update, Delete) operations. Besides that, some of the services have other implemented methods in order to fulfill the application's business requirements. A brief example would be the method *addTopicToDigitalResource*, implemented in the *DigitalResourceService*, where a Topic is added to a Digital Resource.

Alongside the Service layer, the **Controller** layer was developed as well. This layer is responsible for making the appropriate connection between the VRE frontend (UI) and the Service layer. The development of this layer led to the implementation of a set of **REST APIs**. REST (Representational State Transfer) refers to a group of software architecture design constraints that bring about efficient, reliable, and scalable distributed systems and its basic idea is that a resource is transferred via well-recognized, language-agnostic, and reliably standardized client/server interactions [18]. Each Controller represents a well-defined and REST compliant API, and will act as an intermediary between the UI and the Service Layer. In order to do so, **Data Transfer Objects** (DTOs) were introduced. Typically, DTOs are flat data structures that contain no business logic and are used to represent the model sent from/to the API client. The DTO pattern is a structural pattern responsible for decoupling the domain models from the presentation layer, allowing both to change independently [22].

The VRE backend component is divided into 4 folders in order to guarantee modularity and extensibility, having the platform's future in mind. The 4 folders are **api**, containing the APIs, DTOs and Controllers, **services**, containing the DAOs and Services, **model**, containing the Repositories, and **config**, containing the Security configurations and layers that will be analyzed in the last section of this chapter.

4.2 Frontend Component

In this section, the several phases of the frontend development will be explained in detail. First, there will be a presentation of the language and technology chosen to implement this component, followed by the project structure, steps, and logic that led to this structure, and finally an analysis of features present on each UI page.

4.2.1 Technology and Language

The technology and language used to develop the frontend component Virtual Research Environment will be detailed below, accompanied by a brief explanation of its purpose.

- **Angular** - Application design framework and development platform for creating efficient and sophisticated single-page apps [3].

- **Bootstrap** - Front-end open source toolkit, featuring Sass variables and mixins, responsive grid system, extensive prebuilt components, and powerful JavaScript plugins [4].

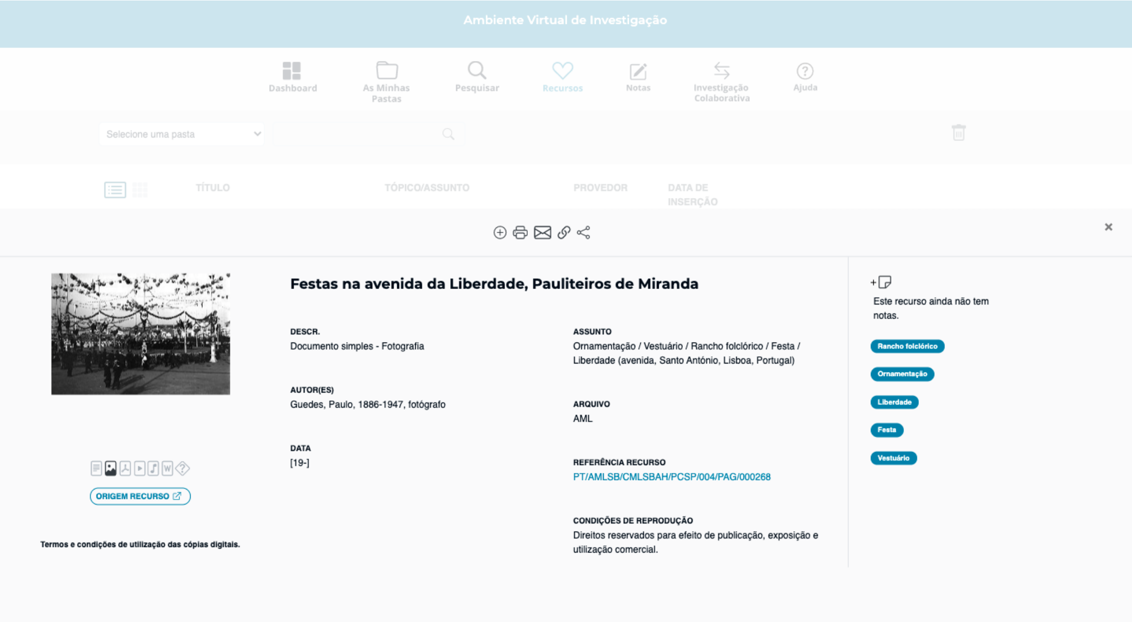
- **TypeScript** - Strongly typed programming language that adds syntax and builds on JavaScript, using type inference [23].

- **Node.js** - Asynchronous event-driven JavaScript runtime, Node.js is designed to build scalable network applications [1]

4.2.2 Project Structure

The frontend component was developed accordingly to the official Angular coding style guide [2], in order to match industry standards concerning style vocabulary, naming conventions, and the single responsibility principle. Although there is no strict rule on how the folders in an Angular project should be structured, there are some universal guidelines and well-known best practices that promote project organization and clarity, as well as better separation of concerns. In the development of the frontend component of VRE, these guidelines were taken into account when structuring the project's main folders, **components**, **core**, and **features**, which will be individually addressed in this subsection.

The **components** folder aggregates all of the application's components. A component can be seen as a building block for one or several features of the VRE. The purpose of this folder is to promote the reusability of such components, as they are tightly coupled to the features of the application and are not intended to exist or be rendered isolated. In this folder, one can find the application's navbar, which is used in every application page, the resource card, displayed in 4.2, which is used to display the metadata of a Digital Resource when the previous is selected, and a generic text field component, since there are different forms in the application for which having a custom text field component facilitates the styling and behavior of the forms.



Festas na avenida da Liberdade, Pauliteiros de Miranda

DESCR.
Documento simples - Fotografia

AUTOR(ES)
Guedes, Paulo, 1886-1947, fotógrafo

DATA
[19-]

ASSUNTO
Ornamentação / Vestuário / Rancho folclórico / Festa / Liberdade (avenida, Santo António, Lisboa, Portugal)

ARQUIVO
AML

REFERÊNCIA RECURSO
PT/AMLSB/CMLSBAH/PCSP/004/PAG/000268

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Direitos reservados para efeito de publicação, exposição e utilização comercial.

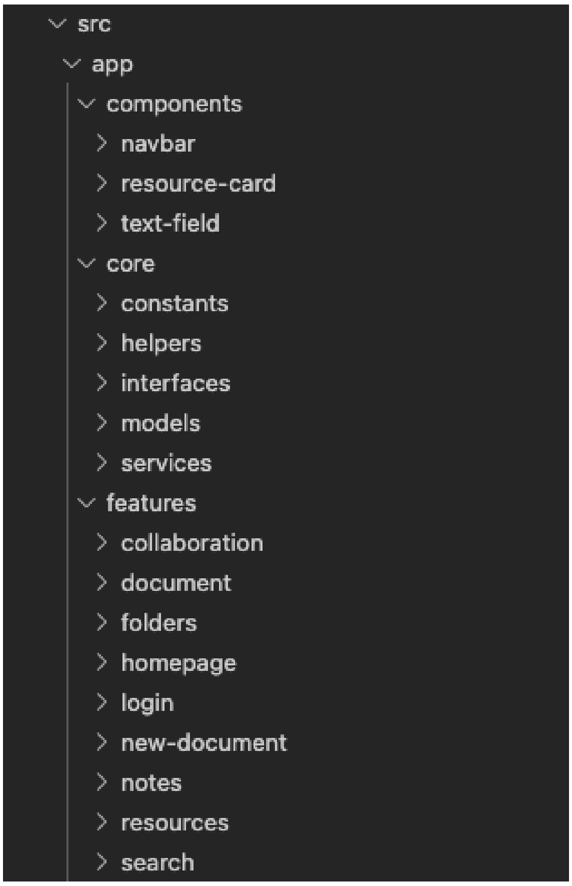
Este recurso ainda não tem notas.

Termos e condições de utilização das cópias digitais.

Figure 4.2: Digital resource card.

The **core** folder, as the name states, contains all the core functionalities behind the UI's behavior. Inside this folder, there are several sub-folders with different purposes: constants, helpers, interfaces, models, and services. The **constants** folder is responsible for maintaining all of the application's constants, which for the time being are only the API URLs. The **helpers** folder is responsible for maintaining all of the files that are used to assist in providing functionality to the application. Currently, it only contains a request interceptor, which is of extreme importance, since it catches all the requests that are made to the backend component, and injects them with the authorization token. The **interfaces** folder keeps all of the frontend component's interfaces, which define the structure of data objects based on the DTOs present on the backend component. The **model** folder was created to eventually save classes that represent data objects, thus expressing the logic, methods, and properties these objects will inherit. Finally, the **services** folder keeps all the services that will call the APIs from the backend component, of which the main responsibility is to perform HTTP calls. Currently, there are services for the Annotations, Digital Resources, Folders, Notes, and Researchers.

The last main folder is the **features** folder, which contains all of the application's pages and functionalities. The content of this folder will be explained in further detail in the following subsection, alongside the application's pages.



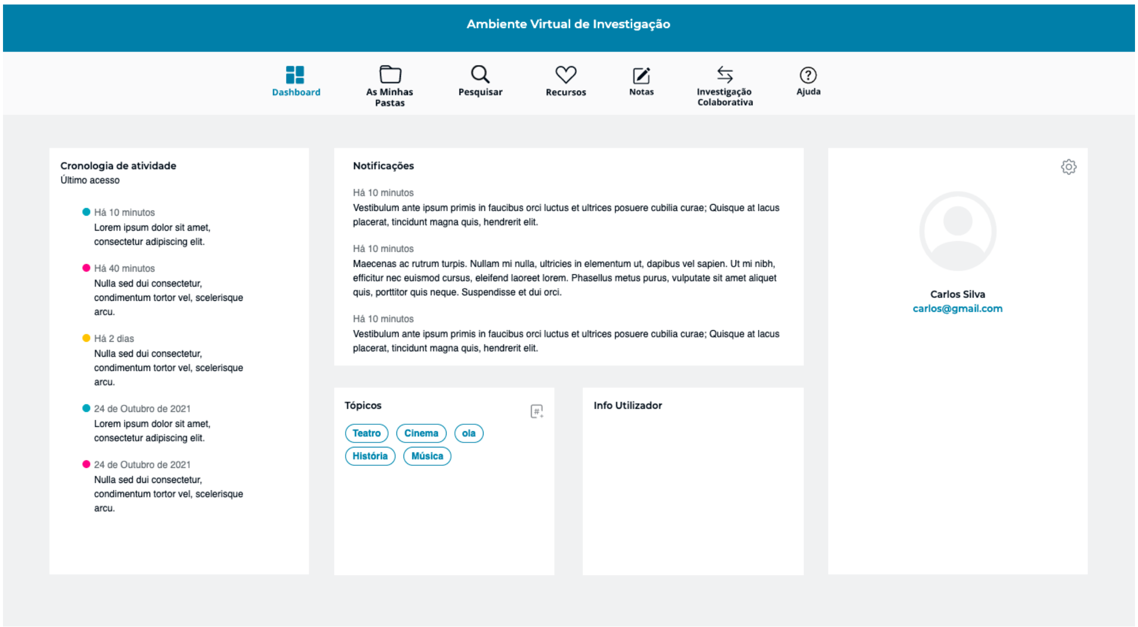
```
src
  app
    components
      navbar
      resource-card
      text-field
    core
      constants
      helpers
      interfaces
      models
      services
    features
      collaboration
      document
      folders
      homepage
      login
      new-document
      notes
      resources
      search
```

Figure 4.3: Folder organization.

4.2.3 Features

Each feature created on the previously mentioned **features** folder corresponds to a sub-folder of the latter, and also to a page of the application. So, it only made sense for the features to be presented next to the screenshots of its content, in order to make the content of each sub-folder more visual and perceptible. In this subsection, the images of the UI pages will be displayed, accompanied by an explanation of the application's frontend features: homepage, folders, search, resources, notes, new-document, and collaboration.

The first page to be created was the dashboard page, which can be considered the application's homepage, and corresponds to the **homepage** folder. On this page, displayed on 4.4, the user can observe his last activities in the platform in the box "Cronologia de atividade", while also having access to the ROSSIO's latest news in the box "Notificações". This page is also the place where the user can add personal topics about himself to his account in the box "Tópicos", and where he can edit his account's information, namely his name, email, and username, for which the form is displayed in 4.5.



Cronologia de atividade
Último acesso

- Há 10 minutos
  Lorem ipsum dolor sit amet, consectetur adipiscing elit.
- Há 40 minutos
  Nulla sed dui consectetur, condimentum tortor vel, scelerisque arcu.
- Há 2 dias
  Nulla sed dui consectetur, condimentum tortor vel, scelerisque arcu.
- 24 de Outubro de 2021
  Lorem ipsum dolor sit amet, consectetur adipiscing elit.
- 24 de Outubro de 2021
  Nulla sed dui consectetur, condimentum tortor vel, scelerisque arcu.

Notificações

Há 10 minutos
Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia curae; Quisque at lacus placerat, tincidunt magna quis, hendrerit elit.

Há 10 minutos
Maecenas ac rutrum turpis. Nullam mi nulla, ultricies in elementum ut, dapibus vel sapien. Ut mi nibh, efficitur nec euismod cursus, eleifend laoreet lorem. Phasellus metus purus, vulputate sit amet aliquet quis, porttitor quis neque. Suspendisse et dui orci.

Há 10 minutos
Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia curae; Quisque at lacus placerat, tincidunt magna quis, hendrerit elit.

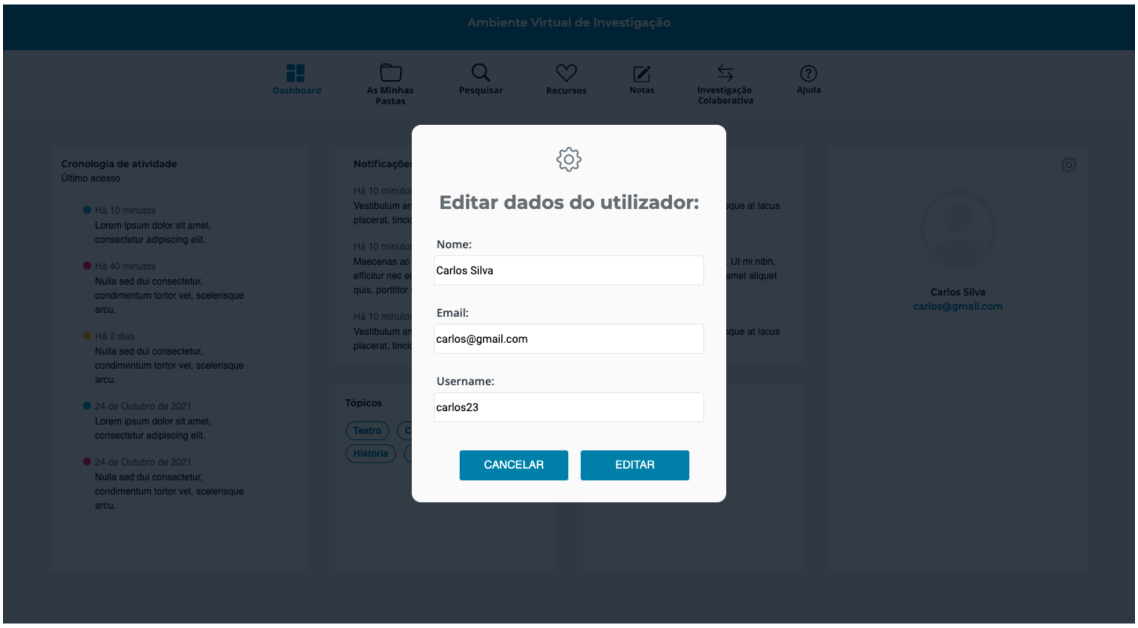
Tópicos

Teatro Cinema ola História Música

Info Utilizador

Carlos Silva
carlos@gmail.com

Figure 4.4: Dashboard page.



Editar dados do utilizador:

Nome: Carlos Silva

Email: carlos@gmail.com

Username: carlos23

Cronologia de atividade
Último acesso

Há 10 minutos
Lorem ipsum dolor sit amet, consectetur adipiscing elit.

Há 40 minutos
Nulla sed dui consectetur, condimentum tortor vel, scelerisque arcu.

Há 2 dias
Nulla sed dui consectetur, condimentum tortor vel, scelerisque arcu.

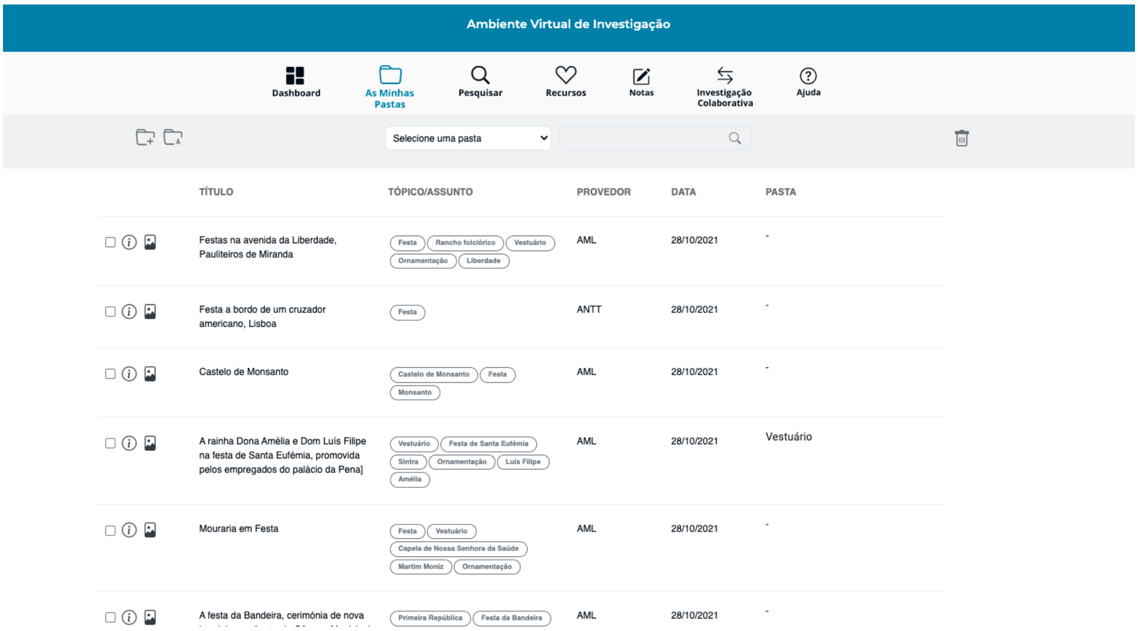
24 de Outubro de 2021
Lorem ipsum dolor sit amet, consectetur adipiscing elit.

