CSE 190: Virtual Reality Technologies

LECTURE #8: HEAD-MOUNTED DISPLAYS

Announcements

Homework project 2

- Due next Friday at 2pm
  - To be demonstrated in VR lab B210
  - Upload code to TritonEd by 2pm

Head-Mounted Displays

Head Mounted Displays

Have CRT or LCD screens with special optics in front of the eyes

Display occludes real world

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

Sensics PiSight

Released April 2006

2200x1200 color pixels per eye

150 degrees field of view

24 OLED microdisplays

6 DOF tracking

$200k

HMDs – Advantages

Provide an immersive experience by blocking out the real world

Easy to set up

Do not restrict user from moving around in the real world

Relatively inexpensive

Can achieve good stereo quality

HMDs – Disadvantages

Poor resolution and field of view (FOV)

Do not take advantage of peripheral vision

Isolation and risks related to not seeing the real world (e.g., stumbling)

Can be heavy and uncomfortable, cumbersome to put on

The new wave of HMDs

Cell phone tech has matured

- High resolution screens (~3k in Galaxy S6-8)
- Integrated fast gyroscopes, accelerometers, magnetometers

Games use real 3D coordinate spaces

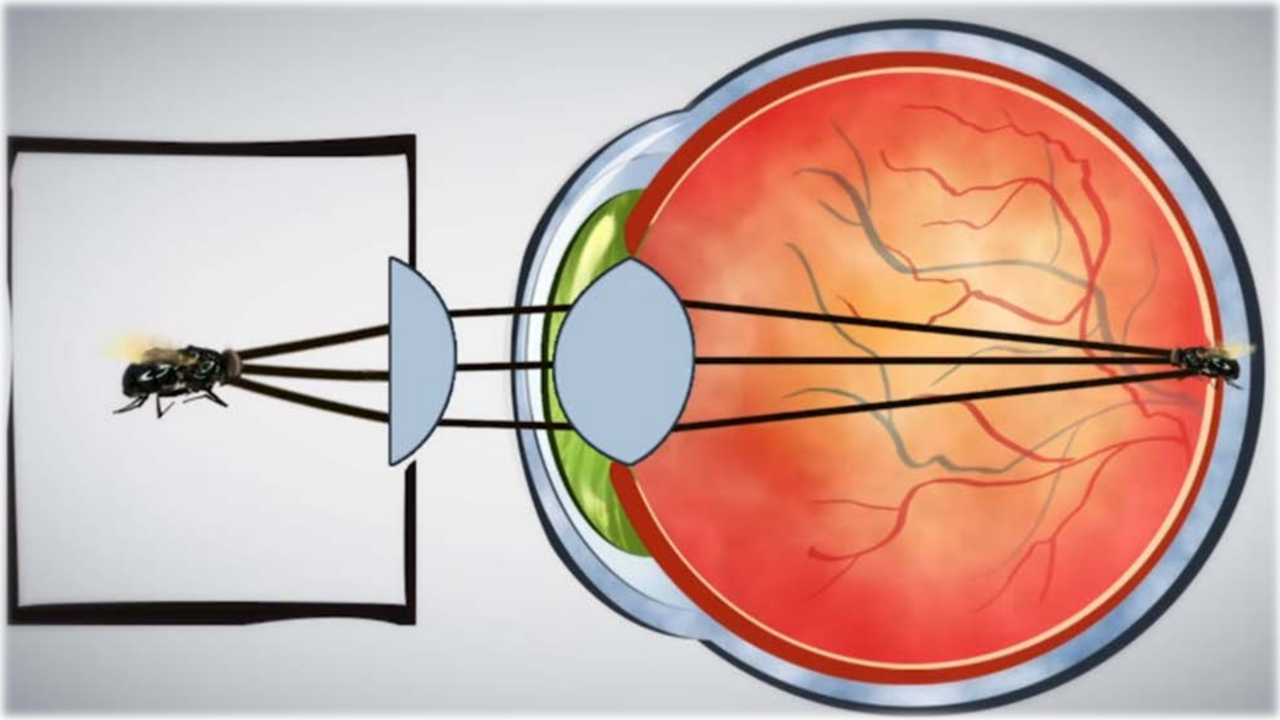
Graphics cards support 3D because of 3D monitors

Real-time rendering quality close to photo-realistic

Lenses for VR HMDs

How lenses for VR HMDs work:

- https://www.youtube.com/watch?v=NCBEYaC876A



Focal Distance

Apparent distance from eye to where the pixels are in focus.

