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Denys Sidorov
Odessa I.I. Mechnikov National University
specialist degree

CROSS-BROWSER COMPATIBILITY ISSUES AND SOLUTIONS IN WEB DEVELOPMENT

Abstract: The article explores the issues of cross-browser compatibility that arise in modern web applications and offers effective solutions to overcome them. Considering the diversity of browsers and devices, the author highlights key aspects such as differences in rendering engines and code interpretation that impact user experience. Methods such as progressive enhancement, graceful degradation, and the use of polyfills are discussed, along with the importance of testing across different platforms. The article emphasizes the need for a proactive approach to ensure compatibility, leading to improved user satisfaction and reduced development costs.

Key words: cross-browser compatibility, web development, polyfills, testing, progressive enhancement, user experience.

Language: English

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Introduction

The modern web landscape is characterized by a wide variety of browsers and devices used to access websites and web applications. Supporting all popular browsers (Google Chrome, Mozilla Firefox, Safari, Microsoft Edge, etc.) is a key requirement for ensuring a positive user experience, but the differences in their functionality and code interpretation create challenges for cross-browser compatibility.

Cross-browser compatibility includes the consistent operation of web applications regardless of the browser used, requiring consideration of numerous nuances, from differences in rendering engines to the specifics of browser updates and versions. Unsatisfactory compatibility often leads to additional costs for fixing errors, impacting both development timelines and budgets.

The purpose of this research is to substantiate the importance of ensuring cross-browser compatibility and to identify effective methods for achieving it, which is especially relevant in light of the continuous increase in quality demands for web products.

Main part. Problems of cross-browser compatibility

In the context of the diversity of modern browsers, the issue of cross-browser compatibility is fundamental for ensuring the stability and accessibility of web applications. Key differences between browsers are related not only to their **rendering engines** but also to security policies, the specifics of media functionality implementation, and memory management mechanisms. Statistics on popular browsers that are actively used by users are shown in fig.1

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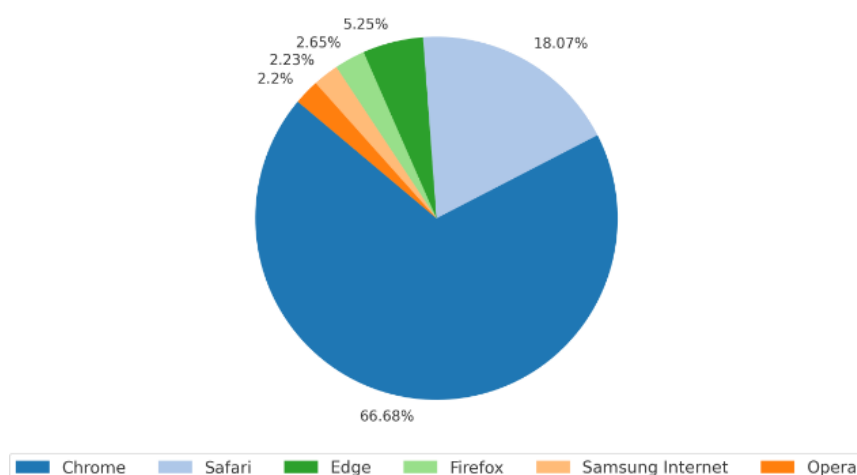


Figure 1. Browser market share worldwide [1].

Data, on one hand, helps to set up proper cross-browser compatibility based on the popularity of certain browsers. On the other hand, it is impossible to predict that a user might be using one browser on a personal computer (PC) and another on a smartphone, which complicates cross-browser compatibility settings. This creates a number of technical difficulties for developers: adapting to one browser often leads to errors in others, requiring significant effort to fix.

Differences in JavaScript interpretation also play an important role. For example, the use of asynchronous code execution methods, such as `async/await`, is supported by most modern browsers, but older versions, such as Internet Explorer, do not support these methods and require alternative approaches [2]. This increases the complexity of writing and testing code, especially for large projects where loading speed and performance are critical metrics. The share of users on outdated browser versions is about 10%, which forces developers to include support for them to prevent possible display and functionality errors [3].

The issue of cross-browser compatibility also applies to multimedia content. For example, video and audio files may play with different parameters depending on the browser and operating system, leading to playback failures or even refusal to load files. Some browsers limit the automatic playback of media to save device resources, especially on mobile platforms, which can negatively impact the user experience.

Comparative analysis of cross-browser compatibility methods

Effectively ensuring cross-browser compatibility requires flexibility, and the most effective approach is to combine several methods. **Progressive enhancement and graceful degradation** methods ensure cross-browser compatibility by creating a minimally functional version of the application for older browsers while adding additional features for modern ones [4].

Progressive enhancement implies that the application is developed by default for a basic version supported by all browsers, and then enhancements for new features are added. This allows key application functionalities to be accessible to a wide range of users without neglecting the modern capabilities of browsers.

Graceful degradation, on the other hand, involves developing with the advanced capabilities available in modern browsers in mind and adding support for simplified versions for older browsers. For example, to display animations in older versions of Internet Explorer, GIF animations can be used instead of CSS animations. This approach optimizes the code and makes it accessible to users of various browsers without sacrificing visual quality and functionality.

Obfuscation and compilation of JavaScript and CSS code improve cross-browser compatibility [5]. Obfuscation allows code to be transformed into a more secure and compact form, which also enhances performance by reducing the load on the browser. Compilation, in turn, uses tools like Babel to convert modern JavaScript versions (e.g., ES6) into older versions supported by outdated browsers. Babel automatically converts syntax and methods into a format that older browsers can process, preserving the functionality of the web application.

Compiling CSS with preprocessors like Sass and Less also allows styles to be adapted to the requirements of different browsers. For example, CSS prefixes for properties `-webkit-`, `-moz-`, `-o-` can be automatically added to ensure the proper functioning of animations and transitions across different browsers, making developers' work easier.

