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# THE ART OF DATA VISUALIZATION: TOOLS & TECHNIQUES FOR COMMUNICATING INSIGHTS

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**Abstract**
The process of presenting data in a graphical or pictorial format that facilitates comprehension is known as data visualization. It aids in factual explanation and decision-making. It will be beneficial to any field of study that requires novel approaches to presenting large amounts of complex data. Modern visualization has been shaped by computer graphics. Data visualization can greatly enhance data understanding and communication. Effective visualization techniques can help individuals to identify patterns, trends, and outliers within data that may not be immediately apparent when presented in numerical or textual formats. Data visualization is briefly introduced in this paper.
***Keywords—*** Data Visualization, Big Data, Computer Graphics, Dashboards, KPIs, Information visualization, Scientific visualization.

## I. INTRODUCTION

It has become necessary to present enormous amounts of data in a manner that is simple to comprehend. Every day, organizations produce data. As a result, there is now a lot more data available on the Internet. This enormous amount of data is difficult for users to visualize, investigate, and utilize. Data visualization is essential for scientific research. Large amounts of data can be processed with computers today. The creation, development, and use of computer-generated graphical representations of data are the focus of data visualization. Effective data representation of data from various sources is made possible by it. This makes it simple for decision-makers to understand the data and allows them to see analytics in a visual format. It assists them in forming an opinion, comprehending information, and identifying patterns.

Information visualization and scientific visualization are other terms used to describe data visualization. In order to make messages or information survive throughout time, humans have always used visualization techniques. It is possible to graphically depict things that cannot be felt, tasted, or smelled.

## II. DATA VISUALIZATION TECHNOLOGY

Any set of data that is precisely stored can be graphically represented using data visualization technology. Data visualization tools and approaches are integrated into data visualization technologies. The methods used to present processed data visually and the format in which it will be presented are referred to as data visualization approaches. On the other hand, data visualization tools refer to the selection of data to be visualized and the methods used to process that data for visualization purposes. By using these tools and approaches, data can be effectively communicated through visual means. The user of the visualization tool can choose which data should be turned into a graphic. Using a data visualization technique, the user can choose the types of charts and how the data will be shown. The type of chart that best fits the data being visualized can be chosen by the user. The phrase "data visualization technique" pertains to the way in which data is portrayed using specific symbols, such as bars in a bar chart or lines in a line chart. This enables the data to be presented in a visually appealing and understandable manner.Data Visualization Technology’s Goals

Data presentation and data exploration are two major objectives of data visualization technologies. Simply displaying the user's already-known facts and numbers is all that is involved in data presentation. Data exploration is the process of revealing hidden patterns in a huge dataset. Before selecting the data visualization tool and technique, it is important to understand the benefits of both of these objectives.

*A. Advantages of Data Visualization Technology*

The advantages of data visualization technology can be classified into two categories: functional and aesthetic. By combining these benefits, data visualization technology becomes an influential and significant tool.

## III. DATA VISUALIZATION TOOLS

When referring to software that can convert data into a graphical format, the term "data visualization tool" describes a methodical procedure of accepting input, processing the data, and producing graphical output in the form of charts. Different visualization tools are available, and they all exhibit data in different ways, so users can select a tool that best fits their visualization requirements. Tools for data visualization should enable a variety of charts, be easy to use, and give accurate results. When contrasting various data visualization tools, variables including whether they are open source or proprietary software, if coding knowledge is required, whether programming languages are used for data processing and chart development, as well as the graphical output format, are taken into account. Some tools are free, while others require purchase. Some tools can be used by non-developers without coding knowledge, while others are designed for developers. The visual output of data can take on different forms, such as charts or maps depending on the context and requirement, and they are commonly used chart types supported by most data visualization tools..

*A. Tableau*

Tableau is one of the most popular data visualization tools used in the industry. It provides a drag-and-drop interface for creating interactive and beautiful visualizations. Tableau allows users to connect to a wide variety of data sources, including spreadsheets, databases, and cloud-based services. It also provides a wide range of visualization types, including bar charts, line charts, scatter plots, heat maps, and geographic maps. Tableau's strength lies in its ability to handle large datasets and to create interactive dashboards and reports that can be shared with others. Tableau also provides a community where users can share their work and learn from others.

