An Interactive Data Visualization for Global Land Temperatures

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Introduction

Data visualization is an impactful tool to reveal information and draw inferences through novel representation of given data. The 2-D interactive data visualization, discussed in this paper, follows a visualization previously created that implements a paper-cutting technique, known as *kirigami,* to create a 3-D physical visualization for the same data set. The primary intent behind creating these two visualizations is to study the experience, affordances and perceptions of each medium to inform future techniques for data visualization.

For this project, a compilation of land temperatures from around the world for the years 1750 to 2012 was referenced from *data.world[1]*. After a quick review of this vast database, it was clear that this information demanded interactive presentation approaches that are impactful and stimulating, thus making the effects of climate change apparent to the viewer. Our attempt here is to demonstrate and compare two data visualization techniques while contextually empowering the data itself.

For the 2-D interactive visualization, we selected a subset of the data; 12 cities around the world and three years: 1912, 1962 and 2012. The most recent and complete data available was for 2012. The cities were selected based on the diversity in geographical positioning and data for 3 years, 50 years apart, was selected to ensure perceivable change in temperature values over the duration.

Motivations

Climate change is rapidly changing the planet we live in and although we are constantly reminded of this change through multiple platforms, it has been a challenge to grasp the extent and impact of it which can be communicated through real measurable information like land temperatures. Such rich data often gets limited to data scientists or analysts and is rarely consumed by the masses. These data visualizations are an attempt to understand and identify techniques that effectively communicate the impact of climate change, utilize clear and concise messaging and expresses the significance through means that are not limited to scientific discourse. These visualizations give an overview of the trends and correlations in land temperatures from diverse parts of the world such that the viewer can easily comprehend this complex dataset and draw inferences.

The practice of creating these visualizations has been a learning experience in trying to understand the data, exploring and refining concepts to best present data to reveal insights, and evolving designs based on desired interactive experience.

Ultimately, these visualizations will be used to conduct an empirical qualitative study to identify key aspects of the designs that influence the experience, interactions and perceptions of the dataset as represented by the visualizations. This paper focuses on the development of the 2-D digital data visualization for such studies.

Related work

Studies suggest that 2-D cartographic designs have a higher efficiency and effectiveness in communicating information spatially [2]. The saliency of visual variables can be perceived easily. Thematic relevance added to this perceptual salience can be beneficial to drawing spatial inferences and decision making.

The visual variables described here are based on *Bertin's visual variables*. Bertin(1983) proposed an approach to presenting information using visual elements[3]. These visual variables can be assigned meaning to represent data through perceivable manipulation[4]. The visual variables are as listed below:

- Position
- Size
- Shape
- Colour – hue/brightness
- Value
- Orientation
- Texture

A cartographic organization or layout embedded with appropriate visual variables that represent meaningful information can enhance the impact and expressiveness of data and provide opportunities for further exploration [6][7]. Moreover, there is a noticeable increase in information visualizations with the growing use of digital screens and interactive technologies. But there is a significant gap in empirical research focusing on the importance of information visualization to ensure thoughtful implementation [5] and to provide a variety of approaches to guide the process of creating expressive information visualizations.

The 2-d interactive visualization presented in this paper utilizes a map view (world map) for spatially organizing temperature data and implements four key principles from Bertin's approach for effectively communicating the information; position, size, colour and value.

Following the completion of these visualizations, an empirical qualitative study will be conducted to understand their effectiveness in depth and inform future information visualization approaches.

Background

Using the Global Land Temperatures data, a 3-D physical visualization for this data set was previously created using paper-cut technique (fig. 1) to show the temperatures for five countries for the years 2012 and 1962. This interactive physical model allows the viewer to see temperature information for 2012 when the model is placed flat on a surface (fig 2). The outer lines represent the line graph of the temperatures from January to December for 2012 for each of the selected countries: Australia, China, South Africa, Sweden and United States of America. These countries were also selected to show variation in geographical locations. The inner cut lines mimic the outer shape and their density is directly proportional to the mean temperatures for each country for the year 2012.

