ESCUELA POLITÉCNICA NACIONAL

FACULTAD DE INGENIERÍA DE SISTEMAS

DESARROLLO DE UN CATÁLOGO DIGITAL DE SOFTWARE PARA PERSONAS CON DISCAPACIDAD VISUAL UTILIZANDO PROTOTIPADO Y USER EXPERIENCE

TRABAJO DE TITULACIÓN PREVIO A LA OBTENCIÓN DEL TÍTULO DE INGENIERO EN SISTEMAS INFORMÁTICOS Y DE COMPUTACIÓN

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CERTIFICACIÓN

Certifico que el presente trabajo fue desarrollado por Richard Alfonso Muñoz Rivera, bajo mi supervisión.

_____

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Yo, Richard Alfonso Muñoz Rivera, declaro bajo juramento que el trabajo aquí descrito es de mi autoría; que no ha sido previamente presentada para ningún grado o calificación profesional; y, que he consultado las referencias bibliográficas que se incluyen en este documento.

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Richard Alfonso Muñoz Rivera

DEDICATORIA

El presente trabajo está dedicado:

A mi madre, por su amor y cariño inconmensurables,

A mi padre, por su amor y consejos sobre la vida,

A mi hijo Ariel, por ser mi inspiración diaria,

A mi esposa María, por haber estado a mi lado en los buenos y malos momentos,

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"Hay una fuerza motriz más poderosa que el vapor,
la electricidad y la energía atómica; la voluntad."
Albert Einstein

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RESUMEN

Con el uso de las TIC's en la educación, varias instituciones han desarrollado su interés en utilizar el Internet para mejorar sus servicios. Sin embargo, varios de estos servicios se ofrecen como aplicaciones las cuales, la mayor parte del tiempo, resultan difíciles de encontrar y descargarlas, no se encuentran correctamente indexadas y categorizadas; mas aún, en el Ecuador no existen catálogos que ofrezcan estas aplicaciones.

El objetivo de este proyecto es desarrollar un catálogo digital de software para personas con discapacidad visual que sea accesible, amigable con el usuario, y permita acercar todas éstas aplicaciones a los usuarios. Se realizó una investigación preliminar para identificar tanto aplicaciones web y móviles, así como catálogos que estén relacionados con la discapacidad visual, utilizando las directrices PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). Se analizaron tanto catálogos web como móvil para determinar las características y necesidades con las que debía cumplir el catálogo digital de software. Posteriormente, se evaluaron las aplicaciones web y móvil utilizando la metodología MARS (Mobile Application Rating Scale). Durante el desarrollo de cada prototipo se utilizaron los cinco planos de UX (User Experience), según su nivel de fidelidad (baja, media y alta).

Para lograr obtener una aplicación totalmente funcional, el "Instituto Mariana de Jesús" colaboró durante el desarrollo de la aplicación brindando comentarios y retroalimentación sumamente importante, así como, ayudar a evaluar cada uno de los prototipos. De esta manera, el catálogo digital de software cumple con las necesidades de las personas con discapacidad visual y apoya su desarrollo tanto educativo como de su día a día.

En conclusión, a pesar de que vivimos en un mundo constantemente cambiante con nuevas tecnologías emergiendo cada día, dichas tecnologías no siempre son accesibles para discapacitados, es por ello la importancia de acercar estas tecnologías para reducir la brecha tecnológica.

Keywords: discapacidad visual, accesibilidad, tecnologías inclusivas, catálogos web, prototipado, experiencia de usuario

ABSTRACT

With the use of ICT in education, many institutions have developed an interest in using the Internet for improving their services. However, most of the services come as applications which most of the time are difficult to find and get, are not well indexed and categorized; moreover, there are no catalogs offering these applications in Ecuador.

The objective of this project is to develop a digital software catalog for the visually impaired that is accessible, user-friendly and brings all these applications closer to users. A preliminary research was made in order to identify web and mobile applications and catalogs that deal with visual impairment using the Preferred Reporting Items for Systematic Reviews (PRISMA) directives. These web and mobile catalogs were analyzed in order to determine which features and needs the digital software catalog should comply with. After that, the mobile and web applications were evaluated using the Mobile App Rating Scale (MARS). The five planes of User Experience were used during the development of each prototype according to its fidelity level (low, medium and high-fidelity).

To achieve a fully functional application, the "Instituto Mariana de Jesús" helped during the development of the application giving rich and valuable feedback, as well as, helping to test every prototype. This way, the digital software catalog complies with the needs of the visually impaired and supports their educational and life development.

In conclusion, even though we live in a constantly changing world with new technologies emerging every day, these technologies are not always accessible to the impaired, that is why it is important to bring these technologies closer to the impaired, making the digital breach narrow.

Keywords: visual impairment, accessibility, inclusive technologies, web catalogs, prototyping, user experience

1 INTRODUCTION

This section describes the precedents, objectives and scope, as well as, the project structure, the theoretical framework and the preliminary research.

1.1 PRECEDENTS

Currently, the use of digital technology and Internet in education has become a powerful tool, since it allows for a better development of abilities and skills, besides improving the different educational processes [1]. However, there is still a significant number of people who do not have access to these resources due to suffering from visual impairment[2].

The visually impaired have great difficulties to learn in a traditional way [2]. For this reason, there are specialized institutions that treat this impairment supported on digital technology to improve learning. Software applications do not eliminate the difficulties in learning processes, but they can help visually impaired people to accomplish specific tasks more suitably [3]. Assistive technology (specifically software) strengthens and improves the capacities of impaired people, promoting a better life quality for them and their families.

According to Consejo Nacional para la Igualdad de Discapacidades (CONADIS), there are a total of 51,495 people who suffer from some kind of visual impairment [4]. Impaired people were included as a priority and special attention group in the 2008 Constitution. In section 3 of the "Ley Orgánica de Discapacidades", article 33 Accessibility to education, the following is stablished [5] : *"La autoridad educativa nacional en el marco de su competencia, vigilará y supervisará, en coordinación con los gobiernos autónomos descentralizados, que las instituciones educativas escolarizadas y no escolarizadas, especial y de educación superior, públicas y privadas, cuenten con infraestructura, diseño universal, adaptaciones físicas, ayudas técnicas y tecnológicas para las personas con discapacidad; adaptación curricular; participación permanente de guías intérpretes, según la necesidad y otras medidas*

de apoyo personalizadas y efectivas que fomenten el desarrollo académico y social de las personas con discapacidad."

It is so that even though it is explicitly declared, there is still a significant breach between technology, education, and accessibility; therefore, only a few institutions can use dedicated applications for the impaired. The main reason why it is difficult for educational institutions to get suitable software is that it is very challenging to search and get the proper software applications that can really help visually impaired people. Most of the time, in order to find one application, it is needed to ask someone who has already used that application or spend time looking for it on the Internet. While there exist institutions that offer software for the impaired, it usually happens that these applications are not well categorized, are only displayed unsorted, lack detail and sometimes, the download links do not work correctly or do not work at all.

Finally, no digital software catalog exists in Ecuador that can help search and get applications for the visually impaired. Each institution search software depending on past use experiences according to their needs, thus, the search becomes messy, and getting to download the application takes more time than expected.

1.2 OBJECTIVES

Following are the objectives considered in order to achieve the completion of this project.

General Objective

To develop a digital software catalog for the visually impaired using prototyping and user experience.

Specific Objectives

- To research and select existing web and mobile applications for visual impairment.
- To evaluate the functionality of at least 26 selected applications.
- To collect the digital software catalog for the visually impaired requirements.
- To design the catalog architecture based on the collected requirements.
- To design three prototypes of the digital software catalog.

- To implement the digital software catalog using prototyping as software development methodology and user experience criteria.

- To evaluate the functionality, usability, and accessibility of the digital software catalog.

1.3 SCOPE

These are the four milestones achieved during the development of this project:

- **Preliminary Research**

  Existing web pages and application catalogs dealing with visual impairment were analyzed deeply to find possible enhancements to implement in the digital software catalog. The research and selection of visual impairment applications followed, which then were evaluated.

- **Prototyping**

  In order to achieve a fully working application, it was necessary to go through three different types of prototypes: low, medium and high fidelity. The first prototype was designed as a wireframe and allowed creating a first glance of how the catalog should look and feel. After that, a medium-fidelity prototype was developed to demonstrate how the software catalog should operate. Finally, after gathering feedback from the stakeholders, the high-fidelity prototype was implemented using user experience criteria and all the enhancements from the early prototypes.

- **User Experience**

  The use of User Experience allowed verifying that all major design aspects were adequate for the digital software catalog.

- **Evaluation of Software Quality**

  The goal of the software catalog is to offer the best possible experience while focusing on functionality, usability, and accessibility; thus, all three prototypes were evaluated so that they comply with the requirements and user experience criteria.

1.4   THEORETICAL FRAMEWORK

1.4.1   Visual Impairment

The World Health Organization (WHO) defines impairment as *"Whichever temporary or permanent loss or abnormality of a body structure or function, whether physiological or psychological. An impairment is a disturbance affecting functions that are essentially mental (memory, consciousness) or sensory (sight), internal organs (heart, kidney), the head, the trunk or the limbs"* [6]. Visual Impairment including blindness means an impairment in vision that, even with correction, adversely affects a child's educational performance [7]. The term includes both partial sight and blindness. Some indicators can tell whether a child has visual impairment [8].

- Appearance of eyes:
    - ◊ One eye turns in or out at any time.
    - ◊ Reddened eyes or lids.
    - ◊ Eyes tear excessively.
    - ◊ Encrusted eyelids.
    - ◊ Frequent styes on lids.
- Complaints when using eyes at desk:
    - ◊ Headaches in forehead or temples.
    - ◊ Burning or itching after reading or desk work.
    - ◊ Nausea or dizziness.
    - ◊ Print blurs after reading a short time.
- Behavioral signs of visual problems:
    - ◊ Eye movement abilities (ocular mobility).
        - o Head turns as reads across page.
        - o Loses place often during reading.
        - o Needs finger or marker to keep place.
        - o Displays short attention span in reading or copying.

- o Too frequently omits words.
- o Repeatedly omits "small" words.
- o Writes up or down hill on paper.
- o Rereads or skips lines unknowingly.
- o Orients drawings poorly on page.

◊ Eye teaming abilities (binocularity).

- o Complains of seeing double (diplopia).
- o Repeats letters within words.
- o Omits letters, numbers or phrases.
- o Misaligns digits in number columns.
- o Squints, closes or covers one eye.
- o Tilts head constantly while working at desk.
- o Consistently shows gross postural deviations at all desk activities.

◊ Eye-hand coordination abilities.

- o Must feel things to assist in any interpretation required.
- o Eyes not used to "steer" hand movements (extreme lack of orientation, placement of words or drawings on page).
- o Writes crookedly, poorly spaced: cannot stay on ruled lines.
- o Misaligns both horizontal and vertical series of numbers.
- o Uses hand or fingers to keep his place on the page.
- o Uses other hand as "spacer" to control spacing and alignment on page.
- o Repeatedly confuses left-right directions.

- Visual form perception (visual comparison, visual imagery, visualization):

  ◊ Mistakes words with same or similar beginnings.

  ◊ Fails to recognize same word in next sentence.

  ◊ Reverses letters and/or words in writing and copying.

  ◊ Confuses likenesses and minor differences.

  ◊ Confuses same word in same sentence.

  ◊ Repeatedly confuses similar beginnings and endings of words.

  ◊ Fails to visualize what is read either silently or orally.

◊ Whispers to self for reinforcement while reading silently.

◊ Returns to "drawing with fingers" to decide likes and differences.

▪ Refractive status (nearsightedness, farsightedness, focus problems):

◊ Comprehension reduces as reading continued; loses interest too quickly.

◊ Mispronounces similar words as continues reading.

◊ Blinks excessively at desk tasks and/or reading; not elsewhere.

◊ Holds book too closely; face too close to desk surface.

◊ Avoids all possible near-centered tasks.

◊ Complains of discomfort in tasks that demand visual interpretation.

◊ Closes or covers one eye when reading or doing desk work.

◊ Makes errors in copying from chalkboard to paper on desk.

◊ Makes errors in copying from reference book to notebook.

◊ Squints to see chalkboard, or requests to move nearer.

◊ Rubs eyes during or after short periods of visual activity.

◊ Fatigues easily; blinks to make chalkboard clear up after desk task.

1.4.1.1 Classification of Visual Impairments

The WHO defines the following types of visual impairments [6]. The Snellen chart is used in order to measure the visual acuity which is printed with eleven lines of block letters and can be used in feet (20/20) or meters (6/6) [9]. The terms moderate low vision (a.k.a partially sighted), severe low vision, legally blind, and totally blind are used in the educational context to describe students suffering from visual impairments. They are defined as follows [7]:

▪ **Normal vision:** Snellen acuities: 4/6, 6/6 or fields: 180º, 140º. In this case, there is no impairment.

▪ **Near-normal Vision:** Snellen acuities: 6/9, 6/18 or fields: 120º, 80º. Slight vision impairment, though should be able to perform all visual tasks. People with this level of vision are likely to be eligible to drive a car.

- **Moderate low vision:** Snellen acuities: 6/24, 6/48 or fields: 60º, 30º. Moderate vision impairment which will require the use of aids and/or accommodations/adaptions for some tasks in the learning environment.

- **Severe low vision:** Snellen acuities: 6/60, 6/120, 3/60 or fields: 20º, 15º. Generally, refers to a severe visual impairment, not necessarily limited to distance vision. Severe low vision applies to all individuals with sight who are unable to read the newspaper at a normal viewing distance, even with the aid of eyeglasses or contact lenses. They use a combination of vision and other senses to learn, although they may require adaptations in lighting or the size of print, and, sometimes, Braille.

- **Legally blind:** Snellen acuities: 6/150, 6/300, 3/75 or fields: 10º. Will require the significant use of aids and accommodations/adaptions for most tasks in the learning environment. Very limited field of vision (20 degrees at its widest point).

- **Totally blind:** Will require the significant use of aids, other senses and the provision accommodations/adaptions for all tasks in the learning environment. Likely to be eligible for additional funding due to vision impairment. In this case, students learn via braille or other non-visual media.

1.4.2 Software Development Methodology Justification

The digital software catalog urges to ease access and make searching intuitive. By combining Prototyping and User Experience (UX) the user needs are the priority which leads to better software design. The digital software catalog core lies on developing all three prototypes and the five planes of user experience.

1.4.2.1 Prototyping

Software prototyping is defined as the activity of creating software application prototypes, namely, incomplete versions of a software application that is currently under development [9].

An important aspect of prototyping is the definition of three levels of fidelity along with four aspects that allow the prototype categorization, each of which must be related to the objectives and product requirements.

There are four categories and are detailed below [10]:

1. **Features:** How many features of the final product does the prototype include?

2. **Functionality:** How much of the functionality of the final product is included in the prototype (for each feature)?

3. **Interaction:** How similar is the interaction with the prototype to the interaction with the final product?

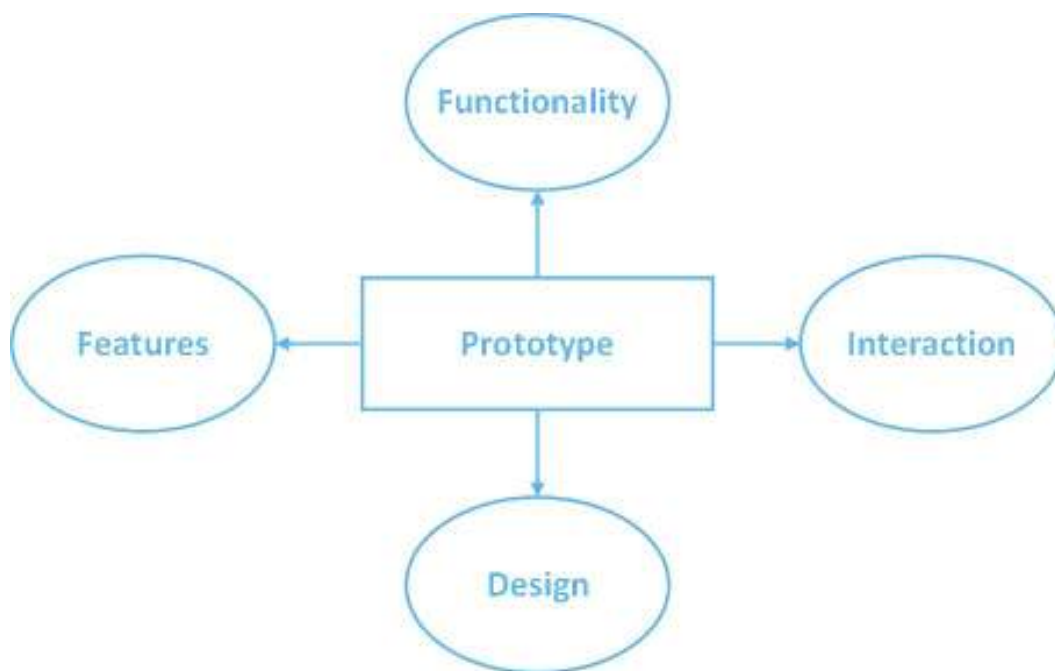4. **Design:** How similar is the prototype in design to the final product (color, design)?

Figure 1.1: Important aspects for categorizing prototypes, based on [10]

There are three levels of fidelity and are detailed below [10]:

1. **Low fidelity:** limited functionality, features and interaction. Its main function is to show visual concepts and design alternatives such as wireframes and mockups.

2. **Medium fidelity:** includes more detail in some of the categories (features, functionality, interaction or design). It allows combining different views, interactions and functions, allowing the user to evaluate the prototype and give feedback about the system.

