Group 2
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Seismic Activity on the San Andreas Fault

[Github repository]

Overview

Earthquakes are a common threat to people living in California. The goal of our project was to visualize the seismic waves of a simulated earthquake caused by the San Andreas Fault to determine the potential impact on California's Highway system, leading to more effective allocation of resources by California's government. The earthquake is simulated in southern California. As seen in image 1 the simulated area's highways are particularly in danger of damage from an earthquake.

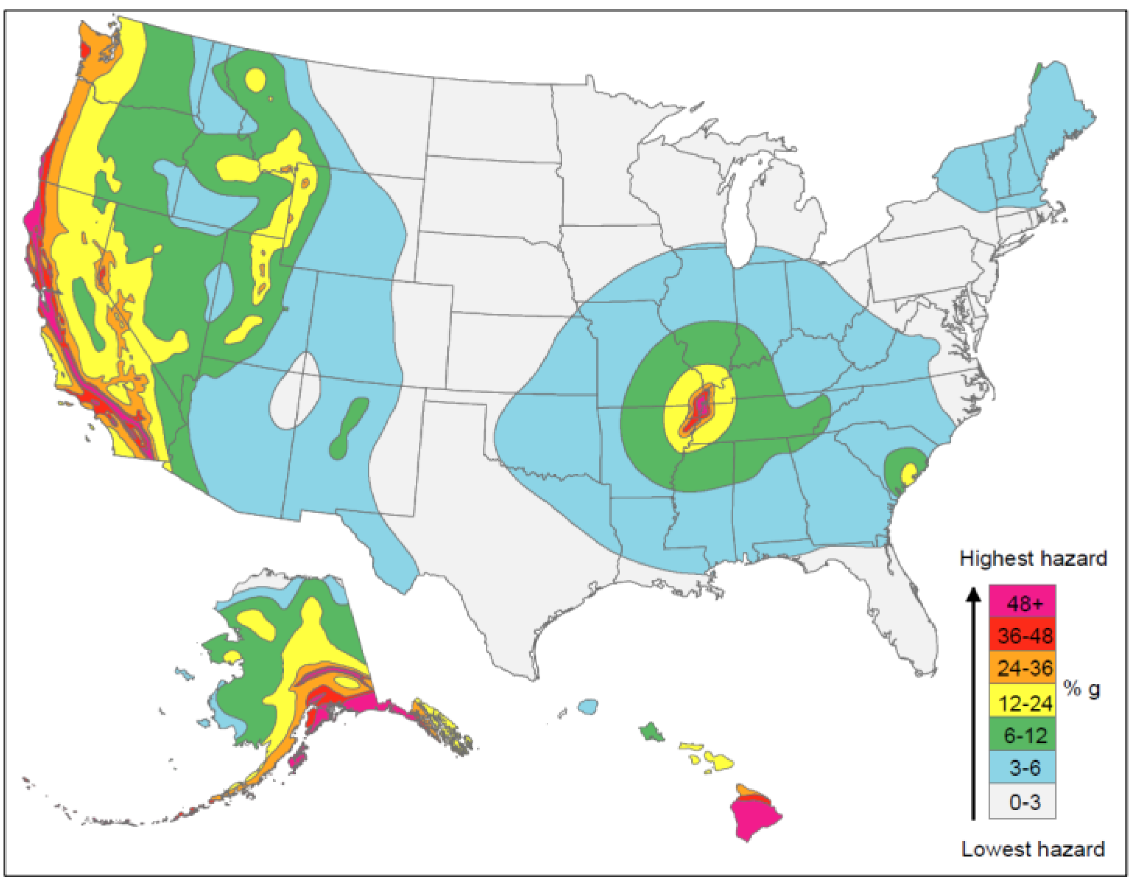
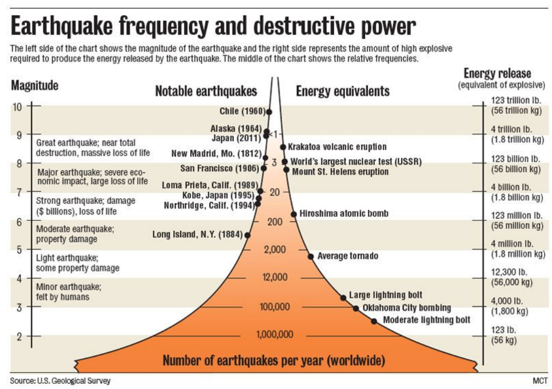


Figure 1. Earthquake Hazard to Highway Systems

This dataset was generated by simulating a magnitude 7.7 earthquake on the Southern San Andreas Fault. This simulated earthquake lasts 60 seconds. Magnitude 7 earthquakes are described as being “very strong” and capable of causing significant damage to poorly protected buildings and roads. According to the California Earthquake Authority, California has a 75% chance of experiencing a magnitude 7 earthquake or greater within the next 22 years. Below is an example of devastation a magnitude 7 earthquake can have on highways, as well as a reference guide for earthquake magnitudes.



From the above image, it is clear the dangers high magnitude earthquakes can have on general infrastructure and human life. Naturally, such a threat inspires many regulatory and government agencies to take preventative measures.

Dataset

The dataset used for this project was provided for the IEEE Visualization Design Contest in 2006. Using this dataset, we aim to answer a similar question to that of the design contest: how would an earthquake affect California’s infrastructure? Answering this question will help officials to anticipate the consequences of such a natural disaster occurring. For example, which highways are particularly vulnerable? Are there any communities which would be cut off should the infrastructure take severe damage?

