Interactive Visualization

Sweden’s vast Bird Fauna

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Chapter 1
Introduction

As a final-year undergraduate student in Data Science, I've spent the past few years honing my skills in understanding and interpreting data, with a passion for transforming insights into meaningful narratives. Last summer, I had the opportunity to visit Sweden, where I was enchanted by the sounds of birds waking me up each morning. The experience left a lasting impression on me and left me curious about the vibrant birdlife of Sweden.

Now, as I prepare to take the next step in my academic journey by applying to master's programs in Sweden, I've decided to combine my passion for data and this personal connection to Sweden's natural beauty. Through this project, I aim to explore and learn about the country I will soon call home for the next two years, as well as the diverse bird species that inhabit it.

The *Birds of Sweden Dashboard* is my attempt to bridge these interests. It serves as an interactive tool to visualize and learn about bird species commonly found in Sweden, their habitats, and their distribution. Beyond fulfilling academic objectives, this project has been a deeply personal journey of discovery.

The data displayed in the dashboard is available at `https://ebird.org/`. Bird data was requested from January 2014 to October 2024, from Sweden only.

The project repository of this report can be found at `https://github.com/okaynils/fhnw-ds-ivi`.

Chapter 2

Performance

When working with interactive visualizations, performance plays an important role in bringing a smooth user experience to the table, especially as datasets grow larger and more complex. With increasing data points and variables, the demand for both computational power and efficient rendering becomes essential. Interactive visualizations can encounter performance bottlenecks due to factors such as data size, rendering techniques, bandwidth, and hardware limitations. For instance, large datasets can overwhelm system memory and I/O bandwidth, leading to suboptimal rendering performance [1]. As data size increases, performance issues can manifest in the form of delayed rendering, increased memory usage, and ultimately, a sluggish or unresponsive interface. These challenges require us as Data Scientists to understand and implement performance-enhancing solutions such as tiling, level of detail (LOD) management, GPU acceleration, and hierarchical data organization. Instruments like LOD management can optimize rendering by adjusting the complexity of the visualization based on the viewer's perspective, and thereby improving performance [2]

In this context, two experiments were conducted to benchmark and understand the performance implications of interactive visualizations, both in terms of data size and choice of visualization libraries. The following sections analyze these experiments, where Figure 2.1 and Figure 2.2 showcase the performance metrics obtained.

2.1 Experiment 1: Impact of Data Size

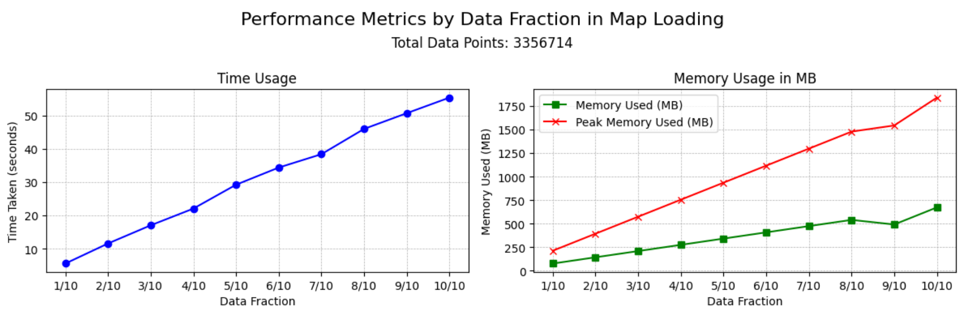

Figure 2.1: Performance metrics for incremental data loading in a map visualization.

Figure 2.1 illustrates the performance metrics captured when incrementally loading fractions of a dataset into a map visualization. In this experiment, each data point represented a bird observation in Sweden, and fractions of the dataset were loaded from 1/10th up to the entire dataset (10/10ths, or 3'356'714 observations). Two metrics were recorded: Time Usage (in seconds) and Memory Usage (in MB).

2.1.1 Time Usage Analysis

The left subplot of 2.1 shows a linear trend in time consumption as the data fraction increases. The time taken rises from approximately 10 seconds for 1/10th of the data to over 50 seconds for the entire dataset. This trend reflects the computational load associated with managing and rendering larger datasets in real-time.

This increase in time usage can be attributed to the overhead of both loading data into memory and the rendering process itself. With each increment, the visualization needs to plot more points on the map, which places a growing strain on both the CPU and GPU, depending on the level of interactivity and graphical requirements.

