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Navigating Through World's Military Spending Data with Scroll-Event Driven Visualization

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A master's capstone project submitted to the Graduate Faculty in Data Analysis & Visualization in partial fulfillment of the requirements for the degree of Master of Science, The City University of New York

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APPROVAL

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ABSTRACT

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Catching up with the current geopolitical event is more important than ever these days. Anti-western nations like Russia, China, Iran, and North Korea constantly challenge the world order set by the United States and its close allies. As a result, the world has seen a rise in military spending consecutively for the last several years. This data visualization project aims to provide an easy-to-read summary of military spending data published by the Stockholm International Peace Research Institute for hotly conflicted regions: East Asia, Europe, and the Middle East.

Scroll-event-driven visualization implemented using Scrollama.js and D3.js combines text, map, and data graphics to provide insight observable from the military spending data set. Also, this project explores the potential of interactive data visualization taking a new role, replacing contemporary printed media by emphasizing graphical elements rather than text in communicating complex ideas.

ACKNOWLEDGEMENTS

I would like to send special thanks to my advisor Ellie Frymire in seeing me through this project and guiding me and other number of students through the world of interactive data visualization.

Thanks to Katherine Behar for introducing me to the art of data visualization, Jason Nielson for always being there to answer all the questions, and Director Matthew K. Gold and rest of the faculties for putting together a great program that is so valuable.

Lastly, very special thank you to my family, my one and only Jiin Lee, and my lovely daughter Irene Hur for patience and support to cheer me throughout this academic career. The world will be a very different place without you pumping life into me.

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TECHNICAL SPECIFICATION

The webpage hosting the visualization is available at https://hhur0104.github.io/data_vis_capstone with the code repository https://github.com/hhur0104/data_vis_capstone

The project was build using HTML, CSS, and JavaScript. Third party libraries are acquired at the time of rendering on end user web browser through CDN addresses. No additional installation is required to access the project.

The project is tested on using Safari and Chrome web browsers. Other web browsers may render the project as intended though not tested. Also, this project is intended only for wide screen monitors and is not designed for small screen devices such as phones and tablet.

The repository contains all source codes and data files needed for the visualization. These include modified military spending data sets in .CSV format along with a .R script file that has procedural code used to modify data sets, 'world-110m.topo.json' that contains geographical information to render the world map, an index.html file, five JavaScript files ('main.js', 'worldmap.js', 'trendCurve.js', 'stickyBar.js', and 'naviBar.js') that render objects in the visualization.

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Introduction

The world is changing fast, making it more difficult for ordinary people to catch up. The world has a lot to catch up on; the social life after the pandemic, inflation, the fear of upcoming economic recession, climate changes, or the development of ChatGPT and myriads of AI solutions. The list can go on. Politics and the relationships between nations also needs attention. Because it can involve military actions, it is quite possibly the issue that can most devastatingly affect ordinary people. Often the decisions are made by only a few people given that the success of military action relies on secrecy. Recently, there have been some troubling developments in geopolitics around the globe. The Russian invasion of Ukraine is pushing Europe to re-armament. China is growing its military capacity and is on the pathway to exert dominance in East Asia. In the Middle East, ongoing civil wars and political uprisings introduce uncertainties in the power balance game. To set the tone and context of this project before proceeding into the description of it, the following is a summary of the current geopolitical state.

Current State of Geopolitics: Chinese Threat

After the fall of the Soviet Union in 1991, the world order led by the United States of America and its close allies brought a period of globalization.[1] Soon after, other socialist countries like China opened the door to adopt capitalism and get access to the world market.[1] Under the shared goal of prosperity, countries and businesses cooperated with each other and made business networks and arrangements without concerning too much political and security concerns. China assumed the role of the world's factory and manufacturer under this new model.[2] China's economic development had afforded its military capability to grow and embolden the Chinese

