URBAN ECHOES

ENGAGING CITY DWELLERS IN THEIR LOCAL BIRD WILDLIFE USING AESTHETIC EXPERIENCES

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MASTER'S THESIS

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Master's Thesis

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ABSTRACT

Short summary of the contents in English...

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LISTINGS

ACRONYMS

HCI Human Computer Interaction
SHCI Sustainable Human-Computer Interaction
SID Sustainable Interaction Design
SDG Sustainable Development Goals
RtD Research trough Design
ACI Animal Computer Interaction

0 FOREWORD

0.1 GENERATIVE AI DECLARATION

For this thesis, I have used Generative AI as a programming aid. The models used in order of magnitude are Claude 3.7 Sonnet, GPT3 and GPT4 in the form of GitHub CoPilot, and ChatGPT 4. All three have been used to provide suggestions and improvements to the codebase and for code generation and completion. ChatGPT have been used for grammar checking. Also ChatGPT have been used to create BibTeX citations for websites with prompts of a similar nature as the following prompt: *https://www.inaturalist.org/ Can you create a BibTeX citation for this website*. Lastly, I have used ChatGPT to do a translation for the Danish evaluation answers. After doing a translation, I read the resulting text and made sure the translation was as accurate as possible. Both the original and translated version can be found in Appendix B.1.

0.2 ADDITIONAL TOOLS

The report is written in LaTeX using the Overleaf service, furthermore, I have used Writefull and Grammarly for grammatical suggestions, both on free trial versions. For coding, I used the Visual Studio Code editor along with extensions for Flutter development, the Android APK was used for a while to run emulators during development, and my private GitHub was for source control, as it provided better integration with Microsoft Azure than my AU GitLab account.

0.3 ACKNOWLEDGMENTS

I would like to thank my supervisor, Peter Gall Krogh, for his help throughout the project. His suggestions and advice, along with excitement for the project has helped a lot during the development and creation of this masters thesis. I would also like to extend my gratitude to all those who participated in my evaluations. Lastly I want to thank Magnus Lasse Lund Bentsen, with whom I did the project work that laid the groundwork for this thesis.

1 INTRODUCTION

1.1 URBAN ECHOES: AN AUDITORY MAP EXPERIENCE FOR AVIAN ENGAGEMENT

In this thesis, I explore Urban Echoes, an aesthetic auditory map designed to engage users with their local avian wildlife. I detail the application's creation, design decisions, and technical implementation, while situating it within existing research. Finally, I present an evaluation of the system and its outcomes and discuss potential directions for future work.

The Urban Echoes is a continuation of a previous concept developed in a 10 ECTS project on more than human-centred design[20] that I conducted together with Magnus Lasse Lund Bentsen, a fellow IT product development master's student, last semester. The 10 ECTS project ended with a report and a rough prototype of this original concept, which can be found in Appendix A.1 and Appendix A.2, respectively. However, the continuation into a master's thesis has seen many alterations in the concept of Urban Echoes; as such, the original work is not required to understand the concept.

1.1.1 Application overview and design

Urban Echoes consist of two primary activities, dubbed the observer and listener activities. Users can make sightings/observations by seeing or hearing birds in their immediate environment. The user can observe by clicking the application's microphone button, as seen in Figure 1.1a and speaking the observed bird's name. This prompts the application to respond, asking for a confirmation by presenting a confirmation card seen in Figure 1.1b along with an audio prompt asking the user if this was the bird they saw. If the user responds "ja"(yes), the observation will be saved and uploaded to a central database, and a successful upload card, as seen in Figure 1.1c will be displayed along with a recorded message telling the user that the observation has been successfully uploaded. The observation will consist of the bird observed featuring both common and scientific names, along with the geospatial location, date and time of day. If the application recognises a different bird from the one the user said, the user can respond with "nej" (no). This prompts the application to ask if the user meant one of the following birds, presenting the most likely alternatives based

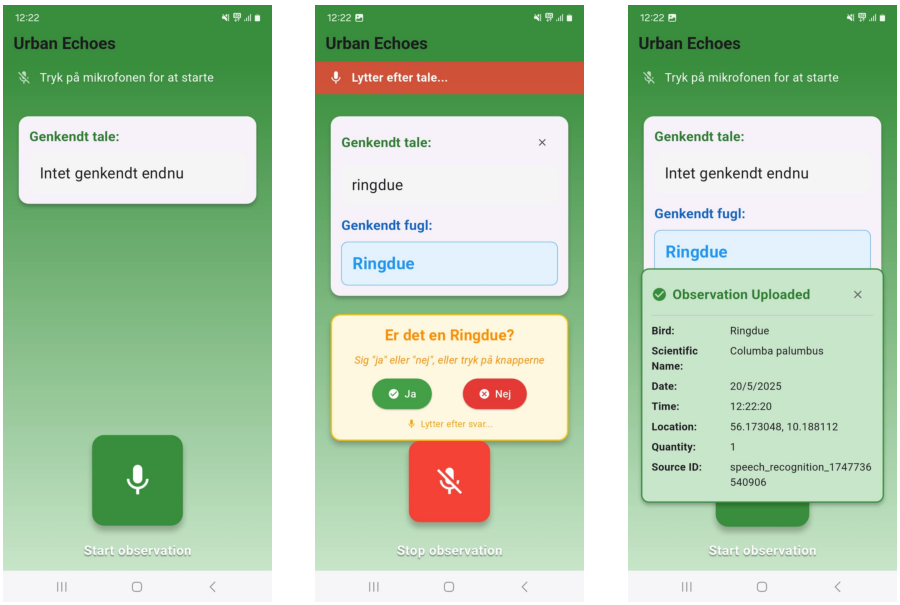
on what it heard. This interaction is illustrated in Figure 1.1d. If the observed bird is not among the alternatives presented, the user can click "ingen af dem" (none of them). The app will then display a search bar where users can manually enter the bird they observed, as shown in Figure 1.1e. This is considered a last resort, as the application is primarily designed to be used through its auditory interface. The listener activity allows users to explore the auditory map created using the observations. A point will represent each observation located at the position where it was recorded. The point will have a radius of 50 meters, with the playback audio increasing in loudness the closer to the observation centre a listener might be. Observation points can overlap with up to five points playing simultaneously. The user can then move around the city to hear the observations made by other users. The application design will be described in more detail in Chapter 3.

1.2 THE ROLE OF TECHNOLOGY IN THE PRESERVATION OF LOCAL ENVIRONMENTS

The call for climate action and nature conservation has in recent years gained more attention, and rightly so. With the global community behind on 41 out of 42 indicators to achieve the 2030 goals of the Paris Agreement[11], the prospects of achieving these goals become more and more difficult.

Within Human-Computer Interaction Human Computer Interaction (HCI), the challenge of addressing climate action has led to the emergence of Sustainable HCI Sustainable Human-Computer Interaction (SHCI) and Sustainable Interaction Design Sustainable Interaction Design (SID), inspired by two influential papers by Eli Blevis [9, 45]. These new fields focused on using technology to promote sustainability in the user's life across many sectors, such as the environment, social justice, public health, and other areas concerning building a sustainable future.

A literature review by Hansson et al. (2021) surveyed the field of SHCI and found that research related to a wide range of the United Nations Sustainable Development Goals Sustainable Development Goals (SDG), with published work that addresses 6 of the 17 goals. This highlights the interdisciplinary and wide-reaching nature of the field [35]. Much of the research focuses on the direct application of technology to address specific challenges related to SDGs. For example, Hansson et al. Hansson, Cerratto Pargman, and Pargman [35] report that of the 26 studies mapped to SDG Goal 12.2 - 'By 2030, achieve sustainable management and efficient use of natural resources' - the majority



(a) Start Screen **(b)** Confirmation Card **(c)** Observation Made

(d) "Was it one of these?" **(e)** Search Bar **(f)** Search Results

Figure 1.1: Screenshots from the Urban Echoes application.

(18 articles) explored ecofeedback or ecovisualization systems. These systems aim to make resource consumption more visible and understandable and promote sustainable behaviours. A more recent and extensive literature review by Besana et al. (2024) expanded on the established framework of how interaction design can promote sustainability. While earlier work identified two approaches—sustainability through design and sustainability in design—Besana et al. rephrased sustainability in design into sustainability by design and present a new third approach, sustainability in design[7]. Each approach encapsulates different ways to work with SID but are not mutually exclusive. Sustainability through design seeks to incite behavioural changes on individual, communal and societal levels. The design itself does not have to be sustainable as long as the behaviours it's promoting are. Sustainability by design treats sustainability as a guiding principle embedded within the product's design, striving to make the outcome itself as sustainable as possible. Finally, sustainability in design shifts focus to the design process, critically examining whether the methods and practices employed are themselves sustainable. Urban Echoes follows the sustainability through design approach; however, since the app is currently at this stage is not optimised for energy consumption, it does not fulfil the criterion of being sustainable by design. The use of Generative AI throughout the project, at least in my opinion, keeps it from being sustainable in design.

The paper "Have We Taken On Too Much?: A Critical Review of the Sustainable HCI Landscape" by Bremer et al. presents another perspective of SHCI being ill-suited to create large-scale change across large and complex problem areas involving various disciplines with the direct application of technology. Instead, they argue SHCI researchers should seek to incorporate Green policy informatics[13] into their projects. Green policy informatics is the idea that technology should help promote climate action by providing tools for transparency and supporting complex decision-making. Beyond that, it should encourage communities and support the push for green policies.

I believe both green policy information and more direct approaches have their merits. My project is closer to the more direct application school of thought of SHCI as there are no direct pathways to incite policy changes or form communities, but rather a focus on inciting the individual's interest in local wildlife. This comes from a focus on individual interests and emotional experiences rather than actively pushing for radical changes or the creation of communities. This distinction is important and can be exemplified in the way the prototype facilitates the creation of a collective artefact in the form of an auditory map. However, the focus is on the observations rather than the individual who recorded them. I will discuss the design choices in

more detail in Chapter 4.

To justify my decision to prioritise the individual's emotions over community creation and focus primarily on those living in urban environments, I will point to the global development of increasing urbanisation. According to UN projections, 68% of the world's population is expected to live in urban settings by 2050[67]. As wild nature is more scarce in urban environments than in rural areas, it follows that contact with wild nature will, for an increasing number of people, be something to seek out instead of something they passively encounter. Exacerbating the problem of scarcity of wild nature in urban settings is the fact that key urban-dwelling animals who thrive in cities such as pigeons, seagulls, raccoons, and rats, have poor reputations, leading to negative or indifferent meetings between urban dwellers and local wildlife[25]. Although many birds are commonly positively received, Urban Echoes aim to create memorable and positive experiences with all birds, even the commonly unpopular ones, such as seagulls and pigeons.

1.3 NOTICING AS A DESIGN TOOL AND NATURE APPRECIATION

The act of *noticing*[66] as introduced by anthropologist Anna Tsing has gained traction within the SHCI community[43]. In this context, *noticing* extends to more than perceiving what is in front of us, but noticing the complex relationships surrounding our object of notice. This includes considering how economic, social, environmental, and other contextual factors shape and transform what is observed. It calls for a heightened curiosity and a sensitivity on the part of the observer—an openness to perceiving more than what is readily apparent.

As designers, we can ask ourselves how the act of noticing can be used to inform more than human-centred design. As previously discussed in chapter 1.1, this project originally started as a 10 etcs exploration of the more-than-human centred design space. Although we were unaware of the concept of *noticing* during that project, we inadvertently did it to some degree during our attempts to understand city pigeons, the focus of the study at the time. I started the master's thesis with the knowledge and newfound appreciation for pigeons acquired during that project. As I got further into my master's thesis, my interest in pigeons expanded into birds in general, and I found myself noticing the birds in the city in ways I had never done before. I started perceiving them more, and noticed which birds were found in

which environments.

This raises the question of how the concept of noticing can be applied in design practice. Noticing, as a means to enhance the designer's ability to decenter the human, has been explored in the literature in the design text *Watching Myself Watching Birds: Abjection, Ecological Thinking, and Posthuman Design*[8] by Biggs et al, where the main author of the paper performed an auto-etnograpic study on how noticing the birds of Indiana changed her perceptions and led to growth both as a designer and person. In the paper, she describes how she develops feelings of abjection in the author's words, a simultaneous fascination and repulsion that arises towards the birds from her process. I did not share this feeling of abjection from noticing the birds; in contrast, I felt a newfound appreciation and excitement from starting to recognise the birds and perceiving them more. That being said, my newfound focus on sonic environments also makes me pay more attention to the city's other sounds, with cars being unpleasant, whereas before I would more so consider background noise and pay it no mind. I want to make it clear that even though my experiences and feelings differed from Biggs' that neither is inherently more correct than the other.

