Slides: http://khr.io/webgl2webinar

Khronos Webinar

WebGL 2.0 is Here: What You Need To Know

2017 April 11

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Logistics

- Submit your questions
  - We'll answer them at the end
  - Please include a slide number if needed
- Open the slides on your computer
  - If you want to try the demos without lag
  - http://khr.io/webgl2webinar

Background on WebGL

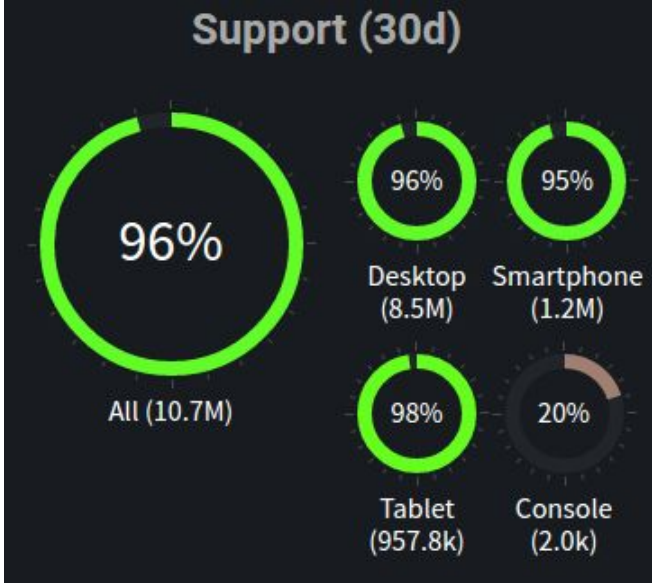
- WebGL 1.0 was released in 2011
  - Exposed 3D rendering to the Web Platform for the first time (GL ES 2.0)
- Used for all kinds of 3D presentation on the web today
  - Artists showcase their work on Sketchfab, with over 1 million models shared and embedded across the web
  - The New York Times publishes visualizations in Three.js
    - Jupiter and Its Moons
    - The Dawn Wall, El Capitan's Most Unwelcoming Route
  - Create amazing, fast, and interactive mathematical visualizations using MathBox

Background on WebGL

- Also widely used in web games
  - Via cross-compilation (asm.js/WebAssembly)
    - Unity's HTML5 target
      - Publish Unity games straight to the Web with HTML5 and WebGL
  - And by pure-web 3D and game engines - mostly open-source
    - PlayCanvas, Turbulenz, BabylonJS, Three.js, …
    - WebGL-accelerated 2D game engines
  - For WebVR content
    - A-Frame, Three.js, …

Why target WebGL?

- Everyone has a web browser
  - No installation
  - WebGL (1.0) “just works” almost everywhere!
    - WebGL Stats - 96%
    - caniuse - 91%
- Many ways to using WebGL
  - Engines, libraries, etc.



And now...

WebGL 2.0 is here!

- WebGL 2.0 now available in Chrome/Firefox!
  - Firefox: Released on all platforms (January)
  - Chrome: Released to desktop platforms (January) - Android coming (late April)
  - Edge/Safari: Plan to ship WebGL 2.0
  - Desktop support already at 58% [WebGL Stats]
- WebGL 2.0.0 conformance status
  - Spec & test suite on track for ratification by Khronos
    - Very thorough - runs 10x longer than WebGL 1.0 tests
  - Chrome
    - Windows/macOS/Linux/Android: Passing 100% in Chrome 58
  - Firefox
    - Windows/macOS/Linux/Android pending; very nearly conformant

WebGL 2.0: Features at a Glance

- WebGL 2.0 exposes the OpenGL ES 3.0 feature set
  - Brings desktop and mobile platforms' features much closer together - better portability
- Many WebGL 1.0 extensions now core
- Features
  - Many sized texture formats
    - Integer/float textures
  - 3D textures, 2D texture arrays
  - Immutable textures
  - Full non-power-of-two texture support
  - Instanced drawing*
  - Multiple render targets*
  - Transform feedback
  - True integer vertex attributes
  - Multisampled renderbuffers
  - Many shading language upgrades
    - texture level-of-detail sampling control (important for physically-based rendering)
    - uniform blocks
    - in/out variables instead of "attribute", etc.
    - control over layout in the shader

