

# A Review of Machine Learning Applications in Web Data Mining

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## Abstract

*The rapid development of Internet technology has resulted in a rapidly changing and intricate digital environment that requires new methods for organizing and evaluating online data. This study examines the use of machine learning (ML) in web data mining, focusing on its ability to extract relevant insights from huge amounts of online data. Web data mining, which is divided into three categories: content mining, structure mining, and use mining, uses machine learning algorithms to efficiently handle both unstructured and structured data. Supervised, unsupervised, semi-supervised, and reinforcement-learning approaches are critical in solving a wide range of difficulties, including recommendation systems, sentiment analysis, fraud detection, and cybersecurity. Emerging concepts, such as deep learning, privacy-preserving data mining, and conversational AI, demonstrate ML's potential to transform web interactions while maintaining ethical principles and user privacy. By incorporating these breakthroughs, web data mining serves as a foundation for smart decision-making and user-centric applications throughout the digital age.*

**Keywords:** Machine learning, web data mining, deep learning, privacy-preserving, recommendation systems, natural language processing

## INTRODUCTION

With the rapid advancement of Internet technology and the network's growing popularity, network culture, with digital information as the symbol and the Internet as the primary carrier, has emerged as one of the most important forms of cultural communication. The Internet's global and open qualities objectively create a hotspot for the spread of all types of negative network cultural material at both domestic and international levels, posing serious security risks to China's cyberspace. How to use high-tech tools to properly audit and monitor network culture content, detect hazardous material on the Internet in real time, and prevent the erosion of poor network culture information has become one of the most pressing scientific and technological issues to be addressed. Web search engines and data mining are essential approaches to addressing this challenge. The primary goal of Web information search is to locate web information resources, which is accomplished by using a technology known as a web crawler (or robot) to automatically roam the World Wide Web, find as much new content as possible based on

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Received Date: February 14, 2025  
Accepted Date: February 16, 2025  
Published Date: March 10, 2025

**Citation:** Hitesh Kumar Rinhayat, Vishakha Tomar, Krishna Nayak. A Review of Machine Learning Applications in Web Data Mining. International Journal of Data Structure Studies. 2025; 3(1): 39–47p.

its search target, and index and store the information searched and updated into a database. Web mining is the application of classic data mining concepts and methodologies to the web, with the goal of extracting interesting, prospective, valuable patterns and hidden information through web resources and activities. Mined information can be utilized for information management, decision support, and process control, as well as data upkeep [1].

Machine learning is generally more efficient in manufacturing than traditional statistical and mathematical models since they are unable to

understand complicated relationships between data sample attributes and forecast unknown feature values for a fresh sample. As a result of this predicament, ML techniques employed in a variety of scientific areas have been applied in the manufacturing field in recent years. The use of machine learning and deep learning techniques is well established in manufacturing given that intelligently studied data is a valuable resource that obtains fresh insights and can provide a major competitive edge. While it is possible to obtain masters in one discipline (manufacturing or machine learning), there are very few researchers who have extensive knowledge in both of these fields. As a result, data scientists and manufacturers collaborate to address ML in production. ML approaches are used to analyze manufacturing data provided by a data technology system. Data analytics determines significant aspects and structures; data mining discovers implicit information, rules, and patterns about the data; and machine learning creates effective models to train a manufacturing system's behavior [2].

Artificial intelligence (AI), specifically machine learning (ML), has expanded quickly in recent years in the context of data processing and computing, allowing applications to operate intelligently. ML is widely regarded as one of the most popular newest technologies in the fourth industrial revolution (4IR or Industry 4.0), as it allows systems to learn and improve from experience without being specifically coded. "Industry 4.0" refers to the continued automation of traditional manufacturing and industrial activities, including exploratory data processing, with new smart technologies such as neural networks for automation. Thus, to intelligently analyze these data and to develop the corresponding real-world applications, machine learning algorithms is the key. The learning algorithms can be categorized into four major types, such as supervised, unsupervised, semi-supervised, and reinforcement learning [3].

Three primary methods of online data mining are widely utilized to extract valuable insights from the web. First, web content mining focuses on gathering knowledge from diverse forms of data available on websites, such as text, images, and videos. This approach is crucial for extracting information-rich content for various applications. Second, web structure mining analyzes the relationships and links between websites to understand their underlying architecture. This method plays a pivotal role in ranking websites, identifying key pages within a network, and detecting spam. Lastly, web usage mining examines user clickstream data to gain insights into browsing behavior. By analyzing this data, businesses can customize web pages, improve recommendation systems, and detect fraudulent activities. Together, these methods form the foundation of web data mining, enabling enhanced decision-making and user-centric web solutions [4].

