An overview of visual intelligent tools based on artificial intelligence

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Abstract:

In recent years, data visualization technology has received widespread attention, offering users a way to gain an in-depth understanding and effective exploration of various datasets by visualizing their composition and characteristics. Simultaneously, with the continuous development of hardware and algorithms, artificial intelligence (AI) has permeated every aspect of contemporary social life. Some studies have proposed the use of intelligent visualization tools that leverage AI to achieve significant results in data analysis, decision support, and automated reporting. However, there is a lack of systematic work to summarize and analyze these literature. In this paper, we conduct a comprehensive review of AI-based intelligent visualization tools and their applications in various domains. Firstly, we introduced the foundational concepts of AI and data visualization and explored the relationship between these two. we provided an overview of prevalent AI-based intelligent visualization tools along with their diverse applications. Our discussion encompassed renowned tools like Tableau, Power BI, QlikView, D3.js, IBM Watson Analytics, and FusionCharts, delving into their distinctive features, functionalities, and practical implementations. Furthermore, we have explored the advantages and challenges of AI-integrated visualization. The advantages include enhanced data understanding and insights, as well as automation of analysis and visualization generation. Some challenges coexist in the meantime, including data quality and accuracy, privacy and security concerns, and user experience and usability issues. Based on our findings, we have added a great deal to the corpus of knowledge by giving a thorough rundown of visualization tools with AI integration and their possible uses. We have also identified existing issues and limitations that need to be addressed for further advancements in this field. Lastly, we have proposed future research directions and development trends to guide researchers and practitioners in fully harnessing the potential of AI and visualization.

Keywords: data visualization, artificial intelligence, overview, smart interaction

1. Introduction

In the big data era, artificial intelligence (AI) and visualization technology integration has become essential tools for data analysis and decision assistance [1]. The process of converting data into visual representations like graphics, charts, and animations is known as visualization. It facilitates the intuitive understanding and interpretation of data, enabling the identification of patterns, trends, and anomalies. Artificial intelligence (AI), on the other hand, utilizes algorithms and models to simulate human intelligence and achieve automation and intelligent task processing. Some representative applications of AI and visualization include machine learning algorithms and visualization, data mining and visualization, and natural language processing and visualization. When AI and visualization technologies are combined, they can create many intelligent visualization tools. These tools leverage AI's ability to analyze, mine, and predict large-scale data and visually present the results. They can help users understand complex data information more quickly and accurately and provide better decision support. This combination allows for advanced data exploration and insight generation, benefiting various domains such as business intelligence, healthcare, civil engineering, finance, and social sciences [1]. Despite its importance, however, there is currently no systematic and comprehensive review paper summarizing AI-based visualization intelligent tools. We propose a systematic review in this paper to explore in depth the intelligent tools generated by the combination of AI and visualization.

Firstly, we provide a detailed introduction to the fundamental concepts of AI and visualization. The creation of computer systems with AI capabilities entails the completion of activities that traditionally call for human intelligence [2]. Visualization is the practice of visually expressing information and data to support knowledge discovery and data exploration [3]. The literature widely acknowl-

edges the relationship and mutual influence between AI and visualization [1]. Artificial intelligence (AI) methods like machine learning and natural language processing improve visualization capabilities by generating insightful conclusions and automating data analysis [1].

The next section is the focus, where we review AI-based intelligent visualization tools and their applications in various domains. In recent years, numerous AI-based visualization intelligent tools have emerged, each with unique features and applications. Tableau, Power BI, QlikView, D3.js, Plotly, IBM Watson Analytics, and FusionCharts.

We explore the benefits and difficulties of combining AI and visualization in the last part. Enhancing data understanding and insight is made possible by the integration of AI and visualization, which offers various benefits. By utilizing AI techniques such as pattern recognition and anomaly detection, visualization can uncover hidden patterns and relationships in complex datasets. Additionally, time is saved and less human labor is required when analysis and visualization production are automated, freeing up users to concentrate on higher-level interpretations. However, several challenges arise when integrating AI and visualization. Ensuring data quality and accuracy is crucial to avoid misleading visualizations and erroneous conclusions. Privacy and security concerns arise when dealing with sensitive data, necessitating the implementation of appropriate safeguards. User experience and usability should also be carefully considered to ensure effective communication of insights. Finally, the conclusion and outlook section evaluates this review paper, highlighting existing problems and shortcomings. It also proposes future research directions and trends, providing guidance and inspiration for further research and application in this field.