*Available via extensions in WebGL 1.0

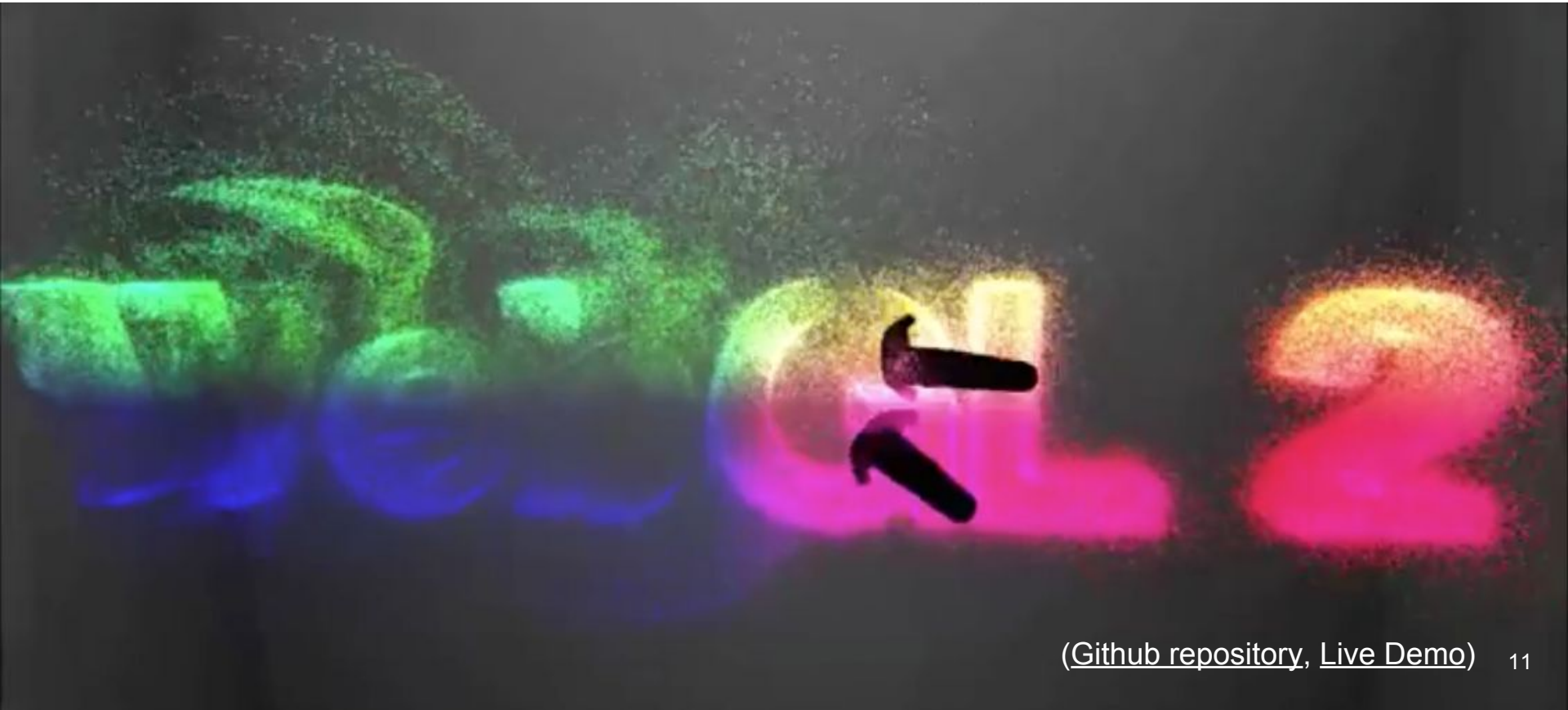
WebGL 2.0: Features at a Glance (continued)

- Features
  - Seamless cubemaps
    - Important for physically based rendering pipelines; can finally use mipmap generation effectively
  - Performant GPU-side copy/compute operations
    - Upload textures from pixel unpack buffers, read pixels into pixel pack buffers, copying between buffers
    - Transform feedback
    - When used in conjunction with 3D textures and 2D texture arrays, have much more computation ability than WebGL 1.0
  - Uniform buffers, Vertex array objects, Sampler objects
  - Query objects, Sync objects