HMD	Focal Distance
Oculus DK1	Infinity
Oculus DK2	1.4 meters
Oculus CV1	2 meters
HTC Vive	~1 meter

Reprojection

Mitigating Rendering Latency

Rendering an image in stereo takes about 10 milliseconds.

By the time rendering is done, the user likely 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 has been around in VR research for decades, but the specific feature was added to the Oculus software in April 2014 by John Carmack.

Standard Timewarp in itself 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.

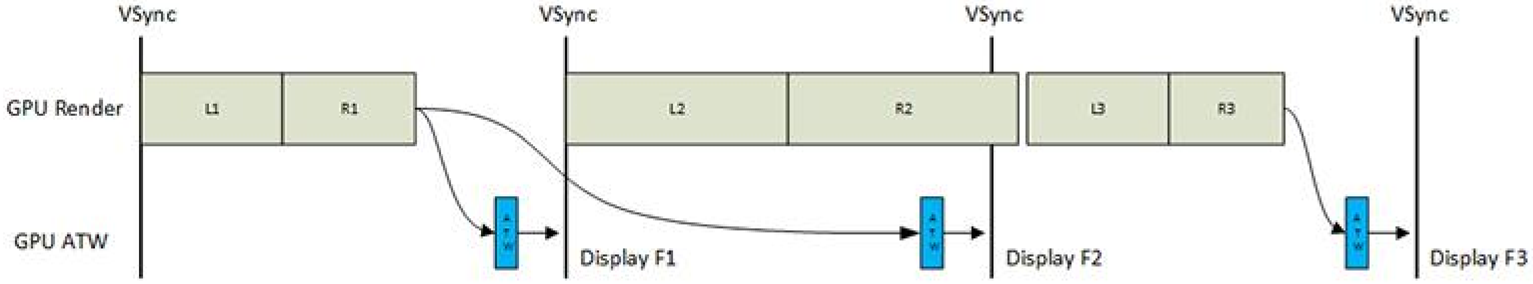
That is, it warps the image geometrically in the direction you rotated your head between the time the frame started and finished rendering. Since this takes a fraction of the time that re-rendering would and the frame is sent to the headset immediately after, the perceived latency is lower since the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

Asynchronous Time Warp (ATW)

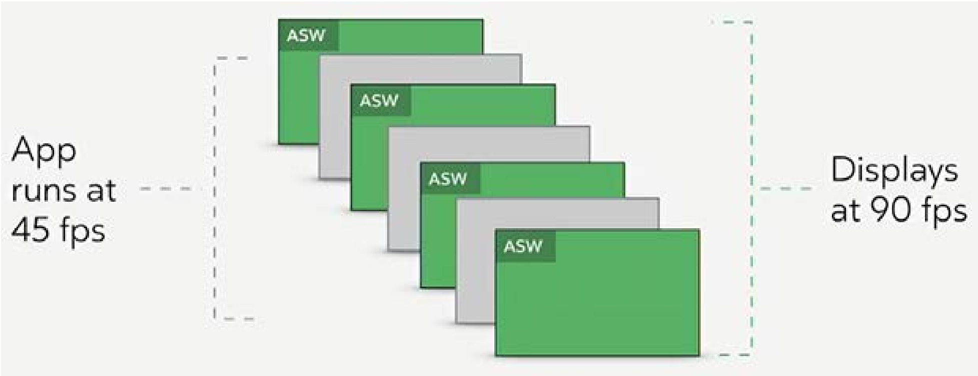
Asynchronous Timewarp takes the same concept of geometric warping and uses it to compensate for dropped frames.

If the current frame doesn't finish rendering in time, ATWreprojects 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)