Communist Party (CCP) to take bold geopolitical stances starting in the 2010s. Particularly in the South China Sea, CCP is engaging in maritime boundary disputes with the neighboring countries[3] and has displayed its intent to continue its reunification effort with Taiwan.[4] This development is alarming to other economically developed East Asian countries like Taiwan, Japan, and South Korea, as these countries rely heavily on crude oils coming from the Persian Gulf through the South China Sea route.[5] Not only that, the coronavirus pandemic in 2020 alerted the U.S. of its vulnerability in manufacturing capability and supply chain reliance on China.[6]

Nevertheless, the U.S. has no shortage of friends to unite its effort to fight these challenges from China in the region. The U.S. regularly conducts joint military training with its Major Non-NATO Allies like the Philippines, Thailand, Japan, and South Korea.[7] Also, it organized the Quadrilateral Security Dialogue, also known as Quad [8], consisting of three other member countries, Australia, India, and Japan, in 2017. The U.S. has been engaging in an economic war against China since then with a coalition effort with most of its allies. This has continued in Biden-Harris Administration. White House published National Security Strategy declaring out-competing China as its foremost priority in its global agenda.[9] And published CHIPS and Science ACT to go along with the effort to isolate China in global high-tech supply chain networks.[10]

Current State of Geopolitics: Russian Invasion

In February 2022, Russia invaded Ukraine for the second time since the annexation of Crimea in 2014. The Russian official narrative of the invasion is to neutralize the neo-Nazi movement in Ukraine.[11] There are many different views to explain why Russia invaded Ukraine, one of which is Russia's frustration against the NATO / EU expansion in Eastern Europe.[11] The exact reasons leading up to both invasions may be debatable, but what is undeniable is the rise of

military alertness in Europe following both invasions. After the fall of the Soviet Union and disband of Warsaw Treaty Organization among socialist nations in Eastern Europe, Europe went through a period of demilitarization, and most countries significantly decreased their military budget.[12] However, after the annexation in 2014, the trend curve is continuously on an upward slope.[13] Since War broke out in 2022, traditionally, more neutral countries like Swiss and Finland have newly flocked to join NATO.[14] More countries pledged to increase their military budgets and support for Ukraine's defense.[14] As a major participant in NATO, the U.S. also pledged massive military aid to Ukraine to support its defense effort. Frustrated with the pace of invasion and sanctions imposed, Putin even flirted with the idea of using nuclear weapons.

Current State of Geopolitics: Chaos in Middle East

The geopolitical tension in the middle east is nothing short of complex. True to its name, the Middle East, as the cradle of civilization, has a history of struggle that goes back thousands of years. Its proximity to Europe and the history of western powers meddling in regional conflicts involving its rich oil reserves add another layer of complexity to the problems. Recently, in the 2010s, many countries in the middle east went through a revolution called Arab Spring that caused political havoc for many countries and led to civil unrest and sometimes outright civil war.[15] There are also opinions that Russia is aggravating the situation in the Middle East by supporting factions favorable to Russian interests to create a political burden and disrupt solidarity in Europe by inducing human rights and refugee crises.[16] Also, the formation of rogue organizations like ISIS created another security concern in the region. In 2021, after 20 years of war, the U.S. pooled out from Afghanistan only to witness the Taliban regime regain control.[17] Based primarily on religion, Iran and Saudi Arabia have struggled for many years, leading to countless drone and terrorist

attacks on each other. Similarly, Israel and Palestine have been clashing with each other on border and territory disputes for years.

Motivation for the project

This project is greatly motivated by personal curiosity about the current state of geopolitics. In *The Absent Superpower*, Peter Zeihan[16] lays out how the energy independence the U.S can gain from the shale revolution will diminish its interest in policing the world and ultimately bring chaos and changes in geopolitics caused by the absence of security alignment U.S set forth during the cold war with its unmatched military capability. He then goes on to plot out in details how each nation will react to the shift. The main theme is that nations will need to be more self-reliant in securing their interests as the U.S. pulls out from the policing role. Moreover, in the absence of a superpower, the world will become more dangerous as competing national interests often leads to catastrophic wars. Because the success of such action relies on secrecy, only a few people make the decisions that can have the most devastating effect to the ordinary people who are left out of decision and information. Thus, regardless of whether the U.S. is losing interest in policing the world is true or not, in fact it is arguable that is not the case, whether the world is becoming more dangerous is still very relevant.

