GW SCHOOL OF ENGINEERING & APPLIED SCIENCE

Augmented and Virtual Reality

CSCI 3907/6907

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Lecture 2

by

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Self-study the tutorials on Unity

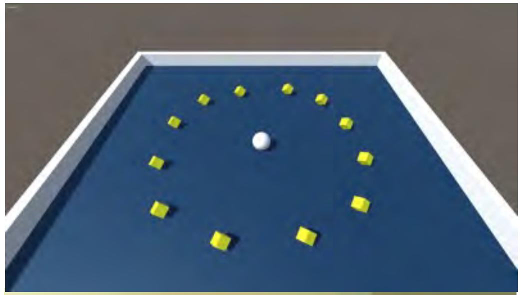
Getting started with Unity

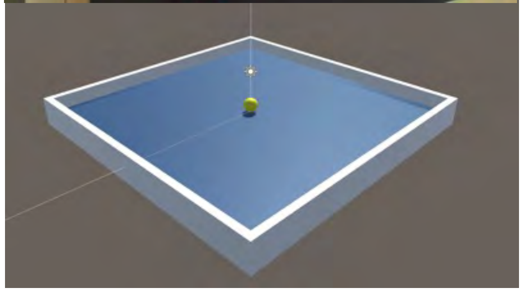
Build your first Unity app: Create a project named “Roll-a-Ball by YOUR INITIALS”
https://learn.unity.com/project/roll-a-ball

OPTIONAL: Other simple Unity tutorials for additional practice
Option 1: Creating a simple diorama
Read more details in Chapter “Understanding Unity, Content, and Scale”
in the textbook “Unity 2020 Virtual Reality Projects”by Jonathan Linowes, 2020.

Option 2: Creating a simple ball game
See https://developer.oculus.com/documentation/unity/unity-tutorial
This tutorial is very similar to the “Roll-a-Ball” project.

No VR Headset is needed for any of these Unity tutorials!





Project I: Experimental VR App

- Implement the simple VR app (tutorial) as in-class exercise today.
  "Unity VR Development Oculus Quest 2021, Getting Started in 15 Mins"
  https://www.youtube.com/watch?v=JyxbA2bm7os

- Submit your experimental VR app concept (1-2 pages proposal) by **Thu., Jan. 27, 2022**

Project I: Experimental VR App

- Propose an experimental VR App to demonstrate your computer science skills in a navigation scenario.
- The goal is finding the shortest path to the destination in an adventurous setting, such as walking in a cave to rescue a person or floating in a space station to go to the transfer chamber to repair air-leak cracks.
- *No shooting or zombie hunting type of themes are allowed*.

Project I: Experimental VR App

The VR app must demonstrate simple AI capabilities:

1) Recalculate the shortest path., i.e., optimize the routing;
2) Guide the user with audio/sound effects, text instructions, and instructional signs/wayfinders;
3) Display relevant performance statistics, such as the distance traveled, on the scoreboard at the end, after completion of the tasks or the journey.

The VR interactions must include:

1) An activity involving Six Degrees of Freedom (6DOF);
2) movement of the user (or avatar) via locomotion (e.g. teleportation).

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How virtual reality really works

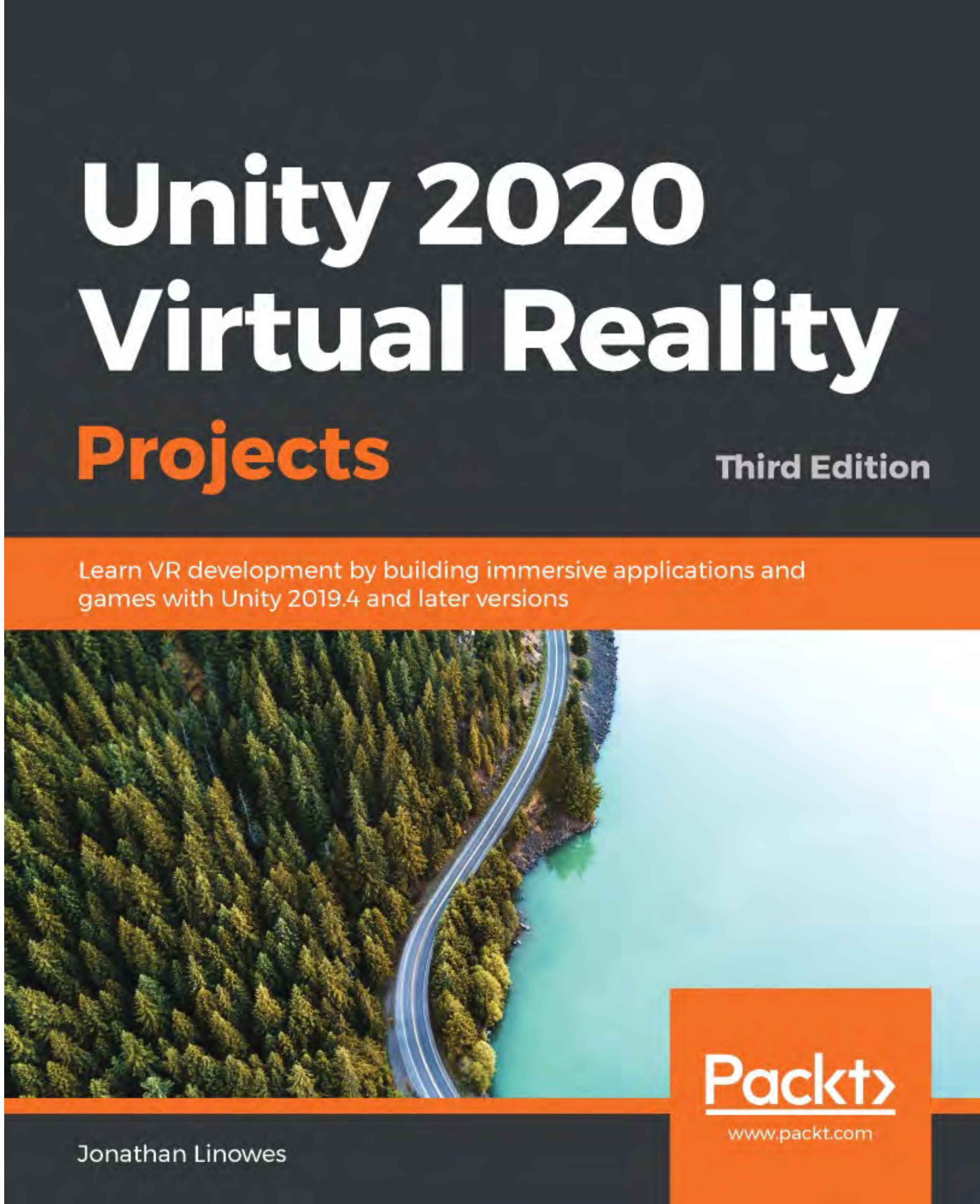
Unity 2020 Virtual Reality Projects
Third Edition

