Create Web AR Experiences

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Focus on standalone AR

- Native AR
  - ARCore
  - ARKit
- Web AR
  - WebXR ⭐
  - Alternatives
    - AR.js (marker, GPS)
    - MindAR (image, face)
    - and more!

cover picture: Artem Bryzgalov https://unsplash.com/@abrizgalov

Setup: testing on your mobile

- Check that your smartphone can read QR codes
- **iOS**
  - default Camera app
- **Android**
  - use Google Chrome + scan button
  - or install a **trustworthy** QR code scanning app like **Trend Micro**
- Other 100% web based alternatives
  - webqr.com
  - qrcodescan.in

Native AR

ARCore

ARKit

ModelViewer

Check if your device supports Native AR

- on your **mobile**, open

https://modelviewer.dev/

- click on the AR icon
- see the astronaut in AR 🎉
  - uses SceneViewer (Android)
  - or QuickLook (iOS)

Android

http://storage.googleapis.com/ar-answers-in-search-models/static/mandalorian/grogu/grogu.glb

- **GLB** file format
- Native **SceneViewer**
  - uses Google's **ARCore**
  - realistic lighting
- ARCore supported devices

iOS

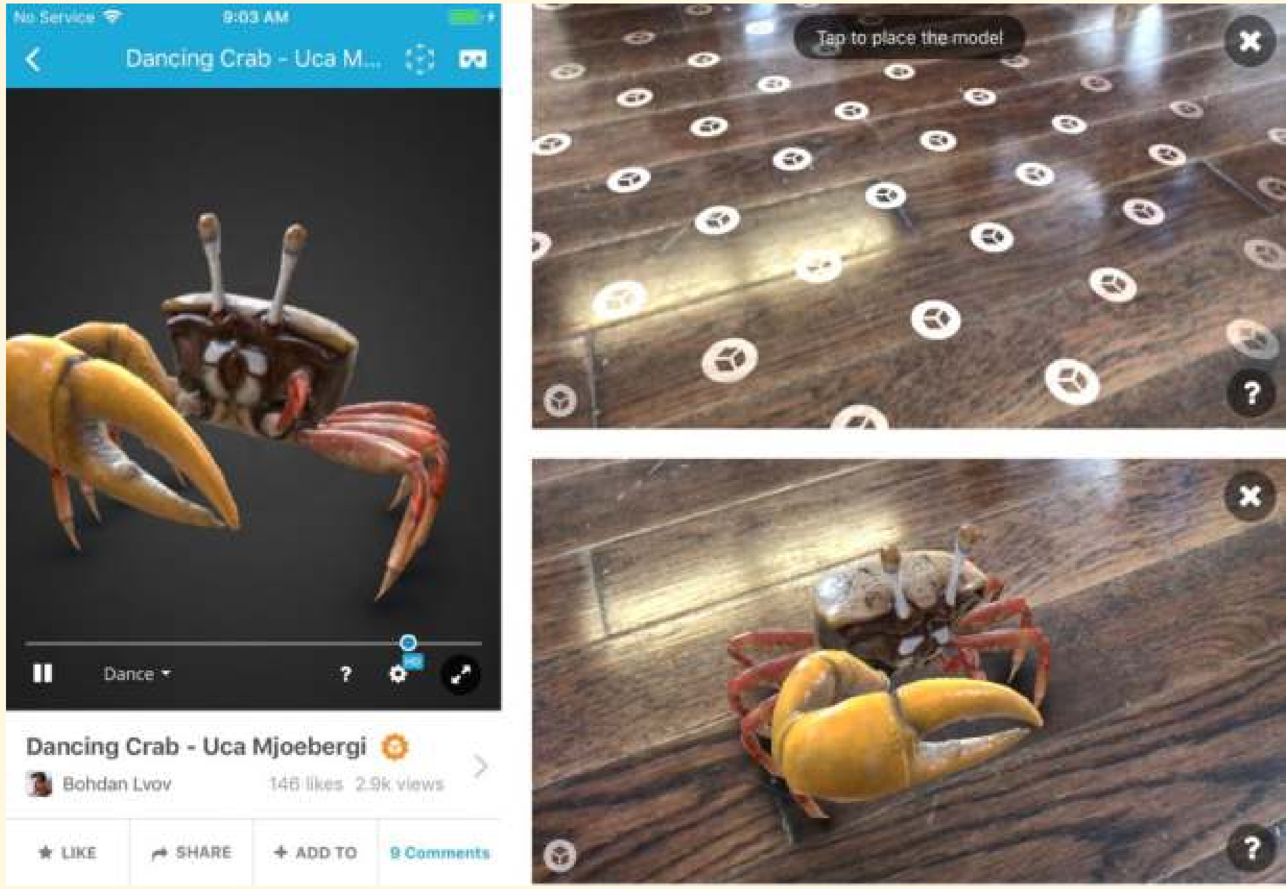
http://storage.googleapis.com/ar-answers-in-search-models/static/mandalorian/grogu/grogu.usdz

- **USDZ** file format
- Native AR **QuickLook Preview**
  - uses Apple's **ARKit**
  - realistic lighting and occlusions

More examples

https://sketchfab.com/

- to hide navigation bar, add https://www.sketchfab.com on your mobile's Home Page



WebAR

- WebXR
- Alternatives

Why use the Web for AR?

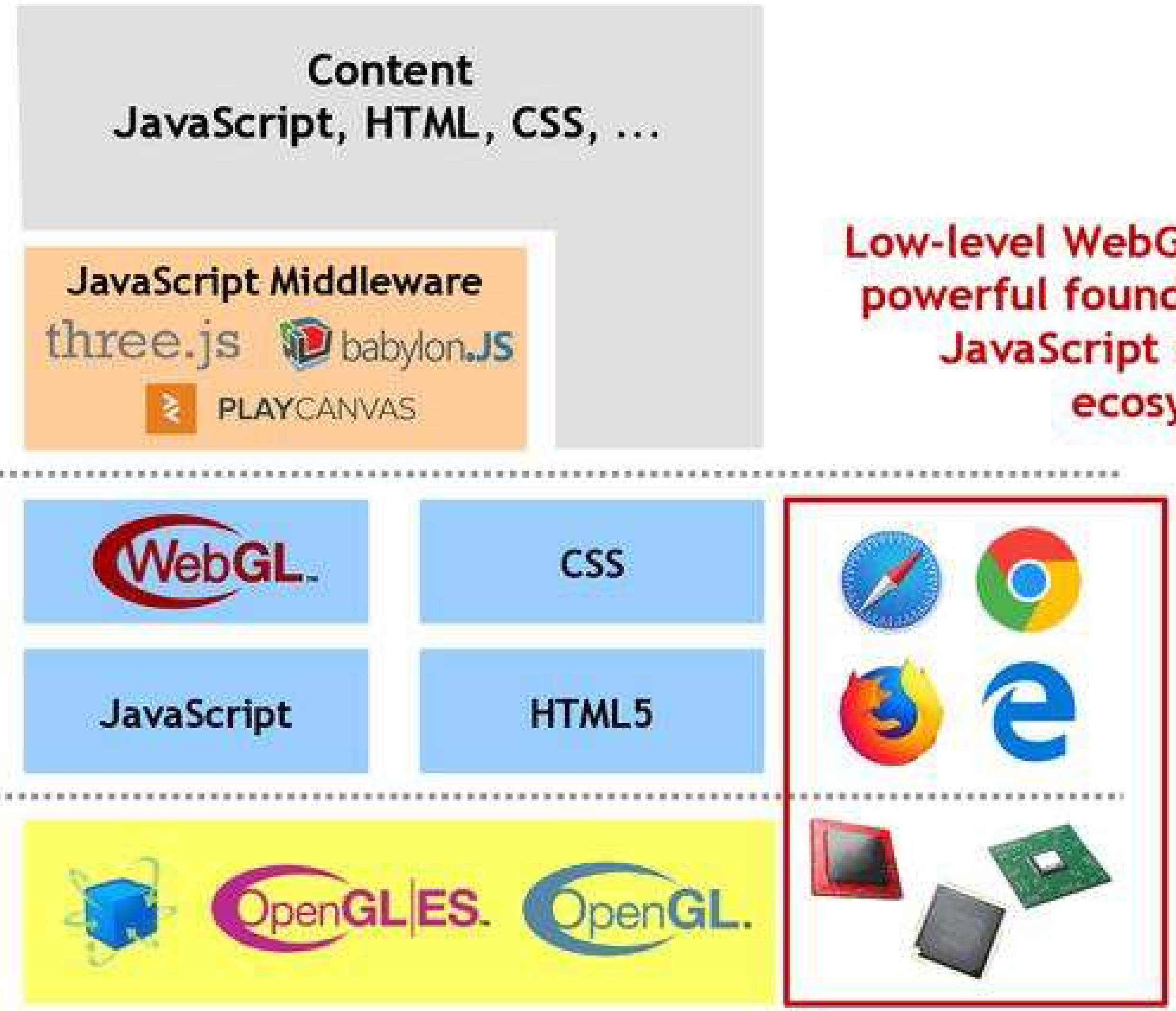
- **mobile** experiences
- **open** technologies
  - **cross-platform**
  - **non-propietary** (unlike Unity or Unreal)
  - **free**
  - **distribute by sharing URLs : no installation, no app store**
- easy integration with many existing Web APIs
  - **anchors the the web to the real world**
  - advanced **interactions**

