THE UCCTHESIS CLASS

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Abstract

This paper revolves around a visualization project based on the Global Terrorism Database (GTD), which aims to help users more intuitively understand the distribution and trends of global terrorist activities by developing an interactive visualization platform. The paper describes in detail the various steps of data collection, processing and visualization, and explores the application of different visualization techniques. The platform provides a variety of interactive functions that enable users to freely explore GTD data and discover the spatiotemporal distribution characteristics of terrorist activities. The project aims to make the data presentation more intuitive and easy to use by optimizing the user experience and introducing dynamic visualization technology.

Declaration

I confirm that, except where indicated through the proper use of citations and references, this is my original work and that I have not submitted it for any other course or degree.

Signed: ______________________________

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Chapter 1

Introduction

1.1 Background

1.1.1 The evolution of global terrorism

Terrorism as a means of violence can be traced back to ancient society. At that time, terrorism was mainly manifested as a challenge to power by individuals or small groups, often in political assassinations and violent rebellions. For example, the Sicarii in ancient Rome were a well-known Jewish extremist group that used daggers to assassinate Roman officials and pro-Roman elements among their fellow Jews in order to resist the rule of the Roman Empire [Jenkins 2024].

In modern times, the nature and scope of terrorism has changed significantly. During the French Revolution in the late 18th century, the Jacobin government consolidated power by implementing a "reign of terror," using public executions and other forms of violent intimidation to eliminate opposition. Terrorism during this period was called "state terrorism," which refers to systematic violence by the state against its citizens [Jenkins 2024] [English 2021] .

In the late 19th and early 20th centuries, terrorist activity gradually turned to anarchism and national liberation movements. Anarchists launched a series of assassinations and bombings in Europe and North America, attempting to destroy the existing social structure through direct action. At the same time, terrorism in national liberation movements began to rise, especially in Russia, Ireland, and the Balkans. For example, the Narodnaya Volya party in Russia promoted political change by assassinating Tsar Alexander II [on Drugs, and Crime 2024].

1.1.2 Terrorism trends in recent years

In recent years, global terrorism has shown some new trends and characteristics. First, the regional distribution of terrorist activities has changed significantly. From the end of the 20th century to the beginning of the 21st century, the focus of terrorism gradually shifted from Europe and Latin America to the Middle East and South Asia. The "911 incident" on September 11, 2001 marked the entry of terrorism into a new stage of globalization and high technology. Since then, terrorist activities in the Middle East have become more frequent, and Afghanistan, Iraq and Syria have become the main hotbeds of terrorism [Jenkins 2024] [English 2021]. At the same time, the nature and strategies of terrorist organizations have also changed. In the mid-20th century, terrorist organizations were mostly ideologically driven, such as the Red Brigades (Brigate Rosse) and the Basque National Liberation Movement (ETA). But in the early 21st century, religious extremism became the main driving force of terrorism, especially the rapid rise of Islamic extremist organizations such as al-Qaeda and the Islamic State (ISIS). These organizations spread extremist ideas, recruit members, and plan transnational terrorist attacks through the Internet and social media [on Drugs, and Crime 2024]. In terms of strategy, terrorist activities in recent years have shown a high degree of decentralization and autonomy. Many terrorist organizations no longer rely on centralized command, but encourage so-called "lone wolf" actions, where individual extremists launch attacks without direct orders. This strategy increases the difficulty of counter-terrorism because lone wolf actors are difficult to detect and prevent in advance [English 2021] [on Drugs, and Crime 2024]. In addition, the targets and methods of terrorism have also diversified. In addition to traditional bombings and assassinations, terrorists are increasingly using car ramming, knife attacks and kidnapping to carry out attacks. Their targets are not limited to government agencies and military facilities, but also include civilians, religious sites and cultural heritage, with the aim of creating greater panic and social unrest [Jenkins 2024] [English 2021].

In summary, the development of global terrorism has evolved from individual violent acts in ancient times to systematic violent activities in modern times, and has shown different characteristics in different historical periods. In recent years, terrorist activities have become more globalized and spread out. The nature of terrorist organizations and their strategies are also constantly changing. These changes present serious challenges to the international community. In response to these challenges, countries around the world need to strengthen their cooperation. They also need to adopt comprehensive counter-terrorism measures to effectively deal with this threat.

1.2 Analysis of terrorist incidents in 2023

1.2.1 Hamas attacks on Israel

On October 7, 2023, Hamas and some other Palestinian armed groups launched a large-scale armed attack from the Gaza Strip. This was the first armed invasion of Israeli territory since the 1948 Arab-Israeli War. The background of this attack is complex. It involves many different factors, such as the long-standing Israeli-Palestinian conflict. It also includes regional political dynamics and Hamasâs own strategic goals.

Firstly, it is important to note that it is not a coincidence that Hamas chose October 7, 2023, to launch this attack. This day coincided with the Jewish religious festival Simchat Torah, and most Israelis were celebrating the festival and were on low alert.

The attack began at 6:30 in the morning, when Hamas fired a large number of rockets into southern Israel, and the range of the attack even affected Tel Aviv and Beersheba [Encyclopaedia Britannica 2024] [Center for Strategic and International Studies 2024].

The attacks were not limited to rocket attacks, but Hamas also attacked from the ground, in the air and at sea. Hundreds of militants crossed the border into southern Israel, carrying out large-scale killings and kidnappings. The attacks reportedly killed more than 1,200 Israelis, making it the deadliest day in Israel's history [Encyclopaedia Britannica 2024]. Hamas's attack strategy includes the use of weapons such as thermobaric grenades, intended to cause maximum casualties [Center for Strategic and International Studies 2024] .

An important goal of the attack was to strike at Israel in retaliation for Israel's long-term blockade and military strikes on the Gaza Strip. Statements from the Hamas leadership and documents found on the bodies of the killed militants show that Hamas's mission was to kill and kidnap as many people as possible. In addition, Hamas also hoped that through this attack, it would disrupt the ongoing peace talks between Israel and Saudi Arabia, which have failed to resolve the Palestinian issue and meet the needs of the Palestinians [Center for Strategic and International Studies 2024].

The attack attracted widespread international attention and condemnation, and Israel immediately launched a large-scale retaliation campaign, continuously bombing the Gaza Strip, causing a large number of Palestinian civilian casualties. It is reported that more than 15,000 Palestinians have been killed in the conflict so far, and this number may continue to rise in the future [Center for Strategic and International Studies 2024].

1.2.2 Analysis of GTI 2024 Report

The Global Terrorism Index (GTI) 2024 report reveals some key trends and findings in global terrorism today. Among them, the most notable are the increase in terrorism fatalities, the regional concentration of terrorist activities, and the uncertainty of the future.

First, the report pointed out that the fatality rate of global terrorist incidents increased significantly in 2023. This trend is partly attributed to the intensification of conflicts in the Middle East and Africa, especially in countries such as Syria, Iraq and Nigeria. Terrorist groups such as ISIS and Boko Haram continue to launch highly lethal attacks in these regions, resulting in large numbers of civilian casualties.

Secondly, the regional concentration of terrorist activities is becoming increasingly evident. Although terrorist incidents have decreased globally, terrorist activities in the Middle East, Africa and South Asia are still active. Countries in these regions often face complex internal conflicts, political instability and the threat of extremism, which allows terrorism to breed and spread [for Economics & Peace 2024]. For example, terrorist organizations in the Sahel region operate across borders, further exacerbating regional insecurity.

The report also highlights the uncertainty of the future global terrorism situation. Although some major terrorist organizations have been hit hard by military strikes, the root causes of terrorism, such as poverty, unemployment, political oppression and religious extremism, have not been effectively addressed. With the changes in global geopolitics, emerging terrorist organizations and lone wolf terrorist attacks may increase. In addition, the ability of terrorists to use the Internet and social media to spread extremist ideas and recruit members is also increasing, increasing the difficulty of global counter-terrorism [for Economics & Peace 2024].

In general, the terrorist incidents in 2023 and the GTI 2024 report reveal the grim situation of global terrorism. The international community needs to strengthen cooperation, take comprehensive measures to deal with this threat, and solve the problems caused by terrorism at the root in order to achieve lasting peace and security.

1.3 Global Terrorism Database (GTD)

The Global Terrorism Database (GTD) is a collection of detailed information on terrorist attacks that have occurred around the world since 1970. The GTD is managed by the National Consortium for the Study of Terrorism and Responses to Terrorism (START) at the University of Maryland [LaFree, and Dugan 2007]. The database contains more than 200,000 records of terrorist attacks. This makes it a very valuable tool for studying the patterns, causes, and consequences of terrorism.

The GTD was created to provide researchers and policymakers with a comprehensive and consistent dataset of terrorist attacks. The goal is to help them better understand the phenomenon of terrorism and its impact.

1.3.1 Data Collection Methods and Sources

GTD's data is mainly collected from public news media reports and electronic news archives. Additionally, it uses information from existing data sets and secondary materials, such as books and journals. Legal documents are also important sources for the data in GTD. The data collection process went through multiple stages, each of which relied on unclassified public resources. The specific process of data collection is as follows [for the Study of Terrorism, and to Terrorism) 2021]:

1. Initial Data Collection (1970-1997)
    - Data on terrorist attacks during these years were collected by Pinkerton Global Intelligence Service (PGIS), a private security agency.
    - These handwritten records were digitized by START in 2005.
2. Data Expansion and Update (1998-2011)
    - Data from January 1998 to March 2008 were collected by the Center for Terrorism and Intelligence Studies (CETIS).
    - Data from April 2008 to October 2011 were collected by the Institute for the Study of Violent Groups (ISVG).

3. Current Data Collection (2012 to Present)
    - All ongoing data collection efforts since November 2011 have been conducted by START staff at the University of Maryland.

Data collection follows strict definition and inclusion criteria to ensure comprehensiveness and consistency.

1.3.2 Data openness and transparency

The openness and transparency of GTD data have important implications for research and policy making. The creators of GTD are committed to achieving maximum transparency and accessibility of the data, making it a valuable research tool. Specifically, the openness and transparency of GTD data are reflected in the following aspects [for the Study of Terrorism, and to Terrorism) 2021]:

1. Open access to data

   The GTD database is publicly searchable, browsable, and downloadable on its official website. Users are free to access the data, but are required to accept the terms of the End User License Agreement.

2. Transparent data collection methods

   GTD's CodeBook describes the data collection methods, inclusion criteria, and variable definitions in detail, ensuring that users can fully understand the context and structure of the data.

3. Comprehensiveness and consistency of data

   GTD data collection covers terrorist attacks worldwide and ensures data consistency, maintaining high standards of data quality even as data collection methods and techniques change over time.

4. Openness to user feedback

   The GTD team encourages users to provide feedback to improve the accuracy and completeness of the database. For example, users can report errors or omissions in the data, and the GTD team will make appropriate modifications based on the new information.

5. Handling of sensitive information

   Although GTD provides detailed event information as much as possible, the team takes measures to protect the information of relevant persons when it comes to personal privacy and security. For example, the geographic location information in the database is only accurate to the city center at most, not to specific addresses.

1.4 Data Visualization

1.4.1 The concept and advantages of data visualization

Data visualization is a technique that converts data into graphs or charts, making complex data sets easier to understand and analyze. Through visual representation, patterns, trends, and anomalies in data can be more intuitively displayed, helping decision makers and researchers obtain valuable information faster and more efficiently.

Visualization tools can reveal patterns and relationships in data, such as scatter plots and heat maps that effectively display correlations between variables and dense or sparse areas in data sets. Visualization can also improve the efficiency of data analysis, helping users quickly identify key trends and anomalies, and further deepen analysis through interactive exploration. Data visualization simplifies the process of conveying complex information, making it easier for policy makers, business managers, and the public to understand and apply this key information [Few, and Edge 2007].

1.4.2 Application in Terrorism Research

Data visualization has a wide range of applications in terrorism research, helping researchers and policymakers better understand and respond to terrorist threats. Here are some specific applications of data visualization in terrorism research:

1. Trend analysis

   Data visualization can be used to analyze the temporal trends of terrorist incidents. Through time series charts, researchers can observe the changes in the frequency of terrorist incidents over time and identify the peaks and troughs of terrorist activities [Vajjhala, Strang, and Sun 2015]. For example, annual or monthly event trend charts can show the intensity of terrorist activities in different years or months, helping to identify seasonal or cyclical terrorist activities.

2. Spatiotemporal distribution

   Geographic visualization tools such as maps and heat maps can show the geographical distribution of terrorist incidents. By marking the locations of incidents on the map, researchers can identify hot spots of terrorist activities and understand the frequency and type of terrorist activities in different regions. For example, heat maps can show the concentration of terrorist activities in the world or a specific region during a certain period of time, providing a basis for formulating counter-terrorism strategies.

3. Pattern recognition

   Data visualization can help identify patterns and relationships in terrorist activities [Vajjhala, Strang, and Sun 2015]. For example, through network diagrams, the connections and cooperation between different terrorist organizations can be shown, helping to understand the structure and operation mode of terrorist organizations. In addition, scatter plots and bubble charts can be used to analyze the relationship between the means, targets, and consequences of terrorist attacks, revealing the characteristics and trends of different types of terrorist activities.

4. Decision support

   Data visualization tools can provide support for counter-terrorism decision-making. For example, dashboards can integrate multiple data visualization forms, such as charts, maps, and indicator cards, to display key indicators and event dynamics in real time, helping decision-makers to keep abreast of the latest developments in terrorist threats and formulate corresponding countermeasures.

In summary, data visualization plays an important role in terrorism research. Through intuitive and dynamic graphical representations, it helps researchers and decision makers better understand the trends, distribution, and patterns of terrorist activities, thereby improving analysis efficiency, enhancing information communication, and supporting effective counter-terrorism strategies and policy formulation.

1.5 Purpose and significance of this study

1.5.1 Research objectives

The main goal of this study is to conduct quantitative analysis and visualization of global terrorist activities based on the Global Terrorism Database (GTD). Specifically, the study will achieve this goal through the following aspects:

1. Data collation and preprocessing

   Collate and clean GTD data to ensure data integrity and consistency, and prepare for subsequent analysis and visualization.

2. Data analysis

   Use statistical analysis methods to conduct in-depth analysis of GTD data to reveal the temporal and spatial distribution characteristics and changing trends of global terrorist incidents. Specifically, it includes analysis of the number, type, target, and fatality rate of terrorist attacks.

3. Data visualization

   Use data visualization technology to transform complex terrorist data into intuitive and easy-to-understand graphics and charts to help users better understand the information behind the data. Visualization tools include maps, time series graphs, heat maps, network diagrams, etc.