*Available via extensions in WebGL 1.0

Teasers

WebGL 2.0 + WebVR



PlayCanvas: *After the Flood* [Video]

Procedural clouds
Procedural water ripples and reflection
Leaf particle system
Animated trees
Mirrored surfaces
Dynamic lights
Online asset streaming
Runtime lightmap baking
& more

moz://a
POWERED BY PLAYCANVAS

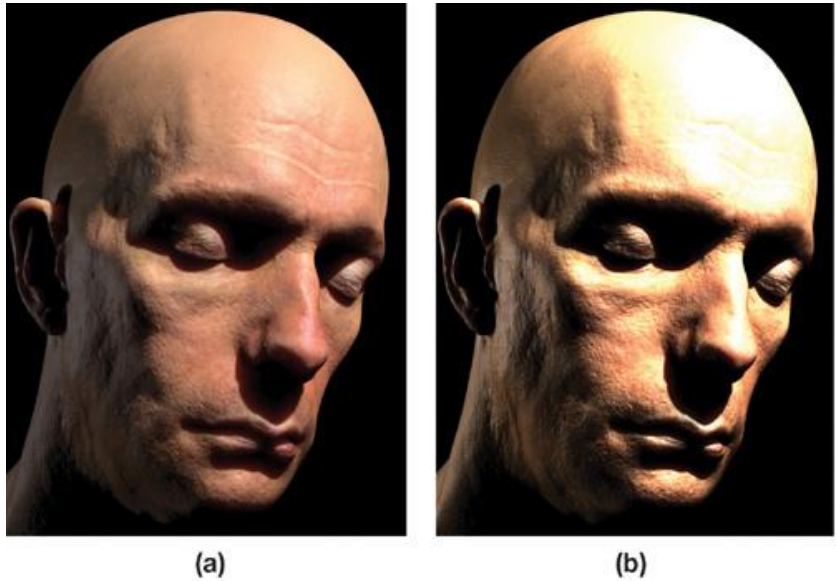
Feature Tour

- With more demos!
  - (And some info on the techniques)
- Featuring:
  - WebGL 2 Samples Pack
    - Short and easy to understand code samples demonstrating WebGL 2.0 features
    - Trung Le & Shuai Shao, Patrick Cozzi
  - WebGL 2 Examples
    - Standalone rendering algorithm demos implemented in raw WebGL 2.0
    - Tarek Sherif

Textures: More Formats

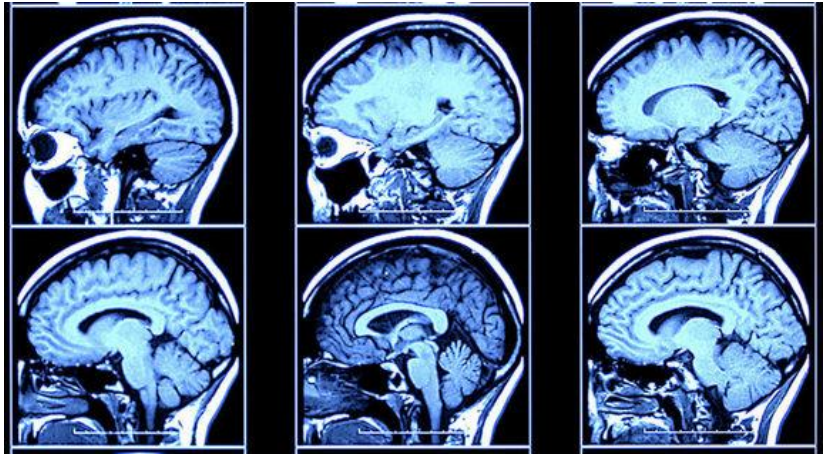
- Floating-point textures, unsigned/signed integer textures
  - A shader can read from and write to a texture with accurate values
    - No losing precision, no clamping (no need to worry about range)
    - Deferred rendering, scientific computation, etc.
  - 8bit, 16bit, 32bit signed/unsigned integer formats; 16bit, 32bit floating-point formats
  - Demo: Integer textures for RNG in Monte-Carlo simulations [Evgeny Demidov]
  - Samples Pack: simple integer texture demo

Textures: More Formats



- sRGB formats
  - Textures for linear rendering techniques [GPU Gems; non-web] (pictured)
  - Gamma correction applied before sampling & filtering - more correct
  - Essential for high dynamic range rendering & Physically based rendering
  - Samples Pack: simple sRGB texture demo
- ETC2/EAC compressed textures via extension
  - (Removed from core spec due to lack of hardware support on desktop platforms.)

