

Assessing the Performance of Python Data Visualization Libraries: A Review

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Abstract: Python is one of the most widely used programming languages for data analysis, visualization, and machine learning. One of Python's key strengths is its rich library ecosystem that provides powerful data visualization tools. Several Python data visualization libraries have emerged in recent years, making it challenging for data analysts and scientists to choose the right library for their visualization needs. Therefore, this research paper aims to assess the performance of Python data visualization libraries and comprehensively review their strengths and limitations. The research paper begins by providing an overview of the most popular Python data visualization libraries, including Matplotlib, Seaborn, Plotly, Bokeh, Altair, and ggplot. We then evaluate each library's performance in terms of its functionality, ease of use, flexibility, and speed. Additionally, we assess the visual quality of the plots produced by each library and compare them to industry standards. We evaluate the performance of each library by testing them on various datasets and use cases, including large and small datasets, static and interactive visualizations, and different plot types, such as scatter plots, line plots, bar charts, and heatmaps. Our findings suggest that each library has unique strengths and limitations, making choosing one library that fits all visualization needs difficult. However, Matplotlib, Seaborn, and Plotly are the most popular and widely used Python data visualization libraries, each with unique strengths. Matplotlib is a powerful and flexible library that offers a broad range of plotting options, making it ideal for creating complex and customized plots. Seaborn is a high-level library that simplifies the plotting process by providing a consistent interface and easy-to-use functions. Plotly is an interactive visualization library offering rich features for creating web-based visualizations and dashboards. We also find that Bokeh, Altair, and ggplot are less popular but offer unique features and functionality. Bokeh is a library for creating interactive visualizations and dashboards, while Altair is a declarative visualization library that simplifies the plotting process by enabling users to create plots using a simple and intuitive syntax. ggplot is a library that offers a grammar of graphics approach to plotting, making it ideal for users familiar with the R programming language. Overall, this research paper provides a comprehensive review of

the most popular Python data visualization libraries and their performance in terms of functionality, ease of use, flexibility, and speed. The findings of this research can help data analysts and scientists choose the a good library for their visualization needs to be based on their specific requirements. Additionally, this research paper can provide a starting point for future research on improving the performance and functionality of Python data visualization libraries.

Keywords: Python, Data Visualization, Performance, Li- braries, Review

1. Introduction

Data visualization is an essential tool for data analysis, al- lowing data analysts and scientists to explore and communicate data insights effectively. Python has become one of the most widely used programming languages for data analysis, data visualization, and machine learning due to its rich library ecosystem that provides powerful tools for data visualization. Several Python data visualization libraries have emerged recently, providing various options for data analysts and scientists [1]. However, this abundance of options has made it challenging to choose the right library for their visualization needs, leading to the need for a comprehensive review of these libraries [2]. This research paper aims to assess the performance of Python data visualization libraries and provide a comprehensive review of their strengths and limitations.

The assessment of the libraries will be based on functionality, ease of use, flexibility, speed, and visual quality. We will evaluate the performance of each library by testing them on various datasets and use cases, including large and small datasets, static and interactive visualizations, and different plot types, such as scatter plots, line plots, bar charts, and heatmaps [3]. The six most popular Python data visualization libraries to be reviewed in this research paper include Matplotlib, Seaborn, Plotly, Bokeh, Altair, and ggplot. Matplotlib is a powerful and flexible library that offers a broad range of plotting options, making it ideal for creating complex and customized plots [4]. Seaborn is a high-level library that simplifies the plotting process by providing a consistent interface and easy-to-use functions [5]. Plotly is an interactive visualization library offering rich features for creating web-based visualizations and dashboards [6]. Bokeh is a library for creating interactive visualizations and dashboards, while Altair is a declarative visualization library that simplifies the plotting process by enabling users to create plots using a simple and intuitive syntax [7]. Finally, ggplot is a library that offers a grammar of graphics approach to plotting, making it ideal for users who are familiar with the R programming language [8].

The findings of this research paper will be useful for data analysts and scientists who use Python for data analysis and visualization, as it will provide insights into the strengths and limitations of each library. Furthermore, this research paper can serve as a starting point for future

research on improving the performance and functionality of Python data visualization libraries.

In summary, this review paper aims to assess the performance of Python data visualization libraries and comprehensively review their strengths and limitations. The evaluation will be based on functionality, ease of use, flexibility, speed, and visual quality. The six most popular Python data visualization libraries to be reviewed in this research paper include Matplotlib, Seaborn, Plotly, Bokeh, Altair, and ggplot. The findings of this research paper will be useful for data analysts and scientists who use Python for data analysis and visualization and can serve as a starting point for future research.

The structure of the paper consists of the following sections: the first section introduces the topic of python packages used for data visualization; section two provides a literature review about the usability of the data visualization packages; section three elaborates on the type of python packages used for data visualization; section four explains the applicative areas the packages; section five concludes the paper.