WebXR

Reminder: WebGL Stack

WebXR ↔️ **WebGL** / WebGPU
OpenXR / Reality Kit / ARKit ↔️ **OpenGL** / DirectX / Metal
HMD + controllers ↔️ GPU + screen

WebGL Stack



Content downloaded from the Web

Middleware provides accessibility for non-expert programmers
E.g. three.js library

Browser provides WebGL 3D engine alongside other HTML5 technologies - no plug-in required

OS Provided Drivers
WebGL uses native OpenGL or OpenGL ES or
Angle = OpenGL ES over DX9/11

Low-level WebGL API provides a powerful foundation for a rich JavaScript middleware ecosystem

Reliable WebGL relies on work by both GPU and Browser Vendors
->
Khronos has the right membership to enable that cooperation

WebGL architecture: software stack

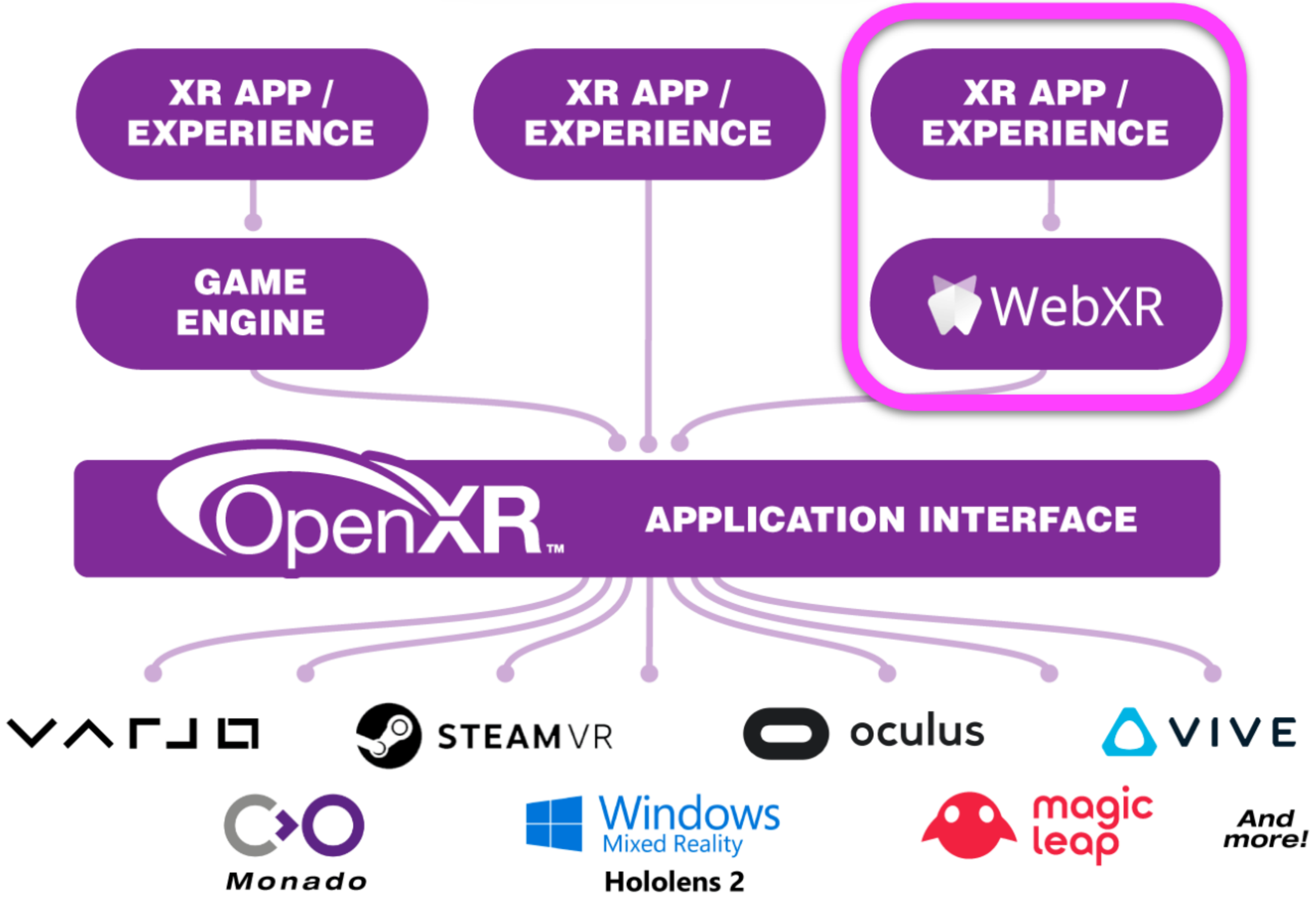
- **Code**: HTML + CSS + JS
  - JS code inside the web page makes WebGL API calls
- **Browser**:
  - browser interprets JS code (using JS Engine)
  - turns WebGL calls into OpenGL calls (binding)
- **OS + Driver**: converts OpenGL calls to
  - DirectX calls on Windows, Metal on Apple (using ANGLE)
  - OpenGL or OpenGL ES calls on other OSes
- **CPU + GPU**: run the **hardware accelerated** code!

Binding example: from JS to C++

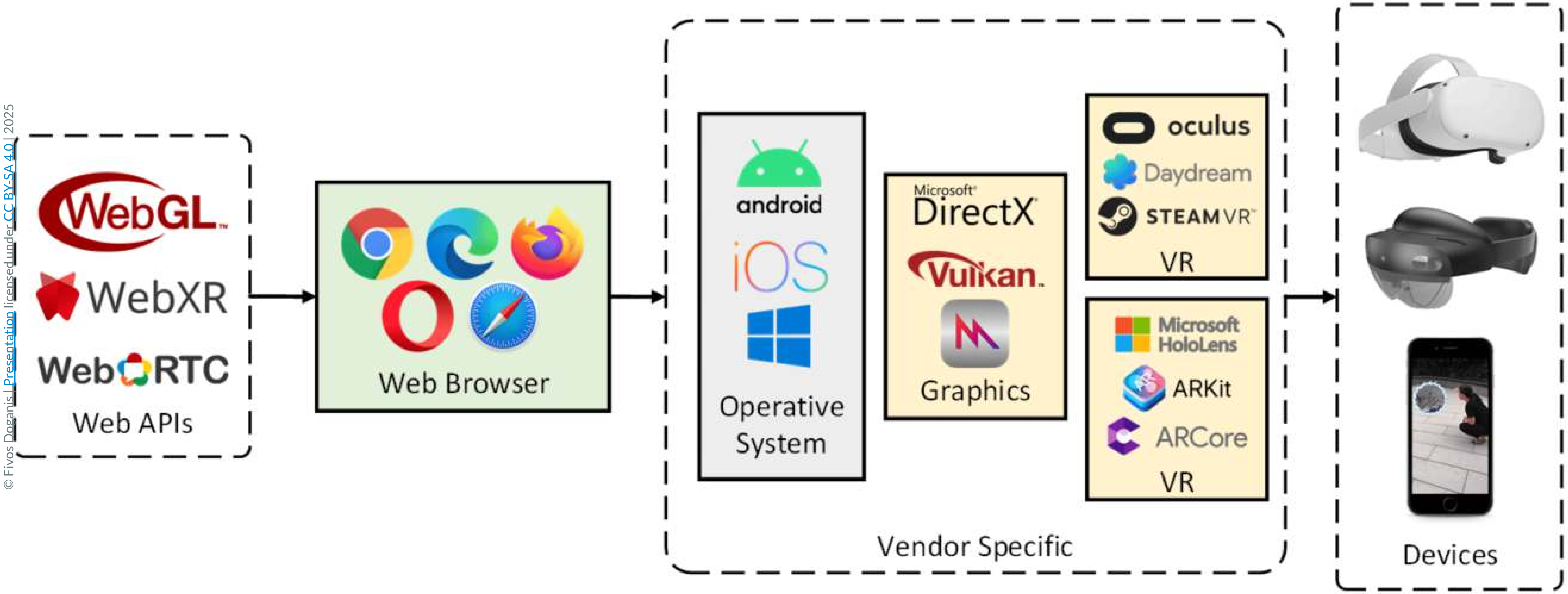
```
gl.drawElements(primitiveType, count, indexType, offset);
```

```
JSValue JSCanvasRenderingContext3D::glDrawElements(JSC::ExecState* exec, JSC::ArgList const& args)
{
    unsigned mode = args.at(0).toInt32(exec);
    unsigned type = args.at(1).toInt32(exec);

    unsigned int count = 0;

    // If the third param is not an object, it is a number, which is the count.
    // In this case if there is a 4th param, it is the offset. If there is no
    // 4th param, the offset is 0
    if (!args.at(2).isObject()) {
        count = args.at(2).toInt32(exec);
        unsigned int offset = (args.size() > 3) ? args.at(3).toInt32(exec) : 0;
        impl()->glDrawElements(mode, count, type, (void*) offset);
    } else {
```

WebXR



OpenXR provides a single cross-platform, high-performance API between applications and all conformant devices.


