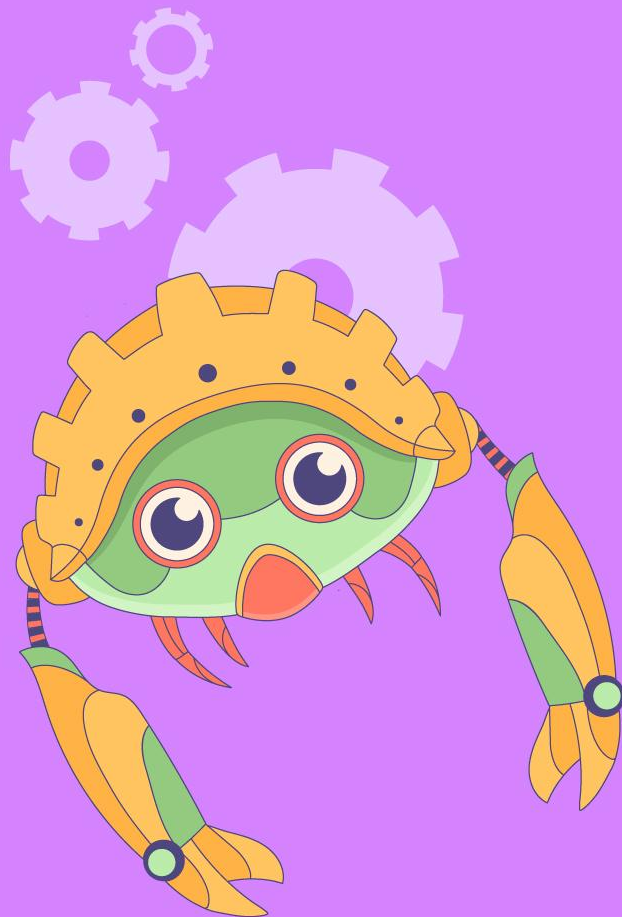


Raph Levien

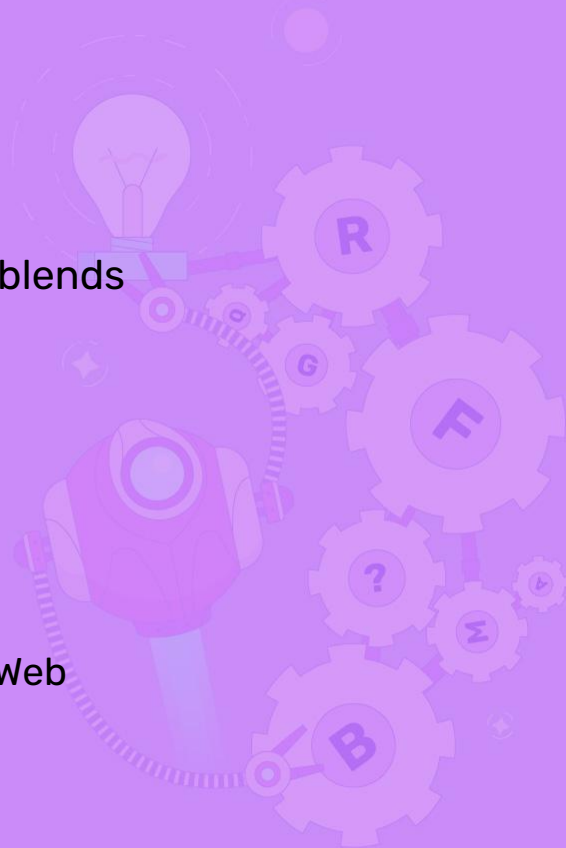
Research Software Engineer, Google Fonts

# Vello: high performance 2D graphics



## ▶ OUTLINE

- Vector graphics imaging model
  - fills, strokes, gradients, text, images, clips, blends
- Offload nearly all rendering work to GPU
  - fast, cheap encoding
  - needs clever algorithms on GPU
- Suitable for highly dynamic scenes
  - does not rely on precomputation
- Written on top of WebGPU
  - good implementations for both native and Web
  - can interop with other wgpu applications



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# USE CASES

When to use Vello?