3. **High fidelity:** it is a fully interactive and functional prototype, representing the product's core functionality and features. Users may not tell the difference between a high fidelity and a finished product.
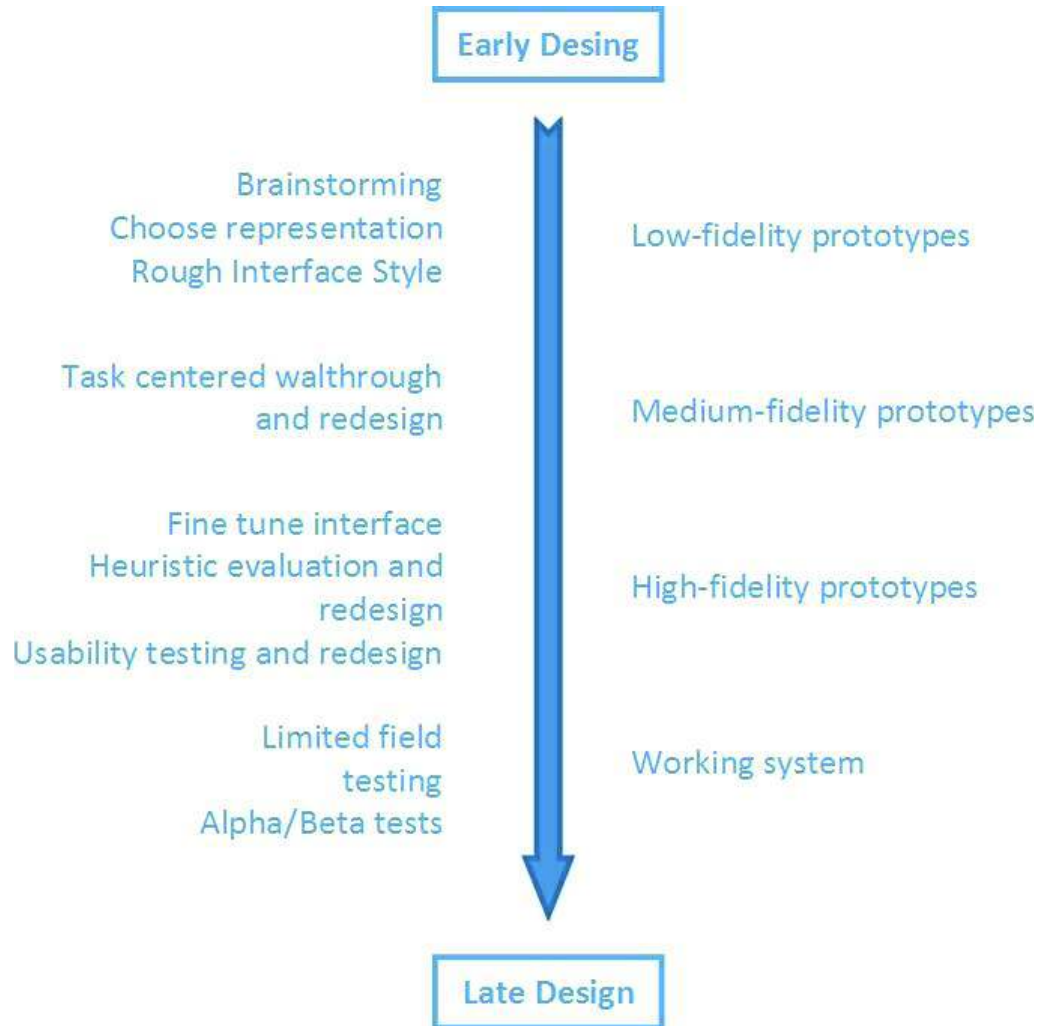
Figure 1.2: Prototyping in the design life cycle, based on [10]

A prototype can be used during the software development process to anticipate any possible change [11].

- ▪ The use of prototyping allows collecting and validating software requirements during the requirements engineering process.

- ▪ A prototype can be used as a rapid software solution supporting user interface design during the system design process.

1.4.2.2 User Experience

According to Garrett, User Experience is the experience a product creates for people who use it in the real world [12]. When a product is being developed, people pay a great deal of attention to what it does. However, it is worth noting that most of the time, a good experience is not based on the inner workings of a product or service, but instead, how it works on the outside, where a person directly interacts with it. Namely, how hard is to do simple things? How easy is to figure it out? How does it feel to interact with the product?

In order to implement user experience in the development of this project, the five planes methodology will be used. The five planes methodology created by Garrett is a path to follow during the design and development process to achieve UX (see Figure 1.3). These five planes consist in ensuring that no aspect of the user's experience with the product happens without conscious. This means taking into account every possible action the user is likely to consider and understand the user's expectations at every step of the way through that process [12] [13]. Each plane is defined as follows:

1. **The Strategy Plane:** The strategy of the site allows defining the scope of the project. The strategy incorporates not only what the people running the site want to get out of it but what the users want to get out of the site as well. This means it allows knowing what product the organization wants and what the users will receive. The elements are the user needs and objectives of the product.

2. **The Scope Plane:** Once the user needs and objectives of the product are established, the specific requirements of the product content and functionality can be set. In other words, the various features and functions of the site are defined. These elements are the definition of the requirements, functionalities and content.

3. **The Structure Plane:** It is defined as the placement of the interface elements on the site. A conceptual design is developed to determine how all pieces fit together. The elements are the design of interaction and information architecture.

4. **The Skeleton Plane:** While the structure deals with the architecture, the skeleton deals with the content placement and interface. Specific features are identified such as user interface, navigation, and design of information and are rearranged to achieve an efficient site. The elements are: design of interface, navigation, and information.

5. **The Surface Plane:** The Surface displays web pages made up of images and text. Some images and text can perform an action if clicked like redirecting to another web page or opening a new tab. The element is the visual design.

1.4.2.3 WCAG 2.0

The Web Content Accessibility Guidelines (WCAG) provides a single shared standard for web content accessibility that meets the needs of individuals, organizations, and governments internationally [14].

The WCAG documents explain how to make web content more accessible to people with disabilities. Web "content" generally refers to the information in a web page or web application, including:

- Natural information such as text, images, and sounds.
- Code or markup that defines structure, presentation, etc.

The guidelines and success criteria are organized around the following four principles (see Figure 1.4), which lay the foundation necessary for anyone to access and use web content. Anyone who wants to use the web must have content that is [15]:

- **Perceivable:** Information and user interface components must be presentable to users in ways they can perceive.

  This means that users must be able to perceive the information being presented (it can't be invisible to all of their senses)

13
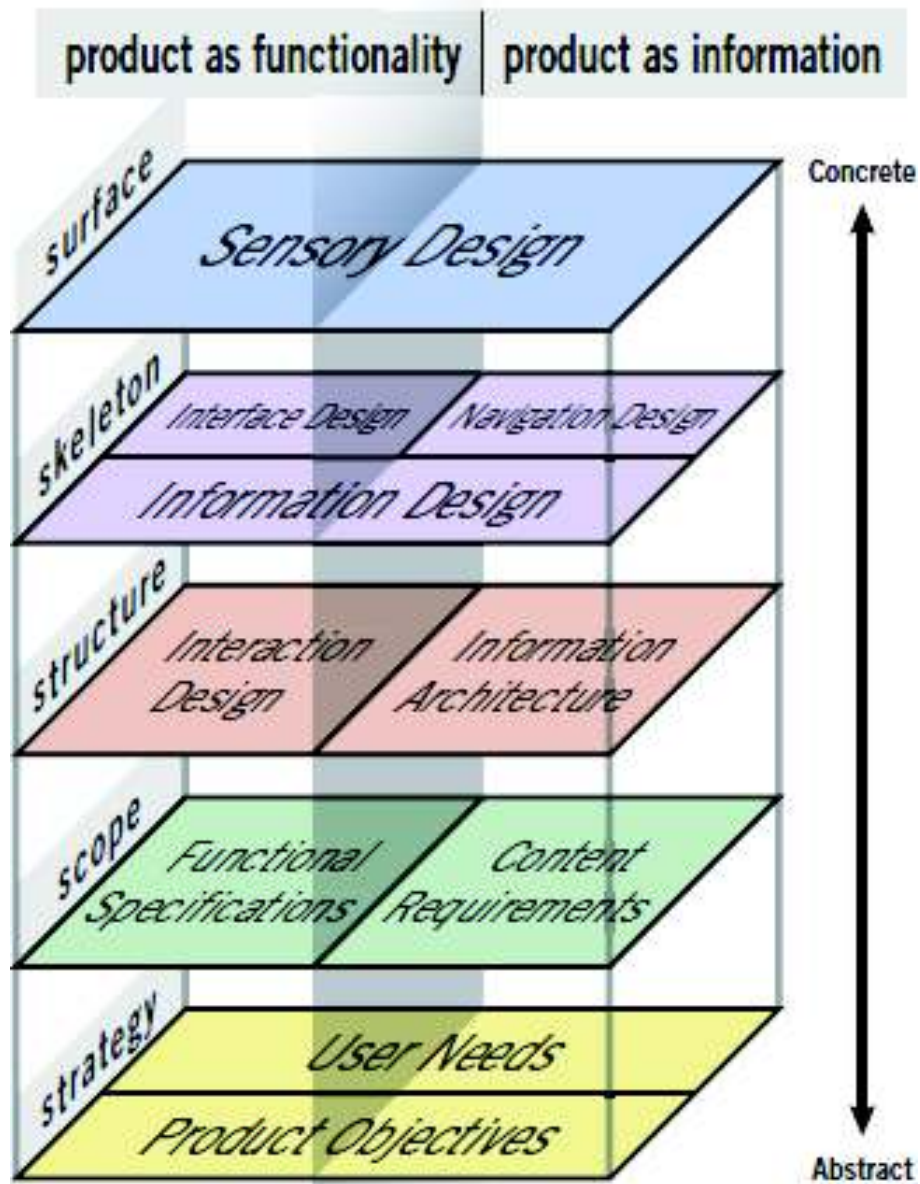
Figure 1.3: The five planes of UX, as illustrated in [12].

- **Operable:** User interface components and navigation must be operable.

  This means that users must be able to operate the interface (the interface cannot require interaction that a user cannot perform)

- **Understandable:** Information and the operation of user interface must be understandable.

  This means that users must be able to understand the information as well as the operation of the user interface (the content or operation cannot be beyond their understanding)

- **Robust:** Content must be robust enough that it can be interpreted reliably by a wide variety of user agents, including assistive technologies.

  This means that users must be able to access the content as technologies advance (as technologies and user agents evolve, the content should remain accessible)

If any of these are not true, users with disabilities will not be able to use the web.

1.4.3 Development Tools

Different tools were used for the development of the project such as text editors, frameworks, source code managers and others. These tools are described as follows:
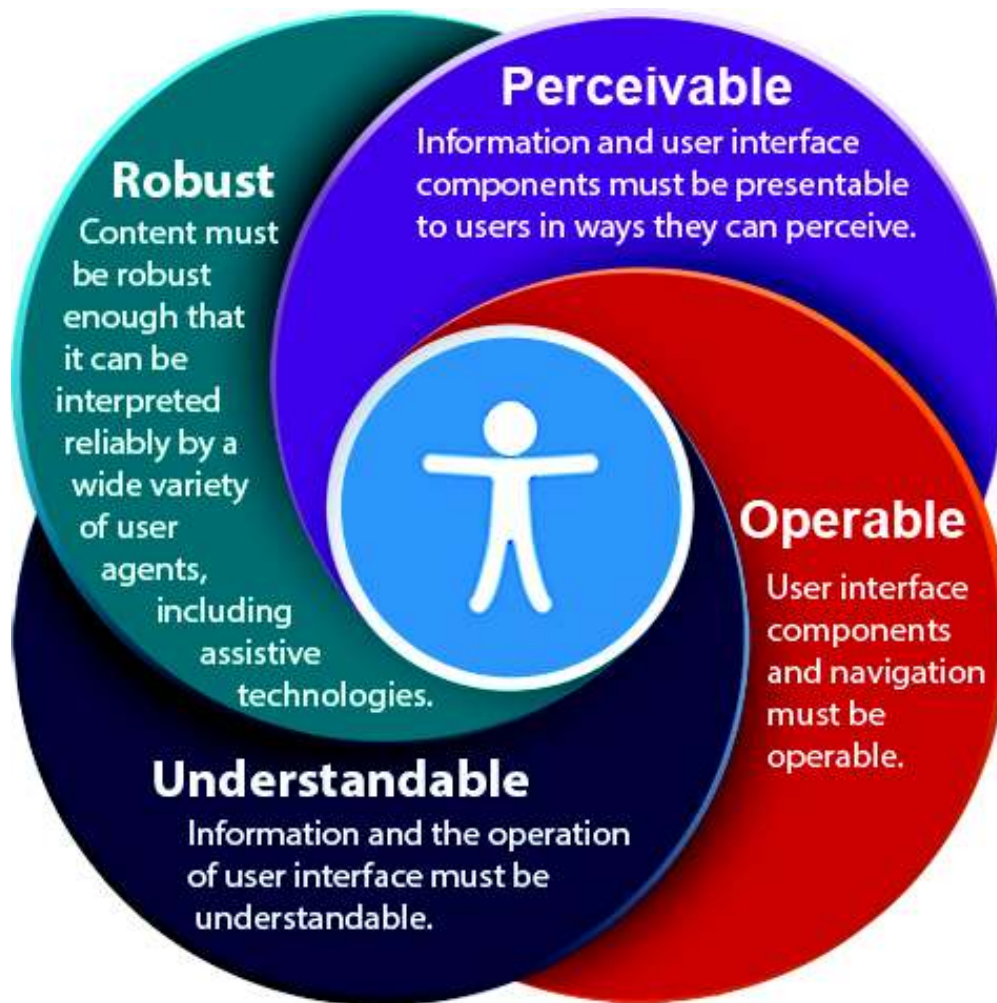
Figure 1.4: The four principles of WCAG, taken from [16].

1.4.3.1   User Interface Design

Nº	Name	Logo	Used for	Description
1	Ninjamock		Wireframing and UID	NinjaMock is a very useful and fast tool to design wireframes; these wireframes help visualize how the site would look and feel. Wireframing works similar to working on a blackboard, allowing low-fidelity prototypes design and focusing on UX [17].
2	Bootstrap		Frontend design	Bootstrap is a free front-end component library. It is an open source toolkit for developing with HTML, CSS, and JS and offers design templates for typography, forms, buttons, navigation and other interface components. It is very useful for creating medium-fidelity up to high-fidelity prototypes [18].
3	Canvasflip		Prototype testing and analytics	CanvasFlip is a collaborative and testing platform based on cloud, which allows designers to create prototypes and analyze them. It can easily show analytics inside prototypes, make interaction heatmaps and get feedback from other users [19].
4	Material Design		Wireframing and UID	Material Design is a design language developed by Google. It is a visual language that synthesizes the classic principles of good design with the innovation of technology and science. It brings a unified experience between platforms and device sizes [15].

Table 1.1: User interface design tools.

Table of the author.

1.4.3.2 Programming Languages

Nº	Name	Logo	Used for	Description
1	Javascript		Frontend development	JavaScript is a lightweight, interpreted or JIT compiled programming language with first-class functions. Most well-known as the scripting language for Web pages, many non-browser environments also use it, such as node.js and Apache CouchDB [20].
2	Typescript		Development	TypeScript is an open-source programming language developed and maintained by Microsoft. It is a strict syntactical superset of JavaScript and adds optional static typing to the language [21].
3	HTML		Content structure	HTML is the language for describing the structure of Web pages using markup. The elements of the language label pieces of content such as "paragraph," "list," "table," and so on [22].
4	CSS		Styling	CSS is the language for describing the presentation of Web pages, including colors, layout, and fonts. It allows one to adapt the presentation to different types of devices, such as large screens, small screens, or printers. CSS is independent of HTML and can be used with any XML-based markup language [23].

Table 1.2: Programming languages.

Table of the author.

1.4.3.3   Frameworks and Libraries

Nº	Name	Logo	Used for	Description
1	Express		Backend development	Express is a web application framework for Node.js. It allows building production-ready web applications and APIs using packages as middleware [24].
2	Angular		Frontend Development	Angular is a JavaScript framework and platform that makes it easy to build web applications. Angular combines declarative templates, dependency injection, end to end tooling, and integrated best practices to solve development challenges [25]. Angular is widely used in mobile, web and desktop applications.
3	Mocha		Testing	Mocha is a feature-rich JavaScript test framework running on Node.js and in the browser, allowing asynchronous testing. Mocha tests run serially, allowing for flexible and accurate reporting, while mapping uncaught exceptions to the correct test cases [26].
4	Passport		Authentication	Passport is authentication middleware for Node.js. Extremely flexible and modular, Passport can be unobtrusively dropped into any Express-based web application [27].

Table 1.3: Frameworks and libraries.

Table of the author.

1.4.3.4 Server-side Applications

Nº	Name	Logo	Used for	Description
1	NodeJs		Backend development	Node.js is a JavaScript runtime built on Chrome's V8 JavaScript engine. Node.js uses an event-driven, non-blocking I/O model that makes it lightweight and efficient. Node.js'package ecosystem, npm, is the largest ecosystem of open source libraries in the world [28].
2	MongoDB		NoSQL Database	MongoDB is a free and open-source cross-platform document-oriented database program. Classified as a NoSQL database program, MongoDB uses JSON-like documents with schemata. [29].
3	Mongoose		Object Data Modeler (ODM)	Mongoose is an object data modeling (ODM) library that provides a rigorous modeling environment for data, enforcing structure as needed while still maintaining the flexibility that makes MongoDB powerful. [30].
4	RoboMongo		NoSQL Management Tool	Robomongo is a shell-centric cross-platform MongoDB management tool. Unlike most other MongoDB admin UI tools, Robomongo embeds the actual mongo shell in a tabbed interface with access to a shell command line as well as GUI interaction. [31].

Table 1.4: Server-side applications.

Table of the author.

1.4.3.5 Repositories and others

Nº	Name	Logo	Used for	Description
1	Code Anywhere		Cross-platform testing	Codeanywhere is a cross-platform cloud IDE which enables users to write, edit, collaborate and run web development projects using the browser and any mobile device [32].
2	Github		Version controlling	GitHub is an open-source development platform which offers hosting service for version control using git [33].
3	Google Forms		Surveying	Google Forms is a tool that allows creating forms and surveys for managing events, fast surveying, collecting user preferences and more. It also analyses and organizes information into charts [34].
4	Visual Studio Code		Coding	Visual Studio Code is a lightweight but powerful source code editor that runs on desktop and is available for Windows, macOS, and Linux. It includes support for debugging, em- bedded Git control, syntax highlighting, intelli- gent code completion, snippets, and code re- factoring. It is also customizable, so that users can change the editor's theme, keyboard short- cuts, and preferences [35].

Table 1.5: Repositories and others.

Table of the author.

1.5 PRELIMINARY RESEARCH

The search and evaluation of the web and mobile applications for the visually impaired followed these steps:

Firstly, the existing web and mobile applications, as well as web catalogs, were looked upon using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) directives [36]. After that, the analysis of the web catalogs followed.

Secondly, all these applications were selected based on features such as communication, location awareness, among others.

Finally, these applications were evaluated using the Mobile Application Rating Scale (MARS).

1.5.1 Web Catalogs

Google search engine was used in order to get most of the web catalogs and applications. The search terms included: web applications for the visually impaired and blind, web catalogs for the visually impaired and blind, mobile applications for the visually impaired and blind, and educational software for the visually impaired and blind. As expected, a lot of results were shown, for this reason, a pre-selection was needed.

The web catalogs that were selected complied with the following criteria: applications for the visually impaired and blind, educational software, supporting software, and learning software. There were some web sites that were excluded from the evaluation because lacked information, did not work correctly, showed outdated software, download links did not work, were blogs, and were not digital catalogs.

The information gathered from each web catalog for the analysis is shown in Table 1.6. The summary of each web catalog can be seen in Table 1.7. The analysis of each web catalog allowed identifying the different types of applications and categories, and more importantly, how the strategies and enhanced features should be implemented in this project.

Feature	Description
Name:	The web catalog name.
URL:	Link to reference web page index.
Country:	The country where the web catalog is being hosted and developed.
Developers:	People or institution who maintain the web catalog.
Access:	How many clicks a user must make to download/get an application.
Details:	The information about the main features of a catalog or application.
Screenshots:	Screenshots of the web catalog.

Table 1.6: Collected information from every web catalog.

Table of the author.