The SHCI community can provide tools through interactive systems that help people notice in otherwise impossible ways, by giving us new senses, different perspectives, and more. Three examples can be found in Rosén et al's work, where they present three design concepts, each exemplifying different ways of noticing in a city gardening community[58]. A control-oriented approach to noticing, focusing on monitoring factors in the case of the gardening community, which included factors such as soil ph values, moisture, etc. The second approach to noticing they present is sensibility-oriented, focusing on developing tacit knowledge over time. Lastly, they present an appreciation approach focused on sensory engagement and exploratory experiences, without the need for practical application[58].

1.3.1 Ontological design and Futuring

Design theorist Tony Fry presents the concept of *futuring*[32], the act of preserving or creating the conditions for a viable future. It stands in opposition to the current trend of *defuturing*[32], which either actively or inadvertently hinders the viability of a livable future[32]. He argues that we need a shift towards sustainment rather than sustainability in design thinking, a more holistic understanding that calls for system-level transformation rather than fixing holes in the existing systems. He urges designers to think critically about what they design, as they are directly designing the future. His work resonates with Arturo Esco-

bar's theory of ontological design, which posits that all acts of design can be seen as interventions in ways of being: we design the world and, in doing so, the world designs us[27]. Ontological design is based on an onto-epistemic view of design where a reciprocal relationship exists between being and knowing, meaning that our ways of being shape our ways of knowing, and vice versa. Given that the literature [8, 43, 51, 58] suggests that the act of noticing is a powerful tool for fostering more-than-human-centred thinking, what does that tell us about the relation between noticing, futuring and ontological design? Tsing's concept of "noticing", in this light, is implicitly an exercise in uncovering the ontology of the object or phenomenon being noticed. By attuning us to more-than-human relations, the user gains new ways of knowing and being that support ecological awareness and ethical responsiveness. As previously discussed, research suggests that such perceptual shifts contribute to increased environmental sensitivity [16], laying the groundwork for more livable futures. When viewed through the lens of ontological design, Urban Echoes can be understood as inviting users to "notice" birds in the urban environment. Urban Echoes aligns closely with "appreciation" oriented noticing, as it allows users to hear bird sounds in relative isolation, particularly when using noise-cancelling headphones. While not itself actively pushing towards systemic changes, the app thereby encourages users towards a larger nature appreciation, which in itself is a small shift towards sustainment.

If you can reference to franscis

1.4 USING AESTHETIC AUDITORY EXPERIENCES FOR ENGAGING PEOPLE IN LOCAL BIRDLIFE

The design seeks to deepen the appreciation of nature by creating an aesthetic experience with the avian wildlife as the focus. Positive experiences support conservation and reintegration efforts. This is supported by Chawla et al. [16] who found that our experiences with nature and connection to it significantly shape our willingness to act on climate change. Specifically, they found that formative experiences with nature are crucial in developing environmental sensitivity, which in their work is the motivation to learn about, care for, and feel concerned for the environment[16]. To create experiences, the design for Urban Echoes is conceptually informed by the view of the aesthetics of interaction, as described by Petersen et al. [54]. In this framework, aesthetics are considered in terms of both context and use. This perspective recognises that while a design may have aesthetic potential in itself, the aesthetics of use emerge through the user's process of sense making and the personal meanings they derive from the interaction. To illustrate how this view can be used to analyse academic work

seeking to engage people in local nature, we can look at Gaver et al.'s Naturewatch Camera[33]. Naturewatch is a citizen science project in which users construct DIY wildlife cameras that autonomously take images of wildlife when within the frame. The aesthetics of use and context can be seen in how users evaluate the cameras, where sense-making and meaning become paramount to the user experience. Users comment on how the cameras have allowed them to observe the lives of the animals in their gardens without the animal recognising their presence, something they have previously been unable to do [33]. The community aspects and sharing of images also play into the aesthetics of the experience, as it's an important part of the context and meaning for the users.

For Urban Echoes, birds have been chosen as the subject for the application because of their prevalence worldwide, the diversity in species, and the perceived pleasant qualities of their inclusion in a soundscape. Bird sounds have even been found to help with stress and attention recovery[56], showcasing the beneficial effect their presence can have on humans. It's important to note that the types of sounds that have these effects depend on personal preference and experience [56].
Digitalised bird sounds have been used in similar work by Lawton et al.[41] who investigated the use of speakers in a forested area to play bird calls. They found that nature soundscapes had numerous beneficial effects even when digitalised, such as making people pay more attention to their visual surroundings, increasing their perceived enjoyment, and making them think about the loss of nature[41]. This hints towards the possibility of increased sonic awareness also raises visual awareness. The Urban Echoes application is geared towards urban dwellers, as urban soundscapes have considerably more noise pollution[55] than rural areas.

The aesthetic experience is then seen as how the users are invited to notice the birds; By cultivating the act of noticing, the design can reshape users' perception and, potentially, human beings, inviting listeners into an ecological mode of attention that is both epistemic and ontological. (need rewrite)

1.5 PROJECT TIMELINE

The idea and concept were expanded from the 10 etc project in the first weeks of the project. Development of the application took place from the end of January to early May 2025, with report writing happening in parallel to the coding, starting in mid-February until the delivery

date in mid-June. Evaluations were held in May, starting on the 12th or the 14th of May; each evaluation ran for a week.

2 RELATED WORK

In this section, I present related work that has either inspired or parallels my project. I also discuss comparable commercial and scientific applications, highlighting their contributions and examining how *Urban Echoes* differs from them.

2.1 RESEARCH THROUGH DESIGN AND DRIFTING

Research trough design[**<empty citation>**] Research trough Design (RtD)
Emergence[34]
The changes that occur between design experiments, as contextual knowledge from previous experiments accumulates in RtD, are described by Krogh et al. using the term *drifting*. They identify five distinct ways in which projects can drift[38], two of which have been followed during the creation of *Urban Echoes*.

The design experiments conducted during the previous 10 ETC project were characterised by *expansive* drifting[38], as the field of more-than-human computer interaction and Animal Computer Interaction (ACI) [44] was explored. The authors expanded their knowledge, and each design experiment informed the next without a clearly defined line between them.

In contrast, the further development of *Urban Echoes* into a master's thesis project has followed a pattern of *serial* drifting[38], where individual design experiments, such as the vertical slice, formed the foundation for subsequent iterations linearly.

2.2 ENGAGING WITH NATURE THROUGH AUDIO CONTENT

Audio-based technologies are promising for fostering connections between humans, animals, and the environment. Several studies demonstrate how soundscapes and audio-augmented experiences can engage participants while raising awareness about ecological systems.

2.2.1 Nature soundscapes: an audio augmented reality experience

Lawton et al. demonstrate how augmented reality with audio has the potential to highlight the loss of nature[41] and make people reflect. To reintegrate animals and keep the ones we have, we need to be aware of the animals, how they adapt to humans and cities and what we can do to create spaces for all. Participants in their project became more aware of the loss of nature, with the soundscapes having the added benefit of fostering feelings of calmness and engagement with the local environment. However, certain trade-offs must be considered when implementing soundscape experiences. Although binaural audio through headphone playback is mentioned as an area of interest in Lawton's, it also has some limitations. As noted by Lawton et. al, "binaural audio, via headphone reproduction, detaches the listener from the real-world sounds in the environment" [41].

For any similar project like Urban Echoes, maintaining a connection to the immediate natural environment is critical to the augmented acoustic reality (AAR) experience. Encouraging participants to pay greater attention to the natural environment aligns with the objectives of Urban Echoes; however, in this project, the playback audio will be fully detached from the present physical environment and instead represent a recorded event. This partly stems from a desire to balance goals with ecological and practical considerations. There has been very little research into the effects of using playback audio of bird sounds in communal spaces, such as cities. However, one paper by Harris et al. investigated the effects of playback audio on two tropical birds. They found it had multiple adverse effects, exposing the birds to danger and increasing stress levels[36]. Beyond this, multiple large birding organisations such as the American Birding Association, Rochester Birding Association, and more advise against using playback, citing problems such as disrupting nesting, breeding and the bird's ability to raise the young[3, 4, 60, 61].

Focusing on individual immersive experiences rather than communal sound installations. The design minimises ecological disturbance while allowing participants to focus on the presented audio content, albeit at the cost of their immediate auditory surroundings. The design tries to remedy this by including the observer role to encourage users to experience real-world sounds and create observations in content-less areas. The underlying hypothesis is that increased sonic awareness also increases the user's visual awareness of nature around them. use noticing again here to support this

2.2.2 Audio-enabled locative media

Urban Echoes also draws inspiration from Audio-enabled locative media like audio walks. The first Audio walks were made somewhat serendipitously by Janet Cardiff in 1991[14]. This first work inspired her whole career, which features the creation of multiple acclaimed works. Her most famous audio walk *Her long black hair*[15]. The audio walk takes the listeners through Central Park South and uses pictures along with the audio and location to create the experience. Common for audio walks is the focus on geographical context, active participation in the form of walking to and from and a narrative structure.

Other examples of audio-enabled locative media can be found in *Placed Sounds*[6] and *Situated Sound*[28], both of which are techniques where sounds or music are positioned in physical space. *Situated Sound* typically describes experiences where, for instance, a user entering a church might first hear music followed by contextual information about the location. *Placed Sound*, on the other hand, places greater emphasis on how the listener engages with and remixes the experience by moving through the environment. A notable example is an album by BLUEBRAIN, which utilised placed sound at the National Mall in Washington, D.C.[10]. Instead of listening to the album linearly, the listener experiences it by walking through the park, with the music tailored to match the visual surroundings—for example, rising harp tones as one ascends the steps of the Lincoln Memorial.
As *Urban Echoes* is based on user-created observations, the "placed sound" is less curated. As will be shown in the Evaluation section 6, the visual environments interplay with the placed sounds of the app, namely observations, played a significant role in shaping the user experience.

2.3 APPLICATIONS FOR ENGAGEMENT WITH BIRDS

There are many free applications for identification and participation in local wildlife. The following is not an exhaustive list, but an exemplar-based description of the field. The most prominent app in the field is Merlin ID[52], developed by the Cornell Lab of Ornithology. The app allows users to identify birds based on their calls and songs. Furthermore, users can take images or describe the bird using pre-made queues and then get shown suggestions based on their answers. Looking at their app page, it's apparent that the app's goal is to engage people in birding and make the hobby more accessible to hobbyists and casual users. To ensure accuracy, MerlinID suggestions are based on regional sightings made on eBird[63], one of the large citizen sci-

ence[37] websites where birders can upload bird sightings.

Compared to Urban Echoes, MerlinID has a larger focus on the educational aspect of learning to recognise birds, helping users increase understanding and knowledge. Furthermore, Merlin ID encourages users to have an increased sonic awareness and listen for the birds in their immediate environment. Urban Echoes, on the other hand, is less concerned with natural sounds and the soundscape. Instead, it presents an exaggerated soundscape to the users. Personal reflections from the use of both apps showed clear strengths with each. With Urban Echoes, the immediate visual environment became the basis for where the bird could have been seen, prompting a reflection on which environments the birds are common in. I also found myself looking for the birds I where hearing. Merlin ID, on the other hand, made me reflect more on acquiring knowledge about the bird, such as species, calls and migration patterns, and trying to find it in the visual environment once I had identified the sound. In this case, the knowledge that I know the bird is here right now made me look more for it. Both applications could benefit greatly from being used in tandem or being integrated, something I will discuss further in chapter 7.5. Another key difference is how the apps support citizen science tasks and integration. Originally, Urban Echoes was intended to be a citizen science project. Still, as the project drifted, this was changed into a project with a higher focus on the aesthetic experiences. Meanwhile, Merlin ID is a great tool for hobbyists to validate their findings before submitting findings to citizen science projects.

2.3.1 Citizen science and bird observation

Citizen science allows regular people to contribute to scientific projects by collecting data on a scale that scientists would otherwise not be able to do[18]. Adopting citizen science within the bird observation community has increased researchers' understanding of bird migration patterns and populations. Since eBirds operate globally, it allows for wider information than regional observation sites like the Danish DOFbasen[22]. Inaturalist[71] is another citizen science application with an accompanying website which focuses on the documentation of wildlife, plants and fungi and thus encompasses a much larger field than eBirds. To keep people engaged, Inaturalist encourages sharing and discussion of nature on the website and application. It lends to a more communal experience than the more individual-focused eBird and Merlin ID. Looking at the real-time map of eBirds, we can see that the global north is overrepresented compared to the global south, indicating a disparity in the amount of data gathered, as seen in Figure 2.1, The light grey dots indicate a recording.

Figure 2.1: A screenshot of the eBird live map, the 31-03-2025[70]

This highlights one potential issue of digitalised citizen science, namely the wealth inequality between the global South and North, which creates a disparity in the number of observations.

An alternative form of citizen science is exemplified by regional bioblitz events, during which scientists and citizens participate in intensive field surveys to document local biodiversity systematically. A research project aimed at creating an app for finding a rare cicada was tested during a bioblitz. The researchers found a strong reluctance toward digital applications among professional and amateur naturalists who participate in bioblitz[47], who preferred more traditional tools such as pen and paper. When asked why they preferred traditional tools over digital, participants mentioned how technology removed them from the nature around them[47].

