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Comparative Review of Graphical User Interface Based Data Visualization Tools

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Data visualization, Data visualization tools, Big data, Data analytic, Interactive visualization software

Abstract: Due to the dizzying development of technology, the concept of big data has given way to huge data. With digital transformation and the Internet of Things, organizing the increasing amount of data and deriving meaningful results has become much more valuable and difficult. Along with this difficulty, visualization tools play an effective role in producing meaningful results faster and more accurately. In this article, a comprehensive literature review has been conducted on data visualization tools with graphical user interfaces that have wide application areas in different disciplines, and 15 widely known data visualization tools are presented comparatively. The important findings obtained as a result of this research and the trends that will be needed in new visualization tools are presented in the conclusion section. The use of complex methods by integrating artificial intelligence to produce meaningful results from data has great potential in the field of data visualization. This study aims to make significant contributions to the studies to be conducted in the field of data visualization.

Grafik Kullanıcı Arayüz Tabanlı Görselleştirme Araçlarının Karşılaştırmalı İncelenmesi

Anahtar Kelimeler
Veri görselleştirme, Veri görselleştirme araçları, Büyük veri, Veri analitiği, Etkileşimli görselleştirme yazılımı

Öz: Teknolojinin başdöndürücü şekildeki gelişimine bağlı olarak büyük veri kavramı yerini huge veriye bıraktı. Dijital dönüşüm ve Nesnelerin interneti ile birlikte artan veri miktarının organize edilip anlamlı sonuçlar çıkarılması çok daha kıymetli ve zor bir hale gelmiştir. Bu zorlukla birlikte, anlamlı sonuçların daha hızlı ve doğru üretilmesi için görselleştirme araçları etkili bir rol oynamaktadır. Bu makale çalışmasında, farklı disiplinlerde, geniş uygulama alanlarına sahip olan grafik kullanıcı arayüzüne sahip veri görselleştirme araçları hakkında kapsamlı bir literatür araştırması yapılmış, yaygın olarak bilinen 15 adet veri görselleştirme aracı, karşılaştırmalı olarak sunulmuştur. Bu araştırma sonucunda elde edilen önemli bulgular ve yeni görselleştirme araçlarında ihtiyaç duyulacak yönelimler sonuç bölümünde sunulmuştur. Verilerden anlamlı sonuçlar üretmek için yapay zekâ ile kompleks yöntemlerin entegre edilerek kullanılması, veri görselleştirme alanında büyük bir potansiyel barındırmaktadır. Bu çalışma ile verilerin görselleştirilmesi alanında yapılacak çalışmalara, önemli katkılar sunulması hedeflenmektedir.

1. INTRODUCTION

With the development of information and communication technologies, the amount of data in the digital environment is increasing significantly. Data is obtained from many digital [1] applications such as web-based platforms, social media applications, smart solutions developed within the scope of the Internet of Things (IoT) [2] and data received from multiple wireless sensors [3–5]. These structures, called big data, are stored in critical data centers [6] [7]. The continuation of modern life continues with the production and consumption of this data [8]. For this reason, it is of great importance that the data is obtained in a healthy way, evaluated and interpreted correctly. In this dense and continuous data flow, the best way to correctly understand the

relationships between the data and present them to users so that they can correctly evaluate the types as in Figure 1 is to visualize the data. In addition, the field of data visualization is also developing with the advancements in the fields of database, graphics and visualization [9] .

The main purpose of data visualization is to represent information more intuitively and effectively using different graphics [10,11]. Effectively represented data facilitates decision-making stages and in this way, analysts can make more accurate decisions with visual support. In the 2019 Future of Partnership report, FSN Publishing Limited [12], states that 81% of CFOs (Chief Financial Officer) are looking for future technology that will help data visualization to make improvements in business partnerships [12]. On the other hand, visualization of big data becomes difficult due to its large volume [13].

