KU LEUVEN
DISTRINET RESEARCH GROUP

Web Fingerprinting

How, Who, and Why?

Nick Nikiforakis

echo `whoami`

- Final year PhD student at KU Leuven
- Working, mainly, on web security and privacy
- Identify online ecosystems
  - Players
  - Interactions
  - Common patterns
- Search for systematic problems

The New York Times

Business Day

Media & Advertising

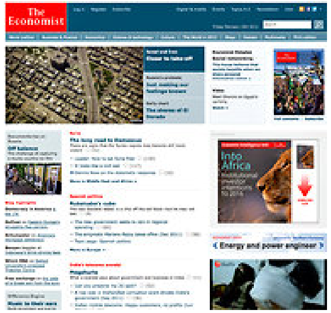
Study Finds News Sites Fail to Aim Ads at Users

By TANZINA VEGA
Published: February 13, 2012

Web sites for newspapers, magazines and television stations might be hungry to make money with digital advertising, but you wouldn't know it by the way some of them do business online.

RECOMMEND
TWITTER
LINKEDIN
SIGN IN TO E-MAIL
PRINT
REPRINTS
SHARE

Enlarge This Image



The Economist's home page is not unusual in displaying ads for the company's products.

A new study released Monday by the Pew Research Center Project for Excellence in Journalism looked at 22 news Web sites and more than 5,300 digital ads. It found that many of the sites had not attracted the same advertisers online as they did on other platforms.

In part, these sites were failing to attract online ads because they were not using technology that would customize ads based on their users' online behavior. For example, a user searching for tickets to a Broadway show might see ads for that show.

The study, which looked at Web sites for 11 newspapers, four magazines and six television outlets, as well as two online-only sites, focused on premium digital ad placements on home pages or at the top of article pages, which have generally cost more to buy.

“One of the great challenges that faces the financial future of journalism is, how can you begin to charge more for digital advertising?” said Tom Rosenstiel, the director of the center. “The

Log in to see what your friends are sharing on nytimes.com. Privacy Policy | What's This?