24 de Outubro de 2021
Nulla sed dui consectetur, condimentum tortor vel, scelerisque arcu.

Carlos Silva
carlos@gmail.com

Figure 4.5: Edit user form.

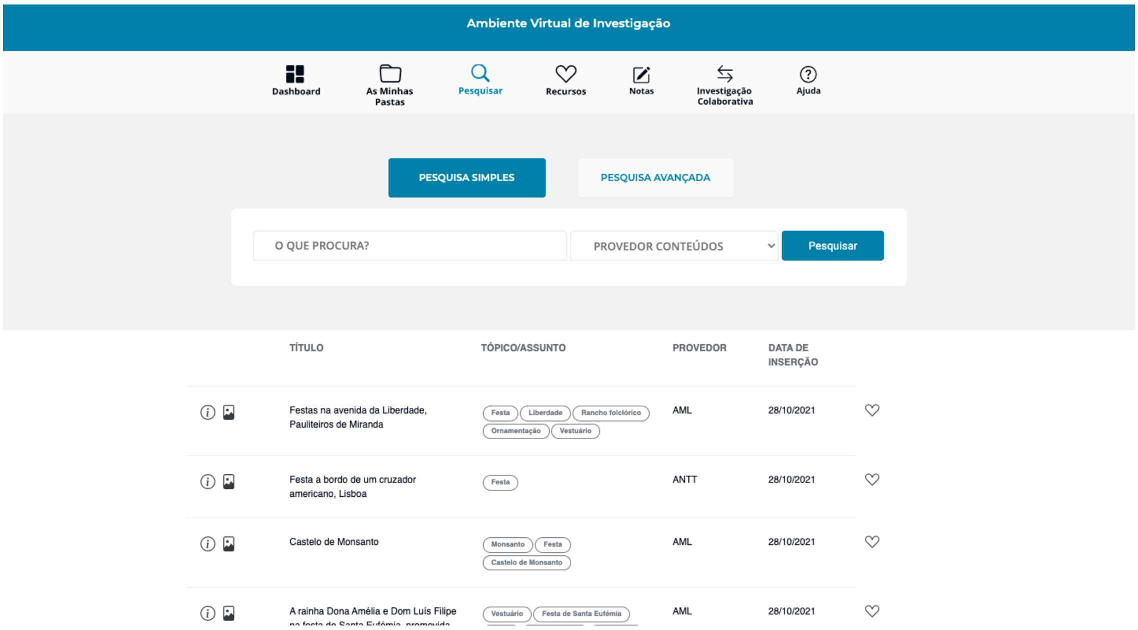
The page that follows the homepage is the folders page, corresponding to the **folders** folder, where the user has access to all his favorite digital resources and notes organized by folders. On this page, the user can create a new folder, edit an existent folder's name, and filter resources by folder. This page also gives users the possibility of erasing one or more resources from their folders, and listing all of their notes. This page is displayed in 4.6.



	TÍTULO	TÓPICO/ASSUNTO	PROVEDOR	DATA	PASTA
□ ⓘ	Festas na avenida da Liberdade, Pauliteiros de Miranda	Festa Rancho folclórico Vestuário Ornamentação Liberdade	AML	28/10/2021	-
□ ⓘ	Festa a bordo de um cruzador americano, Lisboa	Festa	ANTT	28/10/2021	-
□ ⓘ	Castelo de Monsanto	Castelo de Monsanto Festa Monsanto	AML	28/10/2021	-
□ ⓘ	A rainha Dona Amélia e Dom Luís Filipe na festa de Santa Eufémia, promovida pelos empregados do palácio da Pena]	Vestuário Festa de Santa Eufémia Sintra Ornamentação Luís Filipe Amélia	AML	28/10/2021	Vestuário
□ ⓘ	Mouraria em Festa	Festa Vestuário Capela de Nossa Senhora da Saúde Martim Moniz Ornamentação	AML	28/10/2021	-
□ ⓘ	A festa da Bandeira, cerimónia de nova	Primeira República Festa da Bandeira	AML	28/10/2021	-

Figure 4.6: Folders page.

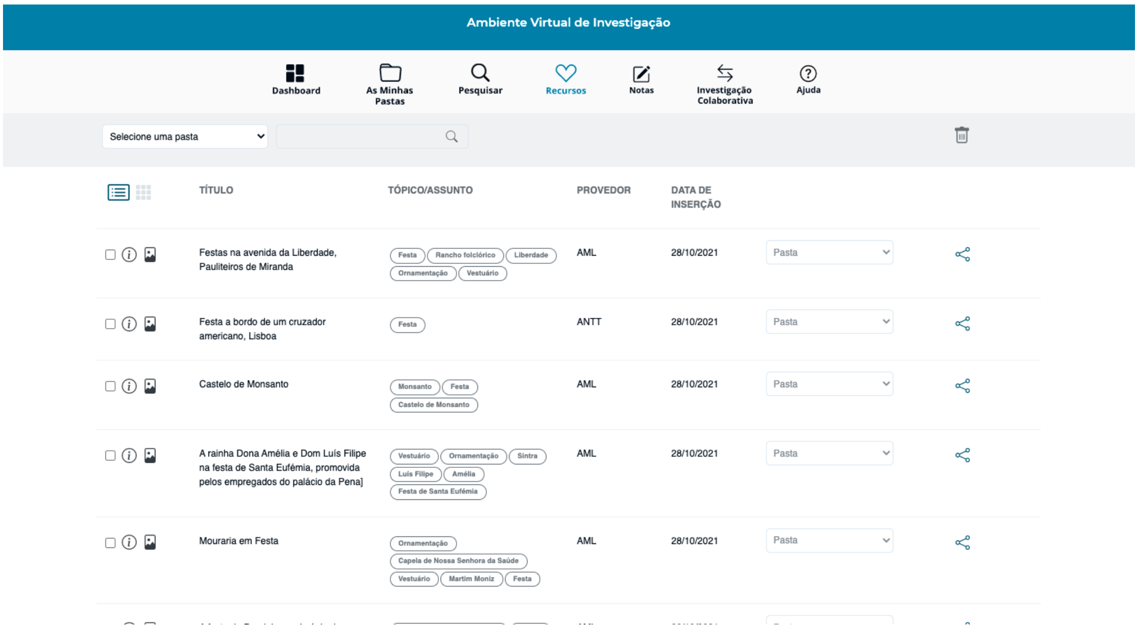
The next page is the search page, present on 4.7, which corresponds to the **search** folder. On this page, users will be able to do a simple and advanced search of all kinds of the resources ROSSIO provides. Once the search is performed, users can open each resource's card in order to have access to more details about the resource's metadata. This page is also the place where users can add a digital resource to their list of favorite resources by clicking the heart next to it.



TÍTULO	TÓPICO/ASSUNTO	PROVEDOR	DATA DE INSERÇÃO
Festas na avenida da Liberdade, Pauliteiros de Miranda	Festa Liberdade Rancho folclórico Ornamentação Vestuário	AML	28/10/2021
Festa a bordo de um cruzador americano, Lisboa	Festa	ANTT	28/10/2021
Castelo de Monsanto	Monsanto Festa Castelo de Monsanto	AML	28/10/2021
A rainha Dona Amélia e Dom Luís Filipe na festa de Santa Eufémia, promovida	Vestuário Festa de Santa Eufémia	AML	28/10/2021

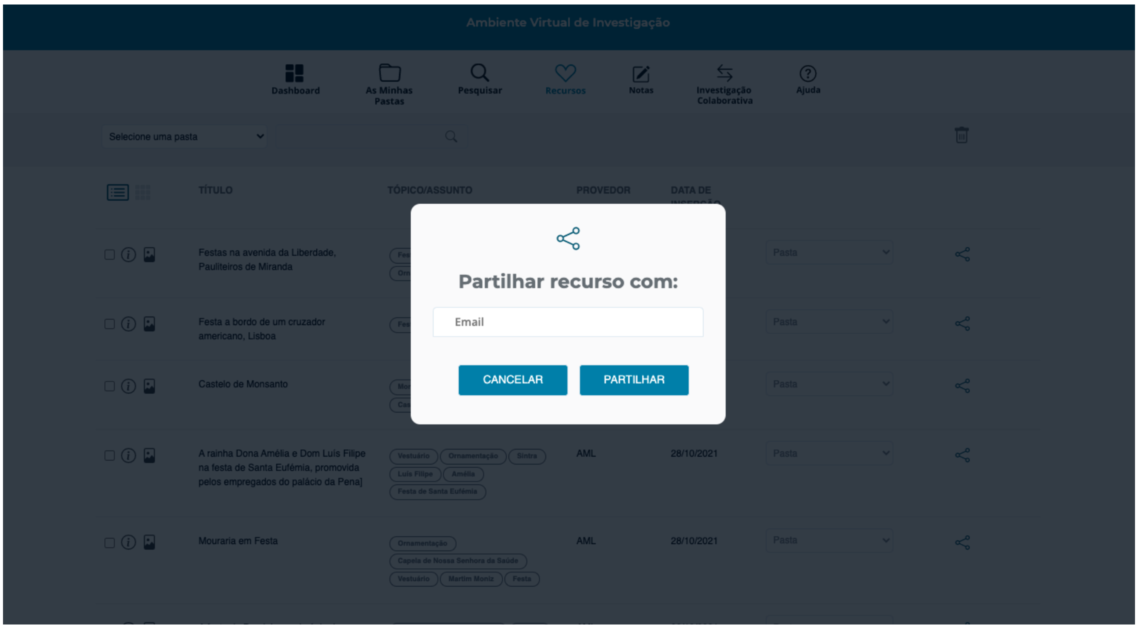
Figure 4.7: Search page.

After adding a resource to his list of favorite resources, a user can consult this resource in the favorite resources page, that corresponds to **resources** folder. On this page, which is displayed in 4.8, the user can also organize and filter the resources in folders, and erase resources from the list. Besides that, the user can share resources with other researchers via their email.



	TÍTULO	TÓPICO/ASSUNTO	PROVEDOR	DATA DE INSERÇÃO		
☐	Festas na avenida da Liberdade, Pauliteiros de Miranda	Festa Rancho folclórico Liberdade Ornamentação Vestuário	AML	28/10/2021	Pasta	
☐	Festa a bordo de um cruzador americano, Lisboa	Festa	ANTT	28/10/2021	Pasta	
☐	Castelo de Monsanto	Monsanto Festa Castelo de Monsanto	AML	28/10/2021	Pasta	
☐	A rainha Dona Amélia e Dom Luís Filipe na festa de Santa Eufémia, promovida pelos empregados do palácio da Pena]	Vestuário Ornamentação Sintra Luís Filipe Amélia Festa de Santa Eufémia	AML	28/10/2021	Pasta	
☐	Mouraria em Festa	Ornamentação Capela de Nossa Senhora da Saúde Vestuário Martim Moniz Festa	AML	28/10/2021	Pasta	

Figure 4.8: Favorite resources page.



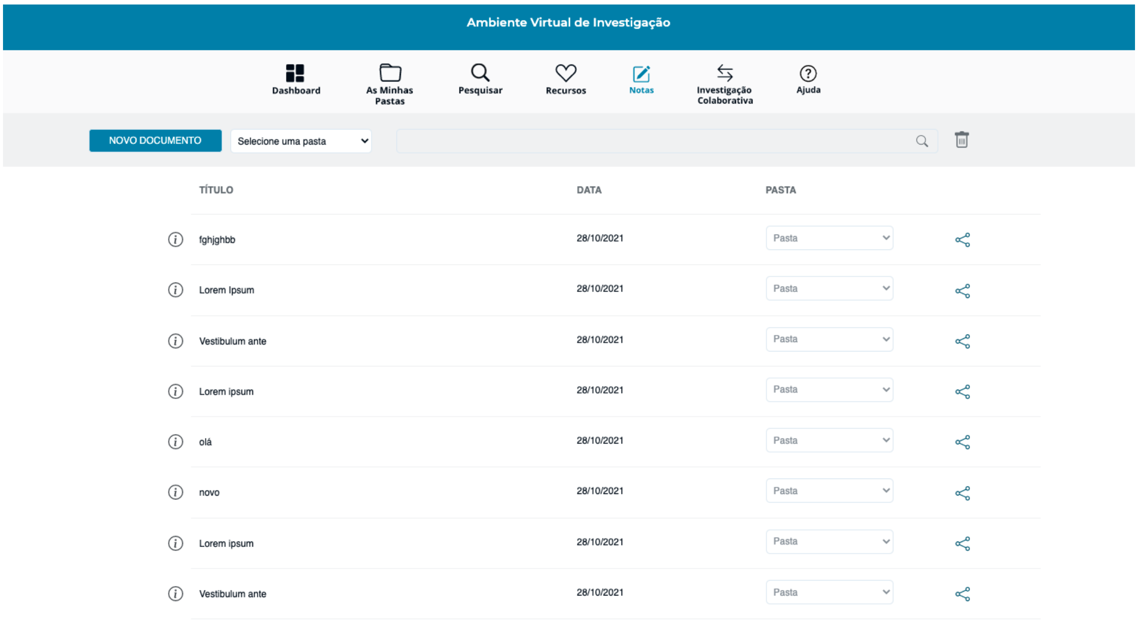
Partilhar recurso com:

Email

CANCELAR PARTILHAR

Figure 4.9: Share resource form.

Similar to the digital resources page, there is a notes page, present in 4.10, which corresponds to the **notes** folder. On this page, the user has access to all his notes and can delete one or more notes. Besides that, the user has access to a button that allows him to create a new document, for which the text editor is displayed in 4.11, and corresponds to the **document** folder.



TÍTULO	DATA	PASTA
fghjghbb	28/10/2021	Pasta
Lorem Ipsum	28/10/2021	Pasta
Vestibulum ante	28/10/2021	Pasta
Lorem ipsum	28/10/2021	Pasta
olá	28/10/2021	Pasta
novo	28/10/2021	Pasta
Lorem ipsum	28/10/2021	Pasta
Vestibulum ante	28/10/2021	Pasta

Figure 4.10: Notes page.

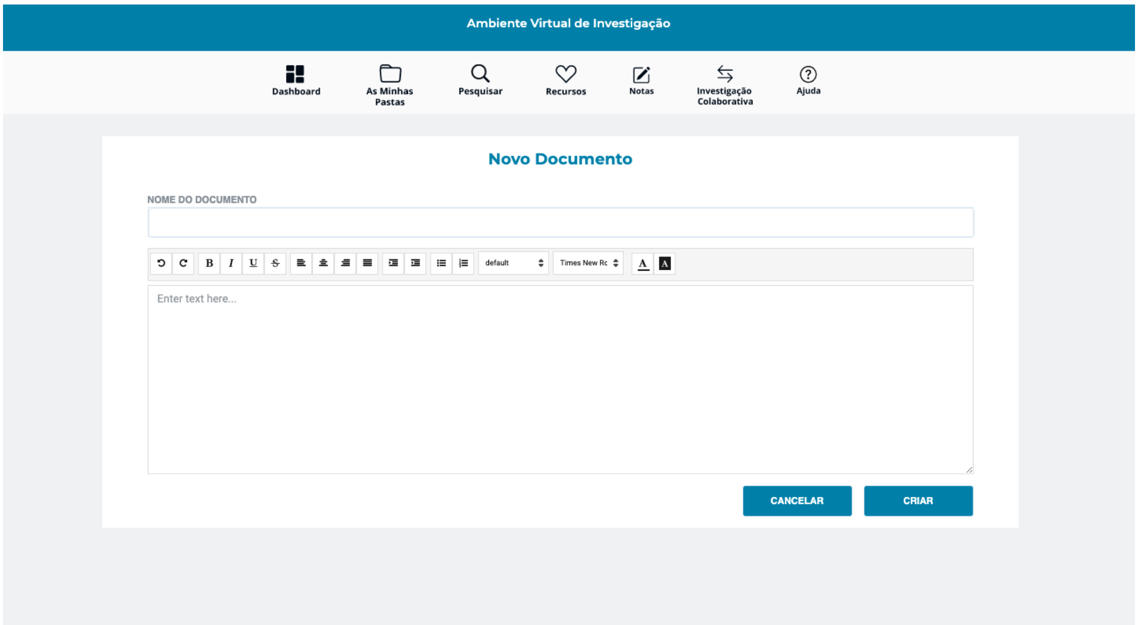
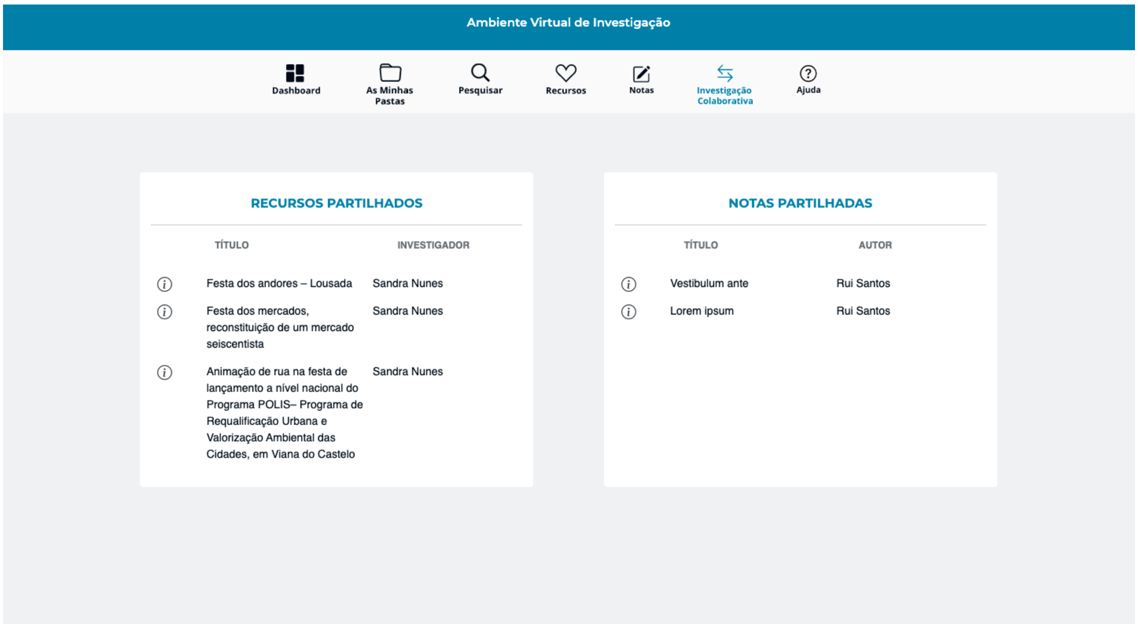


Figure 4.11: Create note page.

