CSE 190: Virtual Reality Technologies

LECTURE #9: VR DISPLAY TYPES

Agenda

App presentation:
- Danny Vo: Skeet: VR Target Shooting

Technology presentation:
- Calvin Chen

Reading: HoloLens 2
- Based on what we discussed about the specs for a perfect VR/AR headset, how close does the Hololens 2 get?
- Which areas does it get closer to a perfect device, where is it still far removed from that goal?

Today's topic: VR Display Types

Screen-Based VR

3D Monitor

PC with 3D capable monitor

Active or passive stereo

A.k.a. “Fishtank VR”

Requires separate tracking system

VR CAVE

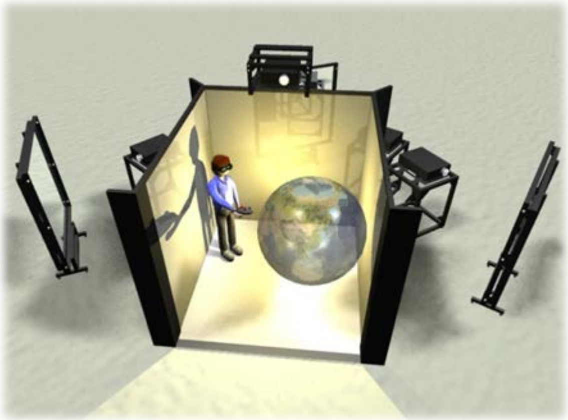
CAVE = CAVE Automated Virtual Environment

Puts user in a room for visual immersion

Usually driven by a cluster of powerful graphics computers

Multiple displays around the user

3D tracking for head and controllers



SunCAVE at UCSD

Since 2017

70 x 55” LCD 4k displays

Passive stereo

36 graphics PCs

71 Nvidia GTX 1080 GPUs

~500 Mpixels

40 Gbps network

Head-Mounted Displays (HMDs)

Head Mounted Displays

Head-worn displays with special optics in front of the eyes

Provide a stereoscopic view that is updated with the user's head motion

VR HMDs occlude the real world

AR HMDs can be translucent or video see-through

Oculus Quest 2

Microsoft Hololens 2

HMD Advantages

Provide an immersive experience by allowing a 360 degree FOR

Easy to transport and to set up

Do not restrict user from moving around in the real world

Inexpensive

High quality stereo without ghosting

Only one computer needed, some are stand-alone

HMDs – Disadvantages

Limited resolution and field of view (FOV)

Do not take advantage of peripheral vision

Can be heavy and uncomfortable, cumbersome to put on

Isolating, collaboration best done virtually (users in same room can't see each other)

Risks related to not seeing the real world (e.g., stumbling)

Sony Playstation VR

Released October 13, 2016

Sold for Play Station 4

Single OLED display

960 x 1080 pixels per eye

100 degrees field of view

90 or 120 Hz refresh rate

Fixed IPD

Headphone jack

Innovative head strap

External camera for tracking

6 DOF tracking with visible light in different colors

Uses Sony Move controllers

Oculus Quest 2

Release date: Oct 13, 2020

Standalone VR HMD
- Inside-out 6 DOF tracking

LCD display

1832 x 1920 pixels per eye

90 Hz refresh rate

90 degrees FOV

Adjustable IPD (3 settings)

Qualcomm Snapdragon XR2

Built-in headphones

Includes 2 controllers

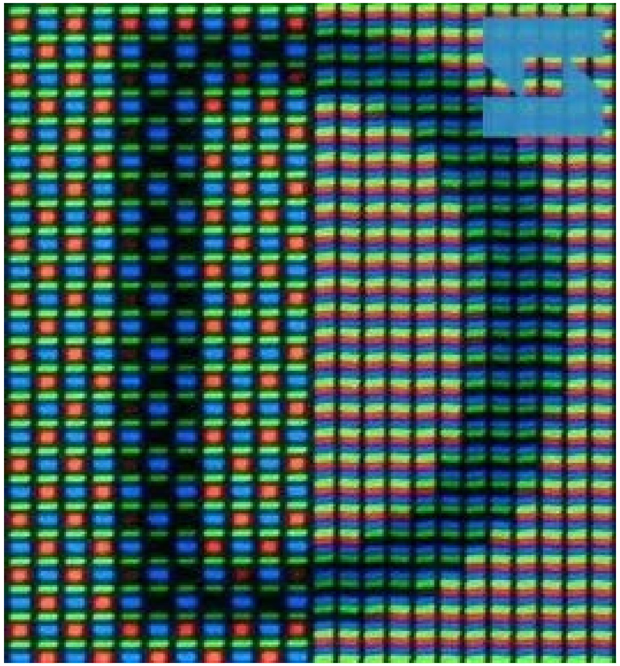
OLED vs. LCD

OLED = Organic Light-Emitting Diode

OLED screens do not need a backlight, as each pixel is able to produce **its own light** when it needs to. This makes **blacks look great** when viewing a picture or video, because the pixels do not have a to provide light at all, rather than LCD displays where the backlight bleeds through and you get a dark grey color where there should be black.