Log In With Facebook

What's Popular Now

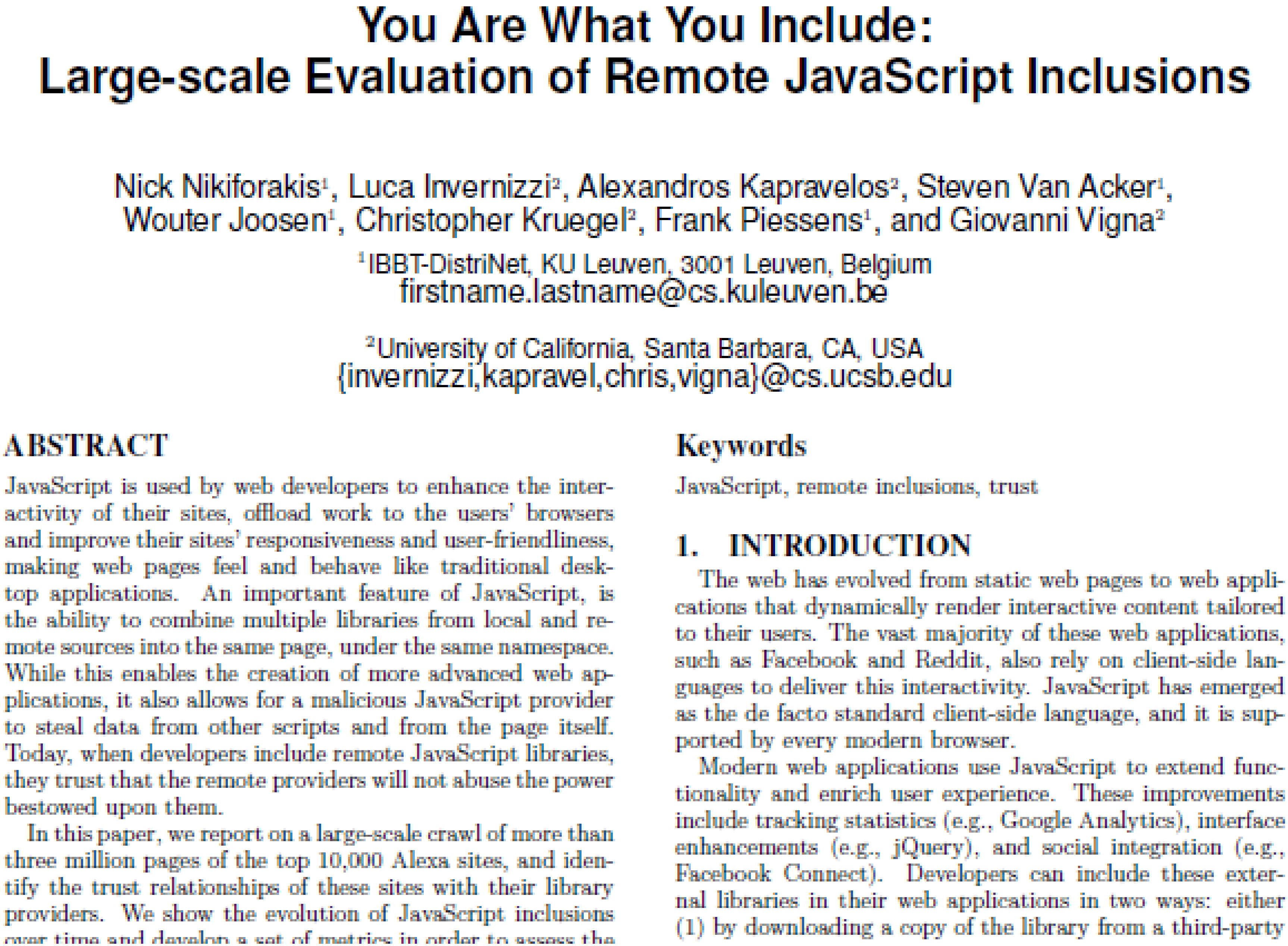
A Senate in the Gun Lobby's Grip

Messing With the Wrong City

MOST E-MAILED | MOST VIEWED

3rd Party Tracking

- “Suddenly” all sorts of websites that you’ve never heard about, can create a browsing profile of you and sell it to advertising companies
  - quantserve.com
  - scorecardresearch.com
  - addthis.com



You Are What You Include: Large-scale Evaluation of Remote JavaScript Inclusions

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ABSTRACT

JavaScript is used by web developers to enhance the interactivity of their sites, offload work to the users' browsers and improve their sites' responsiveness and user-friendliness, making web pages feel and behave like traditional desktop applications. An important feature of JavaScript, is the ability to combine multiple libraries from local and remote sources into the same page, under the same namespace. While this enables the creation of more advanced web applications, it also allows for a malicious JavaScript provider to steal data from other scripts and from the page itself. Today, when developers include remote JavaScript libraries, they trust that the remote providers will not abuse the power bestowed upon them.

In this paper, we report on a large-scale crawl of more than three million pages of the top 10,000 Alexa sites, and identify the trust relationships of these sites with their library providers. We show the evolution of JavaScript inclusions over time and develop a set of metrics in order to assess the

Keywords

JavaScript, remote inclusions, trust

1. INTRODUCTION

The web has evolved from static web pages to web applications that dynamically render interactive content tailored to their users. The vast majority of these web applications, such as Facebook and Reddit, also rely on client-side languages to deliver this interactivity. JavaScript has emerged as the de facto standard client-side language, and it is supported by every modern browser.

Modern web applications use JavaScript to extend functionality and enrich user experience. These improvements include tracking statistics (e.g., Google Analytics), interface enhancements (e.g., jQuery), and social integration (e.g., Facebook Connect). Developers can include these external libraries in their web applications in two ways: either (1) by downloading a copy of the library from a third-party

Motivation & Contributions

- Tracking involves more than just 3rd party cookies
- Fingerprinting: Telling users apart based on their browsing environments, without extra stateful identifiers
- Thorough study of current fingerprinting practices on the web
- Difficulty of hiding the true nature of a user's browsing environment

Users reacted…

- 1/3 of users delete first & third-party cookies within a month after they’ve been setup
- Multiple extensions revealing hidden trackers
  - Ghostery
  - Collusion
- Private mode of browsers used to avoid traces of cookies from certain websites

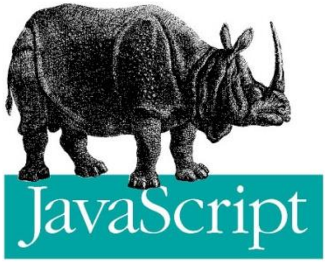
However…

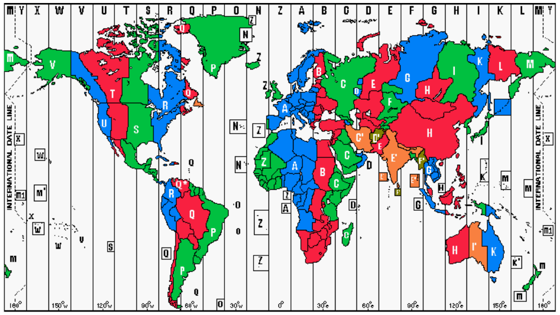
- What if you could track users without the need of cookies or any other stateful client-side identifier?
  - Hidden from users
  - Hard to avoid it / opt-out

Web-based device fingerprinting

- Eckersley showed in 2010 that certain attributes of your browsing environment can be used to accurately track you
- These attributes, when combined, created a quite unique fingerprint of your system?
  - How?