## **MACHINE LEARNING TECHNIQUES FOR WEB DATA MINING**

Machine learning (ML) techniques are important in web data mining because they allow for the analysis, interpretation, and extraction of significant patterns from large amounts of data. These techniques can be classified as supervised, unsupervised, semi-supervised, or reinforcement learning methods. Each method provides distinct possibilities for handling various web data mining difficulties. Below is an in-depth examination of these strategies and their applications.

### **Supervised Learning Technique**

Supervised learning is the process of training a model on labeled datasets that contain explicit input-output pairings. This method is particularly helpful for applications that require exact forecasts based on past data.

#### ***Applications in Web Data Mining***

- *Classification*: Supervised learning is used to classify web pages, emails, or content into predefined categories. For instance, detecting spam emails using algorithms like logistic regression, support vector machines (SVM), or deep neural networks.
- *Sentiment analysis*: Models like Random Forests or Transformer-based models (e.g., BERT) analyze user reviews, comments, or social media posts to determine sentiment polarity.

- *Personalized recommendations*: Algorithms like Decision Trees or Gradient Boosted Machines (GBMs) power recommendation engines by predicting user preferences based on past behavior [5].

### **Unsupervised Learning Techniques**

Unsupervised learning does not rely on labelled data, making it particularly valuable for exploring and uncovering hidden patterns in unstructured web data.

#### ***Applications in Web Data Mining***

- *Clustering*: K-means, hierarchical clustering, and density-based clustering (DBSCAN) are techniques for grouping related web articles, people, or items. Consider segmenting website visitors depending on their surfing patterns.
- *Topic modeling*: Topics are extracted from big text corpora on websites using algorithms such as Latent Dirichlet Allocation (LDA) and Non-Negative Matrix Factorization (NMF).
- *Anomaly detection*: Detect unusual patterns in web traffic or user behavior to identify fraud or security breaches.

### **Semi-Supervised Learning**

Semi-supervised learning fills the gap among supervised and unsupervised methods by combining a small quantity of labeled data with a huge pool of unlabeled data. This is especially beneficial for web data mining, because labeling large datasets is often impractical.

#### ***Applications in Web Data Mining***

- *Content categorization*: Improving web content labelling by combining manually tagged pages with a large number of untagged documents.
- *User behavior prediction*: Enhancing prediction models for user click behavior with minimal labelled data [6].

### **Reinforcement Learning**

Reinforcement learning (RL) is concerned with learning optimal actions in dynamic and interactive situations using feedback in the form of rewards or penalties.

#### ***Applications in Web Data Mining***

- *Dynamic web personalization*: RL algorithms adaptively learn to recommend content or products to users in real-time, optimizing for long-term engagement or conversions.
- *Ad placement and bidding*: RL helps in learning optimal strategies for ad placement and auction bidding in online advertising systems.
- *Crawling and resource management*: Web crawlers powered by RL prioritize the most relevant web pages and allocate resources efficiently.

### **Deep Learning for Web Data Mining**

Deep learning algorithms, a subset of machine learning, are extremely effective in processing complex and multidimensional web data such as text, photos, and videos.

#### ***Applications in Web Data Mining***

- *Natural language processing (NLP)*: Deep learning models like Transformers (e.g., BERT, GPT) enable advanced text mining tasks, such as entity recognition, summarization, and semantic search.
- *Image and video mining*: Convolutional Neural Networks (CNNs) extract features from visual web data, powering applications like image classification or video recommendation.
- *Graph neural networks (GNNs)*: These networks analyze the structural relationships in web data, such as link prediction or community detection in social networks.

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## Hybrid and Ensemble Learning Approaches

Hybrid approaches combine multiple machine learning methods to enhance performance and address specific challenges in web data mining.

### *Applications*

- *Recommendation systems*: Hybrid recommendation models combine collaborative filtering and content-based methods for more accurate suggestions.
- *Fraud detection*: Ensemble techniques like bagging and boosting improve the robustness of fraud detection systems [7].

## CATEGORIES OF WEB DATA MINING

Web data mining is a wide and powerful field that is divided into three categories: web content mining, web framework mining, and web use mining, with each focusing on collecting insights from distinct aspects of the web. These categories work together to evaluate the huge and complicated world of internet data, addressing specific difficulties and allowing innovative applications across sectors.