There is a method of using **polyfills**, which are snippets of code that emulate the functionality of modern features and web Application Programming Interface (API) in older browsers. For example, the `polyfill.io` platform dynamically loads the necessary polyfills for the browser, helping to minimize load and ensure the proper functioning of features like `fetch()`.

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and Promise in JavaScript, which are not supported in older versions of browsers like Internet Explorer. This approach allows web applications to utilize new capabilities without compromising users on outdated platforms.

Polyfills can be useful not only for JavaScript but also for CSS. For instance, CSS3pie provides polyfills for CSS3 properties such as border-radius and box-shadow to work in Internet Explorer 8 and lower. However, developers should carefully analyze which polyfills are necessary for their application, as an excess of polyfills can increase page load time, negatively impacting performance.

Modern frameworks such as React, Angular, and Vue.js integrate mechanisms for ensuring cross-browser compatibility. For example, React uses a virtual DOM (Document Object Model), minimizing manipulations with the real DOM and significantly improving performance, especially when working with a large number of elements on a page. These

frameworks standardize interfaces and application logic, reducing the need for adaptation to each browser.

However, using frameworks is not a panacea. To ensure cross-browser compatibility, especially with outdated browsers, polyfills and additional configurations must also be applied. For example, developers can use Babel, a tool for transpiling code to older JavaScript versions, to ensure compatibility with older browsers. It is important to remember that frameworks and libraries require regular updates, which can also lead to incompatibility with some browsers if support for older features has been discontinued.

The presented methods of cross-browser compatibility can be visualized in a table, presenting the advantages and disadvantages of each, as well as which of the mentioned methods are suitable for specific browser versions (table 1).

Table 1. Comparing the methods of cross-browser compatibility [6, 7].

Method	Advantages	Disadvantages	Suitable for browsers
Progressive enhancement	Improves user experience, universal.	Development costs.	All version.
Graceful degradation	Allows use of new technologies.	Older browsers receive a simplified version.	Modern version.
Polyfills	Access to new features in older browsers.	Increases page load weight.	Modern version.
Obfuscation	Enhances security, reduces code size.	May decrease performance.	All version.
Compilation (e.g., Babel)	Compatibility with older versions of JavaScript.	May complicate debugging.	Older version.

Comparative analysis of methods for ensuring cross-browser compatibility shows that the most effective approaches are polyfills and test automation. Polyfills allow for the use of modern web features even in older browsers, eliminating the need for significant changes in the application logic. However, it can slow down application performance on mobile devices, where computational power is limited.

Recommendations for an optimal approach to ensuring cross-browser compatibility

Testing on different devices and in various browsers is a key element in ensuring cross-browser compatibility. Tools like BrowserStack and Sauce Labs allow for testing web applications on real devices, significantly reducing the likelihood of unforeseen errors. These tools simulate application behavior across various browsers and mobile platforms, reproducing errors that may occur for users and enabling developers to fix them promptly.

Test automation through services like **BrowserStack** helps reduce errors and identify incompatibilities at early development stages. However, the high costs of licenses and the

requirement for regular updates of test scripts can be limiting factors, especially for smaller projects. Real-time error monitoring ensures prompt identification and resolution of issues but requires competent integration into the application, increasing the complexity of implementation and maintenance.

Using compilers and obfuscators like **Babel** and **UglifyJS** helps optimize code for different browser versions. However, excessive use may negatively impact performance, particularly on mobile devices, where every kilobyte of traffic and computational resource matters [8].

Ideally, web pages should display and function the same across all browsers, but in reality, this is rarely achieved due to differences in the interpretation of HTML, CSS, and JavaScript. Browsers utilize different **rendering engines**, and despite the World Wide Web Consortium (W3C) standards, the implementation of certain features varies from browser to browser.

Modern browsers use rendering engines such as Blink in Google Chrome and Microsoft Edge, Gecko in Mozilla Firefox, and WebKit in Safari. These

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engines handle code differently, which can lead to discrepancies in the display and functionality of elements. For example, the CSS property flexbox, widely used for creating responsive designs, does not work correctly in older versions of Internet Explorer, forcing developers to implement workarounds. These differences complicate the development process, increasing project time and costs due to the need for additional testing and fixes.

Mobile devices add another layer of complexity. As of 2023 [3], mobile traffic accounted for 58% of web traffic, making optimization for mobile browsers a top priority. Mobile browsers often use lighter versions of engines or have limited computational resources, necessitating additional content optimization measures – such as image compression, style optimization, and interface adjustments for different screen resolutions. These limitations are especially critical for web applications with high interactivity, where the speed and accuracy of rendering directly impact the user experience.

Finally, differences in user interface (UI) and control element behavior (such as buttons and input fields) can also hinder the provision of a consistent interaction experience. This, in turn, leads to additional development and support costs, as users

encounter errors and seek assistance from support services, increasing the workload on the development team.

Conclusion

Ensuring cross-browser compatibility is a critical challenge in modern web development, driven by the variety of browsers and devices used by users. Discrepancies in the interpretation of HTML, CSS, and JavaScript can lead to significant issues affecting both functionality and user experience.

Various methods exist for ensuring cross-browser compatibility, such as progressive enhancement, graceful degradation, and the use of polyfills, each with its advantages and disadvantages. Effective implementation of these strategies requires a combination of testing, automation, and careful consideration of user behavior. Automated testing tools like BrowserStack and Sauce Labs play a vital role in early detection and resolution of issues during the development process.

Ultimately, a proactive approach that includes robust testing and optimization techniques is necessary to ensure a seamless experience across all platforms and browsers, thereby enhancing user satisfaction and reducing development costs.

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