Browserprint: An Analysis of the Impact of Browser Features on Fingerprintability and Web Privacy

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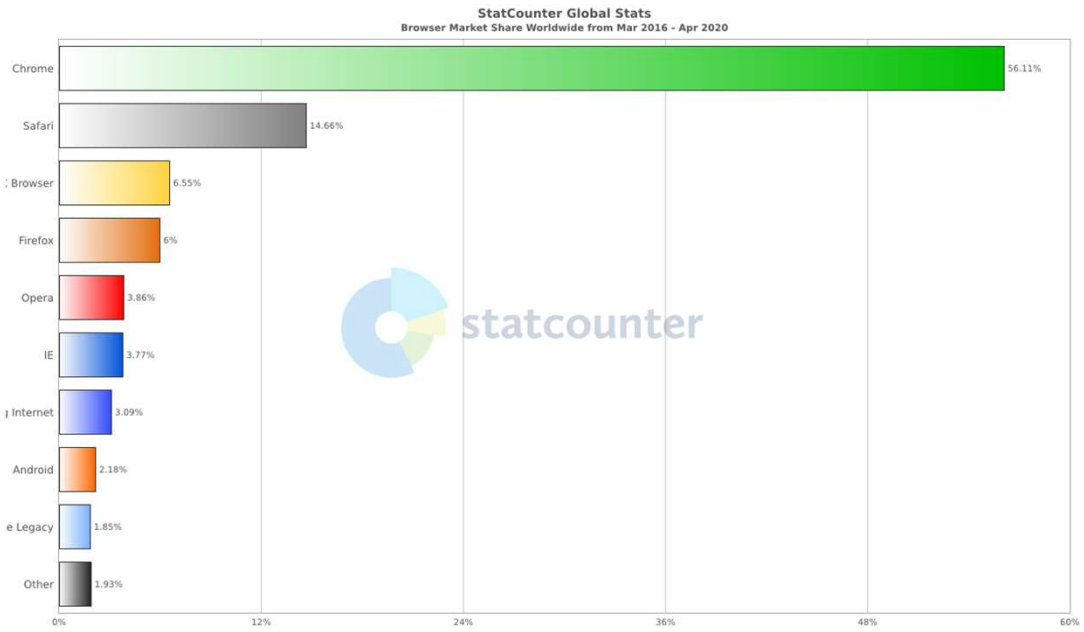
Browser Market Share