OLED drawbacks:

- more expensive to produce
- not as sharp as LCD displays
  - OLED use a different subpixel arrangement than LCD displays, which makes individual pixels more noticeable



OLED LCD

Latest Vive Headsets

Vive Pro 2:

- 2448×2448 pixels per eye
- 120 degree FOV
- 120Hz refresh
- Tethered, available wireless adapter

Vive Focus 3:

- Qualcomm XR2 (same as in Oculus Quest 2)
- 2448×2448 pixels per eye
- 120 degree FOV
- 90Hz refresh
- Swappable battery pack

DEVICE	FOV	REFRESH RATE	TRACKING TECHNOLOGY	PLATFORM SUPPORT	PRICE (USD)	WIRELESS CAPABLE	DISPLAY DETAILS	RESOLUTION PER EYE
Google Cardboard	~90	(as low as) 60Hz (as high as) 144Hz	✗	G	HEADSET $15 FULL KIT ✗	✓	VARIES	(as low as) 540x480 (as high as) 2160x2160
Switch LABO	~90	60Hz	✗	Nintendo	CONSOLE $299 LABO KIT $39	✓	LCD RGB	640x480
Playstation VR	100	120Hz (REPROJECTION)			HEADSET ✗ FULL KIT $349	✗	OLED RGB	960x1080
Oculus Rift S	90	80Hz			HEADSET ✗ FULL KIT $399	✗	LCD RGB	1280x1440
Asus HC102	95	90Hz			HEADSET ✗ FULL KIT $400	✗	OLED PENTILE	1440x1440
Lenovo Explorer	110	90Hz			HEADSET $349 FULL KIT $450	✗	LCD	1440x1440
Dell Visor	110	90Hz			HEADSET $350 FULL KIT $450	✗	LED RGB	1440x1440
Oculus Quest 2	89	120Hz (EXPERIMENTAL)			64GB $299 256GB $399	✓	LCD RGB	1832x1920
Oculus Quest	94	72Hz			64GB $399 128GB $499	✓	OLED PENTILE	1600x1440
Odyssey+	110	90Hz			HEADSET ✗ FULL KIT $499	✗	AMOLED PENTILE	1440x1600
HP Reverb G1	114	90Hz			HEADSET ✗ FULL KIT $599	✗	LCD RGB	2160x2160
HP Reverb G2	115	90Hz			HEADSET ✗ FULL KIT $599	✗	LCD RGB INDEX LENSES	2160x2160

DEVICE	FOV	REFRESH RATE	TRACKING TECHNOLOGY	PLATFORM SUPPORT	PRICE (USD)	WIRELESS CAPABLE	DISPLAY DETAILS	RESOLUTION PER EYE
Vive Cosmos	110	90Hz			HEADSET ✗ FULL KIT $699	✓	LCD RGB	1440x1700
HTC Vive Focus	110	75Hz			HEADSET ✗ FULL KIT $799	✓	AMOLED PENTILE	1440x1600
Cosmos Elite	110	90Hz			HEADSET $549 FULL KIT $899	✓	LCD RGB	1440x1700
PiMAX 8K	170	80Hz			HEADSET $499 FULL KIT $999	✗	LCD RGB	3840x2160
Valve Index	130	144Hz			HEADSET $499 FULL KIT $999	✗	LCD RGB	1440x1600
HTC Vive Pro	110	90Hz			HEADSET $799 FULL KIT $1199	✓	AMOLED PENTILE	1440x1600
PiMAX 8K	170	80Hz			HEADSET $1299 FULL KIT ✗	✗	LCD RGB	3840x2160
PiMAX 5K PLUS	170	144Hz			HEADSET $899 FULL KIT $1399	✗	OLED PENTILE	2560x1440
StarVR ONE	210	90Hz			HEADSET $3200 FULL KIT ✗	✗	AMOLED RGB TOBII EYE	1830x1464
HTC Vive	110	90Hz			HEADSET DISCONTINUED FULL KIT DISCONTINUED	✓	AMOLED PENTILE	1080x1200
Oculus CV1	94	90Hz			HEADSET DISCONTINUED FULL KIT DISCONTINUED	✓	OLED PENTILE	1080x1200
Virtual Boy	~30	50Hz	✗	Nintendo	HEADSET DISCONTINUED FULL KIT DISCONTINUED	✗	LED	384x224 (1×224 scanned)

Discalimers:
Field of view depends highly on the screen size and eye relief (eye to lens distance).
All FOVs listed are the **horizontal** specifications.
All specifications listed are from the "Comparison of virtual reality headsets" Wiki Article

V1.3

HMD Rendering Tricks

Mitigating Rendering Latency

Rendering an image in stereo takes about 10 milliseconds.