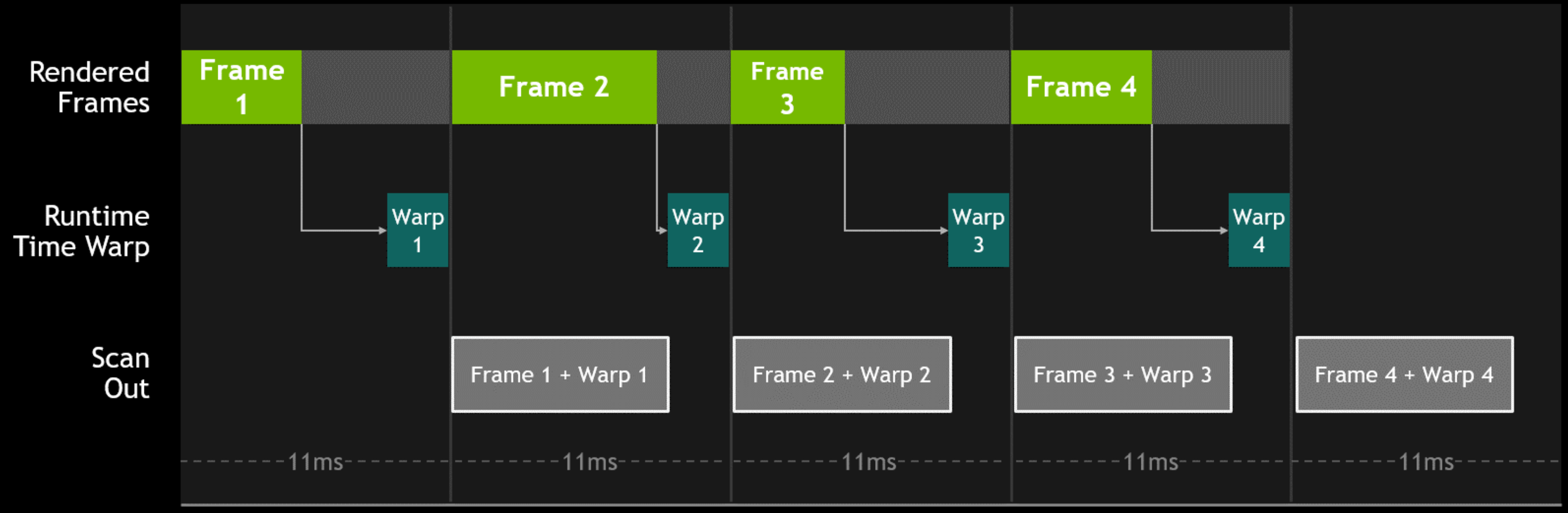
When an application fails to render frames at 90Hz, the Rift driver drops the application down to 45Hz with ASW providing each intermediate frame.

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

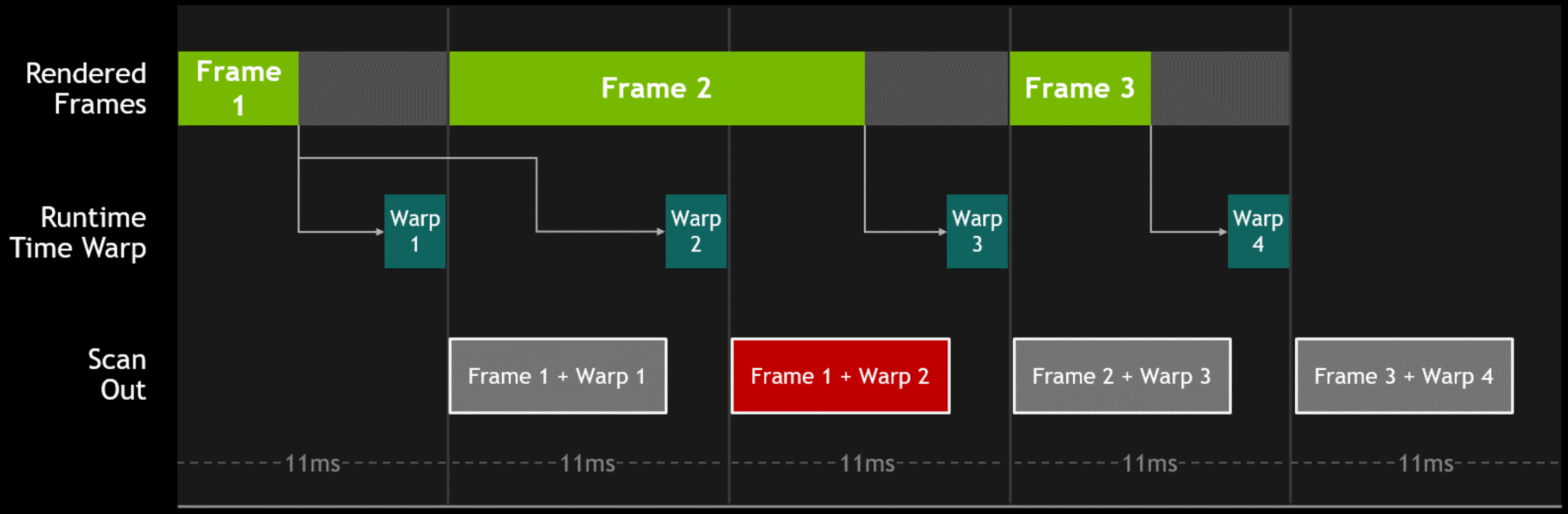
ASW applies animation detection, camera translation, and head translation to previous frames in order to predict and extrapolate the next frame.

