HarfBuzz at 20!

all you *ever* wanted to know about HarfBuzz and then some

behdad

a coffe-table deck for your skimming pleasure—January 2026

Agenda

- **HarfBuzz** History and state of the project
- **Rust** Addressing shaping needs in Rust
- **Standardization** Making changes to the font format
- **Moonshot** Beyond incremental advancements

HarfBuzz

C++ platform with a C library API
and accompanying cmdline tools

HarfBuzz

/hærfˈbɒːz/

From Persian حرف (***Harf***: letter) and باز (***Buzz***: open).
Transliteration of the Persian calque for *OpenType*.

noun

Industry-standard Open Source *text shaping* engine.

adjective

Insincerely talkative. *glib*. A nod to the project's GNOME origins.

What is HarfBuzz?

- To most clients: a ***text shaper***. That is, figure out what glyph shapes need to be displayed and at what positions, to show legible text on screen or in print, in every **language**, **writing system**, and **font**.

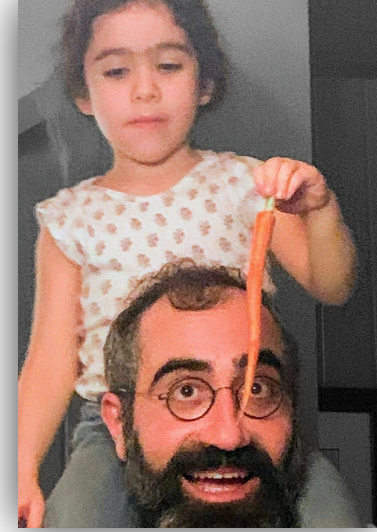
But a lot more, over the years:

- **Integration** glue to various platforms (FreeType, Cairo, GLib, ICU, …)
- A font ***subsetter*** and variable-font ***instancer***. Built on top of the same infrastructure, compiled to `libharfbuzz-subset`.
- More recently: **draw** (monochrome) and **paint** (color-fonts) APIs. No hinting support. Bring your own rasterizer.
- Text-shaping runtime ***tracing*** infrastructure as used in *Crowbar*, a shaping debugger by Simon Cozens, running in the browser on WebAssembly.

History

- **Started** in 2005 by Pango & Qt people to merge the text shaping engines.
- **Moved** to *freedesktop.org* to signal a cross-desktop shaping solution.
- I started a complete **rewrite** in 2006, which is the current HarfBuzz.
- Designed around a few foundational decisions, some of which required **C++**.
- Still, only exporting a clean and ergonomic **C API**.
- No *so-version* jump nor **API/ABI** break since ~2012. Neither on the horizon.
- **Replaced** three Open Source shaping engines: *Pango*'s, *Qt*'s, & *ICU Layout*.
- **Defensive** codebase with novel error-handling patterns that mitigate risk.
- *Extremely low* # of CVEs. Mostly DoS. Barely any crashers & no exploits.
- Code-base is ~100k lines of code. The text shaper is just a fraction of that.
- **Low bus-factor** 🙈. Mostly Khaled Hosny (maintainer) and I (primary developer) plus ~three occasional domain experts.

Vision: the `ffmpeg` of text shaping

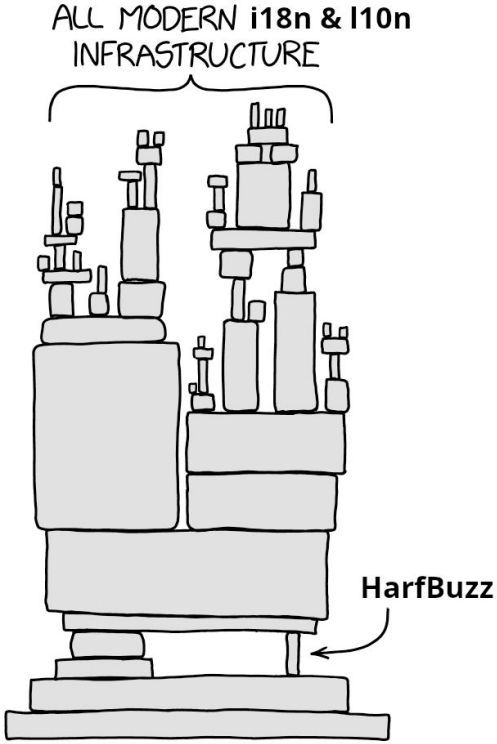


Ubiquitous, pragmatic, understands everything, survives bad input.

Adoption strategy (in hindsight):

- **Market-share** is king.
- Embrace **Open Source**.
- **Permissive license** to maximize reach (old-MIT).
- Linux desktop was *never* gonna be enough.
- Become the **industry standard** for text shaping.
- If we do our job **right**, nobody will notice.
- **Performance** that entices adoption.
- Unmatched **agility**. Zero-day Unicode updates.
- **Robustness** trumps **correctness**, which trumps **performance**. Achieve **all**.
- **Leverage** broad adoption to responsibly experiment at the font-format layer.

HarfBuzz shapes majority of text on modern screens.