Textures: 3D Textures



- 2D texture arrays & 3D textures
  - Volumetric rendering techniques[1] & simulation (fire, smoke, fog, etc.)
  - Medical imagery[1]
  - Cached lighting effects
  - Procedural textures[1]
  - NVIDIA's smoke box demo
  - Has been emulated before in WebGL 1.0, for example in Vicomtech's demos, but now supported natively
  - Samples Pack:
    - Texture array demo, 3D texture demo

[1] GPU Gems chapters

Textures: “Immutable” textures

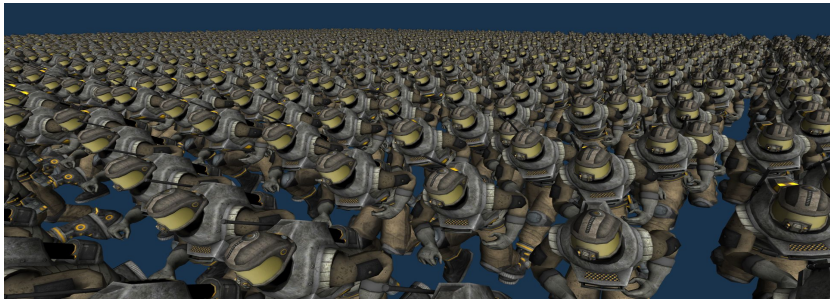
- Dimensions/format/type will not change once initialized
  - Better performance - driver optimizations
  - When implementing WebGL on top of Direct3D, saves a lot of CPU memory
    - Direct3D doesn’t allow level-by-level texture uploading
    - A copy of all levels have to be kept in CPU for mutable textures
- Demo: Flat Wave (immutable RG32F) [Evgeny Demidov]
- Samples Pack: simple demo

Textures: Others

- Full support for non-power-of-two textures
  - Filtering, wrapping, and mipmapping of non-power-of-two textures
  - Long-requested feature; now it’s portable across devices
- Seamless cube maps
  - Used in physically based rendering pipelines
  - Now supported directly

Instancing

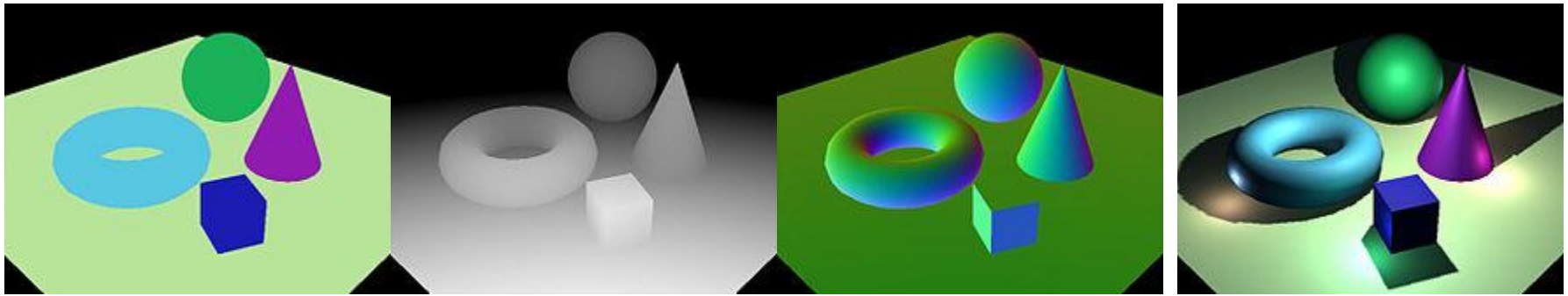
- To draw 1000 soldiers
  - WebGL 1: **1000** draw calls, with different position, posture uniforms, etc.
  - WebGL 2: Only **1** instanced draw call
  - Big performance improvement



- Demos:
  - Three.js demos:
    - instancing demo (single triangle)
    - indexed instancing (single box), interleaved buffers, dynamic updates
  - Brandon's first demo of the extension:
    - WebGL instancing with ANGLE_instanced_arrays
  - Crowd demo [Github] (pictured)
  - Samples Pack: simple demo
  - Google Maps' 3D mode uses instancing support
    - Reduces vertex buffer size by 6x (!) - thanks aappleby@ for the info