2.1.2 Memory Usage Analysis

The right panel of Figure 2.1 captures memory usage with two lines: one for Memory Used and another for Peak Memory Used. Memory Used remains relatively lower, while Peak Memory steadily climbs with each data increment.

The growing gap between regular and peak memory usage can be attributed to the temporary memory required to process the data before rendering. As the data size increases, the visualization needs to allocate more temporary memory for computation, even if the plotted memory stabilizes.

This memory trend suggests that managing data efficiently, such as by tiling or downsampling, could reduce the memory load and make the visualization more responsive without compromising on detail.

2.2 Experiment 2: Impact of Plotting Library on Performance

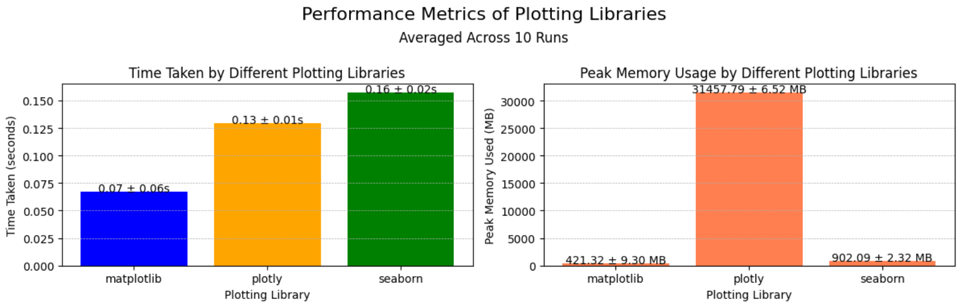

Figure 2.2: Performance metrics for different plotting libraries.

In Figure 2.2, the performance of three plotting libraries — `Matplotlib`, `Plotly`, and `Seaborn` — was measured by plotting the frequency of the 10 most common bird species in Sweden. To ensure accuracy and confidence in the results, each test was run 10 times, and the Time Taken and Peak Memory Usage metrics were averaged across these runs, with standard deviations included to quantify variability.

2.2.1 Time Taken Analysis

The left panel of Figure 2.2 shows that `Matplotlib` remains the fastest library, with an average time of 0.07 seconds $\pm$ 0.06 seconds. `Plotly` and `Seaborn`, however, took considerably longer, with average times of 0.14 seconds $\pm$ 0.02 seconds for `Plotly` and 0.15 seconds $\pm$ 0.01 seconds for `Seaborn`.

The high standard deviation for `Matplotlib` indicates some variability in its runtime, possibly due to fluctuations in processing lower-level operations. In contrast, `Plotly` and `Seaborn` show relatively stable performance with smaller standard deviations, reflecting their structured approach to rendering but at the cost of increased processing time.

`Matplotlib`'s efficiency is likely due to its streamlined focus on static plotting, while `Plotly`'s interactivity and `Seaborn`'s additional styling complexity add to their time overhead. These findings emphasize that while `Matplotlib` is optimal for static visualizations, `Plotly` and `Seaborn` introduce extra time due to their functionality and aesthetic layers, respectively.

2.2.2 Memory Usage Analysis

The right panel of Figure 2.2 reveals a stark contrast in peak memory usage among the libraries. `Plotly` uses significantly more memory, averaging 31,471.73 MB $\pm$ 40.09 MB, highlighting the high cost of interactivity. `Seaborn` requires considerably less memory, averaging 903.09 MB $\pm$ 2.13 MB, and `Matplotlib` remains the most memory-efficient, with an average of 422.25 MB $\pm$ 9.62 MB.

The consistent but high memory usage for `Plotly` suggests that its interactive features, such as hover and zoom functionality, impose a substantial memory footprint. These features, while enhancing user engagement, demand extensive resources for rendering and data management, particularly when handling large datasets or complex visualizations.

Seaborn, despite being built on top of Matplotlib, requires additional memory to manage stylistic elements. Matplotlib's low memory usage reaffirms its suitability for static visualizations where memory constraints are critical. This suggests that when designing interactive visualizations with large datasets, it is essential to account for Plotly's memory requirements, while Matplotlib and Seaborn serve as better choices for simpler plots.