Adoption: Open Source

- **Operating systems:** Android, ChromeOS, Linux distros (Fedora, Ubuntu, …)
- **Browsers:** Chromium, Firefox, WebKitGTK, Chromium derivatives…
- **Desktops:** GNOME, KDE, EFL, Flutter, GTK+ / Qt derivatives…
- **Apps:** LibreOffice, XeTeX, Inkscape, GIMP, VLC, VS Code & other Electron apps, Emacs, many others…
- **Programming languages:** Official OpenJDK Java implementation, .NET API (`HarfBuzzSharp` namespace).

Exceptions:

- ***Wine*** remains the only major Open Source platform to use its own text shaper. Porting to HarfBuzz is theoretically possible, but no one has tried.

Adoption: Proprietary

Many major proprietary platforms use HarfBuzz:

- **Google**’s Chrome, text-ads backend in the data-centers.
- **Adobe** Creative Suite: Photoshop, Illustrator, InDesign.
- **Microsoft** Edge, .NET, VS Code.
- **Amazon** Kindle & FireTV.
- Gaming consoles & engines.
- Smart TVs, car displays.
- Smart watches, VR headsets, other consumer gadgets .
- **Figma**, **Canva**, **Instagram**, etc, etc.
- Almost anywhere that cross-platform text layout is needed.

HarfBuzz: Correctness

- In the initial decade, trying to match Microsoft ***Uniscribe*** / ***DirectWrite***.
- Systematically compared to Uniscribe across a **Wikipedia** corpus. Joint work with Jonathan Kew of Mozilla and Roozbeh Pournader.
- Diverging from Microsoft when warranted and only to improve, *not* **laziness**.
- ***Rule of 2 out of 3***: When Microsoft **DirectWrite** and Apple **CoreText** disagree, side with one of them. Or improve on both.
- Over **6,000** shaping tests. Mostly developed in-house over 15 years.
- Heavily **fuzzed** for robustness, by *oss-fuzz* and Chrome fuzzing infrastructure.

Thanks to billions of users, HarfBuzz is now its own reference point.

market share

is

HarfBuzz: Design

- Robust, portable, user-friendly, correct, fast, memory-efficient, thread-safe.
- For fifteen years we resisted adding *barely any* caches whatsoever.
- Pluggable *unicode-funcs* and *font-funcs* make integration with existing Unicode & graphics systems a breeze.
- Alternative *backends* (Microsoft Uniscribe / DirectWrite, Apple CoreText, etc) make correctness & performance testing & comparisons effortless.
- Sanitization of `mmap`ed font then unchecked access of overlaid structs.
- HarfBuzz as the *universal shaping API*: On iOS, disable the HarfBuzz native shaper and bridge it to Apple's system CoreText library, saving 100s of kilobytes in mobile app binary size, while shipping the same HarfBuzz-using shared client code with Android. As seen in a *major* photo social-network app.

HarfBuzz: Codebase

- *Opinionated* coding. Loved by us, hated by others. Steep learning curve.
- Subset of C++11. *SFINAE*, *CRTP*, & other C++ patterns.
- Operator-overloading for transparent endianness conversion.
- Templates for code reuse.
- Custom subset of C++20 Ranges for functional pipelines.
- State-machines generated using `ragel`. Data tables packed using `PackTab`.
- Walking on the edges of *undefined-behavior*. Memory barriers to the rescue.
- Lock-free synchronization: atomic ints / pointers & `cmpexch`.
- Defensive coding: no `nullptr` or dangling-pointers. NULL regions & *Common Region for Access Protection* (CRAP).
- No required dependencies, not even the C++ STL. Many integration bridges.
- Little tech debt.

