

FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO

Theia: A Mobile Application for Detection and Reporting of Urban Events

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Resumo

Os telemóveis e outros dispositivos móveis tornaram-se essenciais para a nossa vida diária. No entanto, segundo a Comissão Europeia, apenas cerca de 58,51% dos cidadãos da União Europeia utilizaram sites e-governamentais em 2021, o que revela que, apesar da utilidade dos serviços e-governamentais, ainda há muitas pessoas que preferem usar métodos de comunicação mais tradicionais em vez de websites oficiais. Estudos indicam que, embora a população esteja, no geral, disposta a adotar o uso de aplicações móveis para serviços governamentais, essa disposição é fortemente influenciada pela confiança no governo, pelo desempenho da aplicação, pelo esforço necessário para utilizar a aplicação, pela qualidade de informações fornecidas e pelo suporte que a aplicação recebe.

O objetivo deste projeto é desenvolver uma aplicação móvel multiplataforma e de fácil utilização que permita ao cidadão capturar e reportar várias questões urbanas tirando fotos ou gravando vídeos. Estas questões incluem, mas não se limitam a, descarte inadequado de lixo, graffiti, danos nas infraestruturas públicas e problemas de sinalização de trânsito. Além disso, para aumentar a cobertura da cidade e aumentar o volume de uploads de imagens, a aplicação irá conter um modo de captura contínua. Esta função permite que a aplicação opere de forma persistente na janela frontal dos veículos (por exemplo, camiões de recolha de lixo, carrinhas de entrega e transportes públicos), permitindo a recolha contínua de dados ao longo das suas rotas.

A aplicação faz o upload das imagens e vídeos para um servidor com um modelo de Inteligência Artificial que infere ocorrências relevantes.

Antecipamos que esta aplicação aproveitará a tecnologia para melhorar os espaços urbanos, promover a cidadania ativa e agilizar a gestão urbana, tornando-a mais eficiente, inclusiva e responsiva às necessidades específicas dos municípios.

Palavras Chave: Urban management, E-government, Mobile applications, Active citizenship, Urban management processes, Cross-platform mobile application

Abstract

Smartphones and other mobile devices have become essential to our daily lives; however, according to the European Commission, only about 58.51% of European Union citizens made use of e-government websites in 2021, revealing that despite the utility of e-government services, there are still many people who prefer to use more traditional methods of communication over even official websites. Studies find that, while the population is overall willing to adopt the use of mobile apps for government services, this willingness is heavily influenced by their trust in the government, the performance of the application, the effort necessary to use the application, the quality of information provided and the support the application receives.

The objective of this project is to develop a user-friendly, multi-platform mobile application that enables ordinary citizens to capture and report various urban issues by taking photos or recording videos. These issues include, but are not limited to, improper disposal of trash, graffiti, damage to public infrastructure, and traffic sign problems. Additionally, to enhance city coverage and augment the volume of image uploads, the app will feature a continuous capture mode. This function allows it to operate persistently in the front window of vehicles (e.g., garbage collection trucks, delivery vans, and public transports), enabling ongoing data collection throughout their routes.

The application uploads the images and videos to a server with an Artificial Intelligence model that infers relevant occurrences.

We anticipate that this application will leverage technology to enhance urban spaces, promote active citizenship, and streamline urban management, making it more efficient, inclusive, and responsive to the specific needs of municipalities.

Keywords: Urban management, E-government, Mobile applications, Active citizenship, Urban management processes, Cross-platform mobile application

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Abreviaturas e Símbolos

e-gov	Electronic Government
App	Application
OS	Operating System
UI	User Interface
UX	User Experience
CPU	Central Processing Unit
GPU	Graphics Processing Unit
FPS	Frames Per Second
APIs	Application Programming Interfaces
PWAs	Progressive Web Apps
AI	Artificial Intelligence
HTML	Hypertext Markup Language
CSS	Cascading Style Sheets
JS	JavaScript
SUS	System Usability Scale
QUIS	Questionnaire for User Interaction Satisfaction
NASA-TLX	NASA Task Load Index
JPEG	Joint Photographic Experts Group (commonly used as a file format for compressed image files)
BGRA	Blue, Green, Red, Alpha
YUV	Luminance (Y), Chrominance (U, V)

Chapter 1

Introduction

1.1 Context

Urban management is a complex issue that faces many challenges due to the scale at which it operates, with many urban organizations needing to work together to address issues and urban management having to cover an extensive area, often whole cities [3]. Furthermore, organizations must consider the population's diverse needs effectively and promptly, so solutions must be flexible and responsive to feedback [4].

However, communication between the government and its citizens is often inefficient and throttled by ineffective and outdated methods of communication, which often require citizens to fill out lengthy forms online, make long phone calls to phone lines with large queues, and, in some cases to visit busy government offices directly. Moreover, citizens may face difficulties in accurately identifying the location of the incident, especially in large urban areas. Traditional reporting methods may not provide intuitive ways for users to pinpoint the exact spot on a map, resulting in imprecise information that hinders effective responses from urban management authorities. These, combined with the very sparse feedback received after reporting issues, make citizens feel unheard, discouraging them from actively participating in the urban management process, tending to leave them frustrated and helpless when it comes to contributing to the betterment of their community [5].

E-government mobile applications seem to be the way to improve communication and feedback between the government and the population. However, even though the use of mobile services such as mobile applications for e-government has increased over the years [6], there is still reluctance on the part of citizens regarding adherence to this form of communication with the government. In 2021, only about 58.51% of European Union citizens [7] made use of e-government websites. Meanwhile, studies in the USA [8] and the Sultan of Oman [9] found that the main reasons for citizens' reluctance to adhere to these services are heavily influenced by trust in the government, the performance of the application, the effort necessary to use the application, the quality of the information provided, and the support the application receives. Furthermore, other

factors such as the population's digital literacy and demographic makeup are also vital regarding how well an e-government application will be adopted [5].

1.2 Sustainable Development Goals (SDGs)

The United Nations Agenda 2030 is a global plan of action for people, planet, and prosperity, aiming to transform our world by promoting sustainable development in all its dimensions: economic, social, and environmental. At the heart of Agenda 2030 are the 17 Sustainable Development Goals (SDGs), which provide a shared blueprint for peace and prosperity for people and the planet, now and into the future. These goals are an urgent call for action by all countries, developed and developing, in a global partnership [10].

Our project aligns with several of these SDGs, particularly:

- **Goal 9 - Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation:** Our application fosters innovation in urban management by integrating AI technologies to improve service delivery and infrastructure maintenance.
- **Goal 11 - Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation:** By empowering citizens to report urban issues efficiently, we contribute to making cities inclusive, safe, resilient, and sustainable.
- **Goal 16 - Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels:** Enhancing the transparency and responsiveness of urban management fosters stronger, more effective, and accountable institutions.

By aligning with these goals, our project supports the broader vision of sustainable development, promoting active citizenship, and fostering a more inclusive and responsive urban governance framework.

1.3 Motivation

Our motivation is to empower citizens and make urban issue reporting more accessible, efficient, and widespread and, as a result, make urban management more responsive and flexible to the needs of citizens. The app is designed to ensure that users feel acknowledged, encouraging continued use through consistent and fast feedback on their reports. Additionally, we aim to make the application intuitive and accessible to even those with a low level of digital literacy.

Furthermore, with the use of an AI it's possible to not only moderate submissions but also detect various occurrences automatically such as overgrown vegetation, trash in public spaces, graffiti, damage to public property and issues with traffic signs among others which will eliminate the need to have a human manually verify each of the reported occurrences.

These advancements will bring numerous benefits to citizens. Enhanced public safety will be achieved by quickly addressing issues like damaged traffic signs and broken public equipment, improving overall safety in public areas. Cleaner urban spaces will result from the efficient detection and removal of trash, leading to more pleasant environments. Aesthetic improvements will come from managing graffiti and unwanted vegetation, enhancing the visual appeal of urban spaces. Additionally, early identification and repair of damages will ensure public amenities remain in good condition. Increased citizen engagement will be fostered by making the reporting process simple and rewarding, encouraging more people to participate in maintaining their community.

1.4 Goals

The main goals of the project are as follows:

- Develop a user-friendly mobile app for citizens to report urban issues through photos and videos.
- Enable continuous capture mode for ongoing data collection in vehicles (e.g., trucks, vans).
- Address factors influencing citizen adoption (trust, performance, usability) for widespread acceptance.
- Enhance urban spaces by promoting active citizenship and streamlining urban management processes.
- Provide timely and valuable feedback to citizens regarding their submitted captures, fostering a responsive and informative interaction between users and the application.
- Ensure the mobile app is accessible to all users, including those with disabilities, by adhering to accessibility standards and implementing features such as voice commands, text-to-speech, and adjustable font sizes.

These objectives culminate in the central research question guiding this thesis:

How does the development of a user-friendly mobile application, which supports continuous image and video capture from vehicles and includes mechanisms for user feedback, influence the reporting of urban issues by citizens and subsequently improve urban management?

This question aims to explore how technological advancements and user-centric design can enhance citizen engagement and the overall effectiveness of urban management processes.

1.5 Structure

In addition to the Introduction, this thesis comprises several key chapters. Chapter 2 delves into the State of the Art, providing a comprehensive analysis and comparison of various cross-platform frameworks through a systematic literature review. This analysis aims to identify the optimal

framework for developing the Theia application. Chapter 3 outlines the research methodology, detailing the work plan and project timeline. In Chapter 4, the Requirement Analysis for the application is presented. Chapter 5 focuses on the architecture of the Theia app, while Chapter 6 discusses the implementation and features of the application in detail. Chapter 7 showcases and analyzes the results, and explores potential future work. Finally, Chapter 8 presents the conclusions drawn from this research.

Chapter 2

Comparison of cross-platform frameworks

As mobile device usage has increased, the demand for mobile applications to tap into this expanding market has also grown. However, the market remains divided [11], with users opting for devices running on different operating systems. This divergence implies the creation of multiple versions of the same app, tailored for each system, which increases both the development costs and time needed to reach a broad audience. Presently, although only two major operating systems—iOS from Apple and Android from Google [12]—dominate significant market share, companies launching apps still prefer to develop versatile applications that cater to both platforms. This approach avoids the need to create two entirely distinct applications using separate technologies (such as Xcode, SwiftUI, and UIKit for iOS [13] and Kotlin or Java for Android[14]), which typically requires employing two different teams of developers.

Cross-platform applications exist to respond to this need by allowing applications for multiple operating systems to be created from a single code base [15]. Compared to Native applications, this write-once-run-everywhere approach cuts costs, decreases development time, and allows updates and bug fixes to be rolled out simultaneously on all platforms while reaching the broadest possible audience [16]. However, these applications are not without drawbacks since Native applications are easier to publish, rank higher on the platforms' app store, and have better access to the platform's native tools. Furthermore, the use of cross-platform applications is also associated with decreased performance and a lower satisfaction rate compared to Native applications, often associated with the fact that Native applications tend to emulate better the look and feel of their platform [16]. These drawbacks, however, can be minimized depending on the type of cross-platform framework being used, with some becoming entirely obsolete.

Cross-platform apps are divided into different types, which vary across different sources [15], partly due to the vast speed at which the industry develops, quickly leaving behind certain types of frameworks for different ones entirely. Still, presently, the division usually includes a variation of the following five types of cross-platform applications [16] [17]: Web Applications, Hybrid

Applications, Interpreted Applications, Cross-Compiled Applications, and Progressive Web Applications.

Web Applications are web pages designed to be viewed on a mobile device browser and developed using standard web technologies with which developers are usually familiar. This allows them to have a uniform look and feel across platforms and, due to all the processing occurring in the server, the mobile device only has to render the user interface (UI), making these apps easy to update [16]. They are, however, not proper apps and cannot be used offline, downloaded to the user's device, or uploaded to the device's app store. Lastly, they cannot use some of the device's native features and underlying software, like sending push notifications, for example. [17]

Hybrid applications are similar to web apps in that they are also developed using web technologies. However, through a native wrapper, they can access native features that Web Apps cannot use [17]. They are available offline, can be uploaded to devices' App Stores, and usually have small app sizes.[16]

Interpreted Applications interpret the source code at run-time, which allows them to render the user interface with the platform's native components, making it reusable. These applications can be uploaded to the device's app store [16]. That being said, app development depends on the set of features the framework provides, and the interpretation at run-time can also lead to performance issues [18].

Cross-compiled Applications convert the source code into a native application with a cross-compiler. This makes a large portion of the code reusable, and since applications are converted to native apps, they usually perform well. The main disadvantage of this type of application is that the UI and some specific platform features, such as the camera, cannot be reused between platforms.[18]

Progressive Web Apps (PWA) are regular web applications capable of working offline and being downloaded to the users' devices. They are not yet capable of using all mobile devices' Application Programming Interfaces (APIs), are not available in the devices' app stores, are not supported by all browsers, and their performance and energy consumption are still lacking compared to hybrid apps. However, they are almost effortless to implement and allow users to install the app directly from the related websites without the need to go to the app store. [19]

This systematic review aims to compare different cross-platform frameworks to help decide what framework should be used to create the application that will be developed as part of this thesis. The choice of a cross-platform application, as opposed to a native, was made due to the need for the application to reach as many users as possible, leaving us only with the decision of which technology should be used in the development of which this systematic literature review was conducted.

The latest review found on the topic of cross-mobile frameworks [20] described many different cross-platform frameworks. However, it did not make explicit comparisons between them and included frameworks no longer being maintained/ updated, such as Phone Gap [21], leaving a gap in the literature this systematic literature review aims to fill.

This review will mainly focus on comparing frameworks on performance metrics; some more theoretical criteria are also used for comparison, such as the frameworks' learning curve and the size of the developer community. Furthermore, due to the content of the selected papers, the review will mostly make conclusions regarding Flutter, React Native, and PWAs. The analysis concerning mainly these frameworks seems acceptable considering that the first two are the two most popular frameworks currently in the market, as can be seen in Statistica's survey on cross-platform mobile frameworks used by software developers from 2019 to 2022 [22] and on Stack Overflow Trends concerning the popularity of tags of cross-platform frameworks from 2008 to 2023 [23]. PWAs, on the other hand, are an emerging technology that is starting to be used in more noteworthy real-world applications with great success, such as AliExpress's new mobile PWA which has increased conversion rate for new users by 104% [24].

Having established the critical landscape of cross-platform development, it's important to present the research questions that will guide this systematic literature review so that it can shed light on the comparative performance and general characteristics of the different cross-platform frameworks:

- How do different cross-platform frameworks compare to each other performance-wise?
- How do cross-platform mobile development frameworks differ regarding community support, language learning curve, and development speed?
- Are there specific cross-platform frameworks or types of applications that currently face challenges in achieving true cross-platform compatibility, and what areas of improvement are needed to enhance their seamless operation across various devices and operating system versions?

This review is organized as follows: In Section 2.1, the Systematic Literature Review will be explored. In Section 2.1.1, the scope and objectives of this Systematic Literature Review are defined; in Section 2.1.2, the search strategy is described; in Section 2.1.3, the selection criteria are shown and explained; in Section 2.1.4 the data from the chosen articles is extracted; in Section 2.1.5 the research questions are answered, and the data found in the articles is synthesized; in Section 2.1.6 the quality of the methodology used in the articles are evaluated; in Section 2.1.7 the Systematic Literature Review is compared with other existing ones in terms of findings and scope; in Section 2.1.8 gaps in literature and venues for future research are talked about and in Section 2.1.9 the conclusions are presented. Finally, in Section 2.2, the findings will be analyzed in the context of the thesis's objectives.

2.1 Systematic Literature Review

The methodology used in this systematic review is based on the PRISMA technique [25] and consists of four stages, as described below. The search strategy was developed using the PICO

(Population, Intervention, Comparison, Outcome) framework. The PICO elements were defined as follows:

- **Population:** The review includes studies focusing on multi-platform app development.
- **Intervention and Comparison:** Current multi-platform development frameworks and their techniques, such as Flutter, React Native, Xamarin, and others, were evaluated. When available, comparisons between different frameworks or techniques were analyzed.
- **Outcomes:** The primary outcomes of interest include performance, operating system supported version, community size, license, implementation complexity, ease of update, security, development cost, potential users, UI and UX, and access to native API. Secondary outcomes focus on advancements and future perspectives in multi-platform app development frameworks.

2.1.1 Objectives and Scope

To choose articles for this Systematic Literature Review, the following criteria were used to select documents relevant to the systematic literature review:

1. Articles need to be in the English language
2. Articles need to talk about multi-platform app development
3. Articles need to talk about specific frameworks
4. Articles must only make mention of currently supported frameworks
5. Frameworks should be readily available and must have an active developer community
6. Articles must use performance or user feedback as evaluation methods or make a theoretical analysis
7. Articles must be from 2019 on-wards

If the article passed all these criteria, it was read in total to be analyzed.

Furthermore, from the articles selected, features such as the following were assessed:

- Performance
- Operating System supported version
- Community size
- License
- Implementation Complexity

- Ease of update
- Security
- Development Cost
- Potential Users
- UI and UX
- Access to native API

2.1.2 Search Strategy

To select what databases would be used, a search was first conducted on Google Scholar [26] with the following query:

"(multiplatform OR multi-platform OR "multi platforms" OR cross-platform) AND mobile AND (application OR app) AND (framework OR tools OR technology OR development) AND (evaluation OR comparison OR analysis)"

From this search, the databases with the most relevant results, as seen in Table 2.1, were chosen.

Table 2.1: List of databases used

Data Source	Type	URL
Science Direct	Digital Library	https://www.sciencedirect.com
IEEE Xplore	Digital Library	https://ieeexplore.ieee.org
ACM Digital Library	Digital Library	https://dl.acm.org
DiVA	Digital Library	https://www.diva-portal.org

For each database chosen, due to the differences between their search systems, different queries and filters had to be defined, as shown in Table 2.2.

Table 2.2: Database Search Queries and Filters

Database	Query	Filters
Science Direct	("multi-platform" OR multiplatform OR "cross-platform") application NOT "mobile patient" NOT "mobile robot"	Title: mobile development, Subject Areas: Computer Science and Engineering

IEEE Xplore	(multiplatform OR "multi-platform" OR "cross-platform") AND (application OR app) AND (analysis OR evaluation OR comparison)	Document Title: mobile AND development
ACM Digital Library	application AND (analysis evaluation review) AND NOT "mobile patient" AND NOT "mobile computing" AND NOT "mobile robot"	Title: ("multi-platform" multiplatform "cross-platform") AND mobile AND (development framework tools)
DiVA	(multiplatform OR multiplatform OR "multi platforms" OR cross-platform) AND mobile AND (application OR app) AND (framework OR tools OR technology OR development) AND (evaluation OR comparison OR analysis)	

2.1.3 Selection Criteria

The following criteria were applied to ensure the rigor and relevance of this literature review.

1. Articles need to be in the English language
2. Articles need to talk about multi-platform app development
3. Articles need to talk about specific frameworks

This means that articles have to either talk about more than one framework or that if they only speak of one framework, the way in which they are evaluated has to be comparable to the way in which other frameworks are evaluated in different articles so they can be compared meaningfully.

4. Articles must only make mention of currently supported frameworks

"Currently Supported" is defined as frameworks that are consistently updated and have not been announced to be discontinued. This is meant to ensure that the framework being used is and will continue to be up-to-date in the near future.

5. Frameworks should be readily available and must have an active developer community

This ensures the framework's accessibility for application development, coupled with the presence of an engaged developer community. The availability for use signifies practical application, while the active developer community ensures continuous support, enhancement, and sustained relevance of the framework.

6. Articles must use performance or user feedback as evaluation methods or make a theoretical analysis
7. Articles must be from 2019 on-wards

The year 2019 was chosen to be the cut-off year because articles found before this year tended to use, for performance metrics, very outdated devices compared to today's standards, tended to test applications in phones with the Windows Phone Windows 10 Mobile Operating System [27], and tended to mention frameworks that have since been discontinued such as Phone Gap [21].

2.1.4 Data Extraction

A total of 115 documents were collected, of which one was a duplicate, making 114 distinct documents.

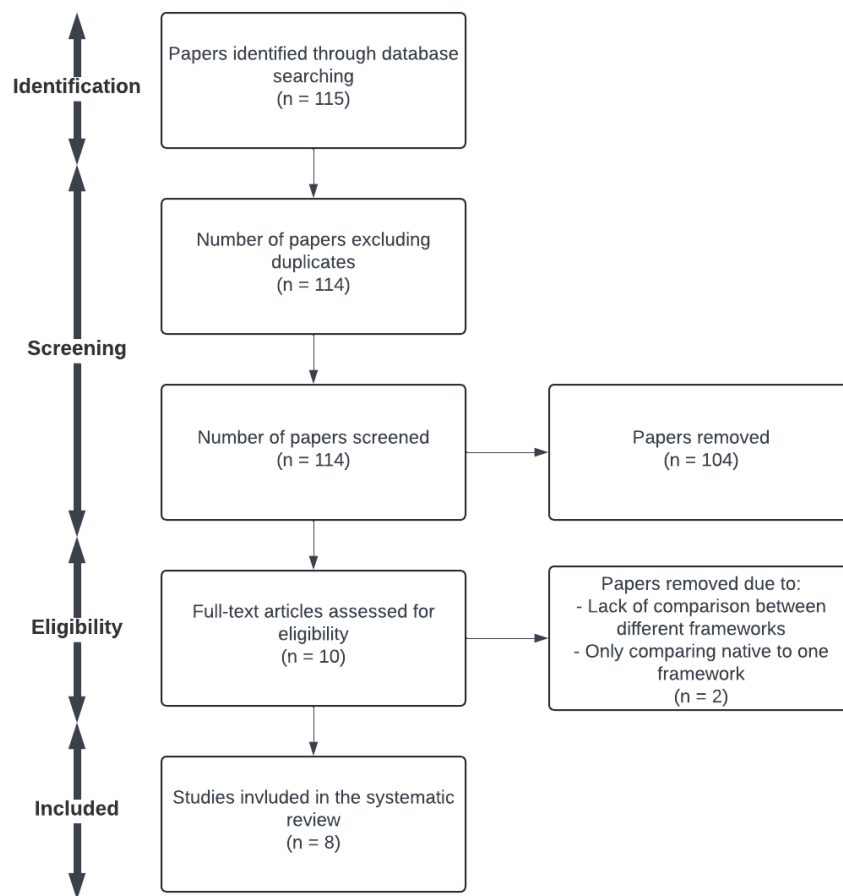
After selection using the criteria described in Section 2.1.3, the total number of documents was reduced to ten. After these ten documents were thoroughly analyzed, two were excluded due to a lack of comparison between different frameworks and instead only comparing native to one framework, making eight documents usable for this review. Figure 2.1 summarizes all the procedures of this systematic review.

Out of the eight chosen articles, one originated from Science Direct, two were sourced from IEEE Xplore, another was retrieved from ACM, and the remaining four were obtained from DiVA. Of these articles, six compared performances between apps created with Cross-platform frameworks and Native apps, and two made theoretical analyses of different frameworks.

The studies were each individually analyzed, and the features described in Section 2.1.1 were extracted. The studies were divided into two types: studies focused on performance metrics and studies with theoretical analysis of frameworks.

In Table A.1 in the Appendix, it's possible to see the summary of each of the six papers focused on performance metrics, and in Table A.2 in the Appendix, the methodology used for testing employed by each paper is displayed. Finally, in Table A.3 in the Appendix, the results obtained in the papers can be seen.

Figure 2.1: Flowchart of the review protocol



All articles except [28] compare at least two different cross-platform frameworks. [28] was considered relevant, however, because its results could be compared to those of other articles, considering that the performance metrics used are the same as the ones in some of the other papers. Papers [29], [30], [31] and [32] not only compare different frameworks but they also compare Progressive Web Apps to other types of cross-platform apps made with a variety of frameworks.

The papers [28], [16], [29] and [30] all tested CPU performance, while [28], [16] and [30] also tested Memory Usage. Finally, Battery Usage/ Energy Usage was tested by [28], [16], [29] and [31].

For other metrics, [16] also tested Code Complexity, Code Reusability measured as the number of times the same code is repeated throughout the code, and Application Size. [29] also measured Time To First Activity, and [30] used as a performance measure Smoothness, measured by how fast the application can draw new content on screen. Finally, [32] used as performance measures Estimated Input Latency, First Contentful Paint, First Paint, and Time to Interactive.

For the papers making theoretical analysis, in Table A.4 in the Appendix and Tables A.5 and A.6 in the Appendix, it's possible to see the individual analysis for each of the two papers. They were separated due to a lack of overlap of the criteria used to compare the frameworks, as shown.

Furthermore, not represented in the table [2] mentions that Flutter, due to being developed by Google, benefits from strict security practices.

2.1.5 Synthesis of findings

In this section, by comparing the results of all the articles, we can reach some conclusions and answer our research questions.

How do different cross-platform frameworks compare to each other performance-wise?

In terms of performance, all papers that compared the performance of apps created using cross-platform frameworks with the performance of Native apps concluded that Native apps perform better, as expected.

Flutter: Regarding the cross-platform frameworks, the studies that used Flutter concluded that Flutter performed better than the other frameworks it was being compared against, namely Capacitor, React Native, and PWAs created with Ionic. Both [16] and [31] found Flutter to have better Battery Usage than the other frameworks tested, and [16] also found that the Flutter application created was smaller than the React Native's and that it had a CPU usage close to the Native implementation. The only aspect where Flutter performed worst was the Code Reusability against React Native, though not by a lot.

React Native: When it comes to React Native in [30], it is concluded that while React Native performs better in terms of Smoothness both when changing pictures and text and when scrolling, in terms of memory performance, it only performs better while changing text, performing much worse when scrolling. In terms of CPU Usage, React Native only performed better while scrolling. Additionally, in [31], where battery performance is tested, the React Native App is one of the worst performing applications, only behind the PWA in the Firefox browser. However, this is less accentuated when testing with real-world apps on a high-end device.

PWAs (Progressive Web Apps): After Flutter and React Native, the most talked about type of app was PWAs made with different frameworks, in [29] with Cordova compared against a Web App created with React, in [30] with Reactjs compared against a React Native app, in [31] with Ionic compared to a Hybrid Capacitor App, a Flutter App, and a React Native app, and finally, in [32] the framework used to create the PWA and a Web App is not disclosed. Still, they are both compared to a Cordova App. Overall, there is a lot of variance in the results obtained, with the PWA occasionally being better or worse than the other applications tested without a clear pattern as to why.

Other than the comparison with React Native in [30] talked above, in [29], the PWAs do worst across the board compared to the Hybrid app except when measuring the Activity Launch Time,

where they did better. It was also found that the browser used heavily influenced the app's performance, with Chrome performing much better than Firefox. Further, in [31] other than performing better than the React Native app and exhibiting much lower energy consumption in the real-world apps than the Hybrid app created with Capacitor, it also corroborates the finding that PWAs run on Firefox perform worse than those run on Chrome. Finally, in [32], results are mixed, and while the PWA seems to perform well across the board, there seems to be no explanation for the significant differences found between the different devices used, especially since they do not seem to correlate with the device type at all. Furthermore, the lack of information regarding what frameworks were used to create the Web App and the PWA makes it hard to draw any conclusions from this study.