Finally, the last page of the application is the Collaborative Research page, present in 4.12, correspondent to the **collaboration** folder. On this page, the user has access to the digital resources and notes that were shared with him by other researchers and is able to observe the title of the resource and the name of the researcher that shared it. The user can also open the resource card, and add annotations to the resource for the researcher that shared it to see, as displayed in 4.2.



RECURSOS PARTILHADOS

	TÍTULO	INVESTIGADOR
ⓘ	Festa dos andores – Lousada	Sandra Nunes
ⓘ	Festa dos mercados, reconstituição de um mercado seiscentista	Sandra Nunes
ⓘ	Animação de rua na festa de lançamento a nível nacional do Programa POLIS– Programa de Requalificação Urbana e Valorização Ambiental das Cidades, em Viana do Castelo	Sandra Nunes

NOTAS PARTILHADAS

	TÍTULO	AUTOR
ⓘ	Vestibulum ante	Rui Santos
ⓘ	Lorem ipsum	Rui Santos

Figure 4.12: Collaborative Research page.

4.3 Security Layer

Concerning the security of the VRE application, one had to implement a reliable authentication mechanism, both in server-side and client-side, which will be explained in detail throughout this section.

ROSSIO's research team decided that an identity provider would be used in order to guarantee authentication throughout the VRE application. An identity provider (IdP) is a federation partner that offers authentication as a service, handling the creation, management, and maintenance of digital identities (users) in a specific system [11]. By integrating an authentication provider in the VRE application, all the responsibilities concerning authentication were delegated to an IdP, and therefore, the only implementation needed was to guarantee a correct and safe connection to it.

Keycloak was the identity provider chosen by ROSSIO's research team. Keycloak is an open-source Identity and Access Management solution aimed at modern applications and services. Being widely used, it makes it easy to secure applications and services with little to no code [13].

In order to secure the developed Spring Boot application with Keycloak, it was necessary to add the Keycloak Spring Boot Adapter JAR to the VRE application. Since Maven is the dependency management tool used in the scope of this dissertation, the first step of the Keycloak integration consisted in adding the following dependency to the project:

```
<dependency>
```

```
        <groupId>org.keycloak</groupId>
        <artifactId>keycloak-spring-boot-starter</artifactId>
    </dependency>
```

The Adapter dependency was also needed:

```
<dependencyManagement>
    <dependencies>
        <dependency>
            <groupId>org.keycloak.bom</groupId>
            <artifactId>keycloak-adapter-bom</artifactId>
            <version>13.0.1</version>
            <type>pom</type>
            <scope>import</scope>
        </dependency>
    </dependencies>
</dependencyManagement>
```

In the context of the VRE, the setup and configuration of the Keycloak client was addressed by the engineer of ROSSIO'S research team, which then provided all the required configuration properties in order to perform a proper integration.

Here are the properties (applied via normal Spring Boot configuration) concerning the Keycloak integration that was set in the backend component:

```
keycloak.auth-server-url=http://localhost:8080/auth
keycloak.realm=rossio-realm
keycloak.resource=Rossio-bearer
keycloak.bearer-only= true
```

In the following segment, each of these properties will be explained in more detail:

- **keycloak.auth-server-url**: The authentication server URL. As for now, the Keycloak authentication server URL is pointing to a local machine for development purposes, but as soon as ROSSIO'S research team hosts the identity provider in a specific server, available through the internet, the updated URL can be easily changed.
- **keycloak.realm**: The realm that was configured for the VRE application in Keycloak. A realm is responsible for the management of users, credentials, and eventual roles or groups within the context of an application.
- **keycloak.resource**: The resource that was configured for the VRE application in Keycloak. It points to a specific resource where the authenticated users will execute actions on.

- **keycloak.bearer-only**: Flag to indicate whether the application only accepts bearer token requests. In the case of the VRE application, the Keycloak will only verify for bearer tokens, which are passed through headers in the different HTTP Requests.

Having all the dependencies and configurations ready, the next step consisted of implementing the *SecurityConfig* class, whose duty is to secure the VRE application. This class extends a class provided by the Keycloak Spring Boot Adapter in order to integrate the authentication server into the VRE application. The overridden methods are thus responsible for initializing the Keycloak Authentication Provider, as well as for pointing to the Spring Boot application properties that were previously defined.

Moreover, this class also has a *configure* method, where some configurations related to CORS are defined, as well as the behavior of the application upon dealing with HTTP requests. Cross-Origin Resource Sharing (CORS) is an HTTP-header based mechanism that allows a server to indicate any origins other than its own from which a browser should permit loading resources [6]. In order to guarantee security and avoid vulnerabilities, it is a priority to clearly specify which origins are allowed to contact the server-side of the VRE application. In this method, a *CorsConfiguration* object is defined, where the allowed methods, the allowed origins and the allowed headers, when making requests, are precisely specified, as it is possible to observe in the following block of code:

```
val corsConfig = CorsConfiguration();
corsConfig.allowedMethods = listOf("*")
corsConfig.allowedOrigins = listOf("http://localhost:4200")
corsConfig.allowedHeaders = listOf("Authorization",
"Access-Control-Allow-Methods", "Cache-Control", "Content-Type")
```

Concerning the *allowedMethods* property, it was defined that all of the HTTP methods can be requested to the server-side of the VRE application, such as GET, HEAD, POST, PUT, PATCH, DELETE and OPTIONS, e.g. The *allowedOrigins* property defines which URLs are entitled to access and execute requests to the backend. As for now, the only URL allowed is the one used for development purposes, but once the VRE application reaches its production stage, a new URL will be specified. With this property assigned, it is possible to have clear control of which entities/resources can execute requests to the VRE application server. Finally, the *allowedHeaders* property defines which headers are allowed when executing requests to the server. The *configure* method guarantees that all the requests are secured with authentication, with all of the specific configurations that were defined.

In conclusion, by having the authentication mechanism secured on the server-side, all the requests made to the backend need to be performed by an authenticated user, otherwise, the server will respond with a 401 (Unauthorized) HTTP response status, indicating the request was not completed because it lacks valid authentication credentials for the requested resource. On the client-side, the requests are executed passing the access token retrieved upon the login operation through the *Authorization* header. Although an interceptor was created in the Frontend Component in order to inject the access token in all the requests made to the server, the full scope of client-side authentication was not contemplated for this first iteration and it will be handled by ROSSIO's research team. Further details on this topic will be addressed in the Future Work chapter.

5

Evaluation

The process of evaluating the Virtual Research Environment was carried through a single iteration of usability tests. In the methodology section of this chapter, the evaluation forms will be presented, as well as the type of user that tested the VRE application. Following that, the usability tests' results will be analyzed alongside bar charts that resume the users answers to each question. Finally, based on the analyzed results, the limitation of the system will be identified, followed by the respective changes that should be made in order to improve the system.

5.1 Methodology

The main goal of the VRE application was to provide an intuitive workspace, where developing work and consulting digital resources could be done within the same application, instead of having to search through multiple tabs that complicate the researchers' workflow. Therefore, it was decided that the best way to evaluate the application, in order to achieve this specific goal, was to perform usability tests. These tests are meant to evaluate how intuitive and user-friendly the application is, and to verify if, overall, it is a practical solution for the challenges that arise from searching for multiple digital resources in the context of social sciences, arts, and humanities. As it was mentioned in previous chapters, the VRE should not only allow the users to do research and work on personal notes but also to work in a collaborative way by commenting and sharing resources.

Since this application has a very specific set of users, it only made sense made sense for the application to be tested by the latter. With the help of ROSSIO's research team, it was possible to organize a session where 25 users that study or work in fields within the previously mentioned areas tested the application, which included archive, libraries, history, arts and humanities, information sciences, education and communication, Portuguese studies, musicology, science management, and university lecturing. What also made this set of users a very interesting and useful sample was the fact that there were users from the age of 22 to 71 testing the application, which is also the scenario to be expected from the final application. Besides that, 54,2% claimed to be familiarized with similar platforms, which allowed them to have a term of comparison for what would be expected from the ROSSIO's virtual research environment.

The test consisted of two forms. In the first form, which can be found in Appendix B, users started by reading a description of the purpose and functionalities of the system, and filling in their personal information, which included a form id, age, gender, work field, and if they were familiar with platforms similar to a VRE. The form id is a number that was given to the users at the beginning of the test in order to know which two forms were filled by the same person while keeping the forms anonymous. After submitting their personal information, users had to perform a series of tasks in the application, for which the instructions were on the form, and, for most of the tasks, had to answer a simple question after finishing them. The UI pages where these tasks could be completed were distributed throughout the application, so the user could have a clear overview of the whole system, and test how intuitive some of the system's most vital functionalities were to complete. The instructions were as clear as possible without helping the user reach a conclusion on what he was supposed to do, leaving the completion of the task solely to intuition.

In the second form, which can be found in Appendix C, the system was firstly evaluated with a series of custom questions, divided into segments, about specific features of the application, each with five response options, from Strongly agree to Strongly disagree. The first segment was about content visualization, where there were questions about information that users could find and organize in the application, like finding the details of a digital resource, and the second segment was about content submission, where there were questions about functionalities in which the user has to submit content to the platform, like creating a folder. At the end of each segment, there was an open answer question where users could give their general feedback on the functionalities that they had previously evaluated.

After the segments containing custom questions, the usability of the system was evaluated by the System Usability Scale (SUS). SUS is an industry standard for measuring the usability of a variety of products, including applications, and can be used on small samples of users with reliable results, which was the case for this testing session. Besides that, it can effectively differentiate between usable and unusable systems. SUS consists of a 10 item questionnaire, each with five response options, from Strongly agree to Strongly disagree:

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

2. I found the system unnecessarily complex.

3. I thought the system was easy to use.

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

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

6. I thought there was too much inconsistency in this system.

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

8. I found the system very cumbersome to use.

9. I felt very confident using the system.

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

At the end of the second form there is a segment with three questions that represent the application's main goals, called Overall Appreciation, that intends to get the user's perspective on how accurately these goals were achieved.

5.2 Results Analysis

In this section, the results of the testing session will be analyzed, starting with the questions concerning the System Usability Scale, and how the results from this questionnaire were calculated and interpreted. After the SUS analysis, the results of the questions that were developed specifically for the VRE will be presented and interpreted as well.

As was mentioned previously, when completing the SUS questionnaire, participants have to rank each question from 1 to 5 on how much they agree with the statement. On this scale, 5 means strongly agree, and 1 means strongly disagree. The result of each user's score is calculated by subtracting 1 from each odd-numbered question, which corresponds to the positively worded questions, and by subtracting the value of each even number question from 5. Once all these values are gathered, they are added up and multiplied by 2,5. The result of this calculation gives us each user's score. In the table 5.1, the results of each user's SUS score are presented, as well as the min, max, and mean of all the scores.

The SUS score gives an overview of the system's usability with a value that ranges from 0 to 100, without pointing out specific flaws of the system. A score above 68 is considered above average, while a score below 68 is considered below average, indicating a system with potential usability problems. For the VRE, the average score was 77,7, which indicated that the system's usability was, overall, more than satisfactory. Another indicator of how easy the interfaces of the system were to use was that 13 out of 25 users had scores above 80. Nonetheless, there were 6 users with a score below 68, which might explain the limitations found in the system. These limitations will be approached in the next section.

User	**SUS Score**
1	87,5
2	95
3	100
4	100
5	77,5
6	70
7	85
8	85
9	67,5
10	50
11	67,5
12	82,5
13	95
14	92,5
15	80
16	75
17	75
18	35
19	67,5
20	65
21	67,5
22	90
23	82,5
24	80
25	70
Mean	**77,68**
Max	100
Min	35

Table 5.1: Results of the System Usability Scale questionnaire.

Besides the SUS, the participants also answered custom questions concerning the tasks they had previously performed. The figure 5.1 shows the answers participants gave when asked if it was easy to access the list of favorite digital resources. For most participants this task was simple, but, as the bar chart reflects, some participants did not think it was obvious. The reason behind that is the fact that the access to the list of favorite resources only has the word "Resources"with a heart above it, instead of saying "Favorite Resources".

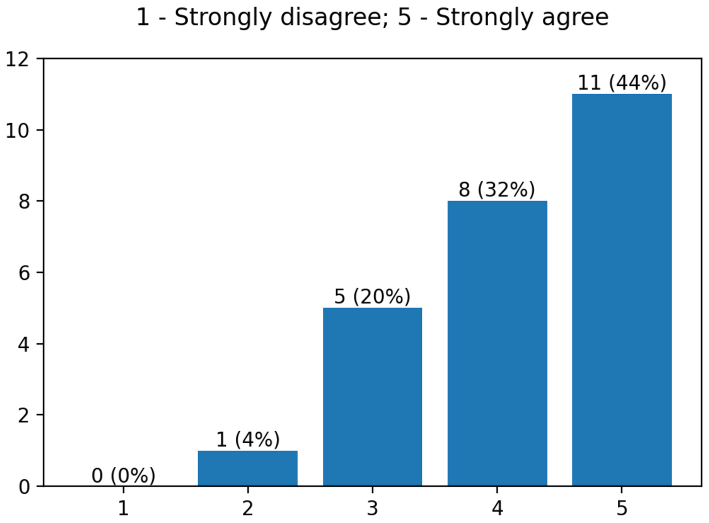


Figure 5.1: It was easy to access the list of favorite digital resources.

In figure 5.2 participants were asked if it was hard to organize digital resources, which they were asked to do in one of the tasks of the first form. Some users did not think this task was very intuitive, but in the end, all of them were able to complete the task. In a real scenario, it would only be a matter of getting used to the system.

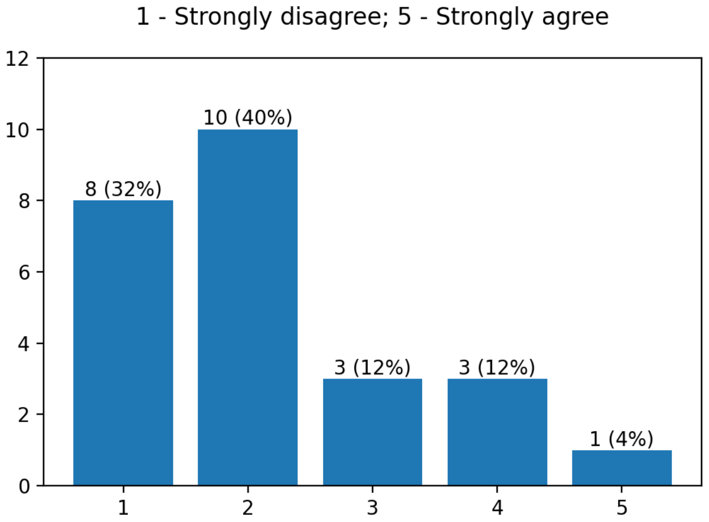


Figure 5.2: It was hard to organize digital resources in folders.

Next are the answers to whether participants though it was easy to access the details of a digital resource. As it is presented in figure 5.3, this was an easy and intuitive task for most participants, since 80% of the participants agreed with this statement.

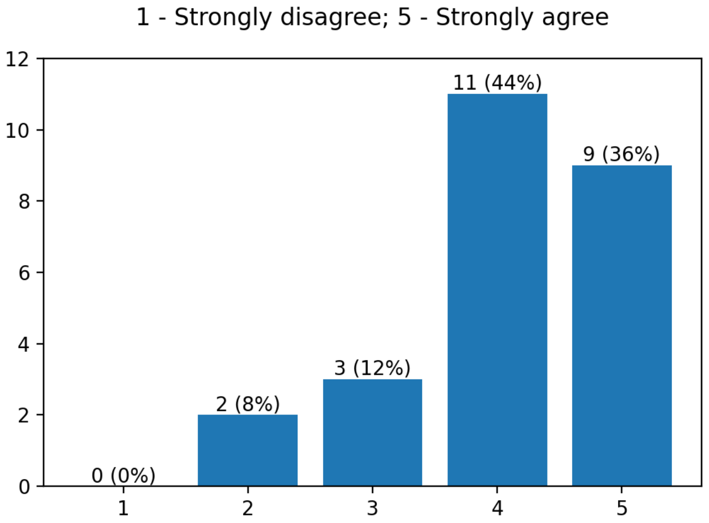


Figure 5.3: It was easy to find the details from a digital resource.

In figure 5.4, participants were asked if it was hard to see the details of their last visit to the website. This task might not have been very clear, since it was a hypothetical scenario about the user they logged in the system with, and not the participant's actual last visit, which was none since this was their first time using the system. Besides that, the size of the text where they could consult these details was too small to be easily noticed.

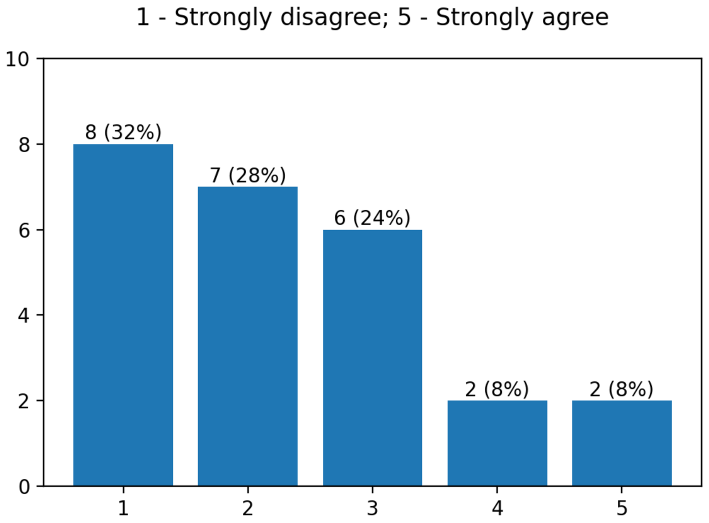


Figure 5.4: It was hard to see the details of the last visit of the website.

Figure 5.5 has the answers to whether the participants thought it was easy to find the notes created by the authenticated user and figure 5.6 asked if it was easy to consult digital resources shared with the authenticated user. These two questions were both tasks that only required participants to find information on the platform, which seemed pretty intuitive for all of them since none disagreed with either statement.

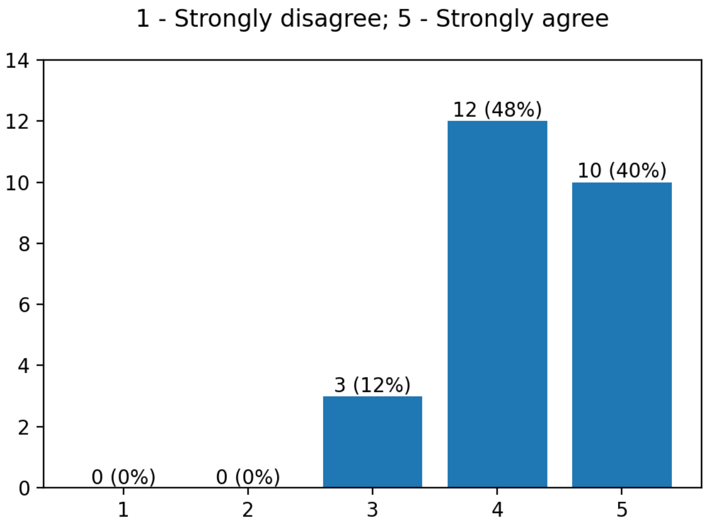


Figure 5.5: It was easy to find the notes created by the authenticated user.