Chapter 3
Design Principles

3.1 Introduction to Shneiderman's Mantra

In the realm of information visualization, effective data exploration is really important. Ben Shneiderman, a prominent figure in human-computer interaction, proposed a foundational guideline known as Shneiderman's Mantra to improve user interaction with complex datasets. The mantra states: *"Overview first, zoom and filter, then details-on-demand"* [3]. This principle stands as a blueprint for designing intuitive interfaces that hold efficient data analysis.

Shneiderman's Mantra emphasizes a hierarchical approach to data exploration:

1. **Overview First**: Present the entire dataset in a high-level view to provide context and scope.
2. **Zoom and Filter**: Allow users to focus on subsets of the data that interest them.
3. **Details on Demand**: Enable access to detailed information about specific data points when required.

This sequence allows interfaces to cater to both regular users and experts and provide scalable means to interact with data of varying complexity.

3.2 Implementation in the Birds of Sweden Dashboard

I developed the Birds of Sweden Dashboard in this course to enable users to navigate and explore Sweden's bird fauna interactively. Implementing Shneiderman's Mantra within this dashboard makes sure that users can effectively analyze bird observation data across the country.

3.2.1 Overview First

Upon launching the dashboard, users are presented with a comprehensive map displaying all bird observations across Sweden (Figure 3.1). This initial view provides an immediate sense of the spatial distribution and density of bird sightings which fulfills the "Overview First" principle.

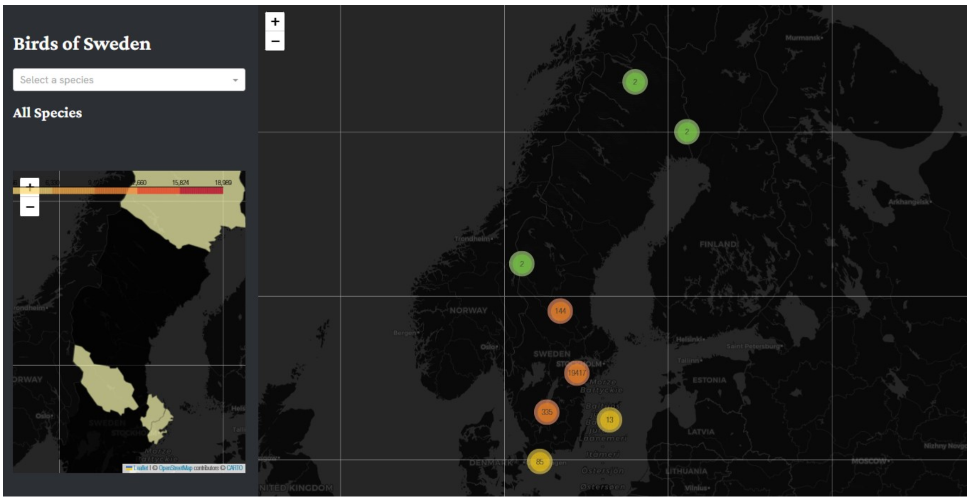

Figure 3.1: Initial overview of all bird observations in Sweden.

The map utilizes a scatter plot where each point represents an observation, allowing users to perceive patterns such as hotspots of biodiversity or migratory pathways. Additionally, the sidebar includes a state observations map that consistently displays the entire country's outline which highlights the number of observations per state. This gives the users a rough overview of the frequency of a selected bird in different regions.

3.2.2 Zoom and Filter

To facilitate more focused exploration, the dashboard incorporates interactive filtering mechanisms. The dropdown menu enables users to search and select a specific bird species from an extensive list derived from the dataset (Figure 3.2). Upon selection, the main map updates to display only the observations pertaining to the chosen species.

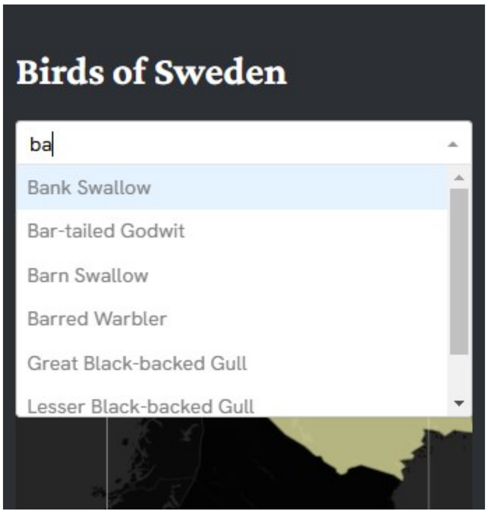

Figure 3.2: Species selection dropdown for filtering observations.