Others: For the less-mentioned remaining frameworks, Cordova was also used to create a Hybrid app. In the study [29], it performed better than the PWA apps in terms of Battery Consumption and CPU Usage and worse in Activity Time Launch.

Finally, for Capacitor, in the study [31], it was found that the performance of the Hybrid app created varied widely with the sample apps, but when testing on real-world apps, it was found to have a higher energy consumption than the other frameworks.

Lastly, in [1] where performance is mentioned, it mostly corroborates the articles' findings except for React Native, which did much worse in the studies discussed.

How do cross-platform mobile development frameworks differ regarding community support, language learning curve, and development speed?

According to the papers focused on theoretical analysis, we can conclude that some differences exist.

In [1], in terms of supported versions, all frameworks are capable of supporting the latest versions of both Android and iOS. Meanwhile, in terms of community, it finds that other than Flutter, which has only recently gained popularity [23], the other frameworks have numerous communities, with React Native having the biggest. That being said, data from Statistica [22] indicates that Flutter is instead the one with the most prominent community, followed by React Native. StackOverflow trends [23] also indicate that this community is the most active out of all the frameworks analyzed.

In terms of languages, Ionic and React Native use regular web technologies, which makes these frameworks have a lower learning curve for developers than Xamarin and Flutter. Xamarin uses C# and .NET, which, while less common than the web technologies, are still used by other frameworks. Only Flutter uses Dart, which means that developers must learn Dart to be able to use Flutter. Furthermore, its Widget-based UI makes it very different from other frameworks, making it the one with the highest learning curve among the frameworks in the article.

In [2], since the only framework specified is Flutter, it is only possible to make conclusions about Flutter. Flutter is open source, has a moderate Implementation Complexity, and a moderate ease of update. Furthermore, due to Google's creation, it can be expected to have very high security

standards. The development cost is moderate, and it has access to the native API. The potential users are classified as limited since, at the time of the paper being published, Flutter only shipped apps for Android and iOS; however, it now supports Mac, Windows, Linux, and web as well [33].

Are there specific cross-platform frameworks or types of applications that currently face challenges in achieving true cross-platform compatibility, and what areas of improvement are needed to enhance their seamless operation across various devices and operating system versions?

In the studies, it was found that the performance of PWA applications, regardless of the frameworks used, was widely different depending on whether they were run using the Chrome browser or the Firefox browser. This appears to be because different browsers have different levels of support for PWA applications [34].

This causes issues because asking a user to switch their everyday browser to be able to experience an application due to compatibility issues is a tall ask. Furthermore, while in theory, PWA apps should be able to work on both iOS and Android, iOS blocks many of the PWA services and causes issues when downloading the PWA as an app [35].

This means that there is still a way to go, not only with the way that PWAs work on iOS but also in terms of browser compatibility to allow them to work seamlessly in any browser.

2.1.6 Methodology Quality

In all the papers, before the test cases are executed, measures are taken to ensure that no other apps or processes affect the results of the experiments except in [16], where nothing is mentioned about the device's preparation before the tests are executed. Similarly, [16] is the only paper that does not describe the tests performed.

Regarding methodology, in [16], the authors mention that the applications created with different frameworks were not completely identical, with the Flutter and React Native apps having animations and the Kotlin application not having any, which could have skewed the results.

In [29], time was measured with a stopwatch, which is error-prone due to the unreliable nature of human reflexes to stop the stopwatch on time. This factor could have easily affected the results.

In [31], it refers that some of the varying results between the sample apps and the real-world apps (namely for the Hybrid and Flutter apps) could be explained by the real-world apps having visual differences that caused them to use more battery than the other apps tested. Furthermore, it is explained that the discrepancy in the scrolling behavior of the sample app on the higher-end device can probably be explained by the scrolling speed being affected by the screen height, making it different from the speed in the lower-end device.

Lastly, in [30], the scrolling experiments were inconsistent between frameworks once again due to the drag event's scrolling speed being dependent on the length of the scrolling page. Furthermore, when measuring smoothness, the clocks of different threads in Chrome were sometimes

slightly out of sync, meaning that some events were detected before their triggering events on another thread. To mitigate their influence on the results, those events were not counted in the frame duration.

2.1.7 Comparison with previous Systematic Literature Reviews

As previously mentioned, the most recent Systematic Literature Review found on this subject, [20], has quite a different scope to the present review as it does not compare different types of frameworks. Instead, it broadly reviews cross-platform approaches, tools, and challenges. Additionally, it also includes frameworks that have since been discontinued and are no longer in use.

Another Systematic Literature Review from 2022, [36] focuses solely on PWAs, which means its scope differs from the one of the present review. However, in terms of findings, they seem to align with this review's, with the mention of issues relating to browser support and the need for improvement in the area.

Another one found on the topic from 2018 of cross-platform frameworks, [37], only examines Model-Driven approaches to cross-platform development, so no comparisons can be made with this review's findings.

This Review, in contrast, was focused on comparing different frameworks and ways of creating cross-platform applications. Due to this, its aim was to use different ways of measuring the comparative advantages and disadvantages of a framework, such as ease of use, performance, and community size, among others. This allows for a more targeted exploration, which allows developers to make more informed decisions regarding framework choices.

2.1.8 Gaps and Future Research

While the papers selected for this systematic literature review provided a solid foundation to compare a couple of different cross-platform mobile development frameworks and types of cross-platform apps, it's essential to acknowledge the limitations of this study and some avenues for future research.

Firstly, it's essential to acknowledge that excluding articles written in other languages but English might have excluded valuable research that would have significantly contributed to this study and potentially limited the scope of this study.

Regarding the evaluated frameworks, only Flutter and React Native, as well as PWAs, were present in enough articles to draw meaningful conclusions on how they compare. A more extensive selection of papers could have allowed other frameworks to be better evaluated. Furthermore, the landscape of cross-platform frameworks is vast, and others that were never mentioned in the selected papers could and should be evaluated.

On the other hand, none of the papers chosen tested the applications for the iOS operating system. This might be due to the higher price point of these devices or the proprietary software, making the development and testing of iOS applications harder and more costly. Regardless, considering that iOS is the only mobile operating system other than Android with any considerable

market share, it's crucial to understand how cross-platform apps perform in this operating system, making further research in this area imperative.

Future research could also benefit from comparing user satisfaction between frameworks since a lot of literature claims that users are generally less satisfied with the look of cross-platform applications when compared to native apps. However, as time has passed and Android and iOS phones have become more similar both on the outside and inside, it would be insightful to find if this dissatisfaction is still present and, if so, if the framework chosen affects user satisfaction.

Another often overlooked but vital aspect of mobile applications is Accessibility. It would be an important avenue of research to find how many accessibility features from the native frameworks, like labels for screen readers, are available to developers when using a cross-platform framework and how hard it is to ensure accessibility for both operating systems simultaneously.

Ultimately, expanding research by testing cross-platform applications on iOS devices, broadening the number of articles analyzed, and expanding the features used to evaluate and compare cross-platform frameworks will help especially improve our understanding of cross-platform development and help developers make more informed decisions on the subject.

2.1.9 Conclusion

In conclusion, when it comes to performance, overall, Flutter seems to perform the best, which is in line with what was expected, considering its nature as a Cross-Compiled framework that tends to have similar performance to native applications, making it a good choice for developers prioritizing high performance.

That being said, from the frameworks analyzed, Flutter is also the one with the highest learning curve, considering not only that Dart is a programming language used only by Flutter but also the fact that the UI creation is completely based on Widgets, unlike other frameworks. On the other hand, React Native seems to suffer a bit in terms of performance; however, using familiar web technologies makes it much more accessible, making it an attractive option for developers familiar with web technologies looking for a smaller learning curve.

Finally, PWAs, while exciting and innovative, still seem to have a long way to go in terms of improvements to ensure a seamless experience, regardless of operating system or browser. Despite this, due to being very easy to implement on preexisting web applications, if such an application already exists, there is also barely any loss on the part of the developer when creating one, with the only consideration being how the user experience will be affected by the existence of the PWA.

So, in summary, developers looking for very high performance and a very close-to-native experience should perhaps opt for the Flutter framework. In contrast, developers who are more familiar with web technologies and want a more accessible option should opt for React Native. Furthermore, as technology evolves and frameworks keep steadily changing and improving, developers must keep a close eye on their advancements and updates to ensure they are working with up-to-date information when making decisions.

This literature research encompasses only a tiny sample of frameworks and articles and a handful of different features for comparison, mainly focusing on performance measures. Future

work could explore different frameworks or comparison criteria and make more robust conclusions by selecting more papers to be analyzed, allowing developers to make more informed decisions regarding mobile cross-platform frameworks.

2.2 Significance of Study

The elaborated Systematic Literature Review and its results are useful to choose the cross-platform framework that will help create the application for this thesis. In this section, the rationale for the selection of said framework will be outlined.

2.2.1 Project Requirements

The application to be created consists of an app that allows users to take pictures and videos of undesirable occurrences in the city, such as littering and graffiti, among others, as they go about their daily lives so that they can be reported to the responsible authorities and corrected. Additionally, it will also include an extra mode, allowing it to be used on a device running Android stationary on a car's window, such as a garbage truck or a delivery van, and constantly record the outside to be able to increase the image pool of submitted pictures by the app. Lastly, other than the increase in quality of life in the city, these images will also be used to train an Artificial Intelligence (AI) to be able to improve its capacity to recognize these occurrences in pictures to bypass the need for human verification of the occurrences.

This means that the application has to have good access to the peripheries of the mobile device, more specifically, the camera. Other than that, it should reach as large of a user base as possible, and it should perform well so it can run smoothly on various devices and provide the users with the best user experience possible. Lastly, users should be able to take photos and videos offline, and they should be automatically uploaded when the user is back online.

2.2.2 Decision Rationale

Considering that the Systematic Literature Review elaborated pointed to Flutter being the best in terms of performance and that it fits all the needs of the application to be developed, the best choice seems to be using Flutter as the development framework for the project.

Additionally, as the project's developer, I am very familiar with using Flutter to create mobile apps which means that the acclimation to the framework will be minimal.

Furthermore, due to the shortcomings of PWAs discussed in the review, such as the significantly reduced reachable user base and the user experience based on arbitrary factors like browser choice, the app to be developed will not be a PWA.

Chapter 3

Research Methodology

To comprehensively investigate the user interface (UI) and functionality of the application, an Exploratory Sequential Mixed Methods research design will be employed. This approach involves both qualitative methods and quantitative methods, ensuring a thorough exploration of the research problem.

The choice of an Exploratory Sequential Mixed Methods approach ensures a comprehensive and nuanced exploration of the user interface and functionality. By starting with qualitative methods, followed by quantitative data collection and analysis, this methodology aims to provide a well-rounded understanding of the application's strengths and areas for enhancement.

3.1 Qualitative Methods

The qualitative methods employed will focus on gaining a deeper understanding of user experiences and preferences. A sample of participants will be selected for a think-aloud study to explore their perspectives on the application's UI and functionality. During these sessions, participants will perform specific fundamental tasks of the application while verbalizing their thoughts, challenges, and reactions in real-time. By collecting this data we can get a good sense of the real hardships the users face while completing these tasks which can be used to improve the application, in the future.

The researcher, during this process, will keep track of the time taken by each participant to complete a task as well as the number of mistakes made while trying to accomplish it (e.g. number of times the user navigates to the wrong screen or clicks in the wrong button).

3.2 Quantitative Methods

Building upon the insights gained from the think-aloud section of the study, a comprehensive quantitative approach will be employed to evaluate the usability and functionality of the application. This phase will involve several key steps and utilize multiple standardized tools to gather detailed numerical data.

3.2.1 NASA Task Load Index (NASA-TLX)

After completing the tasks, the participants will complete an adapted version of the NASA Task Load Index (NASA-TLX). The NASA-TLX is a widely used tool for assessing the perceived workload of participants while performing a task. In this case, it will measure only five dimensions out of the usual six: Mental Demand, Temporal Demand, Performance, Effort, and Frustration; due to the fact that the application does not require physical activity on the part of the user. By collecting this data, we can analyze the workload of the app and identify specific areas that may require improvement.

3.2.2 System Usability Scale (SUS)

The System Usability Scale (SUS) will also be administered to participants at the end of the testing session. The SUS is a reliable, low-cost usability scale that consists of a 10-item questionnaire with five response options for respondents; from Strongly agree to Strongly disagree. This tool will provide a quantitative baseline for assessing the overall usability of the application.

3.2.3 Questionnaire for User Interaction Satisfaction (QUIS)

Finally, participants will also complete the Questionnaire for User Interaction Satisfaction (QUIS). The QUIS survey measures user satisfaction with specific aspects of the human-computer interface. It includes questions on overall reactions to the software, screen factors, terminology and system information, learning factors, system capabilities, and technical manuals. This survey will provide detailed insights into user satisfaction and highlight specific strengths and weaknesses of the application.

3.3 User Profiles

The evaluation of the application will consider two primary user profiles:

- Regular Citizens: Age groups 18-30, 31-45, 46-60; Digital Competency Levels: Low, Moderate, High; Demographic Diversity: Ensuring a mix of genders, educational backgrounds, and occupations.
- Professional Users: Age groups 25-35, 36-50; Digital Competency Levels: Moderate, High; Demographic Diversity: Ensuring a mix of genders, educational backgrounds, and occupations.

3.4 Methodology

This section outlines the step-by-step approach to be taken in developing and evaluating the user-friendly mobile app. The research methodology involves key activities, such as requirements analysis, app development, testing, and user feedback collection through a concluding survey.

This methodology ensures that the application is planned in advance with a focus on the intended user's needs and that its quality is evaluated by users, giving us insightful feedback on how well the project's goals were met.

3.4.1 Requirements Analysis and Prototyping

The initial phase of the project involves a comprehensive requirements analysis. This analysis aims to identify and prioritize both functional and non-functional requirements for the mobile app, ensuring a user-centric design. The needs and goals of the application's intended users will be thoroughly examined to establish a clear understanding of their expectations.

Following the requirements analysis, a series of prototypes will be developed to visualize the app's design and functionality. These prototypes will serve as interactive representations of the app, aiding in the development process. However, due to time constraints, these prototypes will not undergo validation with users.

3.4.2 Implementation

The actual coding and implementation of the mobile app will be carried out based on the finalized prototype. As mentioned before, Flutter will be used to implement this application.

3.4.3 Testing

The testing phase will be conducted in a controlled environment with participants chosen from volunteers and, as mentioned above, will contain both qualitative and quantitative methods. The participants will have to complete a set of tasks that constitute basic and fundamental tasks of the application and, while doing so, will be encouraged to talk-aloud and share their thoughts with the accompanying researcher who will also note the time they take to complete the task. After finishing all tasks they will be asked to fill out the NASA-TLX, SUS and QUIS surveys to give their insights on the app in general in terms of workload, usability and overall system satisfaction respectively. Participants will also have the option to leave comments at the end of the survey in case they want to share any further insights.

Furthermore, a couple of relevant followup questions will be asked by the researcher to further encourage users to give their thoughts on specific aspects of the application.

User Testing Tasks

Before starting, participants can choose whichever language they are more comfortable with and are given credentials to log into the account they will use to complete the tasks. This account will be prepared with a number of real videos and occurrences and will be cleaned of any changes made by users between tests. Task order will also be randomized for each user by the researcher before the test starts.

An initial sample of tasks was created with the following:

- Change the account's name - In this task users will have to change the account's name to theirs.
- Capture an image - In this task users will have to take a picture with the app. If this is the first task using the camera they will have to allow the app the necessary permissions.
- View a picture taken by the user - In this task the user will have to select an image in the list of videos in the app and describe the information they are able to see.
- View an occurrence - In this task the user will have to select an occurrence in the list of occurrences in the app and describe the information they are able to see.
- Capture a video - In this task the user will have to select an image in the list of videos in the app and describe the information they are able to see.
- View a video - In this task the user will have to select a video in the list of videos in the app and describe the information they are able to see.

These tasks were then tested with two real users, one from the 18-30 age group and another from the 46-60 age group. With these tests it was discovered that the task "View a picture taken by the user" was too confusing given the fact that the application treats pictures as single frame videos and this question was removed.

Furthermore, to maximize the extent of the app that was explored by the users the more open questions such as "View a video" and "View an occurrence" were replaced with more direct and specific questions.

During these first tests a couple bugs were also found, namely a typo in the world occurrence when the app was set to Portuguese and an issue where, if a user clicked on a video before images were fully loaded, they would finish loading but the text would still say that no images were available. These bugs were fixed before the real tests started.

With that, the final tasks chosen to be administered are the following:

- Change the account's name - In this task users will have to change the account's name to theirs.
- Capture an image - In this task users will have to take a picture with the app. If this is the first task using the camera they will have to allow the app the necessary permissions.
- Capture a video - In this task users will be asked to record a video using the app. If this is the first task using the camera they will have to allow the app the necessary permissions.
- View video images - In this task users will be asked to select one of the videos already in the app and figure out how to see the frames of the video.
- View occurrence image - In this task users will be asked to see the enlarged image of an occurrence.

- View a video in the map - In this task users will be asked to view a video in a map.
- View other images of the same location as the occurrence with ID 9 - In this task users must first find the occurrence with ID 9. They are informed by the researcher that the only way to see the ID of an occurrence is to click on it. After finding the correct one they must then find a way to view other images from the same location.
- Find an occurrence where the issue found was cardboard abandoned in the street - In this task users can either scroll until they find the occurrence or use filters to find it. Regardless, they will be asked about the filters.
- View the original video of an occurrence - In this task users must choose any occurrence and from it find the video that originated it.

Follow-up Questions

The follow-up questions to be asked by the researcher are:

1. Do you believe that, if you needed to, you would be able to change other account information (such as email or profile picture)?
2. Do you believe that, if you needed to, you would be able to delete your account?
3. Do you believe that, if you needed to, you would be able to change your password?
4. Do you believe that the notifications you received after capturing an image are useful to understand the state of said image?
5. Do you believe that the notifications you received after capturing a video are useful to understand the state of said video?
6. Do you feel like you understand where you can find the filters and know how to use them?
7. Do you understand the difference between a video and an occurrence in the context of the app?

These questions can be asked after a certain task where the users should have learnt this information or at the end of all tasks depending on the order of the task and where they seem more fitting. For example, Question 7 should only be asked after the user had the opportunity to interact with both videos and occurrences at least once.

To keep record of the participants' responses and make later data analysis easier, two google forms were made, one to be filled by the participant and another to be filled by the investigator which can be seen in the Appendix B.

Based on the feedback received during this phase, iterative refinements can then be made to the app. This ongoing refinement process ensures that the app remains responsive to user needs and evolving challenges in urban management.

3.4.4 Data Analysis

Quantitative data analysis will be performed on the survey results. Descriptive statistics and potentially inferential statistics will be employed to interpret the numerical data obtained from the survey.

Usability testing, user satisfaction surveys, and performance evaluation against predefined benchmarks will contribute to the overall validation of the developed app. These quantitative measures aim to provide a comprehensive understanding of the app's success in meeting user expectations.

Chapter 4

Requirement Analysis

For starters, it was necessary to define the application's requirements based on the users needs. After consideration, the User Stories in table 4.1 were defined.

Table 4.1: Theia Application User Stories Table

Number	User Story	Description	Priority	Effort
1	As a user, I want to be able to register an account in the app, so that my data can be saved in my account.	Must provide an email, name and password. User must click on confirmation email to be able to log in after registration.	High	Low
2	As a user, I want to be able to be able to log in, so that I can have access to my data after my session expires.	Must provide email and password. Session must persist until user logs out or after a certain time has passed.	High	Low
3	As a user, I want to be able to log out, so that I can exit my account to log into another one.	Nothing to add.	Medium	Low
4	As a user, I want to reset my password, so that I can still access my account if I lose it.	Nothing to add.	High	Low
5	As a user, I want to be able to manage my account, so that I can update my information.	Name, email, profile picture and password can be changed. If email is changed, server must re-send confirmation email.	High	Low

6	As a user, I want to be able to eliminate my account, so that I can erase my personal data from the app.	Mandatory in the EU by the GDPR as the "right of erasure". Apple Store also mandates an option for account deletion. Same with Google.	High	Low
7	As a user, I want to be able to constantly capture images while driving my vehicle, so that a lot of images can be gathered automatically.	Frame rate must be variable depending on vehicle speed. User must be able to see what the camera is capturing.	High	High
8	As a user, I want to be able to take pictures of occurrences on the street, so they can be evaluated.	Saved as videos with a single image.	High	Medium
9	As a user, I want to be able to see the videos that I recorded and submitted, so that I can keep a record of what I've submitted.	Should show images and videos with IDs, Date and Time, origin of the video clip, thumbnail, Upload Status (waiting, uploaded and uploading) (if uploading with percentage). Should order by most recent to oldest.	High	High
10	As a user, I want to filter videos so that I can more easily find the ones I'm looking for.	Filter by upload status and date.	High	Medium
11	As a user, I want to be able to order videos, so that I can more easily find the ones I'm looking for.	Order by date.	High	Medium
12	As a user, I want to be able to see the details of the videos I've captured, so that I can see their detailed information.	Picture, Time and Date, Upload Status, list of occurrences detected.	High	Medium
13	As a user, I want to be able to see in a map the path of the video I took so that I can remember where the various pictures were taken.	Nothing to add.	Medium	Medium

14	As a user, I want to be able to see the sequence of the continuous images that I took, so that I can see what I've recorded.	Nothing to add.	High	High
15	As a user, I want to be able to further annotate the continuous images after I've recorded them.	User goes through frames and annotates them as they see fit.	Low	High
16	As a user, I want to be able to delete the continuous images I've captured, so that my list isn't full of images and videos I don't want to see.	Needs a warning pop-up since it's a destructive action.	Medium	Low
17	As a user, I want to be able to annotate continuous images in real time so that I can point out where in the video the occurrence I am reporting is while I'm recording it.	Interface during video recording. User can start annotation by clicking a button and stop it by clicking again.	Low	High
18	As a user, I want to be able to configure if images and videos can be uploaded only over Wi-Fi or also through GSM communications, so that I can decide if I want to let the app spend data.	Nothing to add.	Medium	Low
19	As a user, I want to be able to see all my occurrences, so that I can know which occurrences I've captured and their status.	Should show: date and time, event types, status. Paged.	High	High
20	As a user, I want to be able to filter occurrences, so that I can find the ones I'm looking for more easily.	Search by Event Type, Date and Status.	Medium	Medium
21	As a user, I want to be able to order my occurrences, so that I can find them more easily.	Order by Date.	Medium	Medium
22	As a user, I want to be able to see my occurrences' details, so that I can see their detailed information.	Info from the list and occurrence image.	High	Medium

23	As a user, I want to be able to see the original video capture that generated the occurrences.	Just a button that leads users to a different page.	High	Medium
24	As a user, I want to be able to request manual verification of an occurrence, so that events not caught by the AI can be verified.	Just a button in the occurrences details. Only for unconfirmed occurrences.	Low	Low
25	As a user, I want to be able to mark occurrences as in revision, so that other users can know that the problem detected is being taken care off.	For confirmed occurrences only.	Low	Low
26	As a user, I want to be able to mark occurrences as solved, so that other users can know that the problem detected was taken care off.	For occurrences in revision only.	Low	Low
27	As a user, I want to be able to delete my occurrences, so that they aren't taking up space in my occurrences list.	Button in details' page.	Medium	Low
28	As a user, I want to be able to edit the annotations of my occurrences, so that I can change them to be more accurate.	Only occurrences which are not confirmed can be annotated. Change event types.	Low	Medium
29	As a user, I want to be able to receive notifications, so that I can be updated on information in the app without having to open it.	Nothing to add.	Medium	Medium
30	As a user, I want to be able to filter notifications, so that I can better find the ones I'm interested in.	Filter by old and new, date and by type of notification.	Medium	Low.
31	As a user, I want to be able to order notifications, so that I can better find the ones I'm interested in.	Order by date.	Medium	Low
32	As a user, I want to be able to see all my notifications, so that I can keep track of them.	Nothing to add.	Low	Medium

33	As a user, I want to be able to accept a package invite by clicking on the package invite notification, so that it's easier to join other user's packages.	Nothing to add.	Low	Medium
34	As a user, I want to be able to see paid packages, so that I can know what type of packages I can purchase.	Types: Issues, up-to-date and API. Has expiration date. Several packages can be bought at once and combined. Just a page with the options, details and buttons to buy the packages.	Low	Medium
35	As a user, I want to be able to buy the Issues package, so that I can see events and update their state once an issue is resolved.	Has different types of sub-packages for geographical areas, event types and periods. Just redirect user...	Low	Medium
36	As a user, I want to be able to buy the API package, so that I can have access to the API.	Grants access to API by giving user authentication details to access it. Just redirect user...	Low	Medium
37	As a user, I want to be able to invite other users to my package, so that they can also make use of my packages.	If user has an account invite (sends email and notification), otherwise send invitation email.	Low	High
38	As a user, I want to be able to see all my billing information, so that I can keep track of it.	Nothing to add.	Low	Medium
39	As a user, I want to be able to download invoices and receipts for purchased packages, so that I can have easy access to them.	Nothing to add.	Medium	Medium
40	As a user, I want to be able to see the overall usage of my packages, so that I can know how much they are being used.	TO BE DEFINED	Low	High
41	As a user, I want to be able to see the usage of my packages by invitees, so that I can know how much they are using them.	TO BE DEFINED	Low	High

42	As a user I want to be able to export my occurrences as an XML file, so that I can have their info outside of the application.	Nothing to add.	Low	Medium
43	As a user I want to be able to query all images of the location of an occurrence, so that I can verify if the occurrence has been resolved.	See all images from the location.	High	High
44	As a user I want to be able to see the occurrence reports, so that I can have access to information about occurrences found.	Number of occurrences (by type), avg resolution time, zones with the highest occurrence incidence (by type).	Low	Low

From the user stories identified the following were not implemented or completed in the final application:

- In user Story 7 the variable frame rate has yet to be implemented due to time constraints and testing difficulties.
- In user story 12 information regarding occurrences for each video is missing.
- User stories relating to annotations (17 and 28) were not implemented due to their complexity and the incomplete integration of AI with the server.
- User stories related to changing the state of occurrences (24, 25, 26) were not implemented for the same reason—lack of complete AI integration with the server.
- User story 27 has not been implemented.
- User stories related to packages (33-41) were not implemented because further details and considerations are needed by the project team before implementation.
- User stories 42 and 44 were not implemented due to their low priority and lack of time.

Furthermore not every type of notification was implemented since some are dependent on packages, annotations and occurrence states.

Along the development it was also considered the implementation of some gamification mechanisms (such as tasks and objectives) or the use of crypto currency rewards in the application to incentivize users to take pictures and make use of the app, however, those are ideas that would require further thought in the future before any decision can be made and were therefore not considered for now.

Other than the user stories identified, a couple of non-functional requirements were also found which can be seen in table 4.2.

Table 4.2: Theia Application Functional Requirements

Number	Non-Functional Requirements
1	The application must incorporate offline functionality to locally store and retrieve information, allowing users to access features that do not rely on real-time data or external services when an internet connection is unavailable. It is acknowledged that certain features may have limited functionality or be unavailable in offline mode.
2	The application must demonstrate efficient and automatic synchronization of images upon reestablishing internet connectivity, minimizing user intervention and ensuring timely upload without requiring manual initiation.
3	The mobile application must be compatible with the latest versions of major mobile operating systems, including iOS and Android. This ensures optimal performance, functionality, and user experience on current and widely used mobile platforms.

