**STAT679 - Group 2 Project Milestone 1   10/16/2023**

1. **Introduction**

In this project, our team aims to visualize the spatiotemporal relationship between bird migration patterns and climate by overlaying the migration paths upon a heat map of local temperatures and allowing the user to interact with the visualization over time.

**Modality Decision**

Our team has opted for the "Design Studio" modality. We aim to develop a comprehensive data visualization interface focused on bird migration patterns in relation to climate change.

**Hypothetical Client**

Our hypothetical client could be the Department of Ornithology and Climate Studies at a reputable university. The department is interested in the historical relationship between climate and bird migration in the United States. To this extent, we will know we have satisfied them if our visualization can show temporal changes in both temperature trends and migratory patterns for provided species, and additionally enable further investigation of subsets of the data via interactivity.

**Dataset and Tasks**

We obtain bird migration patterns from ScienceBase1 and temperature data from the National Centers for Environmental Information (NCEI)2. From the millions of bird records in ScienceBase, we keep records since 2000 in the continental United States for birds recorded five or more times. From NCEI, we pull monthly temperature averages for each state since 2000. For our hypothetical client, we hope to facilitate the following tasks:

- Visualize the general trend of bird migration over a user-chosen time period..

- Visualize the specific migration of a single bird.

- Study how migration patterns have changed over time.

- Study how temperature pattern have changed over time.

- Study the relationship between temperature and bird migration.

- Create an interactive interface that enables zooming into specific timeframes or species.

**II. Literature Review**

**Spatiotemporal Movement Visualizations**

Spatiotemporal movement data, such as migration patterns, population changes, and animal tracking data, is becoming increasingly available. Despite the high potential of this data, it can be challenging to visualize and analyze effectively. In this section, we review the main approaches, themes, and challenges of spatiotemporal movement data visualization seen in existing literature.

**Figure 1: Chen, Wang & Chen (2015)**

A group of maps of different colors

Description automatically generated with medium confidence

Chen, Wang, & Chen (2015)3 present the visualization seen in Figure 1 above, which captures patterns in land use over time in China’s Zhejiang Province. This is the first of a few examples we will see of authors overlaying color onto a map to encode a variable of interest, a common theme in spatial visualization. The authors face two distinct challenges - first, showing the evolution of land use over time, and how to select appropriate colors for their categorical variables. On the first count, the authors choose to present a number of static visualizations corresponding to different points in time, noting that a) represents 1995, b) represents 2000, and so on up to 2020. This approach, which does not incorporate animation or interactivity, is not as effective as it could be in facilitating the reader to compare land use over time. The reader’s eyes have to dart to six different panels and find the same point to compare each time. On the second count, the authors pick intuitive colors for each category - dark green for forest, blue for water, et cetera. This significantly helps the visualization and informs us to thoughtfully consider our temperature colors, perhaps taking inspiration from color maps in weather forecasts, to use warm/cold colors which invoke notions of higher or lower temperatures.

**Figure 2: Li, Chen & Dong (2019)**

A screenshot of a computer

Description automatically generated

Li, Chen, & Dong (2019)4 present a new flow-based approach for visualizing the spatiotemporal dynamics of human mobility, as seen in Figure 2 abovet. Rather than showing the movement of individual units as we intend to, the authors combine all movement between two nodes into one edge, with size representing volume of flow both for the edges and notes. Once again, we see color encoding a variable interest; it is isolated from the geographic map (of Guangzhou, China) itself for clarity here, but the orange zone between the nodes represents a “contact zone” of potential spread of infectious disease. This furthers the common theme of color being used to convey spatial information. The authors take a novel approach to conveying temporal information, though; using the “clock bar” emphasized in box 4 to show flow between nodes at different times within the day. While this approach does successfully encode flow over the time of a single day (and might be useful for someone hoping to avoid contamination), it does not show trends over time such as weeks, months, or years, and could quickly become visually overwhelming with many nodes.

**Interactive Geospatial Visualization**

In combination with D3 and other existing web packages, Lu, Ai, Zhang, & He (2017)5 create two novel javascript tools to aid in the visualization of air quality data across major urban centers within China. The end result can be seen in Figures 3 and 4 below, which provide users the opportunity to interact with a summarized year of air quality information at given locations within a single figure. While we again see color representing a continuous variable of interest, this work differentiates itself by providing multiple interactive elements and its use of D3. Specifically, users are able not only to change the level of urban centers shown by zooming into the map itself, but can interact with a given location’s icon to select metrics like particle type, year, and time granularities to display. In the context of our own project, while this radial tree format proves particularly useful in visualizing continuous data centered at “hubs,” it may not be ideal to employ as our primary visualization when compared to something like a choropleth, which can more easily associate color with regions of different shapes, and does not create a new “object” on the map which may have the ability to obscure a migration line. This mapping provides an insightful template for the options available within D3 and the level of interactivity we are looking to offer.

**Figure 3: Lu, Ai, Zhang & He (2017) (1)**

A diagram of the months of the year

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**Figure 4: Lu, Ai, Zhang & He (2017) (2)A map with a map of the united states

Description automatically generated with medium confidence**

**Conclusion**

The literature references which we reviewed demonstrate the significant progress that has been made in the field of spatiotemporal movement visualization and interactivity in recent years, and the sheer variety of methods and programming options available. By far the most common theme witnessed was the encoding of continuous variables of interest spatially through the use of intuitive color schemes, while temporal information has seen much more variety and proven more challenging to encode. Authors have taken a number of different approaches to visualizing temporal features (some more commonly seen such as faceting and filtering, and some more unique such as the “clock bar”), but interactivity and animation seem to facilitate understanding better than any static approaches. Programming aside, we suspect the main challenge will lie in ensuring that the temporal aspect of our visualization (and any related interactive elements) can be used effectively to help answer any of our client’s questions of interest. An ideal approach will display the high-level, meaningful information such as changes in temperature ranges and migration paths concisely, while retaining the ability to interactively view lower levels of granularity (specific time periods, species, or locations).

**References**

1. <https://www.sciencebase.gov/catalog/item/632b2d7bd34e71c6d67bc161>
2. <https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/statewide/time-series/3/tavg/all/1/2000-2023>
3. Chen, Y., Wang, Q., & Chen, S. (2015). Visualizing spatiotemporal patterns of land use changes using a time-varying cellular automata model. Computers, Environment and Urban Systems, 54, 362-376. <https://www.mdpi.com/2073-445X/12/8/1525>
4. Li, F., Chen, W., & Dong, W. (2019). Visualizing the spatiotemporal dynamics of human mobility using a flow-based approach. IEEE Transactions on Visualization and Computer Graphics, 25(1), 100-110. <https://www.sciencedirect.com/science/article/pii/S2468502X17300098>
5. Lu W, Ai T, Zhang X, He Y. (2017). An Interactive Web Mapping Visualization of Urban Air Quality Monitoring Data of China. Atmosphere, 8(8), 148. <https://doi.org/10.3390/atmos8080148>