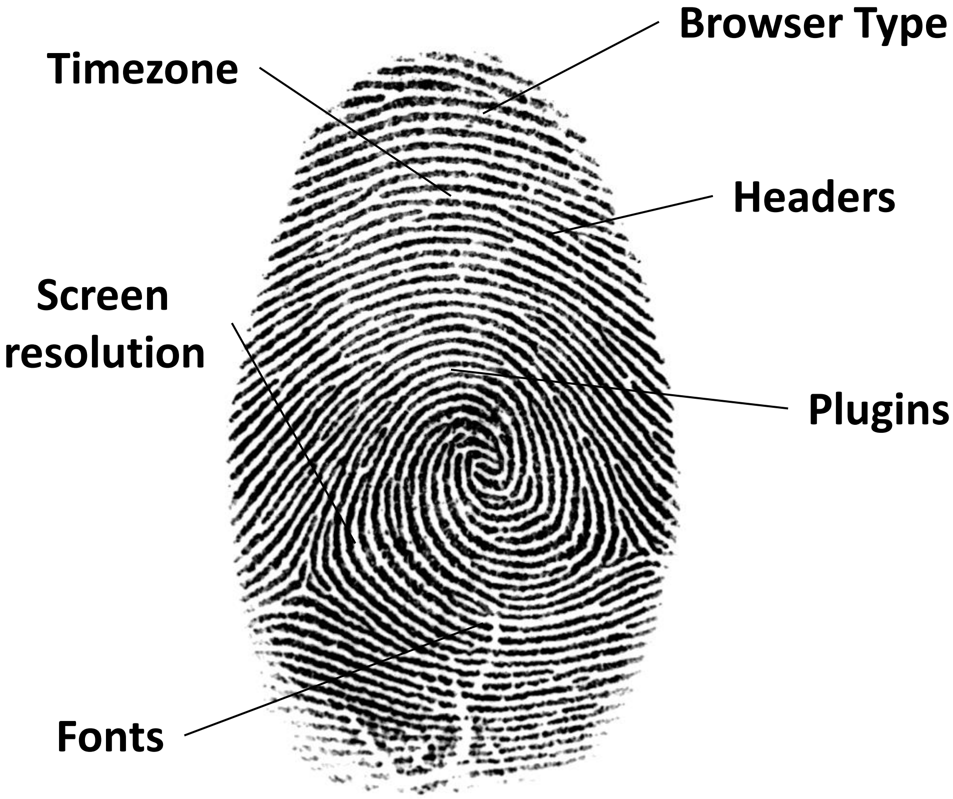
Properties fingerprinted by Panopticlick





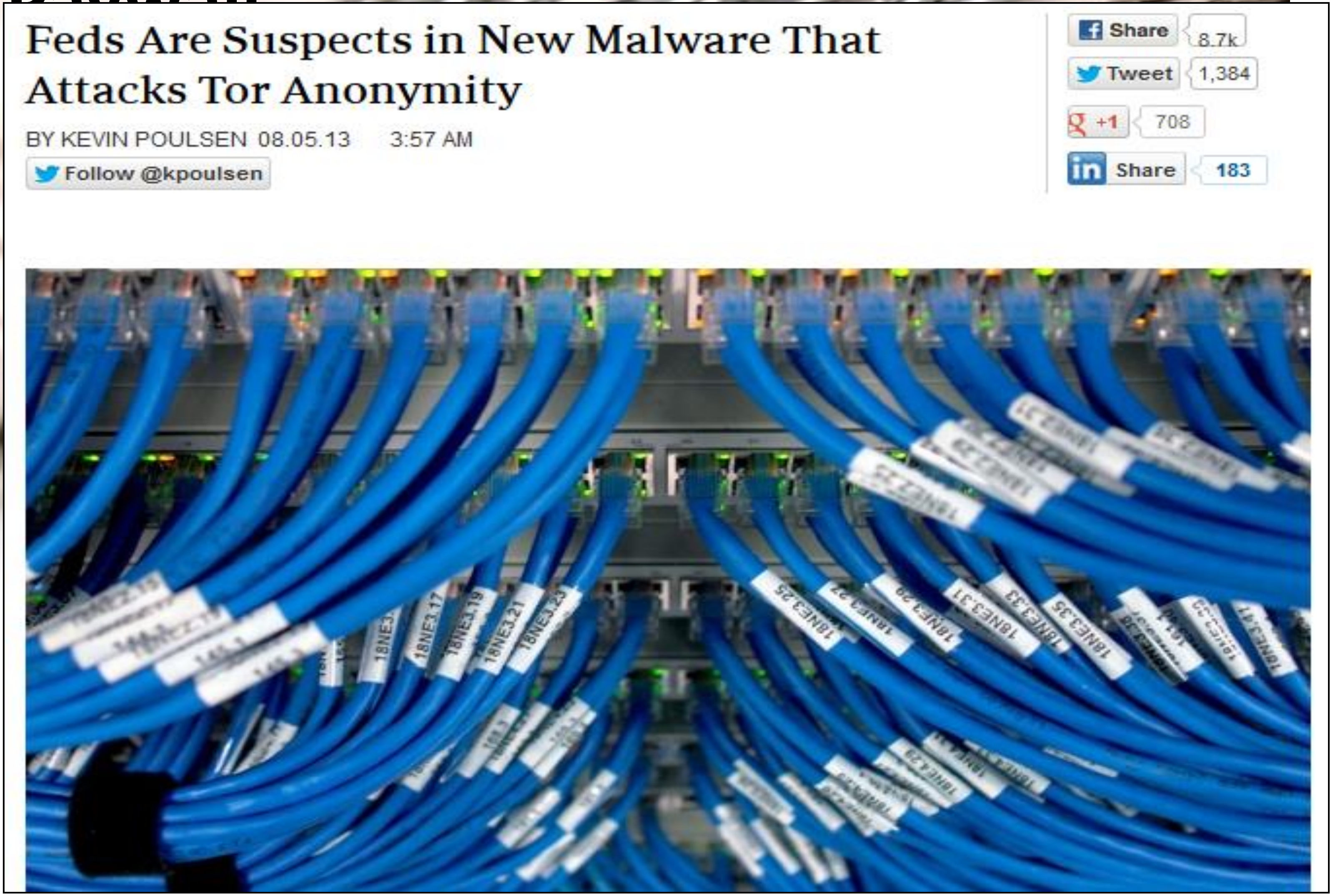
Maverick
Ocean Front Villas
mandarin tea
Regency
Sassafras & Ginger
Dollhouse
Athletics Dept.

