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REVIEW

Data Visualization in the Information Society

Visualización de datos en la Sociedad de la Información

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ABSTRACT

The study addresses the importance of data visualization (DV) in today's society, and its role in the effective communication and interpretation of data in various sectors. The cognitive nature of DV and the impact on decision making were analyzed. Likewise, different DV techniques and applications in fields such as healthcare, business management, scientific research, and academia are explored. Concrete examples of the application of DV in business management, scientific research, journalism, media, politics and government management are provided; and highlights the usefulness in each of these contexts. In addition, various tools and software that are widely used for VD are mentioned.

Keywords: Data Visualization Tools; Society of Information; Data Visualization.

RESUMEN

El estudio aborda la importancia de la visualización de datos (VD) en la sociedad actual, y el papel de esta en la comunicación e interpretación efectiva de datos en diversos sectores. Se analizó la naturaleza cognitiva de la VD y el impacto en la toma de decisiones. Asimismo, se exploran diferentes técnicas de VD y las aplicaciones en campos como la atención sanitaria, la gestión empresarial, la investigación científica y el ámbito académico. Se proporciona ejemplos concretos de la aplicación de la VD en la gestión empresarial, la investigación científica, el periodismo, los medios de comunicación, la política y la gestión de gobiernos; y resalta la utilidad en cada uno de estos contextos. Además, se mencionan diversas herramientas y softwares que son ampliamente utilizados para la VD.

Palabras clave: Herramientas de Visualización de Datos; Sociedad de la Información; Visualización de Datos.

INTRODUCTION

The rise of emerging technologies has completely transformed how information is consumed and processed, influencing every area of knowledge. These technologies have transformed our perception of numerous social processes, allowing organizations and individuals the ability to gather, store, analyze, and utilize extensive volumes of data in ways that were previously impossible. In today's information era, this capability becomes significant across all fields.[1]

The conveniences provided by technology have resulted in what some authors perceive as a "datafication" of society.[2,3] This process enables the management of data using technological tools to convert it into information, aiding in making well-informed decisions about diverse aspects of life.

The need to use these tools for research, administration, education, and other sectors is undeniable as they enable the construction of new knowledge.[1] Given the importance of data analysis, it's crucial that the communication and interpretation of data are effective and accurately represent the reality they describe. For

this to happen, data visualization (DV) plays a crucial role.

DV originates from statistical production, which is perceived as an objective and neutral science, exerting significant influence on decision-making processes.[4,5] DV is considered a discipline where statistics and design intersect, due to its ability to represent and reproduce structures.[4,6]

Every sector of society bears a substantial volume of data, particularly in fields where disruptive technologies or data management techniques like data mining, Big Data, the Internet of Things, or artificial intelligence have been implemented.[7,8,9] In this regard, DV enables the presentation of these substantial data volumes in a concise and appealing manner.[10,11]

The ability to read and create data visualizations is essential for information users who are data literate. However, in some contexts, there is an argument that competencies in textual, mathematical, and visual literacy, as well as the current definitions and frameworks for DV literacy, remain insufficient.[12]

Due to the inherent benefits of DV, it's crucial to further explore knowledge regarding this topic, aiming to reduce the existing gap in DV literacy. Therefore, this article aims to describe the importance of DV in the information society.

METHODS

A literature review was performed concerning DV in the information society. For the review, research articles from databases such as Scopus, SciELO, PubMed, and Google Scholar were evaluated. The search was conducted using the following key terms: "data visualization"; "data visualization in the information society"; "data visualization techniques"; "data visualization applications." Additional information sources were manually identified and included.

The examination encompassed relevant sources of information aligned with the subject matter, aiming to fulfill the set objective. Finally, a total of 32 information sources was gathered, comprising scientific articles, journalistic pieces, books, and informative websites, primarily from 2019 to 2023.