*B. Power BI*

Power BI is a business intelligence tool that provides a range of data visualization options. The software is developed by Microsoft and is designed to work seamlessly alongside different Microsoft goods like SQL Server and Excel. Power BI allows users to connect to a wide variety of data sources, including spreadsheets, databases, and cloud-based services. It provides a wide range of visualization types, including bar charts, line charts, scatter plots, heat maps, and geographic maps. Power BI's strength lies in its ability to handle large datasets and to create interactive dashboards and reports that can be shared with others. Power BI also provides advanced features such as natural language processing and machine learning.

*C. D3.js*

D3.js is a JavaScript library that is widely used for creating interactive and dynamic data visualizations on the web. It allows users to manipulate data and create complex visualizations using HTML, CSS, and SVG. D3.js provides a wide range of visualization types, including bar charts, line charts, scatter plots, heat maps, and geographic maps. Its strength lies in its ability to create custom and interactive visualizations that can be embedded into web applications.

*D. Python*

Python is a general-purpose programming language that has become popular for data analysis and visualization due to its rich set of libraries and tools. Some of the popular libraries used for data visualization in Python are Matplotlib, Seaborn, Plotly, and Bokeh. Matplotlib is the most widely used

library for creating static visualizations such as line plots, scatter plots, histograms, and bar charts. Seaborn is a library built on top of Matplotlib that provides a higher-level interface for creating statistical visualizations such as heatmaps, violin plots, and joint plots. Plotly is a library that provides more interactive visualization options such as interactive scatter plots, line plots, and bar charts. Bokeh is a library that is particularly useful for creating interactive visualizations that can be embedded in web applications. Python's flexibility and versatility make it a popular choice for data visualization.

*E. R*

R is a programming language that is widely used for statistical computing and data analysis. It has several libraries such as ggplot2, lattice, and plotly that provide a wide range of visualization options. ggplot2 is a popular library that provides a flexible and powerful system for creating static visualizations such as scatter plots, bar charts, and line charts. Lattice is a library that provides a similar set of visualization options as ggplot2 but with a different syntax. Plotly is a library that provides more interactive visualization options such as heatmaps, 3D scatter plots, and choropleth maps. R's rich set of libraries and tools make it a popular choice for data visualization.

*F. Excel*

Excel is a spreadsheet program that has been used for decades for data analysis and visualization. It has built-in charting tools that are easy to use and allow users to create various chart types such as line charts, column charts, pie charts, and scatter plots. Excel's charting tools are suitable for simple

*G. QlikView*

QlikView is a business intelligence tool that provides interactive data visualization and dashboarding capabilities. It allows users to connect to a wide range of data sources, including spreadsheets, databases, and cloud-based services. QlikView's strength lies in its ability to handle large datasets and provide real-time analytics. It also provides a wide range of visualization types, including bar charts, line charts, scatter plots, and geographic maps. QlikView allows users to create custom calculations and dimensions, and provides advanced features such as natural language processing and machine learning.

*H. SAS Visual Analytics*

SAS Visual Analytics is a business intelligence tool that provides interactive data visualization and dashboarding capabilities. It allows users to connect to a wide range of data sources, including spreadsheets, databases, and cloud-based services. SAS Visual Analytics provides a wide range of visualization types, including bar charts, line charts, scatter plots, heat maps, and geographic maps. Its strength lies in its ability to handle large datasets and provide real-time analytics. SAS Visual Analytics also provides advanced features such as natural language processing and machine learning.

*I. Google Data Studio*

Google Data Studio is a web-based a data visualization tool that enables users to generate dynamic reports and dashboards. It allows users to connect to a wide range of data sources, including Google Analytics, Google Sheets, and Google BigQuery. Google Data Studio provides a wide range of visualization types, including bar charts, line charts, scatter plots, and geographic maps. Its strength lies in its ability to create custom and interactive dashboards that can be shared with others.