WebGL
WebXR
WebRTC
Web APIs
Web Browser
android
iOS
Operative System
Microsoft DirectX
Vulkan
Graphics
oculus
Daydream
STEAM VR
VR
Microsoft HoloLens
ARKit
ARCore
VR
Vendor Specific
Devices

Hybrid Apps

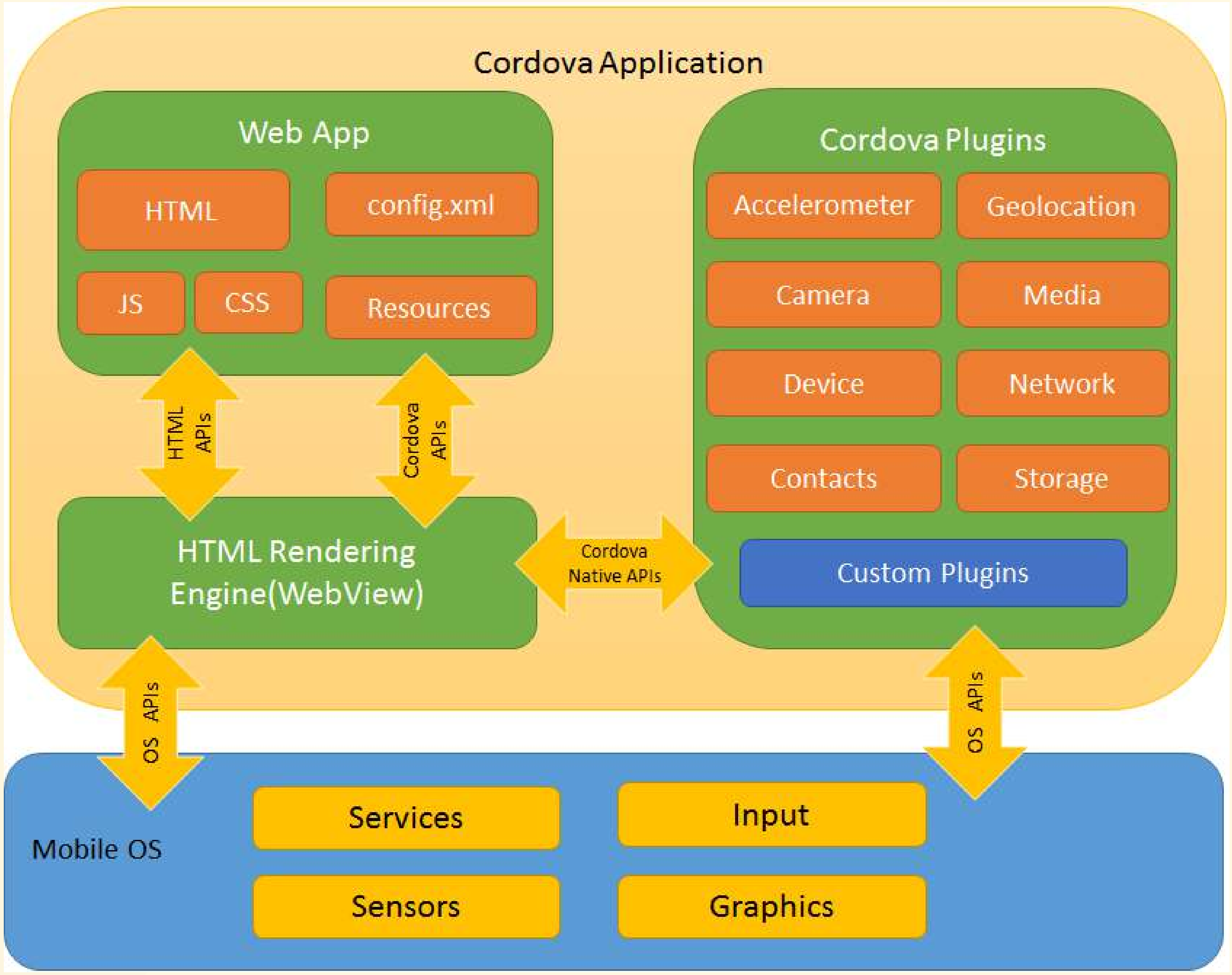
Native + Web

Hybrid Apps

- **Some feature are not available** via JS in the standard browser
  - e.g.: no LiDAR access
- Web Plugins are forbidden
  - security, installation and update issues
- Idea: reuse existing web browser components
  - **native low-level code** (C++, Java, Kotlin, Objective-C, Swift)
  - **create new APIs in JS**, which call the native code
- **issues with non-standard APIs**: if we create our own APIs the code might not be portable

Architecture

- Hybrid App example: ~~PhoneGap~~ **Cordova**
- **NEW**: Ionic Capacitor (WebXR not supported yet)


Cordova Application
Web App
HTML
config.xml
JS
CSS
Resources
HTML APIs
Cordova APIs
HTML Rendering Engine(WebView)
Cordova Native APIs
Cordova Plugins
Accelerometer
Geolocation
Camera
Media
Device
Network
Contacts
Storage
Custom Plugins
OS APIs
OS APIs
Mobile OS
Services
Input
Sensors
Graphics

Why?

- **Pros**
  - **expose missing APIs** in JS: often the only solution!
  - **speed**: call native code, faster than pure JS
  - **portable code**: app logic written in JS
- **Cons**
  - still slower than a 100% native app
  - wasted **performance** when converting between JS and native
  - **lowest common denominator** to satisfy most platforms
  - **non-native look and UI** (not very important for immersive apps)

Setup

How to run the examples locally

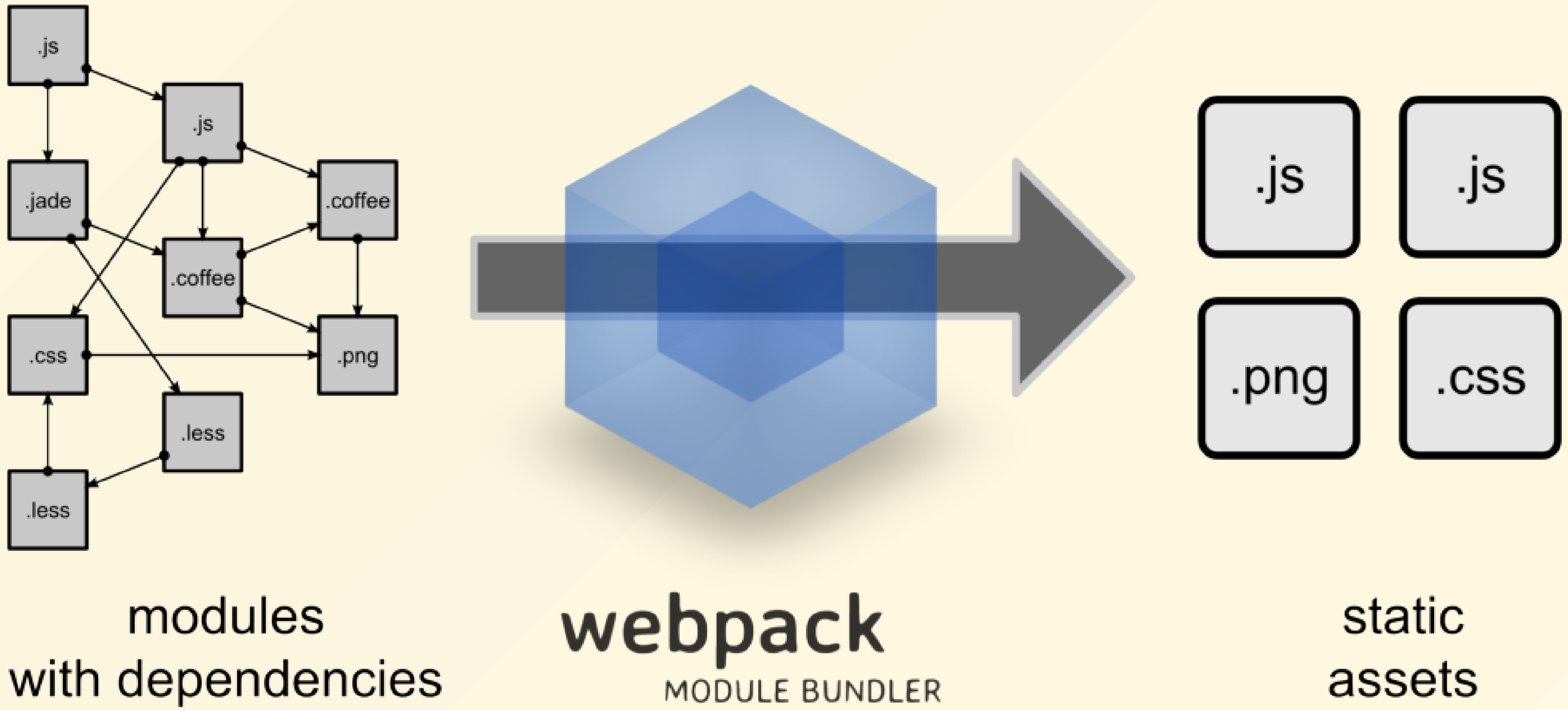
Full setup using NPM

- install Node.js + install npm

```
sudo apt install nodejs
curl -L https://npmjs.org/install.sh | sudo sh
```

