Data Storytelling with Tableau: Unraveling Patterns in Historical USGS Earthquakes (1900-2023)

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Abstract

With a sincere interest in understanding the forces that move our planet, especially after the recent earthquake in the Al Houz area, and a keen interest in data analysis, our research takes a historical turn and comprehensive survey of recorded earthquakes by the United States Geological Survey (USGS).

To identify subtle trends in seismic activity, we use detailed visualizations via Tableau Public and conceptually assemble CSV files. Our objectives extend beyond the intuitive, built-in; we aim to gain a deeper understanding of the forces that control earthquakes.

The method we have chosen involves importing a CSV file into Tableau Public, a powerful open-source tool known for its ability to visualize complex data types. With this approach, we aim to conduct an in-depth study of earthquake systems by identifying seismic hotspots using spatial distribution maps, seeking to understand intimate relationships under the strength between seismicity and factors such as depth.

Ultimately, our goal is to create interactive dashboards that not only display the data collected from our study but are designed to be easy to use. This makes it easier for a wider audience to understand and show under, providing a comprehensive and accessible view of seismic terrain and its challenges.

Keywords: Earthquakes, Seismic activity, USGS, Data visualization, Interactive dashboards

1. Introduction

Earthquakes, as compelling manifestations of the Earth's dynamic forces, possess the potential to reshape landscapes and impact communities. This paper delves into earthquake analysis, an essential discipline dedicated to the comprehensive study of past earthquake events and their associated phenomena. Seismic events, characterized by the sudden release of energy in the Earth's crust, generate waves that propagate through the Earth, causing ground shaking and, in certain instances, leading to significant geological transformations.

Seismic events have captivated human curiosity for centuries, prompting the development of earthquake analysis—an interdisciplinary field encompassing historical records, data analysis, and result interpretation. The recent seismic event in the Al Haouz region of Morocco served as a poignant reminder of the dynamic forces beneath our feet, emphasizing the critical importance of delving into earthquake analysis to comprehend and mitigate geological phenomena. This study aims to address a gap in the analysis of seismic events, focusing on the historical analysis of earthquakes reported by the USGS. By systematically examining this wealth of data, we seek to contribute to a more comprehensive understanding of seismic activity, aiding informed decision-making and enhancing preparedness in earthquake-prone regions.

Through advanced data visualization techniques using Tableau Public and a meticulously curated CSV file, our research endeavors to bridge the gap between raw data and meaningful narratives. We aspire not only to enrich the scientific discourse on earthquake analysis but also to provide practical insights that contribute to the broader understanding of seismic events. Join us in this exploration as we unravel hidden stories within earthquake data, inspired by a commitment to deciphering the mysteries of our ever-evolving Earth.

2. Related Work

Earthquake analysis, also known as seismic analysis, is a critical field of study that involves the examination of historical records, analysis of data collected during earthquake events, and interpretation of the results to gain insights into the nature and behavior of earthquakes. This section reviews some of the significant works in this field.

2.1. Earthquake Data Analysis and Visualization using Big Data Tool (1)

The authors explored and presented a comprehensive analysis of earthquake data in India spanning from 1800 to 2014, emphasizing the use of Big Data techniques, particularly Hadoop Hive, for processing and interpreting large datasets. The inclusion of data visualization tools like Tableau and Power Map Add-Ins adds an extra layer of insight. Additionally, the paper proposes a future research direction involving the development of a predictive model for earthquakes using Big Data methodologies.

2.2. Visualizing Risk Remotely Triggered Earthquakes (2)

Another interesting study that used R and Mapbox to analyze and visualize the data of remotely triggered earthquakes. The author loaded earthquake data into R, calculated the Haversine distance from each earthquake to the main shock, filtered earthquakes based on time and distance, and wrote the data to GeoJSON files for further visualization. This study reflects on the challenges and successes of the project, including the use of Mapbox for geospatial analysis and visualization, and the difficulties of working on the project due to time constraints and lack of experience with JavaScript and web development.

