Investigating the Use of the Thunkable End-User Framework to Develop Haptic-Based Assistive Aids in the Orientation of Blind People

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Abstract: Nowadays mobile devices are essential tools for visiting cultural heritage sites. Thus, it is very important to provide an inclusive cultural mobile experience for anyone. In this study, we investigate how to create accessible apps to enhance the experience of the visually impaired people in outdoor cultural itineraries. In such a context, the integration of specific features for improving accessibility for blind people may require high skills. This study investigates how it is possible to exploit a simple-to-use developing environment, Thunkable framework, which does not require specific technical competencies, to easily develop an accessible app.

1 INTRODUCTION

The World Health Organization states that more than 2.2 billion people have visual impairments, of which 1 billion have preventable or untreated problems (WHO, 2022). This makes tasks that require spatial understanding challenging for them. Technical solutions to perform everyday activities that were not previously possible (Jones et al., 2019; Wang and Yu, 2017), such as touchscreen interactions and many applications for orientation and mobility in both indoor and outdoor environments, but few help with cultural routes. Our study focuses on improving cultural guides for visually impaired visitors. We're developing tools, including an app, that provide tour information and accessibility details. This should improve the experience for visually impaired users and make them part of the tool's target audience. A major barrier to the diffusion of accessibility is the high skill level of the people who develop these accessible digital solutions. Through a case study, we propose how to create inclusive tools that are also easy to develop. Some design aspects related to the inclusion of accessible maps and haptic feedback are also considered in this study. Blind and visually impaired people use screen readers with integrated speech synthesis to navigate websites or mobile applications. However, for the screen reader to work properly, it must be programmed to read and recognize all the information on the screen as faithfully as possible, without causing confusion or creating an additional cognitive load. A focus group was conducted to gain insights from the blind and visually impaired community about digital tools to assist in visiting cultural routes. Participant feedback informed the development of an application to test the potential of the Thunkable[1] framework for creating accessible interfaces. Specifically, this paper investigates:

1) the Thunkable framework as an end-user development tool for the development of an accessible app,
2) the implementation of haptic feedback as an assistive tool in the exploration of a digital map.

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2 RELATED WORK

Smartphones and tablets are widely used by people of all ages, including people with disabilities. They serve as important tools, especially for the visually impaired, acting as assistive technologies. These technologies improve the autonomy, safety, and social engagement of visually impaired people, reducing their isolation. Despite the accessibility features built into cell phones, there are apps tailored to assist blind users with various tasks, especially when they are outside their homes, such as navigating cities or shopping. These apps enable full use of the device through features such as voice commands and auditory feedback.

Bigham et al. (2010) developed VizWiz::LocateI, a cell phone app addressing the challenge of handling excessive information in apps, often visually encoded through text and colors. This complexity poses usability issues for visually impaired users. Innovative solutions include Blindhelper (Meliones, 2016), aiding navigation for the blind. It integrates a smartphone app with an embedded system for accurate pedestrian detection via GPS, obstacle identification, and traffic light status. The app offers voice-guided navigation and user assistance.

Another notable application, BlindNavi, attempts to simplify navigation by combining all relevant information into a single application. This eliminates the need to switch between multiple apps when navigating in nature. It uses technologies such as iBeacon to provide accurate navigation directions to visually impaired users. BlindRouteVision offers a novel approach by using a smartphone app to improve pedestrian navigation for visually impaired people without requiring assistance. This application detects the status of traffic lights and identifies obstacles in the user's path to ensure safer navigation. Augmented reality has also made strides in helping the visually impaired. A mobile application uses augmented reality to suggest optimal routes while taking safety into account. It evaluates predefined parameters to discard routes that pose a potential risk to the mobility of the visually impaired (Medina-Sanchez, 2021). In the area of public transportation, an app has been developed to address a common challenge faced by visually impaired individuals: understanding when to signal a stop on public transit. This app informs users of their location along the route, granting them more independence (Lima, 2018). In contrast, another application employs a camera and voice messages to provide real-time identification of objects, as well as their distance and direction relative to the camera. (Meenakshi, 2022).