See below 👇

Bundlers


.js
.js
.jade
.coffee
.coffee
.css
.png
.less
.less
modules
with dependencies
webpack
MODULE BUNDLER
.js
.js
.png
.css
static
assets

Automatic installation

THREE.js + WebXR with "batteries included"

🎉

THREE Vite WebXR boilerplate

Preconfigured environment (allows to test all official examples)

https://github.com/fdoganis/three_vite_xr ⭐

```
git clone https://github.com/fdoganis/three_vite_xr.git

cd three_vite_xr

npm install
```

Run with `npm run dev` or use `F5` in VS Code

Open `http://localhost:5173` in your browser

Tools

- Web development
  - Web browser (Firefox, Chrome, Safari Mobile)
  - Git
  - Code Editor (VSCode)
- Technologies
  - HTML, JS, CSS
  - WebGL, THREE.js
  - WebXR

Install a browser (desktop)

- Firefox installed by default
  - should be enough!
- Chrome
  - to test compatibility and some features
  - alternative: install Chromium on Linux
    - open-source version without proprietary services

```
sudo apt-get install chromium-browser
```

Install Git

```
sudo apt-get install git

git config --global user.name "myusername"
git config --global user.email myname@mymailprovider.com
```

Install VSCode

```
sudo apt update
sudo apt install software-properties-common apt-transport-https wget

wget -q https://packages.microsoft.com/keys/microsoft.asc -O- | sudo apt-key add -

sudo add-apt-repository "deb [arch=amd64] https://packages.microsoft.com/repos/vscode stable main"

sudo apt install code
```

Remove GPG warnings

```
sudo gpgconf --kill dirmngr
sudo chown -R $USER:$USER ~/.gnupg
```

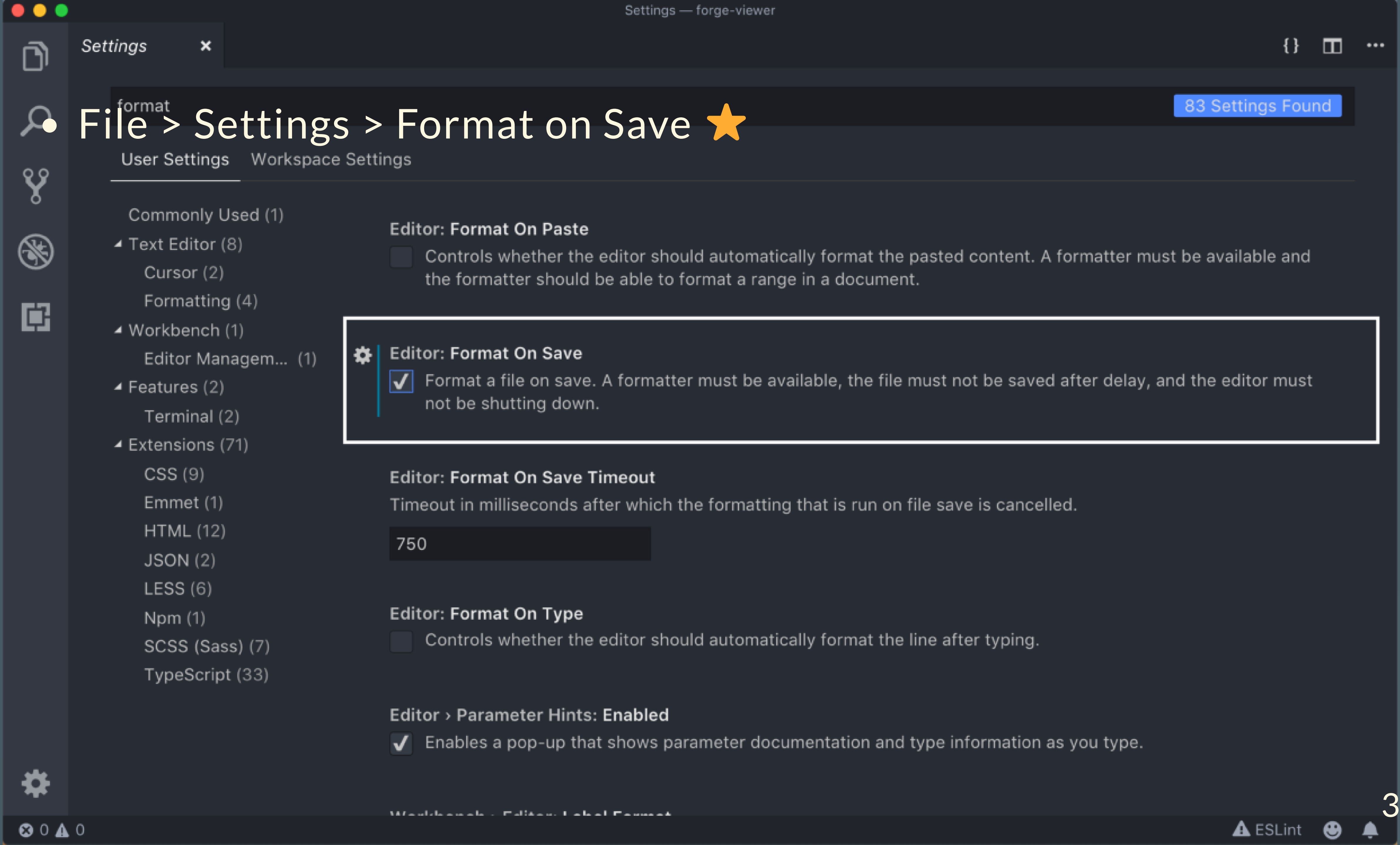
Customize VS Code

- Avoid UI blinking by changing the settings:

```
set window.titleBarStyle to custom
```

- Recommended extensions
  - Live Server
  - Git Graph and/or Git Lens
  - glTF Model Viewer, glTF Tools
  - WebGL GLSL Editor, glsl-canvas
  - Todo Tree, Color Highlight

File > Settings > Format on Save ⭐



Settings — forge-viewer

Settings

format

83 Settings Found

User Settings	Workspace Settings

- Commonly Used (1)
- Text Editor (8)
  - Cursor (2)
  - Formatting (4)
- Workbench (1)
  - Editor Managem... (1)
- Features (2)
  - Terminal (2)
- Extensions (71)
  - CSS (9)
  - Emmet (1)
  - HTML (12)
  - JSON (2)
  - LESS (6)
  - Npm (1)
  - SCSS (Sass) (7)
  - TypeScript (33)

Editor: Format On Paste

☐ Controls whether the editor should automatically format the pasted content. A formatter must be available and the formatter should be able to format a range in a document.

Editor: Format On Save

✓ Format a file on save. A formatter must be available, the file must not be saved after delay, and the editor must not be shutting down.

Editor: Format On Save Timeout

Timeout in milliseconds after which the formatting that is run on file save is cancelled.

750

Editor: Format On Type

☐ Controls whether the editor should automatically format the line after typing.

Editor › Parameter Hints: Enabled

✓ Enables a pop-up that shows parameter documentation and type information as you type.

⊗ 0 ⚠ 0	⚠ ESLint

Local development caveats

- Impossible to load a file without a user action
- CORS: Cross Origin Resource Sharing
  - one of the many security measures used by web browsers

➡️ need to run a server, like Live Server, or using Python:

```
$ cd /home/somedir
$ python -m SimpleHTTPServer

$ python3 -m http.server
```

Then open `http://localhost:8000` in your browser

Install WebXR browser (mobile)

- **Android** 🤖
  - install the latest mobile **Chrome** version (129+)
- **Meta Quest** ♾️ 🥽
  - use default **Browser app**
- **Apple Vision Pro** 🍎 🥽
  - VR only, no AR 😢
- **iOS** 🍎 📱
  - no official WebXR support 😭
  - alternatives below 👇 ~~and here~~ 💀