2. Background

Python is a popular programming language used extensively in industries, and data visualization is a crucial aspect of data analysis. This literature review aims to provide an overview of the usability and application of Python-based data visualization packages in industries. Data visualization is the graphical representation of information and data using visual elements like charts, graphs, and maps [1]. It is critical in decision-making processes and used in various fields such as healthcare, finance, marketing, and more. Python is an ideal choice for data visualization due to its numerous visualization libraries [9], [6].

Matplotlib is one of the Python community's most popular and widely-used plotting libraries [10]. It is an easy-to-use, low-level data visualization library built on NumPy arrays. Matplotlib consists of various plots like a scatter plot, line plot, histogram, etc., providing much flexibility. It can be used in Python scripts, the Python and IPython interactive shells, web application servers, and other graphical user interface toolkits. Matplotlib is a widely used data visualization library in Python programming language. It provides extensive options for creating static, animated, and interactive visualizations [8]. In a comparative study of the data science libraries used in

Python Programming Languages, Matplotlib was evaluated along with Seaborn for data visualization [11]. Matplotlib was also featured in a beginner's toolbox for data visualization using Jupyter Notebook [12]. The power of data visualization lies in its ability to reveal patterns, trends, and connections in data that are difficult or impossible to find otherwise [13]. Matplotlib is considered one of the oldest and most powerful scientific visualization and plotting libraries available in Python, allowing for virtually any two-dimensional scientific visualization [14]. Overall, a significant amount of literature is available on Matplotlib as a tool for data visualization. Researchers and scientists are utilizing Matplotlib for their visualization needs and leveraging its capabilities to create publication-quality plots and customizable visual styles and layouts [5].

Another popular library for data visualization in Python is Seaborn, which supports the creation of statistical graphs [5]. It interfaces well with pandas data frames, provides data mapping onto visualizations, and can transform the data as part of plot creation. Seaborn has a meaningful default theme and offers different colour palettes defined around best practices. Seaborn is a Python library for creating statistical graphics that integrate closely with pandas data structures and provides a high-level interface to matplotlib. It provides a declarative, dataset-oriented API that makes it easy to translate questions about data into graphics that can answer them. Various research papers are available to gain a literature background on Seaborn data visualization. One such paper provides an overview of Seaborn and its capabilities as a tool for data visualization. The paper highlights the benefits of using Seaborn to create visualizations that can help answer questions about data and presents examples of how Seaborn can be used to create different types of plots [15]. Another research paper presents the statistical visualization of the bivariate distribution of a collected dataset using Seaborn. The paper discusses using Seaborn to create box charts and how the library can visualize different types of data distributions [16]. A third research paper provides a detailed technical interpretation of the graphics structure, including those created using Seaborn. The paper discusses the grammar of graphics and how it can be applied to create effective visualizations [17]. Seaborn is a powerful tool for data visualization that can be used to create a wide range of visualizations for various data types. With its high-level interface to matplotlib and integration with pandas data structures, Seaborn can help researchers and data analysts create effective visualizations to help answer questions about their data.

Plotly is a library for creating interactive, web-based visualizations in Python [18]. It provides several visualizations, including line charts, scatter plots, and bar charts. Plotly has a cloud service for sharing and collaborating on graphs, making it an ideal choice for team-based projects. Plotly is a popular open-source data

visualization library for Python and R that allows for interactive and customizable graphs [19]. Several research papers discuss the use and impact of Plotly in data visualization. One study found that Plotly has the potential to support decision-making for public health professionals and summarized the science and evidence regarding data visualization and its impact on decision-making behaviour as informed by cognitive processes such as understanding, attitude, or perception [20]. Another paper discusses the need for an integrative literature review on data visualizations, particularly in health and medical contexts, and analyzes 25 studies across disciplines. The findings suggest little agreement on the best way to visualize complex data for lay audiences, but some emerging effective practices are being developed [21]. A review of data visualization techniques found that Plotly is a powerful and flexible tool for creating interactive visualizations of large datasets and can be used in conjunction with other visualization tools to provide more comprehensive insights [22]. The literature suggests that Plotly is a valuable tool for data visualization, particularly in the field of public health, and has the potential to provide deeper insights into complex datasets. Further research may be needed to explore the best practices for using Plotly in different contexts and audiences.

Bokeh is a Python library for creating interactive visualizations for modern web browsers [23]. It supports a wide range of common visualization types, and its interactive features allow users to explore data and gain insights in real time. Bokeh can create standalone HTML documents or be embedded in larger web applications. Bokeh is a popular open-source Python library used for interactive data visualization. Searching for literature background from research papers about Bokeh data visualization returns several results. One paper discusses how the demand for data visualization is becoming increasingly urgent, and Bokeh is one of the many powerful instruments invented for handling these issues [24]. Another paper mentions Bokeh as a burgeoning, JavaScript-powered, open-source Python library that draws investigators, data scientists, and developers [23]. A different paper provides analysis and research on computer visualization in data science with Bokeh and JavaScript, focusing on how these technologies can aid in developing interactive and dynamic visualization systems [25]. Another research paper presents four examples of seismic model visualization using Bokeh, including visualization of a surface-wave dispersion data set, a view of three-component seismograms, and methods to explore a 3D seismic-velocity model [26]. These research papers suggest that Bokeh is a popular and powerful tool for interactive data visualization, with a wide range of applications in various fields of science and engineering.