When the edges of the paper model are affixed to a frame, the cut lines allow the shape for every country to expand to a specific depth. On the vertical face, the height of this expansion first shows the mean temperature for 1962 (fig. 3). On adding, premeasured weights to the expanded shape, the height increases, now showing the mean temperature for 2012 (fig. 4). This interaction provides a tactile sense of the rate of increase in temperatures over a period of 50 years and the physical flexibility emphasizes the changes over time. The tangible nature of this model provides a cognitively unique interaction experience which can be engaging for data experts and laymen together.

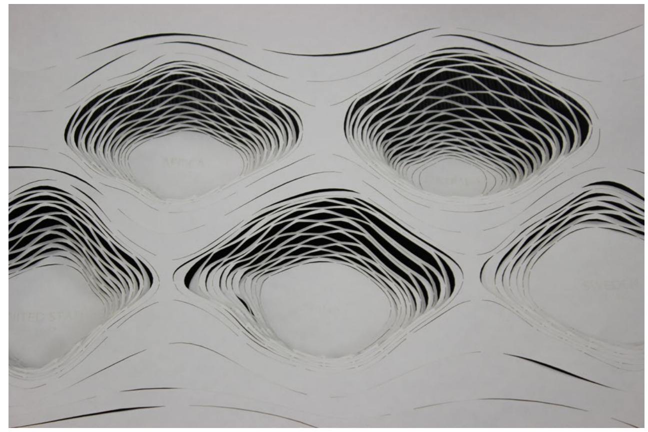


Figure 1 : Paper-cut, Kirigami, data visualization model.

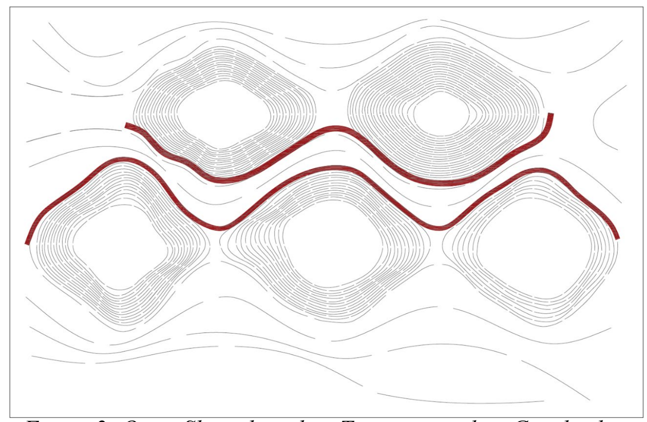


Figure 2: Outer Shape based on Temperature line Graph when flat

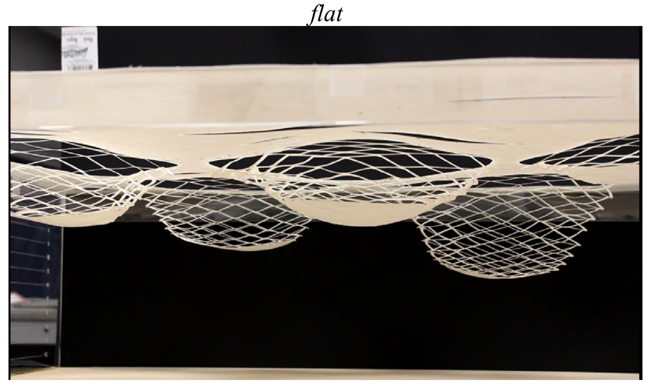


Figure 3: Paper-cut model when suspended over a frame. Expansion along vertical face shows mean temperatures for 1962