2.3. Visual Analysis of Spatio-Temporal Earthquake Events (3)

The article explores the global landscape of earthquakes, focusing on their frequency and underlying causes. Noteworthy seismic belts, particularly the Circum-Pacific Belt, are highlighted, and the Richter Scale is introduced for magnitude assessment. While acknowledging real-time detection technology, the article proposes an innovative strategy for longer-term prediction utilizing data visualization. This involves mapping earthquake data not only by location but also by time. The visual exploration of spatio-temporal patterns seeks to promptly identify trends, contributing to a more profound comprehension of seismic activity and improved preparedness measures. By integrating data visualization techniques like maps and graphs, the research underscores the pivotal role of visual representations in unveiling patterns that have the potential to transform earthquake prediction capabilities and enhance life-saving measures.

2.4. National Seismic Hazard Model (4)

The National Seismic Hazard Model (NSHM), developed by the US Geological Survey (USGS), plays a crucial role in earthquake analysis and disaster preparedness across all 50 states. It integrates scientific insights on earthquake sources, faulting, and ground shaking to provide comprehensive seismic risk assessments. Updated periodically, the NSHM forms the basis for building codes, insurance rate structures, and is a valuable resource for public safety. The upcoming 2023 update will enhance ground motion models and focus on characterizing shaking in sedimentary basins. Beyond building design, the NSHM is expanding its utility to assess seismic risk for critical infrastructure, including pipelines, bridges, and dams. Ongoing research efforts explore earthquake scenarios, ground shaking effects, and multi-hazard interactions for comprehensive risk assessments.

2.5. Time Series Analysis on Earthquakes Using EDA and Machine Learning (5)

This article addresses the seismic threat posed by earthquakes and the imperative to mitigate associated risks through a data-driven analytical approach. The focus is on understanding earthquakes through time series analysis, encompassing two key steps: exploration and prediction. The exploration phase employs exploratory data analysis (EDA), incorporating descriptive statistics and data visualization techniques. In contrast, the prediction phase seeks to forecast the number of earthquakes in the future. The study conducts a comprehensive time series analysis utilizing various machine learning techniques on a global earthquake dataset spanning 1965-2016. The article concludes by presenting insights and lessons learned from the analysis, contributing to a more informed understanding of earthquake patterns and aiding in the development of effective risk mitigation strategies.

3. Project Description

The "Historical USGS Earthquake Analysis" project is an extensive investigation into seismic data recorded by the United States Geological Survey (USGS) from 1900 to 2023. This initiative involves two major phases: meticulous data processing through Tableau and the subsequent development of interactive dashboards. The primary aim is to uncover intricate patterns within historical earthquake occurrences, offering a comprehensive understanding of seismic activity dynamics.

3.1. Project Importance

Recognizing the significance of seismic activity comprehension is crucial for disaster preparedness and risk mitigation. This project highlights the critical role of historical earthquake data analysis in shaping informed decisions for emergency responses, safety measures, and community resilience. The recent seismic event in the Al Haouz region of Morocco serves as a poignant reminder of the urgency for thorough earthquake analysis.

3.2. Project Objectives

The overarching objectives of the project are:

Comprehensive Analysis: Conduct a comprehensive analysis of historical earthquake data reported by the United States Geological Survey (USGS).

Pattern Recognition: Identify subtle trends, patterns, and correlations within the seismic data to enhance understanding.

Spatial and Temporal Insights: Uncover spatial and temporal insights into seismic activity, exploring variations over geographic regions and time periods.

Interactive Dashboards: Develop user-friendly Tableau dashboards for intuitive exploration.

Contribution to Research: Provide valuable findings to the scientific community involved in earthquake analysis.

Public Awareness: Raise public awareness about seismic activities and their implications for safety and preparedness.

3.3. Data Importation and Cleaning Process

3.3.1. Data Importation

The project initiated with the acquisition of seismic data from the Kaggle dataset titled "Significant Earthquake Dataset 1900-2023." The dataset, conveniently available in CSV format, was seamlessly imported into Tableau Public. This step facilitated the quick and efficient transfer of the dataset for subsequent analysis and visualization.