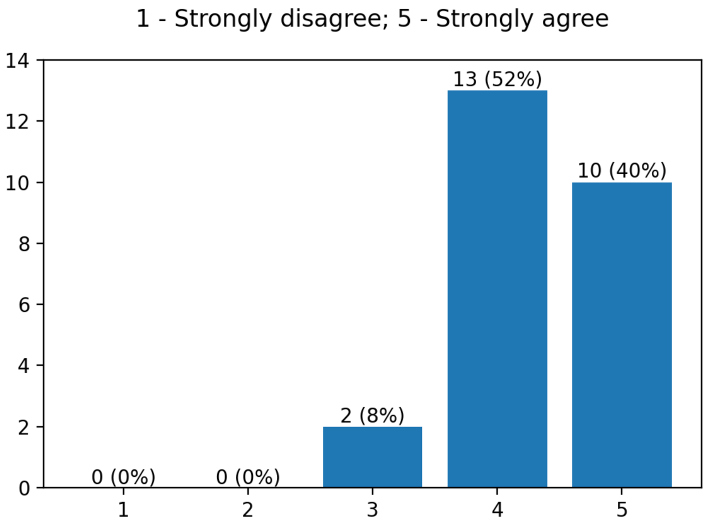


Figure 5.6: It was easy to consult digital resources shared with the authenticated user.

Next, in figure 5.7, participants were asked if they thought that adding a digital resource to the list of favorites was easy. This was a relatively intuitive task for most participants because it's an action similar to liking a post on social media, something that, nowadays, most users are used to doing.

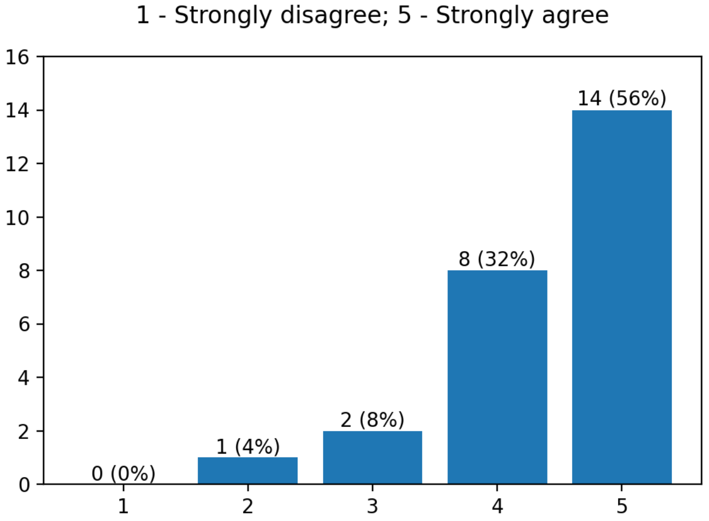


Figure 5.7: It was easy to add a digital resource to the list of favorites.

In figure 5.8, are the answers to whether the participants thought it was hard to create a folder. For most participants, creating a folder was one of the easiest, and most straightforward, tasks, as it is possible to see in the bar chart, where 64% of the answers to the statement were "Strongly disagree".

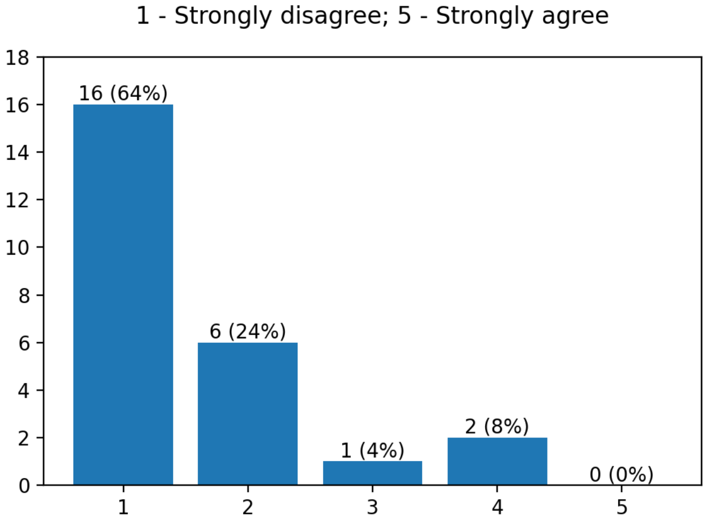


Figure 5.8: It was hard to create a folder.

Next, in figure 5.9, participants were asked if it was easy to edit the authenticated user's data. Although every participant was able to complete the task, and none disagreed with the statement, the number of answers with the value 3 reveal the small issue some participants had with the iconography of the website.

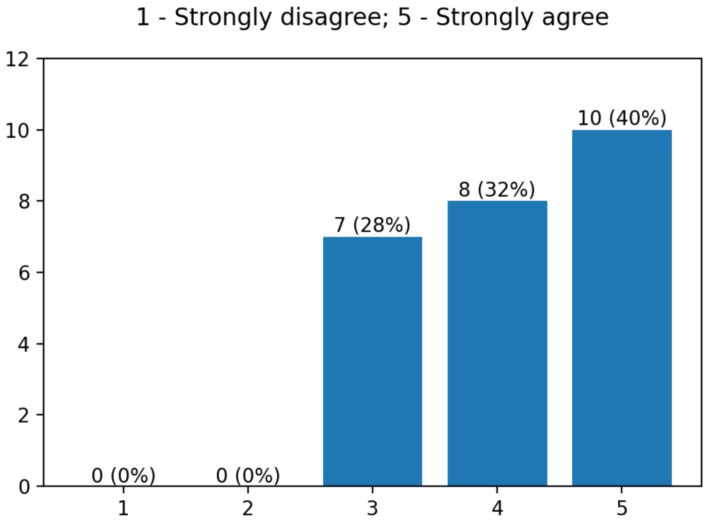


Figure 5.9: It was easy to edit the authenticated user's data.

In figure 5.10 are the answers to whether the participants thought it was hard to create a personal note. Although this seemed to be an uncomplicated task for most participants, two disagreed with the statement, which is very likely related to the positioning of the button in the notes pages, and once again with the size of the text.

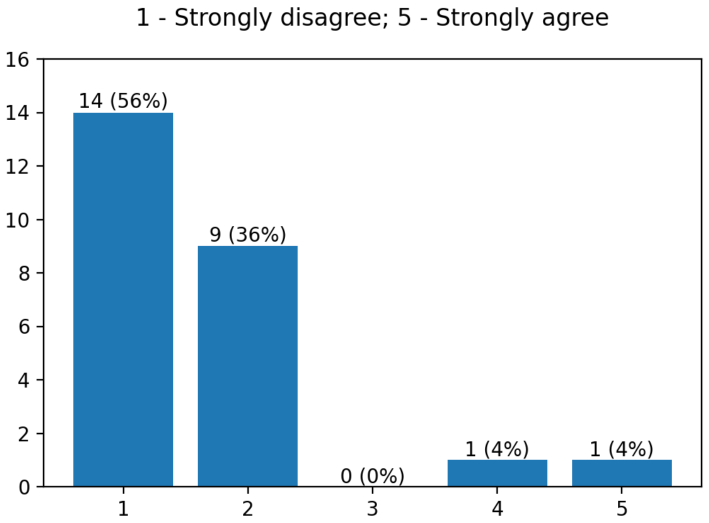


Figure 5.10: It was hard to create a personal note.

Next, participants were asked if it was hard to add an annotation to a resource shared with the logged user, a statement for which the answers are present in 5.11. Most participants thought it was intuitive, but some did not agree, which might be due to the fact that this task involved two steps, first entering the resource card, and then adding the annotation.

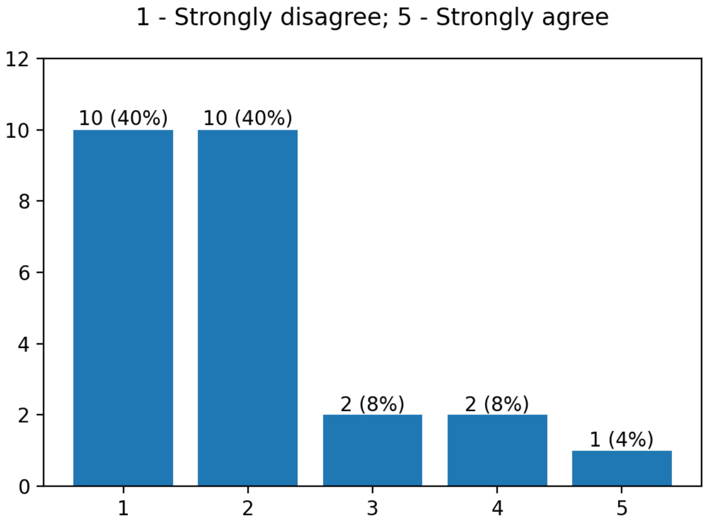


Figure 5.11: It was hard to add an annotation to a resource shared with the logged user.

The last three statements were about the system's overall features and main goals, and were meant to give an overview of the participants' opinions about the system. In figure 5.12, are the answers to whether the participants consider the application a practical solution for Researchers in the areas of Social Sciences, Arts, and Humanities to develop work, where 80% agree with the statement. This bar chart reveals how much of a contribution this platform would be for researchers, while also showing that even if some researchers are still not willing to give up on their current practices, this website is a tool that is lacking to the researchers in these areas.

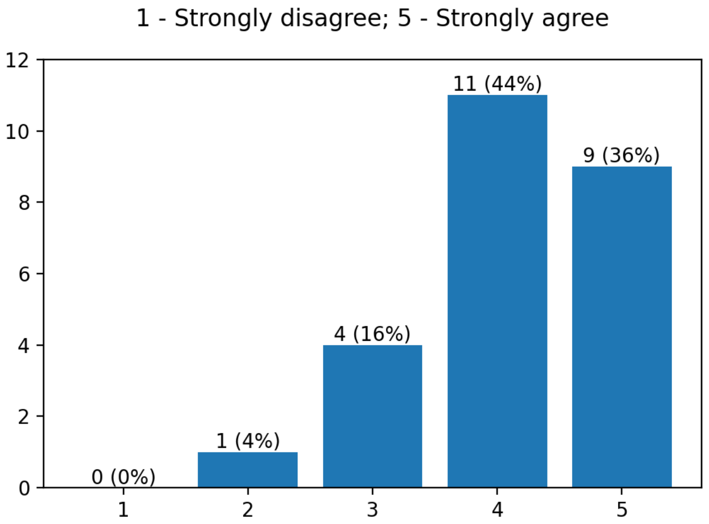


Figure 5.12: I consider the application a practical solution for Researchers in the areas of Social Sciences, Arts and Humanities to develop work.

The statement corresponding to 5.13 was meant to evaluate the collaborative aspect of the VRE. All of the users agreed that commenting on specific resources and notes is helpful to work in a collaborative way, which once again proves the usefulness of this application.

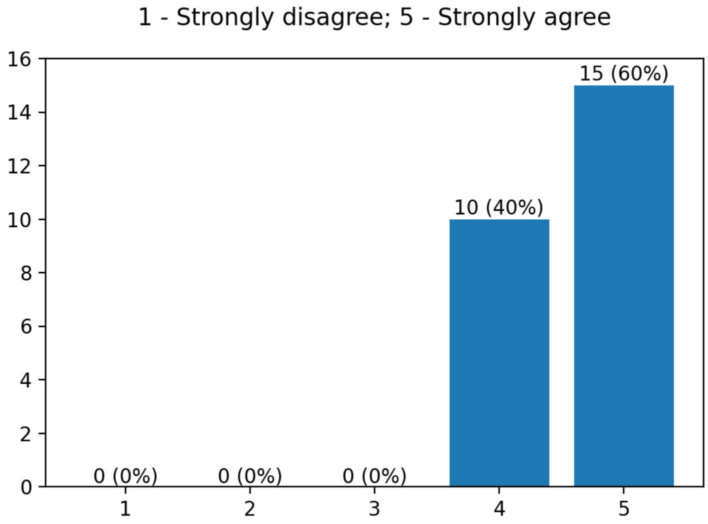


Figure 5.13: I think the possibility to comment on specific resources and notes is helpful to work in a collaborative way.

Finally, figure 5.14, participants were asked if they thought the application is useful to save and organize digital resources, which was one of ROSSIO's main goals, and according to the answers, where 80% of the participants agree with the statement, and none disagree, the VRE website is a solid solution to search for digital resources from multiple providers.

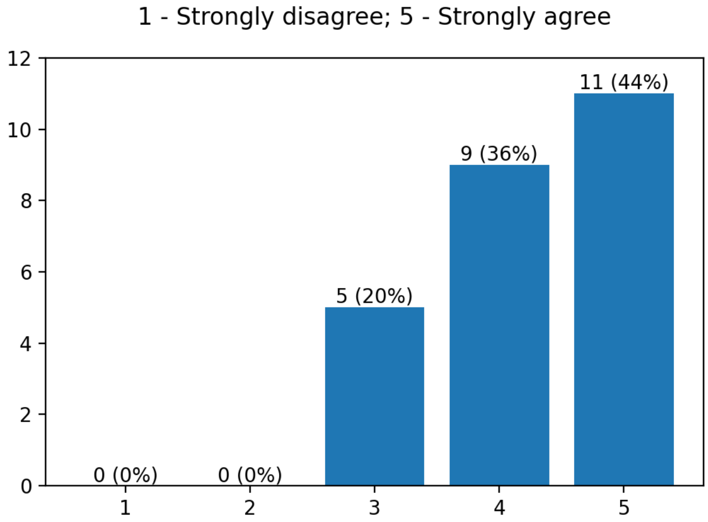


Figure 5.14: I think the application is useful to save and organize digital resources.

As well as the SUS scores, the results of the custom questions manifest the usability of the system. Overall, it was clear that the users considered the system intuitive and useful for their daily activities, and that it would a helpful contribution to their research work.

5.3 Limitations and Proposed Changes

During the usability tests, there were some limitations detected in the application, as well as on the flow of specific tests. From all the limitations that surfaced from the testing session, the ones that were detected by multiple users automatically became proposed changes. The reason behind that is the fact that these were all considered either small changes or crucial aspects that should be improved, that could not have been detected without a testing session. It was also possible to conclude that the problems with the UI were not related to the age or area of activity of the users, or even with how experienced the users were with this kind of platform. This meant that the main problems had nothing to do with the learnability of the system or with the kind of user that was testing it, but rather with how intuitive the tests were to complete. According to the answers given in the open questions of the tests that were analyzed in the previous section, here are the proposed changes that should be applied to the system:

- Improve consistency in the terms used to described the resource's metadata.

  During the testing session, a lot of users had difficulties differentiating between a resource's original date, which is a part of each resource's metadata, and the date of insertion of that same resource in the user's list of favorite resources. That issue was solved by the end of the testing session by changing the field name of the date of insertion to "Date of Insertion"in the favorite resource's list, and leaving the resource's original date as "Date"inside the resource card.

- Use tooltips to help describe the behaviour associated with most icons.

  The VRE was designed to be a compact environment, where the user could find multiple useful functionalities on the same page, usually associated and accessible through an icon. While this is a benefit in terms of productivity and work efficiency, it can be overwhelming for a new user until he gets familiar with the iconography. For that reason, it was proposed that icons should have tooltips.

- Increase size of the icons and the text in all the pages.

  Another issue that was not detected while developing the application was that the size of the icons and text of the application, in general, was too small for the users to navigate the pages comfortably. Thanks to the framework used to develop the frontend component, Angular, and to the way the pages are structured, that problem should be easy to solve in the future.

- Improve accessibility to the resources page.

  During the design stage of the application, it was decided that a digital resource's card would be accessible through an icon. As it was mentioned in a previous point, the icons were not always intuitive for the users. Although this problem can also be solved with a tooltip, for the resource's specific case there was a better, more intuitive solution, that was also implemented immediately. In the favorite resources list or the list that appears after a user searches a term on the platform, the whole line of the resource was made clickable to access the resource, instead of only the icon.

6

Conclusions and Future Work

In this chapter, the final conclusions concerning each chapter will be presented, as well as some ideas on how the work should progress from its current state. Moreover, there will be an analysis on whether the objectives of the dissertation were achieved.

6.1 Conclusion

The purpose of this dissertation was to implement a Virtual Resarch Environment for The ROSSIO Infrastructure. This VRE should make the work of researchers in the Humanities, Arts, and Social Sciences easier, by providing the tools that are most useful for a researcher in a single workplace. Besides that, this project also intended to create an entry point for the metadata gathered by ROSSIO from their multiple collaborators, which should be integrated into the search segment of this application in the future.

By the end of the practical development of this application, one can say that core functionalities of the backend component, according to the specification stated at the beginning of the project, were implemented, as well as the main frontend pages that will be a part of the platform, as they were designed by ROSSIO's research team. All of these aspects were thoroughly explained in the Specification and Implementation chapters, where an overview of the system's functionalities and how they were implemented, and displayed, is presented. Besides that, this chapter also gives insight into ROSSIO's role in the development of the project.

Once developed, the application was evaluated in a testing session, where usability tests were performed by 25 participants that work or study in the targeted areas of activity. These tests provided a lot of positive feedback about the application and led to the conclusion that the application is a helpful contribution to the research and work of its target users. Not only did these tests confirm how much this environment was a missing part of the researchers' daily activities, but also motivated the team to improve and complete the application in its future iterations.

At the final stage of this dissertation, it's fair to say that the objectives and expected contributions set at the beginning of this process, of creating a Virtual Research Environment for ROSSIO, designing and evaluating an intuitive UI, shielded from the system's complexity, and developing a helpful workspace for researchers, were achieved.

6.2 Future Work

This dissertation comprised the first iteration of a full-fledged application, and although the core structure is nearly finished, there are still some functionalities and technical improvements that should be addressed in the future. Some of the most relevant improvements for the future include the API that ROSSIO's research team was working on, the authentication mechanism on the client-side, the management of different user roles to match the scalability of the VRE application, and a clear definition of the project infrastructure when it comes to the several environments that are related with the software development life cycle (Development, Testing, UAT, Production, e.g.), as well as its deployment. As it was mentioned in subsection 3.2.1, ROSSIO's research team is currently developing an API responsible for retrieving data provided by several project partners in a user-friendly format. Since the development of such API is still ongoing, its integration with the VRE application will need to be covered in order to achieve the expected outcome.