Install iOS WebXR browser

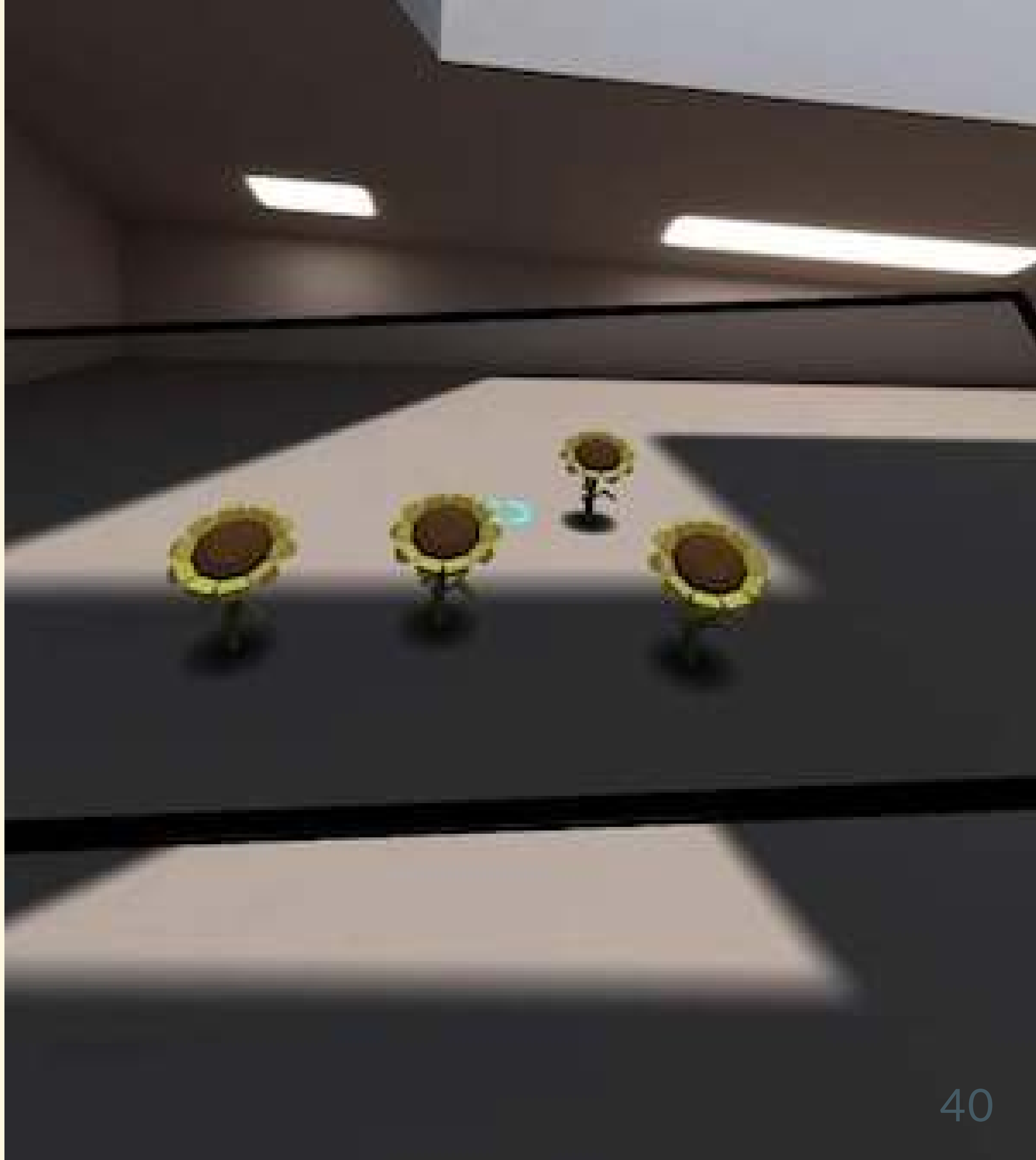
- ➡️ install XR Browser from the App Store "caniuse"

WebXR Report ⭐

Desktop WebXR Emulators

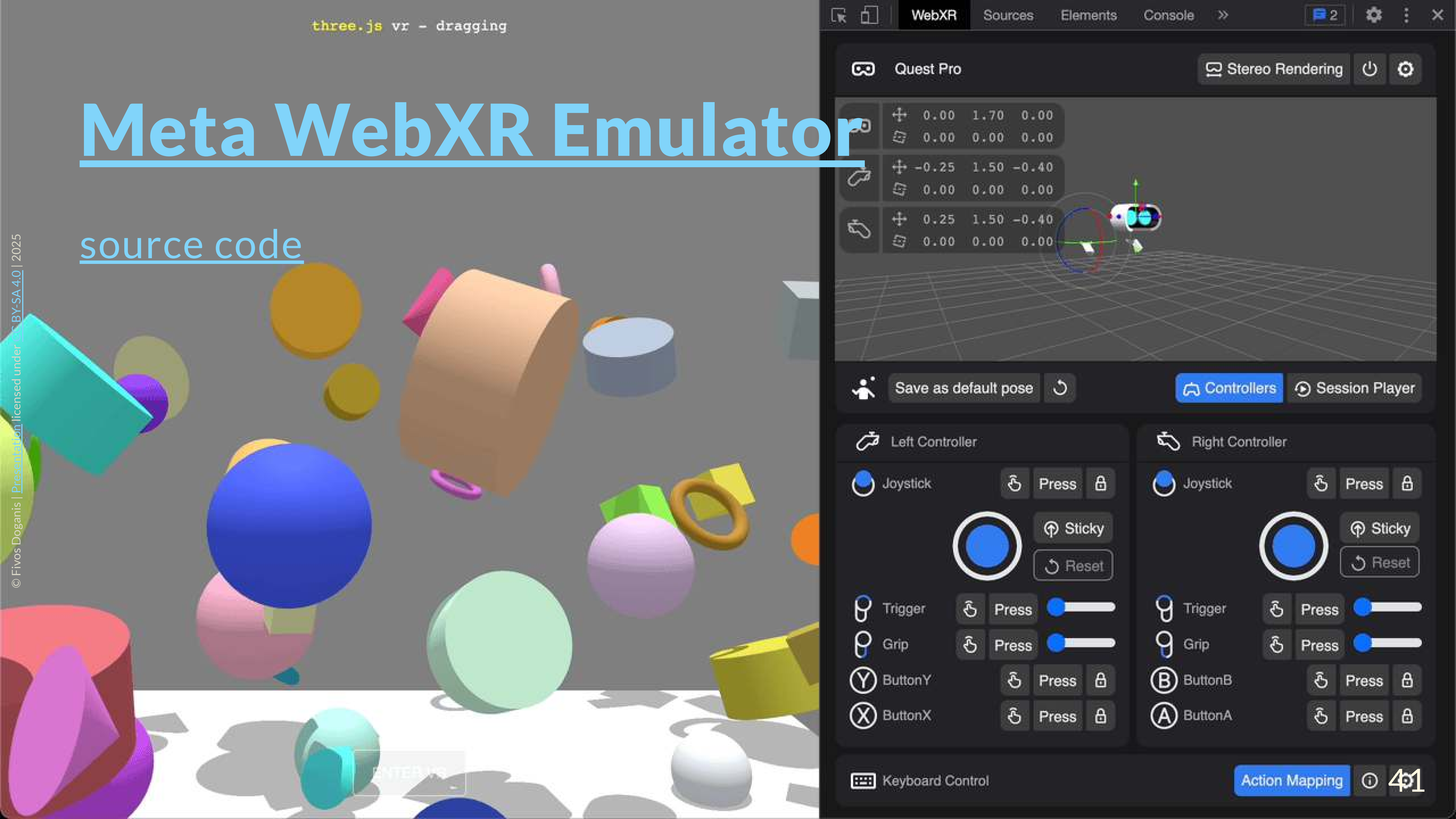
Mozilla WebXR Emulator

- uses WebXR Polyfill
- fake mobile AR device
- very convenient when you don't have an AR device or for debugging
- hand tracking (WIP)
- **NO LONGER ACTIVE**
  forked by Meta 👇



