Final Project: AR Earthquake

Jacob Low

Abstract—Home to the San Andreas Fault line, California is accustomed to earthquakes. Although the majority of earthquakes typically have little to no consequences, they can be extremely dangerous, especially in areas with unsafe buildings and infrastructure. The Loma Prieta earthquake of 1989 struck San Francisco, resulting in the loss of 63 lives, over 3,800 injuries, and $6 billion dollars of property damage. Although many improvements have been made such as seismic retrofitting to brides and buildings, there are still many areas across California with buildings unable to withstand a significant earthquake. This paper will explore the correlation between historical earthquake data and seismic ratings of California hospitals through data visualization. The following visualization method will produce a 3D bar chart overlaying a 2D map of California with AR capabilities.

Index Terms—earthquake, data visualization, augmented reality, computer graphics

1 Introduction

Earthquakes with a minimum magnitude of 4.0 have the potential to cause structural damage. In 2021 alone, California experienced fifty-seven earthquakes with a magnitude between 4.0 and 5.0, three earthquakes between 5.0 and 6.0, and two earthquakes above 6.0. By visualizing the correlation between previous earthquake events and safety ratings of California hospitals, we may be able to identify earthquake hot-spots in need of improved infrastructure.

2 Methods

A 3D bar chart overlaying a 2D map of California can be used to visualize this relationship. The map of California is divided at the county level (58 counties), where each bar corresponds to a specific county. The height of each county is calculated using the number and Structural Performance Category (SPC) rating of the hospitals within the county boundary, and the color corresponds to the number and magnitude of historical earthquake events within the county boundary. The map is divided at the county level because every county typically has unique regulations regarding buildings and safety.

This visualization is created using data sets from the California Health and Human Service Agency, Southern California Earthquake Data Center, and California Open Data Portal. This paper will discuss how to combine the three data sets into a single GeoJSON file and use it to construct the 3D visualization with AR capabilities.

The data set from the California Health and Human Service Agency contains Seismic Ratings and Collapse Probabilities of California Hospitals. Each hospital is given an Structural Performance Category or SPC rating ranging from 1 to 5. A building with an SPC rating of 1 poses ”significant risk of collapse and danger to the general public” [5]. On the other hand, a building with an SPC rating of 5 is ”considerably able to provide services to the public following a strong earth movement” [5]. These rating will be used to calculate the height of each county in the visualization. A county with a greater height, contains more unsafe buildings than that of a county with lesser height.

The data set from the Southern California Earthquake Data Center contains seismological data of earthquake events with a minimum magnitude of 4.0 from the year 2000 to 2022. The size of each earthquake is measured by it’s magnitude. These magnitudes will be used to calculate the color of each county in the visualization.

The data set from California Open Data Portal contains the geometry required to draw each county with computer graphics. This file will be modified to contain the SPC and earthquake calculations for each county. A GeoJSON file is used instead of a TopoJSON file because it is easier to draw using computer graphics. Although the TopoJSON file format is more efficient, the GeoJSON file format is much simpler. Each county can be drawn by connecting the coordinates of each polygon. This visualization draws each county according to the original longitude and latitude coordinates. A projection function is not used because California is relatively small in terms of geomapping, so drawing the counties in this way will not result in significant visual changes.

2.1 Data Extraction and Organization with GeoJSON

The following method to combine the data sets into a single GeoJSON file uses the CSV file containing the SPC ratings and the JSON file containing earthquake events. The creation of this file can be divided into three steps: data extraction, data analysis, and data combination.

2.1.1 Data Extraction

The CSV file is a table where each row represents a different California hospital and each column pertains to a different attribute. The attributes that are relevant to this analysis are the hospital’s county and SPC rating. In order to process the SPC ratings, Python can be used extract the data and organize it for analysis.