As mentioned, Urban Echoes was originally intended to have citizen science aspects, but considering the already excellent tools for birding-related citizen science, adding another tool could potentially harm these, as it could split user bases between the two applications. Another concern is that the users contributing to the projects are often deeply engaged in their local wildlife and nature. Thus, they might find the use of technology to diminish these experiences. Lastly, the amount of work that goes into creating a trustworthy database was not considered a priority for this project. Currently, Urban Echoes uses sightings from eBird to populate the map, along with observations made by users of Urban Echoes. There are very few eBirds observations in Aarhus, but the few that are of rarer birds might excite those who hear them.

2.4 DIGITAL STORYTELLING

With Urban Echoes, I intend for the users to tell a collaborative story with the local environment and birds as actors. Digital storytelling is a great way to provide context and meaning to an aesthetic experience. Audio walks are one such instance where the geographical location provides the context for the audio content, forming a coherent experience. Using the geographic position for context is not unique to audio walks, and examples of different digital storytelling, such as videos and other multimedia content, exist. One such example can be found in *Seven Stories*[50], a research project by Nisi et al., where visual location-specific narratives in the form of videos were used to tell local stories on Madera. They found that the user had problems with orientation and GPS fidelity, relying solely on them to play the videos. This encouraged them to use a marker-based solution for videos instead[50]. When the GPS did not function as expected, the user spent much time looking at the phone instead of the environment. Urban Echoes fully relies on the GPS but does not need the same fidelity as Seven Stories.

It's common for audio walks to have a map showing the user's position and points of interest. As seen in the work of Nisi et al., this can lead to frustrating experiences if the GPS fidelity is low, but a high one is required for the design. An audio guide by Pedersen et al. using only auditory media found that removing the map and guiding the user using sound decreased screen usage and increased both observational gain and engagement[53]. I have decided to have no visual elements for Urban Echoes, keeping the user's attention on their visual surroundings. The audio content, while location and context specific, is intended to be found by walking around without any visual aid from the application. Areas without sound will also provide the user with a story, as the area has few birds or recordings. In the latter case, users are encouraged to walk without headphones or only one to hear their present soundscape and potentially contribute with new observations should they hear a bird. The story told becomes the story of which birds were seen where and when, or conversely, the story of what places they avoid, or that people do not use the app. An imagined scenario could, for example, see a silent forest, as users might have closed the application and instead listen to the soundscape around them. Meanwhile, a winter walk through the same forest could have the user listening to all the birds recorded last spring while the real environment is silent.

The interplay between visual and auditory, and how one affects the other. Looked at how landscapes changed the perception of the sound-

scape[42]. They found that spatial arrangement matters more than individual elements in terms of the perception of the soundscape.

2.5 AUDIO BASED INTERFACES

3 DESIGN ANALYSIS

In this section, I will analyse the design and describe the design decisions made along the way. The sections appear in chronological order and thus reflect how the project developed throughout the thesis writing.

3.1 A DIFFERENT DIRECTION: CREATING A USER-MAINTAINED BIRD DATASET FOR VISUAL RECOGNITION

The original vision of the application differed significantly from its final form, notably in the design of the observation mechanic, while the core listening experience remained relatively consistent. Initially, the observation system was envisioned to function through AI-based bird recognition using sound and images, similar to MerlinID. The app aimed to distinguish itself through its citizen science component, incorporating elements inspired by iNaturalist [71], where users actively contribute to datasets for visual recognition.

In this model, users would take a photo of a bird - or a group of birds - and then annotate the image by drawing a border box around each subject and labelling them, as illustrated in Figure 3.1. Upon uploading the annotated image, the data would be stored as part of a growing object detection dataset. As a form of positive reinforcement, the user would also receive an "observation" entry as a reward for their contribution that the listener could experience.
I wanted to create a user-maintained dataset because, like in other citizen science projects, this approach enables scalability far beyond what traditional methods allow. Moreover, there is a notable lack of high-quality avian datasets for object detection tasks [68]. Visual recognition highly depends on the data used to train the model, with the adage "garbage in, garbage out" illustrating this point. A large, high-quality, and labelled data set could greatly contribute to the field of avian object detection.

As the project progressed, I experienced a larger disconnect between the observation and listening experience, and ultimately decided that the project should focus on one or the other. I decided to focus on the aesthetic experience and nature appreciation over citizen science and

Figure 3.1: Annotated image from the system description document for the initial idea

AI aspects of the project, leading to scrapping these parts for a simpler observation approach.

3.2 AUDIO DESIGN

As an audio-based application, a quality audio design is essential for the user experience of Urban Echoes. When starting the project, I considered the audio quality in terms of sampling rate and bitrate. After discussing my project with audio experts in sound study and sound aesthetics, this perspective changed. They pointed me in the direction of soundscapes[59] and acoustic ecology[59, 69]. Soundscapes and acoustic ecology hint at the interplay between sounds and how they affect each other to form a complete impression, much akin to how each instrument in the orchestra forms the coherent listening experience. In a forest, for example, we might hear the wind blowing, swaying the trees, the small stream rushing near, some small animal in the bushes, and the sound of our boots on the ground. All these sounds are heard and perceived together. We might create a dissonance between the playback soundscape and the limited visual environment by transposing a sound file with all its associated acoustic ecology to be played at another place and time. This can happen when our visual environment has a vastly different acoustic ecology, and this ecology is known to us more than the sound playback we are hearing. Imagine walking down a street in a European city while a recording of the Common Swift is playing. The sound of the bird might be familiar, as the common swift can be found in many European cities. However, if the soundscape of the sound files is that of the sub-Saharan rainforest with all its associated sounds, it is clear that the soundscape does not belong to the street you are walking on. As I seek to give users

an affiliation with their local nature through sound, the soundscape should fit with what we expect.

3.2.1 The Challenge of Aligning the Acoustic Ecology with the Visual Environments

To ensure alignment between the visual environment and the soundscape. I wanted to isolate bird vocalisations from their ecological background so that users could either immerse themselves purely in these vocalisations or, by enabling transparency mode on their devices, allow the real-world soundscape to blend naturally with the playback audio.

I initially experimented with a simple noise gate to isolate bird vocalisations and filter out most of the ecological background to achieve. Unfortunately, this approach was ineffective due to the dynamic range of the bird calls, which led to parts of the calls being inadvertently cut off. I then considered limiting playback to sound files from the user's country. However, this would significantly reduce the applicability of the app in countries with limited available recordings.

I also explored the use of AI-generated audio via the ElevenLabs text-to-sound effects (SFX) feature [26]. Despite being promising in theory, the resulting bird calls lacked realism and were downright awful at worst. Ultimately, I reverted to using high-quality category A recordings from the Xeno-Canto database, selected at random. Although not perfect, this method provided the most consistent and natural listening experience. A final option considered was to train an AI model capable of recognising and removing background noise. Although potentially effective, this was deemed too time-consuming for the current project. Nevertheless, implementing such a filter remains a compelling direction for future work.

3.2.2 Evaluating the sonic aesthetics

To evaluate the Sonic aesthetics, I used a framework by Cunningham et al.[21]. In their view, sonic aesthetics can be evaluated through the following criteria *intensity, pitch, timing, spatial, fidelity, context, originality, and expectation*[21]. The definitions of these dimensions can be seen in the figure 3.2 taken from their paper *Towards a Framework of Aesthetics in Sonic Interaction*[21]
Looking at this framework, Urban Echoes fulfils most of the criteria for highly aesthetic sonic design with a few exceptions. By choosing only sound files with the highest quality rating from Xeno-Canto, and by the qualities of bird songs and calls as aesthetic sounds, we can,

Dimension	Description
Intensity	The perception of loudness of the sound.
Pitch	The fundamental frequency, or musical note, dominant in the sound.
Timbre	The character of the sound and complexity of its frequency spectrum.
Spatial	The position of the sound relative to the listener's position.

(a) Dimensions: Intensity, Pitch, Timbre, Spatial

Fidelity	The production quality of the sound. Considers the clarity of the sound and its intention, including the presence of noise and other artefacts and the discernibility between signal and noise.
Context	The relationship between the sound, interaction task, and any other sensory stimulations (e.g., touch, visual, olfaction). Context may not always be known to the designer (such as for mobile applications).
Originality and Expectation	The level of predictability and familiarity in terms of the overall context of use, as well as in general experience.

(b) Dimensions: Fidelity, context, Originality and Expectation

Figure 3.2: The definitions of the dimensions from the paper *Towards a Framework of Aesthetics in Sonic Interaction* [21]

for most sounds, expect a good timbre and pitch. The intensity is mostly good, but varying loudness of sound files can lead to lower aesthetics, as some files might be too loud while others are too low. Initially used to design and argue for the audio, I decided to include these as evaluation parameters for my test.

I believe both spatially, context and Originality and expectation to be good, am unsure about Fidelity. Could be used as evaluation parameters, if so, should I include the results here?

For my vertical slice of the prototype discussed in Chapter 4.3, I found specific sound files with as little background noise as possible to transpose them. However, for the final prototype,

3.3 DESIGNING THE LISTENER ROLE

The application's listening experience lets users explore the auditory map. The map is explored by walking or otherwise moving, location tracking will work together with audio playback features to play the observations of a given location. During the design of the listening experience, I reflected on what maps can tell us and how we use them.

3.3.1 Mapping the world

When creating a map, we must understand the information we are mapping and how the readers will interpret the map. Questions such as, What are the intentions behind the creation of the map, and What kind of world does the map show? Take, for example, the most classic map projection, the Mercator map projection, where angles are preserved at the cost of inflating the areas of landmasses further towards the poles while minimising the ones closer to the equator. The angel-preserving properties make it useful for nautical navigation, but its ubiquitous application has given rise to a common critique against the projection in how Europe and North America are inflated in a colonialist manner[46]. Bearing these questions in mind helped me focus on what kind of world Urban Echoes mapping would reflect. Since it's meant to be used predominantly within an urban setting, it does not reflect where the most birds can be found. Instead, it will show where users choose to engage with the app. Cities, in this case, could be overrepresented compared to rural areas, with fewer users but possibly larger bird populations. Another aspect to consider in this regard is how the app's functionality relies on a stable connection. Therefore, areas without an Internet connection cannot be experienced or observations made using the application. This can be misleading if I do not clarify that this is not a direct mapping of the local birds.

This view of the interaction as something not just between the application and the user, but the wider circumstances surrounding the design, is also found in the literature, such as with Alex Taylor's "after interaction"[64], where the use of rental bikes paints a unique map of use.

Similarly to how the Mercator projection is useful for nautical navigation, I wanted to investigate the activity Urban Echoes bird mapping would create. As a listing experience, the map is intended to get people to pay attention to their visual environment while immersing themselves in the sonic. Experience the bird where it was seen, even if it is no longer physically there. In places without observations, silence can serve as an invitation to find birds, so observations can be created.

3.3.1.1 Mapping sounds

Used as a sound of maps[65] Either remove or expand

The sound enhanced the traditional map viewing experience[39]. They augmented a digital map of a hiking area by mapping sound files to areas of the map so that when users move their cursor above a certain area, like the forest would hear the associated sound. This helped people with impaired vision gain something from the map viewing

experience and improved the general perception of use.

How big of a discovery radius should an observation have? I had to decide how large the radius for an observation should be; in the end, I decided to go for a 50-meter radius. After testing out some different options, I found that 50 meters gave the best experience in regards to how long you hear the sounds.

3.4 ADDING TIME TEMPORAL ASPECTS SEASONS

I wanted to include temporal aspects in both time of day and season. In learning about birds, I found that these aspects could also be taught to users. There is a connection between breeding cycles and the amount of singing[62]. In Europe, birds often breed around the time when food is the most abundant for their offspring[40]. In northern Europe, birds breed most often in late spring or early autumn[40]. Beyond this, some birds migrate depending on the seasons, which makes the frequency and type of bird vocalisations depend on the season. I wanted the application to showcase the difference in seasons and allow a user to, for example, hear how a place sounds during spring in early December. Therefore, observations are loaded based on seasons. Users can choose which seasons they want to listen to at a given moment, with their current season being the default. I implemented this, but it did not affect the prototype testing. These seasonal changes would require the prototype to be used longer before becoming noticeable. I also wanted to include the effects on time of day, as birds are most active at and around sunrise[57], with activity the lowest during the nights and a local minimum at midday. However, I choose not to implement this for the prototype as I want as high a chance that the evaluators encounter each other's observations. Thus, limiting evaluations to certain times of day would make the chances of this less. However, in an idealised version, the time of day would be reflected in the observations, with the user potentially being able to choose when to listen to the particular area.