by Jonathan Linowes

Packt Publishing

Release Date: July 2020

https://learning.oreilly.com/library/view/unity-2020-virtual/9781839217333



Immersion and Presence

- *Immersion* is the result of emulating the sensory input that your body receives (visual, auditory, motor, and so on). This can be explained technically.
- *Presence* is the visceral feeling that you get being transported there—a deep emotional or intuitive feeling.
- *Immersion* is the science of VR and *Presence* is the art.

“Increase both to the point where it seems so real,
you forget you're in a virtual world.”

VR Experience

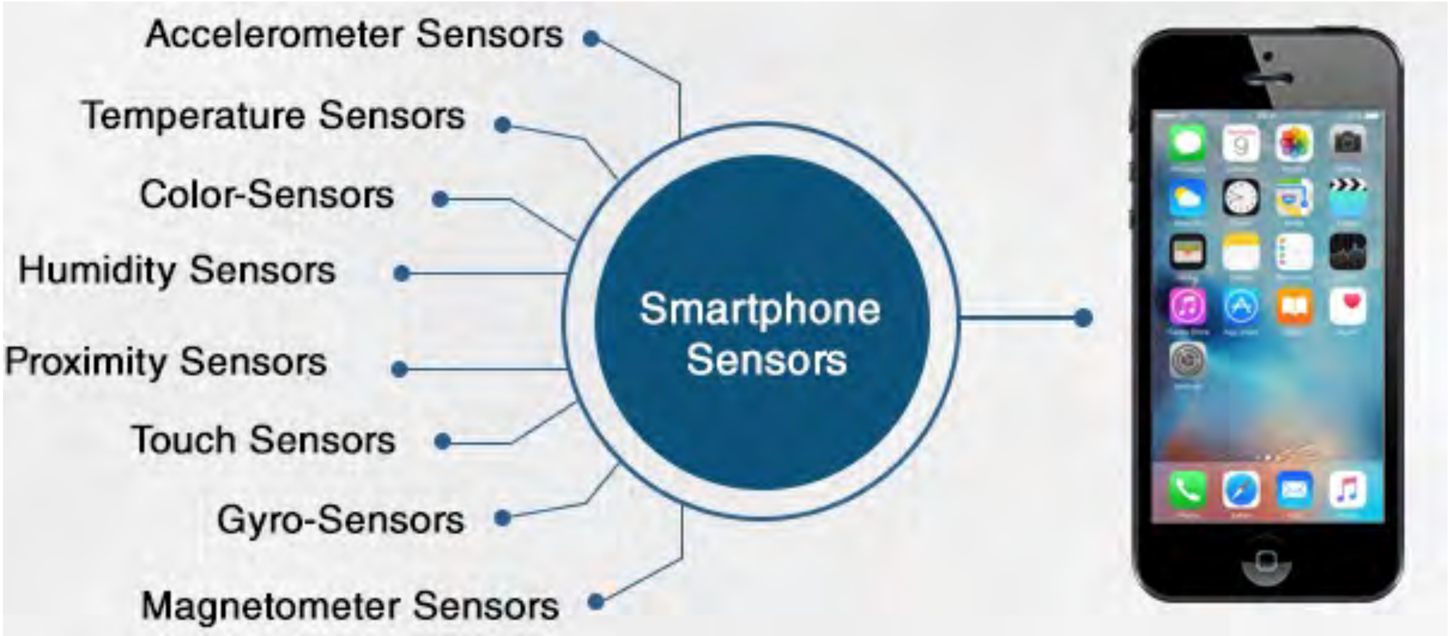
A number of different technologies and techniques come together to make the VR experience work, which can be separated into two basic areas:

- 3D viewing
- Head-pose tracking

cardboard

What makes VR affordable today?

Displays and sensors, like those built into today's mobile devices, are a big reason why VR is possible and affordable today.