The pandas library available within Python handles most of this task. The CSV file is converted into a pandas DataFrame and the attributes are filtered to only include the hospital's county and SPC rating. The SPC data is then cleaned to remove hospitals without any data.

The JSON file is a collection where each object represents an earthquake and the properties are stored in a dictionary. The properties that are relevant to this analysis are the earthquake's location represented by longitude and latitude coordinates, and the magnitude. In order to process the earthquake data, Python can also be used to extract and organize the file so that it can be easily analyzed.

2.1.2 Data Analysis

The height of each county represents the number of unsafe hospitals within the county boundary or the "SPC Score". Since the SPC ratings range from 1 to 5, the county's "SPC Score" is calculated as follows:

Let C represent a county with n hospitals. Each hospital i in range $1 \leq i \leq n$ has an SPC rating S_i:

$$SPCScore_C = \sum_{i=1}^{n} \frac{1}{S_i}$$

The inverse sum is used because the hospitals with a lower SPC rating have a greater chance of collapse than a hospital with a high SPC rating. Using the inverse sum, a greater weight is given to hospitals with an SPC of 1, increasing the county's "SPC Score" by 1, and a lesser weight is given to hospitals with an SPC of 4, increasing the county's "SPC Score" by $\frac{1}{4}$. Hospitals with an SPC rating of 5 are not considered in this calculation because they are capable of withstanding a major earthquake event.

The color of each county represents the county's earthquake history or "Earthquake Score". Since earthquake has a magnitude, the "Earthquake Score" is calculated as follows:

Let C be a county with m earthquake events. Each earthquake event j in range $1 \leq j \leq m$ has a magnitude M_j:

$$EarthquakeScore_C = \sum_{j=1}^{m} M_j$$

Unlike the "SPC Score", a greater magnitude corresponds to a more severe earthquake event. Therefore, we are able to use the sum of magnitudes to calculate the earthquake score for each county. Earthquake events with a magnitude below 4.0 are ignored in this calculation because they typically are not able to cause structural damage.

2.1.3 Data Combination

Once the "SPC Score" and "Earthquake Score" has been calculated for each county, the CSV and JSON files need to be combined with the GeoJSON file. The goal is to add the two new attributes to the "properties" dictionary of the corresponding county's geometry stored in the GeoJSON file. In order to achieve this, the GeoJSON file is loaded as a feature collection using Python. The feature collection is an array of features that represent each county. We then iterate through each county and find it's corresponding "SPC Score" and "Earthquake Score", adding them as new properties to the geoJSON geometry. Once all counties have been processed, the new geoJSON file can be used to create the 3D bar chart visualization.

2.2 3D Bar Chart Creation with Three.js

Before discussing the visualization methods, I wanted to briefly go over the sources I used to create this project. This visualization is built off of a three.js scene from a CSE 160 Assignment from Professor James Davis [2], the method used to convert the GeoJSON features into three.js shapes is a modified version of an example on Stack Overflow [3], and the standard rainbow color scale function is provided by Michele Locati [1].

The first step in creating this visualization is to first draw the 2D map of California using the geometry data stored in the GeoJSON file. The GeoJSON file is loaded into the JavaScript environment and each feature is converted into a 2D Three.js shape. I modified the function provided on Stack Overflow to handle the conversion of both Polygons and MultiPolygons. This change was needed because a few California counties such as Los Angeles and Ventura encompass multiple islands. Each shape is then added to a Three.js group object in order to easily transform all of the shapes together (See Figure 1).

Fig. 1. 2D map of California in Three.js.

Each bar is created using the ExtrudeBufferGeometry function within Three.js. This function extrudes the 2D shape of each county, simulating the bar. The depth of the extrusion corresponds to the county's "SPC Score". Additionally, a directional light is used to define the edges of each extruded shape (See Figure 2).

Fig. 2. 3D map of California with county extrusions corresponding to SPC Score.