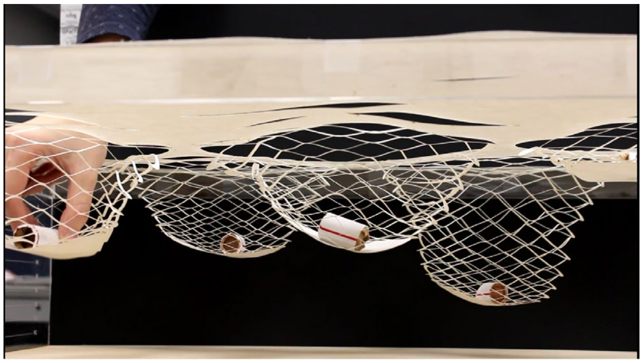


Figure 4: On adding weights the expansion shows mean temperatures for 2012

This physical visualization prompted us to think about how viewers perceive data visualized through different media and what drives their experience. To support further investigation a 2-D digital visualization for a subset of the same data was created in Processing 3+. The following parts explain the process for the design and programming of this 2-D visualization.

Data

The data used for the visualization is quantitative-interval data, sourced from *data.world* [1] which is an online platform with a library for multiple global climate change data sets. The Global Climate Change Data we referenced in this project, starts in 1750 for average land temperature and 1850 for maximum and minimum land temperatures. It also consists of global ocean and land temperatures for the following years until 2013.

Additionally, it has land temperatures sorted by city, state and country (all measured in Celsius). The data recorded consists of average monthly temperatures for each month of every year. This data set covers diverse locations from all over the world and reports Land Average Temperature with 95% confidence interval around the average.

Data challenges

The data set referenced was extremely large and complex with missing information for some years or missing locations. The expanse and detail in this raw data provided a lot of flexibility to visualize it in different ways and often limited selection of locations due to missing information. We could implement multiple approaches to sorting, filtering and analyzing this data which was beneficial for our visualization approach.

However, most of our initial ideas were either too complicated to model in the given duration of this project or the data represented were unclear, chaotic or overwhelming in the design.

After multiple ideation sessions and iterations for design and mapping this data, we decided to select data for 12 cities for the years 1912, 1962 and 2012. This data subset provided enough detail to the viewer to selectively read temperatures for each location to see changes over time and showed enough variation to associatively observe patterns and trends for multiple locations. The cities selected for the visualization are:

1. Los Angeles, USA
2. Wuhan, China
3. Melbourne, Australia
4. Cape Town, South Africa
5. Tokyo, Japan
6. Delhi, India
7. Moscow, Russia
8. Santiago, Chile,
9. Toronto, Canada
10. London, UK
11. Bobo Dioulasso, Burkina Faso
12. Anchorage, USA

System description

This 2-d cartographic visualization design has information laid out on a world map for cognitive ease of spatial orientation and perceptually locating places of geographical interest. The Bertin's visual variables applied in this visualization to appropriately represent data at the intended level of detail and fidelity are as follows:

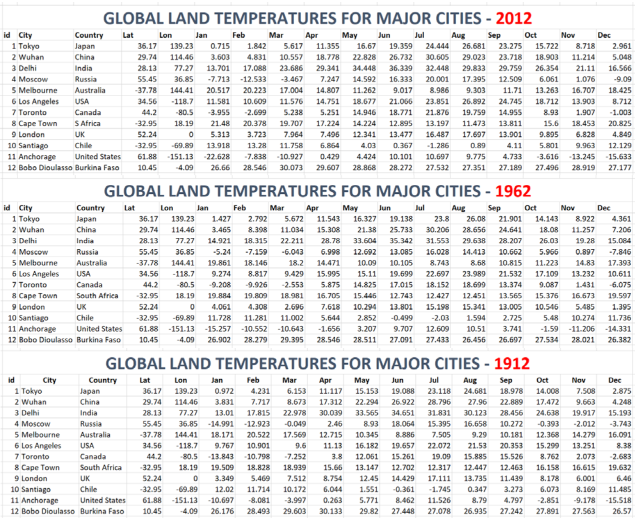
1. **Position**
   Each data point (mean monthly temperature) is represented by an arc surrounding the location of the specific city. The arcs spiral outwards from January to December. The position of the arc determines which month's data it represents.