4. Establish an interactive visualization platform

Develop an interactive data visualization platform that allows users to freely explore and analyze GTD data according to their needs. The platform will provide a variety of visualization options and interactive functions to support users to conduct personalized analysis.

1.5.2 Significance

The practical significance of this study is reflected in the following aspects:

1. Provide support for counter-terrorism strategy

   Through quantitative analysis and visualization of global terrorist activities, this study will provide valuable data support for governments and international organizations to help formulate and adjust counter-terrorism strategies. Specifically, the research results can help identify high-risk areas and high-risk time periods for terrorist activities, and guide resource allocation and the formulation of preventive measures.

2. Improve public safety awareness

   The research results show the distribution and trends of terrorist activities to the public through data visualization, enhancing the public's awareness and understanding of terrorist threats. Through an interactive visualization platform, the public can intuitively understand the dynamics of terrorist attacks and enhance the safety awareness of individuals and communities.

3. Promote academic research

   This study provides a detailed and reliable example of terrorism data analysis for the academic community, promoting the development of the field of terrorism research. The research results can provide reference for other scholars to help them conduct further research and exploration. In addition, the methods and results of this study can also be used in data analysis and visualization in other fields. This helps to promote academic research across different disciplines.

4. Improving policies and practices

   By showing the patterns and trends of terrorist activities, this study can give valuable insights to policymakers and practitioners. These insights can help improve counterterrorism policies and practices. The results can also help identify and fix weaknesses in current counterterrorism strategies. This, in turn, can support the implementation of more effective counterterrorism measures.

5. Supporting international cooperation

   Terrorism is a global problem that needs a united response from the international community. This study helps support international cooperation and information sharing by offering detailed data on terrorist activities and analysis results. It also promotes global counterterrorism efforts and encourages cooperation among nations.

In summary, this study aims to support counter-terrorism strategies and raise public safety awareness. It also seeks to promote academic research, improve policies and practices, and encourage international cooperation. This is done by conducting quantitative analysis and visualization of global terrorist activities using GTD data. The study's results are highly significant not only for academia and policymakers but also for the public. They provide valuable information that can help people better understand and respond to terrorist threats.

1.6 Structure

The main purpose of this paper is to analyze global terrorist events in 2023, especially Hamas's attack on Israel, and explore how to use data visualization technology to enhance the understanding and research of terrorist trends. Through an in-depth analysis of the Global Terrorism Database (GTD) data, this paper aims to reveal the current status of terrorism research and demonstrate the potential application of data visualization technology in this field.

This chapter provides an overview of the evolution of global terrorism and terrorist trends in recent years, followed by an analysis of terrorist events in 2023, with a special focus on Hamas's attack on Israel and the analysis of the GTI 2024 report. This chapter also introduces the Global Terrorism Database (GTD) and discusses data collection methods, data openness and transparency. Finally, this chapter explores the concept of data visualization and its application in terrorism research, and clarifies the purpose and significance of this study.

Chapter 2 reviews the current status of global terrorism research, covering key theories and concepts, research directions, and related data sets and resources. In addition, this chapter reviews data visualization technology, discussing basic concepts, historical developments, and its application in terrorism research, including an overview and analysis of existing projects. The last part of this chapter summarizes the main findings of existing research, research gaps, and future research directions.

Chapter 3 describes in detail the data collection and processing methods used in the study, including data set description, screening criteria, and variable selection. Next, the data processing process is introduced, covering data acquisition, preliminary processing, data merging, and cleaning. In addition, this chapter also introduces the technology stack and system design used in the study, including system architecture and interface design.

Chapter 4 describes in detail the implementation process of the study, including the implementation of the interface, page structure, implementation of key components, and implementation of functions such as filters, interactive maps, and display modules. This chapter also discusses technical challenges and their solutions, especially performance optimization, responsive design, and interaction design challenges.

Chapter 5 introduces the testing methods of the study, including test cases and result analysis, focusing on the performance test results and discussion. In addition, this chapter summarizes the results of the entire study and discusses the research findings and discussions.

Chapter 6 summarizes the research objectives and significance of this study, and proposes the limitations of the study and the direction of future research.

Chapter 2

Literature Review

2.1 Current Status of Global Terrorism Research

2.1.1 Key theories and concepts

The definition of terrorism has long been a subject of debate among academics and policymakers. Generally, terrorism is defined as the use of violence and intimidation to achieve political, religious, or ideological goals. However, international definitions of terrorism differ. The United Nations has not provided a unified definition, and various countries and organizations often define terrorism differently, based on their own legal and political contexts. For example, the U.S. Department of Homeland Security defines terrorism as "violent acts intended to influence public behavior or policy decisions." Meanwhile, the European Union focuses on "violent activities that use fear to achieve political, religious, or ideological goals"[Hoffman 2017].

Studying terrorism is important not just for understanding its roots and trends, but also because it directly impacts policymaking and public safety. The frequent occurrence of terrorism poses a serious threat to global security. It affects international relations, economic stability, and social structure. Understanding the nature and motivations of terrorism is crucial for developing effective counter-terrorism strategies. This not only helps to reduce the damage caused by terrorism but also enhances public safety and social stability[Pape 2006].

Academic research on terrorism involves various theoretical frameworks. From a political science perspective, terrorism is often viewed as a political tool used to achieve specific political goals. Political theory suggests that terrorism can result from political oppression, institutional injustice, or conflict. The sociological perspective, on the other hand, emphasizes the role of social structure and cultural factors in terrorism. It points out that social inequality and exclusion may contribute to the rise of extremism[Bryson 2020]. The psychological perspective focuses on the individual's psychological state and motivation, exploring how individuals are attracted to extreme ideas and ideologies[Horgan 2008].

2.1.2 Research Direction

Research on terrorism mainly focuses on its root causes, impacts, counter-terrorism strategies and evolution.

1. Root causes

   Research on the root causes of terrorism involves a variety of factors, including political dissatisfaction, economic difficulties, social divisions, and psychological factors[Krueger, and Malečková 2003]. Scholars have explored how terrorism is formed in different social and economic contexts, pointing out that socioeconomic inequality, political oppression, and cultural conflicts are the main driving factors.

2. Impacts

   In terms of the impact of terrorism, research shows that terrorism not only damages the social, economic, and political systems of the victim countries, but also poses a threat to international relations and global security[Piazza 2008]. Terrorist incidents usually cause economic losses, social panic, and political instability, and may also lead to countries taking more stringent security measures, thus affecting international cooperation and human rights.

3. Counter-terrorism strategies

   In terms of counter-terrorism strategies, existing research has summarized a variety of response methods, including preventive measures, intervention measures, and recovery measures. Preventive measures such as education and community building aim to reduce the root causes of terrorism, while intervention measures such as intelligence gathering and military operations directly target terrorist activities. Recovery measures focus on restoring social order and public trust after terrorist incidents[Jackson 2016].

4. Evolution

   Research on the evolution and trends of terrorism shows that terrorism is constantly evolving in form and technology. Modern terrorist organizations not only use traditional violent means, but also use the Internet and social media for propaganda and recruitment[Zelin 2021]. In addition, emerging forms of terrorism, such as lone wolf attacks and global terrorist networks, have also become the focus of research.

2.1.3 Related datasets and resources

The dataset I use for this project and thesis is Global Terrorism Database (GTD). GTD is an event-level database that contains more than 200,000 records of terrorist attacks that have occurred around the world since 1970. It is managed by the National Consortium for the Study of Terrorism and Responses to Terrorism (START) at the University of

Maryland[for the Study of Terrorism, and to Terrorism) 2021]. GTDâs data collection method involves extracting information from various sources, including news reports, government reports, and academic research. This approach helps ensure both the breadth and accuracy of the data.

In addition to GTD, other commonly used terrorism data resources include the Uppsala Conflict Data Program (UCDP) and the Terrorism and Extremist Violence in the United States (TEVUS) databases. UCDP provides detailed data on conflicts and violence, including terrorism and other forms of violence. TEVUS, on the other hand, focuses specifically on incidents of terrorism and extreme violence within the United States[Uppsala Conflict Data Program 2020][National Consortium for the Study of Terrorism and Responses to Terrorism 2021].

Each of these datasets has its own strengths and weaknesses. GTD has advantages in data coverage and time span, but it also faces problems of untimely data updates and missing information. The conflict data provided by UCDP is more systematic, but may not cover all small-scale terrorist incidents. TEVUS data are primarily focused on the United States and may not be applicable to studies in other countries.In detail. Table 2.1 lists a comprehensive comparison between them based on specific attributes.

After comparing various data sources, GTD (Global Terrorism Database) was selected for this research. GTD provides a comprehensive database with detailed records of terrorist incidents worldwide, including information on the time, location, participants, and impact of each event. This makes GTD particularly advantageous in terms of data comprehensiveness and detail. Compared to other data sources, GTD's information is rigorously verified and standardized, ensuring accuracy and consistency. Additionally, GTD's open-access nature and extensive academic use make it an excellent choice for supporting in-depth analysis of terrorism. By utilizing GTD, the research can achieve better trend analysis, pattern recognition, and case studies, enhancing the reliability and scientific validity of the findings.

2.2 A Review of Data Visualization Technology

2.2.1 Basic concepts and principles

Data visualization refers to the process of converting data into visual images through graphical means, so that the patterns, trends and anomalies of the data are more intuitive. It is not just about converting data into charts or graphs, but also a technology that presents complex data in a form that is easy to understand and analyze. Through data visualization, analysts and decision makers can understand the meaning behind the data more quickly and make more accurate decisions.

The importance of data visualization lies in its ability to simplify the complexity of data and make large amounts of data easy to interpret. Especially in the era of big data, the scale and complexity of data are increasing, and traditional data analysis methods are difficult to handle such a large amount of information. Through effective visualization technology, users can quickly identify patterns and trends in data and

Attribute	**GTD**	**UCDP**	**TEVUS**
Data Coverage (Years)	1970 - present	1989 - present (varies by dataset)	1970 - present
Geographic Coverage	Global	Global	United States
Data Sources	News reports, various archival sources	Scholarly articles, reports, databases	News reports, government databases, academic sources
Types of Terrorist Events	Includes bombings, assassinations, kidnappings, etc.	Primarily armed conflicts and one-sided violence	Terrorism, hate crimes, extremist activities
Variables Included	Incident date, location, perpetrator, weapon type, etc.	Conflict onset, duration, fatalities, actors involved	Incident date, location, type, perpetrator, etc.
Frequency of Updates	Annually	Annually	Regularly, with frequent updates
Accessibility	Publicly available	Publicly available	Publicly available
Usage Restrictions	None	None	None
Strengths	Comprehensive, long historical coverage	Detailed conflict data, various datasets	Focused on U.S., combines terrorism and extremist violence data
Weaknesses	Potential inconsistencies, broad definition issues	Limited to conflicts, less focus on individual attacks	Limited to the U.S., may miss global trends

Table 2.1: Comparison of Global Terrorism Datasets (GTD, UCDP, TEVUS)

discover potential anomalies and relationships[Heer, and Bostock 2010]. In addition, data visualization also plays a key role in data storytelling, data reporting and data-driven decision-making, enabling information to be presented in a more intuitive and persuasive way[Kirk 2019].

The basic principles of data visualization include accuracy, simplicity and effectiveness. These principles are widely used in various data visualization practices to ensure the effectiveness of graphical presentations and the authenticity of data[Tufte 1985]. Edward Tufte proposed several core principles of data visualization in *The Visual Display of Quantitative Information*. He emphasized some key principles, such as "data-graphic density", "clarity of data presentation" and "perception-based design". The first one implies that data density in the graphic should match the complexity of the data. The chart should present the data as accurately as possible, rather than simplifying the data to the point of losing the richness of the information[Tufte 1985]. Also, visualization should avoid unnecessary decorative elements that may distract attention and lead users to misunderstand the data. Tufte advocates the "data-first" principle, that is, graphic design should put the data itself at the center and avoid unnecessary decorative patterns and colors. Effective data visualization should convey the core information of the data through clear design, so that users can quickly grasp the key points of the data.

2.2.2 History and Development

The history of data visualization can be traced back to the scientific revolution in the 17th century. Early data visualization forms included various maps and statistical charts, the most famous of which may be the first line chart and bar chart created by William Playfair in 1786. These early charts laid the foundation for later data visualization techniques[Playfair 1801].

This chart shows the import and export trends of England to Denmark and Norway from 1700 to 1780. The import amount is represented by a yellow line, and the export amount is represented by a red line. It is worth noting that Playfair uses red areas to represent the amount of trade deficit (imports > exports) and yellow areas to represent the amount of trade surplus (exports > imports). This gives the chart richer information. In addition to seeing the continuous increase in England's exports, it can also make a rough comparison of the deficit and surplus during this period.

This chart has a far-reaching impact. According to modern scholars Rosenberg and others in their book *Cartographies of Time*, "In the next half century, Playfair's line chart established a drawing format with two quantitative axes (one is the time axis, and the other is the axis describing economic indicators such as exports, imports and debt), and became the most recognizable chronological format that was constantly used at the time.

In the 19th century, with the advancement of statistics, the forms and methods of data visualization were further developed. John Snow used a map to show the spatial distribution of cholera outbreaks in London in 1854, which is widely regarded as the pioneering work of modern epidemiological data visualization[Snow 1855]. Data visual-

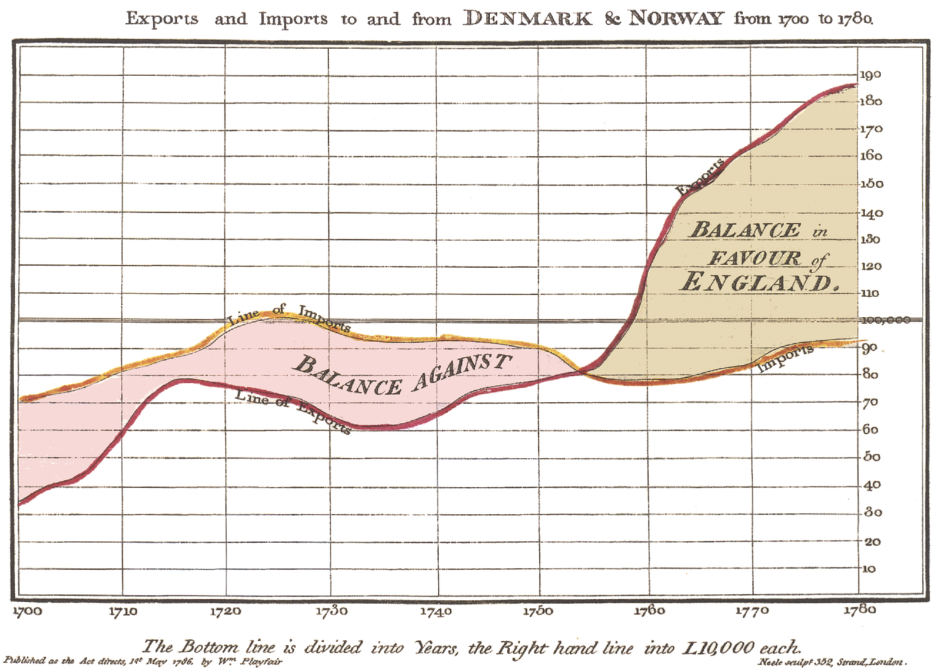

Figure 2.1: William Playfair's Time Series of Exports and Imports of Denmark and Norway is the first line chart and area chart in history

ization during this period began to focus not only on the display effect of data, but also on the practical application of data analysis.

