

Extracting robust fingerprints from mobile devices

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How Unique – and Trackable – Is Your Browser?

Your browser fingerprint appears to be unique among the 2,705,559 tested so far.

Currently, we estimate that your browser has a fingerprint that conveys at least 21.37 bits of identifying information.

The measurements we used to obtain this result are listed below. You can read more about our methodology, statistical results, and some defenses against fingerprinting in [this article](#).

Help us increase our sample size: [✉](#) [👤](#) [📺](#) [📺](#) [📺](#) [📺](#) [📺](#) [📺](#) [📺](#)

Browser Characteristic	bits of identifying information	one in x browsers have this value	value
User Agent	9.92	971.82	Mozilla/5.0 (Macintosh; Intel Mac OS X 10_8_2) AppleWebKit/536.26.17 (KHTML, like Gecko) Version/6.0.2 Safari/536.26.17
HTTP_ACCEPT Headers	3.88	14.75	text/html, */* gzip, deflate en-us
Browser Plugin			Plugin 0: Java Applet Plug-in; Displays Java applet content, or a placeholder if Java is not installed.; JavaAppletPlugin.plugin; (Java applet; application/x-java-applet;version=1.1.3;) (Basic Java Applets; application/x-java-applet; javaapplet) (Java applet; application/x-java-applet;version=1.2.2;) (Java applet; application/x-java-applet;version=1.5;) (Java applet; application/x-java-vm;) (Java applet; application/x-java-applet;version=1.3.1;) (Java applet; application/x-java-applet;version=1.3;) (Java applet; application/x-java-applet;version=1.1.2;) (Java applet; application/x-java-applet;version=1.1;) (Java applet; application/x-java-vm-npruntime;) (Java applet; application/x-java-applet;version=1.2.1;) (Java applet; application/x-java-applet;version=1.6;) (Java applet; application/x-java-applet;version=1.4.2;) (Java applet; application/x-java-applet;pi-version=1.6.0_37;) (Java applet; application/x-java-applet;version=1.4;) (Java applet; application/x-java-applet;version=1.1.1;) (Java applet; application/x-java-applet;version=1.2;). Plugin 1: QuickTime Plug-in 7.7.1; The QuickTime Plugin allows you to view a wide variety of multimedia content in web pages. For more information, visit the QuickTime Web site.; QuickTime Plugin.plugin; (MPEG-4 media; video/mp4; mp4) (AC3 audio; audio/x-ac3; ac3) (Video (protected); video/x-m4v; m4v) (SDP stream descriptor; application/x-sdp; sdp) (AMR audio; audio/amr; amr) (Flash Video; video/x-flv; flv) (RTSP stream descriptor; application/x-rtsp; rtsp,rt) (Matroska/WebM file; audio/webm; mkv,mka,webm) (3GPP2 media; video/3gpp2; 3g2,3gp2) (MPEG audio; audio/mpeg; mpeg,mpg,m1s,m1a,mp2,mpm,mpa,m2a,mp3,swa) (Matroska/WebM file; video/webm; mkv,mka,webm) (NupelVideo; video/x-nuv; nuv) (MP3 audio;

Browser Fingerprinting

- ▶ Unique & trackable
- ▶ Independent from “real” tracking mechanisms such as cookies
- ▶ Privacy threat
- ▶ Defense strategies?
 - Using a “non-rare” browser configuration
 - Disabling JavaScript
 - Using TorButton

Mobile devices?

THE WALL STREET JOURNAL.

EUROPE EDITION Tuesday, November 30, 2010

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Race Is On to 'Fingerprint' Phones, PCs

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By JULIA ANGWIN And JENNIFER VALENTINO-DEVRIES