Several factors must be considered when designing a website or application, such as the use of alternative text, appropriate color contrasts, and the use of markup instead of images to convey information. All of these factors are organized by the W3C in the form of guidelines (W3C, 2023). The goal of this work is to design useful tools for accessible use of itineraries, cultural (and other) routes.

3 METHOD

In this work, we assessed the accessibility support of the Thunkable app development framework, which offers a 'Design' section for UI layout and a 'Blocks' section to link components. The Thunkable Live application must be installed on the mobile device to test the prototype on the smartphone. The main purpose of this work is to find out whether the framework enables the developers to create accessible interfaces. Thus, features such as alternative descriptions, labels of buttons and links, as well as the inclusion of haptic features have been considered in the design. Design specifications have been gathered by involving potential end-users who expressed their expectations and preferences about tools that should be available along the itinerary.

A prototype app has been therefore designed and developed with the Thunkable framework. In order to make the itinerary as inclusive as possible, the use of the QR code was exploited to make the traditional panels that are usually available along the itinerary usable for the blind. This is intended to enrich the user experience and thus be a practical indication for planners.

4 THE APP PROTOTYPE

4.1 User Requirements

To gather information from visually impaired and blind users about their preferences and expectations regarding the application, a series of remote focus groups were organised. Ten users participated in the focus groups, six blind and four visually impaired. The focus groups addressed three different topics: outdoor mobility (in the context of walking with a mobile navigator/orienteer), orientation (and the ability to explore a digital map and how it is perceived by the user), and the user experience (and how different technologies are used in everyday environments, from computers to cell phones).

Some specifications for interacting with the application were discussed with users. These include a simple and direct navigation menu, a help button to always assist the user in navigating, various search options (verbal, keyboard input, and a dropdown menu). In order to be accessible, it is important that a) the correct labelling allows the screen reader to read all the icons, buttons and text, and b) all the elements of the user interface have semantics so that the user knows the function of each element and especially how to interact with them.

The preferences and expectations of blind users can be summarized as follows.

In terms of mobility, users mostly prefer vibration-based instructions, although this could be challenging for those unfamiliar with haptic technology. Instructions on how to use and adjust the vibrations could help. Preferences vary: some prefer continuous vibrations, while others opt for subtle audible cues. Warning signals for distances, stops, benches, crosswalks, and traffic lights are critical. Trail verification is essential for wayfinding, which includes a star-based (from 1 to 5) rating system and customizable text inputs. Marking points of interest with distinct vibrations or voice notifications, as well as retrievable vibrations when a POI is reached, are beneficial. Testing Thunkable's custom haptic capabilities during map development showed great interest. Since the application is not intended to be used only by blind people, it was decided to complete a questionnaire (via Google Form) to understand if and how certain functions and features are useful for sighted people. Questions addressed user characterization (gender, age, how often they hike), information that might be useful for viewing the trail, and points of interest. A question about the type of feedback preferred for detecting POI, and finally, interest in wearing a device that provides more information. Results showed overlap in desired features between the two groups. For example, many (50%) sighted users expressed interest in timely information and in having content read aloud rather than reading from the screen.

4.2 App Architecture

The app was designed to facilitate user interaction and navigation through content with a simple and clear layout. Our goal was to develop an accessible mobile application that would allow visually impaired users to interact via voice commands and multi-touch. We designed the user interface with high-contrast background and foreground colors so that visually impaired users could better identify components on the screen. We developed the application so that it could be used in conjunction with the screen reader by adding a brief description of the components that users could interact with.

Homepage. On the home page, users will immediately find the most important elements, organised into four macro sections: Itineraries, Point of Interest, Reviews and Instructions. A navigation menu at the bottom of the app is very useful to navigate within the different pages without getting lost, with the possibility to return to the home page by simply clicking on the left button. The menu is divided into four main pages: Home, Map, Reviews and Settings (see figure 1).