Unfortunately, due to a lack of resources and high costs, the third non-functional requirement could not be implemented at this time. However, it remains a priority for future development.

After defining these requirements mockups for each of the necessary pages were created with all the necessary functionalities. Later they were altered by a designer to ensure that they looked cohesive and appealing before implementation began.

Chapter 5

Software Architecture

In terms of architecture the Theia mobile app runs on a users mobile device and, when needed, sends requests to retrieve/ send information to a server whose job is to persist information and pass it to the clients.

In the future, the server will also communicate with the AI responsible for labeling occurrences in the pictures taken by the user.

The full overview of the system architecture can be seen in Figure 5.1.

Figure 5.1: Theia Application architecture diagram

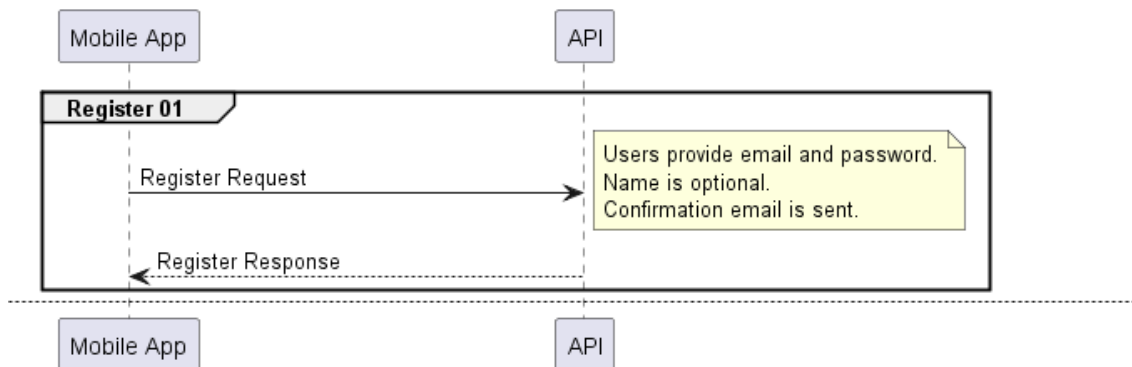


In the architecture of the system developed for managing user interactions and information retrieval, a total of seventeen endpoints were established on the main server. These endpoints facilitate the communication between the client application and the server, enabling the retrieval and submission of information as required, and are the following:

1. Registration Endpoint:

- This endpoint enables clients to register new users by providing essential details such as email and password. Optional fields may include additional user information.
- Upon registration, the server responds with an "OK" message if successful, or provides appropriate error messages such as "Account already registered" or "Invalid email format."

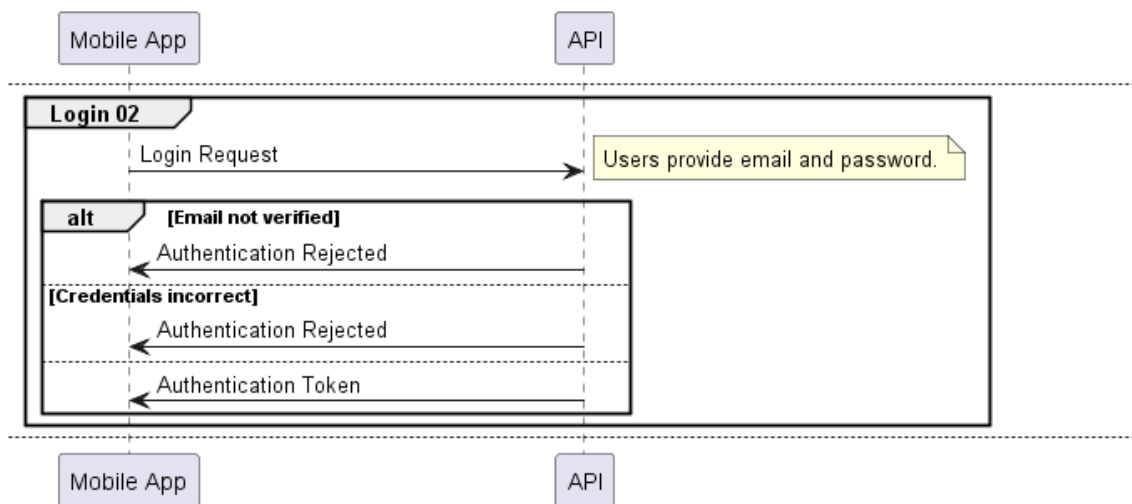
Figure 5.2: Theia Application sequence diagram - Registration Endpoint



2. Login Endpoint:

- Registered users can authenticate themselves through this endpoint, typically requiring account activation via email for security purposes.

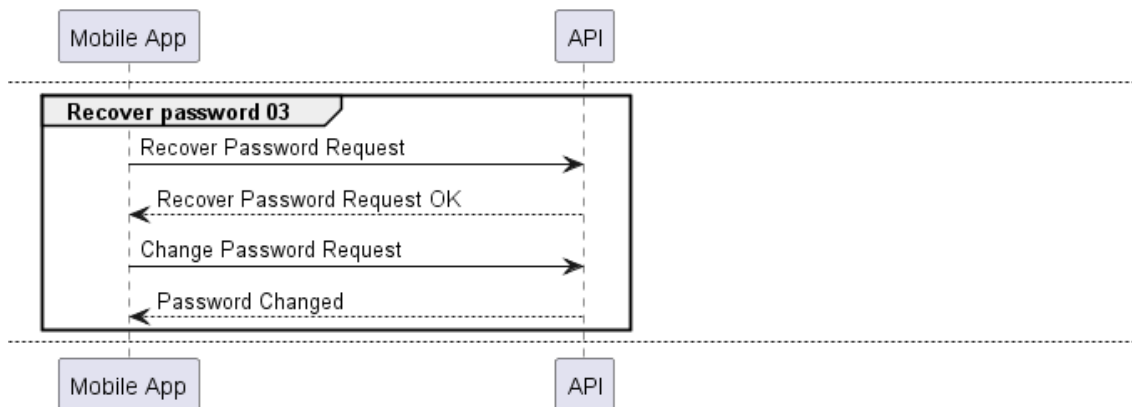
Figure 5.3: Theia Application sequence diagram - Login Endpoint



3. Password Recovery Endpoint:

- Users can initiate password recovery through this endpoint, which involves sending a password reset link or code to the user's registered email address.

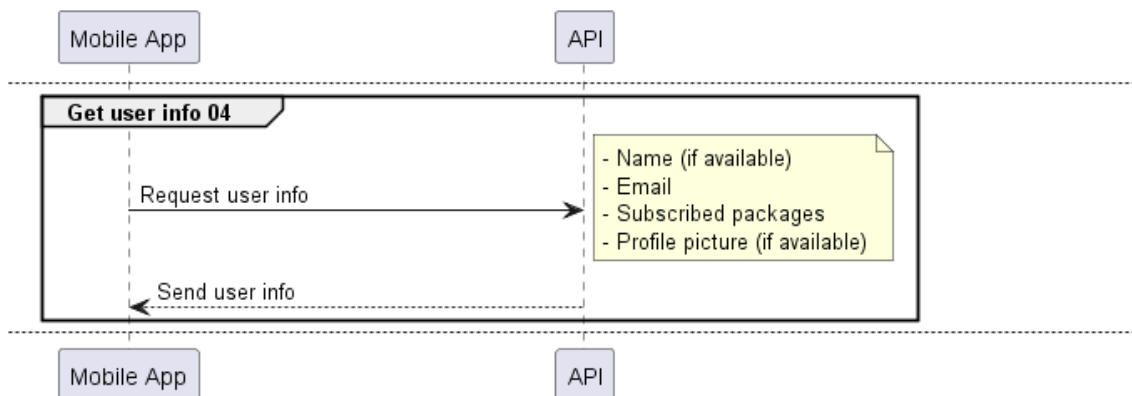
Figure 5.4: Theia Application sequence diagram - Password Recovery Endpoint



4. Get User Info Endpoint:

- This endpoint retrieves user information based on authentication credentials or session tokens. It provides access to user details such as name, email address, and profile picture.

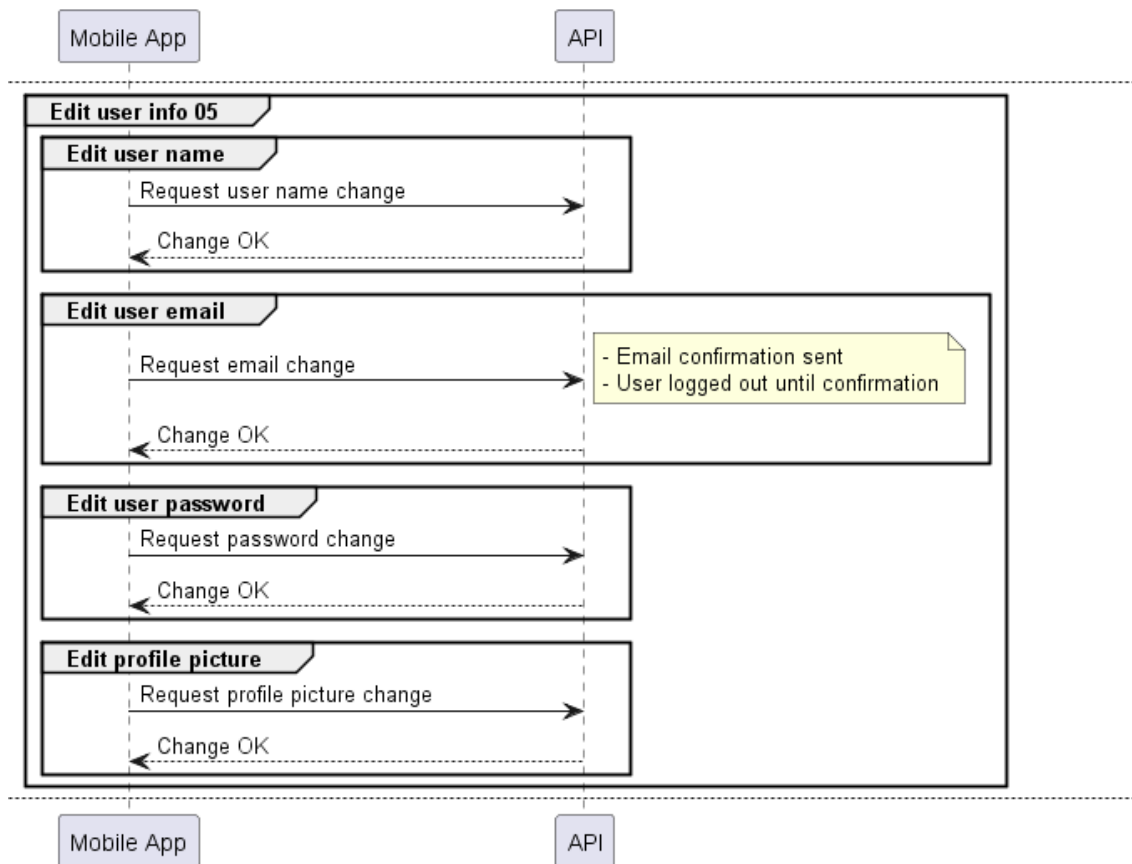
Figure 5.5: Theia Application sequence diagram - Get User Info Endpoint



5. Edit User Info Endpoints:

- Users can update their profile information using these endpoints, allowing modifications to fields such as name, email address, password, and profile picture.

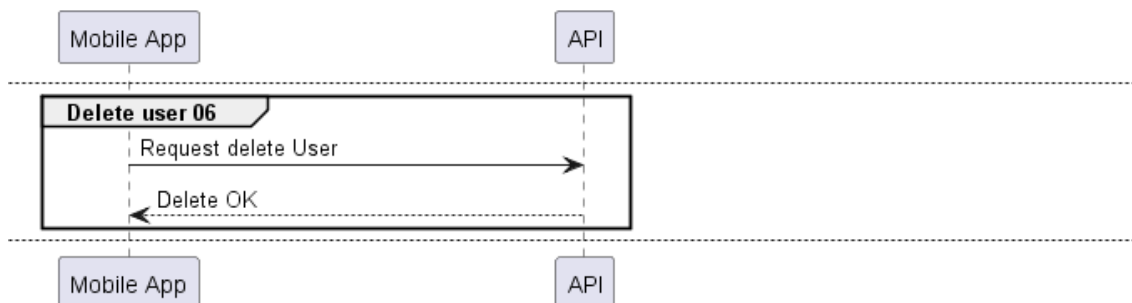
Figure 5.6: Theia Application sequence diagram - Edit User Info Endpoints



6. Delete User Endpoint:

- This endpoint facilitates the deletion of user accounts upon confirmation from the user, ensuring a secure and user-controlled process.

Figure 5.7: Theia Application sequence diagram - Delete User Endpoint

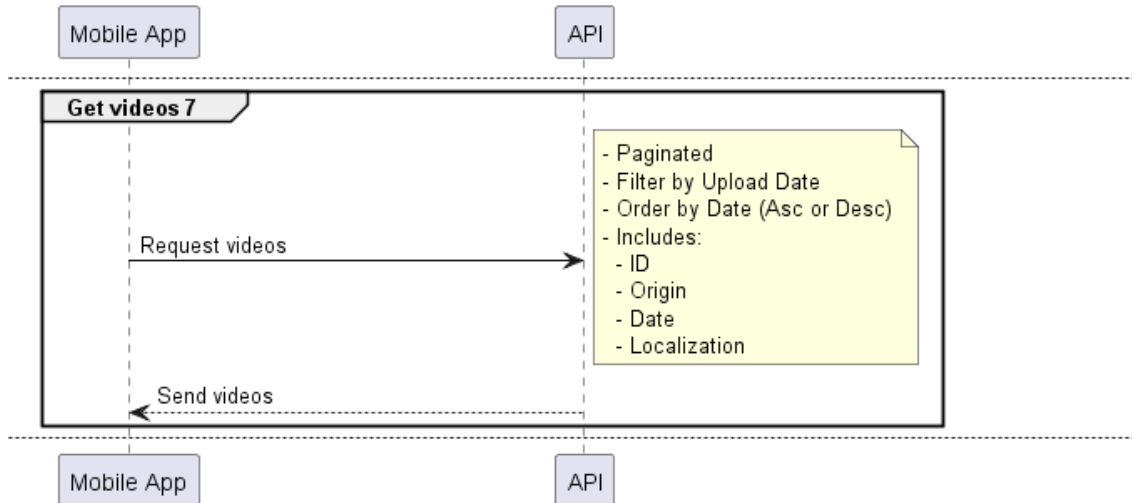


7. Get Videos Endpoint:

- Retrieves a list of videos, paginated and optionally filtered by status and date and/or ordered by date.

- Each video has an ID, origin, date, and localization information.

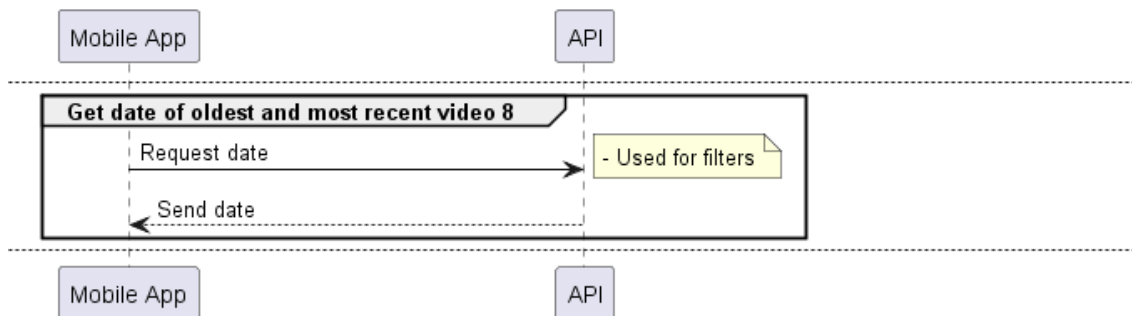
Figure 5.8: Theia Application sequence diagram - Get Videos Endpoint



8. Get Oldest and Most Recent Video Dates Endpoint:

- Returns the date of the oldest and most recent videos available in the system. This is used to make the start and end dates of filters accurate.

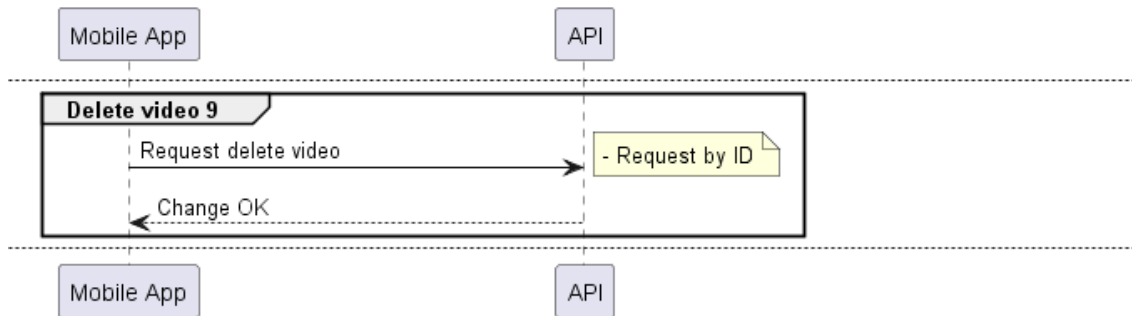
Figure 5.9: Theia Application sequence diagram - Get Oldest and Most Recent Video Dates Endpoint



9. Delete Video Endpoint:

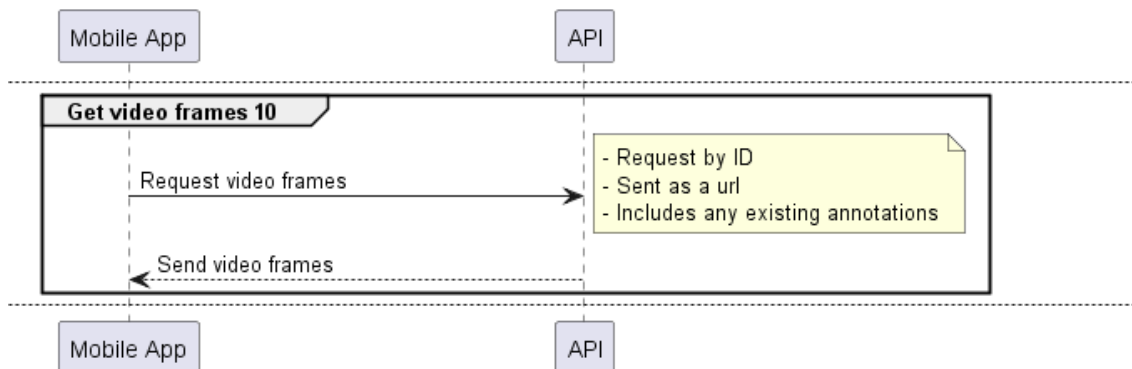
- Allows deletion of a specific video from the system.

Figure 5.10: Theia Application sequence diagram - Delete Video Endpoint

**10. Get Video Frames Endpoint:**

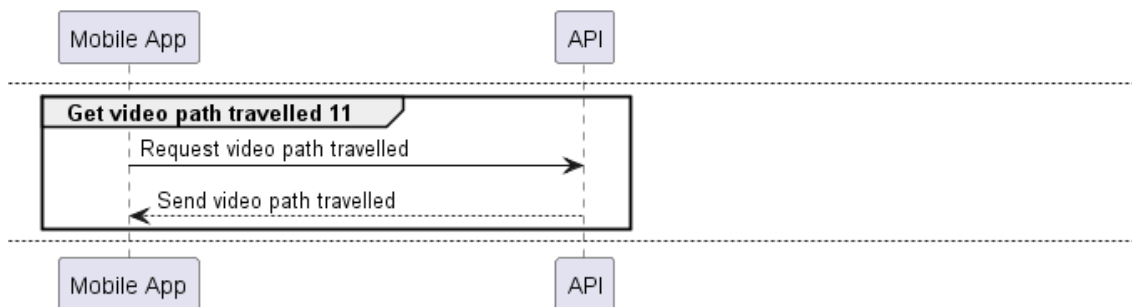
- Retrieves frames of a specific video identified by its ID.

Figure 5.11: Theia Application sequence diagram - Get Video Frames Endpoint

**11. Get Video Path Travelled Endpoint:**

- Retrieves the path travelled for a specific video, including origin and localization details.

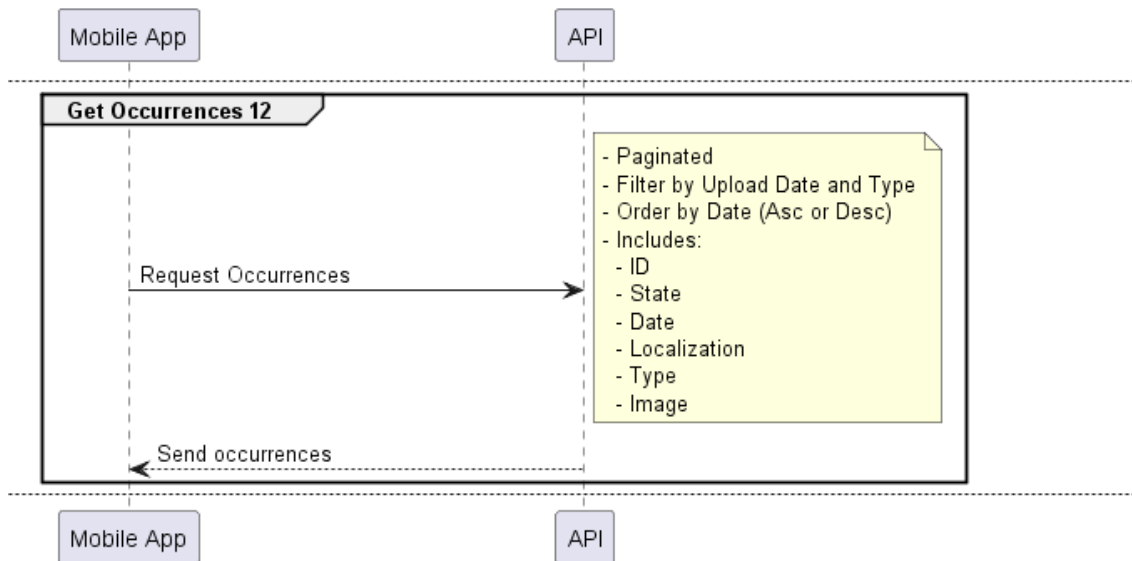
Figure 5.12: Theia Application sequence diagram - Get Video Path Travelled Endpoint



12. Get Occurrences Endpoint:

- Retrieves a list of occurrences, paginated and optionally filtered by state, type, and date and/or ordered by date.
- Each occurrence includes an ID, state, date, localization, type, and its image.

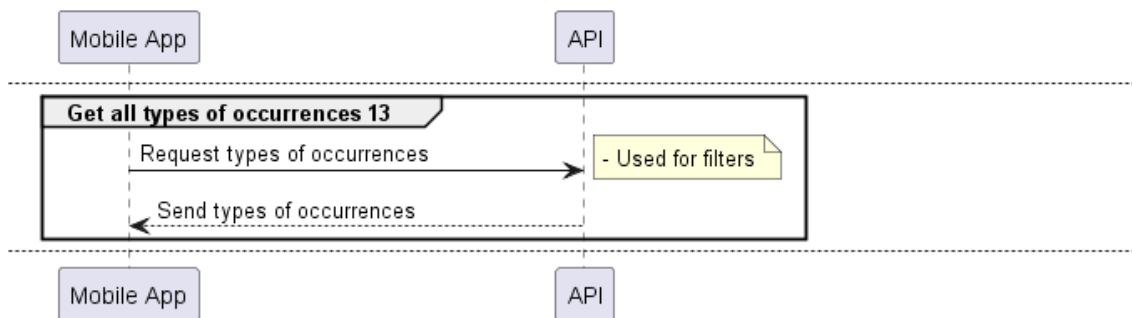
Figure 5.13: Theia Application sequence diagram - Get Occurrences Endpoint



13. Get All Types of Occurrences Endpoint:

- Returns all types of occurrences available in the system. Used for filters.

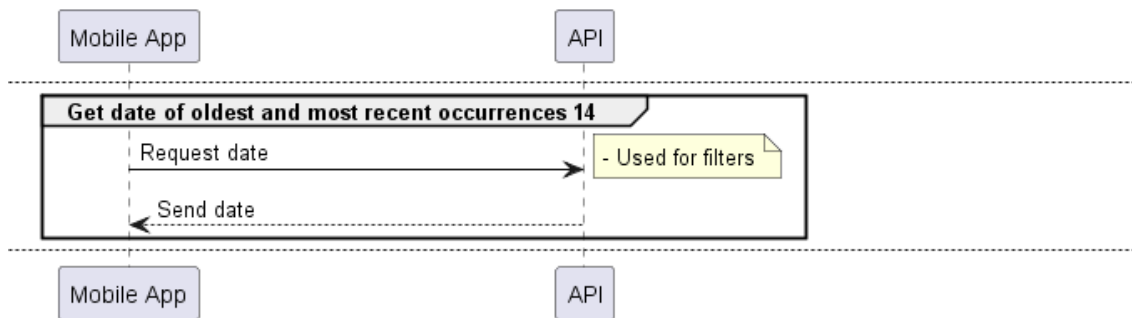
Figure 5.14: Theia Application sequence diagram - Get All Types of Occurrences Endpoint



14. Get Oldest and Most Recent Occurrence Dates Endpoint:

- Returns the date of the oldest and most recent occurrences available in the system. This is used to make the start and end dates of filters accurate.

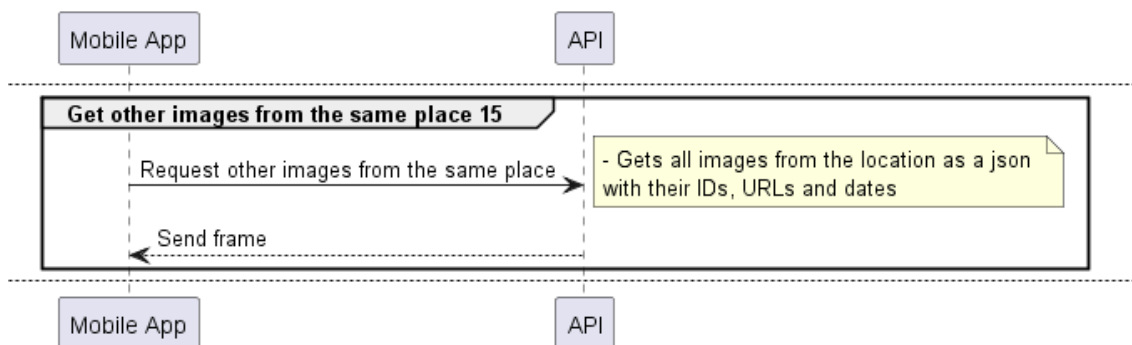
Figure 5.15: Theia Application sequence diagram - Get Oldest and Most Recent Occurrence Dates Endpoint



15. Get Other Images from Same Location Endpoint:

- Provides a JSON file containing URLs, IDs, and dates of other images from the same location, ordered by date.

