

(Cross-)Browser Fingerprinting via OS and Hardware Level Features

Yinzhi Cao
Lehigh University
yinzhi.cao@lehigh.edu

Song Li
Lehigh University
sol315@lehigh.edu

Erik Wijmans
Washington University in St. Louis
erikwijmans@wustl.edu

Roadmap

- Background
- Design
 - Existing features
 - New features
 - Improvement of existing features
- Evaluation
- Conclusion

Background

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User Tracking

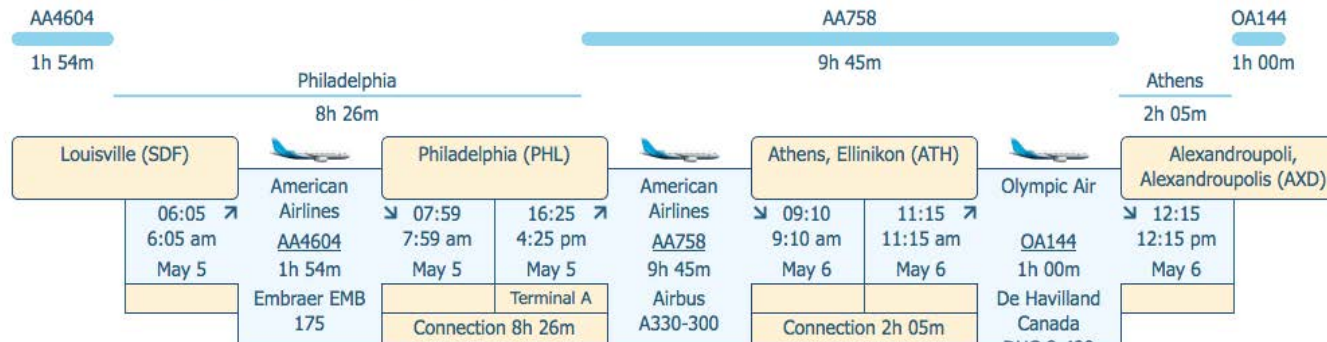


07:00 7:00 am May 5	Airlines AA3905 1h 50m Canadair CRJ	08:50 8:50 am May 5	16:25 4:25 pm May 5	Airlines AA758 9h 45m Airbus A330-300	09:10 9:10 am May 6	11:15 11:15 am May 6	12:15 12:15 pm May 6
		Terminal F	Terminal A		Connection 2h 05m	De Havilland Canada	
		Connection 7h 35m					

3. Flights Louisville - Philadelphia - Athens - Alexandroupoli, Total time: 23h 10m, American Airlines + Olympic ...

★★★★★ Rating: 2.9/5

[Journey description](#)



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Identifier

Stateful

- Definition: Identify users by previously stored information
 - Cookie
 - Supper cookie