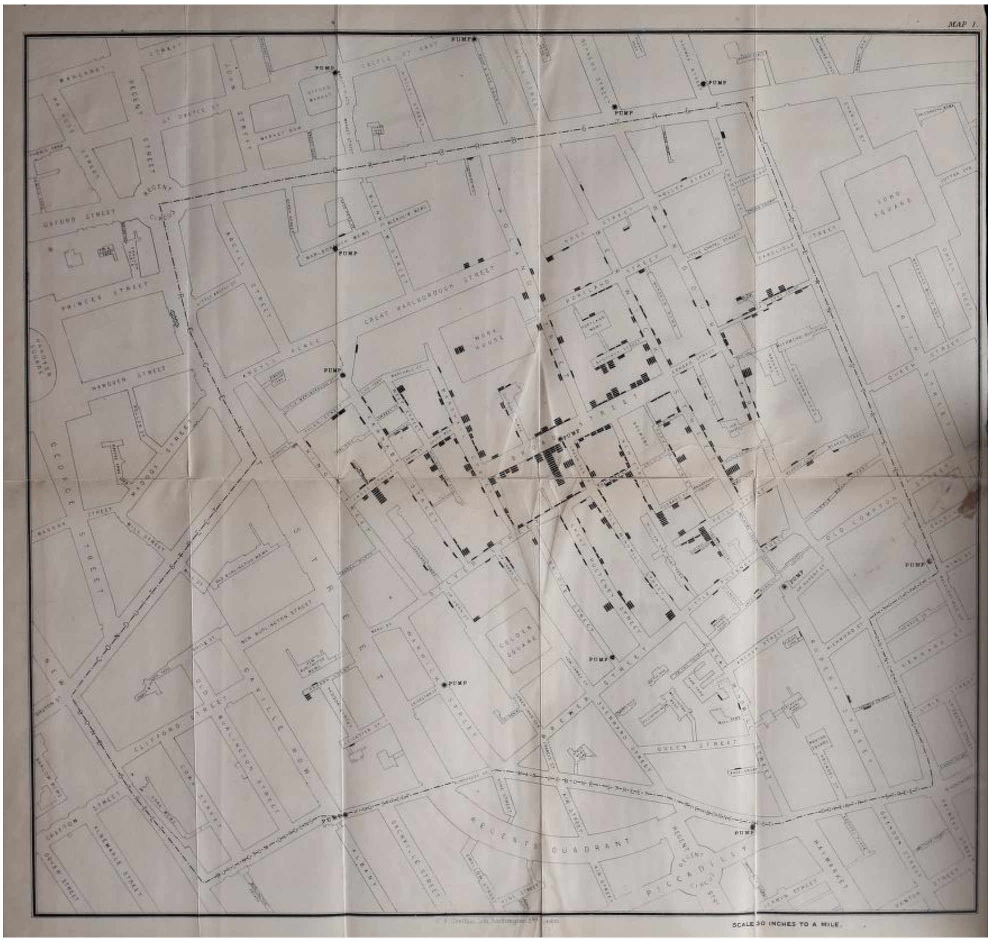

Figure 2.2: John Snow's cholera map

Entering the 20th century, with the development of computer technology, data visualization entered a new stage. Advances in computer graphics have made more complex and dynamic data visualization possible. Modern data visualization includes not only traditional static charts, but also interactive graphics, dynamic visualization, and data presentation in virtual reality[Cleveland, and McGill 1984]. The development of these technologies enables users to explore and analyze data in a more flexible and diverse way.

Data visualization in the 21st century places more emphasis on user experience and data interactivity. Modern tools such as Tableau and D3.js provide users with powerful data visualization capabilities, allowing users to create complex graphics and interact with data dynamically. These tools make data visualization not only limited to professionals, but can also be widely used in business analysis, data journalism, and public data display[Viégas, and Wattenberg 2008].

2.3 Data Visualization Applications in Terrorism Research

2.3.1 Case studies

There are many successful examples of data visualization in terrorism research that demonstrate how graphical methods can reveal the complexity of terrorist activities. For instance, in the study *Mapping Terrorism in Europe*, L. Meier and M. Zingales (2017) applied geographic information system (GIS) technology to visualize terrorist incidents in Europe. They used interactive maps to show the distribution of terrorist incidents across different regions and combined this with time series data to analyze the seasonal fluctuations of terrorist activities. The advantage of their approach is that it allows researchers to visualize large-scale event data in both geographic and temporal dimensions, making it easier to identify hot spots and dynamic changes in terrorist activities. However, this method also has limitations, such as the possibility that the spatial distribution of data could be influenced by reporting bias, especially when records of terrorist incidents are incomplete or inconsistent.

In another study, *Analyzing the Terrorist Social Networks with Visualization Tools* (Yang et al., 2006), Yang, Liu, and Sageman used D3.js to create interactive network diagrams that illustrate the internal structure and personnel dynamics within terrorist organizations. This visualization method enables researchers to deeply explore the complex relationship networks within these organizations, identifying core members, contact nodes, and information flow pathways. D3.js also allows users to interact with the graphics, making it possible to explore various organizational levels and connections. While this approach is beneficial for handling complex network data and providing dynamic analytical perspectives, it also presents challenges, such as computational complexity with large networks and the need for sophisticated user interface design[Yang, Liu, and Sageman 2006].

In the study *A Visual Analytics Approach to Understanding Spatiotemporal Hotspots* [Maciejewski et al. 2009], Maciejewski and colleagues utilized heat maps and time series analysis to uncover spatial and temporal patterns of events. They used heat maps to visually represent areas with high densities of incidents, while time series graphs were employed to analyze trends and fluctuations over time. This method effectively reveals periodic characteristics and changes in trends, offering valuable insights into the evolution of events.

Although this approach is intuitive and easy to understand, it can be limited by the quality of the data and the granularity of time analysis. These constraints may affect the accuracy and depth of the insights gained from the visualization.

2.3.2 Technology and Tools

When visualizing terrorism data, GIS, D3.js, and Tableau are three main technologies and tools. Each of these has different advantages and is useful in different situations. Geographic Information System (GIS) is a very powerful tool for spatial data analysis. It is widely used to process and visualize geographic data. GIS technology can map the locations of terrorist incidents on maps. It can also analyze the spatial distribution and identify hot spots of these incidents. In the study *Advancements and Applications of Drone-Integrated Geographic Information System Technology –A Review* [Quamar et al. 2023], Quamar and his team explored how GIS technology can be used to analyze various types of activities in a spatial way, including terrorist activities. They showed how GIS can reveal patterns of density and distribution across different regions. The strength of GIS is in its ability to manage complex geographic data and provide detailed spatial analysis. However, GIS also has limitations, such as the need for very high-quality spatial data and the requirement for advanced operational skills.

D3.js is a data visualization library based on JavaScript. It is well-known for its flexibility and powerful features. It allows developers to create interactive charts and network diagrams. It also supports the visualization of dynamic data. In terrorism research, D3.js is often used to show the structure, personnel flow, and relationship networks of terrorist organizations. Through interactive graphics, users can explore different levels and dimensions of data in depth[Bostock, Ogievetsky, and Heer 2011]. Although D3.js provides a high degree of customization, it requires developers to have high programming skills and may encounter performance bottlenecks when processing large-scale data.

Tableau is a business intelligence and data visualization tool that is widely used in data analysis and reporting. It provides an intuitive drag-and-drop interface that enables users to quickly create various types of charts and dashboards. In terrorism research, Tableau can be used to create dynamic visualization reports. These reports help analysts and decision-makers gain important insights from data[Reddy, Sangam, and Srinivasa Rao 2019]. The main advantages of Tableau are that it is easy to use and has strong data processing abilities. However, it may not be as flexible as D3.js when it comes to high customization needs. Additionally, the advanced features of Tableau often require paid licenses.

2.3.3 Pattern recognition and trend analysis

Data visualization is very important in recognizing patterns and analyzing trends in terrorist activities. By using graphical methods, researchers can more clearly identify the patterns and trends in these activities. For instance, time series analysis can show the periodicity and changes in trends of terrorist activities. Researchers can use time series graphs to analyze how often terrorist incidents occur and how these trends change over time. This helps them identify peaks and troughs, allowing them to understand the periodic patterns of terrorist activities [Salem, and Naouali 2016]. This kind of analysis can uncover seasonal fluctuations and long-term trends in terrorist activities, providing data support for creating effective counterterrorism strategies.

Heatmaps are another effective tool for showing the spatial distribution and density of terrorist activities. Through heatmaps, researchers can easily see where terrorist incidents are most concentrated in different regions and identify hot spots. This visualization method reveals geographical patterns and spatial clustering of terrorist activities, giving important geographical information to relevant departments.

Additionally, data visualization can be combined with socioeconomic data to analyze the factors driving terrorist activities. For example, researchers can combine data on terrorist incidents with socioeconomic indicators like unemployment rates and poverty levels. This helps them explore the relationship between terrorist activities and socioeconomic factors[HANTAL 2012]. Such a comprehensive analysis can uncover the potential root causes of terrorist activities and provide targeted recommendations for policymaking.

Real-time data visualization technology is also crucial in terrorism research. By using real-time data streaming and dynamic visualization, researchers can track the latest developments in terrorist incidents and respond quickly. This real-time monitoring capability is essential for early warning and emergency response, helping relevant departments take swift action to reduce the impact of terrorist activities.

2.4 Existing GTD-based data visualization projects

2.4.1 Existing Projects Overview

The Global Terrorism Database (GTD) is one of the most comprehensive databases in the world for tracking terrorist incidents. It includes data on terrorist incidents dating back to 1970. Visualization projects based on GTD data aim to show the spatial and temporal distribution, patterns, and trends of terrorism. Several major GTD data visualization projects have been widely used in both academic research and policymaking.

One important project is the GTD visualization tool developed by the National Consortium for the Study of Terrorism and Counterterrorism (START) at the University of Maryland. This tool displays the distribution and changing trends of global terrorist incidents using interactive maps, timelines, and statistical charts. Researchers and policymakers can use this tool to explore patterns of terrorist activities in different regions and time periods. They can identify high-risk areas and periods, helping them develop more effective counterterrorism strategies[LaFree, and Dugan 2007] [for the Study of Terrorism, and to Terrorism) 2021]. A key feature of this project is its user-friendly interface and flexible query capabilities. These features allow users to easily filter and analyze specific types of events, such as the activities of a particular organization or incidents within a specific time frame.

Another significant project is the GTD data visualization platform developed by the Global Terrorism Research Center (GRTC). This platform not only shows the geographical distribution and temporal trends of terrorist incidents but also provides detailed descriptions and background information about each event. Users can delve deeper into specific regions, organizations, or incidents using the platform's filtering and search functions. The platform is designed to serve as a rich information resource for academic research, policymaking, and public education. A major feature of the platform is its comprehensive data presentation, which includes charts, maps, and text descriptions. This allows users to fully understand terrorist incidents from multiple perspectives.

In addition to these, some academic research teams and independent developers have created various visualization tools using GTD data. For example, the Data Science Team at Harvard University developed a machine learning-based visualization tool. This tool automatically identifies and analyzes potential patterns and trends in terrorist incidents. It combines geographic information systems (GIS) with machine learning algorithms to dynamically display the spatiotemporal evolution of terrorist activities. Through this dynamic visualization, users can observe how terrorist activities change over time and across different locations, helping them better understand the motivations behind these incidents.

There are also projects that involve open-source visualization tools developed by independent developers and research institutions. These tools are often highly flexible and customizable, allowing users to adapt them to their specific needs. Users can customize the display method and analysis dimensions of data according to their own needs. For example, some tools allow users to upload customized data sets for comparative analysis with GTD data to reveal deeper patterns of terrorist activities. One advantage of these open source tools is their openness and community support, which allows users to continuously expand and optimize the tool's functionality.

2.4.2 Comparison and Analysis

Although the above projects have achieved remarkable results in revealing the spatiotemporal distribution and patterns of terrorist activities, they also have some limitations and shortcomings. First, these projects have certain problems in the comprehensiveness and accuracy of data. Although GTD data is widely regarded as the most comprehensive terrorism database, some events may be missed or misclassified due to limitations and uncertainties in the data collection process[Sheehan 2012]. This makes the visualization results based on these data likely to be biased.

Second, these projects also have certain limitations in analytical methods and techniques. Most projects mainly rely on traditional statistical analysis and GIS technology, lacking in-depth exploration of complex patterns and relationships. For example, although GTD visualization tools can show the geographical distribution and temporal trends of terrorist incidents, they are limited in identifying and analyzing potential correlations and causal relationships between incidents[Lum, and Isaac 2016]. This limits researchers' understanding of the complex mechanisms behind terrorist activities.

In addition, these projects also have some shortcomings in user experience and interactivity. Although interactive maps and timelines can provide intuitive display methods, it is still difficult for non-professional users to understand and operate these tools. For example, users need to have certain background knowledge and technical skills to fully utilize these tools for in-depth analysis. This limits the application of these tools in public education and policy communication.

My research has introduced several innovations and contributions in the areas of data processing and visualization. Firstly, I have optimized data cleaning and processing techniques to ensure that the data is both accurate and complete. By combining multiple data sources and using improved data correction methods, the final dataset is more reliable and comprehensive.

Secondly, my research emphasizes improving the user-friendliness and ease of use of visualization tools. I have designed a more intuitive and simple user interface, allowing users to easily navigate these tools without needing a professional background. For example, I have developed a series of interactive maps and charts that enable users to view and analyze data on terrorist incidents with simple operations. This approach helps to broaden the audience for these tools, making them accessible to a wider range of people who can benefit from them.