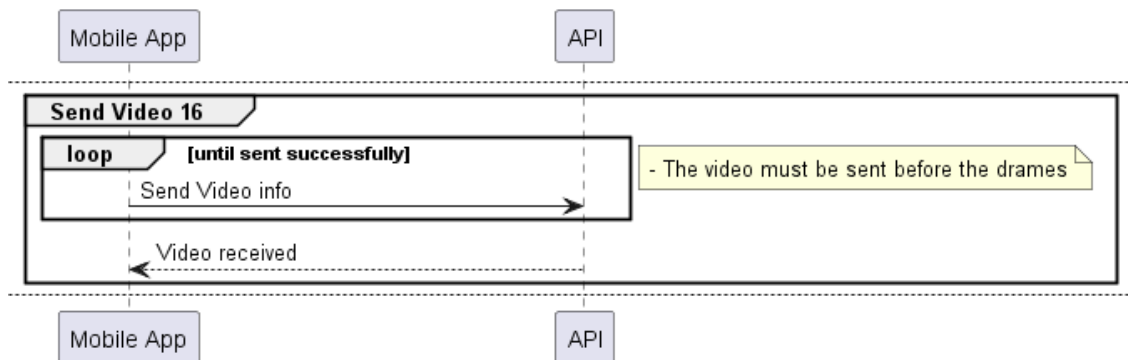
Figure 5.16: Theia Application sequence diagram - Get Other Images from Same Location Endpoint



16. Send Video Endpoint:

- Sends video metadata to the server, including the video ID, start date, end date, start coordinates, end coordinates, origin, the email of the user who recorded the video, and the total number of frames of the video.
- This must be done before sending any of the video's frames.

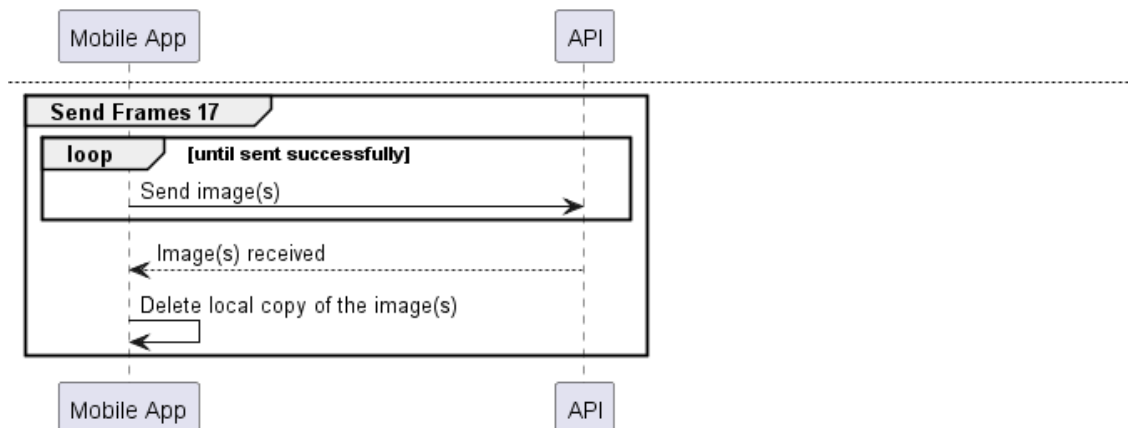
Figure 5.17: Theia Application sequence diagram - Send Video Endpoint



17. Send Frames Endpoint:

- Sends video frames and their metadata to the server, including the ID, date, coordinates, ID of the video to which they belong, and the email of the user who recorded the video.
- While this isn't enforced on the side of the server, currently only 30 frames are being sent in a single request.

Figure 5.18: Theia Application sequence diagram - Send Frames Endpoint



These endpoints collectively support comprehensive management functionalities for users, videos, and occurrences within the system. They ensure robust, secure, and efficient interactions between client applications and the server, adhering to principles of scalability and data integrity.

Chapter 6

Implementation

The Theia mobile application, as mentioned above, was created using Flutter and was made with both Android and iOS in mind and, therefore, only packages and functionalities available for both systems were used, even if the app does not currently work for iOS.

In terms of Android, the application is available for all android devices with the Android version 5.0 Lollipop or above which currently constitutes roughly 99.53% of all the android users as of May of 2024 [38].

In the following sections all the application's functionalities implemented will be described along with any considerations about their implementation.

6.1 General

For the application to properly communicate with the server's API it was necessary to use a Flutter package that allowed for the sending of REST requests. After some consideration, the dio package [39] was chosen over the http package [40] due to the fact that the dio package allows easy updates on the upload and download of files (onSend and onRecieve) something that would be needed when uploading big videos to the server to keep the user informed on the status of the upload.

To allow information to easily persist between different pages and to better organize requests to the API the provider package [41] was used. This allowed us to easily access important information anywhere in the app with providers for language, occurrences, videos, notifications and the user.

To allow some information to persists even after the application is closed the shared_preferences package [42] was used. This allowed not only for the persistence of actual user preferences (such as upload and language preferences) but also for the persistence of some other information that must be available offline (such as local notifications and videos).

Finally, to make navigating the application more organized a Route Generator was created and all the pages the user can navigate to were given route names.

6.2 Language

The application is fully available in both Portuguese and English as seen in Figures 6.1a and 6.1b. On first boot the application defaults to English, however, after the user has chosen their preferred language the application will subsequently initialize with that language instead.

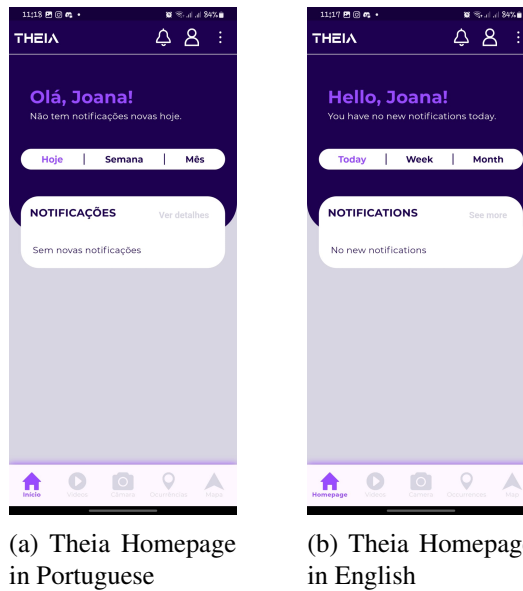


Figure 6.1: Theia Homepage in both languages

On first boot the screen in Figure 6.2a will appear asking the user to choose their preferred language by choosing a flag.

After logging into the application the user can change their language at any time in the configurations page as seen in Figure 6.2b.

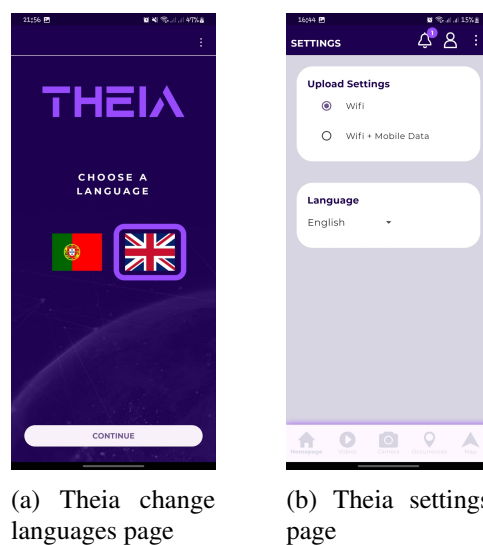


Figure 6.2: Pages to change the application's language in the Theia app

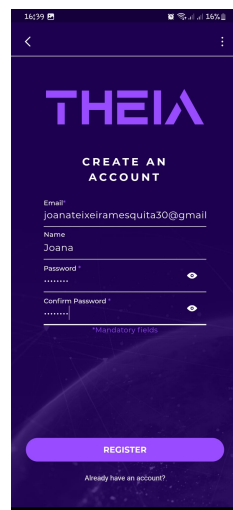
To implement two different languages the intl package [43] and the flutter_localization package [44] were used and each string in the app was manually translated for both languages.

When translating error messages from the server it was instead decided to just write the correct error messages in Flutter according to the error code received.

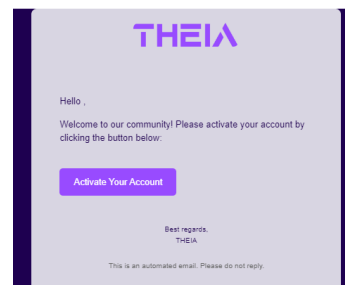
6.3 Register

When a user enters the app for the first time they need to start by registering an account as shown in Figure 6.3a. The user receives an error message if they leave any of the mandatory fields empty, attempt to use a password which does not satisfy the safety criteria (minimum six characters with a number and symbol), attempt to use an invalid email or attempt to create an account with an email already in use.

After registering an account the user will receive an email with a link that they must click on to activate the account as shown in Figure 6.3b.



(a) Theia create account page



(b) Theia activate account email

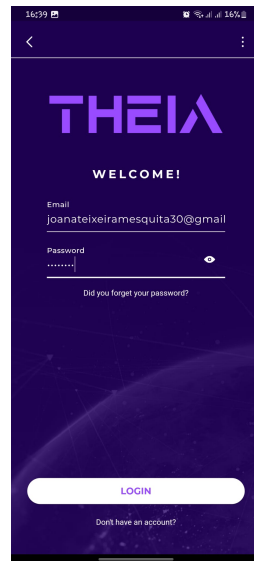
Figure 6.3: Create account page and Activate account email

6.4 Login

To use the application the user must first log in as shown in Figure 6.4. The user will receive an error message if they try to log in with an email that is not registered, input the wrong password, leave any field blank or try to use an invalid email.

After logging in, the application receives the user's profile information as well as a token that will expire if the user logs into the account again. If the token expires while the user is logged in the next time the user makes a request they will be redirected back to the log in page and told that their session has expired.

Figure 6.4: Theia login page



6.5 See Account Information

To see account information the user simply needs to access the profile page by clicking on the icon on the top right corner of the screen as seen in Figure 6.5a.

6.6 Log out

The user can log out from the user profile page as seen in Figure 6.5a. Logging out will erase the user info from the app including the token.

6.7 Delete Account

The user can delete their account through the user profile page as seen in Figure 6.5a. After clicking the button a pop up will show up, Figure 6.5b, asking the user to confirm if they really want to delete their account. If the user confirms the action the account and all associated information including videos will be deleted from the server.

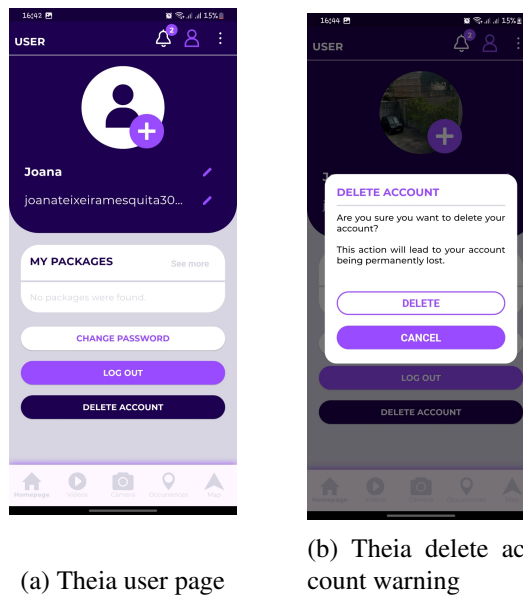


Figure 6.5: User Profile page and Delete Account popup

6.8 Recover Password

If the user has lost their password and wants to recover it they can do so by clicking the "Forgot you password?" button from the Log in page. This will lead them to screen where they'll have to introduce their current email as see in Figure 6.6a.

After pressing the confirm button the user will be informed that an email has been sent to their account.

Opening the email, Figure 6.6b, and clicking the link will lead the user to a web page where they must input their new password twice as seen in Figure 6.6c.

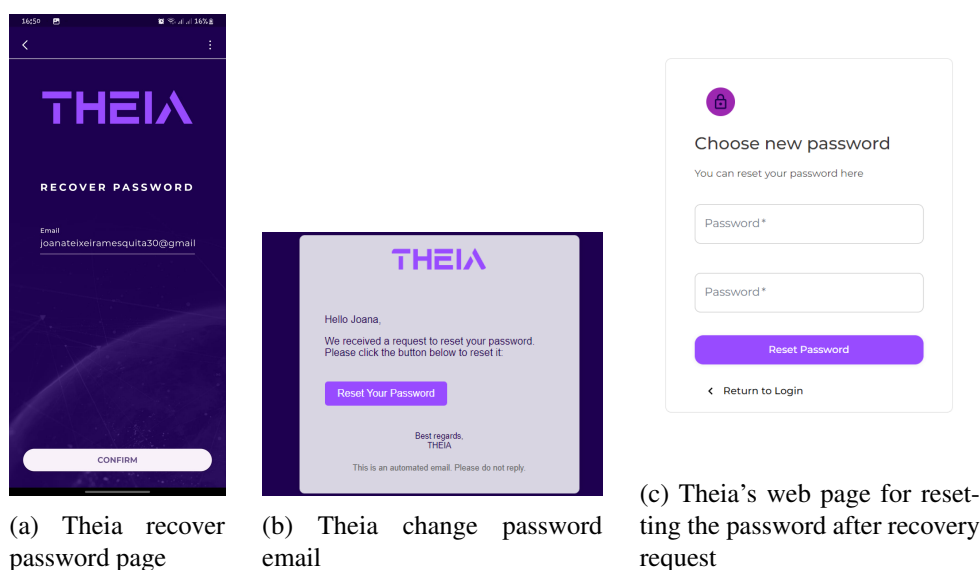


Figure 6.6: Recover Password page, Recover Password email, and Recover Password web page

6.9 Change User Information

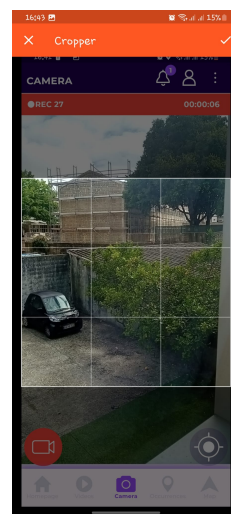
If the user wishes to change any of their account's information such as their name, email, profile picture or password they can do it from the user profile page.

To change their name, email or profile picture the user must click on the edit icon or plus icon next to where they can see their current information. After, as can be seen in Figure 6.7a, they can change the field and press the check mark button to submit.

When changing the profile picture the user can select any image from their gallery, however, to ensure that all images have the right aspect ration the user is asked to crop it into a square shape, Figure 6.7b.



(a) Editing the name in the Theia app

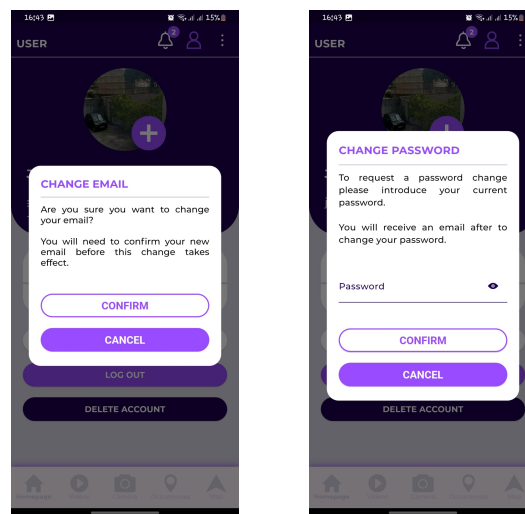


(b) Cropping profile picture in the Theia app

Figure 6.7: User info editing - Part 1

When changing their email the user will receive a warning first, Figure 6.8a, and then will be logged out and must confirm the new email before being able to log in again.

To switch passwords the user must press the change password button in the page and then fill out their current password in the pop-up that shows up, Figure 6.8b. After, they will receive an email and can change their password through the link sent just like when recovering their password.



(a) Theia changing email warning

(b) Theia changing password warning

Figure 6.8: User info editing - Part 2

6.10 View videos

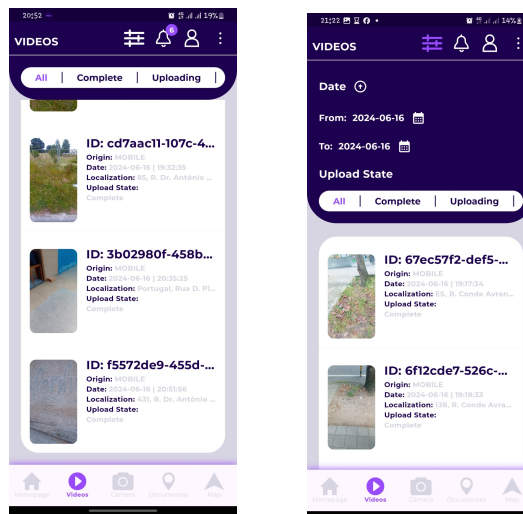
To view videos recorded, the user can access the Video page in the app. From the list, as seen in Figure 6.9a, the user can see information related to the location, device of origin, date, ID and Upload State of each video as well as the first picture of the video in question.

Of these characteristics, currently, the origin can only be a mobile phone but, in the future, there are plans for the creation of a different device also capable of capturing images.

When it comes to Upload States each video can have one of the following three:

- Complete - The video has been uploaded to the server
- Uploading - The video is currently uploading, in this case it's possible to see the progress bar for the video.
- Waiting - The video is saved on the phone and is waiting to be uploaded for one reason or another.

From this page it's also possible to filter results. When a user enters the page they can immediately see the filter for the Upload State on the top which is always visible, however if they press the filter icon on the top bar, Figure 6.9b, they can expand the filter menu and also filter and order by date.



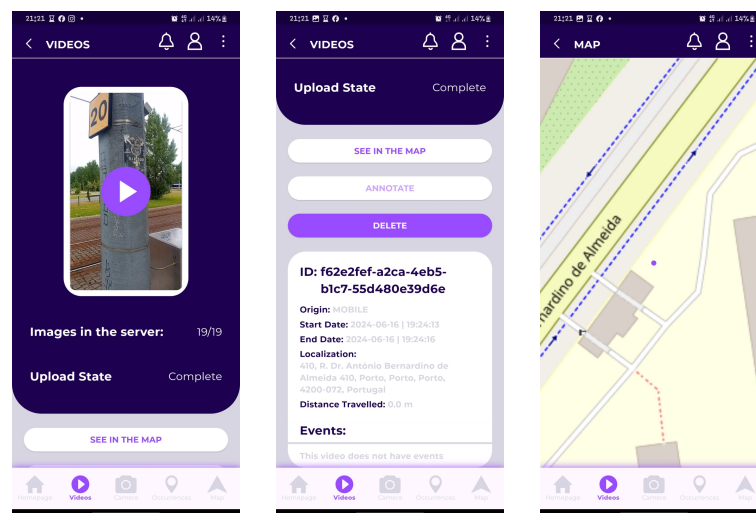
(a) Theia videos page

(b) Videos page with expanded filters

Figure 6.9: Videos page with filters expanded and without

To see more detailed information on a specific video the user can click on it and see the video page, Figures 6.10a and 6.10b, here it's possible to find the end date, distance travelled, number of images of the video, and, in the future, once the AI service is completely connected to the backend and ready to analyze the images captured, occurrences found in the video.

From this page it's also possible to delete a video as long as it's not currently being uploaded and, in the case of videos already on the server, it's possible to see the route of the video in a map, Figure 6.10c.



(a) Theia video details page - Part 1

(b) Theia video details page - Part 2

(c) Route of a video in a map in Theia

Figure 6.10: Theia video details page

Finally, if the user clicks the image on the top of the page they can go through each image of the video on by one, Figures 6.11a and 6.11b.

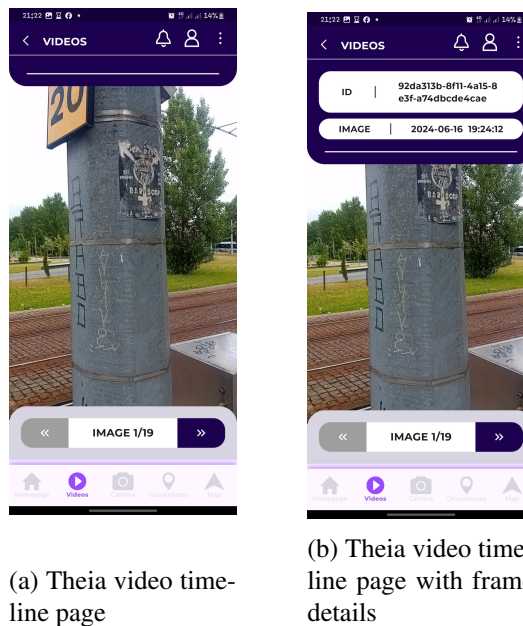


Figure 6.11: Theia video timeline

6.11 Video Recording

In the Theia application it was necessary to take a large number of pictures in very small intervals of time when a user is recording while driving. One of the options considered was simply recording a regular video and then uploading it to the server, however, this comes with the downside that, if something happens that interrupts the recording, all footage is lost no matter how long the recording had been going on for.

Due to this it was decided that, instead, it was safer to very quickly take and save successive pictures as if we were saving individual frames from a video. To do this, at first, there was an attempt to use the normal picture taking function of the Flutter camera package [45], however, after testing, it was discovered that the cool down time between pictures was between 1.5 and 2 seconds making each picture too spaced out.

This led to making use of the camera stream from the same package, usually used for image analysis, that gets images at the same speed and quality as a video would. While this gave us access to every frame of the camera, the images in the Android operating system were not in a format easily convertible to a jpeg image since they were encoded in the YUV_420_888 Android format whose conversion took about 2 seconds. Since we were taking a picture every 200 ms, the phone would end up using all its memory and the app to crash. There were attempts to make this conversion more efficient with the use of different packages but in the end it was decided that this method would not work.

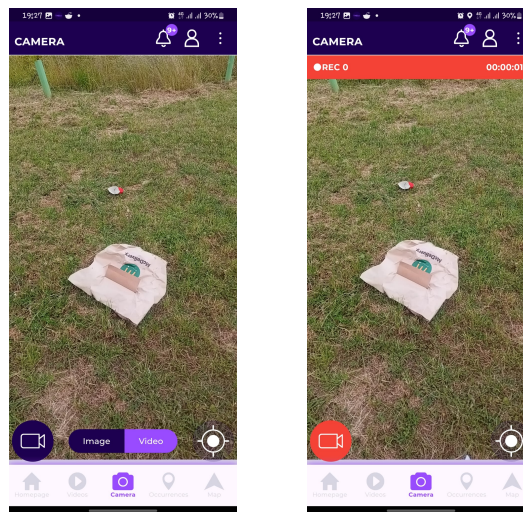
Our next attempt was, instead of converting the images in the user's mobile device at all, saving the planes of the image as bytes to a file with some other necessary information for the conversion of the image saved in the file's name such as the images row stride, pixel stride, height and width giving it a name with the format `image\{timestamp\}_rowStr_640_pixStr_1_width_1280_height_720.yuv`. These files are then sent to the main server which would in turn send them to the sever responsible for conversion. While this worked fine each image of a video took about two seconds to be converted from YUV to jpeg which caused larger videos to take a very long time to finish uploading.

In the end, we went with a mix of both of the previous methods. Images are saved during the recording process as bytes to a file with the previously mentioned information in the title as well as with the row stride of plane 0 and the sensor orientation giving the file's name the format `image\{timestamp\}_rowStr0_1280_rowStr1_640_pixStr_1_width_1280_height_720_sensorOrientation_90.yuv`. However, instead of sending the unconverted file to the server directly, the files are converted in the phone in batches during the upload process using the `processing_camera_image` package [46] and right after using the `image` package [47] to encode them into jpeg files. The jpeg files are then saved and sent to the server while the custom files are deleted. This proved to be a lot more efficient making upload much faster while, at the same time, allowing for future implementation of, for example, client side image anonimization.

Finally, to ensure that saving these files causes as little lag to the application as possible, once an image is selected to be saved it's sent to a `BehaviorSubject` from the `rxdart` package [48] where images will be processed and saved one by one, and the saving itself is done inside a `compute` which guarantees that the saving process runs asynchronously.

In terms of results, images are taken at a maximum resolution of Full HD (1080x1920) and, when the recording function was run on both a lower tier phone (Samsung Galaxy A14 4G with 4GB of RAM and 128GB of memory) and an emulator (Pixel 8 Pro), recording only stopped after they had completely run out of space to save any more pictures without the application crashing. Both in the emulator and the mobile phone there was some lag present, more so on the emulator which has less available ram, but, when briefly tested on higher end devices, that lag was almost non-existent.

In terms of the use of the recording function, the user can access it by going to the camera page in the application, Figure 6.12a. Once there they only need to choose the video option and press the recording button to record a video, Figure 6.12b.



(a) Theia camera page with record video selected

(b) Theia camera page while a video is being recorded

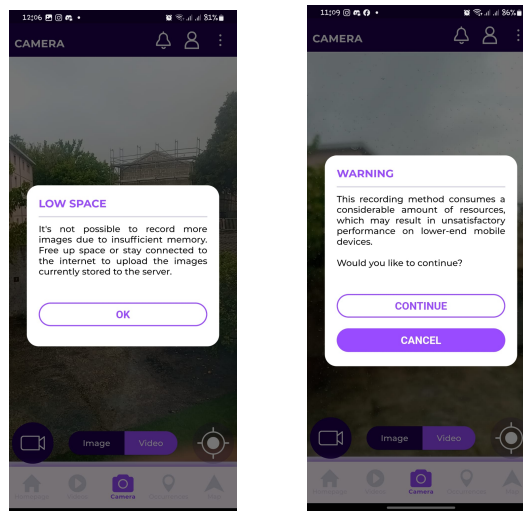
Figure 6.12: Theia camera page for recording videos

Once the user starts recording a video the screen will remain on and they won't be allowed to navigate to any other screens of the application until they finish the recording. Once they do stop recording, after the application is done saving all the frames to the devices memory the user will receive a notification saying that the video is awaiting upload to the server as seen in Figure 6.13.

Figure 6.13: Notification received after stopping recording



To prevent the user from recording a video when the memory is too low a pop-up warning shows up if they try to record a video without enough space in the phone or if they record a video until they run out of space, Figure 6.14a. Additionally, a pop-up shows up to warn users with low ram about the potential lag of recording a video, Figure 6.14b.



(a) Theia warning for devices with low storage

(b) Theia warning for devices with low ram

Figure 6.14: Theia camera page for recording videos

6.12 Take Pictures

Taking pictures simply uses the camera package's regular function for taking pictures since there were no issues with time constraints like with recording videos which mean that they are directly saved as JPEG and do not need to be converted

Pictures are treated by the application as single frame videos and give the same notification of waiting to upload when they are finished saving.

For a user to take a picture, they have to, once again, go to the camera screen but this time choose the picture option, Figure 6.15. After that they just have to press the take picture button.