This includes character movement, camera movement, Touch controller movement, and the player's own positional movement.

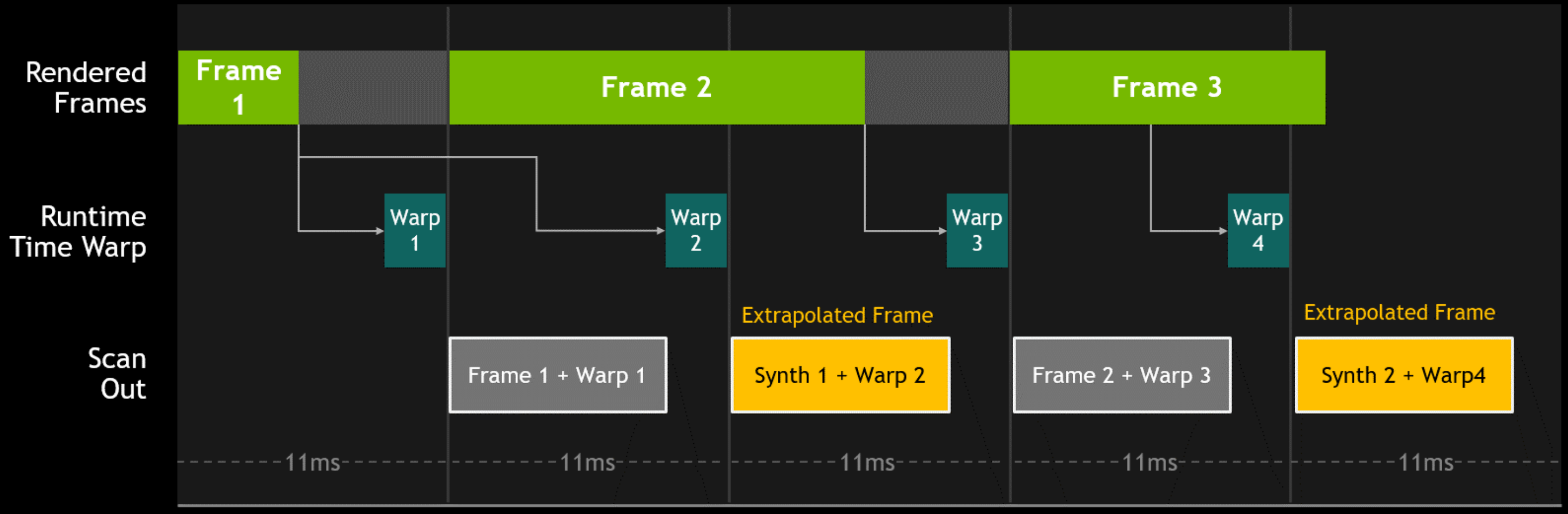
IDEAL VR PIPELINE



DROPPED FRAME



SYNTHESIZED FRAME



ASW – Results

As a result, motion is smoothed and applications can run on lower performance hardware:

- Nvidia 960 or greater (down from GTX 970 or greater)
- Intel i3-6100 / AMD FX4350 or greater (down from Intel i5-4590 equivalent or greater)

ASW tends to predict linear motion better than non-linear motion.

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

ASW 2.0

Asynchronous Spacewarp 2.0 is an update to ASW which greatly enhances the quality of the technique by incorporating understanding of depth. When announcing the technique, Oculus showed the following scenario as an example of the visual artifacts the 2.0 update will eliminate:

https://www.youtube.com/watch?time_continue=4&v=I3LGq5TmMkw

Unlike the other techniques, ASW 2.0 won't work on just any app. The developer has to submit their depth buffer each frame, otherwise it will fall back to ASW 1.0.

