Stereoscopic Visualization Technologies

(SENG 463 - Game Programming)

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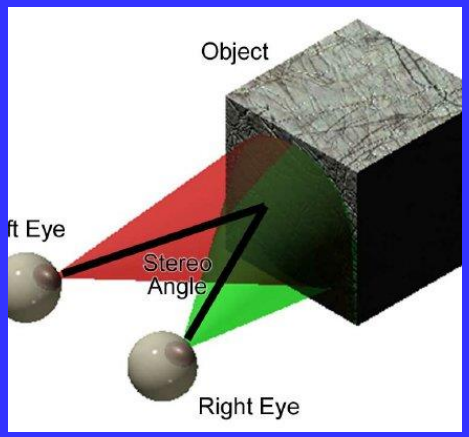
Outline

- What is Stereoscopic Visualization
- Stereoscopic Displays
- Auto-Stereoscopic Displays
- Extended Reality Devices
  - Virtual Reality
  - Augmented Reality
  - Augmented Virtuality
  - Mixed Reality
- A Sample Mixed Reality Application

Stereoscopic Visualization

- *Stereoscopy* refers to:
  - The process of creating or enhancing the illusion of depth in an image
  - By presenting 2 offset images separately to the left and right eyes of the viewer.
- These images are combined by the visual processing system in the human brain to give the perception of 3D depth.



Stereoscopic Visualization

- So all techniques that gives you the illusion of 3D depth are generally named as stereoscopic visualization techniques.

Stereoscopic Visualization

- Parallax is this apparent shift caused by viewing an object from two different vantage points.
- Shift / offset between images changes depending on the distance.
- This is the key to measure things at a distance.

