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A Performance Comparative on Most Popular Internet Web Browsers

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Abstract

Our reliance on the internet increases daily as it depends on the number of services implemented on the internet. With the growth of internet usage dramatically increasing, more users feel the need to explore and utilize it to the fullest. The only way the typical user would be able to access the WWW by using a web browser; hence, the creation of numerous web browsers in the past decade. However, websites are significantly slowed down and websites frequently take a few seconds to fully load.. This is worrisome because slow performance can cause users to leave a loading page, lower search engine rankings, and other negative effects. The purpose of this paper is to compare and evaluate the performance of five commonly used browsers, which are Google Chrome, Mozilla Firefox, Microsoft Edge, Opera, and Brave. The comparison will include CPU, RAM, and GPU usage using Speedometer and MotionMark benchmark tools, which come with the high-performing browsers. The results of this study reveal that Chrome utilizes more CPU and Memory but economically utilizes GPU power. In contrast, Microsoft Edge utilizes CPU and RAM memory economically but uses the GPU more freely.

Keywords: World Wide Web; Web Browsers; Web Performance; Internet Browser;

1. Introduction

While the World Wide Web is the fastest-growing internet service, broadband and mobile internet speeds are getting faster all over the world, in recent years (McKetta, 2019). The need for faster and more reliable web browsers is becoming more of a necessity. A lot of websites greatly depend on the performance of browsers, and if the search engine takes long for the page to load (Galletta, Henry, Nah, 2004; Nielsen, 1999b; McCoy, & Polak, 2004; Rose,

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Lees, & Meuter, 2001; An, 2018; Joby, 2020), it would be worrying, as slow performance can result in users leaving the page before it loads entirely. Slower and low-performing web browsers would lead to negative consequences in the long run, as it could be seen with the once great Internet Explorer (Singhal & Cutts, 2010; Wang & Phan, 2018).
The purpose of this study is to explore various web browsers and compare their performance using a number of criteria and benchmarks done in previous studies, then coming to the ultimate decision on which web browser is the best for normal day-to-day users.
With "web browser performance", we refer to the browser's ability to handle various amounts of interactions, a web browser's responsiveness, its ability to adapt to resource-needing complex scenarios and the trade-offs that could come with the high performance of the browser (CPU, RAM and GPU strain).
The study compares five widely used browsers that can assess website performance. On existing websites, two benchmarking tools were employed, and the results were examined. Although the experiment was just for one website and every website is unique, the details of the comparison between the five web browsers and the usage of two benchmarking tools are included in the paper. However, the experiment's conclusion is generally not relevant outside of the study. Both researchers and practitioners can use the tested websites to assess the effectiveness of other websites in the future.
The research is organized as follows. A review of the literature on Internet browsers and their features is included in Section 2. The research methodology, case study websites, where to find free web performance assessment tools, and comparison findings are all covered in Section 3 of the paper. The performances' evaluation, results and study findings are discussed in Section 4. The study's conclusion is presented in Section 5.

2. Related Work

Literary research in previous research was conducted using the method of narrative literature research. This section is divided into four subsections. Section 2.1 reviews previous literature on the importance of web performance. Section 2.2 discusses good website loading speed. Section 2.3 is about ways and tools to evaluate web performance; and Section 2.4 is about internet browsers and their characteristics.

2.1. Importance of Web Performance

(Rempel, 2015) offered a case study of an internal business online application where users were urged to report subpar performance via their service desk. Performance complaints rose as performance deteriorated. Conversely, when performance increased, the quantity of performance complaints shrank. There were no longer any new performance complaints from users, once performance had stabilized. Rempel believes that a reliable indicator of customer happiness is the volume of performance complaints. (Repl, 2015.)

Google examined its 11 million mobile ad landing sites and provided information on the bounce rate, load time, and other factors (An, 2018). We are aware that most websites load slowly and have a high page weight (measured in bytes) and density of elements. According to a deep neural network, users to mobile websites are less likely to convert the longer it takes for a page to load and the more items there are on it. I assumed (An, 2018.)