Resulting fingerprints



- 94.2% of the users with Flash/Java could be uniquely identified
- Simple heuristic algorithms could track updates of the same browser

Paywall



Feds Are Suspects in New Malware That Attacks Tor Anonymity

BY KEVIN POULSEN 08.05.13 3:57 AM

Fast forward 2 years

- In mid 2012, all we knew is that fingerprinting is possible and that a small number of companies offer it as a service

- Questions that begged answering:
  - How are they doing it?
  - Could they do more?
  - Who is using them?
  - How are users trying to hide?
    - Is it working?

Cookieless Monster:
Exploring the Ecosystem of Web-based Device Fingerprinting

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***Abstract*—The web has become an essential part of our society and is currently the main medium of information delivery. Billions of users browse the web on a daily basis, and there are single websites that have reached over one billion user accounts. In this environment, the ability to track users and their online habits can be very lucrative for advertising companies, yet very intrusive for the privacy of users.**

In this paper, we examine how web-based device fingerprinting currently works on the Internet. By analyzing the code of three popular browser-fingerprinting code providers, we reveal the techniques that allow websites to track users without the need of client-side identifiers. Among these techniques, we show how current commercial fingerprinting approaches use questionable practices, such as the circumvention of HTTP proxies to discover a user's real IP address and the installation of intrusive browser plugins.

At the same time, we show how fragile the browser ecosystem is against fingerprinting through the use of novel browser-identifying techniques. With so many different vendors involved in browser development, we demonstrate how one can use diversions in the browsers' implementation to distinguish

servers. With every request toward a third-party website, that website has the ability to set and read previously-set cookies on a user's browser. For instance, suppose that a user browses to *travel.com*, whose homepage includes a remote image from *tracking.com*. Therefore, as part of the process of rendering *travel.com*'s homepage, the user's browser will request the image from *tracking.com*. The web server of *tracking.com* sends the image along with an HTTP Set-Cookie header, setting a cookie on the user's machine, under the *tracking.com* domain. Later, when the user browses to other websites affiliated with *tracking.com*, e.g., *buy.com*, the tracking website receives its previously-set cookies, recognizes the user, and creates a profile of the user's browsing habits. These *third-party cookies*, due to the adverse effects on a user's privacy and their direct connection with online behavioral advertising, captured the attention of both the research community [2], [3], [4] and the popular media outlets [5] and, ever since, cause the public's

Manual analysis of 3 fingerprinting companies

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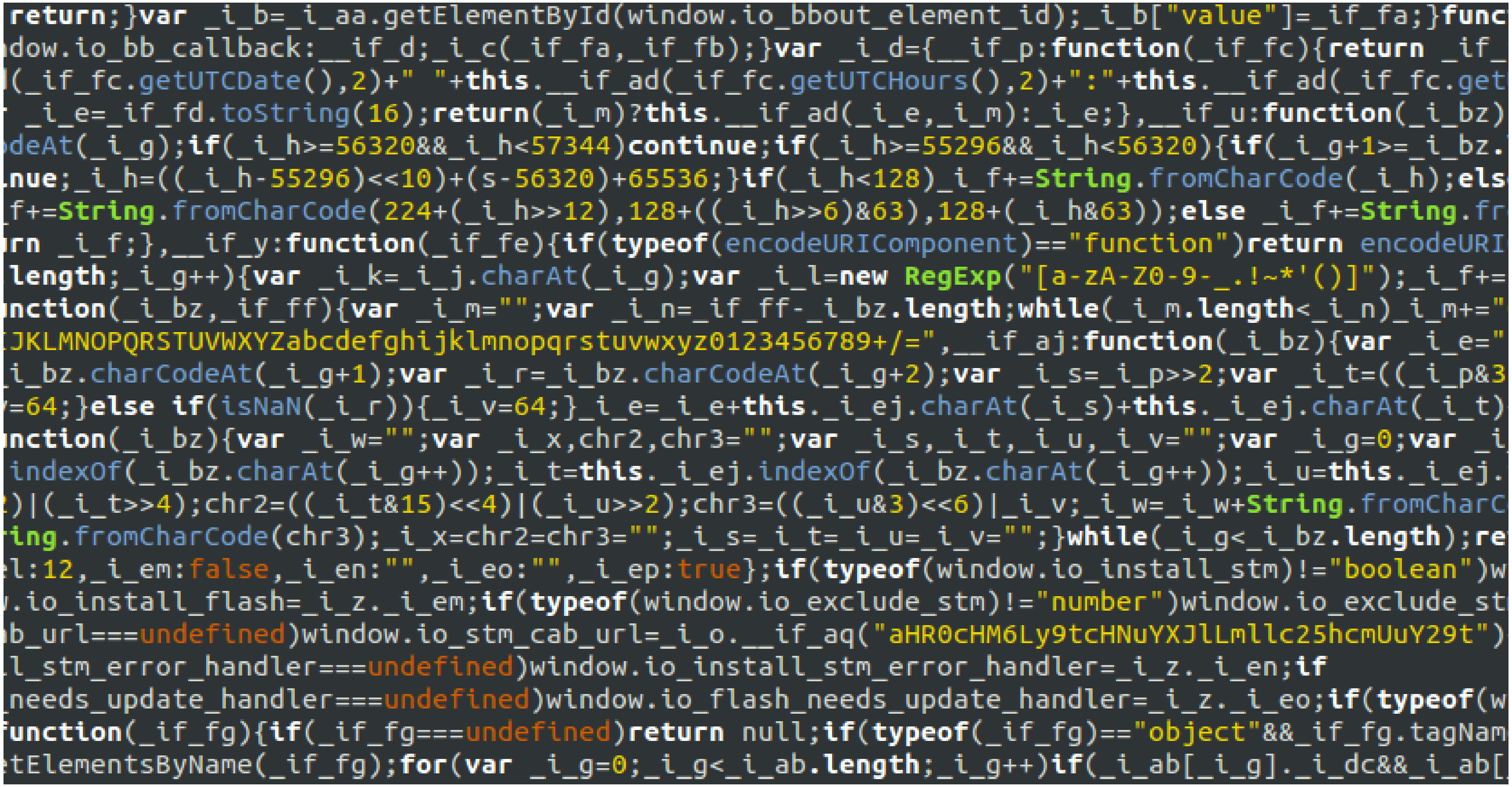
1. Find the domains that they use to serve their fingerprinting scripts
2. Find some websites that use them and extract the code
3. De-obfuscate and analyze
4. Compare and classify