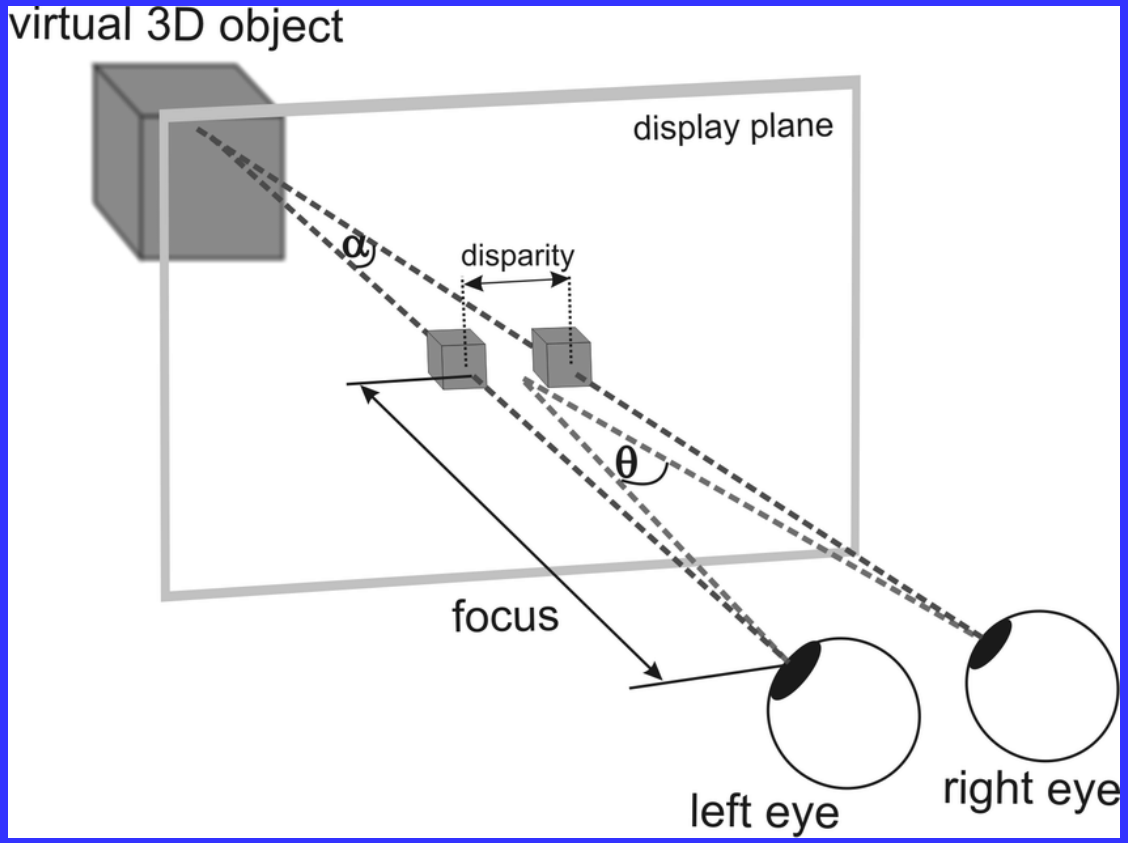
Stereoscopic Visualization

- The offset images are genearted from 2 different locations of eyes.

Parallax angle:
Difference between angles (θ-α) formed by:
both eyes - virtual object
Both eyes - display plane

If angle difference is large, your eyes feel discomfort,

Even more discomfort if virtual object is nearer to eyes than the display plane.



Stereoscopic Visualization

- There are many different 3D Stereoscopic Visualization Technologies in the World.
- It can mostly be categorized as:
  - Stereoscopic Displays
  - Auto-Stereoscopic Displays
  - Extended Reality Devices
    - Virtual Reality
    - Augmented Reality
    - Augmented Virtuality
    - Mixed Reality

Stereoscopic Displays

- A stereoscopic display is a surface or a display that can present 2 different images to left and right eyes of a human seperately.
- Since left and right eyes of human see images from different 3D perspectives,
  - Human feels the illusion of 3D depth.

- These displays can be an ordinary or 3D television, monitor, projector, or even a piece of paper that uses 3D glasses.

Passive Stereoscopic Displays

- Stereoscopic displays are either passive or active

- Passive Stereoscopic displays do not require an electronic glasses to watch.
- Left and right eye glasses are design to have different polarization or color.
- Displays present 2 different images with 2 different polarization or color on top of each other at the same time.