- Basis for high-performance UI
  - drawing layer for experimental Xilem UI toolkit
  - especially for apps with rich content: graphics editors, CAD, etc
- Vector animations
  - Experimental velato crate for playing Lottie animations [demo]
- 2D vector graphics games
- Scientific visualizations

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# SCENE ENCODING

GPUs are wicked fast; can the CPU keep  
the GPU busy?

- CPU-side scene encoding can be bottleneck
  - GPU can outrun it
  - Traditional approach: `&mut RenderContext`
  - restricted to single thread
- Encoding goals:
  - support both retained and dynamic data
  - simple and fast to encode
  - support parallel decode on GPU
  - support multithreading
  - be flexible (support diverse clients)
  - be compact (reduce upload bandwidth)

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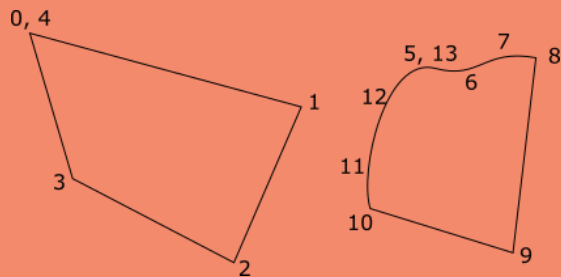
# SCENE ENCODING

GPU-friendly techniques for a complex  
data type

- Scene fragments
  - can be built on multiple threads
  - can be retained
  - “append with transform”
- Variable length path encoding
  - i16 or f32 coordinates
  - last point of previous segment overlaps with first point of next
  - 1 byte tag per path segment
  - new: stroke cap/join styles

# PATH ENCODING

Prefix sums for the win!