Another book that greatly influenced this project is the *The Visual Display of Quantitative Information* by Edward Tufte.[18] Among many valuable fundamentals and design principles he points out, what is particularly needed attention and relevant to this project is the problem of separation of data visuals and texts, or "See Fig.2" problem as he refers to it more anecdotally. The problem is that in printed media, because of the editorial needs caused mainly by limited space, words drive most of the narrative, and visuals only play a secondary supporting role. The same

problem can be easily observable in reading Zeihan's book or any other books on geopolitics. Too often, maps that provide important contextual geographical information is only found in pages and pages later. It is then left up to readers to set the book down to pull up a map and check out the physical locations of nations to understand how geography and geopolitical states is intertwined.

In this project, geopolitics and data visualization intersect. It is to serve my own personal inquiry and curiosity in geopolitics, particularly on the current state of military spending, as well as to explore the potential of scroll based interactive visualization as a solution of "See Fig.2" problem by giving user interaction and visuals more leading role in storytelling.

Objective

In order to assess whether world is becoming dangerous or not, this project aims to tie the status of regional geopolitics by narrating through military expenditure and other relevant contextual data like GDP and foreign arms transfer with a map visualizing geographical information. By doing so, it brings all necessary information in one place in unified way to help readers absorb current geopolitical state that is difficult to comprehend and catch up otherwise. To effectively communicate this information, the implementation must be done in a way that is methodically and specifically designed to make the material easy and captivating to read and follow through.

In order to attract and captivate users' attention, this project complements and extends the final project for the Advanced Interactive Data Visualization course, advised by Ellie Frymire, which has a dashboard like interaction.[19] Although it can nicely outline the overall trend of expenditures changes in time and engage readers to explore the data themselves, it is difficult to offer readers focused attention to specific narrative in the data using dashboard interface. For

instance, in Europe, countries are increasing spending after 2014, most probably in response to the Russian annexation of Crimea. But it is hard to grasp this tendency because the visualization simultaneously describes the changes in many different countries at once. In other words, information conveyed is thrown at readers at the pace set by the developer not by the reader. Thus, the subtle change can be easily overlooked, especially when a reader is unfamiliar with geopolitical events. To complement, since this project focuses more on telling specific narratives ensuing in preselected regions, scroll-event driven interaction will trigger data helping readers tie current and historic context to the military expenditure data. It will describe how much money countries in the region are spending on military expenditure and focus on the records that spew the most concerns. Users' scroll interaction will steer readers through the data visualizations and contextual texts. Such interaction will combine data and text to convey the narrative in a way conventional printing mediums cannot offer, emphasizing the role of data and creative visualization in modern communication.

About the Data

This project uses the military expenditure data published by the Stockholm International Peace Research Institute.[13] According to SIPRI experts, two key factors generally increase a nation's military spending data: the nation's wealth or financial capacity and the perceived threat level.[12] Two factors do not simultaneously need to be met for a country to increase military spending, although they can be. In other words, if either one is met, it can increase the military spending data. Therefore, military expenditure data is a good proxy data to assess the perceived threat level of a nation when juxtaposed with the GDP.

Data published by SIPRI is in ready-use shape. However, to fit the needs of the visualization in this project, some preparations were necessary. For instance, country naming convention in topojson and in SIPRI data set had slight variation which was handled in R code. Also, creating a new data set to minimize data filtering and modification in the JavaScript code, which mainly focuses on rendering visualization, data went through pre-modification in R. Such modifications include identifying top 10 and 20 most spent countries or subsetting the history of military spending for last 10 years. The script is also included in git repository attached to this paper.

Design Elements

This section explains the elements and techniques employed to implement the objectives. In terms of story development, the visual can be divided into five sections: an introductive paragraph, a world overview, and a description of states in three regions: East Asia, Europe, and the Middle East. Two key technical elements are employed to enhance user experience: scroll-event and transition. The story progresses as the user interacts with the mouse scroll, which relies on the mechanisms from the Scrollama JavaScript library. Mechanisms from D3 transitions implement the transition of materials in building new information scenes as the story develops. The Topojson map, text, and D3 graphs provide information in communicating the data narrative. Lastly, deliberate choices of color scheme and font type set the tone of the visualization and provide a unifying theme.