3.5 CREATING A FULLY AUDITORY APPLICATION

The application was interested in

4 DESIGN AND EVALUATION OF SYSTEM ARCHITECTURE

In this section of the Thesis, I review the prototype's system architecture and changes between major iterations. Finally, I evaluate the iterations and how they affected further development.

4.1 FLUTTER AND DART

Most of the application is written in Dart, a language created for mobile and web development with C-like syntax. The choice to use Dart came from a desire to use Flutter[30], a multiplatform open-source framework developed and maintained by Google. I wanted to use a multiplatform framework so that the application could run on Android, iOS, and the web with a single codebase, even if I later decided not to develop a web application. There was no particular reason for choosing Flutter over other multiplatform frameworks like React Native, aside from a personal desire to learn a new language and framework.

Android was chosen as the main development platform, so the app was tested and implemented primarily on Android devices. This decision was based on the more lenient deployment policies compared to iOS and the fact that I own multiple Android devices but no iOS devices.

4.2 GENERAL SYSTEM ARCHITECTURE

Some general description and a UML diagram, maybe

4.3 VERTICAL SLICE OF THE PROTOTYPE

I still believe this section would benefit from discussing design as research as part of the introduction. Alternatively, maybe I could discuss design as research elsewhere. Probably makes most sense in the related work or introduction.

To experience how the prototype would feel, I tested a straightforward small-scale implementation version capable of playing the observa-

tions to create a listener experience.

This presents itself as a vertical slice of the final application capable of all the features related to the audio walk part, but lacking features such as observation recording, logging on and sending, and tracking the trip.

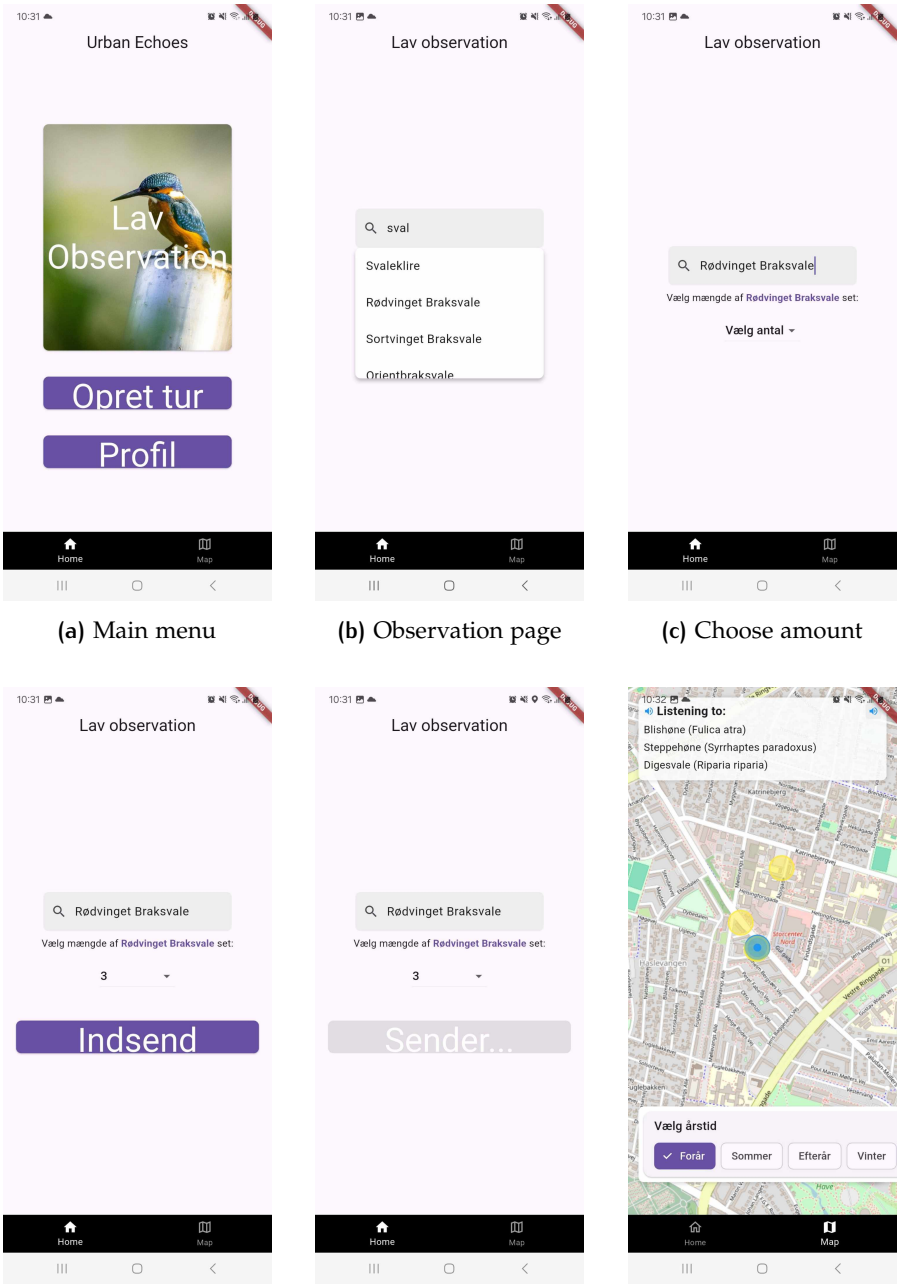
To find out what kind of birds I would use for the vertical slice prototype, I went on a walk in the area and listened to the sounds of the birds. I found that the neighbourhood of the villa, where there are many large gardens with trees, had significantly more birds. Observing the birds, I also found a lot more than when going for a regular walk, highlighting the potential of the observer role as it encourages greater sonic awareness to identify the birds. I found that the birds at long periods did not produce any sounds, which I initially wanted to emulate for the prototype, before I decided on a more exaggerated approach. Additionally, I thought about the radius, and I think somewhere between 30 and 50 meters seems fine without having tested it further. These sounds drown out the birds near the road or during construction work.

The birds I encountered during my short walk were the following:

- Eurasian Blackbird (Turdus merula)
- European Herring Gull (Larus argentatus)
- Common Wood Pigeon (Columba palumbus)
- Eurasian Blue Tit (Cyanistes caeruleus)
- Rook (Corvus frugilegus)
- Common Gull (Larus canus)
- Eurasian Tree Sparrow (Passer montanus)
- European Greenfinch (Chloris chloris)

These were inserted as points into the database with the relevant coordinates and times. A visual interface was provided for debugging purposes to allow me to identify problems with the prototype more easily. Figure 4.1 shows a view of how the visuals looked. Write a description of the visual.

I tested the vertical slice prototype with my advisor and later with a fellow IT product development master's student. A bug related to the GPS functionality somewhat hindered the prototype's evaluation, with the GPS updating infrequently causing certain observations to play for an extended time and others to play at all. However, both tests allowed me to reflect on the successes and what needed to be improved. One finding related to the exaggerated nature of the calls in the application is that when compared to real-life sightings, audio recordings would be both louder and of higher intensity than the actual calls and songs.



(a) Main menu **(b)** Observation page **(c)** Choose amount

(d) Send in the recording **(e)** Sending the recoding **(f)** The listener view

Figure 4.1: The visuals for the vertical slice

The GPS problems came from the screen timeout that the phone would enter after a short use time. I originally tried to solve this by allowing audio and GPS to run in the background. But while I successfully got the audio player to work as a background service, the GPS kept giving me trouble until I decided to have the app prevent the phone from going into Screen timeout as long as the app is in the foreground. Although preventing screen timeout consumes a lot of battery life in my already battery-intensive application, I decided that this was a

sacrifice needed to move on to other areas of development.

4.4 VOICE RECOGNITION AND AUDIO

Initially, I implemented a text-to-speech solution using the Flutter package called *flutter_tts*[24]. This solution used prewritten text pieces, which would be read out when certain conditions were met. I preferred this solution over a pre-recorded audio solution, as adding more birds and languages would be quicker. The app is built for a Danish audience; therefore, the audio language is Danish. Unfortunately, the pronunciation of Danish words with the text-to-speech model sounded almost intelligible. This made me change over to a pre-recorded solution. I recorded the bird names individually to allow them to be inserted into multiple sentences. This made it possible to create dynamic sentences such as (translated to English, though the app uses Danish): "Did you see a" followed by a recording of the bird name, resulting in complete phrases like: "Have you seen a Blackbird?" albeit with a small delay. This also meant the application doesn't have voicelines for every bird found in Denmark, as it was very time-intensive to do the recordings. However, 53 of the most common birds out of the roughly 300 birds in Denmark have been recorded. To test the new functionalities, I made a new debug interface which can be seen in Figure 4.2. These visuals ended up being the basics for the prototype's final look as seen in 1.1.

4.5 BACKEND

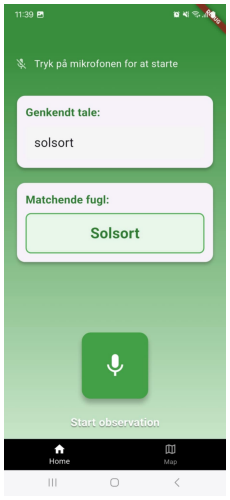
The backend is built using Python and FastAPI and hosted on Microsoft Azure. Microsoft Azure was chosen over other cloud hosting services for several reasons. The service scales well and offers all the features needed for my backend, such as web hosting, PostgreSQL database support and blob storage. Furthermore, students get 100 dollars worth of credit through the GitHub Student package, which means I could use the hosting without paying out of pocket. The choice to run a FastAPI backend was mainly based on my familiarity with it doing previous projects.

4.5.1 Database

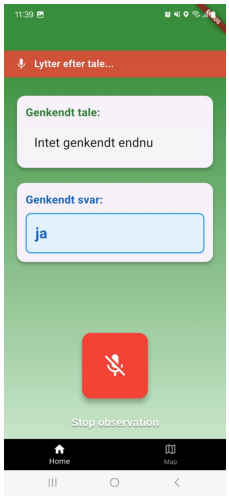
The PostgreSQL database has two tables: `bird_observation_table`, seen in Table 4.1, and `birds`, seen in Table 4.2.
Furthermore, an Azure storage blob holds sound files for all birds found in Denmark. Each bird has 20 associated sound files down-

(a) Listening is triggered by clicking the large green button.

(b) The app is listening and has matched the spoken word with "solsort" (Blackbird).



(c) The recognised speech and matched word are displayed.



(d) The user says "ja" (yes) to confirm the observation, prompting the system to save it in the database.

Figure 4.2: Screenshots illustrating the speech recognition debug visuals in the application.

Field	Type	Description
id	INT	Unique identifier for each observation
bird_name	VARCHAR	Common name of the bird
scientific_name	VARCHAR	Scientific name (e.g., *Corvus corax*)
sound_directory	TEXT	Path to the associated sound file
latitude	numeric	Latitude of the observation point
longitude	numeric	Longitude of the observation point
observation_date	DATE	Date of the observation
observation_time	TIME	Time of the observation
observer_id	INT	Reference to the observer
quantity	INT	Number of birds observed
is_test_data	BOOLEAN	Flag to indicate test or real data
test_batch_id	VARCHAR	ID of the test batch (if applicable)
source_id	TEXT	ID from eBirds on eBird observations

Table 4.1: Schema for the `bird_observations` table

Field	Type	Description
id	INT	Unique identifier for the bird
common_name	VARCHAR	Common name of the bird
scientific_name	VARCHAR	Scientific name (e.g., *Turdus merula*)
danish_name	VARCHAR	Bird's name in Danish
region	VARCHAR	Region where the observation was made
lastobserved	TIMESTAMP WITHOUT TIME ZONE	Date the bird was last observed
is_common	BOOLEAN	Whether the bird is commonly found

Table 4.2: Schema for the `birds` table

loaded from Xeno-Canto. The blob directories are associated with the Database. When an observation is active, the application will stream and play a sound file associated with the link on the blob. For a less data-intensive solution, the app could include all the sound files for regional birds or have them available for download. The app will still need an internet connection as it will need to access points, but these could also be cached, further decreasing the data intensity.

Mabey ER diagram

4.6 SPEECH RECOGNITION, TEXT TO SPEECH AND RECORDINGS

When the user clicks the microphone icon at the bottom of the screen, they will go into listing mode as seen in figure 4.2b. While in listing mode, the application will take the user's speech as input and use the Flutter package *speech_to_text* v7.0.0 [19] to turn it into text. The text will then be matched against a species list, and if a match is found, the system will proceed by prompting the user with the confirmation card as seen in figure 1.1b. Special words such as the seasons and ja(yes), nej(no), and other confirmation words also get checked for matches. Depending on the match, the application can enter different stages, such as the confirmation stage, after the user says ja(yes) to having observed a bird. The list of birds is taken from the species list from netfulg.dk[48] ensures that every species found in Denmark is included in the application. Since the app is intended for a Danish audience, both speech recognition matches and audio playback are in Danish.