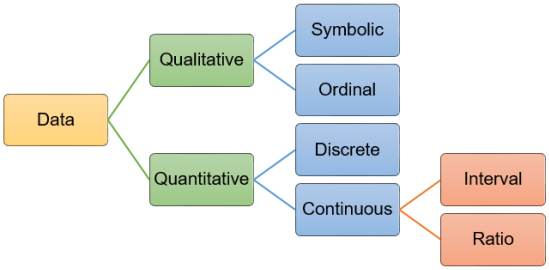

Figure 1. Data Types for Visualization

Data visualization focuses on dealing with unstructured high-dimensional data such as textual, numerical, financial and multimedia data, both before and today in the era of generative artificial intelligence. Data visualization tools try to visualize the endless flow of information collected by intelligent systems in order to increase the value of data with the meaningful insights they provide in the IoT field. Appropriate mechanisms are implemented to ensure that the visualized information is accurate and reliable and to detect these anomalies [14]. For this purpose, there are studies where a large number of visualization libraries are used and examined [15]. As a result of the extensive literature review, it has been determined that the studies on GUI-based data visualization tools are very narrow in scope. For this reason, a comprehensive review is needed. This study aims to close an important gap in the literature regarding GUI-based data visualization tools.

The biggest challenge when working with big data is not only to process the volume of data, but also to analyze different types of data effectively. Big data refers to the collection of large, complex, unstructured and continuous data collected from multiple and often disparate data sources [16]. While the main idea behind IoT is that every object gets an IP address and is connected to other things, Big Data focuses on managing the enormous amounts of data generated from IoT usage [14]. While these processes are carried out, we encounter features such as volume, variety and speed [17] [18]. In order to deal with this data efficiently and effectively, the focus is on capturing, storing, processing and visualizing the data with highly scalable, distributed architectural infrastructures. This study consists of 4 main sections. In Section 2, visualization tools developed and used within the scope of data visualization tools are presented. Studies using data visualization tools are examined in Section 3. The application areas and study results of these studies are summarized and presented in table 2. In section 4, the tools examined within the scope of the article are evaluated in terms of needs and trends obtained from the studies. In addition, suggestions are made for future studies.

2. DATA VISUALIZATION TOOLS

Visualization technologies are applied strongly on data for different purposes. For this purpose, visualizations can be made with both programming languages and certain tools without using any language. Visualization processes are also applied in different areas such as smart cities and big data management. It is seen in the literature that they are applied in very different disciplines in terms of application areas. For example, studies have been conducted in which the author's collaboration relationships are presented with a two-dimensional image according to the minimum spanning tree algorithm to visualize the collaboration of an author with his/her collaborators [19]. When these studies are performed on citations, implicit relationships between authors can also be discovered. In addition, there are studies in various fields such as education [20], Data Analytics [21,22], Internet of Things (IoT) [23], Urban Planning [24], Health [25], Biotechnology [26], Geography [27], Cyber Security [28] and Smart Cities [29] in web-based searches [30], visualization of analysis types [31], data research [32] and visual analysis and discovery of data [33].

Visualization tools enable users to transform each element in the data into interactive visuals. Using these tools, users who do not have coding skills can spend more time on design decisions instead of the implementation process [34] . The visualization tools examined in this study are GUI-based tools that do not require programming language knowledge. Tools where coding and programming language libraries are actively used by the user are ignored in this study.

2.1. GUI Based Tools

This section introduces data visualization tools with graphical user interfaces. These tools are also effectively used as business intelligence tools under the field of data science. They are designed to meet the needs of users without programming knowledge, such as data analysis, filtering, visualization, and reporting. The classification of visualization tools in this group is presented in the table 1.