Multiple Render Targets

- Allow rendering to multiple framebuffers in one pass
  - Multiple fragment outputs from one fragment shader: gl_FragData[...]
- Critical for deferred shading (and related techniques)
  - Render the entire scene just once, into a series of intermediate textures
  - Efficiently shade with many dynamic lights - shade the intermediate textures once per light



[images due to Astrofra via Wikipedia]

Multiple Render Targets

- Big performance gains for many types of scenes (and hardware)
  - N+M compute instead of N*M… but higher memory load!

- Demos
  - webgl2examples: Deferred Rendering [Tarek Sherif]
  - WebGL Deferred Shading [Sijie Tian, etc.] (pictured)
  - Deferred Irradiance Volumes [Florian Bösch]
  - Deferred Rendering [m_panknin]
  - Spiral waves in excitable media [Evgeny Demidov]

Transform feedback

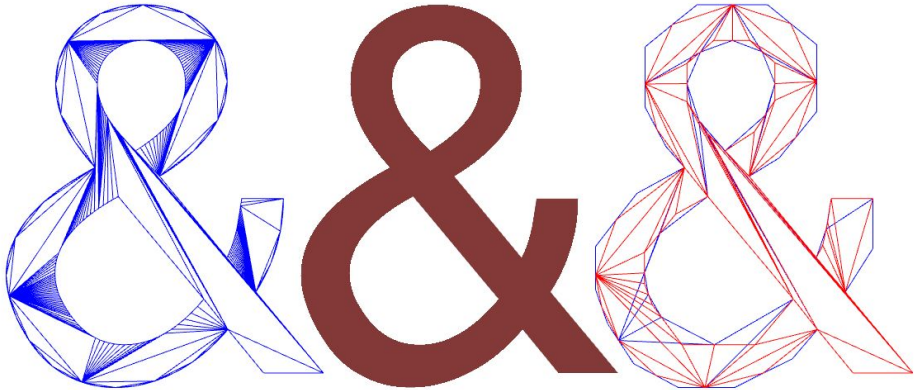
- Save the output of the vertex shader directly into a vertex buffer object
  - Optionally skipping rasterization
- Caching and reusing GPU computation
  - Crowd demo [Github]
    - Instanced rendering of many skinned object
    - Skinning computations for just the few variants, instead of per-instance
- Stateful particle systems
  - Interactive particle demo [Github]
    - Per-particle state, birth/death, steps physics each frame
  - *After the Flood*: particle system leaves
  - Lorenz strange attractor [Evgeny Demidov] (pictured)
  - Samples pack, webgl2examples
- Non-web OpenGL examples:
  - OpenGL 4.0 review [Christophe Riccio], Noise-Based Particles advection shader [Philip Rideout]

Integer vertex data

- Go hand-in-hand with transform feedback, as well as integer texture support
  - E.g. maintain a pseudo-random number generator's state per-vertex
- More generally:
  - Can send multiple integers into the vertex shader
  - Perform logical and arithmetic operations on them
  - Output them (to fragment shader or transform feedback)

Multisampled renderbuffers

- Efficient antialiased offscreen rendering
  - User controls number of samples dynamically
  - Useful for implementing techniques like vector curve rendering
    - Three.js vector curve rendering (pictured), Rendering SVG paths in WebGL
  - Advanced operations on multisample data
  - Samples Pack: simple demo