This filtering capability shows the "Zoom and Filter" principle which should allow users to narrow down the dataset to areas or species of interest. The state observations map in the sidebar also updates accordingly, highlighting only the states where the selected species has been observed, thus providing a filtered geographical context (Figure 3.3).

Figure 3.3: Map displaying observations of a selected species after filtering.

Another filtering dimension was added to first and foremost lower computational requirements by bundling together observations that are close to each other into clusters which get labeled with the number of observations they represent. When zooming further into such a cluster, we can see that the cluster starts to expaned into smaller clusters or individual bird observations (depending on neighbors):

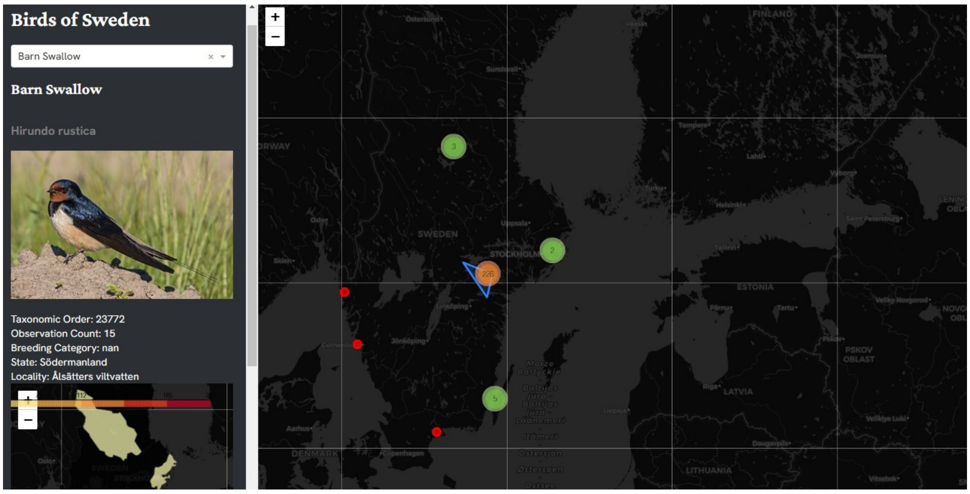

Figure 3.4: Zoomed in map displaying smaller clusters and region.

The Figure 3.4 above now also shows some individual bird observations coming up as red dots we could now hover over these to get more information on the observation (see Figure 4.1). When hovering over a remaining cluster however, a blue region appears which indicates the area further points may lie in. If we click on that cluster we automatically zoom in even further:

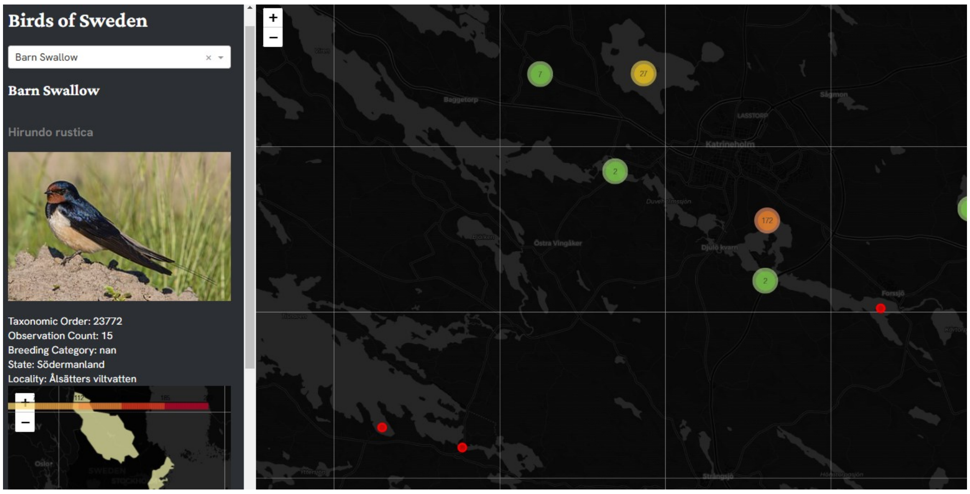

Figure 3.5: Zoomed in map at Katrineholm.

If we now decide to even dig deeper into such a cluster, we can find locations of bird observations that were recorded at the same location. These then get nicely spiraled up, allowing to look at each individual observation in detail:

Figure 3.6: Observation Spiral at Katrineholm.