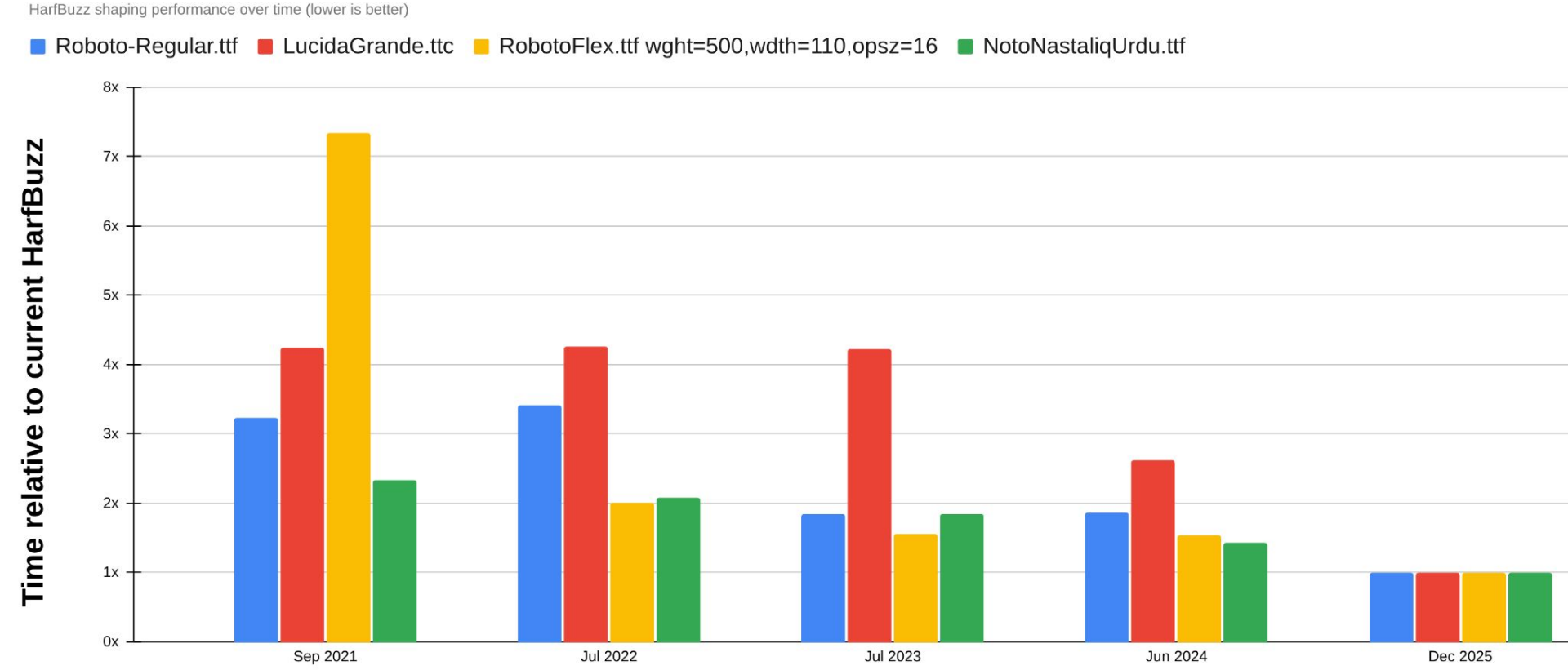
HarfBuzz: Performance

- Consistently most performant shaping engine in its class [discuss `kbts`]. 🏁
- Various novel data-structures, algorithms, and *fast-path*s at work.

Over the past five years:

- Trade kilobytes of cache memory per font file for significant speed gains.
- All caches are shared across threads with lock-free synchronization.

HarfBuzz: Performance improvements over five years



HarfBuzz: Core data-structures

In `shape`:

- **`hb_set_digest_t`** Fast negative filter for set of integers with locality.
- **`hb_cache_t`** Fixed-size bucket-based LRU int-to-int cache.
- **`PackTab`** Compact int-to-int mapping table generator.

In other parts of the library (`subset`, `draw`, `paint`, …):

- **`hb_set_t`** Sparse set-of-ints with locality.
- **`hb_map_t`** Custom hashmap.
- **`hb_decycler_t`** Lightweight DFS cycle detector.

HarfBuzz: Command-line tools

The font-engineer’s Swiss Army knife for text shaping & more.

- **`hb-shape`** The core of HarfBuzz shaping, from the command line, with all kinds of knobs and bells and whistles, producing textual / JSON output.
- **`hb-view`** Use Cairo graphics to render shaped text, including color fonts.
- **`hb-info`** Inspect fonts and extract various information.
- **`hb-subset`** Font *subsetter* and variable-font *instancer*, useful during font production, web-font serving, and printing.

An ecosystem of bindings and ports

Official supported on **`github.com/harfbuzz`**:

- **HarfBuzz:** C++ platform with a C API.
- **HarfRust:** High-fidelity Rust shaper port.
- **uharfbuzz:** Ergonomic Python bindings.
- **harfbuzzjs:** JavaScript & WebAssembly.

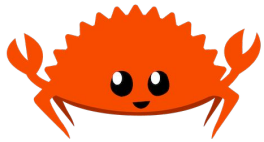
Numerous other bindings and ports too:

- **HarfBuzzSharp:** Part of .NET API.
- **ImageSharp:** Native .NET port.
- **go-text/typesetting:** Go port.
- **luaharfbuzz:** Lua bindings.
- **gobject-introspection:** Clunky auto-generated bindings.

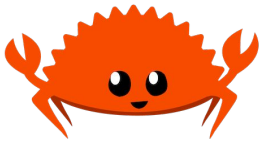
Rust

addressing *safe* shaping
prior art & our offering

`harfbuzz_rs`: Safe high-level bindings to HarfBuzz

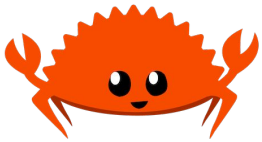


- Started in 2017 by Manuel Reinhardt.
- A high-level safe Rust API to HarfBuzz.
- On top of the `harfbuzz-sys` bindings.
- `harfbuzz-sys` bindings developed by Servo.
- Little adoption otherwise.



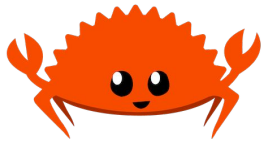
Allsorts: A clean-room text shaper implementation

- Started in 2019 by *YesLogic*, the creators of *Prince* HTML-to-PDF commercial solution.
- Contracted *Nate ‘n8willis’ Willis* to document what HarfBuzz does in its *complex* shapers.
- Clean-room implementation solely based on the OpenType spec and Nate’s produced docs.
- Using custom domain-specific language for font data parsing.
- Still active but incomplete: eg. missing the *Universal Shaping Engine* component, used by dozens of South-East Asian and other writing systems.