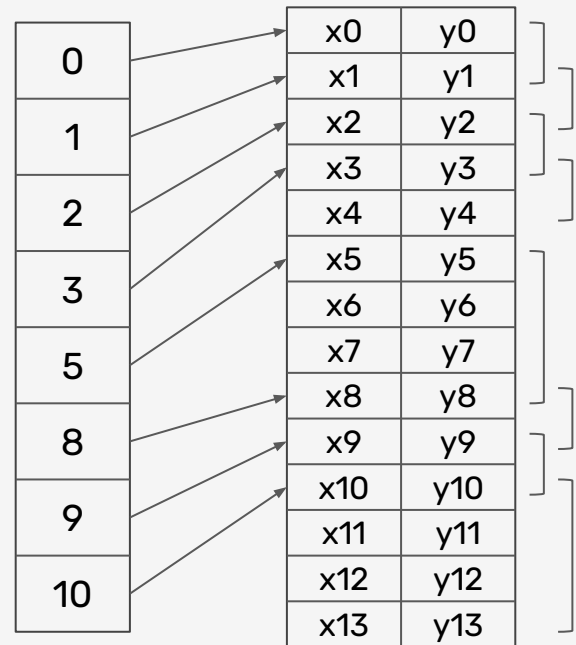
path tag

lineto
lineto
lineto
lineto + end
curveto
lineto
lineto
curveto + end

size

1
1
1
2
3
1
1
4

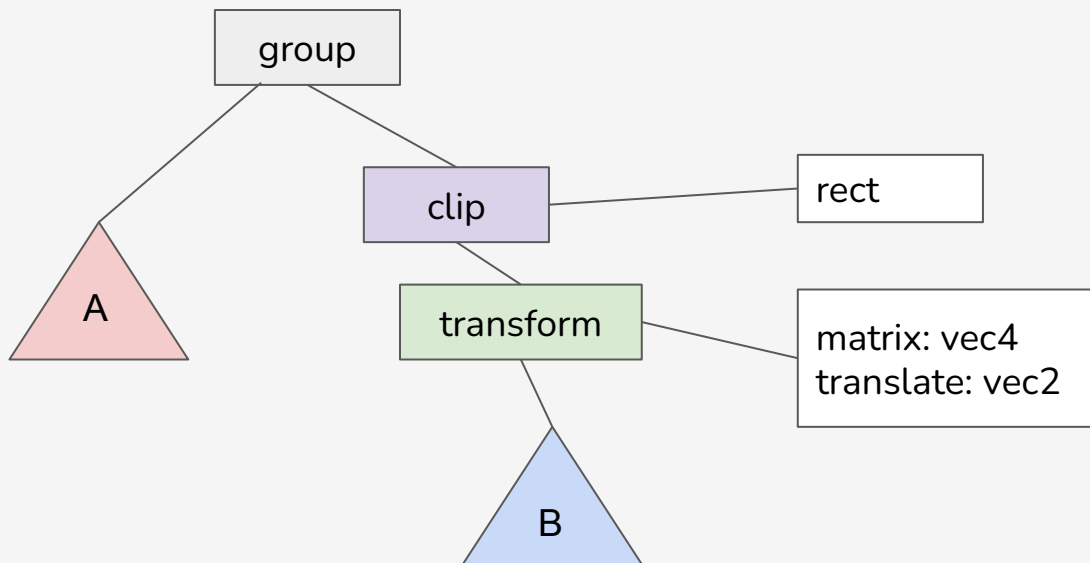
index



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# MULTI-STREAM ENCODING

Efficient manipulation of scene data

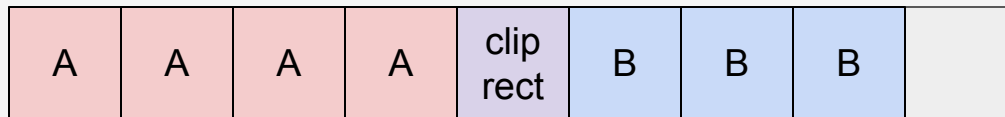


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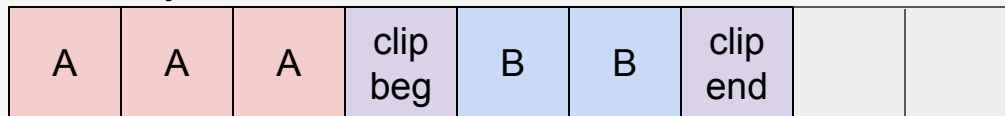
# MULTI-STREAM ENCODING

Efficient manipulation of scene data

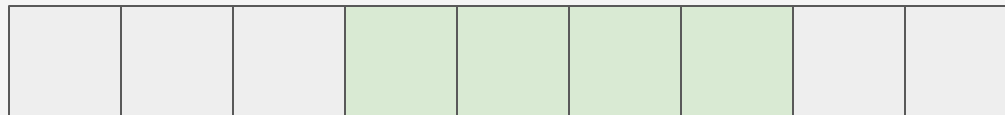
Path data



Draw objects



Transforms





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# FONT LOADING / TEXT

The hard part of any 2D graphics API

- Still a prototype, but rapidly coming into focus
  - Currently using fello crate, migrating to fontations
  - developed by Google Fonts team, used in Chromium
- Glyph run API
  - Vello draws glyph runs, applications do layout
  - prototype parley paragraph layout
  - integration with Cosmic text
- Supports variable fonts
  - including animation of parameters [demo]
- Future: glyph caching, hinting
  - rendering is currently all dynamic vectors

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# BUILDING ON WGPU

Being part of a broader ecosystem

- Back-ends for Vulkan, D3D, Metal, even OpenGL
- web-backend targeting wasm [[demo](#)]
- interop with other wgpu-based applications
  - prototype of Bevy integration
- integration can go in two directions
  - Vello produces textures for rendering in 3D scene
  - 3D (or other) render becomes texture composited by Vello