Concerning the authentication mechanism that was implemented, there are still some improvements that need to be done on the client side. Although the server-side is already integrated with Keycloak, the chosen identity provider, and validating tokens, as well as retrieving a proper response, the client-side is lacking a mechanism to communicate with Keycloak in order to fetch the token when a successful login occurs, and also to perform more advanced functionalities, such as the silent refresh of the tokens or the login operation with SSO. From a technical perspective, there are some open-source libraries that were studied and that are able to integrate such capabilities, but that is a topic that still needs to be addressed, and for now, only the basic functionalities concerning the login process were specified as requirements.

The authorization mechanism was something that was not addressed in this dissertation, because it was clearly defined that for the first iteration of the VRE application, there would be only one role, corresponding to a common user. Since the further goal is to have users with different privileges and even a back-office where an administrator could make changes to the resources displayed in the VRE application, it makes sense to address this topic. Keycloak also provides several features concerning authorization, thus it might be a reliable starting point for that matter.

In a more infrastructure-related topic, the further integration and deployment of the VRE application is something that needs to be specified and implemented. In this first iteration, the only environment used was for development, but it is important to define which environments should be created later on, as the application will eventually reach its production stage, thus being available on the internet. More than that, the deployment process itself was something that was not addressed, and it is of great importance to define which solution might be a better fit for the VRE application since there is a wide range of options concerning hosting, and even some cloud-based solutions such as Microsoft Azure or AWS.

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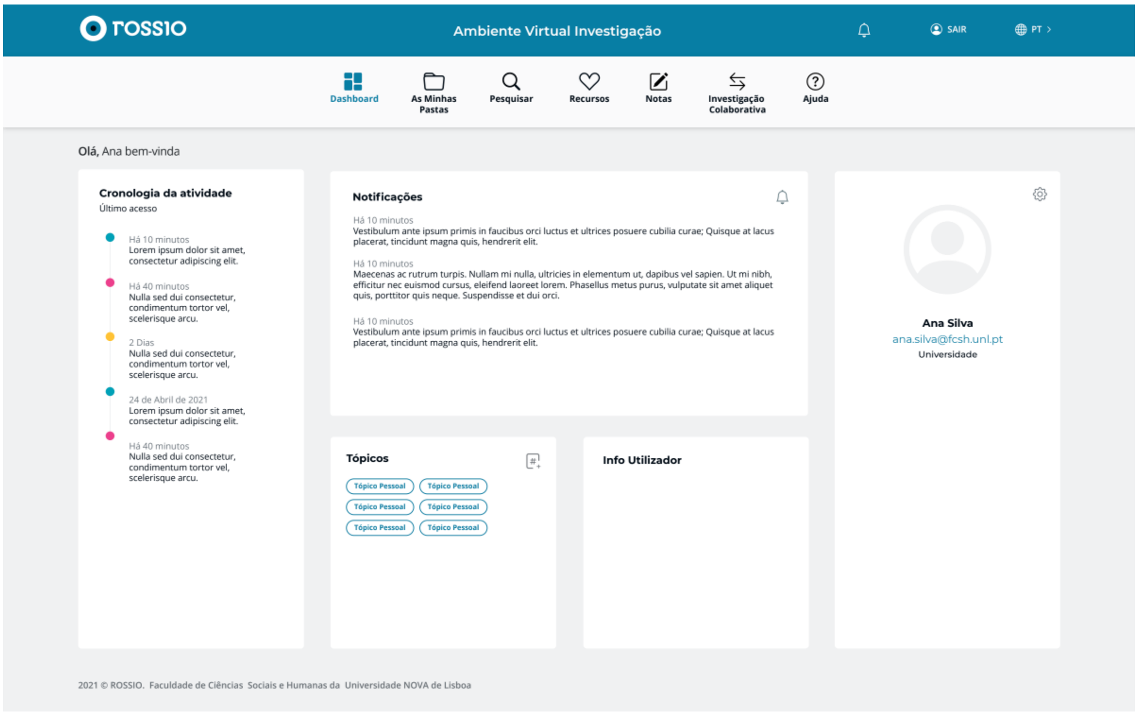
A

Appendix 1 Design



Olá, Ana bem-vinda

Cronologia da atividade

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Info Utilizador

Ana Silva
ana.silva@fcsh.unl.pt
Universidade

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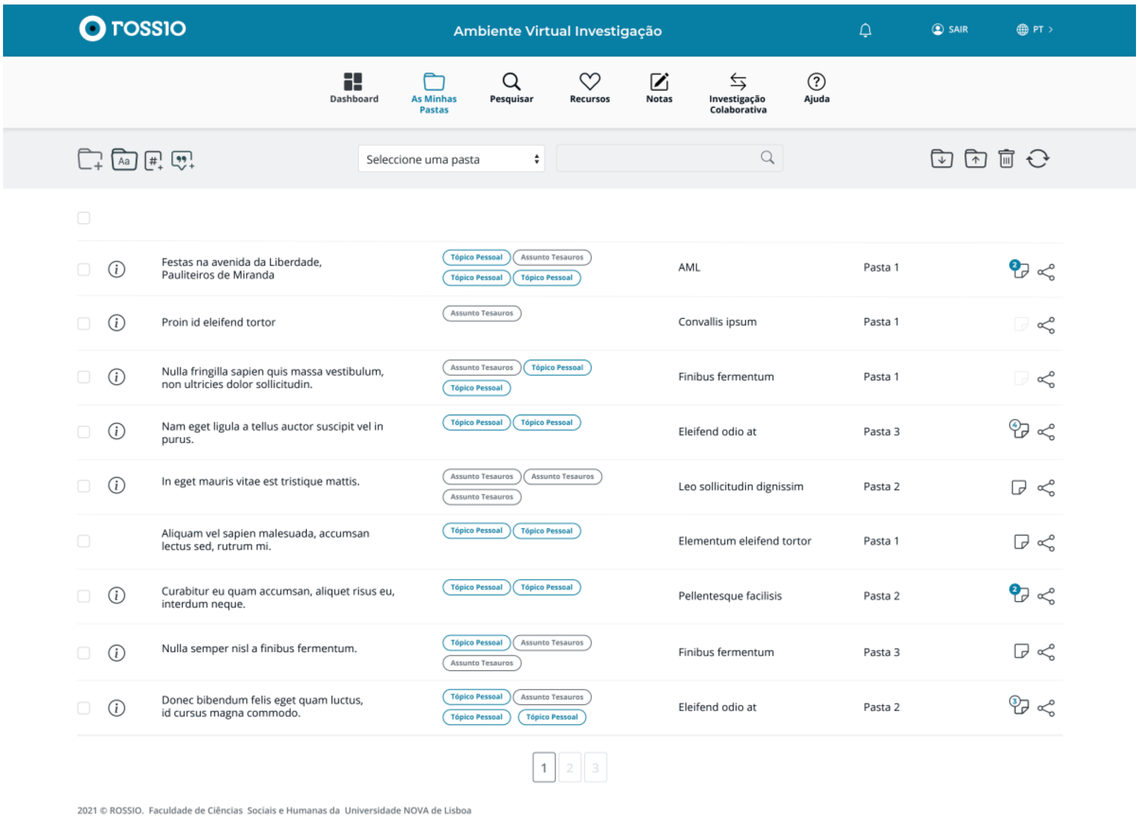

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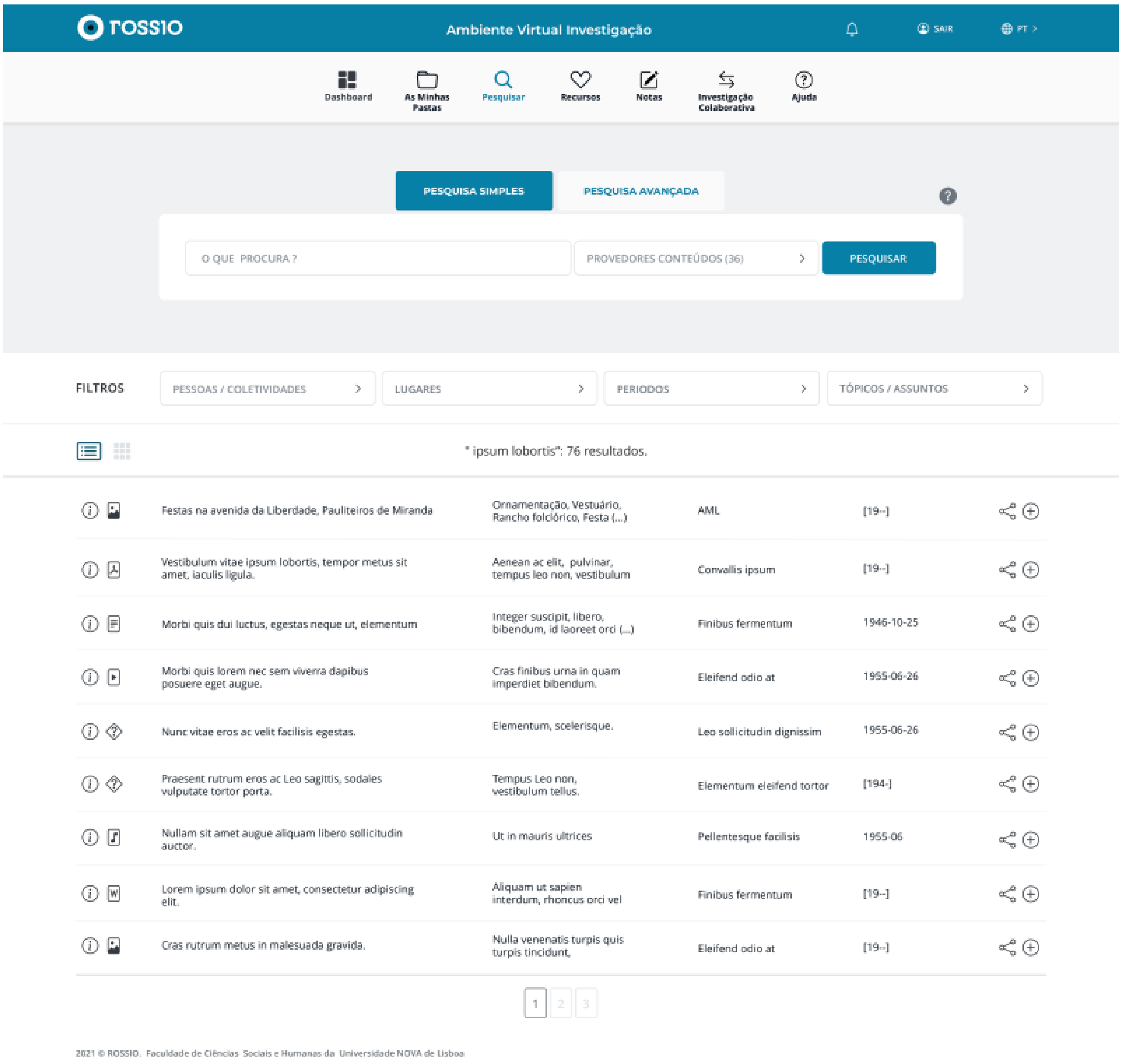

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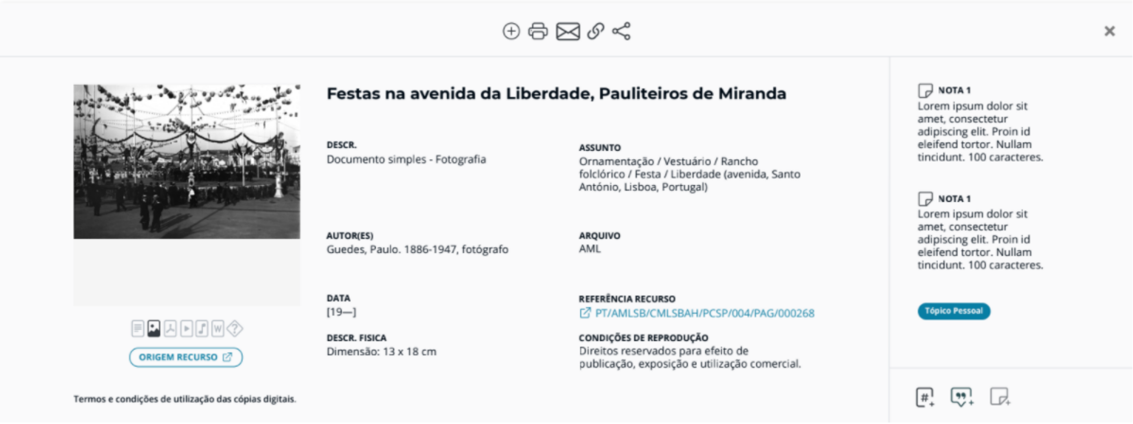

Festas na avenida da Liberdade, Pauliteiros de Miranda

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Documento simples - Fotografia

ASSUNTO
Ornamentação / Vestuário / Rancho folclórico / Festa / Liberdade (avenida, Santo António, Lisboa, Portugal)

AUTOR(ES)
Guedes, Paulo. 1886-1947, fotógrafo

ARQUIVO
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DATA
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PT/AMLSB/CMLSBAH/PCSP/004/PAG/000268

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CONDIÇÕES DE REPRODUÇÃO
Direitos reservados para efeito de publicação, exposição e utilização comercial.

Termos e condições de utilização das cópias digitais.

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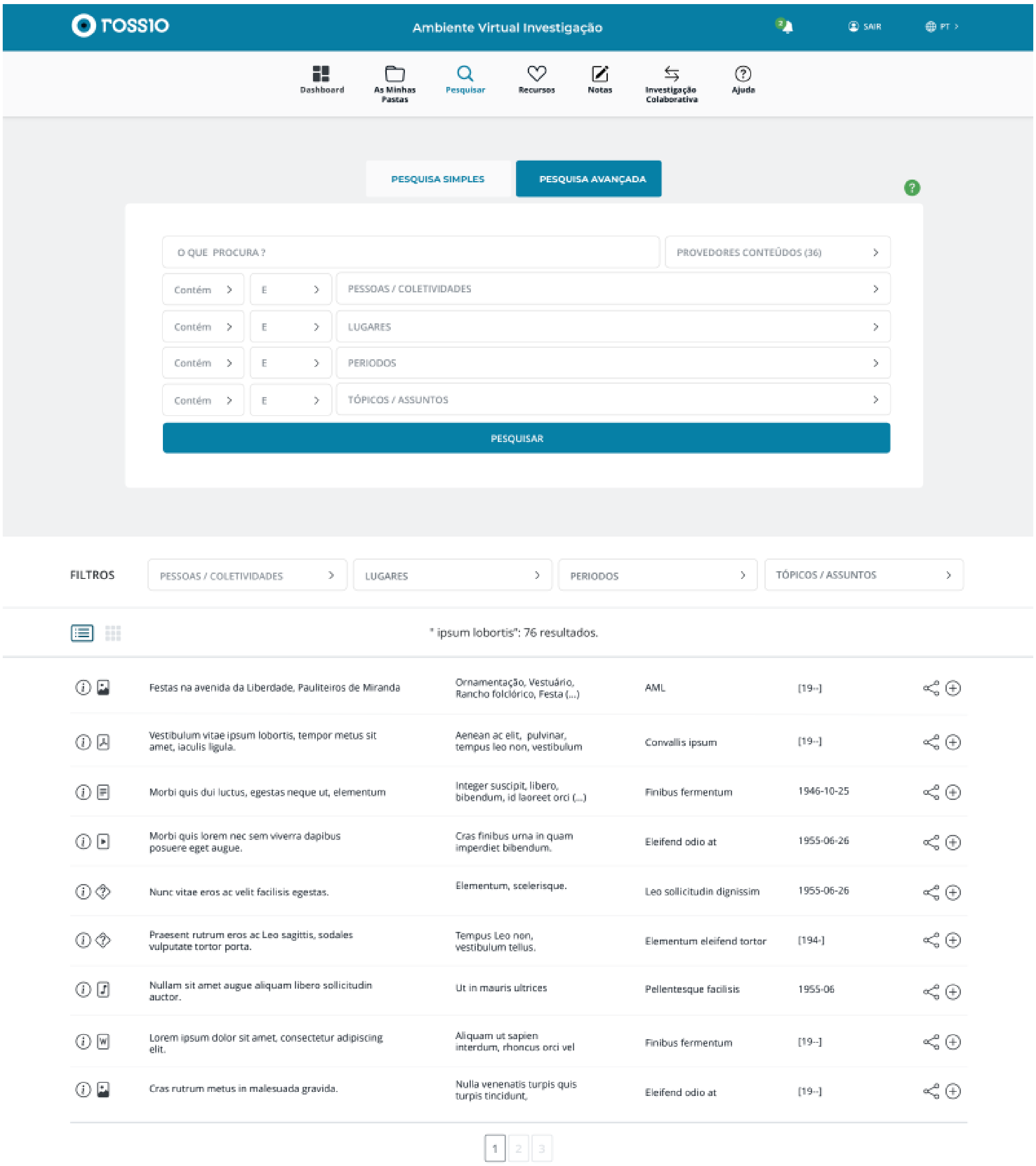

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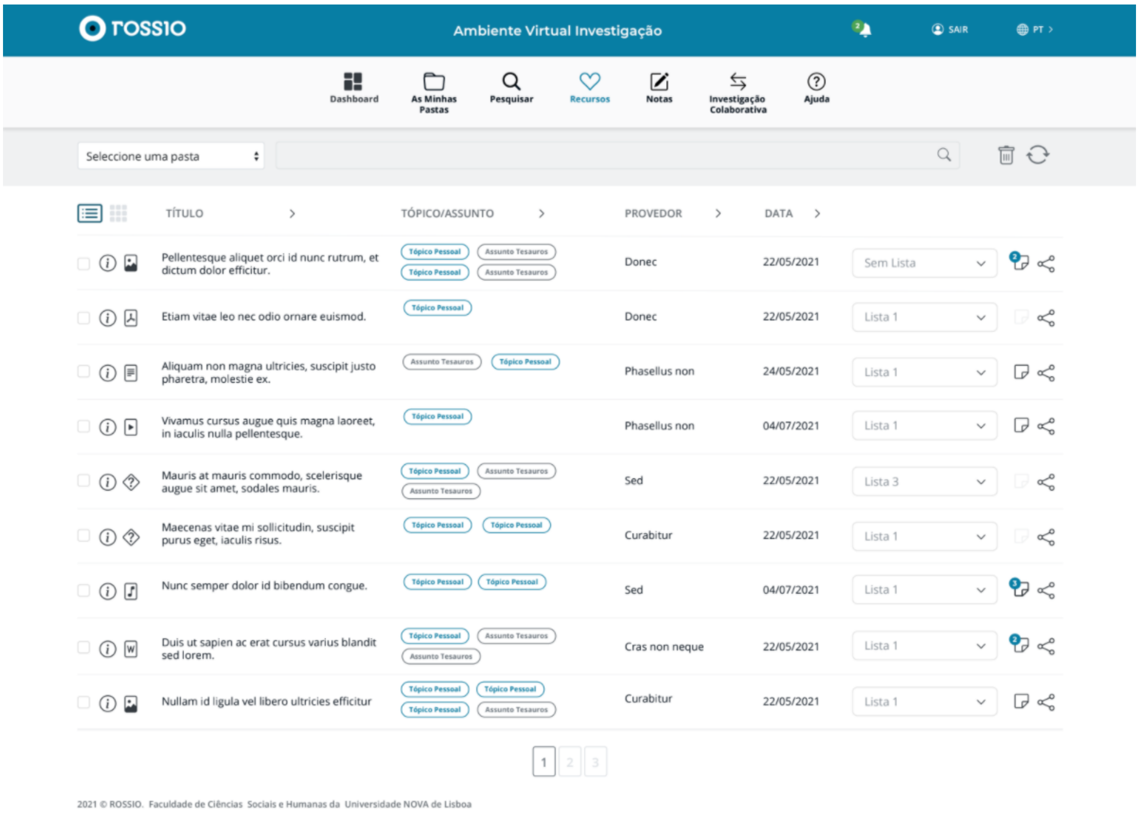