Table 1. GUI-based data visualization tools with outstanding features

Ref	Tool	Release Year	Data Sources	Platforms	Data Import Features	Customization and Advanced Features	Support	Advantages	Disadvantages
[35]	Tableau	2003	csv, xls, json, pdf	Desktop, Mobile, Web	Fast Data Upload, Multiple Data Sources	Advanced Visualization Options	Cloud and Local	Powerful visualization tools, wide data source and AI support	Expensive, time-consuming to learn, complex reporting
[36]	Power BI	2014	csv, xls, json, pdf	Desktop, Mobile, Web	Fast Data Upload, Multiple Data Sources	Advanced Analysis and Reporting	Cloud and Local	Affordable, strong data analysis and reporting features, AI support	Limited features in web version, performance issues
[37]	Looker Studio	2016	csv, xls, json, xml, sql	Web	Multiple Data Sources, Data Source Integration	Customizable Reports	Cloud-Based	Integration with Google ecosystem, free basic version, AI support	Cloud-dependent, limited visualization options
[38]	Amazon Quicksight	2016	csv, xls, json, tsv	Web, Mobile	Multiple Data Sources, Data Source Integration	Fast Visualization	Fully Cloud-Based	Integration with AWS, quick setup, AI support	Limited data sources, steep learning curve
[39]	Oracle Analytics	2019	csv, xls, json, xml	Web, Mobile	Multiple Data Sources, SQL Integration	Advanced Analysis, Database Support	Cloud-Based	Powerful data analysis tools with AI, integration with Oracle	High cost, complex usage
[40]	Sisense	2010	csv, xls, sql	Web, Mobile	Multiple Data Sources, Database Integration	Advanced Data Modeling	Cloud-Based	High scalability, powerful data modeling and AI support	Complex setup, steep learning curve
[41]	Biovia Pipeline Pilot	2018	csv, xls	Desktop	Limited Data Source Integration	Customizable Reports	Local Storage	Scientific data integration, customization possibilities	Desktop-only, limited mobile access
[42]	Domo	2010	csv, json, xml, xls	Web	Fast Data Upload, Multiple Data Sources	Advanced Visualization Options	Fully Cloud-Based	Easy to use, strong integration features	Expensive, limited free version
[43]	Infogram	2012	csv, json, xls	Web, Mobile	Fast Data Upload, Limited Data Sources	Simple Visualization	Cloud-Based	Fast and simple visualization, templates	Limited customization, poor data management
[44]	Carto	2012	csv, GeoJSON, GeoPackage, kml, kmz, tab	Web	Geospatial Data Integration	Map Visualization Options	Fully Cloud-Based	Powerful map visualization, geospatial data support	Only for geospatial data, complex to use
[45]	RAW Graphs	2013	tsv, csv, dsv, json	Web	Fast Data Upload	Simple Visualization	Local Storage	Fast and free, simple visualizations	Limited visualization, inadequate data processing
[46]	Visualize Free	2016	csv, txt, xls	Web	Fast Data Upload	Simple Visualization	Local Storage	Free, fast to use	Limited visualization, poor data management
[47]	Dundas BI	2001	csv, xml, json, SQL, Oracle	Web, Mobile, Embedded	Multiple Data Sources, SQL Integration	Advanced Visualization and Reporting	Cloud-Based	Advanced features, multi-platform support	High cost, steep learning curve
[48]	Qlik Sense	2014	csv, xls, json, sql, odbc	Desktop, Mobile	Fast Data Upload, Multiple Data Sources	Dynamic Reporting and Analysis	Cloud-Based	Multi-source data integration, strong analytical capabilities with AI	High cost, steep learning curve
[49]	Kibana	2013	csv, json, log, Elasticsearch	Web, Desktop	Multiple Data Sources, Elasticsearch Integration	Rich Visualization and Search Features	Cloud-Based	Deep integration with Elasticsearch, powerful visualization and search features, AI support	User interface may be complex

2.1.1. Tableau

Tableau is a widely used desktop software for business intelligence and data analysis [50]. It was selected as one of the market leaders for the 12th time in the Gartner Magic Quadrant for Analytics and Business Intelligence Platforms in 2024 [51]. It can work on local and server data files. It supports data file formats such as txt, json, pdf, csv, Microsoft Access, Microsoft Excel. Apart from these, it also offers an interface that can receive data from

various servers (Salesforce, Oracle, Microsoft, Amazon, Google, etc.) online. It also has the ability to run the desired functions by determining the x and y axes over the fields that can be determined as dimension and measure. It also has the ability to work with maps. For example, in a study conducted to view online shopping preferences and users' shopping activities within the scope of web content mining, [52] was used. In addition, eBay, an auction company, sells products to millions of active users every month and as a result, produces a huge amount of data. eBay uses the Tableau tool to make all this data understandable and visualize big data. Tableau has the ability to transform large and complex data sets into intuitive images. Apart from this, eBay employees can also visualize their customers' search behavior with this tool to track customer feedback and conduct sentiment analysis.