Step 3 took a while…



```
return;}var _i_b=_i_aa.getElementById(window.io_bbout_element_id);_i_b["value"]=_if_fa;}func
dow.io_bb_callback:__if_d;_i_c(_if_fa,_if_fb);}var _i_d={__if_p:function(_if_fc){return _if_
(_if_fc.getUTCDate(),2)+" "+this.__if_ad(_if_fc.getUTCHours(),2)+":"+this.__if_ad(_if_fc.get
 _i_e=_if_fd.toString(16);return(_i_m)?this.__if_ad(_i_e,_i_m):_i_e;},__if_u:function(_i_bz)
deAt(_i_g);if(_i_h>=56320&&_i_h<57344)continue;if(_i_h>=55296&&_i_h<56320){if(_i_g+1>=_i_bz.
nue;_i_h=((_i_h-55296)<<10)+(s-56320)+65536;}if(_i_h<128)_i_f+=String.fromCharCode(_i_h);els
_f+=String.fromCharCode(224+(_i_h>>12),128+((_i_h>>6)&63),128+(_i_h&63));else _i_f+=String.fr
rn _i_f;},__if_y:function(_if_fe){if(typeof(encodeURIComponent)=="function")return encodeURI
length;_i_g++){var _i_k=_i_j.charAt(_i_g);var _i_l=new RegExp("[a-zA-Z0-9-_.!~*'()]");_i_f+=
nction(_i_bz,_if_ff){var _i_m="";var _i_n=_if_ff-_i_bz.length;while(_i_m.length<_i_n)_i_m+="
JKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz0123456789+/=",__if_aj:function(_i_bz){var _i_e="
i_bz.charCodeAt(_i_g+1);var _i_r=_i_bz.charCodeAt(_i_g+2);var _i_s=_i_p>>2;var _i_t=((_i_p&3
=64;}else if(isNaN(_i_r)){_i_v=64;}_i_e=_i_e+this._i_ej.charAt(_i_s)+this._i_ej.charAt(_i_t)
nction(_i_bz){var _i_w="";var _i_x,chr2,chr3="";var _i_s,_i_t,_i_u,_i_v="";var _i_g=0;var _i
indexOf(_i_bz.charAt(_i_g++));_i_t=this._i_ej.indexOf(_i_bz.charAt(_i_g++));_i_u=this._i_ej.
)|(_i_t>>4);chr2=((_i_t&15)<<4)|(_i_u>>2);chr3=((_i_u&3)<<6)|_i_v;_i_w=_i_w+String.fromCharC
ing.fromCharCode(chr3);_i_x=chr2=chr3="";_i_s=_i_t=_i_u=_i_v="";}while(_i_g<_i_bz.length);re