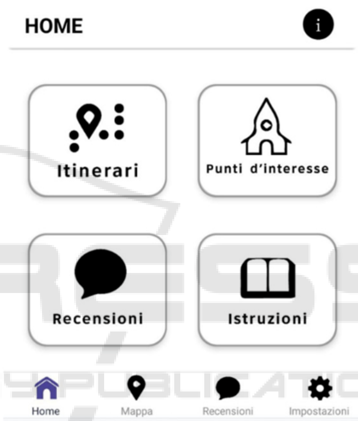

Figure 1: Screenshot of the home page.

Itineraries. In this section, the user can select an item from a list of itineraries, with the possibility of performing a voice search, entering the name in the search box, or selecting by location: Toscana, Liguria, Sardegna, Corsica, PACA (Provenza-Alpi-Costa Azzurra). To implement the list, the 'Data viewer list' component was added, which allows to link a data source and select which data to display. In the case of this project, it was decided to place all the data in Airtable[2], a spreadsheet that can be used to create data tables in various formats. The information to be displayed included the title of the trail, a subtitle representing the region in which it is located, and an image of the trail map. Each itinerary opens a description page with information on name, length, altitude, routes and navigation (for download).

[2] https://www.airtable.com/

Point of Interest. In this section, the user can choose from a list of places of interest with appropriate search options, including selection by category: Church, Hermitage, Parish. The data viewer list was also used in this case, in order to be able to visualise the data via Airtable, but compared to the itineraries, it was decided to add a text alongside the title and subtitle. This text represents the different POI categories. The description page displays information about the name, pictures, five icons for accessibility and five icons for the vehicles you can use to reach the place, as illustrated in figure 6.

Reviews. In the "Reviews" section (see figure 2), the user can see all the comments left by other users. In the preview, the name of the route and the type of disability of the commentator are highlighted. Clicking on one of the comments opens the page with the comment and the rating (stars received) for the different categories: Route, Difficulty, Services, Accessibility.

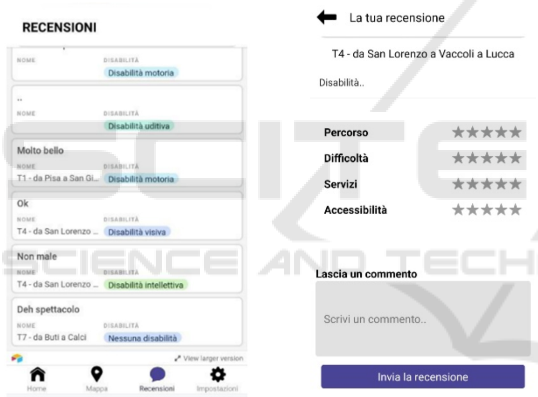

Figure 2: Screenshot of the Review page.

Instructions. Finally, the 'Instructions' button is designed to help users navigate each page. In addition to this button on the home page, a small button has been added in the upper right corner to provide the ability to access the instructions at any time. The tutorials are organised so that the page titles are displayed and clicking on one of these titles displays the explanatory text. The buttons have been designed in line with the app's colour palette, i.e. white text on a purple background.

4.3 Accessibility Features

Blind and visually impaired people use a screen reader with integrated speech synthesis to navigate web portals or mobile devices. However, for the screen reader to work properly, it must be programmed so that all information on the screen is read and recognized as faithfully as possible. By following the W3C Web Accessibility Guidelines (WCAG) 2.2 we were able to make the application suitable for use by visually impaired users and others. According to users' preferences and expectations, the following accessibility features were implemented in the prototype app. This allowed us to test whether the Thunkable development environment enables the inclusion of such features.

Microphone. Using the microphone for searching is a useful navigation option for all user categories. To enable this tool, the voice recognition component has been integrated. This is an invisible component that listens to the target voice and returns a text value after the entire sentence is spoken. It stops listening when all sounds have been revealed.