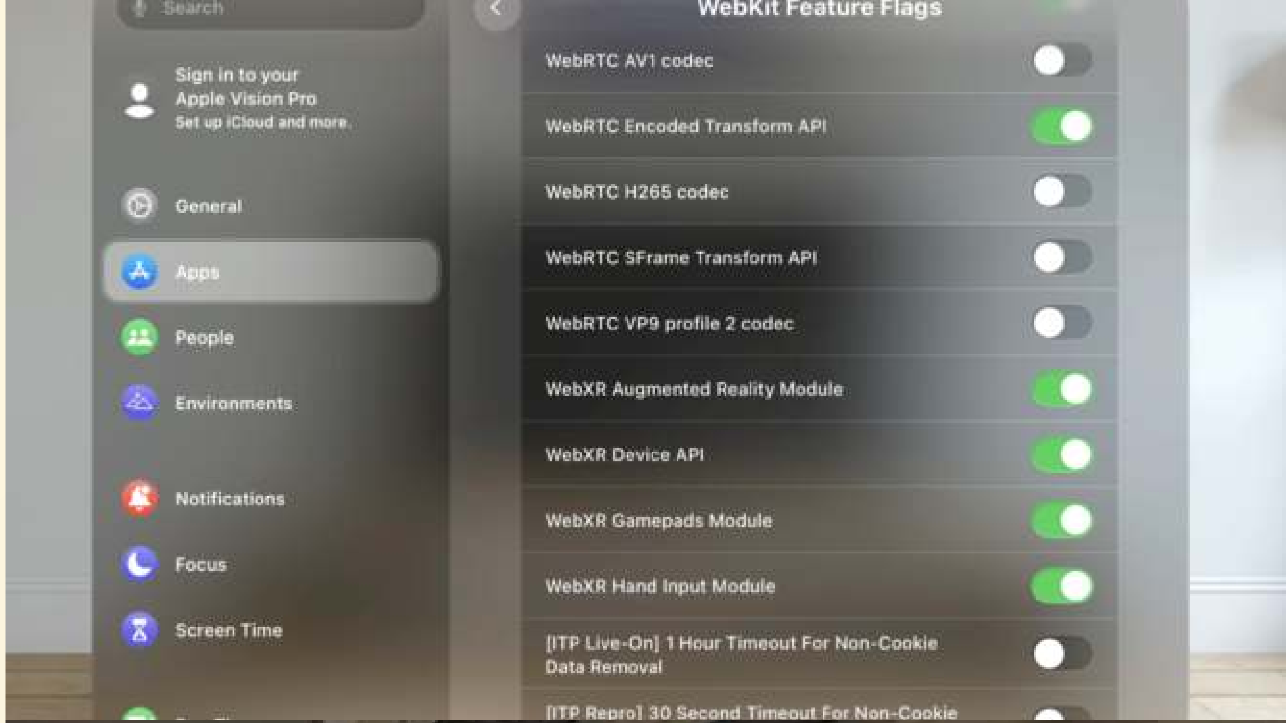
Meta WebXR Emulator

source code

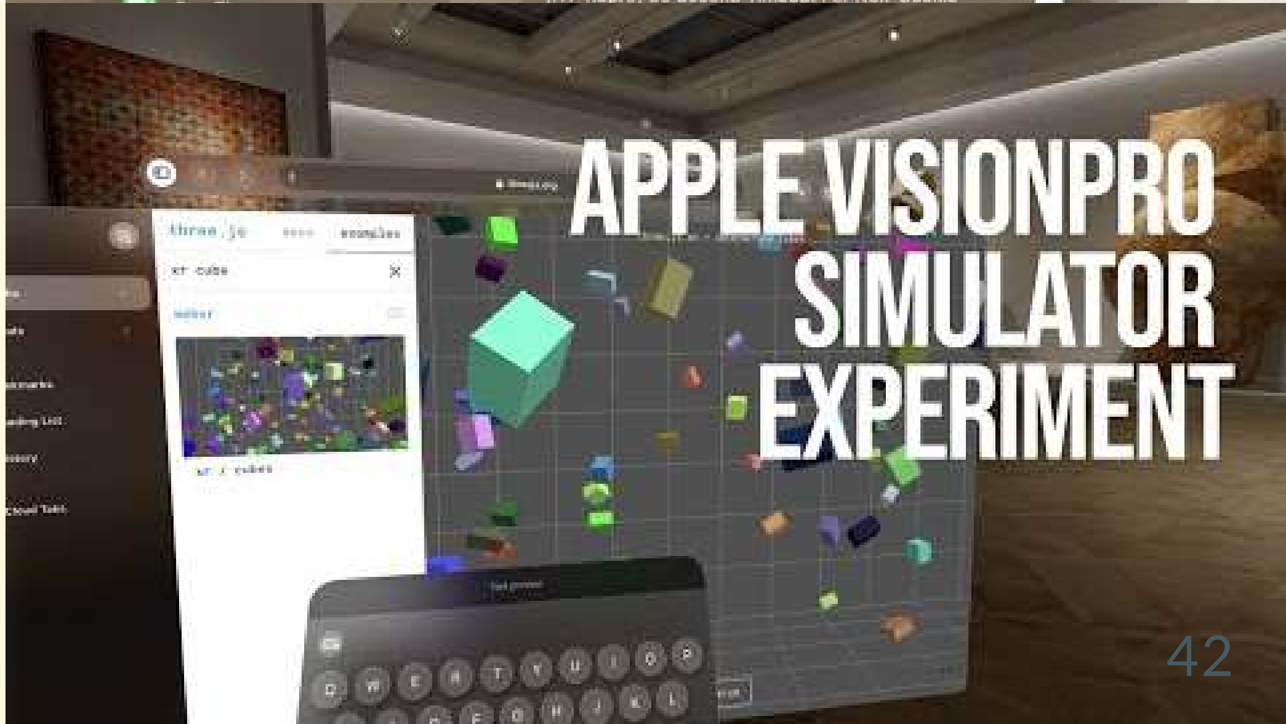


```
 0.00  1.70  0.00
 0.00  0.00  0.00
-0.25  1.50 -0.40
 0.00  0.00  0.00
 0.25  1.50 -0.40
 0.00  0.00  0.00
```

WebXR in Safari inside Apple Vision Pro Emulator


WebKit Feature Flags

WebRTC AV1 codec	Off
WebRTC Encoded Transform API	On
WebRTC H265 codec	Off
WebRTC SFrame Transform API	Off
WebRTC VP9 profile 2 codec	Off
WebXR Augmented Reality Module	On
WebXR Device API	On
WebXR Gamepads Module	On
WebXR Hand Input Module	On
[ITP Live-On] 1 Hour Timeout For Non-Cookie Data Removal	Off
[ITP Repro] 30 Second Timeout For Non-Cookie	



Demo

WebXR Concepts

WebXR Basic Concepts XR + AR ⭐

- **Tracking** (spaces) and **geometry** of the real scene:
  - detect planes and geometry (point cloud or mesh) using SLAM, or similar technologies
- **XR Frame**: RGB image + camera info (pose, focal, tracking, light)
- **Hit test** intersection between a virtual ray and the real scene
  - frequent constraint: RGB camera + depth estimation
- **Anchors** and **worldmap** :
  - points of interest placed by the used
  - updated continuously as the real world gets reconstructed

Advanced WebXR Concepts

- **Occlusion handling**
  - human occlusion (ARKit)
  - real world occlusion (ARKit + LiDAR, ARCore)
- Perception
  - of the environment (Vision, IA, LiDAR)
    - reconstruction + classification floor, wall, table
  - of the user
    - hand gestures, gaze, intentions

Standard APIs

- ~~WebVR~~ ❌ avoid, obsolete
  - but sometimes the only API available
- WebXR ✅ == **"WebVR 2.0 + AR"**
  - ⚠️ 🚧 W3C Draft API, not stable yet, evolving fast
  - Chrome 81+ , AR still experimental, cf. `chrome://flags`
- **Polyfills**
  - allow converting between APIs
  - let you use the latest WebXR API or the old WebVR
  - allow a limited WebXR API emulation if needed

Code examples : WebXR needs 3D

- WebXR + **WebGL**
  - https://github.com/immersive-web/webxr-samples/blob/master/immersive-ar-session.html
  - https://github.com/immersive-web/webxr-samples/blob/master/hit-test.html
- WebXR + **THREE**
  - https://threejs.org/examples/webxr_ar_hittest
- WebXR + **A-Frame**
  - Basketball: https://ada.is/blog/2021/01/14/making-an-ar-game/

WebXR AR Module

API overview using pseudo-code

Security constraints 🚨

- **permissions**
  - camera, location, movement
- ⚠️ **`https` mandatory**
  - use localhost + SSL, or **glitch**, or github.io, vercel etc.
  - ➡️ better: use **Cloudflare** or install ngrok (see README)
    - allows to create a `https` tunnel very easily
- **requires user action to start**
  - AR / VR / XR Button to switch to AR

AR Initialization

```
isSessionSupported(‘immersive-ar’);

// RequestSession on Button press
navigator.xr.requestSession

// Add listener for ARButton Press

// Request reference spaces
localReferenceSpace = await session.requestReferenceSpace(‘local');
viewerReferenceSpace = await session.requestReferenceSpace(‘viewer');

// Request hitTest

session.requestHitTestSource

// RequestAnimationFrame
// NOTE: THREE.js must use
 renderer.setAnimationLoop
 // instead of window.requestAnimationFrame
// Or else use session.requestAnimationFrame(render)
```

Draw

```
// On each Draw
// Callback on every draw, with an XRFrame

const render = (t, frame) => {

    const pose = frame.getViewerPose(localReferenceSpace);

    frame.getPose(localReferenceSpace, viewerReferenceSpace).transform.matrix

    const hitTestResults = frame.getHitTestResults( hitTestSource );
    const hit = hitTestResults[ 0 ];
    reticle.matrix.fromArray( hit.getPose(viewerReferenceSpace ).transform.matrix );

}
```

Selection (onTouch)

Example:
https://github.com/mrdoob/three.js/blob/master/examples/webxr_ar_cones.html

```
// Get hand, controller, or phone
controller = renderer.xr.getController( 0 );

// See also selectstart, selectend, squeeze etc.
controller.addEventListener( 'select', onSelect );

scene.add( controller );

// Before rendering, update the controller, and apply position to mesh (in meters)
mesh.position.set( 0, 0, - 0.3 ).applyMatrix4( controller.matrixWorld );
```

Let's Code!