Stateless

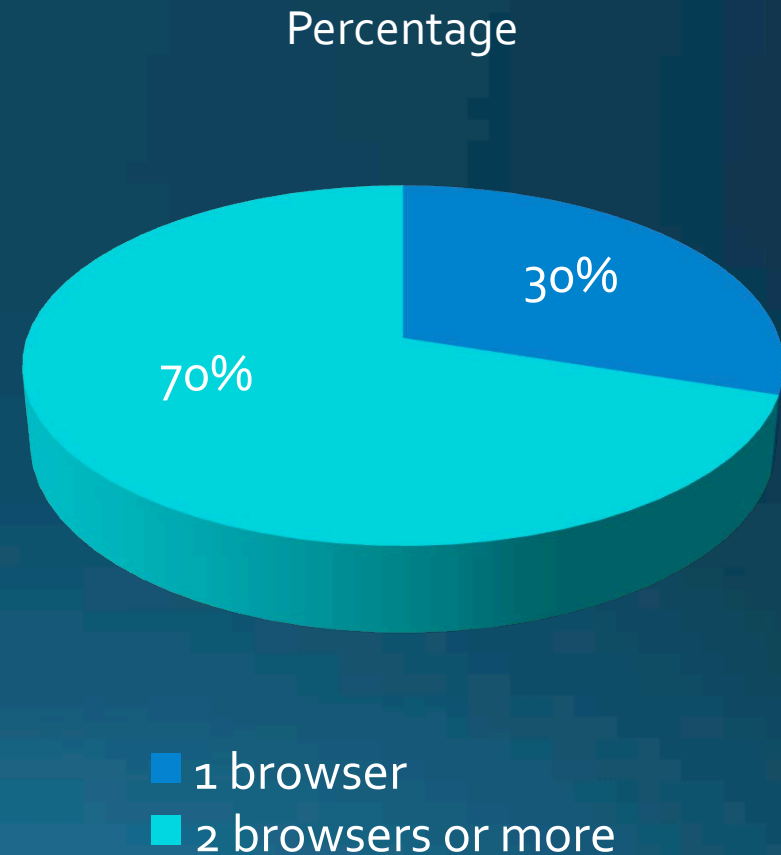
- Definition: Identify users by features without stored information
- AmlUnique^[1], Panoticlick^[2]
 - User agent string
 - List of plugins

[1]: Laperdrix, Pierre, Walter Rudametkin, and Benoit Baudry. "Beauty and the beast: Diverting modern web browsers to build unique browser fingerprints." *Security and Privacy (SP), 2016 IEEE Symposium on*. IEEE, 2016.

[2]: <https://panopticlick.eff.org/>

Cross-browser fingerprinting

- Survey Result: 70% of the surveyed users use two or more browsers regularly
- Problem: Single-browser fingerprinting can't identify user when changing browser
- Key Insight: Adopting hardware and OS level features
 - i.e., cross-browser invariant



Design

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A list of our features

Feature	Single-browser	Cross-browser
WebGL based GPU rendering result	Yes	Yes (Need Modification)
Supported language	Yes	Yes (Need Modification)
Number of CPU virtual cores	Yes	Yes
Screen ratio	Yes	Yes
List of fonts (JS based)	Yes	Yes (Need Modification)
Audio context	Yes	Yes (Need Modification)

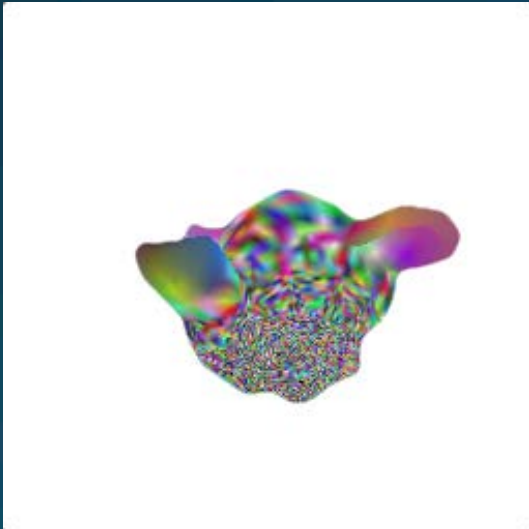
New features

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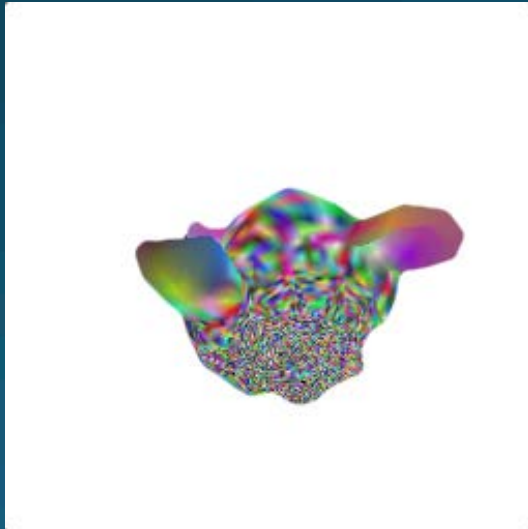
WebGL rendering