This paper comprehensively explores various AI-based intelligent tools and their application scope in different fields, pointing out the advantages of these tools and the challenges they face in their development. These tools will become more and more crucial as technology develops and data volume continues to increase. This article provides a convenient channel for researchers to quickly understand these tools, helping them to carry out relevant research.

2. AI and Visualization Overview

2.1 Definition and Basic Concepts of Artificial Intelligence

Artificial intelligence (AI) is a branch of computer science that focuses on the science and technology of building machines that can perform tasks that used to demand hu-man intelligence [4]. With the use of this technology, theories and approaches that can mimic, increase, and expand human intelligence are researched, developed, and put into practice. AI seeks to comprehend the fundamentals of intelligence and develop intelligent computers capable of thinking and acting in ways akin to those of humans [5]. Narrow and general AI are the two categories into which artificial intelligence can be separated. Narrow AI concentrates on doing particular tasks, while general AI aims to possess human-like intelligence across multiple domains [4].

AI encompasses a broad range of fields, including machine learning (ML), deep learning (DL), natural language processing (NLP), and computer vision (CV).

ML is an important foundation of AI, enabling machines to learn from data, build models that can learn from experience, and utilize these models to make predictions or handle new data [6]. ML relies on basic components such as data, feature extraction, learning algorithms, and model evaluation. Its working principle involves training algorithms with data and analyzing and modeling the data to achieve automatic learning and prediction [7].

A subfield of machine learning termed deep learning (DL) involves multi-layer neural networks In order to raise the accuracy of pattern recognition and prediction. DL leverages the methods and theories of machine learning while bringing more powerful representational capabilities and higher performance. It can be seen as the further development and evolution of machine learning on neural network models [8].

NLP is an important branch of AI, studying how to enable machines to understand, generate, and process human language [9]. NLP applies machine learning algorithms and deep learning methods to language processing, achieving the understanding and processing of natural language through training data and the optimization of model parameters.

Another significant area of artificial intelligence is CV, which studies ways to make computers able to comprehend, evaluate, and interpret pictures and videos. It uses image or video data, extracts specific features from them, applies machine learning algorithms and deep learning methods to process these feature data, and achieves the understanding and processing of images and videos through training data and the optimization of model parameters, thus accomplishing tasks such as feature extraction, object detection, and recognition, image generation, etc. [10].

2.2 Definition and Basic Concepts of Visualization

The technique of displaying data or abstract information

using visual components including graphs, charts, and maps is known as visualization. The main goal of visualization is to provide insights, understanding, and demonstration of complex data through intuitive and easily comprehensible visual representations for users. It helps users understand the structure, features, and distribution of data and facilitates the discovery of correlations, patterns, and trends that might not be seen in the data's raw form [11]. In the design of visualization, the types of data and the goals of tasks need to be considered. Data can be classified as qualitative or quantitative, and tasks can be categorized as comparison, correlation, distribution, trend, etc. Different visualization strategies and graphic formats are needed for different kinds of data and tasks.

2.3 Relationship and Mutual Influence Between AI and Visualization

There exists a close relationship and mutual influence between AI and visualization. The development of AI technology provides strong support and impetus for the advancement of data visualization tools.

Firstly, AI technology can offer more efficient and intelligent functionalities for data visualization tools. Making use of deep learning and machine learning methods, visualization tools can automatically identify features, correlations, and outliers from massive datasets. When choosing visualization solutions, AI can also provide intelligent recommendations by generating the best visualization schemes and types of charts based on users' data and requirements, enabling users to explore and analyze data more easily with visualization tools.

Secondly, visualization can help AI technology better understand and explain data. AI algorithms are usually based on complex mathematical models, and the output results are often difficult to interpret and understand intuitively, resembling a "black box." By visualizing the output results of AI algorithms, abstract data can be transformed into visual images, facilitating users to comprehend and explain the working principles and results of AI algorithms more directly and intuitively [12].