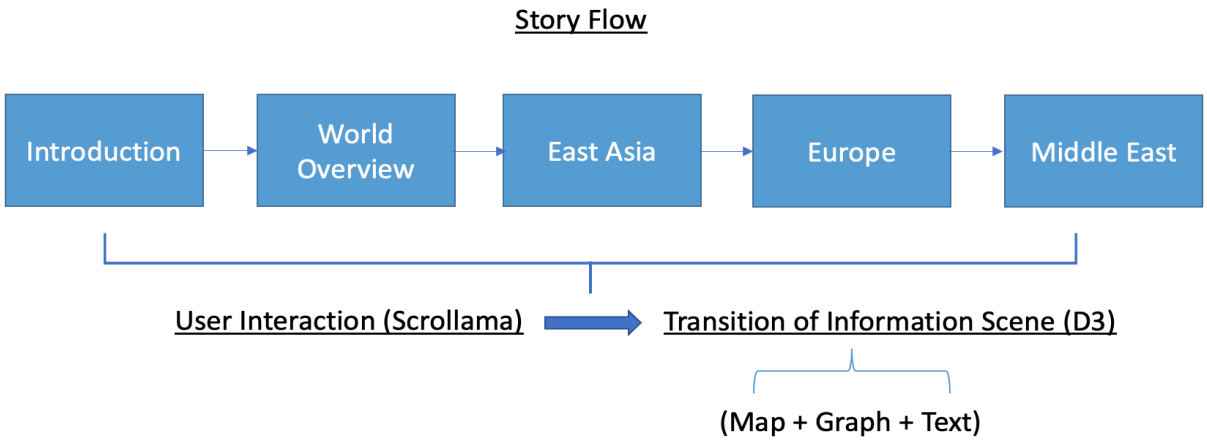

Figure 1. Story Flow and Design Elements used.

The introductive paragraph and world overview section grab readers' attention, entice interest in the topic, and provide contextual background on the topic. In world overview, readers get a glimpse of the current state of the world's military expenditure, such as that only a few nations contribute to the total amount spent or upward trend is prevalent. Then, more detailed information is given in each region following subsequent sections. This flow is designed to gradually bring readers up to date on the topic by incrementally adding complexity and more information as the story progresses. It is assumed that readers are not fondly familiar with current and historical events in geopolitics.

Scrollama.js[20] is a JavaScript library that allows developers to use scroll events without concerning complex calculations to infer screen location during the scroll. Instead, it provides an easy interface using a step-index. Developers simply render renewed scenes based on these indexes. In this project, scroll-driven interaction captivates the user's attention. It also allows the reader to control the pace of the story development instead of going through it at a preset pace. It keeps the experience a bit more attractive by offering readers to play a more active role in engaging in the material.

Transition is another element to make the user experience more enjoyable. Each step in the scroll-event fires transitions to build a new scene of information to describe and to build a narrative found in the military expenditure data and other contextual information. All design elements that provide information, map, graph, and text include transitions to make the experience fun and captivating and draw the user's focus on data visuals during story development. It also saves space needed for materials by simply re-drawing information instead of keeping all the information in place. All these advantages provided by transition allow the story to be more dynamic than the conventional printed medium, which is more static. This element plays a vital role in escaping the "See Figure.2" problem.

Important piece of visual aid in the story is the world map. As mentioned earlier, the perceived threat level of nations plays a vital role in the justification of changes in military spending. Since threat level is closely related to neighboring countries' behavior, geography provides vital contextual information in describing the military expenditure data among closely located nations, which is not easily associable in a table or text. For this reason, the map takes up the majority part of the visualization. The transition of the location on the map is an important aspect to refresh the user's attention as the topic moves from one nation or region to another. The geographical data that provides this is in Topojson format, and this data is drawn using D3 Mercator projection. Using the Topojson format of the geo data is advantageous because it provides what is called a bounding box.[21] Bounds of each nation is used in transition to highlight a nation or region related to text and graph information.

