Interactive Globe: A 3D Visualization Tool for Understanding Global Financial Trends

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Abstract

This paper presents an innovative three-dimensional (3D) interactive globe visualization tool, specifically developed to address the limitations of traditional two-dimensional (2D) data visualization techniques commonly used in financial analytics. While existing methods, such as the Bloomberg Terminal's [1] 2D maps and the Finviz [2] website's heatmaps, provide a basic geographical context and an intuitive interface for tracking stock performance, they lack the depth needed to explore complex global financial interactions and dynamics comprehensively. These conventional approaches, although effective for static snapshot analyses, fail to illustrate the interconnectedness of global markets and the spatial distribution of financial trends effectively.

In response, the proposed 3D interactive globe leverages orthographic projection and D3.js technologies to offer a dynamic, immersive experience that aligns with natural human cognitive processes for spatial recognition and interaction. This tool allows users to manipulate a virtual globe to explore global financial indices with enhanced spatial awareness, highlighted by color intensities that vary according to financial performance. This visualization not only simplifies the complexity of global financial data but also provides a platform for a real-time, intuitive understanding of how regional events affect the global economic landscape. By integrating and expanding upon the shortcomings of existing 2D methods, this paper demonstrates the potential of 3D visualization in transforming the analysis and interpretation of complex financial datasets, offering a more detailed and comprehensive view of worldwide financial markets.

1 Introduction

In the dynamic field of data visualization, the quest to represent complex datasets in a manner that is both richly informative and intuitively understandable is increasingly critical. This challenge is particularly pronounced in the visualization of financial data, where traditional two-dimensional (2D) representations, despite their widespread usage, often fall short in their ability to convey the nuanced intricacies of financial metrics and trends. The limitations of 2D visualizations are primarily rooted in their tendency to require extensive interpretation and their frequent inability to capture and communicate the spatial relationships and patterns that are crucial for comprehensive analysis.

In response to these limitations, this project introduces a novel approach to financial data visualization: the implementation of a three-dimensional (3D) interactive globe with orthographic view. This globe, which forms the central feature of our visualization interface, revolutionizes the way users interact with financial data. Unlike the flat, often static nature of 2D representations, the 3D globe offers a dynamic, immersive experience that aligns more closely with human cognitive processes, enabling a more natural and intuitive exploration of data.

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The superiority of 3D visualization lies in its ability to present data in a format that mirrors the real-world context in which financial events occur. By situating financial data within a 3D geographical framework, this approach provides a holistic view of global market trends, regional economic indicators, and multinational corporation performances. Users can perceive and understand the interconnectedness of global finance, seeing firsthand how changes in one region can ripple across the globe. This spatial awareness is critical in financial analysis, allowing for a deeper understanding of market dynamics and facilitating more informed decision-making.

Moreover, the interactive nature of the 3D globe empowers users to engage directly with the data. Through manipulation of the globe – rotating, zooming, and dragging – users can explore different geographical regions and uncover layers of financial information that are not readily apparent in 2D maps. This interactivity extends beyond mere data exploration; it invites users to probe deeper, to uncover trends, patterns, and anomalies, rendering the data not just visible, but truly comprehensible.

In conclusion, transitioning from a flat, 2D paradigm to an immersive, 3D experience fundamentally transforms the visualization and analysis of complex financial data. This visualization method enhances not merely the aesthetic appeal of data representation but revolutionizes the interaction with and comprehension of financial information. By incorporating a 3D globe into our visualization tool, users gain an immediate spatial awareness of global financial dynamics. This comprehensive view allows for a simultaneous observation of diverse financial markets and their interactions across the globe, highlighting correlations and impacts that might remain obscured in traditional 2D presentations. The subsequent sections of this report will explore related work in this domain, outline the technical approach, present experimental results, and discuss the broader implications and future directions for 3D visualization in the field of finance.

2 Related Work

The field of financial data visualization has predominantly utilized two-dimensional (2D) representations to convey complex financial information. For instance, the Bloomberg Terminal [1] [5] integrates a 2D map interface that visually represents the gains and losses of stocks or indices within specific regions. This method offers an intuitive geographical context but is limited in its ability to capture intricate global financial interactions. Similarly, various platforms employ heatmaps where the size of each square correlates to the market capitalization of stocks, using a color scheme to indicate performance—green for gains, red for losses, and gray for stagnation. While effective for snapshot analyses, this approach lacks the depth required to fully understand broader market dynamics.