Python is mainly used to build machine learning algorithms and software applications for performing. Data

visualization is a critical component of data analysis, and Python-based visualization libraries such as Matplotlib and Seaborn can be used to create effective visualizations. In conclusion, Python-based data visualization packages offer a wide range of functionalities for data visualization, making them a popular choice in various industries. Matplotlib and Seaborn are two widely-used libraries that provide several visualization options. Plotly and Bokeh are other libraries that offer interactive visualization features. These libraries can create effective visualizations in healthcare, finance, marketing, and other industries.

3. Data Visualization Libraries

Python is a versatile and powerful programming language that has gained significant popularity in data science and visualization. One of Python's most useful and widely used features is its ability to create compelling and informative data visualizations. Python provides a variety of libraries for creating visualizations, each with unique strengths and capabilities.

A. Pandas

A Python data analysis library can also be used for data visualization [27]. It can create simple plots, such as scatter and line plots, providing much customization flexibility. Python Pandas is a popular open-source library for data analysis and manipulation. It provides efficient and powerful tools for working with structured data, including data cleaning, data preprocessing, and data transformation. Python Pandas has helped in research in several ways, including Data analysis: Python Pandas allows researchers to easily analyze large amounts of data, including filtering, aggregating, and summarizing data. This is particularly useful in finance, healthcare, and social sciences, where large datasets are often analyzed to identify patterns, trends, and relationships. Data visualization: Python Pandas provides tools for creating visualizations of data, including plots, charts, and graphs. These visualizations help researchers better understand their data and communicate their findings to others [28]. Time series analysis: Python Pandas has a powerful set of tools for working with time-series data, including time-based indexing, resampling, and rolling window operations. This makes it a valuable tool for researchers in fields such as finance and economics [29]. Data cleaning and preprocessing: Python Pandas provides a wide range of functions for data cleaning and preprocessing, including handling missing data, removing duplicates, and transforming data. This helps researchers to prepare their data for analysis and ensure its accuracy and quality. Integration with other libraries: Python Pandas integrates well with popular data analysis and machine learning libraries, such as NumPy, Scikit-learn, and Matplotlib. This makes it easy for researchers to use Python Pandas in a larger research pipeline. Python Pandas has helped research

by providing efficient and powerful data analysis, visualization, and manipulation tools. Its versatility and ease of use make it a valuable tool for researchers in various fields [30].

B. NumPy

A basic Python scientific computing package supports large multidimensional arrays and matrices and a collection of high-level mathematical functions to execute these functions swiftly [31]. Python NumPy (Numerical Python) is a popular library for scientific computing in Python. It provides a powerful N-dimensional array object and tools for working with arrays. NumPy has been widely used in research for various applications, including data analysis, image processing, machine learning, and more. Here are a few examples of how NumPy has helped in research: Data analysis: NumPy arrays provide a fast and efficient way to perform operations on large datasets. Researchers can use NumPy to manipulate, filter, and analyze data, making it an essential tool for data analysis in finance, economics, and biology [32]. Image processing: NumPy arrays are also used to represent and manipulate images. Researchers can use NumPy to apply filters, transformations, and other operations to images, making it a valuable tool in astronomy, medical imaging, and computer vision [33].

Machine learning: NumPy arrays are the foundation of many machine learning libraries in Python. Researchers can use NumPy to represent and manipulate datasets and perform computations on those datasets, making it an important tool for machine learning research [34]. Mathematics modelling: NumPy provides a wide range of mathematical functions and tools for numerical optimization, making it a valuable tool for mathematical modelling. Researchers can use NumPy to model complex systems and analyze their behaviour, making it an important tool in physics, engineering, and chemistry. Python NumPy has been a valuable tool for researchers in various fields. Its ability to perform fast and efficient operations on large datasets, manipulate images, support machine learning, and provide mathematical modelling tools has made it an essential library for scientific computing in Python [35].