### Web Content Mining

It entails collecting useful information from the various types of content found on web pages, including text, photos, videos, and audio. The process frequently works with semi-structured and unstructured information, necessitating advanced techniques such as NLP (natural language processing) for text analysis, recognition of images for visual information, and video analysis for multimedia. Web content mining has a wide range of applications. For instance, sentiment analysis helps businesses gauge customer emotions through reviews or social media posts, while topic modeling allows researchers to identify trends or recurring themes from large volumes of textual data. Multimedia mining extracts meaningful insights from images and videos, such as facial recognition, object detection, or automated content tagging. Additionally, search engines rely heavily on web content mining to retrieve and rank relevant information based on user queries. Despite its immense potential, web content mining faces significant challenges, including managing the sheer volume and diversity of data, handling multilingual content, and ensuring the accuracy of extracted insights from noisy or poorly structured sources [8].

### Web Structure Mining

It focuses on analyzing the relationships between web pages to understand the architecture and connectivity of the web. This involves examining hyperlinks, both within a website (internal links) and between different websites (external links). Using techniques from graph theory and network analysis, web structure mining uncovers patterns that reveal how websites are interconnected. This category plays a pivotal role in enhancing the organization and accessibility of web content. For example, algorithms like PageRank and HITS rank the importance of web pages by analyzing their link structures, which is a cornerstone of modern search engines. Additionally, web structure mining is instrumental in identifying key pages within a website or network, detecting spam or manipulative linking practices, and discovering clusters of related websites or communities based on shared topics or themes. However, the dynamic and ever-changing nature of hyperlinks adds complexity to the task. Links often change, disappear, or become irrelevant over time, making it challenging to maintain an accurate and up-to-date representation of the web's structure. Moreover, managing the massive scale of interconnected pages requires robust computational and algorithmic solutions.

### Web Usage Mining

It focuses on analyzing user behavior and interactions with websites to derive insights into how people navigate and utilize online content. This involves the study of clickstream data, server logs, and other user interaction data. By understanding user behavior, web usage mining enables the development of applications that enhance user experiences. For instance, personalized recommendation systems suggest products or content based on users' browsing history and preferences, improving engagement and satisfaction. Web usage mining is also crucial for fraud detection, identifying abnormal patterns in

**Table 1.** Comparison of categories.

| Category             | Data source                         | Focus                             | Primary techniques                 |
|----------------------|-------------------------------------|-----------------------------------|------------------------------------|
| Web content mining   | Text, images, videos, audio         | Extracting knowledge from content | NLP, image recognition, clustering |
| Web structure mining | Hyperlinks, internal/external links | Understanding web relationships   | Graph theory, PageRank, HITS       |
| Web usage mining     | Clickstream, server logs            | Analyzing user behavior           | Pattern recognition, ML algorithms |

user activity, such as click fraud in online advertising or unauthorized access attempts. Moreover, website optimization benefits significantly from web usage mining by identifying high-traffic areas, popular content, or common navigation paths, allowing businesses to streamline website design and content placement. However, web usage mining faces its own set of challenges, particularly concerning data quality and privacy. User interaction data is often incomplete, noisy, or inconsistent, necessitating sophisticated pre-processing techniques [9]. Furthermore, ethical considerations around tracking user activities, respecting privacy regulations, and preventing data misuse are critical concerns that organizations must address (Table 1).

### **APPLICATIONS OF MACHINE LEARNING IN WEB DATA MINING**

Machine learning has had a significant impact on web data mining, allowing for the extraction of valuable insights from large amounts of internet data. Its applications include a wide number of domains, revolutionizing how organizations engage with their customers and streamlining numerous web processes. Personalized recommendation systems are one of the most common applications. Machine learning algorithms forecast and recommend products, information, or services based on user behavior, preferences, and interaction patterns. E-commerce platforms like Amazon, for example, propose things based on previous purchases and browsing history, whilst streaming services like Netflix and Spotify offer customized recommendations for movies, TV series, and music. These systems frequently use collaborative filtering, content-based filtering, or hybrid approaches, exploiting historical data and similarity patterns to improve user engagement and satisfaction.

Search engine optimization and ranking is another critical application area of machine learning in web data mining. Search engines like Google rely on advanced machine learning models to analyze web content and structure, ensuring that users receive the most relevant and high-quality search results. Machine learning enhances query understanding by interpreting user intent through natural language processing (NLP). It also fuels ranking systems like PageRank, which evaluate web pages' relevance based on their link architecture and user interaction metrics. Furthermore, machine learning personalizes search results by adjusting to user preferences and previous interactions, resulting in a smooth and intuitive search experience. Sentiment analysis and opinion mining are another useful application of machine learning in web data mining. These strategies use textual data including reviews, social media posts, or blogs to determine public sentiment or sentiments toward a specific topic, product, or brand. Businesses use sentiment analysis to evaluate client input and enhance their offers, whereas social media platforms utilize it to track public sentiment trends in real time. This application frequently uses machine learning and NLP to process large amounts of text and extract useful insights, thereby assisting decision-making in marketing, customer support, and product development [10].