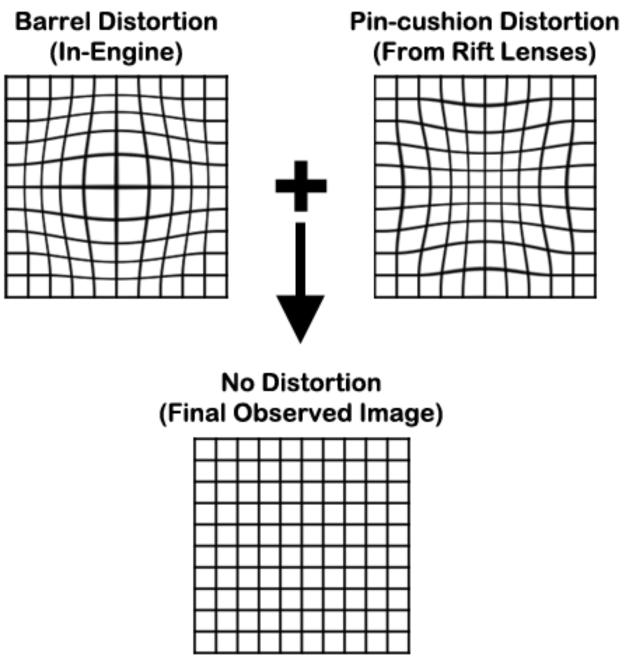
Both Unity and Unreal Engine submit depth by default when using their Oculus integrations.

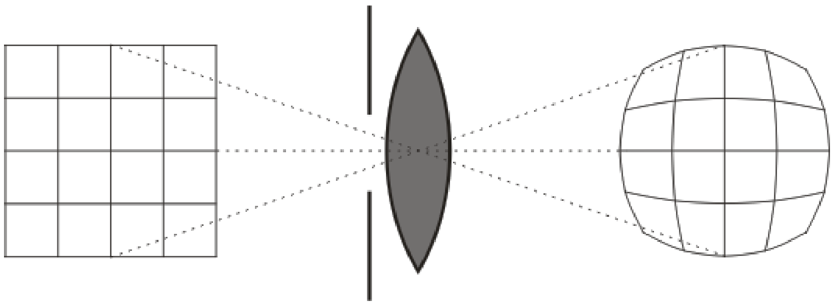
Display Limitations

Lens Distortion

All VR HMDs have lenses which distort the image.

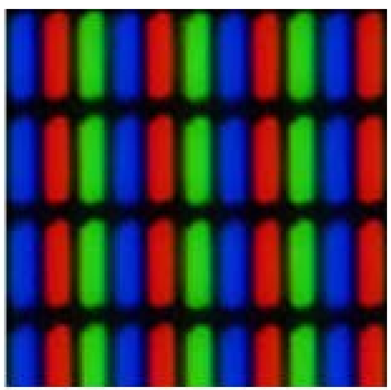
VR engine has to render a pre-distorted image so that the user will see a correct, undistorted image. A simple pixel shader can do this.



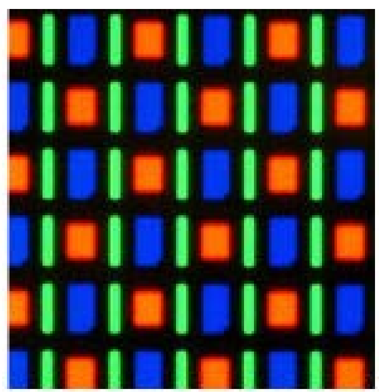


Screen Door Effect

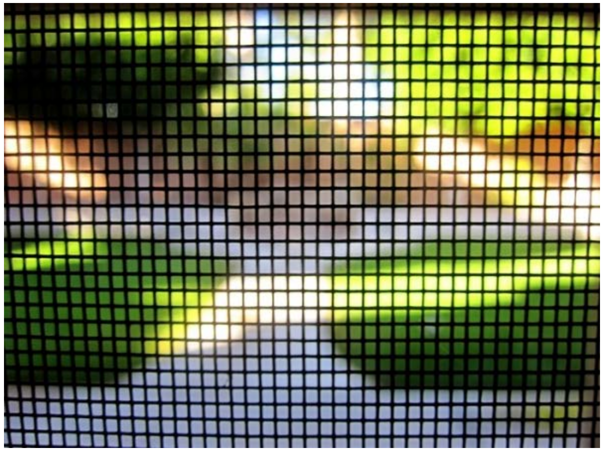
Because pixels on LCD and OLED displays have dead space in-between them image looks like looking through a screen door when looking at it through magnifying lenses.



LCD
DK1



OLED
DK2



Screen Door

Chromatic Aberration

Arises from the inability of a lens to focus all colors in the same place.

FOcal length depends on refraction.

blue and red light have different indexes of refraction → their focal length is also slightly different.

Chromatic aberration is clearly visible on photographs or video as the color channels are not perfectly aligned.

Remedy: apply “Brown's model” distortion correction formula to each color channel independently.