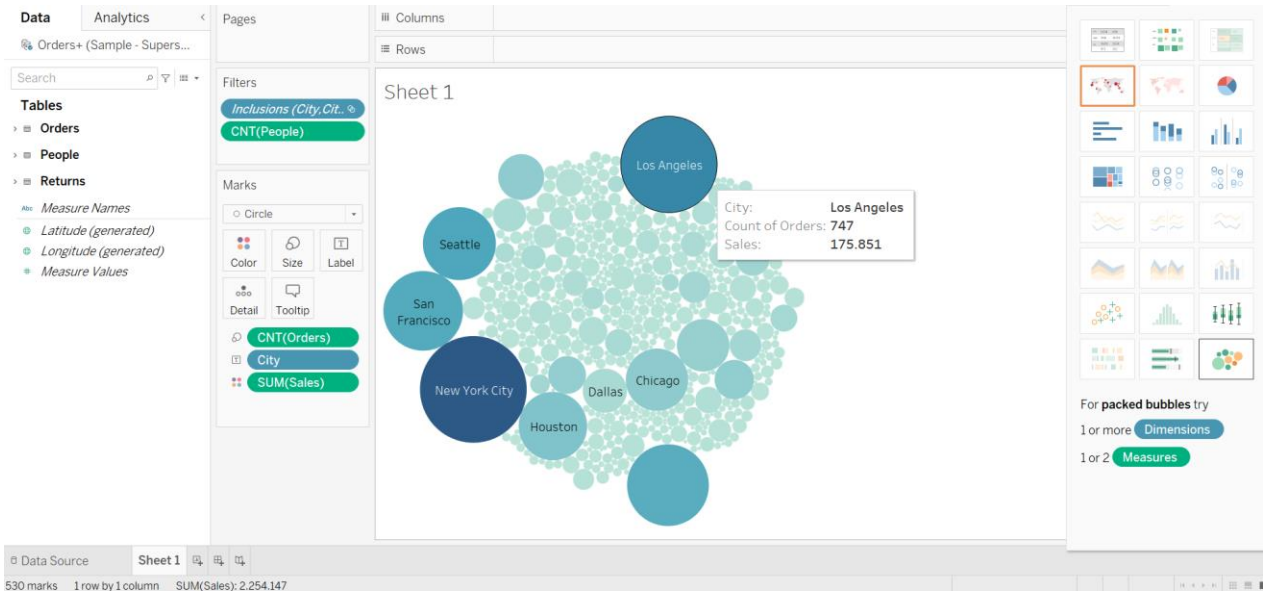

Figure 2. Packed bubbles chart with Tableau tool

2.1.2. PowerBI

It was added to Microsoft Excel in 2011 under the name "Power Pivot". It emerged as a standalone application under the name "Power BI" in 2014. With its easy-to-use interface and drag-and-drop feature, it can transform complex data into meaningful reports. Its success in visualizing the data in these reports has also been an important factor in the preference of the application. In the analytics and business intelligence platform report prepared by Gartner for 2024, Microsoft Power BI , Tableau and Qlik [51] were selected as market leaders.

2.1.3. Looker studio

It is a free application, previously known as Google Data Studio. It allows customization and reporting of data. It is offered within the Google Analytics 360 product suite, which was introduced on March 15, 2016. It is a free online tool for transforming data into dashboards. Looker Studio Pro offers advanced entity management, team collaboration capabilities, and access to technical support for businesses [37] .

2.1.4. Amazon quicksight

It enables data understanding by asking natural language questions, exploring through interactive dashboards, and automatically searching for machine learning-powered patterns and outliers [38]. Amazon QuickSight is built on "SPICE", a **S**uper-fast, **P**arallel, **I**n-memory **C**alculation **E**ngine. Built entirely for the cloud, SPICE uses a combination of columnar storage and in-memory technologies to run interactive queries on large datasets and get fast answers. It enables organizations to scale their business analytics capabilities to hundreds of thousands of users and delivers fast, responsive query performance using a robust in-memory engine (SPICE) [38].

2.1.5. Oracle analytics

Oracle Analytics Cloud and Oracle Analytics Desktop are business-oriented products that load and query data sources, create visualizations to analyze data, create and work with workbooks, and import and export workbooks [39] . Oracle Analytics Cloud was designed from the ground up to be a globally available cloud service. Oracle's suite of analytics applications, Fusion Analytics, is advancing the way organizations deploy analytics.

2.1.6. Sisense

Sisense offers a wide range of BI tools, including data modeling, data visualization, and AI analytics. Founded in 2004 in Tel Aviv, Sisense launched its first product in 2010. In 2019, Sisense acquired Periscope, a fully SaaS company. Sisense Fusion, an AI-driven analytics platform designed to make data analytics simple, scalable, and actionable, was introduced in 2021. It was named a Visionary in the 2022 Gartner® Magic Quadrant™ for Analytics and Business Intelligence Platforms and a niche player in the 2024 version of the same report [51]. The platform is designed to be easily scalable and includes security features such as attack surface monitoring and

disaster recovery. GitLab is used by over 2,000 global companies including Nasdaq, Rolls Royce, Seismic, ZoomInfo and Philips Healthcare [53].