Additionally, my research introduces dynamic visualization technology, which allows users to view and analyze changing data trends in real-time. This dynamic display method provides a more intuitive perspective and helps users better understand the spatiotemporal evolution of terrorist activities. For instance, through a dynamic timeline chart, users can easily see how the frequency of terrorist incidents changes over a specific period, helping them to better grasp the trends and patterns of these events.

In summary, my research provides some improvements and innovations based on the existing GTD data visualization projects by optimizing data processing methods, improving user interface friendliness, and introducing dynamic visualization technology.

2.5 Summary

2.5.1 Key findings

Through a review of the current status of global terrorism research, the following main findings and conclusions can be drawn: The definition of terrorism is widely controversial among academics and policymakers. Although the United Nations has not provided a unified definition, countries and organizations have given different definitions based on their respective legal and political backgrounds. Understanding the root causes and development trends of terrorism has a direct impact on policy making and public safety. Terrorism poses a serious threat to global security, international relations, economic stability and social structure. Studying its nature and motivation is crucial to developing effective counter-terrorism strategies.

Terrorism research involves multidisciplinary perspectives such as political science, sociology and psychology. The political perspective regards terrorism as a political tool, the sociological perspective focuses on social structure and cultural factors, and the psychological perspective explores individual psychological states and motivations. The roots of terrorism involve multiple factors such as political dissatisfaction, economic difficulties, social divisions and psychological factors. Terrorism not only damages the social, economic and political systems of the victim country, but also poses a threat to international relations and global security. Existing research summarizes a variety of counter-terrorism strategies, including preventive measures, intervention measures and recovery measures. Preventive measures such as education and community building aim to reduce the root causes of terrorism, intervention measures such as intelligence gathering and military operations directly target terrorist activities, and recovery measures focus on restoring social order and public trust after terrorist incidents.

The application of data visualization technology in terrorism research, especially tools such as GIS, D3.js and Tableau, helps researchers reveal the spatiotemporal distribution, patterns and trends of terrorist activities. GTD-based data visualization projects, such as START and GRTC's tools, provide intuitive presentation methods that enable researchers and policymakers to better understand the distribution and changes of terrorist activities.

2.5.2 Research gaps

Although many advances have been made in terrorism research, there are still the following deficiencies and research gaps:

1. Lack of uniformity in definition: Different countries and organizations have different definitions of terrorism and lack a unified standard, which makes cross-national research and comparative analysis difficult. Future research needs to explore a more unified and widely accepted definition of terrorism to facilitate data collection and analysis on a global scale.

2. Completeness and accuracy of data: Although databases such as GTD are considered to be comprehensive sources of terrorism data, there are still problems of missing events and misclassification in the data collection process. Future research needs to improve data collection and correction methods to ensure the accuracy and completeness of data.

3. Lack of in-depth analysis: Existing research mainly relies on traditional statistical analysis and GIS technology, and the in-depth exploration of complex patterns and relationships is limited. Future research should explore more advanced analytical methods, such as machine learning and big data analysis, to reveal the complex mechanisms behind terrorist activities.

4. User experience and operability: Although existing visualization tools provide intuitive display methods, it is still difficult for non-professional users to understand and operate these tools. Future research should focus on improving the user-friendliness and ease of use of tools so that more people can use these tools for analysis.

5. Insufficient real-time data monitoring: Existing research still has deficiencies in real-time data monitoring and dynamic visualization. Future research should

explore the application of real-time data streaming and dynamic visualization technology to improve early warning and emergency response capabilities for terrorist activities.

2.5.3 Future Research Directions

Based on the above research gaps and deficiencies, the research directions worth exploring in the field of terrorism research in the future include:

1. Exploration of a unified definition of terrorism

   Future research should strive to propose a definition of terrorism that can be widely accepted internationally to promote data collection, sharing and comparative analysis worldwide.

2. Improving data collection and processing methods

   Future research needs to develop more advanced data collection and correction methods, combining multiple data sources to ensure the comprehensiveness and accuracy of data. This will help provide a more reliable research basis.

3. Application of advanced analytical techniques

   Introduce advanced technologies such as machine learning and big data analysis to deeply explore the complex patterns and relationships of terrorist activities. This will help reveal the driving factors and evolution mechanisms behind terrorist activities.

4. Improving the user experience of visualization tools

   Future research should focus on designing more intuitive and easy-to-use visualization tools so that non-professional users can also use them easily. This will expand the scope of application of visualization tools and promote public education and policy dissemination.

5. Real-time data monitoring and dynamic visualization

   Future research should explore the application of real-time data streams and dynamic visualization technologies to improve the early warning and emergency response capabilities for terrorist activities. This will help relevant departments take quick measures to reduce the impact of terrorist activities.

Through in-depth exploration and application of the above research directions, future terrorism research will be able to more comprehensively understand the nature and motivations of terrorist activities, formulate more effective counter-terrorism strategies, and ensure global security and stability.

Chapter 3

Methodology

3.1 Data Collection

3.1.1 Dataset Description

The Global Terrorism Database (GTD) is a detailed, event-level database that records terrorist attacks occurring around the world since 1970. It is maintained by the National Consortium for the Study of Terrorism and Counterterrorism Strategies (START) at the University of Maryland. GTD is widely recognized for its extensive coverage and rigorous data collection methods, making it an essential resource for researchers, policymakers, and analysts who seek to understand the patterns, causes, and consequences of terrorism.

The origins of GTD can be traced back to Pinkerton Global Intelligence Services (PGIS), which compiled handwritten records of terrorist events from 1970 to 1997. These records were later digitized by START, which expanded the dataset by including additional events and variables. From 1998 to 2008, data collection was managed by the Center for Terrorism and Intelligence Studies (CETIS), and in 2011, it was taken over by the Institute for the Study of Violent Groups (ISVG). Since November 2011, START has independently managed ongoing data collection and management. They have worked to consolidate and standardize the data from different stages, ensuring consistency and reliability.

GTD uses a rigorous and multifaceted approach to data collection. It gathers information from a wide range of public, unclassified sources, such as media articles, electronic news archives, books, journals, and legal documents. The data collection process is supported by advanced technologies, including natural language processing (NLP) and machine learning, which help to filter and refine the vast amount of source material. This methodology ensures that each terrorist event is thoroughly researched and accurately coded according to GTDâs detailed specifications.

GTD is committed to transparency and inclusiveness. Its standards and coding system are fully public and accessible to all users, making it adaptable to various research needs. GTD is inclusive by including a wide range of events, while also providing filtering mechanisms that allow users to adjust the dataset according to their specific definitions of terrorism.

3.1.2 Inclusion Criteria

The GTD defines a terrorist attack as the threat or actual use of unlawful force and violence by non-state actors to achieve political, economic, religious, or social objectives through fear, coercion, or intimidation. For an incident to be included in the GTD, it must meet the following criteria:

1. Intentionality: The incident must be the result of a deliberate and conscious decision by the perpetrator.

2. Violence or threat of violence: The incident must involve some degree of violence or an immediate threat of violence.

3. Non-state actor: The perpetrator must be a non-state actor, meaning the incident excludes acts of state terrorism.

In addition, at least two of the following three criteria need to be met:

1. Political, economic, religious or social objectives: The conduct must be aimed at achieving broader systemic change beyond pure profit or personal motivations.

2. Coercive, intimidating or propaganda intent: There must be evidence that the conduct was intended to convey a message to an audience larger than the immediate victims.

3. Outside legitimate war activities: The conduct must be directed against noncombatants and go beyond what is permitted under international humanitarian law.

3.1.3 Dataset Variables

The data structure of GTD includes several key variables that capture comprehensive details of each event. Table 3.1 lists the variable information of the dataset, and the third column represents the specific variables belonging to a specific category.

3.2 Data Processing

3.2.1 Data acquisition and preliminary processing

To obtain data from the Global Terrorism Database (GTD), users can easily do so by following the steps below. First, visit the GTD official website at https://www.start.umd.edu/gtd/ and click the "USING GTD" option in the website's header navigation bar. Select "Download GTD" in the drop-down menu to enter the data download form page. Users need

Category	Definition	Specific variables
Event information	Includes date, location, summary, and inclusion criteria	eventid, iyear, imonth, iday, etc.
Attack information	Includes type of attack, whether it was successful, and whether it was a suicide attack	attacktype1, attacktype1_txt, attacktype2, attacktype2_txt, etc.
Weapon information	Includes type and subtype of weapon used	weaptype1, weaptype1_txt, weapsubtype1, weapsubtype1_txt, etc.
Target information	Includes type and subtype of target/victim, and specific details of the victim	targtype1, targtype1_txt, targsubtype1, targsubtype1_txt, etc.
Perpetrator information	Includes name of organization, suspected perpetrators, and their affiliations	gname, gsubname, gname2, gsubname2, etc.
Casualties and consequences	Includes number of deaths and injuries, and the wider impact of the attack	nkill, nkillus, nkillter, nwound, nwoundus, etc.
Additional information	Includes source of information and any additional details	addnotes, scite1, scite2, etc.

Table 3.1: GTD dataset variables overview

to fill in their personal information and a valid email address in the form to receive the database download link.

As of the time of writing this article (August 2024), the latest data updated on the GTD official website is recorded until June 2021. The GTD data sheets received by users are divided into two files, both in xlsx format. The first part covers data from 1970 to 2020, and the file name is "globalterrorismdb_0522dist.xlsx". The second part records terrorist incidents from January to June 2021, and the file name is "globalterrorismdb_2021Jan-June_1222dist.xlsx". The detailed records of these two data sheets enable researchers to comprehensively analyze terrorist activities over the past few decades.

The following code is used to read and check the contents of the two data files received. Check the basic information of the data, including the size of the data frame, column names, missing values, etc. This will help us understand the basic structure and quality of the data.

```
import os
os.chdir(r'E:\ucc\project_sjfan')

import pandas as pd
df1 = pd.read_excel('data/globalterrorismdb_0522dist.xlsx')
df2 = pd.read_excel('data/globalterrorismdb_2021Jan-June_1222dist.xlsx')

print("1970-2020 basic info:")
print(df1.info())
print("\nJan-June 2021 basic info:")
print(df2.info())
```

The above code reads two Excel files containing different time periods and performs statistics on their basic information. The running results are as follows.

```
1970-2020 basic info:
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 209706 entries, 0 to 209705
Columns: 135 entries, eventid to related
dtypes: datetime64[ns](1), float64(54), int64(23), object(57)
memory usage: 216.0+ MB
None

Jan-June 2021 basic info:
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 4960 entries, 0 to 4959
Columns: 135 entries, eventid to related
dtypes: datetime64[ns](1), float64(51), int64(29), object(54)
memory usage: 5.1+ MB
None
```

From the basic information of the data frame, we can see:

1. 1970-2020 data file:
    - There are 209,706 records in total.
    - Contains 135 fields.
    - The data types of the fields include: 1 datetime64[ns], 54 float64, 23 int64, and 57 object.
    - The memory usage of the data file is about 216.0+ MB.
2. January to June 2021 data file:
    - There are 4,960 records in total.
    - Contains 135 fields.
    - The data types of the fields include: 1 datetime64[ns], 51 float64, 29 int64, and 54 object.
    - The memory usage of the data file is about 5.1+ MB.

These preliminary inspection results show that the two data files are consistent in field structure, but slightly different in data type and memory usage. This information provides a basis for subsequent data processing and analysis, and also shows that the scale and complexity of the data set require us to consider memory and performance optimization when processing.

3.2.2 Data Merge

```
import os
os.chdir(r'E:\ucc\project_sjfan')

import pandas as pd
df1 = pd.read_excel('data/globalterrorismdb_0522dist.xlsx')
df2 = pd.read_excel('data/globalterrorismdb_2021Jan-June_1222dist.xlsx')
```

✓ 2m 0.9s

Figure 3.1: Read file code execution time

It should be noted that, as can be seen from Figure 3.1, it took 2 minutes and 0.9 seconds to read these two files. To save time, consider preliminary processing of the raw data. Since the fields of the two data files are exactly the same, they can be spliced column by column to obtain the final data table. Specifically, two data tables with sizes (209706, 135) and (4960, 135) will be merged into a data table of (214666, 135). According to the needs of this project, the merged table can be sliced, selecting only fields relevant to the project, and removing irrelevant fields.

In addition, the data table in xlsx format occupies a large amount of memory and takes a long time to read each time. Therefore, it is recommended to convert the data to csv format for later reading. In this way, the csv file can be read directly later, significantly saving time and computing resources. This processing method not only improves the efficiency of data processing, but also facilitates subsequent data analysis work.

```
merge_df = pd.concat([df1,df2])

data = merge_df[['iyear','country_txt','region_txt','provstate','city',
'latitude','longitude','attacktype1','attacktype1_txt','targtype1_txt',
'nkill','nwound']]
data = data.rename(columns={'iyear':'Year','country_txt':'Country',
'region_txt':'Region','provstate':'state','attacktype1':'AttackTypeCode',
'attacktype1_txt':'AttackType','targtype1_txt':'Target','nkill':'Killed','
nwound':'Wounded'})

csv_file = 'data/merged_global_terrorism_database.csv'
data.to_csv(csv_file, index=False)
```

The purpose of this code is to merge two data files and perform necessary preprocessing for subsequent analysis. First, the two data tables of size (209706, 135) and (4960, 135) are concatenated row by row using the pd.concat([df1, df2]) function to generate a new data frame merge_df of size (214666, 135). In the project, specific fields are selected from the merged data frame, including 'iyear, 'country_txt', 'region_txt', 'provstate', 'city', 'latitude', 'longitude', 'attacktype1', 'attacktype1_txt', 'targtype1_txt', 'nkill', and 'nwound'. These selected fields are stored in the data frame.