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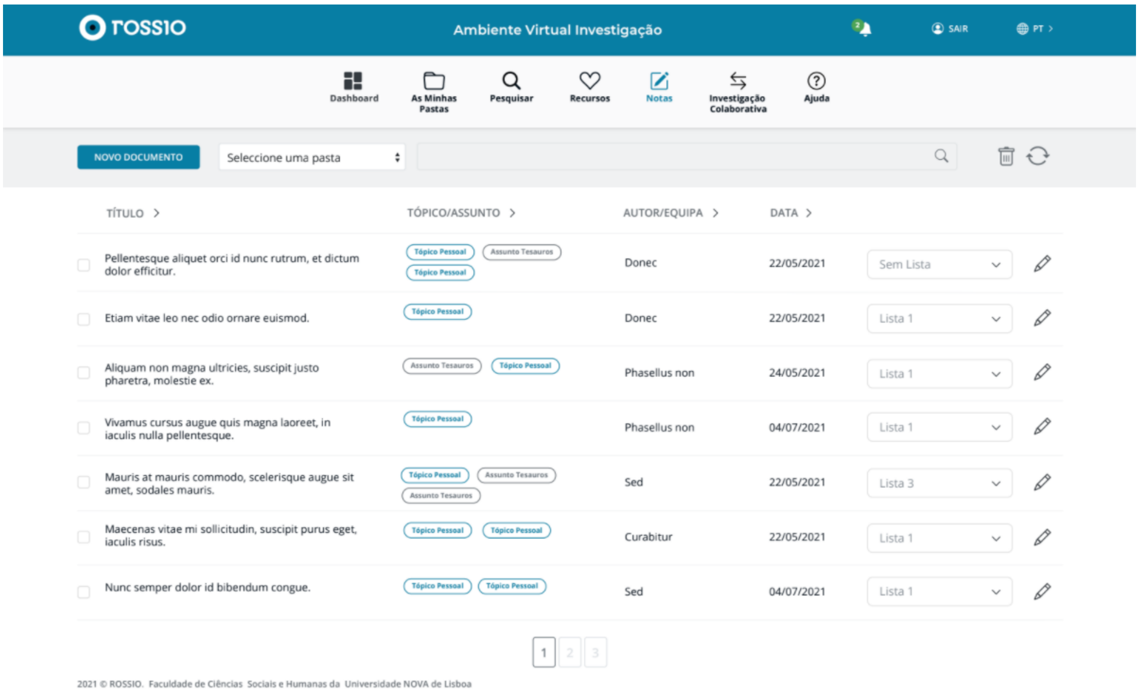

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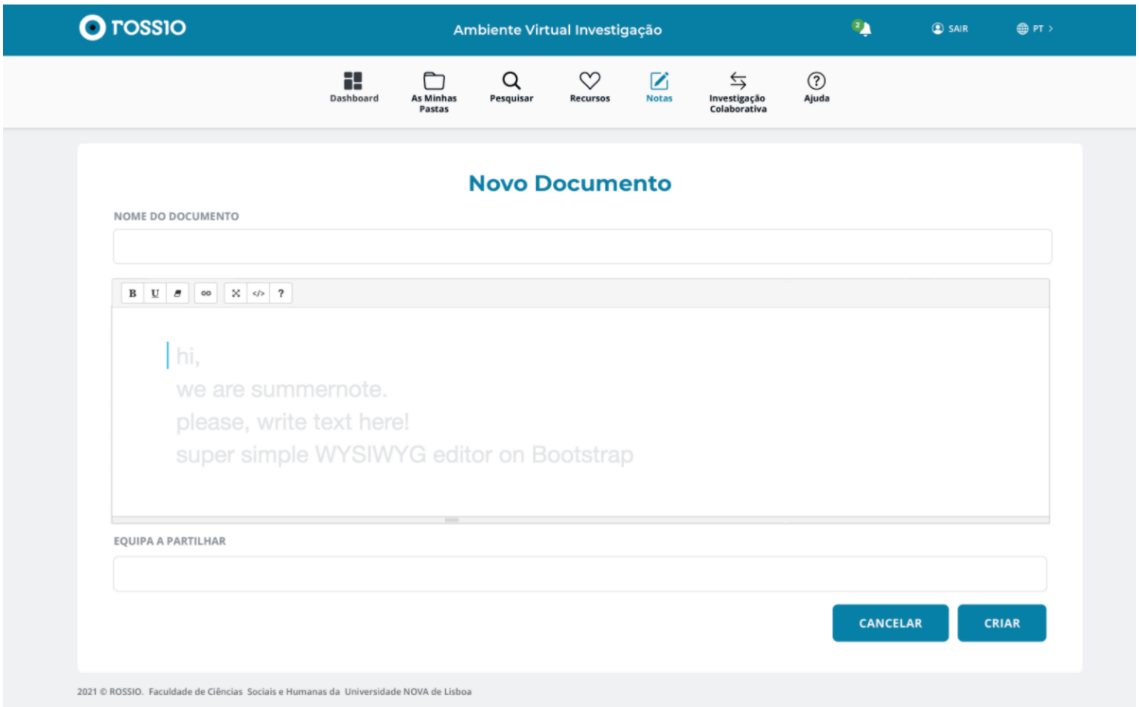

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NOME DO DOCUMENTO

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EQUIPA A PARTILHAR

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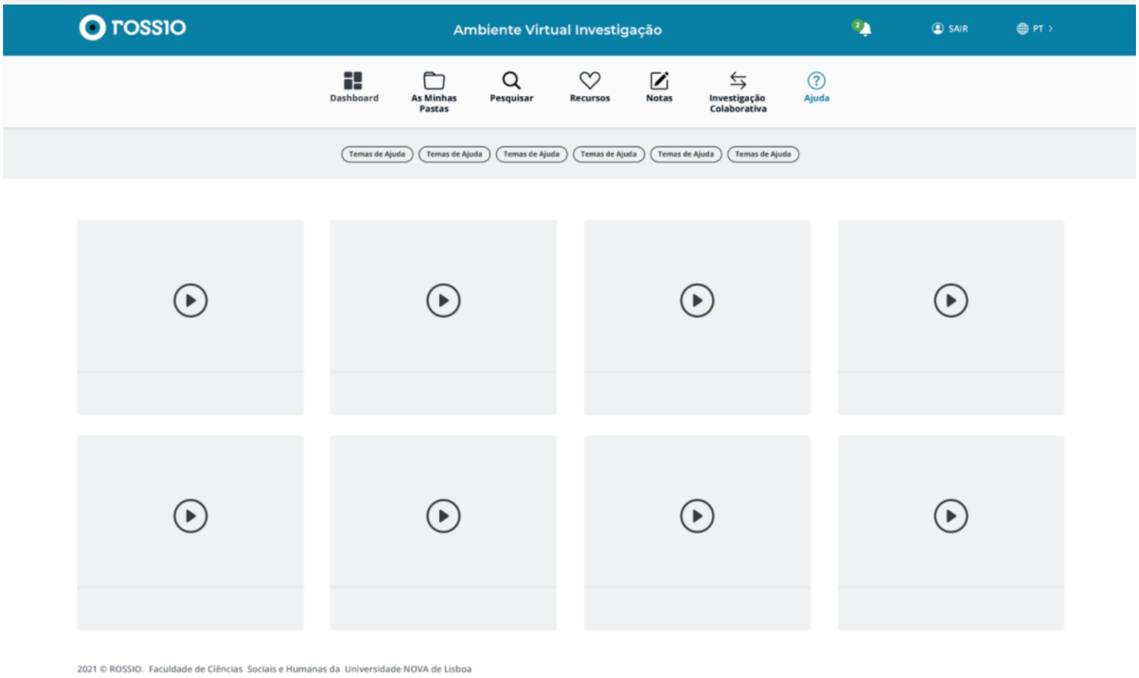

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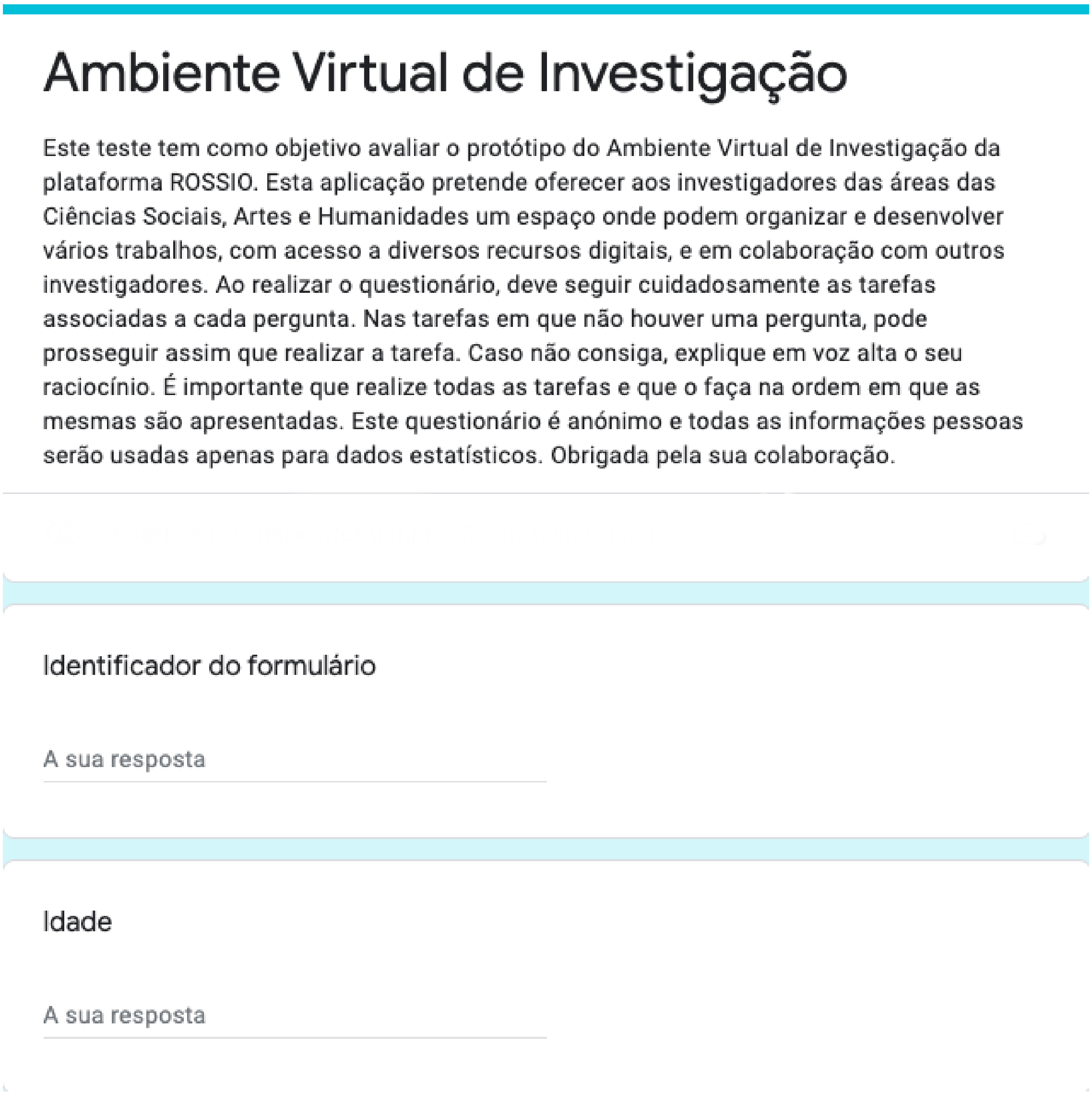
B

Appendix 2 Usability Tests



Ambiente Virtual de Investigação

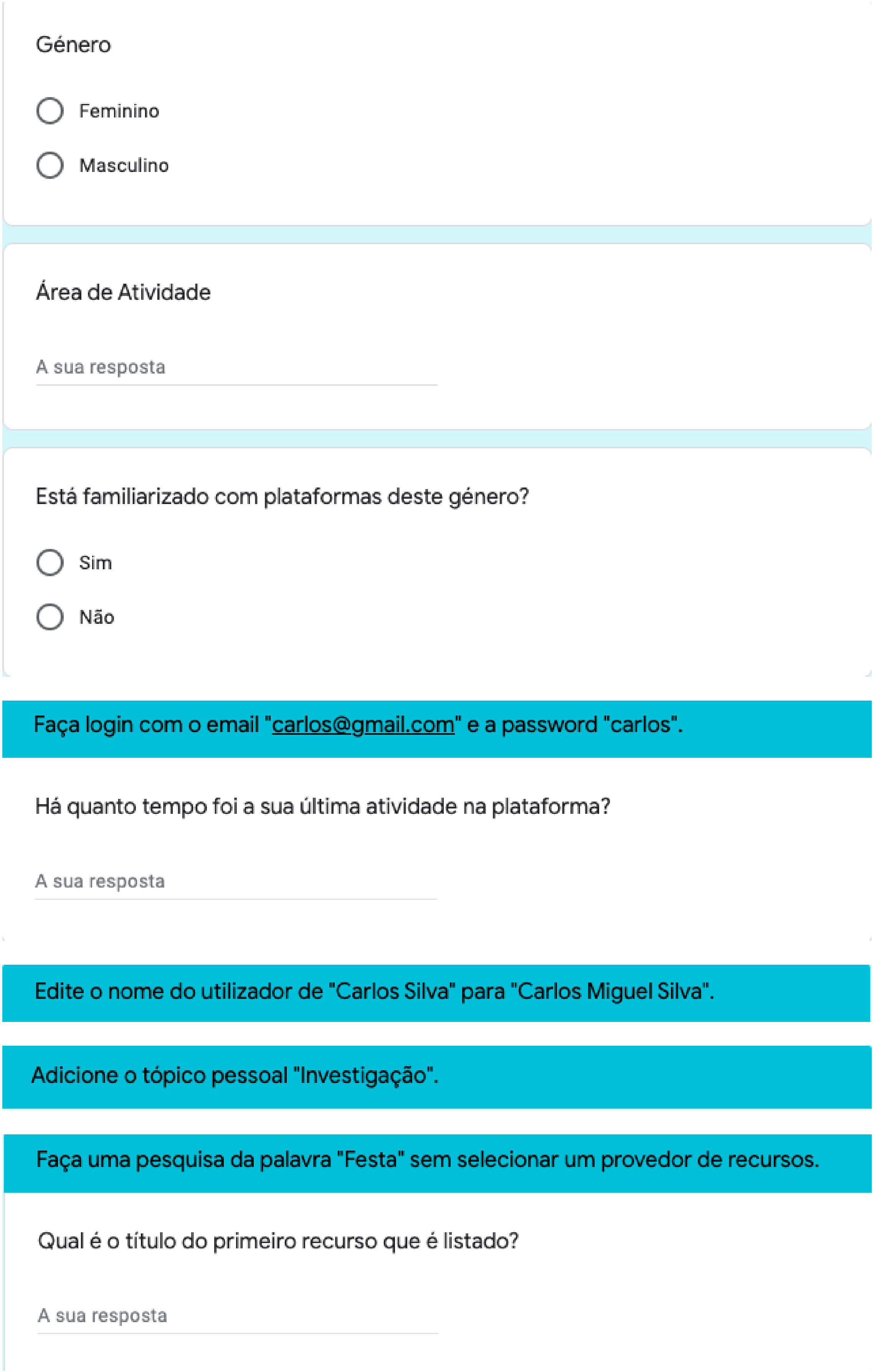
Este teste tem como objetivo avaliar o protótipo do Ambiente Virtual de Investigação da plataforma ROSSIO. Esta aplicação pretende oferecer aos investigadores das áreas das Ciências Sociais, Artes e Humanidades um espaço onde podem organizar e desenvolver vários trabalhos, com acesso a diversos recursos digitais, e em colaboração com outros investigadores. Ao realizar o questionário, deve seguir cuidadosamente as tarefas associadas a cada pergunta. Nas tarefas em que não houver uma pergunta, pode prosseguir assim que realizar a tarefa. Caso não consiga, explique em voz alta o seu raciocínio. É importante que realize todas as tarefas e que o faça na ordem em que as mesmas são apresentadas. Este questionário é anónimo e todas as informações pessoas serão usadas apenas para dados estatísticos. Obrigada pela sua colaboração.

Identificador do formulário

A sua resposta

Idade

A sua resposta



Género

○ Feminino

○ Masculino

Área de Atividade

A sua resposta

Está familiarizado com plataformas deste género?

○ Sim

○ Não

Faça login com o email "carlos@gmail.com" e a password "carlos".

Há quanto tempo foi a sua última atividade na plataforma?