N°	Name	Country	Description
1	Wonder Baby www.wonderbaby.org/	USA	This website contains information about assistive technology not only for the visually impaired, but also for toddlers and youth. It focuses on learning, recreation, and games. Categorization is made as a list. (3 clicks to access).
2	Sonokids www.sonokids.org/	USA	This website contains games for the visually impaired. It offers audio-based game apps for building digital skills. It uses the AppStore as a central hub for accessing the games. (3 clicks to access).
3	Inclusive TLC www.inclusivetlc.com/	USA	This website offers software and hardware for the visually impaired. Most of the applications are for educational purposes, but it also offers games. Some games require special hardware that can be bought in the site. It categorizes software depending on the purpose such as early learning, phonics, literacy and math software. (2-3 clicks to access).
4	American Foundation for the Blind www.afb.org/	USA	This website offers a wide variety of software and hardware for the visually impaired. It is well categorized and also includes programs and services that can be purchased. It focuses on every aspect of visual loss, but it is difficult to access to some resources due to the great amount of information. (3-5 clicks to access).
5	Braille Bug www.braillebug.afb.org/	USA	This website is part of the AFB but focuses on braille and how to assist totally blind people. It offers software for children as well as for teachers and parents. It is very user-friendly and well categorized. (2-3 clicks to access).
6	Family Connect www.familyconnect.org/	USA	This website focuses on visual impairment in children and teenagers. It works as a community to help parents and children stay connected. It offers educational software and applications can be browsed by age. (3 clicks to access).
7	Low Incidence Outreach www.mdelio.org/blind-visually-impaired/	USA	This website offers guides on how to develop visually impaired children skills. It is supported by the Michigan Department of Educations. It does not offer software solutions, but it offers books and materials for the blind, programs for students with visual impairments and workshops. It is very user-friendly. (2-3 clicks to access).
8	Texas School for the Blind and Visually Impaired www.tsbvi.edu/	USA	This website offers a wide variety of resources to support the development of visually impaired students. It ranges from books and texts to multimedia. It also offers scholarships and online learning. It focuses on using games for students with visual impairments to develop their skills. It can be a little hard to access some resources. (3-4 clicks to access).
9	Audio Games www.audiogames.net/	USA	This website focuses on audio games as it names states. The site offers different types of games and displays them as a list. It lacks categorization and search is possible via keywords. (2-3 clicks to access).
10	Teaching Students with Visual Impairments www. teachingvisuallyimpaired.com/	USA	This website offers not only applications for the visually impaired, but also jobs, learning programs, volunteering and other services. The applications cover most of the main subjects in school, such as math, science, literature and social studies. The applications are well categorized and can be downloaded to use in mobile devices; however, most applications are paid. (3-4 clicks to access).
11	Royal Institute for Deaf and Blind Children www.ridbc.org.au/	Australia	This website focuses on helping blind and deaf children. It offers books, CDs, DVDs, and applications. It is well categorized, and the applications can be downloaded from the AppStore and the Play Store. (3 clicks to access).

Table 1.7: Websites and catalogs found.

Table of the author.

1.5.2 Applications

The search of applications followed PRISMA directives and did not consider language nor country.

In this case, Google search engine was used as well, with search terms like: "web applications for the visually impaired", "mobile applications for the visually impaired", "web applications for the blind", and "mobile applications for the blind". As expected, a great number of results showed, most of them were not considered due to not working, not being applications or not dealing with this impairment.

The applications that were selected for the later evaluation complied with the following criteria:

1. Deal with visual impairment.

2. Have good rating and commentaries.

3. Are related to education or learning.

4. Are free of charge.

5. Are web or mobile applications.

It was considered to use Android as the mobile platform for testing and using, this due to Apple devices being expensive and not widely used in educational institutions and foundations. Moreover, the mobile applications were verified to be available to download from the Google Play Store. These applications were downloaded, used thoroughly and evaluated for their inclusion in the catalog. These applications are shown in detail in section 3.1.2.

1.5.2.1 Evaluation of applications

The current tools for software evaluation do not consider special impairments. Instead, they gather assessments based on their popularity and the score people give them. Namely, the quality of these applications is based on the number of downloads, whether they are classified or not and if they are available in the market [37].

The standards used for evaluating software are as follows:

- ISO/IEC 9126 [38] - Software Engineering - Product Quality.
- ISO/IEC 14598 [39] - Software Engineering - Product Evaluation.
- ISO/IEC 25000 [40] - System and Software Quality Requirements and Evaluation (SQUARE).

The ISO 25000 is a revision and agreement between ISO 9126 and 14598. These standards use the source code of the applications and then metrics are used during the product or software development. Due to not having access to the source code of these applications, it was necessary to use a different tool for evaluating the design and usability of these applications. The tool used for doing so is MARS. MARS offers a checklist that allows classifying and evaluating the quality of mobile applications that deal with health [41]. More specifically, MARS can be applied to different health contexts such as impairments.

MARS uses the following quality ratings: Engagement, Functionality, Aesthetics, Information and Subjective Quality. Each of these ratings gets together on a 5-point scale from 1-inadequate to 5-excellent and answer each of the 23 questions in MARS [41].

Using MARS allows analyzing internal consistency and inter-rater reliability for rating analysis. The internal consistency of each rating and the total score of the quality were calculated using the Cronbach's alpha. The Cronbach's alpha is a measure of internal consistency, that is, how closely related a set of items are as a group [29]. The inter-rater reliability of each rating and the total score were determined by the Intraclass Correlation Coefficient (ICC). The ICC allows the proper calculation of each value between ratings and explains the proximity, instead of the similarity of the scoring [41]. These results can be seen in section 3.1.2.1.

1.6 PROJECT STRUCTURE

Following are the sections that make up the project.

- O **Methodology** The methodology section describes how the development of the project was carried out during each of its phases.

- O **Results and Discussion** The results and discussion section shows the results of the preliminary research and the usability evaluation, results are then discussed.

- O **Conclusions** The conclusions evaluate whether the objectives were achieved.

2 METHODOLOGY

This section describes in detail the methodology used during the analysis and development of the project.

2.1 PROJECT ANALYSIS

2.1.1 Strategy

2.1.1.1 Product objectives

The product objectives are planned based on the business objectives, brand identity, and success metrics.

Business Objectives

- To promote the use of software in the learning process of the visually impaired.
- To bring closer the access to existing software for the visually impaired.
- To ease the search of learning software.
- To build a community where people share their experience of using applications for the visually impaired.

Brand Identity

As stated, there are no websites nor application catalogs for the visually impaired in Ecuador. The National Polytechnic School University (EPN) in its mission encourages applying knowledge in the benefit of humankind. Thus, the digital software catalog looks forward to becoming part of the EPN services that aims the community, to become the reference point regarding impairments and inclusion.

A logo was designed to ease the brand identification. The logo is a set of two elements, an image and a name, both making the logo as descriptive as possible (see Figure 2.1). The purpose of the image is to guide the user into what to expect once seen, and so does the name.
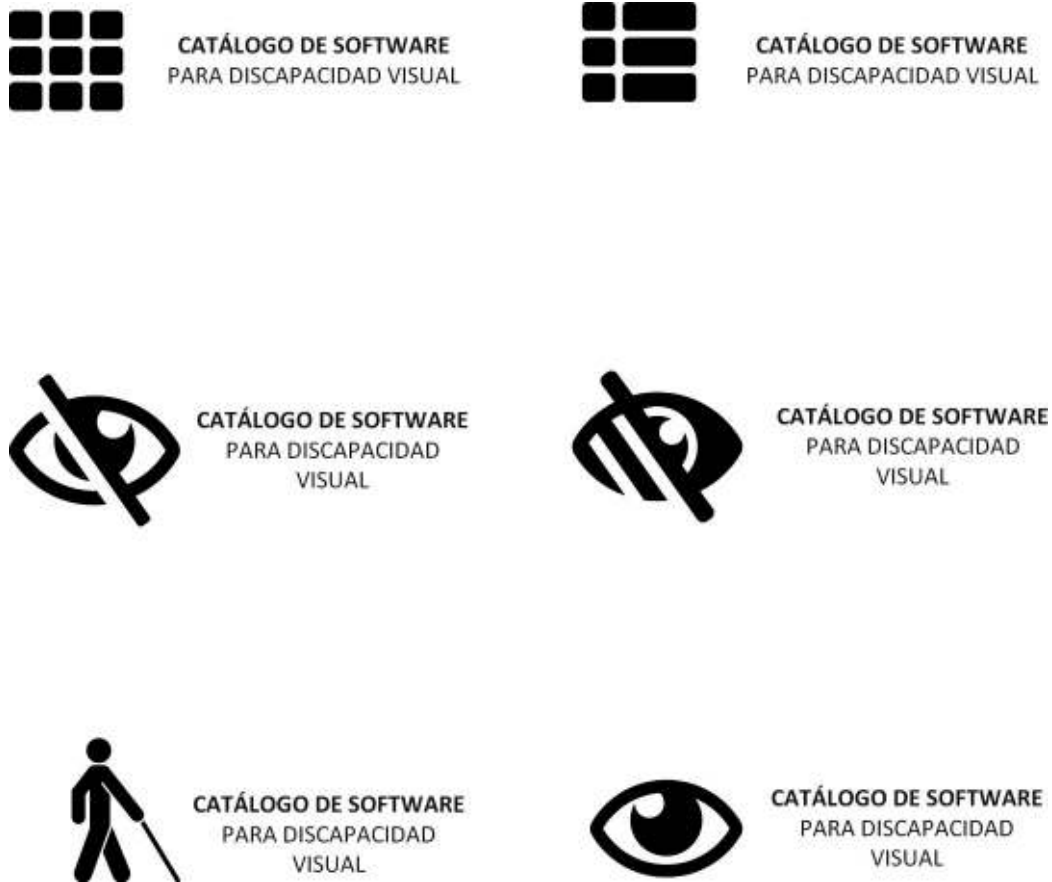
Figure 2.1: Possible logos for the catalog.

After getting feedback and analyzing the possible logos, it was decided to combine an image that depicts a catalog and an image that depicts visual impairment. The result is as follows, keeping in mind it must be simple and clear, and being visually-accessible:

Success Metrics

In order to establish success metrics, the Google Heart Framework was used. HEART refers to Happiness, Engagement, Adoption, Retention, and Task success; all these metrics allow measuring the quality of user experience of a given product or characteristic (see Figure 2.3).

Figure 2.2: Logo design for the catalog.

Figure 2.3: Google HEART Framework for UX, taken from [42].

Category	Goal	Signals	Metrics
Happiness	To ease the search of applications	Surveys	- Ease of use and ease of access - User satisfaction
Task Success	To specify tasks that allow the user to achieve his goal	Number of completed tasks	- Specific tasks for the developed interfaces

Table 2.1: Success metrics.

Table of the author.

Each category has a goal, signals, and metrics to measure the user experience [42]. Even though it is suggested to use all four categories, one can decide which are more suitable for a given project; in this case, Happiness and Task success were selected, the former deals with satisfaction, while the latter deals with effectiveness and efficiency (see Table 2.1). These success metrics were selected as a base-line for the low-fidelity prototype development. Once these metrics were satisfied, the high-fidelity prototype can be achieved.

2.1.1.2 User Needs

The user needs are defined from the usability and user search.

Usability and user search

It was considered how people usually search applications. In the case of mobile applications, people usually search them using marketplace applications like Google Play Store; in this case, people have direct access to the applications, they can see information about the applications, commentaries, and reviews, and if they find they like it, they can ultimately download it.

In the case of web applications, people use Chrome Web Store (Chrome Browser specifically) to get extensions and plugins for the web browser, following the same steps for getting these similar to the mobile ones.

The results obtained from the evaluation of existing websites and application catalogs (see Section 3.1.2.1), allowed identifying the characteristics and needs of the users who visit these sites. These users are a clear example of potential users for the software catalog. Section 3.2.1 lists the found characteristics. It was considered to categorize applications in order to help the user find them.

2.1.2 Scope

The digital software catalog was developed as a website that allows searching applications that focus on learning and improve the living of the visually impaired. At first glance, the catalog works as a promoter, which means, it hosts applications that deal with visual impairment. However, it is expected that applications developed at EPN and other Ecuadorian institutions become part of the catalog. It offers different categories depending on the type of application, i.e. text readers, screen magnifiers, among others. The catalog covers both visual impairment and blindness and focuses on searching and downloading applications.

2.1.2.1 Software Requirements Specification

To start developing the catalog it is necessary to establish the requirements that describe what the system should do and allow the end user to do [12]. The requirements specification built up upon the user needs. As expected, some requirements changed, and others were defined. The requirements are detailed in Table 2.2 after the preliminary research.

The usability tests done in each prototype, allowed adding and removing requirements, based on feedback. The high-fidelity prototype specifications can be seen in Table 2.3.

2.1.2.2 Functional Specifications

The functional specifications are detailed below:

- **Access:** The catalog must display at first glance applications in the homepage.

- **Download application:** Depending on the platform the application runs; the download button will allow:

  - ◊ Direct download (if it is a desktop application).

  - ◊ Redirecting to a website (if it is a web application).

  - ◊ Redirecting to a play store (if it is a mobile application).

Nº	Requirement	Specification
R1	Access	- The user must access the applications directly.
R2	Download application	- The user must download a given application directly.
R3	Feedback	- The user must be able to comment and rate applications.
R4	Questions and answers	- The user must be able to make questions and answers for an application.
R5	Application information	- The user must be able to access the application information and details.
R6	Top applications	- The user must be able to see the top applications based on the score. - The user must be able to see the top applications for each category. - The user must be able to see the latest uploaded applications.
R7	Download history	- The user must be able to see his download history.
R8	Navigation	- The user must be able to navigate through the menu, and categories. - The user must be able to navigate between windows.
R9	Login	- The user must be able to login via username and password.
R10	Search	- The user must be able to search applications.

Table 2.2: Requirements specification after preliminary research.

Table of the author.

- **Feedback:** Each application will have a commentary section. There will be a 5-star rating.

- **Questions and answers:** The application will have a questions and answers section.

- **Application information:** Each application will display its information such as category, description, requirements, and additional information.

- **Top applications:** The catalog displays a top ten application grid showing best rated applications. There will also be a top application grid for each category. The catalog will display the latest uploaded applications.

- **Download history:** The catalog will allow the user to review his download history.

- **Navigation:** The main menu will be located as a navigation bar. It will contain the categories button, the user button, and the search bar. It will be possible to navigate the application thoroughly.

- **User profile:** This section will display the user information as well as his download history.

Nº	Specification	Specification
S1	Access	The catalog allows the user direct access to applications from the homepage.
S2	Application download	The catalog allows the user to download an application or visit its website.
S3	Feedback	The catalog allows the user to comment about the application and rate it.
S4	Questions and answers	The catalog allows the user to make questions and answers about an application.
S5	Application information	The catalog allows the user to see the applications information.
S6	Top applications	The catalog allows the user to navigate through the top applications based on their rating.
S7	Download history	The catalog allows the user to review his download history.
S8	Navigation	The catalog allows the user to navigate through the menu, elements, and windows.
S9	Search	The catalog allows the user to search using the search bar.
S10	Application information	The user must access the applications information.
S11	User profile	The user must access his profile information.
S12	Features	The catalog displays the applications' features.
S13	Website information	The catalog displays the website information.
S14	New applications	The catalog allows displaying recently uploaded applications.
S15	Accessibility menu	The catalog allows the users modify the content depending on their accessibility needs.

Table 2.3: High-fidelity prototype specifications.

Table of the author.

- **Search:** The search bar will be located at the navigation bar.

2.1.2.3   Content Requirements

The content requirements are detailed below:

- **Target audiences:** The target audiences are every people and institution that deal with the learning of the visually impaired.

- **Categories and subcategories:** Each category and subcategory will dis-

play a name and a descriptive image.

- **Application:** Each application will display the following information:

    ◊ Name.

    ◊ Description.

    ◊ Country.

    ◊ Developed by.

    ◊ Release date.

    ◊ Version.

    ◊ Rating.

    ◊ Platform.

    ◊ Application website.

    ◊ Application download link.

    ◊ Minimum requirements.

- **Ordering and grouping:** Every application will be grouped depending on features and rating.

- **Media:** Every application will display an image showing its name and logo, and screens- hots showing how the application works. The images will have a resolution of 200x300 pixels.

- **Questions and answers:** Every application will have a commentaries section, and if the users need, they will be able to start a thread to solve a given problem with the help of the community.

Applications

The evaluated applications (see Section 3.1.2.1) that are part of the catalog are as follows:

1. RAY App for Visually Impaired.

2. Blind Communicator.

3. Google TalkBack.

4. Visor - Low vision magnifier.

5. Vision.

6. Lazarillo GPS for Blind.

7. Help Launcher.

8. Auslan Storytime.

9. TapTapSee.

10. ICSee (I Can See).

11. "Be My Eyes - Helping the blind".

12. SuperVision mini.

13. ClariaZoom - Low vision app.

14. Big Launcher.

15. Selection Reader.

16. Claro Read.

17. Toolwiz Eyes-Voice Guide Cam.

18. Tranquility reader.

19. Colorblind – Dalton.

20. KNFB Reader.

21. Zoom Browser Extension.

22. Visually Impaired.

23. Math Basketball.

2.1.3   Structure

2.1.3.1   Interaction Design

The interaction design resides in two main components: the conceptual model and the error handling.

Conceptual model

The conceptual model of the digital software catalog is an application marketplace, in which people will be able to search and get products (applications). This marketplace becomes a centralized website that eases access to applications. The conceptual model proposed by Jansen & Bloemendal (see Figure 2.4) depicts how an application store works. The triangle represents the app store, and each side corresponds to the End User, Developers, and Owner; while in the inside of the triangle there are the Features, Characteristics, and Policies. The owner has to create, organize and select proper content for the marketplace [43]. Features represent individual parts of the software system that the actors can interact with. Policies represent the rules, regulations, and governing processes that limit the functional reach of the features. The characteristics square represents a set of app store characteristics that cannot be directly influenced by the owner. Features and policies together form the part of an app store that the owner can directly influence [43].

Error handling

In order to handle errors, a system must be prepared to prevent them [12]. The elements implemented in this project to handle errors are below:

- **Error 404 Page:** The correct design of an error 404 page is basic to keep a good user experience. It must handle the following errors: deleted page, broken link, or wrong URL (see Figure 2.5).

- **Download button:** If the download button is not working, a message box should ap- pear telling the user to visit the application home page to get the application.

- **Waiting message:** If the catalog takes too long to load, a message box should appear telling the user to reload the web page.
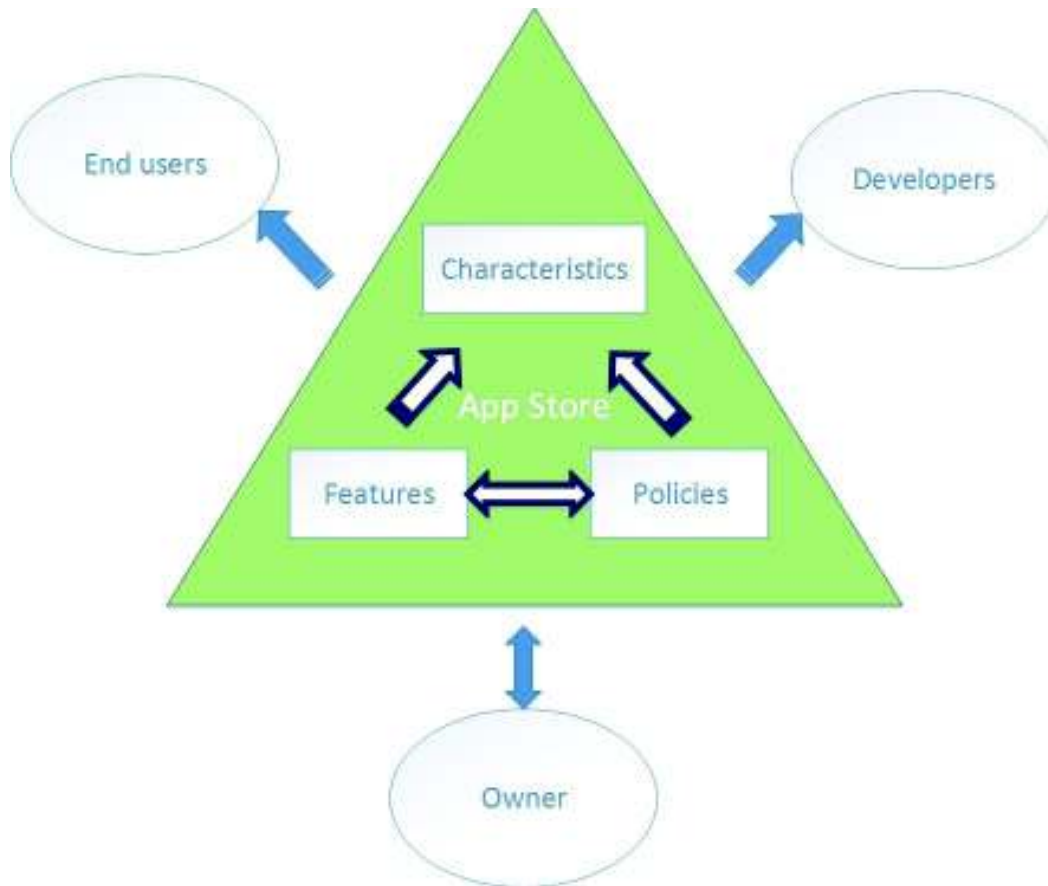
Figure 2.4: Marketplace conceptual model, based on [43].

Figure 2.5: Design of the Error 404 page.

2.1.3.2 Information Architecture

The information architecture eases the understanding of a website; ever since people have had information to convey, they have had to make choices about how to structure information so other people can understand and use it [12]. The elements are structuring content, architectural approach, organizing principles, language, and metadata.

Structuring content

Figure 2.6 shows the sitemap of the web catalog. There are three sections: search bar and user profile, navigation menu, and content itself. The navigation menu contains applications, categories, and subcategories. The content is divided into three sections:

- Top applications.
- Recently uploaded applications.
- Categories.

Architectural approach

The sitemap of the web catalog (see Figure 2.6) follows a hierarchical structure (also known as a tree or hub-and-spoke structure). Figure 2.7 shows an initial functional wireframe of how the catalog should look. The navigation menu allows the user to navigate through every component and module of the catalog. Thus, users can easily access the catalog content. Along with the navigation menu, there is the search bar, which the users can use if they do not want to navigate through the navigation menu nor the categories. See section 2.2.1.1 for a most detailed low-fidelity prototype.

Organizing principles

The organizing principle is the criterion by which one can determine which nodes are grouped together and which are kept separate. The grouping and categorization were determined according to the evaluation of applications and web catalogs, and from the interview hold with Dr. Ximena Silva, director of Instituto Mariana de Jesús, along with other therapists who had vast experience in dealing with visual impairment and blindness.

The following categories and subcategories were determined:

- Low vision.
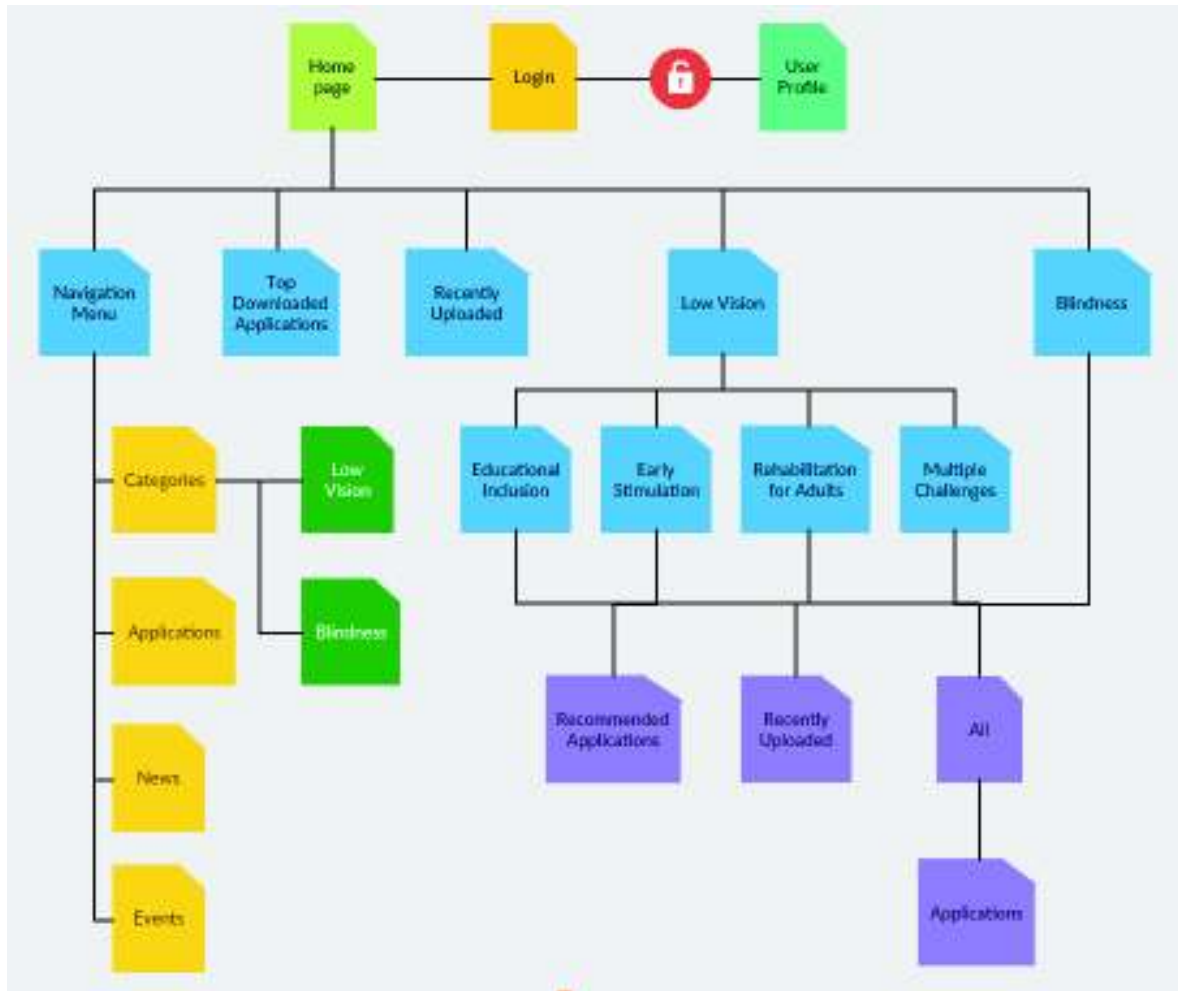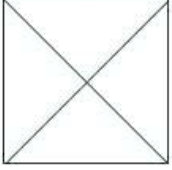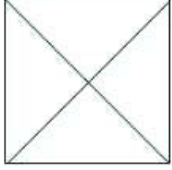
Figure 2.6: Application sitemap.
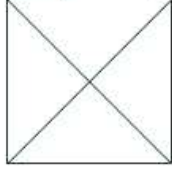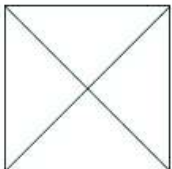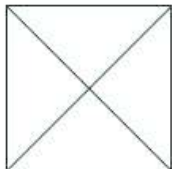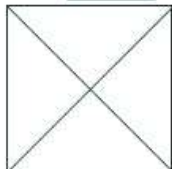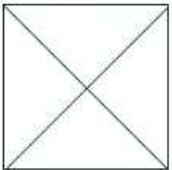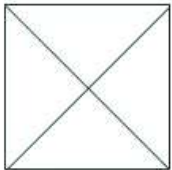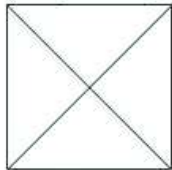
Figure 2.7: First wireframe of the homepage.

      ◊ Educational inclusion.

      ◊ Early stimulation.

      ◊ Rehabilitation for adults.

      ◊ Multiple challenges.

   ▪ Blindness.

Language and metadata

In this case, it is important to display only important data to users. Due to the scope of the project and ease of use, the user will be able to see the following metadata that includes:

- Name of the application.
- Description of the application.
- Country where the application was developed.
- People or institution that developed the application.
- Application release date.
- Application version.
- Application rating.
- Platform were application runs.
- Application website.
- Application download link.
- Minimum requirements.

2.1.4   Skeleton

2.1.4.1   Interface design

Interface design is one of the most important factors in achieving a great user experience. This allows the user to accomplish tasks understandably and easily. One thing to keep in mind is that web applications must be responsive, allowing the user to use the application in any device. Both font size and content structure respond to the device screen size, this way, usability and accessibility fell more natural.

Both the medium-fidelity and high-fidelity prototypes were designed using Bootstrap UI framework due to its extensibility and production-ready aspects (see Figure 2.8).
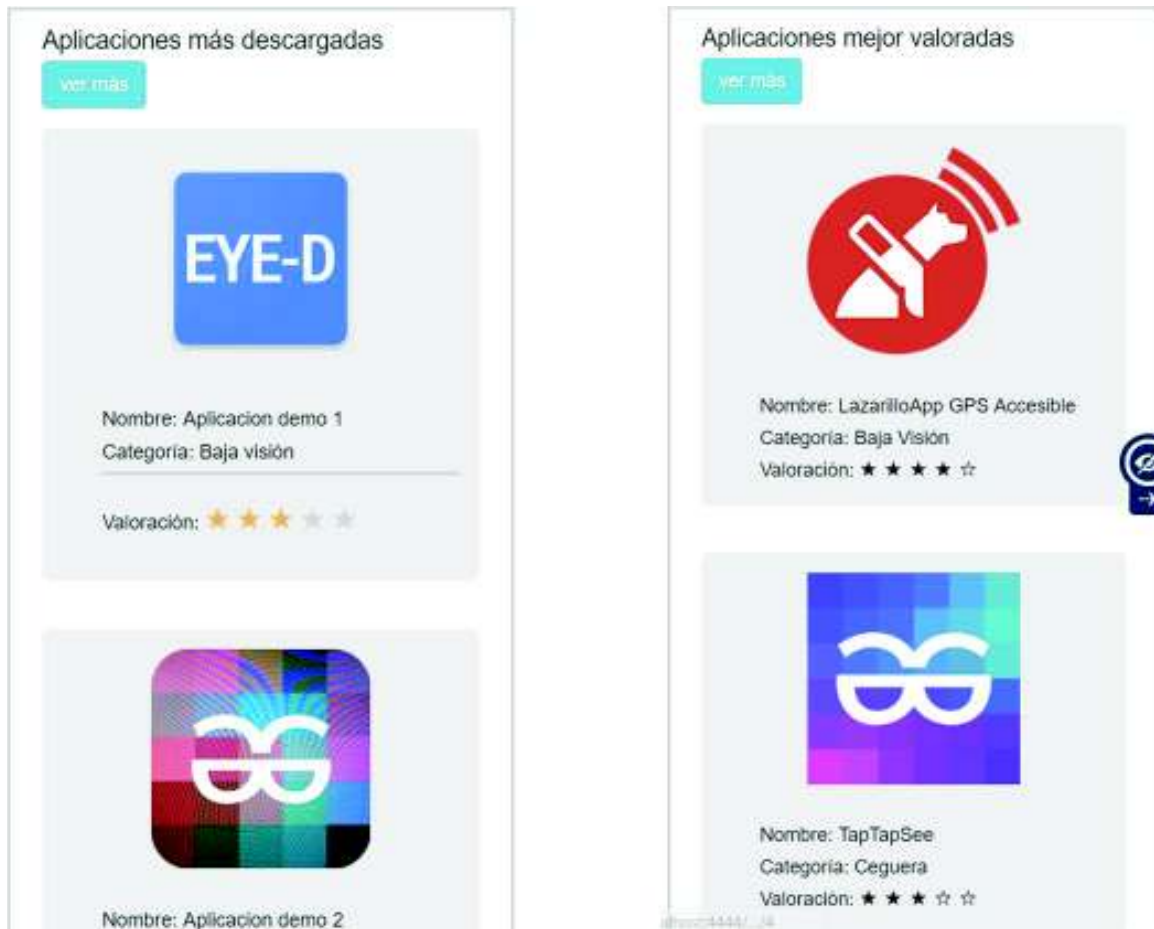
Figure 2.8: Responsive designs for both medium and high-fidelity prototypes.

2.1.4.2 Navigation design

The navigation must be intuitive and user-friendly. The navigation menu allows the user to navigate through every component of the application. As stated before, the application allows responsiveness, so the user has zero problems navigating no matter what device he uses.

The navigation design accomplishes the following three simultaneous goals [12]:

- First, it provides users with all means for getting from one point to another on the site. Navigating elements satisfy users behavior.

- Second, it communicates the relationships between the elements it contains. This allows the users to know and understand what choices are available to them.

- Third, it communicates the relationship between its contents and the page the users currently viewing. This helps users understand which of the available options might best support the task or goal they are pursuing.

2.1.4.3   Information design

Information design comes down to making decisions about how to present information so that people can use it or understand it more easily [12]. The key is to group and arrange the information elements in a way that reflects how users think and support their tasks and goals.

The application information is divided into five sections: navigation bar, main information, questions, commentaries, and additional information (see Figure 2.9). The navigation bar allows users to know where they are.

2.1.5   Surface

Both components and concepts defined in Material Design allowed implementing the necessary aspects described in the high-fidelity prototype section (see Section 2.2.1.3).

Sensorial design

The content, functionality, and aesthetics combine to create a design that satisfies senses while accomplishing all four planes objectives [12]. Material Design is based upon the following principles for designing a sensorial website [15]:

1. **Material is a metaphor:** It is a theory of a rationalized space and a movement system. Material surfaces and borders offer visual signals based on reality. The realistic lightning shows connections, divides space, and points mobile parts.

2. **Highlighted, graphic, intentional:** Elements not only make it comfortable to look at, but they also create hierarchy, meaning and focus.

Figure 2.9: Information design for the application page.

3. **Movement provides meaning:** Movement is meaningful and adequate. It is used to bring the users attention and keep continuity.

2.1.5.1   Follow the eye

The simplest way to evaluate the visual design of a product is to ask: Where does the eye go first? In a more sophisticated way, researchers use eye-tracking equipment to determine exactly what test subjects are looking and how their eyes move around the screen [12].

This aspect allowed determining a better position to locate the navigation menu (see Figure 2.10). The navigation in the site follows this flow: horizontal - moving from left to right, and vertical - navigating from top to bottom.
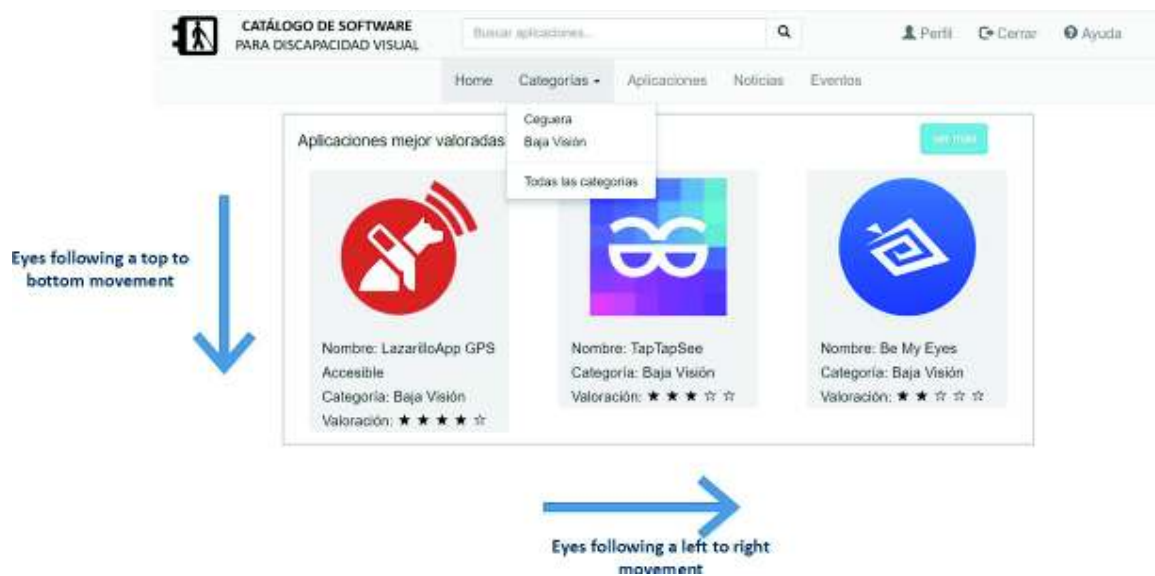
Figure 2.10: Content position using the follow the eye principle.

2.1.5.2   Contrast and Uniformity

In visual design, the primary tool used to draw the user's attention is contrast [12]. A design without contrast causes the user's eyes to drift around without settling on anything in particular.

Given the fact that the catalog targets people with visual impairments, it is essential to allow the users to control the contrast of the site, depending on how they prefer to see the content. Contrast can be used to guide the user's eye around the page or draw their

attention to key elements.

Material Design color tool allowed defining the adequate levels of contrast and uniformity in the colors of the interfaces (see Figure 2.11).

2.1.5.3 Internal and External Consistency

Design consistency must be the same for every aspect and design level during the visual design development, from the navigation bar to the Ok button. Not achieving this can cause the following problems [12]:

- Problems of internal consistency, in which different parts of the product reflect different design approaches.

- Problems of external consistency, in which the product doesn't reflect the same design approach used in other products from the same organization.

In this case, the use of Angular's modularity and components approach helped to achieve great consistency for both the organizing elements, colors, icons, labels, and fonts. High-consistency-level approach can be seen in the high-fidelity prototype in Section 2.2.1.3.

2.2 PROTOTYPE

2.2.1 Development

The low-fidelity prototype was designed from the analysis and results obtained from the strategy and scope planes (see Sections 2.1.1 and 2.1.2). During the development of the low-fidelity prototype and after doing usability testing (see Section 2.2.2) the prototype evolved into a medium-fidelity prototype, and finally, into a high-fidelity prototype. The prototype design process is described in sections 2.2.1.1, 2.2.1.2 and 2.2.1.3.

2.2.1.1 Low-fidelity

For the development of the low-fidelity prototype, the information from the strategy and scope planes was analyzed, thus allowing creating the mockups. A mockup is a model that is
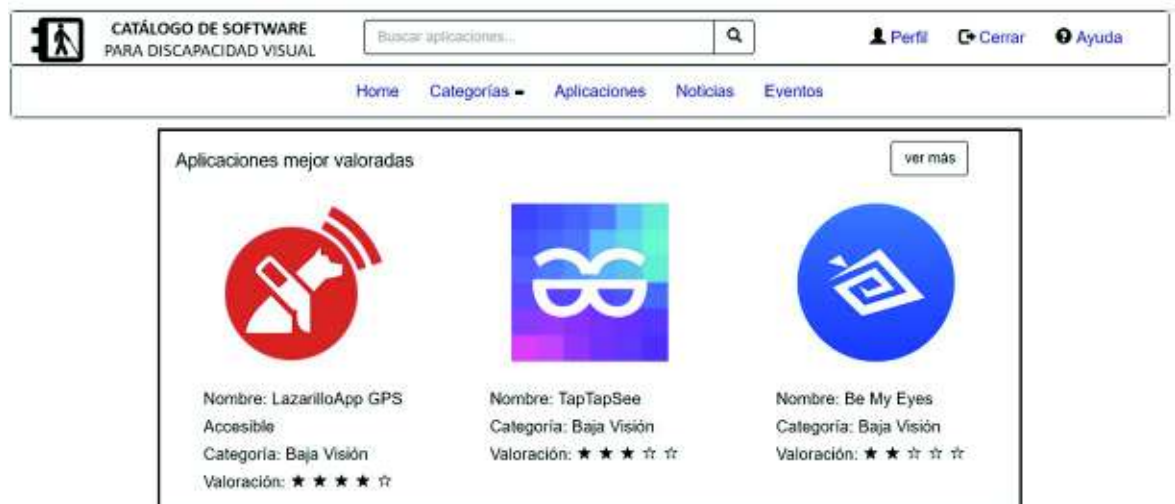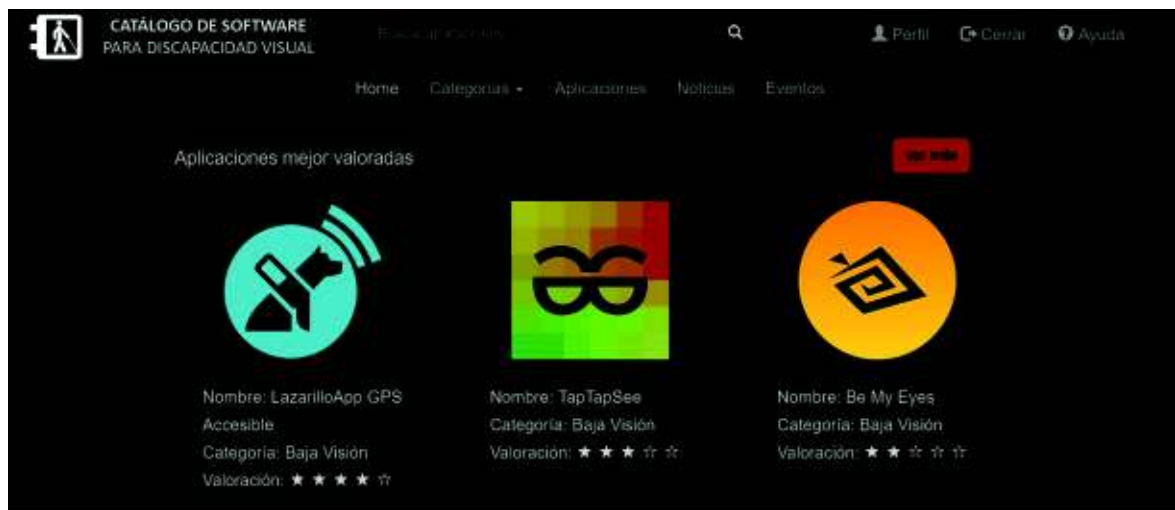
Figure 2.11: Different types of contrast for better visualization.

used for testing and showing how an application should look and feel [17]. The mockups were designed using NinjaMock (see Section 1.4.3.1). Having the final designs, usability testing was done in order to see if the catalog complied with the objectives and user needs.

Mock-up 1 - Homepage

The homepage interface design (see Figure 2.12) solves the applications shortcuts and categorization problems. The interface is composed of three main elements: search bar and user profile; a navigation menu, that allows the user to navigate through every page of the web catalog; and the content, where the applications are organized into sections.

Mock-up 2 - Categories

The interface of every category is divided into sections (see Figure 2.13), showing the following:

- Recommended applications.
- Recently uploaded applications.
- All applications.

Mock-up 3 - Application

An important aspect of the catalog is that the user must have rapid access to each application, that is why, every application is shown in every section, including its name, the category it belongs to, its rating, and its image.

Once the users click on an application, the catalog redirects them to the application interface (see Figure 2.14). The interface is composed of the following sections:

- Application information.
- Commentaries and rating.
- Frequently asked questions.

Mock-up 4 - User profile

The user profile allows the users to manage their information, as well as, see their activity, commentaries, questions made and saved events (see Figure 2.15).
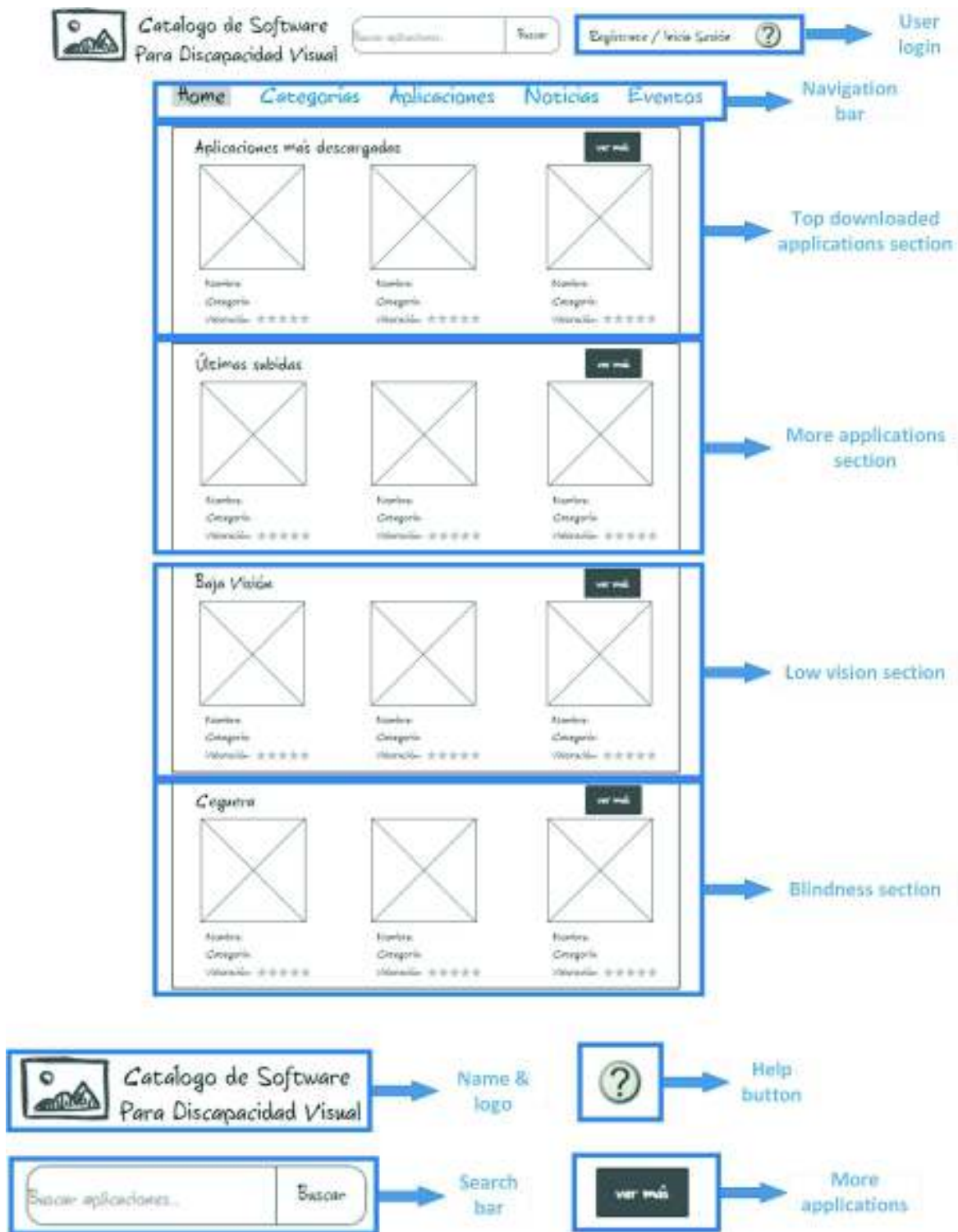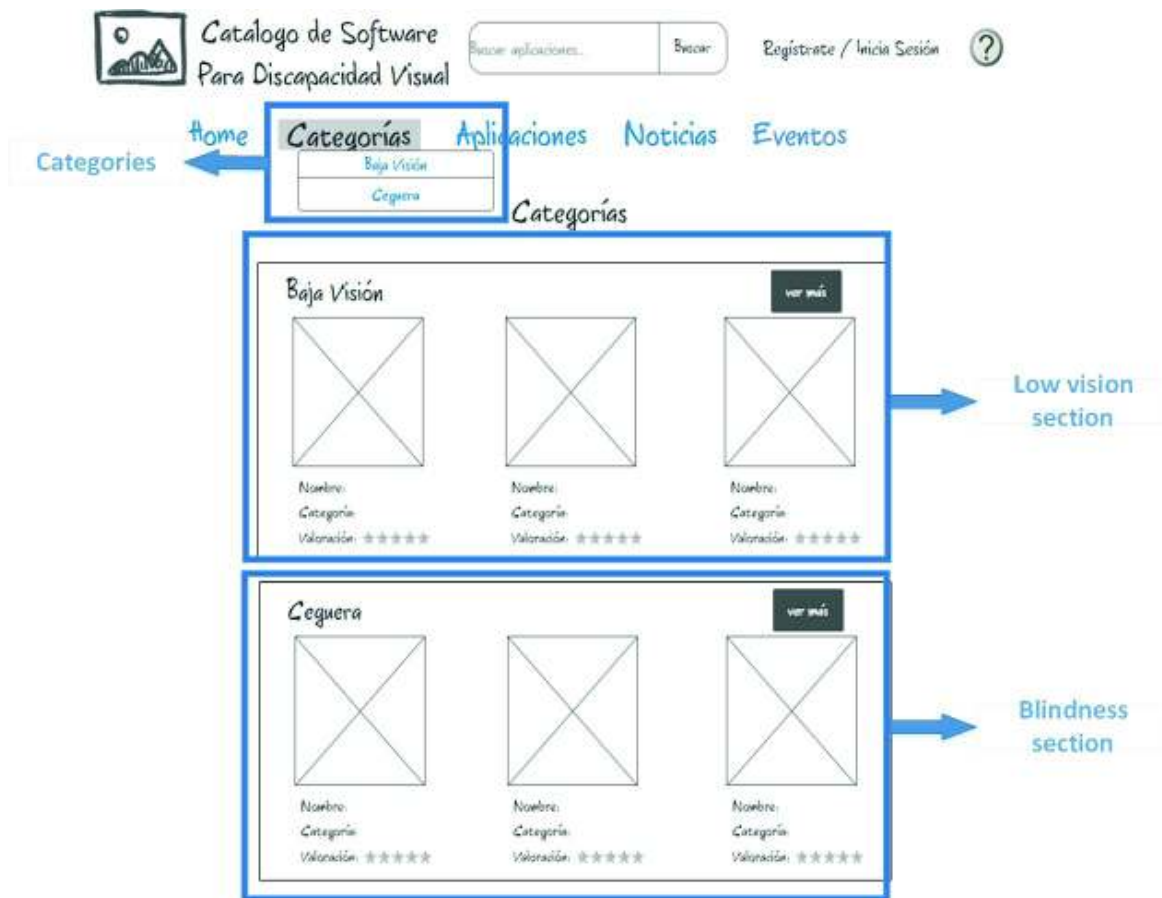
Figure 2.12: Homepage mockup.
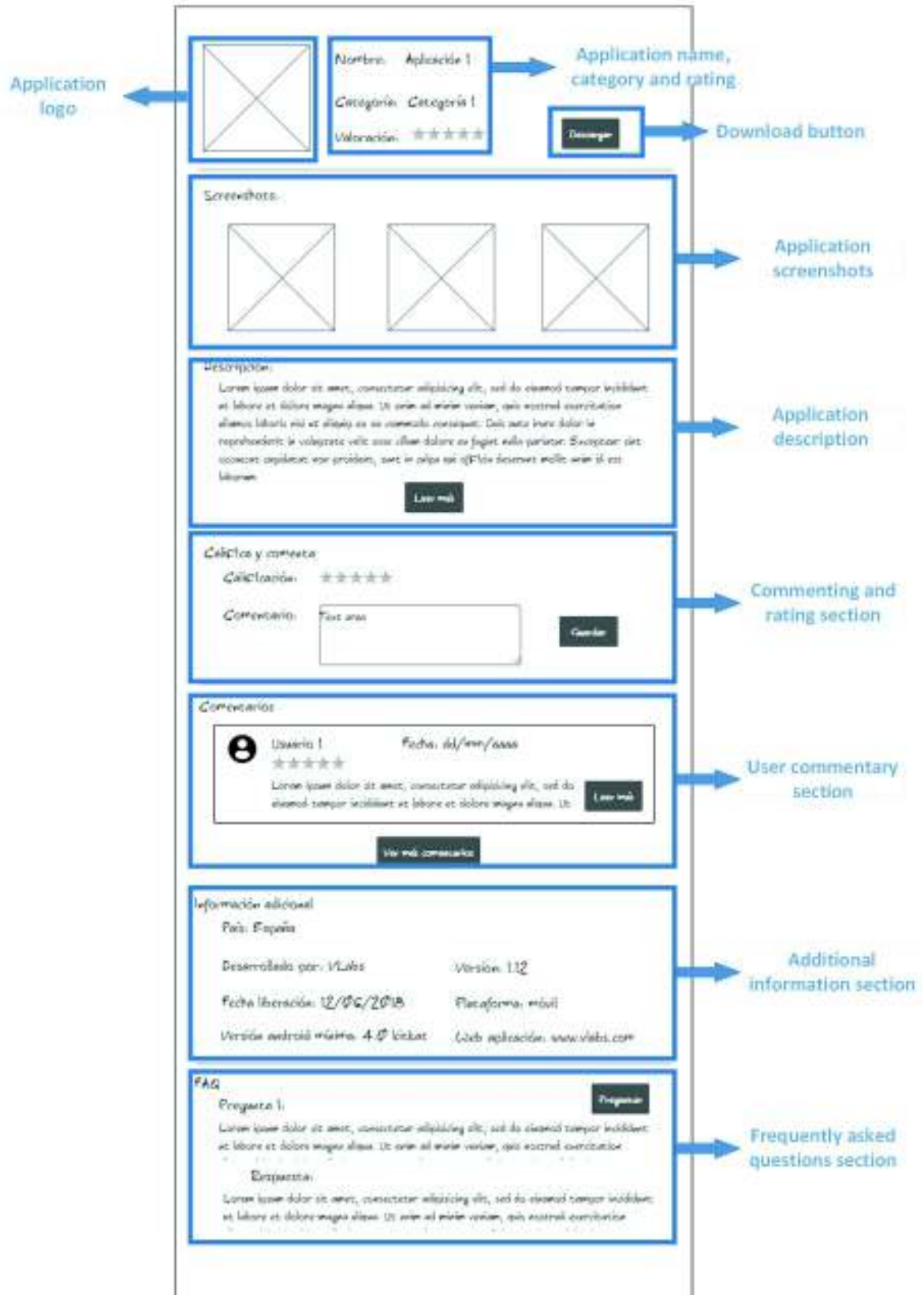
Figure 2.13: Categories mockup.

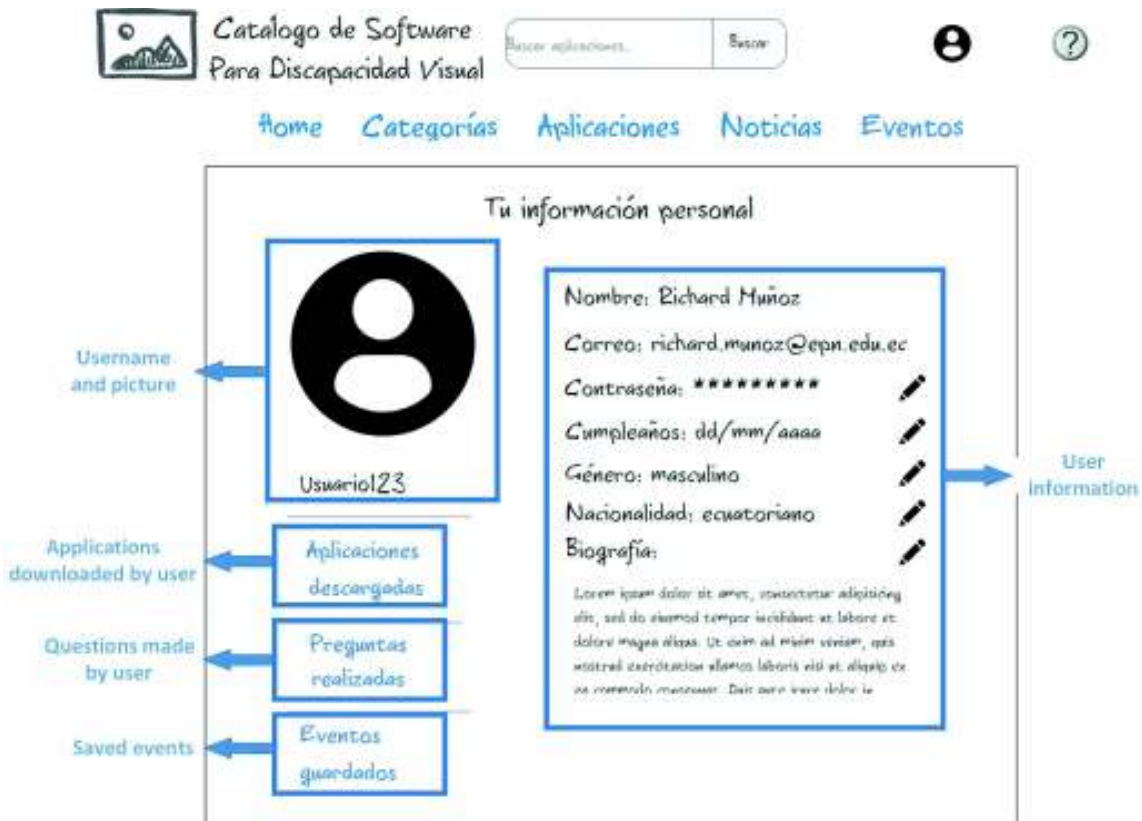**Figure 2.14:** Application mockup.

Figure 2.15: User profile mockup.

2.2.1.2   Medium-fidelity

The medium-fidelity prototype was designed to allow the users to understand better how the catalog works. The main purpose of the medium-fidelity prototype is to allow the user to navigate through the catalog and test every link, button, and component.

The Bootstrap framework (see Section 1.4.3.1) was used for the design and interface development. One of the main features of using Bootstrap is that it allows responsive design and has a wide variety of components to work with. The designed interfaces were the homepage, categories and application. Once the interfaces were done, the prototype was uploaded to Codeanywhere for further analysis and testing.

The medium-fidelity prototype includes three of the applications that were evaluated. All of the content in this prototype is static, which means, it does not retrieve information from any web server or database. Following are some of the interfaces that were designed.

The first interface of the prototype is the homepage (see Figure 2.16). The user can navigate through the navigation menu and its components, or directly through the body sections. Once the users click on a category, they will be redirected to that category page or section.

When the users click on the categories button, they get redirected to the categories interface (see Figure 2.17). Every category has the same structure, that is, recently uploaded applications, recommended applications and all applications. Every section has a 'more' button, which allows the user to see more applications related to that section. The navigation menu is always located over the body, allowing the user to search applications and navigate through the different pages of the website.

After the users click on an application, they get redirected to the application page, which displays information about the application. Figure 2.18 shows the main information and the FAQ section of the application page.

2.2.1.3   High-fidelity Prototype

In order to develop the high-fidelity prototype, it was necessary to analyze all the feedback gathered from testing the low and medium fidelity prototypes. Through usability testing it was possible to define most of the catalog elements and characteristics such as the catalog structure, categorization, information, and navigation.
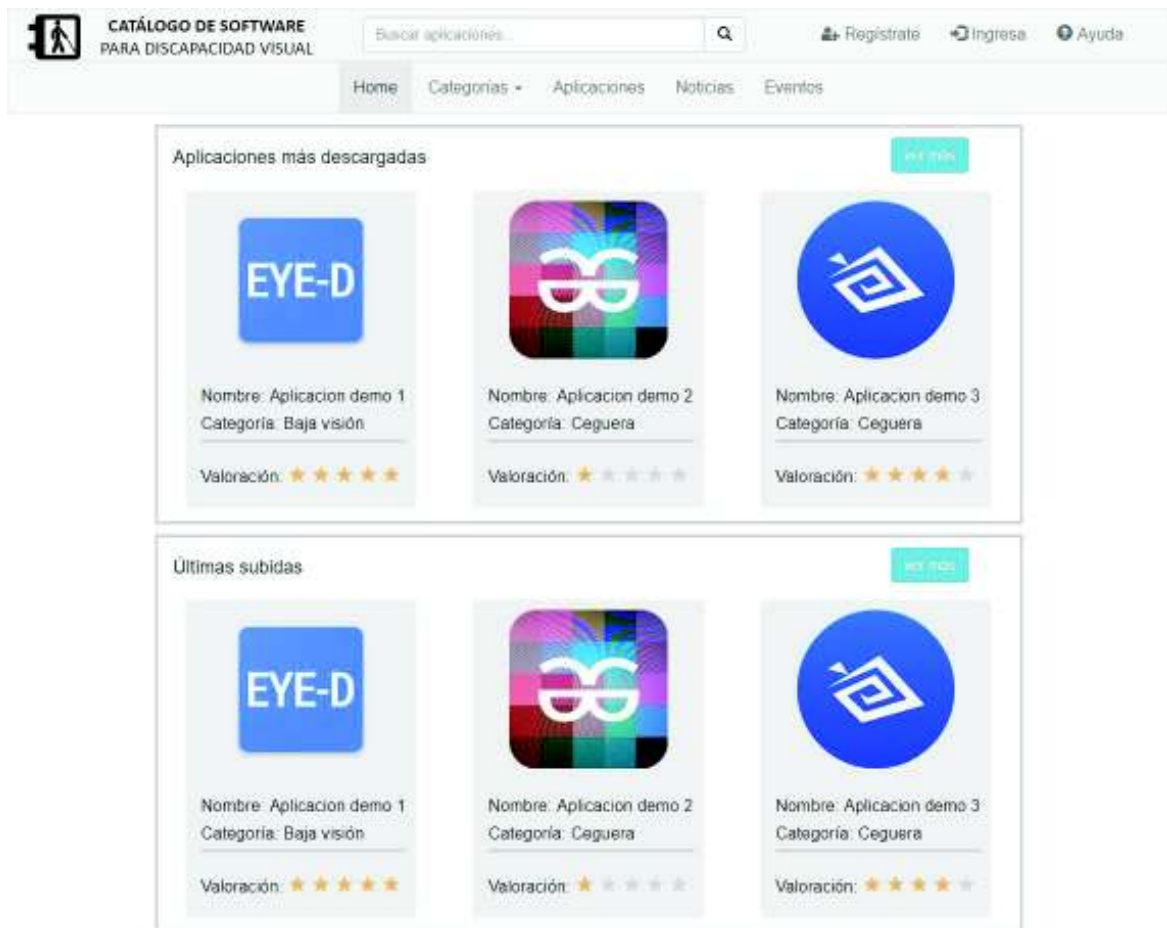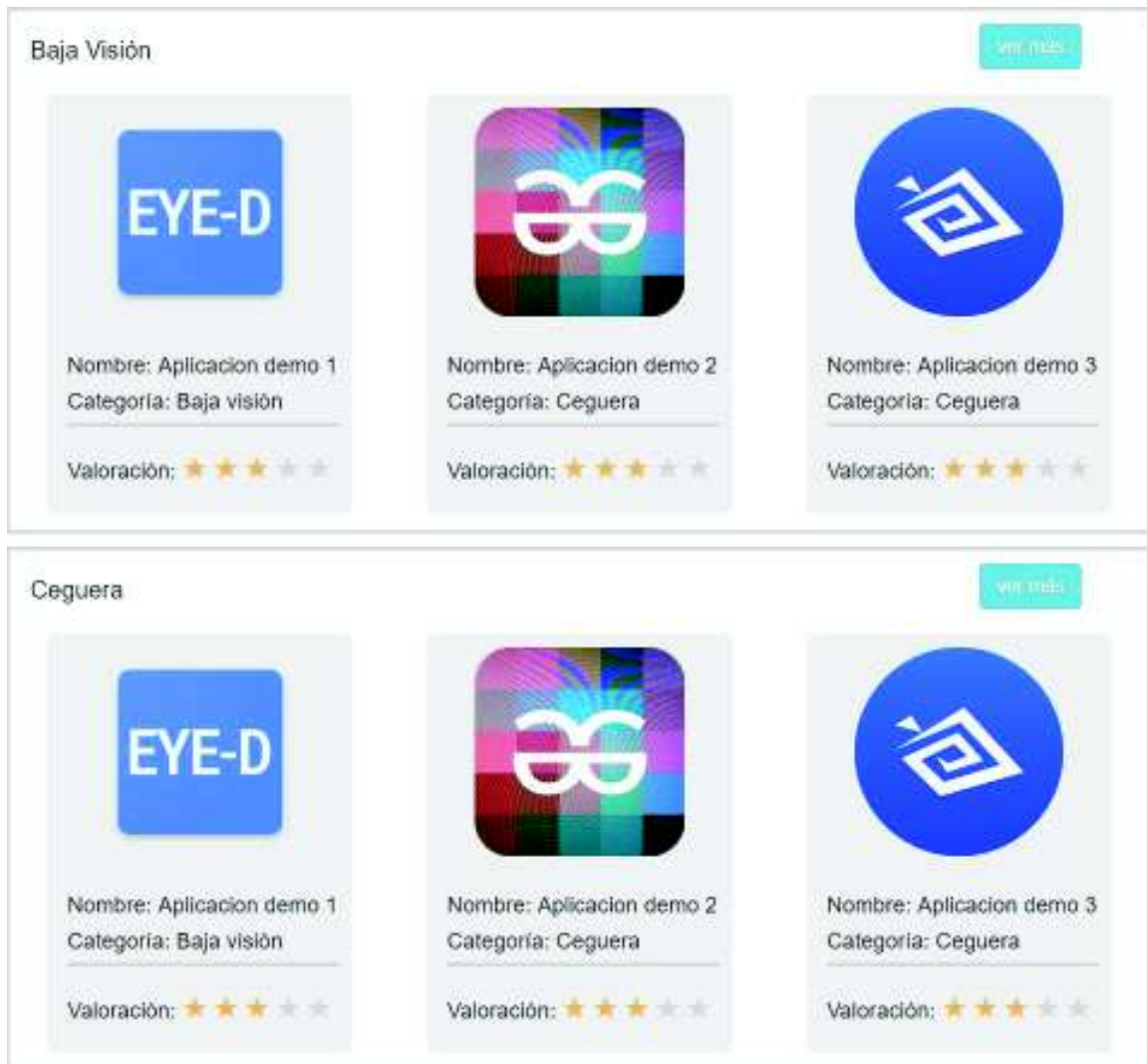
Figure 2.16: Homepage interface.

Figure 2.17: Categories interface.

Figure 2.18: Application interface.

As stated in section 1.4.2.1, the high-fidelity prototype must be as realistic and functional as possible.

Front-end development

The development environment for the high-fidelity prototype was hosted in a laptop running Windows 7 Home Premium 64bits, with an Intel Core i3, 16GB of RAM and a 512GB SSD.

Figure 2.18 shows the development environment configured for the high-fidelity prototype development.

Figure 2.19: Development environment.

The high-fidelity prototype was developed using Angular 5.2.0 and Bootstrap for the front-end. The back-end was developed using Node.js for the server-side language and Express.js as development framework, while the data was managed using MongoDB 3.6. GitHub was used for version control. Visual Studio Code was used for coding and compiling all Angular components and testing.

In the beginning, the catalog based its UI on templates, that is, the data was retrieved from a mock server or file to simulate how it should display the data. This also made easier to know how data should be organized and what parts of the application should become components. By using a mock server, it was easier to define the routes.

Like in most cases, the HTTP client has four methods to process requests, GET, POST, PUT, and DELETE, thus allowing to stablish what would later become the RESTful API.

After having a first working application, more components were defined, as well as, services and models which were organized into different folders. In this case, Angular came in handy for having CLI commands to easily generate them, like ng generate component or ng generate service. Figure 2.20 shows how the final tree project turned out, as shown, both the back-end and front-end can be easily distinguished.
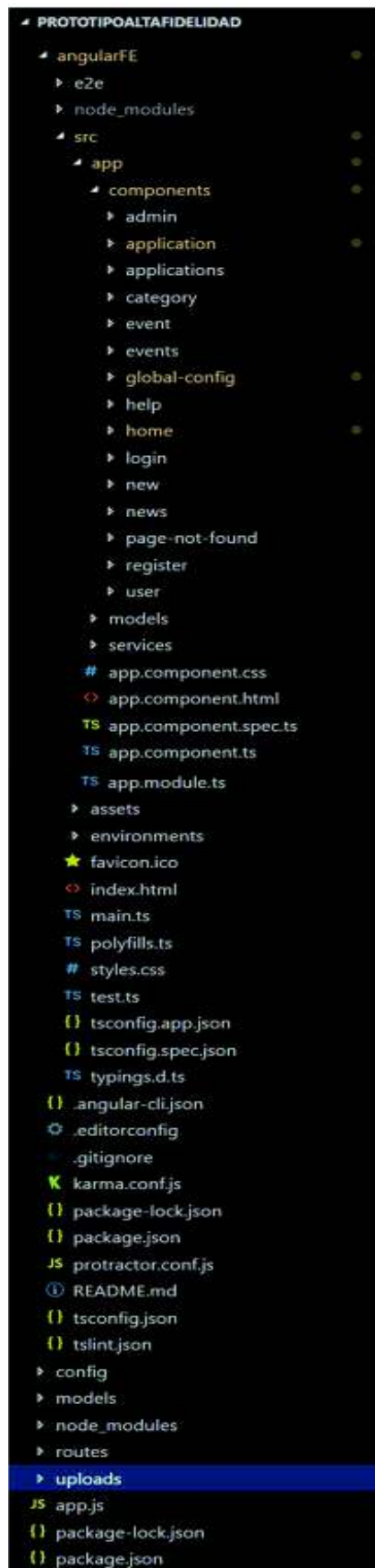
Figure 2.20: Project tree in VS Code.

Homepage

The high-fidelity prototype keeps the same structure as the medium-fidelity prototype, that is, search bar, navigation menu, and main content divided into Best Rated Applications, Recently Uploaded Applications, and Categories (see Figure 2.21). Each section has its own 'more' button, which redirects users to the web page of its name. These sections offer a first glance of what applications are being downloaded and used more often and what are the most recent, which in the end, help users get what they are looking for.

Categories

Like the homepage, the categories page keeps its initial design with some visual improvements from the medium-fidelity prototype. These categories have both subcategories and sections like the homepage.

Application

The application interface resulted into one of the most time-consuming-to-develop one, mostly because it is the one that has more interaction with the user actions. This interface had to be intuitive, and friendly to users, displaying information properly. This interface is divided into seven sections: main information, screenshots, description, rate and comment, commentaries, and frequently asked questions (see Figure 2.22). These sections were organized and selected based on the preliminary research (see Section 1.5).

The download button is located in the main information section, to make it more visible. In the case of downloading an application using a web browser, the download button redirects users to the application store, whereas, if used from a smartphone, the application gets downloaded automatically (using Google Play Store). The screenshots section displays demo images of what it is like to use an application. The comment and rate sections allow users to rate (using a star-rate approach) and comment an application, once done, the comment and rating appear in the comments sections showing both the username and date.

The frequently asked questions (FAQ) section allows users to asked questions about an application, whether it is a question about how an application works or if it runs on a given device, among others.

User profile

The user profile page was kept as simple as possible. There were no big changes from the medium-fidelity prototype, aside from aesthetics. As shown in figure 2.23, the links to

'downloaded applications', 'saved events', and 'questions made' are on the left side of the screen, whereas the user information is on the right side. These links automatically update when the users make actions like downloading applications or saving events, working as a history or log.

Events

The events page kept the same principle; simplicity comes first (see Figure 2.24). It shows the main information of the event, the banner, the date and hour, who organizes the event, the possibility to share the event using a social network, and finally, save the event.

2.2.2   Evaluation of prototypes

The evaluation of prototypes was based on usability, functionality, and accessibility aspects. Different tools and applications were used to know how users interacted with each prototype. This process is outlined below.
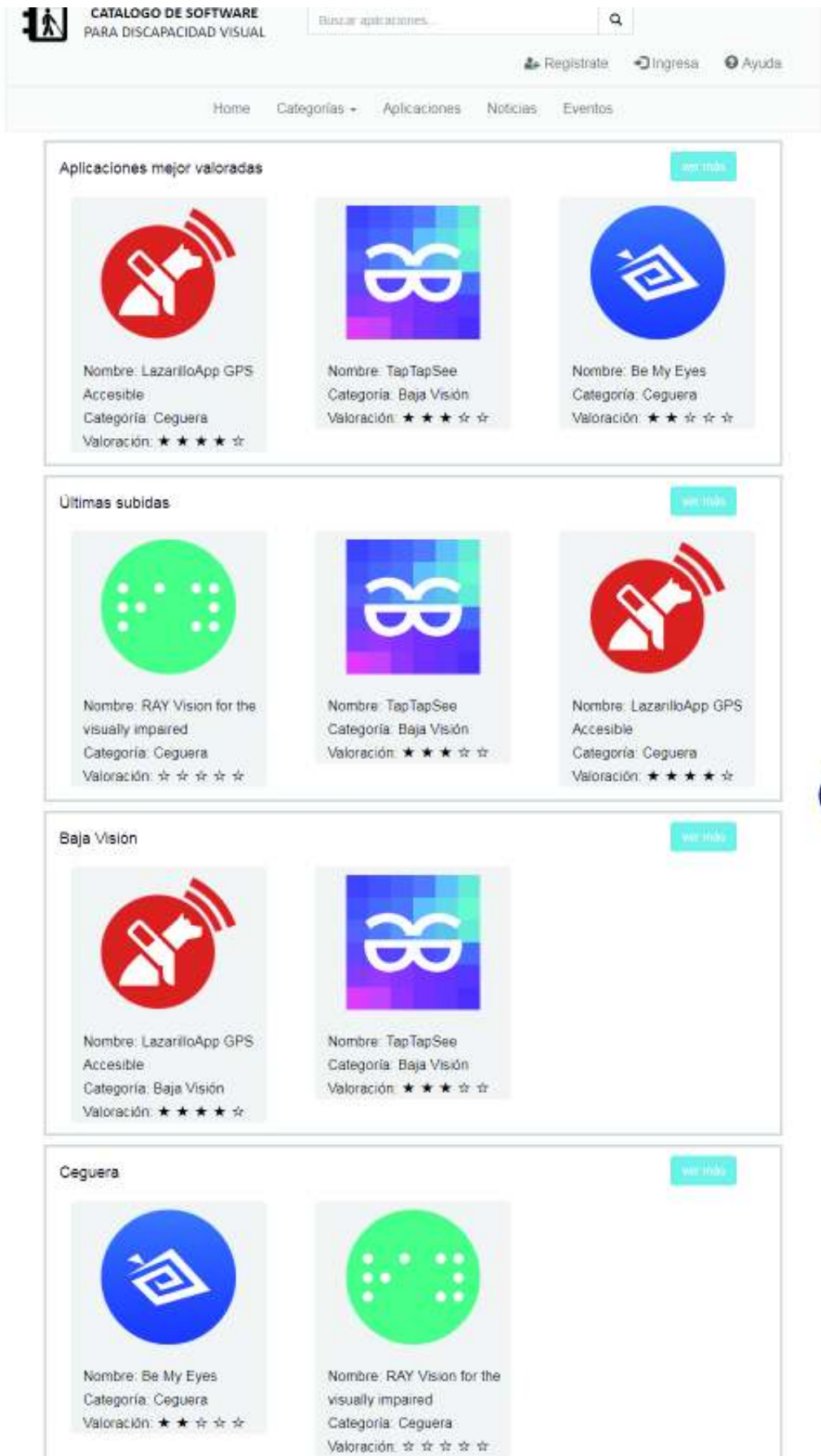
Figure 2.21: High-fidelity homepage interface.

Figure 2.22: High-fidelity application interface.

Figure 2.23: High-fidelity user profile interface.

Figure 2.24: High-fidelity events interface.

2.2.2.1   Low-fidelity prototype

After designing the application mockups, it was necessary to make it navigable. To do so, Canvasflip was the selected application for the job, not only for allowing an easy way to make mockups navigable but also for collecting user-interaction data and statistics. These mockups were validated with personnel from the "Instituto Mariana de Jesus", who remarked the catalog should be as intuitive as possible.

Canvasflip generated links to share among participants, and during the evaluation measured both time and interaction with the mockups. Another feature of Canvasflip is the interaction heatmap, which shows what elements of the catalog the users interact with most (see Figure 2.25).

Figure 2.25: Interaction heatmap.

Navigability

The navigability testing was done using the homepage, the application, the categories, the events, the news, the user profile, and the help pages, for a better understanding of how users traverse between interfaces. Canvasflip uses an arrow-like link to connect between different elements (see Figures 2.26, 2.27).
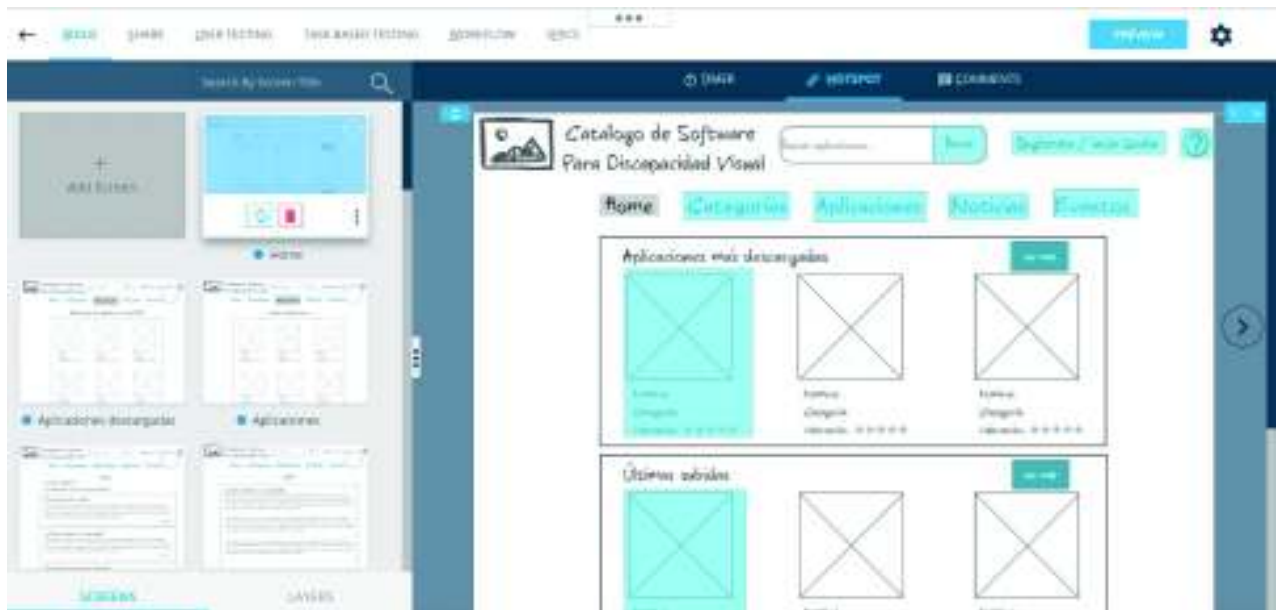
Figure 2.26: Navigable mockups.
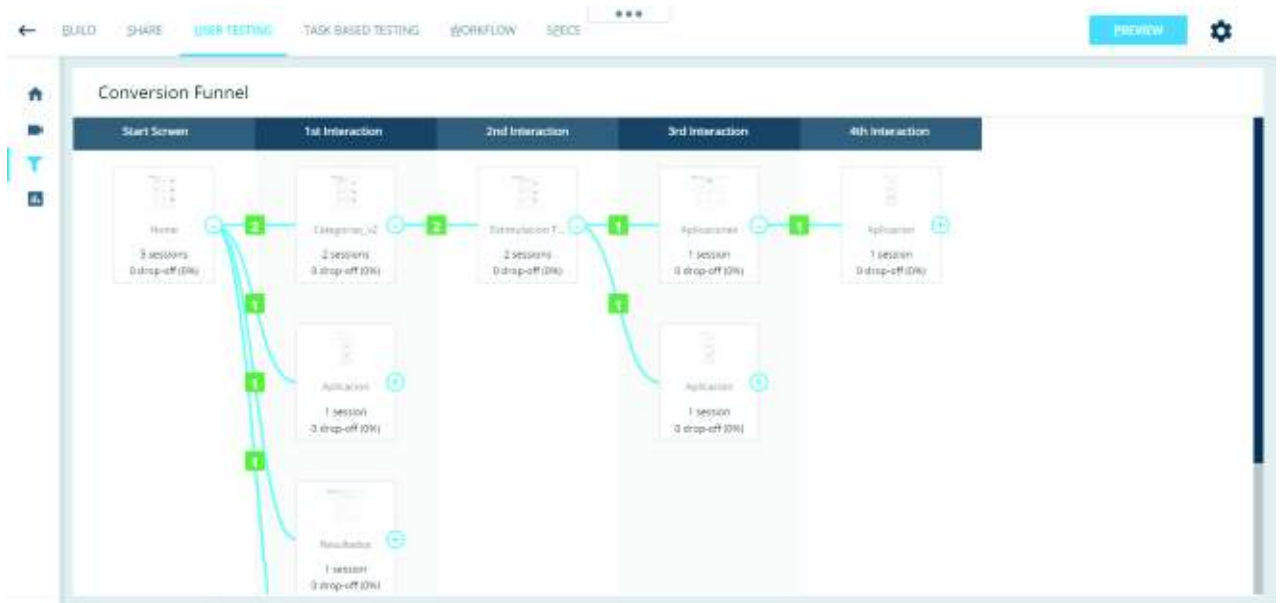
Figure 2.27: Conversion funnel.

2.2.2.2 Medium-fidelity prototype

The medium fidelity prototype evaluation was carried out at "Instituto Mariana de Jesús" with the help of three teachers and two therapists. The evaluation consisted on determining how intuitive and perceivable the prototype was at that moment, whether it should be useful, and how probable it was to be recommended to others. Figure 2.28 shows the survey model.

Figure 2.28: Medium-fidelity prototype survey.

2.2.2.3   High-fidelity prototype

The high-fidelity prototype evaluation was also carried out at "Instituto Mariana de Jesús" with the help of four teachers, two therapists, and the deputy director, Dr. Ximena Silva (see Figure 2.29). In order to have the best possible results, a first introduction about the project was made. A walkthrough of the project was made to show participants what the catalog offers and how it works. Then, the participants spent an average of 10 minutes to test the catalog. The survey followed, which consisted of five questions, and focused on organization, aesthetics, navigation, content, and accessibility. The last question (open one) allowed knowing finer details to improve the experience of using the catalog. Figure 2.30 shows the survey model.

Figure 2.29: Participants evaluating the high-fidelity prototype.

Figure 2.30: High-fidelity prototype survey.

3   RESULTS & DISCUSSION

3.1   RESULTS

This section describes the results obtained in the development of the project. It contains figures and tables that show the results of evaluating the applications for the visually impaired. Moreover, it presents charts of the results obtained from the evaluations of each prototype.

3.1.1   Web Catalogs

A total of 298 results where obtained using Google. The search criteria included websites and catalogs that deal with visual impairment. However, not every result was useful, so it was needed to not consider web catalogs that did not deal with visual impairment or vision loss, leaving only 134 web catalogs to choose from. Finally, there were some websites that were excluded from the evaluation because lacked information, did not work properly, showed outdated software, download links did not work, were blogs, and were not digital catalogs; this left only 11 websites that were analyzed as shown in Figure 3.1.

The obtained information from the 11 web catalogs showed that there were 3 important characteristics that must be considered for developing the catalog, and are detailed below:

1. **Type of Catalog:** During the analysis two different types of catalogs were differentiated: catalogs that are supported by a developer or institution, and catalogs that work as a central hub for applications and other information such as services, parenting, etc. In this case, the former focuses on a specific type of impairment and usually work alongside foundations or medical institutions [44], whereas the latter covers a vast majority of impairments and skills, and applications are usually organized as categories [45].

70

2. **Ease of access:** In order to access or download an application, users have to make at least 3 to 6 clicks. According to Morville and Rosenfeld, this can be reasonable if looking for a specific element, where there is a "correct" answer to their question and the endpoint can be measurable [46]. However, it is highly recommended that users can get what they are looking for in the shortest time possible, in this case, most sites use the "3-clicks-design" for web development [47].

3. **Feedback:** Though most of the catalogs offer a wide variety of applications, none showed evidence or feedback from their users, mostly because none of these catalogs required creating an account for accessing the site.
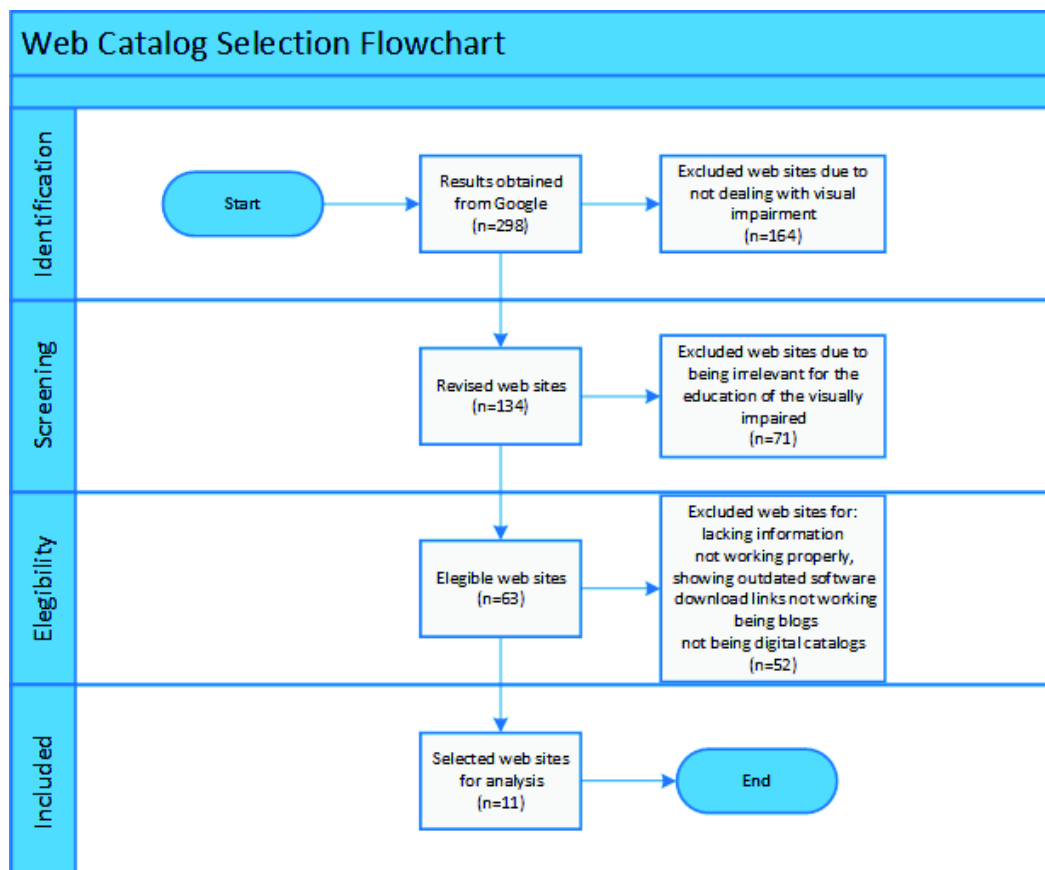
Figure 3.1: Search and selection flowchart for websites and catalogs.

3.1.2 Applications

A total of 621 results were obtained using Google. The search criteria included applications that deal with visual impairment and blindness. According to the criteria used to select the appropriate applications, a total of 46 applications passed the selection.

Among these applications, most of them are from the United States followed by India as shown in Figure 3.2. These applications were evaluated using MARS.
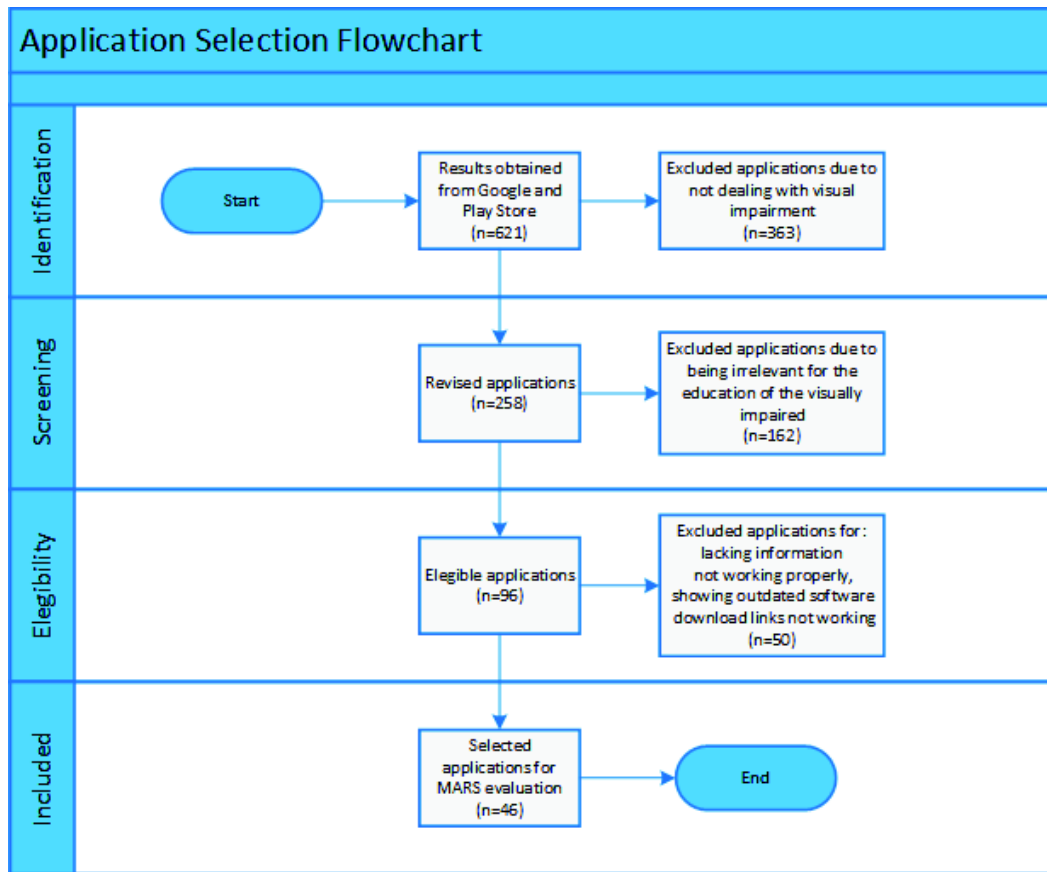
Figure 3.2: Search and selection flowchart for web and mobile applications.

3.1.2.1 Evaluation of applications

MARS was used in order to measure the quality of the selected applications. It consisted on evaluating each application based on a 5-point scale for 5 different sections which are as follows: engagement, functionality, aesthetics, information, and subjective quality. However, MARS recommends taking the rating from the subjective quality as a guide, because it is not totally reliable.

Following are the results of using MARS to evaluate the selected applications.

Nº	Application	Engagement	Functionality	Aesthetics	Information	Total	Subjective*
1	Eye-D (Devices)	3,40	4,00	3,00	3,20	3,40	3,50
2	Visually Impaired	4,20	4,00	3,00	3,50	3,68	4,25
3	Blind Communicator	4,60	4,75	5,00	4,40	4,69	5,00
4	Eye + (For blind & visually impaired)	2,20	2,25	2,67	3,33	2,61	1,75
5	Be My Eyes - Helping the blind	4,00	4,75	4,00	4,17	4,23	4,25
6	ClariaZoom - Low vision app	4,60	4,25	3,00	4,67	4,13	4,75
7	TapTapSee	4,20	4,75	3,33	4,67	4,24	4,75
8	Google TalkBack	4,60	5,00	4,00	4,50	4,53	4,50
9	Big Launcher	3,80	4,50	3,67	4,33	4,08	3,50
10	MessagEase Keyboard	2,80	3,50	4,00	3,17	3,37	1,25
11	KNFB Reader	4,40	3,75	4,33	2,83	3,83	3,00
12	Blind Accessibility Keyboard	4,00	2,00	3,00	2,40	2,85	2,75
13	Walk Helper for Blind	3,20	2,75	3,33	1,40	2,67	1,75
14	Visor - Low vision magnifier	4,00	4,75	5,00	4,17	4,48	4,00
15	ICSee (I Can See)	3,60	4,50	4,33	4,50	4,23	4,00
16	Toolwiz Eyes-Voice Guide Cam	4,00	4,25	3,67	4,00	3,98	4,75
17	SuperVision mini	4,00	5,00	3,67	4,00	4,17	4,00
18	Lazarillo GPS for Blind	4,40	4,50	4,33	4,33	4,39	4,75
19	Blindness Phone	1,40	2,25	1,33	1,67	1,66	1,00
20	VITA (Visually Impaired Translation App)	2,60	2,00	2,33	2,50	2,36	1,50
21	RAY App for Visually Impaired	5,00	4,75	4,67	4,50	4,73	4,75
22	Help Launcher	3,20	4,50	5,00	4,33	4,26	3,50
23	Textifi	2,40	4,00	3,33	2,50	3,06	2,75
24	Chromevox	3,00	2,25	3,67	3,20	3,03	2,75
25	Chromeshades	2,60	3,75	2,67	3,00	3,00	2,50
26	Zoom Browser Extension	3,60	4,25	3,00	4,00	3,71	4,00
27	Oswald	2,40	3,50	3,00	3,00	2,98	2,25
28	Colorblind - Dalton	2,60	4,50	4,33	4,00	3,86	3,75
29	Vision	4,20	4,50	5,00	4,17	4,47	4,25
30	Snap&Read Universal	3,40	3,25	3,67	3,33	3,41	3,00
31	Read Aloud	3,40	3,75	3,00	3,67	3,45	2,25
32	Selection Reader	3,40	4,50	4,33	3,83	4,02	3,50
33	Alpha Text	3,00	3,25	4,00	3,50	3,44	3,75
34	Line Height Adjuster	2,00	3,75	3,00	2,60	2,84	1,50
35	Claro Read	2,00	2,00	5,00	1,00	4,00	1,75
36	Sokhan	2,20	2,75	3,67	1,33	2,49	1,00
37	Metal mouth	2,20	3,00	3,67	3,50	3,09	2,25
38	Tranquility reader	3,60	4,25	3,33	4,33	3,88	4,25
39	Math Basebal	2,40	0,00	4,67	3,17	2,56	2,00
40	Measure It	2,40	3,50	1,67	2,17	2,43	1,00
41	Math Basketball	3,20	4,25	2,33	4,17	3,49	3,00
42	Math Soccer	2,80	3,00	1,67	3,00	2,62	2,50
43	Access Invaders	2,60	2,00	3,33	3,33	2,82	2,50
44	BlindScape	2,00	2,50	1,33	2,00	1,96	1,75
45	Auslan Storytime	3,20	4,00	5,00	4,83	4,26	3,25
46	Eda Toby Play	2,40	4,00	3,33	2,50	3,06	2,75

Table 3.1: Quality score for each evaluated application.

Table of the author.

3.1.3 Evaluation of prototypes

This section describes the results obtained from evaluating each of the prototypes.

3.1.3.1 Low-fidelity prototype

Following are the results obtained from the prototype evaluation using CanvasFlip.

Navigation

CanvasFlip recorded and analyzed the five user tests. The conversion funnel and the interaction heatmap showed how users interacted with the application. The average time spent navigating through the application was 2 minutes and an average of 59 clicks.

The conversion funnel showed that the users first clicked on the categories button (2 sessions), followed by the application section and the search results section (1 session each) in the first interaction. The second interaction corresponds to the subcategories section (2 sessions), followed by the download button and back to the homepage (1 session each). In the third and fourth interaction users navigate through the applications and leave last both the news and events sections. These interactions demonstrate that the application complies with the 3-click-rule.

The interaction heatmap identified the elements the users are more attracted to or feel first to click on. In the homepage mockup, the categories button was the most clicked element of the navigation bar, as well as, each of the subcategories and the applications button. In the application mockup the most clicked elements were the download button, read more button, and the comment button. Following, the user profile mockup showed more interaction in the applications downloaded by user section, questions made, and saved events sections.

Following are the commentaries made after testing the prototype.

- **Categories:** There should be the following categories, Low Vision and Blindness.
- **Subcategories:** Under the Low Vision category there should be the following subcategories, Educational Inclusion, Early Stimulation, Rehabilitation for Adults, and Multiple Challenges.
- **Help button:** It should display help for navigating through the application and user-

related questions, i.e., how to change the password.

- **Font size and color customization:** The user should be able to customize both the font and the color of the elements of the application to make it more user- friendly and accessible.

3.1.3.2 Medium-fidelity prototype

Following are the results obtained from the prototype evaluation.

After testing the catalog, the participants were asked to answer what characteristic should be the most important and results are shown in Figure 3.3.
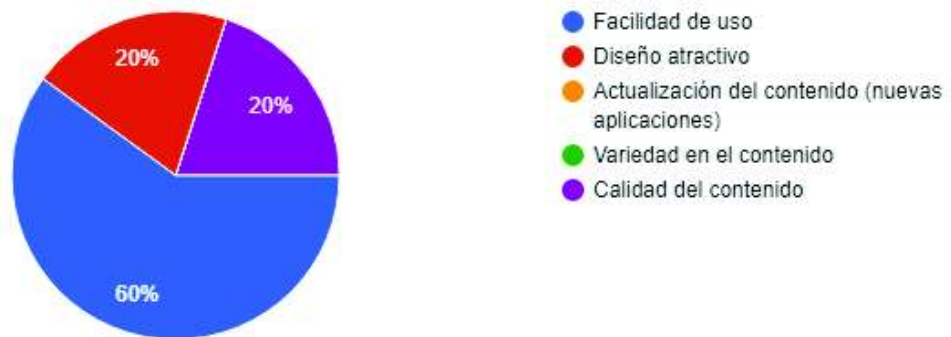
Figure 3.3: Medium-fidelity prototype. Question 1, From the following characteristics choose the one you consider most important for the web application.

The second question was whether the catalog is considered useful or not (see Figure 3.4).

¿Considera usted de utilidad el catálogo de aplicaciones?
5 responses
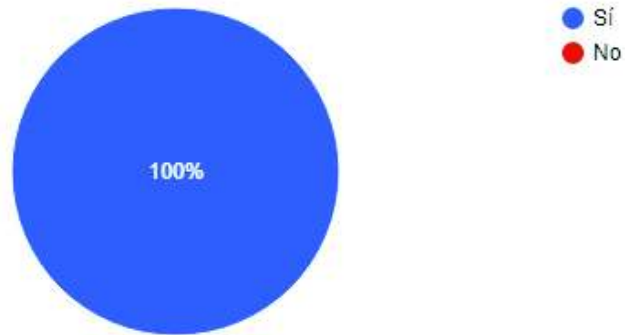
Figure 3.4: Medium-fidelity prototype. Question 2, Do you consider the web catalog useful?

Regarding how frequently participants would use the catalog they responded they would use it weekly (see Figure 3.5).

¿Con qué frecuencia utilizaría el catálogo de aplicaciones?
5 responses
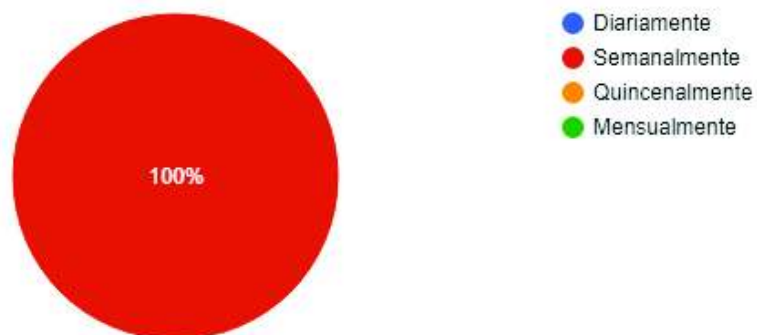
Figure 3.5: Medium-fidelity prototype. Question 3, How often would you use the web catalog?

Regarding whether the content organization was well structured they responded it totally is (see Figure 3.6).

¿Considera usted que la organización del contenido en el catálogo se encuentra bien estructurada?

5 responses

● Sí
● No

100%
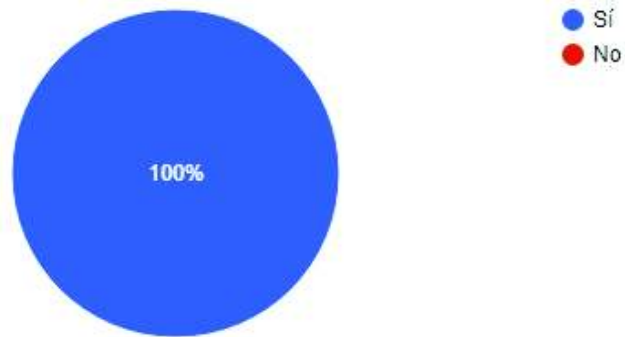
Figure 3.6: Medium-fidelity prototype. Question 4, Do you consider the content organization is well structured?

Sixty percent of the participants responded they would totally recommend the catalog, whereas, forty percent responded with very probably (see Figure 3.7).

¿Qué tan probable es que usted recomiende el catálogo a alguien?

5 responses

● No lo recomendaría
● Poco probable
● Probable
● Muy probable
● Lo recomendaría

60%

40%
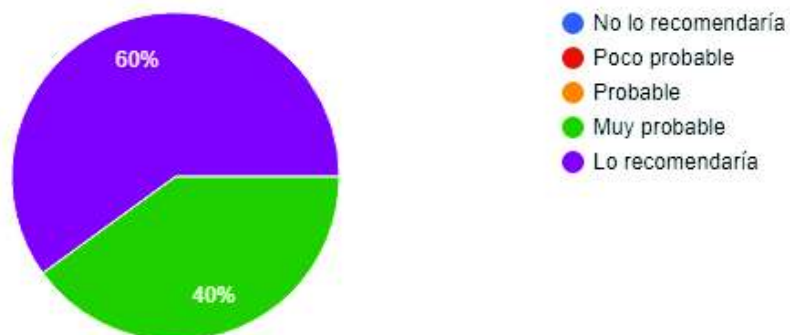
Figure 3.7: Medium-fidelity prototype. Question 5, Would you recommend the web catalog?

Finally, the participants suggested and commented the following:

- The catalog runs a little slow.

- The navigation menu should be responsive and shrink after being redirected.

- The buttons should display a message before clicking on them.

3.1.3.3   High-fidelity prototype

Following are the results obtained from the prototype evaluation.

The participants were asked whether the content organization and presentation were adequate, which 57 percent answered very adequate and 43 percent answered totally adequate (see Figure 3.8).

¿La organización y presentación del contenido es adecuada para su fácil comprensión?

7 responses

- Nada adecuada
- Poco adecuada
- Algo adecuada
- Muy adecuada
- Totalmente adecuada

42.9%

57.1%
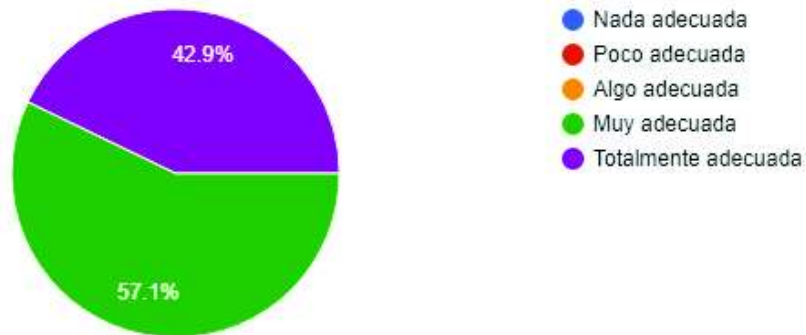
Figure 3.8: High-fidelity prototype. Question 1, The content organization and presentation is adequate for its comprehension?

The same percentage (57 and 43) respectively said the catalog was easy and intuitive (see Figure 3.9).

¿La navegación dentro de la aplicación le pareció fácil e intuitiva?
7 responses
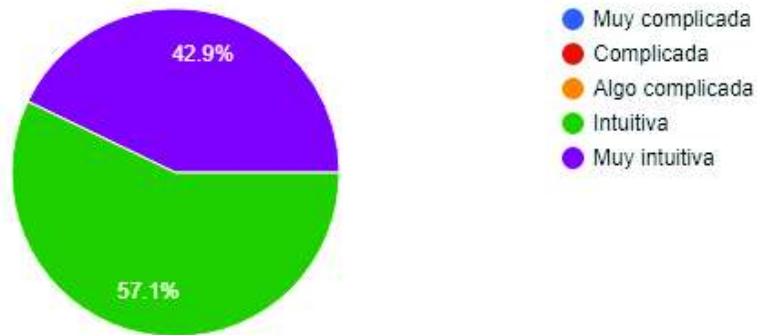
Figure 3.9: High-fidelity prototype. Question 2, Do you consider the navigation easy and intuitive?

For the next question, 71 percent said the visual content and multimedia totally satisfied them, while the other 29 percent said it was satisfying (see Figure 3.10).

¿El contenido visual y multimedia fueron de su agrado?
7 responses
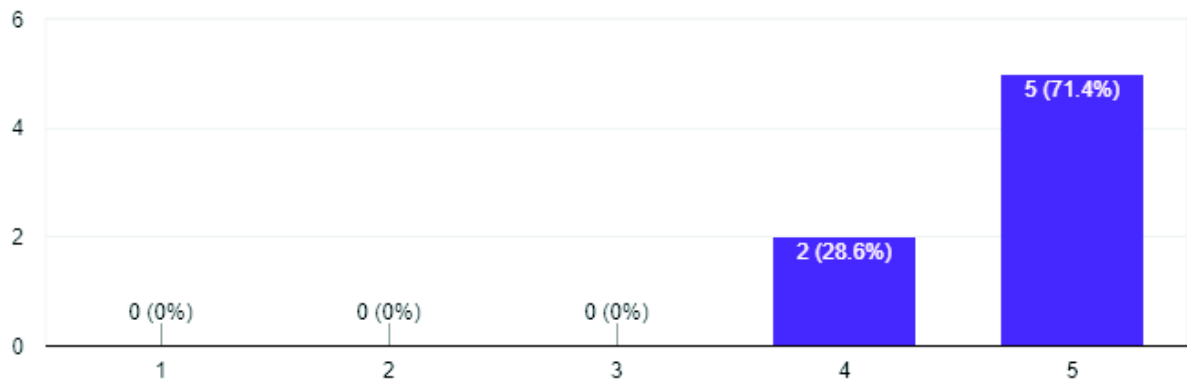
Figure 3.10: High-fidelity prototype. Question 3, Did you like the multimedia and visual content?

Seventy one percent of participants said the accessibility within the catalog was totally helpful, while the other 29 percent said it could be better (see Figure 3.11).

¿Los elementos de accesibilidad facilitaron el uso del catálogo?
7 responses
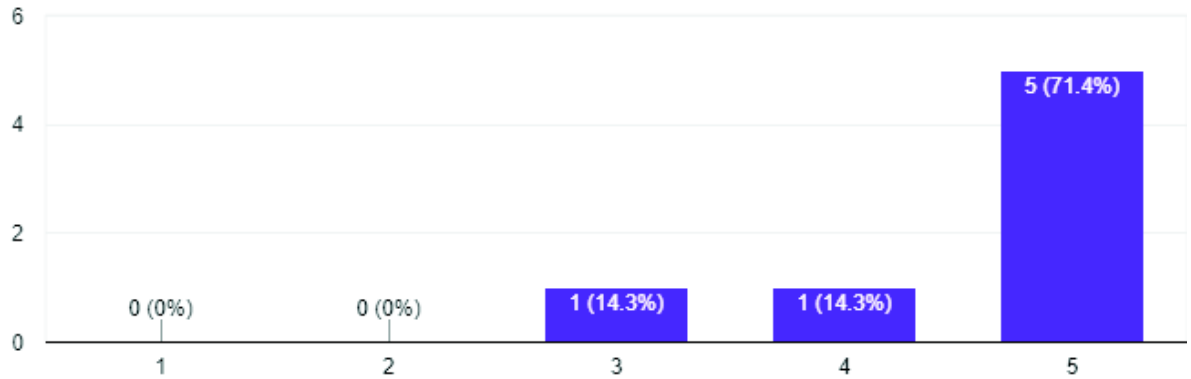
Figure 3.9: High-fidelity prototype. Question 4, Do you think the accessibility items made it easier to use the catalog?

Finally, participants suggested and commented the following:

- It worked perfectly.
- It should load faster.
- The font size and cursor should be bigger.
- The catalog should start with the screen reader active by default.
- It should be recommended to show an introduction for the catalog, why it was created, and its motivations.
- The font size should be bigger. Images took little time to load.

3.2 DISCUSSION

This section shows the discussion about the obtained results from the preliminary research and the work done.

3.2.1 Websites and catalogs

1. **Type of catalog:** there is a big difference between types of catalogs, depending on what needs must be satisfied. For the specific case of visual impairment, developers must work with specialized institutions that deal with this type of impairment, otherwise, the final product may not satisfy the users' needs. Alongside this, a thorough evaluation should follow in order to verify that these applications comply with a quality baseline. In most cases, users choose a certain application based on previous experiences or based on recommendations.

2. **Access:** the results from the research demonstrated that in most cases the access and navigation in current web catalogs is difficult and sometimes was confusing. Most of these catalogs show applications as a list or table, overwhelming users with such vast information. In other catalogs it was observed that links redirected to various pages, not necessarily related to a given application. This can be decisive when users what to make a catalog their preferred one. The '3-click-rule' comes in handy when we want to solve this kind of problems, making websites more intuitive and logical to users.

3. **Feedback:** In most catalogs there were not any commentaries or feedback about their applications. It is recommended to give users the opportunity to give feedback about how their experience was while using applications. This allows growing a community in which users can help each other. However, for this specific case the use of MARS for rating applications allowed having a more reliable criteria for choosing applications. In the application page there are two sections for users to ask questions and, comment and rate an application.

3.2.2   Applications

The results from the preliminary research showed that the United States of America is the country with the highest level of development regarding inclusive technologies. There are foundations, institutions, and organizations that deal specifically with disabilities, and are constantly improving their products and services in order to enhance the life of the impaired.

3.2.2.1   Evaluation of applications

The development of educative applications is cost-limited, that is why in most cases, developers look for donations or public funds in order to bring an application. In the case of India and Greece, the results showed that most applications are developed by freelancers, like Visually Impaired by Jawahar Coder and VITA by Aditya Bharadwaj. These applications are free as well and maintained by donations.

Other applications like Help Launcher or Lazarillo GPS for the Blind are projects supported by institutions dealing with visual impairment from Spain and Chile respectively. In the case of Spain, it is well known that they have a large history of projects dealing with disabilities, specifically Fundación ONCE, that has been for almost 80 years the point of reference in terms of visual impairment.

These applications share common features like big fonts, high contrasts, and focus on one specific functionality, making it easier for users to use them. However, as they focus on functionality, they also lack visual engagement for obvious reasons; but it is important to note that people with visual impairment are not only using these apps but the elderly as well and should improve their visual aspects.

The same problem regards information, as most of these applications barely have information about who developed them or where they are from. They also lack a guide to use them, making them sometimes difficult to use at first, and requiring someone who can help and guide for the first setup and use.

The 23 applications that were selected to be included in the catalog, scored more than 3.2 out of 5, and averaged 4.14 out of 5, making them completely ideal to be used by the visually impaired. Dr. Ximena Silva from Instituto Mariana de Jesús collaborated giving important feedback about these applications and how they should be categorized. The results obtained

from applying MARS for measuring the quality of these applications allowed knowing whether these applications were useful and can be very beneficial once people start using the web catalog.

Regarding the rest of applications, it is important to note that there are people and foundations that are trying their best to develop applications that can improve the life of the visually impaired, but there is still a long way to work on.

3.2.3   Evaluation of prototypes

3.2.3.1   Low-fidelity prototype

Regarding the catalog navigation, the navigation menu collapses when used in a smartphone or tablet, uses the "follow the eye" principle, and remarks each link element when the user clicks on them, allowing the users know where they are in the site. Every single element in the navigation menu is intuitive and accessible. The search bar stayed in the top-center part of the navigation menu, for being the most visible part of it.

Both best rated applications and recently uploaded applications sections are shown first in the catalog for letting users know what is being used. The categories sections follow letting users get them from the homepage or the navigation menu.

The application page only shows what the user really wants to see, avoiding visual overwhelming. Also, this design was made having in mind the use of a screen reader. The order of sections within the application page are sorted by importance, firstly showing the application main information, followed by screenshots, and the description. Below are the sections dedicated to the users, commentaries, rating, and frequently asked questions.

The interaction heatmap showed that users barely check more information about an application and focus more on the first three sections of the application page. The download button is also located in the main information section to the right.

In the user profile page, the use of a silhouette helped identify where the users were. Both sections actions and user information were located to the left and to the right respectively, using modal windows to display the actions links content.

3.2.3.2 Medium-fidelity prototype

The features chosen as most important by participants were: ease of use (60%), attractive design (20%), and quality content (20%). The reason for this is that people with visual impairments rarely focus on the design, and thus, prefer functionality. However, it is important to note that this catalog will be used by everyone and has to offer the best experience for both the visually impaired and the non-visually impaired.

All the participants agreed that the development of the software catalog is totally useful and may be ideal to be used in every school and institution to improve the learning of the vi. They also agreed that they would use the software catalog at least weekly, and that is why it is important to keep developing new applications and improving the existing ones.

The categorization was also very well received, with all of the participants agreeing that both categories and subcategories were adequate and easy to use, keeping this approach for the last prototype.

3.2.3.3 High-fidelity prototype

The high-fidelity prototype was very well received due to considering the feedback from the low and medium fidelity prototype evaluations and, of course, suggestions were made after being evaluated.

Participants agreed that both organization and presentation were totally adequate and very adequate with 57% and 43% each. Participants mentioned that the catalog was visually appealing, and due to the accessibility menu, it was also very user-friendly and intuitive.

It is also important to note that also 57 % and 43& of the participants agreed that the navigation and content in the software catalog were totally intuitive and very intuitive respectively. This can improve the use of the software catalog for both the vi and non-vi.

One issue detected during the evaluation dealt with the Internet connection. Due to the slow connection speed, some visual elements like images took some time to load, and thus, impacting in the final user experience. This can be improved by using thumbnails instead of full resolution images.

3.2.4 Project evaluation

The use of prototyping with user experience allowed developing all three prototypes in less time than usual. Not only it was time-efficient, but also, very flexible to get feedback from users and keep improving the software catalog with each milestone.

Due to the methodology being focused on user satisfaction, the user participates actively on its development, it allows getting better and refined software requirements over time.

The combination of Angular and Node.js turned out to be very useful due to having the same language in both the back-end and front-end (JavaScript). In the case of Node.js, the use of middleware software makes it easier to build applications in less time; and due to Angular's modularity and components, it is very flexible to make the application scalable over time. The software catalog used the MVC pattern during its development, with Angular dealing with routing (controller), models and views (components); and Node.js dealing with the RESTful API (controller). This brings an application with high cohesion and low coupling that has maintainable code. However, it is good practice to use the stable version of Angular and the LTS version of Node.js to reduce incompatibility between modules and reduce errors.

Even though Instituto Mariana de Jesus has many years dealing with the visually impaired, it was evidenced that the personnel lacked knowledge of existing software applications that can benefit the development of the vi, thus creating a great opportunity to use and spread the catalog to use it as a daily basis in most schools and institutions.

4 CONCLUSIONS

- After searching and collecting both web and mobile applications, it was discovered that in Latin America the current technological solutions for the visually impaired lacked development and most did not even comply with WCAG2.0. Whereas, countries such as India, Spain, USA, Germany, and Greece, showed more development in soft- ware regarding accessibility. This makes sense due to these countries having rigorous laws about inclusive technologies.

- The evaluation of the 46 applications showed that even though they may seem simple in both visual appeal and functionality, they work fine for what they are supposed to do, thus, having acceptable quality. These applications were compatible with multiple devices (web browsers and Android versions), making it easer for the user to get them. Most of these applications share two common features: they deal with navigation and magnifying screen content, this means that they help the visually impaired achieve common daily activities.

- The use of prototyping and UX in this project resulted in a friendly and usable web catalog, complying with all four WCAG2.0 principles, making it not only suitable for the visually impaired, but for others both with and without disabilities.

- Dr. Ximena Silva, deputy director of Instituto Mariana de Jesús, agreed that the use of the digital software catalog is very useful and important to improve the learning of the visually impaired. The functionality and usability of the catalog make it a great option to improve current teaching strategies to enhance learning. Teachers and therapists from the institution said that a software that can help search tested applications, can totally improve the life of the visually impaired, and not only that but the learning of others too.

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6 APPENDIX

The following files can be found in the CD.

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