3.2.3 Details on Demand

To offer in-depth information, the dashboard provides detailed data about specific observations and species. When a species is selected, the sidebar displays:

- **Species Name and Scientific Name**: Clarifies the common and scientific nomenclature.
- **Species Image**: Retrieves an image from Wikipedia for visual identification.
- **Additional Information**: Presents taxonomic order, observation count, breeding category, state, and locality.

This implementation of "Details on Demand" ensures that users can access specific information without overwhelming the initial view. Moreover, clicking on an observation point on the map sets the species in the dropdown, updating the sidebar with relevant details (Figure 3.3).

3.2.4 Technical Implementation

The dashboard leverages the Dash framework for Python [4] that enables the creation of interactive web applications. Key implementation aspects include:

- **Data Loading**: The full dataset is loaded to ensure all observations and species are available. A clustering mechanism is applied by Leaflet to manage the rendering of large datasets in a more performant way.
- **Data Cleaning**: Missing values in critical columns such as `LATITUDE`, `LONGITUDE`, and `COMMON NAME` are handled to prevent empty maps or dropdowns.
- **Callbacks**: Dash callbacks are used to update the map and sidebar components dynamically based on user interactions.
- **Geographical Consistency**: The state observations map uses the `fitbounds="geojson"` parameter to always display the entire country's outline, regardless of the data filtered.

3.3 Goals and Hopes for the Dashboard

The primary objective of implementing Shneiderman's Mantra in the Birds of Sweden Dashboard is to enhance user interaction and facilitate the exploration of bird fauna data. The specific goals include:

3.3.1 Improving User Interaction and Experience

By providing an intuitive interface that adheres to established principles of information visualization, users can navigate the dataset effectively, regardless of their familiarity with the data. The hierarchical approach reduces cognitive load and allows for a more engaging experience.

3.3.2 Facilitating Exploration of Sweden's Bird Fauna

The dashboard serves as an educational tool, enabling users to discover patterns and insights within the bird observation data. For instance, users can identify regions with high biodiversity, track migration patterns, or explore species distribution.

3.3.3 Enabling Users to Gain Insights

Through interactive filtering and detailed information access, users can perform analyses that may lead to new findings or support research efforts. Conservationists, ornithologists, and bird enthusiasts alike can leverage the dashboard to inform their work or interests.

3.4 Summarizing the Implemented Design Principles

Implementing Schneiderman's Mantra [3] in the Birds of Sweden Dashboard has resulted in making the dashboard a more streamlined experience. By providing an initial overview that enables focused filtering and that offers detailed information on demand, the dashboard should align with best practices in information visualization. The hope is that this approach improves user engagement and also contributes to a deeper understanding of Sweden's rich bird fauna. Without the implementation or thought of these design principles, users are left with a very complex dataset that is difficult to explore. The lack of structure could actively discourage users from engaging with the data [5].

Chapter 4
HCI Basics

4.1 Introduction

Human-Computer Interaction focuses on creating interfaces that are not only functional but also intuitive and accessible to users. In the context of the *Birds of Sweden Dashboard*, HCI principles guide the design decisions to ensure users can effectively explore and analyze bird observation data across Sweden.

This chapter goes through how Interaction Design principles are applied.

4.2 Interaction Design and the Five Dimensions

4.2.1 What is Interaction Design?

Interaction Design (IxD) is the discipline of designing interactive products and services with a focus on how users will interact with them. It goes beyond the mere functionality of an item, considering users' needs, limitations, and contexts to tailor the experience accordingly [6]. This user-centered approach ensures that the design meets precise demands, facilitating seamless interaction between the user and the product.

4.2.2 Application of Weber's Law and Fitts's Law

Perceptual laws like Weber's Law and Fitts's Law play a significant role in interface design and influence how users perceive and interact with elements. Here, I outline both these principles and then explain what I did to improve the dashboard based on these principles.

Weber's Law Weber's Law states that the just-noticeable difference between two stimuli is proportional to the magnitude of the stimuli [7]. In interface design, this means that subtle differences in element sizes or colors may go unnoticed; If something is too small or too similar to other elements, users may not perceive it.

Fitts's Law Fitts's Law predicts that the time required to move to a target area is a function of the distance to the target and the size of the target [7]. Smaller targets that are farther away are harder and slower to click.