Further blending geographic and financial data, the Finviz [2]website enhances the traditional heatmap by overlaying it onto a world map. This combination provides a spatial representation of market performance across different regions, offering a clearer picture of how financial trends distribute geographically. Although these 2D visualizations have been instrumental, they can obscure more complex data relationships and patterns critical for deeper financial analysis.

Contrasting with these traditional methods, innovative uses of three-dimensional (3D) visualizations in other fields demonstrate the potential for enhanced data representation. For example, Denise Lu's [4] project utilizes a 3D orthographic view of the world to show the paths of lunar eclipses over centuries, offering a global perspective that adds depth and context to the viewer's understanding. In a similar vein, the Highcharts library [3] employs a 3D orthographic globe to represent population density with heatmap patches, where color intensities vary according to the population concentration. These applications illustrate how 3D visualization can provide a more immersive experience, making complex spatial relationships such as concentration distribution to be understand easier and more intuitively accessible.

Adopting such 3D visualization techniques for financial data could transform how analysts and investors perceive and interact with information. Implementing a 3D orthographic view in financial contexts, particularly in analyzing the impact of recent global events, could reveal new insights into regional disparities and interconnections. This method offers a comprehensive view that not only enhances aesthetic appeal but significantly enriches the analytical depth, enabling a more nuanced understanding of global financial markets. Thus, leveraging 3D visualization promises to uncover patterns and correlations that may remain hidden under conventional 2D approaches, providing a superior tool for financial analysis in an interconnected global economy.

3 Approach and Technical Correctness

3.1 Data Sources and Technologies on 3D Globe View

The primary dataset for the 3D visualization project, which represents geographic location of the regions, originates from a comprehensive JSON file detailing numerous countries with their geographic features and coordinates. The JSON format facilitates the description of countries using polygons, which simulate the appearance of a globe with detailed edges along latitudes and longitudes. This method of representation enhances the realism and accuracy of the 3D visualization by closely mirroring the Earth's topographical features.

Adjustments were made to the original dataset to increase geographic accuracy and add detailed data, such as the coordinates of major cities where the indices are centered on. These cities are represented by circles on the globe. The original plan was to vary the size of these circles based on the market cap size of each index. However, due to time constraints, this feature was reserved for future development, allowing potential enhancements in how the size magnitude of each index can be visually interpreted.

3.2 Data Sources and Representation on Indices' Return

The main data underpinning the visualization of global market trends are sourced from Investing.com, encompassing comprehensive coverage of major global indices spanning from January 2015 to April 2024. The choice of using monthly return data in our visualization project balances detail with clarity. Daily and weekly data, while precise, tend to overwhelm with their volume and noise, obscuring long-term trends. Moreover, it would be hard to identify historical trends by seeing the condition of 1-day window. Conversely, yearly data aggregates too many events, losing the nuances of shorter-term economic shifts. Monthly returns provide a suitable middle ground, offering a clear view of significant trends without the excessive granularity of daily data or the overgeneralization of annual data. This approach aligns well with the goal of the project which is to ease the process of identifying global market trends. Then, to facilitate the integration and compatibility with the visualization tools, return data that were only available in CSV format were converted to JSON format using Python scripts. This conversion process ensures seamless interoperability with D3.js and other components of our visualization framework.

The monthly return data from Investing.com are pivotal for analyzing market trends and forecasting future movements in global financial markets. These returns provide insights into the performance of various indices, offering a quantitative basis for comparison and analysis across different geographies and time periods. The returns for each index are calculated using the following formula, where R_t represents the return at time t, P_t is the index level at time t, and P_{t-1} is the index level at the previous time point:

$$R_t = \frac{P_t - P_{t-1}}{P_{t-1}}$$

This formula yields the relative change in the index level from one period to the next, expressed as a percentage. The calculation is straightforward yet powerful, allowing investors and analysts to track the performance of indices over time, adjusting for the scale of the index.

Then, Table 1 provides the listing of major global stock market indices used in this project, alongside their corresponding countries or regions. It includes prominent indices such as the NASDAQ from the United States, the Nikkei from Japan, and the Shanghai Composite from China, among others. Each entry in the table pairs an index with its geographical location, serving as a reference for users to identify and analyze the financial data specific to these regions within the visualization project.