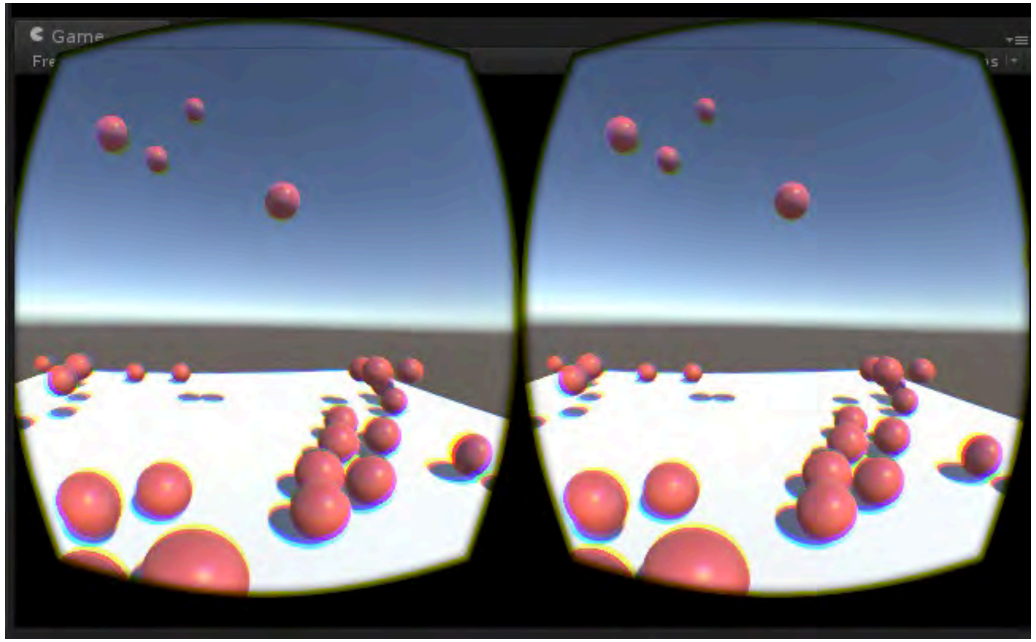
3D viewing

- Stereoscopic 3D viewing
- Split-screen stereography: A stereo photograph has separate views for the left and right eyes, which are slightly offset to create parallax.
- This fools the brain into thinking that it's a truly three-dimensional view.
- The device contains separate lenses for each eye, which let you easily focus on the photo close up:

(B.W. Kilborn & Co, Littleton, New Hampshire, 1876).

VR screen

- Each eye has a barrel-shaped view
- The VR headset lenses:
  - ✓Increase **Field of view** (**FOV**)
  - ✓Make it possible to have the screen so close to your eyes
  - ✓Distort the image (**pincushion effect**)



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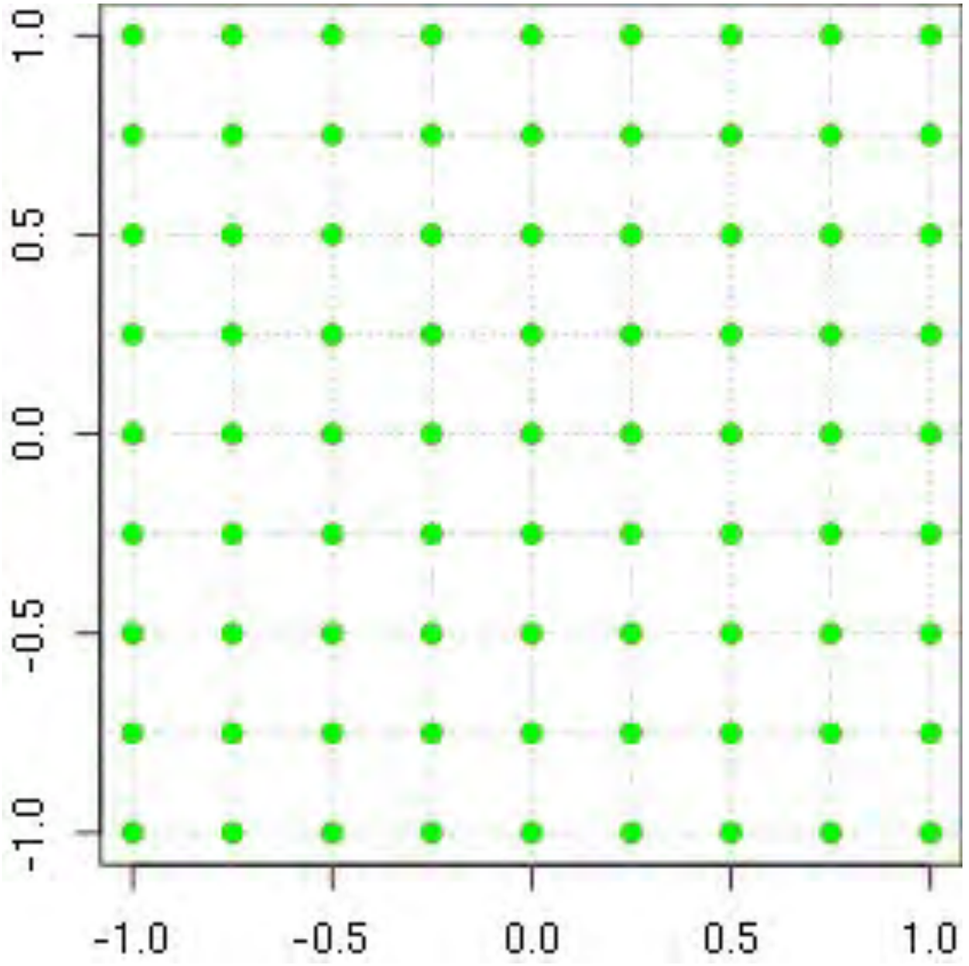
VR screen

- **Ocular distortion correction:** The graphics software SDK does an inverse of that distortion (**barrel distortion**) so that it looks correct to us through the lenses.
- Human FOV 200 –220°
- VR ’21 FOV ~ 100°



Animation of the barrel distortion

https://www.imgtec.com/blog/speeding-up-gpu-barrel-distortion-correction-in-mobile-vr