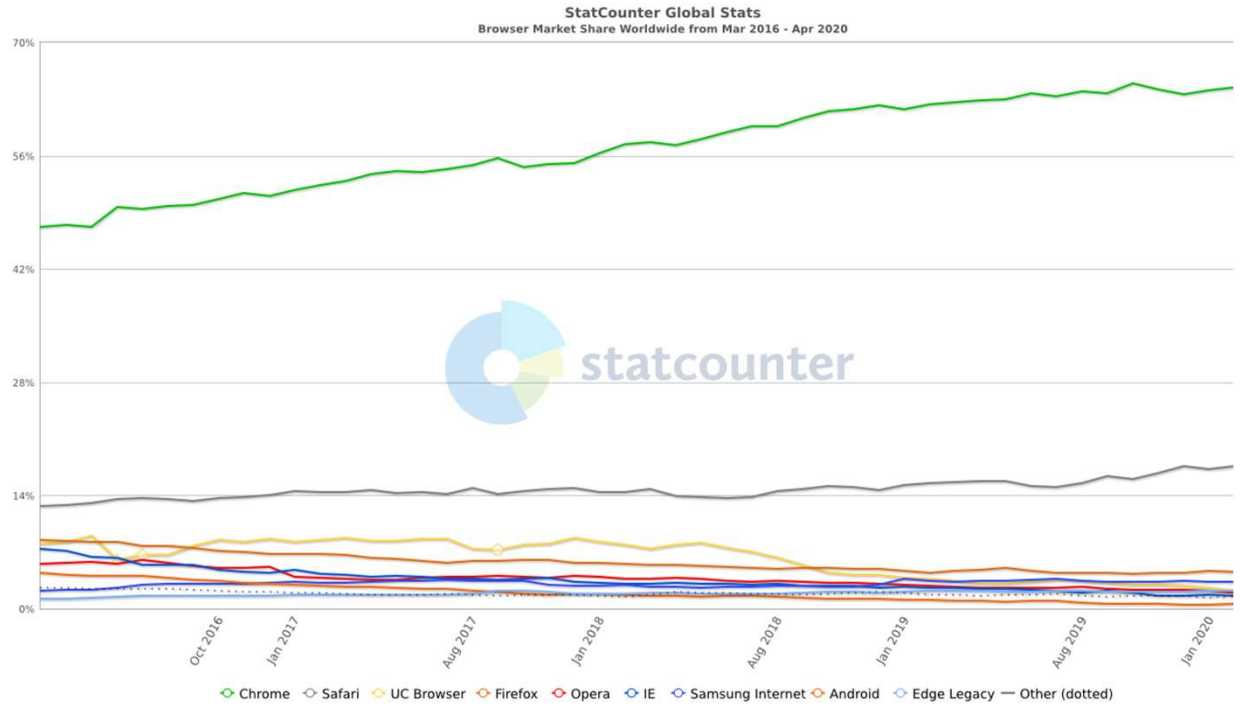


Terminology

- Browser Fingerprinting
  - Many unique details of a user's browser such as its hardware, operating system, browser configuration and preferences can be exposed through the browser
  - An attacker who collects and sums these outputs can create a unique **fingerprint** for tracking and identification purposes
- Browser features
  - All functionality that is available to attackers directly through JavaScript
  - These are the root problem of most web attacks
- Fingerprintability
  - Ratio of browser features that are associated with fingerprinting techniques in a browser version.

Introduction

- Chrome has the highest market share between browsers
- Safari, Firefox, and Opera are the next browsers with high market share
- Opera and Chrome are both Chromium-based and share the same codebase



Research Questions

- Are major versions of Firefox, Chrome, and Opera browsers fingerprintable based on their feature sets?
- Are these browsers becoming more fingerprintable over time?
- With respect to browser bloating, how does Firefox compare to Chrome and Opera?
- Could the private window mode reduce the possibility of being fingerprinted?
- Is there any noticeable difference between Chrome and Opera in case of fingerprintability?

Feature Gathering

- **Feature:** JavaScript objects, methods, and property values built into the global namespace of the browser's JavaScript implementation
- Crafted a JavaScript instrumented webpage that analyzes the visiting browser when it is visited.
- The code probes and iterates through the features supported by the browser
  - Using JavaScript to traverse the tree of non-cyclic JavaScript object references accessible from a pristine *window* object
  - Collects the full feature names
  - Each feature name comprises the sequence of property names leading from the global object to a given built-in JavaScript value.
- Captured feature sets are then stored in a database, tagged with identifying metadata

Testing Platform

- Used BrowserStack platform to visit the feature extractor webpage in headful mode
  - Cloud-based browser testing platform
- All of the tests are run on a single device with a single device configuration and OS
- Include all the major browser versions release during March 2016-April 2020
  - Chrome 49-81
  - Firefox 45-75
  - Opera 36-68

Browser Fingerprinting APIs

- We generate a list of suspicious APIs associated with fingerprinting
- Contains 313 JavaScript APIs
- These APIs provide functionality. However, they can be abused by creating a unique fingerprint of the client's browser.
- Literature Review
  - Extract suspicious APIs discussed in prior works: Panopticlick, AmIUnique, Hiding in the Crowd, and FPDetective.
  - These APIs Form 10% of the list
- Experimental Analysis

Experimental Analysis

- Crawling websites and Extracting Suspicious APIs from the data
- A crawler that visits EasyList domain file. Contains 13,241 domains
- Processed the raw data and collected all the API usages.
  - API usage of 8,682 domains with 56,828 origins was collected
- Manual Analysis to check if the APIs actually expose user information
  - Check Mozilla's MDN web docs
  - API is classified as a suspicious fingerprinting API if it can provide the information to filter certain users out
- Keyword search in all the crawled domains (BatteryManager)
- Expand the list by visiting known fingerprinting websites such as amiunique.org