Figure 6.15: Theia camera page with picture selected



6.13 Upload Videos

One important requirement of the application was that it needed to be able to always upload a video when possible even if the app had suddenly closed or the user lost connection to the internet. To ensure this, workmanagers from the workmanager package [49] were used to upload the videos to the server. When a recording ends, other than the video frames being saved, some video information necessary to uploading the video such as the path to frames that are part of the video is also saved to a file. The path to this file is then passed to a workmanager with a Connectivity restriction, either unmetered if the user hasn't allowed upload over mobile data or connected if they have. The operating system then takes care of scheduling the workmanager when appropriate and possible.

Inside the workmanager the file with the video data is opened and converted to an object for easier data access and the workmanager will check for the existence of each frame. If one of the frames is missing the workmanager will return false and retry later, if after three minutes there are still frames missing, the workmanager will just assume those frames were lost and upload the video without them.

The workmanager will also check if the user is logged in by checking for the existence of a token since it needs a bearer token to upload the video. If it can't find any token it will return false and retry later.

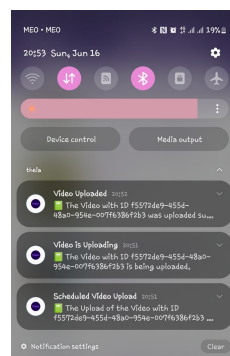
In terms of processing done the work manager is also responsible for the conversion of the custom image files talked about in Section 6.11, in batches of 30 or less, before sending them to the server.

The workmanagers also need to communicate with the main application to, for example, generate notification and report upload progress. To do this two SendPorts are used "videoChannel" and "notificationsChannel" which are listened to by the Providers who act accordingly.

Finally after the video and frames have been uploaded to the server, the workmanager is responsible for cleaning up all the files that are no longer necessary before returning.

Uploading a video does not require any input at all from the user but they can keep themselves informed about the upload status of their videos either through the notifications sent, Figure 6.16, or from the videos page.

Figure 6.16: Theia notifications of a video being sent



6.14 View Occurrences

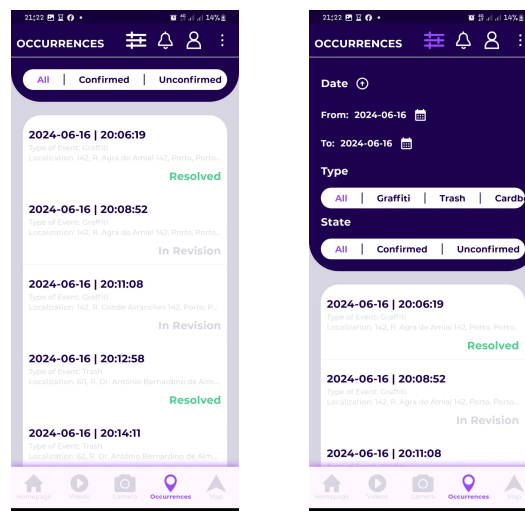
A user can see all occurrences by accessing the occurrences page in the application, Figure 6.17a. An occurrence is a confirmed event found in one of the videos taken by the user.

When accessing the list of occurrences it's possible to see for each occurrence its ID, location, type and state.

Occurrences can have the following states:

- Confirmed - The occurrence has been confirmed
- Unconfirmed - The occurrence was not found by the AI
- Submitted - The occurrence was submitted for confirmation by the AI
- Submitted for manual confirmation - The occurrence was submitted for manual confirmation
- Definitely unconfirmed - The occurrence was not found during manual confirmation
- Resolved - The occurrence has been resolved
- In Revision - The occurrence is being currently reviewed and dealt with

Once again from the top menu the user can filter by state and, if they click the filter button on the top bar they can expand the filter menu, Figure 6.17b, and also filter by type, date and order by date.



(a) Theia occurrences page

(b) Occurrences page with expanded filters

Figure 6.17: Occurrences page with filters expanded and without

To see detailed information on an occurrence the user must click on the card corresponding to the one they want to see which will lead them to the page of the occurrence.

In the occurrence's details page, Figures 6.18a and 6.18b, other than the information shown before, it's also possible to see the picture of the occurrence and, if the user clicks on it, they can enlarge it, Figure 6.18c.

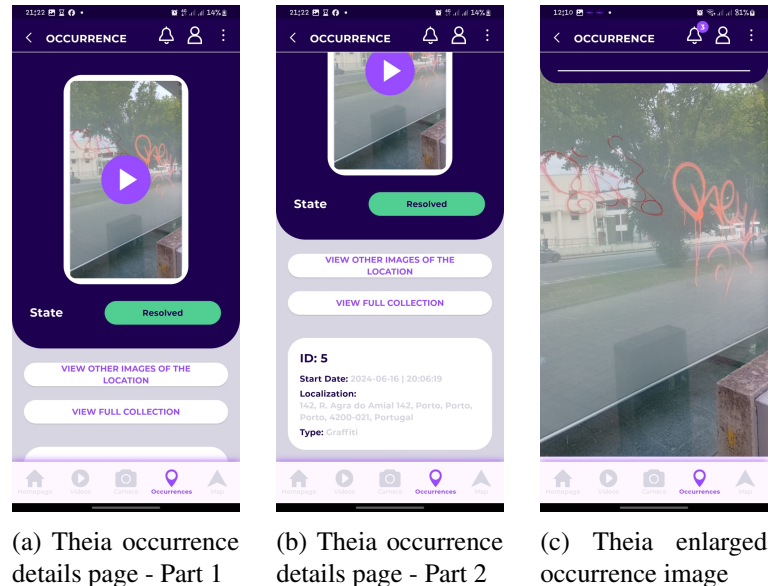


Figure 6.18: Theia occurrence details

For occurrences with the states Confirmed, Resolved and In Revision they can also press the button "View Other Images From Location" to see other occurrences from the same place ordered chronologically which can help users get a sense of the impact of reporting these urban issues by showing them a before and after of the specific location as seen in Figure 6.19.

Figure 6.19: Theia occurrences view others from the same location



For all occurrences it's also possible to see the original video in which the occurrence is inserted by pressing the button "View Full Collection".

6.15 Notifications

Currently the application only has local notifications related to video upload, however, once occurrences and events are being generated by the AI service and things like payed packages are implemented in the app there are plans to create more types of notifications.

A notification will pop-up at the top of the screen but they are also accessible in the notifications page, Figure 6.20a, where they can be sorted by type, status (new or old) and date as well as ordered by date, Figure 6.20b. New notifications also show up in the apps homepage where the user can sort them by today, this week or this month, Figure 6.20c.

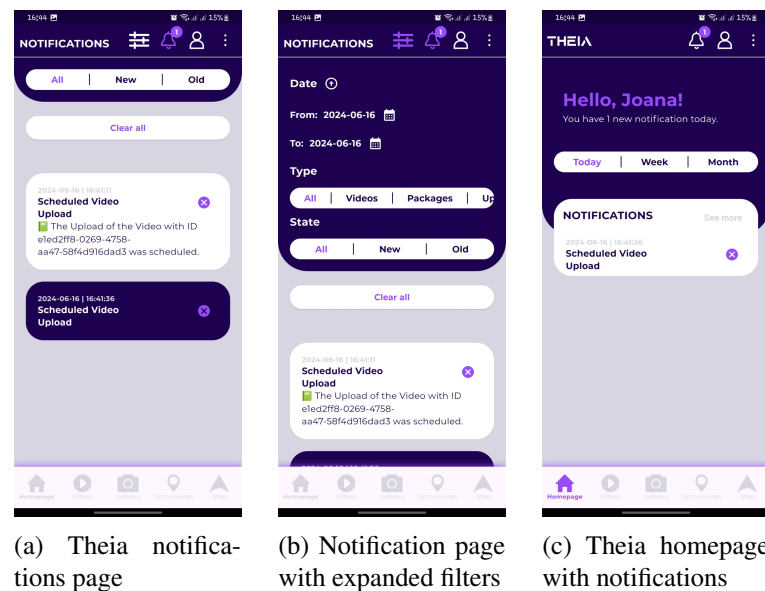


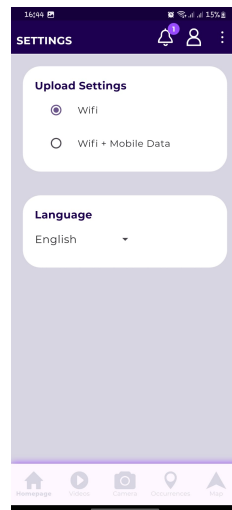
Figure 6.20: Theia notifications

In the notifications page the user can also dismiss notifications, expand them to see more information (making them read) and clear all notifications.

6.16 Settings

The user also has the option to choose between uploading images only through WiFi or through WiFi and mobile data (with WiFi only being the default setting) by accessing the settings page, Figure 6.21.

Figure 6.21: Theia settings page



6.17 Others

For all list shown in the application an infinite scroll list from the `infinite_scroll_pagination` package [50] is used as well as paginated requests to the server so that retrieving information doesn't take too long.

When getting images from the server instead of receiving them in bytes which would require more time, only the url (or urls if many images are needed) to get the image is sent by the server. Then, with the help of the `Image.Network` widget from Flutter, the image is loaded into the app. This not only saves time making extra request to retrieve images but the `Image.Network`'s inbuilt caching makes it so once an image is loaded, specially when going through a timeline of many images, it takes less to no time to load when it's once again needed.

Chapter 7

Results and Discussion

User tests were conducted with a total of 20 different participants who had never had any contact with the application. Due to time constraints, none of them are what would be considered professional users meaning that all participants belonged to the regular citizen's user group.

Participants were allowed to choose between using a phone with the application preinstalled or their own mobile phones and many chose to use their own. iPhone users, since installation of applications not from the app store is not as easy and the app has not been thoroughly tested for iOS, had to use the available Android phone.

Of those 20 participants, 10 (50%) belonged to the 18-30 user group, 4 (20%) to the 31-45 user group, 5 (25%) to the 46-60 user group and 1 (5%) to the 60+ user group as can be seen in Figure 7.1a. In terms of gender, 11 (55%) participants were female and the remaining 9 (45%) were male as seen in Figure 7.1b.

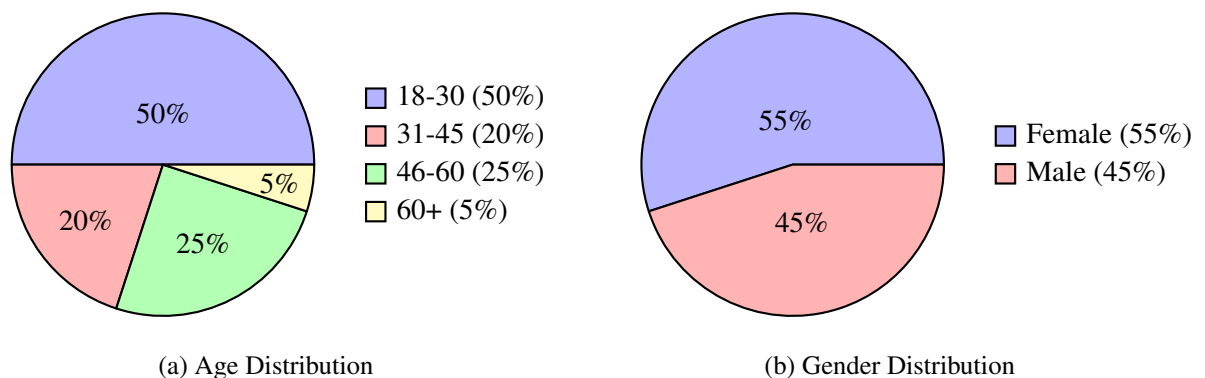


Figure 7.1: Distribution of participants across different age groups and genders.

In terms of level of digital competence, this was evaluated by users themselves and it must be noted that they tended to gravitate towards selecting moderate even though, during the testing of the application, many of the users who did so proved themselves to either have a higher or lower level of digital competency than they seemed to believe. As it stands, 15 (75%) of users described their digital competence as moderate, 4 (20%) as high and 1 (5%) as low, Figure 7.2a. In terms of occupation, 11 (55%) of users were employed, 7 (35%) were students with one being a high

school student and 6 being university students and 2 (10%) were currently unemployed, Figure 7.2b. Both students and employed professionals studied or worked in very diverse areas and were not people with experience building software.

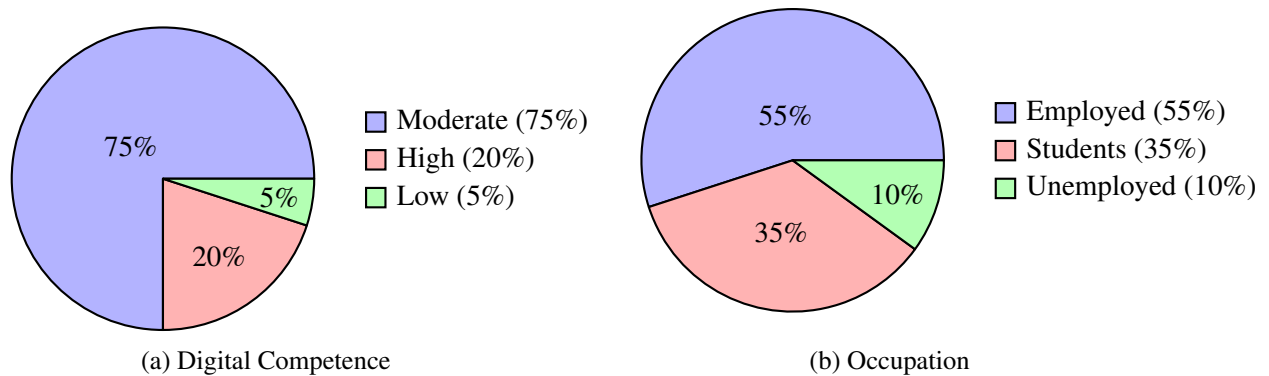


Figure 7.2: Distribution of participants across different levels of digital competence and occupations.

Finally, in terms of education level, 15 (75%) people were either currently enrolled or had finished studies up to higher education, 4 (20%) people were either enrolled or had finished studies up to high school and 1 (5%) person had finished studies up middle school, Figure 7.3.

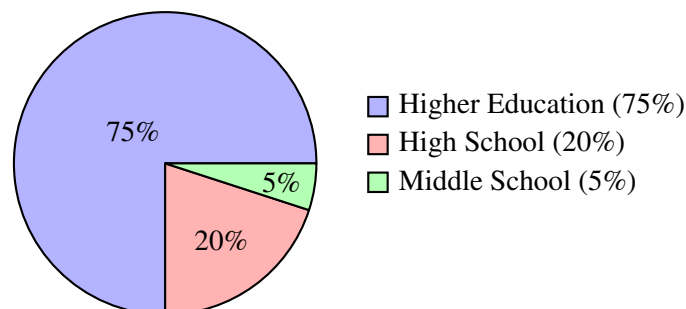


Figure 7.3: Education Level Distribution

The full results can be seen in the tables in Appendix C.

7.1 Tasks

In terms of tasks it was found that the time to complete a task was heavily influenced by the order in which the user got the tasks. For example, if a user got a more complex task such as "View other images of the same location as the occurrence with ID 9" first, they would usually take longer to complete that task, but, due to the amount of exploration they would have to do to complete it, they would generally be faster during the following tasks. On the other hand, if they got easier tasks first they would have a chance to more gradually acclimate to the application and the time they used to complete tasks would, in general be more consistent.

This, combined with the fact that, in various tests, the participant's phone was used, meaning that most participants were working with mobile phones with different specs, makes the time taken for each task not very consistent amongst participants. However, the average time taken by participants to complete tasks, does generally match the complexity of the tasks.

"Capturing an image" was the task executed the fastest by users with an average time of 14.35 seconds followed closely by "View video images" with an average time of 14.55 seconds.

The next fastest tasks were "View occurrence image" with an average time of 18.75 seconds, "Find an occurrence where the issue found was cardboard abandoned in the street" with an average time of 23.1 seconds, "View a video in the map" with an average time of 23.9 seconds, "Capture a video" with an average of 29.4 seconds and "View the original video of an occurrence" with an average of 30.26 seconds. In the case of the "Capture a video" task the times are clearly influenced by the varying duration of the videos taken by the different participants.

The "Change the account's name" task is clearly an outlier here since it constitutes one of the simplest tasks but has an average time of 40.95 seconds. This is due both to a couple participants that took longer than a minute and, in two cases, longer than two minutes, to complete this task for reasons that will be discussed further ahead. If the times for these 4 participants are removed from the average the result would be instead 19.85 seconds.

Finally, "View other images of the same location as the occurrence with ID 9" was the tasks that took the longest with an average of 52 seconds and the longest time to complete by any participant at 2 minutes and 22 seconds.

However, it should be noted that the choice to record times during think-aloud sessions may not have been ideal, as participants tend to take longer while thinking aloud than they would otherwise. Additionally, while errors were counted, they were more frequent in initial tasks compared to later ones and were often not related to a specific task but to user acclimation of the application. Thus, drawing conclusions about the number of errors specific to each task was not very conclusive.

In the next few sections the feedback and thoughts of the participants will be discussed in detail with all of the results available in Appendix C.

7.1.1 General

While completing tasks some participants had some general feedback that was not related to any task in particular.

One participant pointed out that in the mobile phone they used to do the tasks, while changing the language in the language changing screen, the text would change heights vertically. This is due to the character number difference between the languages and should not be happening.

A couple participants, mostly from the 45-60 and the 60+ age groups, took a bit to acclimate themselves to the app's navigation system, specially the navigation bar. A common complaint, was that the color of the icons and labels, as well as the size of the font of the button to navigate to other pages was hard to read and made it look like those items were disabled and not clickable. This was an issue specially when finding the occurrences' page, where, since there is no universal

icon to represent occurrences, it's necessary to read the label to find it. This makes it necessary to test different colors and font sizes to make sure the navigation bar is as easy to use as possible.

One user expressed that they are not used to seeing the continue button of pop-ups as an outlined button and the cancel button as a coloured button and it would make more sense to them if they were switched. Since no other user had any similar complaints, however, currently this change is not being considered.

A different participant complained that clicking in the occurrence's navigation button while viewing a specific occurrence did not bring them to the occurrences' list. The option to navigate back to the main page from sub-page using the navigation bar should be working and the inability to do so constitutes a bug that will need to be solved in the future.

Yet another participant expressed that it was not very obvious when you could scroll down or not in some pages. This is due to the fact that, in some phones with certain screen sizes, it might not be obvious that there is more information below. This issue is being considered but currently we do not know what will be done to make it more obvious when a page is scroll-able.

There was also some confusion about the images being treated as videos. Perhaps some consideration should be had about treating them as separate entities and calling the video page "Captures", for example.

On the other hand, a bug was found when a participant accidentally closed the app while doing a task. After reopening the app they started consistently getting their notifications in English instead of Portuguese despite the app language being set to Portuguese. The cause is still under investigation, however, the issue is probably related to how the app is using context to remember its language.

Finally a couple participants complained about the default order of the various lists in the app being from oldest to newest, specially when it comes to notifications. The newest to oldest order does indeed make more sense as the default and this will need to be changed.

7.1.2 Change the account's name

In general, the most common mistake which was made by participants while attempting to change the account's name was navigating to the settings page instead of the user profile page. Where to find this option tends to vary from application to application so this is not necessarily an issue with the app and more something users have to figure out themselves, which they did quite easily on the second try.

On the other hand a less common issue but one that affected the time taken to complete the task a lot more severely was the size and color of the edit buttons. Some users from the 45-60 user group found them difficult to see with some attempting to long press the account name to change it. The same issue happened with the confirm button which shares the same light purple color and size. This calls for considerations on the look and size of those buttons and the placement of the edit option.

Other than that, one user pointed out that the icon for changing the profile picture being a plus was strange and it would probably be better if it was consistent with the other edit buttons.

Additionally, a couple users seemed to see the confirm button for changing the name, Figure 7.4a, as an icon that showed if the name was taken or not. This could perhaps be solved by making the button circular with the tick not filled in such as in Figure 7.4b.



Figure 7.4: Comparison of Old and New Icons

Other than these issues a couple more serious bugs were found. For one, when one of the participants accidentally minimized the app after changing the name and opened it once again, the name in the main page was not changed to the correct one. The root of this issue is still being evaluated but it's probably related to the name not being saved in permanent memory when it's changed.

On the other hand, when a participant tried to eliminate the account after one of the follow-up questions an unexpected error toast was shown and the account was not eliminated. While the cause of this error is still being evaluated it is likely an issue with the server's endpoint, probably related with foreign key deletion.

Finally, after completing this task, every single participant said they felt capable of changing other profile information such as the profile picture, email and password as well as eliminating their account.

7.1.3 Capture an image

When doing this task a couple of the participants were confused as to why the notifications talked about videos instead. When it was explained that in the application pictures are treated as single frame videos the consensus seemed to be that, even then, it would be much less confusing if the notifications talked about images.

Still related to notifications, a couple participants also mentioned that it would make more sense if notifications related to the same image replaced each other. This simply requires making notifications of the same image in the app have the same ID which is pretty easy and straightforward and it would help make users feel less overwhelmed.

Additionally, a major complaint and source of confusion was the way in which the user changes from the video recording function the photo taking function. Users found it hard to tell at first glance which mode was enabled and got confused by the currently disabled annotations button in the recording screen, thinking it was the button to take a picture. This issue could perhaps be solved by first changing the icon used for annotations to one that does not resemble the taking pictures button and then changing the look of the button to switch between modes from the one in Figure 7.5a to the one in Figure 7.5b.



Figure 7.5: Comparison of Old and New Widget

Lastly, one user noted that they would find a zoom in and zoom out option in the camera useful which is being considered for a future feature. They also noted that their first instinct when not immediately finding the button was to just tap the screen to take a picture, something that should be given some thought.

Finally, when asked if the received notifications were useful to understand the state of the picture taken every participant answered positively.

7.1.4 Capture a video

During this task, other than comments regarding the notifications, confusion with the annotation and the switch mode buttons, one person mentioned that they would find it useful if the notification telling the user that the video is uploading had a progress bar showing the progress.

Almost every user found the recording video screen even less intuitive than the take picture screen which calls for a serious and important visual overhaul.

A critical bug was found where, if the user does not have the location turned on, nothing will be recorded and the user will not be asked for location permissions. This means that the user will believe they are recording when in reality nothing is happening. Instead, the application should always request that users turn on location if they have it off. This constitutes a high priority bug.

Another critical bug is the fact that, currently, users are capable of stopping the recording of a video before any frames are saved not creating a video at all.

Another bug found happened when a participant was looking at notifications from the notifications' page as they came in. The notifications' page should reload when a new notification appears, however, currently it's not.

Lastly, when asked about the usefulness of notifications responses were the same as in the "Capture an Image" task which makes sense considering how similar the notifications are.

7.1.5 View video images

Most of the mistakes made in this task were just related to getting used to the navigation of the app and were committed by people who had this task early on.

One participant, however, suggested that, other than the buttons to allow moving between frames, it would also make sense to be able to swipe right or left to navigate them.

Another participant said that they didn't immediately notice the swipe down menu on top and that it should perhaps have a different sized bar or icon. This is being currently considered.

7.1.6 View occurrence image

A sizeable portion of participants were confused about the play icon being used for enlarging the picture and suggested that instead an icon of a magnifying glass would be more appropriate.

No further commons or notable mistakes were made during this task.

7.1.7 View a video in the map

One user suggested the option to switch the map between the current view and satellite view. This is being considered.

7.1.8 View other images of the same location as the occurrence with ID 9

Users did not face any particular issues during this task nor had any specific feedback.

7.1.9 Find an occurrence where the issue found was cardboard abandoned in the street

Only one user found the filter right away and all the others resorted to scrolling down until they found the correct occurrence. When asked if they hadn't noticed the filter many users had the same feedback saying that the expand filters button being on the top bar made it seem like it was part of the profile information and not of the occurrences' page. Some also said that they are more used to seeing the funnel icon as a filter icon then the one used in the app. Various suggestions were made by different users about how to make the expand filters more visible from just changing the placement of the filters' button to make it more visible right away, to making the filters menu a drag-gable menu, to simply changing the icon. Currently, the solution being considered is changing the placement of the button since it's the easiest to implement, however, if in the future this turns out to be less intuitive than dragging down the menu it will be changed.

A couple users also tried to use the phones back button to close the filter menu and were confused when it instead went back a page.

One person suggested adding a search bar to search occurrences by location.

Another person was confused by the type of the occurrence being written as "Type of Event" and thought it would be better if it said either "Type" or "Type of Occurrence". This is a mistake on our part from old mock-ups where occurrences were named events and, upon further inspection, the events list in the video details page should also be called an occurrences list.

With all that being said in general users said that the filter function would be very useful when the list grew bigger, it simply needed to be more visible.

7.1.10 View the original video of an occurrence

A lot of the participants, both the ones using the app in English and the ones using it in Portuguese, had a hard time finding the correct button and ended up doing it by trial and error. The overall consensus was that, if the button had a more straightforward name such as "View full video" or

"View original video" instead of "View full collection" they would have found it much faster. The icon for enlarging the image also partially contributed to the difficulty here since it made users think they were about to play a video.

One of the participants also suggested having the occurrences of a video show up as a list in the video page because the way things were organized they ended up having a hard time distinguishing between videos and occurrences. This is an intended feature, with the list already existing in the videos, the only thing missing is the back-end sending the information so it can be shown to users.

At the end of all tasks users were asked if they understood the difference between videos and occurrences since they are both extremely important for understanding how to use the app and all participants said that they were able distinguish the two.

7.2 NASA Task Load Index (NASA-TLX)

Participants rated the workload of the application as relatively low, with an average score of 3.72 out of 10 and a median value of 3.6. The workload varied between a minimum score of 1 and a maximum of 6.2, suggesting that, in general, users did not perceive the app's workload as burdensome. The standard deviation for this general workload score was 1.38, indicating moderate variability in participants' perceptions of workload.

Regarding specific dimensions, the findings are as follows:

- **Frustration:** Users reported minimal frustration, with an average score of 1.65, a median of 1, and a standard deviation of 0.875. The low median suggests that half of the users reported frustration scores at or below 1, while the standard deviation indicates that most users had consistent experiences with minimal frustration.
- **Mental Demand:** The cognitive load was relatively low, with an average score of 3.15, a median of 3, and a standard deviation of 1.22. The median of 3 indicates that half of the users perceived moderate mental demand, while the standard deviation suggests some variability in perceived mental demand among users.
- **Effort:** Participants felt little need to exert significant effort, with an average score of 3.3, a median of 3, and a standard deviation of 1.22. The median of 3 indicates that half of the users felt the effort was moderate, while the higher standard deviation suggests more variability in the perceived effort required.
- **Performance:** Users rated their own performance slightly higher, with an average score of 4.95, a median of 4.5, and a standard deviation of 2.855. The median of 4.5 indicates that half of the users rated their performance above average, while the relatively high standard deviation indicates significant variability in how users assessed their own performance.
- **Temporal Demand:** Time pressure was noted as the most significant factor, with an average score of 5.55, a median of 5, and a standard deviation of 2.874. The median of 5 indicates

that half of the users perceived high time pressure, while the high standard deviation suggests considerable variability in perceptions of temporal demand across users.