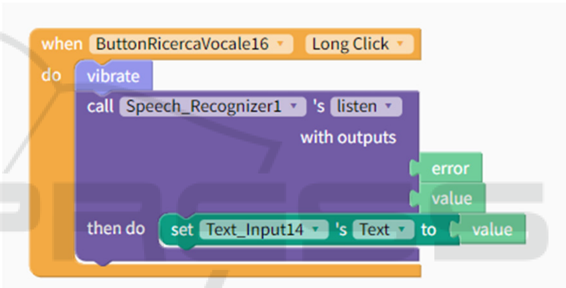

Figure 3: Microphone usage code.

As illustrated in figure 3, for the text value it returns, 'Text's input text' was set to the value of the speech recognizer. So as soon as the speech is finished, the text is transferred to the search box.

When the user taps the microphone once, a short vibration alerts them that it is a record button. If, on the other hand, it is held down, a longer vibration alerts the user to the possibility of recording. Since it is not enough to convey information only via a vibration, this feedback was combined with a voice output for better understanding.

Page Structure. Navigation between pages is made difficult when information is arranged without a logical structure. Moreover, too much information on a single page leads to such confusion that users are forced to abandon the page, leaving them frustrated. Thus, it is important to arrange all elements and information in a simple and easy-to-understand way, create simple pages and move excess information. Additional information can be activated via buttons if the user has an interest in going deeper, saving time listening to the excess information. Finally, on the travel page, it was decided to structure the information about altitudes and elevations in a way that can be better read by the screen reader, avoiding columns that are difficult to decipher by the screen reader.

Alternative Text/Description. According to W3C guidelines, it is necessary to insert alternative text for images, video graphics and buttons. Since there is no way to insert alternative text for images in Thunkable, all images have been converted to buttons. This makes it possible to insert text that is not visible on the page, but can be recognized by the screen reader and thus read by users. For accessibility reasons, each button has text describing its function and explaining what it depicts.

Digital Map. The biggest challenge was making the map accessible, as Thunkable does not have the tools to create it. To make the map more user-friendly, the first step was to include a pop-up warning about activating GPS. Activating the code starts the position sensor, which detects the user's current position and displays it on the map with a different colored marker. Then all the markers of the points of interest of the different locations are displayed as illustrated in figure 4.

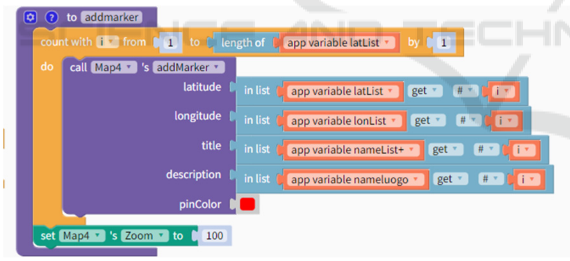

Figure 4: Example of code to add marker.

As illustrated in figure 5, the 'Navigate by Region' button allows the user to select one of the six regions to avoid moving around the screen and losing control of the map. By selecting the region, the map zooms in on the selected location with its points of interest. Clicking on POI activates a dual recognition vibration with speech synthesis that announces the name (Paratore, 2023).

Dark Screen Mode. Dark mode or dark theme indicates a negative contrast polarity in which text and background colors are inverted and it is an excellent aid for visually impaired people as, thanks to the dimming of the screen allows them to see and read content and reduces eye fatigue. During the questionnaire administered to blind and visually impaired users, it emerged that most visually impaired users prefer dark mode mainly because of the sunlight reflecting off the screen does not allow them to view the content present. Therefore, it was decided to include this mode in the project as well.

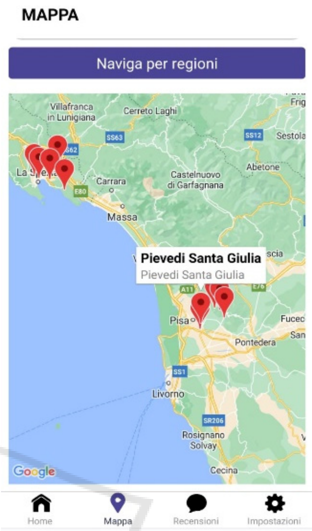

Figure 5: Map showing the points of interest and the "Navigate by Region" button.