3.3.2. Data Cleaning in Tableau

The data cleaning process in Tableau began with the handling of empty records, where any instances of missing or null values were identified and replaced to ensure the dataset's completeness. Subsequently, duplicates within the dataset were systematically identified and removed to enhance data integrity and eliminate redundancy. To refine the dataset and extract relevant information, new variables were created. For instance, from the "place" variable (e.g., "130 km SW of Tual, Indonesia"), a new variable named "Country/State" was generated by extracting only the country or state information. Key measures were then established to facilitate specific visualizations and analyses. These measures included "Total Earthquakes," showcasing the total number of earthquakes using the count function based on unique earthquake IDs, and "Top 10," a measure designed to filter and display only the top 10 records for specific visualizations. Additionally, essential seismic characteristics were captured through measures such as "Max Magnitude," "Max Depth," "Average Magnitude," and "Average Depth."

3.3.3. Data Exploration Using Excel

Insights Gain: Before diving into Tableau, preliminary insights were gained through data exploration using Excel's built-in data analysis tools. This step aided in understanding the dataset's structure, identifying potential variables for analysis, and aligning the data with project objectives.

Variable Selection: Based on insights gained during the data exploration phase, the project team strategically selected variables that would serve the project's objectives. This informed decision-making ensured a focused and effective approach to subsequent analysis and visualization.

3.4. Guiding Principles in the Data Visualization Design Process

Throughout the data visualization design process for this project, a set of guiding principles, influenced by "Data Visualisation: A Handbook for Data-Driven Design" by Andy Kirk (6), and incorporating key Gestalt Principles and Edward Tufte's principles, shaped the creation of visualizations. The first three principles emphasized the core aspects of good visualization design. Trustworthiness, the first principle, focused on reliability, transparency, and accuracy, ensuring that visualizations are both true and trusted, fostering confidence in the presented information. The second principle highlighted accessibility, tailoring visual representations to be easily perceived, interpreted, and comprehended, enhancing overall accessibility. Elegance, the third principle, struck a balance between aesthetics and functionality, creating visually pleasing and enduring visualizations without compromising trustworthiness and accessibility. In the final dashboard visualizations, Gestalt Principles played a crucial role, including Proximity for grouping related elements, Similarity for visually grouping similar elements, and Closure for holistic understanding of presented data. Additionally, Tufte's principles were adhered to, such as maximizing the Data-Ink Ratio to eliminate non-data ink and presenting high Data Density to ensure each pixel contributes meaningfully to the overall message.

3.5. Tools Utilized in the Project

The project seamlessly integrated a suite of professional tools, each playing a pivotal role in different stages of seismic data analysis and visualization.

- **Tableau Public** (7): Emerged as the primary data visualization tool, empowering the creation of interactive and informative dashboards.
- **Figma** (8): A leading design collaboration tool, instrumental in designing visually appealing and cohesive backgrounds for the dashboards, contributing to an enhanced aesthetic and user experience.
- **Kaggle** (9): A renowned platform for data science, served as the foundational source, providing the comprehensive "Significant Earthquake Dataset 1900-2023" that underpinned the project's analysis.
- **Excel** (10): A versatile spreadsheet software, with its built-in data analysis tools, played a key role in the initial exploration phase, facilitating the extraction of valuable insights from the dataset.

3.6. Visualizations Design and Rationale: Transforming Data into Insights

Our visualization approach seamlessly integrates spatial and temporal insights into seismic activity, utilizing geographic maps with additional layers of year and month filters. The color scheme highlights quake intensity, while data point sizes emphasize total quakes. Information bubbles offer details on average depth, magnitude, locations, and total quakes, striking a balance between trustworthiness, accessibility, and elegance, contributing significantly to our spatial analysis objective.

The line chart details annual earthquake frequency with month filters for temporal analysis, ensuring accuracy and simplicity. A divergent orange color scale aids trend identification, providing a comprehensive overview of earthquake frequency trends in historical seismic data.