Each bar is colored according to the standard RGB color scale function provided by Michele Locati. The function takes the minimum and maximum "Earthquake Scores" across the entire data set and returns an RGB string corresponding to the "Earthquake Score" of each county. The county is colored according to the RGB string.

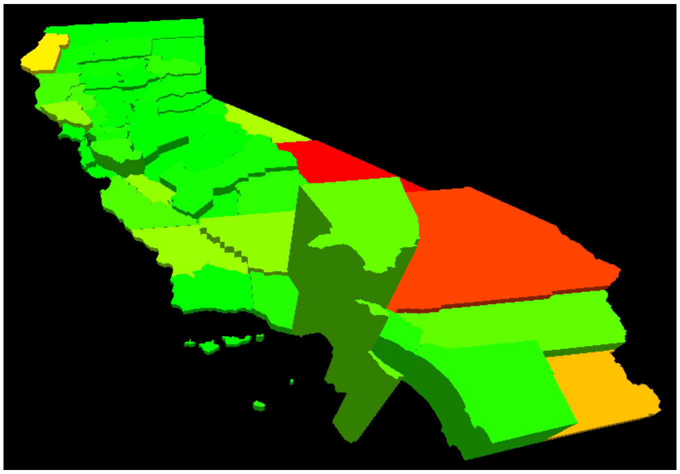

Fig. 3. 3D map of California with county colors corresponding to Earthquake Score.

However, this bars and colors are meaningless without a legend. I created a simple height and color legend using three.js billboards and cubes in order to make the visualization more self explanatory. I also used billboard to label each county in the visualization (See Figure 3).

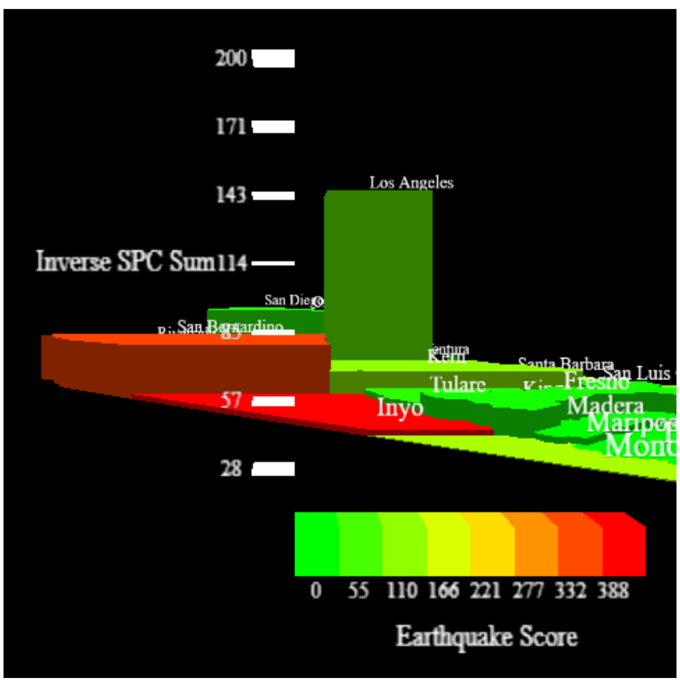

Fig. 4. Perspective view of the Three.js legend next to the 3D map.

2.3 AR Implementation with Mozilla XREngine

After the Three.js scene is complete (See Figure 5), the Mozilla WebXR Viewer and XREngine library implement the scene as an AR visualization tool. I chose to use these tools because they are compatible with IOS devices. However, the XREngine is not compatible with most browsers such as Chrome or Safari, so the Mozilla XRViewer application must be used to display the visualization.

Starting from the "AR Anchor" example provided in the WebXR Viewer Standard Examples, I modified the program to display the 3D earthquake scene on interaction instead of a simple cube. The visualization is placed such that the plane parallel to the 2D map is perpendicular to the AR device. Once the visualization has been anchored, the user can view it from any angle with the AR capabilities (See Figure 6).

