Web Data Processing in the Digital Age: Challenges and Solutions

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Abstract

In the contemporary digital landscape, web data processing plays a critical role in extracting valuable insights from vast amounts of information generated online. This paper provides an overview of web data processing, highlighting its fundamental concepts. Additionally, it examines key challenges related to data characteristics such as volume, variety, velocity, integration, veracity, and privacy. To address these challenges, the paper presents popular solutions and tools for effective data processing, emphasizing their importance in enhancing data analysis. Finally, the findings related to web data processing challenges are summarized based on the information presented.

Key words: web data processing, data analysis, NoSQL, real-time processing

JEL: C88, L86.

1. Overview of web data processing

Data Processing (DP) involves transforming raw data into meaningful information through organizing, indexing, and manipulating it to reveal valuable relationships and patterns useful for problem-solving. Technological advancements have greatly enhanced DP capabilities, transitioning from manual, labor-intensive methods to automated processes handled by machines and computers. The specific techniques used in DP vary depending on the type of data [5].

Web data processing specifically focuses on handling data from web-based sources, such as websites, social media, or online databases, often using techniques like web scraping, API access, and parsing of HTML or JSON data. Data only gains value when transformed into useful information through thorough analysis, processing, and interpretation [13]. Moreover, web data processing can manage structured, semi-structured, and unstructured data from various web sources.

Scientific literature indicates that web data processing involves the following phases, as shown in Fig. 1.

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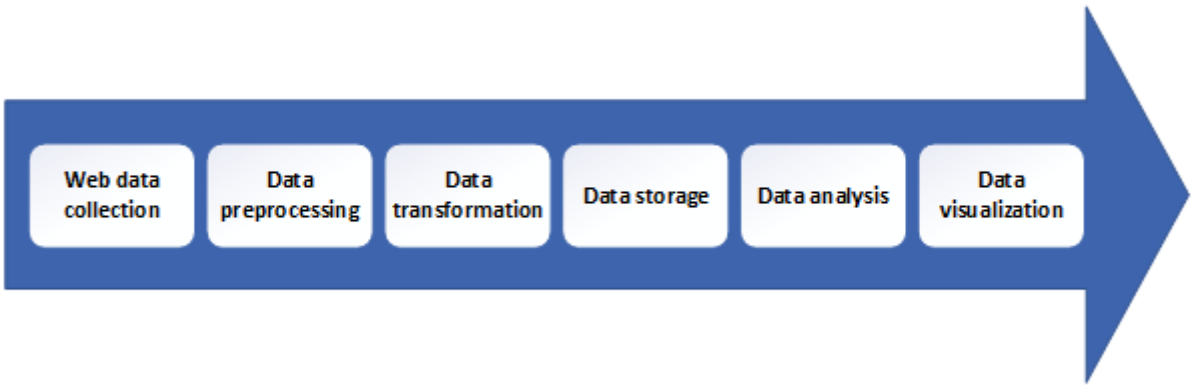

Figure 1: Phases of web data processing

Web data collection is the process of gathering information from various online sources, such as websites, social media, and APIs, using techniques like web scraping, data mining, and automated tools to extract structured or unstructured data for analysis and decision-making. This is the process of gathering semi-structured, large-scale, and redundant data, which includes web content, web structure, and web usage. This data is typically collected by crawlers and is commonly used for information extraction, information retrieval, search engines, and web data mining [8].

Data preprocessing converts raw data into a format that is easier and more efficient for user-specific processing. Its primary goal is to extract standardized data from the original format, preparing it for use in navigation pattern discovery algorithms. This stage encompasses data cleaning, user identification, and session identification [9].

The data transformation process involves several steps, with each step changing the data in different ways. This includes adjusting the structure of the data (schema-related transformations) and modifying the actual data values (instance-related transformations). In the context of metadata and data warehouses, data transformation refers to converting data from the format of its original source to the format needed for the destination [1].

Data storage refers to the process of saving and preserving digital information on a device or medium for future access or retrieval. As technology rapidly advances, data storage has become a critical element of modern computing systems [14].

Data analysis is the process of cleaning, transforming, and modeling data to uncover valuable insights that inform business decisions. The goal is to extract meaningful information from raw data to support decision-making. This practice involves organizing and structuring data, which is essential for understanding the information it holds [6].