4.6.1 Text to speech

I implemented a text-to-speech functionality in the application for announcing bird names and playing a few voice lines, such as "Have you observed a (bird name)"[1] and "Observation for (bird name) has been created."[2]. The text-to-speech was implemented using a library called *flutter_tts* v4.2.2 [24]. After testing the library's Danish capabilities, I found that it struggled with pronunciation to the point of it becoming almost unintelligible. I therefore decided to go for an adioplayback solution instead, where I would record voicelines.

4.7 AUDITORY CONSIDERATIONS AND HOW IT TRANSLATES TO CODE

1 Actual sentence in application said in Danish: *Har du observeret en (fuglens navn)*
2 Actual sentence in application said in Danish: *Observation for (fuglens navn) er oprettet*

5 IMPLEMENTATION

In this section, I will go more in-depth with the implementation of the different components of the final prototype. All the code can be found on GitHub following the link in Appendix C.1. The application's general architecture follows the Provider pattern to establish a hierarchical dependency injection system. Listing 5.1 illustrates how various provider types manage service dependencies, ranging from basic stateless services to complex coordinating services that orchestrate multiple components. The full setup is provided in Appendix D. A provider pattern was chosen due to the separation of logic through dependency injection, making the system more manageable, modular and understandable.

```
MultiProvider(
  providers: [
    // Core state managers
    ChangeNotifierProvider<PageStateManager>(create: (context) =>
        PageStateManager()),

    // Basic services
    Provider<DatabaseService>(create: (context) =>
        DatabaseService(), lazy: false),

    // Services with dependencies
    ListenableProvider<ObservationUploader>(
      create: (context) => ObservationUploader(
        databaseService: Provider.of<DatabaseService>(context,
            listen: false),
        // Other dependencies...
      ),
    ),

    // Complex coordinating service with multiple dependencies
    //Speech coordinator
    ChangeNotifierProxyProvider4<...>(...),
  ],
  child: MaterialApp(...),
)
```

Listing 5.1: MultiProvider setup in Flutter

5.1 AUDITORY MAP(LOCATION SERVICE)

The auditory map is created and managed by a class called location_service with the following dependencies

- bird_sound_player
- azure_storage_service
- background_audio_service
- season_service
- location_manager

Before delving into how it works, I wish to describe the dependencies so that a greater understanding of the system is gained.

5.1.1 bird_sound_player

This module initialises a pool of five audio players(the exact number is set in the service_config file), manages which players are available, and handles the playback of bird sounds using the available players. The audio players used are from the Flutter library audioplayers version 6.2.0[49].

5.1.2 background_audio_service

This class ensures that sounds keep playing even when the application is minimised or the screen is turned off. Unfortunately, sounds will not change while the app runs in the background, as I were not able to get location tracking working as a background service.

5.1.3 season_service

A simple class for tracking the seasons. This means keeping track of the current seasons as well as finding seasons for other observations based on their dates. I decided that the application should allow users to change seasons and then hear only observations made in that season. The class is not used in the prototype as I removed the feature to change between seasons, as there were so few bird observations and since the participants in the evaluation would all be using it during the same season.

5.1.4 azure_storage_service

This class followed a singleton pattern and has two responsibilities. Firstly, it should initialise the connection to the Azure storage blob holding all the sound files.

```
Future initialize() async {
  try {
    if (_initialized && _storage != null) return true;

    _storageAccountName = dotenv.env['AZURE_STORAGE_ACCOUNT_NAME
        '] ?? '';
    final connectionString =
        dotenv.env['AZURE_STORAGE_CONNECTION_STRING'] ?? '';

    if (_storageAccountName!.isEmpty || connectionString.isEmpty)
         {
      debugPrint('Azure Storage credentials are missing');
      return false;
    }

    _storage = AzureStorage.parse(connectionString);

    _initialized = true;
    debugPrint('Azure Storage Service initialized successfully');
    return true;
  } catch (e) {
    debugPrint('Error initializing Azure Storage Service: $e');
    _initialized = false;
    return false;
  }
}
```

Listing 5.2: Azure Storage Service Initialization Method

Its second responsibility is to list all the files in a certain folder of the blob storage. This is used as the bird sound plays a random sound file from a certain folder when playing a bird sound.

5.1.5 location_manager

The `LocationManager` class is responsible for tracking the user's location. It uses the `LocationRepositoryInterface` as an abstraction layer over the Flutter package `geolocator`[5].

```dart
void _handlePositionUpdate(Position position) {
  _currentPosition = position;

  // Skip processing if not enough time has elapsed
  final now = DateTime.now();
  if (now.difference(_lastPositionUpdate).inMilliseconds < 500) {
    return;
  }
  _lastPositionUpdate = now;

  if (_config.debugMode) {
    debugPrint('[LocationManager] Position update: ${position.
        latitude}, ${position.longitude}');
  }

  // Skip if position hasn't changed significantly
  if (_lastProcessedPosition != null) {
    final distance = _locationRepository.distanceBetween(
      _lastProcessedPosition!.latitude,
      _lastProcessedPosition!.longitude,
      position.latitude,
      position.longitude
    );

    if (distance < _config.distanceFilter / 2) {
      if (_config.debugMode) {
        debugPrint('[LocationManager] Skipping position update (
            moved only ${distance.toStringAsFixed(1)}m)');
      }
      return;
    }
  }

  _lastProcessedPosition = position;

  // Call the callback
  if (onPositionUpdate != null) {
    onPositionUpdate!(position);
  }
}
```

Listing 5.3: Dart Function: _handlePositionUpdate

5.1.6 How it all works together

The location services work by making a call to the backend that retrieves all the observations of that season. It uses the location manager to track the user's position and then retrieves sounds from the storage blob using Azure_storage_service based on the user's location. Then it uses bird_sound_player to play the sounds retrieved, which internally makes sure to use the available audio players. Background audio services play the sounds should the user turn off their screen, but since the tracking stops working at this point, the sounds will keep repeating, thus it realistically did not play that big of a role within the evaluated prototype.

5.2 DATABASE SERVICE

This class is responsible for creating and maintaining a connection with the database. This also includes closing the connection. Beyond this it has a function to fetch all the observations from the database to populate the map. Lastly, it provides a function for uploading observations to the database.

5.3 OBSERVATION UPLOADER

Once again uses the provider pattern and dependency injection. It uses a DatabaseService, an UploadNotificationService instance and an ObservationService. The class is responsible for validating and preparing observation data, preventing duplicate uploads, uploading observations to a remote API, notifying the user of success or failure, and tracking internal state (uploading, error, disposed).

5.4 RECORDINGPLAYERSERVICE

Plays the audio files that I recorded. It has functions to play sound files where a bird's name is said, along with a function to play longer sentences based on a prompt key. Additionally the class has functions like playBirdQuestion, seen in Appendix **??** that combines a prompt with a bird name and notifies the listeners that wait for the question to finishes.

5.5 SPEECH COORDINATOR SERVICE

Speech coordinator service is a large class extending the ChangeNotifier class and following the provider pattern. It's responsible for the speech interface, which includes word recognition, playing the right sound files, listening for confirmations and providing listeners such as the UI with updates. It uses previously discussed services, such as RecordingPlayerService and ObservationUploader. In addition BirdRecognitionService, WordRecognitionService, and SpeechRecognitionService are used as dependencies, each responsible for parts of the speech recognition process.

5.6 BACKEND

A FastAPI backend written in Python and hosted on a student subscription to Azure provides an endpoint for fetching observations. There are other endpoints, but these are not used in the version of the prototype that was evaluated. The backend can be found in Appendix D.2. As part of the backend, a Postgres database holds a table for observations. Additionally, I run an Azure storage blob for the sound files. All sound files have been collected from xeno-carto[31] and are organised in folders based on the scientific name of the bird. These folders are associated with the observations in the database, allowing me to fetch random sound files from specific folders based on the bird observed in a given observation. I use scientific names for the back-end as they are language-independent, making it more scalable.

6 EVALUATION

In this section, I describe the evaluation covering the subjects methodology, participants, and the perspective for the qualitative data analyses. Afterwards, I present the evaluation results in three parts: the interview section, a thematic analysis and lastly responses that did not fit into the thematic analysis but merit more discussion. The chapter concludes with a discussion section where the findings are discussed.

6.1 METHODOLOGY

The prototype was evaluated for a week, with most participants starting the evaluation on the 12th of May and ending on the 19th of May. Three evaluations ran from the 14th to the 21st and were scheduled later, as not all participants had time to start the evaluation on the 12th. During the week, each evaluator was asked to use the application at least once a day for a week. After each use, they were asked to write down their thoughts with an emphasis on writing, preferably 5 lines or more each day. Lastly, they were asked to write final reflections about how they used the app during the week. This study is inspired by diary studies[29] but does not feature prompts. I decided not to include any prompts to allow the evaluators' epistemic knowledge to show. However, not including prompts might have found fewer similarities in the answers than if I had done otherwise. The resulting diaries, both original and if the original was written in Danish, then translated, can be read in the Appendix B.1.

Each evaluation started with the participant downloading the application. Afterwards, the evaluator and the participant went on a short walk where the participant learned to use the app and could have questions about the app answered. This walk also served to discuss the initial thoughts about the application. After each walk, a small semi-structured interview[1] Interviews lasting approximately 15–30 minutes were conducted with all participants, except for Participants 1 and 2.[1] All interview transcripts are in the appendix B.2. Here, the evaluator could grasp the participants' initial experiences with the application and how much of an interest they had in the local

1 Participants 1 installed the app remotely and did not participant in the initial walk or interview and participant 2 took longer with the walk which meant there were no time for the interview both were therefore excluded from the interview portion of the study.

bird wildlife. In addition, the interview serves as a starting point for reflection for the participants.

6.1.1 Participants

The study involved ten participants, aged 21 to 61, comprising four women and six men. The majority were students, with eight participants currently enrolled in study programs. Among these, three pursued a Master's degree in IT Product Development. The remaining students were enrolled in a Bachelor's program in Molecular Medicine, a Master's program in Economics, a Bachelor's program in Chemistry, and a Professional Bachelor's program in Diaconia and Social Education. The remaining three participants were employed: one as a Ph.D. candidate in the Department of Chemistry at Aarhus University, one as a system developer in the Department of Physics, and one as a pedagogue at a school. Two participants were already interested in birds, and most were waiting to learn more about their environment.

In addition, an eleventh individual participated in limited capacity due to their Android device running an older operating system, which restricted them to using only the listing activity of the experience. This participant is currently pursuing a Bachelor's degree in Biology.

6.1.2 The perspective for the qualitative data analyses

The study consists of qualitative data with 11 participants' responses, each participant provided varying degrees of responses, as some participants did not go for a walk every day and wrote short responses. To find themes in the responses, I conducted a thematic analysis of the responses, following the approach outlined by Braun and Clarke [12, 17], the results of which are in Appendix B.3. The resulting themes form the basis for the results presented in Section 6.2.2, accompanied by illustrative participant quotes. Certain responses—closely tied to the participants' epistemic backgrounds—offered unique and insightful observations that did not fit within the thematic analysis. These responses opened up entirely new avenues for development not previously considered by the author, and thus I felt they deserved their section 6.2.3.

6.2 RESULTS

The results have been split into three sections: the interview section, which consists of my reflections on the interview answers, a section

showcasing the patterns that occurred as part of the result of the diary study, and lastly, a section presenting more individual perspectives I found particularly interesting.

6.2.1 Interview results

As previously discussed, Participants 1 and 2 were not interviewed. Furthermore, I accidentally overwrote interview 5, and as such, the interview section consists of only 9 participants.

8 Participants had an overall initial positive response to the application, and all 9 participants noticed more birds than when going for a regular walk. This difference could be due to how they were actively looking for the birds to record them, and looking for the birds they were hearing through the app. All 9 participants used the Merlin ID app to help them identify the birds. However, the 2 participants who had a pre-existing interest in birds and, for the most part, did not use Merlin ID, resorting to only using it when unsure about the observed bird. Multiple participants asked about combining the functionality of the apps in order not to have to change between apps all the time. Something which became a reappearing trend in the dairy study result

Several participants reported going on regular walks, often seeking out areas with nature during these outings. They described the walks as relaxing and helpful for clearing the mind. For some, the soundscape played an important role in this experience: Natural sounds such as birdsong and the wind in the trees contributed to a sense of calm. Others, however, preferred to listen to music while walking. In contrast, many participants found the urban soundscape to be noisy and overstimulating, leading to discomfort when walking near roads or in areas with significant industrial, mechanical, or human-made noise. One participant, however, occasionally appreciated industrial areas—particularly when they had a certain aesthetic cohesion. For example, he described enjoying the atmosphere of the harbour, where even a boat's horn—typically considered an unpleasant sound—could become a positive part of the experience. He clarified, though, that this appreciation did not extend to traffic or road noise.