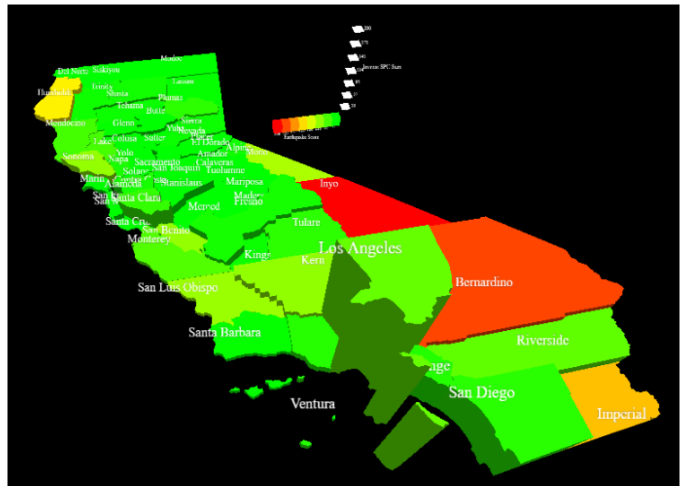

Fig. 5. Final Three.js Earthquake Visualization.

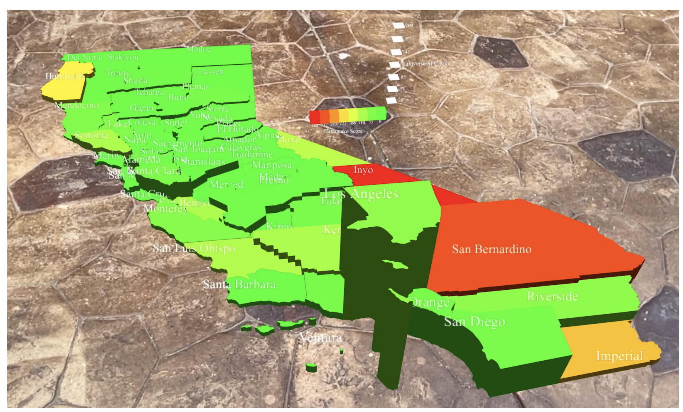

Fig. 6. Screenshot from AR interaction.

3 Results

The 3D map visualization with AR capabilities can be used to identify which counties in California need to improve their infrastructure to increase public safety. For example, San Bernardino County has the third highest bar height and is colored orange. This means the county has significant earthquake history and many buildings with low SPC ratings. In the event of a major earthquake event, San Bernardino is more likely to endure property damage compared to most other counties.

4 Limitations

This visualization method is limited to the scope of the data. The earthquake data set contains all earthquake events with a magnitude greater than 4.0 from 2000 to 2022. In future exploration, a larger data set capturing data from as many years as possible should be used to increase the accuracy of the ”Earthquake Score”.

Additionally, the Seismic Ratings and Collapse Probabilities of California Hospitals data set only contains SPC rating from California hospitals. In future exploration, it would be useful to gather data from as many types of buildings as possible to increase the accuracy of the ”SPC Score”.

5 User Interface

This visualization is web-based and runs on the Mozilla XRViewer which is available on IOS devices via the following URL:

AR Earthquake Visualization

The Three.js version of this visualization must be viewed on a computer via the following URL:

Three.js Earthquake Visualization

If you want to run the source code from your local machine, download the code from the repository and install the following packages: For the three.js version of this project, Three.js must be installed locally via the command ”npm install three” in the directory containing the file ”eq.html”. After the installation completes, ensure the folder titled ”node_modules” is in the ”web_eq” folder. To view the visualization with a browser, the HTML page must be hosted on a local python server. For the AR version of this project, the XREngine library files are included in the Git repository containing the source code.

I also created a choropleth map using D3 to further analyze the data that can be viewed on any web browser via the following URL:

D3 Earthquake Visualization

References

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