CSE 190: Virtual Reality Technologies

LECTURE #8: HEAD-MOUNTED DISPLAYS

Announcements

Homework project 2

- Due next Friday, May 4th at 2pm
  - To be demonstrated in VR lab B210
  - Upload code to Ted by 2pm

Opportunity at Clarke Center

The Center for Human Frontiers at the Qualcomm Institute is looking to hire **paid student interns** with development experience in **Unity, C#,** procedural computer graphics and virtual/augmented/mixed reality technologies. Projects involve developing interactive visualizations that integrate biometrics into simulations. Additional interests in neuroscience and audio/video production is a plus.

A secondary project will look at audio augmented reality as a means for engaging with non-human subjectivity and the complexity of the biosphere.

Interested students should write to Patrick Coleman at **pcoleman@ucsd.edu** with a cover letter, resume, and links to recent work that demonstrate your skills.

Virbela

Virbela is recruiting virtual world programmers, computer graphic modelers and web developers as either summer interns and/or entry-level employees. Virbela develops virtual worlds for a wide range of clients. They are currently housed in the Qualcomm Institute Innovation Zone.

Virbela is particularly interested in people with experience in Unity and C# for virtual world development, as well as those with 3D modeling experience (environments and characters).

Additional appointments in web development and data analytics are also possible. Contact Alex Howland ahowland@virbela.com

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

Oculus Rift DK1

Released March 2013

Single LCD screen

Focus on fast gyroscope for head tracking

Head orientation tracking only

Field of view: 110 degrees

Oculus Rift DK2

Released July 2014

Single OLED screen

Same gyroscope as DK1

Adds camera for location tracking

Field of view: 95 x 105 degrees

	DK1	DK2
Screen Resolution:	1280 x 800	1920 x 1080
Pixel Layout	RGB	Pentile
OLED	NO	YES
Screen Size	7”	5.7”
Screen Manufacturer and model	Innolux HJ070IA-02D 7″ LCD	Samsung Galaxy Note 3
Latency	50ms – 60ms	20ms – 40ms (presumed)
Low Persistence	NO	YES
Refresh Rate	60Hz	75Hz
Orientation Tracking	YES	YES
Positional Tracking	NO	YES
Gyroscope, Accelerometer, Magnetometer	YES	YES
FOV	110	100
3D	Stereoscopic	Stereoscopic

HTC Vive

Oculus Rift CV1

Sony Playstation VR

Sold for Play Station 4

1920x1080 pixels

OLED

Field of view: 100 degrees

Innovative head strap

Uses Move controllers

New VR Aim controller, released 5/16, $60

	HTC Vive	Oculus Rift	PlayStation VR
Display Type & Size	Dual low-persistence Samsung AMOLED (Diamond PenTile subpixel matrix*)	Dual low-persistence Samsung AMOLED (Diamond PenTile subpixel matrix*)	Low-persistence AMOLED (RGB subpixel matrix)
Display Size	91.9 mm × 2, 447 ppi	90 mm × 2, 456 ppi	5.7-inch
Resolution	1200 × 1080 (per eye)	1200 × 1080 (per eye)	960 × 1080 (per eye)
Refresh Rate	90Hz	90Hz	90Hz, 120Hz
Field of View	~110H × 113V-degrees at optimal 8 mm lens-to-eye distance	~94H × 93V-degrees at optimal 12 mm lens-to-eye distance	~100-degrees at optimal lens-to-eye distance

Source: http://www.tomshardware.co.uk/vive-rift-playstation-vr-comparison,review-33556-3.html

Lens Type	Fresnel	Hybrid Fresnel	Standard
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Lens Adjustment	IPD (60.8-74.6 mm), lens-to-eye distance ("eye-relief" adjustment)	IPD (58-72 mm), lens-to-eye distance (adjustable with optional glasses spacer)	Software IPD, lens-to-eye distance
Sensors	Accelerometer, gyroscope	Accelerometer, gyroscope, magnetometer	Accelerometer, gyroscope
Tracking Technology	6 DOF IR Laser-based 360-degree tracking using "Lighthouse" Base Stations	6 DOF Constellation camera optical 360-degree IR LED tracking	6 DOF PlayStation Camera optical 360-degree LED tracking