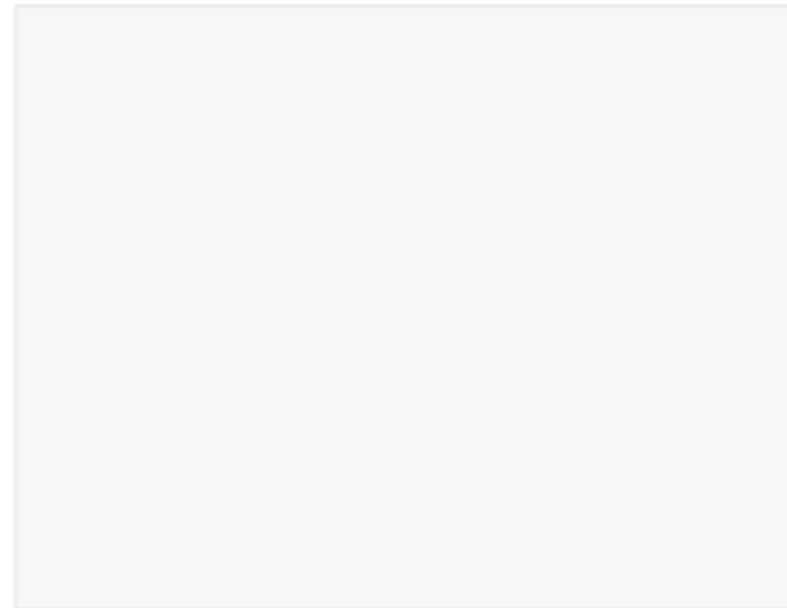
IRVINE, Calif.—David Norris wants to collect the digital equivalent of fingerprints from every computer, cellphone and TV set-top box in the world.



Companies are developing digital fingerprint technology to identify how we use our computers, mobile devices and TV set-top boxes. WSJ's Simon Constable talks to Senior Technology Editor Julia Angwin about the next generation of tracking tools.

He's off to a good start. So far, Mr. Norris's start-up company, BlueCava Inc., has identified 200 million devices. By the end of next year, BlueCava says it expects to have cataloged one billion of the world's estimated 10 billion devices.

Advertisers no longer want to just buy ads. They want to buy access to specific people. So, Mr. Norris is building a "credit bureau for devices" in which



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They Know What You're Shopping For

Mobile Web

- ▶ Panoptick fingerprints contain at least 18 bits of entropy
- ▶ Mobile browsers are much less diverse
 - No plugin infrastructure
 - Less various screen sizes
 - Adding fonts to device not possible

Mobile Web

- ▶ No reliable method for device fingerprinting through mobile web browsers known today
- ▶ iOS
 - Access UDID through mobileconfig profile file
 - User interaction required, rendering practical use limited

Apps?

Identifiers (Android)

- ▶ **IMEI (MEID or ESN for CDMA phones)**
 - Not available for WiFi-only devices
 - Requires `READ_PHONE_STATE` permission
 - Implementation bugs

- ▶ **MAC Address (WiFi or Bluetooth)**
 - Have to be turned on
 - Requires permissions (`ACCESS_WIFI_STATE` or `BLUETOOTH`)

Identifiers (Android)

- ▶ Serial Number (Android \geq 2.3)
 - Required only for non-phones
- ▶ ANDROID_ID
 - Implementation bugs (not unique for some devices)
 - Can change upon factory reset

Identifiers (iOS)

- ▶ Unique device identifier (UDID)
 - Access not allowed for AppStore apps anymore
- ▶ IdentifierForVendor (iOS \geq 6)
 - Value is only the same for apps that come from the same vendor running on the same device

Identifiers (iOS)

- ▶ AdvertisingIdentifier (iOS \geq 6)
 - Opt-out possible for user
- ▶ MAC address of WiFi-Interface
 - Unclear status regarding AppStore rules: might be blocked in the future

**Panoptick-like
fingerprinting for
mobile devices?**

Smartphone fingerprinting

- ▶ Evaluation based on iOS
 - Rather restrictive platform
 - Results that work for iOS can be easily extended to more open platforms
- ▶ Approach
 - Identification of device properties
 - Classification based on diversity and stability
 - Combination of properties in order to calculate unique identifiers