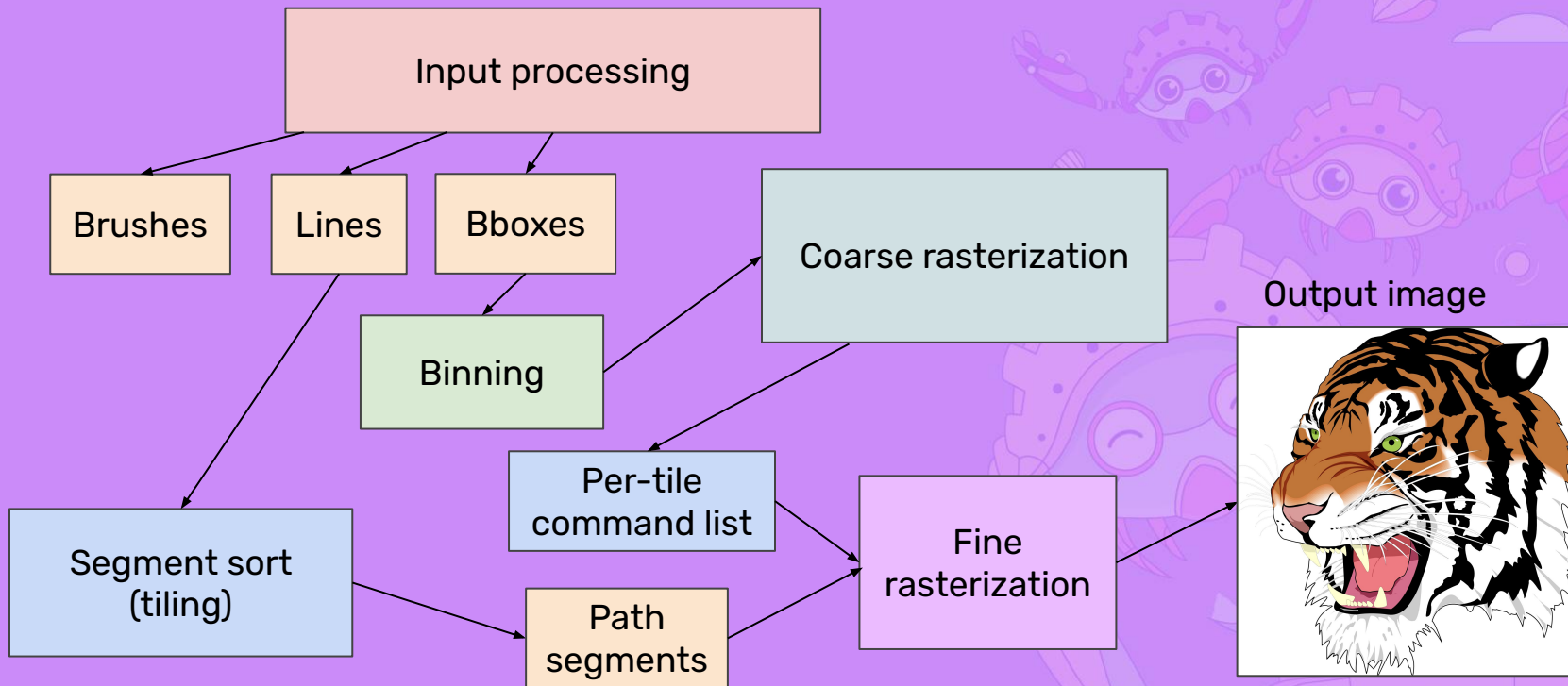
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# PIPELINE OF COMPUTE SHADERS

An exciting but challenging computing platform

- Approximately 10x throughput vs CPU
- Can support complex data structures and algorithms
  - scenes are inherently tree structured (clips and blends apply to children)
  - many patterns based on prefix sum
  - global reach of data dependencies, yet still efficiently parallel
  - stack monoid algorithm for parentheses matching
  - computation of bounding boxes of deeply nested clips
- WebGPU brings portability, proper spec, tools

## ► Architecture overview

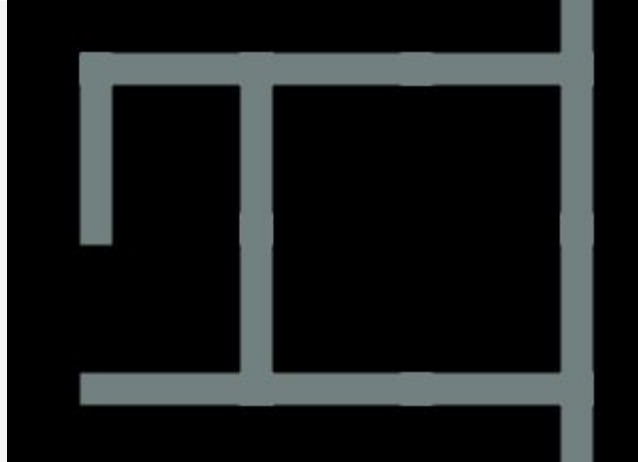


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# MULTISAMPLED PATH RENDERING