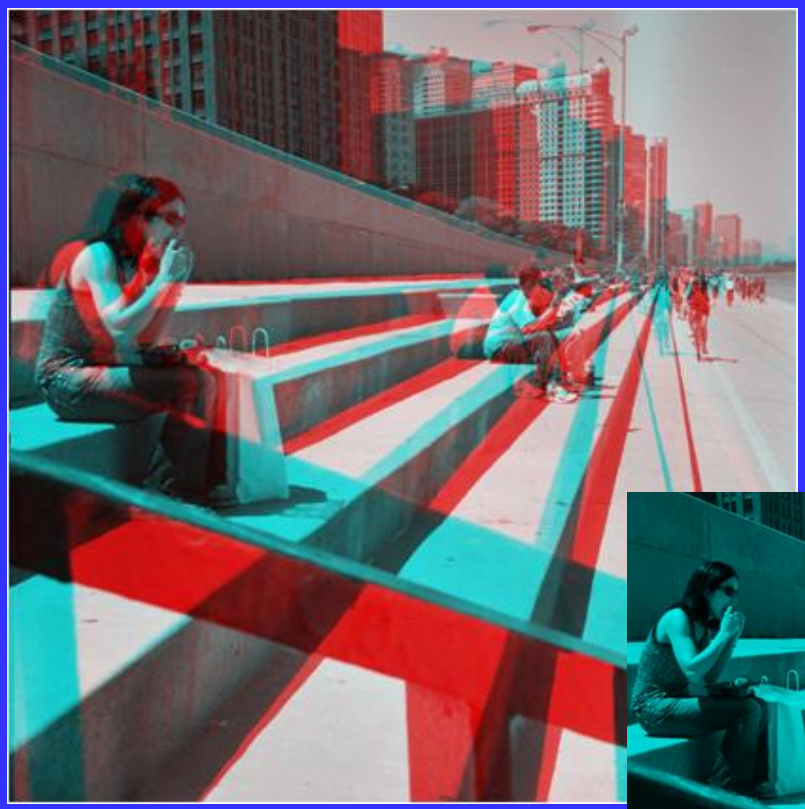
Passive Stereoscopic Displays

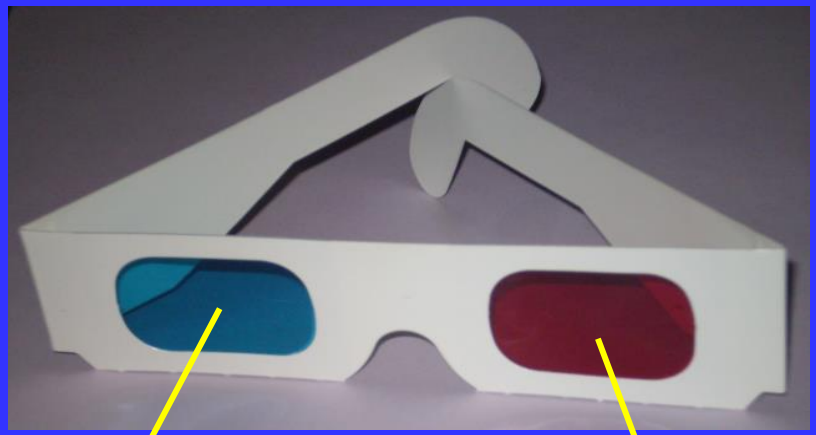
- With left eye glass you can only see the left eye image and
- With right eye glass you can only see the right eye image.

- 3 common techniques:
  - Anaglyph glasses
  - Polorized glasses
  - Interference filtered glasses

Passive Anaglyph Glasses

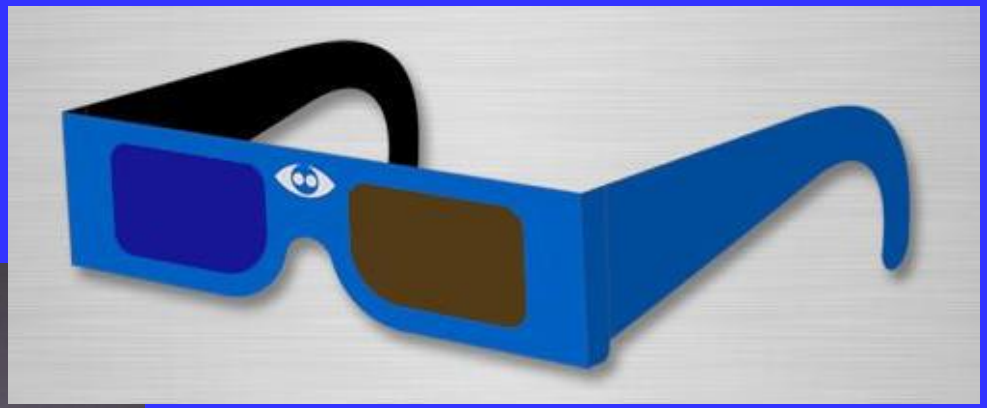
- Two different images are put on each other with different color specturms, natural colors lost.





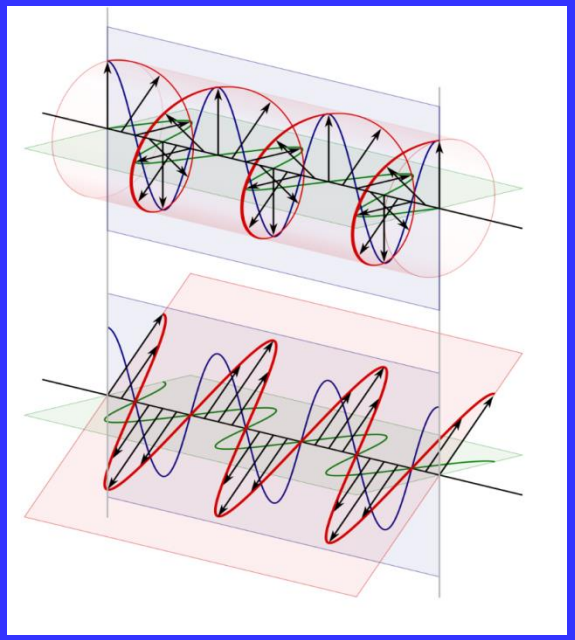
Passive Anaglyph Glasses

- Common red-cyan.
- ColorCode 3D (patented)



Passive Polarized Glasses

- Two different images are put on each other with different light polarization.
- Left and right glass of glasses are designed to show different polarized lights.
- Natural colors are preserved.