Existence of particular apps

Number of Songs

Address Book

Calendar

Photos

Free Storage

Device Uptime

Number of Videos

Timezone

Number of Apps

WiFi Status

Battery Status

Bluetooth Status

Jailbroken

Software Version

Device Name

Device Color

Storage Capacity

ID #

Generating Robustness

Two important aspects



Diversity



Stability

Generating Robustness

Diversity



Stability



Property	Stability	Diversity
Device Type	stable	weak
Device Color	stable	weak
Device Name	medium	strong
Free Storage	low	strong
Total Storage	stable	weak
Total Storage in /	stable	weak
Used Storage in /	low	strong
Total Storage in /private/var	medium	weak
Used Storage in /private/var	low	strong
Total Storage in /dev	medium	weak
Used Storage in /dev	low	strong
iOS Version	medium	weak
URL Schemes	high	strong

```
if ([[UIApplication sharedApplication] canOpenURL:[NSURL URLWithString:@"whatsapp://"]] {  
    NSLog(@"Whatsapp installed");  
    self.bWhatsapp = true;  
}  
else {  
    self.bWhatsapp = false;  
}
```

```
twitter://  
atomic://  
cydia://  
tweetbot://  
comgooglemaps://  
youtube://  
fb://  
whatsapp://  
soundcloud://  
wolframalpha://  
skype://  
mobileiron://
```

```
googlechrome://  
dolphin://  
kindle://  
path://  
shazam://  
vimeo://  
findmyfriends://  
spotify://  
remote://  
navigon://  
tomtomhome://  
evernote://
```

Property	Stability	Diversity
Number of Pictures	low	medium
Number of Contacts	low	medium
Number of Videos	medium	weak
Nth Contact	high	strong
Nth Picture	high	strong
Jailbroken	high	weak
Battery Charge Level	low	weak
System Uptime	medium	strong
Timezone	high	weak
Process List	medium	strong
WiFi Status	low	weak
Bluetooth Status	low	weak
Device Orientation	low	weak

diversity

stability

	unique	strong	medium	weak
stable	(UDID)			/ (total) Total Storage Device Color Device Type
high		URL Schemes Nth Picture Nth Contact		Timezone Jailbroken
medium		Process List System Uptime Device Name		Number of Videos iOS Version /dev (total) /private/var (total)
low		Free Storage /dev (used) /private/var (used) / (used)	Number of Contacts Number of Pictures	WiFi Status Bluetooth Status Device Orientation Battery Charge Level

Extracting Fingerprints

- ▶ Set of **independent** properties
- ▶ Scoring based on significance
 - Range of possible values
 - Outsider values are promoted
- ▶ Distance measurement

Extracting Fingerprints

- ▶ *Unique and stable* properties are used to reduce number of candidates for returning users
- ▶ Example: Device is black → remove all known white devices from candidates list

Extracting Fingerprints

- ▶ How to decide which properties are significant and independent?
- ▶ **Machine Learning**
 - Evaluation of machine learning algorithms using Weka 3
 - Machine learning algorithms select stable values
 - Dependencies are highlighted

Significant Properties

- ▶ J48 algorithm
- ▶ Unique classification
 - Hash value of 10th picture
 - Device type
 - Total disk space
- ▶ Hash value of 10th picture alone not unique?

Significant Properties

▶ Attribute Ranking:

- 0.9656 Hash value of 10th picture
- 0.8577 Number of contacts
-
- 0.5401 Facebook App installed

Some Math...

$$N(D) = \{D' : \sqrt{w_i(d_1 - d'_1)^2 + \dots + w_k(d_k - d'_k)^2} \leq t\}$$

Even more Math...

$$D = (d_1, \dots, d_n)$$

$$M(D) = \{D' \in \mathcal{D} : (|d_1 - d'_1| \leq t_1, \dots, |d_n - d'_n| \leq t_n)\}$$

Defense Strategies

▶ User

- Follow the crowd
- Actively use your device

▶ Platform owner

- Restrict access to system properties if possible
- Return inexact values (e.g. uptime in hours/days)

Future Work

- ▶ Extending the set of test devices
- ▶ Implementation for Android platform
- ▶ Development of fingerprinting framework

Conclusions

- ▶ Approach for mobile device fingerprinting
- ▶ Rather agile devices, still fingerprinting is possible
- ▶ Privacy threat / targeted advertising
- ▶ Unsatisfying countermeasures