Problem:

- By the time rendering is done, the user may have moved their head.

Pose Prediction

Predict what head pose is when images are displayed by extrapolating current head motion.

Two options:

Constant rate: Assume the currently measured angular velocity will remain constant over the latency interval.

Constant acceleration: Estimate angular acceleration and adjust angular velocity accordingly over the latency interval.

Time Warp

The idea of Timewarp was added to the Oculus software in April 2014 by John Carmack.

Standard Timewarp does not help with framerate. It was made to lower the perceived latency of VR.

Timewarp reprojects an already rendered frame just before sending it to the headset to account for the change in head rotation.

It warps the image geometrically in the direction you rotated your head between the time the frame started and finished rendering. Since this takes a fraction of the time that re-rendering would and the frame is sent to the headset immediately after, the perceived latency is lower since the result is closer to what you should be seeing.

Time Warp Explained

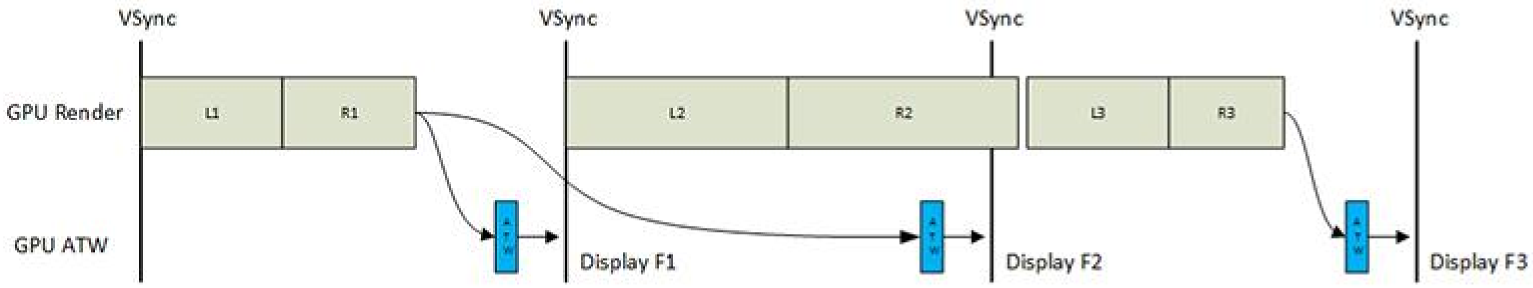
https://www.youtube.com/watch?v=WvtEXMlQQtI&t=2s

Asynchronous Time Warp (ATW)

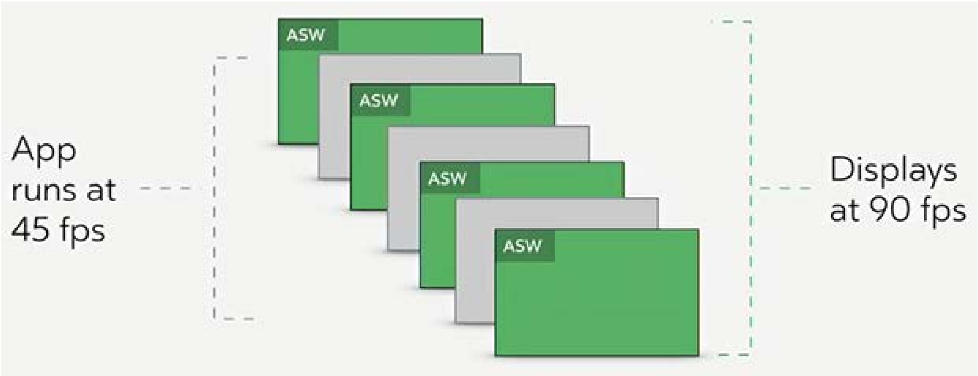
Asynchronous Timewarp takes the same concept of geometric warping and uses it to compensate for dropped frames.

If the current frame doesn't finish rendering in time, ATW reprojects the previous frame with the latest tracking data instead.