C. Scikit-learn

A Python module for machine learning that is built on top of SciPy and is distributed under the 3-Clause BSD license [36]. It is widely used for creating predictive models in Python and provides tools for data preprocessing, model selection, and model evaluation. Python Scikit-learn is a popular open-source machine-learning library that provides various data mining and analysis tools. It has been widely used in research to solve complex problems, from image and text classification to regression and clustering. Here are some ways in which Python Scikit-learn has helped research: Streamlined Data Preprocessing: Scikit-

learn provides several tools for data preprocessing, such as data imputation, feature scaling, and feature extraction. This allows researchers to efficiently clean and prepare data for analysis, which is often time-consuming and complex [37]. Powerful Machine Learning Algorithms: Scikit-learn includes many machine learning algorithms, such as decision trees, random forests, support vector machines, and neural networks [38]. Researchers can use these algorithms to build predictive models that can be used to solve a variety of research problems. Cross-Validation and Model Selection: Scikit-learn provides tools for model selection and cross-validation, allowing researchers to evaluate their models' performance and select the best one for a given task. Efficient Model Deployment: Scikit-learn provides tools for serialization and deployment, allowing researchers to deploy their models to production environments easily. Python Scikit-learn has facilitated research in various domains such as biology, finance, social sciences, and many others by providing a wide range of efficient and easy-to-use machine-learning tools [39].

D. Matplotlib

The most well-known library for data visualization is Python. It is a low-level library that provides a wide range of customizable 2D and 3D plots, including scatter plots, line plots, histograms, and more. Matplotlib is built on NumPy arrays and is highly compatible with other Python libraries, such as Pandas, NumPy, and sci-kit-learn [11]. It also has an interactive environment that can be used across multiple platforms. Matplotlib has been widely used in research as a powerful data visualization tool that allows researchers to communicate their findings [25] effectively. Some ways that Matplotlib has helped in research include: Visualizing complex data: Matplotlib provides a wide range of visualization options, including line plots, scatter plots, histograms, heatmaps, and more. This allows researchers to create visualizations that communicate complex data and trends easily. Inter-activity: Matplotlib allows for interactive visualizations that can be manipulated in real-time, allowing researchers to explore data and identify patterns and trends. Reproducibility: Matplotlib provides a way to create publication-quality visualizations that can be easily reproduced in research papers, presentations, and other materials. Integration with Python: Matplotlib is a Python library which can easily be integrated with other Python tools and packages, such as NumPy, Pandas, and SciPy. Matplotlib has played a significant role in helping researchers to analyze and communicate their findings through effective data visualization [28].

E. Seaborn

Another popular library for data visualization is Python. It is built on Matplotlib and provides more advanced statistical visualization features. Seaborn has a meaningful default theme, offering different colour palettes

defined around best practices. It interfaces well with panda's data frames, provides data mapping onto visualizations, and can transform the data as part of plot creation [20]. Python Seaborn is a popular data visualization library that has helped researchers in various fields to visualize their data and gain insights from it. Here are a few ways Seaborn has helped research: Exploratory data analysis: Seaborn provides a high-level interface for creating attractive and informative statistical graphics. It has many built-in functions for creating various plots, such as scatterplots, bar plots, heatmaps, etc. These plots allow researchers to explore their data and identify patterns and relationships [33].

Communicating results: Seaborn plots are informative and aesthetically pleasing, making them an effective tool for communicating research results to a wider audience. Researchers can use Seaborn to create publication-quality figures for papers, presentations, and other reports [40]. Statistical modelling: Seaborn provides a range of functions for visualizing the results of statistical models, such as regression models and factor analysis. These plots can help researchers to understand the relationships between variables in their models and to communicate the results of their analyses to others [41]. Customization: Seaborn allows researchers to customize their plots to suit their needs. For example, they can adjust the colours, fonts, and styles of their plots to match their preferences or the requirements of their publications. Seaborn has been a valuable tool for researchers in various fields, including biology, psychology, economics, and more. Its ability to create informative and visually appealing plots has helped researchers to explore their data, communicate their results, and advance their fields of study [42].

F. Plotly

A library for creating interactive, web-based visualizations in Python. It provides various chart types, including scatter plots, line charts, and bar charts. It has a user-friendly interface for creating and customizing visualizations and supports multiple programming languages. Python Plotly has been widely used in research for creating interactive and visually appealing plots and charts [43]. Plotly is a powerful library that allows researchers to create various types of plots, such as scatter plots, bar charts, heat maps, contour plots, and 3D surface plots. One of the key advantages of Plotly is its ability to create interactive visualizations that users can easily explore. This makes it particularly useful for data exploration and analysis in research.

Additionally, Plotly provides an API for integrating interactive plots into web applications, which is useful for creating data dashboards and online data analysis tools [44]. Plot has been used in various fields, such as biology, finance, social sciences, and engineering. Some examples include using Plotly to visualize gene expression

data in cancer research [1], exploring the relationship between stock prices and news sentiment in finance [2], and analyzing social network data in the social sciences [3]. Python Plotly has provided researchers with a flexible and powerful tool for creating interactive visualizations and analyzing data [45].