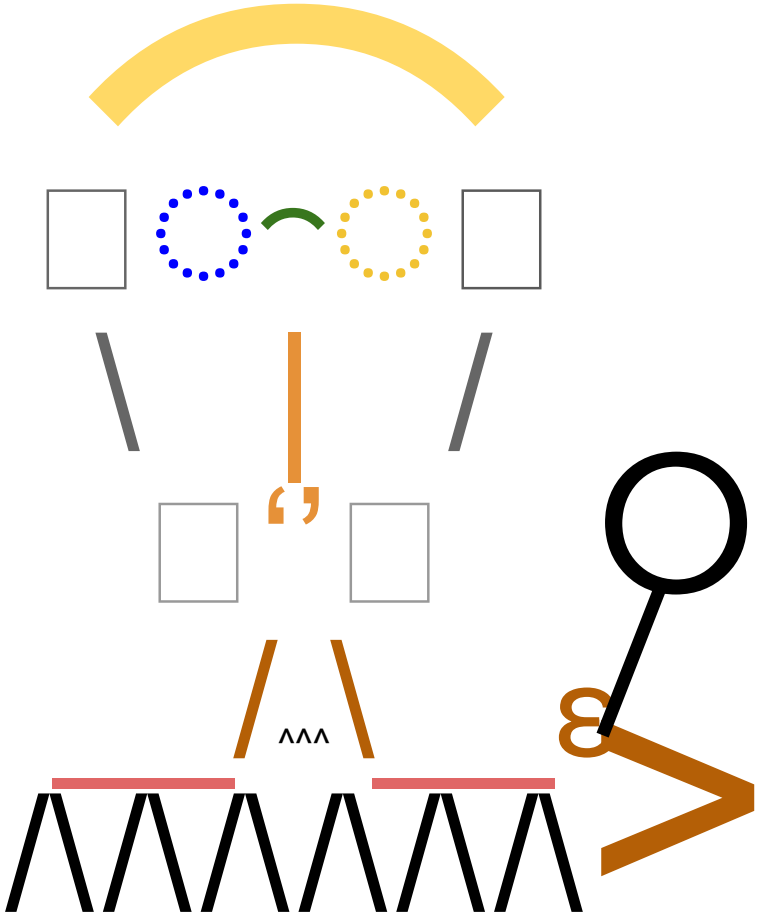
RustyBuzz: A fully safe port of HarfBuzz to Rust

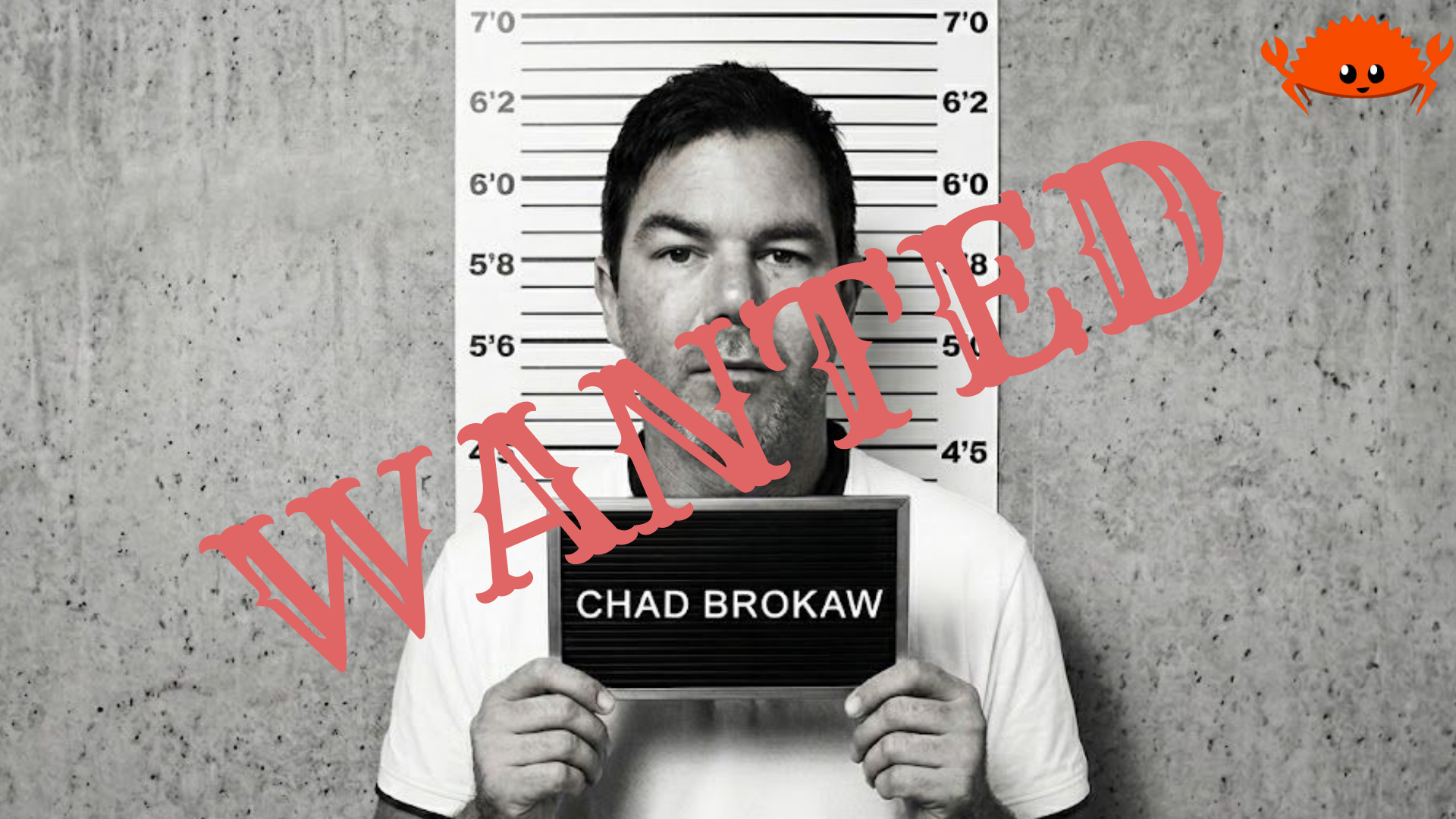
- Started in 2020 by the prolific *RazrFalcon*.
- Loyal port of HarfBuzz's shaping logic to fully safe Rust.
- Originally needed by RazrFalcon for `resvg`.
- Based on the `ttf-parser` crate (*RazrFalcon*, 2019) for reading font data.
- Was quickly and widely adopted, by `cosmic-text`, Typst, others.
- Deprecated by RazrFalcon in 2023.
- *Laurenz Stampfl* took over updating it to latest HarfBuzz code.
- Currently stale, matching HarfBuzz 10.1.0 from November 2024.
- For all realistic purposes, deprecated & unmaintained.