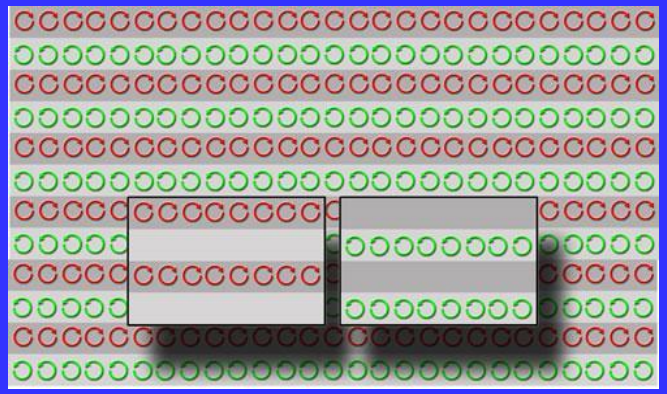


Circular polarization

Linear polarization

Passive Polarized Glasses

- Some cinema glasses, projectors and 3DTVs such as LG are/were using polarized glasses.



Polarized row interlaced televisions

Odd and even rows are
left and right circular polarized

Interference Filtered Glasses

- Two different images are put on each other with different red, green, blue light wave lengths.
- Left and right glass of glasses are designed to show different wave lengths of RGB.
- For instance, front part of red specturm is shown to left eye and end part of red specturm is shown to right eye.
- Natural colors are preserved.

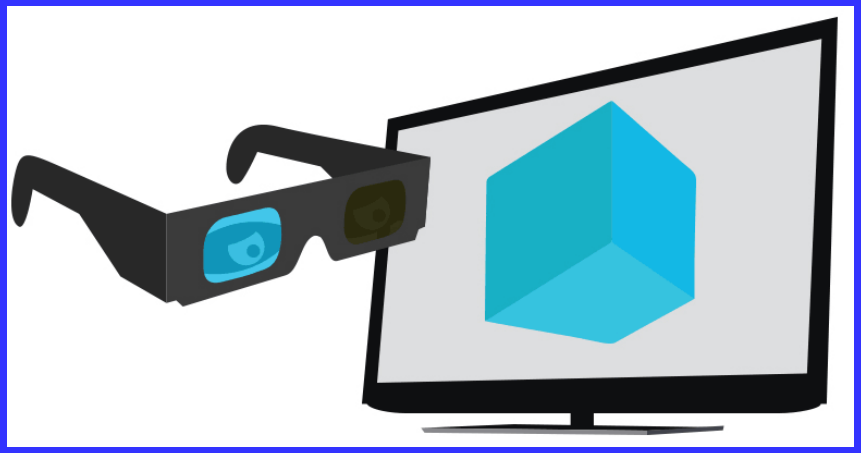
- Infitec 3D (Dolby 3D) and Omega 3D (Panavision 3D) use this technique.