Next, these fields are renamed to make the data easier to understand. The renaming follows these specific rules:

- 'iyear' is renamed to 'Year'
- 'country_txt' is renamed to 'Country'
- 'region_txt' is renamed to 'Region'
- 'provstate' is renamed to 'state'
- 'attacktype1' is renamed to 'AttackTypeCode'
- 'attacktype1_txt' is renamed to 'AttackType'
- 'targtype1_txt' is renamed to 'Target'
- 'nkill' is renamed to 'Killed'
- 'nwound' is renamed to 'Wounded'

Finally, the processed data frame is saved as a CSV file with the filename *data merged_global_terrorism_database.csv*. The *index=False* option is set to ensure that the row index is not included in the file. This conversion stores the data in a smaller csv format for subsequent reading and analysis.

```python
merge_df = pd.concat([df1,df2])
data = merge_df[['iyear','country_txt','region_txt','provstate','city','latitude','longitude','attacktype1',
                 'attacktype1_txt','targtype1_txt','nkill','nwound']]
data = data.rename(columns={'iyear':'Year','country_txt':'Country','region_txt':'Region','provstate':'state',
                    'attacktype1':'AttackTypeCode','attacktype1_txt':'AttackType','targtype1_txt':'Target',
                    'nwound':'Wounded'})
csv_file = 'data/merged_global_terrorism_database.csv'
data.to_csv(csv_file, index=False)

data = pd.read_csv('data/merged_global_terrorism_database.csv')
data.shape
```

✓ 1.3s Python

```
(214666, 12)
```

Figure 3.2: Time of re-reading the CSV file

Figure 3.2 shows the reading time after the data is initially processed and converted to CSV format. Specifically, the time required to reread the CSV file is only 1.3 seconds, and the size of the merged data is (214666, 12). This result shows that the efficiency of data reading is significantly improved by preliminary processing of the data and converting it to CSV format.

The preliminary processing includes splicing the two data files by row and selecting fields related to the project. These fields cover key information such as year, country, region, province/state, city, latitude, longitude, attack type, target type, number of deaths and number of injuries. This processing method not only reduces the data redundancy caused by irrelevant fields, but also optimizes the data structure, thereby speeding up the reading speed.

Converting the data to CSV format further improves the processing efficiency. Compared with the xlsx format, the CSV format occupies less memory and reads faster, so it is more suitable for processing large amounts of data. This optimization process verifies the importance of data processing and storage format selection, and lays a good foundation for subsequent data analysis. Through this series of optimization steps, the data processing process of the project has been significantly improved and achieved the expected results.

3.2.3 Data cleaning

For the data file *data* after preliminary processing, further data cleaning is required to ensure the integrity and accuracy of the data. The data cleaning steps include checking all columns, handling missing values, and handling duplicate values.

1. View all columns of the data

   First, view all columns in the data frame to understand the overall structure and content of the data.

   ```
   Input:
       print(data.columns)
   ```

```
Output:
    Index(['Year', 'Country', 'Region', 'state', 'city', 'latitude',
    'longitude','AttackTypeCode', 'AttackType', 'Target', 'Killed',
    'Wounded'],
    dtype='object')
```

The above code shows all the fields in the data table, and the details are listed in the Table below. The explanations of these fields come from the CodeBook provided by the Global Terrorism Database (GTD) official website.

2. Missing value handling

   Next, check the missing values in the dataframe "data". The line *data.isnull().sum()* checks for missing values in each field of the dataframe. Specifically, *data.isnull()* generates a boolean dataframe of the same size as "data", where each element corresponds to a value in "data". If a value is missing (i.e. NaN), the boolean value at that position is True, otherwise it is False. *.sum()* sums the boolean values of each column. Since True is considered 1 and False is considered 0 in numerical calculations, the result returned by *.sum()* is the number of missing values in each field.

   In short, this line of code returns a series containing the number of missing values in each field, which helps identify which columns have missing values and the number of missing values.

```
Input:
    print(data.isnull().sum())

Output:
    Year                0
    Country             0
    Region              0
    state               0
    city              427
    latitude         4726
    longitude        4727
    AttackTypeCode      0
    AttackType          0
    Target              0
    Killed          12951
    Wounded         20705
    dtype: int64
```

   According to the above output, we can see that some fields in the data table have missing values. The specific situation is as follows:

   (a) There are 427 missing values in the "city" field.

Field	Attribute	Meaning
Year	iyear	This field contains the year in which the incident occurred. In the case of incident(s) occurring over an extended period, the field will record the year when the incident was initiated.
Country	country_txt	This field identifies the country or location where the incident occurred.
Region	region_txt	This field identifies the region in which the incident occurred.
state	provstate	This variable records the name (at the time of event) of the 1st order subnational administrative region in which the event occurs.
city	city	This field contains the name of the city, village, or town in which the incident occurred.
latitude	latitude	This field records the latitude (based on WGS1984 standards) of the city in which the event occurred.
longtitude	longtitude	This field records the longitude (based on WGS1984 standards) of the city in which the event occurred.
AttackTypeCode	attacktype1	This field captures the general method of attack and often reflects the broad class of tactics used, but indicated by numbers
AttackType	attacktype1_txt	This field captures the general method of attack and often reflects the broad class of tactics used
Target	targtype1_txt	The target/victim type field captures the general type of target/victim.
Killed	nkill	This field stores the number of total confirmed fatalities for the incident. The number includes all victims and attackers who died as a direct result of the incident.
Wounded	nwound	This field records the number of confirmed non-fatal injuries to both perpetrators and victims.

Table 3.2: Data fields and their meanings

(b) There are 4726 missing values in the "latitude" field.

(c) There are 4727 missing values in the "longitude" field.

(d) There are 12951 missing values in the "Killed" field.

(e) There are 20705 missing values in the "Wounded" field.

For the "city", "latitude", and "longitude" fields, although there are missing values, we choose to keep these null values. The reason is that these fields record the specific geographical information of the incident. Although some data is missing, keeping these fields can provide richer geographical analysis dimensions for those complete records. In addition, the missing geographic location information may be due to the failure to record the location in detail in the incident report, so keeping the null value instead of filling other default values can avoid introducing erroneous information.

On the other hand, for the fields "Killed" and "Wounded", since they record the specific numbers of deaths and injuries in the incident, missing values may mean that casualties were not recorded in the report, or that the incident did not cause any casualties. In order to ensure consistency and accuracy in subsequent data analysis, we choose to use "0" to fill these missing values. This treatment can prevent calculation errors caused by missing values in statistical analysis, and "0" can reasonably represent the situation of an incident without casualties in this case.

```
Input:
    data['Killed'] = data['Killed'].fillna(0)
    data['Wounded'] = data['Wounded'].fillna(0)
    print(data.isnull().sum())

Output:
    Year                0
    Country             0
    Region              0
    state               0
    city              427
    latitude         4726
    longitude        4727
    AttackTypeCode      0
    AttackType          0
    Target              0
    Killed              0
    Wounded             0
    dtype: int64
```

The above code fills the missing values in the "Killed" and "Wounded" columns and prints the missing values of each field after filling. It can be seen that there are no missing values in the "Killed" and "Wounded" columns.

3. Duplicate value processing

   Finally, it is important to detect and delete duplicate data in the data frame to ensure the uniqueness and accuracy of the data.

   To achieve this, you can start by detecting duplicate values in the data frame. Use the *duplicated().sum()* method to count the number of duplicate rows. If any duplicate data is found, it should be removed using the *drop_duplicates()* method. This process helps ensure that the dataset remains accurate and consistent.

```
Input:
    duplicate_count = data.duplicated().sum()
    print(f"Number of duplicate rows: {duplicate_count}")

    data = data.drop_duplicates()

Output:
    Number of duplicate rows: 37282
```

   According to the output of the above code, there are 37,282 rows of duplicate data in the data table. This indicates that these rows contain repeated records within the dataset, which could potentially impact the accuracy of subsequent analysis and results.

   To ensure the uniqueness and consistency of the dataset, the *drop_duplicates()* method is applied in the code to delete these duplicate rows. By removing the duplicate data, each record in the dataset becomes independent and unique, which helps prevent biases or inaccuracies in the statistical analysis. This step is essential for improving the quality of the data and enhancing the reliability of the analysis results.

3.3 Technology Stack

This project selected a series of technology stacks suitable for data visualization and analysis to achieve intuitive display and user interaction of global terrorism data. Specifically, the following technologies are included:

1. Dash: As the main front-end framework, Dash is an open source tool based on Python that can quickly build highly interactive data visualization web applications. Dash was chosen because it can be seamlessly integrated with data analysis libraries in the Python environment (such as Pandas), and complex interactive interfaces can be built without front-end development experience. This project mainly uses Dash for layout and function implementation.

2. Bootstrap: To enhance the user interface design and improve the responsive layout capabilities of the application, this project utilizes Bootstrap. Bootstrap is a widely used CSS framework that offers a comprehensive set of UI components. By using Bootstrap, we can quickly create a visually appealing and consistent front-end interface, ensuring that the application is both user-friendly and responsive across different devices.

3. Python: Python was chosen as the core programming language for the project due to its powerful capabilities in data processing and analysis. Additionally, Python offers extensive library support, such as Pandas and Plotly, which simplifies the data processing workflow and enhances data visualization. These libraries make it easier to handle complex data tasks and create insightful visual representations, contributing to the overall effectiveness of the project.

4. Pandas: Pandas is utilized for data cleaning, processing, and analysis in this project. As the most commonly used data analysis library in Python, Pandas supports the efficient processing and manipulation of various data formats. It is particularly well-suited for handling large-scale datasets, such as global terrorism data, making it an ideal choice for managing and analyzing the extensive data involved in this project.

5. Plotly: Plotly is a powerful data visualization library selected for this project due to its ability to generate high-quality interactive charts. Its tight integration with Dash allows for the dynamic display of complex data patterns and trends within web applications. All map and chart visualizations in this project are implemented using Plotly, making it a crucial tool for effectively presenting the data in an interactive and visually appealing manner.

3.4 System Design

3.4.1 System Architecture

The overall architecture of the system is divided into three main parts: the front-end, back-end, and data storage. The front-end utilizes Dash and Bootstrap to create the user interface and data visualizations. The back-end is powered by Python, which handles data processing and logic control. For data storage, the system uses the local file system to store data downloaded from the open-source platform. This architecture ensures efficient interaction between the user interface, data processing, and storage components.

Front-end is responsible for user interface display and interaction, using Dash to build a dynamic data visualization interface, and Bootstrap to provide UI components and layout support. Back-end processes data requests and calculation logic, uses Python to write API interfaces, and realizes communication with the front-end. The processed data files are stored locally, and the back-end reads the data from them and passes it to the front-end for display.

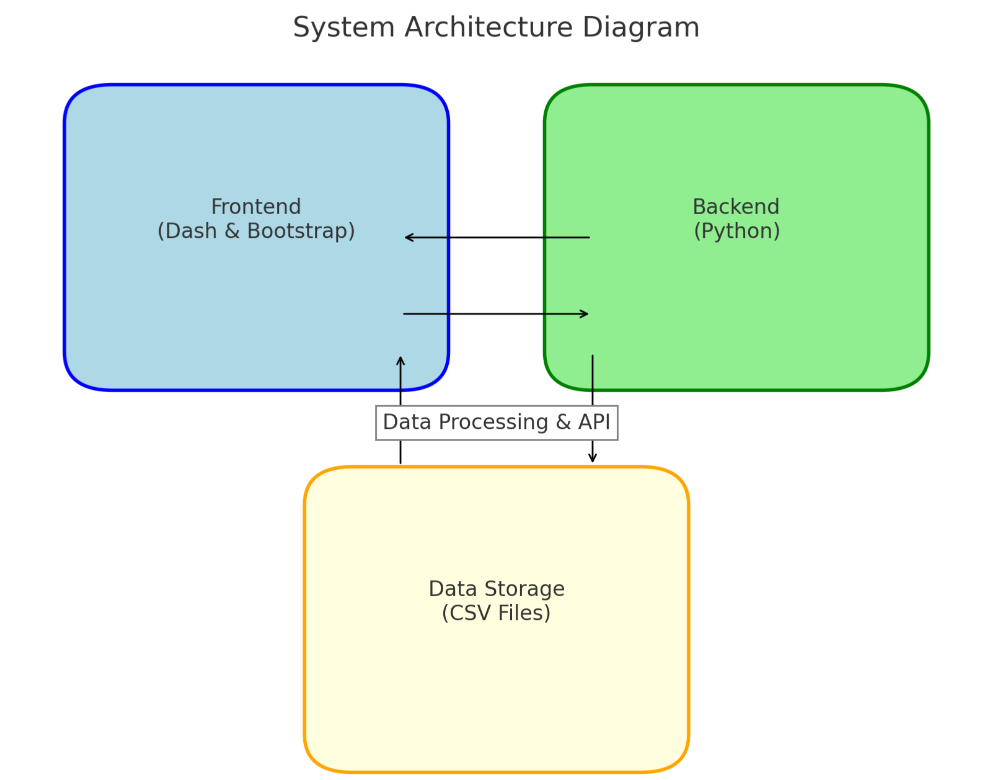

Figure 3.3: System architecture diagram

The system is mainly divided into the following modules:

1. Data collection module: responsible for downloading global terrorism-related data from the open source data platform and storing it locally.
2. Data processing module: using Pandas to process and clean data, including data screening, format conversion and other operations.
3. Visualization module: Based on Dash and Plotly, the processed data is displayed in the form of charts, supporting users to interact with the charts.
4. Front-end interaction module: Through the callback mechanism provided by Dash, dynamic interaction between users and data is realized, such as setting filter conditions and real-time updating of charts.

3.4.2 Interface Design

In the user interface design of this project, the system is mainly composed of three core parts:

1. Title bar: Located at the top of the page, it serves as the title area of the dashboard. The title bar not only displays the name of the dashboard, but also directly connects to the page for obtaining the source data. Users can easily access and verify the accuracy and reliability of the data source by clicking on the title, thereby enhancing trust in the results of data analysis.

2. Interaction and chart area: This section consists of a filter component and two chart components. The filter component allows users to flexibly select specific years, regions, or event types through drop-down menus, sliders, etc. The chart component will dynamically respond to the user's selection and update the data chart that matches the filter conditions in real time. This interactive design improves the efficiency of data exploration and enables users to easily obtain the trends and distribution of terrorist incidents under specific dimensions.

3. Map visualization component: Located at the bottom of the interface or other appropriate locations, it is used to display the geographical distribution of global terrorist incidents. The map component not only intuitively presents the density and distribution of events in different regions, but also supports further user interaction, such as clicking on a specific region to view detailed event information in that region.

