Geographical Simulation of Climate Change

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Overview

This application is a 3D geographical simulation of the rise of temperatures on the Earth from 1910 to 2010. The simulation offers an immersive experience, allowing users to explore and interact with a realistic model of the Earth while filtering temperature data by decade.

Description

This geographical simulation focuses on visualizing the average global temperature increase over time. When the simulation is set in motion, colorful splines appear in various regions on the globe, representing temperature changes over time. The length of the splines corresponds to the specific year within the simulation, visually depicting the magnitude of temperature variations. Additionally, the color gradient of the splines provides further insight into temperature trends, with yellow indicating warmer temperatures and shades of red or pink indicating higher temperature deviations. The simulation serves as a powerful educational tool, showcasing the long-term trends of global temperature increase. It highlights the consistent upward trend in average temperatures over the past century, particularly emphasizing the accelerated rise in the latter half of the 20th century due to intensified human activity. By providing a geospatial context for temperature data, the simulation contributes to raising awareness about the urgency of addressing climate change and its consequences for ecosystems, communities, and future generations.

Objectives

The primary objectives of this geographical simulation project have evolved to focus on the visualization of climate change and its impact on temperature. Initially, we aimed to create a geographical simulation showcasing the past, present, and future of sunken cities worldwide.

However, due to data limitations in this specific domain, we redirected our efforts towards exploring climate change and its correlation with temperature. The main objective of the simulation is to provide a comprehensive visual representation of the rise in global temperatures over time. By leveraging historical temperature data, the simulation aims to demonstrate the continuous warming trend Earth has experienced and its profound consequences. This aligns with scientific consensus that increased human emissions of greenhouse gasses have driven changes in Earth's climate. By providing an immersive and informative experience, our application seeks to engage users and promote a deeper understanding of the ongoing climate crisis. While the objectives initially focused on sunken cities, the shift towards climate change and temperature visualization allows for a broader understanding of the implications of global warming. By providing a compelling visual narrative, the simulation contributes to the broader discourse on climate change, encouraging individuals, communities, and policymakers to take action in mitigating its far-reaching effects.

Implementation Details

We initially wanted to use ArcGis because the software and its corollaries are known for their mapping abilities. However, we decided to explore other avenues due to two main reasons. The first was the fact that many key features were locked behind a paywall. This was restrictive for us due to the fact that we were on a strict time schedule and we did not have full confidence that ArcGis had all the capabilities that we needed. The second was the specificity needed to use their API. Certain functionalities that the API provides require extensive datasets for different topics like population, elevation, etc. We wanted to solely focus on climate change, so we decided to explore alternative avenues.

Ultimately, Three.js seemed to have all the functionality we needed while also being light enough to package in this application. Even more fortunately, there was already a community of people who have made similar core applications with the WebGL Globe Google Experiment. We took inspiration from many of their applications and used it to understand the core functionalities of Three.js and D3.js (D3 was used for live document manipulation given data). After researching and fully understanding how to use Three.js, we could move on to making our visualizer.

Some notable technologies used in the application included using multiple textures overlaid on the Earth to make the globe stand out more. Including our initial texture map of the earth, we applied: bump maps, cloud maps, and specular maps. For the sky, we used six different textures for space and stitched them together seamlessly to make a sky box. Other technologies included making Phong and Lambertian Material classes to map coordinates to the 3D plane. We also used many algorithms learned in the class such as conversion to barycentric coordinates, linear interpolation, flat shading, making our own Lambertian illumination model, and making a Phong shading model.

Group Member Work Distribution

The group divided the work based off of skills and knowledge about the software we used to build our simulation. As a group we brainstormed ideas for this project and we learned towards a geographical simulation that would be attractive and useful for educational purposes. Eromonsele was more knowledgeable on JavaScript and Node.js, so he agreed to do the majority of the technical work, including all the research and implementation of the visualizer. Joyce and Maliya worked on doing the more administrative and organizational tasks that included creating the presentation, setting the timeline for things to be completed, completing the proposal and this report.