Haptic. Haptic systems are critical in providing users with a variety of feedback on their actions, often using sound and vibration. This project focused on optimizing haptic feedback, primarily through sound and vibration, for assistive smartphone technologies. The design was primarily aimed at improving the effectiveness of interactions, especially for blind users. To make vibration informative for blind users, a combination of adaptive vibration and audio feedback was considered. A specific example is the use of double vibration patterns with a short pause to distinguish interactions. These intuitive vibrations were complemented by clear explanations on the app's user interface to enhance usability. The study also explored the integration of auditory cues with haptic feedback, as both modalities can convey information synergistically. This hybrid approach was evident in voice search, where different vibrations combined with voice instructions improved users' understanding of available actions.
In addition, the study presents an innovative approach by combining audio feedback with haptics. A notable example is the "play or pause" function on the page describing points of interest (POI). This feature consists of two different buttons, "Play" and "Stop","

which allow the user to trigger the voice output of the description text or to pause it if needed. The choice of these buttons is based on the recognition that not all users rely exclusively on screen readers. These buttons provide a comprehensive solution for the different user groups of the app with different preferences. It's worth noting that this feature isn't only beneficial for the visually impaired, but enriches the experience for all users.

Customization. A button is located on the description page of all POIs. It is used to change the text size, which by default starts at 18 and goes up to 50. It is also possible to have the description read aloud using a text-to-speech function. Finally, it is possible to change the color of the text. A very useful feature not only for the visually impaired, but also for the color blind or people with other visual impairments.

Figure 6: Screenshot of the description POI page.

5 EVALUATION

5.1 User Testing

In collaboration with the Italian Association of the Blind (Unione Italiana Ciechi e Ipovedenti), a test was conducted to evaluate the use of the prototype by visually impaired people. During the tests, the difficulties encountered by the users were observed and analysed in order to identify the possible problems and find solutions to improve the application or the function.

For the tests, an Android-based smartphone was chosen as the test device, on which the Thunkable Live development platform was installed. In this way, it is possible to perform a live test considering all the developed components mentioned in the previous section.

Tasks. To evaluate usability, a series of tasks were outlined for users to complete. These tasks involve goal-oriented activities, requiring descriptions of the steps taken, task duration, and whether they were successfully accomplished. Six tasks were proposed to each user:

1. From the 'map section', navigate by choosing a region and find the different POIs of the selected region.
2. Within the 'POI page', filter the search in "Church," by category selection, choose one and read the description page.
3. Perform a search for POIs via the search box.
4. In the 'Itineraries page', search for a route via voice search, select the route and read the found page.
5. In the description of the itineraries, add a user review.
6. Read the reviews added by other users.

SUS – System Usability Scale (Sauro, 2011)**.** Once the user-test tasks have been completed, users are presented with a short questionnaire to be completed, the System Usability Scale. The SUS is a 10-item questionnaire with 5 response options, where 1 indicates "strongly disagree", while 5 indicates "strongly agree". The questionnaire is composed as follows:

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

5.2 Participants

Only 5 users gave their consent to participate in the test": 4 blind and 1 visually impaired, aged from 45 to 60. Four users were male and one female. Two of blind participants (one male and one female) are very expert users while the other ones considerate themselves as intermediate users.

5.3 Results

During the test, time was measured and interaction with the product was analysed: all tasks were completed smoothly in a short time, in average about five minutes, for completing all the tasks. The interaction did not show major difficulties in understanding the use of the interfaces except in a few cases that were reported in order to improve the application.

Limitations. The development of the app encountered several challenges that underscored the complexity of creating an optimal user experience for people with visual impairments. One major hurdle was the use of the map function, particularly the accurate selection of markers for navigation. This underscored the need for precise design of haptic feedback to effectively distinguish between different inputs.

Inconsistencies in the wording of the rating page on different devices also proved to be a drawback. The content appeared in different languages on different cell phones, which can create a language barrier for users. This underscores the importance of thorough cross-device testing to ensure consistency regardless of user location or device settings.