3. AI-based Intelligent Visualization Tools and their Application

3.1 Tableau

One of the best data visualization tools is Tableau, which helps customers make data-driven decisions by letting them explore and understand their data through interactive and understandable visuals. It offers a variety of functionalities and features, demonstrating significant value in practical applications:

(1)Automatic identification and recommendation of suitable visualization types using AI technology to better present data: Based on the characteristics and relationships of the data, Tableau can automatically select the best visualization methods, such as line charts, scatter plots, heat maps, etc.

(2)Intelligent data cleaning and preprocessing using AI technology to make data more accurate and reliable: By using machine learning algorithms, Tableau can automatically identify and correct errors, missing values, and outliers in the data, improving data quality and reliability.

(3)Advanced AI-powered data analysis and prediction: Tableau leverages machine learning algorithms to discover patterns, trends, and anomalies in the data, then uses those results to produce predictions and classifications. These tools assist users to go deeper into the data and gain more insightful comprehension. [13].

(4)Real-time interactivity: Tableau's drag-and-drop, filtering, control panel, and other capabilities let users analyze and explore data in real time. This real-time interactivity allows users to explore and visualize data more flexibly [13].

(5)Application instances: Based on these features and characteristics, Tableau is a popular tool in the fields of business intelligence, data analysis, and data visualization. It is used to explore and analyze data, create interactive reports and dashboards, and support decision-making and business optimization. For example, in marketing, Tableau can help analyze market data, consumer trends, and competitive intelligence, supporting decision-making and optimizing market strategies. In the biomedical field, Tableau can be used to visualize and analyze data on various diseases, assisting doctors in diagnosis and treatment decisions [14].

3.2 Power BI

Microsoft produced Power BI, a powerful business intelligence tool that encourages collaboration and data analysis by permitting users to build interactive dashboards and reports from a range of data sources. It offers a variety of functionalities and features, demonstrating significant value in practical applications:

(1)AI-powered automatic identification and recommendation of the best visualization types: To highlight the features and correlations of the data, Power BI can dynamically choose the best chart formats, including bar charts, line charts, pie charts, etc., based on the data type and relationships [15].

(2)Intelligent data cleaning and preprocessing: Using artificial intelligence (AI), Power BI can automatically identify and manage abnormalities, missing numbers, and mis-

takes in the data. By using machine learning algorithms, Power BI can intelligently clean and fill data, improving data quality and accuracy [16].

(3)Advanced data analysis and prediction using AI technology: Power BI comes with powerful machine learning algorithms for data mining, clustering analysis, time series analysis, etc. These features enable users to uncover hidden patterns and trends in the data for data-driven decision-making.

(4)Real-time data analysis and monitoring: Real-time data sources can be connected to Power BI, helping users monitor changes in data in real time and take prompt action [17].

(5)Support for connecting various data sources: Power BI's ability to connect to several data sources increases its adaptability to user requirements.

(6)Application instances: Within the domain of business intelligence, data visualization, and data analysis, Power BI is extensively utilized due to its features and attributes. Data exploration and analysis, real-time dashboards, interactive reporting, and data exploration are all made possible by it, and it is a crucial tool for collaborative work and data-driven decision-making in enterprises. For example, in marketing analysis, Power BI can help analyze market trends, consumer behavior, and product sales, optimizing marketing strategies and decisions [18]. In supply chain management, Power BI can be used to monitor and analyze various aspects of the supply chain, achieving timely and accurate supply chain optimization.

3.3 QlikView

With its associative data format and user-friendly interface, QlikView is a business discovery platform that lets users swiftly analyze and display large, complicated data sets and provide insights at the speed of thought. It offers a range of functionalities and features, demonstrating significant value in practical applications:

(1)AI-powered automatic visualization: Based on the properties and relationships of the data, QlikView has the ability to automatically choose the best chart types, including word cloud charts, scatter plots, and maps, to display the data [19]. This allows users to conveniently present data and gain valuable insights.

(2)Intelligent data cleaning and preprocessing using AI technology: QlikView can automatically detect and fix anomalies, missing values, and errors in the data, improving data quality and accuracy [20]. With this intelligent data cleaning, users can analyze and visualize data more effectively, avoiding erroneous analysis results.

(3)Data analysis and prediction using AI technology: QlikView comes with powerful machine-learning algo-

rithms for clustering analysis, building predictive models, etc. [21]. These features enable users to discover hidden patterns and trends in the data and make choices based on data.