Application to the Dashboard I addressed the issue of small scatter points on the map that made hovering and clicking difficult, **violating Fitts's Law**. By implementing the `hovermode='closest'` setting in the scatter mapbox, the interactive area around each data point was expanded, creating larger cursor bubbles. This adjustment made interactions easier and reduce the effort required to precisely target small points. Additionally, it enhanced accessibility by accommodating users with motor impairments or those using touch devices, ensuring a smoother and more inclusive experience.

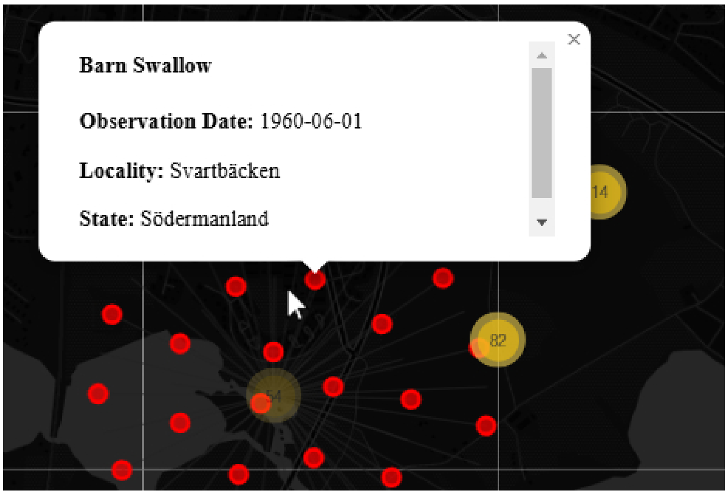

Figure 4.1: Tooltip displayed if cursor is near a data point.

4.2.3 The Five Dimensions of Interaction Design

Gillian Crampton Smith and Kevin Silver defined five dimensions that interaction designers consider when designing interactions [6]:

1. **Words (1D)**: Text elements like button labels that provide necessary information to users.
2. **Visual Representations (2D)**: Graphical elements such as images, typography, and icons that aid user interaction.
3. **Physical Objects/Space (3D)**: The medium through which users interact with the product, like a mouse, keyboard, or touch screen.
4. **Time (4D)**: Media that change over time, including animations, videos, and sounds.
5. **Behavior (5D)**: How the previous dimensions define the interactions a product affords, including user actions and system reactions.

Interaction designers utilize these dimensions to consider interactions holistically, envisioning real-world user demands for designs not yet introduced.

4.2.4 Application to the Birds of Sweden Dashboard

The *Birds of Sweden Dashboard* incorporates the five dimensions of interaction design to enhance user experience:

Words (1D) The dashboard uses clear and concise text to guide users:

- **Button Labels and Dropdown Options**: The species selection dropdown is labeled "Select a species," providing a straightforward instruction.
- **Informational Text**: The sidebar displays species names, scientific names, and additional details, ensuring users understand the information presented.

Visual Representations (2D) Graphical elements are employed to facilitate understanding:

- **Maps**: The main map and the state observations map visually represent bird observations geographically.
- **Images**: Species images retrieved from Wikipedia help users visually identify birds.
- **Icons and Typography**: Consistent use of fonts and styling enhances readability and aesthetic appeal.

Physical Objects/Space (3D) Users interact with the dashboard through various physical mediums:

- **Mouse**: Primary interaction for clicking, hovering, and navigating the map.
- **Keyboard**: Supports navigation through the dropdown and accessibility features.
- **Touch Devices**: Basic touch interactions are possible, though optimization is needed.

Time (4D) Temporal elements enhance the interactive experience:

- **Interactive Map Updates**: The map dynamically updates when a species is selected, providing immediate feedback.
- **Hover Effects**: Tooltips appear when hovering over data points, offering additional information.

Behavior (5D) The dashboard's behavior defines user interactions:

- **User Actions**: Selecting species, zooming the map, and clicking on data points are intuitive actions supported.
- **System Reactions**: The dashboard responds to user inputs by updating visuals and information displayed, reinforcing progress toward user goals.

4.3 Cognitive Walkthrough

A cognitive walkthrough was performed using Rick Spencer's *Streamlined Cognitive Walkthrough Method* [8] to evaluate the dashboard's usability. The walkthrough focuses on typical tasks that users might perform. It aims to assess whether the interface supports these tasks effectively.