It is called "asynchronous" because it occurs in parallel to rendering rather than after it. The synthetic frame is ready before it's known whether or not the real frame will finish rendering on time.



Asynchronous Space Warp (ASW)



When an application fails to render frames at 90Hz, the Rift driver drops the application down to 45Hz with ASW providing each intermediate frame.

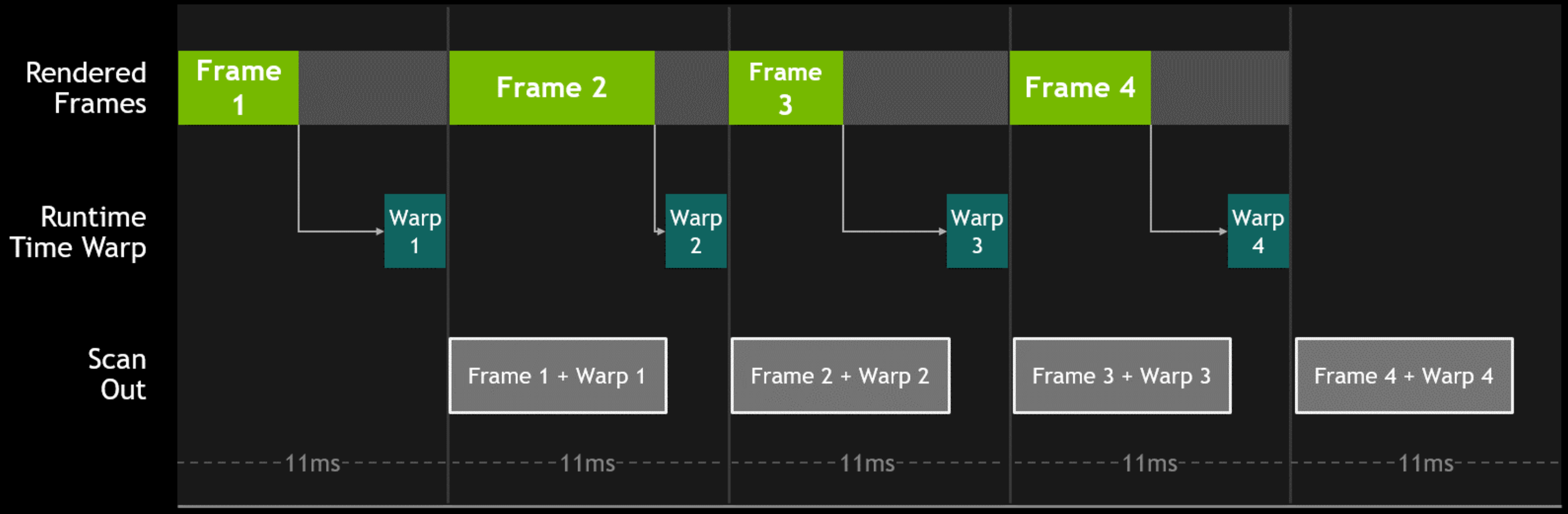
ASW works in tandem with ATW to cover all visual motion within the virtual reality experience.

ASW applies animation detection, camera translation, and head translation to previous frames in order to predict and extrapolate the next frame.