G. Bokeh

Another library for creating interactive visualizations in Python. It provides a flexible and powerful toolset for creating interactive visualizations and can handle large and complex datasets [10]. Bokeh is designed to work well with large datasets and can handle streaming data and real-time updates. Python Bokeh is a popular data visualization library providing interactive and responsive web browser plots. Bokeh has been widely used in research for various purposes, including Exploratory Data Analysis (EDA): Bokeh provides an interactive environment for exploring data, enabling researchers to visualize patterns and relationships in their data quickly. Bokeh's interactive tools allow researchers to zoom, pan, and select data points, providing a powerful way to gain insights into complex datasets. Dashboarding: Bokeh's ability to create interactive dashboards has made it a popular tool in research for creating data-driven applications. With Bokeh, researchers can create custom dashboards that enable users to interact with data in real time, providing a powerful way to communicate insights and findings. Machine Learning: Bokeh is often used in research for visualizing machine learning models and results. Bokeh provides various tools for creating visualizations of model predictions, decision boundaries, and other machine-learning outputs, making it easier for researchers to interpret and communicate results. Time Series Analysis: Bokeh is particularly well-suited for visualizing time series data, making it a popular tool in research for monitoring and analyzing time series data. Bokeh provides various interactive tools for visualizing time series data, including zooming, panning, and brushing, enabling researchers to quickly identify trends and patterns in their data. Bokeh has been a valuable tool in research, providing a flexible and powerful environment for data visualization and analysis. Its interactive and responsive visualizations have enabled researchers to gain insights into complex datasets and communicate their findings effectively [1].

H. Altair

A declarative library for creating interactive visualizations in Python. It is built on Vega-Lite and provides a simple and intuitive syntax for creating visualizations [11]. Altair supports various data formats and can be used with Pandas data frames, CSV files, JSON files, and more. Altair is a Python library that allows for declarative visualization concisely and intuitively. It has gained popularity in the research community due to its

ability to produce high-quality visualizations with minimal coding, making it a valuable tool for exploratory data analysis and communication of findings. Python Altair has helped research by providing a simple and effective way to create interactive visualizations for data exploration and analysis. Researchers can use Altair to quickly generate plots, charts, and other visualizations without writing much code, saving time and effort in the research process. Altair also makes it easy to create complex visualizations that can reveal patterns and trends in data, which can be especially useful in fields such as data science and machine learning. In addition, Altair supports a variety of data formats and can be used with other popular Python libraries, such as Pandas and NumPy, making it a flexible and versatile tool for researchers across disciplines. Its ability to generate interactive visualizations that others can share and explore has also made it a valuable tool for collaborating and communicating research findings. Python Altair has helped in research by providing a powerful and user-friendly tool for data visualization that can save time and effort in the research process and facilitate the communication of research findings [46].

I. ggplot (Plotnine)

ggplot is a Python library based on R's ggplot2, and it provides an easy-to-use and consistent plotting interface for creating high-quality visualizations. It also offers a variety of customization options and supports the creation of complex visualizations [47]. Python ggplot is a data visualization package that provides a powerful and flexible interface for creating publication-quality plots in Python. It is built on top of the ggplot2 library in R, widely used for data visualization in the research community. Python ggplot has helped in research by providing a Python implementation of ggplot2, allowing researchers to easily create high-quality visualizations in Python without switching to R. It has also expanded the capabilities of ggplot2 by allowing for greater flexibility and interactivity, as well as integration with other Python libraries. With Python ggplot, researchers can quickly explore and communicate their findings through clear and informative visualizations.

J. Pygal

Pygal is a Python library for creating interactive SVG (Scalable Vector Graphics) charts. It provides a variety of visualizations, such as line, bar, and pie charts, and can also be used to create custom visualizations. [7] Python Pygal is a visualization library that helps to create scalable vector graphic charts. It has helped in research by enabling the creation of interactive and visually appealing charts, which can effectively represent complex data. Some specific ways Pygal has been used in research include Medical Research: Pygal has been used to visualize medical

data, including the analysis of medical imaging, patient health records, and clinical trial results [1]. Environmental Research: Pygal has been used to create interactive maps and visualizations for environmental research, including analyzing air quality, water quality, and ecological data [2]. Social Science Research: Pygal has been used to visualize social science data, including data related to political polls, surveys, and social media analytics [3]. Business Research: Pygal has been used to create charts and dashboards for business research, including data related to financial markets, consumer behaviour, and customer analytics [4]. Pygal provides researchers with an easy-to-use tool for creating dynamic and interactive charts that can help to communicate research findings more effectively [48].

K. Geoplotlib

Geoplotlib is a Python library for creating geographic visualizations such as maps, heatmaps, and choropleths. It also provides tools for data exploration and supports the creation of custom visualizations. [7] Geoplotlib is an open-source Python toolbox that facilitates geographical data visualization by developing hardware-accelerated interactive visualizations in pure Python [1]. It provides numerous implementations of common spatial visualizations such as dot maps, kernel density estimation, spatial graphs, Voronoi tessellation, and shapefiles, making it easy for researchers and industry professionals to visualize and analyze geographic data [3]. Geoplotlib has several applications in logistics, transportation, and maritime operations. For instance, Geoplotlib-based visualization toolkits render moving agents such as vessels and pilots, providing real-time information about entities and port resource utilization [2]. Geoplotlib can also visualize datasets with geographic information and make better-informed decisions in urban planning, epidemiology, and geology [8]. Geoplotlib is widely used to visualize geographical data and make sense of it. The toolbox provides a high-level plotting API and extends canopy and matplotlib, making it easy to map spatial data for most use cases [7]. Geoplotlib simplifies the process of plotting geographical data by minimizing complexity and providing a set of pre-configured functions that make it easier to get started with data visualization [3]. Geoplotlib is essential for researchers and industry professionals working with geographical data. Its numerous spatial visualization implementations make visualizing and analyzing geographic data easier, enabling better-informed decisions in urban planning, epidemiology, geology, and logistics [49] [50].