Fraud detection and security also benefit significantly from machine learning in web data mining. In e-commerce, machine learning models analyze transaction patterns to detect fraudulent activities, such as unusual purchasing behavior or fake accounts. In digital advertising, these models identify click fraud by recognizing abnormal click patterns on ads, protecting businesses from financial losses. Moreover, cybersecurity systems use anomaly detection algorithms to monitor web traffic and user behavior, flagging suspicious activities like phishing attempts or unauthorized access. These applications rely on the ability of machine learning models to learn from historical data and recognize deviations from

normal patterns, ensuring robust protection in dynamic online environments. Social network analysis leverages machine learning to understand relationships, behaviors, and interactions within online communities. By analyzing the structural and behavioral data of social networks, machine learning models identify communities, influential users, and emerging trends. For example, clustering algorithms detect user groups with shared interests, aiding in targeted marketing and content delivery. Predictive models forecast viral trends by analyzing interactions, hashtags, and content propagation patterns. These insights empower businesses and organizations to engage effectively with their audience and make informed decisions.

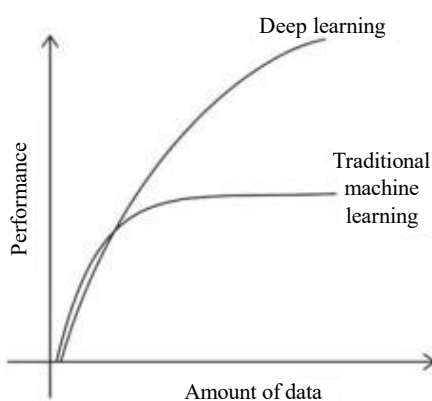
Machine learning adds significant value to web content and structure mining. Machine learning methods allow for effective information organizing and retrieval by assessing web page content and structural relationships. Latent Dirichlet Allocation (LDA) and other topic modeling algorithms identify important topics from text data, assisting in the classification and categorization of web content. Machine learning also plays a vital role in detecting spam or malicious links, ensuring safer browsing experiences. Knowledge graphs, built using machine learning, extract entities and relationships from web content, providing structured representations for search engines and virtual assistants. Machine learning's uses include real-time personalization and adaptive design for the web, in which websites automatically modify information, layouts, or suggestions based on user preferences and behavior. For example, e-learning platforms tailor learning routes to individual students, whereas dynamic web sites optimize content placement to increase engagement and conversions. Similarly, advertisers employ machine learning to tailor adverts, ensuring that they reach the intended audience at the appropriate moment [11].

## EMERGING TRENDS AND FUTURE DIRECTIONS

### Rise of Deep Learning in Web Data Mining

Deep learning has emerged as a disruptive force in web data mining, allowing for the analysis and processing of complex and multidimensional data such as text, photos, and videos. Deep learning architectures such as neural networks outperform typical machine learning models in extracting characteristics from raw data, considerably improving performance across a wide range of applications. Text analysis models such as Transformer-based architecture (e.g., BERT, GPT) have set new standards for the processing of natural languages (NLP). These models can recognize context, semantics, and relationships within text, making them ideal for applications like semantic search, document summarization, and question responding. For example, BERT has been employed in search engines to increase query comprehension, resulting in better alignment with user intent. Figure 1 compares the performance of typical machine learning methods against deep learning techniques.

Convolutional neural networks, also known as CNNs, have transformed visual data mining tasks such as image categorization, identifying objects, and video analysis. For example, CNNs can analyze product images on e-commerce websites to enable image-based searches or detect visual patterns in



**Figure 1.** Why deep learning [12].

multimedia content for automated tagging. Similarly, Graph Neural Networks (GNNs) are gaining traction for mining web structure data. They excel in tasks such as link prediction, community detection, and fraud detection by effectively leveraging graph-based representations of web data. The rise of deep learning also brings challenges, including computational intensity and the need for large labelled datasets. However, advancements in pre-trained models, transfer learning, and federated learning are helping mitigate these challenges, making deep learning more accessible and scalable for web data mining applications [13].