2.2. *Suitable Website Loading Speeds*

Performance, attitudes, and behavioural intents of 196 respondents were evaluated as they completed an information retrieval task on a website with artificial delays of 0, 2, 4, 6, 8, or 12 seconds, according to Galetta et al. (2004). Decreased performance, attitudes, and behavioural intentions were linked to increased latency. Websites should ideally load for less than 8 seconds, to promote high customer satisfaction. The delay should be around 4 seconds to persuade the visitor to keep exploring the website or return later. As consumers become more accustomed to the site, the role of delay becomes more crucial. The authors note that a more exact description, say 2-4 seconds, is not achievable because of the 2-second timeframe used in this investigation. Garetta and others (2004)

On the other hand, Galletta, Henry, McCoy, and Polak (2006b) note that website lag and other website design factors

affect user behaviour in both groups and individuals. The authors conducted an experimental study to investigate how user behaviour, attitudes, and behavioural intentions are affected by website latency, website breadth, and content familiarity. According to research, all three variables significantly affect user behaviour and preferences, which in turn affects users' intentions to visit a website again. The three elements' impacts, however, are multiplicative rather than additive, so difficulties with one or more of them can be overcome by adjusting one or more of the others. Lag is reduced if content friendliness is anticipated, and the site is simply a few tiers broad. Furthermore, slight lags can make up for the complexity of the site structure and the unfamiliarity of the material. The authors have also proposed that additional elements, such as user motivation and screen size, may also be studied. Garretta and colleagues (2006)

2.3. *Evaluating Web Performance*

PageSpeed by Google and Yahoo! Tools like YSlow recommend best practices for enhancing web performance (Nicolaou, 2013). When creating websites for desktops, those techniques work effectively. Some of the techniques work just as well when targeting mobile devices, but some should only be used sparingly, while others should be disregarded. This is due to the difficulties with mobile networks and the slower parsing and execution of JavaScript code on mobile devices compared to PCs (Nicolaou, 2013).
(Ismailova and Inal, 2016) analysed the usability and effectiveness of official websites in Turkey, Kyrgyzstan, Azerbaijan, and Kazakhstan. Since it is readily available online (at http://tools.pingdom.com/fpt/) and frequently used by researchers in this field, performance was evaluated using a speed test tool called Pingdom (p. 990). The Google PageSpeed tool is also mentioned by the authors as a tool for discovering issues with page loading. 2016 (Ismailova & Inal, 2016).
The four tools listed by Gash (n.d.) for evaluating web performance are Lighthouse, PageSpeed Insights, Webpage Test, and Pingdom. Although there are many other tools available, these are "among the most popular and useful" (Gash, n.d.). It is advisable to utilize a variety of techniques and "compare the analysis for both common factors and distinct outliers" (How to Think About Speed Tools, 2019).

2.4. *Using Web Browsers In This Study*

Mozilla Firefox: Mozilla Firefox is a free, cross-platform, graphical web browser created by the Mozilla Foundation and many volunteers. It was first known as "Phoenix" and briefly as "Mozilla Firebird."
There are both positive and negative assessments of Mozilla Firefox's features, which set it apart from competing web browsers. To prevent interface clutter and enable the browser to be provided as a tiny, pared-down core easily modifiable to match different users' needs, but it lacks some functionality seen in other browsers. Mozilla Firefox relies on the extension system to let users adapt the browser to their needs rather than including all functionality in the standard release.
Microsoft Edge: Created in 2015 to replace the defunct "Internet Explorer," Microsoft Edge is an open-source cross-platform program. Since then, it has received numerous updates, the most current of which being the Chromium-based Microsoft Edge.
The Chromium Project serves as the foundation for Microsoft Edge, which can therefore run extensions and other programs designed for Google Chrome. Additionally, Microsoft Edge offers a one-of-a-kind in-browser Microsoft store through which you can download programs that are not compatible with Google Chrome. It also offers data synchronization with Microsoft accounts, which means that even if you use Edge on a different device, your data will be instantly accessible.
Google Chrome is a widely used open-source, cross-platform web browser. The open-source Chromium Project served as the foundation for Google Chrome. The fact that Chrome is so tightly connected with other Google services and websites, sets it apart from other common browsers. The search box and address bar were originally combined in a significant web browser, Chrome, and most of its rivals have subsequently followed suit. Additionally, users can sign in using their Google accounts, allowing them to sync bookmarks and open websites on several devices (Steele, 2013).
Brave: Launched in 2016, Brave Browser is another Chromium-based browser that is used to browse and run web pages. It functions similarly to Chrome or Edge and can access the Chrome Web Store to install necessary