For earthquake magnitude distribution, a bar chart with temporal analysis options and a divergent orange and blue color scale is employed, contributing to our objective of identifying patterns in seismic data.

Seismic activity patterns are explored using a line chart, focusing on time, depth, magnitude, and quake type. Quake types are distinguished by a color scheme, adhering to trustworthiness and accessibility principles.

Average magnitude distribution by earthquake type is presented in a pie chart, allowing detailed analysis through filters for year, month, quake type, and average magnitude. This visualization maintains trustworthiness and accessibility while offering insights into the distribution of average magnitudes across quake types.

The impact of earthquakes on the top 10 affected areas is highlighted in a horizontal bar chart, adhering to trustworthiness, accessibility, and elegance principles, offering an intuitive representation of earthquake impacts on specific areas.

The correlation between depth and magnitude is explored through a scatter plot with filters for temporal analysis, providing insights into the correlation between earthquake depth and magnitude.

Dynamic sheets for key metrics involve a series of visualizations focusing on total earthquakes, maximum magnitude, maximum depth, average magnitude, and average depth, contributing to the comprehensive analysis of seismic data while adhering to trustworthiness, accessibility, and elegance principles.

3.7. Dashboard design process

3.7.1. Find inspiration

During the initial stage of dashboard design, inspiration was drawn from diverse sources such as Tableau Public for insights into effective data presentation, Pinterest for visually appealing layouts and color schemes, and YouTube for practical insights into advanced Tableau functionalities. Leveraging these platforms aimed to assimilate best practices and creative ideas, enhancing the visual appeal and functionality of the forthcoming dashboards.

3.7.2. Device and Size Selection

In the second phase of dashboard design, optimization for desktop viewing was prioritized for a seamless and immersive experience. The chosen dimensions of 1500 pixels in width and 1000 pixels in height strike a balance between comprehensive data representation and a visually engaging layout, catering to users accessing the dashboards primarily from larger screens. This deliberate choice reflects an effort to ensure the effectiveness of seismic data visualizations while catering to the intended user experience.

3.7.3. Figma Integration for Dashboard Background Design

In crafting an immersive and visually engaging desktop dashboard, Figma played a pivotal role in designing background images. The decision to use Figma was based on its versatility and collaborative features, seamlessly integrating with Tableau for a cohesive user experience.

The selected light blue divergent color scheme, consciously chosen in Figma, aimed to create a visually pleasing and harmonious environment for users exploring seismic data. These calming tones enhance the overall user experience, fostering clarity throughout the exploration of seismic insights.

Meticulously crafted in Figma, each background image serves as a distinctive backdrop for a specific dashboard page. The Earthquake Overview Dashboard image emphasizes broad earthquake distribution, maintaining a balanced composition to highlight data visualizations. The Seismic Analysis Dashboard image complements analytical exploration, focusing on magnitude distribution and correlation patterns. The Project Overview Image, curated for neutrality, supports sections like Creator Insights and Dataset Details seamlessly.

In the dashboard implementation, navigation buttons play a crucial role, adopting a vibrant orange hue when selected for a clear visual cue. The dark blue sidebar, hosting the USGS logo, signifies the authoritative source of seismic data. Strategically placed navigation buttons enhance streamlined exploration, ensuring brand consistency and a visually appealing layout. Interactive filters within the dark blue sidebar contribute to an organized and efficient user interface.

The serene light blue background color sets a calm tone for seismic data exploration, while white backgrounds for each visualization section create clear demarcation and emphasize individuality, aiding visual clarity for an enjoyable user experience.

3.7.4. Designing Tableau Dashboards: Crafting a Visual Experience

In the meticulous crafting of Tableau dashboards, the integration of aesthetic vision and insightful data representation takes center stage. A pivotal aspect of this design process lies in the fusion of meticulously designed background images created in Figma. This integration not only adds a layer of visual cohesion but also serves as a foundational element for a user's immersive exploration of seismic data.