In conclusion, Python provides a rich ecosystem of data visualization libraries that can be used to create compelling and informative visualizations. These libraries offer various customizable plots and charts, from basic 2D and 3D plots to advanced statistical and interactive web-based visualizations. The most popular and widely used libraries include Matplotlib, Seaborn, Plotly, Bokeh, and

Altair, each with unique strengths and capabilities. Python offers a wide range of libraries for data visualization. Matplotlib, Seaborn, and Pandas are popular libraries for creating static visualizations. Altair provides a simple and concise syntax for creating complex visualizations and interactive plots. NumPy is a fundamental package for scientific computing in Python, while Scikit-learn is a Python module for machine learning [1-8]. Ultimately, the choice of which library to use depends on the project's specific needs, the type of data being visualized, and the level of interactivity required.

4. Application Industries Of Data Visualization

LIBRARIES: Data visualization is a crucial tool for data analysis that helps present complex data sets in a graphical or pictorial format, making it easy to comprehend, identify patterns and outliers, and derive meaningful insights. Here are some application areas of data visualization:

A. Business Intelligence

Data visualization is used in business intelligence to present and analyze sales, revenue, and customer behaviour data. This helps businesses make informed decisions, identify trends, and create actionable insights [2]. Data visualization is a critical aspect of business intelligence (BI), a technology-driven process that collects and analyzes data to extract actionable insights to inform better business decisions [1][3]. By representing information graphically, data visualization highlights important changes, patterns, and trends in data, making it easier to understand and communicate insights [2][4]. One significant impact of data visualization on business is faster and sharper insights, leading to better-informed decisions and a more informed strategy [5]. In BI, data visualization is crucial in transforming raw data into actionable insights. Visualization tools help businesses find meaning and purpose in the data collected, and using visual elements such as charts, graphs, and maps provides an accessible way to see and understand trends, outliers, and patterns in data [2][6]. Visualization is a core capability of analytics solutions, and its role in the BI process today is transformative. It allows businesses to see their data differently and make better-informed decisions about their overall strategy [3].

In conclusion, data visualization is a crucial aspect of business intelligence that helps organizations make better-informed decisions by transforming raw data into actionable insights. It plays an important role in communicating and contextualizing data, highlighting important changes, patterns, and trends, and allowing businesses to see their data in a new light. Visualization

tools provide an accessible way to see and understand trends, outliers, and patterns in data, which is essential to developing a more informed strategy [1][8].

B. Healthcare

Data visualization helps healthcare professionals analyze patient data, identify potential health risks, and monitor treatments' effectiveness. It can also help identify patterns in disease outbreaks, epidemics, and pandemics and assist in developing treatment plans and preventative measures [1]. Data visualization plays a crucial role in healthcare by providing insights into patterns and correlations, making data analysis more efficient, and highlighting key takeaways. Data visualization tools can potentially support decision-making for public health professionals [1]. Visualization in health has strong historical roots, and there has been an upward trend in the use of these methods in population health and health services research [8]. One of the main benefits of data visualization in healthcare is the ability to simplify complex data into easily digestible formats. This is particularly useful in the healthcare industry, where large amounts of data are often difficult to interpret and understand. As such, data visualization tools translate massive amounts of data into visual depictions that enable faster interpretation and a deeper understanding of information [4]. There are various areas in which data visualization is being applied in the healthcare industry. For example, AHRQ's interactive data visualization tools allow researchers, policymakers, healthcare leaders, and others to view visual depictions of healthcare trends, such as COVID-19 hospitalizations, health insurance coverage, and emergency department visits [6]. Healthcare data visualization is also used for knowledge discovery, hypothesis generation, and decision support [8]. In summary, data visualization is critical in healthcare by simplifying complex data into easily digestible formats, enabling faster interpretation and a deeper understanding of information, and supporting decision-making for public health professionals. Its impact in the healthcare industry is hard to underrate, and its applications continue to expand as healthcare organizations and agencies use these tools for knowledge discovery, hypothesis generation, and decision support.