These findings suggest that while users generally did not find the application's workload heavy, there is variability in how users perceive specific workload dimensions. Factors such as frustration, mental demand, effort, and performance show varying degrees of dispersion in user experiences, which may impact overall user satisfaction and task performance.

Lastly, we calculated the correlation values for each of the dimensions. The resulting correlation matrix, Table 7.1, reveals several insights into the relationships between workload dimensions. Notably, strong positive correlations, such as the 0.7823 correlation between Effort and Mental Demand, indicate that as Mental Demand increases, so does perceived Effort. This suggests that tasks perceived as mentally demanding require higher effort from users.

Table 7.1: Correlation Matrix of Workload Dimensions

	MD	TD	Perf	Eff	Frust	Legend:	
MD	1.0000	0.2123	0.6319	0.7823	0.1628	MD	Mental Demand
TD	0.2123	1.0000	0.0178	0.5366	0.0543	TD	Temporal Demand
Perf	0.6319	0.0178	1.0000	0.0769	0.0769	Perf	Performance
Eff	0.7823	0.5366	0.0769	1.0000	0.0178	Eff	Effort
Frust	0.1628	0.0543	0.0769	0.0178	1.0000	Frust	Frustration

Conversely, weak correlations, like the 0.0178 between Temporal Demand and Performance, suggest that temporal constraints do not strongly influence perceived performance levels. Understanding these relationships helps in designing interfaces that balance workload dimensions effectively, ensuring tasks are neither overly demanding nor excessively time-constrained, thereby optimizing user experience and task performance.

7.3 System Usability Scale (SUS)

With the responses from participants the SUS scores were calculated using the following steps:

1. Each participant's responses to the 10 SUS items (Q1 to Q10) were adjusted based on their position:
 - For odd-numbered items (Q1, Q3, Q5, Q7, Q9), 1 was subtracted from the participant's score.
 - For even-numbered items (Q2, Q4, Q6, Q8, Q10), the participant's score was subtracted from 5.
2. Adjusted scores were summed for each participant.
3. The sum of adjusted scores was multiplied by 2.5 to obtain the overall SUS score for each participant.

The overall SUS scores range from 0 to 100, with higher scores indicating better usability. Here's how the scores can be interpreted:

- **0-50: Poor usability** – Scores in this range indicate significant usability issues that need urgent attention.
- **51-70: Marginal usability** – Scores suggest usability could be improved, with users likely experiencing some frustration or difficulty.
- **71-85: Good usability** – Scores indicate generally positive usability, with users finding the application fairly easy to use.
- **86-100: Excellent usability** – Scores in this range indicate outstanding usability, with users perceiving the application as highly intuitive and easy to use.

Based on the collected SUS scores, the average SUS score across participants was calculated to be 70, with a median of 72.5, falling within the "Marginal usability" range. The median SUS score of 72.5 indicates that half of the participants rated the application's usability higher than this score, while the other half rated it lower. Out of the total participants, ten achieved SUS scores indicating "Good Usability," while one participant's score indicated "Poor Usability." The remaining participants had SUS scores indicating "Marginal Usability," suggesting areas where the application could benefit from improvement in usability.

On a detailed analysis, scores were the least favorable on "Q3 - I thought the system was easy to use." with a score of 4 indicating that some people seemed to have struggled harder to use and understand the application than others which should be addressed.

Worth mentioning as well, despite the overall score not being too bad, is "Q1 - I think that I would like to use this system frequently." with average score of 4.45. While filling the questionnaire one person commented that they just don't have an interest in this type of application, another said that they would only use an application like this to report certain types of occurrences because they found that they would not want to report things such as graffiti and another said that while they found the app useful and interesting they did not think that this was the type of app that someone would have to use very frequently since a person does not come across occurrences that often in a days time.

7.4 Questionnaire for User Interface Satisfaction (QUIS)

Due to the fact that only two users ever encountered error messages during the testing of the app the question "How satisfied were you with the error and recuperation messages of the application?" was not counted for the following analysis. That being said, both the users who encountered error messages said their were very satisfied with them.

The QUIS results for the Theia app indicate a high level of satisfaction among users with the app's interface. The average score, calculated at 8.21 out of 9, reflects a strong positive perception

of the interface design and usability. This average score suggests that the majority of users find the interface highly satisfactory.

The median score, which stands at 8.38, further reinforces this positive trend. A median score close to the average indicates that most users rated the interface very positively, with few extreme ratings skewing the data.

The standard deviation of 0.84 indicates that responses were relatively consistent around the average score. A low standard deviation suggests that there is little variability in users' perceptions, signifying a high degree of agreement among respondents regarding the quality of the interface.

Overall, these QUIS results paint a picture of the app as having successfully delivered a user interface that meets or exceeds user expectations. This positive feedback is crucial for maintaining user satisfaction and loyalty. However, it also highlights the need to continuously monitor user feedback and make incremental improvements to ensure that the interface remains user-friendly and meets evolving user needs.

In this way, the QUIS results validate Theia's efforts in providing an excellent user interface experience. Moving forward, ongoing efforts should focus on leveraging these strengths while addressing any identified areas for improvement to further enhance user satisfaction and usability.

In conclusion, the results and feedback gathered from user tests indicate that the development of a user-friendly mobile application for reporting urban occurrences, augmented with mechanisms for user feedback, holds promising implications for urban issue reporting and management. This thesis has addressed the research question by demonstrating the application's positive impact on citizen engagement. Participants efficiently performed tasks such as capturing images and videos, viewing occurrences, and providing feedback on usability aspects. Despite challenges such as varying digital competences and device specifications among users, the application was generally well-received, with users expressing constructive feedback that can inform iterative improvements.

Furthermore, the findings suggest that enhancing navigational clarity, improving visual cues for interactive elements, and refining notification systems could further enhance user experience and increase the application's effectiveness in facilitating urban issue reporting. By iteratively addressing these aspects based on user feedback, the application has the potential to streamline citizen reporting and contribute to more efficient urban management practices, fostering a more responsive and engaged urban community.

7.5 Future Work

In terms of programming work, the issues in Table 7.2 should be addressed in the future. This table includes both the bugs and improvements talked about previously but also the user stories that remained in the backlog from the last iteration of the app. Currently the process of addressing these issues has already started with numbers 1 to 14, 16 to 19, 22 and 27 to 29 having been implemented already and in the process of being thoroughly tested.

Table 7.2: Theia's current backlog

Number	Category	Description	Priority	Effort
1	Bug	Solve issue where height of text in language selecting page changes on some phone screen ratios.	Low	Low
2	Improvement	Make sure text in the navigation bar is not too small and has a readable color that does not make users think the options are inactive.	Medium	Low
3	Bug	Solve issue where navigation bar does not work if user attempts to go back to the main page of the section from a sub-page.	Medium	Low
4	Bug	Solve issue where notification language is defaulting to English when user minimizes the app and reopens it.	Medium	Medium
5	Improvement	Fix order of lists so it goes from the most recent icon to the oldest by default.	Low	Low
6	Improvement	Make edit icons more visible.	Medium	Low
7	Improvement	Make change profile picture button consistent with other edit buttons in the user profile.	Low	Low
8	Improvement	Change the icon for the confirm button when user is changing their profile information.	Low	Low
9	Bug	Solve issue where if the user closes the app and re-enters it the changed user name does not update.	Medium	Medium
10	Bug	Solve issue where account can't be eliminated.	High	Medium
11	Improvement	Make picture taking notifications talk about images and not videos.	Low	Low
12	Improvement	Make notifications from the same video replace each other.	Low	Low
13	Improvement	Change the look of the button to switch between the video and picture mode.	Low	Medium
14	Improvement	Change annotation icon.	low	Medium
15	Improvement	Add zoom in and zoom out option for the camera.	medium	Low
16	Improvement	Change layout of the recording screen to make it more intuitive.	Medium	Medium

17	Bug	Solve issue where user does not get asked to turn on location before starting a video.	Medium	High
18	Bug	Solve issue where app may allow a user to record an empty video.	High	Low
19	Bug	Solve issue where the notifications page will not update automatically when a new notification comes in.	Medium	Medium
20	Improvement	Allow user to move between video frames by swiping left or right on the screen.	Low	Medium
21	Improvement	Make swipe down menu more obvious.	Low	Medium
22	Improvement	Replace play icon in an occurrence's details with a magnifying glass icon.	Medium	Low
23	Improvement	Allow user to switch between satellite mode and the default mode in the map.	Medium	Low
24	Improvement	Change location of the filters' button in all pages.	Medium	Medium
25	Improvement	Make phone's back button close expanded filter menu.	Low	Medium
26	Improvement	Add search by location to videos and occurrences.	Low	Medium
27	Bug	Change "Type of Event" text to "Type of Occurrence" in occurrence's page.	High	Low
28	Bug	Change "Events" in video details page to "Occurrences".	High	Low
29	Improvement	Change "View full collection" To "View full video" in the occurrence's details page.	High	Low
30	User Story	As a user, I want to be able to see the occurrences present in my video from the video's page, so that I can more easily find my video's occurrences.	High	Low
31	User Story	As a user, I want to be able to annotate continuous images in real time, so that I can point out where in the video the occurrence I am reporting is while I'm recording it.	High	Low
32	User Story	As a user, I want to be able to edit the annotations of my occurrences, so that I can change them to be more accurate.	Low	High
33	User Story	As a user, I want to be able to request manual verification of an occurrence, so that events not caught by the AI can be verified.	Low	Low

34	User Story	As a user, I want to be able to mark occurrences as in revision, so that other users can know that the problem detected is being taken care off.	Low	Low
35	User Story	As a user, I want to be able to mark occurrences as solved, so that other users can know that the problem detected has been taken care off.	Low	Low
36	User Story	As a user, I want to be able to delete my occurrences, so that they aren't taking up space in my occurrences' list.	Medium	Low
37	User Story	As a user, I want to be able to accept a package invite by clicking on the package invite notification, so that it's easier to join other users' packages.	Low	Medium
38	User Story	As a user, I want to be able to see paid packages, so that I can know what type of packages I can purchase.	Low	Medium
39	User Story	As a user, I want to be able to buy the Issues package, so that I can see occurrences and update their state once an issue is resolved.	Low	Medium
40	User Story	As a user, I want to be able to buy the API package, so that I can have access to the API.	Low	Medium
41	User Story	As a user, I want to be able to invite other users to my package, so that they can also make use of my packages.	Low	High
42	User Story	As a user, I want to be able to see all my billing information, so that I can keep track of it.	Low	Medium
43	User Story	As a user, I want to be able to download invoices and receipts for purchased packages, so that I can have easy access to them.	Medium	Medium
44	User Story	As a user, I want to be able to see the overall usage of my packages, so that I can know how much they are being used.	Low	High
45	User Story	As a user, I want to be able to see the usage of my packages by invitees, so that I can know how much they are using them.	T Low	High

46	User Story	As a user I want to be able to export my occurrences as an XML file, so that I can have their info outside of the application.	Low	Medium
47	User Story	As a user I want to be able to see the occurrence reports, so that I can have access to information about occurrences found.	Low	Low
48	User Story	As a user, I want the recording function of the app to not take the same amount of pictures always, so that I can avoid having many repeated images when the phone is barely moving.	High	High

On the other hand, some issues that should be considered but are not quite ready to be added to the backlog are the following:

- Consider if the appearance of cancel and continue buttons should be switched or not.
- Consider allowing user to edit the user fields by doing a long press on them.
- Consider how to make it more obvious that it's possible to scroll down in a page.
- Consider if images really should be treated as videos in the app or not.
- Consider taking pictures by tapping on the screen.
- Consider adding a progress bar to uploading notifications.
- Consider the use of a mechanism to incentivize users to use the application more often.

Additionally, the application should be thoroughly tested for iOS in the near future to guarantee that all its functionalities work in this operating system as they should.

After all bugs and improvements described have been implemented new user tests should be conducted to receive new feedback on how to improve the application further. These tests should preferably be conducted on both Android and iOS devices and not just Android and should include not only regular citizens but also professional users.

Accessibility features were not implemented beyond the standard functionalities provided by mobile devices. Addressing these accessibility concerns is an essential part of future work. Enhancing accessibility could include implementing features such as voice commands, improved screen reader compatibility, adjustable text sizes, high contrast modes, and alternative navigation options for users with disabilities. These improvements will make the app more inclusive and user-friendly for individuals with various needs.

Additionally, we are planning to implement device-side anonymization of images to guarantee user privacy. This feature will ensure that any identifiable information within images is obscured or removed before the images are uploaded or shared. This could involve techniques like blurring

faces or other sensitive details automatically. By incorporating this functionality, we aim to protect user privacy and comply with stringent data protection regulations.

It is also important to note that a discussion with an ethics committee, or equivalent body, is necessary to address issues related to user privacy and data treatment. This will help ensure that the application adheres to ethical standards and best practices in handling user data.

Chapter 8

Conclusion

Throughout this dissertation, we have embarked on a journey to develop Theia, a mobile app designed to revolutionize urban issue reporting. Our efforts have culminated in a robust platform poised to facilitate meaningful interactions between residents and local authorities, thereby enhancing urban living.

From the outset, the motivation behind Theia stemmed from the need to streamline the reporting process for urban issues. Our exploration into various cross-platform frameworks led us to select Flutter, a decision driven by its performance, suitability for our project's needs, and our team's familiarity with it.

Detailed analyses of requirements and software architecture laid a solid foundation for Theia's development. These phases ensured that the app not only meets functional needs but also adheres to principles of scalability, maintainability, and security, essential for its long-term viability.

The implementation phase was characterized by rigorous development efforts, leveraging state-of-the-art tools and technologies. Challenges were encountered and overcome, contributing to a feature-rich application designed to enhance user experience and operational efficiency.

Evaluation through testing and user feedback underscored Theia's efficacy in meeting its objectives, albeit with areas for improvement, notably in system usability, which received a "Marginal usability" score.

In the future, Theia holds promise not only as a technological innovation but also as a catalyst for community empowerment. By enabling residents to report issues promptly, Theia facilitates responsive actions from authorities, thereby fostering a more responsive and engaged urban environment.

While the results are promising, this study acknowledges its limitations, including the scope of testing environments and user demographics. Future research endeavors could explore broader testing scenarios, encompassing diverse user bases and platforms like iOS, to further validate and refine Theia's capabilities.

In conclusion, the development and deployment of Theia exemplify the transformative power of combining innovative technology with community engagement. As we look ahead, the continued evolution of Theia promises to contribute positively to urban communities, fostering a more

connected and responsive urban environment.

References

- [1] Timur Fatkhulin, Rafif Alshaw, Alena Kulikova, Alexander Mokin, and Anna Timofeyeva. Analysis of software tools allowing the development of cross-platform applications for mobile devices. In *Systems of Signals Generating and Processing in the Field of on Board Communications*, pages 1–5. IEEE, 2023.
- [2] Kewal Shah, Harsh Sinha, and Payal Mishra. Analysis of cross-platform mobile app development tools. In *IEEE Systems of Signals Generating and Processing in the Field of on Board Communications*, 2019.
- [3] B.K. Chakrabarty. Urban management: Concepts, principles, techniques and education. *Cities*, 18(5):331–345, 2001.
- [4] Nicholas Benequista. Putting citizens at the centre: Linking states and societies for responsive governance. In *The Politics of Poverty, Elites, Citizens and States*, page 10, 2010. Conference Paper.
- [5] Haroula N. Delopoulos. Barriers and opportunities for the adoption of e-governance services. *World Academy of Science, Engineering and Technology*, 66:623–627, 2010.
- [6] E-government availability of mobile services. <https://www.statista.com/statistics/421693/e-government-availability-mobile-services/>, Accessed: 2024-01-30. Statista.
- [7] European Commission. E-government activities of individuals via websites. https://ec.europa.eu/eurostat/databrowser/view/isoc_ciegi_ac/default/table?lang=en. [Accessed: November 26, 2023].
- [8] J. (Jove) Hou, L. Arpan, Y. Wu, R. Feiock, E. Ozguven, and R. Arghandeh. The road toward smart cities: A study of citizens’ acceptance of mobile applications for city services. *Energies*, 13(Special Issue Big Data and Smart Cities):2496, May 2020.
- [9] S.K. Sharma, A. Al-Badi, Nripendra P. Rana, and L. Al-Azizi. Mobile applications in government services (mG-App) from user’s perspectives: A predictive modelling approach. *Government Information Quarterly*, 35(4):557–568, 2018.
- [10] United Nations. Transforming our world: the 2030 agenda for sustainable development. <https://sdgs.un.org/2030agenda>, 2015. Accessed: 2024-07-15.
- [11] StatCounter. Worldwide mobile os market share. <https://gs.statcounter.com/os-market-share/mobile/worldwide/#monthly-200901-202310>, 2023.

- [12] StatCounter. Worldwide mobile os market share (monthly, september 2023 - october 2023). <https://gs.statcounter.com/os-market-share/mobile/worldwide/#monthly-202309-202310>, 2023, October.
- [13] Apple Inc. App development training. <https://developer.apple.com/tutorials/app-dev-training>.
- [14] Google. Kotlin | android developers. <https://developer.android.com/kotlin>.
- [15] W. S. El-Kassas, B. A. Abdullah, A. H. Yousef, and A. M. Wahba. Taxonomy of cross-platform mobile applications development approaches. *Ain Shams Engineering Journal*, 8(2):163–190, 2017.
- [16] B. Suri, S. Taneja, I. Bhanot, H. Sharma, and A. Raj. Cross-platform empirical analysis of mobile application development frameworks: Kotlin, react native and flutter. In *Proceedings of the 4th International Conference on Information Management & Machine Intelligence (ICIMMI '22)*, pages 1–6, 2023.
- [17] S. Xanthopoulos and S. Xinogalos. A comparative analysis of cross-platform development approaches for mobile applications. In *Proceedings of the 6th Balkan Conference in Informatics (BCI '13)*, page 213–220, 2013.
- [18] C. P. Rahul Raj and Seshu Babu Tolety. A study on approaches to build cross-platform mobile applications and criteria to select the appropriate approach. In *2012 Annual IEEE India Conference (INDICON)*, page none, 2012.
- [19] T. A. Majchrzak, A. Biørn-Hansen, and Tor-Morten Grønl. Progressive web apps: the definite approach to cross-platform development? In *Proceedings of the 51st Hawaii International Conference on System Sciences*, pages 5735–5744, 2018.
- [20] M. S. Farooq, S. Riaz, A. Alvi, Asghar Ali, and I. U. Rehman. Cross-platform mobile development approaches and frameworks. *VFAST Transactions on Software Engineering*, 10(2):79–93, 2022.
- [21] Adobe. Adobe phonegap end of service. <https://helpx.adobe.com/experience-manager/kb/adobe-phonegap-end-of-service.html#:~:text=Adobe%20is%20discontinuing%20PhoneGap%2C%20PhoneGap,Need%20help%3F>.
- [22] Statista. Worldwide software developer working hours. <https://www.statista.com/statistics/869224/worldwide-software-developer-working-hours/>, Accessed on December 22, 2023.
- [23] Stack Overflow. Stack overflow developer survey trends. <https://insights.stackoverflow.com/trends?tags=react-native%2Cflutter%2Cxamarin%2Cnativescript%2Cionic-framework%2Ccocos2d-x%2Ctitanium%2Cphonegap-build%2Csenchatouch%2Cappcelerator%2Ccordova%2Ccoronasdk%2Cqt-creator>, Accessed on December 22, 2023.
- [24] Web.dev. Aliexpress case study. <https://web.dev/case-studies/aliexpress>, Year of publication. Accessed on Month Day, Year.

- [25] D. Moher, A. Liberati, J. Tetzlaff, D.G. Altman, and Group P. Preferred reporting items for systematic reviews and meta-analyses: the prisma statement. *Journal of Clinical Epidemiology*, 62(10):1006–1012, 2009.
- [26] Google LLC. Google scholar. <https://scholar.google.com>.
- [27] Microsoft. Windows 10 mobile end of support. <https://learn.microsoft.com/en-us/lifecycle/announcements/windows-10-mobile-end-of-support>, 2023.
- [28] T. Dorfer, L. Demetz, and S. Huber. Impact of mobile cross-platform development on cpu, memory and battery of mobile devices when using common mobile app features. *Procedia Computer Science*, 175:189–196, 2020.
- [29] E. Denis. A comparison of hybrid and progressive web applications for the android platform. Master’s thesis, Blekinge Institute of Technology, 2021.
- [30] F. Camille. Comparison of smoothness in progressive web apps and mobile applications on android. Master’s thesis, KTH School of Electrical Engineering and Computer Science, 2020.
- [31] S. Huber, L. Demetz, and M. Felderer. A comparative study on the energy consumption of progressive web apps. *Information Systems*, 108, 2022.
- [32] K. Jonathan and M. Pontus. Progressive web apps and other mobile developing techniques: a comparison. Master’s thesis, Malmö University, 2019.
- [33] Flutter. Flutter sdk release notes - supported platforms. <https://flutter-io.dev/development/tools/sdk/release-notes/supported-platforms>, Accessed on December 22, 2023.
- [34] Can I Use. Can i use - pwa (progressive web app) compatibility. <https://caniuse.com/?search=PWA>, Accessed on December 22, 2023.
- [35] Maximiliano Firtman. Progressive web apps on ios - maximiliano firtman’s notes. <https://firt.dev/notes/pwa-ios/>, Accessed on December 22, 2023.
- [36] Reza Fauzan, Ice Krisnahati, Bima Dinda Nurwibawa, and Della Aulia Wibowo. A systematic literature review on progressive web application practice and challenges. *The Journal of Technology and Science*, 33(1):43–58, 2022.
- [37] Hanny Tufail, Farooque Azam, Muhammad Waseem Anwar, and Iqra Qasim. Model-driven development of mobile applications: A systematic literature review. In *2018 IEEE 9th Annual Information Technology, Electronics and Mobile Communication Conference (IEM-CON)*, pages 1165–1171. IEEE, 2018.
- [38] StatCounter Global Stats. Android os version market share worldwide. <https://gs.statcounter.com/os-version-market-share/android>, 2024. Accessed: 2024-06-13.
- [39] flutter.cn. dio. <https://pub.dev/packages/dio>, 2024. Accessed: 2024-06-13.
- [40] dart.dev. http. <https://pub.dev/packages/http>, 2024. Accessed: 2024-06-13.

- [41] dash-overflow.net. provider. <https://pub.dev/packages/provider>, 2024. Accessed: 2024-06-13.
- [42] Flutter Team. shared_preferences. https://pub.dev/packages/shared_preferences, 2024. Accessed: 2024-06-13.
- [43] dart.dev. intl. <https://pub.dev/packages/intl>, 2024. Accessed: 2024-06-16.
- [44] flutter.dev. flutter_localization. https://pub.dev/packages/flutter_localization, 2024. Accessed: 2024-06-16.
- [45] flutter.dev. camera. <https://pub.dev/packages/camera>, 2024. Accessed: 2024-06-16.
- [46] Author Unknown. Processing camera image example. https://pub.dev/packages/processing_camera_image/example, 2024. Accessed: 2024-06-27.
- [47] loki3d.com. Image package. <https://pub.dev/packages/image>, 2024. Accessed: 2024-06-27.
- [48] fluttercommunity.dev. rxdart. <https://pub.dev/packages/rxdart>, 2024. Accessed: 2024-06-16.
- [49] fluttercommunity.dev. workmanager. <https://pub.dev/packages/workmanager>, 2024. Accessed: 2024-06-16.
- [50] edsonbueno.com. infinite_scroll_pagination. https://pub.dev/packages/infinite_scroll_pagination, 2024. Accessed: 2024-06-16.

Appendix A

Comparison of cross-platform frameworks

Table A.1: Summary of articles

Article	Ref	Frameworks	Performance Measures
Impact of mobile cross-platform development on CPU, memory and battery of mobile devices when using common mobile app features	[28]	React Native	CPU Usage, Memory Load and Battery Status
Cross-Platform Empirical Analysis of Mobile Application Development frameworks: Kotlin, React Native and Flutter	[16]	React Native and Flutter	CPU Usage, Memory Usage, Code Complexity, Application Sizes, Battery Usage
A comparison of Hybrid and Progressive Web Applications for the Android platform	[29]	PWA with Cordova framework on Google Chrome and on Firefox and a Hybrid app with Cordova	Battery, CPU Usage and Time To First Activity

Comparison of Smoothness in Progressive Web Apps and Mobile Applications on Android	[30]	React Native and PWA in Reactjs	Memory performance, CPU usage, and Smoothness
A comparative study on the energy consumption of Progressive Web Apps	[31]	PWAs in Ionic and a Capacitor hybrid app both tested on Chrome, Firefox, and Webview wrappers, Flutter, and React Native	Energy Consumption
Progressive Web Apps and other mobile developing techniques: a comparison	[32]	Web App, Cordova App, PWA	Estimated Input Latency, First Contentful Paint, First Paint and Time to Interactive

Table A.2: Test Cases of Articles

Ref	Application Used	Test Cases	Test Devices
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[28] App for finding restaurants using built-in geolocation. The application is composed of two pages where the first one is a map and the second one is a scrollable page

Case #1 - CPU and Memory Test:

1. Start the measurement tool (Recording time: 3 min. 16 sec.).
2. Press the home screen button and wait 2 seconds.
3. Start the installed app by an intent.
4. Run the app for 3 minutes.
5. Press the home screen button and wait 2 seconds.
6. Open recently opened apps and wait 2 seconds.
7. Close the app.

Case #2 - Battery Test:

1. Start the measurement tool (Recording time: 15 min. 16 sec.).
2. Press the home screen button and wait 2 seconds.
3. Start the installed app by an intent.
4. Run the app for 15 minutes.
5. Press the home screen button and wait 2 seconds.
6. Open recently opened apps and wait 2 seconds.
7. Close the app.