Correcting Optical Distortions

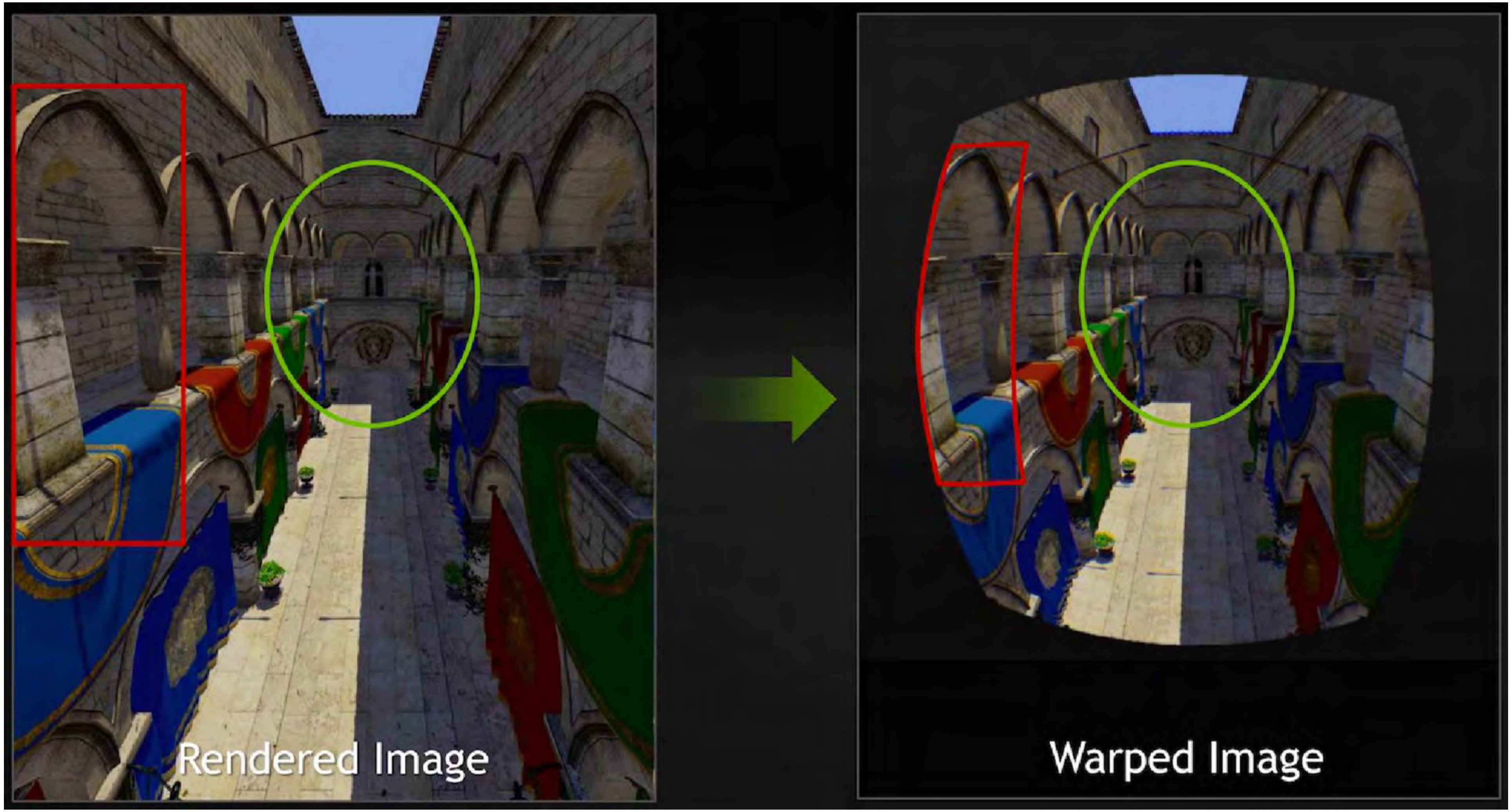
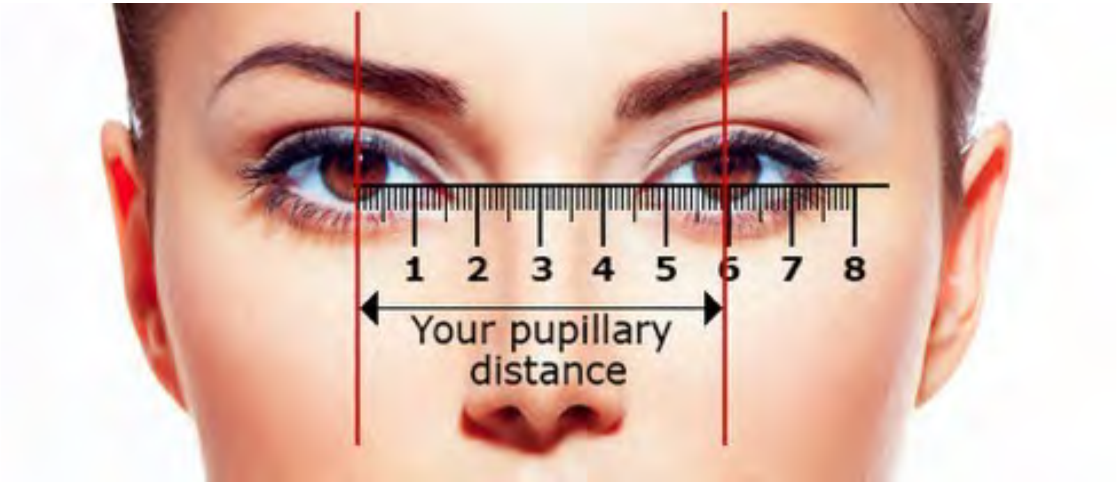


Fig. 7.15 from VR Book by Steve LaVelle

VR screen

- **Inter Pupillary Distance (IPD):** The distance between eyes
  - used to calculate the parallax
  - can vary from one person to the next
- **Color separations:** Light is refracted at different angles
- **Chromatic aberration correction:** **H**elps make the image look crisp



VR screen

Screen-door effect:

- The black, empty spaces between pixels when seen up close.
- Less noticeable on higher-resolution **pixels per square inch** (PPI) displays.

Head-pose tracking

- **Motion sensor (IMU):** Detects spatial acceleration and rotation rates on all three axes, providing the **six degrees of freedom (6DOF)**.
- **Motion detection:** When you move your head, the current viewpoint is calculated and used when the next frame's image is drawn

Head-pose tracking

- **Inside-out positional tracking:**
  - An array of (invisible) infrared LEDs on the HMD are read by an external optical sensor (infrared camera) to determine your position
  - You need to remain within the *view* of the camera (e.g. Oculust Rift)
- **Outside-in positional tracking:**
  - Two or more dumb laser emitters are placed in the room and an optical sensor on the headset reads the rays to determine your position (e.g. HTC VIVE)
- **Windows MR headsets:**
  - Integrated cameras and sensors to perform spatial mapping of the local environment around you:
    - ❖ Locate and track your position in the real-world 3D space.
    - ❖ Accurately find the position of your head and handheld controllers.