Data visualization is a modern concept that involves more than just displaying data graphically. It aims to uncover and communicate the insights within the data. An effective visualization should help viewers understand the structure and meaning behind the information. The term is closely related to information visualization, a field that includes visual representation of all kinds of information, not limited to data, and is strongly connected to research in computer science [3].

2. Challenges in web data processing

Web data processing is essential for business, research, and technology today, offering valuable opportunities for data collection. However, it also presents several challenges. Processing web data requires

strategies to handle its large size, different formats, reliability, and speed of creation. It's crucial to use effective methods to gain insights while keeping data secure and respecting user privacy. The primary challenges identified in the literature include the following terms:

• Volume. Volume indicates the amount of data that is generated and collected. The sheer scale and growth of data surpass conventional storage and analysis methods. While advancements in storage technology and decreasing costs have mitigated challenges related to storage capacity, processing remains a significant challenge. The rapid increase in data volume fundamentally impacts data processing, management, and decision-making, as the growth of data often outpaces the computational power available for processing it. This discrepancy creates challenges for organizations trying to efficiently analyze and utilize large amounts of data.

• Variety. Data variety refers to the richness and diversity of data representations, including text, images, video, and audio. From an analytical standpoint, it poses one of the greatest challenges to effectively utilizing large volumes of data. Issues such as incompatible data formats, misaligned data structures, and inconsistent data semantics create significant obstacles that can result in analytic sprawl.

• Velocity. Data velocity refers to the speed at which data is generated. There are two methods for processing data: batch processing and stream processing, which is a form of real-time processing. In batch processing, data is collected and stored before being processed, while real-time processing occurs continuously. Stream processing is essential for selecting a data analytics solution, as it typically requires timely and rapid analytical results. It demands rapid processing and analysis capabilities, enabling organizations to make timely decisions based on the most current information, which presents a significant challenge [7].

• Integration. Integration of diverse data sources is critical, as combining data from various platforms and formats can be cumbersome and requires sophisticated techniques to ensure coherence and usability. Data integration refers to the process of merging data from multiple sources to create a unified view. This integration presents significant challenges, as different environments often consist of a wide range of devices, each potentially utilizing various protocols, formats, and standards. The objective is to overcome these challenges, ensuring that data from diverse sources can be combined and utilized cohesively, thereby maximizing the value derived from this data [4].

• Veracity. Data veracity pertains to the quality and accuracy of data, determining how much trust can be placed in the collected data when making critical decisions. Data can be classified as good, bad, or undefined, which can lead to issues such as inconsistency, incompleteness, ambiguity, latency, deception, and approximations. The presence of these issues significantly affects the ability of organizations to rely on data for decision-making processes. Inaccurate or misleading data can result in poor strategic choices, inefficiencies, and ultimately, financial losses. In light of these challenges, organizations should implement effective strategies to safeguard data sensitivity and ensure compliance with regulatory requirements [7].

• Privacy. Privacy is a critical aspect of data management that highlights the relationship between the collection of sensitive information and its dissemination. The challenge of safeguarding personally identifiable and sensitive data, such as health records, financial information, and biological traits, has become increasingly significant as individuals grow more aware of how their personal data is handled. To address these concerns, privacy laws have been established to regulate data collection and processing, and companies are mandated to provide transparent privacy policies while designating data protection officers to oversee data management practices [2].

Fig. 2 presents the challenges of web data processing in relation to data characteristics, covering aspects such as volume, variety, velocity, integration, veracity, and data privacy.