Samsung Galaxy S10e

- Processor: Exynos Octa Core 9820
- Processor Frequency: 2 x 2.73 GHz — 2 x 1.95 GHz — 4 x 1.95 GHz
- RAM: 6 GB
- Battery: 3,100 mAh
- Display size: 3.74 inch
- Display resolution: 1,080 x 2,280
- Android Version: Android 10, API Level 29

Samsung Galaxy S8

- Processor: Exynos Octa Core 8895
- Processor Frequency: 4 x 2.31 GHz — 4 x 1.69 GHz
- RAM: 4 GB
- Battery: 3,000 mAh
- Display size: 5.8 inch
- Display resolution: 1,080 x 2,220
- Android Version: Android 9, API Level 28

- | | | |
|---|---|--|
| [16] A single page Tic-tac-toe game with a simple UI | Not Specified | Android vivo U10 |
| [29] A single page application that generates recipes for drinks through requests to an API | The app was manually launched, and 20 requests to the API were made in 60 seconds. This was done for each app 30 times on each phone. | Model and brand not specified. <ul style="list-style-type: none"> • OS: Android OS v8.0 (Oreo) • Chipset: HiSilicon Kirin 658 • CPU: 4x2.1 GHz Cortex-A53 & 4x1.7 GHz Cortex-A53 • GPU: Mali-T830MP2 • Memory: 4 GB • Display: 1080 x 1920 pixels |
| [30] App with three screens: One for clicking, one for scrolling and a home screen where the user can navigate to the other two | Changing a text.
Scrolling a text.
Changing a picture.
Scrolling pictures. | Samsung S6 (Android v7.0)
Samsung S5 (Android v5.0)
Huawei P9-Lite (Android v7.0) |

[31] A contact management app and fifteen real-world apps: NewPipe, F-Droid, and Tiny Weather Forecast in Native Android; Ulangi, Bus Timetable, and YumMeals in React Native; Flutter Ebook App, Metal Releases, and No Man’s Sky in Flutter; AliExpress, Versus and Swiggy as examples of PWAs, and Sworkit and JustWatch as Capacitor Apps and Untappd as an Apache Cordova app	i1 - Open the navigation drawer menu with a left-to-right swipe gesture, and after one second, close it with a tap outside the drawer menu. The interaction is repeated five times. i2 - Scroll down the list entries with five consecutive bottom-to-top swipe gestures. i3 - Tap on the top-right “Add Entry” menu icon to navigate to the entry form screen and after one second, tap on the top-left back button to navigate back to the list screen. The interaction is repeated five times. i4 - Enter form data for the input fields “Firstname”, “Lastname”, and “Phone”. (For real Apps, only i2 could be used.)	Samsung Galaxy S9: • CPU: Snapdragon 845, 4 × 2.7 GHz / 4 × 1.8 GHz • RAM: 4 GB • Android Version: Android 10 • Battery: 3000 mAh Samsung Galaxy S21: • CPU: Snapdragon 888, 1 × 2.9 GHz / 3 × 2.80 GHz / 4 × 2.2 GHz • RAM: 8 GB • Android Version: Android 11 • Battery: 4000 mAh
[32] Product Selector used by Axis resellers and customers (Converted from web app into a PWA)	For Estimated Input Latency: 1. Click on a product 2. Compare products 3. Select "outdoor ready" filtering checkbox For First Contentful Paint, First Paint and Time To Interactive: 1. Turn on the app (Four times for each phone)	Xiaomi mi mix 3 - High End OnePlus One - Low End Huawei P10 lite - Mid Range Samsung S6 Edge -Mid Range

Table A.3: Summary of results

Ref	Results
[28]	Case #1 - CPU and Memory test: CPU usage value peaks when the app is opened and closed. The React Native app consumes about 4 times more CPU in the S10e and twice more on the S8. Memory consumption increases at start-up. After the visible increase at the beginning, the React Native app consumed essentially the same amount of memory throughout, while the native app tended to decrease its memory consumption over time. Case #2 - Battery test: To obtain relevant results, the test was executed 10 times in a row, taking 2 hours and 31 minutes. The battery usage of both apps increased linearly on both devices, with React Native consuming more battery in both cases (6% more on the S10e and 8% more on the S8). Additionally, the S8 consumed about 40% more battery than the S10e.
[16]	Application Size - Kotlin used the least space, followed by Flutter and React Native, which used a significantly higher amount of space. Performance Comparison - React Native has the highest CPU and memory usage, with Kotlin having the smallest. Meanwhile, Flutter's CPU usage was significantly lower than React Native's and closer to Kotlin's. Battery-wise, both Flutter and React Native consume a lot more battery than Kotlin. Code Reusability - React native has the most reusable code (about 95% of the code is repeated) compared to Kotlin and Flutter, where 85% and 90% of the code is reusable, respectively. Code Complexity - Code complexity is the same for the three apps.
[29]	Battery Consumption - The hybrid application did the best, only wasting an average of 0.109% of the battery, followed by the PWA used on Chrome (PWA-C) with 0.119% and the PWA used on Firefox (PWA-F) with 0.206%. CPU Usage - Once again, hybrid did the best with an average of 0.056% of CPU usage, followed by the PWA-C with 0.07% and the PWA-F with 0.11%. Activity Launch Time - This time, the PWA-C had the best mean activity launch time of 171.0ms, followed by the PWA-F with 631.76ms and the Hybrid with 919.06ms.

[30] Smoothness:

The Interpreted App has the best smoothness, followed by the native app and the PWA when Changing pictures and text.

Meanwhile, when scrolling, the native application has the best smoothness, followed by the Interpreted app and the PWA.

The PWA app is the one whose smoothness varies the least between the different devices.

Memory Performance:

The native app has the best memory performance overall.

When changing text, the Interpreted app does better than PWA. However, when changing pictures, it's slightly worse, and it's much worse while scrolling.

CPU Usage:

Native has, once again, the best performance across the board.

Otherwise, PWA apps generally performed best when changing pictures and text, while interpreted apps did slightly better when scrolling.

[31] Sample Apps:

The Native app is the best across the board except in scenario i1 for Android S9, but it doesn't seem to have any statistical significance.

Otherwise, the Flutter app has the second-best energy consumption, often very close to the native implementation.

The PWA running on Firefox and its web wrapper do worse than the ones running on Chrome.

The React Native app has a significantly higher energy consumption than the PWA running on Chrome, making it one of the worst in energy consumption.

Meanwhile, the Capacitor app has widely varying results, exhibiting in i1 higher energy consumption on both devices than the PWA Chrome app but lower for all other tests in the Galaxy S9 device. On the other hand, the Capacitor app on the Galaxy S21 device only has lower energy consumption for test i2, with all others being higher.

Real World Apps:

Native apps are still much better than Chrome PWA.

The results from the sample apps between the PWAs (Chrome) and the React Native apps only hold for the lower-end device.

The magnitude of the difference between React Native apps and the PWA is lower.

Flutter exhibits slightly higher energy consumption.

The Chrome PWA also exhibits significantly lower energy consumption than the Hybrid app (Capacitor).

[32] First Paint:

Overall, the PWA app was the fastest to First Paint, only being slower on the Samsung Galaxy S6 Edge device (our mid-tier device). Afterward, the Web App did best, followed by the Cordova app, except when tested on the OnePlus One and the Samsung Galaxy S6 Edge (the lower-end and mid-tier devices).

First Contentful Paint:

The PWA took the least time in the Xiaomi Mi Mix3 and the OnePlus One devices (the high-end and lower-end devices), took longer than both other apps in the Samsung Galaxy S6 Edge (mid-end), and took longer than only the Web App, and not by a lot, in the Huawei P10 Lite (mid-end).

Overall, the Cordova App took less time than the Web App except in the Huawei P10 Lite (mid-end).

Estimated Input Latency:

The PWA has the best input latency on all devices for clicking on a product, followed by the Web App and the Cordova App.

When comparing products, the PWA has the worst latency on all phones except the Huawei P10 Lite, where the Web App has worse latency, followed by the PWA and the Cordova App.

When using checkboxes, the PWA has the best latency for the Samsung Galaxy S6 Edge and the OnePlus One, the highest for the Huawei P10 Lite but not by a lot, and the second lowest for the Xiaomi Mi Mix 3.

Time To Interactive:

The PWA has the best time for the OnePlus One and Huawei P10 Lite devices, but the Cordova and the Web apps are not far behind.

It performs the worst on the Samsung Galaxy S6 Edge phone and the second worst on the Xiaomi Mi Mix 3, but the difference between the different apps is pretty slight.

Total Time Taken:

PWA was the fastest app on all phones, but the Samsung Galaxy S6 Edge phone, where the web app was the fastest.

Table A.4: Analysis of the "Analysis of Software Tools Allowing the Development of Cross-Platform Applications for Mobile Devices" [1] paper

Framework	Programming Supported Language Version	Community	Performance	Application Examples
-----------	--	-----------	-------------	-------------------------

Ionic	JavaScript, HTML, CSS + Angular, React, Vue	iOS 10.0+; Android 4.0+	Numerous	Average due to web tech	Swokit and Shirp
Flutter	Dart	iOS 11.0+; Android 4.1+	Few but actively developing	Very high	Google Ads, Alibaba, eBay, SpaceX Go
React Native	JavaScript + React	iOS 11.0+; Android 5+	Very numerous	High, close to native	Pinterest, Skype, Facebook
Xamarin	C# + .NET	iOS 9.0+; Android 4.4+	Numerous	Fairly high	SmartHotel360

Table A.5: Analysis of the "Analysis of Cross-Platform Mobile App Development Tools" [2] paper Part 1

Framework	Programming Language	License	Implementation Complexity	Ease of Update
Native	Java/Kotlin Swift/Objective-C	Android: Open-source; iOS: Closed-source	High	Low
Web Apps	HTML, CSS, JS, TS,...	Open-source	Low	High
Hybrid Apps	HTML, CSS, JS, Node.js,...	Open-source	Moderate	Varying
Interpreted Apps	JS, JSX, Markup,...	Generally open-source	Low to moderate	Varying

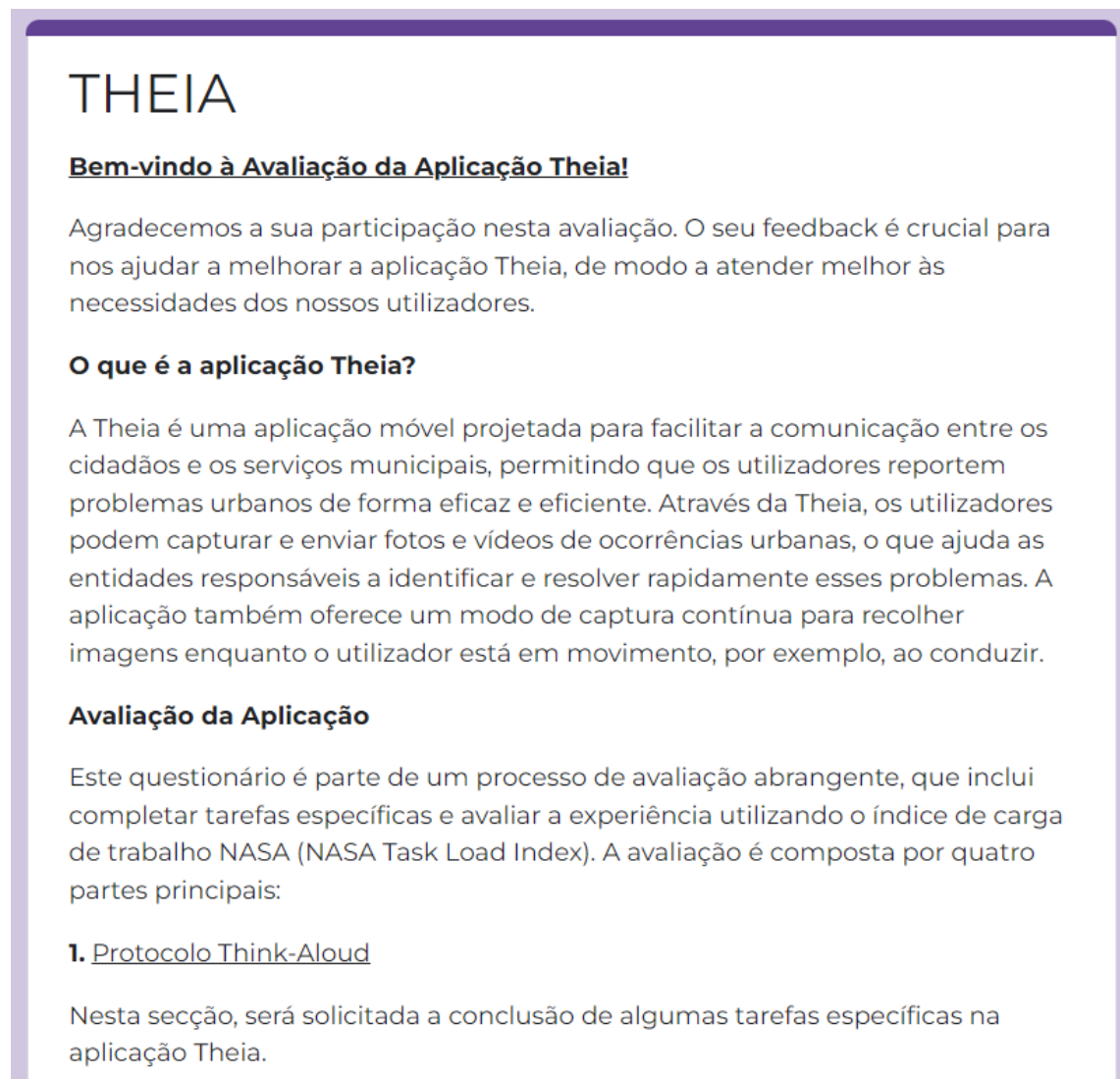
Widget Apps (Flutter)	Dart	Open-source	Moderate	Moderate
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Table A.6: Analysis of the "Analysis of Cross-Platform Mobile App Development Tools" [2] paper Part 2

Framework	Security	Development Cost	Potential Users	UI/UX	Access to Native API
Native	Very high	High	Limited	Excellent	Yes
Web Apps	Very low	Low	Maximum	Moderate	Yes, but only with HTML5
Hybrid Apps	Low	Large	Moderate	Moderate	Yes, through plugins
Interpreted Apps	Varying	Moderate	Large	Fairly Good	Yes
Widget Apps (Flutter)	High	Moderate	Limited	Very Good	Yes

Appendix B

Forms



THEIA

Bem-vindo à Avaliação da Aplicação Theia!

Agradecemos a sua participação nesta avaliação. O seu feedback é crucial para nos ajudar a melhorar a aplicação Theia, de modo a atender melhor às necessidades dos nossos utilizadores.

O que é a aplicação Theia?

A Theia é uma aplicação móvel projetada para facilitar a comunicação entre os cidadãos e os serviços municipais, permitindo que os utilizadores reportem problemas urbanos de forma eficaz e eficiente. Através da Theia, os utilizadores podem capturar e enviar fotos e vídeos de ocorrências urbanas, o que ajuda as entidades responsáveis a identificar e resolver rapidamente esses problemas. A aplicação também oferece um modo de captura contínua para recolher imagens enquanto o utilizador está em movimento, por exemplo, ao conduzir.

Avaliação da Aplicação

Este questionário é parte de um processo de avaliação abrangente, que inclui completar tarefas específicas e avaliar a experiência utilizando o índice de carga de trabalho NASA (NASA Task Load Index). A avaliação é composta por quatro partes principais:

1. Protocolo Think-Aloud

Nesta secção, será solicitada a conclusão de algumas tarefas específicas na aplicação Theia.

Figure B.1: Google Forms Questionnaire for the User - Part 1

2. Volume de Trabalho - Task Load Index (NASA-TLX)

Nesta secção, será avaliado o volume de trabalho necessário para a utilização da aplicação em cinco das seis dimensões do NASA-TLX, nomeadamente: exigência mental, quantidade de tempo, desempenho, esforço e frustração sentida.

3. Usabilidade - Escala de Usabilidade do Sistema (SUS)

Nesta secção, irá avaliar a sua experiência geral com a aplicação com base em dez afirmações. Cada afirmação deve ser classificada numa escala de 1 (Discordo Totalmente) a 5 (Concordo Totalmente). A SUS ajudar-nos-à a entender quão eficaz, eficiente e satisfatório é o desempenho da aplicação no seu ponto de vista.

4. Interface do Utilizador - Questionário de Satisfação da Interface do Utilizador (QUIS)

Esta secção consiste num conjunto de perguntas que medem a sua satisfação com a interface de utilizador da aplicação. Irá avaliar cada item numa escala de 1 (Muito Insatisfeito) a 9 (Muito Satisfeito). O QUIS é projetado para nos fornecer feedback detalhado sobre a acessibilidade, aparência e experiência geral do utilizador da aplicação.

Figure B.2: Google Forms Questionnaire for the User - Part 2

Instruções:

- Por favor, responda a todas as questões tendo em conta a sua experiência na utilização da aplicação Theia.
- Não existem respostas certas ou erradas, estamos interessados nas suas opiniões e experiências genuínas.
- Se encontrar alguma dificuldade ou tiver sugestões, por favor mencione-as nas secções de comentários opcionais fornecidas.

As suas respostas serão mantidas confidenciais e serão usadas apenas para melhorar a aplicação Theia. Agradecemos o seu tempo e esforço para nos ajudar a melhorar a aplicação para todos os utilizadores.

Vamos começar!

Figure B.3: Google Forms Questionnaire for the User - Part 3

Dados Pessoais

Para fins de análise estatística e para entender melhor os diferentes perfis dos utilizadores, por favor, forneça as seguintes informações. A sua resposta será anónima e confidencial.

Número de Participante *
A ser dado pelo(a) investigador(a)

Your answer _____

Idade *

- ☐ 18-30
- ☐ 31-45
- ☐ 46-60
- ☐ 60+

Figure B.4: Google Forms Questionnaire for the User - Part 4

Género *

- ☐ Feminino
- ☐ Masculino
- ☐ Prefiro não dizer
- ☐ Other: _____

Nível de Competência Digital *

- ☐ Baixo (Uso básico de Telemóvel)
- ☐ Moderado (Uso regular de aplicações e serviços de internet)
- ☐ Alto (Uso avançado de tecnologia, confortável com resolução de problemas)

Ocupação *

- ☐ Estudante
- ☐ Profissional
- ☐ Aposentado
- ☐ Other: _____

Figure B.5: Google Forms Questionnaire for the User - Part 5

The image shows a Google Forms questionnaire with two sections. The first section is titled 'Área' and contains a text input field with the placeholder text 'Your answer'. The second section is titled 'Nível de Escolaridade' and contains four radio button options: 'Ensino Básico', 'Ensino Secundário', 'Ensino Superior', and 'Other:'. The 'Other:' option has a text input field next to it.

Área

Your answer _____

Nível de Escolaridade

☐ Ensino Básico

☐ Ensino Secundário

☐ Ensino Superior

☐ Other: _____

Figure B.6: Google Forms Questionnaire for the User - Part 6

Secção 1: Think A-Loud

Nesta secção, o(a) Investigador(a) dar-lhe-á tarefas para completar. É incentivado(a) a expressar as tuas opiniões em voz alta. Queremos que realize as tarefas da melhor forma que conseguir.

Por favor, não avance para a próxima secção do questionário antes do(a) investigador(a) lhe pedir.

Secção 2: NASA Task Load Index (NASA-TLX)

Por favor, preencha as seguintes perguntas:

Quão mentalmente exigente foi a tarefa? *

1 2 3 4 5 6 7 8 9 10

Pouco Exigente ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Muito Exigente

Quanto tempo sentiu que teve para completar a tarefa? *

1 2 3 4 5 6 7 8 9 10

Pouco Tempo ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Muito Tempo

Figure B.7: Google Forms Questionnaire for the User - Part 7

The image displays three separate questionnaire sections, each with a light purple border. Each section contains a question, a 10-point scale, and radio button options.

Section 1: The question is "Quão bem acha que executou a tarefa? *". Below it is a horizontal scale from 1 to 10. Under the scale are ten radio buttons. The text "Muito Bem" is to the left of the first radio button, and "Muito Mal" is to the right of the last radio button.

Section 2: The question is "Quanto esforço sentiu que precisou de despender para completar a tarefa? *". Below it is a horizontal scale from 1 to 10. Under the scale are ten radio buttons. The text "Pouco Esforço" is to the left of the first radio button, and "Muito Esforço" is to the right of the last radio button.

Section 3: The question is "Quão frustrante foi completar a tarefa? *". Below it is a horizontal scale from 1 to 10. Under the scale are ten radio buttons. The text "Pouco Frustrante" is to the left of the first radio button, and "Muito Frustrante" is to the right of the last radio button.

Figure B.8: Google Forms Questionnaire for the User - Part 8

Secção 3: Escala de Usabilidade do Sistema (SUS)

Por favor, avalie as seguintes afirmações:

Acho que gostaria de usar esta aplicação frequentemente.

1 2 3 4 5

Discordo Totalmente ☐ ☐ ☐ ☐ ☐ Concordo Totalmente

Achei a aplicação desnecessariamente complexa.

1 2 3 4 5

Discordo Totalmente ☐ ☐ ☐ ☐ ☐ Concordo Totalmente

Achei a aplicação fácil de usar.

1 2 3 4 5

Discordo Totalmente ☐ ☐ ☐ ☐ ☐ Concordo Totalmente

Figure B.9: Google Forms Questionnaire for the User - Part 9

The image displays three separate questionnaire items, each within its own rounded rectangular box. Each item consists of a statement in bold, followed by a horizontal 5-point Likert scale. The scale is represented by five empty circles, with the numbers 1 through 5 positioned above each circle. The leftmost circle is preceded by the text 'Discordo Totalmente' and the rightmost circle is followed by 'Concordo Totalmente'.

Acho que precisaria do suporte técnico para conseguir usar esta aplicação.

1 2 3 4 5

Discordo Totalmente ☐ ☐ ☐ ☐ ☐ Concordo Totalmente

Achei que as várias funções desta aplicação estavam bem integradas.

1 2 3 4 5

Discordo Totalmente ☐ ☐ ☐ ☐ ☐ Concordo Totalmente

Achei que havia muita inconsistência nesta aplicação.

1 2 3 4 5

Discordo Totalmente ☐ ☐ ☐ ☐ ☐ Concordo Totalmente

Figure B.10: Google Forms Questionnaire for the User - Part 10

The figure displays three separate Google Forms questionnaire items, each within its own white box with a light purple border. Each item consists of a statement in bold black text, followed by a five-point Likert scale. The scale is represented by five empty circular radio buttons, with the number '1' above the first, '2' above the second, '3' above the third, '4' above the fourth, and '5' above the fifth. The text 'Discordo Totalmente' is positioned to the left of the first radio button, and 'Concordo Totalmente' is positioned to the right of the fifth.

Item 1: Imagino que a maioria das pessoas aprenderiam a usar esta aplicação muito rapidamente.

Item 2: Achei a aplicação muito complicada de usar.

Item 3: Senti-me muito confiante a usar a aplicação.

Figure B.11: Google Forms Questionnaire for the User - Part 11

The figure displays a single Google Forms questionnaire item within a white box with a light purple border. It consists of a statement in bold black text, followed by a five-point Likert scale. The scale is represented by five empty circular radio buttons, with the number '1' above the first, '2' above the second, '3' above the third, '4' above the fourth, and '5' above the fifth. The text 'Discordo Totalmente' is positioned to the left of the first radio button, and 'Concordo Totalmente' is positioned to the right of the fifth.

Item 4: Precisei de aprender muitas coisas antes de conseguir usar a aplicação.

Figure B.12: Google Forms Questionnaire for the User - Part 12

Secção 4: Questionário de Satisfação da Interface do Utilizador (QUIS)

Por favor, avalie a sua satisfação com a interface da aplicação.

Quão satisfeito está com a facilidade de aprender a usar a aplicação? *

1 2 3 4 5 6 7 8 9

Muito Insatisfeito ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Muito Satisfeito

Quão satisfeito está com o tempo de resposta do sistema? *

1 2 3 4 5 6 7 8 9

Muito Insatisfeito ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Muito Satisfeito

Quão satisfeito está com a navegação da aplicação? *

1 2 3 4 5 6 7 8 9

Muito Insatisfeito ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Muito Satisfeito

Figure B.13: Google Forms Questionnaire for the User - Part 13

The image shows a Google Forms questionnaire with four questions, each with a 9-point Likert scale. The questions are about visual layout, interface consistency, message clarity, and overall functionality. Each question is marked as required with a red asterisk.

Quão satisfeito está com o layout visual da aplicação? *

1 2 3 4 5 6 7 8 9

Muito Insatisfeito ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Muito Satisfeito

Quão satisfeito está com a consistência da interface da aplicação? *

1 2 3 4 5 6 7 8 9

Muito Insatisfeito ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Muito Satisfeito

Quão satisfeito está com a clareza das mensagens e avisos da aplicação? *

1 2 3 4 5 6 7 8 9

Muito Insatisfeito ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Muito Satisfeito

Quão satisfeito está com a funcionalidade geral da aplicação? *

1 2 3 4 5 6 7 8 9

Muito Insatisfeito ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Muito Satisfeito

Figure B.14: Google Forms Questionnaire for the User - Part 14

The image shows two separate Google Forms questionnaire sections. Each section has a title, a 9-point scale, and radio button options for 'Muito Insatisfeito' and 'Muito Satisfeito'.

Section 1:

Quão satisfeito está com os recursos de acessibilidade da aplicação? *

1 2 3 4 5 6 7 8 9

Muito Insatisfeito ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Muito Satisfeito

Section 2:

Quão satisfeito está com as mensagens de erro e recuperação da aplicação? *

1 2 3 4 5 6 7 8 9

Muito Insatisfeito ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Muito Satisfeito

Figure B.15: Google Forms Questionnaire for the User - Part 15

The image shows a Google Forms questionnaire section with a purple header and a white body. It includes a title, a thank-you message, a request for additional comments, and a text input field.

Secção 5: Comentários Finais

Agradecemos a sua participação e feedback! Por favor, utilize o espaço abaixo para quaisquer comentários adicionais ou sugestões que gostaria de compartilhar, sobre a sua experiência com a aplicação Theia.

A sua opinião é fundamental para o aprimoramento da aplicação Theia. Muito obrigado pelo seu tempo e colaboração!

Comentários Adicionais

Your answer

Figure B.16: Google Forms Questionnaire for the User - Part 16

Número do participante *

Your answer

Ordem das tarefas *

<https://www.random.org/lists/>

Your answer

Tarefa 1 - Mudar o nome da conta *

Your answer

Tempo *

Your answer

Erros cometidos *

Your answer

Figure B.17: Google Forms Questionnaire for the Investigator - Part 1

Completoou a tarefa

☐ Sim

☐ Não

Perguntas extra

☐ Acha que conseguiria mudar outras informações da sua conta (Ex. email, foto de perfil)?

☐ Acha que, se precisasse, conseguiria apagar a sua conta?

☐ Acha que conseguiria mudar a sua palavra-passe

Tarefa 2 - Capturar uma imagem *

Your answer

Tempo *

Your answer

Figure B.18: Google Forms Questionnaire for the Investigator - Part 2

Erros cometidos *

Your answer

Completo a tarefa

☐ Sim

☐ Não

Perguntas extra

☐ Acha que as notificações recebidas representam bem o estado da imagem (Se já foi carregada para o servidor, se está à espera de ser enviada para o servidor,...)

Tarefa 3 - Capturar um vídeo *

Your answer

Tempo *

Your answer

Figure B.19: Google Forms Questionnaire for the Investigator - Part 3

Erros cometidos *

Your answer

Completo a tarefa

☐ Sim

☐ Não

Perguntas extra

☐ Acha que as notificações recebidas representam bem o estado do vídeo (Se já foi carregado para o servidor, se está à espera de ser enviado para o servidor,...)

Tarefa 4 - Visualizar as imagens de um vídeo *

Your answer

Tempo *

Your answer

Figure B.20: Google Forms Questionnaire for the Investigator - Part 4

Erros cometidos *

Your answer

Completo a tarefa

☐ Sim

☐ Não

Tarefa 5 - Visualizar a imagem de uma ocorrência *

Your answer

Tempo *

Your answer

Erros cometidos *

Your answer

Figure B.21: Google Forms Questionnaire for the Investigator - Part 5

Completou a tarefa

☐ Sim

☐ Não

Tarefa 6 - Visualizar um vídeo no mapa *

Your answer

Tempo *

Your answer

Erros cometidos *

Your answer

Completou a tarefa

☐ Sim

☐ Não

Figure B.22: Google Forms Questionnaire for the Investigator - Part 6

Tarefa 7 - Visualizar outras imagens do mesmo local da ocorrência com ID 9 *

Your answer

Tempo *

Your answer

Erros cometidos *

Your answer

Completo a tarefa

☐ Sim

☐ Não

Tarefa 8 - Visualizar um ocorrência que diz respeito a cartão abandonado na rua *

Your answer

Figure B.23: Google Forms Questionnaire for the Investigator - Part 7

The image shows a Google Forms questionnaire for an investigator, consisting of five sections stacked vertically. Each section has a title and a response area.