How the Vive Lighthouse Works

- Visualize how the HTC Vive and lighthouse system calculates positions in a room environment.
- Works like how ships used to navigate near the shore by counting time between flashes of nearby lighthouses.
- At 60hz in multiple axis and measured at multiple spots.

https://youtu.be/oqPaaMR4kY4

HTC Vive Lighthouse Chaperone Tracking System

- The controllers and VR headset are tracked in room.
- Positions can be calculated with high accuracy and low latency

https://youtu.be/J54dotTt7k0

Head-pose tracking

- **Head-pose:** The position, tilt, and the forward direction of your head. Used by the graphics software to redraw the 3D scene from this vantage point.
- **Screen Refresh Rate:** The screen update rate – measured as Frame Per Second (FPS).
  Example: HTC VIVE headset operates at 90 FPS
- **Latency:** The image is a little out of date with respect to your current position.

Head-pose tracking

- **Motion sickness:** Occurs when you're moving your head and your brain expects the world around you to change exactly in sync.
  - ❖Caused by latency in VR.
  - ❖Any perceptible delay can make you uncomfortable and can make you feel nauseous.
- ***Sensor-to-pixel*** **delay:** Latency can be measured as the time from reading a motion sensor to rendering the corresponding image.

"A total latency of 50 milliseconds will feel responsive, but still noticeable laggy.
20 milliseconds or less will provide the minimum level of latency deemed acceptable" Oculus's John Carmack

Latency compensation (strategies by Oculus)

- **Timewarp:** Tries to guess where your head will be by the time the rendering is done and uses that future head pose instead of the actual detected one.
- Latency can be reduced via the faster rendering of each frame (keeping the recommended FPS):
  - ✓Can be achieved by discouraging your head from moving too quickly
  - ✓Using other techniques to make yourself feel grounded and comfortable

Latency compensation (strategies by Oculus)

- Improve head tracking and realism:
  - Rift uses skeletal representation of the neck
  - All the rotations that it receives are mapped more accurately to the head rotation.
  - Looking down at your lap creates a small forward translation since it knows it's impossible to rotate one's head downwards on the spot.

Enhancing VR Experience

- Head tracking
- Stereography
- 3D audio
- Body tracking
- Hand tracking (and gesture recognition),
- Locomotion tracking (for example, VR treadmills)
- Controllers with haptic feedback.

The goal of all of this is to increase your sense of immersion and presence in the virtual world.

Types of VR experiences

- **Diorama**: Observing from a third-person perspective. Your each eye is a separate camera that gives you a stereographic view.
- **First-person experience**: You're a freely moving avatar and can walk around and explore the virtual scene using an input controller.
- **Interactive virtual environment**: You can interact with the objects. Objects may respond to you. You may be given specific goals to achieve and challenges with the game mechanics.
- **3D content creation**: E.g. Google Tilt Brush, Oculus Medium, and Google Blocks

Types of VR experiences

- **Riding on rails**: You're seated and being transported through the environment (or the environment changes around you).
  - For example, riding a rollercoaster, a real estate walk-through, or a slow, easy, and meditative experience.
- **360-degree media**: Provides an effective sense of presence. You are positioned at the center and can look all around.
  - Some purists don't consider this *real* virtual reality, because you're seeing a projection and not a model rendering.
- **Social VR**: Multiple players enter the same VR space and can see and speak with each other's avatars.