Conflation artifacts and their solution

area  
anti-aliasing



←  
conflation  
artifact

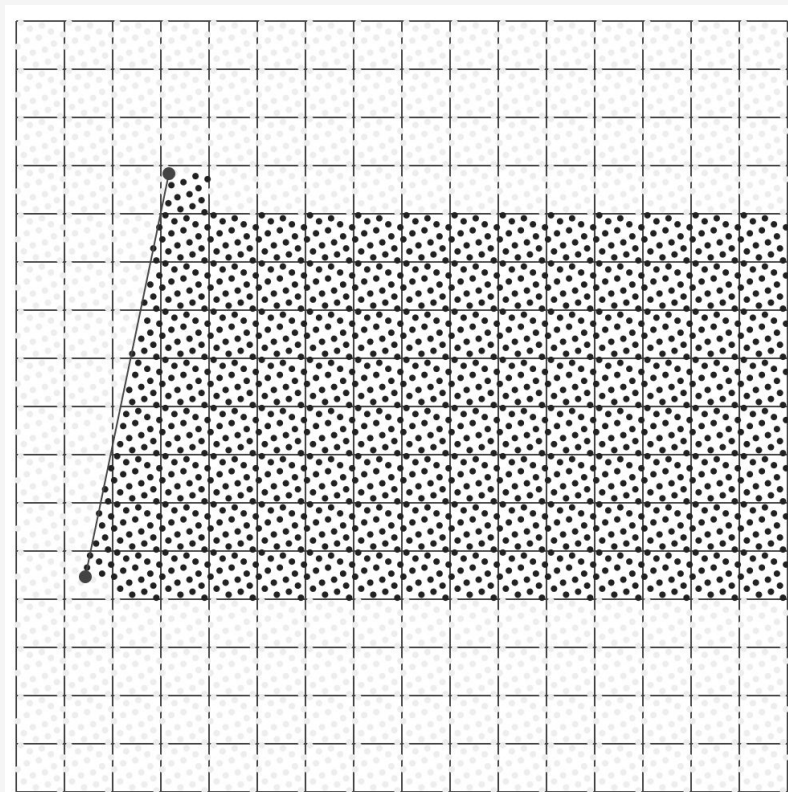
multi-  
sampled  
anti-aliasing



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# MULTISAMPLED PATH RENDERING

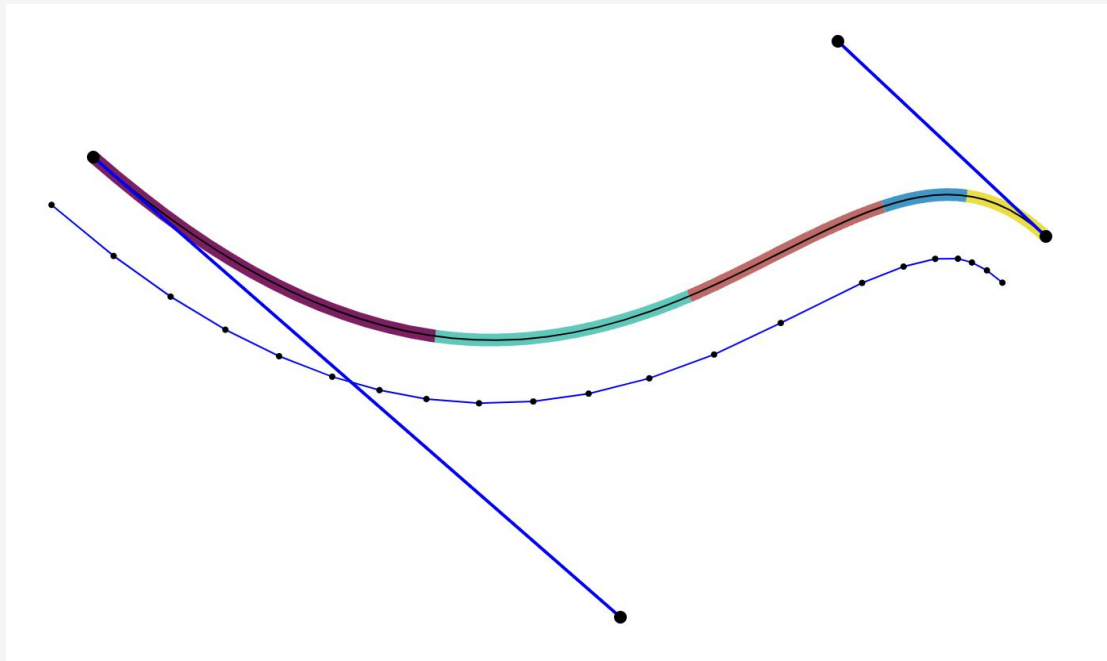
Lots and lots of winding number  
evaluations