4.3.1 Tasks

Selected Tasks Four key tasks were identified:

1. Explore the overall distribution of bird observations.
2. Find information about a specific bird species.
3. Identify regions where a selected species is commonly observed.
4. View detailed information about a specific observation.

4.3.2 Action Sequences and Walkthrough Analysis

The action sequences are presented on the left, with the corresponding walkthrough on the right.

Task 1: Explore Overall Distribution of Bird Observations

Action Sequence	Walkthrough Analysis
1. Open the dashboard. 2. Observe the initial map displaying all observations.	• **Will the user know what to do?** Yes; the map is immediately visible upon opening the dashboard. • **Will the user know they are making progress?** Yes; the dense distribution of data points indicates active observations.

Table 4.1: Cognitive Walkthrough for Task 1

Task 2: Find Information About a Specific Bird Species

Action Sequence	Walkthrough Analysis
1. Locate the species dropdown in the sidebar. 2. Click on the dropdown to view options. 3. Type or scroll to find the desired species. 4. Select the species from the list.	• **Step 1**: The dropdown is labeled and prominently placed, so users will know what to do. • **Step 2**: Clicking the dropdown is a common interaction. • **Step 3**: Users can type to search or scroll through the list. • **Step 4**: Upon selection, the map and sidebar update, so users know they are making progress.

Table 4.2: Cognitive Walkthrough for Task 2

Task 3: Identify Regions Where the Selected Species is Commonly Observed

Action Sequence	Walkthrough Analysis
1. Observe the main map after species selection. 2. Note the distribution of observation points. 3. Look at the state observations map in the sidebar.	• **Step 1**: The map is the focal point, so users know what to do. • **Step 2**: Clusters indicate regions with frequent observations, helping users track progress. • **Step 3**: The sidebar map provides a choropleth view. Color intensities reflect observation counts, so users understand their progress.

Table 4.3: Cognitive Walkthrough for Task 3

Task 4: View Detailed Information About a Specific Observation

Action Sequence	Walkthrough Analysis
1. Hover over a data point on the main map. 2. Click on the data point. 3. Observe any additional information displayed.	• **Step 1**: Users may naturally hover, but tooltips might not be expected if points are small. • **Step 2**: Clicking is not immediately obvious; a prompt could help. • **Step 3**: The sidebar updates, but additional visual feedback (e.g., animation) would improve the experience.

Table 4.4: Cognitive Walkthrough for Task 4

Chapter 5
Evaluation

Evaluating the usability and user experience of an interactive visualization is of importance to ensure it meets the needs of its intended audience. This chapter presents an evaluation of the *Birds of Sweden Dashboard* through a qualitative user study involving five participants from a range of backgrounds. The goal is to gain insights into how different users perceive and interact with the dashboard, identifying strengths and areas for improvement.

5.1 Methodology

There are multiple ways of evaluate a piece of software. For this evaluation, I have chosen a **qualitative interview** approach to gather detailed feedback (like the user's thoughts, feelings and hands-on experience) on the user experience of the dashboard. Unlike quantitative methods, qualitative interviews allow for open-ended responses that provide more detailed insights into user behavior and preferences [9], [10].

This method is appropriate in this case for measuring user experience in the context of the dashboard, as it enables the identification of usability issues and the collection of detailed feedback that can inform future design enhancements.

5.1.1 Participants

Five users with varying backgrounds, expertise, and interests related to bird observation and data visualization were involved in a qualitative interview:

1. **Participant 1** – A 31-year-old bird enthusiast and amateur photographer who enjoys birdwatching during her travels across Sweden.
2. **Participant 2** – A 50-year-old conservationist and hobby ornotihologist.
3. **Participant 3** – A 23-year-old web developer studying Data Science.
4. **Participant 4** – A 24-year-old carpenter, now studying Data Science.
5. **Participant 5** – A 65-year-old retiree who recently started birdwatching as a hobby and is not very tech-savvy.

5.2 Interview Questions

Five open-ended questions were designed to explore key aspects of the user experience. Here I present these questions and their purposes:

1. **How intuitive did you find the navigation and interaction with the dashboard?**

   Purpose: To assess the overall usability and whether users can navigate the interface without confusion.

2. **What features did you find most useful or engaging, and why?**

   Purpose: To identify which elements of the dashboard are most valued by users, informing future enhancements.

3. **Were there any difficulties or frustrations you encountered while using the dashboard?**

   Purpose: To uncover usability issues or pain points that need to be addressed.