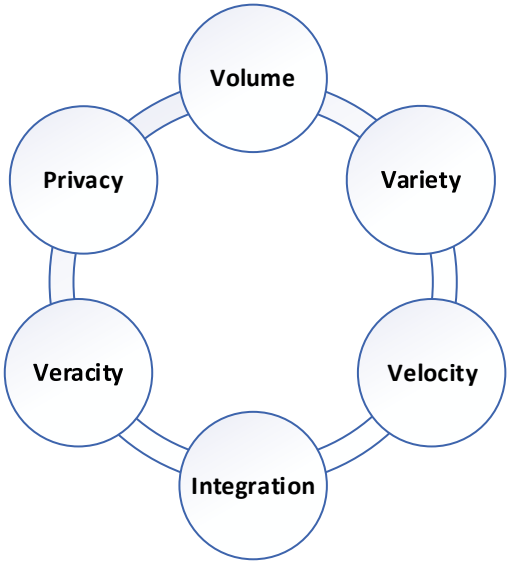

Figure 2: Key challenges in web data processing related to data characteristics

3. Solutions for web data processing challenges in today's digital landscape

In today's data-driven landscape, efficient web data processing is essential for organizations seeking to harness the power of large datasets. As businesses and researchers increasingly rely on vast amounts of data generated from various sources, the demand for robust solutions capable of managing, analyzing, and visualizing this data has never been greater. These solutions encompass a wide array of technologies, each designed to address specific challenges related to data storage, processing, and analysis. Some of the most popular among them will be explored.

Apache Storm is a powerful computational framework specifically designed to process large volumes of data that arrive at high velocities in real time. Unlike traditional batch processing systems, which can introduce latency, Storm excels in scenarios where immediate analysis and response are critical. It leverages the YARN (Yet Another Resource Negotiator) architecture to facilitate efficient clustering and management of multiple data processing engines, allowing for seamless integration and operation of various computational tasks. This makes Storm an ideal solution for applications that demand real-time analytics, such as financial transaction monitoring, machine learning, and the continuous oversight of operational processes. By providing the ability to analyze data as it streams in, Apache Storm empowers organizations to make timely decisions and gain valuable insights from their data flow [2].

NoSQL stands for "not only SQL" and refers to a group of databases that do not follow traditional relational database management systems (RDBMS). These databases are often used for handling large sets of data on a web scale. NoSQL is not just a single technology; it includes various products and ideas related to data storage and processing. The main idea is that while relational databases are useful in certain situations, NoSQL offers alternatives when they are not the best fit. MongoDB is an example of a NoSQL database that uses distributed file storage. It falls somewhere between relational and non-relational databases. MongoDB is particularly good for storing documents and focuses on improving the efficiency of storing and accessing large amounts of data [12].

Data visualization tools can be categorized into three main types: spreadsheets, specialized software, and programming libraries. Spreadsheets, such as Microsoft Excel and Google Sheets, are commonly used for

basic visualizations like bar charts, line graphs, and scatter plots. In contrast, dedicated data visualization software like Tableau, QlikView, and Power BI offers advanced features for creating interactive visuals, including dashboards, heat maps, and network diagrams. For those with programming skills, libraries like Matplotlib, ggplot2, and D3.js provide the flexibility to create custom visualizations, although they require a higher level of technical expertise. Together, these tools enable users to analyze and present data effectively across various domains [11].

While simple Python scripts can manage small datasets, larger systems require robust processing frameworks to handle big data effectively. One prominent example is Apache Hadoop, originally developed by Yahoo to create a search engine. It is a scalable batch-processing framework that can grow from a single machine to large clusters of servers, enabling efficient parallel computing. Another significant framework is Apache Spark, which combines batch and stream processing capabilities. Spark processes data faster than Hadoop by optimizing in-memory processing and is flexible in deployment. It simplifies program writing through its library ecosystem, although it may require more RAM, increasing costs. Overall, both frameworks are essential for managing and processing large volumes of data effectively [5].

Cloud storage solutions guarantee that data is duplicated across multiple nodes and appropriately organized. They can identify conflicts and integrate changes made by different users within the same document [2].

TensorFlow is a popular deep learning library developed by researchers at Google, recognized for its flexibility and scalability in data analysis and modeling. It supports various neural network models, utilizing stochastic gradient descent as the primary optimization method. TensorFlow simplifies the implementation of these models and optimization algorithms, which can often be time-consuming and error-prone. Key features include functions for graph construction, execution tools, and visualization capabilities [10].

Conclusion

In conclusion from the presented research, we can summarize the following notes:

- Web data processing focuses on managing data from online sources like websites, social media, and databases. It often uses methods such as web scraping, accessing APIs, and reading HTML or JSON data.
- Web data processing involves following phases: web data collection, data preprocessing, data transformation, data storage, data analysis and data visualization.
- Challenges in web data processing are related to the characteristics of data. These challenges are defined by features such as volume, variety, velocity, integration, veracity, and privacy.
- There are various solutions for data processing, including Apache Hadoop, TensorFlow and Power BI.

Acknowledgement

This work was financially supported by the UNWE Research Programme (Research Grant No. 22/2024/A).

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