Swash: Because *why not*

- Started in 2021 by *Chad Brokaw* with great ambitions.
- Chad Brokaw's implementation from scratch because he's Chad Brokaw.
- Initially used in Chad Brokaw's Parley text layout engine.
- Chad Brokaw got offered a job by Google Fonts.
- Fortunately for the ecosystem, Chad Brokaw abandoned Swash.
- Chad Brokaw still addressing the Rust safe shaping need, at Google.

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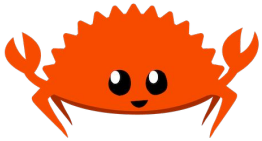
CHAD BROKAW
WANTED

Google Oxidize

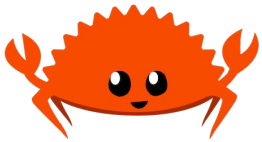


“Wherein we contemplate moving shaping, rasterization, font compilation, and general font inspection and manipulation from Python & C++ to Rust.”

—*Rod Sheeters*

Tech-lead & manager, Google Fonts

January 9, 2022

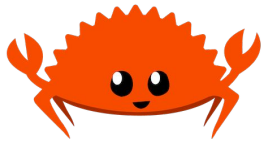


Google Oxidize

- Multiple full-time Google Fonts engineers allocated to the effort.
- *Fontations* set of crates: `font-types`, `read-fonts`, `write-fonts`, `skrifa`, `klippa`, …
- Use procedural macros to codegen font table compilation / decompilation code from semantic declarations.
- `skrifa` is the shape extraction library, replacing FreeType. Supports hinting: both font-side hinting & FreeType-style autohinting. Bring your own rasterizer.
- `fontc` replaces Python `fontmake` as the font compiler from various sources.
- Active and high-speed development.
- Text shaping *was* left at TBD.

HarfRust

one crate to rule them all

HarfRust

/hærfˈrɒːst/

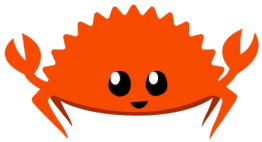
From Persian حرف (***Harf***: letter) and راست (***Rust***: true / straight).
Transliteration of the Persian calque for *TrueType*, the precursor to OpenType.

noun

The same trusty Open Source *text shaping* engine, in fully safe Rust.

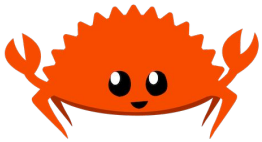
not to be confused with

RustType, a font rasterizer in Rust. Small fraction of *FreeType* functionality.



HarfRust: Safe, correct, and performant Rust port

- Born in 2024 as a fork of RustyBuzz by Chad Brokaw at Google Fonts.
- First (0.1.0) release in June 2025.
- Use Oxidize's `read-fonts` crate instead of unmaintained `ttf-parser`.
- Up to date with latest HarfBuzz shaper code.
- Always in sync with latest HarfBuzz release moving forward.
- Chad Brokaw as the lead & maintainer. I am a contributor.