Storytelling with 360º Media

2017 Nor’easter Winter Storm Stella Envelops New York’s Times Square

https://youtu.be/4AVB_Ch6rmw

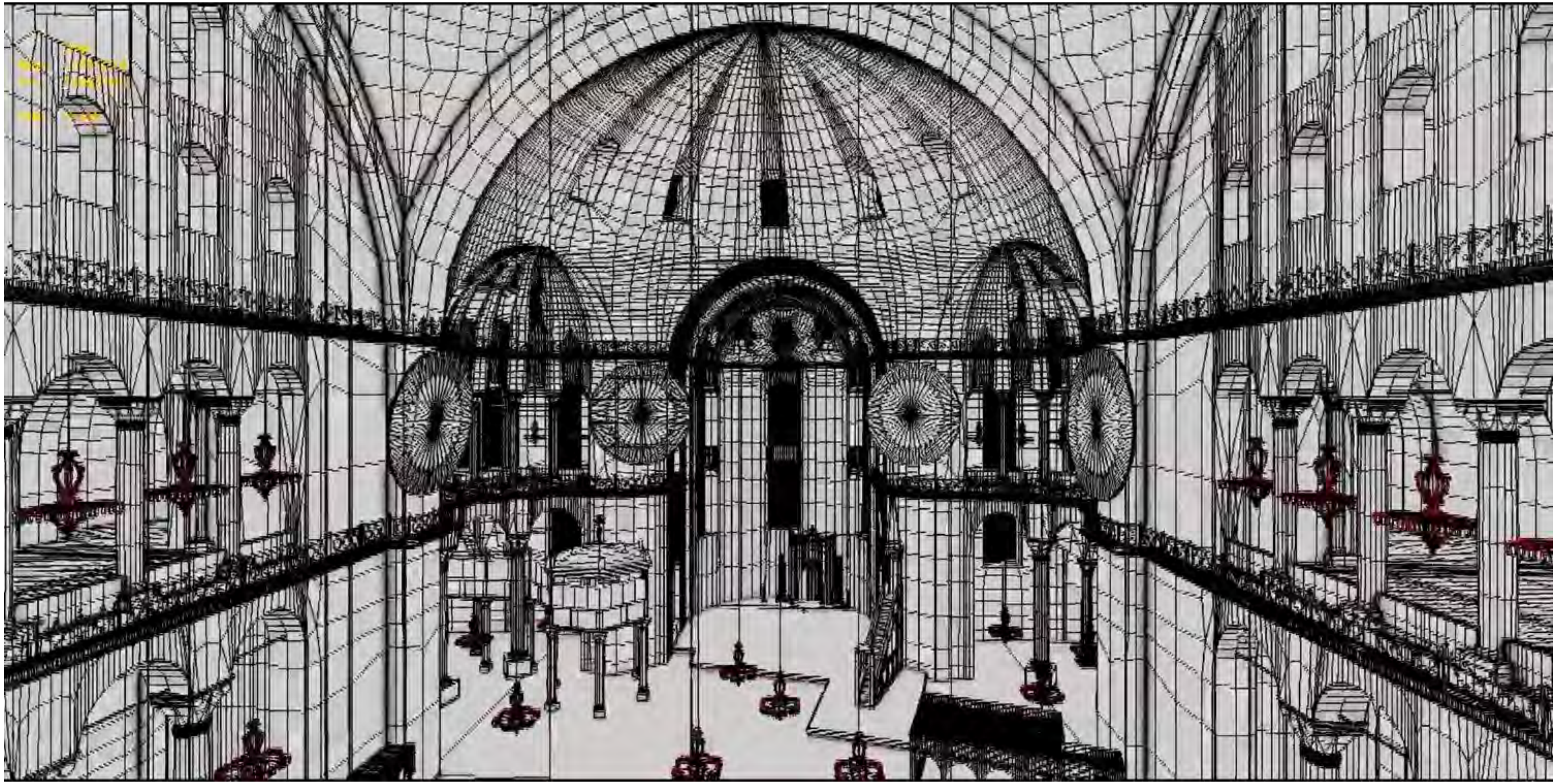
Storytelling with 360º Media

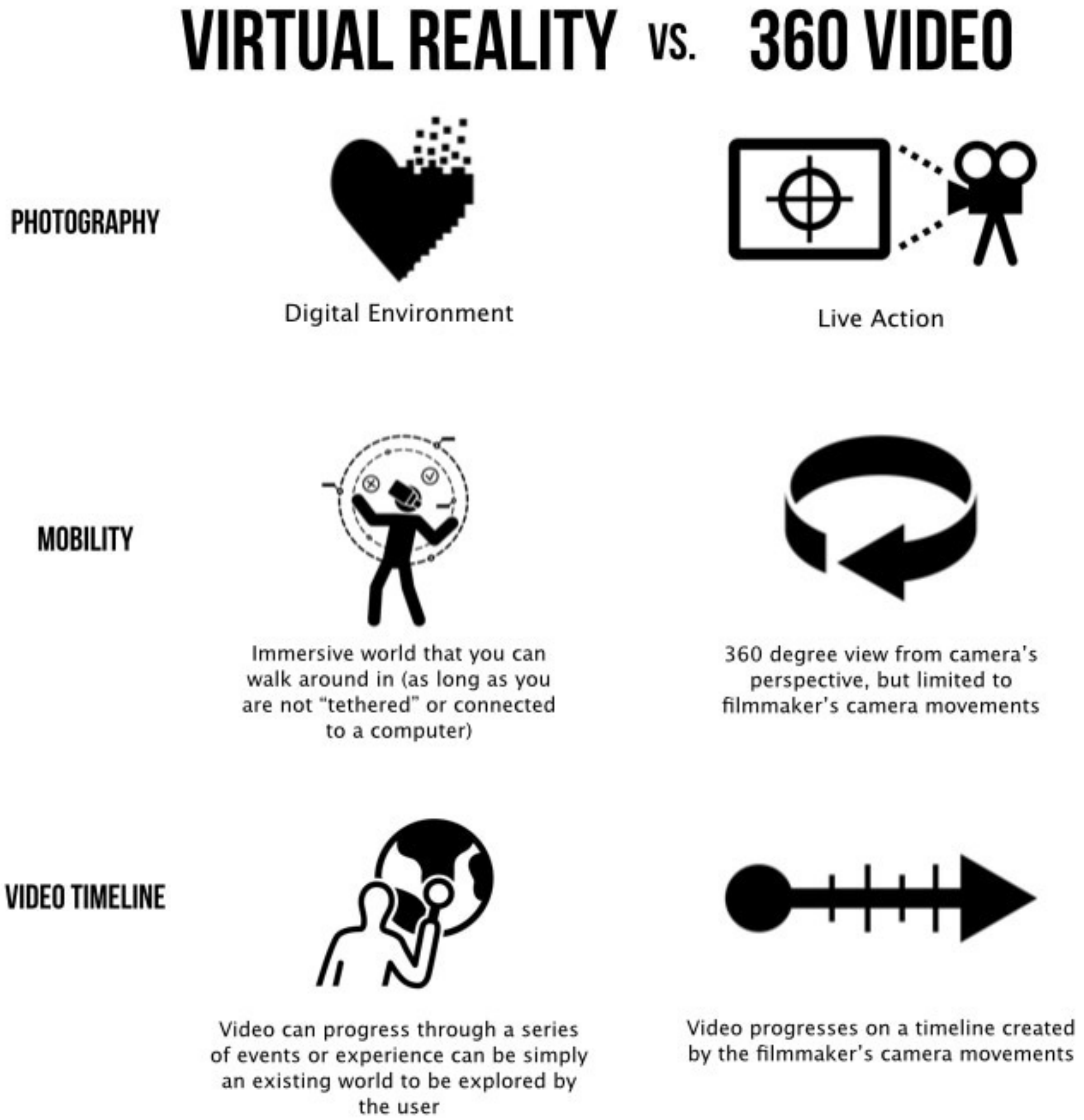
INVASION! | Animated 360 VR Movie
https://youtu.be/SZ0fKW5PttM

360 Media Demo: Tourism

https://vimeo.com/vrtu/hagiasophiasol

360 Media from 3D Model





https://filmora.wondershare.com/virtual-reality/difference-between-360-video-vr.html

Creating Immersive 360˚ Videos

https://www.warpvr.com/blog/the-12-best-360-cameras-for-every-price-range

Large-Sensor Professional 360 Camera

https://360rumors.com/professional-360-camera-comparison-chart-360-cameras-largest-sensors/

360 Cameras for Virtual Tours

https://truevirtualtours.com/article/best-360-cameras-2019

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VR Locomotion

Unreal Engine VR Cookbook: Developing Virtual Reality with UE4

Mitch McCaffrey

©2017 Addison-Wesley Professional

https://learning.oreilly.com/library/view/unreal-engine-vr/9780134649252/ch09.html

Simulator Sickness

- **Motion sickness:** Arises from physical motion.
- **Simulator sickness:** The by-product of subjecting users to a perceived motion (in VR, in our case) that differs from what their bodies tell them.
- **Vestibular system:** The main detector of these discrepancies between real-world motion and artificial motion.
- **Vection:** The feeling of motion that a player gets from the visual system alone. More vection equals more discomfort.