2.1.7. Biovia pipeline pilot

Pipeline Pilot, a desktop software program sold by Dassault Systèmes for processing and analyzing data, initially used in the natural sciences, has expanded its core ETL and analytics capabilities over time. Pipeline Pilot supports end-to-end automated workflow creation and execution. It can connect to internal and external data sources. It can access and analyze all types of scientific data. It can connect to external data sources of types Sql/NoSql/Mql, tabular data, structured data (json, xml, etc.), office documents (ppt, xls, etc.), pdf, Streaming (Kafka), 3DExperience Platform, REST/SOAP/HTML/S3 via an extensive API library. It also includes ready-to-use connections to various 3rd party databases [41].

2.1.8. Domo

Domo's data visualization software has an intuitive dashboard. It also automates reporting, allowing you to present an automatically updated report. Domo also works on mobile platforms. It is a cloud-based platform that offers business intelligence tools tailored to a variety of industries, including financial services, healthcare, manufacturing, and education, and roles such as CEOs, sales, BI specialists, and IT professionals. Most of the work on Domo can be done without using SQL [42].

2.1.9. Infogram

Infogram is a web-based application for creating graphs and charts related to data. Registered users can upload their own data files (.xls, .csv, .xlsx) to the website and also export data to GoogleDrive, Dropbox, OneDrive or JSON stream. Personalized chart suggestions are also provided with AI support. The problem with Infogram is that the project is created with a public URL, so there is no data privacy. If users want to protect the privacy of their data, the only way is to become a paid member [43]. A membership is also required to download the visualizations prepared with the online editor.

2.1.10. Carto

Founded in Madrid in 2012 by Javier de la Torre and Sergio Álvarez, CARTO has become the world's leading location intelligence platform, enabling hundreds of thousands of users to unlock the power of spatial analysis. It's a cloud-based tool that can visualize without coding. Data scientists, developers, and analysts use CARTO to optimize business processes and predict future outcomes with the power of spatial data science. It's a cloud computing platform that provides GIS, web mapping, and spatial data science tools for businesses in real estate, financial services, telecommunications, government, and more. CARTO is a location intelligence platform that enables organizations to use spatial data and analytics for more efficient delivery routes, better behavioral marketing, strategic store layouts, and more [54] [44].

2.1.11. RAW graphs

RAW Graphs is an open web-based tool that can be used directly without registration. It supports data formats such as tsv, dsv, csv, json or xls files, even online data from a public API or public cloud platform. It provides users with 21 types of graph models for data visualizations and also supports creating custom vector-based visualizations natively on top of the D3.js library by M. Bostock. They can also export the created graph as a vector (svg) or raster (png) image, or embed their graphs in web pages using the codes automatically generated in raw graphs [55] [45].

2.1.12. Visualize free

Visualize Free is a free and lightweight web-based application that requires registration before use. Users can upload data files (xls, xlsx, csv or txt) with a 5 MB file limit. Users can easily visualize their data with multiple charts by dragging and dropping data to shape the size of the chart. Free visual analysis is provided so that users can compile detailed analysis of the uploaded data. Charts created from data uploaded to Visualize Free can be downloaded and shared in pdf, xls or ppt format [46].

2.1.13. Dundas dashboard

Dundas BI is a data visualization platform that includes integrated dashboards, reporting tools, data analytics, and browser-based business intelligence. It allows end users to create interactive, customizable dashboards and reports, run ad hoc queries, analyze and drill down into their data and performance metrics. The Dundas BI platform allows users to connect and integrate with any data source in real time on any device. Dundas BI is part of insightsoftware [47]. With its touch-based interface and responsive design, it allows users to create and view dashboards and reports on any device from desktop to mobile. The software is designed to be embedded. It provides full customization and integration support through a programmable open API platform offering .NET, REST, and JavaScript APIs. Dundas BI can be installed anywhere and supports a SaaS/Multi-tenant architecture that allows all clients to be on a single server [17].

2.1.14. Qlik sense

Qlik [48] is a visualization software developed by Qlik, which allows users to analyze large amounts of data by visualizing them, and provides interactive reporting, data analysis, visualization, and self-service analysis capabilities, allowing users to work more interactively with data [56]. It can pull data from different data sources (databases, Excel files, cloud storage, etc.) and combine and analyze this data [57]. It uses a special engine called Associative Engine. This engine ties all the data together, allowing users to easily connect and navigate between data. It can work in both local (on-premise) and cloud (Qlik Sense Cloud) environments. It is ranked in the

Leaders category in the 2024 Gartner Magic Quadrant for Analytics and Business Intelligence Platforms [51].