- Most of WebGL animations are rendered by GPU
- Different GPUs render pictures in different ways

Result of GPU 1



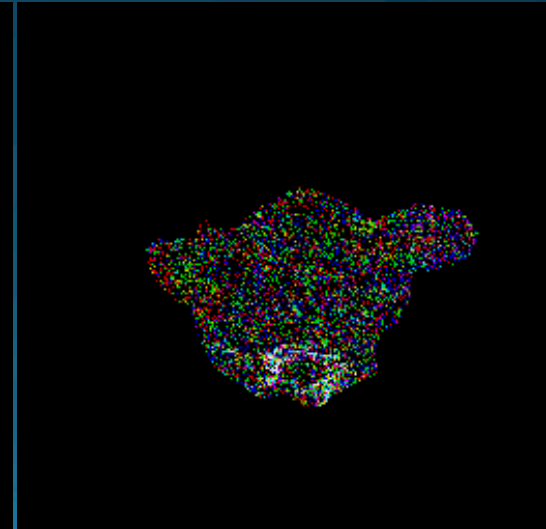
Result of GPU 2



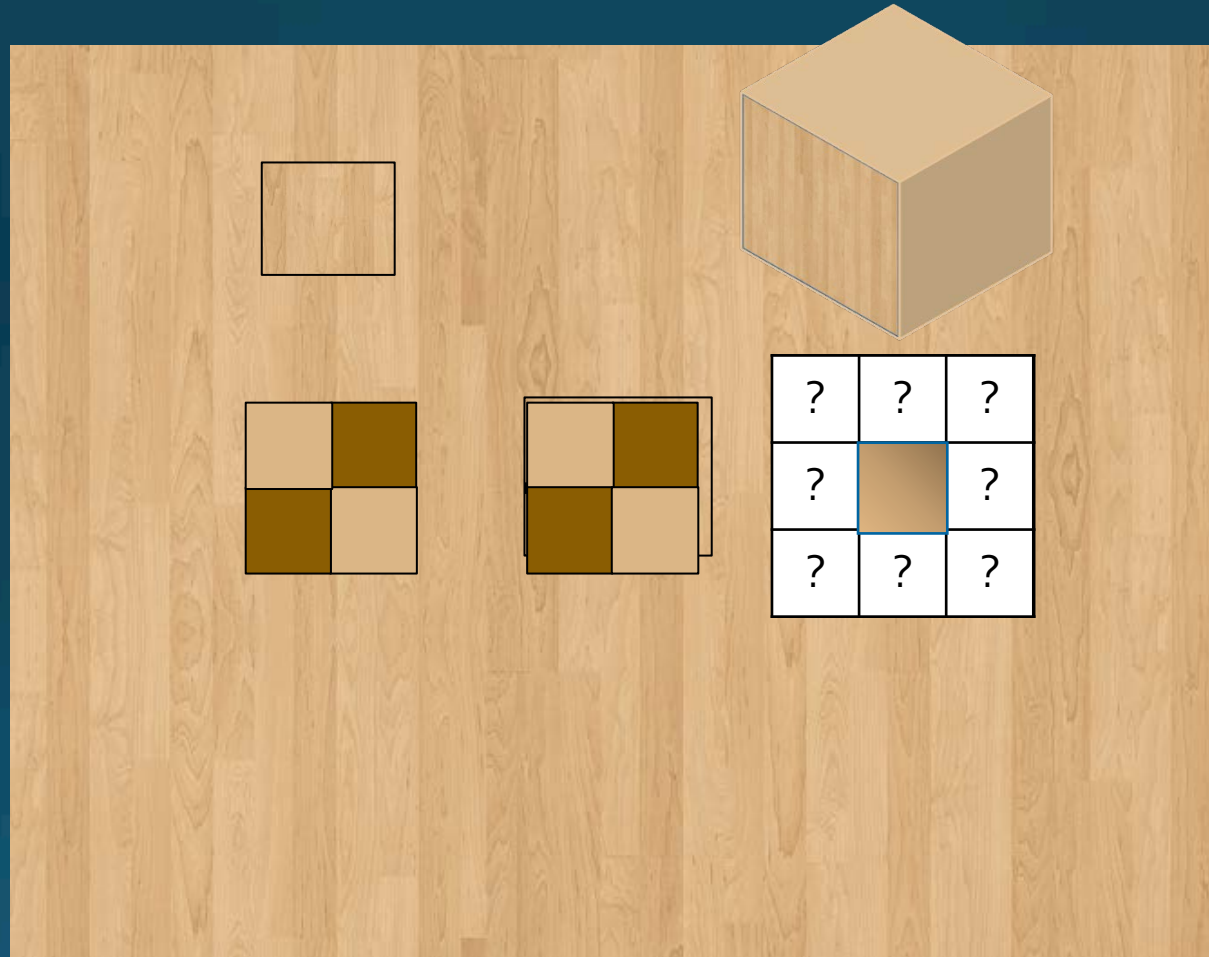
Subtraction of
result 1 and result 2