Simulator Sickness

- **Optic flow:** Any motion in your scene that signals to players that they are moving.
- Know your target audience for your game/experience
- Target your locomotion design choices to them.
- The less (artificial) acceleration, the more comfortable users will be.
- Many factors that increase the comfort of your experience can also decrease the immersion.

Example: “Titans of Space” VR

- **Cockpit** is one way to reduce vection/simulator sickness because they reduce the total optic flow in a scene.
- Help with vection by providing players with a frame of reference, grounding them to a scene.
- Not applicable to all experiences.

Locomotion Types

Movement in VR is still an experimental field.

Many different techniques can be used to ensure that your users have the most comfortable experience:

- Natural
- Teleportation
- Vehicle
- Physical
- Artificial

Natural locomotion

Natural locomotion methods are generally one-to-one in their translation of real-world movements into player movements

- Advantages:
  - Least likely to induce simulator sickness
- Disadvantages:
  - Limited by the player's physical space. Limited to the HMD's tracking space
- Variations:
  - Redirected walking (moving the virtual world to keep the player inside the play space)

Teleportation

Can be combined with natural locomotion to extend the range of the method beyond the player's physical space.

- Advantages:
  - Allows the player to move past physical boundaries
  - Little nausea induced
- Disadvantages:
  - Can cause discomfort
  - Disorienting
  - Can still cause vection through micro-teleporting
- Variations:
  - Visualizing the play space before teleporting
  - Physical object teleporting beacon (can eliminate micro-teleporting)
  - Node based (allowing the player to teleport only to fixed locations)

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VR HUD Navigation Challenge

NIST Public Safety Communication Research (PSCR) Prize Challenge 2018:

- Leverage VR Technology and Showcase:
  - ✓ Use VR for safe, low-cost rapid assessment of UIs
  - ✓ Repeatable test measuring efficiency, effectiveness, and user satisfaction of the UIs

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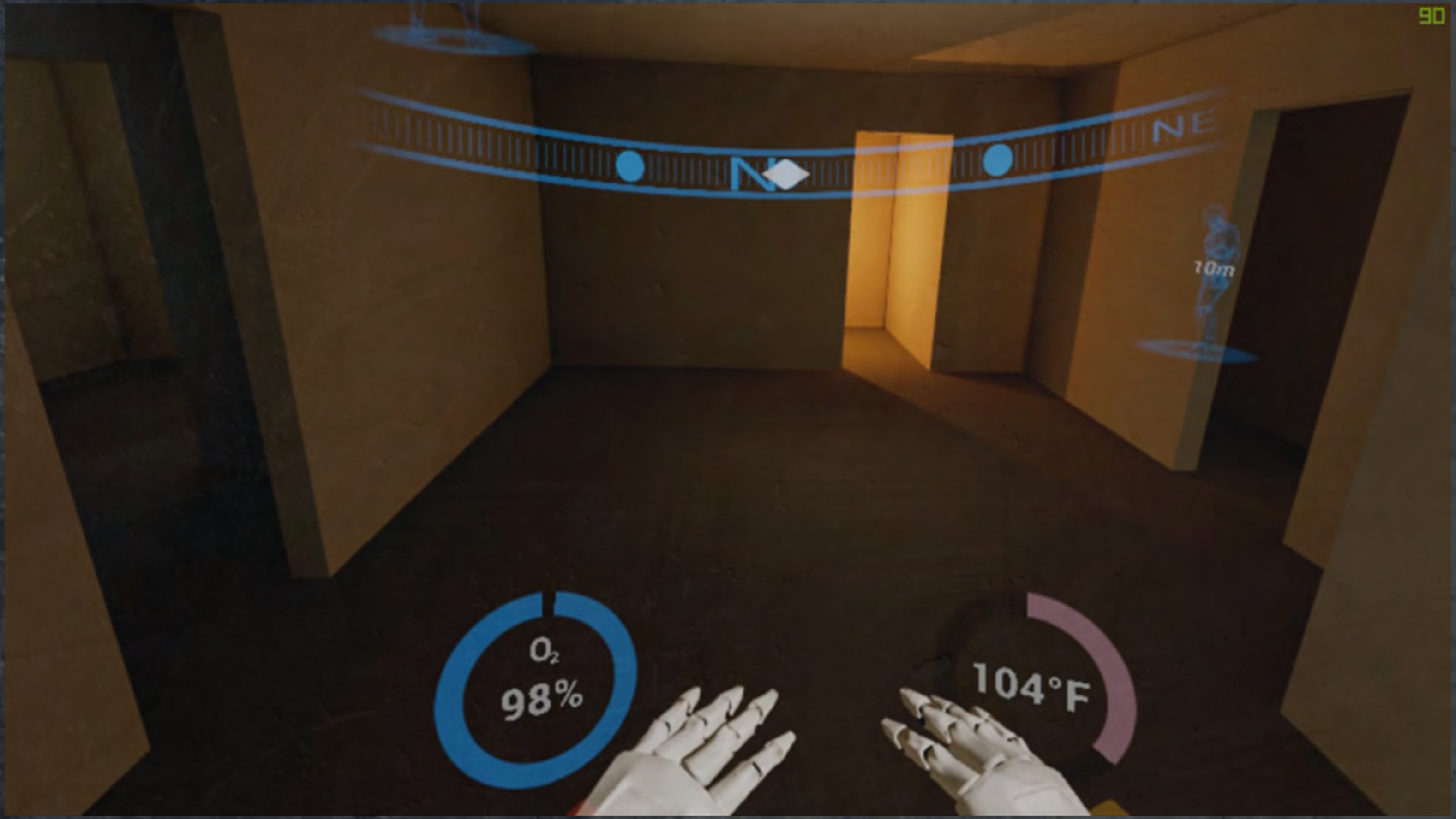
VR HUD Navigation Challenge