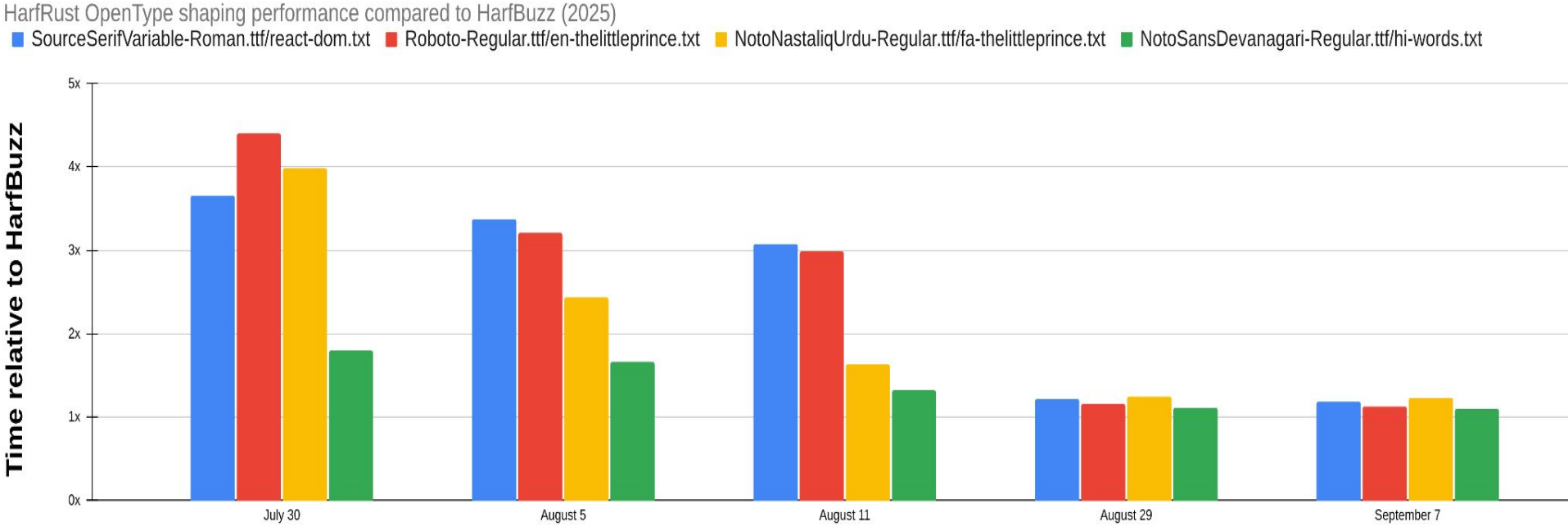
HarfRust: Notable users

- The venerable `cosmic-text` crate
- Parley text layout engine by Chad Brokaw, et al.
- Blitz browser
- Canva. They recently hired Raph Levien and are heavily invested in Rust graphics & text rendering stack.
- Several systems slow to jump at HarfRust, as C++ HarfBuzz mature & stable.
- **Soliciting commitment from other suitors.**
- **We will help you with *your* integration.**

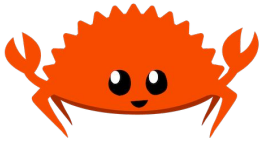
HarfRust: Correctness

- Fails **18** out of **6232** HarfBuzz shaping tests.
- Remaining fails are of legacy fonts or obscure historical cases that might never be needed / addressed.