WebXR + THREE.js ⭐

- download https://github.com/fdoganis/three_vite_xr
    - see above
- choose a webxr example
    - preferably with `ar /` in its description
    - ths simplest is **AR Cones** : https://threejs.org/examples/webxr_ar_cones
- make it run on your phone (or on an emulator)
    - you can generate a QR code with the URL! 👇

Creating your own QR code

- https://duckduckgo.com
  - "qr " + url
  - ⚠️ you must modifiy the link in THREE.js examples to remove iframes (**iframes are not supported by XR Viewer on iOS**) : ~~(https://threejs.org/examples/?q=cones#webxr_ar_cones)~~ ➡️ https://threejs.org/examples/webxr_ar_cones
- Alternatives:
  - use Google Chrome's QR code generator
  - https://www.the-qrcode-generator.com/
  - https://codepen.io/chriscoyier/pen/QyPbXz

Build: reminders

- `npm install`
- `npm run build`
- if you have any issues, check the security constraints

Replace the cone with another model

- SketchFab ⭐
  - A-Frame component
  - Downloaded model
- ~~Google Poly~~ 💀 ➡️ poly.pizza
  - example
  - A-Frame component
  - Downloaded

Add XR to your THREE.js project! ⭐

Port your THREE.js project to use the real world!

- start with THREE.js' `webxr_ar_cones` example above
- replace the cone creation with your solar system
  - create the solar system only once
  - change its position if it has already been created

Challenges 💪

- 1️⃣ place the solar system on top of a horizontal plane
  - use a hit test
  - see https://threejs.org/examples/?#webxr_ar_hittest
- 2️⃣ select a sphere and move it
  - use `attach` while dragging it
  - see https://threejs.org/examples/#webxr_xr_dragging
- 3️⃣ interpolate between the two positions
  - `new TWEEN.Tween(obj.position).to({x:, y:, z:}, 500).start()`
  - see this TWEEN.js example

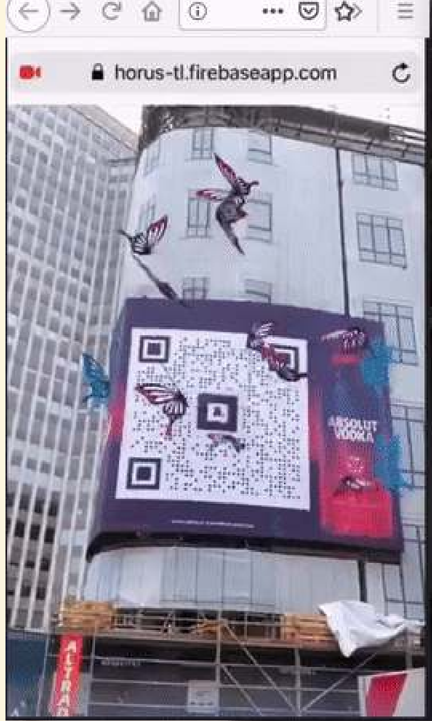
60 FPS

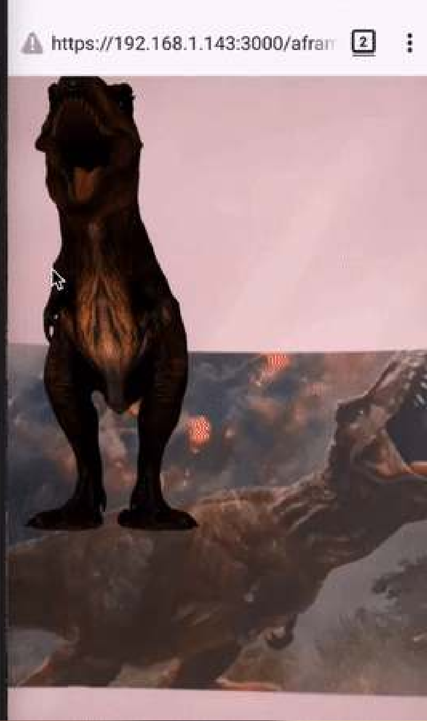
Alternative AR Libraries

- ~~three.ar.js~~, ~~aframe-ar~~: obsolete, avoid
- JeelizAR ⭐
  - lightweight fast (deep learning for object and face detection)
- MediaPipe, Handsfree.js encapsulates JeelizAR and TensorFlow.js
- ~~awe.js~~: not free
- ~~8th Wall~~
  - not free, proprietary and very restrictive license, **avoid**!
  - does not allow evaluation if you are a developer!
- ~~Wikitude~~: not free, no web

More libraries

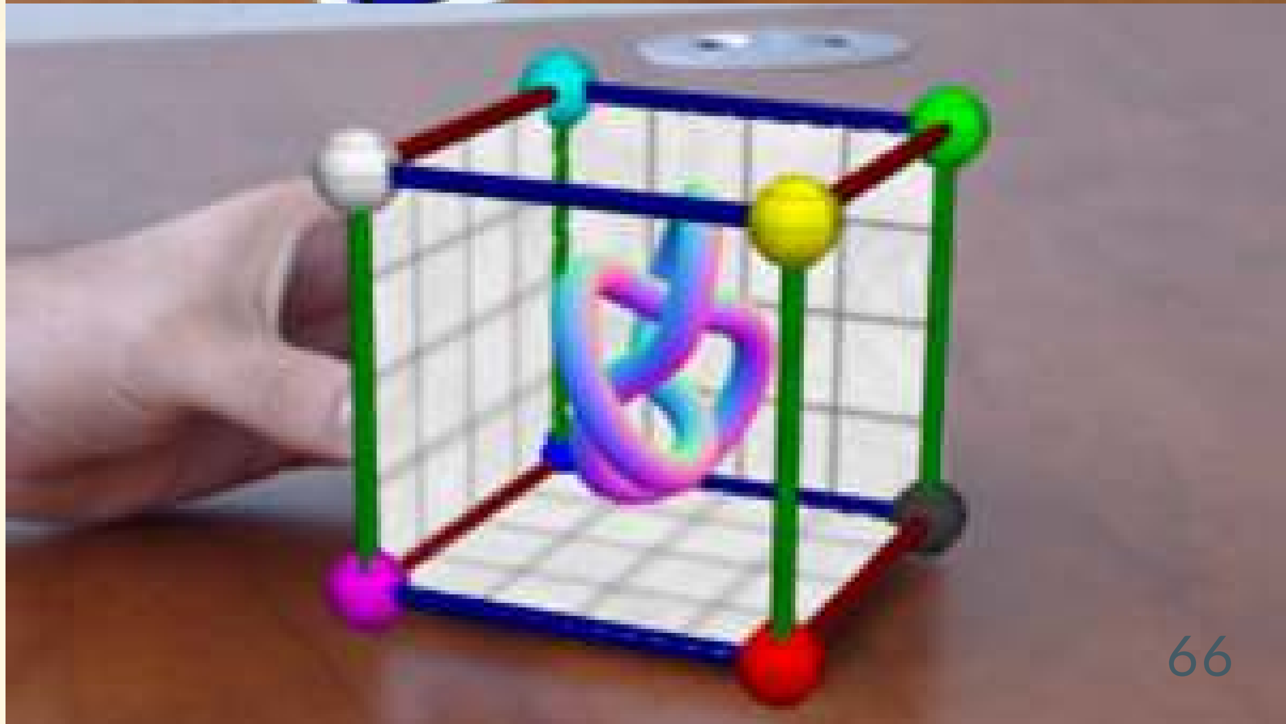
- **AR.js**
  - THREE.js + marker
  - THREE.js + NFT
  - **locar.js** : THREE.js + GPS
- **MindAR**
  - simple **image tracking** with THREE.js
  - **face tracking** with THREE.js