2. **Colour**
   The arcs represent mean temperatures for each month through their colour. The colours are correlated to the temperature value with the hues specifically selected for perceivable delineation in values.

3. **Size**
   The arcs rotate around the city location in a circular pattern which expands when selected to lock-in-place by the viewer. This transformation in size enhances focus on the areas of interest and affords selective and associative reading of data. Additionally, the size of the arcs informs the month and can benefit associative reading of data when comparing information for two cities in the same month.

4. **Value**
   The opacity of the arcs changes when at least one of the city is selected by the viewer. The data arcs for that city brighten due to increase in opacity for enhancing legibility. Simultaneously, the arcs for all other (unselected) cities reduces to lower focus, and yet show the data options that are available for selection.

For this visualization, the data for the 12 cities was sorted in three CSV (comma separated values) files (fig. 5). Each one of the files corresponded to each of the years for which the temperature data was selected, i.e. 2012, 1962 and 1912. Each file consisted of the names of the city, corresponding name of the country, latitude and longitude information and mean temperatures for each month from January to December for that year.



GLOBAL LAND TEMPERATURES FOR MAJOR CITIES - 2012

id	City	Country	Lat	Lon	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Tokyo	Japan	36.17	139.23	0.715	1.842	5.617	11.355	16.67	19.359	24.444	26.681	23.275	15.722	8.718	2.961
2	Wuhan	China	29.74	114.46	3.603	4.831	10.557	18.778	22.828	26.732	30.605	29.023	23.718	18.903	11.214	5.048
3	Delhi	India	28.13	77.27	13.701	17.088	23.686	29.341	34.448	36.339	32.448	29.833	29.759	26.354	21.11	16.566
4	Moscow	Russia	55.45	36.85	-7.713	-12.533	-3.467	7.247	14.592	16.333	20.001	17.395	12.509	6.061	1.076	-9.09
5	Melbourne	Australia	-37.78	144.41	20.517	20.223	17.004	14.807	11.262	9.017	8.986	9.303	11.71	13.263	16.707	18.425
6	Los Angeles	USA	34.56	-118.7	11.581	10.609	11.576	14.751	18.677	21.066	23.851	26.892	24.745	18.712	13.903	8.712
7	Toronto	Canada	44.2	-80.5	-3.955	-2.699	5.238	5.251	14.946	18.771	21.876	19.759	14.955	8.93	1.907	-1.003
8	Cape Town	S Africa	-32.95	18.19	21.48	20.378	19.707	17.224	14.224	12.895	13.197	11.473	13.811	15.6	18.453	20.825
9	London	UK	52.24	0	5.313	3.723	7.964	7.496	12.341	13.477	16.487	17.697	13.901	9.895	6.828	4.849
10	Santiago	Chile	-32.95	-69.89	13.918	13.28	11.758	6.864	4.03	0.367	-1.286	0.89	4.11	5.801	9.963	12.129
11	Anchorage	United States	61.88	-151.13	-22.628	-7.838	-10.927	0.429	4.424	10.101	10.697	9.775	4.733	-3.616	-13.245	-15.633
12	Bobo Dioulasso	Burkina Faso	10.45	-4.09	26.66	28.546	30.073	29.607	28.868	28.272	27.532	27.351	27.189	27.496	28.919	27.177