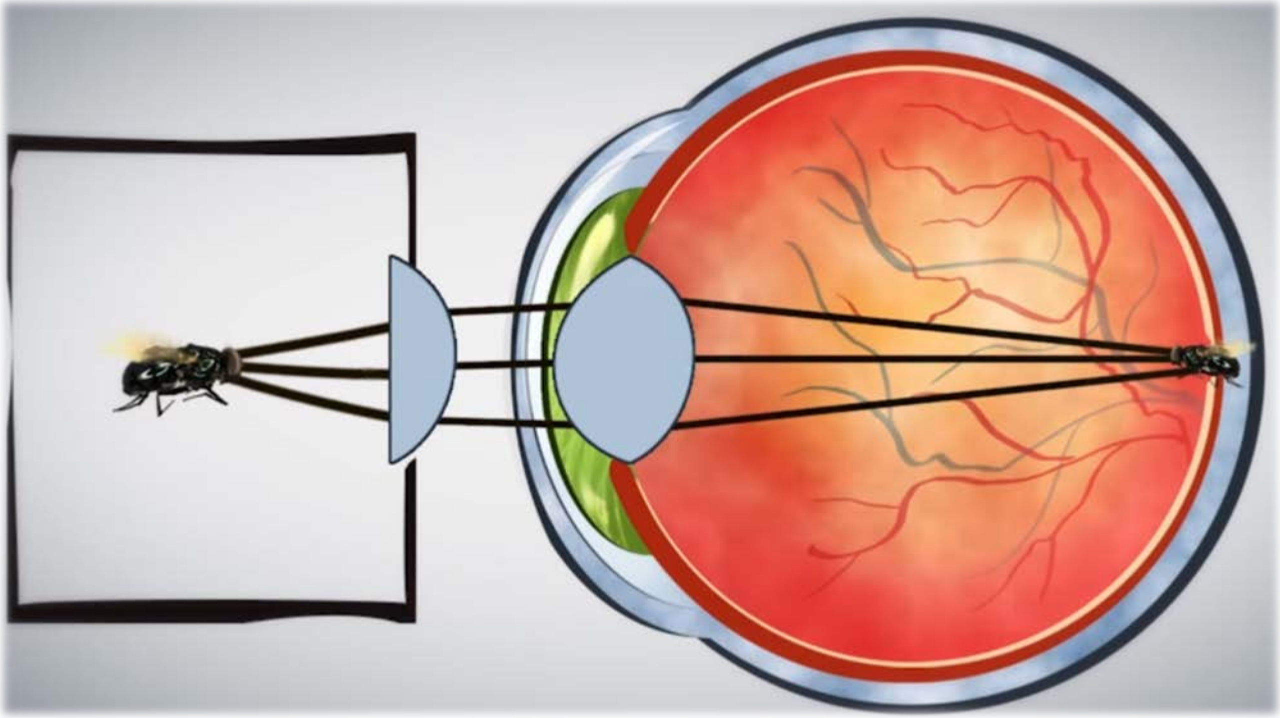
Lens Type	Fresnel	Hybrid Fresnel	Standard
Integrated Camera	Yes	No	No
Audio	Microphone, jack for external headphones	Microphone, integrated supra-aural 3D spatial audio headphones (removable)	Microphone, jack for external headphones
Wireless	Bluetooth 4.1 (in Link Box for Base Stations and cell phone)	Bluetooth for remote (and for Touch controllers later)	TBA
HMD Ports	HDMI 1.4, USB 3.0 x 2	Proprietary headset connector (HDMI/USB 3.0)	None

Lens Type	Fresnel	Hybrid Fresnel	Standard
HMD Cable Length	5 m (plus 1 m from Link Box to PC)	4 m	~4 m (plus ~2 m from Processing Unit to PlayStation 4)
Materials Used	Plastic, glass, foam rubber	Plastic, IR-transparent fabric, glass, foam rubber	Plastic, glass, foam rubber
Dimensions	~190mm × ~127mm × ~89 – 127mm (W × H × L, length excludes headband, min eye-relief to max eye-relief)	~171 (~216) × ~102 mm (W (width including headphones) × D)	187 × 185 × 277 mm (W × H × L, excludes largest projection, headband at the shortest)
Weight	563g (excluding cable)	470g (excluding cable)	~610g (excluding cable)

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	Infinity? 1.3 meters?