l:12,_i_em:false,_i_en:"",_i_eo:"",_i_ep:true};if(typeof(window.io_install_stm)!="boolean")w
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b_url===undefined)window.io_stm_cab_url=_i_o.__if_aq("aHR0cHM6Ly9tcHNuYXJlLmllc25hcmUuY29t")
l_stm_error_handler===undefined)window.io_install_stm_error_handler=_i_z._i_en;if
needs_update_handler===undefined)window.io_flash_needs_update_handler=_i_z._i_eo;if(typeof(w
unction(_if_fg){if(_if_fg===undefined)return null;if(typeof(_if_fg)=="object"&&_if_fg.tagNam
tElementsByName(_if_fg);for(var _i_g=0;_i_g<_i_ab.length;_i_g++)if(_i_ab[_i_g]._i_dc&&_i_ab[
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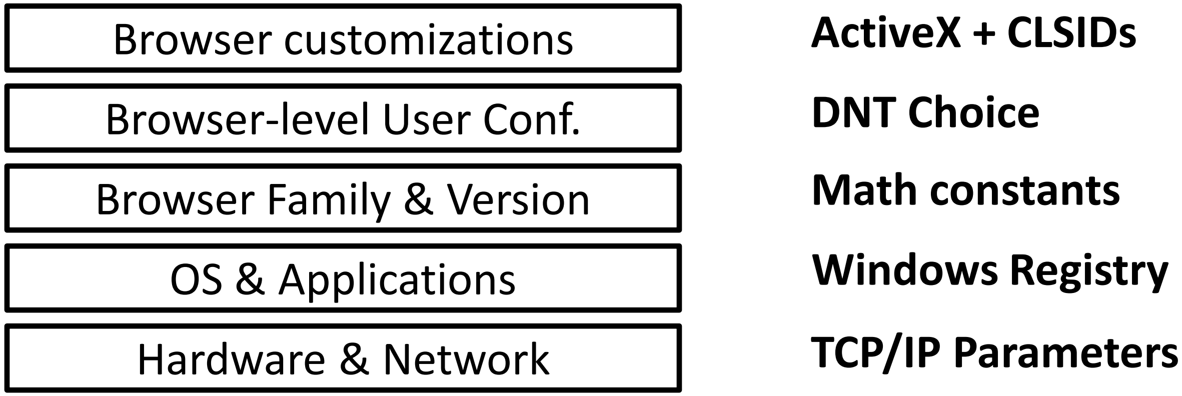
Results

- After extracting all features, we created a taxonomy of all fingerprinted features, and compared each company to Panopticlick
- Collectively, Panopticlick was fully covered



Browser customizations	**ActiveX + CLSIDs**
Browser-level User Conf.	**DNT Choice**
Browser Family & Version	**Math constants**
OS & Applications	**Windows Registry**
Hardware & Network	**TCP/IP Parameters**

Non-trivial extras

- Non-plugin font detection
  - Comparison of text’s width & height
- Native Fingerprinting plugins
  - Accessing highly-specific registry value
- Fingerprint delivery mechanisms
- Proxy detection

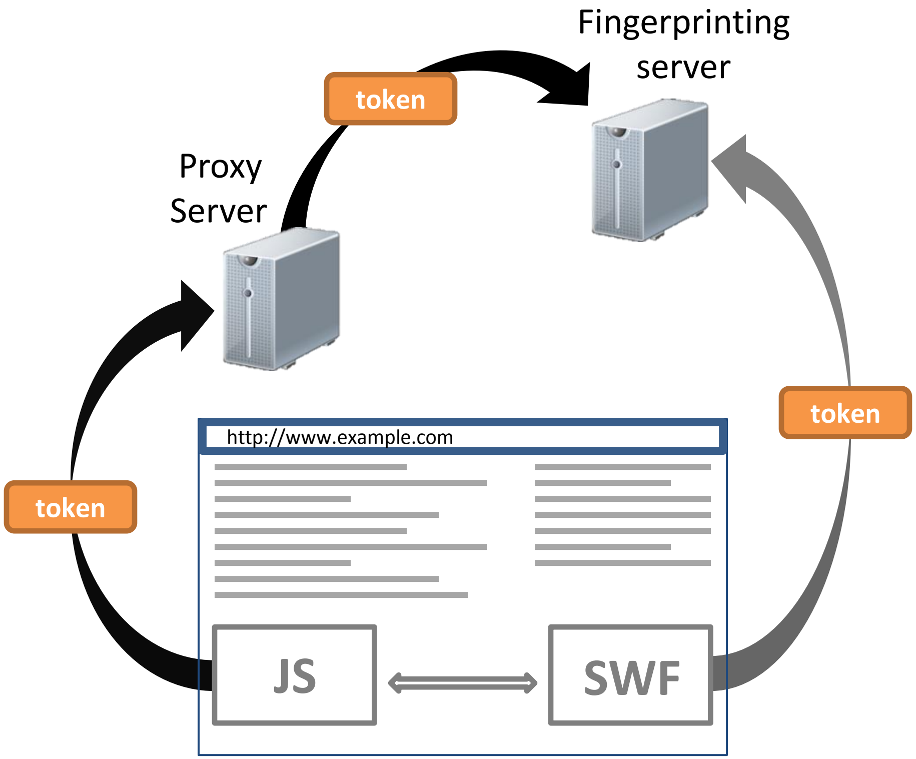
Font Detection through JavaScript

String	**Dimensions**
I_DO_NOT_NEED_FLASH	500 x 84
I_DO_NOT_NEED_FLASH	520 x 84
I_DO_NOT_NEED_FLASH	580 x 87
I_DO_NOT_NEED_FLASH	399 x 82

Non-trivial extras

- Non-plugin font detection