DEVELOPMENT

General aspects of DV

DV has become a significant field of research in the 21st century, wielding a substantial impact across all disciplines and numerous daily activities. DV enables the graphical and concise representation of data, making interpretation and drawing conclusions more accessible. Visual representations of data are easier to comprehend than textual information, as the human brain processes graphical images more effortlessly than numerical text tables.[12,13, 14]

DV involves representing data to visualize elements that would have otherwise been unnoticed when analyzing the data source. It can uncover connections among areas that are significantly distant from the original data, thereby detecting patterns within previously hidden data.[15,16,17]

Displaying information in standardized formats simplifies data comparison and grouping, enabling the identification of dependencies or trends, and determining data that deviates from general consistent patterns. Therefore, the development of DV methods has an essentially cognitive nature.[15,16,17]

The use of DV techniques has expanded notably, particularly in fields like cartography, demography, and data sciences, from research to management. The combination of techniques like data mining, semantic web, linked open data, and other advanced visualization techniques allows for accessing and highlighting the value of scientific knowledge.[18]

DV techniques

There are multiple techniques and approaches to data visualization that enable users to explore, analyze, and gain a better understanding of the data. Some of these techniques include:[19,20,21]

Smart automatic graphs: These graphs automatically generate the best image based on the given data, although they might not always reflect precisely the visualization that the user has in mind.

Correlation matrices: They display the correlation between multiple sets of data, continuously updating their relationships.

Network diagrams: Illustrate the relationships and connections of complex data in the form of nodes and edges.

Interactive visualizations: They allow users to explore and manipulate data through filtering, sorting, highlighting, zooming, and more.

Real-time visualizations: They show data that update automatically in accordance with the source, such as sensors, social media, etc.

Visualizations with R or Python: They enable the development of personalized and advanced visual elements using specific programming languages and libraries.

Word cloud: A visual representation in which the size of each word represents its frequency within a body

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of text.

Sankey Diagram: This type of flowchart visually represents the flow quantity between various stages or categories within a process.

3D data visualization: It enables the exploration of data from various angles and perspectives, often used to represent spatial, geometric, or volumetric data.

Data visualization in virtual or augmented reality: It creates virtual environments enabling immersive and natural interaction with data. This is used to simulate scenarios, experience sensations, or evoke emotions through data.

Data sonification: It involves generating sounds or music to represent data, used for showcasing temporal, frequency-related, or harmonic information, such as seismic signals, brainwaves, or heart rhythms.

These DV techniques rely on advanced technologies such as artificial intelligence, image processing, or sound analysis, as well as specific tools like virtual reality glasses, headphones, or speakers. They pose new challenges and opportunities for data design, interpretation, and communication.

Application of DV in different sectors

DV in healthcare systems

DV is fundamental for data analysis and drawing conclusions. It allows decision-makers to view analytics in a more easily accessible presentation. Therefore, it is crucial in public health research, facilitating the visualization of patterns and trends in disease outbreaks, epidemiological data, and healthcare discrepancies. This aids in improving global preparedness and response to epidemiological threats.[22]

In medical and healthcare settings, it enables a wider range of people to apply the benefits these provide in managing teams and infrastructures, designing and monitoring critical operations, and making strategic decisions. The instant visualization of reports and medical records delivers personalized healthcare, saving time and ensuring effective decisions critical to patients' health.[23]

The frequent analysis of patient data is a useful application of DV, resulting in reduced medical errors and much more effective preventive measures. The visualizations derived from Big Data analysis in the healthcare sector encompass various branches: genomics, epidemiology, clinical trials, clinical operations, citizen collaboration, teleassistance, and administrative management.[7,23,24]

During the COVID-19 pandemic, some experiences highlighted how DV enabled the comparison of economic metrics with the level of action taken to contain and manage the pandemic. This encompassed mortality indicators and infection rates within a specific timeframe. During this phase, DV was essential in describing the situation, as there were no precedents of the disease that could serve as a paradigm for potential pandemic scenarios.[22]

DV in economic and business management

Within the context of business intelligence, data visualization is essential for exploring, analyzing, and understanding large amounts of information. This, consequently, facilitates informed decision-making to improve business effectiveness. Therefore, its significance grows over time within organizations.