extensions.
Brave Browser stands out from other browsers because it is fiercely anti-ad and prioritizes privacy more than the competition. All adverts are removed from Brave and replaced with alternatives. All ad trackers that entice users to click on advertisements on other browsers are also disabled. Brave offers private access to the internet while blocking cookies, ads, and phishing attempts.
Opera: Opera is a multi-platform web browser and internet suite that may be used to surf the internet, send and receive emails, manage contacts, participate in online chats, and show widgets. Both Opera's mobile web browser Opera Mini and most of its desktop applications are available without cost.
Opera is a proprietary application created by Oslo, Norway-based Opera Software. It works with many different versions of Microsoft Windows, Mac OS X, Linux, FreeBSD, and Solaris, among other operating systems. Additionally, it is utilized in mobile phones, smartphones, PDAs, game consoles, and interactive televisions. Other businesses have obtained licenses to use Opera technology in their goods, including Adobe Creative Suite.

Having a secure web browser that can protect users' privacy and information is critical to keep users safe and keeping their data secure. Social networking sites, email, e-commerce, and e-health applications are just a few of the crucial services and applications that may be accessed through a web browser. However, the same browser is also used to access less reliable websites, so putting the onus of "browsing safely" on the end-user is unrealistic. (Willem De Groef, 2011) users must ensure that the web browser they use on a regular basis protects their information from security threats that could include cookie-logging, data theft and phishing attacks *(Dhaya and. Kanthavel,2020)*.

Accessibility is an important determining factor on whether the user should use a web browser or not. Web accessibility refers to the ability of people with disabilities to see, comprehend, interact with, and contribute to the Web.(Boukari Souley, 2012) web accessibility provides benefit for others such as people with poor sight, epilepsy and other disabilities that may hinder their experience browsing, examples of accessibility features that users should look for include zoom-in, dark mode, virtual keyboard, screen-readers and other features that follow International Accessibility Standards.

3. Methodology

In this study, we evaluate various web browsers and compare their performance in three experiments. In the first two experiments, we compare and evaluate five of the most common web browsers such as Microsoft Edge, Chrome, Firefox, Brave and Opera using two different benchmarking tools: Speedometer and MotionMark. In the third experiment, we extend the comparison analysis using Task Manager tool, which is implemented into every computer device to compare the browsers' performance based on the following Criteria:
Memory Usage: The amount of RAM a browser can use could be shocking sometimes that we, as users, don't really notice. Browsers use memory to cache elements that would make up web pages; newer web browsers use multi-threaded processes (with each process taking up some space off the memory), so the processes quickly add up.
CPU Usage: Central Processing Unit usage depends on how integrated and efficient the web browser is with the computer device. The number of web-pages open and the contents of the web pages provide the processes that the CPU should handle. With web browsers being threaded, it depends on how quickly the browser could finish a task to lessen the strain placed on the CPU.
GPU Usage: The usage of the Graphics Processing Unit depends on the visuals or graphics on the web page, if a GPU is present in the computer device, it moves some of the tasks to the GPU instead of the CPU, to process them and improve rendering times. GPUs render CSS graphics, animations, and a plethora of visual graphics in a web page.
We will follow the steps taken by tech professionals to evaluate the performance of fresh PC components using benchmarking programs. Benchmarking evaluates how well your computer's components perform in comparison to similar components. Users can monitor their components' performance and determine whether any of them are malfunctioning by benchmarking.
For instance, if your CPU is highly functional but your GPU is not, you can have problems playing video games at their highest settings. If both your CPU and GPU are working properly but one of them starts to overheat, your computer may suddenly shut down. Be aware that stress testing is not the same as benchmarking. Stress testing for