Country/Region	Index
China	Shanghai Composite
Japan	Nikkei
United States of America	NASDAQ
Australia	ASX
Brazil	Bovespa
France	CAC
Germany	DAX
United Kingdom	FTSE
Hong Kong	Hang Seng
South Korea	KOSPI
Mexico	BMV
Indonesia	Jakarta
India	Nifty
Russia	MOEX
Netherlands	AEX

Table 1: Corresponding indices and their countries or regions

These data setup form the backbone of our project which will enable a dynamic and interactive visualization that brings global financial markets to life. By applying these formulas within our 3D globe interface, users can not only observe but interact with the data, gaining a deeper understanding of how global events and economic shifts influence financial indices. Ultimately, this project sets a new standard for how financial data can be visualized and understood in an increasingly interconnected world.

3.3 Data Integration and Visualization Techniques

3.3.1 Data Integration

The project mainly utilize the power of D3.js, especially its `d3.geoOrthographic` module to craft an immersive 3D-like view of the Earth. This module is critical for projecting the world in a way that mimics a globe, providing users with a more realistic and interactive visualization experience. The implementation involves several key steps:

- **Setting up the projection:** An orthographic projection is initialized with specific settings to optimize the view of the globe. The projection is set to a scale of 295 to fit within the SVG container perfectly and translated to the center of the width and height to ensure it is centered on screen. The clip angle is set at 90 degrees to limit the view to one hemisphere at a time, enhancing the globe's 3D effect.

- **Path generation:** A path generator is created using `d3.geoPath()`, which is configured to use the defined orthographic projection. This generator is crucial for drawing the geographic features on the SVG based on the GeoJSON data.

- **Loading and rendering GeoJSON data:** The GeoJSON data, which includes the geographic outlines of countries, is loaded asynchronously using D3's `d3.json()` function. Once loaded, the data is used to draw the spherical background and each country's borders on the globe. Each country path is individually appended to the SVG and styled accordingly.

- **Integrating Financial Data with Globe Visualization:** As financial indices data is mapped to corresponding countries, the `getColorForChange()` function dynamically adjusts each country's color based on its financial performance. The color intensity reflects the magnitude of changes: for gains, green intensifies with increasing positive returns, becoming brighter for larger gains and darker as gains approach zero. Conversely, for losses, red deepens with increasing negative returns, turning brighter with larger losses and darker as losses diminish towards zero. This nuanced color coding provides an intuitive visual cue of market trends, enhancing the user's ability to quickly assess and interpret complex global financial dynamics.

- **Event Listener for Interactive Time Control:** An event listener is attached to a temporal slider, enabling users to select specific times for data visualization. This slider controls the time frame of the displayed data, allowing users to observe historical and current market trends. The `updateVisualization()` function updates the globe with new data each time the slider is moved, reflecting the financial changes at the selected time. This functionality not only increases user engagement by providing control over the data display but also enhances the analytical depth by showing temporal changes in market conditions.

Together, these elements form a sophisticated system that not only visualizes but also facilitates the manipulation of a 3D globe, enabling an interactive exploration of the complex interplay between geographical and financial data. By integrating these components, the project supports a deeper understanding of how global events and economic shifts influence financial indices, setting a new standard for visualizing financial data in an interconnected world.

3.3.2 Interactivty Functionalities

To enhance user engagement and analytical flexibility, the project incorporates several key interactive functionalities within the globe visualization interface. Firstly, a drag function is implemented, allowing users to click and drag to rotate the globe across a full 360-degree axis. This functionality empowers users to view the Earth from any vantage point, facilitating a comprehensive global perspective or focusing on specific geographical regions of interest.

Secondly, the interface includes zoom capabilities, enabling users to either zoom in for a more detailed examination of financial trends within a particular region or zoom out to obtain a broader, more general overview of global market activity. This feature is crucial for adjusting the scale of observation, allowing users to tailor the visualization to their specific analytical needs.

Lastly, a temporal slider has been integrated into the interface. This slider acts as a date input tool, permitting users to select specific time instants for analysis. By moving the slider along a timeline, users can dynamically change the displayed data to reflect financial trends at chosen moments. This temporal control is essential for conducting time-series analyses, observing how financial indices have evolved over time, and identifying patterns or anomalies in the data corresponding to historical events.

Together, these interactive elements not only enhance the usability of the visualization tool but also significantly deepen the user's ability to analyze and interpret complex financial data in a spatial-temporal context. The combination of dragging, zooming, and temporal sliding creates a rich, user-driven exploration environment that caters to both novice users and financial experts.