A sua resposta

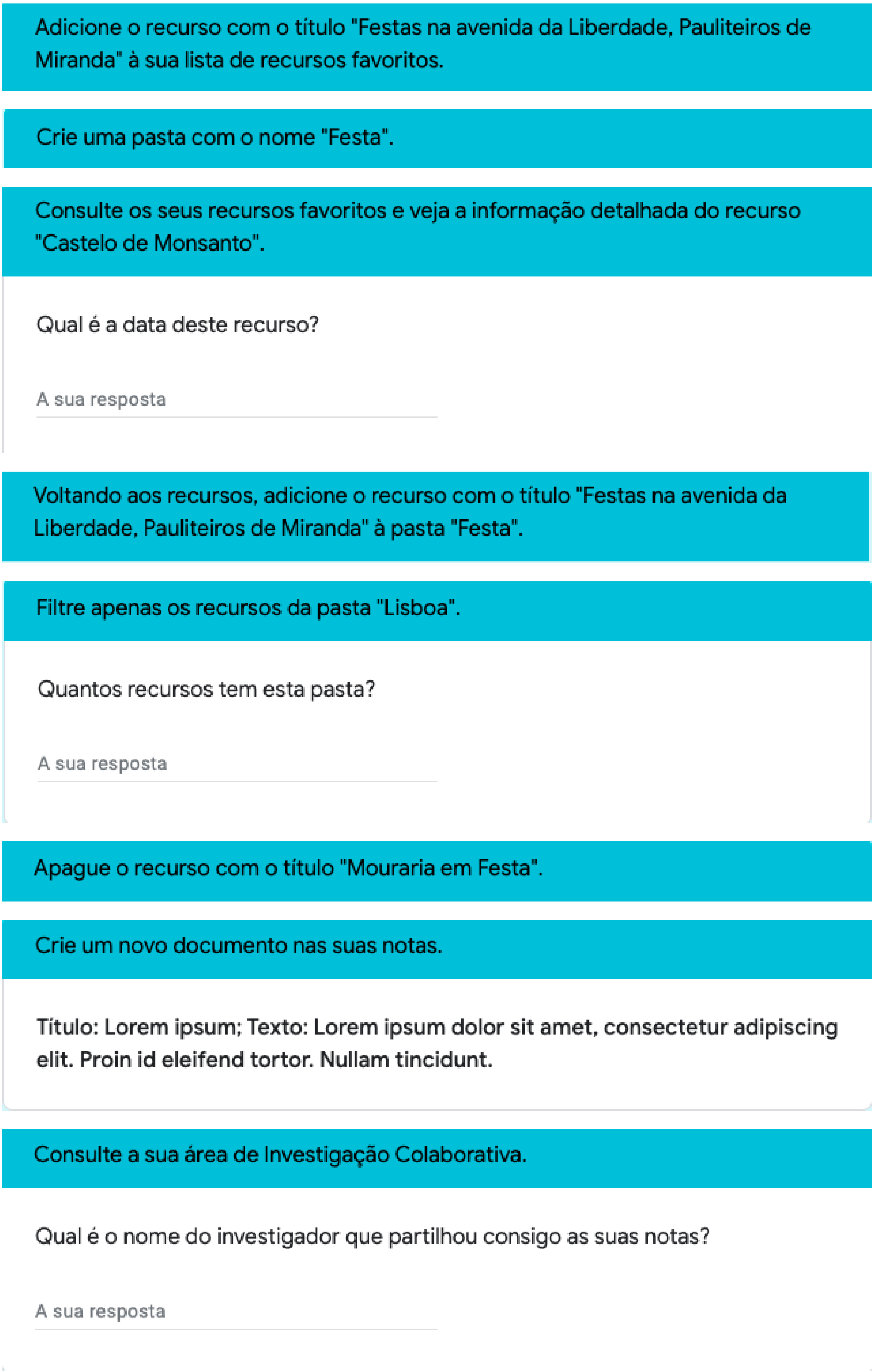
Edite o nome do utilizador de "Carlos Silva" para "Carlos Miguel Silva".

Adicione o tópico pessoal "Investigação".

Faça uma pesquisa da palavra "Festa" sem selecionar um provedor de recursos.

Qual é o título do primeiro recurso que é listado?

A sua resposta



Adicione o recurso com o título "Festas na avenida da Liberdade, Pauliteiros de Miranda" à sua lista de recursos favoritos.

Crie uma pasta com o nome "Festa".

Consulte os seus recursos favoritos e veja a informação detalhada do recurso "Castelo de Monsanto".

Qual é a data deste recurso?

A sua resposta

Voltando aos recursos, adicione o recurso com o título "Festas na avenida da Liberdade, Pauliteiros de Miranda" à pasta "Festa".

Filtre apenas os recursos da pasta "Lisboa".

Quantos recursos tem esta pasta?

A sua resposta

Apague o recurso com o título "Mouraria em Festa".

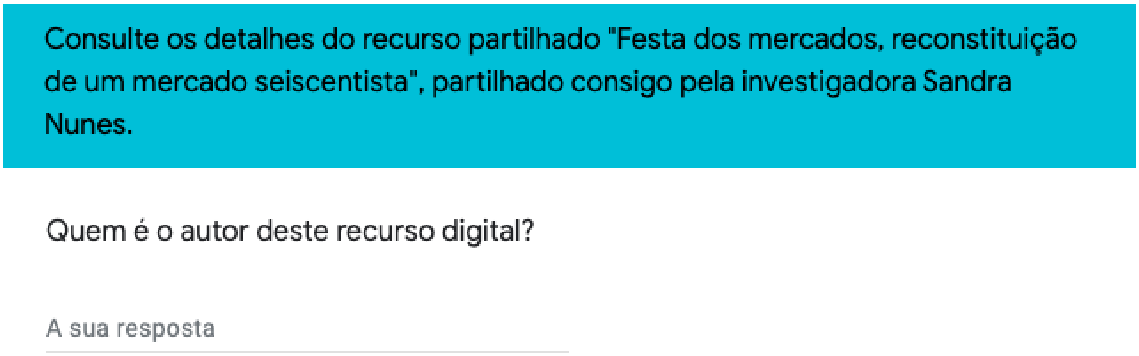
Crie um novo documento nas suas notas.

Título: Lorem ipsum; Texto: Lorem ipsum dolor sit amet, consectetur adipiscing elit. Proin id eleifend tortor. Nullam tincidunt.

Consulte a sua área de Investigação Colaborativa.

Qual é o nome do investigador que partilhou consigo as suas notas?

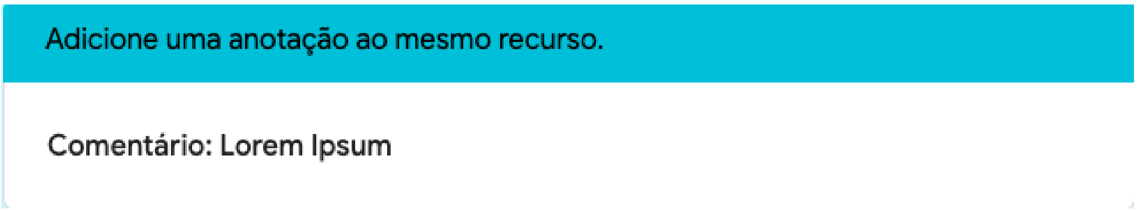
A sua resposta



Consulte os detalhes do recurso partilhado "Festa dos mercados, reconstituição de um mercado seiscentista", partilhado consigo pela investigadora Sandra Nunes.

Quem é o autor deste recurso digital?

A sua resposta

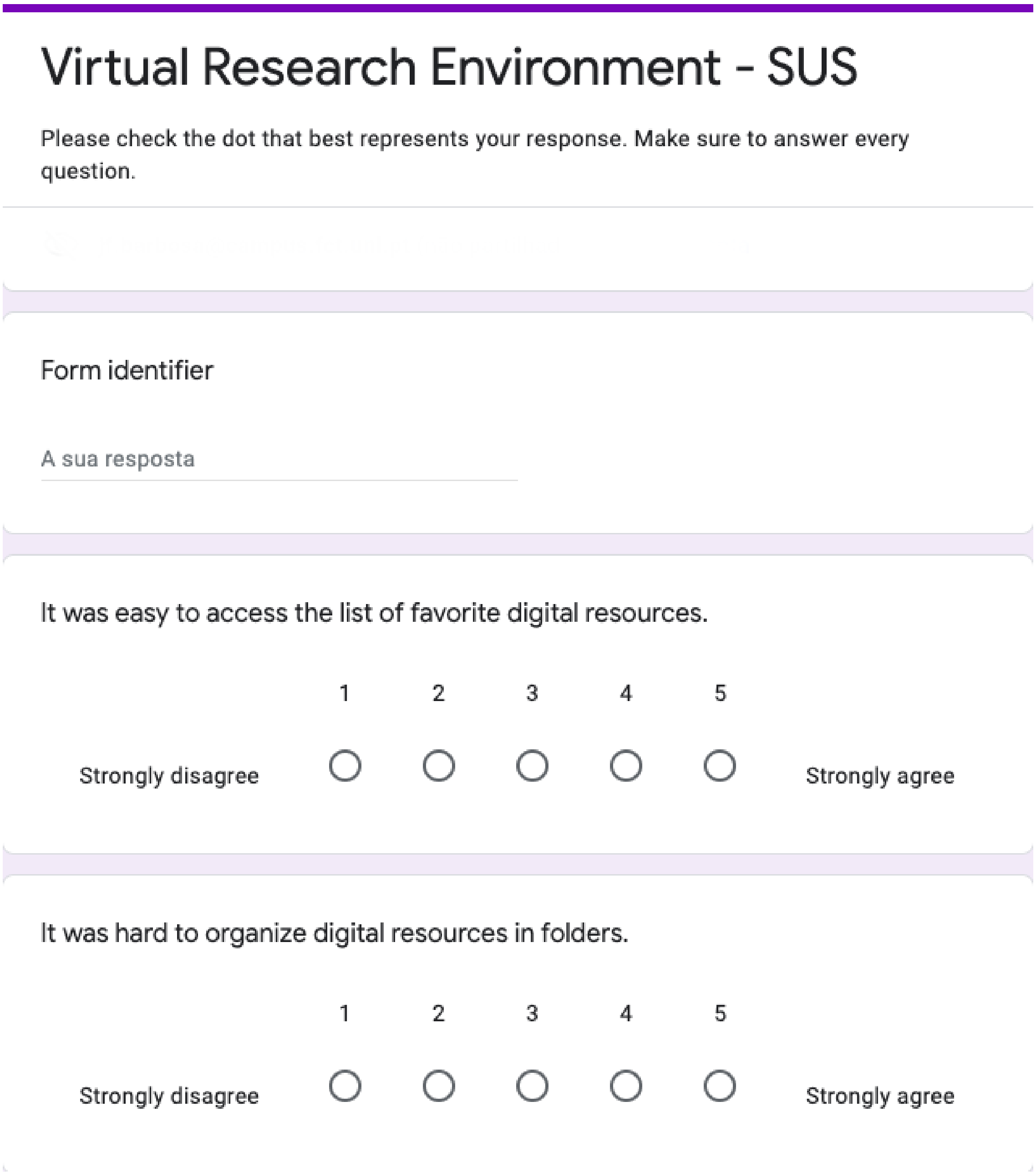


Adicione uma anotação ao mesmo recurso.

Comentário: Lorem Ipsum

C

Appendix 3 Evaluation Questionnaire



Virtual Research Environment - SUS

Please check the dot that best represents your response. Make sure to answer every question.

Form identifier

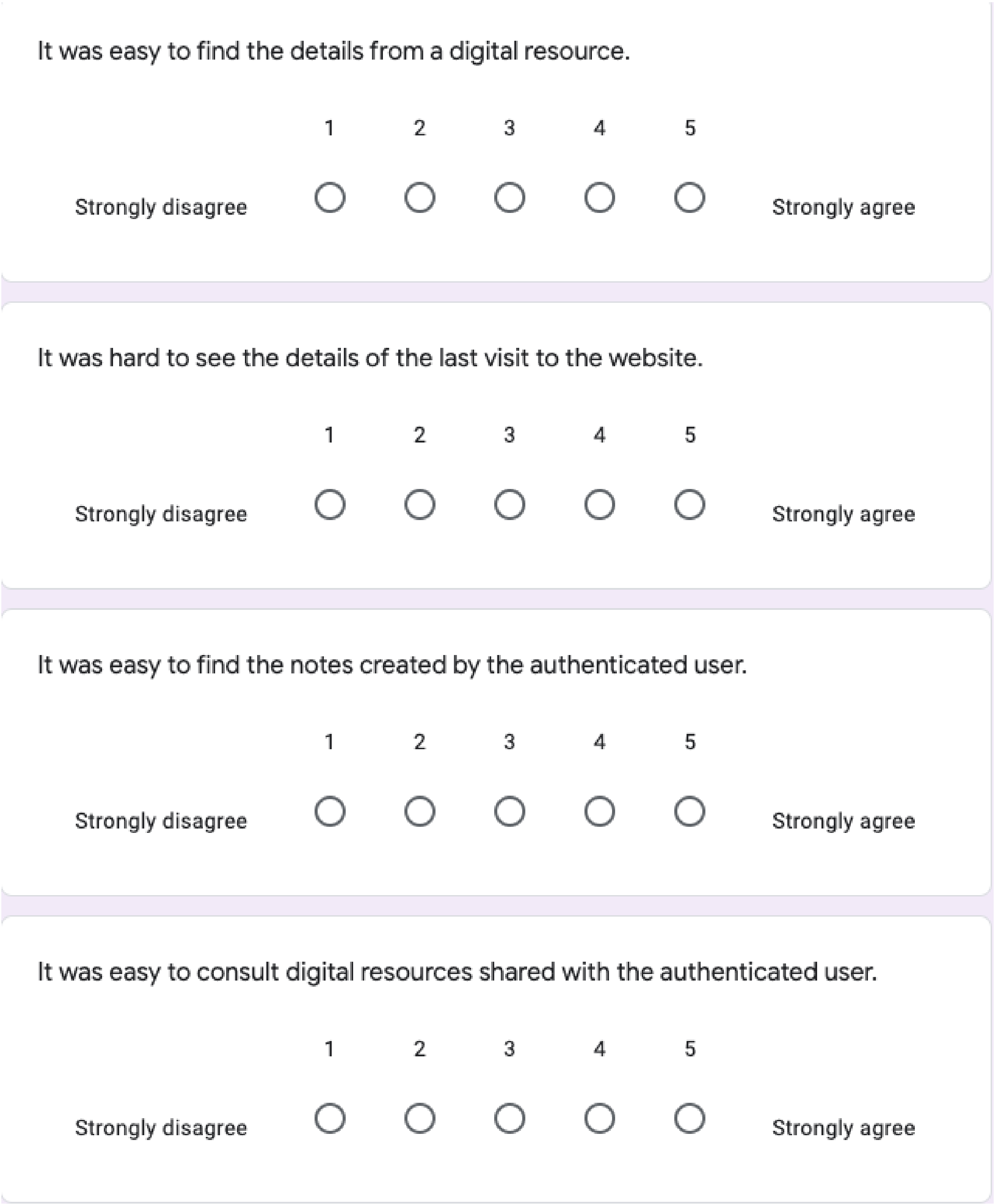
A sua resposta

It was easy to access the list of favorite digital resources.

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

It was hard to organize digital resources in folders.

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree



It was easy to find the details from a digital resource.

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

It was hard to see the details of the last visit to the website.

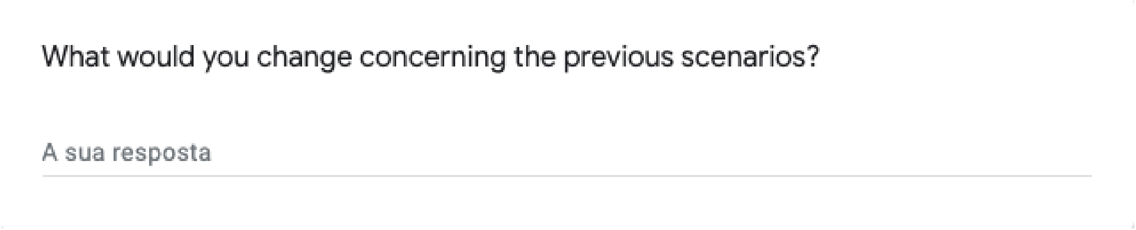
	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

It was easy to find the notes created by the authenticated user.

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

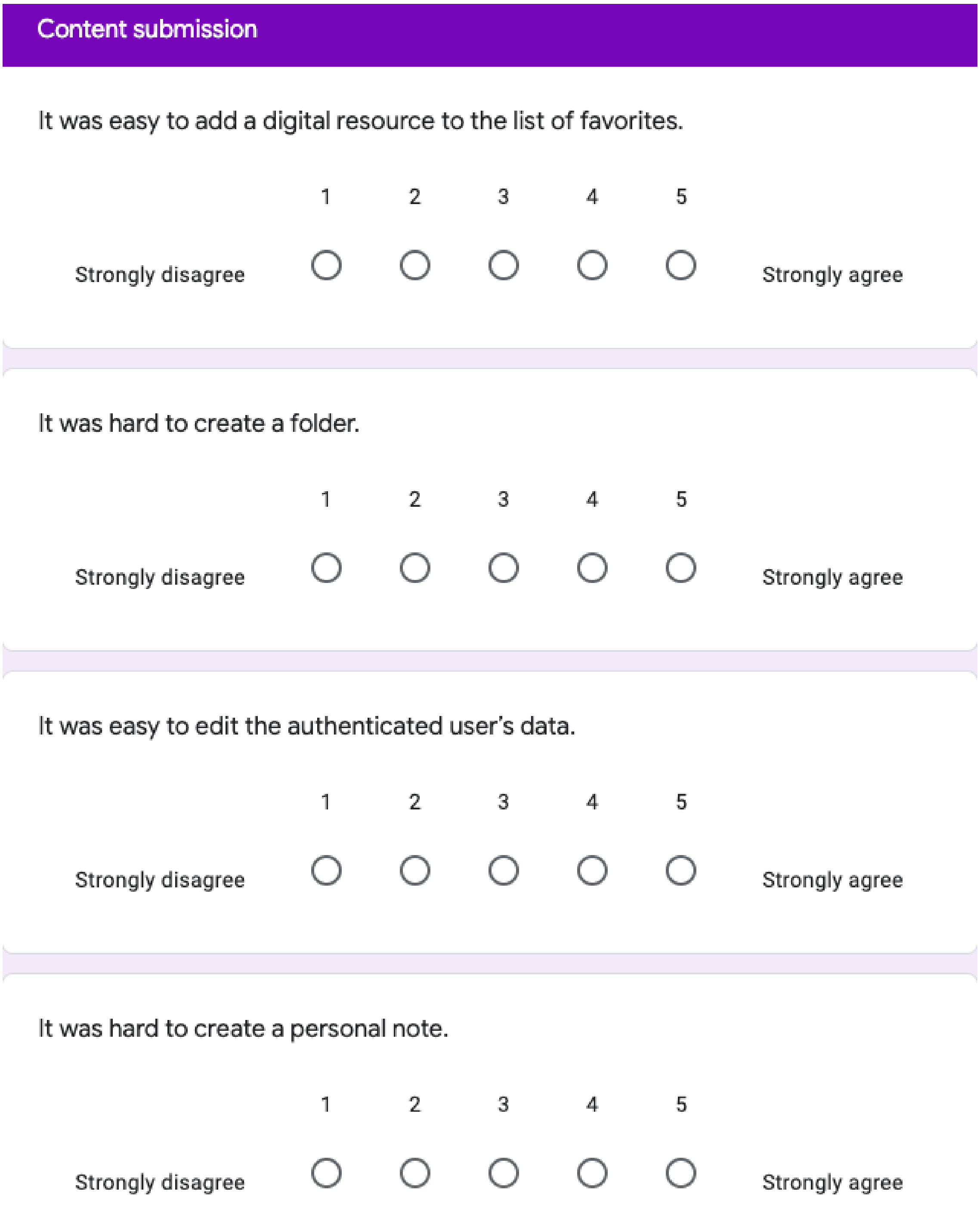
It was easy to consult digital resources shared with the authenticated user.