Subtraction of result 1
and result 2 (x200)



Example: texture mapping

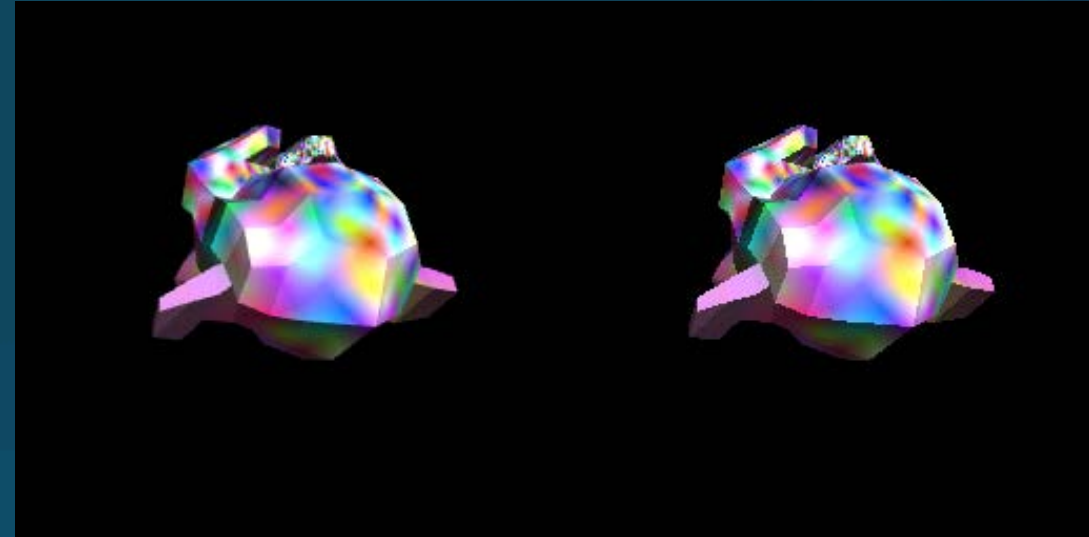


WebGL Rendering

- Texture
- Light
- Camera
- Model
- Transparency
- Complex Lights
- Anti-aliasing
- Special textures