GLOBAL LAND TEMPERATURES FOR MAJOR CITIES - 1962

id	City	Country	Lat	Lon	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Tokyo	Japan	36.17	139.23	1.427	2.792	5.672	11.543	16.327	19.138	23.8	26.08	21.901	14.143	8.922	4.361
2	Wuhan	China	29.74	114.46	3.465	8.398	11.034	15.308	21.38	25.733	30.206	28.656	24.641	18.08	11.257	7.206
3	Delhi	India	28.13	77.27	14.921	18.315	22.211	28.78	33.604	35.342	31.553	29.638	28.207	26.03	19.28	15.084
4	Moscow	Russia	55.45	36.85	-5.24	-7.159	-6.043	6.998	12.692	13.085	16.028	14.413	10.662	5.966	0.897	-7.846
5	Melbourne	Australia	-37.78	144.41	19.861	18.146	18.2	14.471	10.09	10.105	8.743	8.68	10.815	11.223	14.83	17.393
6	Los Angeles	USA	34.56	-118.7	9.274	8.817	9.429	15.995	15.11	19.699	22.697	23.989	21.532	17.109	13.232	10.611
7	Toronto	Canada	44.2	-80.5	-9.208	-9.926	-2.553	5.875	14.825	17.015	18.152	18.699	13.374	9.087	1.431	-6.075
8	Cape Town	South Africa	-32.95	18.19	19.884	19.809	18.981	16.705	15.446	12.743	12.427	12.451	13.565	15.376	16.673	19.597
9	London	UK	52.24	0	4.061	4.308	2.696	7.618	10.294	13.801	15.198	15.341	13.005	10.546	5.485	1.395
10	Santiago	Chile	-32.95	-69.89	11.728	11.281	11.002	5.644	2.852	-0.499	-2.03	1.594	2.725	5.48	10.274	11.736
11	Anchorage	United States	61.88	-151.13	-15.257	-10.552	-10.643	-1.656	3.207	9.707	12.609	10.51	3.741	-1.59	-11.206	-14.331
12	Bobo Dioulasso	Burkina Faso	10.45	-4.09	26.902	28.279	29.395	28.546	28.511	27.091	27.433	26.456	26.697	27.534	28.021	26.382

GLOBAL LAND TEMPERATURES FOR MAJOR CITIES - 1912

id	City	Country	Lat	Lon	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Tokyo	Japan	36.17	139.23	0.972	4.231	6.153	11.117	15.153	19.088	23.118	24.681	18.978	14.008	7.508	2.875
2	Wuhan	China	29.74	114.46	3.831	7.717	8.673	17.312	22.294	26.922	28.796	27.96	22.889	17.472	9.663	4.248
3	Delhi	India	28.13	77.27	13.01	17.815	22.978	30.039	33.565	34.651	31.831	30.123	28.456	24.638	19.917	15.193
4	Moscow	Russia	55.45	36.85	-14.991	-12.923	-0.049	2.46	8.93	18.064	15.395	16.658	10.272	-0.393	-2.012	-3.743
5	Melbourne	Australia	-37.78	144.41	18.171	20.522	17.569	12.715	10.345	8.886	7.505	9.29	10.181	12.368	14.279	16.091
6	Los Angeles	USA	34.56	-118.7	9.767	10.901	9.6	11.13	16.182	19.657	22.072	21.53	20.353	15.299	13.251	8.38
7	Toronto	Canada	44.2	-80.5	-13.843	-10.798	-7.252	3.8	12.061	15.261	19.09	15.885	15.526	8.762	2.073	-2.683
8	Cape Town	South Africa	-32.95	18.19	19.509	18.828	18.939	15.66	13.147	12.702	12.317	12.447	12.463	16.158	16.615	19.632
9	London	UK	52.24	0	3.349	5.469	7.512	8.754	12.45	14.429	17.111	13.735	11.439	8.178	6.001	6.46
10	Santiago	Chile	-32.95	-69.89	12.02	11.714	10.172	6.044	1.551	-0.361	-1.745	0.347	3.273	6.073	8.169	11.485
11	Anchorage	United States	61.88	-151.13	-10.697	-8.081	-3.997	0.263	5.771	8.462	11.526	8.79	4.797	-2.851	-9.178	-15.518
12	Bobo Dioulasso	Burkina Faso	10.45	-4.09	26.176	28.493	29.603	30.133	29.82	27.448	27.078	26.935	27.242	27.891	27.563	26.57

Figure 5: CSV files for selected data subset.