DV in business management is concentrated on problem-solving across diverse organizational sectors through information extraction, filtering, and modeling. This supports the satisfactory increase in the use of technological tools to develop DV and business intelligence.

A study by Cruz-Osorio *et al.*[25] presents experiences in designing visualization architectures, ranging from designing indicators, visualization dashboards, and extraction development to the process and implementation of the model. The study led to a faster use of data and the incorporation of information within the company. As a result, it concluded that it is convenient to implement the tool to enhance business intelligence in production and financial areas.

DV in scientific research and academic settings

In academic settings, university students, educators, and scientists use technological tools to retrieve, process, analyze, and visualize information. This aids in objectively communicating and representing the results of their findings and knowledge.[1] In this context, the analysis and visualization of information stimulate both creative and critical thinking, encouraging the formulation of questions, hypotheses, and conclusions based on the visualized data.

The tools and competencies for DV in the sciences are progressively becoming more imperative. These techniques had been commonly used in specific fields,[14] yet the availability of certain tools and the increasing interest in accessing data for gaining knowledge have led to the use of such platforms to support research. Both quantitative and qualitative research use these techniques, chosen by the researcher according to their suitability for each analysis.[26]

This implies that, from the planning phase of the study it is important to consider how data will be

represented. Graphs, just like statistical tests, are chosen based on the study's objectives, variable types, and the statistical analyses intended to be represented. While DV is highly beneficial, improper use can result in discrepancies with reality and lead to a wrong interpretation of studies.[27]

Data representation in metric studies allows for didactic comprehension and visual representation of large amounts of data. The exponential rise in scientific production has necessitated the management of a huge quantity of data, from its retrieval through diverse bibliographic databases to its processing and analysis. This challenge requires techniques to process significant volumes of data and has created new trends in their visualization methods.[1]

The visualization of bibliometric information results from the emergence of specific methodologies and tools designed for this field, complemented by databases, indicators, and processing software tailored for bibliometric analyses. At the same time, alternative approaches are emerging, backed by data treatment and analysis, aimed at using, comprehending, and communicating information within academic, university, and industrial settings.[1]

Scopus, a bibliographic database, offers bibliometric analysis tools that rely on document citation counts indexed within it. These tools include result analysis, citation reports, document metrics, author analysis, and publication comparisons. Moreover, it is among the preferences of many researchers for these types of studies due to its capabilities in DV related to bibliometric indicators such as impact, productivity, collaboration, among others.[28]

Additionally, tools like Bibliometrix, based on R, facilitate the visualization of bibliometric data and the analysis of scientific production. These tools are valuable for assessing research influence and impact, identifying trends and patterns, and making informed decisions in academic and scientific fields.[29]

Another notable example in the field of DV is the MetaMetrics tool, an interactive data dashboard that produces reports on metadata quality in scientific journals. This system collects data from the Open Journal Systems (OJS) of journals affiliated with institutions in the Network of Macro-Universities of Latin America and the Caribbean. This study demonstrates that DV applied to metadata helps to identify errors in bibliographic descriptions that obstruct the indexing process of journals in international indexes.[30]

It can be stated that DV facilitates the communication and dissemination of research findings by making them more appealing, accessible, and understandable for the general public or other researchers. In scientific research, it is a powerful and versatile tool that can aid in generating knowledge, innovation, and social change, provided it is conducted with rigor, honesty, and responsibility.[31]

DV applied to journalism and media

Within the context of the above-mentioned "datafication", data journalism has become a key element in the current landscape. In this field, a new profile of journalists has emerged, equipped with fresh skills and using innovative methods to gather and present data-based content.[32]

Media professionals strive to build a graphical set from data that reflects potential relationships or trends among them. The primary goal is to simplify data presentation through visual communication, ensuring easy understanding without the need for intricate explanations.[32]