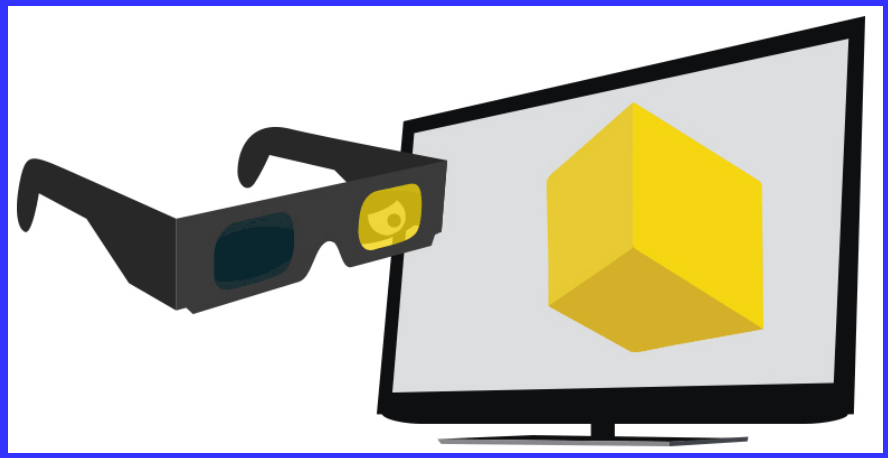
Active Stereoscopic Displays

- Active Stereoscopic displays require an electronic (active shutter) glasses to watch.
- Left and right eye glasses are design to show images presented in different time zones.
- Displays present 2 different images at different time zones (Not at the same time).
- Image alternating is so fast that eye cannot feel that switching.

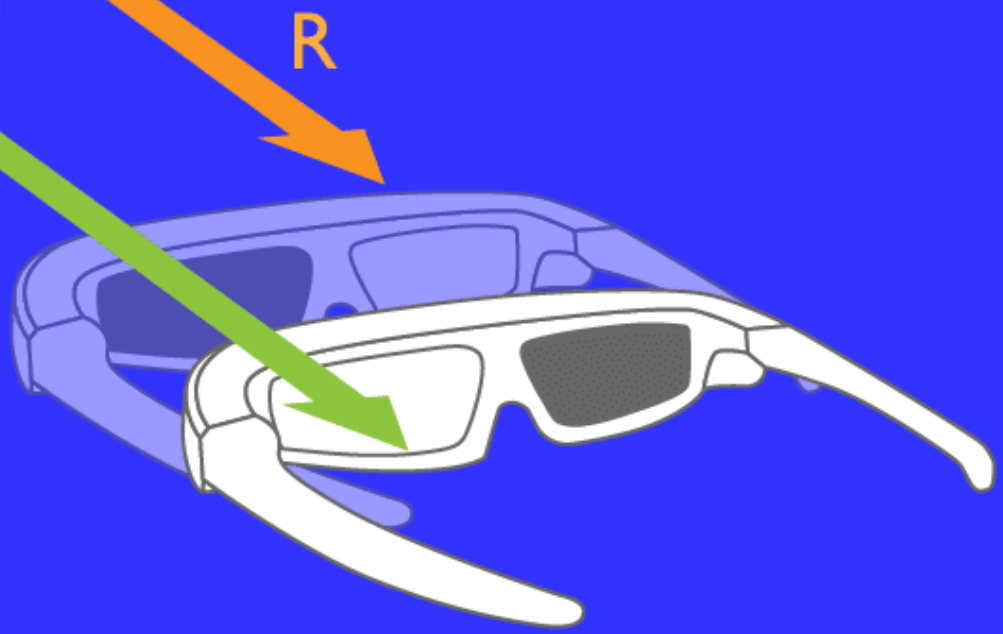
Active Stereoscopic Displays

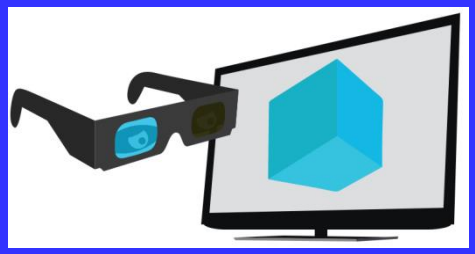
- With left eye glass you can only see the left eye image in first ½ of the time period and otherwise see black image and
- With right eye glass you can only see the right eye image in last ½ of the time period and otherwise see black image.