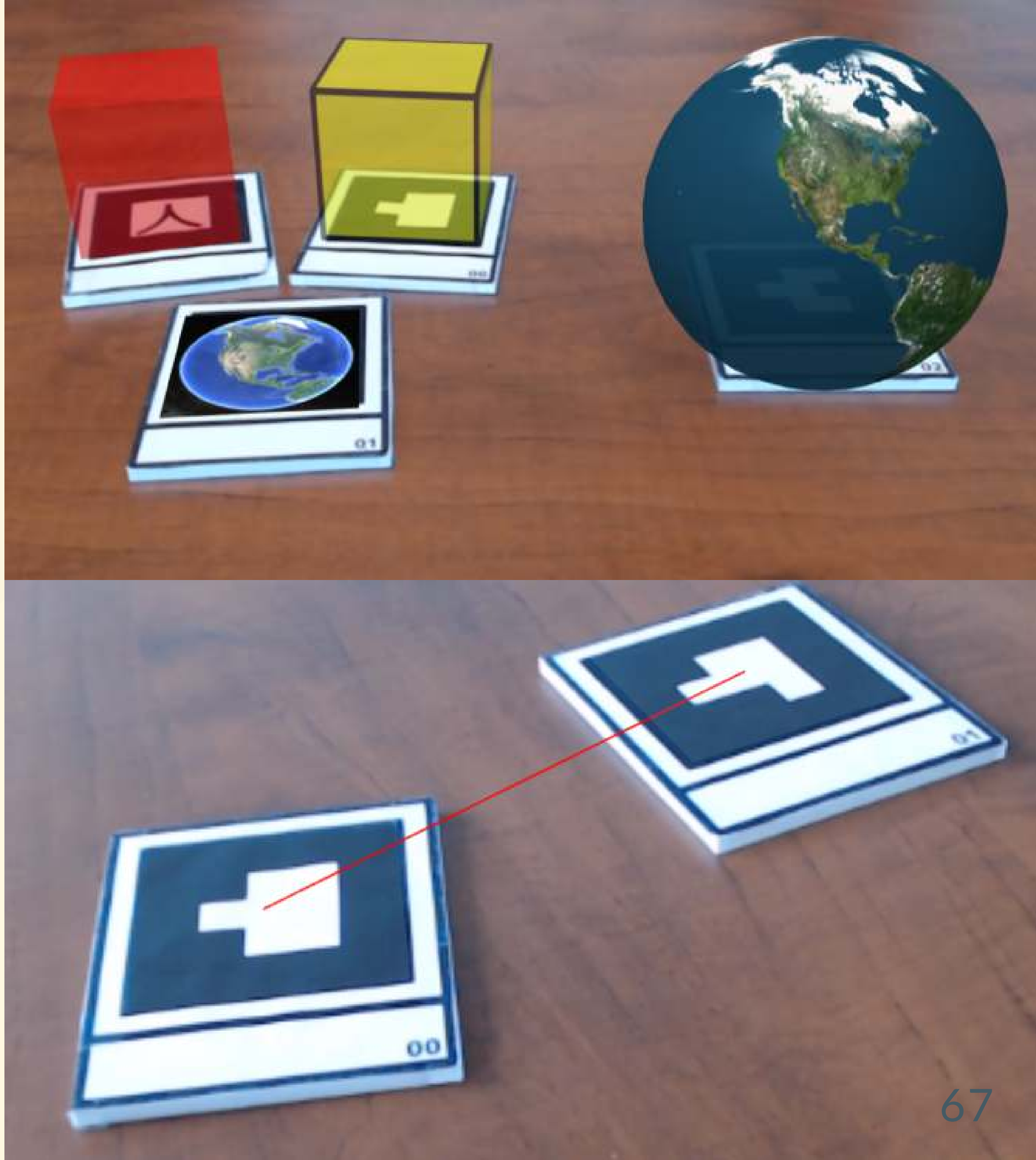
App examples

- Many (old) examples using **AR.js + THREE.js** + THREEx
  - official
    - basic example
    - you can choose between live video, simple photo and a video a file!
  - Lee Stemkoski



More examples

- Official A-Frame examples
- Lee Stemkoski
    - A-Frame
    - **A-Frame + AR.js**
- FrameVR
    - course for beginners
    - inspiration for your projects



Computer Vision

- OpenCV.js : official JS port (wasm via emscripten)
  - terrible documentation but nice tutorials, see this Mozilla article
- JSFeat: lightweight 100% js library (old code)
- Tracking.js: computer vision lib (old code)
- headtrackr, PicoJS: face tracking
- ARuCo Marker tracking: ARToolkit alternative
- Tensorflow.js: recent Vision + IA demos
  - PoseNet
  - HandPose 3D

Extras

Courses

https://medium.com/sopra-steria-norge/get-started-with-augmented-reality-on-the-web-using-three-js-and-webxr-part-1-8b07757fc23a ⭐

https://codelabs.developers.google.com/ar-with-webxr#0

https://medium.com/arjs/webar-playground-ar-in-a-few-clicks-67a08cfb1534

https://blog.halolabs.io/building-ar-vr-with-javascript-and-html-97af4434bcf6

Guides

https://developer.apple.com/design/human-interface-guidelines/ios/system-capabilities/augmented-reality/

Code links : Browser-based AR and VR

http://webglworkshop.com/presentations/Workshop31-ar-vr.html#/21

https://webxr.io/webar-playground/

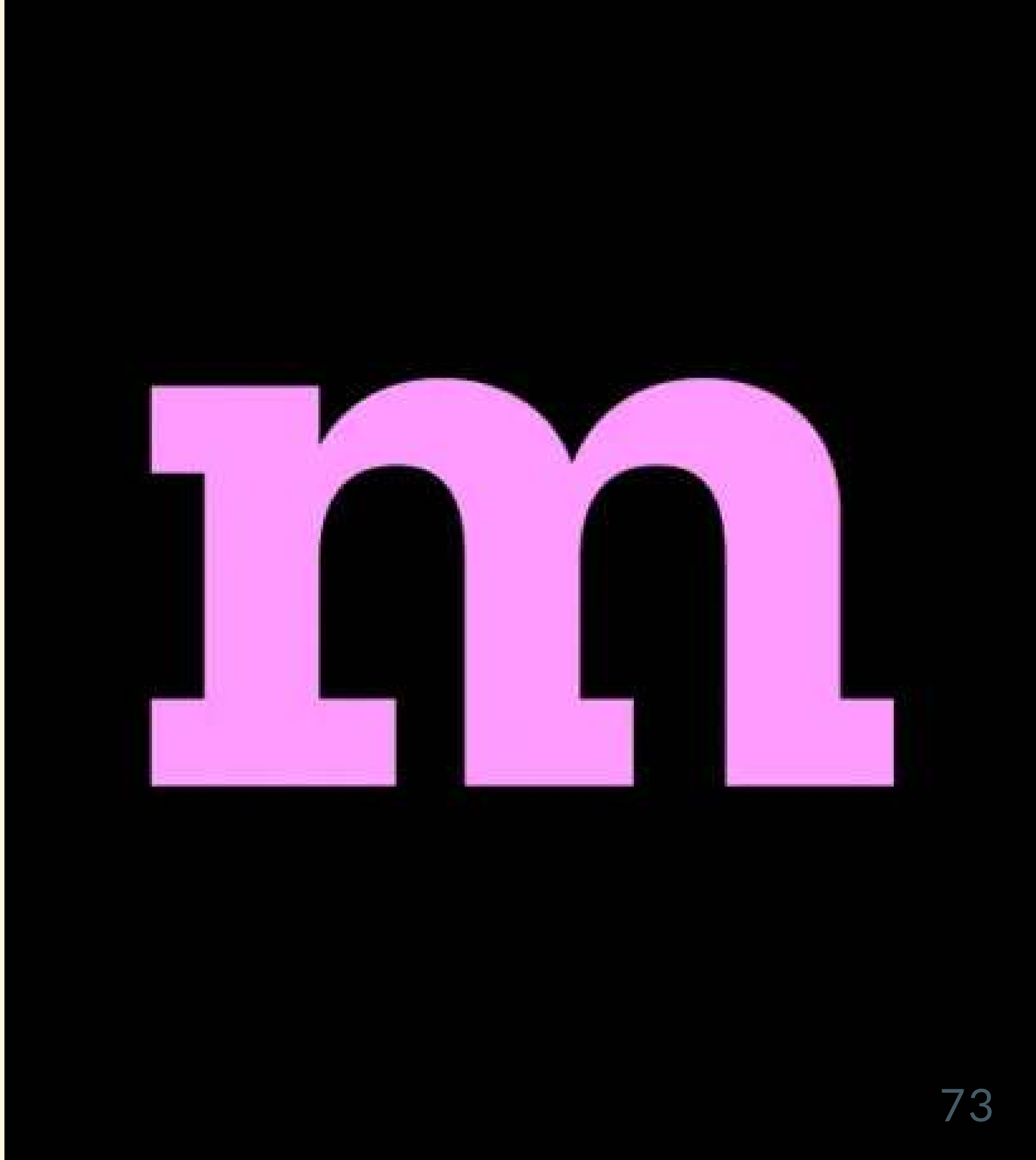
http://learningthreejs.com/blog/2015/07/16/hatsune-miku-dancing-in-augmented-reality/

http://studioknol.com/phase-two-building-with-virtuality/

https://github.com/rodrigocam/ar-gif
https://github.com/XingMeansOK/slamjs_samples (RGBD)

Mozilla's (deprecated) XR Viewer (1)

- Install Mozilla's WebXR Viewer from the App Store



Mozilla's (deprecated) XR Viewer (2)

- **DO NOT use** URLs with **iframes**!

For example:

https://threejs.org/examples/?q=cones#webxr_ar_cones

will NOT work (you will get a confusing "WebXR not available" message on your XR Button)

Use this URL instead:

https://threejs.org/examples/webxr_ar_cones

Mozilla's (deprecated) XR Viewer (3)

- **DO NOT use Dark Mode**, otherwise all the colors in your 3D **graphics will look inverted**
  - you can **force XRViewer to always use the light theme**
    - check the in-app **settings**

Mozilla's (deprecated) XR Viewer (4)

- Remember to **clear your cache** frequently if you are developing an app and you are not seeing your code changes
    - check **Data Management** from the in-app **settings**

Mozilla's (deprecated) XR Viewer (5)

- the site https://webxr-ios.webxrexperiments.com/ seems to be down.
  Symptom: "Start AR" has no effect.
- use updated WebXR polyfill
- ➡️ provide your own polyfill in the general settings:

Settings / XRViewer / WebXR Polyfill URL :
https://arenaxr.org/webxrios.js

URL copied from Anthony Rowes' "XR Browser" (maintained!) app