Cell Phone VR

Google Cardboard

Uses existing Android smart phone

Built-in magnet button

- Uses magnetometer

Inexpensive: <$10

Gear VR

Requires Galaxy Note 4/S5/S6/S7/S8

Field of view: 96 degrees

Accelerometer, Gyroscope, Compass

Low photon latency <20ms

60 Hz

AMOLED display

Resolution: 2560x1440

Oculus involved in cell phone driver design

Carl Zeiss VR One

For Galaxy S5 or Iphone 6

High quality lenses

Issues Today

HMDs are closed, no see through

AR coming but not as mature as VR HMDs

Need to become wireless/more powerful graphics

Input device dilemma for cell phone VR: positional tracking

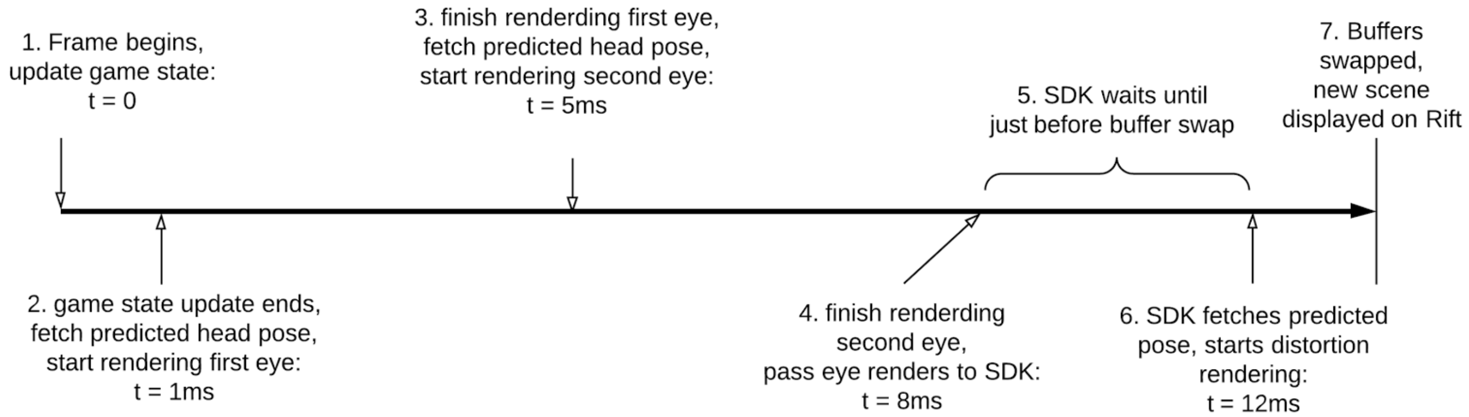
Drivers: most Windows only, few Mac OS, no Linux