  - Comparison of text’s width & height
- Native Fingerprinting plugins
  - Accessing highly-specific registry values
- Fingerprint delivery mechanisms
- Proxy detection

Proxy-detection



Adoption

Dataset A

- Crawled top 10,000 sites, searching for inclusions from the 3 fingerprint providers

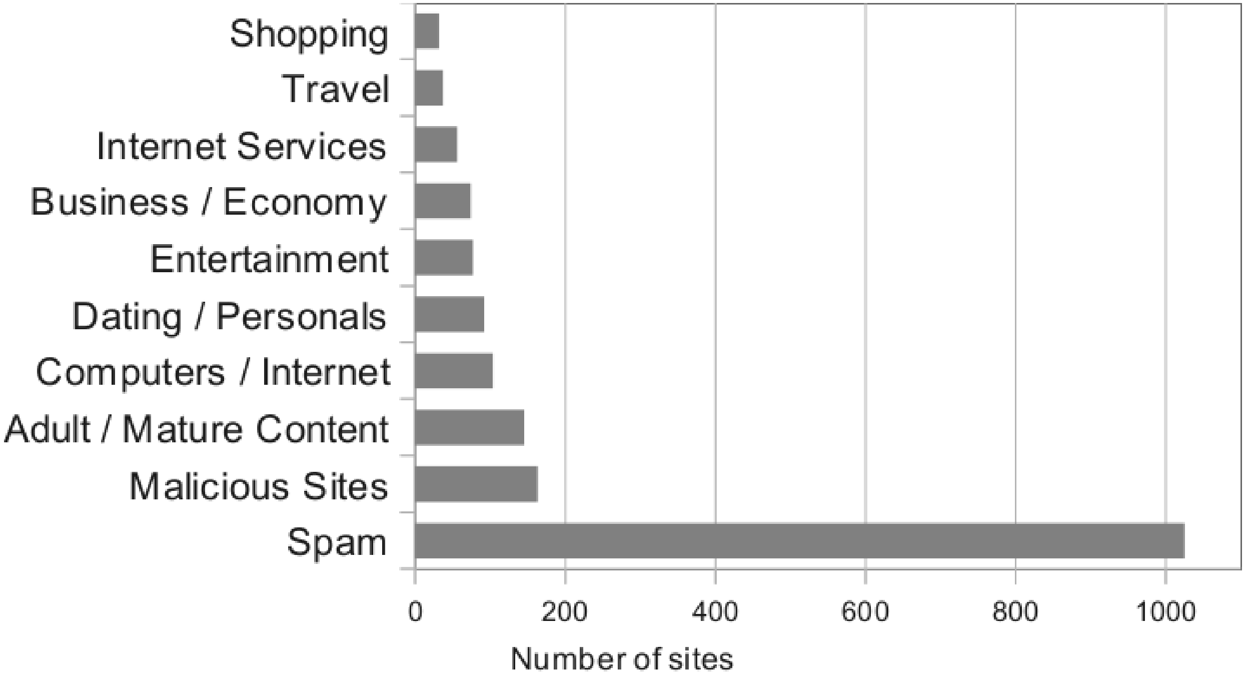
- 40 sites discovered
  - Porn & dating sites most prominent
    - Shared credentials & Sybil attacks

  - skype.com the highest ranking one

Adoption

Dataset B

- 3,804 domains from Wepawet



Status

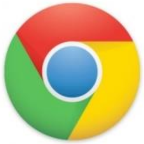
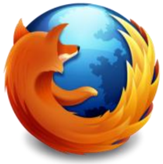
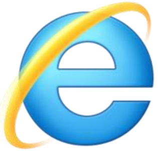
- Fingerprinting is out there
  - Quite a number of new techniques over Panopticlick
- Large and popular sites are using them
- Could they be doing more?
  - How do the browser internals relate to a browser’s identity?

DIY Fingerprinting

- We decided to try some fingerprinting of our own
- Focus on the two special JS objects that fingerprinters probe the most:
  - navigator
  - screen
- Perform a series of everyday operations and search for differences across browsers
  - Add properties
  - Remove properties
  - Modify properties

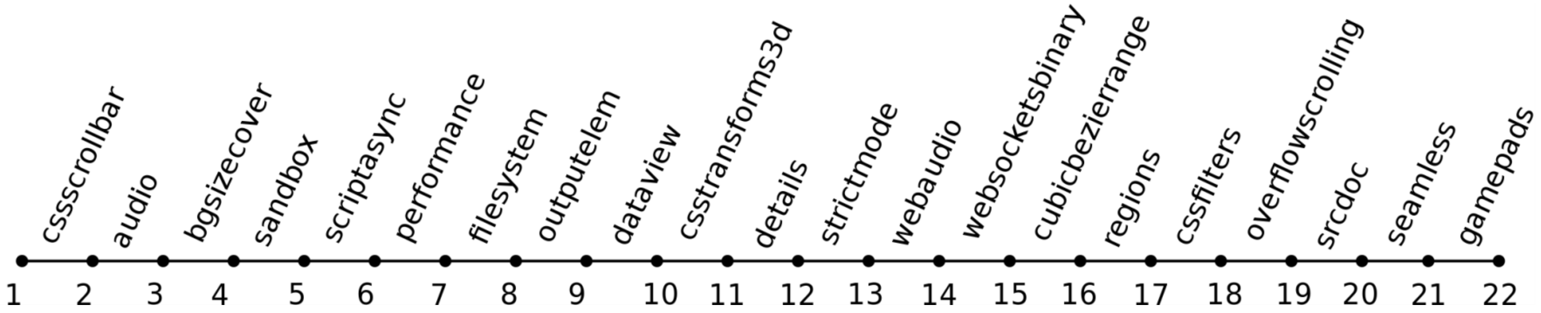
Novel methods discovered

- E.g., Natural ordering of properties can give away a browser family, and occasionally, a browser version

navigator.geolocation	navigator.appCodeName	↔	navigator.appCodeName
navigator.onLine	navigator.appName	↔	navigator.appName
navigator.cookieEnabled	navigator.appVersion		navigator.appMinorVersion
navigator.vendorSub	navigator.language		navigator.cpuClass