Data journalism has embraced information visualization by incorporating digital tools within newsrooms and integrating media into the network. This change is largely due to the increasing availability of data for journalism. [32,33] Data journalism appears to hold a promising future, attributed to the ongoing advancements in tools for recording, gathering, processing, and visualizing data. There is a growing demand for these professionals from both traditional media and new media platforms.[32,34]

DV in politics and government management

DV has the power to analyze and disseminate political messages, while also enabling the transformation of social and cultural reality. An example of this is "data feminism," which suggests a critical view of data and its use. Its objective is to employ data for structural change and to visualize minority populations, women, and diverse communities.[4]

On the other hand, Camacho-Mata's research[35] aims, through DV, to offer an intuitive method of identifying relationships and drawing conclusions among various environmental and social indicators. It focuses on the Red List Index, the Human Development Index, population density, and CO2 emissions across countries in the Americas from 2005 to 2018. This case serves as an example of applying DV to the examination of social issues with an ecological and sustainable development focus.

The paradigm of the information society, aimed at making informed decisions, has led to a rise of DV for government management. It provides multiple ways to enhance the design and management of public policies. The uses of data visualization in public policies encompass a broad spectrum, including early disease detection, targeted subsidy allocation, environmental damage detection, and the improvement of public transportation.[36]

For instance, in India, nighttime satellite imagery was employed to assess the country's electrical coverage. In Colombia, an analysis was conducted to examine the relationship between crime and urban infrastructure to predict areas in the city prone to increased crime in the future. Meanwhile, in the Philippines, the Open Road app was created, allowing users to monitor public-funded road projects.[37]

Software and DV tools

The tools for DV provide a range of functions and capabilities, enabling users to choose the one that best fits their specific requirements. There are several platforms and software that facilitate this process, each with their own features and advantages. Some of these include: [38]

- *Microsoft Power BI:* It's a data analysis and business intelligence platform enabling the creation of dynamic, interactive dashboards with extensive data sources and customizable options. It's a market leader and offers two versions: Power BI Desktop y Power BI Pro.
- *Tableau:* It's one of the world's most renowned and extensively used DV tools. It allows users to convert data into effective and appealing representations through its intuitive and robust interface. It provides a range of products, such as Tableau Desktop, Tableau Server, Tableau Online y Tableau Public (free).
- *Google Charts:* It´s a no-cost, open-source web tool used for the creation of DV using Google's technology. It provides an extensive range of charts including bars, lines, areas, pie charts, maps, networks, and more. These can be easily incorporated into websites or applications.
- *Zoho Analytics*: It´s a cloud-based data analysis platform allowing the generation of reports and dashboards using data from diverse sources like files, databases, and web applications. It offers an easy-to-use and adaptable interface, featuring drag-and-drop functions, filters, formulas, and more. This platform includes a free version and several paid options.
- *Datawrapper:* It´s a web-based tool designed specifically for journalists, editors, and communicators to create DV. It may be used to create quick and easy charts, maps, and tables without the need for programming. It offers both a free version and multiple paid versions.
- *Qlik Sense:* It´s a data analysis and business intelligence platform that allows interactive and customized exploration and discovery of data, employing *Qlik*'s associative technology. It provides an intelligent and adaptable user interface with drag-and-drop functions, search capabilities, storytelling features, and more. *Qlik Sense* offers both a free version and several paid versions.

Choosing these or other DV tools should be based on various factors. The specific project requirements, data quality, and software usage costs must be taken into account. A tool with an active community and a strong technical support can be extremely valuable. It should be highlighted that a certain level of technical proficiency is required to use these platforms effectively.

CONCLUSIONS

DV plays a critical role in the information society by enabling informed decision-making in diverse fields. In the current era, where data generation happens at an unparalleled speed, the importance of DV is amplified due to the demand for effective methods to make sense of this data. This involves enhancing proficiency in DV and responsibly employing techniques to ensure accurate representation and interpretation of data.

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