*J. IBM Cognos Analytics*

IBM Cognos Analytics is a business intelligence tool that provides interactive data visualization and dashboarding capabilities. It allows users to connect to a wide range of data sources, including spreadsheets, databases, and cloud-based services. IBM Cognos Analytics provides a wide range of visualization types, including bar charts, line charts, scatter plots, and geographic maps. Its strength lies in its ability to handle large datasets and provide real-time analytics. IBM Cognos Analytics also provides advanced features such as natural language processing and machine learning.

*K. Microsoft Excel Power View*

Microsoft Excel Power View is a data visualization tool that is integrated into Microsoft Excel. It allows users to create interactive visualizations such as charts, maps, and tables. Microsoft Excel Power View provides a wide range of visualization types, including bar charts, line charts, scatter plots,

heat maps, and geographic maps. Its strength lies in its ability to create interactive visualizations directly within Excel.

*L. SAP Lumira*

SAP Lumira is a data visualization tool that enables users to generate dynamic reports and dashboards. It allows users to connect to a wide range of data sources, including spreadsheets, databases, and cloud-based services. SAP Lumira provides a wide range of visualization types, including bar charts, line charts, scatter plots, heat maps, and geographic maps. Its strength lies in its ability to create custom and interactive dashboards that can be shared with others.

In conclusion, there are many data visualization tools available in the market, each with its own strengths and weaknesses. Choosing the right tool depends on the specific needs of the organization and the project at hand. However, the tools mentioned above are among the most popular and widely used in the industry, and offer a wide range of capabilities for creating beautiful and insightful visualizations.

TABLE I. COMPARATIVE STUDY OF DATA VISUALIZATION TOOLS

| **Tool** | **Points of Comparison** | | | |
|---|---|---|---|---|
| | ***Language*** | ***Ease of Use*** | ***Flexibility*** | ***Cost*** |
| Tableau | None | Easy | Moderate | Expensive |
| Python | Python | Moderate | High | Free/Open-Source |
| R | R | Moderate | High | Free/Open-Source |
| Power BI | DAX | Easy | Moderate | Expensive |
| Excel | None | Easy | Moderate | Expensive |
| Google Data Studio | SQL | Easy | Moderate | Free |
| D3.js | JavaScript | Difficult | High | Free/Open-Source |
| QlikView | Proprietary | Moderate | High | Expensive |
| SAP Lumira | None | Moderate | Moderate | Expensive |
| Microsoft Excel | None | Easy | Moderate | Expensive |
| Power VIew | DAX | Easy | Moderate | Expensive |

Fig. 1. Comparative Study of Data Visualization Tools

## IV. DATA VISUALIZATION TECHNIQUES

Visualization techniques are tools that enable users to represent and communicate complex data sets visually. There are numerous visualization techniques available, ranging from simple charts and graphs to more complex visualizations, such as heat maps and network diagrams. Here are a few examples of visualization techniques: ( Datasets used for reference are:

Amazon Prime TV Shows Dataset (https://www.kaggle.com/datasets/nilimajauhari/amazon-prime-tv-shows) and

Tableau Superstore Dataset (https://community.tableau.com/s/question/0D54T00000CWeX8SAL/sample-superstore-sales-excelxls) )

*A. Bar Charts*

Bar charts are one of the most common visualization techniques used in data analysis. Bar charts are used to represent categorical data

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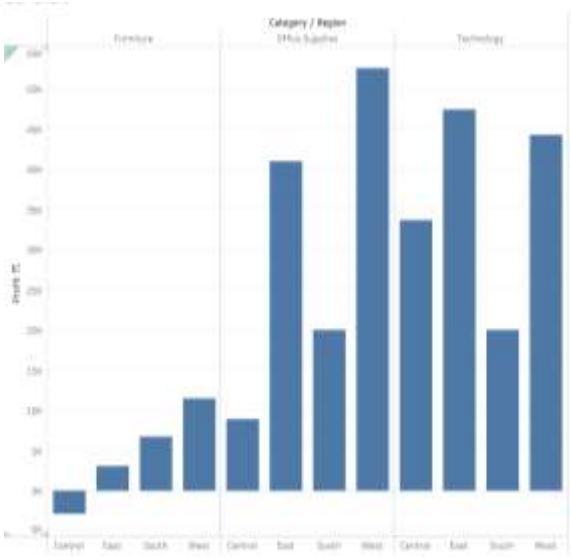

Fig. 2. Bar Chart

*B. Scatter Plots*

Scatter plots are used to visualize the relationship between two variables. Each data point is represented as a point on the graph, with the position of the point indicating the value of the two variables.