navigator.vendor	navigator.mimeTypes		navigator.platform
			

Other methods…

- Family-specific methods & properties
  - screen.mozBrightness
  - navigator.webkitStartActivity
  - screen.logicalXDPI
- Mutability of special objects
- Evolution of functionality
- Miscellaneous



Status

- Fingerprinting is out there
  - Quite a number of new techniques over Panopticlick
- Large and popular sites are using them
- There could be more fingerprinting done by the companies
- How could a user react?

Browser extensions

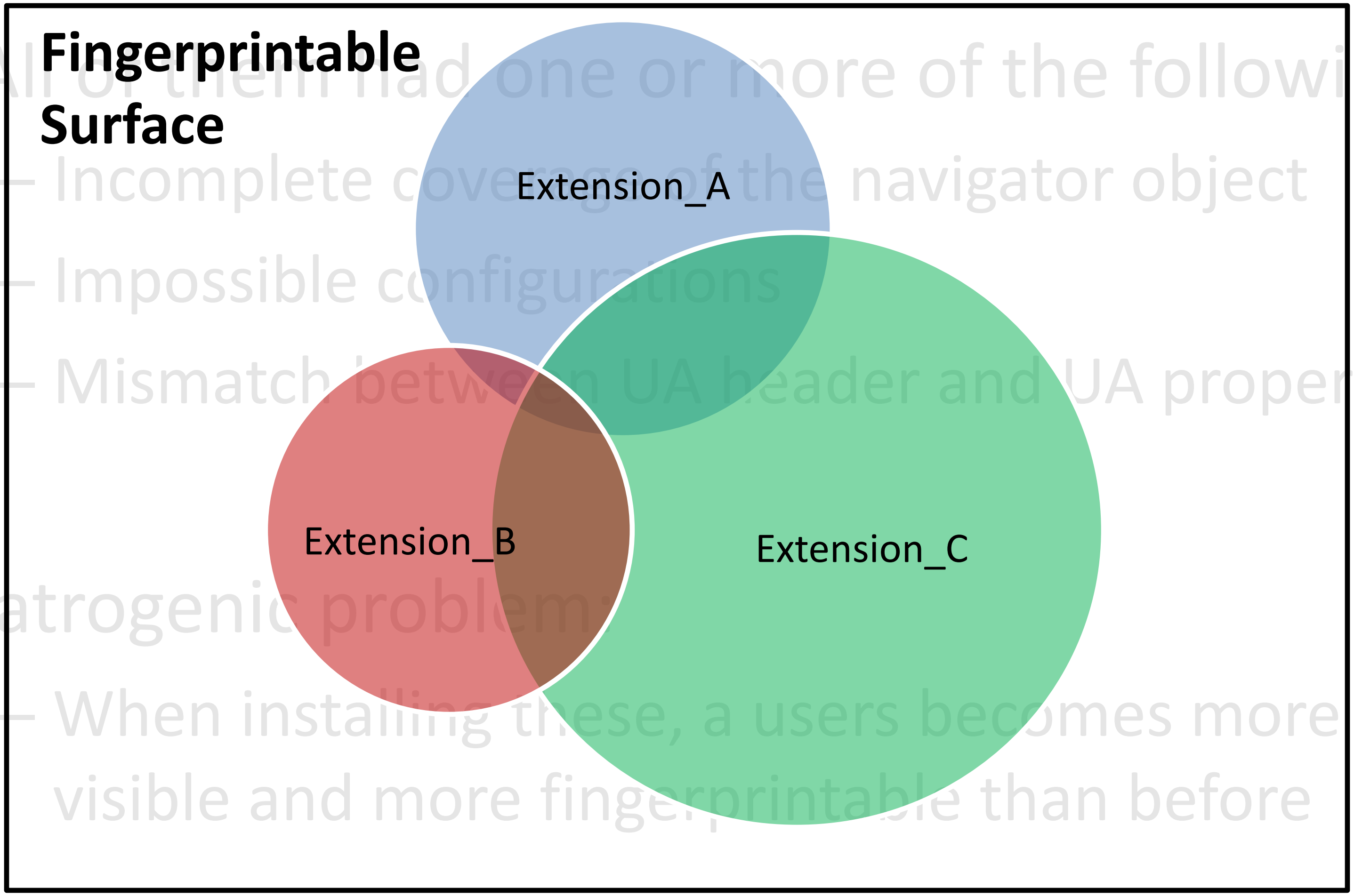
- Reviewed 11 different browser extensions that spoof a browser’s user-agent
  - 8 Firefox + 3 Chrome
  - More than 800,000 users
- Advice to use such extensions:
  - Previous research in web tracking
  - Underground hacking guides
- How do they stand-up against fingerprinting?

Worse than nothing…

- All of them had one or more of the following:
  - Incomplete coverage of the navigator object
  - Impossible configurations
  - Mismatch between UA header and UA property

- Iatrogenic problem:
  - When installing these, a user becomes more visible and more fingerprintable than before

Worse than nothing…



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Conclusion

- Fingerprinting is a real problem
- Browsers are so complex that it is really hard to make them seem identical
- Current browser extensions should not be used for privacy reasons
- Long term solutions will most-likely not be pure technical ones
  - Legislation required, like in stateful tracking

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