Screen reader accessibility issues were another problem. Some screen readers had difficulty recognizing the microphone button for voice input, which hindered voice search functionality. Additionally, the 'Search' button lacked clear warnings upon activation, potentially confusing users during search operations. The absence of comprehensive auditory and tactile cues highlighted the necessity for more intuitive and complete feedback mechanisms.

Concerning the SUS questionnaire, the results collected so far show a positive average, where the user did not find difficulties in using the system, finding it simple and well organized. Figure 7 shows the results of the SUS questionnaire.

6 CONCLUSIONS AND FUTURE WORK

This work investigated the accessibility by design offered by the Thunkable Framework. The study found that creating an accessible app with Thunkable is suitable for people without programming skills. However, ensuring accessibility often requires specific customization, as certain features are not directly supported by the framework. In particular, being compliant with accessibility principles such as alternative image descriptions requires specific solutions. This challenge, already noted in other development environments such as App Inventor (Leporini, 2020), underscores the importance of the

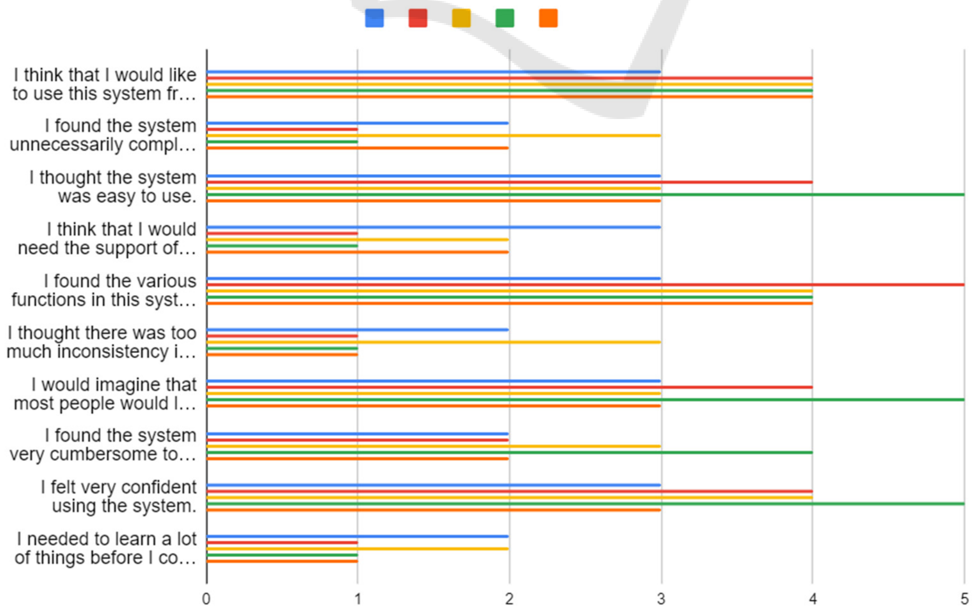

Figure 7: The results of the SUS questionnaire responses.

contributions of this study. The key innovation lies in the development of an app prototype using the Thunkable framework. This app is designed to facilitate navigation and exploration of outdoor environments, with a focus on travel routes. The app seamlessly provides information about itineraries and points of interest along the routes and allows users to post and access reviews from others. The app also integrates a digital map for navigating different regions. What makes the app special is the explicit consideration of accessibility during development. This includes the inclusion of alternative text, voice dictation via the microphone, and the implementation of haptic feedback, which enhances the user experience when exploring the digital map.

The evaluation found that some adjustments are needed to address the limitations of the Thunkable platform. Therefore, a recommendation for future development of this project is to improve accessibility through targeted design. It might be useful to provide users with an overview of the route within the routes in the form of a video presentation or photos of key points. Also, it would be a good option to offer the possibility to select a language other than Italian.

During the evaluation, difficulties arose in the map design, so some information essential for good usability could not be included. In this case, with a view to the future, the code could be modified to store points of interest and users' favourite routes.

The Thunkable platform is constantly being updated, and new features could overcome the highlighted limitations, making it easier to exploit multimedia and multimodal functionalities for enhancing inclusion; as a result, we intend to conduct a new test with a larger number of participants shortly.

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