Anti-aliased

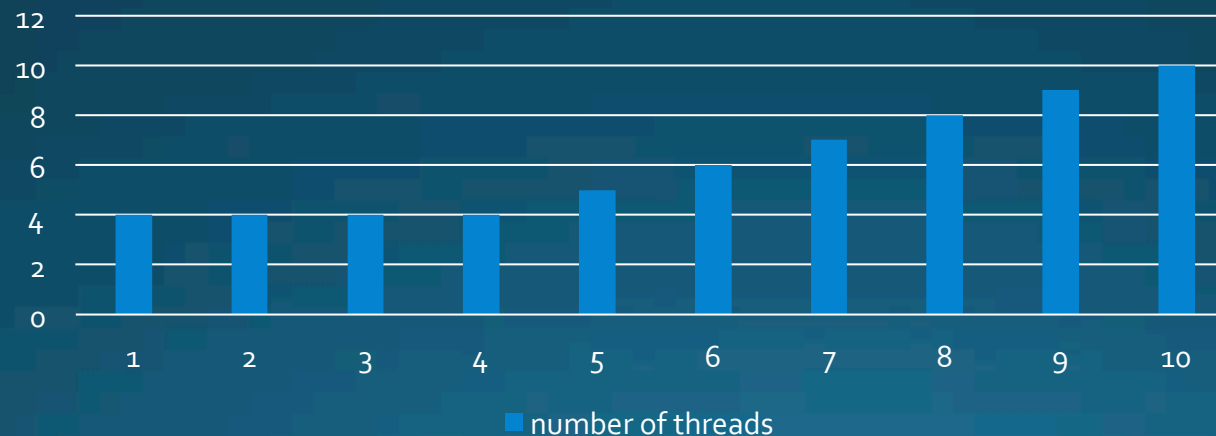
Not anti-aliased



Virtual CPU cores

- Ways to get
 - New API (`navigator.hardwareConcurrency`)
 - Side channel detection (Run different number of JavaScript workers and measure the time)^[3]

Example time usage of a 4 cores machine



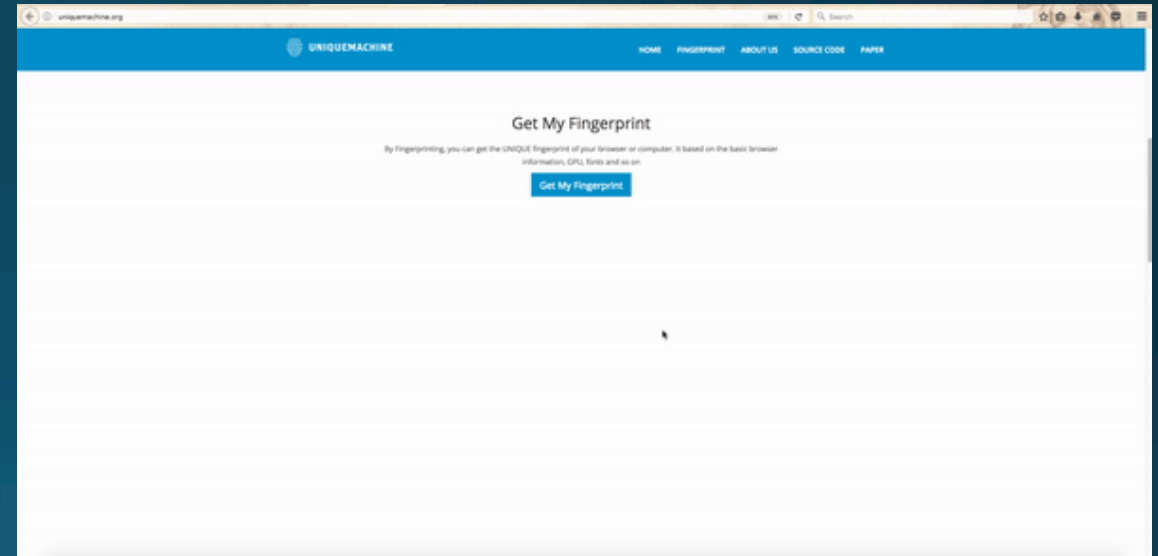
[3]: <https://github.com/oftn-oswg/core-estimator>

Improvement of existing features

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Screen resolution and depth

- Existing Solution: `screen.width`, `screen.height`
 - Including AmIUnique etc.
 - Not stable for even single browser
- Problem: affected by screen zoom levels
- Method to solve this problem
 - Use the detected resolution times zoom level
 - Screen ratio