computers places a lot of strain on the parts. This is helpful for overclocking since overheating components might cause the PC to crash under a heavy load. On the other hand, benchmarking measures performance at various intensities. There are numerous benchmarking programs available online, yet none of them are superior to the others. But depending on what you want to assess, benchmarking tests do get more difficult.

For all of the experiments a 16 RAM, i7 Intel CPU, 500SSD storage space and 64-bit windows 11 computer was used.

3.1. *Speedometer Experiment 1*

Speedometer is a benchmarking test that examines the browsers' ability to run over 200 website searches, with the test taking around two minutes to complete. Speedometer is used to test the responsiveness of the browsing engine through every website it visits and calculates the time it takes to load each page. The responsiveness of a browser depends on how the multi-threaded processes are processed through the CPU.

Fig.1. (a) Speedometer 2.0 experiment browser test; (b) Speedometer 2.0 experiment browsers' test results.

Fig. 1. (a) and (b) show how Speedometer 2.0 benchmark test functions. It tests the browsers' speed and responsiveness as it stimulates a number of user interactions (loading and running web pages) and it calculates the number of pages that successfully open or load during the test run. The results are displayed in Runs/Minute.

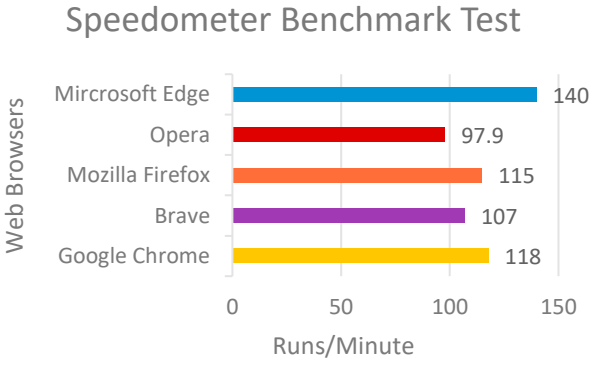

Fig. 2. Speedometer 2.0 experiment results for the web browsers.

Fig. 2. shows the benchmark Speedometer results, after being tested by us on various web browsers. Although Speedometer tests how efficiently browsers run numerous websites and web pages and how they load, we have to

keep in mind that these browsers may not be optimized for the test or if the scores displayed have an accurate representation of the browser's performance. But, given the numbers from the Speedometer test, it shows that Microsoft Edge takes the lead with about 140runs/min.

3.2. *MotionMark Experiment 2*

MotionMark is a benchmark test that focuses on the graphical performance of web browsers. It renders a lot of elements on the screen using HTML, CSS, and JavaScript. MotionMark runs several animations on the web browser and tests their ability to handle the animations at 60 frames per second (the test is run for about five minutes). The performance of the browser improves as the score rises.The test is graphic-dependent as it is used to test the browser's ability to render and animate objects simultaneously at 60fps and determine how much it utilizes the GPU.