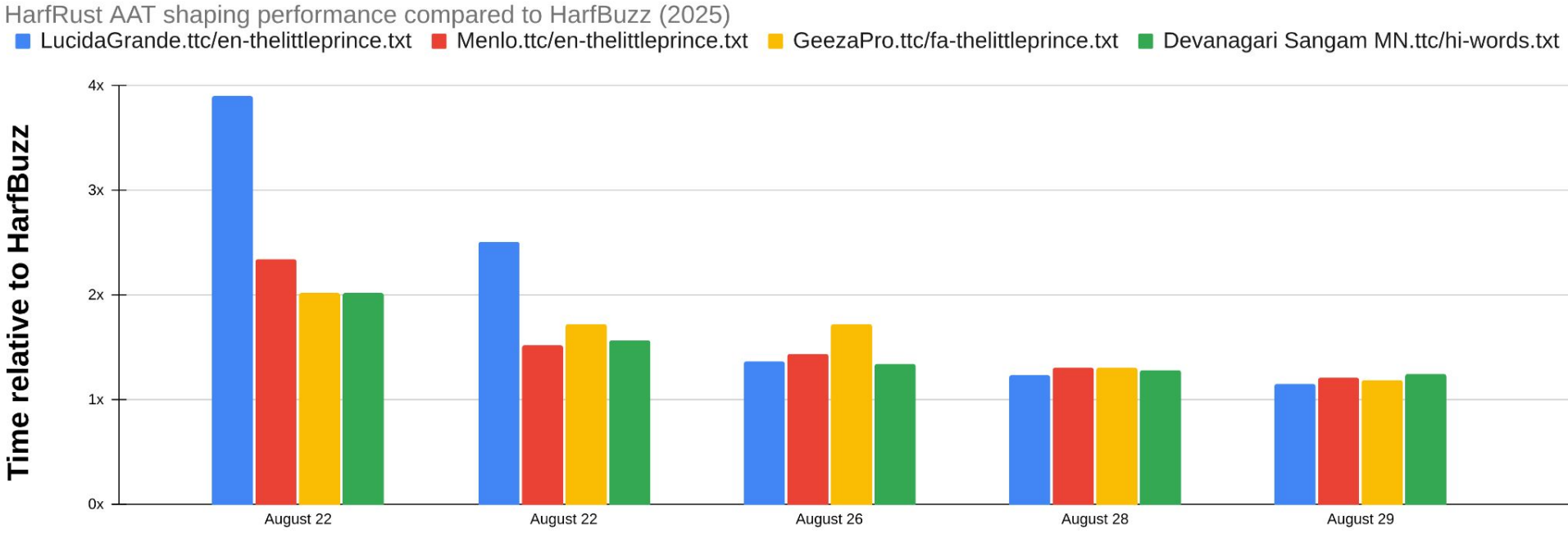
HarfRust: Performance: OpenType

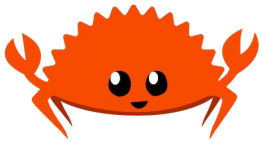


HarfRust: Performance: AAT



AAT is Apple's alternative to OpenType shaping, which while semi-retired, is still used in many Apple platform system fonts and hence important to browsers.



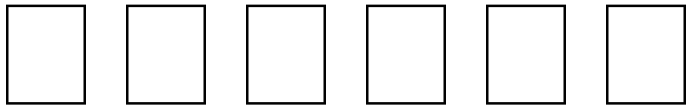


HarfRust: Performance Analysis

- All algorithmic and caching schemes from HarfBuzz ported.
- From 4x slower than HarfBuzz, down to <25% slower on key benchmarks.
- The gap has regressed since 🙈: different architecture for reading font data.
  - HarfBuzz does a *pre-sanitization* pass over the font table data, then uses unchecked access to clean `mmap()`ed pages during shaping.
  - HarfRust uses Fontations' codegen-ed structs & Rust checked array access.
- New optimizations frequently speed up HarfBuzz more than HarfRust.
- We are exploring making Fontations reading faster and embrace the pre-sanitization model. Early results are very promising.
- "C++ is still perf king for those who know how to hold it" —*Chad Brokaw*

Standardization

extending the font format



Font format as bottleneck

In 2014 while at Google, I noticed that:

- Google was commissioning the production of internationalized Noto fonts to Monotype and releasing those as Open Source fonts.
- Google ships such fonts in Android, and to Chrome via Google Fonts service.
- Android and Chrome use Open Source libraries HarfBuzz and FreeType, for text shaping and drawing respectively.
- The only part that we *didn't* have control on was the font format.

If we can extend the font format, we can unlock new kinds of innovation.

Font format innovation path: OpenType

- OpenType is the dominant font format specification.
- OpenType is property of Microsoft.
- Industry-wide collaborations with Microsoft have produced impressive results in the past: *variable fonts* and *COLRv1* for example.
- However, Microsoft's willingness to incorporate new changes in OpenType is subject to their engineering and editorial resource availability, which has *allegedly* been going down over the years.
- High chance of impasse. A different strategy is needed.
- After the *color fonts* snafu, Google reluctant to ship its own format extensions.
- Unless **standardized** or **shipped by another major player** first.
- In 2023, Apple silently shipped our proposed *avar2* technology. Chrome still *doesn't*.

Font format innovation path: ISO Open Font Format

- In mid 2000s, to curb competition, Microsoft donated a copy of OpenType to ISO for standardization.
- By 2007, ISO *Open Font Format* (*OFF*), formally known as ISO/IEC 14496-22 was born.
- Microsoft maintains OpenType as a separate specification to this day.
- ISO contribution process is slow, painful, and based on an “ad-hoc” working group’s consensus.
- The ad-hoc group’s recommendations are then voted on by the national delegations.
- The whole process takes between three to five years, from proposal to released standard.

Font format innovation path: ISO Open Font Format

- Chrome is reluctant to ship proposals before late stages of standardization.
- Android is reluctant to ship font format extensions not supported by Chrome.
- Chrome can be open to supporting what other platforms already support.
- This puts us in a double-bind: if we innovate in the file format, we either have to wait 4 years before Chrome will ship it, or hope that Apple would go ahead and ship it (and with no announcement for that matter).
- While in the meantime, Microsoft and Apple feel free to ship font format extensions in their products, and then *maybe* submit to ISO.
- This is a structural problem, not a failure of any single party.

Font format innovations: a timeline

- **1997** OpenType 1.0 was released by Microsoft and Adobe, bringing to an end the *Font Wars* of the 1990s. Documentation leaves a lot to be desired.
- **2000s** Microsoft support Indic scripts in *Uniscribe*, their shaping engine.
- **2007** *ISO Open Font Format* is released, as a derivative of OpenType.
- **2009** Introduction of Microsoft's proprietary *DirectWrite* as successor to Uniscribe, as *de facto* shaping standard.
- **~2012** Apple, Google, Microsoft, and Adobe+Mozilla each invented a different way to support color fonts. All four find themselves standardized at the ISO Open Font Format as competing techs.
- **2014** I organized an informal OpenType face2face meeting with Microsoft, Apple, Adobe, other experts to advance Indic-like text shaping.