Audiocontext

Fingerprinting audio card

- Method: Input some audio resources and capture the results^[4]
- Problem: Influenced by both browsers and audio card

Our improvement: AudioContext

- sampleRate (44100)
- maxChannelCount (2)
- numberOfInputs (1)
- numberOfOutputs (0)
- channelCount (2)
- channelCountMode (explicit)
- channelInterpretation (speaker)

[4]: Englehardt, Steven, and Arvind Narayanan. "Online tracking: A 1-million-site measurement and analysis." *Proceedings of the 2016 ACM SIGSAC Conference on Computer and Communications Security*. ACM, 2016.

List of fonts

- Method: JavaScript based^[5]
 - Try to use different fonts
 - If not installed, back to default font
 - Measure the width of characters

Default font
 αβχδεφγηηφκλμνοπθ
 ρστ
 Width 2 inches

Abadi MT Condensed light
 abcdefghijklmnopqrst
 Width 1.5 inches

- Improvement: Select different subsets from 4,422 fonts (based on different OS)
 - E.g., Segoe WP and FreeMono

[5]: <https://github.com/Valve/fingerprintjs2>

Evaluation

- Background
- Design
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Evaluation

- 3,615 fingerprints
 - Amazon Mechanical Turk
 - Microworkers
- All over the world

Normalized entropies

	Ours	AmlUnique	Panoticlick
User Agent	0.612	0.570	0.531
List of Plugins	0.526	0.578	0.817
List of Fonts(Flash)	0.219	0.446	0.738
Screen Resolution	0.285	0.277	0.256
Timezone	0.340	0.201	0.161
Cookie Enabled	0.001	0.042	0.019

Overall results

	Single-browser		Cross-browser		
	Uniqueness	Entropy	Uniqueness	Entropy	Stability
AmlUnique	90.84%	10.82			
Known features			68.98%	6.88	84.64%
Ours	99.24%	10.95	83.24%	7.10	91.44%

Uniqueness: The percentage of fingerprints which are unique in all fingerprints

Stability: The percentage of fingerprints which are same in different browsers

New features results

	Single-browser	Cross-browser	
	Entropy	Entropy	Stability
Screen Ratio	1.40	0.98	97.57%
List of Fonts (JavaScript)	10.40	6.58	96.52%
Audio Context	1.87	1.02	97.48%
CPU Virtual cores	1.92	0.59	100.00%
Writing Scripts	2.87	0.51	97.91%
GPU Texture test	3.5	2.26	81.47%
GPU Light test	3.52	2.27	81.23%
All cross-browser features	10.92	7.10	91.44%

Cross-browser Fingerprinting Uniqueness and Stability

Browser	Chrome	Firefox	Edge	IE	Opera	Safari	Others
Chrome	99.2% (100%)						
Firefox	89.1% (90.6%)	98.6% (100%)					
Edge	87.5% (92.6%)	97.9% (95.9%)	100% (100%)				
IE	85.1% (93.1%)	91.8% (90.7%)	100% (95.7%)	100% (100%)			
Opera	90.9% (90.0%)	100% (89.7%)	100% (100%)	100% (60.0%)	100% (100%)		
Safari	100% (89.7%)	100% (84.8%)	N/A	N/A	100% (100%)	100% (100%)	
Others	100% (22.2%)	100% (33.3%)	–	–	100% (50%)	–	100% (100%)

Uniqueness (Stability)

Observations

- Our fingerprintable features are highly reliable
 - The removal of one single feature has little impact on the fingerprinting results
- DataURL is implemented differently across browsers.

Conclusion

- Background
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 - New features
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Conclusion

Single browser

- Improved the uniqueness of existing work
 - 90.84% (AmlUnique) -> 99.24% (ours)

Cross browser

- A reliable and usable approach to fingerprint machine
- 83.24% uniqueness and 91.44% stability

Thank you!

- Website: <http://www.uniquemachine.org/>
- Questions?