2.1.15. Kibana

Kibana is an open-source data visualization platform that integrates with Elasticsearch [49]. It helps users visualize, analyze, and create reports on Elasticsearch data [58]. Kibana is often used in conjunction with Elasticsearch and Logstash (ELK Stack), as seen in figure 3, where the trio simplifies the data collection, indexing, and visualization processes.

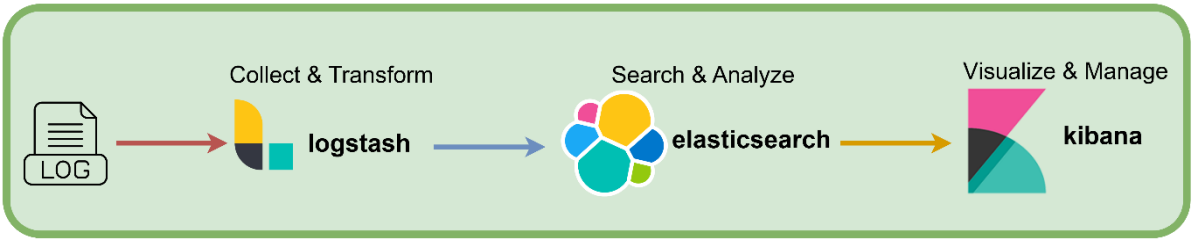

Figure 3. ELK Stack

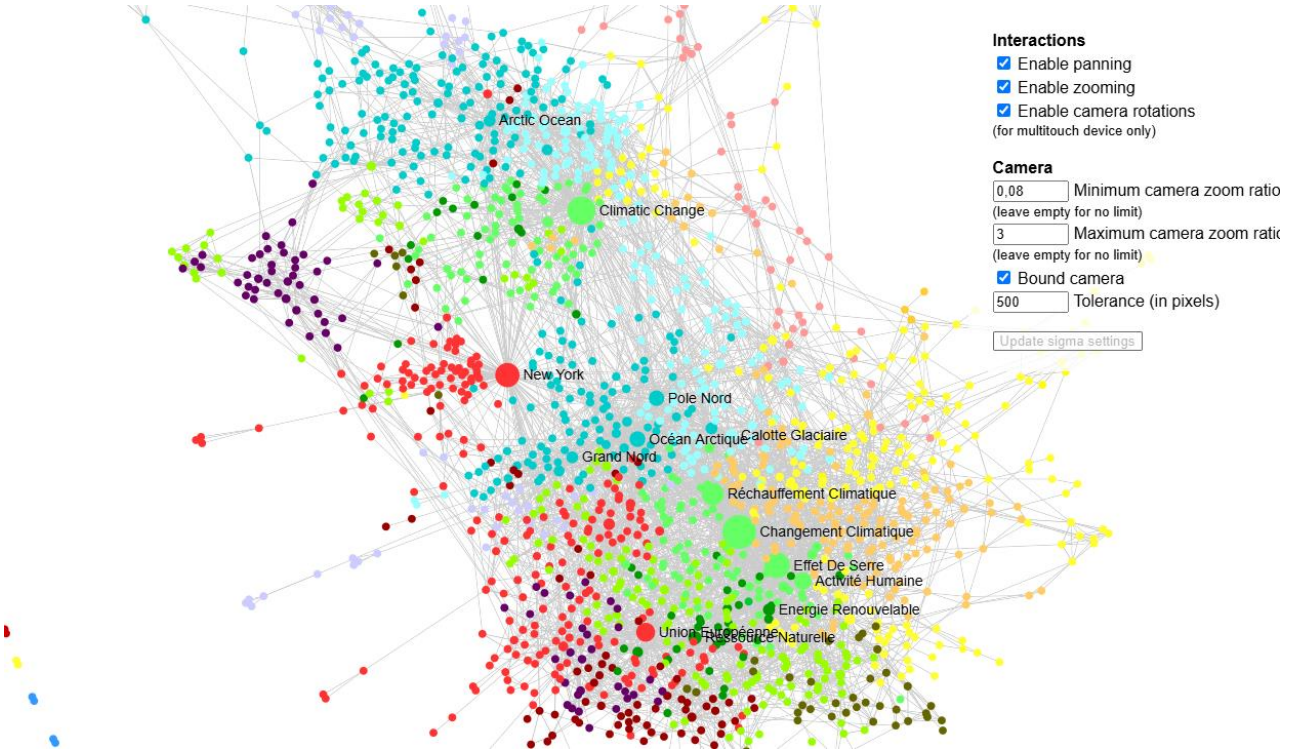

Figure 4. A graph visualization application with Sigma.js

3. GUI-BASED APPLICATIONS EXAMPLES

In this section, studies on the use of data visualization tools with visual user interfaces in the literature are examined and summarized in a table. These studies were obtained by filtering the literature through application-oriented articles.

The application areas of these studies and the diversity and richness of the fields are shown in the table. In addition, the results of these current studies are listed and presented in the table. When the application areas are examined, it is seen that the application examples are concentrated in the fields of Software and Data Analytics, Education and Technology, Environmental Technologies and Internet of Things (IoT), Urban Planning and Data Analytics, Health and Social Sciences, Artificial Intelligence and Data Analytics, Biotechnology and Health, Health and Data Visualization, Geography, Smart Cities and Transportation, Environment and Health, Academic Research and Data Analytics, Industrial Production and Digital Management Systems, Cyber Security and Smart Cities. These studies, which date back to recent years, show that data visualization tools with visual interfaces will be used in studies in many different disciplines in the future. In this context, the methodologies of the relevant studies were examined and the techniques and algorithms used by data visualization tools were evaluated. The analyses conducted reveal how interactive visualization features improve user experience and accelerate decision-making processes. In addition, the effectiveness of data