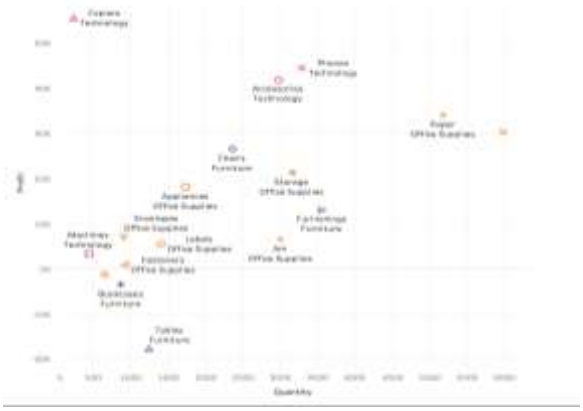

Fig. 3. Scatter Plot

*C. Heat Maps*

Heat maps are used to represent data sets with large numbers of variables. Each variable is represented as a color, with darker colors indicating higher values and lighter colors indicating lower values.

| Category | Sub-Category | Quantity Total |
|---|---|---|
| Furniture | Bookcases | 868 |
| | Tables | 1,241 |
| | Chairs | 2,356 |
| | Furnishings | 3,563 |
| Office Supplies | Supplies | 647 |
| | Envelopes | 906 |
| | Fasteners | 914 |
| | Labels | 1,400 |
| | Appliances | 1,729 |
| | Art | 3,000 |
| | Storage | 3,158 |
| | Paper | 5,178 |
| | Binders | 5,974 |
| Technology | Copiers | 234 |
| | Machines | 440 |
| | Accessories | 2,976 |
| | Phones | 3,289 |

Fig. 4. Heat Map

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*D. Treemaps*

Treemaps are used to represent hierarchical data sets. Each level of the hierarchy is represented as a rectangle, with the size of the rectangle indicating the size of the data set at that level.

Fig. 5. Tree Map

*E. Geographic Maps*

Geographic maps are used to represent data sets with a geographic component. Each data point is plotted on a map, with the position of the point indicating its geographic location

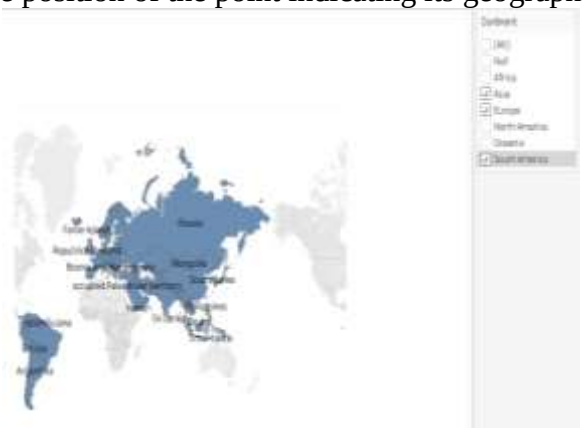

Fig. 6. Geographic Map

*F. Line Graphs*

Line graphs are similar to bar charts in that they are used to show trends over time. However, instead of using bars to represent data points, line graphs use lines. This allows for a more continuous representation of data, which can be useful for identifying patterns and trends that are not as clear in a bar chart.