Performant GPU-side copy/compute operations

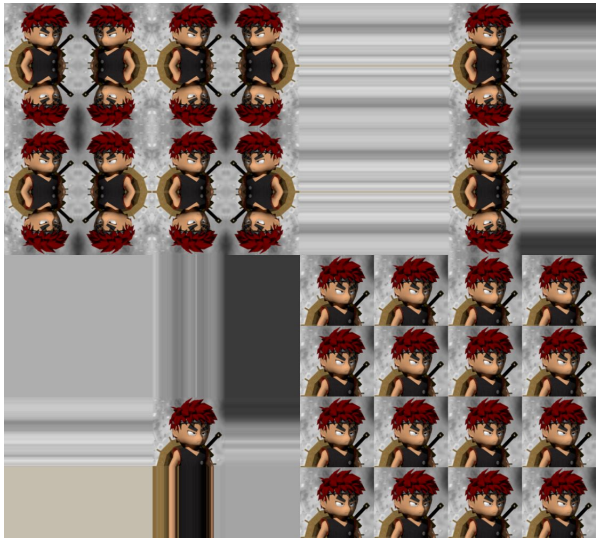
- Copies between textures, pixel buffer objects
- Transform feedback
- Rendering to 2D texture arrays and 3D textures
  - Rendering to slices of 3D textures [Evgeny Demidov]
  - Samples Pack: rendering to texture array
- Many volume rendering algorithms [GPU Gems]
- With 3D textures and 2D texture arrays, 3D GPU fluid simulations

More features for performance optimization

- Uniform buffers (potentially significant speedups)
  - Allows updating many uniforms in a batch with one API call
  - samples pack, webgl2examples
- Vertex array objects (also a WebGL 1.0 extension)
  - Encapsulates all state that is associated with the vertex processor
    - Holds references to the vertex buffers, index buffer, and layout specification
    - Usually set up once - much quicker to switch VAO than all vertex state
- Occlusion queries
  - Used to determine if a render will be visible
    - E.g. occlusion-query a bounding box to see if it's visible, for culling
  - Samples Pack: simple demo

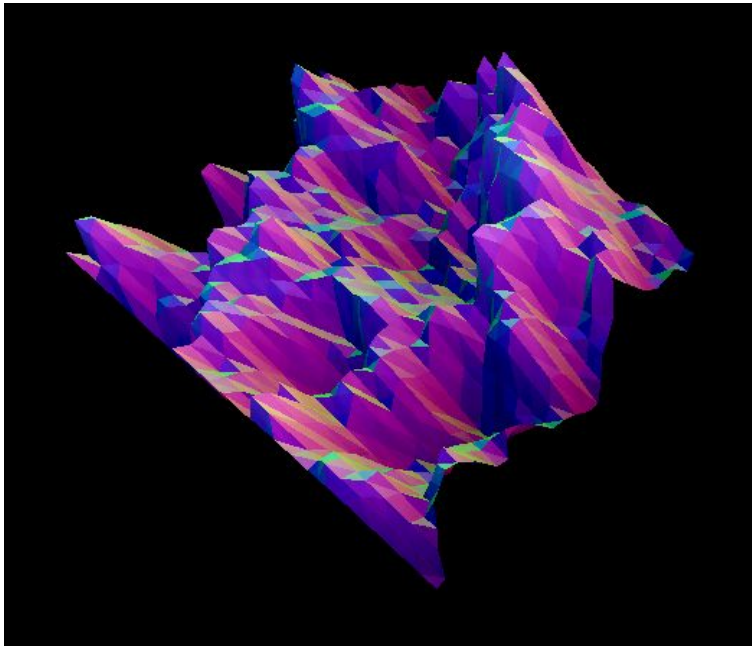
Sampler objects

- Stores the sampling parameters for texture access inside of a shader
- Use N samplers with M textures - N+M objects instead of N*M
- Samples Pack: simple demo (pictured)
  - One texture with 4 different samplers



GLSL ES 3.00: `#version 300 es`

- Samples Pack:
  - Texture lookup in vertex shader, e.g. terrain, bump mapping (pictured)
  - Centroid interpolation
  - Fragment discard
  - Flat/smooth interpolators
  - Non-square matrices
  - Sampling mipmapped textures by LOD
  - …



And more!

- There are more features not listed here
- And many new effects not yet implemented
  - Anything that's possible with OpenGL ES 3.0
    - Terrain Rendering with Geometry Clipmaps [ARM Mali Developer Center]
    - …

- Dive in with the WebGL 2.0 Spec
  - Check out WebGL 2 Samples Pack for minimal examples

PlayCanvas: *After the Flood*

- Techniques used
  - HDR+MSAA rendering (floating point + multisampling)
  - Using z-buffer as a texture (depth textures)
  - Procedural clouds (3D textures)
  - Hardware percentage-closer filtering for shadow maps
  - Alpha to coverage
  - Particle system leaves (transform feedback)