- Tempo ***: A text input field with the placeholder "Your answer".
- Erros cometidos ***: A text input field with the placeholder "Your answer".
- Completou a tarefa**: A radio button question with two options: "Sim" and "Não".
- Perguntas extra**: A checkbox question with the text "Sente que sabe onde encontrar e como usar os filtros?".
- Tarefa 9 - Vizualizar o vídeo que deu origem a uma ocorrência ***: A text input field with the placeholder "Your answer".

Figure B.24: Google Forms Questionnaire for the Investigator - Part 8

The image shows a Google Forms questionnaire for an investigator, divided into four sections. Each section has a title, a red asterisk indicating it is required, and a text input field labeled 'Your answer'.

- Tempo ***: A text input field for the time taken.
- Erros cometidos ***: A text input field for errors made.
- Completou a tarefa**: A section with two radio button options: 'Sim' (Yes) and 'Não' (No).
- Perguntas extra**: A section with a checkbox question: 'Percebe a diferença entre uma ocorrência e um vídeo?' (Do you perceive the difference between an occurrence and a video?).

Figure B.25: Google Forms Questionnaire for the Investigator - Part 9

Appendix C

Results

ID	Task Order	Q1	Q2	Q3	Q4	Q5	Q6	Q7
1	6-5-1-9-4-3-7-2-8	x	x	x	x	x		x
2	6-4-2-3-5-9-8-1-7	x	x	x	x	x	x	x
3	4-7-5-9-8-3-1-2-6	x	x	x	x	x	x	x
4	3-4-2-1-5-9-8-7-6	x	x	x	x	x	x	x
5	7-1-5-3-8-4-9-6-2	x	x	x	x	x	x	x
6	1-3-8-6-4-5-9-2-7	x	x	x	x	x	x	x
7	4-8-5-9-7-3-2-6-1	x	x	x		x	x	x
8	7-6-3-2-8-1-5-4-9	x	x	x		x	x	x
9	9-5-3-7-2-4-1-8-6	x	x	x	x	x	x	x
10	9-3-6-8-7-4-1-2-5	x	x	x	x	x	x	x
11	3-2-4-1-5-8-6-7-9	x	x	x	x	x	x	x
12	9-5-3-1-4-8-7-6-2	x	x	x	x	x	x	x
13	5-6-4-9-7-3-2-1-8	x	x	x	x	x	x	x
14	1-6-2-9-5-4-7-3-8	x	x	x	x	x	x	x
15	1-8-3-4-7-5-6-2-9	x	x	x	x	x	x	x
16	2-8-1-6-4-5-7-9-3	x	x	x	x	x	x	x
17	8-3-9-2-4-6-1-5-7	x	x	x	x	x	x	x
18	3-7-6-9-5-2-8-1-4	x	x	x	x	x	x	x
19	1-9-5-2-6-8-7-3-4	x	x	x			x	x
20	8-6-5-3-1-2-4-7-9	x	x	x	x	x	x	x

Table C.1: Task order per participant and answers to the follow up questions

Legend for Questions:

Q1: Do you believe that, if you needed to, you would be able to change other account information (such as email or profile picture)?

Q2: Do you believe that, if you needed to, you would be able to delete your account?

- Q3: Do you believe that, if you needed to, you would be able to change your password?
- Q4: Do you believe that the notifications you received after capturing an image are useful to understand the state of said image?
- Q5: Do you believe that the notifications you received after capturing a video are useful to understand the state of said video?
- Q6: Do you feel like you understand where you can find the filters and know how to use them?
- Q7: Do you understand the difference between a video and an occurrence in the context of the app?

Table C.2: User Demographic Data

ID	Age	Gender	Tech Proficiency	Occupation	Field	Education
1	18-30	Female	High	Student	Fine Arts	Higher Education
2	18-30	Female	Moderate	Student	Genetics	Higher Education
3	18-30	Female	Moderate	Student	Design	Higher Education
4	18-30	Female	High	Student	Architecture	Higher Education
5	18-30	Male	Moderate	Unemployed	-	Basic Education
6	18-30	Male	Moderate	Student	Applied Mathematics and Data Science	Higher Education
7	18-30	Female	Low	Student	Art and Design	Higher Education
8	18-30	Male	Moderate	Unemployed	-	Secondary Education
9	18-30	Male	Moderate	Professional	Retail Worker	Secondary Education
10	31-45	Male	Moderate	Professional	Private Security/Vigilante	Secondary Education
11	46-60	Female	Moderate	Professional	Teaching Portuguese and French	Higher Education
12	31-45	Male	Moderate	Professional	Engineering	Higher Education
13	31-45	Female	Moderate	Professional	Engineering/Architecture	Higher Education
14	31-45	Female	Moderate	Professional	Viticulture and Enology	Higher Education
15	18-30	Female	High	Student	Secondary Education	Secondary Education
16	46-60	Female	High	Professional	International Office	Higher Education
17	46-60	Male	Moderate	Professional	Commercial	Higher Education
18	46-60	Female	Moderate	Professional	Nursing	Higher Education
19	46-60	Male	Moderate	Professional	Security Forces	Higher Education
20	60+	Male	Moderate	Professional	Education	Higher Education

Table C.3: NASA Task Load Index (NASA-TLX) Ratings

ID	Mental Demand	Temporal Demand	Performance	Effort	Frustration Level
1	1	2	1	2	1
2	1	1	1	1	1
3	4	7	2	4	2
4	2	2	2	2	2
5	3	5	9	3	2
6	2	10	9	2	1
7	3	5	4	4	1
8	2	3	4	3	2
9	1	10	3	3	1
10	4	5	2	4	1
11	5	3	3	3	3
12	5	6	8	4	1
13	2	6	6	3	3
14	4	10	10	5	2
15	5	10	9	6	1
16	2	6	4	2	1
17	6	5	6	5	1
18	4	8	6	4	4
19	4	4	5	3	2
20	3	3	5	3	1

Table C.4: System Usability Scale (SUS) Responses

ID	Q1: Likelihood to Use	Q2: Un-necessary Complexity	Q3: Ease of Use	Q4: Need for Technical Support	Q5: Integration of Functions	Q6: Inconsistency	Q7: Learnability	Q8: Cumbersome	Q9: Confidence
1	4	1	5	1	5	2	5	1	5
2	4	1	5	1	5	1	5	1	5
3	4	3	4	2	4	1	4	1	4
4	5	1	5	1	5	1	4	2	5
5	3	2	4	1	4	1	5	1	4
6	5	1	5	1	5	1	5	1	5
7	5	1	5	1	4	1	5	1	5
8	4	1	3	2	3	2	4	2	4
9	4	1	5	1	4	1	5	1	4
10	5	2	4	1	5	1	5	1	5
11	5	1	4	1	5	1	4	1	4
12	5	1	5	1	5	1	5	1	5
13	2	3	3	2	3	2	3	2	4
14	5	1	1	1	3	1	4	1	4
15	5	1	5	1	5	3	5	1	5
16	5	1	4	1	5	1	1	1	5
17	5	1	2	1	4	1	5	1	5
18	5	2	3	1	3	2	5	2	2
19	5	1	4	1	4	1	3	1	4
20	4	1	4	1	4	1	5	1	2

Table C.5: Questionnaire for User Interaction Satisfaction Responses

ID	Q1: Learn-ability	Q2: System Response Time	Q3: Navigation	Q4: Visual Layout	Q5: Interface Consistency	Q6: Message Clarity	Q7: Overall Functionality	Q8: Accessibility Features	Q9: Error Handling
1	9	9	6	8	9	9	8	9	9
2	9	8	9	9	9	9	9	9	5
3	7	9	6	8	9	9	8	5	5
4	9	9	9	9	9	9	9	9	9
5	8	4	7	7	8	5	7	6	5
6	9	9	9	9	9	8	9	9	5
7	8	8	9	9	8	8	8	9	5
8	7	7	8	8	7	7	8	7	7
9	9	9	9	8	9	8	9	9	9
10	7	9	9	9	9	9	8	9	5
11	9	9	9	9	9	9	9	9	5
12	9	9	8	7	8	9	9	8	5
13	5	6	6	6	6	7	8	7	5
14	8	7	7	7	7	7	7	7	5
15	9	9	9	9	9	9	9	9	5
16	8	9	9	9	9	9	9	9	5
17	9	9	9	9	9	9	9	9	9
18	8	8	7	9	8	8	8	8	5
19	8	5	8	8	8	8	8	8	5
20	8	9	8	9	8	8	9	8	5

Table C.6: Participant Comments

Participant	Comments (Portuguese)	Comments (English translation)
1	Penso que seria desnecessário haver duas abas para as ocorrências e vídeos, questiono se poderia haver uma aba onde poderíamos ver os vídeos que demos upload e, talvez ao clicar, ver o seu estado de análise. Secalhar também chamar às imagens de vídeos gera alguma confusão. No geral, achei fácil de utilizar, acho que teria sido mais rápida se tivesse utilizado dados móveis do que eduroam, que é muito lenta.	I think it would be unnecessary to have two tabs for occurrences and videos; I question whether there could be a tab where we could see the videos we uploaded and maybe click to see their analysis status. Perhaps calling images videos also causes some confusion. Overall, I found it easy to use; I think it would have been faster if I had used mobile data instead of eduroam, which is very slow.
2	Devem mudar no início, (idiomas) para que as frases estejam no mesmo sítio e não mudem de posição vertical.	They should change in the beginning (languages) so that the sentences are in the same place and do not change vertically.
3	Talvez seria melhor atualizar a notificação de upload conforme ele é realizado, ao invés de enviar várias notificações diferentes.	Perhaps it would be better to update the upload notification as it is done, instead of sending several different notifications.
4	-	-
5	-	-
6	-	-
7	-	-
8	-	-
9	-	-
10	-	-
11	-	-
12	-	-
13	-	-
14	-	-
15	-	-
16	-	-
17	Esta aplicação (como todas as outras) carecem de utilização frequente, o que facilita o uso e a intuição.	This application (like all others like it) do not need frequent use, which facilitates ease of use and intuition.
18	-	-
19	-	-
20	-	-

Table C.7: Results of think-aloud for task 1 (Change the account's name)

ID	Task	Task (English)	Time	Errors Made	Completed Task
1	-	-	14s	0	Yes
2	-	-	14s	0	Yes
3	Icon de mudar a imagem devia ser um ícone de edit.	Icon to change the image should be an edit icon.	15s	0	Yes
4	-	-	22s	0	Yes
5	-	-	13s	0	Yes
6	Clicou primeiro nas configurações.	Clicked settings first.	57s	1	Yes
7	Clicou primeiro nas configurações.	Clicked settings first.	26s	1	Yes
8	-	-	16s	0	Yes
9	-	-	11s	0	Yes
10	-	-	47s	0	Yes
11	Foi às configurações primeiro. A cor do botão de OK é um pouco difícil de ver.	Went to settings first. The OK button color is a bit hard to see.	1m9s	1	Yes
12	-	-	27s	0	Yes
13	Foi às configurações primeiro.	Went to settings first.	24s	1	Yes
14	-	-	33s	0	Yes
15	-	-	17s	0	Yes
16	Mudar o nome ou e-mail dando long press seria mais intuitivo. Botões difíceis de ver.	Changing the name or email with a long press would be more intuitive. Buttons are hard to see.	1m38s	1	Yes
17	-	-	26s	0	Yes
18	Ícone para confirmar não passa a ideia certa.	Icon for confirm does not convey the right idea.	2m15s	1	Yes
19	Foi às configurações. Botões da navbar são muito claros e parecem inativos.	Went to settings. Navbar buttons are too light and seem inactive.	35s	1	Yes
20	Ícone de guardar não é muito explícito.	Save icon is not very clear.	2m0s	1	Yes

Table C.8: Results of think-aloud for task 2 (Capture an image)

ID	Task	Task (English)	Time	Errors Made	Completed Task
1	-	-	12s	0	Yes
2	Clicou no botão de anotações. Ordem das notificações está errada na homepage.	Clicked on the annotation button. Notification order is wrong on the homepage.	29s	1	Yes
3	-	-	11s	0	Yes
4	-	-	13s	0	Yes
5	-	-	7s	0	Yes
6	Notificação ter video em vez de imagem causa alguma confusão.	Notification having video instead of image causes some confusion.	15s	0	Yes
7	As notificações deveriam dizer imagem e não video.	Notifications should say image and not video.	8s	0	Yes
8	As notificações deveriam dizer imagem e não video.	Notifications should say image and not video.	6s	0	Yes
9	Notificações deviam falar de imagens não videos	Notifications should talk about images, not videos.	9s	0	Yes
10	-	-	10s	0	Yes
11	-	-	10s	0	Yes
12	-	-	9s	0	Yes
13	-	-	8s	0	Yes
14	Cor de seleção de modo de foto no menu não é muito intuitiva	Photo mode selection color in the menu is not very intuitive.	21s	0	Yes
15	-	-	8s	0	Yes
16	-	-	33s	0	Yes
17	Notificações deveriam falar de imagens e não videos	Notifications should talk about images, not videos.	6s	0	Yes
18	Icons no ecrã de gravar confundem	Icons on the recording screen are confusing.	24s	1	Yes
19	Botões pouco intuitivos. Possibilidade de carregar no ecrã para tirar foto. Adicionar opção de zoom. Notificações do mesmo vídeo poderiam substituir-se.	Buttons are not very intuitive. Possibility to tap on the screen to take a photo. Add a zoom option. Notifications for the same video could be replaced.	22s	1	Yes
20	Botão de tirar foto é confuso	Photo button is confusing.	26s	1	Yes

Table C.9: Results of think-aloud for task 3 (Capture a video) - Part 1

ID	Task	Task (English)	Time	Errors Made	Completed Task
1	-	-	28s	0	Yes
2	-	-	21s	0	Yes
3	Carregou no botão das anotações. Botão de anotações causa confusão. BUG: Aplicação a dar notificações em inglês com a app em português após minimizar.	Clicked on the annotations button. Annotations button causes confusion. BUG: App gives notifications in English with the app in Portuguese after minimizing.	30s	1	Yes
4	Acidentalmente rejeitou permissões da câmera.	Accidentally denied camera permissions.	50s	1	Yes
5	Está mais habituado a ver o botão colorido (cheio) como o botão de continuar.	More used to seeing the colored (full) button as the continue button.	7s	0	Yes
6	-	-	31s	0	Yes
7	-	-	21s	0	Yes
8	-	-	15s	0	Yes
9	-	-	22s	0	Yes
10	Clicou no botão errado (anotações). BUG: Notificações novas a não aparecer logo na página de notificações.	Clicked the wrong button (annotations). BUG: New notifications not appearing immediately on the notifications page.	47s	1	Yes
11	Posicionamento dos botões pouco intuitivo.	Button positioning is not very intuitive.	50s	1	Yes
12	Carregou no botão errado.	Clicked the wrong button.	36s	0	Yes

Table C.10: Results of think-aloud for task 3 (Capture a video) - Part 2

ID	Task	Task (English)	Time	Errors Made	Completed Task
13	Não é muito óbvio como começar o vídeo. Dar a opção à pessoa a possibilidade de reportar o que viu no vídeo.	Not very obvious how to start the video. Give the option for the person to report what they saw in the video.	15s	1	Yes
14	Interface do vídeo causa confusão.	Video interface causes confusion.	20s	0	Yes
15	-	-	18s	0	Yes
16	-	-	48s	0	Yes
17	Cores do menu para trocar entre tirar fotos e gravar um vídeo não passam a ideia correta de qual modo está ativo.	Menu colors for switching between taking photos and recording a video do not convey the correct idea of which mode is active.	22s	0	Yes
18	Interface um pouco confusa em termos de ícones e botões.	Interface a bit confusing in terms of icons and buttons.	34s	1	Yes
19	Ícone de começar a gravar devia estar no topo do botão para trocar entre modos. Substituir notificações para o mesmo vídeo.	Record button icon should be at the top of the mode switch button. Replace notifications for the same video.	19s	1	Yes
20	Não é muito intuitivo onde clicar.	It is not very intuitive where to click.	54s	1	Yes

Table C.11: Results of think-aloud for task 4 (View video images)

ID	Task	Task (English)	Time	Errors Made	Completed Task
1	-	-	14s	0	Yes
2	-	-	8s	0	Yes
3	-	-	38s	0	Yes
4	-	-	17s	0	Yes
5	-	-	6s	0	Yes
6	-	-	7s	0	Yes
7	Navegou para o ecrã errado.	Navigated to the wrong screen.	29s	1	Yes
8	-	-	6s	0	Yes
9	-	-	4s	0	Yes
10	-	-	20s	0	Yes
11	-	-	18s	0	Yes
12	Não viu a lista de vídeos, foi pelas ocorrências.	Did not see the list of videos, went by occurrences.	28s	1	Yes
13	-	-	5s	0	Yes
14	-	-	5s	0	Yes
15	-	-	3s	0	Yes
16	-	-	5s	0	Yes
17	-	-	26s	0	Yes
18	-	-	14s	0	Yes
19	Seria bom poder arrastar no ecrã para ir para a imagem seguinte.	It would be good to swipe on the screen to go to the next image.	37s	1	Yes
20	-	-	1s	0	Yes

Table C.12: Results of think-aloud for task 5 (View occurrence image)

ID	Task	Task (English)	Time	Errors Made	Completed Task
1	Alguma confusão entre o que distingue vídeos de ocorrências.	Some confusion between what distinguishes videos from occurrences.	10s	0	Yes
2	-	-	9s	0	Yes
3	Icon de play na imagem causa confusão.	Play icon on the image causes confusion.	14s	0	Yes
4	-	-	9s	0	Yes
5	-	-	6s	0	Yes
6	-	-	6s	0	Yes
7	-	-	8s	0	Yes
8	-	-	6s	0	Yes
9	-	-	4s	0	Yes
10	-	-	9s	0	Yes
11	Icon da localização induz em erro, não é imediatamente óbvio onde encontrar as ocorrências.	Location icon is misleading, it's not immediately obvious where to find the occurrences.	56s	0	Yes
12	-	-	9s	0	Yes
13	Cor da barra de navegação quando os ícones não estão selecionados a cor induz em erro.	Navigation bar color when icons are not selected is misleading.	1m24s	0	Yes
14	-	-	7s	0	Yes
15	-	-	4s	0	Yes
16	-	-	5s	0	Yes
17	Play na imagem da ocorrência dá ideia de que vai passar um vídeo e não aumentar a imagem.	Play on the occurrence image gives the idea that it will play a video, not zoom in on the image.	19s	1	Yes
18	Icon da imagem deveria ser algo mais como uma lupa dá a ideia que abre um vídeo.	Image icon should be something more like a magnifying glass; it gives the idea that it opens a video.	54s	1	Yes
19	Icon deveria ser uma lupa.	Icon should be a magnifying glass.	25s	0	Yes
20	Botão faz parecer que é um vídeo, não uma imagem.	Button makes it seem like it's a video, not an image.	31s	0	Yes

Table C.13: Results of think-aloud for task 6 (View a video in the map)

ID	Task	Task (English)	Time	Errors Made	Completed Task
1	-	-	44s	0	Yes
2	Entrou nas imagens de um vídeo.	Entered the images of a video.	1m8s	1	Yes
3	-	-	9s	0	Yes
4	-	-	9s	0	Yes
5	-	-	5s	0	Yes
6	-	-	8s	0	Yes
7	-	-	7s	0	Yes
8	-	-	0s	-	Yes
9	-	-	5s	0	Yes
10	-	-	40s	0	Yes
11	Confusão com a navegação.	Confusion with navigation.	1m2s	1	Yes
12	-	-	7s	0	Yes
13	-	-	6s	0	Yes
14	-	-	9s	0	Yes
15	-	-	4s	0	Yes
16	-	-	1m44s	1	Yes
17	Seria interessante poder ver imagem de satélite.	It would be interesting to see satellite imagery.	5s	0	Yes
18	-	-	27s	0	Yes
19	-	-	7s	0	Yes
20	-	-	52s	0	Yes

Table C.14: Results of think-aloud for task 7 (View other images of the same location as the occurrence with ID 9)

ID	Task	Task (English)	Time	Errors Made	Completed Task
1	-	-	59s	2	Yes
2	-	-	40s	0	Yes
3	-	-	1m13s	1	Yes
4	-	-	43s	0	Yes
5	-	-	1m7s	0	Yes
6	-	-	12s	0	Yes
7	-	-	51s	0	Yes
8	Confundiu-se inicialmente com a navegação.	Initially confused with navigation.	59s	1	Yes
9	-	-	15s	0	Yes
10	-	-	41s	0	Yes
11	-	-	1m22s	0	Yes
12	-	-	35s	0	Yes
13	-	-	27s	0	Yes
14	-	-	19s	0	Yes
15	-	-	18s	0	Yes
16	-	-	53s	0	Yes
17	Carregar novamente no botão na nav bar deveria voltar à lista inicial.	Clicking the button on the nav bar again should return to the initial list.	1m6s	0	Yes
18	Dificuldade a ver as ocorrências no menu de baixo, cor muito clara.	Difficulty seeing occurrences in the bottom menu, color too light.	2m22s	1	Yes
19	Não é imediatamente óbvio que se pode dar scroll para baixo em alguns ecrãs.	It's not immediately obvious that you can scroll down on some screens.	50s	0	Yes
20	-	-	1m28s	0	Yes

Table C.15: Results of think-aloud for task 8 (Find an occurrence where the issue found was cardboard abandoned in the street) - Part 1

ID	Task	Task (English)	Time	Errors Made	Completed Task
1	Não usou filtros.	Did not use filters.	9s	0	Yes
2	Não usou filtros.	Did not use filters.	9s	0	Yes
3	Categorias um pouco confusas, trocar cartão por lixo reciclável por exemplo daria uma categoria mais compreensível. Diferença entre lixo reciclável e lixo indiferenciado. Botão de filtro poderia ter posicionamento diferente. Estar no topo dá a ideia que tem a ver com as informações da conta.	Categories a bit confusing; changing "cardboard" to "recyclable waste" for example would provide a more understandable category. Difference between recyclable waste and non-recyclable waste. Filter button could be positioned differently. Being at the top gives the idea it is related to account information.	34s	1	Yes
4	Icon dos filtros em cima não se vê bem.	Filter icon on top is not visible well.	9s	0	Yes
5	Usar o back button do dispositivo deveria fechar os filtros.	Using the device's back button should close the filters.	7s	0	Yes
6	-	-	10s	0	Yes
7	Não viu o tipo de evento nas cartas.	Did not see the event type on the cards.	42s	1	Yes
8	Não viu o tipo de evento nas cartas.	Did not see the event type on the cards.	21s	1	Yes
9	-	-	7s	0	Yes
10	Posicionamento do botão para expandir os filtros pouco óbvio. Reparou logo nos filtros mas não no botão.	Button placement for expanding filters is not very obvious. Noticed filters right away but not the button.	47s	0	Yes
11	-	-	17s	0	Yes
12	-	-	7s	0	Yes

Table C.16: Results of think-aloud for task 8 (Find an occurrence where the issue found was cardboard abandoned in the street) - Part 2

ID	Task	Task (English)	Time	Errors Made	Completed Task
13	Adicionar localização aos filtros.	Add location to filters.	7s	0	Yes
14	Posicionamento do botão dos filtros não é claro.	Filter button placement is not clear.	6s	0	Yes
15	-	-	9s	0	Yes
16	Achou que na homepage haveria maneira de aceder a outros ecrãs.	Thought that on the homepage there would be a way to access other screens.	51s	1	Yes
17	Opções do menu com cor demasiado clara. Botões dos filtros difíceis de ver. Tipo de evento não é imediatamente claro, trocar por tipo de ocorrência poderia ajudar.	Menu options with too light a color. Filter buttons hard to see. Event type is not immediately clear, changing to occurrence type could help.	1m24s	1	Yes
18	Botão dos filtros não se nota muito. Icon não muito intuitivo.	Filter button is not very noticeable. Icon is not very intuitive.	11s	0	Yes
19	Icon dos filtros poderia ser o funeral.	Filter icon could be a funeral.	9s	0	Yes
20	Cor da navbar não se lê bem. Botão dos filtros não é fácil de perceber.	Navbar color is hard to read. Filter button is not easy to understand.	1m6s	1	Yes

Table C.17: Results of think-aloud for task 9 (View the original video of an occurrence) - Part 1

ID	Task	Task (English)	Time	Errors Made	Completed Task
1	Confusão entre vídeo e ocorrências. Pôr ocorrências a aparecer nos vídeos.	Confusion between video and occurrences. Make occurrences appear in videos.	51s	3	Yes
2	-	-	10s	0	Yes
3	Se calhar a seção de vídeos poderia chamar-se uploads para se perceber que é aquilo a que o utilizador dá upload.	Maybe the video section could be named "uploads" to make it clear that it is what the user uploads.	9s	0	Yes
4	Se calhar mudar "View Full Collection" to "View Full Video" ou "Original Video".	Maybe change "View Full Collection" to "View Full Video" or "Original Video".	50s	2	Yes
5	-	-	8s	0	Yes
6	O botão se calhar devia ser "Ver vídeo de origem" ou "Vídeo completo".	The button should maybe be "View Source Video" or "Full Video".	33s	1	Yes
7	"View full collection" não é muito explícito.	"View full collection" is not very explicit.	16s	0	Yes
8	Nome do botão pouco explícito.	Button name is not very explicit.	54s	0	Yes
9	Nome do botão pouco explícito.	Button name is not very explicit.	1m23s	0	Yes
10	Dificuldades de navegação. Nome do botão pouco explícito.	Navigation difficulties. Button name is not very explicit.	2m	2	Yes
11	-	-	13s	0	Yes
12	Nome do botão pouco explícito. Cor da barra de navegação do fundo dá a ideia que os botões não estão ativos.	Button name is not very explicit. Bottom navigation bar color gives the impression that the buttons are not active.	36s	0	Yes

Table C.18: Results of think-aloud for task 9 (View the original video of an occurrence) - Part 2

ID	Task	Task (English)	Time	Errors Made	Completed Task
13	Nome do botão induz em erro.	Button name is misleading.	39s	0	Yes
14	-	-	10s	0	Yes
15	Nome do botão pouco explícito.	Button name is not very explicit.	15s	0	Yes
16	-	-	15s	0	Yes
17	Nome do botão pouco explícito.	Button name is not very explicit.	1m1s	0	Yes
18	-	-	14s	0	Yes
19	Icon de vídeo não ajuda na im-agem da ocorrência, confunde. Nome do botão pouco explícito.	Video icon does not help with the occurrence image, it confuses. Button name is not very explicit.	50s	1	Yes
20	Não é imediatamente óbvio que se pode dar scroll para baixo.	It is not immediately obvious that you can scroll down.	8s	0	Yes