The system fetches data from these CSV files by column and utilizes it to create the interactive display. Fig. 6 shows a concept sketch of the system display. The interactive display has the following components:

1. **World map** in background - scaled to 1280px by 1024px for optimum visual detail
2. **Markers for cities** – plotted by calculating pixel position using latitude and longitude information
3. **Temperature Legend** – demonstrates the colours corresponding to the temperature ranges
4. **Year Buttons** – allow the viewer to toggle between the three selected years (2012, 1962 and 1912). This prompts the system to access data from the correct CSV file.
5. **Temperature Arcs** – surround each city marker and show temperature data. The closest(smallest) arc depicts the temperature value for January in the selected year, the arcs spiral outwards with the farthest(largest) arc depicting temperature value for December in the chosen year (fig. 8). The colour of the arc corresponds to the temperature value as shown by the legend. The data is accessed from the CSV file to create the arcs at the proper position with the proper colour.

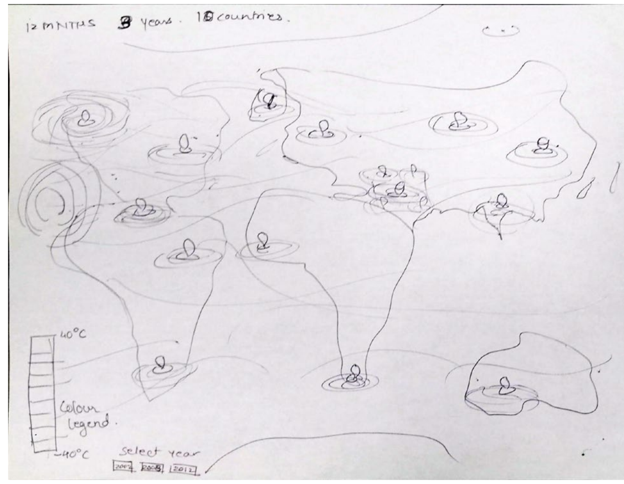


Figure 6: Concept sketch for the system display

At the start of the program, the display shows the world map with the 12 cities marked on it and temperature arcs for 2012 (fig. 7). The arcs for each city oscillate (rotate back and forth) at a random speed to abstractly suggest the dynamic nature of temperature change. In the future stages of development, this oscillation will be correlated to the mean temperatures for the year selected.

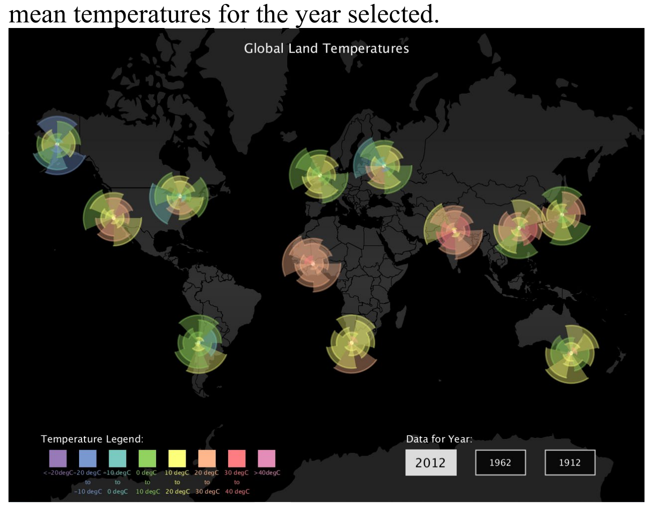


Figure 7: System display at the start of the program

Figure 8: Temperature Arcs for Santiago, Chile.

System Interactions

1. Mouse hover
When the viewer hovers over a city marker, the temperature arcs stop oscillating and the name of the city and the name of the country appear on top. This interaction is meant to help the viewer cognitively align with the visual variables displayed (fig. 8).