Another piece that composes an information scene is textual information. These words deliver important guide and context to explain information conveyed in the data. Although the text plays the major role in communicating the information, compared to contemporary printed media,

it makes up only a small part of the scene. Other elements like transitions, map and graphs makes up majority part of the presentation. These elements along with the text in a scene provide an alternative presentation of information that avoids "See Figure 2" problem. As a part of the information scene, text is also an element that goes through transition triggered by scroll-event. The transition is implemented using D3 tween mechanism that renders sentences as if it is being typed in real time.

Lastly, a graph is included in the scene to visualize the amount of military spending for the region or nation highlighted in the scene. The objective of this graph is to make the comparisons of magnitudes of the expenditures easy and intuitive. The transition of this bar highlights the fluctuation in the amount of spending, which also guides users to make the comparison in magnitude intuitively. The bar graph is implemented using D3 scales and a rect object that translates dollar amounts to pixel units. Smooth end of the rect object to place and join this visual more smoothly with the map.

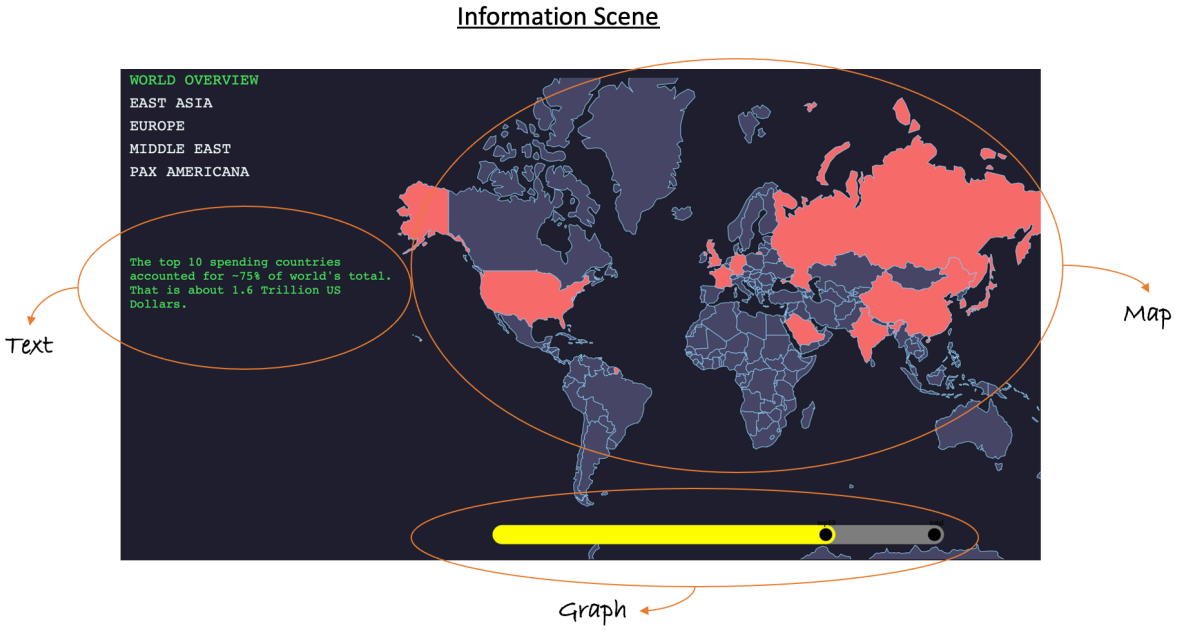

Figure 2. Information scene consists of Map, Text, and Graph. All elements include transitions.

As seen in Figure 2, the background color is set to dark navy, and color components in each of the elements in the information scene have contrasting colors. The font type used in the text is monospaced consoles to create a vibe of a console's monitors in Sci-fi / War movies. Both design choices in unity create a similar tone seen in Sci-fi / War movies and games such that reader is being briefed in a war / battle situation.