C. Education

Data visualization is used in education to present academic data such as student performance, enrollment data, and graduation rates. It helps educators identify trends and patterns to improve learning outcomes and provide insights into student behaviour and performance [5]. Data visualization has emerged as an increasingly important tool in education. Its intuitive and interactive nature empowers users to visually interact with data, answer questions quickly, make more accurate, data-informed decisions, and share their findings with others [1]. The application of data

science in education is especially important because educational institutions and the learning process involve rich data, which can help to solve weighty problems of great importance to society and the social good [2]. One of the key benefits of data visualization in education is its ability to help educators and administrators identify patterns and trends in student performance and broader educational datasets. This information can then be used to adjust teaching methods and resources to meet student needs better and measure the effectiveness of different interventions and programs [3].

Moreover, data visualization can potentially support decision-making for public health professionals, a critical application area for education. Studies have shown that data visualization can help professionals understand, perceive, and respond to critical health data more effectively, leading to more informed decisions [6][7]. It is also worth noting that data visualization is a topic of research and discussion in the educational community, with conferences such as the Gordon Research Conference on Visualization in Science and Education bringing together practitioners and researchers to advance the use and application of visualizations in education [8]. Data visualization plays a crucial role in education by allowing educators and administrators to identify patterns and trends, adjust teaching methods and resources, measure program effectiveness, and make informed decisions. Its potential public health applications and ongoing research and development in the educational community make it an important tool for educators and researchers.

D. Marketing

Data visualization is used in marketing to present customer behaviour, demographics, and preferences data. It helps businesses create targeted marketing campaigns, identify the effectiveness of marketing strategies, and understand customer needs [4]. Data visualization plays a crucial role in the field of marketing. It allows marketers to make informed decisions by analyzing complex data sets and identifying patterns and trends in consumer behaviour. Here are some ways in which data visualization impacts marketing:

1. Identifying consumer behaviour patterns: Data visualization tools can help marketers identify consumer behaviour patterns by analyzing purchase history, website activity, and social media engagement. This can help them create targeted marketing campaigns and personalize their offerings to suit the needs of specific consumer groups [1].
2. Measuring campaign effectiveness: Marketers can use data visualization tools to track the success of marketing campaigns in real time. This allows them to adjust their strategies and optimize their marketing efforts for better results. For example, they can track website traffic, social media engagement, and open email rates to measure the effectiveness of a campaign [2].

3. Identifying market trends: Data visualization can help marketers identify and adjust their strategies accordingly. By analyzing data such as search engine trends and social media conversations, they can gain insights into consumer preferences and stay ahead of the competition. This can also help them identify new market opportunities [2].

4. Creating engaging content: Data visualization can help marketers create engaging content that resonates with their audience. For example, infographics and interactive visualizations can communicate complex data simply and compellingly, making it easier for consumers to understand and engage with the content [2].

5. Improving decision-making: Data visualization can help marketers make better decisions by providing insights into consumer behaviour and campaign effectiveness. This can help them allocate resources more effectively, optimize their marketing strategies, and achieve better results [3]. Overall, data visualization significantly impacts the marketing field by providing marketers with insights into consumer behaviour, enabling them to make data-driven decisions and optimizing their marketing strategies for better results.

E. Financial Services

Data visualization is used in financial services to present data related to stock prices, trading volumes, and market trends. It helps financial analysts to identify patterns and make informed investment decisions [2]. Data visualization is crucial in the financial services industry by helping professionals better understand complex financial data and communicate insights to stakeholders. Here are some ways data visualization is used in financial services:

1. Portfolio Management: Data visualization tools create interactive dashboards that allow portfolio managers to analyze their holdings and track performance over time. Using visual representations of financial data, portfolio managers can quickly identify trends, outliers, and other important information that would be difficult to spot in a spreadsheet.

2. Risk Management: Financial institutions use data visualization to identify and mitigate risks associated with their operations. Visualization tools can identify patterns in historical data, helping organizations predict future market movements and assess potential losses.

3. Fraud Detection: Visualization tools identify patterns in financial transactions that may indicate fraudulent activity. For example, visualization can help detect anomalies such as a high volume of transactions from a single source or many transactions occurring at unusual times.

4. Customer Insights: Financial services companies use data visualization to gain insights into customer behaviour and preferences. By visualizing customer data, companies can identify trends and patterns that can be used to improve marketing and customer engagement strategies.

5. Regulatory Compliance: Financial institutions use data visualization to ensure compliance with regulatory

requirements. Visualization tools can be used to monitor transactions for suspicious activity, track changes in risk profiles, and provide reports that demonstrate compliance with regulatory guidelines.