Earthquake Overview Dashboard

The Earthquake Overview Dashboard serves as a panoramic canvas, providing users with a comprehensive insight into earthquake distribution, temporal trends, and key affected areas. The carefully curated background image, designed in Figma, encapsulates the broad geographical scope of earthquake occurrences. A harmonious color scheme emanates a sense of clarity and ease, guiding users through the selected visualizations, including the Geographic Map, Annual Earthquake Statistics (Time Series), Top 10 Affected Areas, and Dynamic Sheets for Key Metrics.

Seismic Analysis Dashboard

Delving into the intricate layers of seismic analysis, this dashboard explores magnitude distribution, correlation patterns, and seismic behavior. The backdrop, intricately designed in Figma, complements the analytical nature of the dashboard. As users navigate through the Dynamic Sheets for Key Metrics, Magnitude Distribution, Correlation between Magnitude and Depth, Seismic Activity Patterns, and the Pie Chart illustrating Average Magnitude Distribution by Earthquake Type, the background image provides a visually engaging context to the seismic insights.

Project Overview Dashboard

Beyond the seismic data, the About the Project page acts as an informational nucleus. The background image, meticulously curated in Figma, offers a neutral and informative canvas for users to explore Creator Insights, delve into Dataset Details, and understand Project Objectives. The deliberate use of Figma in crafting these background images ensures a seamless visual transition between the different facets of the project.

3.7.5. Design Justification: Prioritizing User Experience for Seamless Seismic Exploration

The choice to center the Tableau dashboards around the user experience is grounded in the principles of user-friendliness, self-explanatory design, and an overall commitment to accessibility and engagement. This approach aligns with the overarching goal of making the seismic data accessible and understandable for a diverse audience.

User-Friendly Design: The dashboards are crafted with a user-centric mindset, prioritizing ease of navigation and interaction. The user-friendly design ensures that individuals, regardless of their familiarity with seismic data analysis, can intuitively explore and comprehend the visualizations. Navigation buttons and clear sections guide users seamlessly, empowering them to navigate the dashboards effortlessly.

Self-Explanatory Visualizations: Visualizations within the dashboards are designed to be self-explanatory, reducing the need for extensive guidance or external assistance. Each chart and graph is thoughtfully labeled, and tooltips provide additional information, enhancing user understanding. This approach ensures that users can interpret seismic insights independently, fostering a sense of empowerment and engagement.

Intuitive Exploration: The dashboards are structured to facilitate an intuitive exploration of seismic data. By incorporating interactive elements, such as dynamic sheets and user-friendly filters, individuals can tailor their exploration based on specific timeframes or parameters of interest. This intuitive approach empowers users to customize their experience, making the dashboards adaptable to various levels of expertise.

Clear and Concise Information: Emphasis is placed on presenting information in a clear and concise manner. The chosen visualizations, accompanied by minimalistic yet informative backgrounds, contribute to a dashboard layout that avoids overwhelming users with unnecessary details. This simplicity promotes a focused and effective communication of seismic patterns and insights.

Engaging User Journey: By integrating Figma-designed backgrounds, the dashboards provide an engaging visual journey. The background images, carefully chosen to complement each page's theme, contribute to a cohesive and aesthetically pleasing environment. This design choice enhances the overall user experience, making the exploration of seismic data not just informative but also visually enriching.

4. Evaluation

Within this section, we embark on a thorough evaluation of our developed Earthquake Dashboard. Our primary focus lies on assessing the functionality, usability, and reliability of the dashboard through key testing methodologies. This evaluation encompasses rigorous testing of filters and interactions, validation of buttons and links, cross-verification for data accuracy, and consideration of performance metrics. Through these focused evaluations, our objective is to gain insights into the dashboard's strengths, identify areas for potential improvement, and ensure its alignment with the overarching research goals.