4 Experimental Results and Technical Correctness

This section explores the experimental outcomes and evaluates the technical accuracy and efficiency of the developed 3D globe visualization tool. The findings are presented in four main subsections: practical application scenarios of the visualization, a shallow theoretical performance analysis of the system, possible evaluation methods, and limitations as well as the potential future work.

4.1 How to Run the Code Locally

Before delving into the experimental results, it is possible for one to run the visualization tool on their computers locally. The following steps outline the process to set up and execute the code using Visual Studio Code:

- Download the ZIP file containing the source code from the provided repository.

- Unzip the downloaded file to a local directory of your choice.

- Open the Visual Studio Code application. If not already installed, download and install it from the official website.

- In Visual Studio Code, open the folder where the source code was unzipped.

- Open `index.html` file in one of the editors, then right-click on the editor, and select `Open with Live Server`. This action requires the Live Server extension, which can be installed from the Visual Studio Code marketplace if not already available.

- Upon executing the above step, one's default web browser will automatically launch and display the 3D global view of the financial data visualization project.

4.2 Intended Application of the Visualization

The 3D globe visualization serves as an essential tool for finance and economic professionals as well as enthusiasts interested in analyzing the performance of stock indices following major global events. For instance, to understand the impact of the COVID-19 pandemic on the global financial markets, users can navigate to the early months of 2020 using the timestamp slider. By specifically examining the situation in February or March 2020, users can visually perceive the extensive losses experienced globally, as evidenced in Figure 1 by the prevalence of red hues across the regions on the globe. This intuitive color coding highlights significant downturns in market performance, offering users a vivid representation of the pandemic's immediate financial effects. This functionality not only provides a rapid visual assessment of market conditions but also facilitates a deeper analysis of economic repercussions during critical periods.

A further example of using this visualization involves examining the recovery phase of financial markets post-COVID-19. Users interested in assessing the speed and nature of the market rebound after the initial shock can advance the timestamp slider to later months in 2020 or early 2021 (see Figure 2). This analysis helps in distinguishing whether the market experienced a sustained recovery, marked by consistent green hues indicating gains across various