One participant found it hard to identify which bird sounds were real and which were from the app, forcing him to rely on visually seeing and entering the birds rather than identifying them through sound. Another participant shared this sentiment, saying the experience was somewhat confusing and overwhelming, as they had to relate to both the digital birds and real ones. They did, however, find it intriguing

and fun to have a digital element to the bird-watching experience.

One participant was concerned about hearing certain types of birds, namely pigeons and seagulls, as they are quite common in Aarhus. The participant dislikes these birds. When asked why the participant thought this way about the animals, he cited seagulls as food thieves and aggressive, calling their calls unpleasant. As for pigeons, when asked why he disliked them, he somewhat changed his stance and mentioned how he thinks of them as pests, but not as bad as the seagulls. He finds their song/call to be pleasant, but still does not find it as pretty as, for example, the blackbird's song.

Some general concerns with technical issues were shared amongst participants, such as the playback voice being low compared to the bird sounds, and the record button sometimes being a bit unresponsive. One participant in particular had a lot of issues with the observation mechanism, finding the speech interface slow and bothersome, and wished they could use the search system included as a last resort, as the only method for uploading. This participant also faced more difficulties with uploading, with uploads often failing throughout the entire week, something that would rarely happen to other participants but would happen almost every third time for this participant. They also got so frustrated with the speech recognition that they made a false upload during the initial walk after the system heard the bird wrong.

A participant commented on how they could see the application being used as a pedagogical tool to engage people with special needs, such as individuals with Down syndrome, in bird wildlife. They attributed the app's simple interface and task-based/playing interaction of finding and recording birds as observations.

As I walked with them, I also made some observations myself. Most participants walked with the phone out and looked at it when making observations. When not, they were actively looking around the environment, often stopping to identify or look for a bird.

6.2.2 Dairy study thematic analysis

Table 6.1 can be used to identify the themes and the magnitude of responses for each theme. One participant may have written multiple responses that were coded to specific themes.

Category	Theme	Count
Positive (30)	Increased knowledge of local birds	8
	Increased awareness and found more birds	18
	Noticing	4
Neutral (22)	Use of app with other media	2
	Integration between merlinID and Urban Echoes	3
	Want more information	5
	Difference in use based on time of day	4
	Importance of how sounds reflect the real world	8
Negative (26)	Uncomfortable with voice recognition as an interface	11
	Technical issues/Bugs	6
	Confusion due to app and real sounds mixing	2
	Fatigue stemming from repeated use	7
Mics		6

Table 6.1: Themes and magnitude of responses categorised as Positive, Neutral, or Negative

6.2.2.1 Positive

The most common finding amongst participants was an increased awareness of both sonic and visual elements in their environment. The increased awareness led the participants to notice more birds than usual. It also became apparent that participants sought to connect their auditory and visual environments. A general positive attitude towards this increased awareness was also present in these responses.

> Within about 1 km of Børglum Kollegiet: In the immediate area of Børglum (< 1 km), I was able to hear birdsong through the app. I liked how the resulting attention towards possible bird sightings made me more focused, and gave me a "mental pause" in that way, more so than music would usually do. - Participant 9

It became evident in some participants' responses that the increased awareness and sightings of birds resulting from thereof helped the participants become more engaged in birds. Furthermore, they started to recognise the birds, their calls, and learn their names, increasing

their knowledge of the local fauna.

> On the days I have used the app and the times I've been outside, I have become more aware of birdsong and other sounds in the area. I recognise more bird calls now.- Sometimes I've used a mindfulness approach and paid more attention to bird sounds and being present in the moment when listening to the recordings while walking alone. I stop and listen and try to look for the birds—and sometimes, the same bird playing in the app is also there in real life, singing right where I am. - Participant 1

A few participants also began to notice the birds, in a manner akin to Anna Tsing's notion of noticing — an attuned and situated form of attention to the more-than-human. One participant began reflecting on how urban environments might better accommodate birds, observing patterns in their groupings, noticing which birds resided where, and wondering whether they formed communities of their own. This participant thought this information could be used for city planners and communities to help birds of a certain area, as seen in the quote and Figure 6.1. Another participant similarly started to notice what kind of birds were in their local area, but to them it was morose a source of fatigue as the same birds kept appearing. This participant's response was not coded for noticing, as I found it just shy of the attunement described within Tsings' noticing. A different participant had some of their responses coded for noticing due to their focus on biodiversity, considering which types of birds could be found in different areas and was surprised by the variety of birds found in urban and suburban environments. A third often paused to engage in what they described as a mindfulness practice — staying present in the moment while looking for and then observing the birds they heard through the application.

> I've been noticing that within the more Urban areas, the birds seem to have a large preference for one type of environment, therefore making the type of birds you'll see or hear in certain environments very low in diversity. Today I walked through a small neighbourhood with, honestly, a large amount of birds for an Urban area, but they were 95 per cent just one kind of bird. I've noticed the same in another neighbourhood with another type of bird. Maybe it says something about their preferred environment, or maybe they choose to flock together in certain areas like a neighbourhood. Either Way, it made me think that you could possibly set up amenities for the birds that the app plots in certain areas to encourage birds to live within cities - Participant 4

Figure 6.1: A quick sketch by participant 4 drawn after explaining her idea for bird neighbourhoods

6.2.2.2 Neutral

Participants 3,4, and 5 all used the application during the late evening and nighttime. Their reflections point towards how different times of day affect the user experience, both in terms of lower bird activity making observations harder, and in how the audio connects with the visual environment, the audio which evokes ideas of high levels of bird activity does not match the evening/night activities for he birds

> "The bird noises from the app didn't match up with the behaviour of the birds in this instance. Although it is obvious that the birds would need to rest, the behaviour seen in real life vs heard through the app was extremely disconnected."
> - Participant 4

The importance of the visual environment and the real world in relation to the sound was evident in many responses. With positivity in responses where the environments match, and a disconnect when they do not match. This fits with the earlier discussions in section 3.2.1 about aligning the acoustic Ecology with the Visual Environments.

> It feels nice to hear the ambient sound in the headphones almost perfectly match what I could hear IRL. I noticed myself taking longer than usual, just taking in all the sounds of nature, the birds, trees rustling or creaking, a lawnmower in the distance. All together, I feel refreshed. - Participant 7

Two participants used the application's listener role along with other audio content, one an audiobook and the other music. They both

had positive experiences with using the app alongside this additional audio content.

> Tiredly walked to return bottles at 9 PM. On the way there, I noticed how many of the same bird species there are in Aarhus. It started to feel a little less exciting to enter blackbirds and wood pigeons over and over again. But then it suddenly got exciting when I turned a corner and heard a great tit and a jackdaw — you get a little rush from discovering a new bird. On the way back from the bottle machine, I was carrying two bags, so I couldn't enter any birds. Instead, I tried listening to an audiobook while the app was still on. It was actually really cool — just as Kublai Khan had conquered a Chinese army, the great tit, jackdaw, blackbird, and wood pigeon I had previously entered all started singing over the battle description. I thought it was pretty cool to hear bird sounds without entering them. - Participant 3

Participants 5 and 11 disagreed on whether or not having to say the bird's real name instead of its common name was annoying or beneficial. Participant 5's reflection also showcases a fault in the suggestion section, with the suggestion algorithm giving results that are too far removed from the spoken word.

> "I heard quite a few birds and also saw some. It would be smart if the app could recognise birds' common names and suggest the correct species. For example, the hooded crow is usually just known as a crow. If you say crow, many suggestions appear, but not hooded crow. If a crow showed up, it would be easier to select the right bird." - Participant 5(translated from Danish)

> "Again, learning birds' real names – it's good that you're forced to give a name to a bird in the database." - Participant 11 (translated from Danish)

Many participants wanted the app to provide more information about the birds they make observations on or hear. Some also requested maps of observations.

> "Generally, I think I've learned about different bird calls/appearances, and there's potential to learn even more. That is also to some extent with the help of Merlin, but your app makes me repeat it, which can help learning (bird Duolingo?) Sound versus visual; data visualisation: detail vs immersion. Would like to be able to dig more into the observations made nearby. Maybe I can look at a map to see where the birds were spotted." - Participant 11

Furthermore, some wanted more integration with MerlinID or the features of MerlinID in Urban Echoes.

> "Went on a longer walk in Nordby Hills with my family. The app isn't always handy to use when walking with others, mainly because it takes time to first open Merlin ID and then Urban Echoes. Integration between the two apps would definitely be a big improvement — maybe with automatic data collection when Merlin ID suggests you've heard a particular bird. It was still fun to discuss with the others which birds we could see and hear. I really enjoy discovering new birds — heard a chiffchaff, a greylag goose, and a bird I've forgotten the name of, but one I hadn't seen in Aarhus. You get the feeling of collecting Pokémon. I think it would be cool with a Pokédex-style feature where you could see the birds you've "collected" — to make it a bit more gamified." - Participant 3

6.2.2.3 Negative

Some experienced difficulty differentiating between real-world sounds and those from the application. While this speaks to the generally high and lifelike audio quality, it also created confusion among these participants, leading to false observations.

> The app worked well; I didn't go on the longest walks and didn't mark all the birds I encountered, partly because I didn't know their names. I also heard bird sounds from the app. That was, of course, a nice touch, but at one point I got a bit confused because I thought it was a real bird and tried to mark it in the app. - Participant 5

Five out of eleven participants experienced some level of fatigue with the use of the application during the week. Perhaps this stemmed from feeling an obligation to use the application and report on the findings. The most common type of fatigue came from responses that said that the app had become something they felt they had to use rather than something they actively wanted during that walk. It should be noted that most of these participant were positive in their final reflections. However, repeated use, along with having to write feedback, might have made this fatigue appear faster and more frequently than in the intended use case. However, a participant experienced fatigue due to the number of repeating birds of the same kind. He suggested having a filter to avoid hearing these when you did not want it, something which is against the intended application of Urban Echoes.

> "On the way there, I noticed how many of the same kinds of birds there are in Aarhus. It started to get a bit less exciting to enter blackbirds and wood pigeons over and

> over again. But then it suddenly became exciting when I walked around a corner and heard a great tit and a jackdaw — you get a little rush from finding a new bird." - Participant 3(translated from Danish)

The most common negative coding in the responses related to the speech interface. The act of saying bird names out loud in public for the interaction made many participants feel like they drew unwanted attention. This was exacerbated when they had to repeat themselves if the application did not hear correctly. Some participants said only making observations when nobody was around, while others simply felt uncomfortable. This all hints towards how, at least in Denmark, speech interfaces are not socially acceptable for public spaces. Another complaint about the speech interface was how slow it was compared to using a more traditional search bar approach. This, however, is probably more a result of the direct application rather than an inherent limitation of speech interfaces.

> Another reason I would love this feature [talking about the search bar] is because I hate making verbal observations in public. As such, if I were a normal user, the lack of this feature would be enough for me to stop using the app entirely. So I think giving the user the option to choose to make the observation through verbal or written means would be an improvement to the app." - Participant 6

Several participants recorded frustrations with the technical aspects of the application. Issues related to the microphone button, speech recognition and upload difficulties plagued many participants' experience. A critical bug related to the confirmation card not appearing with some birds proved so detrimental that an update fixing this problem was pushed on the second day of the evaluation, and all participants then had to update.

> "Record button does not change back to green, but stops using the microphone. With a repeat press (while it is red and inactive) will turn the microphone back on. So it functions as it should, but the visuals are off. It was windy, so it was very hard to log observations. And therefore I think a search option from the start menu would be a huge quality of life feature. " - Participant 6

6.2.3 Analytical Exceptions and Developmental Implications

This section is made up of the responses that did not fit into the themes but nevertheless have some developmental implications.

Participant 7 thought of a share feature where they would be able to share what they are hearing with someone not located at the same geographical position. The share feature was something also originally envisioned as part of the application, but was not implemented for the prototype. Having it be brought up in the evaluations, however, shows the value of such a feature, which would be a prime candidate for further development.

> "Something that came to mind when making new observations and hearing the ones from yesterday. Is that it could be great if I could share the observation, the sound ambience, with someone who isn't in the same locale as me. To share with them how it sounds to be here in nature." - Participant 7

One participant who is on the autism spectrum and struggles with overstimulation also noted how it helped them pay attention to the sounds of nature, something they normally struggle with in cities due to the noisy soundscape. How the app could help people struggling with overstimulation from the city soundscape was not something I had considered when developing the app.

> "I found the app made a notable difference in the more urban environments, where it was very easy to spot the birds but hard to hear them. When the birds were flying in the sky and between buildings, they stood out easily, but due to noise pollution from cars and people, it was hard to hear them. Especially as an autistic individual, it is very hard not to get overstimulated by the noises in the city and not even enjoy the sounds of nature at all. Using the headphones with the app, I was able to synchronise the sound of the birds as I saw them." - Participant 4

As mentioned in the Section 6.2.1, one participant currently under education within social pedagogy found Urban Echoes to have some educational applications, especially if further development expanded on educational aspects. Beyond educational aspects, the participant also suggested adding more gamified elements after having a discussion with their educator about the app.