UX/UI Design

- Intuitive
- Non-Invasive
- Qualitative



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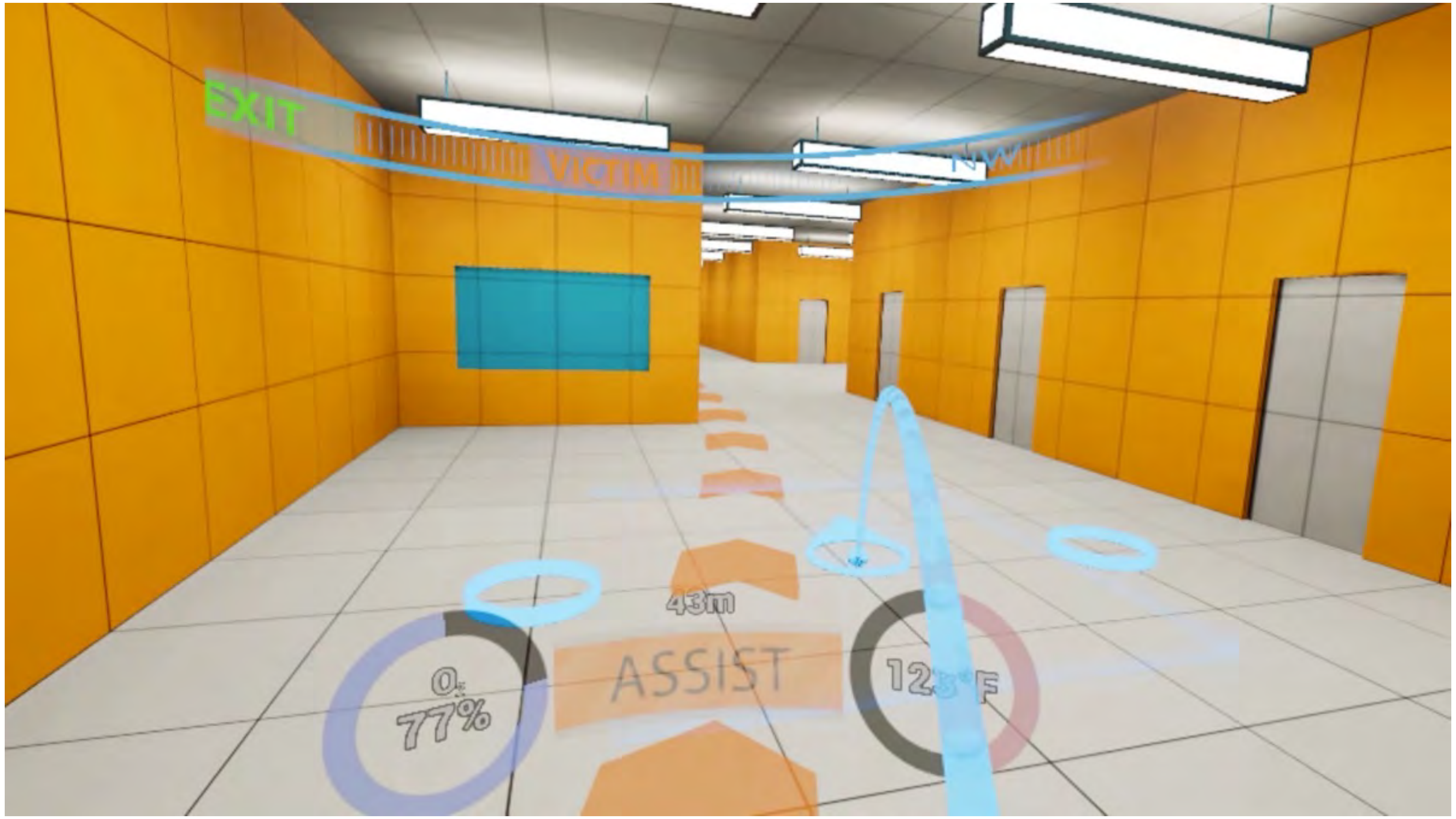
VR HUD Navigation Challenge

UX/UI Evaluation Criteria

- Navigation Elements
- Time to Complete Mission
- Varying Lighting

Teleportation Demo – Navigation



https://vimeo.com/vrtu/vrhudnavigationtutorial

Vehicle locomotion

Vehicle locomotion is a one-to-one method with the virtual vehicle (car, ship, or otherwise) as the reference frame for the user.

- Advantages:
  - Less optic flow means less vection
  - Grounding decreases the potential for nausea
- Disadvantages:
  - Not suitable for many experiences
- Variations:
  - Temporary grid allowing the player to get the same grounding as a vehicle

Physical locomotion

Generally, physical locomotion involves some sort of physical action in the real world that gets translated into another motion in the virtual world.

- Advantages:
  - Leads to novel locomotion methods that can suit specific games nicely
  - Can reduce vection because of the user's expectation of the motion
- Disadvantages:
  - Possibly gimmicky
  - Chance for simulator sickness in sensitive users
- Variations:
  - Skiing
  - Climbing
  - Flying (wing flapping)
  - Running
  - World pulling (pulling the world around the player with motion controllers)

Artificial locomotion

Artificial locomotion has little real-world player movement translated into the virtual world. Instead, it relies on more traditional game input (such as a gamepad thumbstick).

- Advantages:
  - Freedom to move around without dependencies on a player’s physical space
  - Quick to port non-VR games to VR
- Disadvantages:
  - Causes simulator sickness in many players
- Variations:
  - Snap turning
  - Turret movement

Overview of different locomotion methods on HTC Vive

A demonstration of various different proven and experimental locomotion methods for HTC Vive virtual reality.

https://youtu.be/p0YxzgQG2-E