visualization tools used in different disciplines was compared and it was determined in which areas they were more widely preferred. It was seen that the majority of the studies focused especially on big data analytics, machine learning-supported visualizations and real-time data monitoring systems. Based on these findings, it is also seen that there is a great potential in the

field of graph-based visualization of data. Especially in network (graph)-based data visualizations, libraries such as Sigma.js offer powerful and interactive solutions. Sigma.js is widely used in fields such as social network analysis, biological networks, and internet traffic monitoring, and can dynamically visualize large-scale network data. It also provides a flexible structure to make data visualization processes more meaningful with customizable node and edge styles, as seen in Figure 4. With these features, Sigma.js supports decision-making mechanisms by making data analysis processes more intuitive.

Commonly used tools such as Tableau and Power BI have achieved successful results in analytical data engines and education-focused decision support systems. Looker Studio and RAW Graphs have been used in environmental data analysis and health research to reveal the effects of factors such as air pollution on human health. Amazon Quicksight and Carto have provided effective visualization solutions in areas such as urban planning and transportation in the context of smart cities and urban data analytics. In the field of health and biotechnology, the use of tools such as Domo, Oracle Analytics and Biovia Pipeline Pilot is notable. In particular, studies using Oracle Analytics have shown that neuropsychiatric symptoms increase the social costs of dementia, while Domo has emerged as a reliable decision support system for healthcare professionals in Saudi Arabia. In the fields of industrial production and cybersecurity, Qlik Sense has been used to increase the effectiveness of digital management systems, while Kibana has been applied to develop ontological models for analyzing cyber threats in smart cities.