Figure 3.4 shows the components of the project interface:

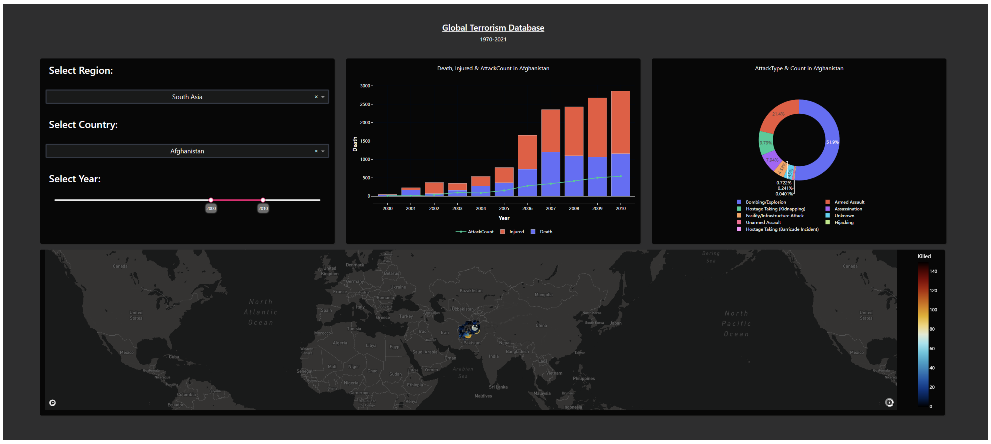

Figure 3.4: User interface design

The system implements dynamic data display and interaction between the above user interface components through the callback mechanism provided by the Dash framework. Specific functions include:

1. Data filtering: Users can select specific years, regions or event types through filtering components (such as drop-down menus and sliders). The system will update the content of related charts in real time according to the user's filtering conditions to ensure the pertinence and accuracy of data display.

2. Chart linkage: When a user interacts on a chart (such as clicking on an event type in a bar chart), other charts will be updated synchronously to display detailed data of the event type. This linkage mechanism enhances the intuitiveness of data analysis and helps users better understand the relationship between different data dimensions.

3. Real-time update: The system is designed to calculate and process data in real-time in the background based on the user's interactions. It then presents the updated results on the front-end interface. This design ensures that users receive instant feedback during data exploration, which significantly enhances the overall user experience. By providing immediate responses to user actions, the system allows for a more interactive and engaging data analysis process.

Chapter 4

Implementation

4.1 Overview

The extensiveness and complexity of global terrorist activities make it challenging to systematically analyze and understand them. To gain a better understanding of the spatiotemporal distribution and trends of these activities, an effective visualization tool is essential. Such a tool allows users to intuitively view and analyze data, thereby supporting decision-making and research. The visualization page of this project is designed to provide users with a comprehensive analysis platform, helping them explore and understand various patterns and trends in global terrorist activities by integrating data from the Global Terrorism Database (GTD).

The design of this visualization tool uses the Global Terrorism Database as its primary data source, covering terrorist incidents from 1970 to June 2021. GTD is one of the most comprehensive terrorist incident databases globally, recording detailed information on terrorist incidents worldwide, including location, time, event type, target, responsible group, casualties, and more. By leveraging this database, the project offers in-depth analysis and insights, enabling users to better understand the dynamics of terrorist activities.

The core features of the visualization page include an interactive map and two charts, all of which are dynamically updated based on user-selected filters. Users can utilize the filter component located at the upper left of the page to filter data by region, country, and year. The filter component is divided into three parts: region selection, country selection, and year selection. The region and country selections are presented as drop-down menus, allowing users to choose from a predefined list of regions and countries. The year selection is implemented through a slider bar, enabling users to select a specific time range. As users adjust these parameters, the other components on the page, such as maps and charts, automatically update to reflect the selected criteria.

One of the primary components of the page is the interactive map, which displays the locations of all terrorist incidents within a selected country during the time period specified by the user. This map allows users to visually explore the geographical distribution of terrorist activities, providing valuable insights into regional and temporal patterns. Each circular mark on the map represents an incident, and the size and color of the circle reflect the number of incidents and the impact. Users can click on the circular mark on the map to view detailed information about the incident, such as the type of incident, the number of casualties, etc. The design of the map allows users to intuitively see the geographical distribution of terrorist incidents and further explore the details of incidents in specific regions.

Above the map, the page displays two charts, namely a stacked bar chart and a pie chart. These two charts provide further analysis of terrorist incidents and help users understand the trend and type distribution of incidents. The stacked bar chart shows the trend of casualties and the number of attacks in terrorist incidents in the country within the time range selected by the user. By stacking different colors, users can clearly see the changing trends of casualties and attacks in different years. The pie chart shows the type of terrorist incidents in the country during the time period, and uses different colors to distinguish different types of incidents, such as explosion/explosive attacks, armed attacks, hostage hijacking, etc. Users can quickly grasp the distribution of different types of terrorist incidents within a country during a specific time frame by viewing the pie chart. The design of the visualization page emphasizes the user's interactive experience. All charts and maps are dynamically updated, ensuring that every user selection is instantly reflected on the page, which provides a highly responsive and engaging user experience. This design approach not only makes data exploration more intuitive and flexible but also helps users analyze and interpret data from multiple perspectives.

Additionally, the page's design focuses on visual appeal, making complex data easier to understand through a simple layout and well-chosen color schemes. This attention to visual beauty enhances the overall user experience by presenting information clearly and attractively.

Overall, this visualization tool offers users a powerful platform for analyzing global terrorist incidents by integrating data from the Global Terrorism Database and utilizing advanced data visualization technology. Through the use of maps and charts, users can intuitively observe the geographical distribution and temporal trends of events. They can also gain a deeper understanding of specific events through interactive features. This multi-dimensional data visualization is well-suited not only for academic research but also for providing decision support to policymakers and security agencies. It helps them better understand and respond to terrorist threats around the world.

4.2 Interface Implementation

4.2.1 Page structure

This text describes a simple and easy-to-understand page layout design. It helps users easily browse and analyze data in the Global Terrorism Database. The page layout is divided into three main parts. The first part is the navigation bar. The second part is the filter component. The last part is the area for interactive charts and maps.

1. Navigation Bar

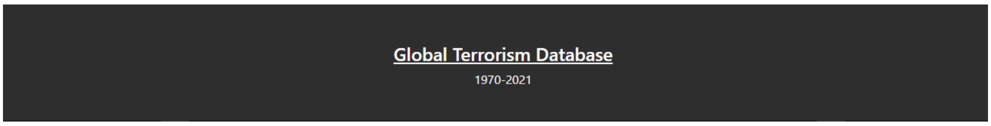

Figure 4.1: Navigation Bar

The navigation bar is placed at the top of the page. It stretches across the entire width of the page. This design makes sure that users can easily reach important features and project details. The name of the project, "Global Terrorism Database," along with the time range of the data (1970-2021), is shown in the middle of the navigation bar. The name not only clarifies the theme of the page, but is also designed as a hyperlink that will navigate to the official website of the data source after clicking, providing users with more information about the source of the data. The navigation bar does not contain other menu options, aiming to keep the interface simple and focused.

2. Filters

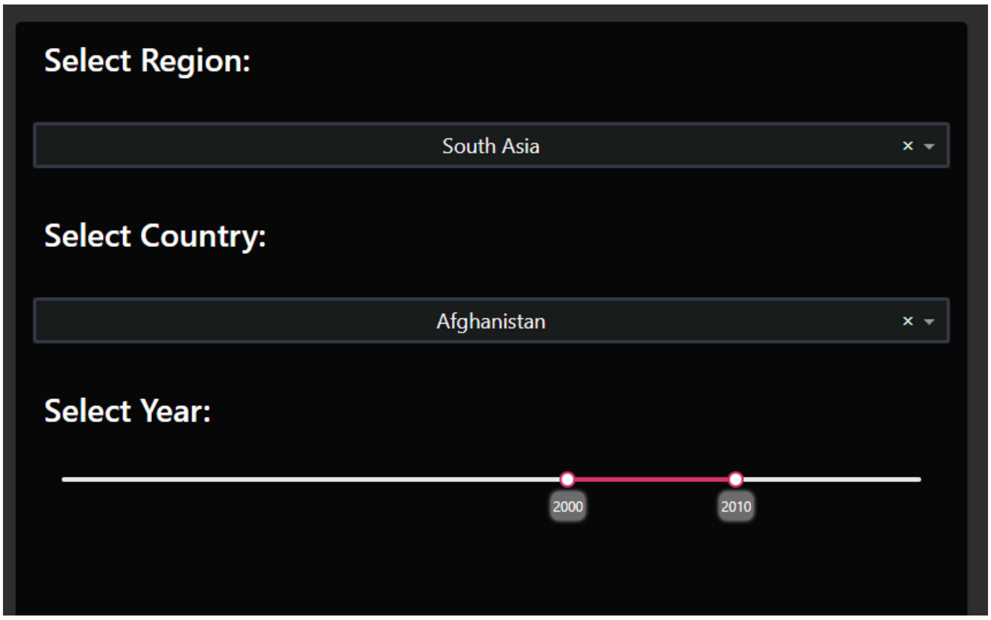

Figure 4.2: Filters

The filter component is positioned in the upper left corner of the page. It takes up the left side of the page, just below the navigation bar. This placement was chosen to make sure users can easily find and use the data filtering function. There is a drop-down menu that lets users choose a specific geographic area, such as a continent or region, to narrow down the data shown. Another drop-down menu lets users select specific countries from the chosen region to further refine the data displayed. Additionally, there is a slider component that allows users to choose a specific time range. This slider is designed to help users accurately pick a range of years to see how terrorist incidents changed over a certain time period.

3. Interactive charts and map area

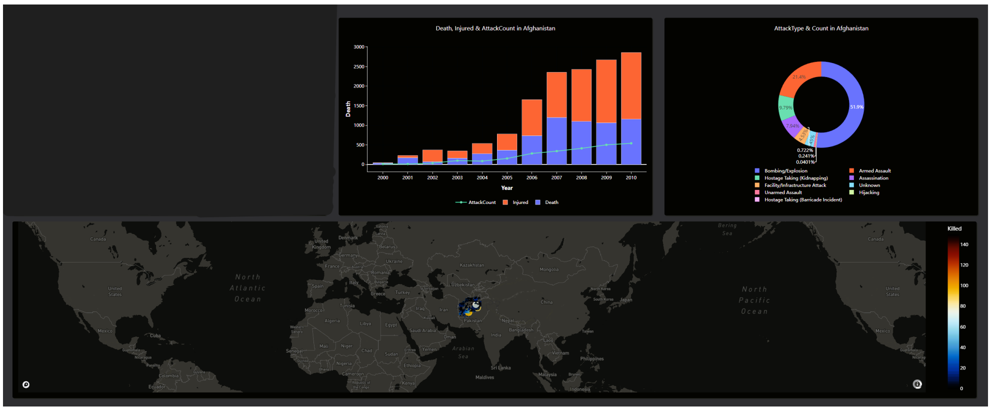

Figure 4.3: Interactive charts and map

The interactive charts and map area is placed in the center and bottom parts of the page. This section is the main display area for the entire page. It stretches across the full width of the page to ensure that data visualization is presented in the best possible way.

At the bottom of the page, you will find the map, which also spans the entire width of the page. The map shows the geographical distribution of all terrorist incidents within a specific country during the time period chosen by the user. Circular markers on the map represent events. The color and size of these markers indicate the type of event and the number of occurrences, respectively.

Users can explore the distribution of events in various regions by using the zoom and pan functions on the map. By clicking on an event marker, users can see detailed information about the event, such as the type of event and the number of casualties.

Above the map, in the left area, is the Stacked Bar Chart. This chart shows the trend in casualties and the number of attacks in terrorist incidents within a specific country during the selected time range. The stacked sections of different colors represent different statistical items, such as the number of deaths, injuries, and number of incidents.

The Pie Chart is located to the right of the stacked bar chart and is used to show the distribution of terrorist incident types in the country during the time period. The fan-shaped sections of different colors represent different types of terrorist incidents, such as explosions, armed attacks, hijackings, etc.

4.2.2 Key Components

1. Interactive Map

   - Mapview: The interactive map occupies the lower half of the page and spans the entire width of the page. This design allows the map to display a wide range of geographic data, making it easier for users to conduct global analysis. The map supports interactive operations such as zooming and panning. Users can view different areas by dragging the map, or focus on specific areas through the zoom function. The circular marks on the map represent terrorist incidents. Users can click on these marks to view detailed information about the incident, such as the location of the incident, the type of incident, and the number of casualties.
   - Data presentation: The event markers on the map use Plotly's IceFire continuous color mapping to indicate the number of deaths (Killed) caused by the incidents that occurred at that location. The colors gradually transition from cold tones (such as blue) to warm tones (such as red), indicating the number of deaths. The closer the color is to the warmer tone, the more deaths there are. This color coding helps users quickly identify which areas have caused more deaths. The size of each circular marker is proportional to the number of attacks (AttackCount) at that location. The more attacks there are, the larger the bubble. This design allows users to intuitively identify areas where terrorist activities frequently occur.
   - Map Interaction: Each event marker on the map is clickable, and when clicked, an information box pops up to display detailed information about the event. This interactive design allows users to explore the background and details of each event in depth.

2. Charts

   - Bar chart and line chart: The bar chart is located in the left area above the map and is used to show the number of terrorist incidents in a country and the casualties caused in a specific time period. The line chart is superimposed on the bar chart to show the trend of the number of attacks. The bar chart is designed to show the severity of the incident through stacked sections of different colors (for example, red for deaths and blue for injuries). The line chart helps users understand the time trend of the number of attacks and discover the changing patterns within a specific time period.
   - Pie chart: The pie chart is located to the right of the bar chart and shows the distribution of terrorist incidents in a country during a specific time

period. The pie chart uses different colored sectors to distinguish incident types, such as explosion/explosive attacks, armed attacks, hijackings, etc. Through the pie chart, users can quickly understand the proportion of a certain type of terrorist incident in the total incidents and view detailed data by clicking on a specific sector.

- Chart interaction: When the user hovers over a section of a bar chart or pie chart, the system will display detailed data for that section, such as the number of deaths in a specific year or the number of a certain type of incident. The user can also click on a sector of the pie chart to further filter the distribution of that type of incident on the map.

3. Filters

   The filter component is located in the upper left corner of the page and is the main tool for users to filter data. The filters include region selection, country selection, and year selection, with a compact layout and easy operation. Users can select a region or country through the drop-down menu to limit the range of data displayed. Year selection is achieved through a slider bar, and users can select a specific time period by dragging the slider. This design ensures that users can quickly filter out event data of interest.