Optimizations: Asynchronous Time Warp

Image space scene shift just before frame display

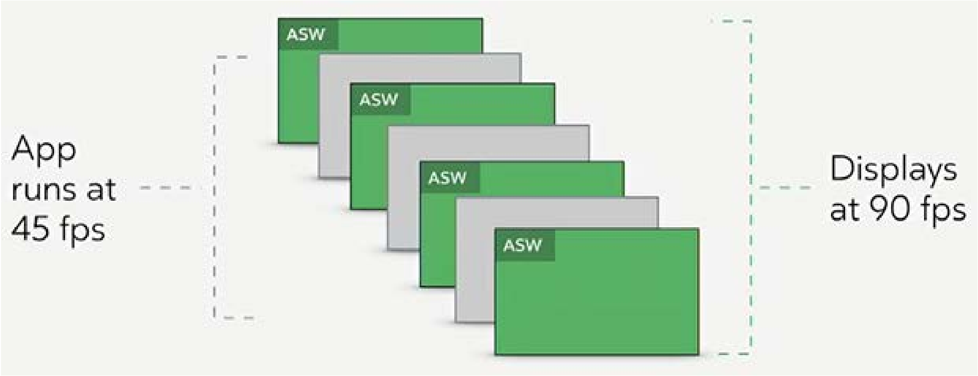
Reduces latency

Only works for head orientation changes



http://rifty-business.blogspot.com/2014/08/using-timewarp-on-oculus-rift.html

Optimizations: Asynchronous Space Warp



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 the next frame.