(4)Real-time data monitoring and analysis: QlikView has the ability to connect to real-time data sources, enabling users to track data changes and present the latest results in real time [22]. This allows users to have real-time insights into data changes and make immediate decisions and adjustments.

(5)Application instances: Based on these features and characteristics, QlikView is mainly applied in the fields of business intelligence and data analysis, being highly powerful in user-centric analysis and decision support. For example, in logistics and procurement management, QlikView can help solve shortage problems through its automated visualization capabilities. In the finance sector, QlikView can be used to perform net interest margin analysis, helping financial institutions gain a deeper understanding of the differences between interest income and expenses to assess profitability and risk sensitivity [23].

3.4 D3.js

An interactive, configurable, and dynamic data visualization tool for the web is called D3.js. It is a JavaScript library. Developers may create aesthetically appealing and highly customizable visual effects with its sophisticated toolkit. It offers a range of functionalities and features, demonstrating significant value in practical applications:

(1)Data analysis using AI technology: By combining with AI algorithms, potential patterns, and trends in the data can be discovered during the visualization process, providing deeper insights [24]. This makes it possible for users to comprehend and evaluate the data more thoroughly.

(2)Flexible visualization techniques and tools with high customizability: D3.js builds visual graphics based on the data in a data-driven way, allowing users to customize and design the appearance and interaction of graphics according to their needs [25]. This flexibility makes D3.js a powerful visualization tool that can meet various requirements.

(3)Dynamic visualization and interactivity: By using transitions and animation effects, data changes can be visualized more intuitively and dynamically, capturing users' attention [26]. Additionally, D3.js provides rich interactive features, allowing users to interact with visual graphics through mouse operations and touch events.

(4)Application instances: Based on these features and characteristics, D3.js is widely used in web development and data visualization. It is used to build interactive, customized data charts, and visual effects, applicable to

various industries and domains. For example, in the field of real-time analysis and interactive visualization of data, D3.js has analyzed the performance differences between server-side rendering and client-side rendering, helping researchers and developers gain a deeper understanding of the advantages and disadvantages of these two rendering methods [27]. In the field of dynamic and interactive data visualization based on D3, in-depth exploration and innovation have been made, helping researchers and developers achieve more rich and interactive data visualizations [28].

3.5 Plotly

Plotly is an online platform and data visualization library. With the help of Plotly create interactive dashboards, charts, and plots. It works with multiple programming languages and offers an abundance of customization choices. It offers a range of functionalities and features, demonstrating significant value in practical applications:

(1)AI-powered intelligent chart generation: Plotly can automatically generate the most suitable chart types based on the characteristics of the dataset and user requirements, reducing the manual effort of selecting and designing charts.

(2)Interactive visualization and dynamic updates: Plotly provides rich interactive features, allowing users to interact with charts through hover, zoom, selection, etc. Additionally, Plotly supports dynamic updates, allowing real-time presentation of data changes and trends.

(3)Support for Multidimensional visualization and Large-scale data processing: Plotly can handle data with multiple dimensions and visualize it as high-dimensional charts, helping users discover hidden patterns and correlations in the data. Moreover, Plotly can efficiently present visualizations of large datasets.

(4)Aesthetically pleasing data visualization experience: Plotly offers a variety of chart types and customizable style options, allowing users to create visually appealing and attractive charts. Plotly's designs focus on details and user experience, with clear layouts, elegant color combinations, and balanced proportions [29].

(5)Application instances: Based on these features and characteristics, Plotly is a popular tool in the data science and visualization domains, especially in web applications and reporting. It supports multiple programming languages and can be used to build interactive charts, graphics, and dashboards. For example, using Pyspark and Dash-Plotly technologies for Olympic data analysis and visualization, various dynamic and interactive charts and dashboards were created using Dash-Plotly. By using this method, researchers may better comprehend Olympic data and identify trends and patterns within it [30].

3.6 IBM Watson Analytics

The cloud-based data analysis and visualization platform IBM Watson Analytics has the following features and attributes, which show great utility in real-world applications:

(1)Predictive analytics and decision optimization: With the use of IBM Watson Analytics' strong predictive analytics features, users may forecast future trends and results using models and previous data. Additionally, it provides decision optimization capabilities, offering optimal solutions for decision-making based on user-defined constraints and objectives.