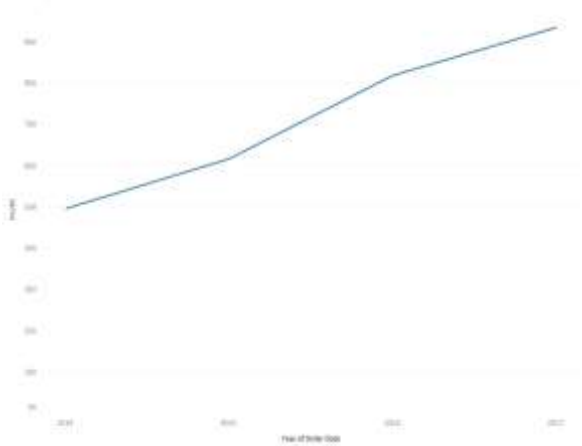

Fig. 7. Line Graph

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*G. Pie Charts*

Pie charts are used to represent the proportions of different categories within a data set. Each category is represented as a slice of the pie, with the size of the slice indicating the proportion of the data set that belongs to that category. Pie charts are beneficial for assessing the proportional sizes of several groups, but can be less effective than other visualization techniques when it comes to showing trends over time or comparing large numbers of categories.

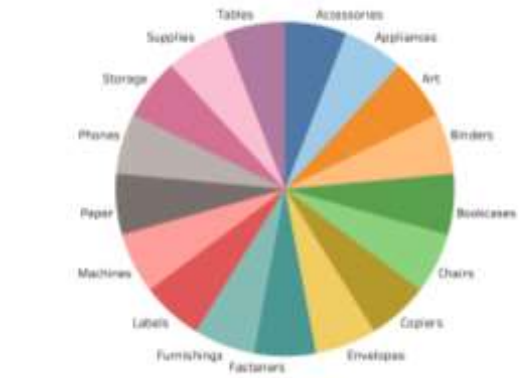


Fig. 8. Pie Chart

*H. Dashboards*

All of your data is shown visually on a dashboard. Although it has a wide range of applications, its main purpose is to present information quickly and provide a comprehensive overview of key performance indicators (KPIs) or other important metrics. The information for a dashboard often comes from a linked database and is shown on its own page. It is adjustable, giving you the option to select the data you want to view and whether or not you want to include charts or graphs to represent the data.


Fig. 9. Example of a Dashboard which shows various KPIs

There are many other visualization techniques available, each with its own strengths and weaknesses. The choice of visualization technique depends on the specific needs of the data analyst and the characteristics of the data set being analyzed. Effective visualization techniques can help users to identify patterns and trends in data, communicate findings to stakeholders, and make informed decisions based on data-driven insights.

TABLE II. COMPARATIVE STUDY OF DATA VISUALIZATION TECHNIQUES

| **Techniques** | **Points of Comparison** | | | |
|---|---|---|---|---|
| | ***Complexity of Data*** | ***Interactivity*** | ***Data Size Limitations*** | ***Accessibility*** |
| Bar Charts | Simple-Complex | Low-Moderate | Small-Large | Accessible |
| Line Charts | Simple-Complex | Low-Moderate | Small-Large | Accessible |
| Scatter Chart | Simple-Complex | Moderate-High | Small-Large | May require statistical knowledge |
| Heat Maps | Complex with multiple variables | Moderate-High | Large | May require technical expertise |
| Pie Charts | Simple | Low | Small with few categories | May be misleading |
| Tree Maps | Complex with nested data | Low-Moderate | Large with hierarchical structures | May require technical expertise |

Fig. 10. Comparative study of Data Visualization techniques

## V. APPLICATIONS

The purpose of the majority of visualization designs is to support cognition and decision-making. While creating and planning a visualization model, it is necessary to keep in mind how it will be applied. Data visualization involves selecting and examining the data points that serve as its foundation in addition to just visualizing numerical data.

One of the most important areas in computer science is data visualization, which has many uses. To analyse certain datasets over numerous areas of medicine and science, a number of application-specific tools have been created.

### *A. Public Health*

Data visualization is an important tool for public health professionals as it can help them better understand complex data and communicate that information to others. It can also help in Communicating disease outbreaks, Identifying health disparities and Planning and prioritizing public health initiatives.By using data visualization, public health professionals can make informed decisions and take action to improve the health of the communities they serve.

### *B. Renewal Energy*

Data visualization plays an important role in renewable energy as it allows for the analysis and communication of complex data related to energy production, consumption, and efficiency.