Experimental Settings

To create the geographical simulation of climate change, the following settings and methodologies were employed:

- Data Collection: Temperature records were obtained from NASA. More specifically, we used data files from NOAA GHCN v4 and ERSST v5. NASA then combines these data sets and uses proprietary calculations and models to calculate the global and historical monthly means every year.
- Timeframe: The simulation focused on the period from 1910 to 2010, covering a century of temperature changes. This time frame was selected to analyze and visualize long-term trends in global temperature variations.
- Geographical Representation: The simulation utilized a 3D model of the Earth, implemented using Three.js and D3.js technologies. The Earth model was accurately represented with textures, bump maps, cloud maps, and specular maps to provide a realistic visual representation. All continents were accounted for, including Antarctica.
- Interactive Features: Users were able to interact with the simulation by rotating the globe and filtering temperature data by decades. The interactive elements were implemented using JavaScript and user interface components provided by Three.js and D3.js libraries.
- Visualization Techniques: The simulation employed color-coded splines to represent temperature changes over time. The length of the splines corresponded to the specific year within the simulation, showcasing the magnitude of temperature variations.

- Data Manipulation: NASA's data was pulled and then modified into a mock database for our uses. Our database made the code in this format:

  [["year", [lat, long, value], [lat, long, val]]]

  After so, the earth was then broken up into small regions. For each region, we took the average temperature of the points found in that region and used that to represent the temperature of said region. Data processing techniques, such as interpolation and mapping, were applied to ensure accurate representation of temperature trends across different regions.

By employing these experimental settings, the geographical simulation was able to effectively visualize the rise of temperatures on Earth from 1910 to 2010 and provide insights into the effects of climate change.

Results Analysis

The geographical simulation of climate change successfully visualized the rise of temperatures on Earth from 1910 to 2010, providing valuable insight into the effects of global warming. The analysis of the simulation results revealed several key findings.

As the years got higher, the simulation depicted a clear consistent upwards trend in global temperature over the past century. The visualization showcased how average temperatures have gradually increased, particularly in recent decades. It also revealed many temporal patterns, one of which being that the rate of temperature rise accelerated in the latter half of the 20th century, which highlights the intensified impact of human activity on climate change. Furthermore, the visualization also highlighted certain regions and hotspots. Using a globe model, we were able to ocularly filter by certain continents or countries and see that certain areas experienced more significant temperature changes compared to others. For example, Eurasia has the highest average temperature in current times. Also, one can see that regions closer to the poles experienced some above-average temperatures and temperature increases, indicating the pronounced impact of climate change on polar regions. The visualizer helped identify climate anomalies, where temperatures deviated significantly from the long-term average. One example of this is the Philippines in the 1930s. Finally, the visualizer allows us to link historical events to the rise in temperature. For example, with the advent of World War II, one can see the sharp shift in temperature from the 1920s to the 1930s. Another is the massive baby boomer generation. The sharp rise in total world population can be seen by the amount of temperature increase from the 40s to the 80s. Overall, the results obtained from the simulation align with scientific consensus on global warming and provide tangible evidence of the ongoing climate crisis. By visualizing temperature data in a geospatial context, the simulation contributes to raising awareness about the urgency of addressing climate change and its implications for ecosystems, communities, and future generations.

Future Work

While the current implementation of the geographical simulation of climate change provides valuable insights into historical temperature trends, there are several areas that can be further enhanced and expanded upon in future work. Firstly, we would like to incorporate predictive capabilities into the visualizer. By integrating climate models and projections, the simulation can be extended to forecast future temperature trends, enabling users to visualize and understand the potential implications of continued climate change. Another addition we would love to add in the future is sea level visualization. Incorporating a visualizer for sea level rise would significantly enhance the comprehensiveness of the simulation by showing the gradual inundation of land and provide insights into the potential consequences of sea level rise. In terms of data, we would also like to incorporate additional climate variables such as precipitation, wind patterns, or carbon dioxide levels in the future. Finally, optimizing the performance of the application is something else we'd like to do in the future since this application involves large datasets and complex visualizations. This would ensure smoother user interactions and enable the simulation to handle larger datasets for more accurate and detailed representations.

References

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