4.1. Filter and Interaction Testing

The evaluation process included rigorous testing of filters, focusing on the application of year and month filters to all visualizations, excluding those displaying the year as a variable. The primary objective was to verify the correct functionality of the filters, ensuring accurate data filtration based on the selected year and month. For example, applying a year filter should exclusively present earthquake data for that specific year, while a month filter should narrow down the displayed data to the chosen month. The importance of accurate filter functionality lies in preventing the presentation of erroneous data, thereby avoiding potential misinterpretations.

4.2. Button and Link Validation

Another crucial aspect of the evaluation involved comprehensive testing of buttons and links to guarantee their accuracy in leading users to the intended destinations and performing expected actions. Ensuring the seamless functionality of buttons and links was paramount to preventing user confusion and fostering an effective user experience. Furthermore, the evaluation extended to hovering over data visualizations to retrieve information about specific data points. For instance, hovering over a data point in a seismic activity pattern visualization should yield accurate information about that particular pattern.

4.3. Cross-Verification for Data Accuracy

To make sure the information shown on the dashboard is correct, we double-checked what we found while using the dashboard. We compared this with the original data source to confirm that the graphs and charts on the dashboard matched the real information. This careful process helped the team be sure that the filters, buttons, and links in the dashboard work well, giving users a reliable and easy experience when exploring the data.

4.4. Performance Metrics

In the performance metrics testing, the memory usage of the Historical Earthquake Dashboard was found to be 170 MB. This indicates that the dashboard is efficient in terms of memory usage, which is crucial for maintaining a smooth and responsive user experience. However, it's important to note that the memory usage can increase under heavy load or when handling large datasets. The load time of the dashboard was measured to be approximately 4 seconds. This is a reasonable load time considering the complexity and amount of data being handled by the dashboard. However, it's worth noting that the load time can vary depending on the user's internet connection speed. Faster connections will generally result in quicker load times. The response time to user input was measured to be around 3 seconds. This is a relatively fast response time, which contributes to a smooth and intuitive user experience. However, it's important to keep in mind that response times can be affected by various factors, including the complexity of the user input and the current load on the server. All these tests were conducted using Google Chrome, a widely used web browser known for its speed and efficiency.

5. Discussion

While our current study strives to unravel the complexities of earthquake analysis, it is crucial to acknowledge certain limitations and outline potential areas for improvement and considerations for future investigations.

Our analysis is contingent on the quality and completeness of the data provided by the USGS, introducing potential challenges related to data accuracy and completeness. Additionally, the spatial and temporal resolution of our dataset may constrain the detailed analysis of seismic events. The focus on data reported by the USGS also presents a limitation in terms of geographical scope.

Future studies could explore avenues to enhance data visualization techniques, considering more advanced features or interactive elements to provide users with a richer experience. The integration of multidisciplinary data, encompassing geological and environmental factors, could contribute to a more holistic understanding of earthquake dynamics. Furthermore, the potential inclusion of real-time monitoring capabilities in the dashboard could improve its utility and responsiveness.

As we move forward, these considerations offer a roadmap for refining and expanding the scope of our research. By embracing these potential improvements, future studies can contribute even more profoundly to our understanding of seismic events and, consequently, enhance global resilience to earthquake-related challenges.

6. Summary and conclusions

In summary, the "Historical USGS Earthquake Analysis" project has been a journey of exploration and innovation, driven by the pursuit of deeper insights into seismic activity dynamics. From meticulous data processing to the creation of interactive dashboards, every step of this project has been guided by a commitment to advancing earthquake analysis and enhancing public awareness. Throughout our endeavor, we have strived to ensure that our visualizations not only convey complex seismic data effectively but also provide a seamless and engaging user experience. By drawing inspiration from various sources and adhering to user-centric design principles, we have crafted dashboards that offer valuable insights into historical earthquake occurrences. While our project has contributed to the scientific discourse on earthquake analysis, it also highlights areas for future research and improvement. Addressing challenges such as data accuracy and geographical limitations will be essential in further refining our understanding of seismic activity. By continuing to explore new methodologies and technologies, we can further advance our understanding of seismic events and ultimately contribute to building more resilient communities worldwide.

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