> "If these small issues are resolved, I believe — as stated — that Urban Echoes has great educational potential. Beyond fostering connection with nature, there are other pedagogical perspectives worth exploring. I hope that further development of the app will include a strong focus on its educational applications."- Participant 9

6.3 DISCUSSION

The application effectively encouraged users to be attentive to their auditory and visual environments. Several participants reported excitement when discovering and identifying new bird species in their local surroundings, often noting that the number and diversity of birds exceeded their expectations. Biggs describes a similar phenomenon in *Watching Myself Watching Birds*[8], where she recounts how, after noticing birds, they seemed to appear everywhere. A participant in this study reported a similar realisation, remarking that despite having lived in the same city for their entire life, they had never noticed the abundance and variety of birdlife all around them. This individual now consistently sees and hears birds throughout their daily activities. Likewise, during the application development, I became more aware of avian life. I had not paid attention to my local birds before this project. There is a broader discussion about how many people simply exist with the birds. Paying them little attention, and to the point of blending into the background; however, with very little effort, we start to notice the birds. That Urban Echoes was able to significantly heighten participants' awareness concerning birds and, for some, cultivate a deeper sense of excitement about local bird populations, represents a major success criterion for the application.

6.3.1 Temporality

One key finding from the evaluation was the impact of temporality on the user experience. The responses highlighted that a cohesive and enjoyable experience depended on the alignment between the auditory and visual environments. In particular, a temporal mismatch, such as hearing bird sounds at times when birds are typically inactive, was found to be a disorienting experience. One participant remarked that the sounds could feel disconnected when played at night, as the surrounding environment was quiet and birds were not visibly present. This suggests a need for greater user control over the temporal settings of the application. Allowing users to select the time of day for auditory playback could help mitigate this issue by offering a more contextually appropriate experience. For instance, subdued or quieter nighttime soundscapes could be used as a default for nighttime use, with an option for users to override the current temporal setting and explore different soundscapes, such as a morning chorus, regardless of the actual time. Further discussions with one participant on this subject also raised the idea of long-term temporal dissonance. One example of this thought-up longer time use case involved a formerly forested area that had been converted into an industrial zone. In such cases, the ability to "go back in time" and hear what the space may have sounded

like 20 years ago could offer emotional or reflective value, even if the auditory and visual environments no longer align. This introduces a broader design question: Can intentional temporal dissonance, such as hearing daytime at night or historical soundscapes, provide a meaningful experience? While speculative, it may be valuable to offer users both realism and imaginative temporal exploration, depending on their goals.

6.3.2 Fatigue after consecutive use

During the evaluation, 5 out of 11 participants reported experiencing fatigue or a sense of obligation to go on walks and use the app as the study progressed. This suggests that the application may not be suited for daily use over extended periods, but rather for more occasional engagement. The value of the app may lie in its ability to enrich specific moments of attention, such as exploring a new area, or when seeking the experience the app provides, rather than becoming a routine or habitual tool. Since the participants were encouraged to go for daily walks, these feelings of fatigue might be more prevalent than if used more naturally over a longer period.

6.3.3 Information

Another success criterion for the application was an increase in users' knowledge of their local avian wildlife. Learning calls, species name and appearance. The app largely succeeded in this endeavour, particularly with the help of MerlinID, which was used in conjunction with Urban Echos by all participants. Urban Echoes effectively provided the motivation and experiential context for users, many of whom had little prior interest in birds, but did not offer built-in mechanisms to identify or learn more about the birds themselves. In contrast, MerlinID is well-designed for bird identification and learning, but it assumes that the user already has a certain level of curiosity or interest in birdwatching. In this sense, the two applications complemented each other: Urban Echoes sparked interest, while MerlinID enabled users to deepen their understanding. Multiple participants expressed a desire for additional information about the birds they encountered through Urban Echoes, those they recorded or those they heard. Specifically, they requested access to details such as species names, images, and other contextual information to help identify and learn more about the birds they were listening to. These responses point towards an app design where more of the learning experience is situated at Urban Echoes. This could eliminate the use of an external app like MerlinID, as the user would be able to learn and identify the birds through the images in combination

with the name and call of the bird. In older versions of the prototype, the name of the bird was displayed on screen while the call was played, but I chose to remove this feature for later versions to make users pay more attention to their environment instead of looking at their phones. However, after the evaluations, I believe future development would benefit from including more educational aspects. A user wishing for an experience with less information will, after all, be able to simply put the phone in their pocket and immerse themselves within the soundscape.

6.3.4 Evaluating the Aesthetics in Sonic interaction

Use the previously discussed framework seen in figure 3.2 The current approach of picking sound files with high-quality ratings from Xeno-Carto gives me very little control over *Intensity, Pitch, Timbre, Fidelity* [21]. That being said, only two responses were coded for *intensity*—one commented on the voice and playback audio being low compared to the sounds, while another felt they were too loud when used at nighttime. To ensure higher aesthetics on these parameters, sound files could be hand-picked; however, this would be a rather time-intensive task.

More relevant for the application, both in terms of what is more controllable and what responses were coded for, are *Context, Spatial, Originality,* and *Expectation*.

Context: Generally, the context was positive, but as previously discussed, when the context did not match the sound, the experience suffered. Nighttime use, in particular, is an area that needs more work to create better contextual alignment.

Spatial: This was split among users and responses—some found it confusing and disorienting, while others had an easier time.

Originality and Expectation: This was fine.

Many reposes were coded for the sound being pleasant and proving a calmness to a higher degree than for example music. I think this highlights that there were an overall aestheticist sonic experience It was also mentioned as a more pleasant alternative to urban noise of traffic and people. The dichotomy between urban noise, such as traffic, typically perceived as undesirable, and natural sounds like birdsong or running water, commonly associated with positive experiences, also appears in soundscape research as a key variable influencing well-being and environmental perception[2].

6.3.5 Audio interface

In addition to the previous discussion points, this study also highlighted specific challenges associated with using an auditory interface. Some participants found the interface slow or cumbersome, particularly because they had to listen to full sentences before being able to respond or take action. However, this perceived slowness may be more a result of the particular design choices in this implementation rather than a fundamental limitation of audio interfaces in general. For instance, shorter audio cues or non-verbal sounds could potentially replace longer spoken instructions to improve responsiveness. A more inherent difficulty with auditory interfaces, however, appears to be related to speech recognition. Many participants reported feeling uncomfortable using voice commands in public settings, indicating a social barrier to adopting speech-based interaction for use in public settings. (perhaps see if this is in line with previous research)

7 CONCLUSION

In this thesis, I investigated *Urban Echoes*, an aesthetic auditory map experience designed to engage people with their local avian wildlife. The application was tested for a week by 11 participants. *Urban Echoes* succeeded in engaging users with their local wildlife, as the prototype consistently increased users' awareness and perception of local birds. Participants also expanded their knowledge of birds' calls, names, and habitats. The aesthetic experience was, for most participants, perceived as pleasant. However, technical issues diminished the overall experience, at times reducing engagement and making interaction more cumbersome. Broader implications regarding the public acceptability of speech interfaces were also uncovered.

Both application activities *Listener, observer* contributed to the goal of engagement with birds, but the observer mode was consistently seen as a greater source of frustration and fatigue. Additionally, repeated use of the application in the same geographic areas led to reduced novelty and decreased engagement with the application, as users would already be familiar with the birds in the area.

7.1 DID URBAN ECHOES SUCCEED AS AN ONTOLOGICAL DESIGN

While few responses were explicitly coded for *noticing*, I argue that *Urban Echoes* succeeds when viewed through the lens of ontological design. A consistent finding was that *Urban Echoes* heightened users' awareness of birds beyond their prior baseline. This constitutes a subtle but meaningful shift in one's way of being. Although a more definitive assessment of deeper epistemic or ontological change would require a longer evaluation period and more in-depth follow-up interviews, the findings suggest that the application initiated ontological transformation for several participants.

On a more personal level, designing and creating *Urban Echoes* has greatly expanded my knowledge of and interest in birds. The work has changed my onto-epistemic perspective on how we coexist with avian life, especially with pigeons, who were the original focus of the project.

7.2 DESIGN IMPLICATIONS FOR SIMILAR PROJECTS

Findings related to *Urban Echoes* can provide design implications for similar systems.

7.2.1 Location-based sound and the aesthetic quality of natural sounds compared to urban soundscapes

The playback of bird sounds was perceived as restorative by some, despite being digitised. Generally speaking, it was pleasantly perceived and contrasted with the sounds common in urban soundscapes, such as traffic and mechanical noise (find some literature)
In general, this project points towards the potential for systems that utilise user-created location-based audio content. (Find some literature)

7.2.2 The individual's perception using Speech interface in a public setting

The findings of this project found limitations in the practical deployment of speech interfaces in public, non-controlled settings. Some issues related to the specific implementation in *Urban Echoes*, such as the slowness of the interface, but larger technological and social implications remain. The speech interface, at least in a public setting in Denmark, was perceived as unacceptable to use, drawing unwanted attention. Different public settings might provide different results, but this would need to be further investigated. In Denmark, however, the speech interface provides a significant barrier to entry and hinders usability.

7.2.3 Knowledge

More information and knowledge are expected by users.

7.3 USING AESTHETIC AUDITORY EXPERIENCES FOR ENGAGING PEOPLE IN LOCAL BIRDLIFE RESPONSE (NEED ANOTHER TITLE

7.4 THE ROLE OF TECHNOLOGY IN THE PRESERVATION OF LOCAL ENVIRONMENTS(NEED ANOTHER TITLE)

7.5 FUTURE WORK

Another interesting avenue of work would be integrating the features of Urban Echoes into large birding applications like MerlinID or GoBirds. Integrating UrbanEchoes into MerlinID, for example, would allow observations to be created when the user records a bird for identification.

The design could be changed to a critical design that challenges anthropocentric assumptions about urban space, such as encouraging users to think about co-living instead of coexisting with wildlife in cities. Deigning spaces for meetings,
Unsure if it could be used as citizen science, with many more observations than eBirds, as people observe the regular birds. Looking at DOFbasen[23], there are more observations in the Danish area than eBirds.

To use the sightings as a reliable database, it's necessary to have verification of the sightings. A few approaches to this could be the use of cross-referencing the sightings with eBird and other users. A user with a history of making high-credibility observations could have a higher certainty measure when uploading an observation. Another approach for verification could use AI for sound identification or image recognition, but this would also force users to either take a picture or a recording.

Using AI to isolate birds in the recordings from Xeno-carto, maybe find some references or describe how a model could look/function. The model could be trained on the recordings from Xeno-Carto. Furthermore, the sound files could be checked for recording level and normalised so all sounds are in the same loudness range. The downside of this approach would be reducing the sustainability in design, as Generative AI models generally have a high training cost in terms of energy. This could be mitigated by only training the model exclusively on days with excessive amounts of green energy produced.

7.6 FINITO

Part I

APPENDIX

A PROJECT WORK ON MORE THAN HUMAN-CENTRED DESIGN

A.1 THE REPORT FROM THE PROJECT WORK

. **Link to a GitLab project containing the report Link:** https://gitlab.au.dk/pigeon-project/exploring-multi-species-perspectives-in-hci-through-th

A.2 THE EARLY PROTOTYPE FOR URBAN ECHOES

Link to GitLab containing the source code for the project prototype Link: https://gitlab.au.dk/pigeon-project/audioapp

B EVALUATIONS

B.1 DIARY STUDY RESPONSES

Link to Google Docs folder containing the evaluation diary responses Link: https://drive.google.com/drive/folders/1lUAUgP384W6d9hCbFUsGoeR75pICr5usp=sharing

B.2 INTERVIEWS

Link to Google Docs folder containing the interview notes Link: https://drive.google.com/drive/folders/18Wezf2twcPnk5ZnoG_evCXTw7fCqPF4z?usp=sharing

B.3 THEMATIC ANALYSE

Link to Miro board containing the evaluation diary thematic analysis https://miro.com/app/board/uXjVIxEIwWs=/?share_link_id=365318141653

C GITHUB

C.1 PROJECT GITHUB

Link the project GitHub containing the project code https://github.com/Jakob-worm/UrbanEchoes