(2)Collaboration and Sharing Capabilities: IBM Watson Analytics supports team collaboration and sharing of analysis results. Users can collaborate in real time with team members, share data and analysis views, and engage in discussions and comments. This allows team members to actively participate in the data analysis and decision-making process.

(3)Intelligent data exploration and analysis: With the use of machine learning and artificial intelligence, IBM Watson Analytics can automatically explore and analyze data. It understands the semantics of the data and extracts hidden patterns and insights, providing users with intelligent insights about the data. This makes it possible for consumers to find patterns and connections in the data rapidly [31].

(4)Natural language query and storytelling capabilities: Users can interact with IBM Watson Analytics using natural language queries, asking questions, and getting intuitive answers about the data. Additionally, IBM Watson Analytics supports storytelling capabilities, presenting data analysis results in the form of stories to help users better understand the story behind the data [32].

(5)Application instances: Based on these features and characteristics, IBM Watson Analytics provides a different data analysis experience than other visualization software through its intelligent data exploration and analysis, natural language query and storytelling, predictive analytics, and decision optimization capabilities. Its goal is to help users understand data faster and smarter, gain valuable insights from it, and support wiser decision-making and actions. For example, in the medical field, IBM Watson Analytics has helped users achieve better results in decision-making through data analysis, data visualization, and decision optimization [33].

3.7 FusionCharts

FusionCharts is a JavaScript-based data visualization li-

brary that offers the following features and characteristics, demonstrating significant value in practical applications:

(1)Diverse chart types: FusionCharts provides a wide variety of chart types and style options. With over 90 chart kinds supported, customers can select the best form of chart for their purposes, including pie charts, radar charts, bar charts, line charts, and more.

(2)Powerful real-time data visualization capabilities: FusionCharts has powerful real-time data visualization capabilities, able to handle large-scale, high-frequency data and present the changes and trends of the data in real time.

(3)Ready-made templates and styles: FusionCharts offers a range of ready-made templates and styles, allowing users to quickly create visually appealing charts. These templates and styles are carefully designed to meet the needs of different industries and applications and can be customized according to user preferences and brand styles [34].

(4)Cross-platform and device compatibility: FusionCharts can run on multiple platforms and supports various devices, including desktop computers, mobile devices, and web browsers. This allows individuals to share and access their dashboards and visual reports anytime, anywhere.

(5)Compatibility and ease of integration: FusionCharts is compatible with various programming languages and frameworks, including JavaScript, HTML5, Python, PHP, and more. It provides easy-to-integrate APIs and plugins, allowing users to easily embed FusionCharts into their applications and websites.

(6)Application instances: Based on these features and characteristics, FusionCharts provides users with a powerful and flexible data visualization solution through its diverse chart types, powerful real-time data visualization capabilities, rich templates and styles, cross-platform support, and ease of integration. Whether developers or data analysts, both can use FusionCharts to create impressive visual reports and dashboards. For example, FusionCharts can be used for building information platforms.

3.8 summary

The characteristics of AI-based intelligent visualization tools mentioned earlier are summarized in Table 1.

Table 1. AI-based intelligent visualization tool.

Tools	Characteristic	reference
Tableau	Dynamic Reports, Intuitive Interface, Drag-and-Drop Functionality, Accessibility for Non-Technical Users	[13]

Table 1. (continued)

PowerBI	Extensive Data Analysis, User-Friendly Interface, Data Extraction, Manipulation, and Loading (ETL) Capabilities, Integration with Various Data Sources, Swift Business Insights Uncovering, Collaboration on Analysis Outcomes	[35]
QlikView	Highly Interactive Interface, Memory-Driven Data Loading, Fast and Smooth Data Browsing, Efficient Data Analysis	[20,21]
D3.js	Powerful Drawing Capabilities, Flexible Visualization Customization, High Flexibility and Customizability, Dynamic Visualization, Unique and Highly Customized	[26]
Plotly	Variety of Chart Types, Interactive Features, Beautiful Data Visualizations, Aesthetically Distinctive	[29]
IBM Watson Analytics	Natural Language Processing, Analysis Results Presented as Stories, Decision-Making Support	[31,32]
FusionCharts	Templates and styles, Professional and diverse, Industry-specific, Quick creation	[34]

4. Advantages and Challenges of Integrating Artificial Intelligence with Visualization

4.1 Advantages: Enhanced Data Understanding and Insights

Enhancing data understanding and insights is a major benefit of combining artificial intelligence and visualization. Large and complicated datasets can be efficiently analyzed using visualization tools using AI algorithms and methodologies, giving users deeper insights into the data. Patterns, trends, and correlations in the data that might not be immediately apparent using conventional visualization techniques can be found with the assistance of AI. Fur-

thermore, AI algorithms can be used for predictive analytics based on the data, providing further insights.