Table 1. Applications of GUI-based visualization tools in literature

Ref.	Date	Tool	Application Field	Conclusion
[59]	2011	Tableau	Development of a custom analytical data engine that integrates with the Tableau data visualization system, focusing on efficient data processing	The developed Tableau Data Engine is shown to provide efficient data processing with real-life visualization scenarios in desktop and server environments.
[20]	2024	Power BI	Development and implementation of a Power BI based interactive data visualization platform	Improving educational decision-making processes
[23]	2024	Looker Studio	Air quality, IoT	Creation of AQuality32 for open source air quality monitoring
[24]	2024	Amazon Quicksight	Urban visual analytics	A roadmap for the effective development and improvement of urban visual analytics systems
[60]	2024	Oracle Analytics	Determining the social costs of dementia and neuropsychiatric symptoms (NPS)	The NPS has been shown to triple the societal costs of dementia, resulting in long-term care services and benefits for more people.
[21,22]	2024,2018	Sisense	Recommendation systems, Developments in visual exploratory data analysis (EDA)	Automatic recommendation systems have achieved significant success for visualization panels, Traditional data exploration tools have evolved in recent years to analyze large data sets.
[26]	2016	Biovia Pipeline Pilot	HIV infection, eye diseases, immunology	In dry eye disease patients with HIV infection, EGF and IP-10 levels were found to be high and GRO levels were found to be low.
[25]	2024	Domo	Health data analytics, visual analytics, decision support systems and health information technologies	DOMO BI visual analytics tool has been found to be the most secure and robust tool for healthcare professionals in Saudi Arabia
[61]	2023	Infogram	Web-based data visualizations, COVID-19 tracking tools, and visual analytics	Dashboards and tracking tools presenting data related to the COVID-19 pandemic face challenges in providing accurate and reliable information to the public due to the lack of data sources and design differences.
[27]	2017	Carto	Visualization of heterogeneous spatiotemporal data (vehicle routes, points of interest, etc.) obtained from embedded sensors in cities	A web-based smart urban visualization system called SURV that provides interactive maps and 3D visualizations using HTML, CSS, Mapbox.js, CARTO.js, and Python
[62]	2024	RAW Graphs	Analyzing the relationship between air pollution and abdominal aortic aneurysm (AAA) using data visualization techniques	Vehicle emissions have a strong temporal relationship with AAA mortality, and air pollution has a similar relationship to cigarette smoking on AAA mortality.
[63]	2018	Visualize Free	Visualization and visual analysis of scientific data	It provides a comprehensive overview of existing data visualization tools, techniques, and systems and proposes new solutions to open problems encountered in academic data visualization.
[29]	2023	Dundas BI	Developing an end-to-end solution based on IoT for smart factories to facilitate data-driven decisions in industrial production.	Successful development of a middleware application that collects data via OPC-UA protocol and integrates with BI toolsy
[64]	2025	Qlik Sense	Increasing the effectiveness of the Digital Shopfloor Management (SFM) system by identifying a suitable platform for managing digital daily meetings.	It demonstrates that a hybrid Digital SFM solution, where Microsoft SharePoint is used as the main platform and Qlik Sense is integrated for data visualization and consolidation, offers a balanced and effective approach.
[28]	2025	Kibana	Development of ontological models to analyze and represent cyber threats in smart city infrastructures (SCI)	This study proposes a framework called Scope that extends UCO and CASE ontologies, enabling better identification, sharing, and analysis of SCI-specific threats, digital evidence, and cybercrimes.

4. CONCLUSION

With the development of IoT, as the number of smart devices increases and IoT networks continue to flow data from various sources, the field of visualization will also develop in a way that is open to innovation and change. This review presents important findings in terms of innovative approaches in the field of data visualization and their effects on user experience. Most of the tools examined accelerate data visualization processes and present complex data sets in an understandable way thanks to their user-friendly graphical interfaces. Especially features such as interactive, 3D visualization and dynamic time series analysis make it easier for users to explore data. Tools such as Tableau, Power BI and Qlik Sense are particularly notable for their drag-and-drop functionality and data integration capabilities. Their ability to work with many different formats regardless of data sources and to produce fast visualizations are among their prominent features. However, some tools still have a high learning curve and technical hurdles. Especially in projects that require big data processing and in-depth modeling and analysis, existing tools often encounter performance issues. In addition, the future of visualization tools will be shaped by their integration with artificial intelligence (AI) and machine learning (ML), in particular. In addition to adding more powerful AI-powered features for data modeling and predictive analysis, the use of generative AI will allow users to visualize not only current data but also future trends, allowing them to make meaningful interpretations. In addition, cloud-based platforms and mobile compatibility are becoming increasingly important. Web-based and mobile visualization tools will increase user flexibility by making it faster and easier to access and share data. Another potential possibility is that the ability of tools to seamlessly connect more data sources will enable more efficient use in big data analytics and real-time data visualizations. The limited flexibility of graphical interfaces is also a limitation for more advanced users. Most tools struggle to offer advanced functionality such as customizable analysis features, advanced data processing techniques, customizable reporting, or dynamic data processing. Furthermore, the lack of data visualization typologies leads to an inability to effectively present data contextually. Performance improvements require optimizing timing and processing capacity when working with large datasets.

In this study, data visualization tools with graphical user interfaces comprehensively examine and the user interaction, effectiveness and limitations of existing tools in data analysis were evaluated. Future developments will enable more sophisticated and contextual analyses in data analysis, supported by AI. The effectiveness of these tools will increase depending on how users interact not only with existing data but also with the broader data ecosystem.

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