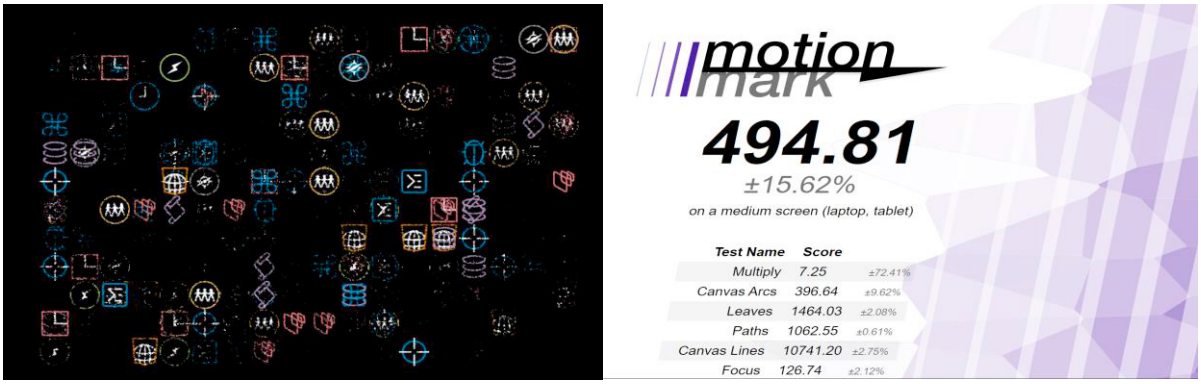

Fig. 3. (a) MotionMark Web browser test; (b) MotionMark experiment browsers' test results.

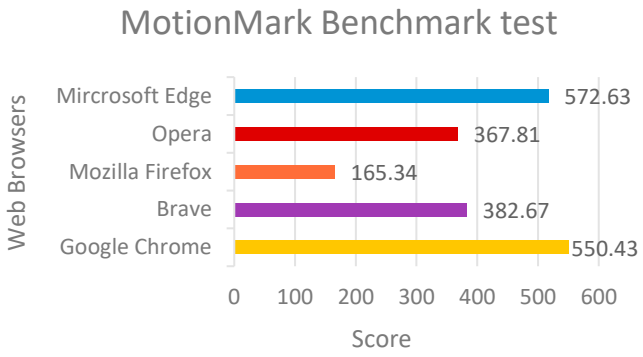

Fig. 4. MotionMark test results done by us.

Fig. 4. shows the benchmark MotionMark numbers, after being tested by us on various web browsers. MotionMark tests the browser's ability to handle and render various elements displayed using HTML, CSS and JavaScript by displaying them on the screen simultaneously then calculating the results during every stage of the test (Fig. 3(a) and (b)). Given the numbers provided by MotionMark, it shows that Microsoft Edge takes the lead in terms of performance, when loading and rendering high-motion and extreme element display scenarios.

3.3. *Task Manager Experiment 3*

In this experiment we use a built-in tool in every computer device that is very simple to use, which is the Task Manager tool that displays how much an application consumes in real-time. We will be testing the performance of the five browsers using a web page (Janky Animations) that adds moving objects on the screen and it will test the limits of each browser. With no extra tabs open, except Incognito mode on all browsers, which will run each web page.