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

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

Oculus Rift CV1 Teardown

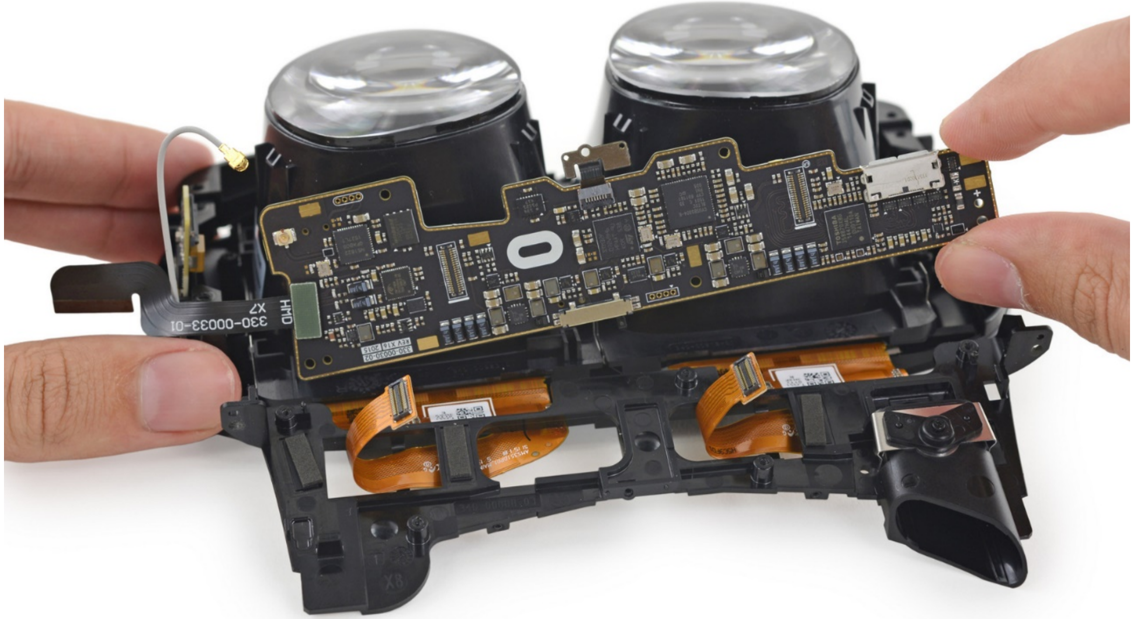
Oculus Rift: Ear Phones

Face Foam

Separable lens/electronics assembly

LEDs and Microphone

Motherboard



Separate lens/display assemblies

Lenses: DK2 vs. CV1

Circular vs. Asymmetric

CV1 Lens

Asymmetric

Hybrid Fresnel lens

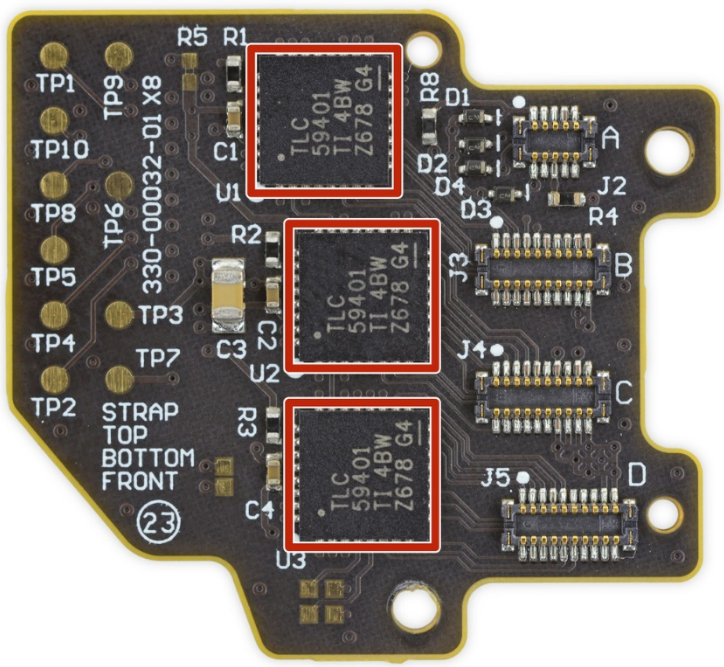
Focus varies along vertical axis of lens

→ Push lens higher or lower to focus

Adjustable IOD

Adjusts between 5 and 95 percentile of people’s IPD (Inter Pupillary Distance)

LED Driver Board



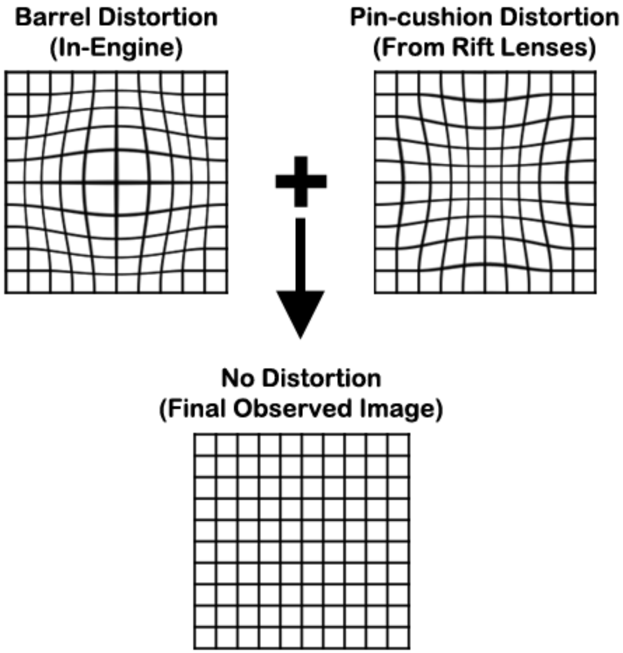
Headband Springs

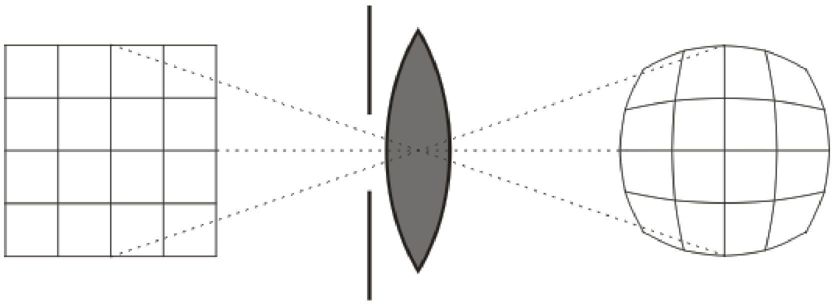
Give headband an extra inch of play

Lens Distortion

All VR HMDs have lenses which distort the image.

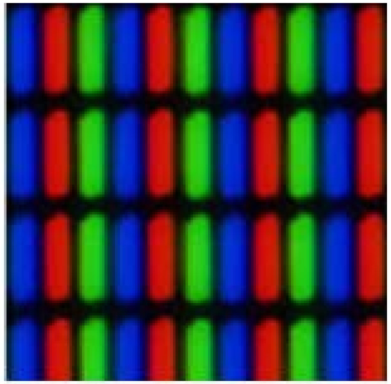
VR engine has to render a pre-distorted image so that the user will see a correct, undistorted image. A simple pixel shader can do this.