Limitations

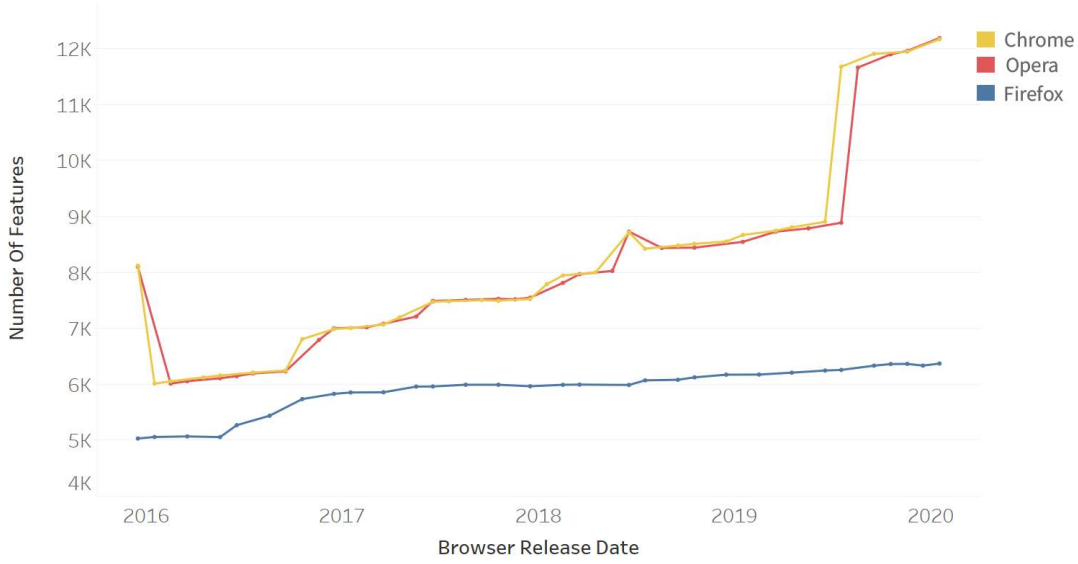
- Might not have all the fingerprinting APIs since we only crawled EasyList domains
- Manual Analysis might be affected by misonceptions between what is discussed in the Mozilla API page and the real API usage

Results

- Analysis of the Browser Features
- Browser Fingerprintability
- Unique Feature Set

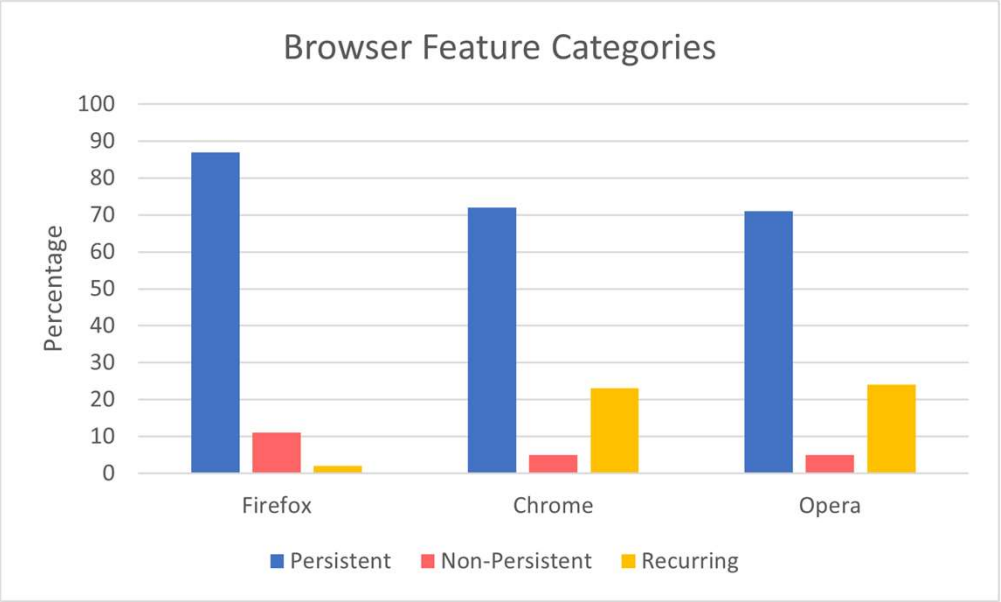
Feature Trends

- Browsers are becoming more bloated over time.
- Chrome and Opera share the same codebase. The trends are similar but minor differences exists between them
- Firefox contains much less features compared to Chromium-based browsers