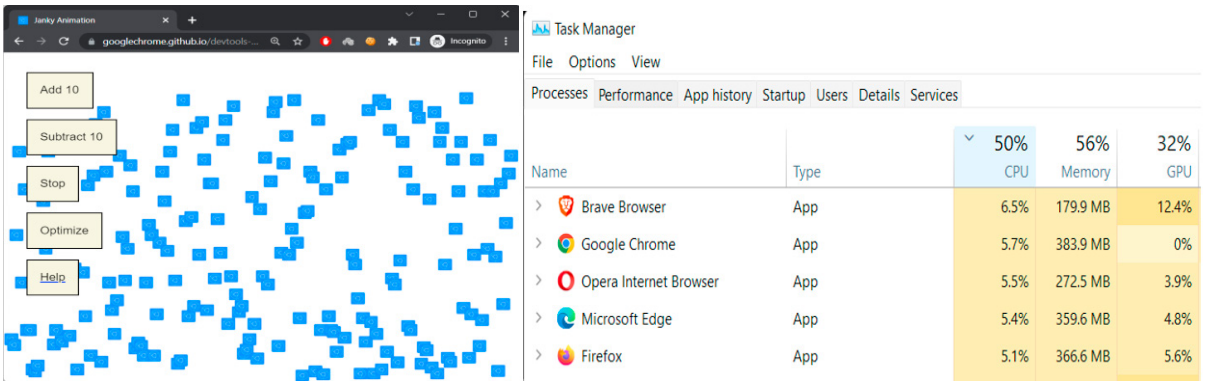

Fig. 5. (a) Janky Animations web page; (b) Using the Task Manager to compare browsers.

The Task Manager application helps tell us what application uses more CPU, RAM and GPU (as shown in Fig. 5), we added 200 animated squares from Janky Animations then waited for 5 minutes and noted down the CPU, Memory and GPU usage shown in Table 3. The strain on computer components depends on the threads of every web browser. Google Chrome and other chromium-based browsers are multi-threaded web browsers, which makes them extremely efficient at processing tasks.

4. Results and Findings

The aim of this study is to evaluate how quickly specific programs or instructions are handled and carried out by each of these web browsers. The test would be run on specific web browser setups. In order to give consumers, the information they need to use, install, and recommend the major web browsers taken into account in this work, web browser performance research was carried out.

The first experiment involves running five different web browsers individually with Speedometer Test. The following observations have been made based on the experiment's results, which are displayed in Table 1 below. Ultimately, Microsoft Edge performed the best followed by Google Chrome, Mozilla Firefox, Brave and Opera.

Table 1. Speedometer test results

Web Browsers	Study Results	Others Results
Microsoft Edge	140	131
Google Chrome	118	121
Brave	107	102
Opera	97.9	116.6
Mozilla Firefox	115	95.5

The second experiment involves running five different web browsers individually with MotionMark Experiment. The following observations have been made based on the experiment's results, which are displayed in Table 2

below. Microsoft Edge performed the best followed by Google Chrome, Brave, Opera and Mozilla Firefox.

Table 2. MotionMark test results

Web Browsers	Study Results	Others Results
Microsoft Edge	572.63	517
Google Chrome	550.43	496.32
Brave	382.67	444.6
Opera	367.81	373.27
Mozilla Firefox	165.34	145.93

The third experiment involves running five different web browsers simultaneously and having a web page display animated 200 elements and checking the CPU, GPU and RAM usage during the experiment, the experiment was run for over 5 minutes, with us taking notes of the peak usage afterwards.

Table 3. CPU GPU and memory usage

Web Browsers	CPU(%)	GPU(%)	Memory(MB)
Microsoft Edge	13.6	7.3	305
Google Chrome	18.1	5.9	355.1
Brave	14	8.4	239.56
Opera	15.3	9.7	316.6
Mozilla Firefox	16.5	10.5	364.8

There is no clear winner in the test, as trade-offs could be seen with Chrome, which utilizes more of CPU and Memory but economically utilizes GPU power. While Microsoft Edge utilizes CPU and RAM memory economically, it uses the GPU more freely. Note that the results are only valid for this test run and the results may vary from one user to another.

5. Conclusion

Five different web browsers were the subject of this study. The evaluation was created to be a deciding factor when examining the functionality of various web browsers. Results will vary depending on the browser that is installed on your computer, as well as its memory, speed, and brand. This study will educate the public on browser technology and, in the end, help users choose the best web browser for their specific needs.

Although Chrome is the most used web browser with over 65% usage rate. There's no denying that it is one of the best-performing web browsers which comes at the price of high hardware usage, but, with the release of Microsoft Edge, it has proven that web browsers could become even faster, while using less recourses. Microsoft Edge has taken the lead scoring the highest in every evaluation, during the Speedometer and MotionMark experiments and utilizing the least amount of hardware components during the given experiments.

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