Comparative Evaluation of Web Browser Performance Against Popularity Level

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***Abstract* — Nowadays, users has a wide range of options to choose their preferred web browser, each offering unique features, advantages, and drawbacks, where sometimes with the abundance of choices, it's difficult for users to decide which web browser are most suitable for their needs and priorities. Additionally, with some web browser being more popular than others, with this research, we want to find the correlation of web browser popularity with their features, advantages, and drawbacks. The methods we used are qualitative, where we comparing five different web browsers, namely Google Chrome, Microsoft Edge, Mozilla Firefox, Opera GX, and Safari. The results of this study are expected to provide users with a clearer understanding of the strengths and weaknesses of each browser, helping them to make a more informed decision based on their individual needs and priorities.**

Keywords— Web browser comparison, Cyber security, Performance analysis, Resource management, Browser popularity.

I. INTRODUCTION (*HEADING 1*)

Web browser is a crucial component in exploring the digital world, serving as the first gateway for users to access the internet. With the advancement of technology and communication, the need for fast, efficient, and secure internet access has become a top priority for users, where It is essential for web browsers to effectively counter various evolving cyberattack methods.

A major challenge faced today is the limited information regarding of research on web browser performance in a broader context. With a widely variety of web browsers available, each offering unique features, advantages, and drawbacks. Where with a comprehensive research about the features of a web browser, users can rely on these factors to choose the most suitable browser for internet access.

This topic is important and crucial, considering that in today's era, our daily lives are inseparable from internet access, whether for personal or professional needs. Choosing the right browser that meets specific criteria can enhance various aspects, such as system resource efficiency and improved cybersecurity for users.

In conducting a web browser evaluation, one of the main challenges is the compatibility differences between browsers and the devices used to access them, such as Safari, which is only compatible with the iOS operating system. Additionally, the dynamic nature of each web browser, which is constantly evolving and subject to changes, poses another challenge. These factors can result in unstructured data and may lead to findings that become less relevant within a short period.

Several studies have examined the effectiveness of search engines in delivering relevant information, particularly in the context of scientific information retrieval. A common issue identified is that users often fail to obtain relevant results despite using the same keywords. For instance, Yoyok Rohani conducted a study comparing Google and Bing by measuring precision (the accuracy of search results) and recall (the search engine's ability to find all relevant information). The findings reveal that both search engines exhibit low precision, mainly due to the dominance of websites containing product information, organizational content, dictionaries, and encyclopedias, while scientific sources are relatively limited [4].

Another study evaluated search engine performance based on search strategies and keyword techniques such as phrase search and using multiple search sites. It found that Google achieved a data relevance rate of 85%, while Yahoo reached 81%. However, Yahoo struggles with recognizing symbols in search queries, whereas Google performs better in terms of search speed [5]. In a separate study by Fahmi Amrullah et al., the focus was on comparing the features of Google, Yahoo, and Bing, highlighting how differences in functionality impact user experience.

The study examined core features such as web search, image and video results, news, maps, and translation services. Google outperformed the others by offering 17 out of 19 tested features, while Yahoo and Bing each provided 13. This advantage, coupled with the use of the PageRank algorithm—which ranks web pages based on the number and quality of incoming links—solidifies Google's position as the leading search engine [6].

This study aims to **analyze and compare the performance of popular web browsers based on various benchmarks and aspects, ultimately providing users with an optimal browser choice that aligns with their individual needs and priorities.**

The research questions developed in this study are:

1. What are the key aspect for comparing web browsers?
2. Does browser compatibility affect web browser efficiency?
3. Which web browser is the most optimal and efficient based on the defined benchmarks?

To answer these research questions, we are using a qualitative data collection method by reviewing previous studies related to the research topic and giving out questionnaires. Additionally, we conduct experiments to determine the optimal web browser based on the established benchmarks.

II. Related Works

A. Configure the web browsers

With the widely range of option for web browsers available, with their own unique features, advantages, and drawbacks, we chose five of the most popular web browsers[1], those are Google Chrome, Safari, Mozilla Firefox, Opera GX, and Microsoft Edge. These browsers were selected based on their widespread popularity and influence in the digital field. We aim to determine whether web browser popularity is driven by functionality, marketing, or other external factors. Effectiveness and efficiency of the process depends on the performance of the web browser [16].

B. Features, Advantages, and Drawbacks

Google Chrome is a web browser developed by Google LLC and was released in 2008. Among the many web browsers available, Google Chrome is currently one of the most popular web browsers [1], dominating the browser market with 59.7% of internet users relying on it for daily internet browsing activities [1][4]. One of the key features that contribute to Google Chrome's popularity and high user satisfaction is its diverse selection of extensions and the security measures implemented the users. Google Chrome applies a three-layer security system to enhance user safety when a user are using extensions available in the Chrome Web Store [2].