2. Click to hold
When the viewer clicks on a city marker, all the temperature arcs for that city stop oscillating, expand a little and their brightness increases to enhance details. At this point, the arcs surrounding other cities dim down by lowering their opacity (fig. 9). The viewer can then select to hold multiple cities by clicking on them and make comparisons or correlations (fig. 10). The viewer can re-click to deselect a chosen city.

3. Select Year
To display data for one of the other years, the viewer can click on the year buttons on the bottom right corner. The system will then access the data file for that year and the display will adapt to show temperatures for the newly selected year (fig. 11). The user can toggle between the year buttons even when no city is on hold.

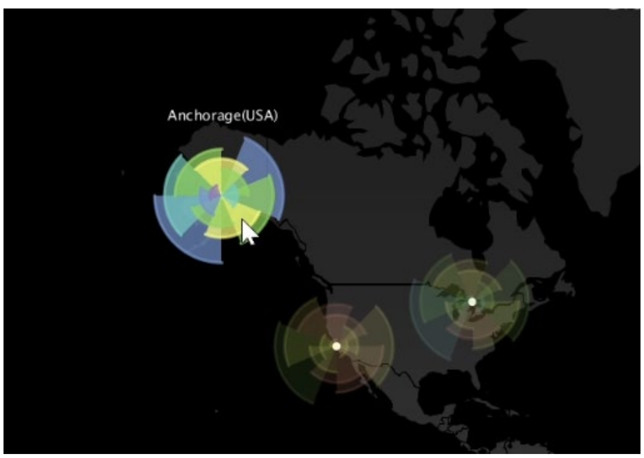


Figure 9: Click to hold, enlarge and brighten data arcs for a city

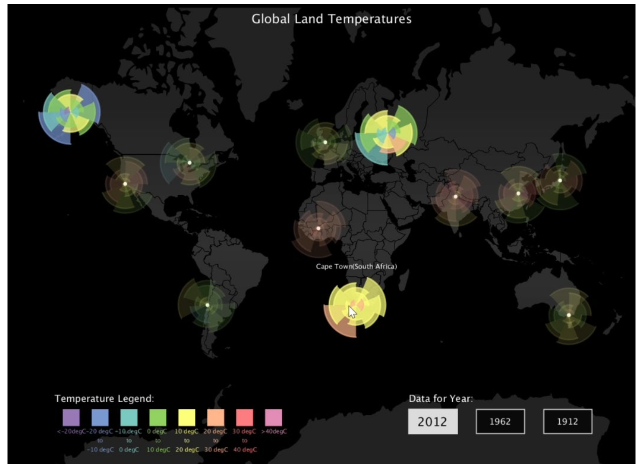


Figure 10: Select multiple cities to compare data

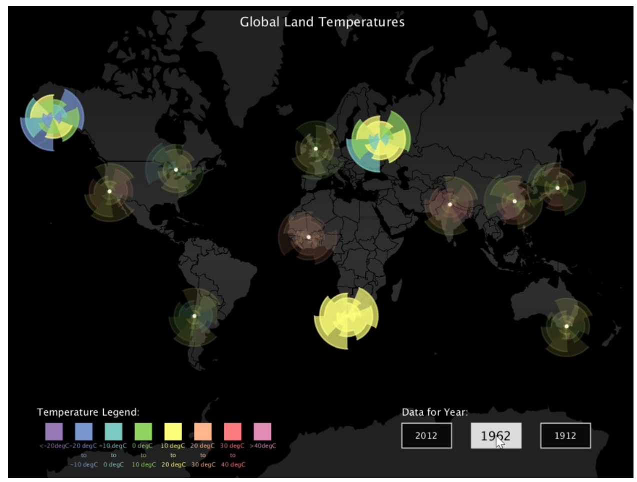


Figure 11: Display data for another year by selecting the year button.

