Development

Developing Immersive Applications

Created by: Chek Tien TAN

Learning Objectives:

- describe common tools for developing immersive applications
- differentiate WebXR and OpenXR standards
- setup programming environment for building WebXR applications
- implement a minimal WebXR scene with Babylon.js

Key APIs

API	Type	Platform	XR-Specific
WebXR	Open Standard	Web	Yes
OpenXR	Open Standard	Native	Yes
Vulkan	Open Standard	Native	No
WebGL	Open Standard	Web	No
WebGPU	Open Standard	Web	No
OpenGL	Open Standard	Native	No
DirectX	Proprietary	Native (Windows)	No
Metal	Proprietary	Native (Apple)	No

Key Points:

- **WebXR** — web standard for VR/AR, browser-based, high accessibility (e.g., no install)
- **OpenXR** — cross-platform native standard for VR/AR, high low-level customizability
- **WebGL/WebGPU** - web graphics APIs (current and next-gen)

Development Frameworks

Framework	Type	WebXR	Key Features
Unity	Native Engine	Partial	Industry standard, C#, asset store
Unreal Engine	Native Engine	Partial	High-fidelity graphics, Blueprint
Babylon.js	Web Framework	Full	TypeScript, WebXR helpers (this module)
Three.js	Web Framework	Manual	Most popular, flexible, manual setup
A-Frame	Web Framework	Full	HTML-based, beginner-friendly
PlayCanvas	Web Framework	Full	Web editor, collaborative

Development Frameworks

Framework	Type	WebXR	Key Features
CoSpaces	No-Code Tool	N/A	Educational, drag-and-drop
Spatial	No-Code Tool	N/A	AR/VR creation without coding

Choosing a Framework:

- **Maximum accessibility?** WebXR (Babylon.js, Three.js, A-Frame)
- **Novel hardware interaction?** OpenXR SDK in C++
- **High visual fidelity?** Unity or Unreal Engine
- **No coding experience?** CoSpaces or Spatial

WebXR Support Across Browsers

Feature Name	Standardisation	Chrome	Safari on visionOS	WebXR Viewer	Magic Leap Helio	Samsung Internet	Meta Quest Browser	Microsoft Edge	Wolvic	Pl Bro
WebXR Core	Explainer Spec MDN	Chrome 79	Behind a feature flag	iOS	Magic Leap Helio 0.98	Samsung Internet 12.0	7.0, December 2019	Edge 87 on Windows Desktop Edge 91 on Hololens 2	0.9.3, February 2022	Supp
WebXR AR Module	Explainer Spec MDN	Chrome for Android, 81		iOS	Magic Leap Helio 0.98	Samsung Internet 12.1	24.0, October 2022	Edge 91. Hololens 2 only	Wolvic Chromium 1.1	3.3
WebXR Gamepads Module	Explainer Spec MDN	Chrome 79			Partially supported on Magic Leap Helio 0.98	Samsung Internet 12.0	7.1, December 2019	Edge 87 on Windows Desktop Edge 91 on Hololens 2	0.9.3, February 2022	Supp

https://immersiveweb.dev

Babylon.js vs Three.js

Quick comparison:

- Babylon.js: built-in WebXR helpers, TypeScript-first, feature-rich
- Three.js: manual WebXR setup, lighter core, more DIY flexibility
- Babylon trades size for convenience; Three trades boilerplate for control

Babylon.js vs Three.js

Both frameworks:

- Can be used to build WebXR applications
- Support VR controllers, hand tracking, and AR passthrough
- Can run on Meta Quest devices using Quest controllers

Project Setup Basics

Development Environment:

- **Node.js + npm** — JavaScript runtime and package manager
- **TypeScript** — Typed superset of JavaScript
- **Vite** — Fast build tool and dev server
- **package.json** — Project dependencies and custom scripts
- **package-lock.json** — Locks exact dependency versions
- **tsconfig.json** — TypeScript compiler configuration
- **vitest.config.ts** — Testing framework configuration

Basic Workflow:

`npm install` — Install dependencies

`npm run dev` — Start development server

`npm run build` — Build for deployment

(mini-)DevOps

Why these files matter for teams:

- **package-lock.json** — Ensures everyone installs identical dependencies
- **.gitignore** — Prevents committing build artifacts and node_modules
- **.github/workflows/xxx.yml** — Automates tests on every push/PR

Benefits:

- Reproducible builds across different machines
- Catch bugs early with automated testing
- Clean git history without unnecessary files
- Consistent development environment for all team members

Babylon.js App Boilerplate

Engine + render loop setup:

```
import { Engine } from "@babylonjs/core";
import { App } from "./app";

const canvas = document.getElementById("renderCanvas");
const engine = new Engine(canvas, true);

const app = new App(engine);
app.createScene().then(scene => {
  engine.runRenderLoop(() => { scene.render(); });
});

window.addEventListener("resize", () => engine.resize());
```

Babylon.js createScene Snippets

IPA1 basics:

Key steps:

- instantiate a new `Scene` with the engine
- add a quick console log for debugging
- create default camera and light helpers
- replace with specific cameras later (e.g., `ArcRotateCamera`)

WebXR Setup in Babylon.js

Adding WebXR to your scene:

```
// Makes a non-blocking method call to initialize components
const ground = MeshBuilder.CreateGround("ground", { ... });
const xr = await scene.createDefaultXRExperienceAsync({
  floorMeshes: [ground], // Enable teleportation
  uiOptions: {
    sessionMode: "immersive-vr"
  }
});
```

Various components initialized automatically:

- VR/AR mode button in the UI
- Controller input handling (grip, trigger, buttons)
- Teleportation system (if floorMeshes provided)
- Hand tracking support (if device supports it)

WebXR Setup: Babylon.js vs Three.js

Compare with manual WebXR setup in Three.js:

```
// Three.js requires manual WebXR setup
const session = await navigator.xr.requestSession("immersive-vr", {
  requiredFeatures: ["local-floor"]
});
const gl = canvas.getContext("webgl", { xrCompatible: true });
await gl.makeXRCompatible();

const glBinding = new XRWebGLBinding(session, gl);
const layer = new XRWebGLLayer(session, gl);
session.updateRenderState({ baseLayer: layer });

const referenceSpace = await session.requestReferenceSpace("local-floor");
```

(continued) Manual WebXR setup in Three.js:

```
// Manual render loop with XR frame handling
function onXRFrame(time, frame) {
  const pose = frame.getViewerPose(referenceSpace);
  // Update camera matrices, render to each eye's viewport
  // Manual rendering code here...
  session.requestAnimationFrame(onXRFrame);
}
session.requestAnimationFrame(onXRFrame);
// No built-in controllers, teleportation, or hand tracking!
```

WebXR Debugging Tools

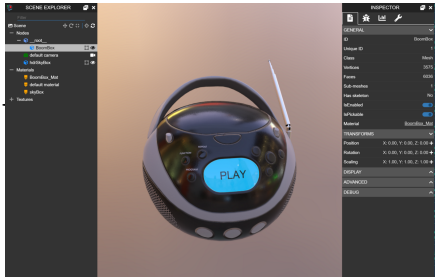
Essential debugging approaches:

- **console.log()** — Basic debugging for variable inspection
- **Chrome DevTools** — Browser console for runtime errors
- **WebXR Inspector** — Built-in Babylon.js debugging overlay
- **WebXR Emulator Extension** — Test without physical device

WebXR Inspector

Toggle inspector with keyboard shortcut:

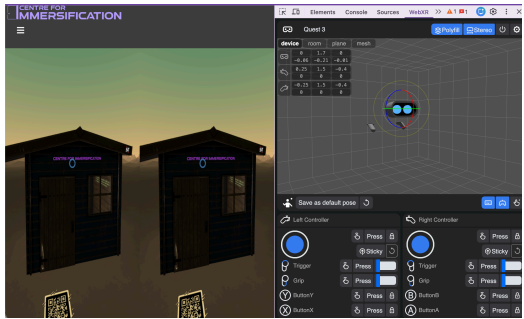
```
window.addEventListener("keydown",
  (event) => {
    if (event.ctrlKey && event.key === "i") {
      if (scene.debugLayer.isVisible()) {
        scene.debugLayer.hide();
      } else {
        scene.debugLayer.show();
      }
    }
  });
```



WebXR Emulator Extension

Test WebXR without a headset:

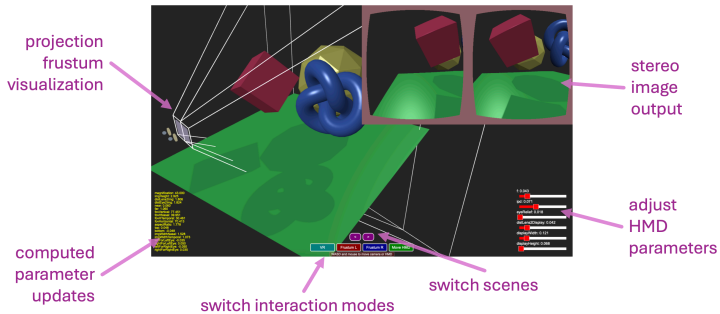
- Browser extension for Chrome/Edge/Firefox
- Simulates different VR/AR devices (Quest, Vive, etc.)
- Test controller inputs with keyboard/mouse
- Useful for rapid development iteration



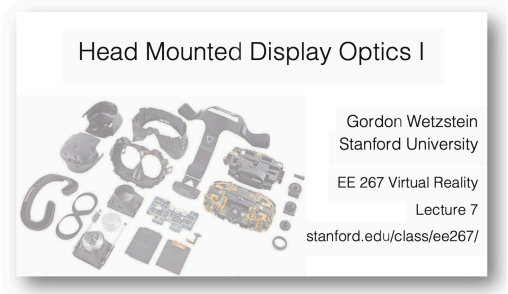
HMD Simulator

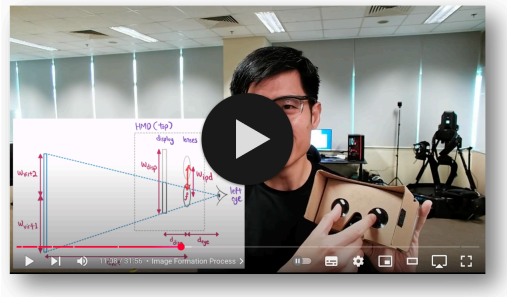
Purpose: Understanding Hardware-Software Connection

- Visualize how HMD hardware parameters affect rendering
- Experiment with lens properties, IPD, FOV, eye relief
- See real-time impact on the rendered view



Hardware & Software Connection



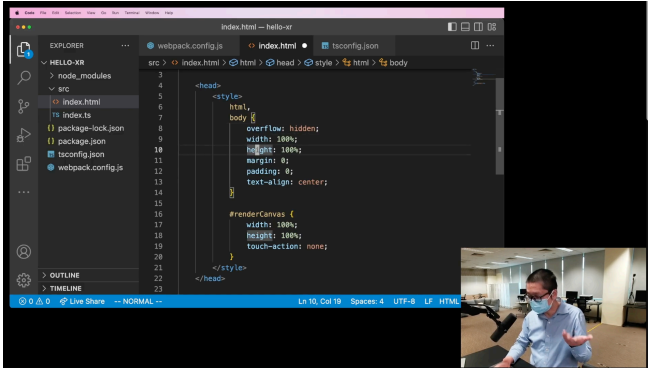


Stanford EE267: `https://stanford.edu/class/ee267/lectures/lecture7.pdf`

Immersification Video: `https://youtu.be/OKD4jrnn4WE`

Video Tutorial

Live Coding Basics:



https://youtu.be/iDCnmggNIy8

Summary

Today we covered:

- Key graphics/XR APIs: WebXR, OpenXR, Vulkan, WebGL, DirectX, Metal
- Development frameworks: Unity, Unreal, Babylon.js, Three.js, A-Frame
- Project setup with Node.js, TypeScript, Vite
- HMD Simulator for hardware-software connection

Next Steps:

- Review project setup video tutorial
- Experiment with HMD Simulator
- Browse Stanford EE267 lecture notes on HMD optics

Further Reading

WebXR & OpenXR Standards:

- WebXR's Immersive Web Working Group
- WebXR Resources (immersiveweb.dev)
- OpenXR API (Khronos Group)
- Mozilla's Hello WebXR demo

Development Frameworks:

- A-Frame website
- BabylonJS Documentation
- BabylonJS GitHub repository
- BabylonJS Playground and Inspector demo