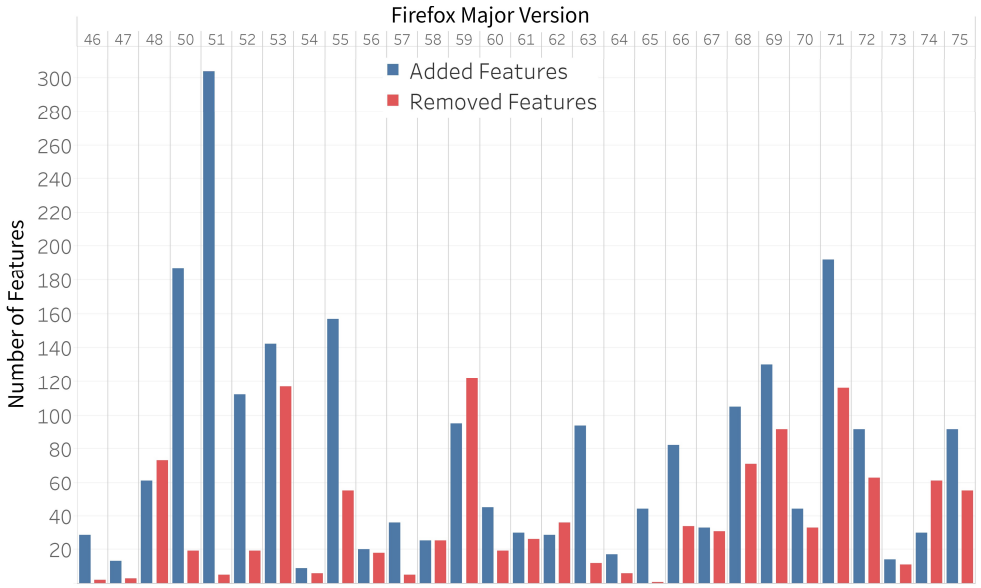


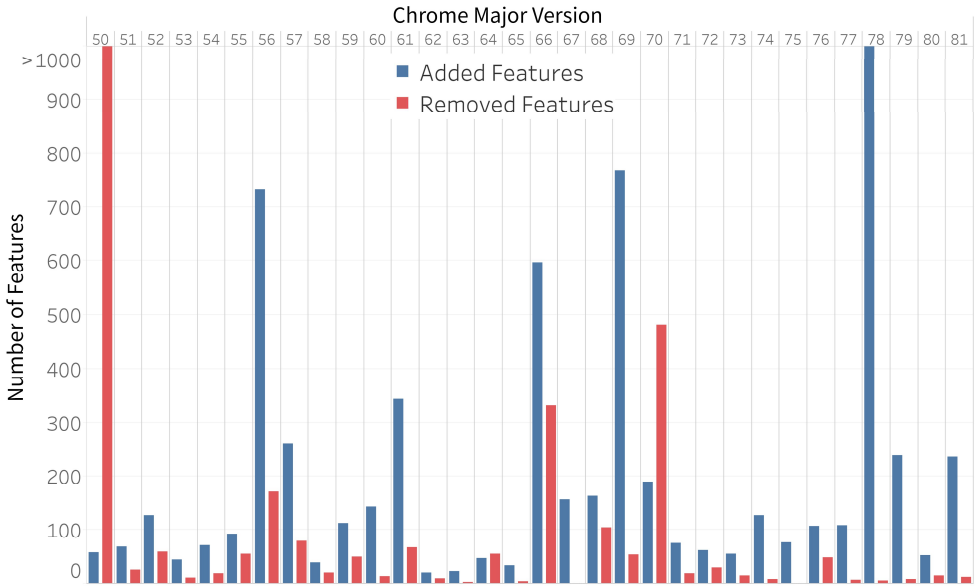
Feature Categories

- Persistent Features
  - Added to a specific version, and that continue to exist
- Non-Persistent Features
  - Existed in older versions of the browser, but were removed, and never appeared again
- Recurring Features
  - Added and removed from the browser from time to time