Here are some specific examples of how data visualization can be used in renewable energy: Renewable energy potential mapping, Energy consumption and generation monitoring, Energy efficiency analysis, Renewable energy investment analysis.

Overall, data visualization is an important tool for renewable energy stakeholders.

### *C. Fraud Detection*

Data visualization is crucial in fraud detection as it allows fraud investigators to identify patterns and anomalies in large sets of data. It can help in Transaction monitoring, Identity verification, Link analysis and Case management.

By using data visualization, fraud investigators can analyze large sets of data more efficiently and effectively and take appropriate action to prevent financial losses.

### *D. Genetics*

Data visualization can be used in genetics to visualize complex genetic data and identify patterns and anomalies that may indicate a genetic disorder or predisposition to a disease. By using data

visualization, researchers can gain insights into the genetic mechanisms underlying diseases and develop more targeted treatments.

*E. Music*

Data visualization can be used to visualize musical data, such as rhythm, tempo, and melody, to help musicians analyze and create new music. By visualizing musical data, musicians can identify patterns and structures in music and develop new techniques for composition and performance.

*F. Space Exploration*

Data visualization can be used in space exploration to visualize astronomical data, such as star formation and galaxy clusters. By using data visualization, astronomers can identify new celestial objects and gain insights into the origins and evolution of the universe.

## VI. CHALLENGES

The sheer volume of data in large, time-varying datasets makes visualization of data a challenging task. Users may be able to take preemptive action in response to problems by using real-time data visualization. The technique of interactively exploring time-varying data involves an animation creation approach. By imitating the anatomy of storytelling approaches, it visualizes temporal events. Different users have varying degrees of proficiency in data visualization and decision-making under time pressure. Analyzing a data visualization technique's value is difficult to assess. This has led to the development of several visualization algorithms and accompanying applications. The majority of these applications haven't made use of the new devices' direct manipulation capability or ability for multi-touch interactions.

For creating visualizations, big data—both organized and unstructured—presents a particular set of difficulties. This is because we have to consider the 3V's of the big data viz. volume, velocity and varieties. Large data visualization and analysis are currently being hampered by a new set of problems pertaining to efficiency, operability, and degree of differentiation. Creating a sizable modeled data set takes time and effort. Making a choice about the best visual to employ is likewise challenging.

## VII. CONCLUSION

The technique of portraying data in a clear and efficient way using graphics or pictures is known as data visualization. It has developed into a powerful and widely used tool for the analysis and decoding of large and complex data. It is now a quick and easy way to communicate ideas in a way that everybody can understand. It must communicate difficult concepts clearly, exactly, and effectively. These benefits have allowed data visualization to be beneficial in many academic domains. Different visualization techniques may be more effective for different types of data or different purposes. For example, scatterplots may be useful for examining relationships between continuous variables, while bar charts may be better for comparing

The design and aesthetics of data visualizations can have a significant impact on their effectiveness. Factors such as color choice, layout, and labeling can all influence how easily individuals are able to understand and interpret visualizations.

Future directions in data visualization research

Some in-depth findings are as follows :

1) The visual representation of uncertainty is an important aspect of data visualization that is often overlooked. Visualizing uncertainty can help viewers understand the limitations of the data and the potential for error in the conclusions drawn from it.
2) The use of interactive data visualization tools can lead to deeper insights and understanding of complex data. Interactive tools can allow users to manipulate and explore data in real-time, revealing patterns and relationships that may be missed with static visualizations.

3) The choice of visualization technique can impact the effectiveness of the communication of data. For example, certain visualization techniques may be more effective for representing temporal data or multivariate data.
4) The use of data visualization in education can lead to improved learning outcomes. Visualization can
5) Help students understand complex concepts and relationships by making them more concrete and accessible.
6) The use of data visualization can lead to increased engagement and interest in data-driven topics. Interactive and engaging visualizations can help to bring data to life and make it more relevant to viewers.

## CONFLICT-OF-INTEREST STATEMENT

The authors have no conflicts of interest to declare. All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report.

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