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree



What would you change concerning the previous scenarios?

A sua resposta



Content submission

It was easy to add a digital resource to the list of favorites.

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

It was hard to create a folder.

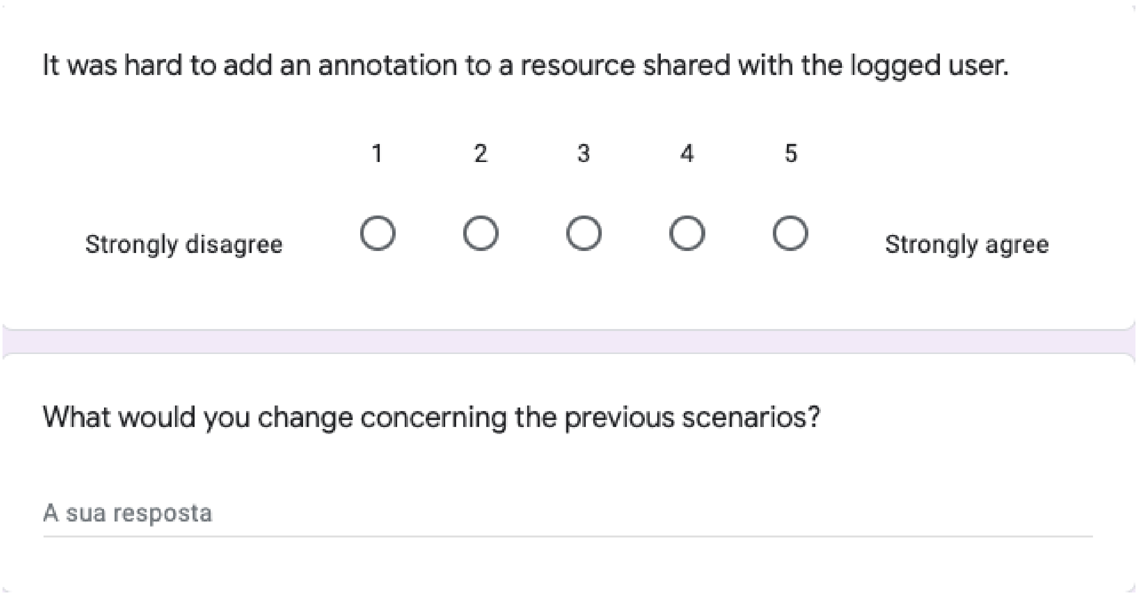
	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

It was easy to edit the authenticated user's data.

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

It was hard to create a personal note.

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

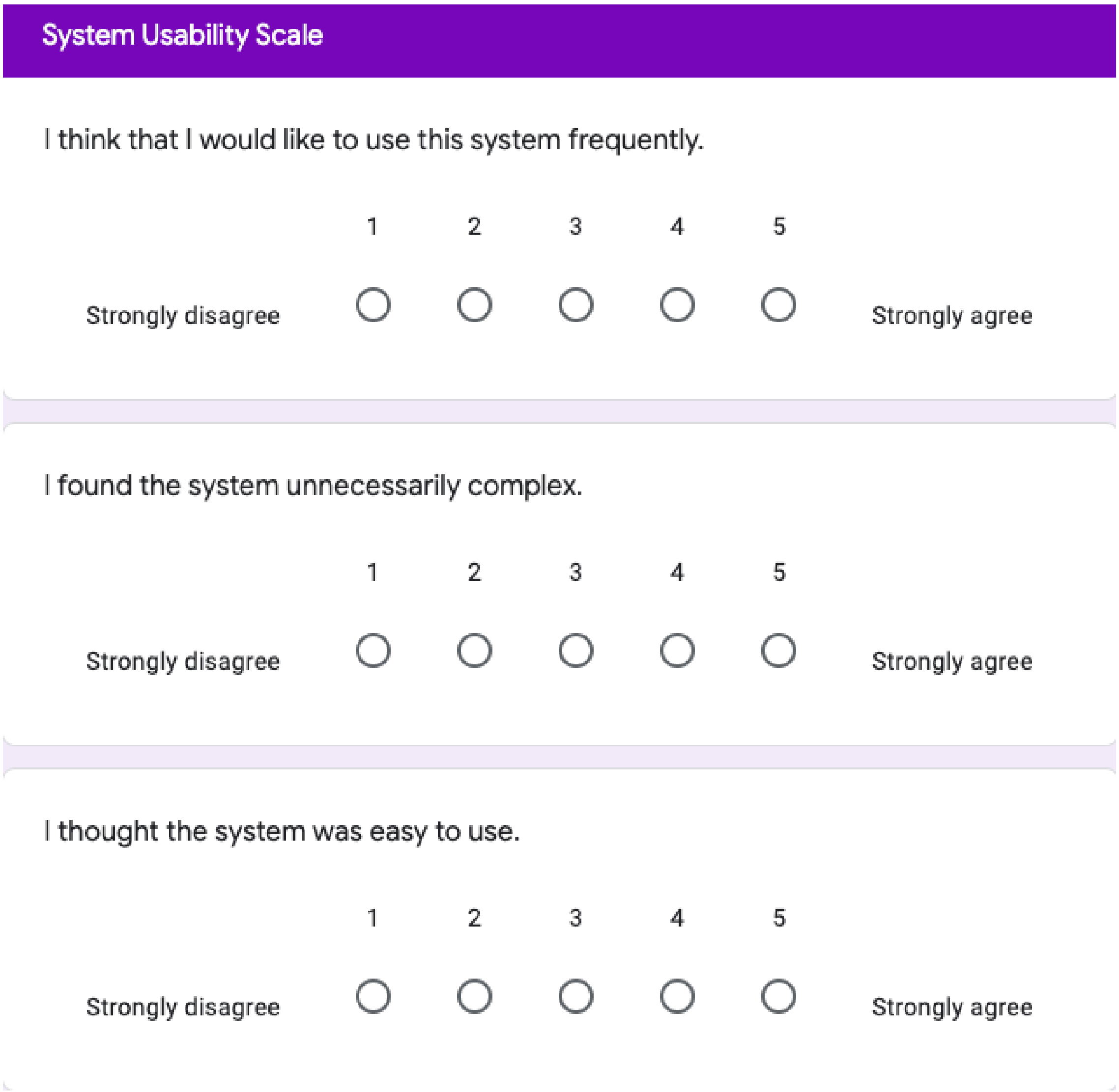


It was hard to add an annotation to a resource shared with the logged user.

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

What would you change concerning the previous scenarios?

A sua resposta



System Usability Scale

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

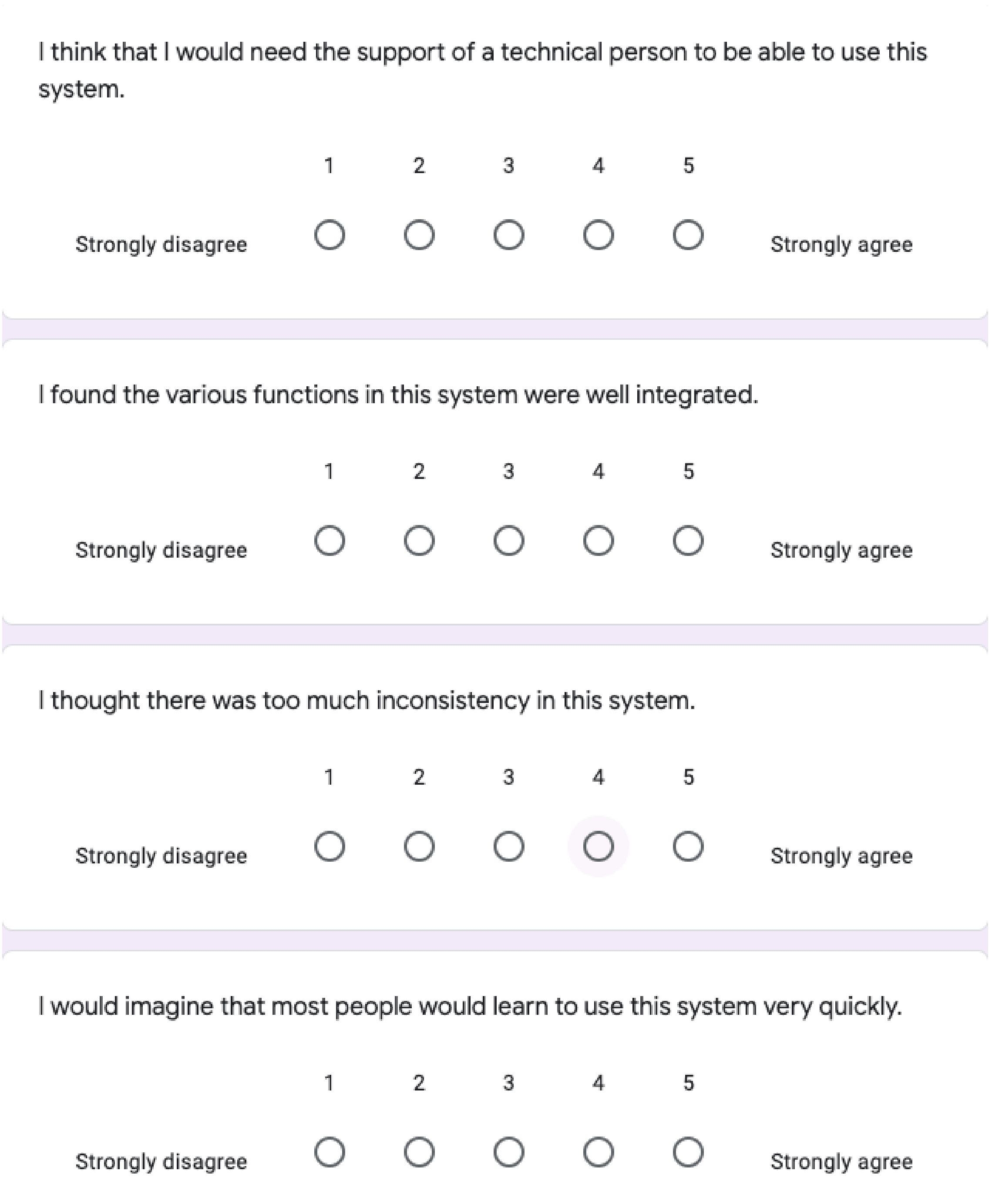
	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I found the system unnecessarily complex.

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I thought the system was easy to use.

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	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	○	○	○	○	○	Strongly agree

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

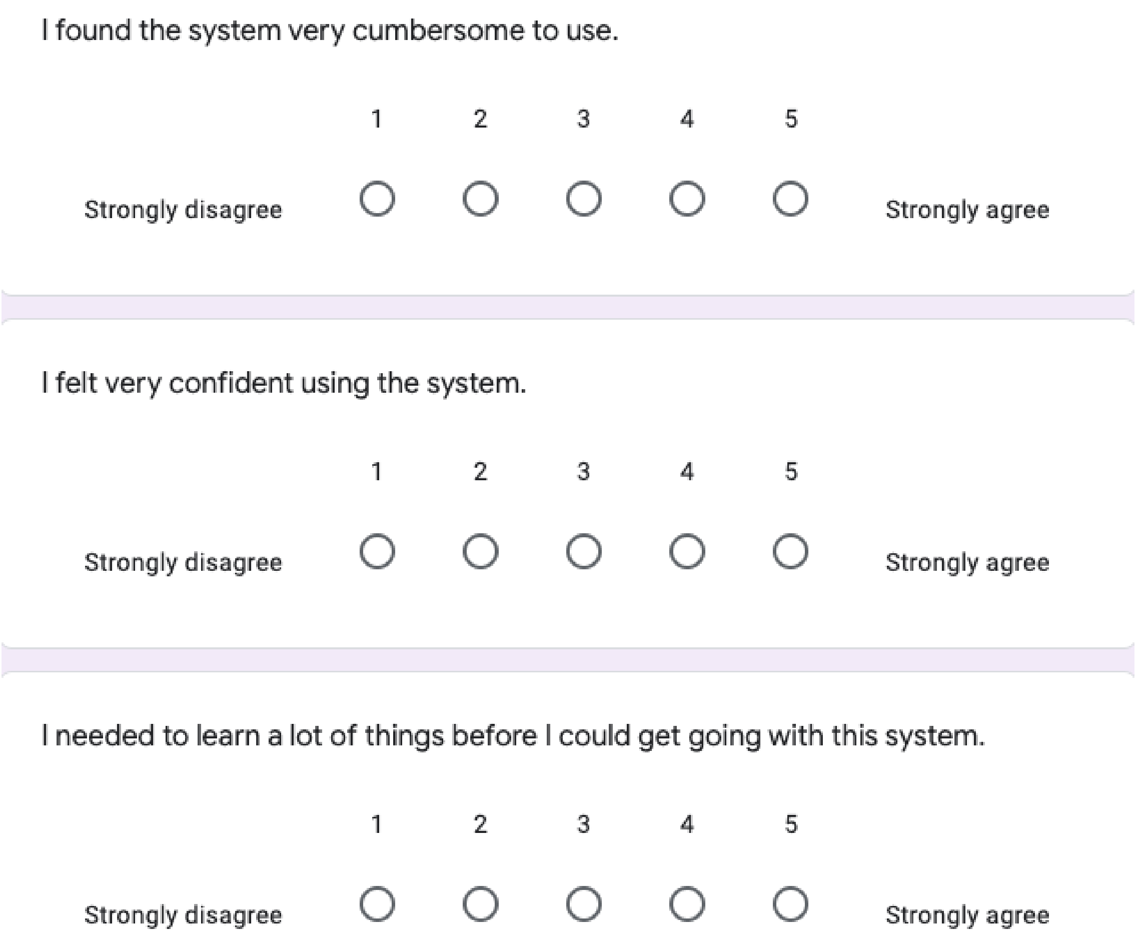
	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

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.

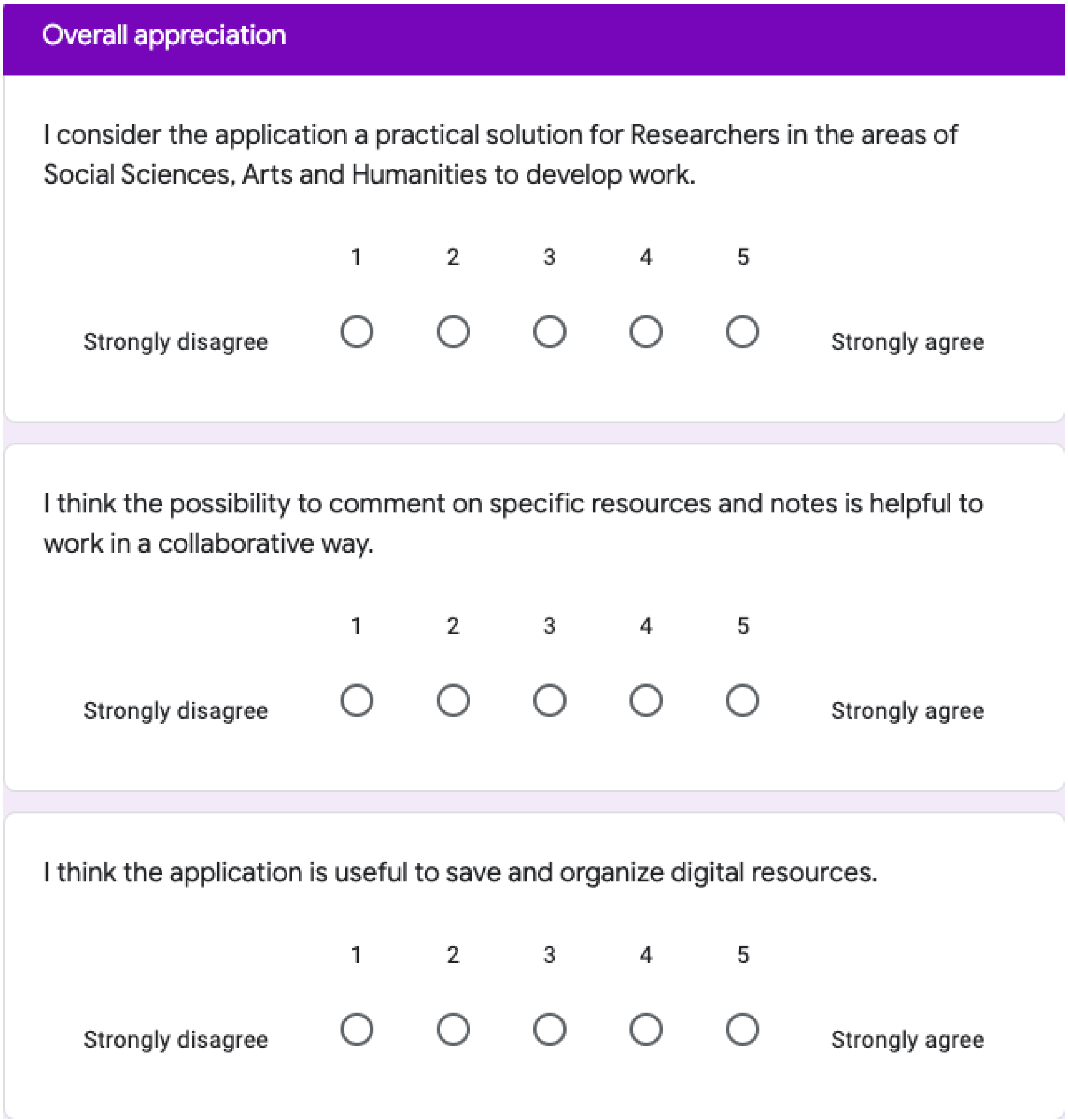
	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

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



Overall appreciation

I consider the application a practical solution for Researchers in the areas of Social Sciences, Arts and Humanities to develop work.

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I think the possibility to comment on specific resources and notes is helpful to work in a collaborative way.

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I think the application is useful to save and organize digital resources.

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree