
# Augmented Reality Birdwatching in Mindo

Master degree in Computer Engineering – Mobile Computing

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Leiria, March of 2020


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Dissertation Report under the supervision of Professor Alexandrino José Marques Gonçalves, Professor Rita Margarida Teixeira Ascenso and Professor Nuno Carlos Sousa Rodrigues.

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# Originality and Copyright

This project report is original, made only for this purpose, and all authors whose studies and publications were used to complete it are duly acknowledged.

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# Abstract

The project reported in this dissertation presents the development of an Android mobile application to be used for birdwatching in Mindo - Ecuador. The application has as target audience tourists and as main goal to share information about the species that inhabit the aforementioned place to improve tourist experience; it provides routes to follow with points of interest in which the users can find bird species. In addition to this, the application provides scientific information and highlights the most important characteristics of bird species, information about the threats that may be exposing these species to extinction and multimedia content like images, videos and sounds of those species.

As a distinctive feature, this application uses augmented reality to enhance birdwatching experience; it allows the user to interact in a different way with nature and offers the opportunity to perceive virtual 3D models of some birds and take photos of it to share on social networks or simply to save on the device.

To manage all the content of the application, a web-based backoffice was also developed, to add, edit or remove routes, spots and species including their information, images, videos and sounds.

The augmented reality, together with the user-friendly interface make the application very interactive and attractive to the user, likewise, the backoffice allows a simple administration of the content.

**Keywords:** Android application, Augmented Reality, Birdwatching

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# List of Abbreviations and Acronyms

| | |
|---|---|
| AR | Augmented Reality |
| IBA | Important Bird Area |
| DB | Data base |
| XML | Extensible Mark-up Language |
| HTML | Hypertext Mark-up Language |
| SUS | System Usability Scale |

# 1. Introduction

Mindo is a region located in the canton San Miguel de los Bancos in the Pichincha province, Ecuador. Its main town bears same name and is known for its natural beauty and great variety of flora and fauna, which makes it a jewel for tourism, attracting hundreds of tourists both national and foreign all time. It is a place recognized by the large number of birds that inhabit the ecosystem, which makes it a perfect place for birdwatching, a widely practiced activity by tourists, either as a recreational way or to socialize by using old fashion methods to share and learn more about birds. Currently, the instruments used for birdwatching are a notebook or field notebook, pencil, pen, or ballpoint pen to write down when watching, binoculars or telescope and cameras or video as well.

"Bird-watching, the observation of live birds in their natural habitat, a popular pastime and scientific sport that were developed almost entirely in the 20th century" [1].

Nowadays, technology is a great ally for outdoor activities since it increases the possibility of easily get information from a mobile app or internet. This is perfectly suited for birdwatching, the main topic of this project, where, along with other scientific information, it is intended to use Augmented Reality (AR) technology in mobile devices to support birdwatching. AR has become a very affordable technology for this activity, offering the possibility to create enhanced experiences for the user and providing the ability to educate or share knowledge with people through this means.

It should be considered that Ecuador is a rich country in terms of nature, but it is not a place where technological innovation is an explored field. With this statement, there is a competitive advantage which makes this project attractive.

## 1.1. Motivation and Objectives

Mindo, specifically the Protected Forest Mindo Nambillo, is a place with great natural wealth, it has numerous birds species coexisting in the ecosystem what led it to be declared the first Important Bird Area (IBA) of South America in 1977, making it a perfect place for birdwatching [2].

It is a popular tourist place visited either by local and foreign people, which causes the displacement of some species and is one of the main reasons that makes a great importance to raise awareness among tourists and all people about the preservation of the ecosystem and the maintenance of its biodiversity.

There are many birds and birdwatching tours in Mindo, but sometimes, due to bird's nature, it is difficult to watch and identify some species. Consequently, there is the need to provide the possibility of bird observation and provide full information about species through a customized mobile application of these touristic spots.

Considering the dissemination and easy access to technology, in addition to the low costs of smartphones with Android as operative system, it would be desirable to use an application to share information, educate people and promote tourism in the area to increase the interest in birdwatching and introduce the risks to which the birds are exposed.

### 1.1.1. Tourism

In order to promote tourism on the country, the government of Ecuador launched in 2014 the most aggressive tourism campaign to date named "All you need is Ecuador", starting on February 28, with content in digital media using the hashtag #ALLYOUNEEDIS. Then, on April 1, officially launches the campaign with physical means around the world and in mid-April through mass media. After this campaign, the Ecuadorian government has launched multiple campaigns focused on tourism, in which Mindo stands out as one of the country's great attractions [3].

Mindo is in the Pichincha province, two hours away from the capital city of Ecuador, Quito, at 1250 meters above sea level, with temperatures that vary between 16 °C and 22 °C. It is considered one of the places with the greatest biodiversity on the planet. In 1998, it was declared as a protective forest and conservation area for species. In addition, the water resource of Mindo is one of the most valued of the place, being an important part of the protected area [4].

**Figure 1 - Spectacled bear**

Due to the large number of birds that inhabit Ecuador, this is one of the main destinations for birdwatchers around the world. Being surrounded by nature, Mindo is a perfect place to watch wildlife. Many mammals can be found, like spectacled bear (figure 1), tapirs, armadillos, cougars and about 500 to 550 species of birds like the *Colibri thalassinus* (figure 2), many of which are endemic [5]. Currently, there are several companies that offer tourist packages for birdwatching, with guides and using traditional non-technological resources.

**Figure 2 - Green Violetear (*Colibri thalassinus*)**

There can be found also approximately 2000 species of plants and about 40 species of butterflies [6].

In addition to birdwatching, Mindo offers other tourist activities, such as:

- Canopy: It consists of crossing over the trees hanging from a cable system with safety equipment;
- Canyoning: It consists of descents in rocky canyons, rivers, and waterfalls with help of a cable system, safety equipment and specialized clothing;

- Butterfly garden: This is a place where can be seen a different variety of butterflies in captivity;
- Waterfalls: The Mindo Nambillo reserve has many medium-height waterfalls and clearings in which it is possible to bathe;
- Tarabita: It consists of a chair or basket held by a cable and driven by a motor, which is used to cross over canyons;
- Nightlife: There are some bars and night clubs to enjoy nightlife;
- Hotels/hostels: There are many hotels and hostels where, in addition to offering accommodation, these offer exclusive tourist activities.

These are some of the reasons why Mindo is a place widely frequented by tourists, especially by foreign, where birdwatching activities are one of the most attractive activities to do and must be promoted worldwide [7].

### 1.1.2. Objectives

The main goal was to develop an Android application to share information and multimedia content about some Mindo hotspots for birdwatching and show bird species to facilitate the access to scientific information to tourists and public in general, also, to implement a feature with augmented reality to create different and new experiences for the user.

To achieve this goal, several requirements have been specified:

- Highlight useful information about bird species;
- Provide image, video, and sound galleries about bird species;
- Provide virtual bird models to work with AR;
- Provide hotspots and routes to serve as virtual guide for the tourists;
- Make the app work offline;
- Make the app bilingual (English – Spanish);
- Create a web site to manage bird species information (app database).

## 1.2. Schedule

The work was scheduled to be completed in 360 days, as can be seen in figure 3.

| | Task Mode | Task name | Duration | Start | Finish | Predecessors |
|---|---|---|---|---|---|---|
| 1 | | **Report writing** | **360 days** | **Thu 10/11/1** | **Wed 2/26/2** | |
| 2 | | State of art writing | 130 days | Thu 10/11/1 | Wed 4/10/1 | |
| 3 | | App documentation writing | 130 days | Thu 4/11/19 | Wed 10/9/1 | 2 |
| 4 | | Results writing | 100 days | Thu 10/10/1 | Wed 2/26/2 | 3 |
| 5 | | Prototype development | 30 days | Fri 2/1/19 | Thu 3/14/19 | |
| 6 | | Surveys creation | 40 days | Fri 3/15/19 | Thu 5/9/19 | 5 |
| 7 | | **On-site information gathering** | **17 days** | **Fri 5/10/19** | **Mon 6/3/19** | **5** |
| 8 | | On-site information gathering | 15 days | Fri 5/10/19 | Thu 5/30/19 | 6 |
| 9 | | On-site surveys | 2 days | Fri 5/31/19 | Mon 6/3/19 | 8,6 |
| 10 | | On-line surveys | 6 days | Fri 5/31/19 | Fri 6/7/19 | 8,6 |
| 11 | | Survey data analysis | 5 days | Mon 6/10/1 | Fri 6/14/19 | 9,10 |
| 12 | | **App development** | **80 days** | **Mon 6/17/1** | **Fri 10/4/19** | **11** |
| 13 | | Multimedia data base creation | 60 days | Mon 6/17/1 | Fri 9/6/19 | |
| 14 | | Info data base creation | 60 days | Mon 6/17/1 | Fri 9/6/19 | |
| 15 | | **Interface creation** | **80 days** | **Mon 6/17/1** | **Fri 10/4/19** | |
| 16 | | Menu creation | 10 days | Mon 6/17/1 | Fri 6/28/19 | |
| 17 | | Navigation creation | 25 days | Mon 6/17/1 | Fri 7/19/19 | |
| 18 | | Interface content development | 80 days | Mon 6/17/1 | Fri 10/4/19 | |
| 19 | | 3D model creation & animation | 50 days | Mon 6/17/1 | Fri 8/23/19 | |
| 20 | | Backoffice development | 60 days | Mon 10/7/1 | Fri 12/27/19 | 15 |
| 21 | | **App testing** | **25 days** | **Mon 12/30/1** | **Fri 1/31/20** | **15,20** |
| 22 | | App testing | 20 days | Mon 12/30/1 | Fri 1/24/20 | |
| 23 | | In-situ testing | 5 days | Mon 1/27/2 | Fri 1/31/20 | 22 |
| 24 | | Bug fixes | 20 days | Mon 2/3/20 | Fri 2/28/20 | 23,22 |

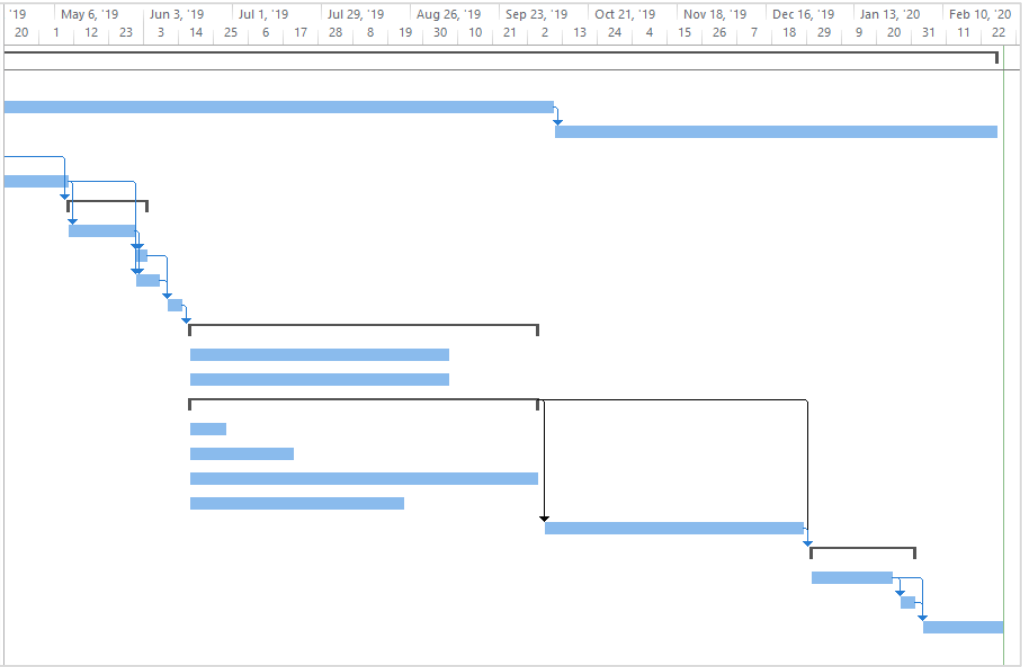


**Figure 3 - Work development schedule**

This project began to be developed on October 2018, as presented in figure 3, it has as main tasks: the data collection *in-situ* and perform the surveys, the application development, the backoffice development, the tests, and the dissertation writing along all the period.

## 1.3. Scientific paper

As a contribution to the scientific community, a scientific paper was produced based on the conducted work, which was presented at the 1st International Congress on Advances in Emerging Trends and Technologies in Quito, Ecuador (https://icaett-conferences.org/icaett2019/), on May 29, 2019.

## 1.4.Dissertation structure

In chapter 1, it is made an introduction to the project, together with objectives and the schedule to develop it.

In chapter 2, it is discussed the state of art, an analysis of AR technology and of the available frameworks/SDKs and finally some similar work

the state of art is discussed, it is analyzed the AR technology and available frameworks/SDKs to find one that fits the requirements of this project and finally some similar works.

In chapter 3, there is an analysis of the tools used to develop the application, followed by the development of the application and backoffice.

In chapter 4, the results obtained in this work are presented and the app tests analyzed.

Chapter 5 presents the conclusions and future work.

# 2. State of Art

In chapter 2, it is discussed the state of art, an analysis of AR technology and of the available frameworks/SDKs and finally some similar work.

## 2.1. Augmented Reality

The use of AR enrich user's experience in several fields, from Civil and Infrastructure to Engineering and Education to offer interaction with the environment without the need for physical objects but through the use of digital objects [8] [9].

The word “augmentation” from AR means creating new virtual objects and placing them in the scene, it could imply superimpose 3D virtual objects over the real ones. It is about creating new environments from the real world. For this, AR may be applied to all senses, like the use of 3D sound to give the user the sensation of being in that new environment surrounded with new things and which is in harmony with the real world [10].

The AR could also offer the possibility of bidding personalized content, that is, in an environment in which some interaction with AR has been implemented, content can be provided for children and adults, without the need to make any changes in the real-world objects.

AR is a variation of Virtual Environments (known as virtual reality) with the difference that in Virtual Environments, all objects are virtual, so the user does not see the real world. In AR the user perceives the world with superimposed virtual objects that coexist in the same space and can even appear to change or affect the objects of the real world [10].

Currently, AR is a technology that is in a mature stage of development, however technology continues to be improved, making it more efficient in terms of processing, recognition of images and surfaces and positioning.

In the next section will be made a study of existing AR technologies (applicable to this work), available frameworks/SDKs and a comparison of them considering their advantages and disadvantages.

## 2.2. How AR Works

AR consists of three steps: Recognition, Tracking and Mixing [11].

In the recognition stage, an image, object, body, or space is analyzed. Next, in the Tracking stage, the spatial context is analyzed in real-time, that is, the whole scene included around the object that was analyzed in the first stage. Finally, in the third stage, Mix, a virtual object like video, 2D, 3D, text, etc., is superimposed on the scene.

### 2.2.1. Tracking techniques

Tracking is the process to determine the user position and orientation in the environment, this is important to get more realistic and accurate results when placing virtual objects in the environment [12].

#### Marker-based tracking

Marker-based AR uses objects from the physical world as a point of reference to superimpose virtual objects, as can be seen on figure 4. For this, the camera constantly captures the objective to process and estimate the position of virtual object related to the real world [11].

**Figure 4 - Marker-based AR**

#### Marker-less AR tracking

Marker-less AR uses a combination of electronic devices such as accelerometer, compass, and GPS to process and estimate the position of the virtual object related to the real world [11], as can be seen on figure 5.

**Figure 5 - Marker-less AR**

### 2.2.2. Superimposition techniques

The way in which AR is projected into the virtual world determines the level of interaction that the user could have, these ways are: Projection-based superimposition and Object superimposition-based AR.

#### Projection-based superimposition

Projection-based AR works using artificial light onto real world surfaces, this allows a more direct interaction with the user thanks to the possibility of sensing the change of light, to work, this calculates the distance at which the virtual object was initially projected with the distance at which the projection is located when the user interacts, thus offering a similar sensation to touching the said virtual objects [13], as can be seen on figure 6.

**Figure 6 - Projection-based AR**

#### Object superimposition-based AR

Object superposition based on AR totally or partially replaces the objects of the real world, this can be done in two ways [13]:

- Completely hide the object of the real world, for which it has a total mapping of the environment to recreate it by removing the desired object.
- Move the object of the real world, for this, in addition to fully recognize the environment must recognize the object to be moved [14], as can be seen in image 7.

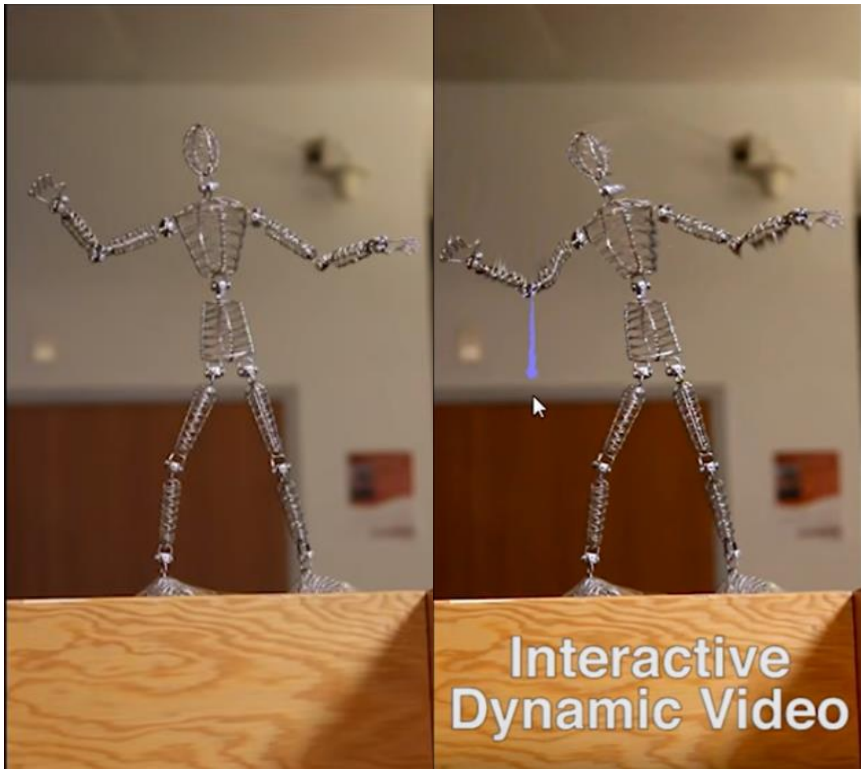


**Figure 7 – Moving an object from the real world [14]**

## 2.3. Current technologies

There are several ways to implement applications with AR, with different technologies. For this work it will be used plane detection and extended tracking.

### 2.3.1. Plane detection

The plane detection is based on detecting characteristic points on the surface with texture recognition and depth to determine if the object is a plane [15].

### 2.3.2. Extended tracking

Extended tracking is the technology that allows to, once a target is detected and the superposition of the virtual object created, this remains available in the same place, even if

the objective has gone out of focus, allowing the user to move freely, almost without limits, without losing virtual objects, it also allows creating content in 360° [16].

This technology is supported by electronic sensors such as the compass and the accelerometer to detect the movement of the device, calculate its position and keep the virtual object in the same place that, in the real world, was created [16].

## 2.4. AR performance

In the context of mobile applications development, the performance that AR must have is closely related to the way it is implemented. Several factors must be considered, but some that affect the most to the performance of an application were selected and the following considerations were done: static vs. dynamic AR, user interaction capabilities and composition strategies [10].

### 2.4.1. Static vs. Dynamic AR

The static implementation is based on the superposition of static objects on the real world, while in the dynamic are used animations or videos. Both use motion tracking to track the real world and place the virtual object over this so, the performance is related to the streaming capabilities of the devices. Below will be analyzed some advantages of each one:

- Simplicity: Implementing static AR is much simpler than with video, this is because the transmission of the static object is lighter than the transmission of several frames per second, as it would be the implementation by video, in this case, a delay in the transmission of frames could be caused, which would lead to a distortion of the video, making the experience less satisfactory;
- Resolution: The video limits the resolution that can be presented for the user to see, it may occur because of the size of the display is not large enough or because the size of the objects in the video are smaller than it is supposed to be. The harmony with the real world is achieved with the combination of objects that compose a video scene, this makes more complicated to implement it in comparison to the static object, in which a single element is created and in which is easier to define its size to fit in harmony with the real world.
- Experience: Dynamic AR can contain videos, animations, interaction with the user and sounds while Static AR does not contain any of these properties, by this, using

Static AR could not cause the sensation of interaction with the real world and become boring or monotonous for the user.

### 2.4.2. User Interaction Capabilities

The possibility that a virtual object can interact with the user, whether by touch, voice recognition or specific movements, requires constant analysis of the user interface and sensors, by this reason it could be overloaded if a group of too many interaction listeners attached to too many objects are enabled. To avoid this problem, it is advisable to limit the interaction with the user to a static interface in which actions can act on a specific object but are not necessarily tied to it. In addition, it should always be aware that the scene is being analyzed in real time, which could further overload the processing and decrease the performance of the app.

### 2.4.3. Composition Strategies

The AR provides the possibility to create environments up to 360° which can be very useful to create an immersive experience for the user, however, it must be considered the number of virtual objects that will compose the scene and the points or reference images or planes that will be used to create it. In addition, apart from the purely technical analysis, advantages or disadvantages should be considered when presenting a user with a 360° scene and considering factors such as: user orientation, the possibility of physically moving within the environment, security, blind spots and sounds. This could cause that the scene offers a poor immersive experience due to the scene performance, which not only does not meet the expectations but lead to the rejection by the user.

## 2.5. AR Design Guidelines

The development of AR applications proposes a design challenge, not only in terms of interfaces, but also the content that is presented and the way in which the virtual objects interact with the environment and the user.

For this, it is necessary to consider some design guidelines, for the application to be aesthetically pleasing, so the user intends to use it again. Some guidelines recommended by Google are [17]:

### 2.5.1. Environment

These are the guidelines to be considered when positioning virtual objects and interacting with the environment.

#### Physical environments

The space in which the user is going to make use of augmented reality must be considered, whether large or small, indoors or outdoors, the design of augmented reality must be the same for any of the spaces in which the user can make use of this feature.

#### Define size

Depending on the purpose of the application it must be defined the space that will be used to project the virtual objects. Developer must find the right size, not too big or too small for the user to view the real world and virtual objects correctly.

### 2.5.2. User

The guidelines to be considered regarding the user and the environment in which the user is using the application.

#### Encourage movement

Since most users have not experienced 360° applications as AR applications are, they should be encouraged to move to discover more than they can see in a static position.

#### Types of movement

According to the type of movement that is desirable to interact with the application, the app must indicate and guide the user through the different types of movement that are available.

#### Accessibility

Different methods of interacting with the augmented reality application must be implemented to provide accessibility, these methods should always be explained to the user in order to give them the possibility to use it.

#### Safety & Comfort

It is important to keep users safe and comfortable while using the application, for this, the following points should be considered:

- Keep the user safe: remind the user to constantly check their surroundings;
- Do not make users walk backward;
- Avoid long play sessions;
- Get comfortable;
- Take a break.

### 2.5.3. Content

The guidelines to be considered regarding the content of the application are directly related to the user interests, so it could be said that the application may be attractive to the user, some criteria to be considered are:

#### Modeling

It is better to use life-size objects and modify their size as necessary, as well as detailed objects even if the user is not going to see all details at first sight.

#### Texturing

The texture of the objects should be as like the real world, without repetitive patterns since they look false to the human eye. However, the textures should not be heavy, the resolution should be at most 2k.

#### Light, ambient occlusion and shadow planes

The lighting of the environment must interact or change the virtual object, in addition, the handling of the shadows should be as realistic as possible, otherwise the object will look more like a still image than a virtual object.

#### Depth and presence

The depth perception should be used when making an app with AR, it can be achieved changing the lighting and/or shadows. The perspective should change too, this can be achieved by managing the location and size of the virtual object, always considering the environment, so the objects are correctly located and it feels like they are really located in it.

#### Plane discovery

Surfaces must be detected whether horizontal, vertical, or inclined, and this will be communicated to the user to know that the virtual object can be positioned on it. Depending on the surface the objects will be located and interact differently with the user and the environment.

#### Optimal placement range

The positioning of the object must be in a range and distance in which the visualization of it is the most comfortable and convenient to interact as needed by the application. Three existing positions must be considered: low position, high position and medium position; it should be considered that these positions could change depending on the inclination of the device.

#### Placement

Depending on the behavior that is desired for the application, the way of positioning the objects must be considered, which can be: automatic, manual, or dragging.

#### Anchoring

If there are objects composed of several other objects (for example a chess board with its pieces), the objects that compose the big one must be anchored, such as the chess board pieces anchored to the board.

#### Selection

The user must be able to select and interact with the object, for this, user should always receive a confirmation that it is interacting with the object.

#### Translation, multiple surfaces, and translation limits

The user must first select the object and then drag the object to move it. The surfaces to which it can move and the limits on which the object can move must be considered, either by distance or by plane change (for example from horizontal to vertical).

#### Rotation

The user must select the object first and then, either via gestures or by buttons, rotate the object as the user wishes.

#### Scaling

The user must select the object and scale it, however, the developer must limit the minimum and maximum sizes (or deny scaling), considering the objective of the application.

### 2.5.4. Interaction

The developer must previously define what levels of interaction the application is intended to have.

#### Initialization

The transition to the AR function must be clear to the user and indicate that it is started, it can be achieved using an icon or visual effects.

#### Offscreen and audio exploration

If virtual objects are positioned outside the user's visual field, clues of where they are located must be provided so that the user moves and finds them.

#### Haptic feedback

Vibration is commonly used as haptic feedback, but this is not recommended to be used on applications with AR, low frequency sounds can be used instead.

#### Reset

The user must be able to reset the AR experience, either using the back button or using a specific interface button.

#### Interface

The experience must be immersive and not distract the user, the developer should use the least amount of 2D components or alerts (as popups) and make the interface components as simple and comprehensive as possible, so the user does not have to think about the behavior of the buttons before using them.

#### Onboarding & instructions

A fluid and intuitive experience should be provided using (if any) existing usage patterns. If a guide on the use of the application is necessary, the functions should be indicated step by step and not all in a single tutorial so that the user can assimilate this information.

Landscape & portrait

The possibility of using the device in portrait and landscape mode should be provided, but if not possible due to the requirements of the application, it should be clearly established the mode of use of the app.

Errors

The user must be notified when there is an error such as: low light, camera movement is too fast or camera sensor blocked, and allow the user to recover as soon as possible from them.

## 2.6. Frameworks/SDKs

This sub-chapter analyzes available frameworks and presents a comparison of these to determine which is the most appropriate to use in the present project.

### 2.6.1. Google ARCore

ARCore is the Google framework for building applications with AR and its operation could be summarized in that it basically does two things: tracks the position of the device, whether it moves or is static, and creates its own version of the real world to its understanding. To achieve this, ARCore uses the camera to identify points of interest named "features" and tracks how these points move over time, along with other sensors such as the accelerometer and compass, it determines the position and orientation of the device as it moves through space [18]. Some of the ARCore APIs are available for Android and iOS.

Google ARCore has 3 fundamental characteristics to integrate the virtual with the real world, this are [18]:

- Motion tracking, that allows the phone to understand and track its position relative to the world;
- Environmental understanding, that allows the phone to detect the size and location of all types of surfaces: horizontal, vertical, and even angled surfaces like the ground, a coffee table, or walls;
- Light estimate, that allows the phone to estimate environment's current lighting conditions to project this into the virtual objects.

### 2.6.2. Vuforia

Vuforia is the most complete and used framework to develop applications with AR, incorporating technologies such as image and object recognition, supported by a database that can be in the cloud (cloud recognition) or in-device, recognition of several images at the same time (multi-image recognition), plane detection, extended tracking, video playback and virtual interfaces [19] [20].

Vuforia is available for development with programming common tools such as Visual Studio, XCode, and Visual Studio and it is integrated natively in Unity [20].

Likewise, Vuforia is compatible with a wide variety of phones and tablets with Android and iOS and for several smart lenses like Microsoft HoloLens, ODG R7 and Vuzix M300 [20].

### 2.6.3. Wikitude

Wikitude incorporates technologies such as object recognition, SLAM (Simultaneous Localization and Mapping), instant tracking for plane detection, image recognition, recognition of several images at the same time (multi-image recognition), Geo-AR (Geo-localization + AR), extended tracking and cloud recognition. In addition, it is available for multiple platforms such as Android, iOS, Windows and several smart lenses [21].

Wikitude is available for development in various frameworks such as: Unity, Cordoba, Titanum and Xamarin.

### 2.6.4. EasyAR

EasyAR is an SDK that incorporates technologies such as SLAM, 3D object tracking, screen recording and image tracking, however, some of these technologies are available only for the paid version. It is available for Android and iOS via API and offers integration with Unity [22].

### 2.6.5. MaxST

MaxST is an SDK that incorporates technologies such as instant tracker, SLAM, object tracker, image tracker, marker tracker and QR / Barcode Scanner. It is available for Android and iOS and is optimized for Smart glasses. A prominent service of MaxST is AR Collaboration, which serves to make a kind of video conference in which the user can

generate virtual objects, draw or write in the scene and this will be presented to the counterpart of the video call [23].

### 2.6.6. Framework/SDK Comparison

In the table below, there is a list of some of the best Framework/SDK to develop this kind of project. For this analysis only the features needed to accomplish this project have been considered, plus the cost and watermark.

**Table 1 - Framework/SDK comparison**

| | ARCore | Vuforia | Wikitude | EasyAR | MaxST |
|---|---|---|---|---|---|
| Image recognition | ✓ | ✓ | ✓ | ✓ | ✓ |
| 3D recognition | ✓ | ✓ | ✓ | - | ✓ |
| Geo-location | ✓ | - | ✓ | - | - |
| SLAM | ✓ | ✓ | ✓ | - | ✓ |
| Extended tracking | ✓ | ✓ | ✓ | - | ✓ |
| Free with Watermark | - | ✓ | ✓ | - | ✓ |
| Free (no watermark) | ✓ | - | - | - | - |
| Cost | Free | $42/month | $2490 | Free | $499 per-app |

Considering the advantage of no watermark, available features, engine power, ease of use and costs shown in the comparative table, in addition to being a Google tool and Android compatibility is the best among others, it is concluded that the best framework/SDK to develop this work is ARCore.

## 2.7. Geolocation

Geolocation is used to know where the user is located, this allows to create smarter applications with more and better features. Geolocation is based on the use of several sensors such as GPS, network location and / or Wi-Fi to determine the location of the device [24].

### 2.7.1. Global Positioning System (GPS)

Considered the most accurate positioning system but the one that consumes more energy, GPS uses satellites to fix the position of the mobile unit. To get the position, the device receives several signals of a segment of satellites, then it calculates the time taken to receive the signal with nanoseconds precision, whit this information it calculates the device position on the earth surface [25].

### 2.7.2. Cell-ID

Cell identification (Cell-ID) determines the device location related to the location of the control cell or base station, this method is the less precise because of the coverage of the cell and therefore, the accuracy of the location of the device can vary from 2km to 20km [25].

### 2.7.3. Wi-Fi

This is less accurate than the GPS but more accurate than cell ID, it uses the location of the connection point to which the device is connected plus the distance to where the Wi-Fi sender is located to provide information about the location. The accuracy of this also depends on the information provided in the database about the locations of the access points in the network supplying the service [26].

## 2.8. Similar works

There are some works developed with AR that integrate animals in education, some published as thesis/dissertation, others as papers and others simply provided by a company with profit intentions. There are also some works without AR focused on birdwatching. Below is the analysis of some of them.

### 2.8.1. AR in zoology

The work called “Augmented reality applied in the design of learning activities in zoology” (AR in zoology) is an application developed to support the teaching of zoology. This application operates with cards used in common classes in schools as targets for AR. When a card is focused, a digital model of the corresponding animal is projected over it, as can be seen on figure 8.

The app uses animal sounds and has two modes of operation to make learning activity even more interactive, however, through an analysis it was noticed that the sound is not a great contribution to the application and could even be counterproductive when using the application inside of a classroom [27]. This application uses:

- **Framework:** Vuforia
- **Android API:** 19 (KitKat)
- **Target devices:** Smartphones
- **AR activators format:** Cards


**Figure 8 - Augmented reality applied in the design of learning activities in zoology**

As this app is intended to be used mainly by children, the interfaces have bright colors and striking shapes.

### 2.8.2. AR for Studying the Lives of Animals

The work called “An Augmented Reality Application for Studying the Lives of Animals” (AR for studying the Lives of Animals) is an application about the life of animals. It uses some animals, but it is focused mainly on the life of a lion. The operation of the application is the following: when the marker that activates the AR of the lion is detected, the scene

begins. Using animations, sounds and time markers, the life of a lion is shown, including activities such as hunting food, eating, being attacked and dying [28], as can be seen on figure 9. This application uses:

- **Development:** Visual Studio, C#, Unity
- **Graphic design:** Adobe Illustrator
- **AR activators format:** Book


**Figure 9 - An Augmented Reality Application for Studying the Lives of Animals**

Although the characteristic of AR is the strong part of this application, the interface is saturated with letters, which makes it less user friendly.

### 2.8.3. AR to increase learning in museums

The work called "User of augmented reality to increase learning in museums" (AR to increase learning in museums) is an application that uses AR inside a museum. Focused on the section of a rainforest, it has three modes of operation: the first is a section with static information about the animals, the second one uses AR with image targets to create virtual objects of the corresponding animal and the third, as can be seen on figure 10, uses a book with illustrations that activate the AR, this one offers interactive playing activities designed for learning [29]. This application uses:

- **Framework:** Vuforia
- **Development:** Unity
- **AR activators format:** *In-situ* image targets, book


**Figure 10 - Use of augmented reality to increase learning in museums**

Both the interface and the AR are a good design example in this application, however, when reading the text when using the AR, the contrast of the letters could prevent it from being well distinguished in certain circumstances, such as white backgrounds.

### 2.8.4. AR as education by using animal announcer

The work called "Augmented reality as education by using animal announcer based on Android application" (AR as education by using animal announcer) is an application focused on initial teaching about animals. Using cards as image targets, the AR is activated and shows a virtual model of the animal and reproduces its' sound [30], as can be seen on figure 11. This application uses:

- **Framework:** Vuforia
- **Development:** Unity
- **Modeling:** Blender
- **AR activators format:** Cards

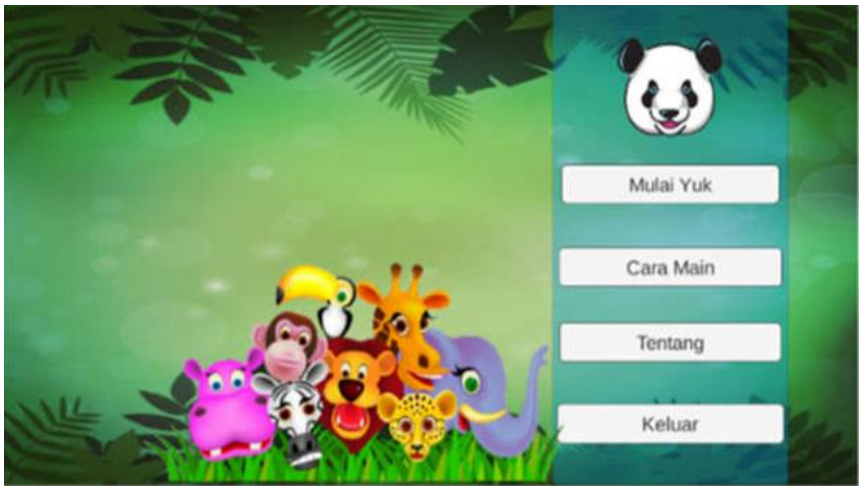


**Figure 11 - Augmented reality as education by using animal announcer based on android application**

Since this application is intended to be used by children, the design is very simple, also the use of AR is simple and quite basic.

### 2.8.5. AR to support the experiential quality of life-like in a museum

The work called "The design of a smartphone-based AR application to support the experiential quality of life-like in a museum" (AR to support the experiential quality of life-like museum) is an application to be used inside of a museum [31]. It has various modes of use:

- Adding on with an AR environment: Create an AR environment simulating that the user is surrounded by several animals, as can be seen on figure 12, here it is used: ground plane detection and extended tracking;
- Virtual guide: Activated by an image target, it presents a virtual model of an animal and information about it;
- Looking at the showcased animals through AR: Activated by an image target, it presents a virtual model of the animal corresponding to the exhibition;
- Interacting with the virtual animals: When an animal has appeared, through gestures on the screen is creates an interaction with the animal, this can be a movement or even follow the user;
- Adding fictitious elements of hybrid animals: When two animals approach each other, an animation is presented and, with the use of an algorithm, the animal parts are mixed, generating a hybrid of these.

This application uses:

- **Framework**: ArKit
- **Development**: Unity

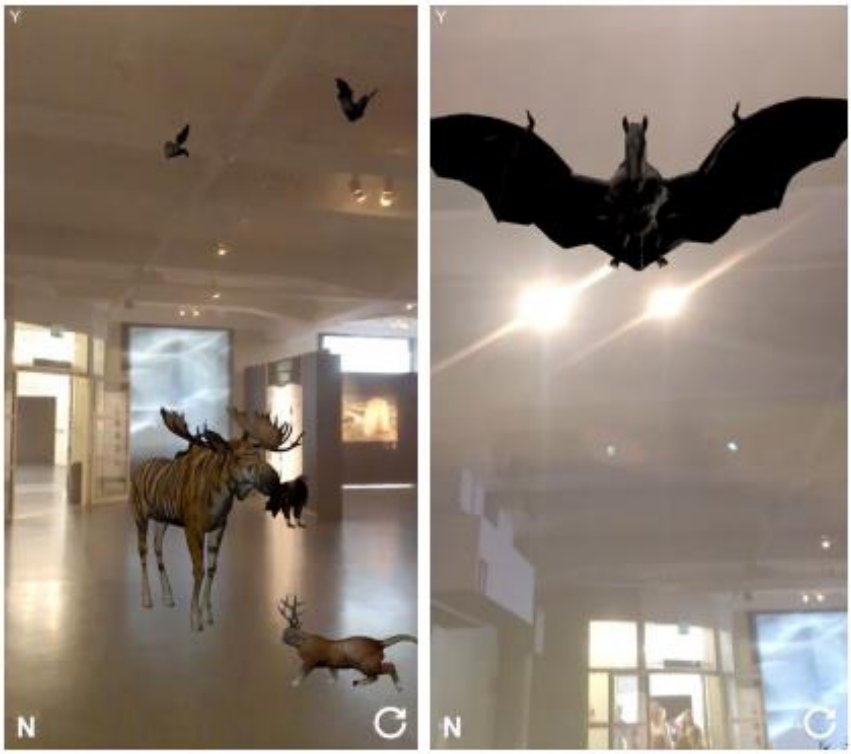

**Figure 12 - The design of a smartphone-based AR application to support the experiential quality of life-like in a museum**

This app is totally focused on the use of AR, it is a good example of using AR indoors with very useful and striking features.

### 2.8.6. Warbler Guide App

Warbler Guide App was developed as a companion of The Warbler Guidebook, by Tom Stephenson and Scott Whittle, it was developed by the Princeton University Press and it is available for Android and iOS.

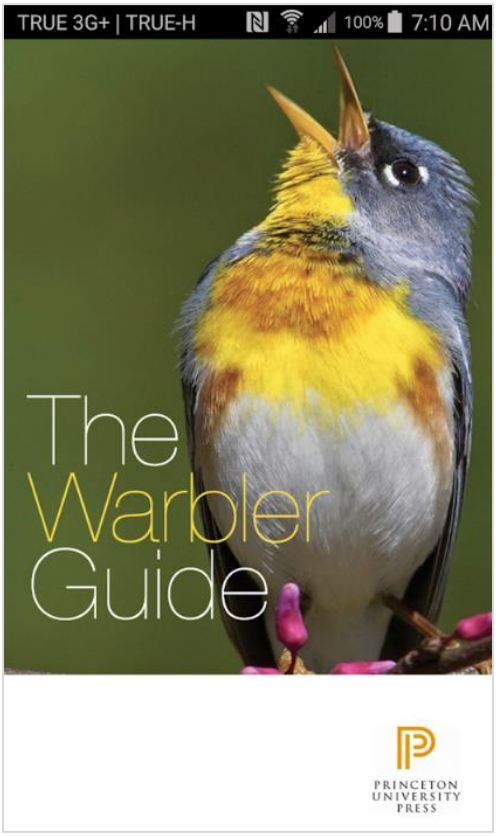


**Figure 13 - The warbler guide**

This app presents relevant information of the warblers, such as specific characteristics, sounds, place where they are, migration routes, among others. It offers the feature of doing searches by sound, color, and specific details of the bird. It also has high resolution 3D models and offers an interactive view of them [32].

### 2.8.7. South American Birds Sounds

It is an application that has information about over 11400 species divided into families. With the use of an internet connection, it provides information about birds and multimedia content with sounds, images and videos [33].


**Figure 14 - South American Birds Sound**

An application with very useful content, the only negative, is the need of an internet connection to view the multimedia content.

### 2.8.8. Bird Data - Ecuador

This app offers information about birds in Ecuador, scientific information, range, subspecies and other information about more than 1600 species with an option to download photos, maps and sounds [34].

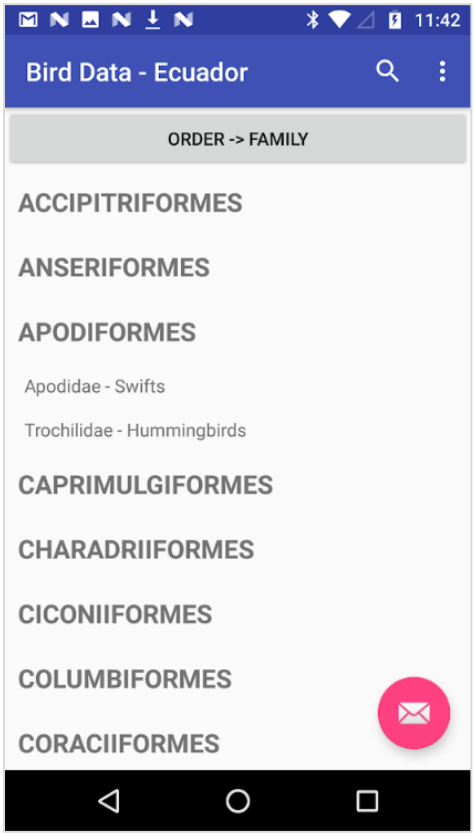


**Figure 15 - Bird Data – Ecuador**

A simple application with bird information from Ecuador, with a fairly basic interface.

### 2.8.9. Similar works analysis

An analysis was made to evaluate which are the characteristics that make this work the better option for users. For this purpose, numbers were used instead of the complete names to represent the apps in the following table (Table 2):

1. AR in zoology;
2. AR for Studying the Lives of Animals;
3. AR to increase learning in museums;
4. AR as education by using animal announcer;
5. AR to support the experiential quality of life-like in a museum;
6. Warbler Guide App;
7. South American Birds Sounds;
8. Bird Data – Ecuador.

**Table 2 - Similar works analysis**

| | AR | Animal Bio | Animal Gallery | Animal Videos | Animal sounds | Touristic routes | Works Offline |
|---|---|---|---|---|---|---|---|
| **1** | ✓ | X | X | X | ✓ | X | ✓ |
| **2** | ✓ | ✓ | X | X | ✓ | X | ✓ |
| **3** | ✓ | ✓ | X | X | X | X | ✓ |
| **4** | ✓ | X | X | X | ✓ | X | ✓ |
| **5** | ✓ | X | X | X | X | X | ✓ |
| **6** | X | X | ✓ | X | ✓ | X | - |
| **7** | X | ✓ | ✓ | ✓ | ✓ | X | - |
| **8** | X | ✓ | ✓ | X | ✓ | X | - |

✓: Feature exist X: Feature doesn't exist -: Feature exists partially

Once made this analysis, it can be evidenced that this project has some unique and relevant characteristics that will offer the user a better experience than those offered by other related works.

# 3. Development

This section describes the methodology used to develop this work, the scope of this work, as well as the functionalities identified in the requirements, prototypes, app development and test cases.

## 3.1. Methodology

This work was developed with an agile approach, but it does not use a defined methodology, however, the methodology was based on iterations. For this it was held meetings every 2 or 3 weeks, in which the work status and tasks were reviewed. When changes were requested, new tasks are defined for the next iteration.

## 3.2. Acceptance survey

It was developed a survey using some variables of the UTAUT model to define if the application to be developed would be interesting for users and if they intend to use it. To achieve the needed requisites [35], the number of respondents was defined considering the Central Limit Theorem, which indicates that if you have a large group of independent variables and all of them follow the same distribution model, its sum is distributed according to a normal distribution [36]. This survey was reviewed over some iterations until the final version was obtained. The survey consisted of 24 questions and was conducted online through google forms (Appendix A and B).

## 3.3. Acquired materials

Since there are skills that are not mastered, such as graphic design and 3D animation, the logo, brand book and 3D models were developed by a third party.

A freelancer was hired to develop the logo and the brand book of the application, for the logo, it was provided several versions of it until reaching the final one. For brand book it was described the essence of the app.

For 3D models, the hummingbird was purchased at https://www.turbosquid.com, and the toucan was downloaded from a free repository: https://poly.google.com.

## 3.4. Requirements

To collect and define the requirements of the app, the potential client in Mindo's tourism office was contacted, as well as the dissertation supervisors, to define a feasible scope to be realized within the available timeline. The requirements where defined for the Android app, with and without AR; and a backoffice to manage the contents.

### 3.4.1. Android app requirements

- Offline: The app must work offline, with local files that must be downloaded at the first time of use. If there is an update, this will be made at the starting of the app;
- Multilanguage: The app must be bilingual (Spanish – English), not only in interfaces but also, if applicable, in the multimedia content;
- Content with AR: The app should offer AR content;
- Content without AR: The app must also offer content without AR such as information about species, images, sounds and videos;
- Easy to use: The interfaces of the application must be intuitive and user-friendly.

#### Functionalities with AR

These functionalities must work for each spot/bird that activates AR:

- Detect horizontal planes: The augmentation will be made if a horizontal plane is detected;
- Show virtual animated objects: The object should be animated to get more attention from the user;
- Take a photo: Option to take a photo of user's screen view;
- Share content on social networks: Option to share content on social networks.

#### Functionalities without AR

These functionalities must work for each bird species.

- Provide birdwatching routes: It must provide routes for the user to follow, aided by the GPS;
- Display bibliographic info: Bibliographic relevant information must be shown to the user;

- Display when bird species are in danger of extinction: The user must display an alert when a specie is in danger of extinction;
- Display why species are endangered: If is the case, the user must have complete information about why the specie is in danger of extinction;
- Display photo/image gallery: If it is available, the user must have a photo/image gallery of bird species;
- Display photo/image in full screen: If it is available, the user must have the possibility to see the photo/image in full screen;
- Display video gallery: If it is available, the user must have a video gallery of bird species;
- Display video in full screen: If it is available, the user must have the possibility to watch the video in full screen;
- Display sound gallery: If it is available, the user must have a sound gallery of bird species.

### 3.4.2. Backoffice requirements

The backoffice must provide the capability to manage and update app information.

- Use a login page: The access to the backoffice must have access control;
- Add/Edit bird bibliographic information: Must be capable of adding/editing bird bibliographic info;
- Allow to Upload and Delete bird images: Must be capable of adding/editing bird images;
- Allow to Upload and Delete bird videos: Must be capable of adding/editing bird videos;
- Allow to Add/Edit info about bird species danger: Must be capable of adding/editing in danger bird species information;
- Add/Edit hotspot info: Must be capable of adding/editing hotspot info;
- Add/Edit route info: Must be capable of adding/editing route info.

## 3.5. Project Architecture

Considering the requirements of the project, 3 scenarios have been defined in which the development and implementation should be conducted, which were: Android application,

Cloud services with Firebase and website (for the backoffice). For the android application, the SQLite database (included in Android) was used for storage and internal storage to store the multimedia content downloaded from the cloud. For cloud storage Firebase was used, with Cloud Firestore services for information storage and Cloud Storage to store multimedia content. Finally, for the backoffice, Angular 2 was used to develop the user interface.

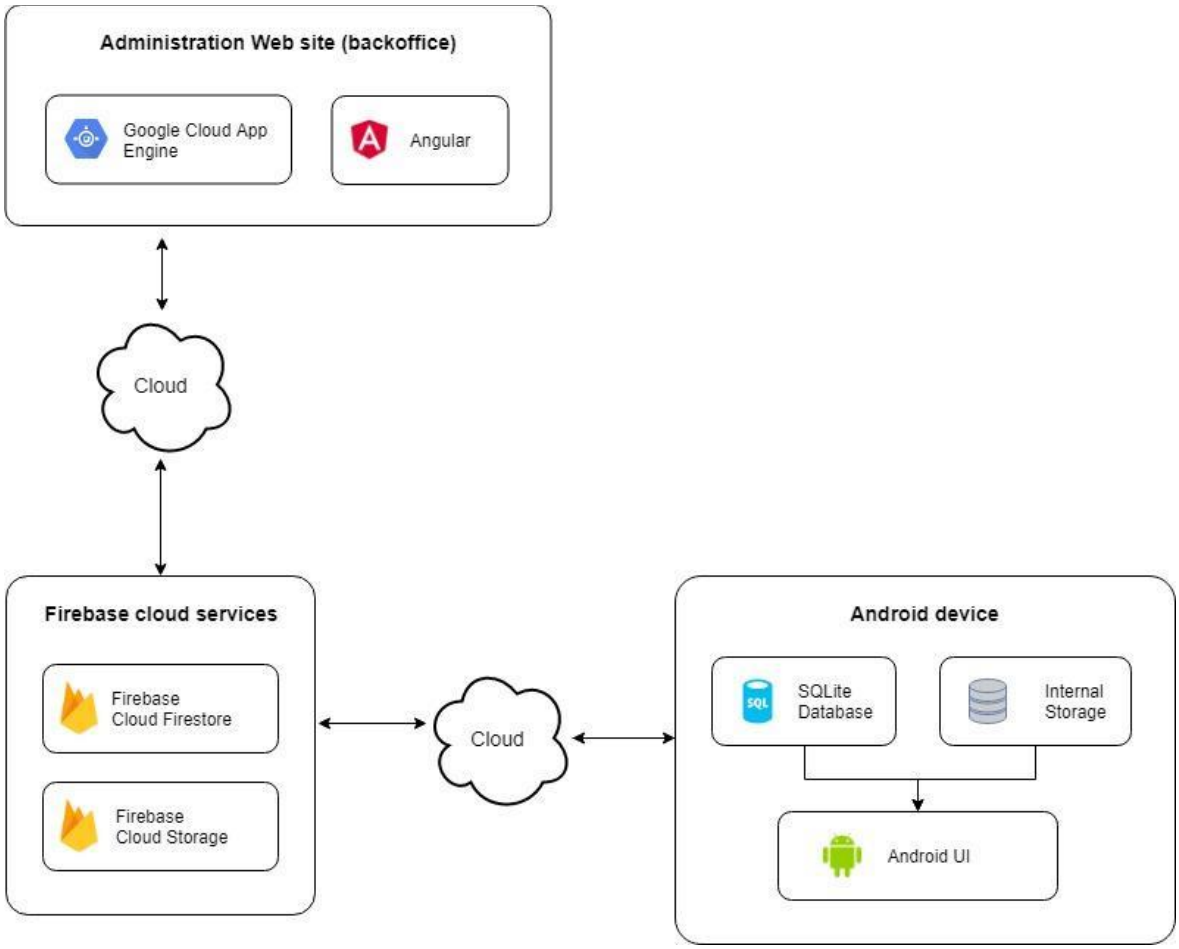


**Figure 16 - Project architecture**

Figure 16 depicts the architecture of the project, emphasizing on the communication between the backoffice and the Android application that is conducted through cloud services.

## 3.6. App scope

This project is focused on birdwatching in Mindo, it should be considered that even though it seeks to promote tourism in the area does not seek to promote any tourist establishment.

The scope regarding the number of bird species that will be included in the application is limited to 200 and the number of 3D virtual objects to two dues to time and economic limitations.

## 3.7. Development tools

Considering the analysis conducted in section 2.6, it has been decided to use ARCore to develop the AR functionality, along with Sceneform to import and render the virtual objects to the application, and Android API level 24. For the prototypes was used Adobe XD and for the backoffice Angular 2 with Angular CLI. The standards of Google Material Design were used to define the design of the app.

### 3.7.1. ARCore

ARCore allows to make an AR application with Android native libraries to provide the best performance to it. There is a plugin in Android studio to make even easier the development of apps with AR.

### 3.7.2. Sceneform

Sceneform allows to render 3D scenes without any knowledge on OpenGL. Using the plugin for Android Studio it is easy to import, view and build 3D objects [37].

### 3.7.3. Adobe XD

Adobe XD is an easy free tool that provides templates to follow the guidelines of Google Material. In addition, Adobe XD provides the option to publish an online app prototype for review, available worldwide to anyone who requires it.

### 3.7.4. Android API level 24

The Android API level used for this work is 24 that stands for Android Nougat. With this API level it is ensured that 57.9% of existing Android devices will be able to execute the application (to February 3, 2019) [38], as can be seen on figure 17.

| Version | Codename | API | Distribution |
|---|---|---|---|
| 2.3.3 - 2.3.7 | Gingerbread | 10 | 0.3% |
| 4.0.3 - 4.0.4 | Ice Cream Sandwich | 15 | 0.3% |
| 4.1.x | Jelly Bean | 16 | 1.2% |
| 4.2.x | | 17 | 1.5% |
| 4.3 | | 18 | 0.5% |
| 4.4 | KitKat | 19 | 6.9% |
| 5.0 | Lollipop | 21 | 3.0% |
| 5.1 | | 22 | 11.5% |
| 6.0 | Marshmallow | 23 | 16.9% |
| 7.0 | Nougat | 24 | 11.4% |
| 7.1 | | 25 | 7.8% |
| 8.0 | Oreo | 26 | 12.9% |
| 8.1 | | 27 | 15.4% |
| 9 | Pie | 28 | 10.4% |

**Figure 17 - Android version distribution (to February 3, 2019)**

We may notice that this percentage is not considerable, but it needed to be limited to this version of Android due to the ARCore constrains that require an Android API 24 or higher.

### 3.7.5. Angular 2 and Angular CLI

Angular is a development platform for building mobile and desktop web applications using TypeScript/JavaScript [39]. The angular CLI is a tool that allows the developer to create the application structure in an easy and standard way.

### 3.7.6. Google Material Design

“Material Design is a visual language that synthesizes the classic principles of good design with the innovation of technology and science” [40].

Android material aims to unify the design through different platforms offering the developer the possibility to customize interfaces to create an own and innovative enterprise image.

Inspired by objects, textures, and colors of the real world, it creates hierarchy, meaning and focus on such a way that users are immersed when viewing applications.

Material design offers to developers a complete guide to build apps and web sites in which describes every feature of material design and how to implement it.

### 3.7.7. Firebase

Firebase provides services for data storage with high availability and efficiency in data transmission. Its API is simple to integrate with native Android and, in addition, it offers plans with very affordable costs. For this work it was used the Blaze plan (pay per use), which allows us to integrate the project with Google Cloud Platform too [41].

## 3.8. Prototyping

It was used Adobe XD to build the prototypes considering the guidelines provided by Google in Material Design and inspired on Adobe Portfolio designs.

### 3.8.1. App design

It is needed to get the Google Material UI Kit for Adobe XD to build Android prototypes in this application.

The main menus are inspired by the layout of Adobe Portfolio, as can be seen on figure 18.

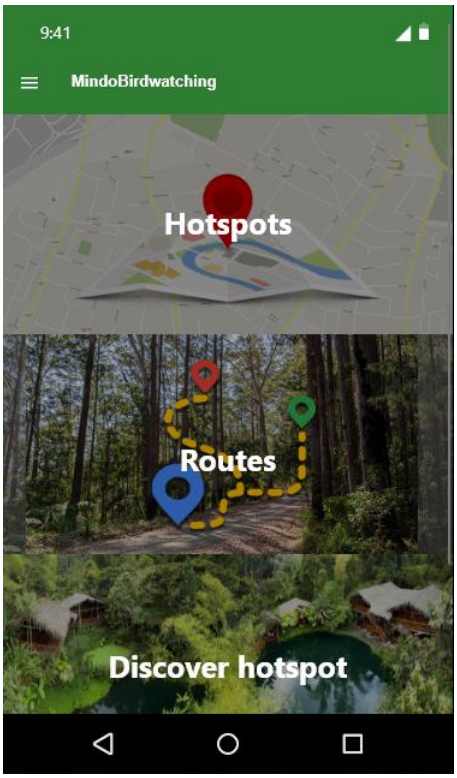


**Figure 18 - Main menu prototype**

The main menu, top app bar and bottom app bar follows the guidelines of Google Material as well as font sizes, the colors were selected in accordance with the Material Color pallet and, most of the icons were provided by Google Material, as can be seen on figure 19.

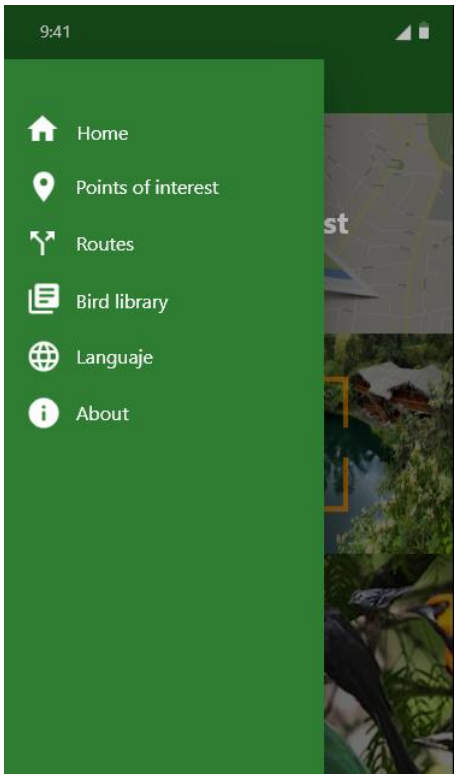


**Figure 19 - Menu and app bars prototype**

Once the prototypes met the requirements, the development of the application was started based on these and using the technologies previously exposed.

## 3.9. Development

The development was primarily focused on the main features of the app: main menu, hotspots, routes and bird library with location and maps, reading/saving files from/to internal storage, multi-language, storing and reading information from SQLite.

After these, it was implemented the Geofences with notifications and the AR option with plane detection and virtual objects. Finally, for the option to share or save a photo it was used PixelCopy to take the screenshot (SurfaceView object) and transform it into a bitmap [42], to allow to treat it as desired, either share or save it into the mobile device.

## 3.10. Database structure

By using Firebase Cloud Firestore that is a NoSQL database it was defined a simple structure to facilitate search for information, as well as the facility to store information in several languages. In addition, in this database is stored the information of the location where the

images, videos and sounds are, to locate them later when using Firebase storage in a simple way.

Five main collections were created for this, which are:

### HOTSPOT

This document contains the hotspot information, grouped in maps for each language and an array with available birds, as references, for the hotspot (birdColRef), as can be seen on figure 20.

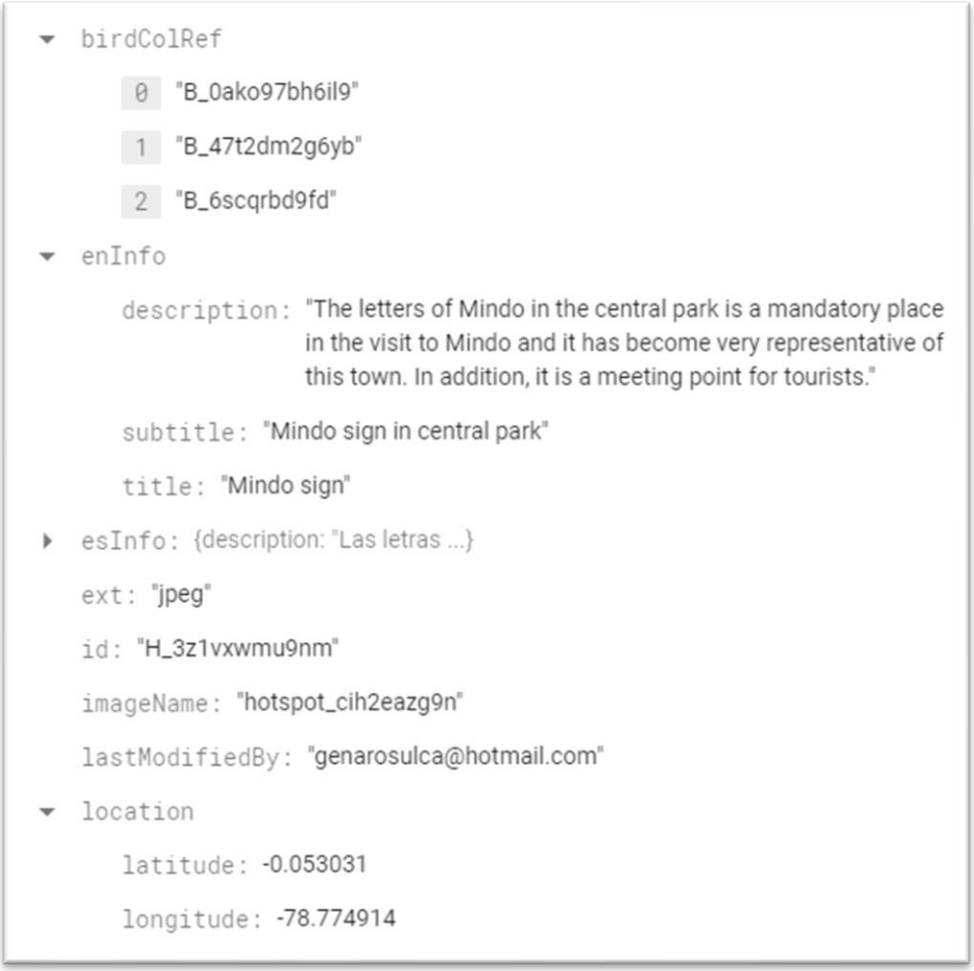


**Figure 20 - Hotspot document**

### ROUTE

This document contains the route information, grouped in maps for each language, an array with available birds, as references (birdColRef) and an array with available hotspots, as references too, on the route (poiColRef), as can be seen on figure 21.

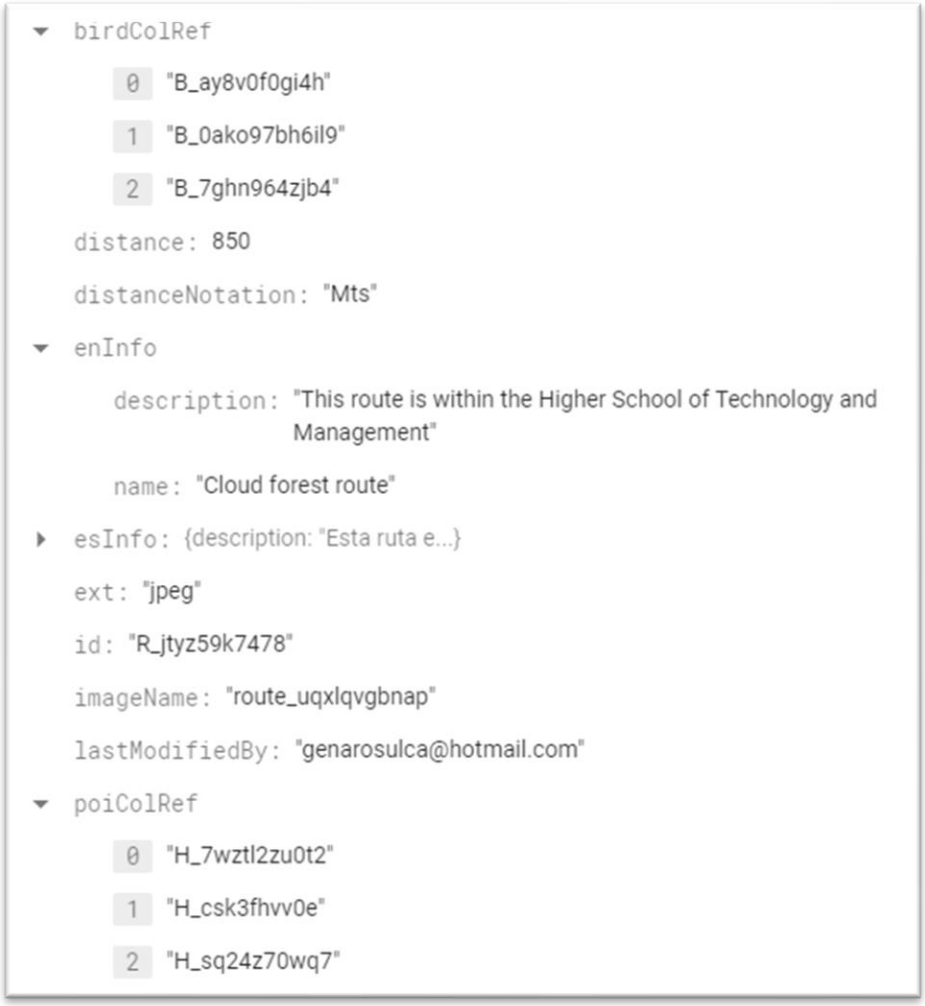


**Figure 21 - Route document**

### FAMILIES

The family document contains the information of the bird family, grouped in maps for each language, as can be seen on figure 22.


**Figure 22 - Family document**

BIRD

This document contains the information of the bird grouped in maps for each language, a matrix with the information of the image gallery, another one for videos and another one for sounds, as can be seen on figure 23. In addition, there is the field “activateAR”, which serves to indicate whether or not it will be AR implementation available in the application, it should be noted that this field will not be accessible for modification from anywhere other than the firebase console.

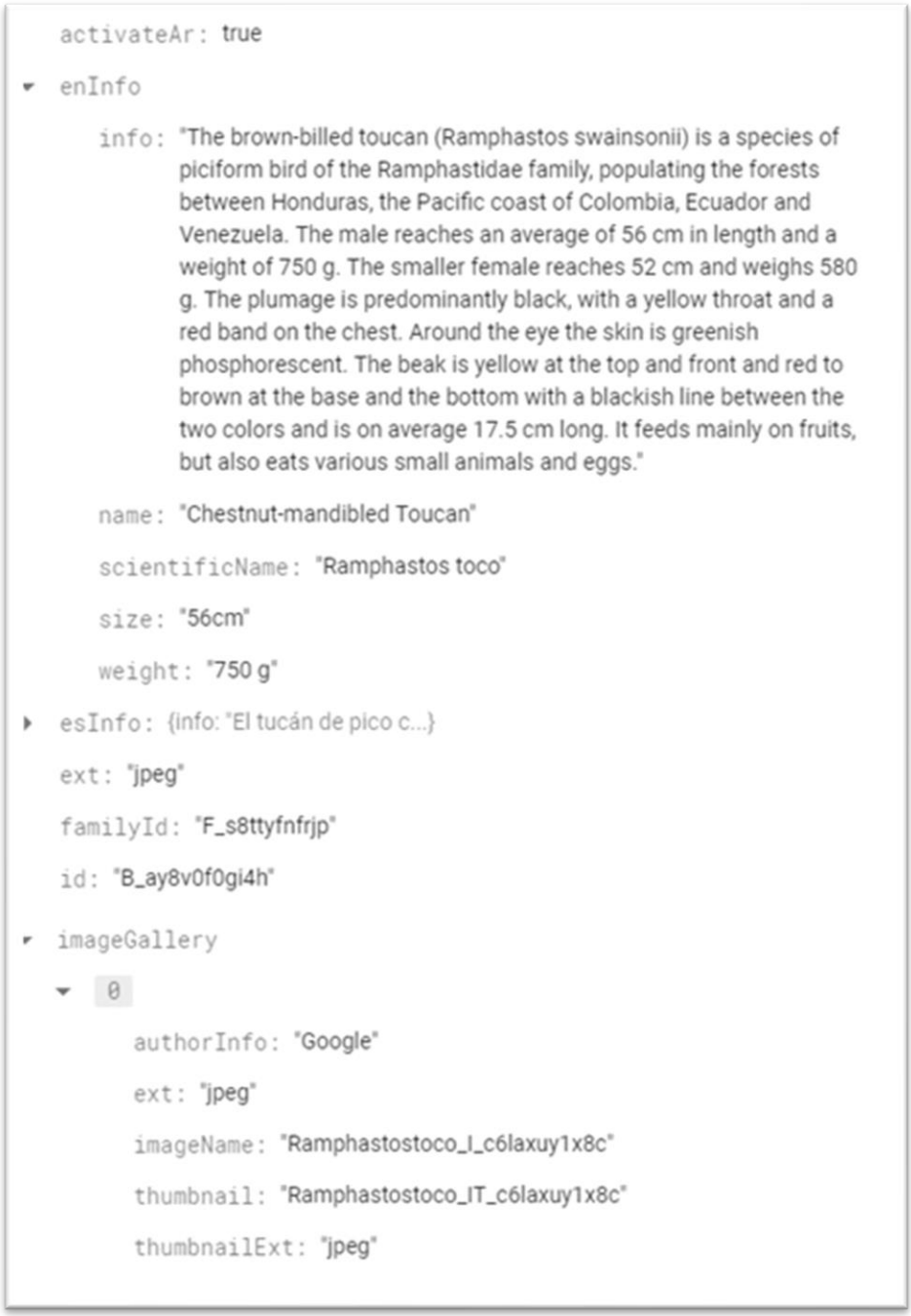
activateAr: true
enInfo
info: "The brown-billed toucan (Ramphastos swainsonii) is a species of piciform bird of the Ramphastidae family, populating the forests between Honduras, the Pacific coast of Colombia, Ecuador and Venezuela. The male reaches an average of 56 cm in length and a weight of 750 g. The smaller female reaches 52 cm and weighs 580 g. The plumage is predominantly black, with a yellow throat and a red band on the chest. Around the eye the skin is greenish phosphorescent. The beak is yellow at the top and front and red to brown at the base and the bottom with a blackish line between the two colors and is on average 17.5 cm long. It feeds mainly on fruits, but also eats various small animals and eggs."
name: "Chestnut-mandibled Toucan"
scientificName: "Ramphastos toco"
size: "56cm"
weight: "750 g"
esInfo: {info: "El tucán de pico c...}
ext: "jpeg"
familyId: "F_s8ttyfnfrjp"
id: "B_ay8v0f0gi4h"
imageGallery
0
authorInfo: "Google"
ext: "jpeg"
imageName: "Ramphastostoco_I_c6laxuy1x8c"
thumbnail: "Ramphastostoco_IT_c6laxuy1x8c"
thumbnailExt: "jpeg"


**Figure 23 - Bird document**

VERSION

This document contains the information of the current version of the database, as can be seen on figure 24.

It should be noted that all documents have the "lastModifiedBy" field, which registers the last user that make changes to the document.


**Figure 24 - Version document**

## 3.11. App development

The development of the application was done in native Android, with Java language to process logic and XML to build the interface.

### 3.11.1. Permissions

To make use of certain resources such as the camera, it is necessary to define the permissions in the AndroidManifest.xml of the application, the permissions that are defined are:

- Read / write in external storage
- Internet access
- Access to location / change of location
- State of the network
- Using the camera

### 3.11.2. Colors and dimensions

To standardize colors throughout the application, this were defined in *colors.xml*:

- Primary: #2e7d32
- Primary dark: #1b5e20

Likewise, some measures were defined to be used in several parts so that if there is the need to change them, it can be done in a simple and fast way, those were defined in *dimens.xml*, it is worth to say that this was defined according to Material specification [43]:

- body_text_size: 16sp
- title_text_size: 20sp
- main_card_text_title: 34sp
- sub_card_text_title: 25sp
- sub_card_text_description: 16sp
- title_card_size: 70dp
- title_big_card_size: 40dp
- list_card_size: 220dp
- bottom_nav: 56dp
- ic_size: 20dp
- layout_margin: 15dp

### 3.11.3. Location and Geofences

To get the location it was used the Android *LocationManager* and *LocationRequest* to update it frequently in a range of 5 to 10 seconds with high precision.

Subsequently the geofence monitoring was started, with a radius of 25m and transitions to enter and exit geolocations defined to show or hide notifications.

When entering a geofence, a notification with high priority is displayed, in which it is defined that the touch action opens the application in the “Discover hotspot” menu. This menu is only available when the user enters to a geofence. When leaving the geofence the notification and respective characteristics are hidden.

### 3.11.4. Main menu

For the main menu it was used cards in which the image and the respective text were placed, in addition it was implemented the feature to hide or show the option “Discover hotspot” when necessary.

A sidebar which allows the access to all main options of the application was also implemented, in addition, an option to change the language and the app info in an “Configuration*”* section.

For the “About” section it was used a popup to show the information about the application, namely context of the Master dissertation, supervisors, and dissertation academic year date.

The configuration section displays the current language and offers the option to change it between English and Spanish. For the implementation of this feature it was used the Android feature using *strings.xml* files for each language.

### 3.11.5. Show images

To show the images, those are read as files from the internal storage, transformed into a drawable and placed in an *ImageView*.

### 3.11.6. Hotspots

In the hotspot list, the information of all the hotspots is read from the internal DB to show it as a list with images. When entering to a hotspot it is shown the information pertaining to it.

It was used a bottom bar to separate the description and map section, and it uses fragments to show each section.

In the hotspot description there were created links to the respective available bird species.

It was used the Google maps API to show maps embedded on the app, in which the location of the hotspot is defined and then the camera moves with a fixed zoom to display it correctly. In addition, it was activated a feature to show the user's current location.

### 3.11.7. Routes

In routes list, the route info is read from the internal DB to show the available routes and when interacting with one of these, the information pertaining to the route is read from DB.

It was used a bottom bar to separate the description and map section, and it uses fragments to show each section.

In the description of the route there were created links to the birds and hotspots associated with the route.

It was used the Google maps and Directions API to first create the map and then locate the points where the hotspots associated with the route are located, finally it draws the line that indicates which is the suggested route.

In addition, it was activated a feature to show the user's current location.

### 3.11.8. Bird families

In the list of families, the information is read from the database and when interacting with one of these, it loads the information of the species related to the family. This information is available in "Bird library*"* section of the app.

The search option is shown in the list of families and in the list of species. This search can be done by families or by species which defines the query that is used to search in the DB. In case of finding matches, these are shown in the list in the same way that in the list of families or species, if none is found, a *Toastr* with the corresponding message is displayed.

When entering a species, it is loaded the information corresponding to the species, including, if it exists, a gallery of photos, a gallery of videos and sounds. It should be noted that to load galleries information, only the names and locations of the files are read from DB.

It was used a bottom bar to separate bibliography, image gallery, video gallery, sound gallery and the AR feature which is shown when the species has the property "activateAR" as true.

#### INFO SECTION

It will be shown general info of the species for all species, if the species is endangered, it will be shown a section with the corresponding information.

#### IMAGE SECTION

For this section, the files are browsed in the internal storage. For performance reasons, it uses 600px thumbnails in the gallery and when the image is requested to be displayed in full screen, it is presented in its original size. User can navigate through all images in full screen, like in the phone gallery app, it was used a component called Glide to obtain this behavior.

#### VIDEO SECTION

For this section, the thumbnail files are browsed in the internal storage, when the full screen is requested, the video is loaded from the internal storage and reproduced using the *VideoView* component of *exomedia*, which provides video controls and screen playback.

#### SOUND SECTION

For this section, the sounds are loaded from internal storage and it is shown a button with icons for play and pause as required. It was used the Android *MediaPlayer* component to play sounds and is locked to allow only one sound to be played each time.

#### AR FEATURE

For this section, it was used the planes detection of ARCore and using listeners on pints to be touch y user to render the object on the place that has been touched, also, it is show a button to take the photo, when interacting with it, it is used PixelCopy to take the screenshot without interface buttons, once the image has been obtained, it is rendered and shows the buttons to discard, which simply discards the photo; share, which uses the option of Android to share through the applications of the device as a photo; and the save button, to save the picture in the internal storage of the device.

### 3.11.9. Load database

In case of being the first time the user runs the application, it will proceed to download the information database from the internet, otherwise, the database version will be checked to verify if there is a new version. If is the case, a popup will be prompt to notify the user with

the options to update or omit said database update. If the user agrees to update, it proceeds to download, otherwise it navigates to the main menu.

It was used the official firebase client for Android, Firebase Firestorage to load the information from the cloud. The process runs in background, opening a thread exclusively for this. A collection is loaded and once it has been saved in the internal database, the next collection is loaded, as the information is read in another thread, it is synchronized in such a way that when the information is read, it is forwarded to the next collection. Once it has finished saving all the information of all collections, it will proceed to load the images from firebase storage, using *storageReference*. The file reference is read, downloaded, and stored it in internal storage. Since this process is performed in background, it uses a recursive function to save file by file and display the progress, in percentage, to the user. Once all multimedia files have been downloaded, the DB version number is created or updated and then redirected to the main menu.

The app verifies if the user is connected to a Wi-Fi network in order to check if there is a new version of the database, to allow to download this information, if there is no such connection it is not possible to download such information.

## 3.12. Backoffice development

The Angular CLI was used to generate the base structure of the project, components, services, and routing needed to develop the backoffice.

Angular Bootstrap was used for the interfaces, to use its components in a simple way and ease development. To interact with Firebase, it was used the official firebase library for Angular 2.

### 3.12.1. Login

To perform the login, it is necessary to sign in by email and password through *angularFireAuth*, in addition, in this screen is shown an option to choose the language to be used on the application.

LAYOUT

Three sections were defined for the page layout, that are:

- Sidebar menu: To navigate between sections in an easy way;
- Header: Contains the title, buttons to close the sidebar and logout and the option to change language;
- Body: Shows the content of the page.

Four main sections were defined for this administration portal: "Points of interest", "Routes", "Families" and "Species".

### 3.12.2. Common components

There are general components that were used throughout the application:

#### LOADING COMPONENT

For the loading spinner, it was used the external library *ng2-loading-spinner* and a div in the layout, which is invoked each time a transaction needs to be made and is hiden when the transaction with the DB is finished.

#### SEARCH COMPONENT

The search component for the search feature used in the lists of Hotspot, Routes, Families and Birds was made using the *Typehead* component of Bootstrap, for which, the pipe async is used to bind the model value of the filter, this allows the input to listen when the user inputs a key and it immediately it starts searching in the list.

#### MENU IMAGE UPLOAD

To load the images for the menu, first, these are compressed on the server because it does not need to be in high-resolution image. For this is used a Canvas from HTML5, which is first resized and then a Blob is created to later save it as File.

#### MULTIMEDIA FILE UPLOAD

This component is used to add images, videos, or sounds. It loads files in background, allowing the user to upload several files simultaneously. Once a file starts loading, a progress bar is displayed for each file. In addition, to upload images and videos, it is created a thumbnail with a maximum width of 600px, which is also loaded to the database.

### IMAGE PREVIEW

For the image preview, a popup was used, without frames or any component of the layout, to present the image in an clear way. To close the popup, there is an “X” at the top right corner, and it can also be closed by clicking outside of the popup.

### CONFIRMATION POPUP

The confirmation popup has two options, one to confirm and the other to cancel, and an "X" at the top right corner to close it.

### FLOATING BUTTON

The floating button has a fixed position, always located in the bottom right of the page. It can be assigned to this any action that is necessary depending on the section needs.

### LISTS

The List component of HTML was used with Bootstrap styles to show lists. In the right of the list items, there are buttons with options to interact with each one, these options are: Edit and Delete. The Delete option shows a confirmation popup before delete the list item.

For the list of species there are other options in the list items, which are: Images, Videos and Sounds, which serve to navigate to the respective sections and view, edit, add or delete information related to each record.

### ACCORDION

The *ng-bootstrap accordion* was used to separate the information of each idiom. There is a special configuration to be noted on this component: the *destroyOnHide* property that was set to false, because when the default value is true, it resets the model value when the accordion is closed, which causes the validations to not work and of course loss of configurated data. Option c*loseOthers* was also set to true to allow only one section (idiom) to be triggered at a time.

### FIREBASE

For firebase transactions it was created a service in which the functions that call the respective collection to obtain the information are located.

Likewise, methods to save and update information were created, which use a subscription that responds to the status of the transaction.

### 3.12.3. Hotspot

When navigating to the hotspot section, it is shown a list of the available hotspots, with an input to filter it. The floating button component is used to navigate to the "Add hotspot" section.

ADD HOTSPOT

In this section is show the form to add the corresponding information. To perform this task these components are also used: *menu image upload*, *preview images* and *list* to show the associated species and, as said before, the accordion to separate the information. In addition, there is the option "Add species" that shows a popup to add the species that are available in this hotspot. Note that this popup also implements the input to filter the list by a search criterion.

A validation was also implemented to control that the same geographical point cannot be saved more than once.

### 3.12.4. Routes

In this section is shown a list with the available routes, with an input to filter it. The floating button component is used to navigate to the "Add routes" section.

ADD ROUTES

In this section is show the form to add the corresponding information. It also uses the components *menu image upload*, *preview images* and *list* to show the associated hotspots.

### 3.12.5. Families

In this section is shown a list with the available families with an input to filter it. The floating button component is also used to navigate to the "Add families" section.

In the list of families, there is a link to show the bird species related to that family, on click, it navigates to the species section, if navigating this was, the list of species shows only the bird species associated with the family.

ADD FAMILIES

In this section is show the form to add the corresponding information. *Multimedia file upload* and *preview images* components are also used.

There is a validation to control that no more than one family is added with the same scientific name.

### 3.12.6. Birds

In this section is shown a list of available species with an input to filter it. The floating button component is also used to navigate to the "Add species" section. In addition, in each record of the list, there are options to navigate to the sections of "Images", "Videos" and "Sounds".

ADD SPECIES

In this section is show the form to add the corresponding information. *Menu image upload* and *preview images* components are also used.

There is an input with typehead is used to enter the scientific name of the family to which the species belongs to, this works when the user write one letter and searches for that criterion in the list of all the families. This combo is disabled when the user navigates to this section from a family, in this case it displays that family.

There is also a checkbox in the form, which is used to indicate if the species is endangered, when activated, it displays a section in each language to add information about this topic.

There is a validation here to control that no more than one species with the same scientific name is added (Figure 25).

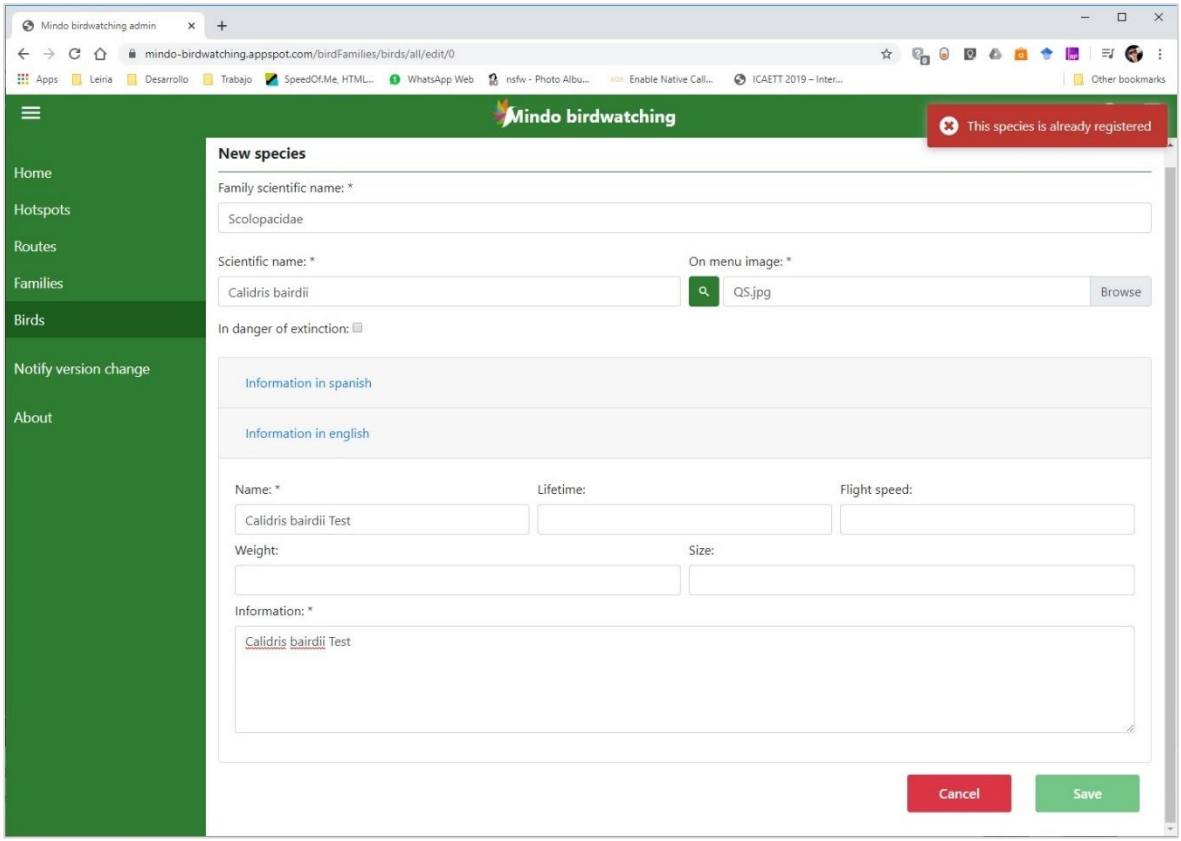


**Figure 25 - Repeated species validation**

### IMAGES

This section was implemented as a gallery, in which the images loaded for the species are displayed and below each one, there is a button to eliminate it. Clicking on an image displays a popup (using the *image preview* component) to see the image in larger size. In addition, the floating button is also used to display a popup that allows the user to upload images using the m*ultimedia file upload* component.

#### *Add images*

To upload images was used the *multimedia file upload* component, restricted only to JPG files; the author credits of the image are required as a mandatory field.

### VIDEOS

This section was implemented as a gallery where the thumbnails of the videos are shown. When user click on one of these thumbnails, a popup opens and play the video with its respective multimedia controls in it, this is made using the *HTML5 video* component.

*Add videos*

To upload videos, it was used the *multimedia file upload* component, restricted to allow only to load MP4 files. The author credits of the video are required as a mandatory field.

SOUNDS

In the sound gallery it is shown the sound player, using the *HTML5 audio* component to allow this section to be shown as a gallery. There is a button to delete the sound bellow each sound player.

*Add sounds*

To load sounds it was used the *multimedia file upload* component, restricted only to MP3 files. The author credits of the sound are required as a mandatory field.

### 3.12.7. Notify version change

When user click on this option, a confirmation popup is displayed (using the Confirmation popup component), in case of user confirms the version change, the version number of the database is changed and the android application is notified about this update.

### 3.12.8. Language

Language strings are in separated files for each one (English and Spanish), which is loaded according to the language selected by the user.

## 3.13. Test cases

The following test cases were defined to verify that the application is working correctly and to perform the on-site tests with the end users.

**Table 3 - Test cases**

| Test case | Description | Prerequisites | Required sequence to complete the test | Special remarks |
|---|---|---|---|---|
| **1** | Get information, birds that can be sighted and location of a hotspot | • Enter the Mindo birdwatching app | 1. Enter the Hotspots menu<br>2. Select a hotspot<br>3. Watch information and birds that can be seen<br>4. Switch to map tab | N/A |

| Test case | Description | Prerequisites | Required sequence to complete the test | Special remarks |
|---|---|---|---|---|
| | | | 5. Watch the hotspot on the map | |
| **2** | Get information about a route, the birds that can be seen, the hotspots that the route goes through and watch the route on the map | • Enter the Mindo birdwatching app | 1. Enter the Routes menu<br>2. Select a route<br>3. Watch information, birds that can be seen and hotspots that the route goes through<br>4. Switch to map tab<br>5. Watch the route on the map | N/A |
| **3** | Get information of a species | • Enter the Mindo birdwatching app | 1. Enter the Bird library menu<br>2. Select a family<br>3. Select a species<br>4. Watch species information | N/A |
| **4** | View images of a species | • Enter the Mindo birdwatching app<br>• View information of a species | 1. Switch to images tab<br>2. Select an image to view<br>3. Browse between images in the gallery | N/A |
| **5** | View videos of a species | • Enter the Mindo birdwatching app<br>• View information of a species | 1. Switch to videos tab<br>2. Select a video to watch | N/A |
| **6** | Play sounds of a species | • Enter the Mindo birdwatching app<br>• View information of a species | 1. Switch to sounds tab<br>2. Play a sound | N/A |
| **7** | Reach a hotspot | • Enter the Mindo birdwatching app | 1. Enter the Hotspots menu<br>2. Select a hotspot<br>3. Switch to map tab<br>4. Touch on the hotspot marker on the map | N/A |

| Test case | Description | Prerequisites | Required sequence to complete the test | Special remarks |
|---|---|---|---|---|
| | | | 5. Use the Google button to get directions<br>6. Start the route in Maps<br>7. Follow directions | |
| **8** | Travel a route | • Enter the Mindo birdwatching app | 1. Enter the Routes menu<br>2. Select a route<br>3. Switch to map tab<br>4. Touch the "START ROUTE" button<br>5. Start the route in Google Maps<br>6. Follow directions | N/A |
| **9** | Visualize a species with AR | • Enter the Mindo birdwatching app<br>• Reach a hotspot<br>• View information of a species via "Discover hotspot" menu option | 1. Select the AR tab<br>2. Focus a flat surface until it is identified (until a grid of white dots comes out)<br>3. Touch one of those white dots<br>4. Visualize the 3D object with augmented reality | The species that have AR are:<br>• Toucans: Chestnut-mandibled toucan<br>• Hummingbirds: Hoary Puffleg |
| **10** | Share a photo with AR | • Enter the Mindo birdwatching app<br>• View information of a species via "Discover hotspot" menu option<br>• Visualize a species with AR | 1. Touch the button that has a camera icon<br>2. Touch the share button<br>3. Use one of Android's sharing options | N/A |
| **11** | Save a photo with AR | • Have entered the Mindo birdwatching app<br>• View information | 1. Touch the button that has a camera icon<br>2. Touch the save button<br>3. Close or minimize the application | N/A |

| Test case | Description | Prerequisites | Required sequence to complete the test | Special remarks |
|---|---|---|---|---|
| | | of a species via “Discover hotspot” menu option<br>• Visualize a species with AR | 4. Open device gallery<br>5. View the photo on the gallery | |

After completing the test cases, the user fills a survey that will work to obtain results about the usability and satisfaction of users when using the application.

## 3.14. Usability test survey

To carry out the usability test, the System Usability Scale was used, as it is a reliable tool to measure the usability of a system. The survey consists on a 10 items predefined questionnaire with five response options for respondents; from Strongly agree to Strongly disagree and uses a well-defined way to interpret scores [44] (Appendix D and E).

# 4. Results

In this chapter are analyzed 4 topics about the development of the work: the acceptance survey, the Android application, the backoffice and the app tests.

## 4.1. Acceptance survey

Once the surveys that were carried out had influenced on some decisions related to this work. Next, it will be presented some examples of questions from this survey:

- How do you classify your knowledge about bird species?

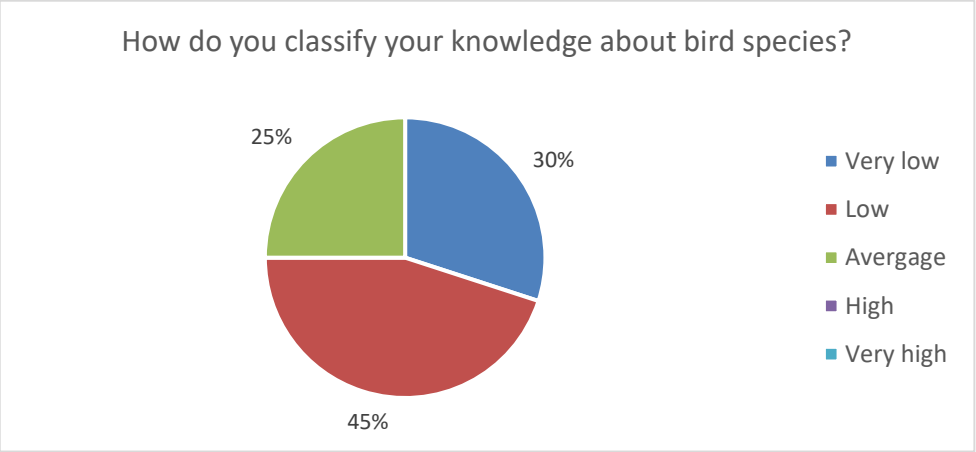


**Figure 26 - Question: How do you classify your knowledge about bird species?**

This indicates that 75% of the people surveyed do not have a good knowledge about birds, as can be seen on figure 26.

- Would you like to use an application for cell phone / tablet to learn more about birds using augmented reality?

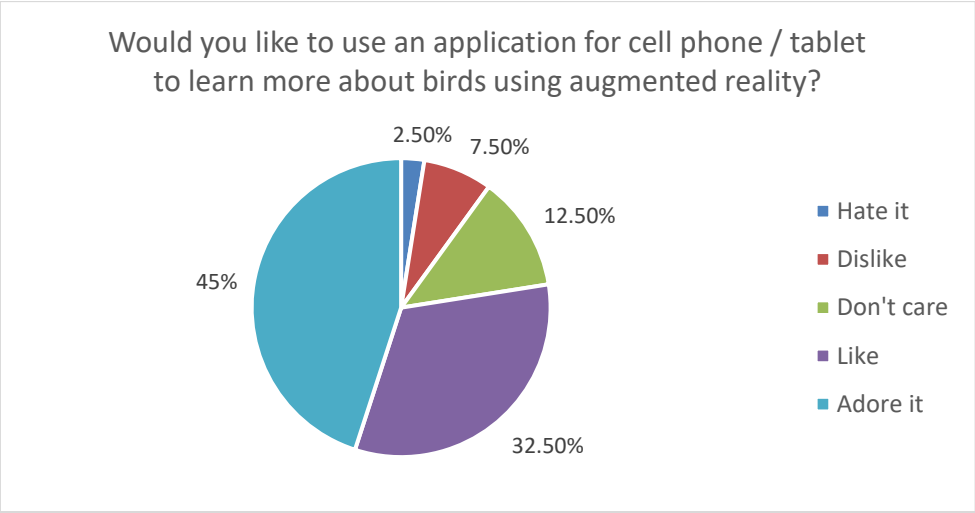


**Figure 27 - Question: Would you like to use an application for cell phone / tablet to learn more about birds using augmented reality?**

This suggests that 77.5% of surveyed people are interested in a smartphone or tablet application that allows them to learn about birds, as can be seen on figure 27.

- What kind of cellphone do you have?

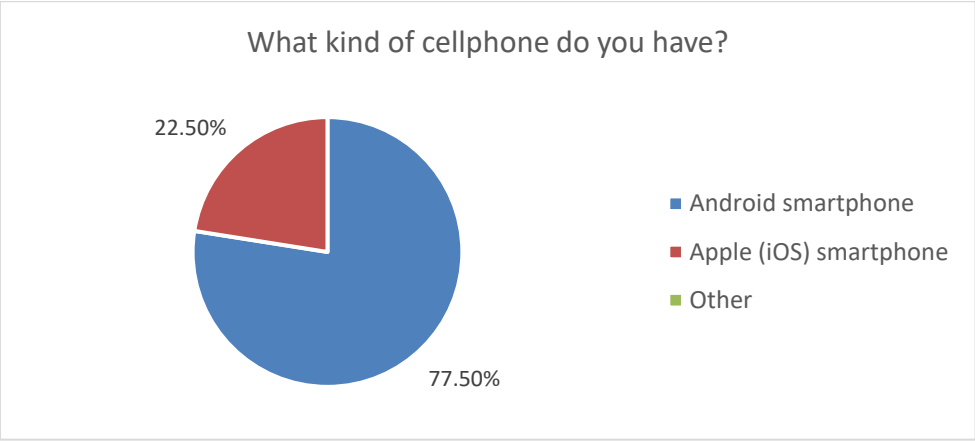


**Figure 28 - Question: What kind of cellphone do you have?**

This indicates that 77% of the surveyed people have or use a smartphone or tablet with Android as operative system, so it is correct to develop the work for that platform, as can be seen on figure 28.

The results of this survey can be found on appendix C.

## 4.2. Android application

At the moment, the application is hosted in Google Drive, in the following link: https://drive.google.com/open?id=1MM08PNmEgejsH5hmRWPMdroAWN3oAg9e, since, while this work is being conducted, it is not planned to upload it to the Google's Play Store.

The application has six important functionalities, which are: Load database, Main menu, Hotspots, Routes, Bird library and Discover hotspot, which will be described below.

### 4.2.1. Load database

Each time the app is opened it checks if there is a new version of the database, if so, it is requested permission to load and save on the local database of the device. To perform this action, it is mandatory a Wi-Fi connection, if there is not available a Wi-Fi connection it will be shown a modal to inform this to the user, as can be seen on figure 29.

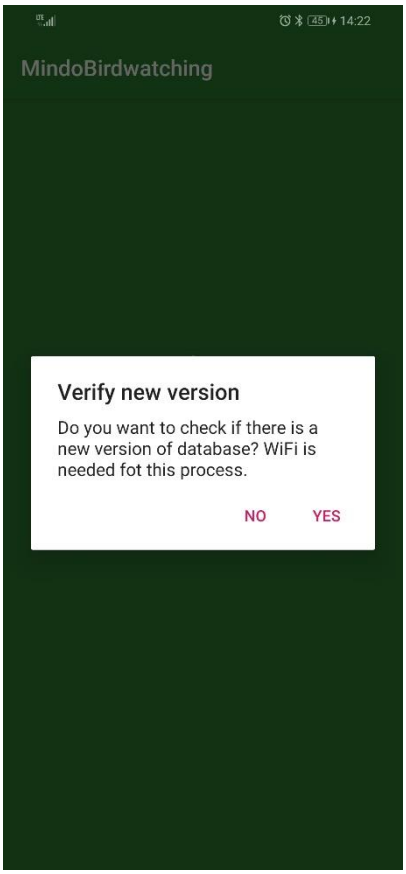


**Figure 29 - Verify new version**

Once there is a Wi-Fi connection, the app verifies if there is a new version of the database, if so it will show a modal informing about the existence of the new version of database and options for the user to confirm if he wants or not to update it, as can be seen on figure 30.

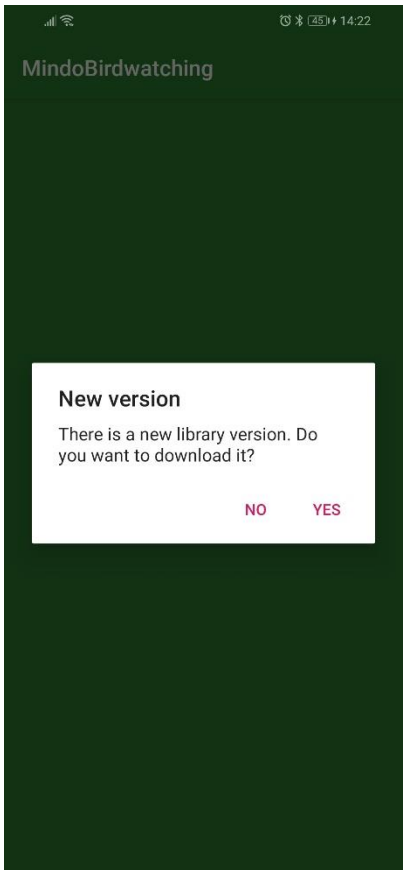


**Figure 30 - Confirm new version download**

If the user agrees to update the database, a spinner and the current percentage of download will be displayed, as can be seen on figure 31.

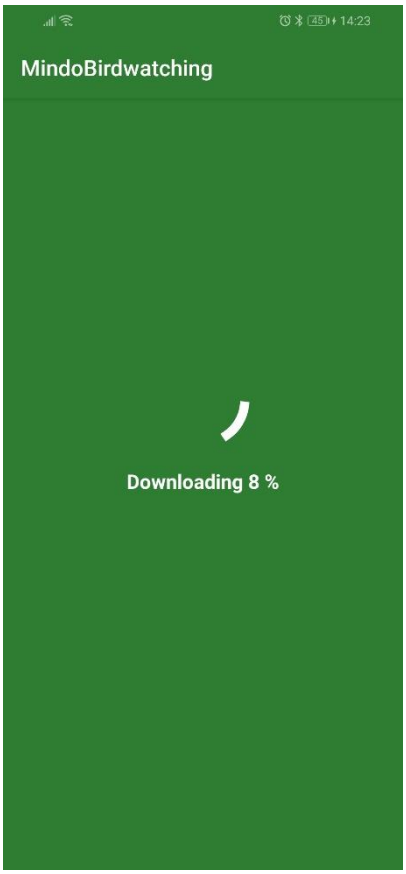


**Figure 31 - Download progress**

On the first execution of the app the Wi-Fi connection will be checked to create the database automatically.

### 4.2.2. Main menu

The main menu always shows the three main options of the app, Hotspots, Routes and Bird Library, as can be seen on figure 32.

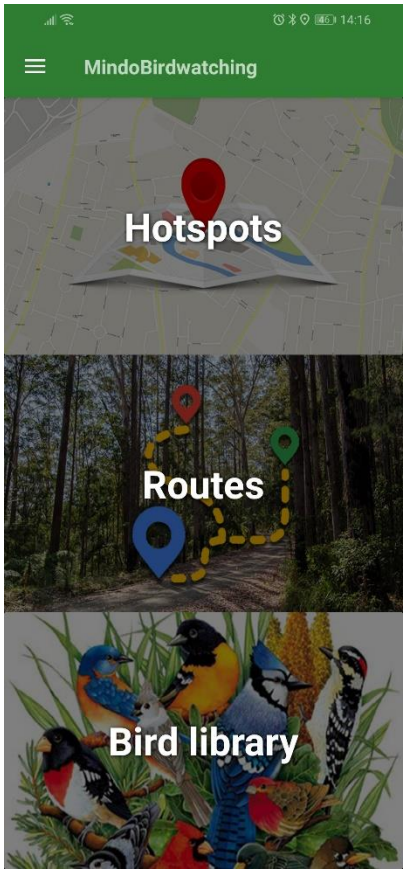


**Figure 32 - Main menu**

The first time the application is opened, this will show a popup in which the user has the possibility of activating notifications for all hotspots or not, as can be seen on figure 33.

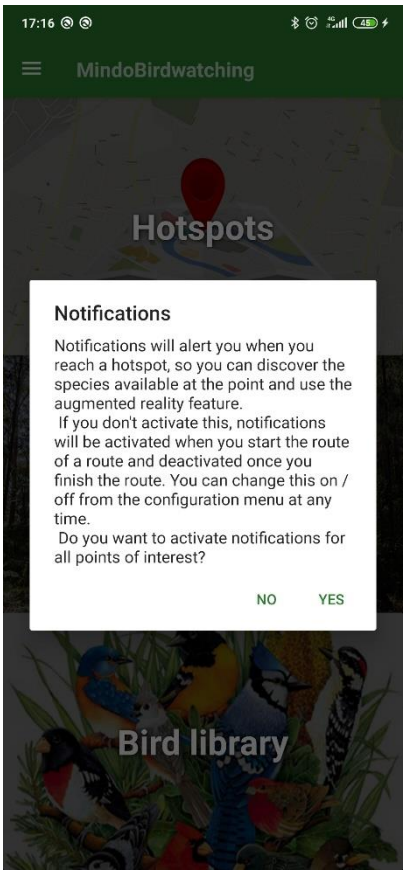


**Figure 33 - First time notifications configuration**

Throughout the application a side menu is available, from which the user can easily navigate between the main sections, as can be seen on figure 34.

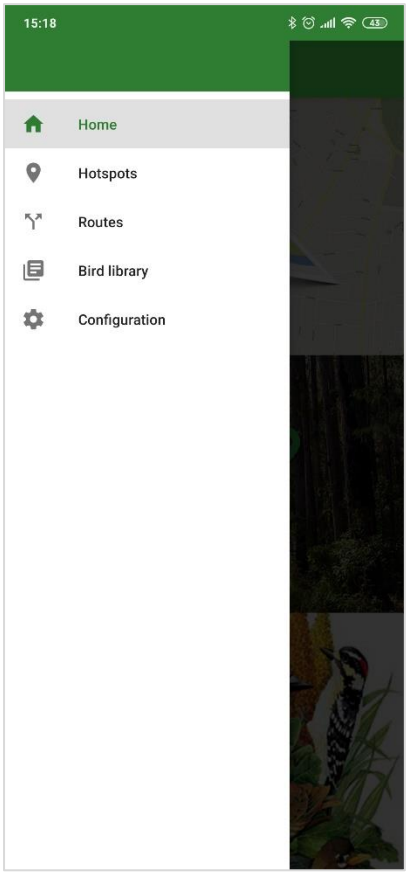


**Figure 34 - Sidebar menu**

The side menu always highlights the section in which the user is at and of course it is close when the user navigates to another section.

### 4.2.3. Hotspot

In the Hotspot menu, a list of available Hotspots is displayed, it contains an image and a brief description of it, as can be seen on figure 35.

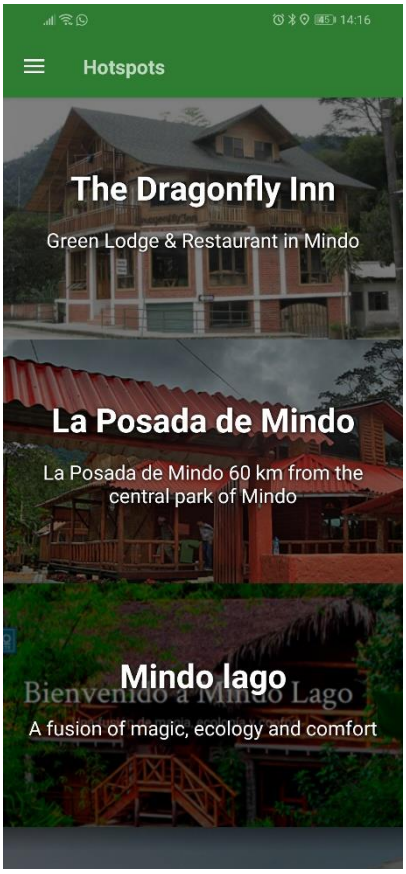


**Figure 35 - Hotspot list**

Hotspot info section shows information about the hotspot and a list of the birds that can be found there. User can navigate to the species to get information about those by tapping over the name of the species, as can be seen on figure 36.

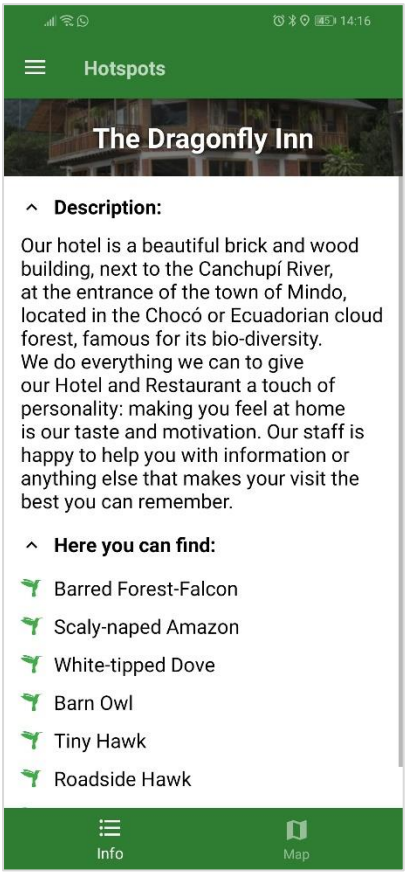


**Figure 36 - Hotspot info**

The Hotspot map section displays a map with a marker located in the hotspot and also the location of the user, however, it is centered on the hotspot, so if the user is too far from the hotspot, its location won't be shown, as can be seen on figure 37.


**Figure 37 - Hotspot map**

Selecting the marker shows the name of the hotspot and options to see it in google maps and navigate to the location using google maps.

### 4.2.4. Routes

In the Routes menu, a list of available Routes is displayed, it contains an image and the name of the route, as can be seen on figure 38.

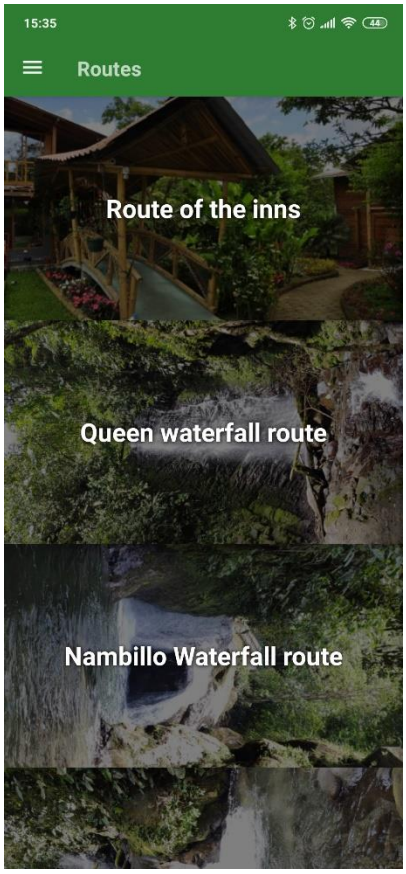


**Figure 38 - Routes list**

The Route info section shows to the user the distance covered by the route, a description of it, a list of the hotspots that compose the route and the species that can be found along it. The user can select the hotspots and species to get information about each one of them by tapping on the name of it, as can be seen on figure 39.

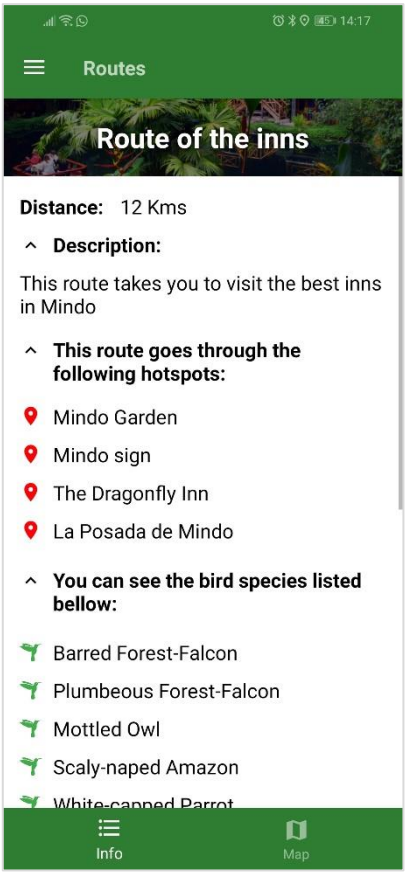


**Figure 39 - Route info**

The Route map section will display a map with several markers located in the hotspots that compose the route and also the location of the user, however, it will be centered within the bounds of the hotspots, so if the user is too far from those, user's location won't be seen.

A suggested path to navigate through the route is also shown, however, it will only use the trails that exist on the map, so it may not be as accurate or optimal to walk considering that most of it will be on the jungle, as can be seen on figure 40.


**Figure 40 - Route map**

This route suggestion can only be displayed if the user have internet connection since it uses the Google's directions API. This content can be downloaded previously, as well as when using the Google Maps app and the navigation is downloaded to cache. Although, and as expected if the application is closed, this information will be deleted.

### 4.2.5. Bird library

When entering the Bird library, it is shown a list of available bird families that contains an image and the name of the family, as can be seen on figure 41.

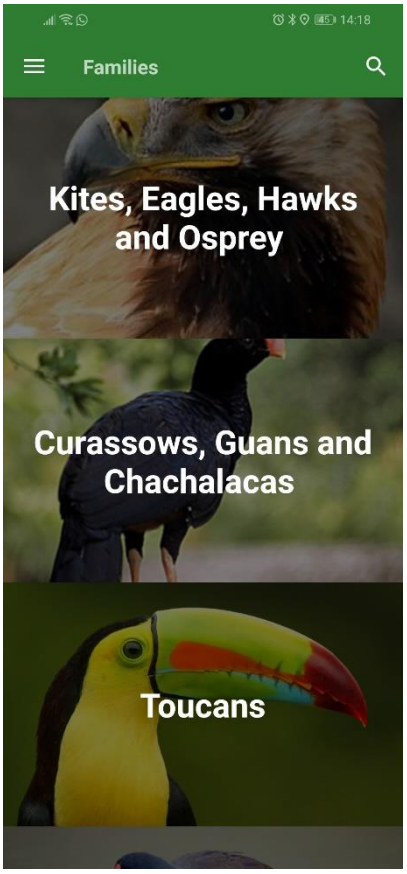


**Figure 41 - Families list**

There is also a feature to make a search by family or by bird, as can be seen on figure 42.

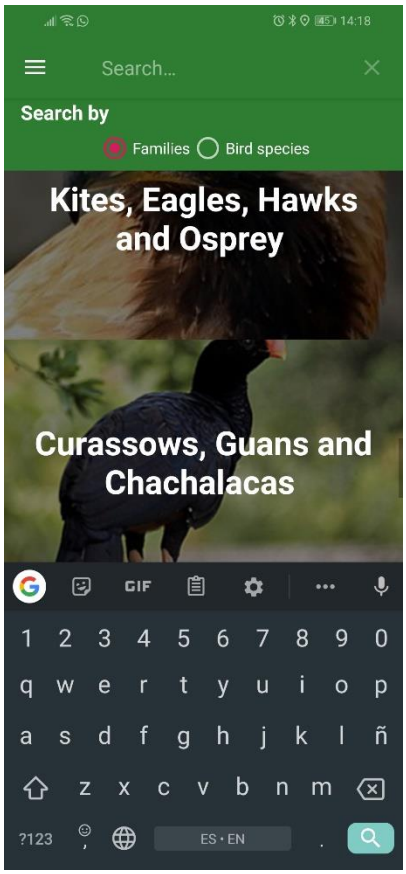


**Figure 42 - Search feature**

When selecting a bird family, all birds that belong to that family are displayed, with an image and the name of the species, as can be seen on figure 43.

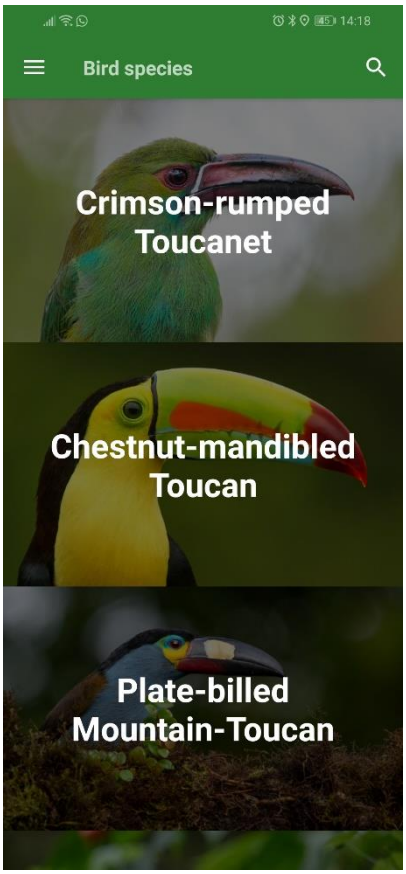


**Figure 43 - Bird species list**

In this section there is a bottom bar to navigate between Bibliography, Image gallery, Video gallery, Sound gallery and the AR option, if available, which is accessible only when coming from discover hotspot.

In the Bibliography section is shown an image of the species along with some relevant information, such as: Scientific name, bird family, weight, size, among others. If this species is endangered it will be shown information related to this topic, as can be seen on figure 44.

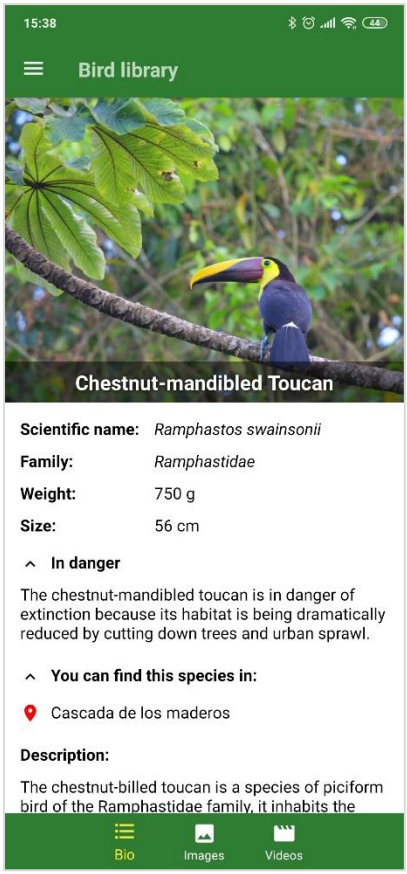


**Figure 44 - Species info**

The Images section shows the image gallery where the user can interact and see them in full screen, as can be seen on figure 45.


**Figure 45 - Species image gallery**

The Videos section shows the video gallery where the user can interact with the thumbnails and play the video in full screen, as can be seen on figure 46.

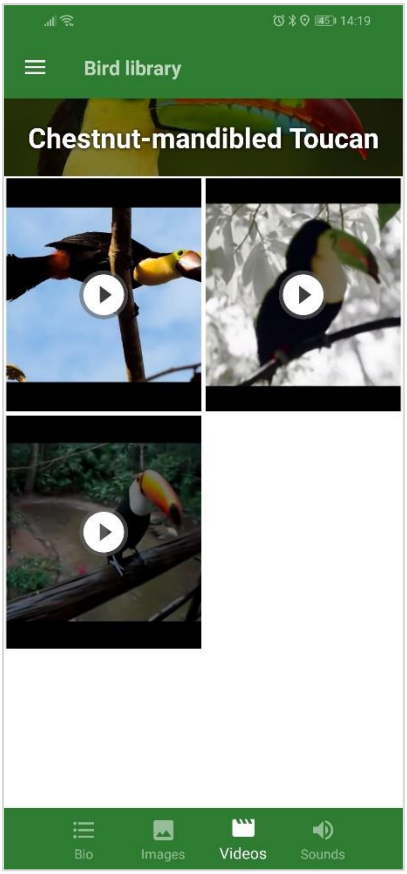


**Figure 46 - Species video gallery**

The Sounds section shows the sound gallery where the user can interact and play some bird sounds, as can be seen on figure 47.

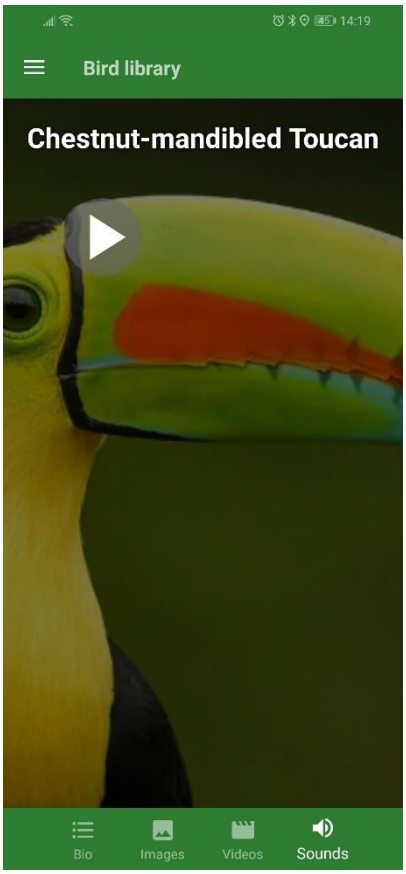


**Figure 47 - Species sounds gallery**

The bird sound can be played just one sound at time, if the user wants to play more than one, it will stop the previous sound and play the next one.

### 4.2.6. Discover hotspot

When the user is within 25 meters of a hotspot, a notification will be displayed, notifying that a hotspot has been reached, in addition, in the main menu will be displayed a new card entitled "Discover hotspot", which will have as a background image the hotspot which has been reached and also the name of it. Likewise, in the "Hotspots" card, there will be an icon that indicates to the user the it has reached a hotspot, as can be seen on figure 48.

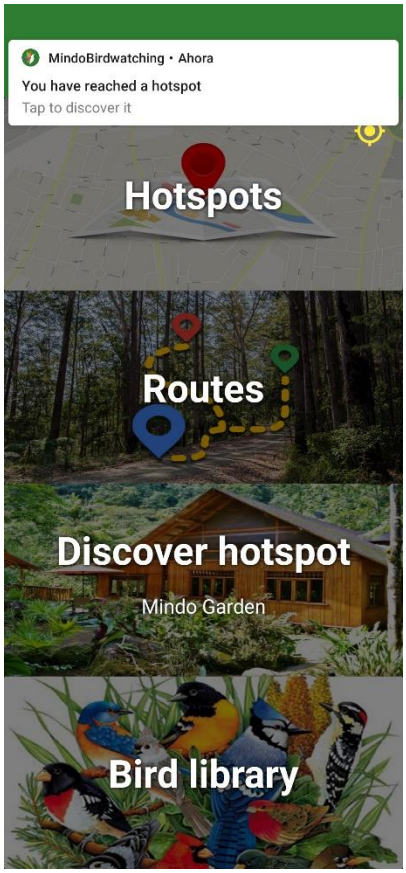


**Figure 48 - Geofence entering, notification and discover hotspot option displayed**

When entering the "Hotspots" menu, the hotspot card of the hotspot that was reached will be presented first, with an icon that indicated this on the right top corner, as can be seen on figure 49.

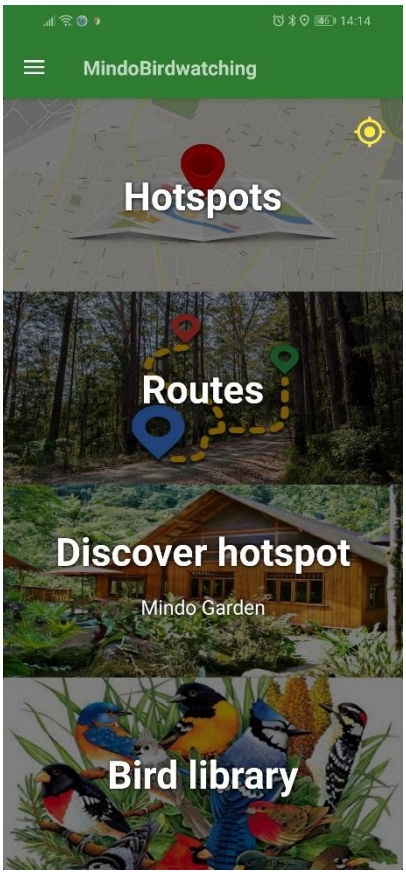


**Figure 49 - Hotspot list with actual hotspot**

When entering the "Discover hotspot" section, a list of the species that can be sighted in that hotspot will be displayed, in case there is an AR option for one of those species, this species will be shown first in the list, with an icon which indicates the existence of it on the upper right corner, as can be seen on figure 50.

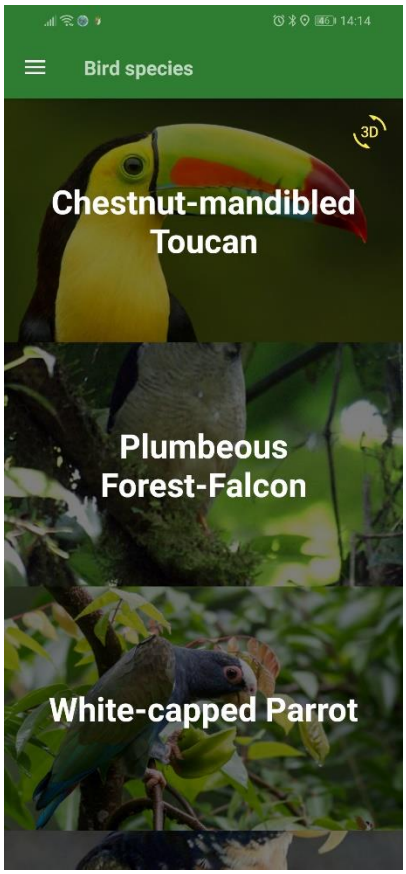


**Figure 50 - Bird species list with AR available sign**

Upon selecting the species, the "Bird Library" menu will be show. In case there is an AR option for the species, the 3D icon will be displayed in the bottom bar, which allows access to the AR option, as can be seen on figure 51.


**Figure 51 - Bird info in discover hotspot**

Here, the interaction with all the sections available is identical as in the "Bird library" when navigating from other locations.

### AR Feature

When using the AR feature, the detection of flat surfaces is used to overlay the digital models of the birds. When this option is selected, the camera is activated, and an animation that indicates how the user must move the cell phone to detect flat surfaces is displayed, as can be seen on figure 52.

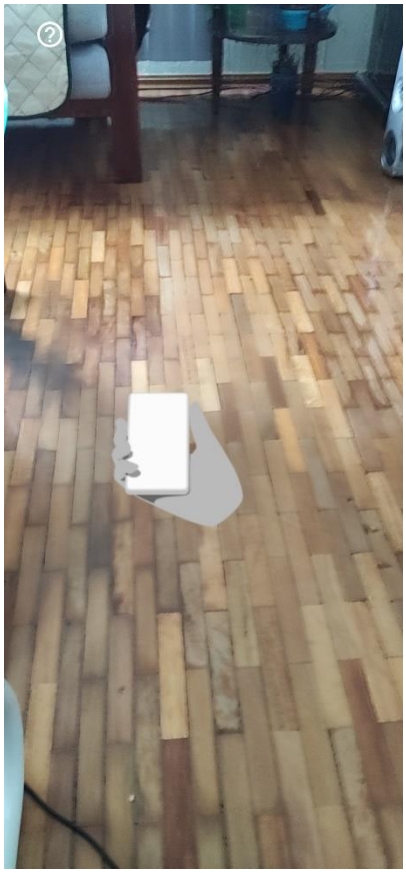

**Figure 52 - AR camera scanning flat surfaces**

By selecting the help button, help information is displayed in full screen. This can be dismissed by selecting the “CLOSE” button, as can be seen on figure 53.

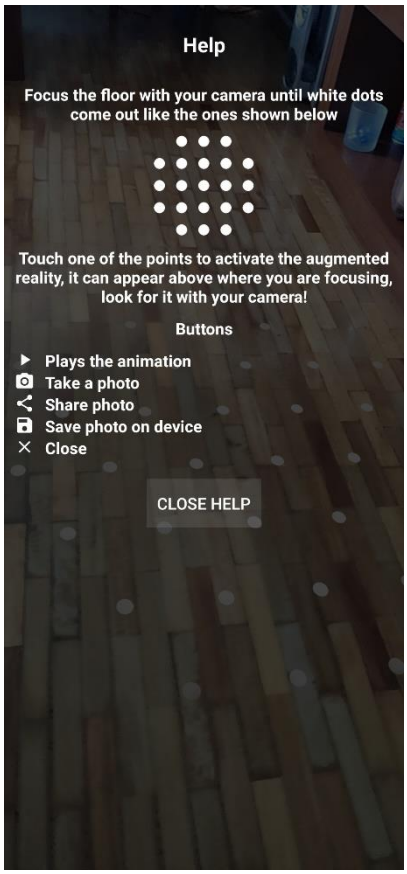


**Figure 53 - AR help**

Once the flat surface is detected, several white points are shown in a way that when one this is selected, the virtual object will be projected anchored to it, as can be seen on figure 54.

**Figure 54 - Virtual object rendered**

Once the 3D virtual object is putted on place, the animation will be triggered (if it has animation) and the option to take a photo will be presented. When using this option, it is taken a photo will and some options are shown, such as share, save the photo on the device or discard it, as can be seen on figure 55.

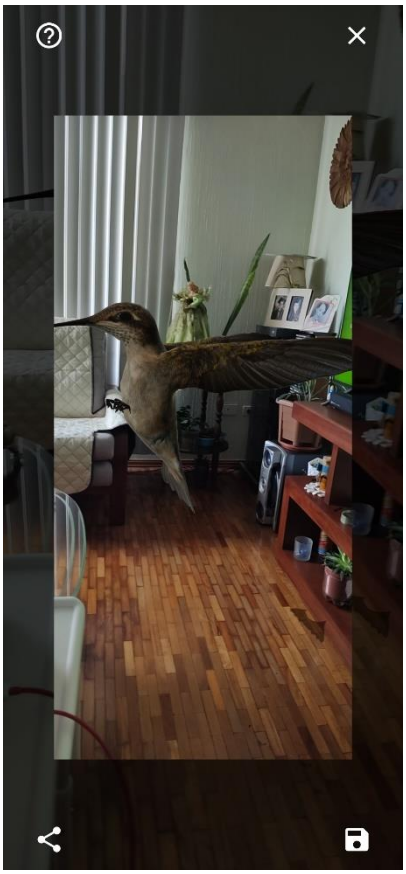

**Figure 55 – Take photo option**

In case of selecting save photo, it will be saved in the storage of the device, on a folder called “mindoBirdwatching”.

In case of sharing the photo, the default Android share option will be triggered, which allows sharing in several applications available in the phone.

### 4.2.7. Configuration menu

The configuration menu shows the options to change language, enable notifications for all hotspots and the option to open the "About" popup, as can be seen on figure 56.

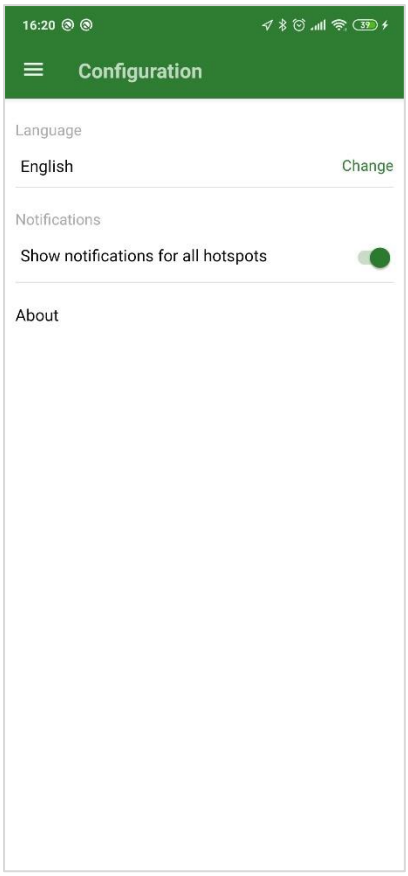


**Figure 56 - Configuration screen**

If the user changes the language, this will reload all application to change everything to the new language.

## 4.3. Backoffice

The web-based application that serves as backoffice is hosted in Google Cloud, at the address https://mindo-birdwatching.appspot.com; it uses the same color scheme and icons of the mobile application. The credentials to login into the backoffice are:

- Email: mindobirdwatching@gmail.com
- Password: Password01

### 4.3.1. Login

In the login page, the user must enter email and password (previously given by the administrator) to enter and be able to use the web application; in addition, the user can choose the language to be used on the web application, as can be seen on figure 57.

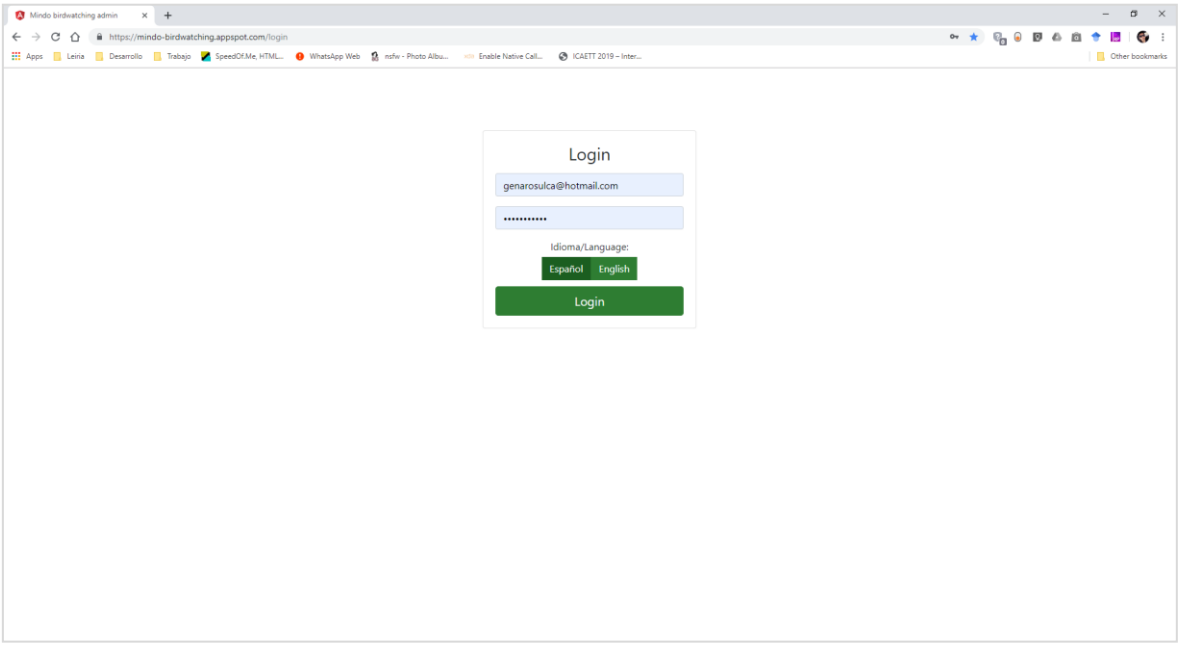


**Figure 57 - Login page**

### 4.3.2. Main page

The main page shows a sidebar menu at the left side, this menu allows to navigate between the different main sections. This sidebar can be hidden if needed using the button at the left top corner, as can be seen on figure 58.

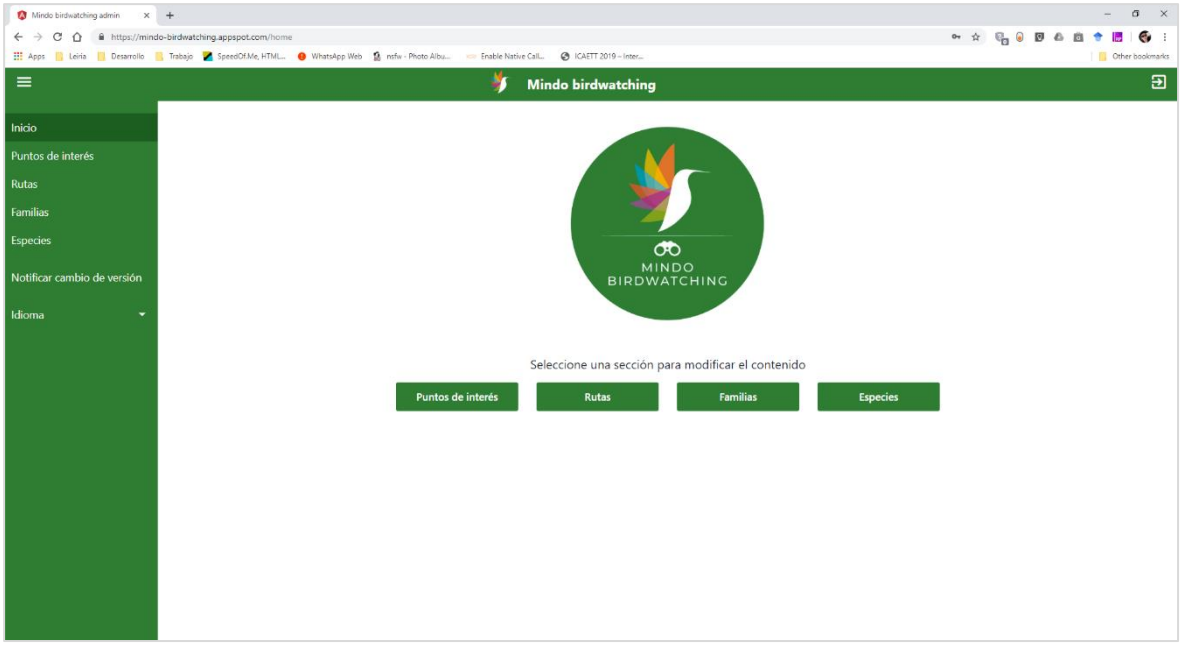


**Figure 58 - Main page**

### 4.3.3. Hotspot

When entering the hotspot section, a table with the list of available hotspots is shown, each record has a button to edit the information and another to delete said record. Above this table, there is an input to filter the contents of the table. In addition, the button to add a new hotspot is shown in the lower right corner, as can be seen on figure 59.

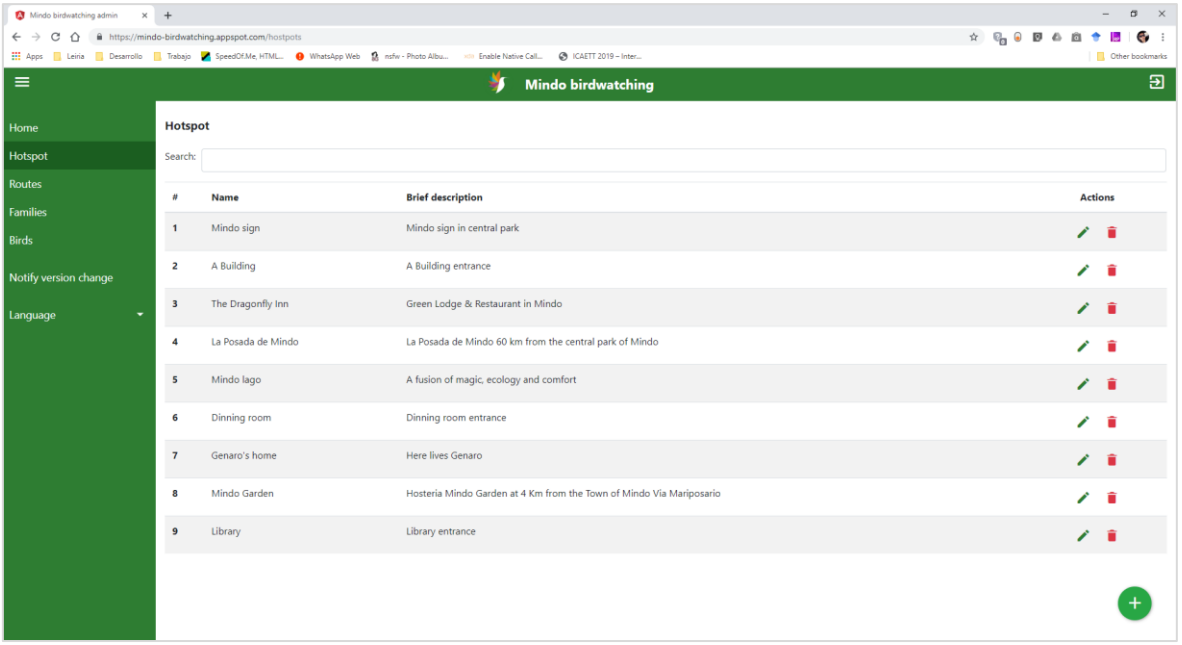


**Figure 59 - Hotspot list**

### Add/Edit hotspot

When entering Add/Edit hotspot, it will be shown a form to enter the information. This form is segmented in two entries to display and separate the information in English and Spanish, as can be seen on figure 60. The form is validated to control that it cannot be saved in case of missing any of the required fields. Furthermore, there is another validation to control that two identical locations in with latitude and longitude cannot be added.

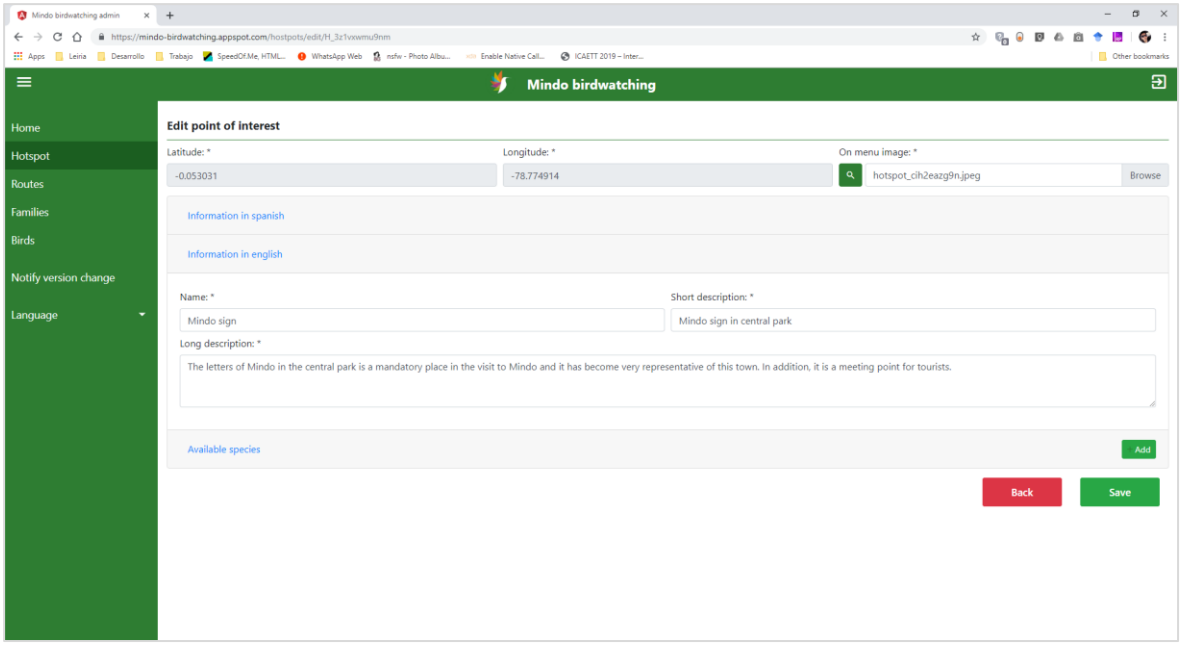


**Figure 60 - Add/Edit hotspot**

There is also an input to load the image that appears in the menu. On the left side of this input, there is a button with a magnifying glass icon, which serves to preview the image that is loaded or will be loaded, as can be seen on figure 61. In the lower right are the buttons to save the record or go back without saving it.

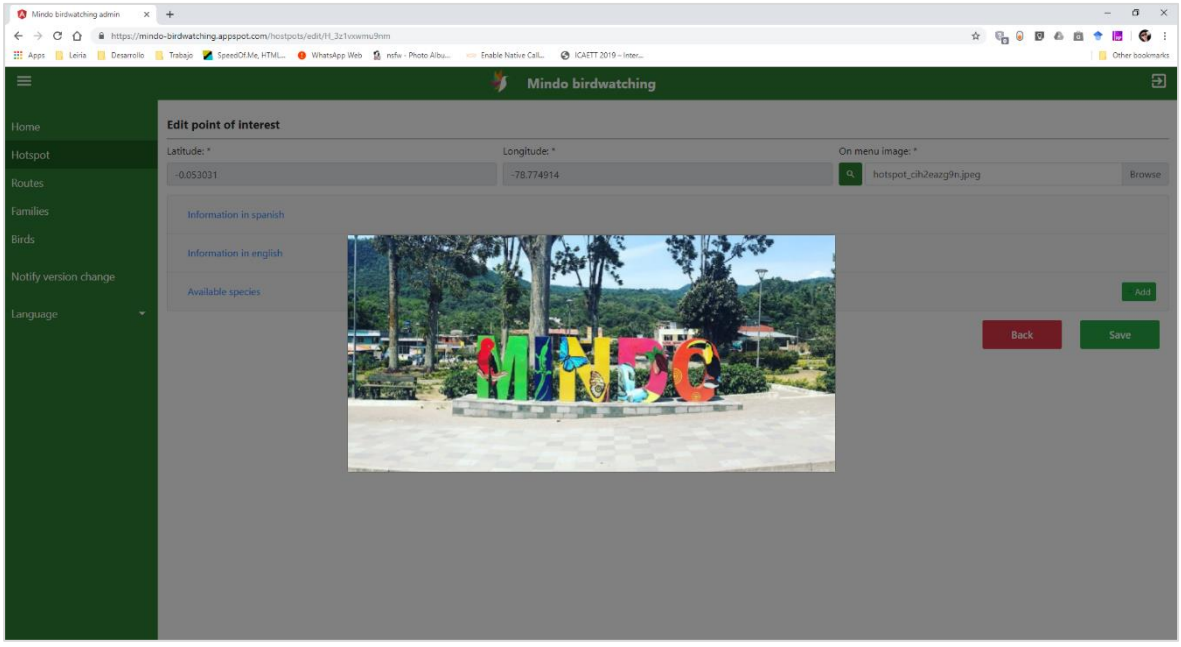


**Figure 61 - Hotspot menu image preview**

At the bottom of the form, there is a section with a table that contains the birds associated to the hotspot. At the right side of the header of this section, there is a button to Add a species

that opens a popup to select the birds in order to make a new relationship them or eliminate it from the respective hotspot, as can be seen on figure 62.

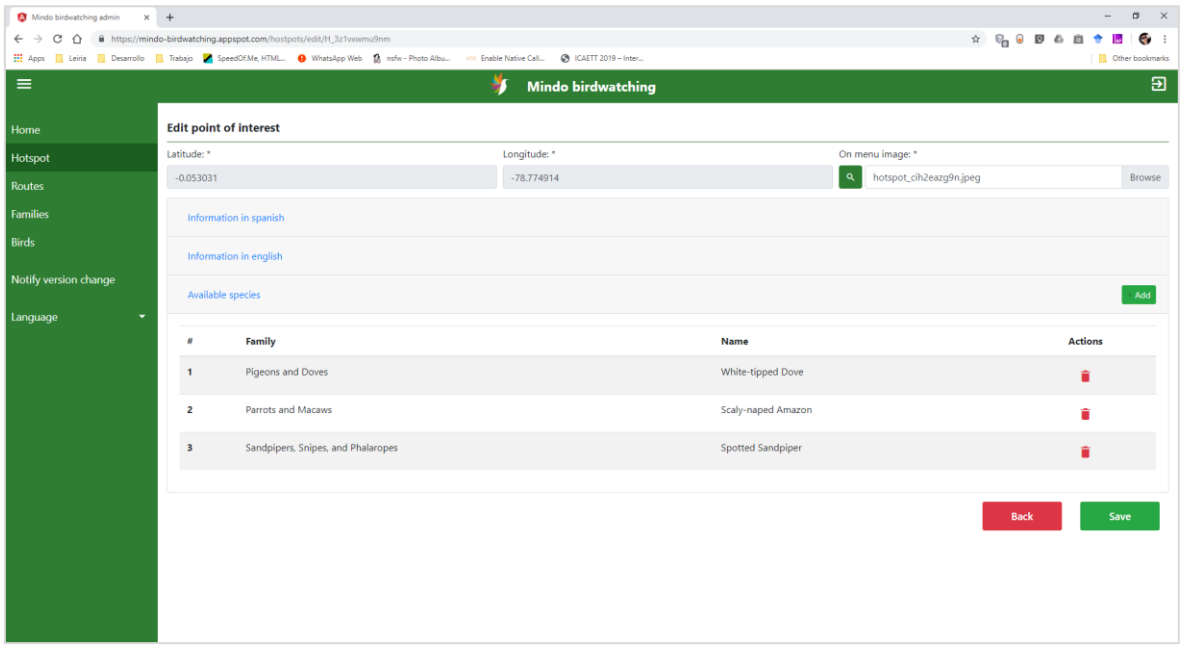


**Figure 62 - Hotspot related birds list**

This popup shows a table with the list of available species, an input to filter this at the top of it and an action button in each record to add or eliminate the relationship of the species with the hotspot, as can be seen on figure 63.

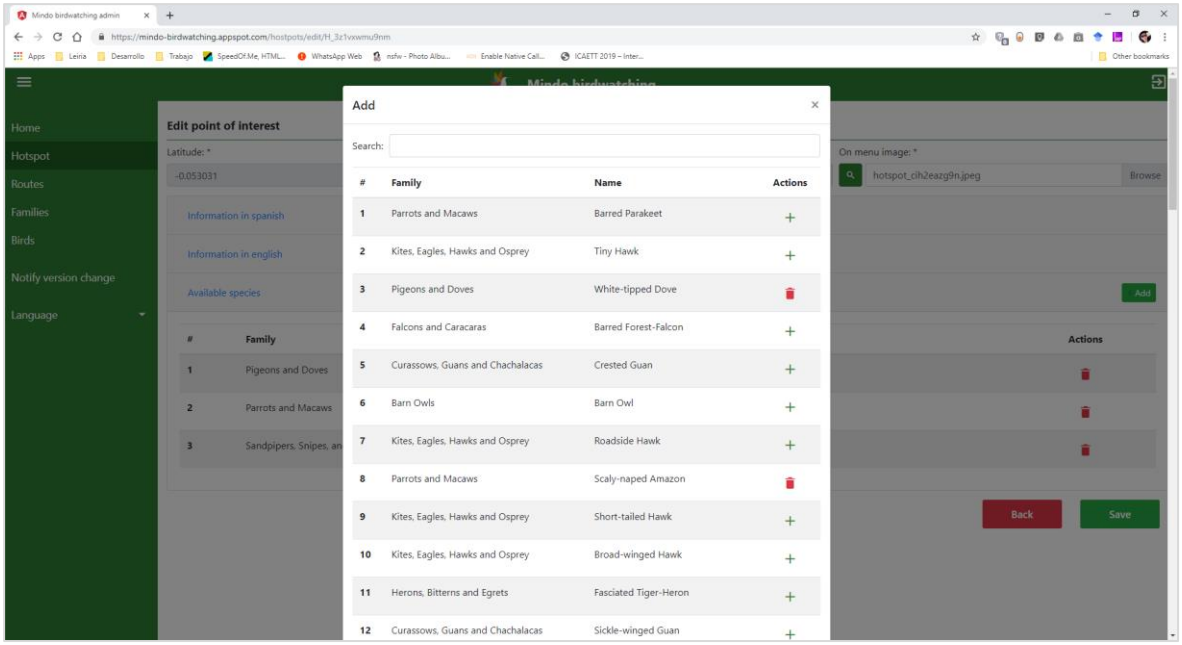


**Figure 63 – Hotspot, add related birds**

### 4.3.4. Routes

When entering the routes section, a table with the list of available routes is shown, each record with a button to edit the information and another one to delete the record. Above the table there is an input to filter the contents of the table. In addition, the button to add a new hotspot is shown in the lower right corner, as can be seen on figure 64.

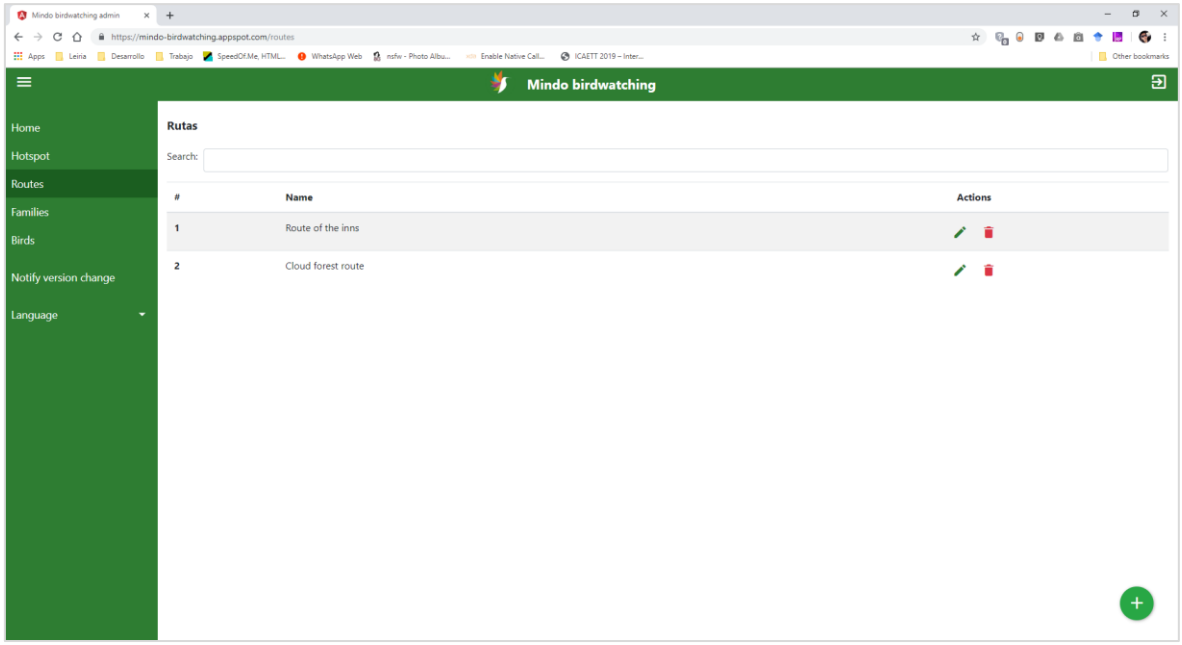


**Figure 64 - Routes list**

### Add/Edit route

When entering Add/Edit route, it will be shown a form to enter the information, it is divided in two entries to separate the information in English and Spanish, as can be seen on figure 65. The form validates data inputs to control that it cannot be saved in case of missing any of the required fields.

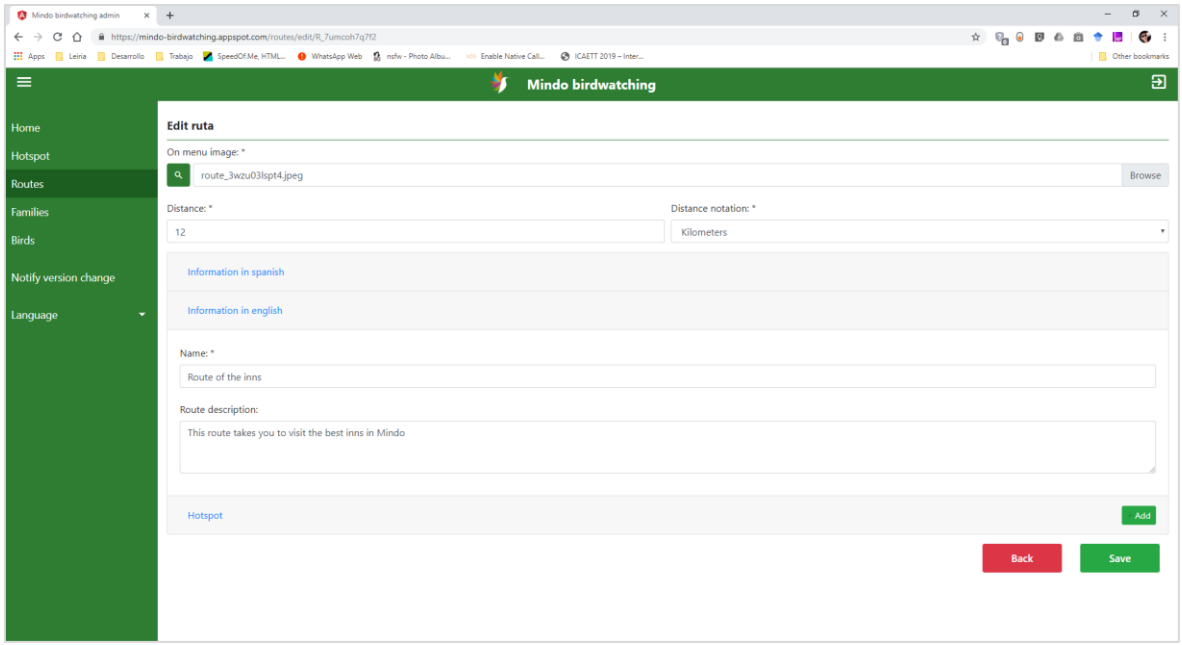


**Figure 65 - Add/Edit route**

There is also an input to load the image that appears in the menu. On the left side of this input, there is a button with a magnifying glass icon, which serves to preview the image that

is loaded or will be loaded, as can be seen on figure 66. In the lower right are the buttons to save the record or go back without saving it.

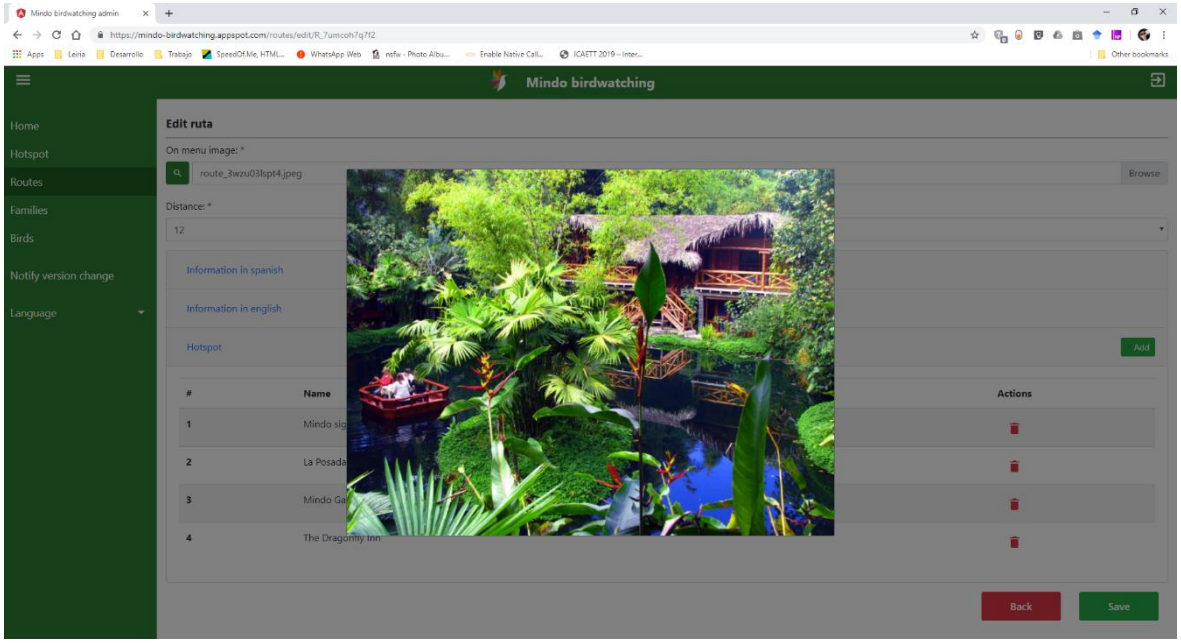


**Figure 66 - Route menu image preview**

At the bottom of the form, there is a section with a table that contains the hotspots associated to the route. At the right side of the header of this section, there is a button to Add a hotspot that opens a popup to select the hotspots in order to make a new relationship them or eliminate it from the respective route, as can be seen on figure 67.

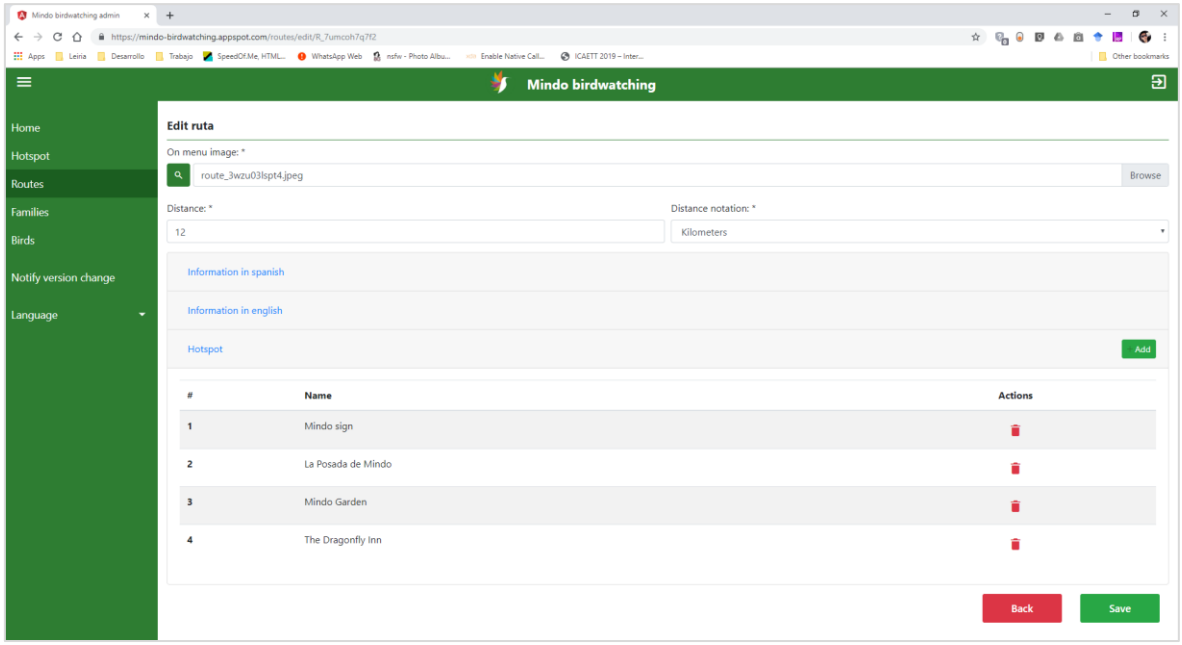


**Figure 67 - Route related hotspots list**

This popup shows a table with the list of available hotspots, an input to filter this at the top of it and an action button in each record to add or eliminate the relationship of the hotspot with the route, as can be seen on figure 68.

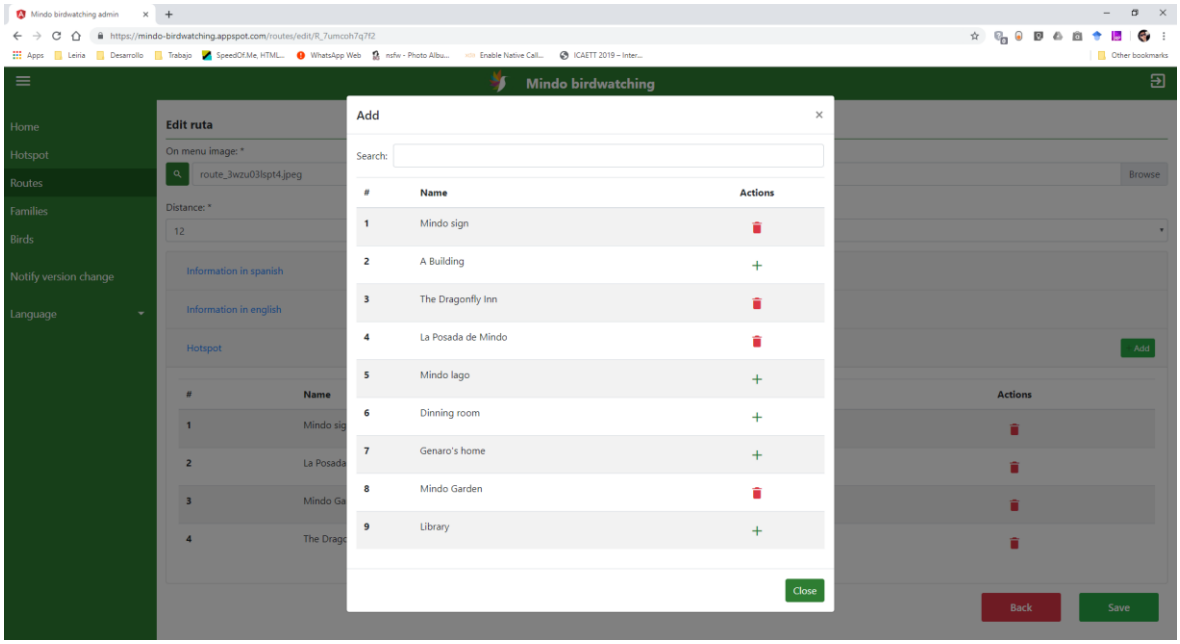


**Figure 68 - Route, add related hotspot**

### 4.3.5. Families

When entering the families' section, a table with the list of existing bird families is shown, each record with a button to edit the information, other to navigate to the birds that are related

to the family and another to delete the record. Above the table there is an input to filter the contents of the table. In addition, the button to add a new bird family is shown in the lower right corner, as can be seen on figure 69.

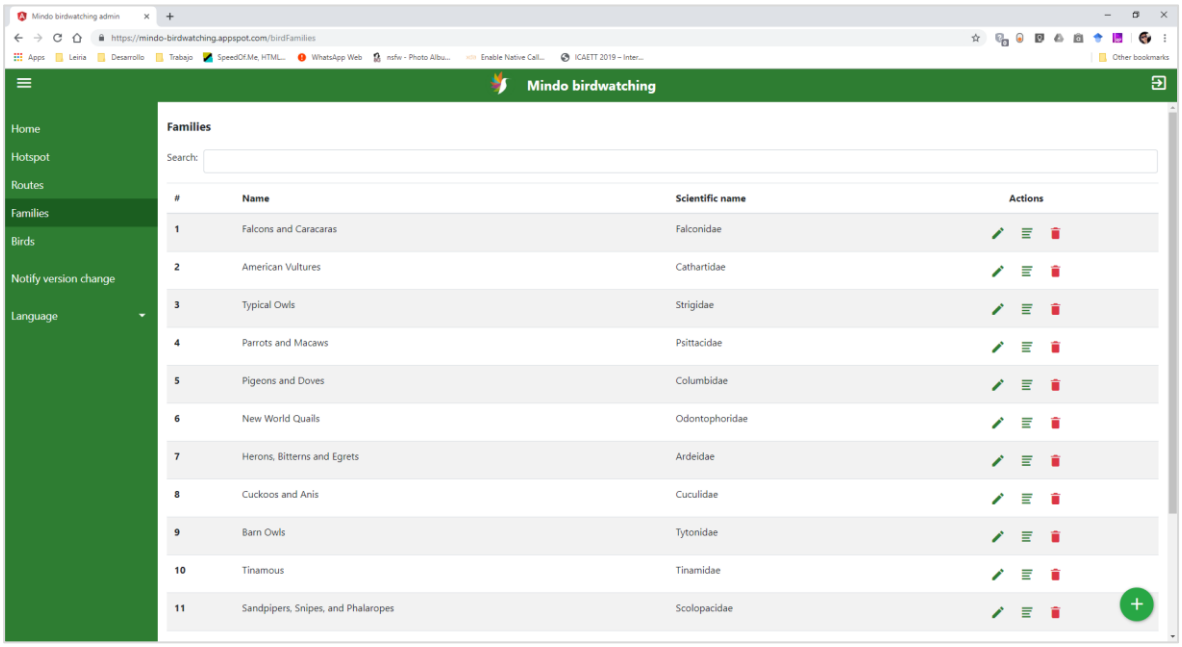


**Figure 69 - Families list**

### Add/Edit family

When entering Add/Edit family, it will be shown a form to enter the information, it is divided in two entries to separate the information in English and Spanish, as can be seen on figure 70. The form validates data inputs to control that it cannot be saved in case of missing any of the required fields or a scientific name that already exists.

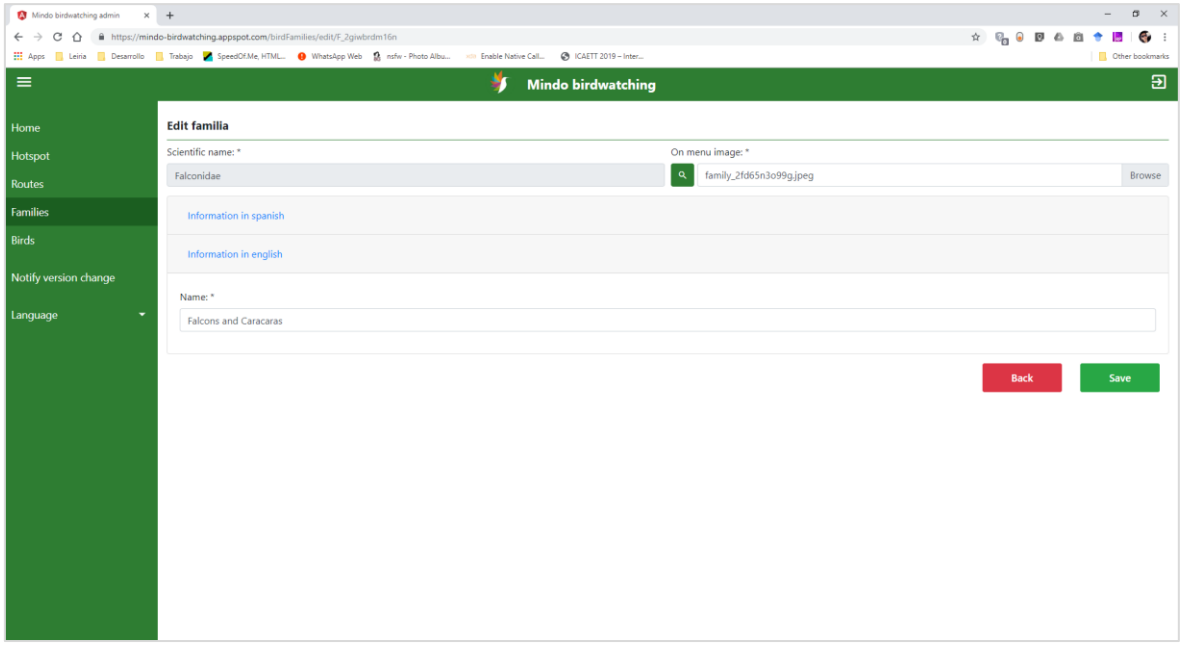


**Figure 70 - Add/Edit families**

There is also an input to load the image that appears in the menu. On the left side of this input, there is a button with a magnifying glass icon, which serves to preview the image that is loaded or will be loaded, as can be seen on figure 71. In the lower right are the buttons to save the record or go back without saving it.

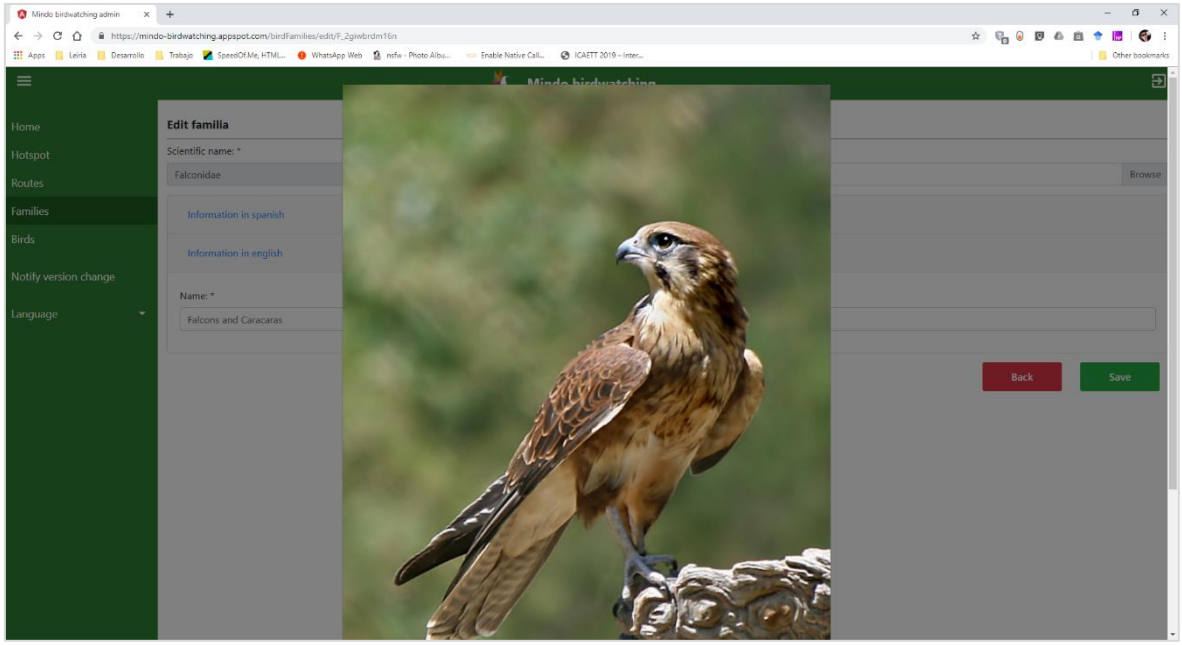


**Figure 71 - Families menu image preview**

### 4.3.6. Birds

When entering the birds' section, a table with the list of existing bird species is shown, each record with a button to edit the information, to manage images, manage videos, manage sounds and other data to delete the corresponding record. Above the table there is an input to filter the contents of the table. In addition, the button to add a new bird species is shown in the lower right corner, as can be seen on figure 72.

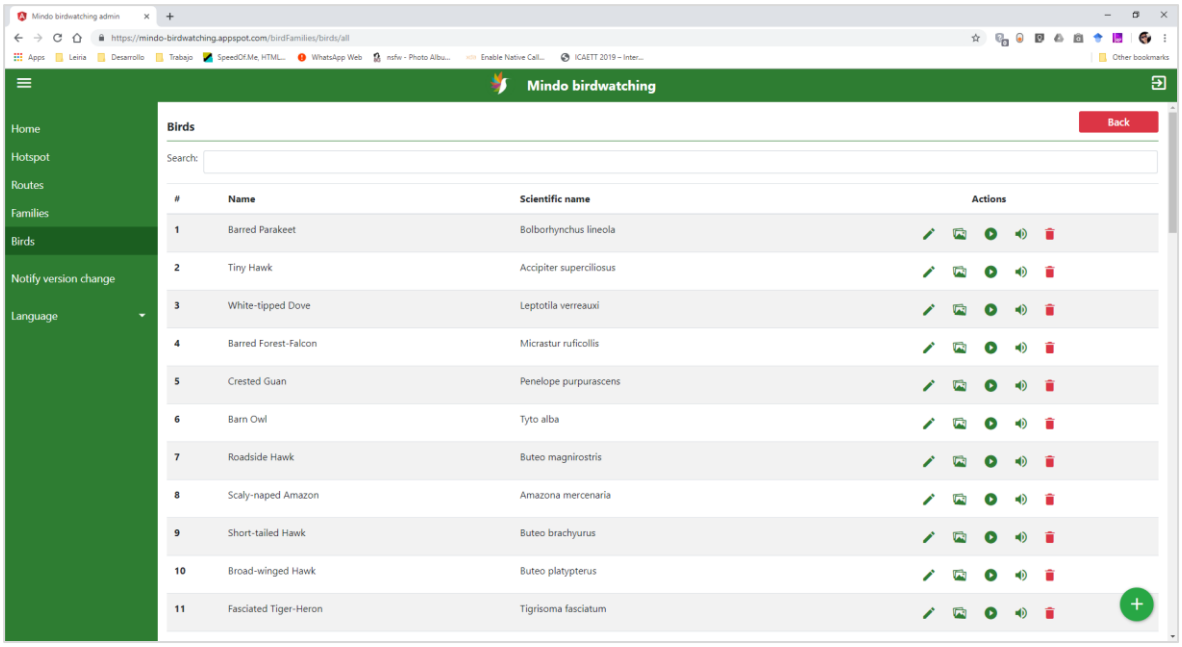


**Figure 72 - Birds list**

#### Add/Edit birds

When entering Add/Edit hotspot, it will be shown a form to enter the information. This form is segmented in two entries to display and separate the information in English and Spanish, as can be seen on figure 60. The form is validated to control that it cannot be saved in case of missing any of the required fields. Furthermore, there is another validation to control that two identical locations in with latitude and longitude cannot be added

When entering Add/Edit a bird information, it will be shown a form to enter the information, as can be seen on figure 73. For the field "Family scientific name", there are some considerations:

- In case the user choses to create a new record from the family section, this input will contain the name of that family;
- In case of having entered from the birds' section, the family to which is desired to associate the species can be searched;
- The record can be only saved with existing scientific family names.

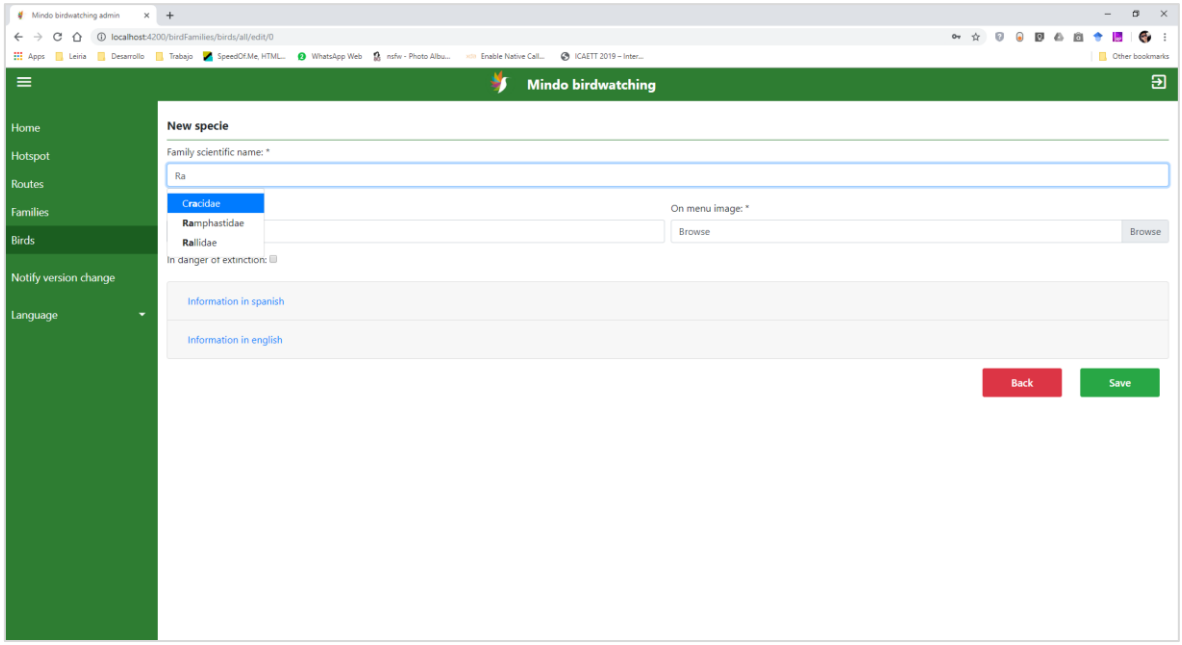


**Figure 73 - Add/Edit bird – Search family**

To add the species information, it will be shown a form to enter the information, it is divided in two entries to separate the information in English and Spanish, as can be seen on figure 74. The form validates data input to control that it cannot be saved in case of missing any of the required fields or birds with a scientific that already exists.

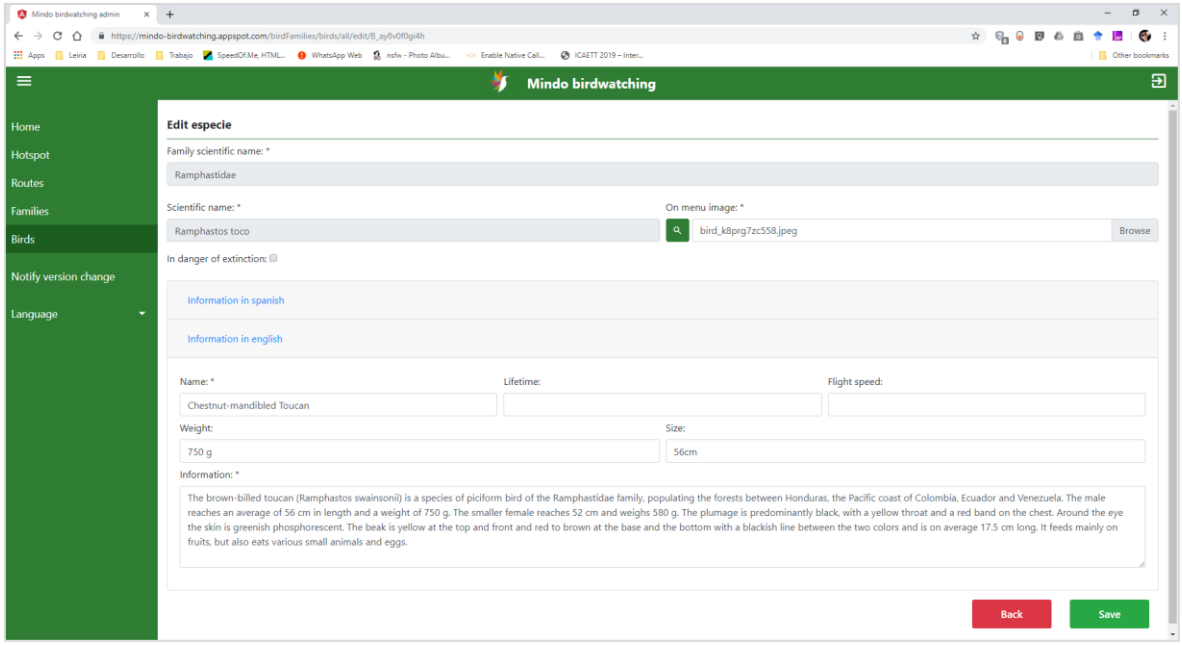


**Figure 74 - Add/Edit bird - Info**

There is also an input to load the image that appears in the menu. On the left side of this input, there is a button with a magnifying glass icon, which serves to preview the image that

is loaded or will be loaded, as can be seen on figure 75. In the lower right are the buttons to save the record or go back without saving it.

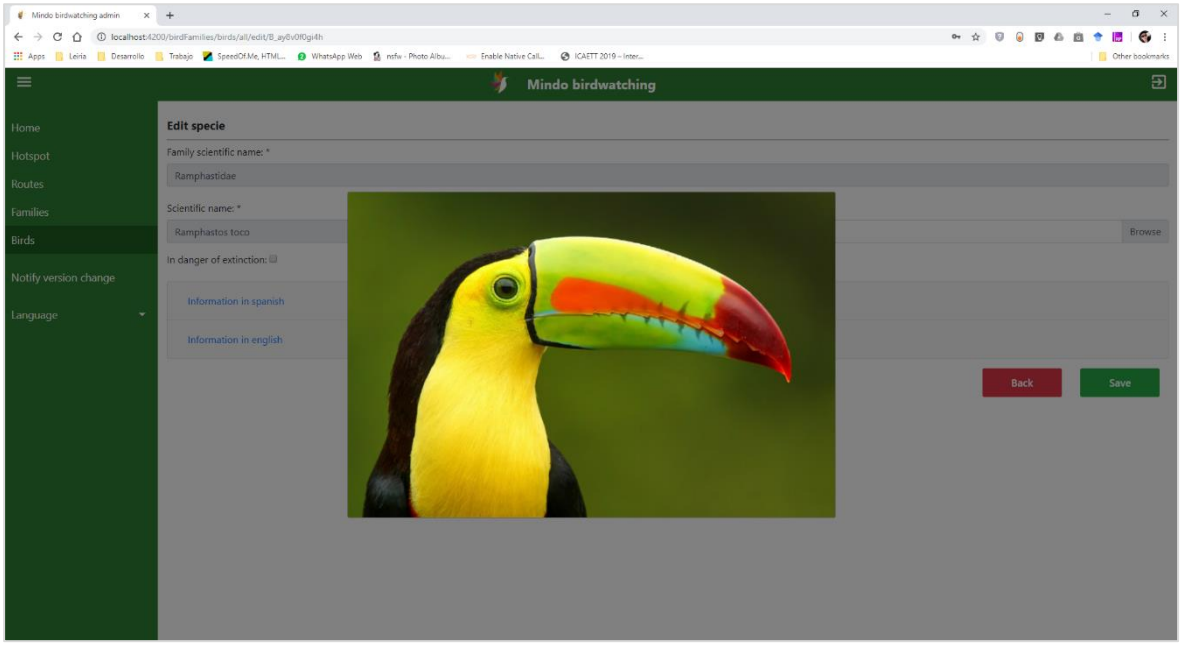


**Figure 75 - Bird menu image preview**

### Add/Edit bird images

When entering Add/Edit bird images, it is shown a gallery of available images for the selected species, with a button to delete it at the bottom of the picture, as can be seen on figure 76.

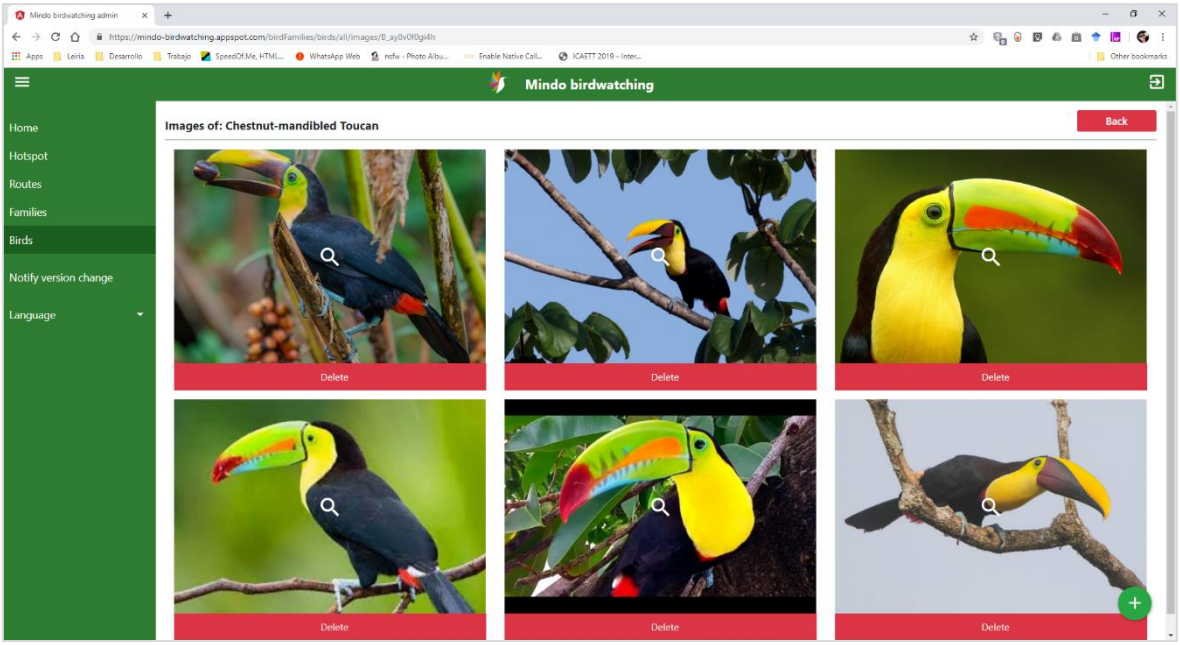


**Figure 76 - Add/Edit bird images - Gallery**

Clicking on an image opens a popup to show a preview of the original size image, as can be seen on figure 77.

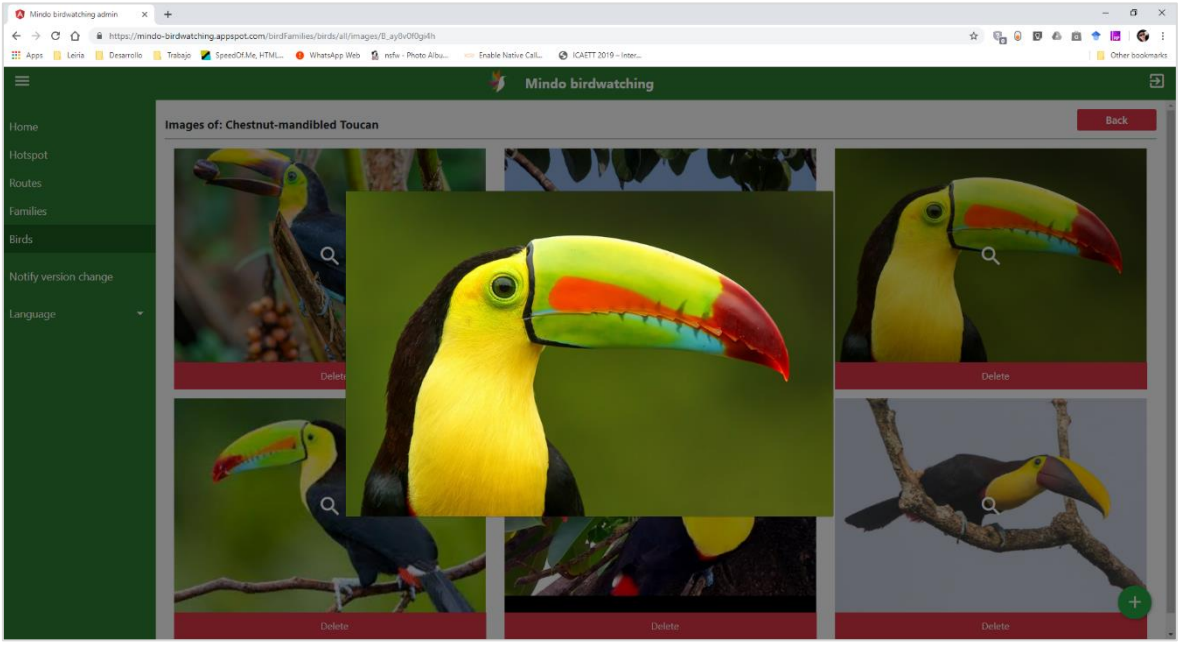


**Figure 77 - Add/Edit bird images – Image preview**

When clicking on the floating button in the lower right corner, it opens a popup to upload a new image for the species, as can be seen on figure 78.

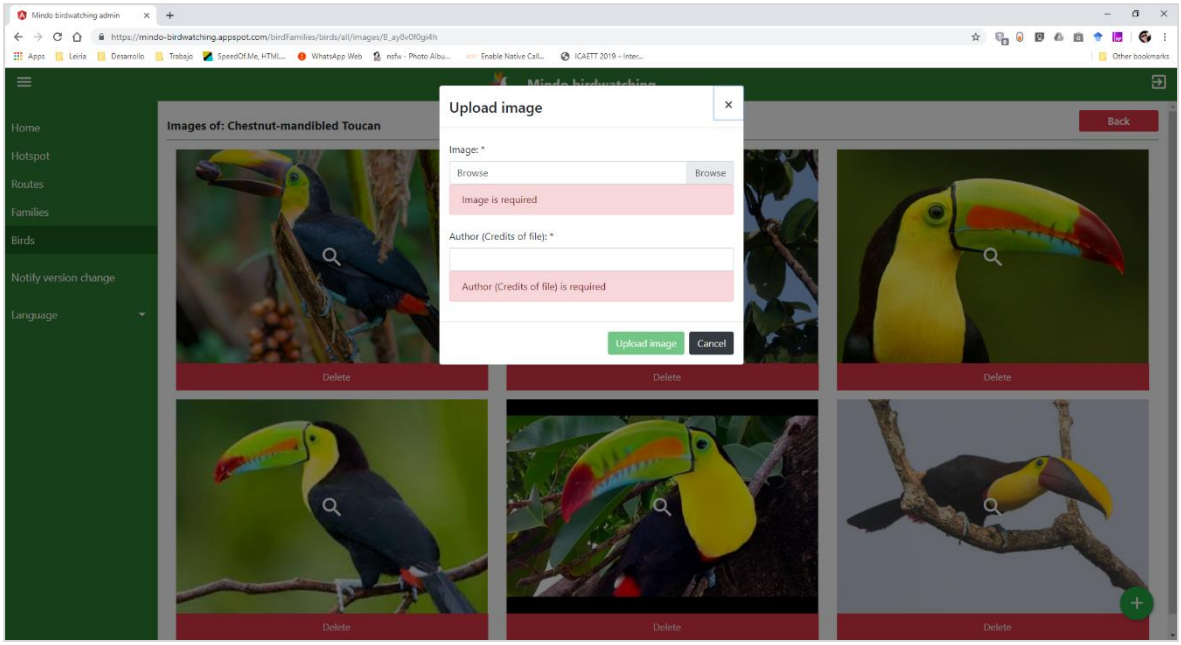


**Figure 78 - Add/Edit bird images - Upload image**

### Add/Edit bird videos

When entering Add/Edit bird videos, it is shown a gallery of available videos (as thumbnails) for the selected species, with a button to delete it at the bottom of the picture, as can be seen on figure 79.

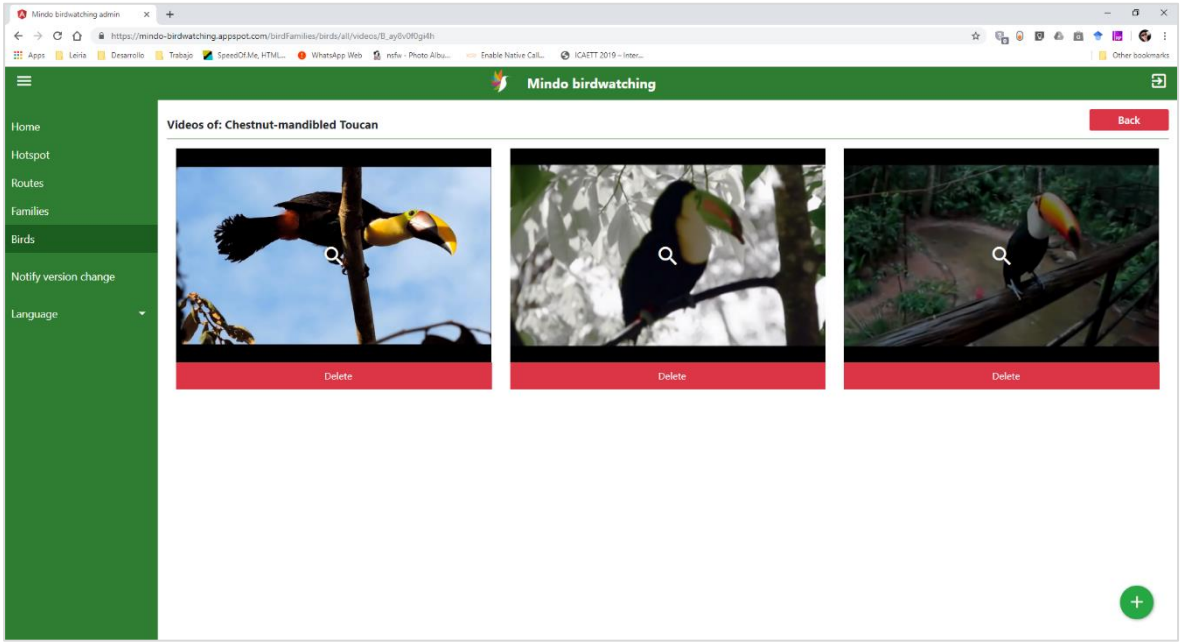


**Figure 79 - Add / edit bird videos - Gallery**

Clicking on one of the images (thumbnails of the video) opens a popup to play the video, as can be seen on figure 80.

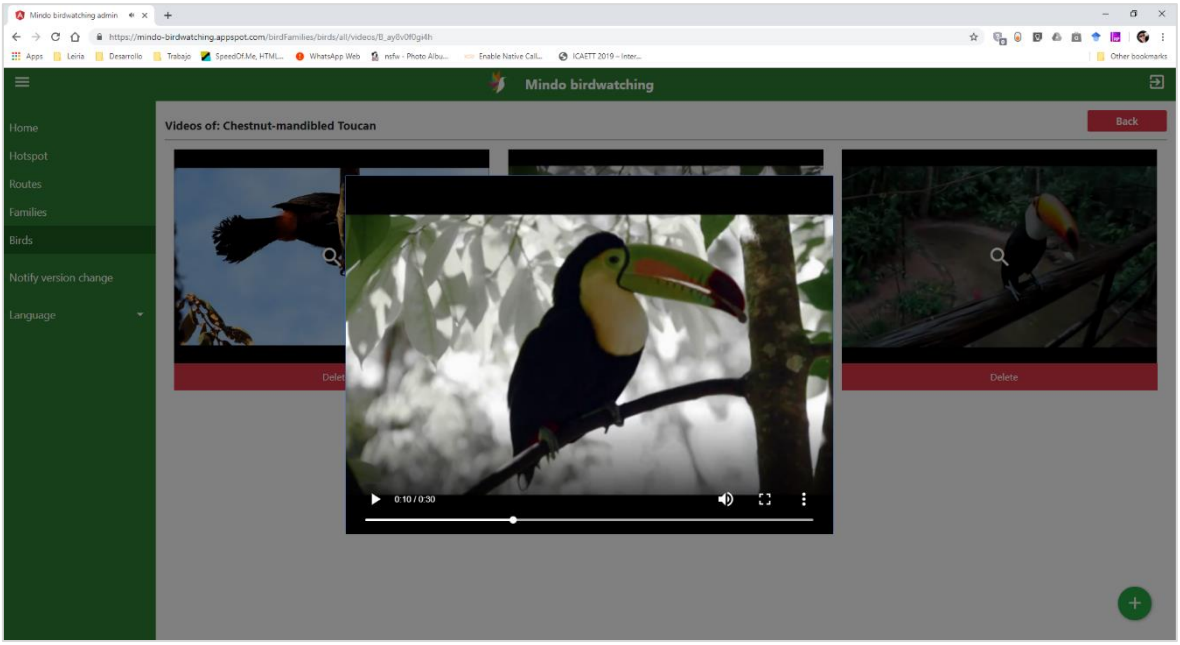


**Figure 80 - Add/Edit bird videos - Video preview**

By clicking on the floating button in the lower right corner, it opens a popup to upload a new video for the species, as can be seen on figure 81.

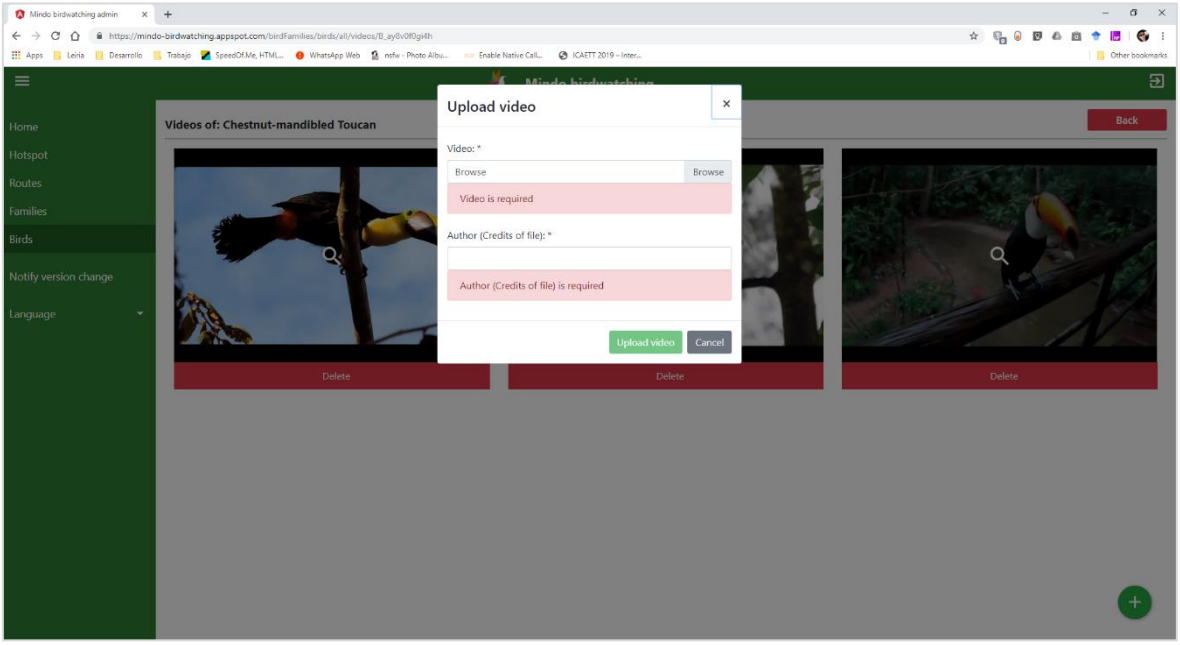


**Figure 81 - Add/Edit bird videos - Upload video**

### Add/Edit bird sounds

When entering Add/Edit bird sounds, it is shown a gallery of available sounds for the selected species with their own interface to reproduce the multimedia content and a button to delete it at the bottom of the interface of each sound, as can be seen on figure 82.

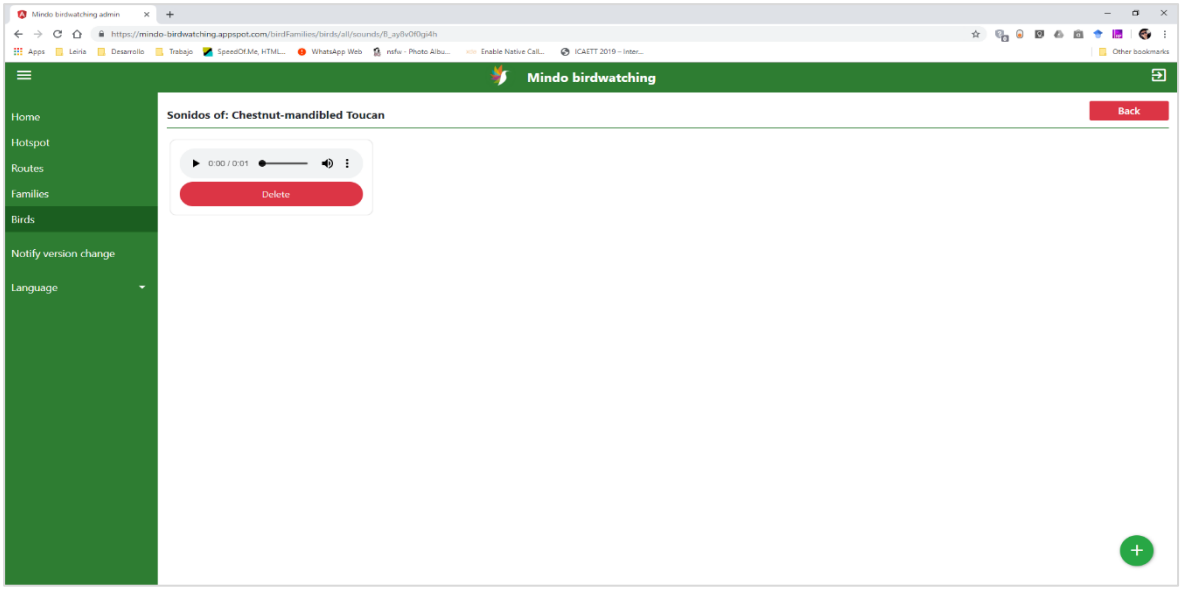


**Figure 82 - Add/Edit bird sounds - Gallery**

When clicking on the floating button on the lower right, it opens a popup to upload a sound clip for the species, as can be seen on figure 83.

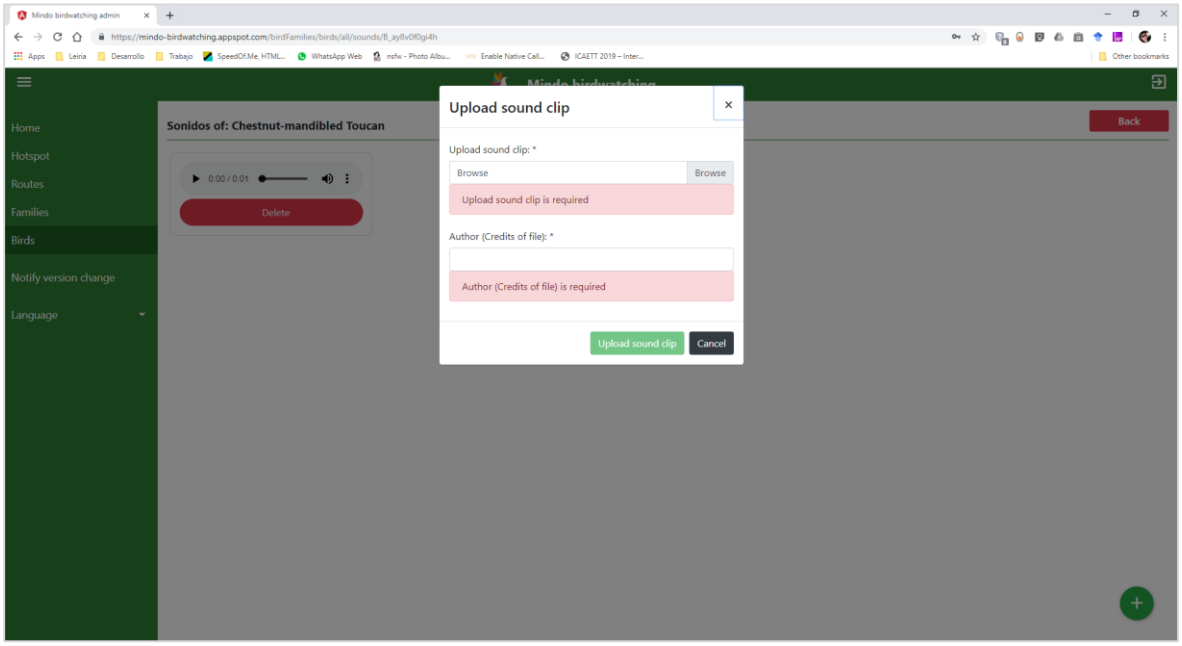


**Figure 83 - Add/Edit bird sounds – Upload**

### Upload percentage component

In all sections to manage the galleries, there is a common component, which appears in the bottom left corner and serves to show the upload percentage of the multimedia file, in order to load several files at the same time, as can be seen on figure 84.

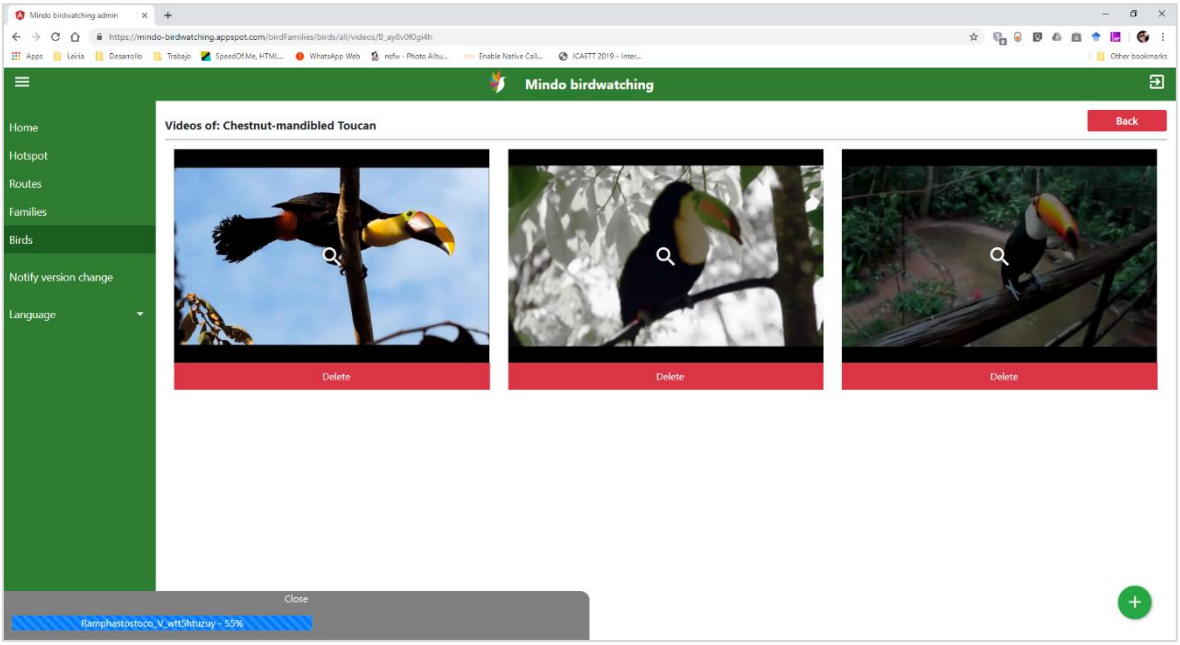


**Figure 84 - Upload percentage component**

### 4.3.7. Database

When entering to database page, the user can change the version of the database and define if the notifications about updates will be available or not, as can be seen on figure 85.

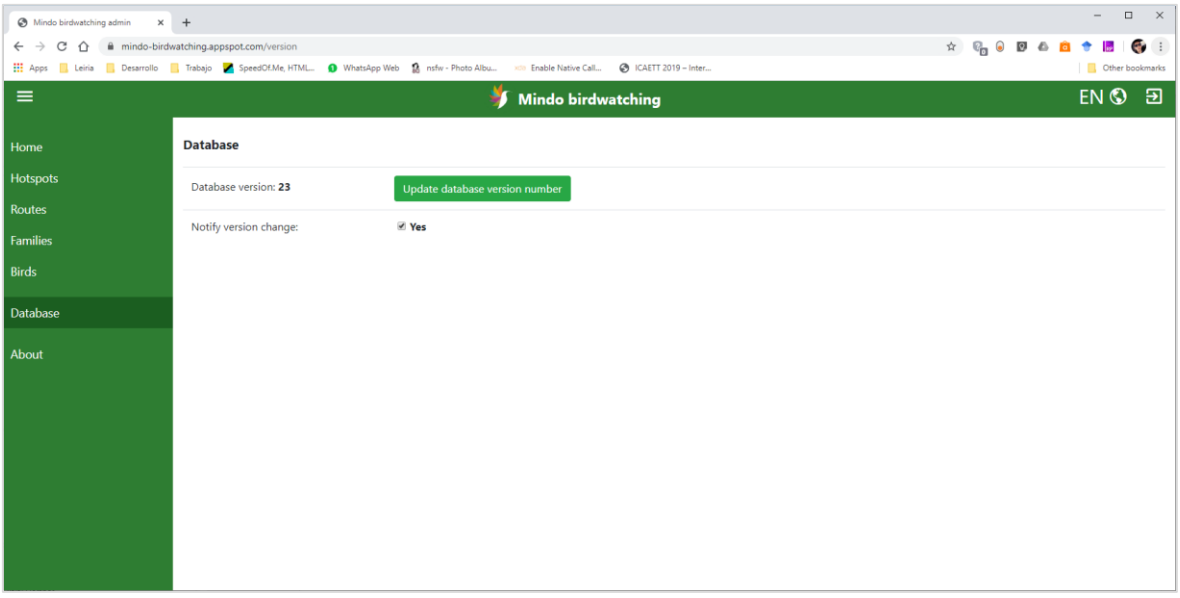


**Figure 85 - Version change confirmation**

When the user clicks the option to update database version, a popup to confirm this action or not will be prompted.

## 4.4. App test

Using a 10-question survey based on the SUS reference, an app test was carried out in Mindo. It lasted 2 days, on the route of the waterfall sanctuary in Mindo and was conducted to 24 users that answered the usability surveys.

It was used the SUS methodology to analyze the results [40], which is:

- For each of the odd numbered questions, subtract 1 from the score;
- For each of the even numbered questions, subtract their value from 5;
- Take these new values which you have found and add up the total score. Then multiply this by 2.5.

Although even though the qualification of each question individually does not have a "value" in the SUS methodology, some questions and answers can be analyzed to get an idea of what the testers think about the app, for example:

- **Question: I thought the app was easy to use**

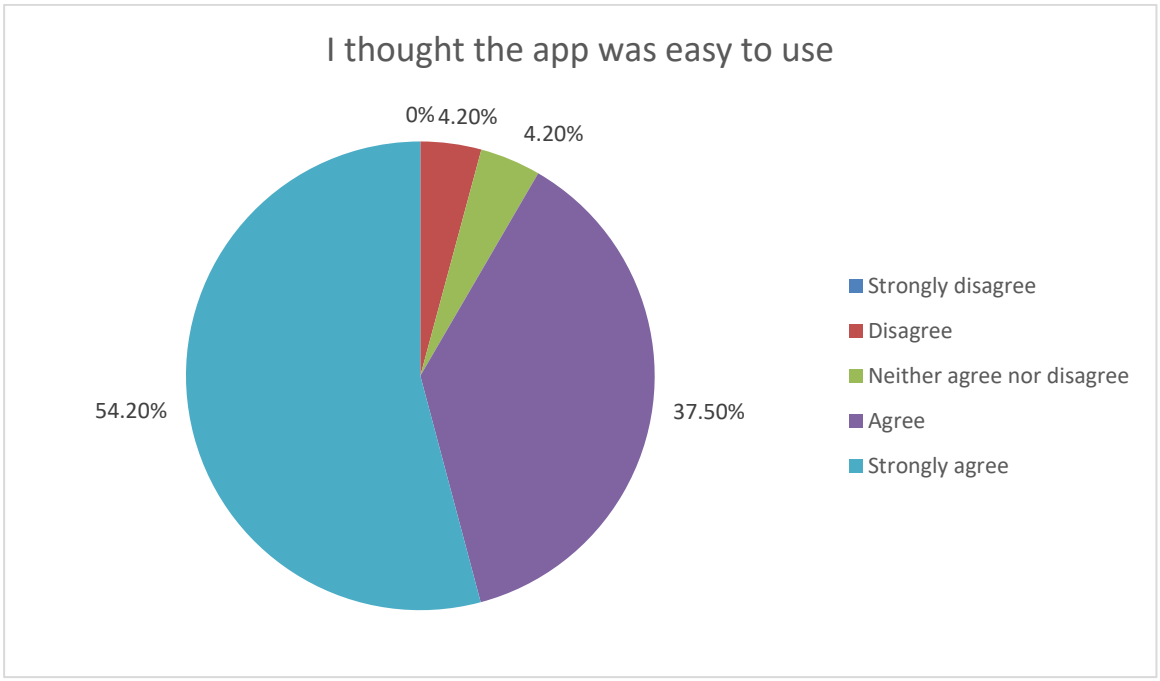


**Figure 86 – Question: I thought the app was easy to use**

More than half of the users (54,2%) answered “strongly agree”, as can be seen on figure 86, this suggests that the application was easy to use, indicating that the interface is user-friendly and intuitive.

- **Question: I needed to learn a lot of things before I could get going with this app**

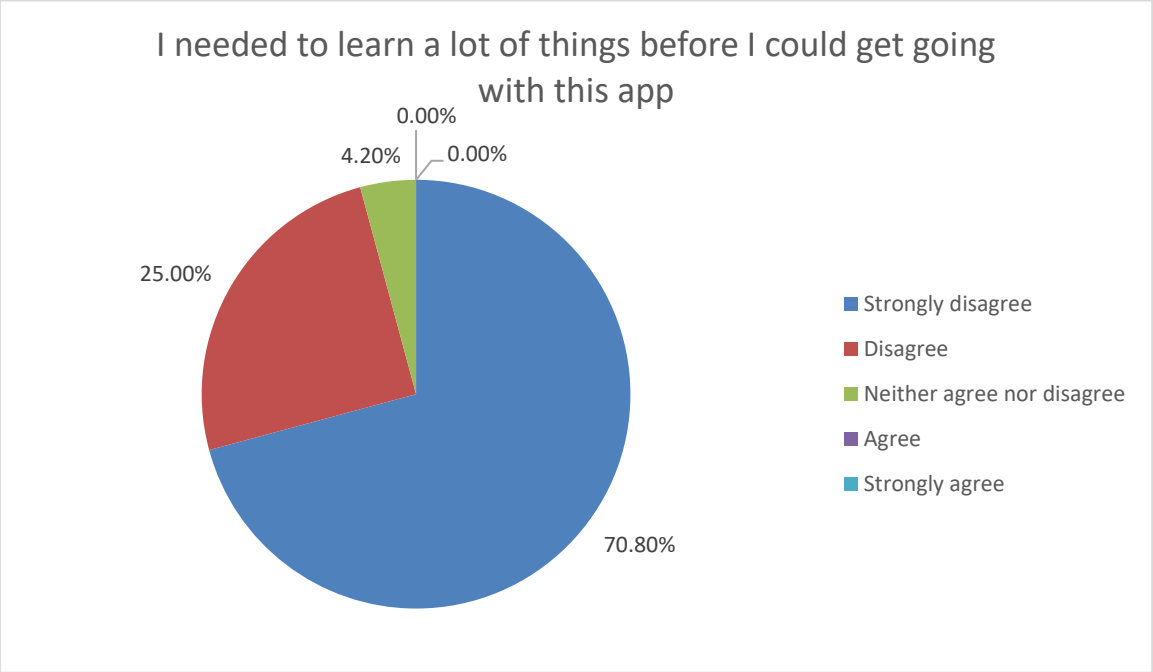


**Figure 87 - Question: I needed to learn a lot of things before I could get going with this app**

70.8% of the users answered, “strongly agree”, as can be seen on figure 87, this suggests that the application can be used by individuals without special knowledge in the field of computer science or mobile devices, facilitating access to everyone, especially children and the elderly.

All results about the usability survey can be found on appendix F.

Evaluating the answers obtained using the SUS methodology, an 82.2 on average usability rating of the application was obtained. Considering that:

- 80.3 or higher is a good app;
- 68 or thereabouts is a good app but it could be improved;
- 51 or under is bad and it should be improved.

We can conclude that the usability tests for the app were highly positive. The tabulation results can be found on appendix G.

# 5. Conclusion and future work

This project aimed to develop an app for birdwatching that, in addition to the common features (present in other existing applications), such as displaying information and multimedia content, it implements a function with AR. In addition, it was developed a web application that serves as backoffice to manage the information. The app presents routes composed by several hotspots for birdwatching and allows access to information about the birds that live in the Mindo area. All content in this app (informative text and multimedia) make the application more attractive for users, but the augmented reality, distinctive feature of this application, with the options to capture photos with a 3D bird model using AR, which can only be taken in a hotspot in Mindo, for certain bird species, and share it with his friends and family generates curiosity in people, making this app a desirable one to be downloaded.

In addition, this app is supported by a web-based application as backoffice that gives to it a great potential to promote tourism in the area, displaying content about tourist attractions and creating routes with hotspots not only to do birdwatching, but also to visit Mindo town and its surroundings.

The possibility of using the application without the need for an internet connection is an important feature, since when doing tourism in Mindo, most of the time the user will be in the forest, where the mobile phone signal has no coverage.

The website created to manage the information of the application (informative text and multimedia content related to birds, routes and hotspots) offers the advantage that anyone, allowed by the administrator and with login credentials, can populate and manage the information of the database due to its simple and user-friendly interface.

For future work it would be worth to have more hotspots, more species and more animated 3D models for other species. Likewise, it is planned to create a module in which the user can use the app to recognize the bird based on the sound (as has been seen in other apps). It would be also recommended to implement a kind of observation logbook. In addition, the basis of the application would serve to implement similar work in any other location, taking benefit that at least 90% of the information is obtained from the external database not from the code of the application.

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# Appendices

## Appendix A: Survey on birdwatching for a master's dissertation



### Survey on birdwatching for a master's thesis

This questionnaire is being undertaken as part of a master's dissertation entitled "AUGMENTED REALITY BIRDWATCHING IN MINDO". Its results, after being examined by Polytechnic Institute of Leiria supervisors, will be used for a statistical study to be carried out in order to develop part of this project work

* Required

### Regarding bird watching.

Birdwatching refers to the observation of live birds in their natural habitat.

1. **Your interest in bird watching is** *
   *Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Low | ◯ | ◯ | ◯ | ◯ | ◯ | High |

2. **How do you classify your knowledge related to birdwatching?** *
   *Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Low | ◯ | ◯ | ◯ | ◯ | ◯ | High |

3. **How do you classify your knowledge about bird species?** *
   *Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Low | ◯ | ◯ | ◯ | ◯ | ◯ | High |

4. **Would you like to have an app, that allows you to take pre-defined routes, passing through several spots for birdwatching?** *
   *Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Dislike | ◯ | ◯ | ◯ | ◯ | ◯ | Like |

5. **Would you like to have an app, that provides several spots for birdwatching, without pre-defined routes?** *
   *Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Dislike | ◯ | ◯ | ◯ | ◯ | ◯ | Like |

## Regarding technology

6. **What kind of cellphone do you have?** *
*Mark only one oval.*

- ◯ Android cellphone
- ◯ Apple cellphone
- ◯ Other: _____

## Regarding augmented reality.

Augmented reality is a technology that allows overlapping virtual objects over the real world (for this work) with the use of a cell phone and its camera.

7. **Do you think that the use of augmented reality is mandatory for an app for birdwatching?** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Disagree | ◯ | ◯ | ◯ | ◯ | ◯ | Agree |

8. **Have you ever used an app with augmented reality?** *
*Mark only one oval.*

- ◯ Yes
- ◯ No

9. **If previous answer was "Yes". How often do you use applications with augmented reality?**
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Low frequency | ◯ | ◯ | ◯ | ◯ | ◯ | High frequency |

10. **If previous answer were "Yes". How do you classify your ability to use augmented reality?**
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Low | ◯ | ◯ | ◯ | ◯ | ◯ | High |

11. **Do you think that using apps with augmented reality is easy?** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Disagree | ◯ | ◯ | ◯ | ◯ | ◯ | Agree |

12. **How do you classify your knowledge about what augmented reality is?** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Low | ◯ | ◯ | ◯ | ◯ | ◯ | High |

13. **Would you like to use an application for cell phone / tablet to learn more about birds, using augmented reality?** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Dislike | ◯ | ◯ | ◯ | ◯ | ◯ | Like |

14. **Do you think that using an app with augmented reality will be easier to access information about birds?** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Disagree | ◯ | ◯ | ◯ | ◯ | ◯ | Agree |

15. **Do you think that using an app with augmented reality will increase your interest in birdwatching?** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Disagree | ◯ | ◯ | ◯ | ◯ | ◯ | Agree |

16. **Do you consider that learning to use applications with augmented reality may result easy?** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Disagree | ◯ | ◯ | ◯ | ◯ | ◯ | Agree |

17. **Do you have the necessary resources to use an app with augmented reality? (example smartphone)** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| None | ◯ | ◯ | ◯ | ◯ | ◯ | Many |

18. **Do you know people that can help you with the use of augmented reality if necessary?** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Few | ◯ | ◯ | ◯ | ◯ | ◯ | Lots |

19. **Do you think that using augmented reality can improve your overall birdwatching experience?** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Disagree | ◯ | ◯ | ◯ | ◯ | ◯ | Agree |

20. **Do you think that using augmented reality for birdwatching can be an enjoyable experience?** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Disagree | ◯ | ◯ | ◯ | ◯ | ◯ | Agree |

21. **Would you like the application, in addition to virtual animations, to reproduce sounds of birds as well?** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Disagree | ◯ | ◯ | ◯ | ◯ | ◯ | Agree |

22. **Using augmented reality will help you to learn things that would be impossible without it?** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Disagree | ◯ | ◯ | ◯ | ◯ | ◯ | Agree |

## Regarding personal information

23. **Age** *

24. **Gender** *
*Mark only one oval.*

- ◯ Female
- ◯ Male
- ◯ I prefer not to say

25. **Country where you live** *

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Appendix B: Survey on birdwatching for a master's dissertation (Spanish version)



# Encuesta sobre observación de aves para tesis de maestría.

La presente encuesta se realiza como parte de una disertación para maestría, titulada “AUGMENTED REALITY BIRDWATCHING IN MINDO” (ORNITOLOGÍA CON REALIDAD AUMENTADA EN MINDO). Los resultados obtenidos, después de ser revisados por los supervisores de la tesis de maestría del Instituto Politécnico de Leiria, serán utilizados para realizar un estudio estadístico que formará parte del mencionado trabajo.

* Required

## Acerca de la observación de aves.

Observación de aves, se refiere a la actividad centrada en la observación y el estudio de las aves silvestres en su hábitat natural.

1. **Su interés en la observación de aves es** *
   *Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Bajo | ◯ | ◯ | ◯ | ◯ | ◯ | Alto |

2. **¿Cómo calificaría su conocimiento relacionado con la observación de aves?** *
   *Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Bajo | ◯ | ◯ | ◯ | ◯ | ◯ | Alto |

3. **¿Cómo calificaría su conocimiento sobre aves?** *
   *Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Bajo | ◯ | ◯ | ◯ | ◯ | ◯ | Alto |

4. **¿Le gustaría tener una aplicación que te permita seguir rutas predefinidas, pasando por varios lugares para observar aves?** *
   *Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Me desagradaría | ◯ | ◯ | ◯ | ◯ | ◯ | Me agradaría |

5. **¿Le gustaría tener una aplicación que ofrezca varios lugares para la observación de aves, sin rutas predefinidas?** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Me desagradaría | ◯ | ◯ | ◯ | ◯ | ◯ | Me agradaría |

## Acerca de tecnología

6. **¿Que tipo de celular utiliza?** *
*Mark only one oval.*

- ◯ Celular Android
- ◯ Celular Apple
- ◯ Other: _____

## Acerca de realidad aumentada.

La realidad aumentada es una tecnología que permite superponer objetos virtuales sobre el mundo real (para este trabajo) con el uso de un celular y su cámara.

7. **¿Cree usted que el uso de realidad aumentada es obligatorio para una aplicación para observación de aves?** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| En desacuerdo | ◯ | ◯ | ◯ | ◯ | ◯ | De acuerdo |

8. **¿Ha utilizado alguna vez alguna aplicación con realidad aumentada?** *
*Mark only one oval.*

- ◯ Sí
- ◯ No

9. **Si su respuesta a la pregunta anterior fue "Si", ¿Que tan a menudo utiliza aplicaciones con realidad aumentada?**
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| A veces | ◯ | ◯ | ◯ | ◯ | ◯ | Frecuentemente |

10. **Si su respuesta a la pregunta anterior fue "Si", ¿Cómo calificaría su habilidad para utilizar realidad aumentada?**
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Baja | ◯ | ◯ | ◯ | ◯ | ◯ | Alta |

11. **¿Cree usted que utilizar aplicaciones con realidad aumentada es fácil?** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| En desacuerdo | ◯ | ◯ | ◯ | ◯ | ◯ | De acuerdo |

12. **¿Cómo calificaría usted su conocimiento acerca de que es realidad aumentada?** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Bajo | ◯ | ◯ | ◯ | ◯ | ◯ | Alto |

13. **¿Le gustaría utilizar una aplicación para Smartphone / Tablet para aprender más acerca de aves utilizando realidad aumentada?** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Me desagradaría | ◯ | ◯ | ◯ | ◯ | ◯ | Me agradaría |

14. **¿Cree usted que utilizando una aplicación móvil con realidad aumentada sería más fácil acceder a información acerca de las aves?** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| En desacuerdo | ◯ | ◯ | ◯ | ◯ | ◯ | De acuerdo |

15. **¿Cree usted que utilizar una aplicación con realidad aumentada aumentará su interés en la observación de aves?** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| En desacuerdo | ◯ | ◯ | ◯ | ◯ | ◯ | De acuerdo |

16. **¿Cree usted que aprender a utilizar aplicaciones con realidad aumentada resultará fácil?** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| En desacuerdo | ◯ | ◯ | ◯ | ◯ | ◯ | De acuerdo |

17. **¿Posee usted los recursos necesarios para utilizar una aplicación móvil con realidad aumentada? (por ejemplo smarphone)** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Ninguno | ◯ | ◯ | ◯ | ◯ | ◯ | Varios |

18. **¿Conoce usted personas que puedan ayudarle a utilizar una aplicación con realidad aumentada en caso de ser necesario?** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Ninguna | ◯ | ◯ | ◯ | ◯ | ◯ | Varias |

19. **¿Cree usted que utilizar realidad aumentada puede mejorar su experiencia en la observación de aves?** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| En desacuerdo | ◯ | ◯ | ◯ | ◯ | ◯ | De acuerdo |

20. **¿Le gustaría que la aplicación, además modelos virtuales animados, posea sonidos de las aves?** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| En desacuerdo | ◯ | ◯ | ◯ | ◯ | ◯ | De acuerdo |

21. **¿Cree usted que utilizando realidad aumentada puede aprender cosas que serían imposibles sin ella?** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| En desacuerdo | ◯ | ◯ | ◯ | ◯ | ◯ | De acuerdo |

## Acerca de su información personal.

22. **Edad** *

23. **Género** *

*Mark only one oval.*

- Mujer
- Hombre
- Prefiero no decirlo

24. **País en el que vive** *

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# Appendix C: Survey on birdwatching for a master's dissertation, survey results

| Timestamp | Su interés en la observaci | ¿Cómo calificaría su cond | ¿Cómo calificaría su cond | ¿Le gustaría tener una ap | ¿Le gustaría tener una ap | ¿Que tipo de celular utiliz | ¿Cree usted que el uso de |
|---|---|---|---|---|---|---|---|
| 3/27/2019 21:34:44 | 4 | 2 | 2 | 5 | 5 | Celular Android | 5 |
| 3/27/2019 21:35:13 | 4 | 1 | 2 | 4 | 4 | Celular Apple | 3 |
| 3/27/2019 21:35:20 | 4 | 2 | 2 | 4 | 3 | Celular Apple | 4 |
| 3/27/2019 21:36:12 | 3 | 3 | 3 | 5 | 5 | Celular Apple | 5 |
| 3/27/2019 21:36:24 | 3 | 1 | 1 | 3 | 3 | Celular Android | 3 |
| 3/27/2019 21:36:45 | 5 | 1 | 1 | 5 | 5 | Celular Android | 3 |
| 3/27/2019 21:37:56 | 3 | 1 | 1 | 4 | 2 | Celular Android | 5 |
| 3/27/2019 21:38:37 | 3 | 1 | 2 | 5 | 5 | Celular Android | 3 |
| 3/27/2019 21:38:52 | 4 | 2 | 1 | 3 | 5 | Celular Android | 1 |
| 3/27/2019 21:39:05 | 3 | 1 | 1 | 3 | 4 | Celular Android | 5 |
| 3/27/2019 21:43:09 | 5 | 1 | 2 | 5 | 5 | Celular Apple | 3 |
| 3/27/2019 21:48:38 | 2 | 1 | 1 | 4 | 4 | Celular Android | 3 |
| 3/27/2019 21:49:18 | 4 | 3 | 2 | 4 | 4 | Celular Android | 4 |
| 3/27/2019 21:49:38 | 3 | 2 | 3 | 4 | 4 | Celular Android | 4 |
| 3/27/2019 21:49:58 | 4 | 2 | 2 | 3 | 5 | Celular Android | 2 |
| 3/27/2019 21:50:16 | 5 | 3 | 3 | 5 | 3 | Celular Android | 4 |
| 3/27/2019 21:52:43 | 4 | 3 | 3 | 5 | 5 | Celular Android | 5 |
| 3/27/2019 21:56:41 | 3 | 3 | 3 | 5 | 5 | Celular Android | 3 |
| 3/27/2019 21:58:52 | 3 | 2 | 2 | 2 | 2 | Celular Android | 2 |
| 3/27/2019 22:08:00 | 3 | 3 | 3 | 3 | 4 | Celular Apple | 4 |
| 3/27/2019 22:14:30 | 3 | 2 | 2 | 4 | 1 | Celular Android | 2 |
| 3/27/2019 22:27:08 | 3 | 2 | 2 | 4 | 4 | Celular Android | 3 |
| 3/27/2019 22:36:02 | 3 | 1 | 2 | 3 | 3 | Celular Android | 2 |
| 3/27/2019 22:48:43 | 4 | 1 | 1 | 5 | 5 | Celular Android | 3 |
| 3/27/2019 22:49:15 | 3 | 3 | 3 | 4 | 4 | Celular Android | 2 |
| 3/27/2019 23:04:57 | 2 | 2 | 1 | 3 | 3 | Celular Android | 4 |
| 3/27/2019 23:43:22 | 5 | 2 | 2 | 5 | 5 | Celular Android | 4 |
| 3/28/2019 0:24:29 | 4 | 3 | 3 | 4 | 4 | Celular Android | 4 |
| 3/28/2019 7:41:04 | 5 | 3 | 3 | 2 | 5 | Celular Android | 4 |
| 3/28/2019 8:10:39 | 5 | 2 | 2 | 5 | 5 | Celular Android | 3 |
| 3/28/2019 8:49:18 | 1 | 1 | 1 | 2 | 1 | Celular Android | 3 |
| 3/28/2019 9:32:12 | 4 | 1 | 1 | 5 | 5 | Celular Android | 3 |
| 3/28/2019 10:11:24 | 5 | 1 | 1 | 5 | 5 | Celular Apple | 1 |
| 3/28/2019 10:13:27 | 4 | 2 | 2 | 5 | 4 | Celular Apple | 3 |
| 3/28/2019 12:01:51 | 5 | 2 | 2 | 5 | 5 | Celular Android | 3 |
| 3/28/2019 12:45:28 | 4 | 2 | 2 | 5 | 5 | Celular Android | 4 |
| 3/28/2019 12:54:21 | 2 | 1 | 1 | 4 | 4 | Celular Android | 4 |
| 3/28/2019 15:13:13 | 4 | 2 | 2 | 5 | 3 | Celular Apple | 4 |
| 3/28/2019 17:15:45 | 4 | 1 | 2 | 3 | 4 | Celular Android | 5 |
| 3/29/2019 18:50:29 | 3 | 2 | 3 | 4 | 1 | Celular Apple | 1 |

| ¿Ha utilizado alguna vez a | Si su respuesta a la pregu | Si su respuesta a la pregu | ¿Cree usted que utilizar a | ¿Cómo calificaría usted s | ¿Le gustaría utilizar una a | ¿Cree usted que utilizand | ¿Cree usted que utilizar u |
|---|---|---|---|---|---|---|---|
| Sí | 4 | 5 | 4 | 5 | 5 | 5 | 5 |
| Sí | 1 | 3 | 3 | 3 | 4 | 5 | 4 |
| Sí | 3 | 3 | 3 | 2 | 4 | 5 | 5 |
| No | | | 1 | 1 | 5 | 5 | 4 |
| No | | | 3 | 2 | 3 | 4 | 5 |
| No | | | 5 | 1 | 5 | 5 | 3 |
| Sí | 4 | 5 | 4 | 4 | 5 | 5 | 5 |
| Sí | 1 | 3 | 4 | 2 | 5 | 5 | 4 |
| No | | | 5 | 3 | 5 | 4 | 4 |
| Sí | 1 | 2 | 4 | 2 | 4 | 4 | 4 |
| Sí | 2 | 4 | 4 | 4 | 5 | 5 | 5 |
| Sí | 5 | 5 | 5 | 5 | 4 | 4 | 4 |
| No | | | 4 | 3 | 4 | 4 | 4 |
| Sí | 2 | 5 | 5 | 3 | 3 | 3 | 3 |
| Sí | 2 | 4 | 2 | 2 | 4 | 4 | 5 |
| Sí | 2 | 2 | 2 | 2 | 3 | 3 | 4 |
| No | | | 4 | 3 | 5 | 5 | 5 |
| Sí | 1 | 3 | 5 | 4 | 5 | 5 | 5 |
| Sí | 2 | 4 | 5 | 4 | 2 | 2 | 4 |
| No | | | 3 | 4 | 4 | 3 | 3 |
| Sí | 1 | 3 | 3 | 3 | 4 | 3 | 5 |
| Sí | 2 | 3 | 5 | 5 | 5 | 5 | 4 |
| Sí | 2 | 3 | 3 | 3 | 3 | 4 | 3 |
| Sí | 1 | 5 | 5 | 5 | 5 | 5 | 3 |
| Sí | 1 | 3 | 4 | 5 | 5 | 3 | 4 |
| No | | | 3 | 3 | 4 | 4 | 4 |
| No | | | 5 | 2 | 5 | 5 | 5 |
| Sí | 1 | 3 | 4 | 3 | 4 | 4 | 4 |
| No | | | 5 | 1 | 5 | 5 | 5 |
| No | | | 3 | 3 | 5 | 5 | 5 |
| Sí | 1 | 3 | 4 | 4 | 1 | 3 | 1 |
| Sí | 4 | 4 | 4 | 5 | 5 | 5 | 4 |
| Sí | 1 | 1 | 1 | 1 | 3 | 3 | 1 |
| No | | | 3 | 3 | 4 | 4 | 4 |
| Sí | 2 | 2 | 3 | 2 | 2 | 2 | 5 |
| No | | | 2 | 2 | 4 | 4 | 4 |
| Sí | 2 | 2 | 3 | 2 | 5 | 5 | 3 |
| No | | | 3 | 2 | 5 | 3 | 4 |
| Sí | 3 | 4 | 4 | 4 | 4 | 5 | 4 |
| Sí | 1 | 2 | 2 | 3 | 2 | 5 | 3 |

| ¿Cree usted que aprende | ¿Posee usted los recurso | ¿Conoce usted personas | ¿Cree usted que utilizar r | ¿Le gustaría que la aplica | ¿Cree usted que utilizand | Edad | Género | País en el que vive |
|---|---|---|---|---|---|---|---|---|
| 5 | 5 | 5 | 5 | 4 | 5 | 30 | Hombre | Ecuador |
| 4 | 5 | 5 | 5 | 5 | 3 | 26 | Mujer | Ecuador |
| 5 | 5 | 5 | 5 | 5 | 5 | 27 | Hombre | Ecuador |
| 3 | 3 | 3 | 5 | 5 | 5 | 27 | Mujer | Ecuador |
| 4 | 1 | 1 | 3 | 4 | 3 | 25 | Mujer | Ecuador |
| 5 | 5 | 1 | 5 | 5 | 2 | 27 | Mujer | Ecuador |
| 5 | 5 | 5 | 5 | 5 | 5 | 33 | Hombre | Ecuador |
| 5 | 2 | 5 | 4 | 5 | 5 | 28 | Hombre | Ecuador |
| 5 | 5 | 5 | 4 | 5 | 5 | 33 | Mujer | Ecuador |
| 4 | 4 | 4 | 4 | 4 | 4 | 32 | Mujer | Ecuador |
| 5 | 5 | 4 | 5 | 5 | 4 | 28 | Mujer | Ecuador |
| 5 | 5 | 5 | 5 | 5 | 2 | 26 | Mujer | Ecuador |
| 4 | 4 | 3 | 4 | 5 | 3 | 29 | Mujer | Ecuador |
| 4 | 4 | 4 | 5 | 5 | 5 | 29 | Hombre | Ecuador |
| 4 | 2 | 3 | 5 | 4 | 4 | 23 | Mujer | Ecuador |
| 4 | 4 | 3 | 4 | 5 | 4 | 38 | Hombre | Ecuador |
| 4 | 4 | 5 | 4 | 5 | 5 | 52 | Mujer | Ecuador |
| 5 | 5 | 5 | 5 | 5 | 5 | 31 | Hombre | Ecuador |
| 4 | 5 | 4 | 2 | 3 | 3 | 26 | Hombre | Ecuador |
| 4 | 4 | 3 | 3 | 3 | 3 | 22 | Hombre | ECUADOR |
| 4 | 5 | 5 | 5 | 5 | 2 | 18 | Mujer | Ecuador |
| 5 | 5 | 5 | 5 | 5 | 4 | 21 | Hombre | Ecuador |
| 5 | 5 | 3 | 4 | 4 | 2 | 27 | Hombre | Ecuador |
| 5 | 3 | 1 | 5 | 1 | 5 | 31 | Hombre | Ecuador |
| 4 | 4 | 5 | 5 | 5 | 3 | 27 | Mujer | Ecuador |
| 4 | 3 | 4 | 4 | 5 | 4 | 37 | Mujer | Ecuador |
| 5 | 5 | 5 | 5 | 5 | 5 | 28 | Mujer | Ecuador |
| 4 | 3 | 2 | 4 | 4 | 3 | 29 | Mujer | Ecuador |
| 5 | 5 | 5 | 5 | 5 | 5 | 42 | Mujer | Ecuador |
| 5 | 4 | 2 | 5 | 5 | 3 | 29 | Mujer | Ecuador |
| 5 | 4 | 3 | 1 | 5 | 1 | 24 | Hombre | Ecuador |
| 4 | 5 | 5 | 4 | 5 | 4 | 27 | Hombre | Ecuador |
| 5 | 1 | 1 | 1 | 5 | 1 | 28 | Hombre | Ecuador |
| 4 | 4 | 4 | 4 | 4 | 4 | 27 | Hombre | Ecuador |
| 5 | 5 | 5 | 5 | 5 | 5 | 26 | Mujer | Ecuador |
| 3 | 1 | 4 | 4 | 5 | 4 | 34 | Mujer | Ecuador |
| 3 | 5 | 5 | 5 | 5 | 4 | 61 | Hombre | Ecuador |
| 4 | 5 | 5 | 4 | 5 | 5 | 34 | Mujer | Ecuador |
| 4 | 5 | 4 | 4 | 5 | 4 | 28 | Mujer | Ecuador |
| 3 | 5 | 5 | 5 | 3 | 4 | 25 | Hombre | Ecuador |

# Appendix D: Usability test (English version)



## Usability test

This survey is to rate the usability of the application MindoBirdwatching and is being undertaken as part of a master's dissertation entitled "AUGMENTED REALITY BIRDWATCHING IN MINDO". Its results, after being examined by Polytechnic Institute of Leiria supervisors, will be used for a statistical study to be carried out in order to develop part of this project work

* Required

1. **I think that I would like to use this app frequently** *
   *Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Strongly disagree | ◯ | ◯ | ◯ | ◯ | ◯ | Strongly agree |

2. **I found the app unnecessarily complex** *
   *Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Strongly disagree | ◯ | ◯ | ◯ | ◯ | ◯ | Strongly agree |

3. **I thought the app was easy to use** *
   *Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Strongly disagree | ◯ | ◯ | ◯ | ◯ | ◯ | Strongly agree |

4. **I think that I would need the support of a technical person to be able to use this app** *
   *Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Strongly disagree | ◯ | ◯ | ◯ | ◯ | ◯ | Strongly agree |

5. **I found the various functions in this app were well integrated** *
   *Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Strongly disagree | ◯ | ◯ | ◯ | ◯ | ◯ | Strongly agree |

6. **I thought there was too much inconsistency in this app** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Strongly disagree | ◯ | ◯ | ◯ | ◯ | ◯ | Strongly agree |

7. **I would imagine that most people would learn to use this app very quickly** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Strongly disagree | ◯ | ◯ | ◯ | ◯ | ◯ | Strongly agree |

8. **I found the app very cumbersome to use** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Strongly disagree | ◯ | ◯ | ◯ | ◯ | ◯ | Strongly agree |

9. **I felt very confident using the app** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Strongly disagree | ◯ | ◯ | ◯ | ◯ | ◯ | Strongly agree |

10. **I needed to learn a lot of things before I could get going with this app** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Strongly disagree | ◯ | ◯ | ◯ | ◯ | ◯ | Strongly agree |

## Personal information

11. **Age** *

12. **Gender** *
*Mark only one oval.*

- ◯ Female
- ◯ Male
- ◯ Prefer not to say

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# Appendix E: Usability test (Spanish version)



## Pruebas de usabilidad

Esta encuesta es para evaluar la usabilidad de la aplicación MindoBirdwatching y se la realiza como parte de una disertación para maestría, titulada “AUGMENTED REALITY BIRDWATCHING IN MINDO” (ORNITOLOGÍA CON REALIDAD AUMENTADA EN MINDO). Los resultados obtenidos, después de ser revisados por los supervisores de la tesis de maestría del Instituto Politécnico de Leiria, serán utilizados para realizar un estudio estadístico que formará parte del mencionado trabajo.

* Required

1. **Creo que me gustaría usar esta aplicación frecuentemente** *
   *Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Muy en desacuerdo | ◯ | ◯ | ◯ | ◯ | ◯ | Muy de acuerdo |

2. **La aplicación me pareció innecesariamente compleja** *
   *Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Muy en desacuerdo | ◯ | ◯ | ◯ | ◯ | ◯ | Muy de acuerdo |

3. **Creo que la aplicación fue fácil de usar** *
   *Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Muy en desacuerdo | ◯ | ◯ | ◯ | ◯ | ◯ | Muy de acuerdo |

4. **Creo que necesitaría ayuda de una persona con conocimientos técnicos para usar esta aplicación** *
   *Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Muy en desacuerdo | ◯ | ◯ | ◯ | ◯ | ◯ | Muy de acuerdo |

5. **Las funciones de esta aplicación están bien integradas** *
   *Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Muy en desacuerdo | ◯ | ◯ | ◯ | ◯ | ◯ | Muy de acuerdo |

6. **Creo que había demasiada inconsistencia en esta aplicación** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Muy en desacuerdo | ◯ | ◯ | ◯ | ◯ | ◯ | Muy de acuerdo |

7. **Imagino que la mayoría de la gente aprendería a usar esta aplicación muy rápidamente** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Muy en desacuerdo | ◯ | ◯ | ◯ | ◯ | ◯ | Muy de acuerdo |

8. **Encuentro que la aplicación es muy difícil de usar** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Muy en desacuerdo | ◯ | ◯ | ◯ | ◯ | ◯ | Muy de acuerdo |

9. **Me siento confiado al usar esta aplicación** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Muy en desacuerdo | ◯ | ◯ | ◯ | ◯ | ◯ | Muy de acuerdo |

10. **Necesité aprender muchas cosas antes de ser capaz de usar esta aplicación** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Muy en desacuerdo | ◯ | ◯ | ◯ | ◯ | ◯ | Muy de acuerdo |

## Información personal

11. **Edad** *

12. **Género** *
*Mark only one oval.*

- ◯ Mujer
- ◯ Hombre
- ◯ Prefiero no decirlo

Appendix F: Usability test results

| Creo que me gustaría | La aplicación me pare | Creo que la aplicació | Creo que necesitaría | Las funciones de esta | Creo que había demas |
|---|---|---|---|---|---|
| 2 | 2 | 4 | 1 | 4 | 1 |
| 2 | 1 | 4 | 1 | 4 | 1 |
| 3 | 1 | 5 | 1 | 5 | 1 |
| 2 | 1 | 5 | 1 | 5 | 1 |
| 4 | 1 | 5 | 1 | 5 | 1 |
| 2 | 1 | 5 | 1 | 4 | 1 |
| 3 | 3 | 2 | 3 | 3 | 1 |
| 1 | 2 | 3 | 2 | 3 | 1 |
| 3 | 2 | 4 | 1 | 4 | 1 |
| 4 | 1 | 5 | 1 | 4 | 1 |
| 3 | 1 | 5 | 1 | 5 | 1 |
| 2 | 1 | 5 | 1 | 5 | 1 |
| 3 | 1 | 4 | 1 | 3 | 1 |
| 2 | 1 | 5 | 1 | 4 | 2 |
| 3 | 1 | 4 | 1 | 4 | 2 |
| 2 | 1 | 5 | 1 | 5 | 1 |
| 2 | 1 | 4 | 1 | 4 | 2 |
| 1 | 2 | 4 | 2 | 4 | 2 |
| 2 | 1 | 5 | 1 | 5 | 1 |
| 3 | 1 | 5 | 1 | 3 | 1 |
| 3 | 1 | 5 | 1 | 5 | 1 |
| 4 | 1 | 5 | 1 | 5 | 1 |
| 2 | 2 | 4 | 1 | 3 | 1 |
| 3 | 1 | 4 | 1 | 4 | 1 |

| Imagino que la mayor | Encuentro que la apli | Me siento confiado al | Necesité aprender mu | Edad | Género |
|---|---|---|---|---|---|
| 3 | 2 | 3 | 2 | 49 | Hombre |
| 4 | 2 | 3 | 1 | 47 | Mujer |
| 4 | 1 | 5 | 1 | 18 | Mujer |
| 5 | 1 | 5 | 1 | 21 | Mujer |
| 4 | 1 | 5 | 1 | 31 | Mujer |
| 4 | 1 | 5 | 1 | 35 | Hombre |
| 3 | 3 | 2 | 3 | 55 | Mujer |
| 3 | 3 | 3 | 2 | 58 | Hombre |
| 3 | 2 | 4 | 1 | 31 | Mujer |
| 4 | 1 | 5 | 1 | 33 | Hombre |
| 5 | 1 | 5 | 1 | 16 | Mujer |
| 4 | 1 | 4 | 1 | 37 | Mujer |
| 3 | 1 | 4 | 1 | 37 | Mujer |
| 4 | 1 | 5 | 2 | 37 | Hombre |
| 3 | 1 | 4 | 1 | 37 | Mujer |
| 4 | 1 | 4 | 1 | 37 | Mujer |
| 3 | 2 | 3 | 2 | 46 | Mujer |
| 4 | 2 | 4 | 2 | 49 | Hombre |
| 5 | 1 | 5 | 1 | 23 | Hombre |
| 4 | 1 | 5 | 1 | 27 | Hombre |
| 5 | 1 | 5 | 1 | 18 | Hombre |
| 5 | 1 | 5 | 1 | 21 | Mujer |
| 3 | 1 | 5 | 2 | 46 | Mujer |
| 4 | 1 | 4 | 1 | 47 | Mujer |

## Appendix G: Usability test, results tabulation

| # | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Result | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 3 | 3 | 4 | 3 | 4 | 2 | 3 | 2 | 3 | 70 | |
| 2 | 1 | 4 | 3 | 4 | 3 | 4 | 3 | 3 | 2 | 4 | 77.5 | |
| 3 | 2 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 92.5 | |
| 4 | 1 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 92.5 | |
| 5 | 3 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 95 | |
| 6 | 1 | 4 | 4 | 4 | 3 | 4 | 3 | 4 | 4 | 4 | 87.5 | |
| 7 | 2 | 2 | 1 | 2 | 2 | 4 | 2 | 2 | 1 | 2 | 50 | |
| 8 | 0 | 3 | 2 | 3 | 2 | 4 | 2 | 2 | 2 | 3 | 57.5 | |
| 9 | 2 | 3 | 3 | 4 | 3 | 4 | 2 | 3 | 3 | 4 | 77.5 | |
| 10 | 3 | 4 | 4 | 4 | 3 | 4 | 3 | 4 | 4 | 4 | 92.5 | |
| 11 | 2 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 95 | |
| 12 | 1 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 3 | 4 | 87.5 | |
| 13 | 2 | 4 | 3 | 4 | 2 | 4 | 2 | 4 | 3 | 4 | 80 | |
| 14 | 1 | 4 | 4 | 4 | 3 | 3 | 3 | 4 | 4 | 3 | 82.5 | |
| 15 | 2 | 4 | 3 | 4 | 3 | 3 | 2 | 4 | 3 | 4 | 80 | |
| 16 | 1 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 3 | 4 | 87.5 | |
| 17 | 1 | 4 | 3 | 4 | 3 | 3 | 2 | 3 | 2 | 3 | 70 | |
| 18 | 0 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 67.5 | |
| 19 | 1 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 92.5 | |
| 20 | 2 | 4 | 4 | 4 | 2 | 4 | 3 | 4 | 4 | 4 | 87.5 | |
| 21 | 2 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 95 | |
| 22 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 97.5 | |
| 23 | 1 | 3 | 3 | 4 | 2 | 4 | 2 | 4 | 4 | 3 | 75 | |
| 24 | 2 | 4 | 3 | 4 | 3 | 4 | 3 | 4 | 3 | 4 | 85 | |
| | | | | | | | | | | | 82.29 | Average |