AI-integrated visualization tools also enable interactive exploration and manipulation of data, enhancing users' understanding of underlying patterns and structures. With the help of AI, users can easily navigate through large volumes of data, filter and drill down to specific subsets, and dynamically modify visualization parameters to discover new insights. This enhanced data understanding leads to more informed decision-making and better business outcomes.

Furthermore, AI-integrated visualization tools provide real-time data analysis and visualization, allowing users to monitor and respond to changing data patterns and trends in a timely manner [17,22]. Organizations can gain real-time insights into their operations, identify abnormalities or outliers, and take prompt corrective action when they are able to process and analyze data in real time.

In summary, AI-integrated visualization enhances data understanding and insights by effectively analyzing and visualizing complex datasets through the use of AI algorithms and techniques. This improves decision-making, enhances business performance, and provides a competitive edge in the data-driven world of today.

4.2 Advantages: Automation of Analysis and Visualization Generation

Another significant advantage of AI-integrated visualization is the automation of analysis and visualization generation. Conventional methods for data processing and visualization can take a long time and involve a lot of human labor. AI-integrated visualization technologies automate these tasks by allowing AI algorithms to autonomously analyze data, spot patterns, and provide visual representations of the data without requiring human input. In the process of analysis and visualization, This automation reduces the likelihood of human error and inconsistent results in addition to saving time.

Additionally, AI-integrated visualization tools can automatically generate interactive and dynamic visualizations based on the data [26,28]. These visualizations can adapt to changes in the data and provide real-time updates, ensuring that the visualizations always reflect the latest information. This automation of visualization generation allows users to focus on interpreting and exploring the data rather than the creation of visualizations.

Through automated analysis and visualization generation, AI-integrated visualization tools enable organizations to analyze and visualize data more efficiently, free up resources for other tasks, and expedite the decision-making process.

4.3 Challenges: Data Quality and Accuracy

Ensuring the quality and accuracy of the data utilized in the analysis and visualization process is one of the major issues of AI-integrated visualization.

AI algorithms heavily rely on the quality of data inputs to generate accurate and meaningful insights. If the data used is incomplete, inaccurate, or biased, the results generated by AI algorithms can be misleading or incorrect. This becomes particularly important when dealing with large and diverse datasets from different sources, as data integration and quality assurance become challenging tasks.

To address this challenge, organizations need to implement robust data governance and data quality management practices. This includes ensuring data integrity, establishing data standards and processes, and implementing data validation and verification mechanisms. By ensuring the quality and accuracy of data, organizations can enhance the reliability and effectiveness of insights generated by AI-integrated visualization tools.

4.4 Challenges: Privacy and Security

Another challenge of AI-integrated visualization is ensuring the privacy and security of data. AI algorithms often require access to sensitive and confidential data for analysis and insight generation [36]. However, the use of such data raises concerns about privacy and security.

To secure the security and privacy of data, organizations must put in place robust data protection procedures. Data encryption, access control, and data anonymization procedures are to be put into practice. Additionally, organizations need to comply with relevant data protection regulations and ensure the responsible and secure handling of data.

Organizations must also think about the moral ramifications of utilizing visualization tools with AI integration. AI algorithms may uncover sensitive information or biases in the data, leading to ethical dilemmas. Organizations need to establish ethical guidelines and frameworks for the use of AI and ensure that the generated insights are fair, transparent, and unbiased.

In conclusion, integrating artificial intelligence with visualization offers several advantages, including enhanced data understanding and insights, as well as automation of analysis and visualization generation. However, there are issues with security and privacy in addition to the accuracy and quality of data. By taking care of these issues, businesses may fully utilize AI-integrated visualization tools to enhance corporate performance and make well-informed decisions.

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