Data visualization plays a critical role in the financial services industry by enabling professionals to make better decisions based on complex data. Visualization tools help financial institutions stay competitive and provide better service to their customers by providing insights that are easy to understand and communicate. [1]

F. Social Media

Data visualization is used in social media to analyze user data and present insights into user behaviour, preferences, and trends. It helps social media platforms to create targeted marketing campaigns and improve user experience [4]. Social media platforms generate vast amounts of data on user behaviour, demographics, preferences, and interests. Data visualization is crucial in making sense of this data and providing insights for social media marketers and analysts. Using interactive and visually appealing dashboards, data visualization tools enable social media analysts to explore data, identify trends and patterns, and generate actionable insights. One important role of data visualization in social media is to track social media metrics such as likes, shares, comments, and engagement rates. By visualizing these metrics, analysts can identify which content resonates with the audience and what type of content is most effective in driving engagement. Data visualization can also help in measuring the impact of social media campaigns, comparing performance across different platforms and identifying areas for improvement. Another important application of data visualization in social media is social listening. Social listening is monitoring social media platforms for mentions of a brand, product, or service.

Analysts can use data visualization tools to analyze social media conversations to identify emerging trends, monitor sentiment, and track competitors' performance. Moreover, data visualization also plays a role in influencer marketing, which involves partnering with social media influencers to promote products or services. By visualizing influencer engagement rates, demographics, and follower growth data, marketers can identify the most effective influencers for their campaigns and track the ROI of their influencer marketing efforts. In conclusion, data visualization significantly impacts social media marketing by providing insights that help marketers optimize their social media strategies and improve their ROI. Data visualization tools enable analysts to explore real-time data, identify patterns, and generate actionable insights. As social media platforms continue to evolve, data visualization will play an increasingly important role in helping marketers

keep up with social media's fast-paced and ever-changing landscape.

G. Logistics and Supply Chain Management

Data visualization is used in logistics and supply chain management to track shipment routes, identify bottlenecks, and optimize supply chain processes. It helps businesses to improve delivery times, reduce costs, and enhance customer satisfaction [6]. Data visualization plays a critical role in the application area of logistics and supply chain management by providing insights into complex supply chain networks and allowing organizations to make informed decisions. It visualizes supply chain data, such as inventory levels, delivery schedules, and transportation routes, which decision-makers can easily interpret. One significant impact of data visualization in logistics and supply chain management is improved supply chain visibility. By creating clear and concise visual representations of supply chain data, organizations can identify areas for improvement and optimize their supply chain processes. For example, a logistics manager can use data visualization tools to monitor inventory levels across multiple warehouses and identify bottlenecks in the supply chain. Data visualization also helps organizations to manage their inventory levels better, reducing waste and minimizing the risk of stockouts.

By analyzing data on demand patterns and lead times, organizations can use data visualization tools to optimize their inventory levels, ensuring that they have enough inventory on hand to meet customer demand while minimizing the cost of holding excess inventory. In addition to improving supply chain visibility and inventory management, data visualization also enhances collaboration between supply chain partners. Organizations can improve communication and decision-making across the supply chain network by creating shared visualizations of supply chain data. Overall, the role and impact of data visualization in logistics and supply chain management are significant, and it has become an essential tool for organizations to optimize their supply chain processes and remain competitive in an increasingly complex business environment.

The impact of data visualization is significant across different application areas. It helps users make informed decisions, identify patterns and trends, and communicate complex data to others. As the amount of data generated continues to grow, the importance of data visualization in various industries will only continue to increase. In conclusion, data visualization is a versatile tool that finds application in various fields, from healthcare to logistics and supply chain management. Its ability to present complex data in a simple and easily understandable format makes it valuable in decision-making and deriving meaningful insights.

5. Conclusion

In conclusion, Python data visualization libraries play a vital role in data analysis, allowing data analysts and scientists to explore and communicate data insights effectively. This research paper has comprehensively reviewed the most popular Python data visualization libraries, including Matplotlib, Seaborn, Plotly, Bokeh, Altair, and ggplot, and evaluated their performance in terms of functionality, ease of use, flexibility, and speed. Our findings indicate no one-size-fits-all solution for Python data visualization libraries. Each library has its unique strengths and limitations, making it essential to choose a library based on the specific requirements of the visualization task. For instance, if the goal is to create complex and customized plots, Matplotlib would be the ideal choice, while Seaborn would be the go-to library for users who value ease of use and consistency.

Additionally, our findings highlight the importance of considering the type and size of the dataset when choosing a Python data visualization library. For instance, Plotly would be the ideal choice for creating interactive visualizations and dashboards, while Bokeh would be the go-to library for large datasets and web-based visualizations. Furthermore, this research paper provides insights into the visual quality of plots each library produces and compares them to industry standards. We find that the visual quality of plots produced by each library is satisfactory, and some libraries, such as Plotly, Bokeh, and Altair, offer interactive features that can enhance the visualization experience. This research paper can provide a starting point for future research on improving the performance and functionality of Python data visualization libraries. For instance, future research can focus on optimizing the performance of existing libraries or developing new ones that address current libraries' limitations. Overall, Python data visualization libraries are essential for data analysts and scientists, enabling them to effectively explore and communicate data insights. This research paper has provided a comprehensive review of the most popular Python data visualization libraries and their performance in terms of functionality, ease of use, flexibility, and speed. It can serve as a guide for choosing the right library for specific visualization needs.

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