4. User Experience Design

   - Responsive Design: The page uses responsive design to ensure good display on different devices. Through CSS elastic layout and media queries, the page layout automatically adjusts according to the screen size. On large-screen devices, charts and maps are displayed side by side, while on small-screen devices, the layout is arranged vertically to adapt to touch operations. Navigation bars and filters automatically collapse on small screens to reduce space usage while maintaining functional usability.
   - Color and Visual Hierarchy: The page uses a color scheme of dark background and high-contrast foreground elements, using bright colors and gradients of warm and cool colors to highlight important data. The font selection uses a simple and easy-to-read sans serif font, and the title and key data are larger and bold to help users quickly grasp the core information. By adjusting the size, color and position of elements, the page creates a clear visual hierarchy to guide users' attention to important information.
   - Accessibility Design: The page design takes into account the needs of color-blind and visually impaired users, ensuring that the color contrast of key data is sufficient and can be clearly identified even in color-blind mode. At the same time, different shapes and line styles are used to supplement color coding. The page complies with the Web Content Accessibility Guidelines, ensures that the text contrast is high enough, supports font size adjustment, and optimizes the experience of keyboard navigation and screen readers to facilitate all users to access and understand the content.

4.3 Function Implementation

4.3.1 Implementation of filters

The main part of the filter component includes three filter conditions: "Select Region", "Select Country" and "Select Year". The component is implemented through *dcc.Dropdown* and *dcc.RangeSlider*, which are used for drop-down selection and time range selection respectively.

```
def FilterInfo():
    return html.Div(
        [
            html.Div(
                [
                    html.H3('Select Region:',className='filter_item'),
                    dcc.Dropdown(
                        list(all_options.keys()),
                        'South Asia',
                        id='Region'
                    )
                ]
            ),
            html.Div(
                [
                    html.H3(f'Select Country:',className='filter_item'),
                    dcc.Dropdown(
                        id='Country'
                    )
                ],style={'paddingTop':'40px'}
            ),
            html.Div(
                [
                    html.H3('Select Year:',className='filter_item'),
                    dcc.RangeSlider(
                        min=year_min,
                        max=year_max,
                        step=1,
                        marks=None,
                        value=[2000,2010],
                        tooltip={"placement": "bottom", "always_visible": True},
                        id='Span-year'
                    )
                ],style={'paddingTop':'40px'}
            )
```

```
        ]
    )
```

- Select Region: A *dcc.Dropdown* dropdown is used, and the user can select a predefined list of regions. The region selection is the first filter on the page, and the content of other filters is dynamically updated based on this selection.
- Select Country: The content of the country selection is dynamically generated based on the region selected by the user. When the user selects a region, the country dropdown is automatically updated to all countries in that region. This is achieved through the callback function *set_cities_options*, which updates the list of countries based on the selected region.
- Select Year: A *dcc.RangeSlider* component is used, and the user can select a range of years by dragging the slider. The minimum and maximum values of the slider are set to the earliest and latest years in the data, respectively, and the default value is set to between 2000 and 2010. Each movement of the slider triggers a reload of the data and an update of the chart.

```
@app.callback(
    Output('Country', 'options'),
    Input('Region', 'value'))
def set_cities_options(selected_country):
    return [{'label': i, 'value': i} for i in all_options[selected_country]]

@app.callback(
    Output('Country', 'value'),
    Input('Country', 'options'))
def set_cities_value(available_options):
    return available_options[0]['value']
```

When the user changes the filter options, the front end triggers the callback functions associated with them, which filter the data according to the user's selection. For example, when the region or country selection changes, the related map and chart data will be filtered to show events within the selected region and time period.

The core implementation of data filtering is done through data processing functions defined in the *api.py* file, such as *get_bar_data* and *get_pie_data*. These functions filter the data set according to the filter conditions and then return the results to the front end for visualization.

4.3.2 Implementation of interactive maps

In this project, Plotly and Mapbox libraries are used to implement interactive map visualization. Specifically, *scatter_mapbox* is used to map the processed terrorist incident data onto the map.

```
geo_df_filter = geo_df[(geo_df['Region']==region) & (geo_df['Country']==country)
    & (geo_df['Year']>=span_year[0]) & (geo_df['Year']<=span_year[1])]

fig = px.scatter_mapbox(geo_df_filter, lat="latitude", lon="longitude",
    color="Killed", size="AttackCount",color_continuous_scale=px.colors.
    cyclical.IceFire,
    size_max=15,zoom=2,hover_data = geo_df_filter.columns)

fig.update_layout(
    font = {'family':'sans-serif','color':'white','size':12},
    paper_bgcolor = '#070707',
    plot_bgcolor = '#070707',
    margin=dict(r=0, l =0, b = 0, t = 0),
    mapbox=dict( accesstoken='pk.eyJ1IjoicXM2MjcyNTI3IiwiYSI6ImNra
    GRuYTF1azAxZmIycWs0cDB1NmY1ZjYifQ.I1VJ3KjeM-S613FLv3mtkw',
    style='dark')
    )
```

The map uses Mapbox as the underlying map engine, and sets style='dark' to provide a dark background for the map to match the overall design style of the page. The initial zoom level of the map (zoom=2) is configured to display terrorist incidents around the world, allowing users to explore in a wide geographic area.

The terrorist incident data includes information such as geographic coordinates (latitude and longitude), the number of deaths caused by the incident ('Killed'), and the number of attacks ('AttackCount'). These data are loaded onto a map and visualized using the *scatter_mapbox* function:

- Latitude and longitude: Use the 'lat="latitude"' and 'lon="longitude"' parameters to map the events to specific locations on the map.
- Color mapping: The 'color="Killed"' parameter specifies the color of the bubble to represent the number of deaths at that location. The color mapping uses Plotly's 'IceFire' continuous color scheme, which gradually changes from cold to warm tones, representing the number of deaths.
- Bubble size: The 'size="AttackCount"' parameter controls the size of the bubble, which represents the number of attacks at that location. The maximum size of the bubble is set by 'size_max=15' to ensure that different events can be clearly distinguished even when data points are dense.

The background and font colors of the map are set to dark tones, and are unified to '#070707' through the paper_bgcolor and plot_bgcolor configuration items to ensure good contrast and readability on a dark background. In the mapbox configuration of the map, the Mapbox access token is used to access advanced map features. All interface elements (such as legends, zoom controls, etc.) are integrated into the map's boundaries to save space and improve user experience.

When you click an event mark on the map, Plotly will automatically display a popup box (Popup) to display detailed information related to the event. This information includes the specific location of the event, time of occurrence, number of fatalities, type of attack, etc. All this data is specified through the hover_data parameter, allowing users to obtain detailed information about the event in real time when interacting with the map. The map is set to a global perspective by default. Users can zoom and pan through mouse or touch operations to explore the distribution of terrorist incidents in different areas. In order to ensure performance under large data volumes, the map uses Mapbox's vector layer technology, which can maintain efficient rendering and smooth interactive experience when there are many data points.

In order to avoid lags when the amount of data is large, the data filtering (geo_df_filter) method is used in the code. When the user selects a specific region, country, and time period, only relevant data is loaded and rendered. This on-demand loading method significantly improves the map's response speed, ensuring that the map's response remains smooth when users perform complex interactive operations (such as rapid zooming and panning).

4.3.3 Implementation of the display module

```
death,wounded,attackCount = get_bar_data(region,country,span_year)
span_year_ls = list(range(span_year[0],span_year[1]+1))

fig = go.Figure(
    [
        go.Bar(x=span_year_ls,y=death,name='Death'),
        go.Bar(x=span_year_ls,y=wounded,name='Injured'),
        go.Scatter(mode='markers + lines',x=span_year_ls,y=attackCount,
        name='AttackCount')
    ]
)
fig.update_layout(
        barmode = 'stack',
        titlefont = {'color':'white','size':20},
        font = {'family':'sans-serif','color':'white','size':12},
        hovermode = 'closest',
        paper_bgcolor = '#070707',
        plot_bgcolor = '#070707',
        legend = {'orientation':'h','bgcolor':'#070707','xanchor':'center',
        'x': 0.5, 'y': -0.2},
        margin = {'r':0,'l':60,'b':100,'t':20},

        xaxis = {'title':'<b>Year</b>','color':'white','showline':True,
            'showgrid':True,'tick0':0,'dtick':1,'gridcolor':'#010915',
```

```
            'showticklabels':True,'linecolor':'white','linewidth':1,
            'ticks':'outside','tickfont':{'family':'sans-serif',
            'color':'white','size':12}
                    },
        yaxis = {'title':'<b>Death</b>','color':'white','showline':True,
        'showgrid':True,'gridcolor':'#010915','showticklabels':True,
        'linecolor':'white','linewidth':1,'ticks':'outside',
        'tickfont':{'family':'sans-serif','color':'white','size':12}
        }
)
```

The stacked bar chart is used to show the number of deaths (‘Death‘) and injuries (‘Injured‘) in a country each year. The data is drawn using the ‘go.Bar‘ method. The stacking effect is achieved using ‘barmode='stack'‘, which allows users to intuitively see the overall casualties each year. The line chart is superimposed on the stacked bar chart to show the number of attacks (‘AttackCount‘) in the country each year. It is drawn using the ‘go.Scatter‘ method, with ‘mode='markers + lines'‘ set to connect the trend of the number of attacks in each year with lines while displaying the data points.

The layout of the chart is carefully designed to ensure good readability on a dark background. Elements such as titles, axis labels, and legends are all in white fonts and are configured in detail using the ‘update_layout‘ method. The grid lines of the X-axis and Y-axis are set to a darker color to maintain data visibility without interfering with the overall aesthetics of the chart.

```
data = get_pie_data(region,country,span_year)

fig = px.pie(
    data_frame=data,
    values='Count',
    names='AttackType',
    hole=0.65
)

fig.update_layout(
    paper_bgcolor = '#070707',
    plot_bgcolor = '#070707',
    font = {'family':'sans-serif','color':'white','size':12},
    legend = {'orientation':'h','bgcolor':'#070707','xanchor':
    'center','x': 0.5, 'y': -0.2},
)
```

Pie charts are used to show the distribution of different types of terrorist incidents in a country over a specific time period. The data is plotted using the ‘plotly.express.pie‘ method to show the percentage of each attack type. Each pie section in the pie chart uses a different color to represent a different attack type, and the ‘px.colors.qualitative‘

color scheme ensures that each type of event is clearly distinguishable. The legend is placed next to the chart, allowing users to easily match colors to event types.

Pie charts have basic interactive features, such as displaying specific values when the mouse hovers, and clicking on a pie section to highlight or select a specific type of event. Users can use this chart to quickly understand the percentage of different attack types in the total number of events.

4.4 Technical Challenges and Solutions

In the process of realizing the Global Terrorism Database Visualization Project, the development team faced a number of technical challenges. Here are the main challenges and their corresponding solutions.

4.4.1 Performance Optimization

- Challenges

  Since the Global Terrorism Database contains a large amount of event data (covering decades, multiple regions and countries), directly loading and rendering all the data may result in slow page loading and poor user experience. In addition, with the increase in user interaction, frequent data updates and chart redrawing may cause the front-end rendering speed to slow down, especially when dealing with large data sets.

- Solution

  The project adopts data preprocessing and on-demand loading strategies. By cleaning, aggregating and transforming the original data, only the key information required for visualization is retained, thereby reducing the amount of data loaded on the front-end. In addition, when the user selects different regions, countries and time periods, only the relevant subset of data is loaded in the background and passed to the front-end. This on-demand loading method effectively reduces the initial loading time and improves the responsiveness of the page.

  The project also uses a variety of means to improve the front-end performance, including lazy loading technology and reducing unnecessary DOM operations. The rendering of the chart is also optimized, using Plotly's efficient rendering mode to ensure that the page maintains a smooth user experience even in the case of complex charts. The rendering performance is further improved by optimizing the configuration of the chart and reducing unnecessary animation effects.

4.4.2 Responsive Design Challenge

- Challenges

When implementing responsive design, ensuring that the page has good usability and aesthetics on a variety of devices (from desktop to mobile devices) is a complex task. Since the page contains multiple interactive charts and maps, maintaining good display effects on different screen sizes requires fine-tuning.

- Solution

  Through CSS media queries and flexible layout (Flexbox) technology, the page layout can be dynamically adjusted according to the screen size. For small-screen devices, the page layout is adjusted from horizontal to vertical arrangement, and the size of charts and maps is scaled to ensure that the content is clearly visible on mobile devices. In addition, the navigation bar and filters are optimized to ensure that they do not take up too much space on small screens and are easy to operate.

4.4.3 Interaction design challenges

- Challenges

  The interactive features in the project (such as smooth zooming and panning of maps, dynamic updating of charts) require processing large amounts of data and complex event processing logic. It is easy to encounter performance bottlenecks and poor user experience when implementing these features.

- Solution

  For map interaction, the project uses Mapbox's vector layer technology. This technology ensures that the map responds quickly and stays smooth when users zoom and pan. For chart interaction, Dash's callback function mechanism is implemented. This mechanism ensures that the chart updates in real-time based on the user's filtering conditions. Additionally, asynchronous data processing technology is included in the project. This helps prevent the main thread from getting blocked during complex interactive operations, which enhances the smoothness of the user experience.

Chapter 5

Evaluation

5.1 Test Method

5.1.1 Overview

This section aims to assess the overall performance and functional effectiveness of the global terrorism data visualization system. The system's main functions include map visualization, data filtering, and timeline features. The design goal is to make sure that users can easily interact with the system through a simple and intuitive interface. It allows users to transform complex data tables into charts that are easy for everyone to understand. In order to ensure the practicality and ease of use of the system, we pay special attention to the system's response speed and the smoothness of user interaction in data-intensive scenarios.

The main test scope of this evaluation includes two aspects: timeline functional testing, that is, measuring the system's response speed when loading a large amount of global terrorist incident data to evaluate the system's performance, and user experience testing, that is, through user feedback and operation analysis, evaluating the intuitiveness and fluency of the system in functional use, ensuring that users can successfully complete operations such as data filtering and timeline adjustment.

5.1.2 Test Cases

In order to comprehensively evaluate the performance and functional performance of the global terrorism data visualization system, we designed the following test cases. These use cases cover the key functions and user interaction scenarios of the system, aiming to verify the system's responsiveness, stability and user experience.

1. Use Case 1: Timeline Function Test

    - Test Objective: Test the operation smoothness and responsiveness of the timeline function in different year ranges.

- Test Data: Use a complete dataset containing global terrorism events.
- Test Steps: 1. Select a shorter time range (such as 1 year) on the timeline and observe the event distribution update on the map.

  2. Adjust the timeline to a longer time range (such as 30 years) and observe the event distribution update on the map.

  3. Test the dragging function of the timeline to see if the map can be updated in real time and display the corresponding data.
- Expected Result: The system should update the data displayed on the map within 2 seconds after the time range is adjusted, and there should be no obvious delay when dragging the timeline.