Development Process

Two major parts of the development process include story building, which comprises data curation and exploration and implementation of the design elements with coding. The first step was exploring the military data set and identifying insights to include in the story. From the exploration, it was clear that only a handful of nations take up most of the worldwide military expenditure. This observation determined that the story would need to focus on a few key nations and regions.

In parallel, a survey of related visualization works was undertaken. One prime example is *T-Day: The Battle for Taiwan* from Reuters.[22] This work captures the essence of solving the "See Figure 2" problem. Interactively animated graphical elements and text information work together in communicating the complex issue of possible war scenarios, especially for readers who are not aware of geography and names.

Figure 3. Visualization of Taiwan-China war scenario. The Battle for Taiwan from Reuters.

In implementation, the first approach in design to achieve the objective was similar to Reuter's work, with a map taking up the entire information scene with text information appearing in the center. However, this design did not work well in this project for two reasons. Unlike the Taiwan war scenario, which focuses on a narrow seaway between China and Taiwan, this project requires visualization of regions in the broader span. Text information in the center overlays the regions or nations highlighted, which means information is laid out separately rather than simultaneously. The second, more technically trivial problem was that the CSS statement "overlay: stick" to make text information scroll up on top of the map works differently in web browsers. It worked as intended in Chrome, with text to overlay on top of the map; on Safari, it did not appear on top of the map. The current design approach was then employed to ensure compatibility and to render information at the same time side by side.

In general, the development process for this project was not linear but circular in shape. The story and design layout went through multiple rounds of implementation to find the optimal layout to land on the current version for effective communication of the data narrative. However,

the current version still needs further work. The areas of improvement and necessary future work are discussed in more detail in the next section.

Evaluation and Future Works

Overall, the scroll-event driven d3 transition implemented in this visualization works reasonably well to draw readers' attention and to keep the interest in place throughout the story development. The bar graph at the bottom of the information scene provides a sense of continuity of narrative found in the military spending data for the region highlighted and offers a comparable view of the spending. Also, the text transition on the left works in harmony with other elements in the scene to point out and summarize the main narrative intended for readers to take. These three elements in the information scene, text, graph, and map, work in congruence to guide readers to make a connection between the military spending trend in geographical context with current and historical events in geopolitics.

However, the transitions of these elements are happening all at once. Because of that, the elements may compete to gain the reader's attention instead of working together to offer a contextual background of the information conveyed. Then, this layout may overwhelm readers by introducing an unnecessary burden on them to pick which elements to focus on first and subsequently after. A potential workaround for this problem is introducing transition delays to guide the reader's focus. For example, after the map viewpoint moves to the respective region in focus, a text transition happens to provide information, and then a transition for a bar graph to provide more context.

Currently, there are thirty information scenes that render according to user’s scroll event which might be too lengthy to make the topic easily communicable. If transitions are to be

implemented with delays, it may elongate user's experience proportionally and make the topic too dense. This is a critical downfall since major objective of this visualization is to make the topic of geopolitics and military spending data more accessible. To overcome this, there is navigation menu on the top left-hand corner of the information scene so that readers can assess the remaining loads of contents and be aware of the progress. This menu is clickable so that readers can skip to the part that is more interesting to them or to go back to the point of interests without manually scrolling. Extra visual aid such as small circular pie chart or status bar, refer to figure 4, that summarizes the pages left on the topic can be beneficial.

Better organization in story line will also make the visualization more accessible. More objective assessments on accessibility of content involving user testing can greatly benefit this. Breaking up the visualization into series instead of single piece material may also help in this regard.

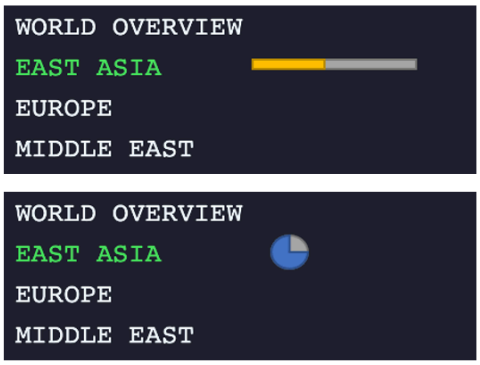

Figure 4. Possible options for Progress Monitor

The finished work also lacks compatibility. Compatibility tests on multiple web browsers show some inconsistency in user experience. For instance, in chrome there is laggy response in rendering transition, while in safari, transitions are generally more smooth but erroneous text transition occurs occasionally. More work on performance assessments and defensive code building is necessary to make the visualization more robust on multiple platforms.