D CODE SNIPPETS

D.1 MULTI PROVIDER SETUP

```dart
Widget build(BuildContext context) {
  return MultiProvider(
    providers: [
      // State managers
      ChangeNotifierProvider<PageStateManager>(
        create: (context) => PageStateManager(),
      ),
      ChangeNotifierProvider<MapStateManager>(
        create: (context) => MapStateManager(),
      ),
      ChangeNotifierProvider<NavigationProvider>(
        create: (context) => NavigationProvider(),
      ),
      ChangeNotifierProvider<UploadNotificationService>(
        create: (context) => UploadNotificationService(),
      ),
      Provider<DatabaseService>(
        create: (context) => DatabaseService(),
        lazy: false,
      ),
      Provider<ObservationService>(
        create: (context) => ObservationService(
          apiUrl: dotenv.env['API_URL'] ?? 'https://api.
              urbanechoes.org',
        ),
      ),
      ListenableProvider<ObservationUploader>(
        create: (context) => ObservationUploader(
          databaseService: Provider.of<DatabaseService>(context,
              listen: false),
          observationService: Provider.of<ObservationService>(
              context, listen: false),
          notificationService: Provider.of<
              UploadNotificationService>(context, listen: false),
        ),
        dispose: (context, uploader) {
          debugPrint('ObservationUploader provider dispose called
               - keeping uploader active');
        },
      ),
      ChangeNotifierProvider<RecordingPlayerService>(
```

```
37          create: (_) => RecordingPlayerService(debugMode:
                debugMode),
38          lazy: true,
39        ),
40        ChangeNotifierProvider<SpeechRecognitionService>(
41          create: (_) => SpeechRecognitionService(debugMode:
                debugMode),
42          lazy: true,
43        ),
44        ChangeNotifierProvider<BirdRecognitionService>(
45          create: (_) => BirdRecognitionService(debugMode:
                debugMode),
46          lazy: true,
47        ),
48        ChangeNotifierProvider<WordRecognitionService>(
49          create: (_) => WordRecognitionService(debugMode:
                debugMode),
50          lazy: true,
51        ),
52        ChangeNotifierProxyProvider4<
53          SpeechRecognitionService,
54          BirdRecognitionService,
55          WordRecognitionService,
56          RecordingPlayerService,
57          SpeechCoordinator>(
58          create: (context) => SpeechCoordinator(
59            speechService: Provider.of<SpeechRecognitionService>(
                  context, listen: false),
60            birdService: Provider.of<BirdRecognitionService>(
                  context, listen: false),
61            wordService: Provider.of<WordRecognitionService>(
                  context, listen: false),
62            audioService: Provider.of<RecordingPlayerService>(
                  context, listen: false),
63            observationUploader: Provider.of<ObservationUploader>(
                  context, listen: false),
64            debugMode: debugMode,
65          ),
66          update: (context, speechService, birdService, wordService
                , audioService, previous) {
67            if (previous == null) {
68              return SpeechCoordinator(
69                speechService: speechService,
70                birdService: birdService,
71                wordService: wordService,
72                audioService: audioService,
73                observationUploader: Provider.of<
                      ObservationUploader>(context, listen: false),
74                debugMode: debugMode,
75              );
76            }
77            previous.updateServices(
```

```
            speechService: speechService,
            birdService: birdService,
            wordService: wordService,
            audioService: audioService
          );
          return previous;
        },
      ),
      ChangeNotifierProvider<SeasonService>(
        create: (_) => SeasonService(),
      ),
      Provider<AppStartupService>(
        create: (_) => AppStartupService(),
      ),
      Provider<bool>.value(value: debugMode),
      ChangeNotifierProvider<LocationService>.value(value:
          locationService),
    ],
    child: MaterialApp(
      title: 'Urban Echoes',
      theme: ThemeData(
        primarySwatch: Colors.blue,
        bottomNavigationBarTheme: const
            BottomNavigationBarThemeData(
          backgroundColor: Colors.black,
          selectedItemColor: Colors.white,
          unselectedItemColor: Colors.grey,
        ),
      ),
      home: const InitialScreen(),
    ),
  );
}
```

Listing D.1: MultiProvider setup in Flutter

D.2 FASTAPI BACKEND CODE

```
from fastapi import FastAPI, HTTPException, Query, Depends
import requests
import psycopg2
import random
import os
import logging

from fastapi.middleware.cors import CORSMiddleware
from dotenv import load_dotenv
from psycopg2.extras import RealDictCursor

load_dotenv()
```

```
13
14 app = FastAPI()
15
16 app.add_middleware(
17     CORSMiddleware,
18     allow_origins=["*"],  # Change to specific domains for
       security
19     allow_credentials=True,
20     allow_methods=["*"],
21     allow_headers=["*"],
22 )
23
24 # Configure logging
25 logging.basicConfig(level=logging.INFO)
26 logger = logging.getLogger(__name__)
27
28 # Database connection function
29 def get_db_connection():
30     return psycopg2.connect(
31         user=os.getenv("DB_USER"),
32         password=os.getenv("DB_PASSWORD"),
33         host=os.getenv("DB_HOST"),
34         port=os.getenv("DB_PORT", 5432),
35         database=os.getenv("DB_NAME ", "urban_echoes_db "),
36         sslmode="require"
37     )
38
39 EBIRD_API_URL = "https://api.ebird.org/v2/data/obs/geo/recent"
40 EBIRD_TAXONOMY_URL = "https://api.ebird.org/v2/ref/taxonomy/ebird
       "
41 XENO_CANTO_API = "https://www.xeno-canto.org/api/2/recordings"
42 EBIRD_API_KEY = os.getenv("EBIRD_API_KEY")
43 DATABASE_URL = os.getenv("DATABASE_URL")
44
45 if not EBIRD_API_KEY:
46     raise ValueError("EBIRD_API_KEY is missing! Set it in Azure."
         )
47
48 if not DATABASE_URL:
49     raise ValueError("DATABASE_URL is missing! Set it in Azure.")
50
51 LAT = 56.2639 # Copenhagen coordinates TODO change to your
       location
52 LON = 9.5018  # Copenhagen coordinates TODO change to your
       location
53
54 async def get_danish_taxonomy():
55     """Fetch the eBird taxonomy with Danish names."""
56     headers = {"X-eBirdApiToken": EBIRD_API_KEY}
57     params = {"fmt": "json", "locale": "da"}
58
59     try:
```

```
60          response = requests.get(EBIRD_TAXONOMY_URL, headers=
                headers, params=params)
61          response.raise_for_status()
62          taxonomy_data = response.json()
63          return {species["speciesCode"]: species["comName"] for
                species in taxonomy_data}
64      except requests.exceptions.RequestException as e:
65          raise HTTPException(status_code=500, detail=f"Error
                fetching taxonomy: {str(e)}")
66
67  @app.get("/observations")
68  def get_observations(after_timestamp: str = Query(None,
        description="Fetch only observations created after this
        timestamp")):
69      """Fetch bird observations from the database, with optional
            filtering by timestamp."""
70      try:
71          conn = get_db_connection()
72          cursor = conn.cursor(cursor_factory=RealDictCursor)
73
74          if after_timestamp:
75              cursor.execute("""
76                  SELECT id, bird_name, scientific_name,
                        sound_directory, latitude, longitude,
77                          observation_date, observation_time,
                                observer_id, created_at,
78                          quantity, is_test_data, test_batch_id
79                  FROM bird_observations
80                  WHERE created_at > %s
81                  ORDER BY created_at ASC
82              """, (after_timestamp,))
83              logger.info(f"Fetching observations created after {
                    after_timestamp}")
84          else:
85              cursor.execute("""
86                  SELECT id, bird_name, scientific_name,
                        sound_directory, latitude, longitude,
87                          observation_date, observation_time,
                                observer_id, created_at,
88                          quantity, is_test_data, test_batch_id
89                  FROM bird_observations
90                  ORDER BY created_at ASC
91              """)
92              logger.info("Fetching all observations")
93
94          observations = cursor.fetchall()
95          logger.info(f"Returning {len(observations)} observations"
                )
96
97          cursor.close()
98          conn.close()
99
```

```
        return {"observations": observations}
    except Exception as e:
        logger.error(f"Error fetching observations: {str(e)}")
        raise HTTPException(status_code=500, detail=f"Internal
            Server Error: {str(e)}")

@app.get("/birds")
def get_birds():
    try:
        conn = get_db_connection()
        cursor = conn.cursor(cursor_factory=RealDictCursor)
        cursor.execute("SELECT common_name, scientific_name,
            danish_name FROM birds")
        birds = cursor.fetchall()
        cursor.close()
        conn.close()
        return {"birds": birds}
    except Exception as e:
        logger.error(f"Error fetching birds: {str(e)}")
        raise HTTPException(status_code=500, detail="Internal
            Server Error")

@app.get("/birdsound")
def get_bird_sound(scientific_name: str):
    params = {"query": scientific_name}
    response = requests.get(XENO_CANTO_API, params=params)

    if response.status_code != 200:
        return {"error": "Failed to fetch recordings"}

    data = response.json()
    recordings = data.get("recordings", [])

    if not recordings:
        return {"error": "No recordings found"}

    high_quality = [rec for rec in recordings if rec.get("q") in
        ["A", "B"]]

    if not high_quality:
        return {"error": "No high-quality recordings available"}

    selected = random.choice(high_quality)
    sound_url = f"https://www.xeno-canto.org/{selected['id']}/
        download"

    return sound_url

@app.get("/search_birds")
def search_birds(query: str = Query(..., min_length=1,
    description="Bird search query")):
    """Search birds by Danish name dynamically"""
```

```
    try:
        conn = get_db_connection()
        cursor = conn.cursor()
        cursor.execute("""
            SELECT common_name, scientific_name
            FROM birds
            WHERE common_name ILIKE %s
            LIMIT 10
        """, (f"%{query}%",))
        birds = [{"common_name": row[0], "scientificName": row
            [1]} for row in cursor.fetchall()]
        cursor.close()
        conn.close()
        return {"birds": birds}
    except Exception as e:
        logger.error(f"Error searching birds: {str(e)}")
        raise HTTPException(status_code=500, detail="Internal
            Server Error")

@app.get("/birdsOLD")
async def get_bird_list():
    """Fetch recent bird observations with Danish names and
        corresponding sounds."""
    headers = {"X-eBirdApiToken": EBIRD_API_KEY}
    params = {
        "lat": LAT,
        "lng": LON,
        "fmt": "json",
        "maxResults": 100,
        "includeProvisional": True
    }

    try:
        danish_names = await get_danish_taxonomy()
        response = requests.get(EBIRD_API_URL, headers=headers,
            params=params)
        response.raise_for_status()
        bird_data = response.json()

        birds = []
        for bird in bird_data:
            species_code = bird.get("speciesCode")
            scientific_name = bird.get("sciName")

            bird_info = {
                "danishName": danish_names.get(species_code, bird
                    .get("comName")),
                "scientificName": scientific_name,
                "observationDate": bird.get("obsDt"),
                "location": bird.get("locName"),
                "speciesCode": species_code
            }
```

```
193             birds.append(bird_info)
194
195         return {
196             "birds": birds,
197             "count": len(birds),
198             "location": f"Coordinates: {LAT}, {LON}"
199         }
200     except requests.exceptions.RequestException as e:
201         raise HTTPException(status_code=500, detail=f"Error
                fetching bird data: {str(e)}")
202
203 @app.get("/health")
204 async def health_check():
205     """Health check endpoint to verify that the API is running.
            """
206     return {"status": "ok"}
```

Listing D.2: Full FastAPI Backend Code

D.3 PLAYBIRDQUESTION

```
1     \begin{lstlisting}
2     Future<void> playBirdQuestion(String birdName) async {
3     if (_isMuted) return;
4
5     _logDebug('Playing bird question for: $birdName with
          callbacks');
6
7     // Stop any current playback
8     await stopAudio();
9
10    try {
11      // Reset sequence counter and set type
12      _sequenceCompletedCount = 0;
13      _expectedCompletions = 2; // Intro + Bird Name
14      _lastPlaybackType = 'bird_question';
15
16      // Cancel any existing subscriptions first
17      _introCompleteSubscription?.cancel();
18
19      // Prepare the bird name path
20      String simplifiedName = _simplifyName(birdName);
21      String birdPath = 'audio/recorded/birds/$simplifiedName.mp3
            ';
22      String silentPath = 'audio/seilent.mp3'; // Path to silent
            audio file
23
24      // 1. Set up the completion handler for the intro (one-time
             listener)
25      _introCompleteSubscription =
```

```
26            _introPlayer.onPlayerComplete.listen((event) {
27          _logDebug('Intro completed, playing bird name immediately
                ');
28          if (!_isMuted) {
29            // Try to play bird name, catch any errors
30            _birdPlayer.play(AssetSource(birdPath)).catchError((
                  error) {
31              _logDebug(
32                  'Error playing bird file: $error, using silent
                      file instead');
33              _birdPlayer.play(AssetSource(silentPath));
34            });
35          }
36
37          // Cancel this subscription after it's used
38          _introCompleteSubscription?.cancel();
39          _introCompleteSubscription = null;
40        }, cancelOnError: true);
41
42        // 2. Start playing intro
43        await _introPlayer
44            .play(AssetSource('audio/recorded/har_du_observeret_en.
                  mp3'));
45        _isPlaying = true;
46        notifyListeners();
47      } catch (e) {
48        _logDebug('Error in playBirdQuestion: $e');
49        _isPlaying = false;
50        _lastPlaybackType = '';
51        notifyListeners();
52      }
53    }
```

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