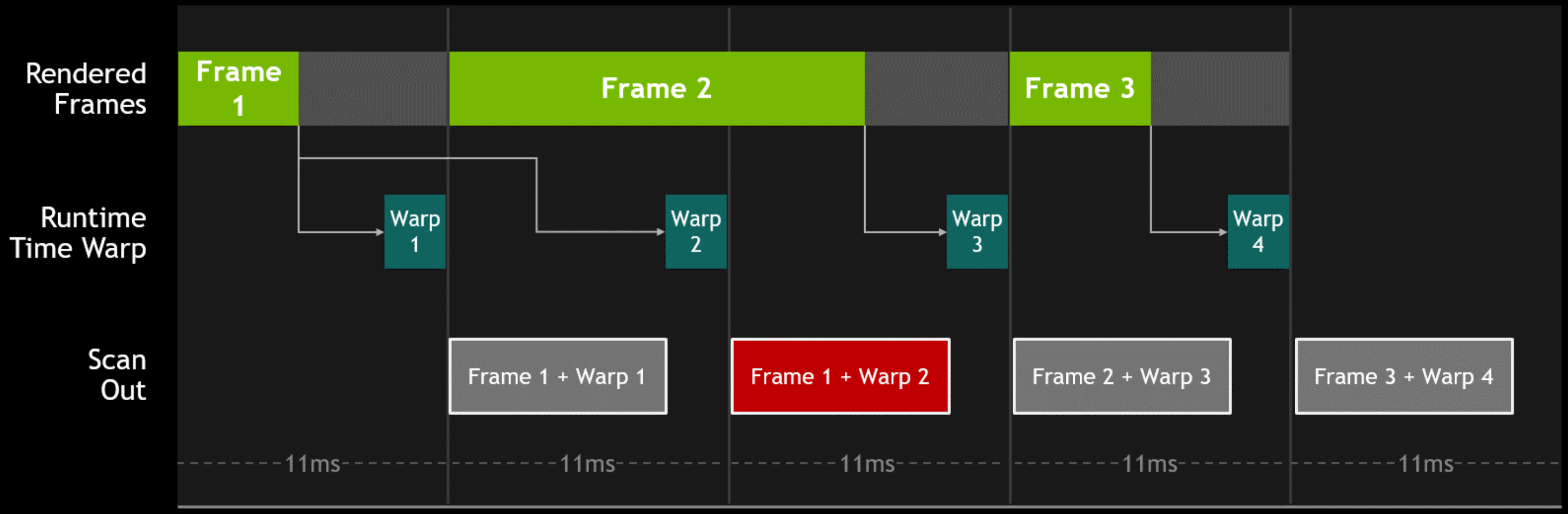
ASW Explained

https://www.youtube.com/watch?v=eAl2l_1KfqQ&t=1239s

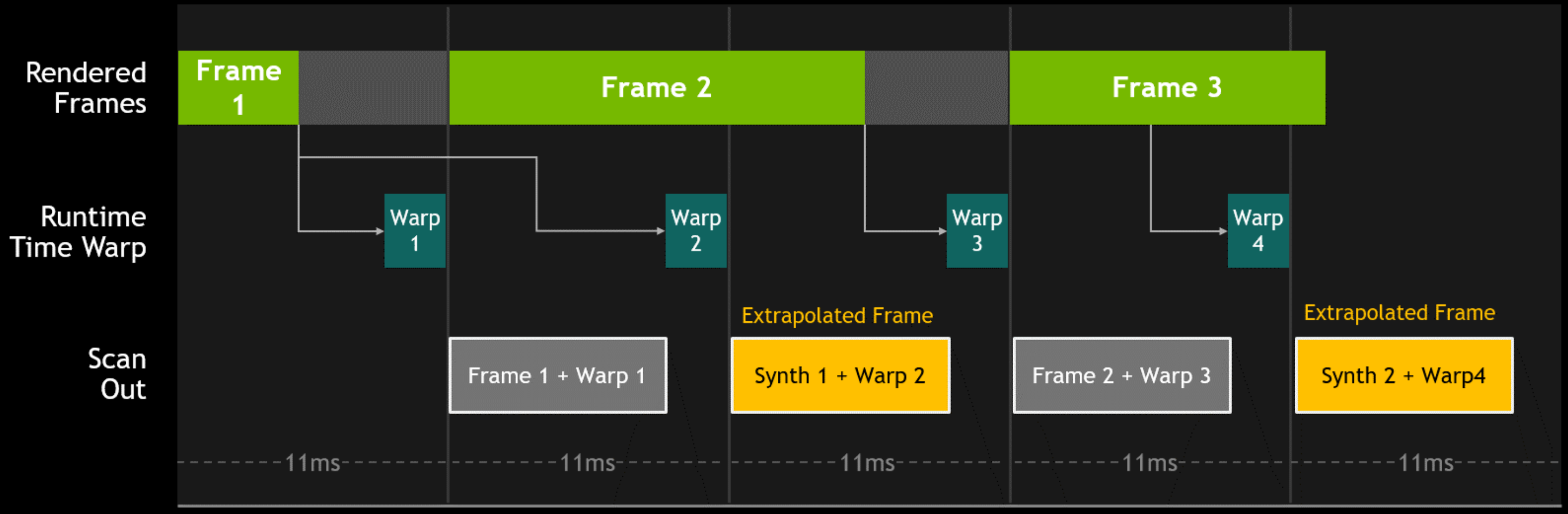
IDEAL VR PIPELINE



DROPPED FRAME



SYNTHESIZED FRAME



ASW – Visual Artifacts

ASW has problems with:

- Quick brightness changes
- Rapidly-moving repeating patterns in the environment
- Head-locked elements that move too fast to track properly

Spacewarp is a band-aid rather than a real performance optimization

Alternatives to ASW:

- Reduce rendering resolution
- Reduce polygon complexity
- Reduce texture detail
- Reduce time spent on non-rendering tasks