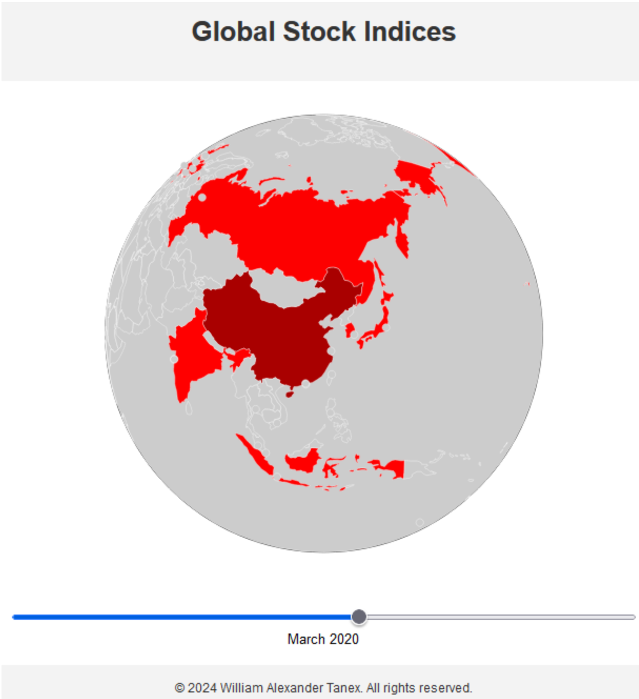

Figure 1: Indices Performance on March 2020

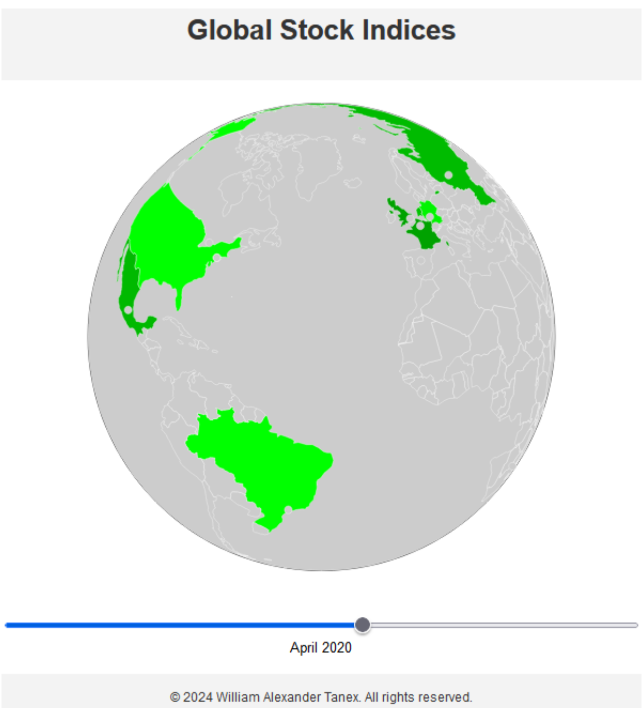

Figure 2: Indices Performance on April 2020

regions, or if it was merely a series of corrections without genuine recovery. For instance, by moving the slider to view the market conditions in September 2020 (see Figure 3) and comparing it to the conditions in early 2020, users can effectively track the transition from widespread economic downturns to potential recoveries or further declines. This capability allows users to critically evaluate whether the rebounds were robust and justified by market fundamentals or if they were short-lived corrections influenced by transient factors. Such insights are invaluable for making informed decisions regarding future investments or economic strategies.

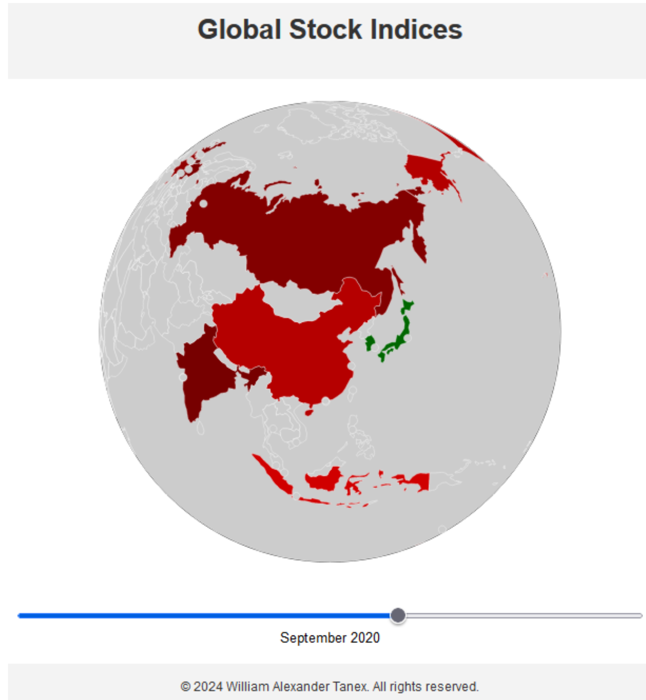

Figure 3: Indices Performance on September 2020

4.3 Theoretical Performance Analysis

Currently, the visualization tool processes and displays monthly return data from January 2015 to April 2024 for 15 major global indices. Given this setup, each index is represented by 112 monthly return data points. This relatively modest dataset size allows for quick data processing and responsive interactions within the visualization platform, ensuring a seamless user experience.

As the project progresses towards full development, it is anticipated to include up to 1000 indices globally, with each country potentially represented by at least two indices. Even with an expanded dataset of 1000 indices, each still having monthly data, the system is designed to remain scalable and perform efficiently. The calculated load will manage the visual representation swiftly, maintaining system responsiveness.

However, looking forward to more sophisticated enhancements, such as the incorporation of daily return data and adjustable time ranges for return calculations, performance could become a concern. Processing daily data significantly increases the volume of data points, which could impact the responsiveness of the system. As users adjust the time range for analyzing returns, the system must dynamically calculate and render new data sets in real-time, which requires robust backend computation and optimized data handling strategies to maintain performance.

These experimental results and technical assessments indicate that while the current setup of the visualization tool is efficient and effective, future enhancements aimed at increasing data granularity and user control will require careful consideration of performance optimization strategies to ensure the tool remains fast and responsive.