As we made progress on this project, we recognized some additional questions that are worth answering. The dataset provides the velocities of the seismic wave at any given point over time. When considering the infrastructure target of this project, it would be good to know what magnitude would result in significant damage to roads or bridges.

The dataset is divided into individual time steps and scalar fields (x,y,z). These files are first converted from raw binaries to vtk format. They are then loaded into paraview as individual time series scalars before being folded into a time series vector field. The magnitude of this vector field is then displayed with high values given full opacity (red), and lower values proportionally smaller amounts (blue). This simulation is then mapped to the state of california by overlaying a mesh of california's borders & highways on top of it. By visually analyzing this data and extracting high values, we can determine which highways would likely be compromised.

Outcomes

After finishing the visualization we analyzed the animation to determine which highways would be affected by the earthquake. As shown in table 1, we categorized each highway into three categories: highly affected, slightly affected, and unaffected. Highways hit by the strongest waves were categorized into the Highly affected category; highways not hit by any wave were categorized into the unaffected category, and all other highways were categorized as slightly affected.

In "Classification of road damage due to earthquakes" the authors introduced a new metric for measuring damage caused to road networks by earthquakes called the Road Damage Scale (RDS). The authors defined RDS as follows.

> 2.1 Damage scale 1
>
> The roads are in a satisfactory condition and can be used with minor repairs. The roads coming under this category are completely accessible and can be used for all post-earthquake relief works. Usually, this kind of damage occurs when the roads are of good quality and far away from the epicenter.
>
> 2.2 Damage scale 2
>
> Less damaged roads can be represented by this scale. The damages may be moderate cracks, failure of sides and shoulder/footpath of the roads. This kind of damage can be expected to occur close to epicenter during moderate earthquakes and away from epicenter for larger earthquakes. The roads are accessible and minor to moderate repair works may be needed for them to function effectively.
>
> 2.3 Damage scale 3
>
> This scale is used to represent moderate damage of roads with big cracks due to earthquake-induced liquefaction, landslide, and other effects. Roads partially blocked due to building collapse, landslide, partially washed away due to storm surges, tsunami, etc. These damages may occur due to any magnitude from moderate to high depending upon the distance from the epicenter. This category of damaged roads is partially accessible for vehicle movement. Either one side or both sides of roads may be used, but the damage occurred can be seen distinctly. These roads require moderate to major repair or cleaning work.

2.4 Damage scale 4

This scale demonstrates high damage to roads which render the roads partly inaccessible. Big cracks, failure of pavement layers as block, big holes, and heavy damage at one side of the road can be classified as this category. Roads are blocked due to building collapse, landslides, washed away due to storm surges, tsunami, etc. These roads require major repair and reconstruction in some parts of the road.

2.5 Damage scale 5

Damage scale of 5 is uppermost in the proposed scale. Most of the time, this scale represents very high damage of roads close to epicenter of earthquake and having moderate to major earthquake. The roads are completely rendered useless and are totally inaccessible. One of the major reasons for this is their proximity to epicenters and very high magnitudes of the earthquakes. Complete failure of pavement surface and sublayers due to landslide and liquefaction. These roads require complete reconstruction for effective traffic movement [2].

According to the authors of “Classification of road damage due to earthquakes,” earthquakes of similar magnitude to the simulated earthquake caused road damage from RDS 3 to RDS 5. We assumed that the most powerful seismic waves of the simulated earthquake would cause similar damage.

Table 1. Highways Affected

Highly Affected Highways (RDS 5 - 3)	Slightly Affected Highways (RDS 3 - 1)	Unaffected Highways (RDS 0)
ST-1	ST-178	I-80
US-101	ST-43	I-280
ST-23	ST-135	I-305
ST-33	ST-99	I-580
ST-118	ST-46	I-680
I-5		I-880
I-405		ST-3
ST-2		ST-12
I-10		ST-16
I-110		ST-17
ST-22		ST-20
I-710		ST-36
I-605		ST-51
ST-14		ST-70
ST-138		ST-84
ST-134		ST-85
I-210		ST-89
ST-14		
I-15		

ST-18 US-395 ST-58 ST-79 I-40 ST-62 ST-166 I-8 ST-7 US-95	ST-92 ST-113 ST-116 ST-120 ST-128 ST-139 ST-140 ST-156 ST-162 ST-299 US-50

Describe finished differs from goals

Due to time constraints, the geopolitical overlay of California had to be cut. Rather, a point based trace of California's border and highway markers was used instead. While this still encodes the same information, it isn't as intuitive as seeing the geographical overlay. Annotations in the animation also had to be abandoned, as editing them in post production would have taken too much time to learn and is technically outside of the domain of this class.

Project Evaluation

Workload distribution:

For the majority of the project, the actual distinctions between assignments are rarely honored as the sequential nature of this project necessitated an "all hands on deck" approach to solving problems. That being said, as the project began to take momentum, each team member adopted the following general specializations:

- **Josh**: Displaying California border and highways overtop the data. Researching estimated damage of earthquakes. Analyzation of earthquake animation to determine highways affected
- **Jeremy**: Data munching and vtk conversion. Team/personnel management.
- **Colton**: Animations and paraview pipeline. Public relations liaison. Documentation review and code contribution.

Retrospective

Having accomplished this assignment, our team feels that there are many things which could be improved upon with more time. Sadly, many of the team's initial efforts proved fruitless as certain development paths proved non-viable. However, given those limitations, we are satisfied with the results.

References

California Earthquake Authority. (n.d.). CEA - earthquake risk. California Earthquake Risk - Seismic Risk for CA's Major Metros | CEA. Retrieved April 19, 2022, from https://www.earthquakeauthority.com/California-Earthquake-Risk

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