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# EULER SPIRAL STROKING

A mathematically elegant curve for solving  
a thorny problem



[demo]

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# INTEGRATIONS

When to use Vello?

- Rive-bevy [demo]
- Path rendering in Skia Graphite back-end (experimental)
- vong game by Spencer Imbleau
- Blitz (UI renderer for Dioxus)
- HelloPaint by Lucas Meurer (Rust version in development)

GPU shaders adapted:

- PhETSIM (JavaScript)
- Gio UI (Go)
- Traverse Research project (game)



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# ROADMAP

Lots of work to do

- 0.1 release
  - polishing and robustness work
- writeups and documentation
- image filters
- glyph hinting and caching (issue 204)
- descriptor indexing for more efficient images

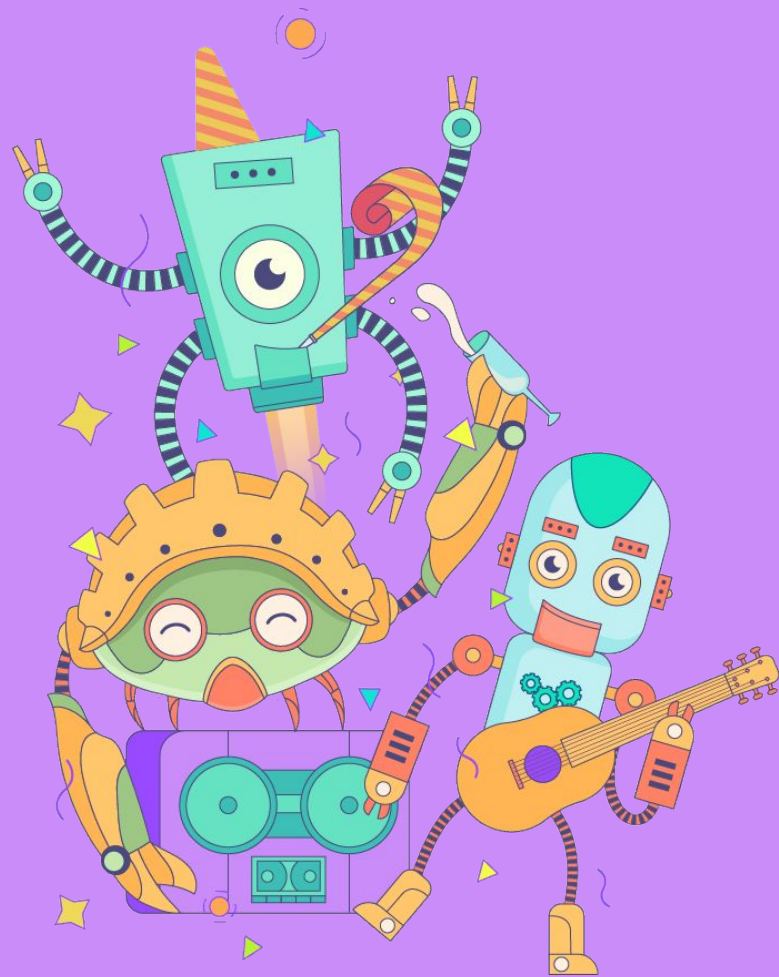
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# GET INVOLVED

A vibrant community effort

- repo: [linebender/vello](https://github.com/linebender/vello)
- discussion: [xi.zulipchat.com](https://xi.zulipchat.com)
  - Vello mostly in #gpu stream
- Weekly [office hours](#)

Thanks for  
listening!  
Questions?



# RAPH LEVIEN

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