### **Integration of Natural Language Processing (NLP) and Web Data Mining**

As the web becomes more text-rich, natural language processing (NLP) becomes increasingly important in web data mining. NLP allows robots to comprehend, analyze, and synthesize human language, which is critical for analyzing internet information such as blogs, articles, reviews, comments on social media, and search queries. New methods of natural language processing, such as few-shot learning and zero-shot learning, are tackling the issue of limited labelled data. These methods enable models to perform effectively on novel tasks with little training data, making them excellent for assessing rare or specialized content. Zero-shot models, for example, may classify or extract information from text without requiring explicit task training. Applications of NLP in web data mining include:

- *Semantic search*: By understanding the context and meaning behind search queries, NLP enables more accurate and relevant search results.
- *Sentiment analysis*: Businesses utilize natural language processing (NLP) to assess public perception and sentiment through reviews from customers, social networking posts, and feedback.
- *Chatbots and virtual assistants*: Conversational AI systems use natural language processing to communicate with people and provide advice, recommendations, or support.

Additionally, advancements in multilingual NLP are breaking language barriers, enabling the analysis of global web data. As a result, NLP is transforming web data mining by making it more context-aware, user-friendly, and inclusive [14].

### **Focus on Privacy-Preserving Data Mining**

Privacy-preserving data mining has become a critical focus area as user privacy concerns and regulatory frameworks like GDPR and CCPA gain prominence. Web data mining involves analyzing vast amounts of user data, which often includes sensitive information. To address privacy concerns, new techniques are being developed to ensure that data analysis does not compromise user confidentiality. Federated learning is a decentralized machine learning strategy that trains models directly on user devices rather than transmitting raw data to a central server. This strategy guarantees user privacy while also lowering data transit costs. For example, Google uses federated learning to provide tailored services such as keyboard suggestions while keeping user data local to the device.

Another key technique is differentiating confidentiality, which puts noise into data or analytic findings to prevent individual users from being identified. Companies like Apple and Microsoft employ differential privacy methods to hide user data in analytics and machine learning. Another promising approach is homomorphic encryption, which allows computations on encrypted data without decryption. This ensures that the data is protected throughout the evaluation process. This approach, when combined with secure multi-party computation (SMPC), allows businesses to collaborate on data mining without revealing sensitive information. By incorporating these privacy-preserving strategies, web data mining can continue to prosper while respecting user rights and following ethical norms, paving the path for a secure and trustworthy digital environment [15].

### **Enhanced User Experience with Conversational AI**

Conversational AI, powered by advanced machine learning and NLP, is transforming the way users interact with web platforms. Conversational AI systems, such as chatbots and virtual assistants, are becoming increasingly intuitive, context-aware, and capable of delivering personalized user experiences.

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Modern chatbots use state-of-the-art NLP models like GPT and BERT to understand user queries, respond in natural language, and handle complex conversational flows. These chatbots are deployed across various industries:

- *Customer support*: Many organizations utilize AI-powered chatbots to handle routine customer inquiries, lowering wait times and operational expenses.
- *E-commerce*: Conversational AI systems assist users in finding products, placing orders, and resolving issues, enhancing the overall shopping experience.
- *Healthcare*: Virtual assistants guide patients in booking appointments, accessing health information, or managing medications.

Voice-based interfaces, driven by conversational AI, are also on the rise. Voice search capabilities are included into devices such as smart speakers and mobile phones, making it easier for users to locate information, execute jobs, and control gadgets. Virtual assistants such as Amazon Alexa, Google Assistant, and Apple Siri are good instances of conversational AI that improves user ease. The future of conversational AI is to make interactions more human-like, context-aware, and multimodal. Conversational AI systems will close the communication gap between humans and machines by including visual signals, emotional intelligence, and multi-lingual support. This trend is a huge step forward in enhancing web accessibility, engagement, and satisfaction [16].

## CONCLUSION

Web data mining, powered by machine learning, has become an indispensable tool for extracting actionable insights from the ever-expanding digital landscape. This review highlights how ML techniques, from traditional supervised and unsupervised learning to advanced deep learning and reinforcement learning, are transforming the way web data is analyzed and utilized. Applications like tailored suggestions, identification of fraud, and optimization for search engines demonstrate ML's versatility and efficiency in handling a wide range of web-based difficulties. Furthermore, emerging trends like privacy-preserving data mining, enhanced NLP, and conversational AI underline the importance of innovation in maintaining relevance, user trust, and ethical standards. As the field evolves, the integration of advanced ML techniques and a commitment to addressing privacy and scalability challenges will drive the future of web data mining, empowering industries and individuals alike to navigate the complexities of the digital era.

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