Feature Add and Removals

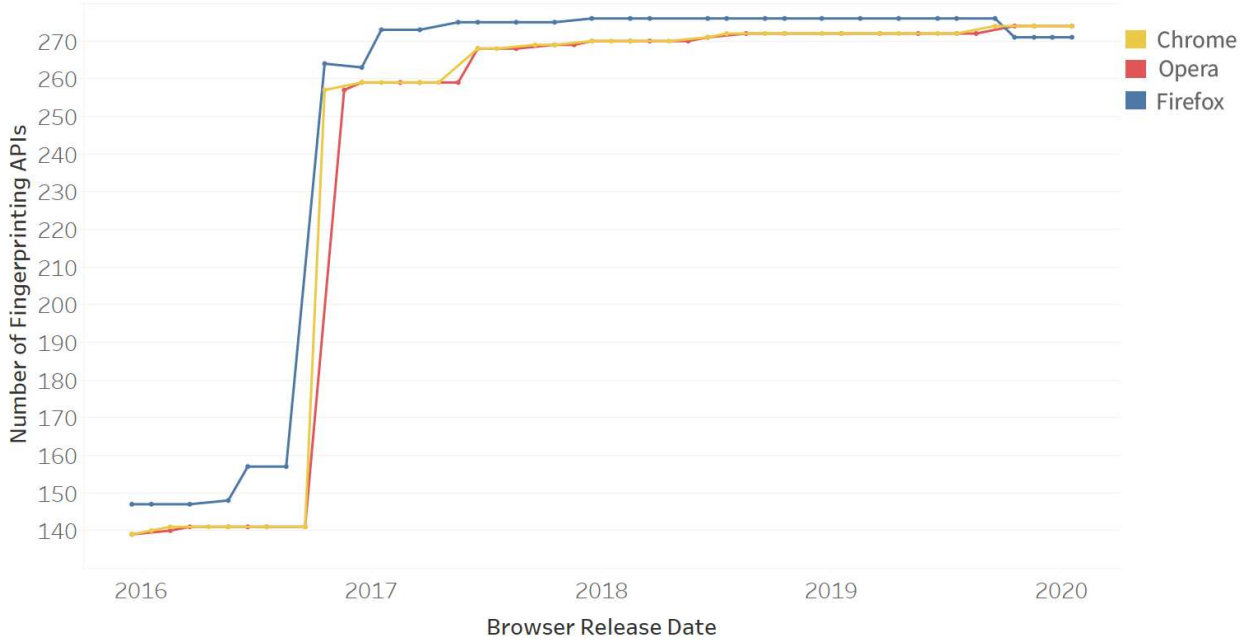




- Although both browsers are having more features over time, Adding and Removing Feature Trends are different.
- Firefox tries to maintain its total number of features

Browser Fingerprintability

- Browsers are becoming more fingerprintable over time
- Chrome 81 has 274 fingerprinting APIs! (The total number of suspicious APIs is 313)
- Adding more features is leading to having more fingerprintable APIs



Analyzing Spikes in the Graph

- January 2017
  - *WebGL 2.0* API Support was added to Chrome, Firefox, and Opera.
  - Provides a new rendering context, and supports objects for the HTML5 canvas element
  - *HTML5* was enabled for all users by default in Chrome
  - Adobe Flash Player was disabled and only allowed to run with specific user permissions.
  - More than 100 fingerprinting APIs were found
- September 2017
  - *NetworkInformation* API was added to Chrome
  - Provides information about the connection a device is using to communicate with the network
- April 2017
  - *BaseAudioContext* API was added to Firefox
  - Acts as a base definition for online and offline audio-processing graphs

Analyzing Spikes in the Graph

- These APIs exist in our suspicious fingerprinting APIs list.
- Surprisingly, some of these APIs were not even mentioned directly in Chrome and Firefox release notes.
- Even a minor feature addition to a browser, which might not have been discussed in the release notes, could include fingerprintable APIs.

Incognito and Private Window Mode

- There is a small difference between total number of features in normal mode and incognito mode
  - Chrome 80's normal mode has 11,946 features.
  - Chrome 80's incognito mode has 11,936 features.
- Every fingerprinting API exists on both normal and incognito mode

- Incognito and Private Window mode have no impact on fingerprintability

Unique Features Set

- For each browser version in our study, we created a Feature Set
  - Includes all the extracted features
- There exist no two browsers that possess the same feature set
  - Only by looking at the feature set, each browser version is uniquely fingerprintable.
  - Add, remove, and re-adding features make them more fingerprintable
- Feature sets have become more similar recently.

Prior Work

- Multiple works on browser fingerprinting
  - Synder et al. Uses same method of feature collection. They measure the feature usage among the Alexa top websites.
  - Chenxiong et al. Propose a debloating framework for the browser that removes unused features
  - Eckersley. How a unique fingerprint is formed by combining wide range of browser properties
  - Cao et al, Olejnik et al, Nikiforakis et al, Mowery et al. Study on a single fingerprinting method

- Our aim was to collect data and analyze the trends to see whether we are becoming better at managing browser fingerprinting
- No study have looked at popular browsers historically and have attempted to determine how their fingerprintability has evolved over the years

Summary

- We extracted every browser feature in all browser versions using the browser APIs. We created a list of fingerprinting APIs based on different prior works.
- We show that all major Mozilla Firefox, Google Chrome, and Opera browser versions between 2016 until 2020 are uniquely fingerprintable based exclusively on the presence or absence of browser features
- We conclude that incognito mode has no impact on fingerprintability
- We analyze Mozilla Firefox, Google Chrome, and Opera and report major differences between feature introduction and removal trends.
- Although Chrome and Opera are both based upon Chromium and share the same codebase, there are still differences in their feature introduction and removal patterns.
    - But this shared codebase makes them very similar in our fingerprintability analysis.

Questions?