4. **How well does the dashboard cater to your specific needs or interests related to bird observation?**

   Purpose: To evaluate the dashboard's effectiveness in meeting the diverse needs of different user groups.

5. **What improvements or additional features would you suggest for the dashboard?**

   Purpose: To gather user-driven ideas for enhancements that could improve satisfaction and usability.

5.3 Results

The interviews were conducted during a one-week period and transcribed for analysis.

The participants' responses are summarized below. Tables are used to present the key points from each interview for clarity.

Note: The participants long form answers have been summarized using GPT-4o to provide a more concise overview of the responses.

Participant	**Responses**
Question 1: Navigation and Interaction Intuitiveness	
Participant 1	Found the dashboard mostly intuitive. Initially unsure about how to interact with map points but appreciated the straightforward species selection once she became accustomed.
Participant 2	Navigated easily due to familiarity with similar tools; praised the clean, professional interface but noted the potential for advanced navigational aids for detailed searches.
Participant 3	Found the interface user-friendly and intuitive, commended the responsive design, though noted minor inconsistencies in menu transitions.
Participant 4	Experienced slight confusion with sidebar updates not being immediately noticeable; suggested clearer visual cues for when data changes.
Participant 5	Initially overwhelmed but adapted quickly after a brief exploration. Appreciated the clear dropdown menu once located but felt it could be made more visible.
Question 2: Most Useful or Engaging Features	
Participant 1	Enjoyed the species images and detailed descriptions, particularly appreciating the ability to locate her favorite birds' habitats.
Participant 2	Valued the observation distribution visualizations, which were highly useful for understanding migration patterns.
Participant 3	Was particularly impressed by the interactive maps and their hover effects, which dynamically updated related data.
Participant 4	Found the state-level observation map valuable for identifying regions that might require conservation efforts.
Participant 5	Loved the ability to explore species and their habitats through the interactive maps, finding the feature highly educational and engaging.

Table 5.1: Participant Responses to Questions 1 and 2

Participant	Responses
Question 3: Difficulties or Frustrations	
Participant 1	Struggled to hover over small map points; suggested larger clickable areas or a zoom-in feature to make interactions easier.
Participant 2	Felt the lack of advanced filtering options (e.g., by date range or observation count) limited deeper analyses.
Participant 3	Noted issues with mobile responsiveness, particularly on tablets where some menu elements were misaligned.
Participant 4	Encountered challenges when using assistive technology; highlighted the importance of improving accessibility features.
Participant 5	Was initially confused about the species selection due to the dropdown's placement and size but adapted after finding it.
Question 4: Catering to Specific Needs or Interests	
Participant 1	Found the dashboard catered well to her interest in discovering new birdwatching spots and learning about bird habitats.
Participant 2	Appreciated the geographical data but desired more detailed analytics and tools to support academic research needs.
Participant 3	Found the dashboard inspiring for his studies in design and praised its application of interaction design principles.
Participant 4	Saw potential for using the dashboard in conservation planning but wanted more data layers, such as vegetation and climate overlays.
Participant 5	Enjoyed learning about bird species and habitats, which added excitement to her beginner birdwatching efforts.
Question 5: Suggestions for Improvement	
Participant 1	Suggested adding bird call sounds for a richer experience and a tutorial to guide new users through the dashboard.
Participant 2	Recommended incorporating time-series data to observe seasonal trends and changes in bird populations over the years.
Participant 3	Proposed improving mobile responsiveness and adding gesture controls to enhance usability on touchscreens.
Participant 4	Highlighted the need for accessibility features like screen reader support, high-contrast modes, and keyboard navigation.
Participant 5	Suggested simplifying the interface with larger text and icons to make it more beginner-friendly and accessible.

Table 5.2: Participant Responses to Questions 3, 4, and 5

5.4 Analysis

The qualitative interviews revealed some common patterns across five major themes. Participants generally found the dashboard intuitive, particularly those with technical backgrounds. However, less tech-savvy users encountered initial confusion and mentioned the need for improved onboarding and more visible interactive elements, such as the species dropdown. The interactive map and species information were consistently praised for their engaging and visually appealing design.

Despite these strengths, several usability issues were identified. Challenges included difficulties with small interactive areas, and limited accessibility features as well as mobile optimization problems. Recommendations for improvement emphasized accessibility enhancements, mobile responsiveness, interactive features like bird sounds and tutorials, and advanced tools such as time-series data to better support diverse user needs.

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