2. Use Case 2: Data Filtering Function Test

   - Test Objective: Verify the accuracy and responsiveness of the system's data filtering function.
   - Test data: Use the same global terrorism incident data set to simulate a scenario where users filter data by time, location, and event type.
   - Test steps: 1. Select a specific year period (such as 2000-2010) in the map interface and filter.

     2. Further refine the filtering conditions, such as selecting a specific country or region.

     3. Observe and record the system's response time to the filtering operation and the accuracy of the result display.
   - Expected results: The system should return the filtering results within 2 seconds, and the results should fully match the filtering conditions.

5.2 Results Analysis

5.2.1 Performance Test Results

1. Use Case 1: Timeline Function Test

   In the timeline function test, we evaluated the system's timeline adjustment capabilities. The specific operation includes dragging the timeline from a 1-year interval (such as selecting event data within a year) to a 51-year interval (1970 to 2021), and the entire page load time is 2.65 seconds.

   Result Analysis:

   - Response Time: The test results show that the system can load and display all relevant data within 2.65 seconds when handling a large range of time adjustments, which is quite close to the expected 2-second target and performs well. Even in the case of a large time span, the system can still quickly

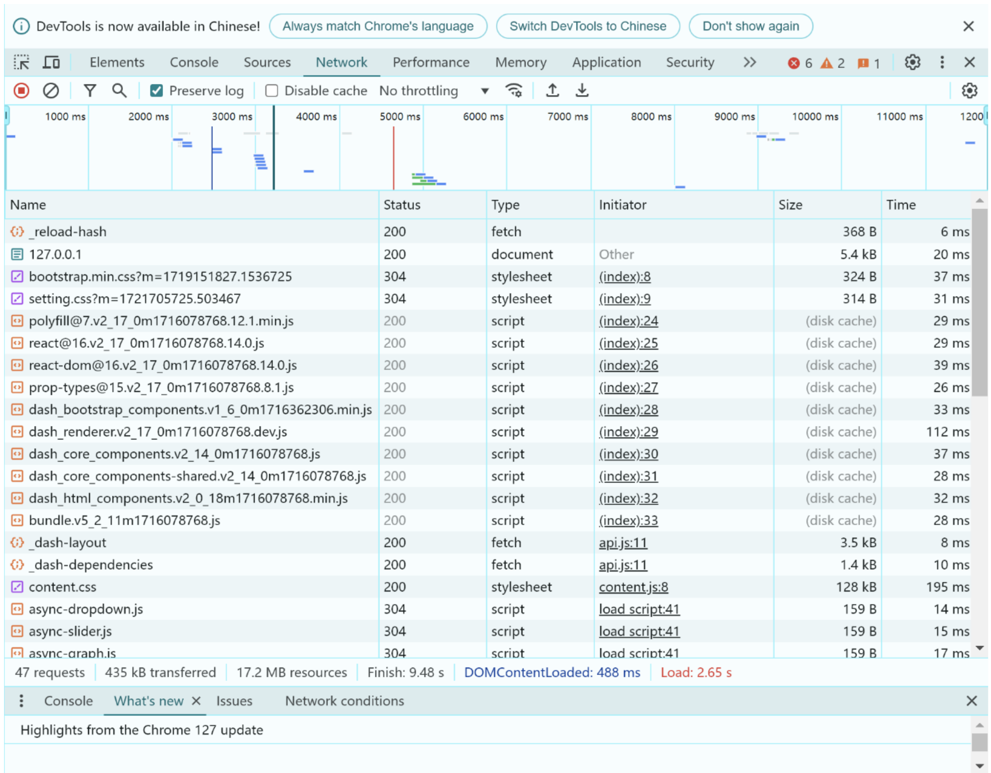

Figure 5.1: Timeline function test load time

update the event distribution on the map, indicating that the system has good performance when handling timeline adjustments.

- Operation Fluency: During the process of dragging the timeline, the system can update the data distribution on the map in real time, indicating that the system has good fluency when users operate. Users can quickly adjust the time range and immediately see the corresponding data changes, further improving the user experience.

Overall, the timeline function test results show that the system has good performance and smoothness when processing data with a large time span, and can quickly respond to user operation needs. Although the loading time is slightly longer than expected, this time delay does not have a significant impact on the user experience in actual use scenarios.

2. Use Case 2: Data Filtering Function Test

In the data filtering function test, we conducted a detailed performance evaluation of the system, including selecting the years on the map from 2000 to 2010, the region is East Asia, and further refines to Japan. After performing this series of filtering operations, the system took 4.34 seconds to return the results.

Result Analysis:

- Response Time: The test results show that the system has a response time of 4.34 seconds when processing more complex filtering conditions, which is slightly higher than the expected 2-second target. Nevertheless, when multiple filtering conditions are included, the system can accurately return data that meets the conditions, indicating that the system's filtering function is reliable in data processing and result matching.
- Accuracy: According to the test operation, the filtering results are accurate and meet the user-specified year, region, and country conditions. The user can correctly see the data of terrorist incidents that occurred in Japan between 2000 and 2010, indicating that the system performs well in the accuracy of data screening.

In summary, although the response time of the system in complex screening operations is slightly slow, the accuracy and reliability of the screening function have been verified. This shows that the system needs to be further optimized when processing large amounts of data to improve user experience and operational fluency.

5.2.2 Results and Discussion

Through the analysis of the results of the above test cases, it can be seen that the system shows certain performance bottlenecks in the case of multi-condition screening,

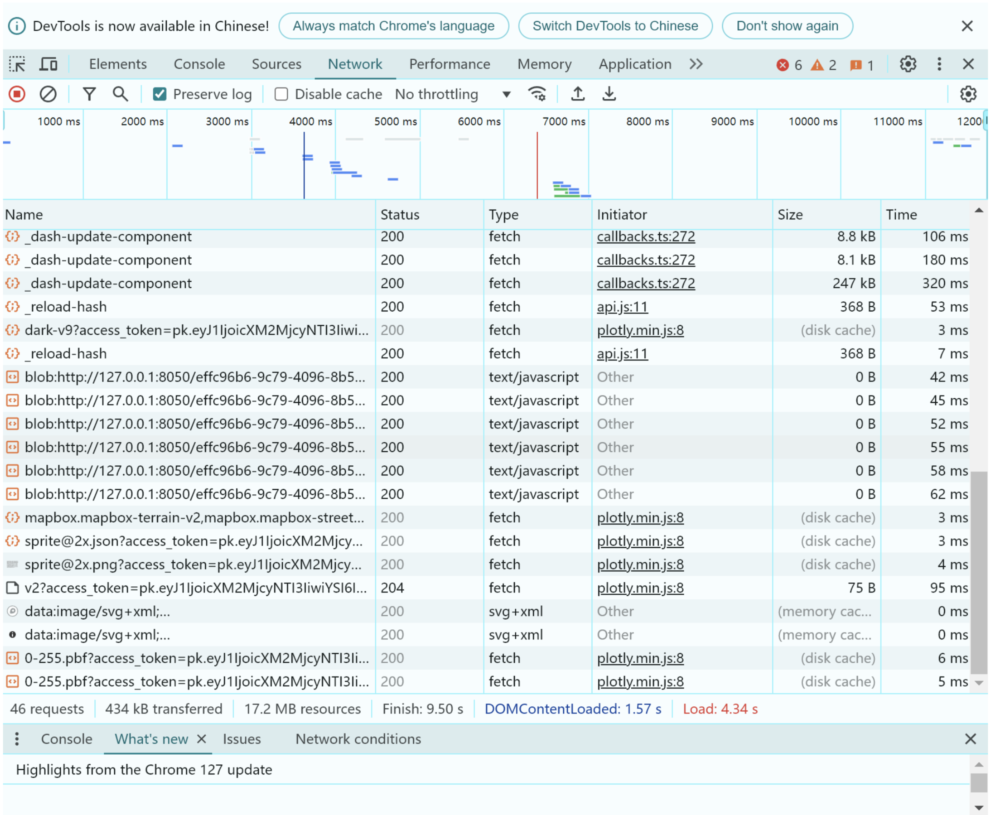

Figure 5.2: Data filtering function test load time

especially the response time is slightly insufficient. However, the accuracy and reliability of its screening results are still high, indicating that the core functions of the system are sound. It is recommended to further improve the response speed of the system in the future optimization process to improve the user experience. The system shows good operational fluency and fast loading time when processing data with a large time span, which can meet the user's needs to quickly adjust the time range. This shows that the system has good capabilities in visualizing large-scale time series data.

5.3 Conclusion

Through functional and performance testing of the global terrorism data visualization system, we comprehensively evaluated the system's performance in actual usage scenarios. This evaluation covered the system's key functions, including map loading, data filtering, and timeline adjustment, and the test results provided valuable feedback and insights.

First, in the data filtering function test, the system successfully completed the multi-condition filtering operation, and although the response time was slightly higher than expected, reaching 4.34 seconds, the accuracy of the filtering results was verified. This shows that the system performs well in terms of accuracy and reliability in data processing, but it is still necessary to further optimize the performance, especially the response speed when facing complex queries, to improve the overall user experience.

The timeline function test demonstrated that the system efficiently processes data spanning a large time range. The system successfully loaded and displayed all relevant data from 1970 to 2021 in just 2.65 seconds. This indicates strong data processing capabilities and smooth operation, meeting users' needs for time series data visualization. However, even though the timeline function's performance is close to expectations, further optimization could still enhance the user experience, especially during data-intensive operations.

Overall, the global terrorism data visualization system performs well in its core functions and provides a good user experience, meeting the basic design goals. The system effectively transforms complex terrorism data into intuitive and easy-to-understand visual charts. However, the test results also reveal that there is still room for improvement in handling large-scale data and complex queries. Future efforts should focus on optimizing the system's response time to ensure a consistent and high-quality user experience across a wider range of scenarios.

These test results provide a clear path for further development and optimization, laying a solid foundation for the system's continuous improvement. In general, the current version of the system has achieved its design goals, demonstrates good scalability, and has the potential to further enhance performance and user satisfaction in future updates.

Chapter 6

Conclusion

6.1 Restatement of the research objectives and significance

The primary goal of this study is to carry out a quantitative analysis and visualization of global terrorist activities using the Global Terrorism Database (GTD). The study aims to uncover the spatiotemporal distribution patterns and changing trends of terrorist incidents through advanced data analysis and visualization techniques. By doing so, it seeks to offer intuitive and easy-to-understand analysis tools that can be useful for researchers, policymakers, and the public in related fields. This study is committed to developing an interactive and user-friendly data visualization platform that enables users to flexibly explore and analyze GTD data according to their own needs, so as to have a deeper understanding of the information behind terrorism data.

Through the three steps of data collation and preprocessing, data analysis and data visualization, this study successfully transforms complex terrorism data into intuitive and easy-to-interpret graphics and charts, providing users with a new perspective to observe global terrorist activities. In particular, through time series analysis and geographic heat map display, this study reveals the annual and monthly changes in terrorist incidents, as well as the density and concentration of terrorist activities in different regions. These visualization tools are not only helpful for academic research, but also can provide valuable data support for decision makers, helping them to identify high-risk areas and high-risk time periods, so as to formulate more effective counter-terrorism strategies.

The practical significance of this study is reflected in many aspects. First, it provides strong data support for the formulation of anti-terrorism strategies worldwide, especially by revealing the high-incidence areas and times of terrorist activities through quantitative analysis, providing a scientific basis for resource allocation and the formulation of preventive measures. Second, this study enhances the public's awareness and understanding of the threat of terrorism through data visualization, enabling individuals and communities to pay more attention to security issues and improve their self-prevention awareness. In addition, the study also has an important role in promoting the academic community, providing a detailed and reliable example of terrorism data analysis, promoting the further development of the field of terrorism research, and providing a reference for interdisciplinary research.

6.2 Research limitations and future research directions

This study has some limitations. First, due to the diverse sources of GTD data, data quality may be affected by incomplete information or reporting bias, which may affect the accuracy and comprehensiveness of the analysis results. Although the study has tried its best to clean and correct the data, these problems cannot be completely eliminated. Second, although the visualization platform developed in the study has achieved certain results in user experience and functionality, the system may encounter performance bottlenecks when processing large data sets or complex queries, affecting the user's interactive experience. In addition, the current analysis mainly relies on traditional statistical methods and geographic information system (GIS) technology, and the mining of some more complex patterns and causal relationships is still insufficient. Future research can introduce advanced technologies such as machine learning and big data analysis to further improve the depth and breadth of analysis.

Based on the achievements and limitations of this study, future research can be expanded and deepened in several important directions. First, real-time data monitoring and dynamic visualization is an area worthy of key exploration. Current research is mainly based on historical data for analysis, while terrorist activities are sudden and uncertain. The ability to obtain and process real-time data will significantly improve the timeliness and effectiveness of counter-terrorism measures. Future research can introduce real-time data streams and dynamic visualization technologies to help decision makers quickly identify and respond to ongoing terrorist threats through constantly updated charts and maps.

Secondly, the application of advanced data analysis technology will also be an important direction for future research. Although this study mainly relies on traditional statistical analysis methods, the driving factors and patterns behind terrorist activities are often complex and changeable. The introduction of machine learning, deep learning and big data analysis technologies can better identify the potential laws and trends of terrorist activities. For example, the use of predictive models can provide early warning of potential high-risk areas or time periods to help relevant departments take preventive measures. In addition, social network analysis and sentiment analysis technologies can be used to study the internal structure and information dissemination paths of terrorist organizations, thereby providing support for the formulation of more accurate counter-terrorism strategies.

In terms of user experience and interface design, future research should pay more attention to the ease of use and universality of visualization tools. Although the current visualization platform has achieved a relatively friendly user interface, there is still a certain threshold for users who lack professional background to use these tools. In the future, the user's learning curve can be further reduced and the scope of application of the tool can be expanded by simplifying the operation process, adding guiding prompts and customized functions. In addition, adding multilingual support and culturally adaptable design can allow the platform to be applied in a wider international environment and promote global anti-terrorism cooperation.

Finally, improvements in data collection and processing methods are also key links in future research. The integrity and accuracy of terrorism data directly affect the reliability of research results. Future research should explore more comprehensive and detailed data collection methods, such as identifying and supplementing data gaps through cross-border cooperation and using artificial intelligence technology. At the same time, more efficient data cleaning and error correction algorithms should be developed to ensure the quality and consistency of data and provide a solid foundation for subsequent analysis.

In summary, future research will not only be limited to the existing technical framework, but should also actively introduce new technologies and methods to meet the ever-changing challenges of global terrorism. Through these improvements and innovations, researchers and decision makers will be able to better understand the complexity of terrorism and develop more effective response strategies, ultimately contributing to global security and stability.

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