These three layers of protection include **privilege separation**, where Chrome extensions are divided into two categories. The first category is **content scripts**, which interact with web pages but do not have privileged access, and the second category is **core extensions**, which a chrome extensions have a full privileges but do not interact directly with websites [2][9]. The second layer is **Isolated Worlds**, where content scripts can modify website content, but the website itself cannot access the functions of the content scripts. The final layer is **Permissions**, which requires each extension to have a list of permissions that define its access to the browser's API before being registered [2]. Other than widely ranged on extensions provided in Google Chrome, additionally **Chrome's omnibox allows for an efficient searching and browsing** improving the performance of Chrome, and its **cross-platform compatibility** makes it accessible across many devices. Lastly, Chrome's also transparent about server privacy and information which made it a preferred choice among users[15][4].

Safari is a web browser released by Apple Inc. in 2003 with exclusivity, as it can only be accessed on devices running the iOS operating system. Safari holds a 3.66% share of the web browser market [1]. One of Safari's main advantages over other web browsers is its strong commitment to user privacy [3][9], making it one of the most secure browsers in terms of privacy protection. Apple implemented **Intelligent Tracking Prevention (ITP)** as a feature in the Safari web browser in response to growing user concerns about privacy and data tracking [7]. ITP works by restricting privacy permissions on frequently visited websites [8]. However, the implementation of ITP within the Safari ecosystem has been criticized for its shortcomings, as it has led to various data exploitation issues, such as **unintentional site tracking, revealing users' browsing habits, and other privacy concerns** [8].

Opera GX is a web browser that targets users with an interest in online gaming, offering various features tailored to enhance their experience. These features include a **free Virtual Private Network (VPN)** to improve security and privacy while browsing the internet [10], an **ad blocker**, **performance limiter** to optimize efficiency during heavy activities such as gaming, and a **modern, futuristic interface**. Opera Browser holds a **1.21% share of the web browser market** [1].

Mozilla Firefox is a web browser known for its strong security and privacy features. In addition to its desktop version, Firefox also developed Firefox OS for mobile devices. Research indicates that Firefox OS utilizes Web API to access hardware features, but the lack of security restrictions in this system increases the risk of exploitation [11]. Moreover, Firefox is widely used in software testing due to its compatibility with automation tools like Selenium IDE [12]. Despite its privacy-focused design, some user data can still be accessed through digital forensic techniques [12].

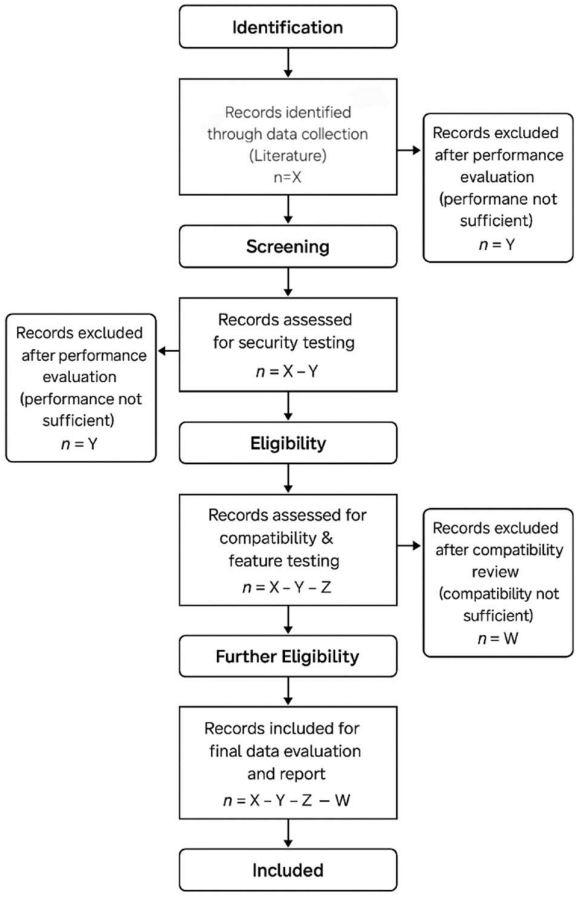
Firefox is also recognized for its open-source nature, allowing developers and security experts to continuously improve and audit its codebase for vulnerabilities. Its commitment to user privacy is further reinforced by features such as Enhanced Tracking Protection (ETP), which blocks third-party cookies and trackers by default. Additionally, Mozilla frequently updates Firefox with security patches to address emerging threats, ensuring a safer browsing experience for its users [12]. Firefox supports most operating systems, including windows, with additional add-on manager to check any available updates to improve user experience [16].