WebGL 2 Examples - Tarek Sherif

- https://github.com/tsherif/webgl2examples
  - Rendering algorithms implemented in raw WebGL 2
  - Order-Independent Transparency & Screen Space Ambient Occlusion
    - Vertex Arrays,
      Uniform Buffers,
      Multiple Render Targets,
      Float Textures,
      texelFetch, Instancing
  - Depth of Field (pictured)
    - Vertex Arrays,
      Uniform Buffers,
      Depth Textures,
      texelFetch, Instancing

Looking Forward

- What's in the future?
  - Compute shader extension
    - For advanced effects and GPGPU computation
    - Parallel data structures & algorithms
    - Physics simulations
    - Ray tracing
    - AI? Neural networks?
    - …
  - A next-generation web graphics API
    - Widespread interest from developers and browsers to create a new Web graphics API
      - Pre-validated design to reduce draw call overhead
      - Implementable with excellent performance on Vulkan, Metal, and D3D12
      - Secure design for the Web
      - JavaScript & WebAssembly

Conclusion

- The amazing power of the graphics processor is available to web developers
- WebGL 2.0 provides a much needed upgrade to the capabilities
  - OpenGL ES 3.0 feature set
  - Will enable more amazing applications to be built

- Now we need you:
  What will you create with these graphics capabilities?

Many thanks to the many WebGL 2.0 contributors

- **Khronos Group**
- **ANGLE team**
  - Geoff Lang, Jamie Madill, Corentin Wallez, Shannon Woods
- **NVIDIA Mobile Graphics Team**
  - Olli Etuaho, Kimmo Kinnunen, Amal Prabhu, Barthold Lichtenbelt
- **Intel Web GPU Team**
  - Yunchao He, Qiankun Miao, Yang Gu, Xinghua Cao, Jiawei Shao, Yizhou Jiang, Guanxian Li, Chenglei Ren
- **Firefox team**
  - Jeff Gilbert
- **Chrome GPU team**
  - Brandon Jones, Victor Miura, & many more
- **WebGL working group members**
  - Mark Callow, Rafael Cintron (Microsoft), Dean Jackson (Apple)
- **Mobica** (Janusz Sobczak and team)
- **Unity**
  - Jonas Echterhoff, Christophe Riccio, Marco Trivellato, ...
- **WebGL2Samples Pack team**
  - Trung Le & Shuai Shao, Patrick Cozzi; University of Pennsylvania
- **PlayCanvas, Sketchfab, Floored, Google Maps**
- **The Three.js community**
  - esp. Ricardo Cabello
- **...and many more community collaborators**
  - **Authors of linked demos**
  - Tarek Sherif, BioDigital
  - Alec Miller, Figma
  - Evgeny Demidov
  - Florian Bösch
  - m_panknin
  - Sijie Tian
  - …

Appendix: WebGL 2.0 Feature List

- OpenGL Shading Language ES 3.00
- 2D array and 3D textures
- Multisampled renderbuffers
- Transform feedback
- Uniform buffer Objects
- Vertex Array Objects
- Sampler Objects
- Pixel Buffer Objects
- Buffer-to-Buffer Copies
- Boolean occlusion queries
- Instanced rendering
- Multiple render targets
- Texture storage specification
- R and RG textures
- Seamless cube maps
- Non-power of two textures
- Texture LOD clamps
- Mipmap level base offset and max clamp
- At least 32 textures, at least 16 each for vertex/fragment shaders
- 16-bit and 32-bit floating-point textures
- 32-bit, 16-bit and 8-bit signed and
- Unsigned integer format renderbuffers, textures and vertex attributes
- 8-bit sRGB textures and framebuffers
- 11/11/10 floating-point RGB textures
- Shared exponent RGB 9/9/9/5 textures
- 10/10/10/2 unsigned normalized and unnormalized integer textures
- 10/10/10/2 signed and unsigned
- normalized vertex attributes
- 16-bit floating-point vertex attributes
- 8-bit-per-component signed normalized textures
- Sized internal texture formats

Questions?

- WebGL spec, GitHub, mailing list, etc.
  - webgl.org
- WebGL 2 Samples Pack
  - github.com/WebGLSamples/WebGL2Samples
- Tarek Sherif's WebGL 2 Examples
  - github.com/tsherif/webgl2examples

- Ken Russell and Zhenyao Mo also here for questions