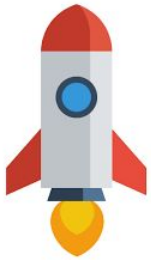
Font format innovations: a timeline

- **2015** Microsoft announced *Universal Shaping Engine* (USE), a more systematic and advanced version of HarfBuzz's homegrown *South-East Asian* shaper. HarfBuzz implemented USE quickly and HarfBuzz 1.0.0 was released on July 26, 2015.
- **2016** Based on industry-wide interest, Microsoft invited Adobe, Apple, and Google to collaborate together on what became *OpenType 1.8 Variable Fonts* on September 14th, 2016. The Open Source stack & Chrome are first to ship.
- **2017** Microsoft reduced resources to OpenType and font software drastically, assigning *Peter Constable*, the OpenType editor, to other projects.
- **2019** With *Dominik Röttsches* and others at Google, we proposed *COLRv1*. With Microsoft buy-in, the work was added to OpenType.

Font format innovations: our roadmap

- **2022** I proposed a set of changes collectively called *Boring-Expansion* to the ISO Open Font Format, with Google's financial support and backing. This is an incremental extension of the font format to address decades-long limitations. Other parties participated in technical discussions. The final result is due to be released as ISO spec in the first half of 2026. 🏁 [was it?]
- **2026** Started next phase of *Boring-Expansion*: new proposals to significantly speed up the slowest text shaping needs, code-named *layout-ng*.

Moonshot



WebAssembly *in* the font

Beyond-Emulation: WebAssembly for President!

- Time to *really* put the *smarts* into the *fonts*.
- Current code-*vs*-data boundary is quite arbitrary:
  - **Font file** provides *data* for how to convert from Unicode text into positioned glyphs.
  - **Layout engine** controls the layout based on font shaping result & Unicode properties. Sometimes with full programmability, as in *LuaTeX* or *SILE* typesetting systems.
- *Securely* inject programmability into the font file.
- *WebAssembly* already portable assembly format with tooling.
- *Generic* solution to many hard shaping problems.
- No *specific* shaping engine changes needed!
- Another use-case: *Graphite*, *DecoType ACE*, alt. shapers.

WebAssembly in smart-fonts! Parallel precedents

- OpenGL 1 fixed-pipeline	→	OpenGL 2+ / WebGPU *programmable* shaders
- Static web-servers	→	CGI, Perl, PHP, Python, JS… *scripting*
- CGI, etc, web-server scripting	→	WebAssembly in edge-computing
- Static web content	→	JavaScript / WebAssembly programming
- Linux physical servers	→	Linux as container of *many* virtual servers
- Pre-digital typesetting	→	METAFONT, TeX, LuaTeX

Beyond-Emulation: BIG question

Beyond-Emulation: the elusive Nastaliq style of Arabic

Requires collision-avoidance or approximation of:

- Easy to code in eg. C / Rust.
- Hard to express as data rules.

OpenType
(No mitigations)

OpenType
(Best effort)

WASM

Beyond-Emulation: Arabic typesetting

Many alternative models developed over the decades:

- *Graphite*
- *DecoType*
- *DigitalKhaatt*

Other custom-built solutions, some only available in Iran or Pakistan.

- We don’t *want* to standardize one solution. It would be way too *specific* for a *generic* font format.

Beyond-Emulation: SIL Graphite

SIL Graphite is an alternative shaping model to OpenType Layout.

Only Firefox, LibreOffice, XeTeX, and possibly minor clients support it, by configuring HarfBuzz with the extra `libgraphite2` backend.

Instead: compile `libgraphite2` to WebAssembly to embed in the font.

- 90kb `Wasm` table payload (40kb as WOFF2 compressed).
- 3x slower (with JIT) than natively compiled library.

Beyond-Emulation: how it looks like

`Wasm` table in the font includes the shaping bytecode. Currently HarfBuzz-centric.

```
#define HB_WASM_INTERFACE(ret_t, name) __attribute__((export_name(#name))) ret_t name

#include <hb-wasm-api.h>

bool_t
shape (void *shape_plan,
       font_t *font, buffer_t *buffer,
       const feature_t *features, uint32_t num_features)
{
  if (!shape_with (font, buffer, features, num_features, "ot"))
    return false;

  // Modify buffer;

  return true;
}
```

Beyond-Emulation: how it works

- Proof-of-concept experimental implementation in HarfBuzz.
- Using the nimble `bytecodealliance/wasm-micro-runtime` C API.
- The runtime lacks basic security features like *timeboxing*.
- WebAssembly specification still *very* heavy-handed on instances:
  - Memory allocations happen in multiples of 64kb.
  - No virtual address-space or memory mappings between the host and the guest.
  - Multiple address-spaces envisioned but not fleshed out in the spec.
  - Acceptable performance *unachievable* without runtime instance sharing.
- Rust might have more battle-tested WebAssembly host runtimes.
- Fonts have been built both from C / C++ and Rust shaping logic code.
- `https://github.com/harfbuzz/harfbuzz-wasm-examples`
- `llama.ttf`, `translate.ttf`, etc.

Beyond-Emulation: where to go from here

- Research-level project for the foreseeable future.
- Might never happen in browsers & operating-systems.
- Maybe just enabled by trusted **desktop-publishing** systems.
- Rewrite the WebAssembly shaping API to be more independent of HarfBuzz internal data representations.
- Assess implementing in HarfRust using a Rust-based WebAssembly host.
- Viewed another way: a HarfBuzz-originated text shaping ***plugin*** **system**.
- Ultimately: a solution to the ***font format extension*** **bottleneck**.