4.4 Proposed Evaluation Method

To rigorously assess the potential of the novel 3D globe visualization method for financial data, a comprehensive evaluation approach is proposed. This evaluation will focus on several key aspects to determine the method's effectiveness and user engagement compared to traditional 2D visualizations. Here are the proposed methods of assessment:

- **User Experience Surveys:** Conduct surveys among a diverse group of users, including financial analysts, educators, and casual users, to gather feedback on the usability, intuitiveness, and overall experience of the 3D globe visualization. Questions will focus on the ease of understanding complex financial trends, the usefulness of interactive features, and overall satisfaction with the interface.
- **Comparative Analysis and Usability Testing:** Conduct a comprehensive assessment by comparing the 3D visualization tool with an existing visualization method that uses a similar number of channels in a comparable manner, alongside arranging side-by-side testing sessions. These sessions will involve participants using both the traditional 2D and the novel 3D visualization tools to perform specific tasks, such as identifying trends, predicting market changes, or retrieving data about specific indices. This comparative analysis will not only measure the time taken to complete these tasks and the accuracy of the task outcomes but also focus on the effectiveness of channel utilization and how well each method conveys complex financial data. The results will help highlight the unique advantages or potential areas for improvement in the 3D visualization, providing insights into the user's subjective ease of use and overall engagement with each method.
- **Analytical Performance Metrics:** Use built-in analytics to track how users interact with the 3D globe. Metrics such as the number of interactions per session, the average duration of use, and frequency of use can provide quantitative data on user engagement and preference for the 3D method over traditional methods.
- **Expert Reviews:** Invite domain experts in finance and data visualization to review the tool. Expert reviews can provide insights into the scientific accuracy, market relevance, and innovation level of the visualization method, offering a professional perspective on its potential impact in real-world scenarios.

By implementing these diverse evaluation methods, the project can effectively measure the potential and performance of the 3D globe visualization in enhancing the understanding and analysis of global financial data, thereby proving its value over traditional visualization techniques.

4.5 Limitations and Future Work

This project has established a strong foundation for the 3D visualization of financial data, yet several limitations have been identified that provide opportunities for further development. One significant issue is the accuracy of geographic data; some countries have incorrect coordinates, leading to issues like abstract boundaries and the notable absence of a major country like Australia in the visualization. Future revisions will need to focus on adjusting and verifying geographic data to correct these inaccuracies.

Additionally, the current visualization covers only some major global indices, resulting in many regions appearing grey and undeveloped on the globe. This lack of data detracts from the visualization's potential to provide a truly global perspective. Expanding the coverage to include more indices and thereby illuminating more regions on the globe is a critical area for future development.

Originally, the project planned to incorporate a hover function that would allow users to see detailed data about indices when hovering over countries. Due to time constraints, this feature was not implemented but remains a priority for enhancing user interaction by providing instant insights into specific data points.

Another potential improvement involves varying the size of the circles that represent the indices to reflect their market cap size, which would visually convey the magnitude of their impact or returns more effectively. This feature would add a significant depth to the visualization, allowing for a more nuanced understanding of market dynamics.

Furthermore, introducing a comparison view for two indices at a single time instant would offer invaluable insights, especially during critical global events like the COVID outbreak in March 2020. Users could select two indices by clicking on the countries in the globe, initiating a side-by-side detailed comparison to analyze the differential impacts of such incidents on various markets.

Lastly, there is an opportunity to enhance the dataset by allowing users to select the date range for calculating returns, instead of being restricted to monthly returns. This flexibility would enable users to tailor the visualization to specific analysis needs and time frames, greatly enhancing the tool's utility and adaptability.

These enhancements would not only address the current limitations but also significantly expand the capabilities and reach of the visualization tool, making it a more powerful and comprehensive platform for financial analysis.

5 Conclusion

The development of the 3D interactive globe visualization tool represents a significant advancement in the field of financial data analysis. This innovative approach has demonstrated substantial improvements over traditional 2D visualizations by enabling a more intuitive and holistic exploration of complex financial landscapes. The tool's ability to project global financial indices in a three-dimensional space allows analysts and enthusiasts alike to perceive market trends and correlations across different regions with unprecedented clarity. The integration of interactive functionalities, such as zooming, rotating, and time-lapse features, further enriches the user experience, making it possible to track changes over time and understand the global impact of regional events on financial markets.

Looking forward, the application of this 3D visualization technology holds promising potential for broader adoption in various financial and educational settings. As the tool continues to evolve, incorporating real-time data feeds and expanding the range of indices represented could significantly enhance its utility and accuracy. Moreover, future developments could include more sophisticated analytical tools within the interface, allowing users to perform detailed comparative analyses directly within the visualization. These enhancements will undoubtedly solidify the role of 3D visualization in transforming data into actionable insights, thereby supporting more informed decision-making in the ever-complex domain of global finance.

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