Microsoft Edge is a web browser developed by Microsoft, known for its integration with Windows operating systems and its security features. While Edge offers a private browsing mode called *In-Private Mode*, forensic analysis has shown that traces of user activity can still be recovered, raising concerns about its effectiveness in maintaining

privacy [13]. Research indicates that artifacts such as browsing history, cached files, and session data remain accessible even after an In-Private session ends [13]. Furthermore, Edge stores autofill data and saved credentials in structured databases, which can be extracted using forensic tools [14]. These findings suggest that while Microsoft Edge implements privacy measures, there are still potential vulnerabilities that can be exploited in forensic investigations.

III. Research Workflow Methodology

A. Workflow Flowchart Design



B. Workflow Description

I. Start

The evaluation process begins, initiating the system evaluation workflow.

II. Defining Benchmarks

Establishing the parameters we are going to use as the criteria for the web browser must meet, these include:

- **Web browser performance:** Ensuring the web browser are running to its max performance potential.
- **Security:** Assessing potential vulnerabilities, especially on data breach and virus spread.
- **Compatibility:** Verifying that the web browser can run across different devices, platforms, and environments.
- **Key features:** Examining the key features of a web browser and its usability for users.

III. Data Collection

Gathering relevant information, to help us to identify key trends and analize the expected system behavior. This process includes reviewing academic papers, technical documentation, and industry reports that provide insights into web browser performance, security, compatibility, and key users.

IV. Performance Testing

This stage, conducting tests to measure system performance, that include:

- Speed Testing: Measuring response times and execution efficiency under different workloads.
- Resource usage measurement: Measuring the resources needed to run the web browser, such as CPU, memory and bandwidth consumption.
- Load Testing: Evaluating performance under high user loads.
- Stress Testing: Testing the web browser under extreme conditions.

V. Performance Evaluation

Reviewing the result of the testing and compare it to the related information gathered from data collection. If the conditions are met with the expectations, continue the workflow.

Decision point: if the result of the testing is not met, modifications and optimizations are needed before redoing the test. If the result is met, proceed to security testing.

VI. Security Testing

Running security tests to identify vulnerabilities and ensure data protection. The methods are:

- **Thread Modelling:** Assessing potential security risks.
- **Field Testing:** Testing how easy it is to find a virus on each web browser.

VII. Security Assessment

Reviewing the result of the testing and compare it to the related information gathered from data collection. If the conditions are met with the expectations, continue the workflow.

Decision point: if the result of the testing is not met, modifications and optimizations are needed before redoing the test. If the result is met, proceed to compatibility and feature testing.

VIII. Compatibility and Feature Testing

Ensuring the system works across different environments and supports required functionalities. The testing includes:

- **Cross-platform compatibility:** Testing on different operating systems (Windows, macOS, Linux)
- **Software integration:** Testing how each browser interacts with other application and services.

- **Feature key points:** Evaluating each browser's key feature and assessing it with the potential use of a user.
- **Compatibility insights:** Testing on which version of the device supported and the minimum requirements to run the web browser.

IX. Compatibility Review
Reviewing the result of the testing and compare it to the related information gathered from data collection. If the conditions are met with the expectations, continue the workflow.
Decision point: if the result of the testing is not met, modifications and optimizations are needed before redoing the test. If the result is met, proceed to data evaluation.

X. Data Evaluation
Analyzing all gathered test results to identify trends, inconsistencies, or areas for improvement. With the data gathered from all of the test (security, performance, compatibility and features), we compare it from the expected result that we have concluded on the data collection.

XI. Report
Compiling all the data gathered and result of the comparison from data evaluation by summarizing the findings from the result of the test. The report includes:
- **Performance metrics:** Detailed structure of speed, efficiency and resource usage for each browser.
- **Security findings:** Identify the potential security holes on each browser.
- **Compatibility insights:** Make a summarized detail on what is the minimal compatibility criteria for each browser.
- **Key features usability:** Explain the detail of each key features and its usability for users for each browser.
- **Overall conclusion:** Make a conclusion ranking to find out which overall browser and compare it to the popularity ranking for each browser.

XII. Final Conclusion
Making a final decision on the web browsers based on the criteria and the result of the testing, and compare it to the ranking of popularity for each web browser.

XIII. End
End of the process.
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