On similar note, in current implementation, the visualization is intended for standard horizontal aspect ratio monitor screens such laptops and desktops. Implementing responsiveness, making the visualization more compatible for small screen devices such as phones and tablet, can be another massive undertaking that can result in making this visualization more available and reachable to variety of user base. Here, determining the order of presentation and transition of design elements as well as optimizing map's lay out for a small screen will invite new challenges that can open up new possibilities of potent interactive data visualization that stays relevant in current needs of media communication.

Conclusion

Geopolitical relations are shifting, becoming too complex to understand, and more expert knowledge is needed. However, both the general public and decision-makers need to understand this better. The consequences of bad decision makings are just too significant to be overlooked. Data visualization offers a simplistic explanation of the narrative and insights into complex data. A good data visualization offers simplicity and clarity in communication as the world becomes increasingly complicated and isolated due to the expertise required to understand. This project is an attempt to do so. This project combines text, map, and data graphics to highlight insights from the military spending data set. Employing scroll-event-driven interaction captivates users to explore the narrative at their own pace while providing various contextual information in one place. With this information illuminated more clearly, it is possible to reduce the bridge between experts and the public, inform non-experts on current geopolitical states, and ultimately, bring more inclusive ideas and discussions in policy making. Although the project has much room to improve, attempts such as this in exploring the new possibilities of interactive data visualization are worthwhile and bring new innovative ideas in communication.

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APPENDIX A. LIST OF VARIABLES

target_mod.csv – Contains information about country Information

Variable	Description
Country	String. Name of country as specified in SIPRI database
SubRegion	Categorical. Subregion of country as specified in SIPRI database
X2021	Numeric. Military spending in millions of US Dollars
Region	Categorical. Region of country as specified in SIPRI database
top10	TRUE or FALSE, TRUE if country ranks in top 10 most spent in world
top20	TRUE of FALSE, TRUE if country ranks in top 20 most spent in world
big2021	TRUE or FALSE, TRUE if country spent more in year 2021 than in 2020

trend-lastSvn.csv – Contains history of military spending for highlighted countries

Variable	Description
Year	Numeric. Specifies referenced year. Range: 2011 to 2021
China	Numeric. Military spending in billions of US Dollars for China
SouthKorea	Numeric. Military spending in millions of US Dollars for South Korea
Japan	Numeric. Military spending in millions of US Dollars for Japan
Taiwan	Numeric. Military spending in millions of US Dollars for Taiwan
Russia	Numeric. Military spending in millions of US Dollars for Russia
Ukraine	Numeric. Military spending in millions of US Dollars for Ukraine
UK	Numeric. Military spending in millions of US Dollars for UK
Germany	Numeric. Military spending in millions of US Dollars for Germany
France	Numeric. Military spending in millions of US Dollars for France
SaudiArabia	Numeric. Military spending in millions of US Dollars for Saudi Arabia
Iran	Numeric. Military spending in millions of US Dollars for Iran
Israel	Numeric. Military spending in millions of US Dollars for Israel

APPENDIX B. GLOSSARY OF FUNCTIONS

handleResize() - Resizes window and dimensions when resize event is triggered

changeColor(index) - Call animate functions for map and bar graph according to scroll index. Includes logical statements to specify boundary box so that map moves from one location to another appropriately.

handleStepEnter(response) - Scrollama.js event handler function to render graphics on mouse scroll enter event triggered by user interaction

animate(state) in worldmap.js - Specifies transitions of the world map according to scroll index stored in state object

animate(state) in stickyBar.js - Specifies transitions of the bar graph according to scroll index stored in state object