System implementation

The following UML (Unified Modeling Language) diagram shows the programming structure for this visualization system implemented in Processing 3+ (fig. 12). The Map implements the key functionality of the interactive visualization created in the sub classes and fetches data from the CSV files. Any modifications or additions in the CSV file will be easily adopted by the system. Data for additional years can also be easily added by adding CSV files for each year.

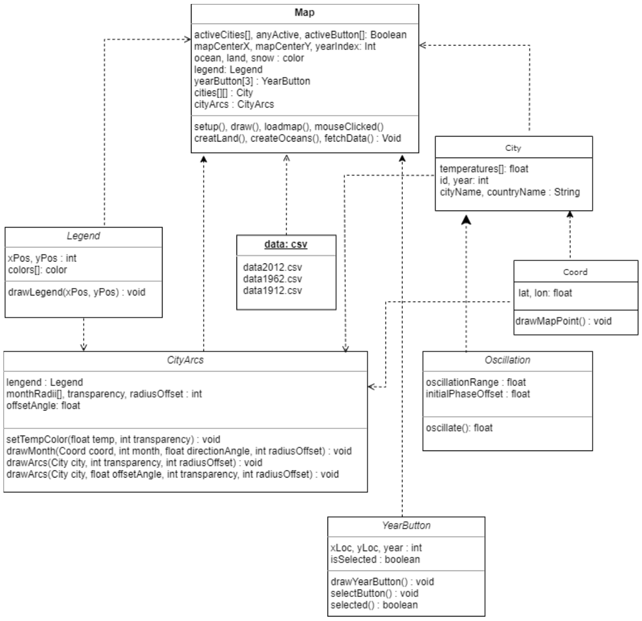


Figure 12: System UML Diagram

Discussion

This 2-D interactive representation of global land temperatures demonstrates a comparable visualization approach to the previously created physical visualization using paper-cut technique. Although, there are multiple digital interactive visualizations for climate change that have been generated in past, the primary objective behind the set interaction experience and fidelity of this project has been determined for the purposes of conducting a qualitative study to compare the two visualization approaches. Additionally, the process of creating these visualizations was of utmost importance in learning the process of creating information visualizations through experience.

The intention is to demonstrate unique and diverse approaches in which the same information can be visualized differently and understand how the viewing experience varies with respect to sorting, filtration and assessment of this information. Each approach also provides different cognitive experiences through their interaction modes while ensuring that the context for this data in maintained. The experience of these interactive visualizations is intended to deliver impactful and compelling messaging to a larger audience which may or may not be adept in this field. We believe that both visualizations emphasize the effects of climate change through representation of this temperature data in very different yet engaging and expansive ways. The proposed qualitative study will help us evaluate how these visualizations are perceived by data visualization experts and non-experts.

Conclusion and Future Work

The 2-D data visualization described in depth in this paper was an initial prototype of the design. Both visualizations discussed here provide a deep understanding of the benefits and limitations of implementing different media to visualize data. The process also helped discover alternative approaches to visualizing certain elements that were not considered in the prior plans.

There are multiple improvements required in both visualizations before they can be presented to an audience for qualitative feedback. Specifically, for the interactive digital visualization, a better sense of temporal transformation needs to be integrated that can be compared with the tangible weights used in the physical visualization. Currently, the rate of change in temperatures over 50 years is not fully realized when the viewer toggles between the years.

A larger data set needs to be incorporated in the physical visualization along with a grid for ease of readability of the data points. Similarly, the digital visualization could incorporate presentation techniques like zoom-in or out and pan for enhancing legibility of details.

Once the improvements have been made, the visualizations and a study protocol will be presented to peers including visualization experts and non-experts for evaluation. Following this, a qualitative study will be conducted to gain more insight into the experiential aspects of these two data visualization approaches mainly focusing on – (1) the perception of different visual, tangible and interactive elements, (2) the affordances of the two media and (3) overall experience of consuming information in each format. Such a study will provide a better understanding of the factors affecting the perception of various visual elements for most effective implementation in future data visualizations.

Acknowledgements

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