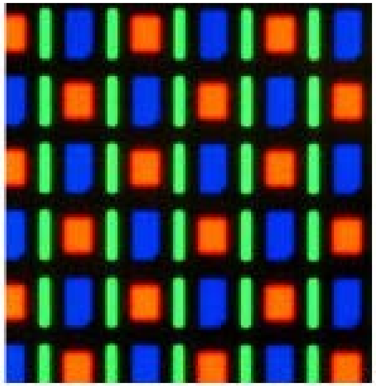


Screen Door Effect

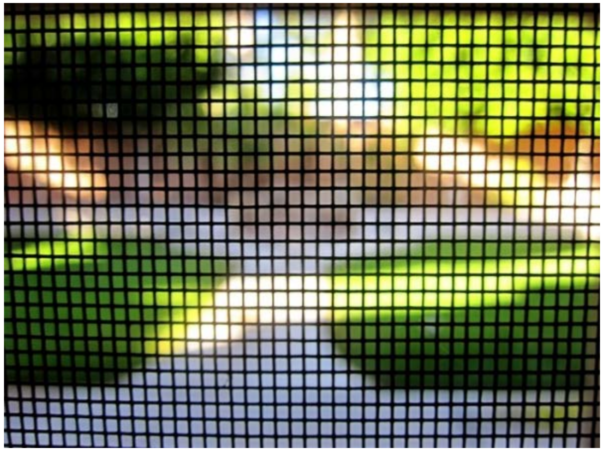
Because pixels on LCD and OLED displays have dead space in-between them image looks like looking through a screen door when looking at it through magnifying lenses.



LCD
DK1



OLED
DK2



Screen Door

Chromatic Aberration

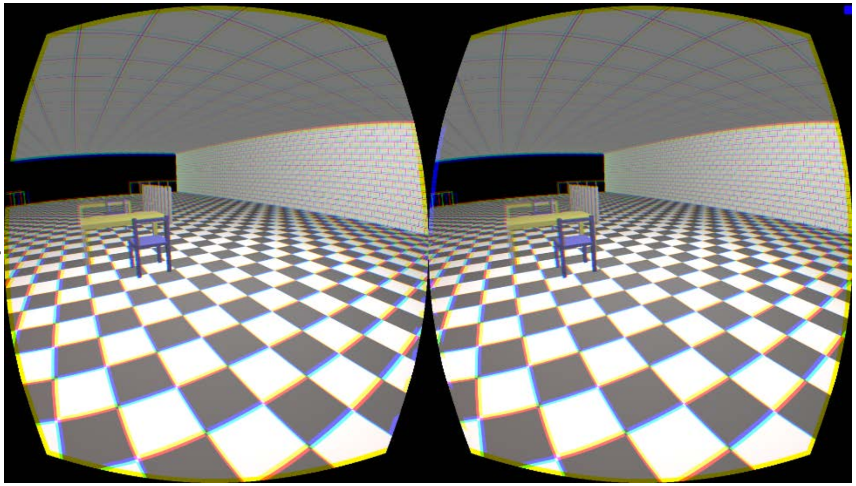
Arises from the inability of a lens to focus all colors in the same place.

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.



Related Technologies

Google Glass

Small display in front of one eye

Not designed for VR

Project ends in Jan 2015

Explorer Edition available for selected users ($1,500)

Built-in Android 4

640x360 pixels

Built-in 5 MP camera

Wi-Fi, Bluetooth

16GB RAM

Gyroscope, accelerometer, compass, light sensor

Augmented Reality

Some of the best AR goggles:

- Osterhout Design Group R-7: small (right)
- Microsoft HoloLens: great tracking (below, left)
- Meta 2: yet to be released (below, right)

Auto-Stereoscopic Displays

Lenticular

Volumetric

Holographic