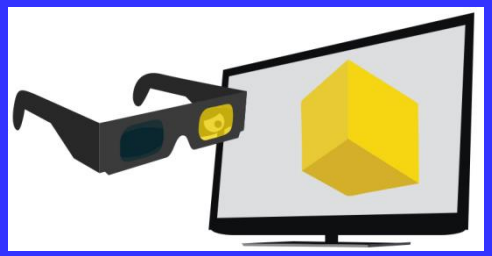




Active Stereoscopic Displays







Active Stereoscopic Displays

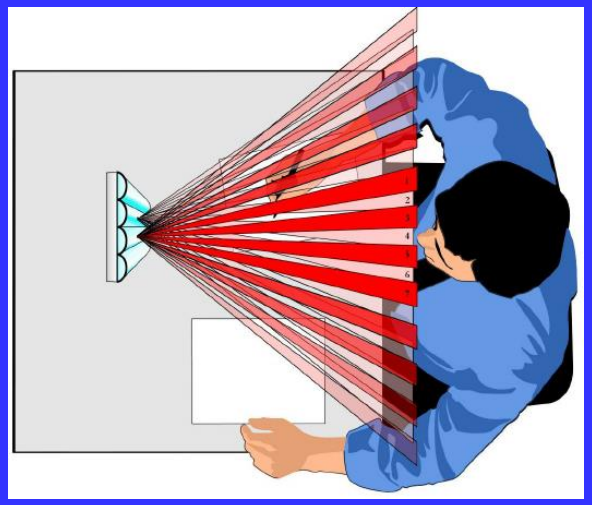
- Some Projectors and 3DTVs such as Samsung are/were using active shutter glasses.
- Almost all 3D Monitors (3D Ready Displays) use active shutter glasses (commonly uses Nvidia 3D vision glasses).
- Nvidia graphic cards have automated stereo visualization support
- Nvidia Quadro graphic cards have quad buffers

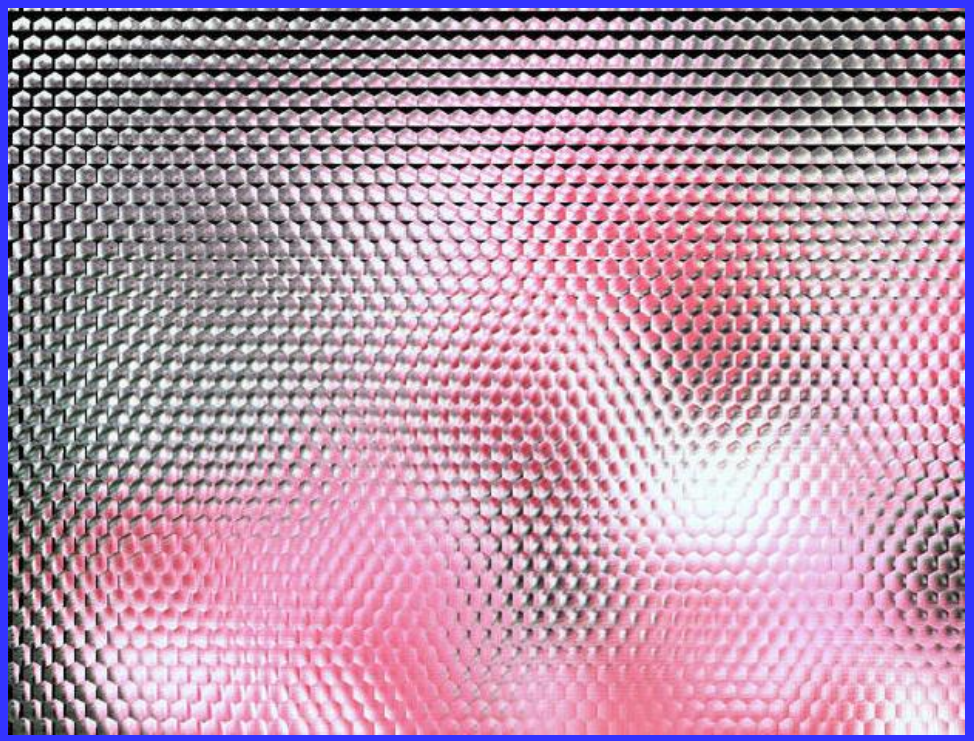
Auto-Stereoscopic Displays

- An auto-stereoscopic display is a surface or a display that can present different images to left and right eyes of a human to see 3D without glasses.
- It is commonly called "glasses-free" or "glassesless“ displays.
- Commonly, parallax barriers or lenticular lenses are used to show glasses free 3D images.

Auto-Stereoscopic Displays

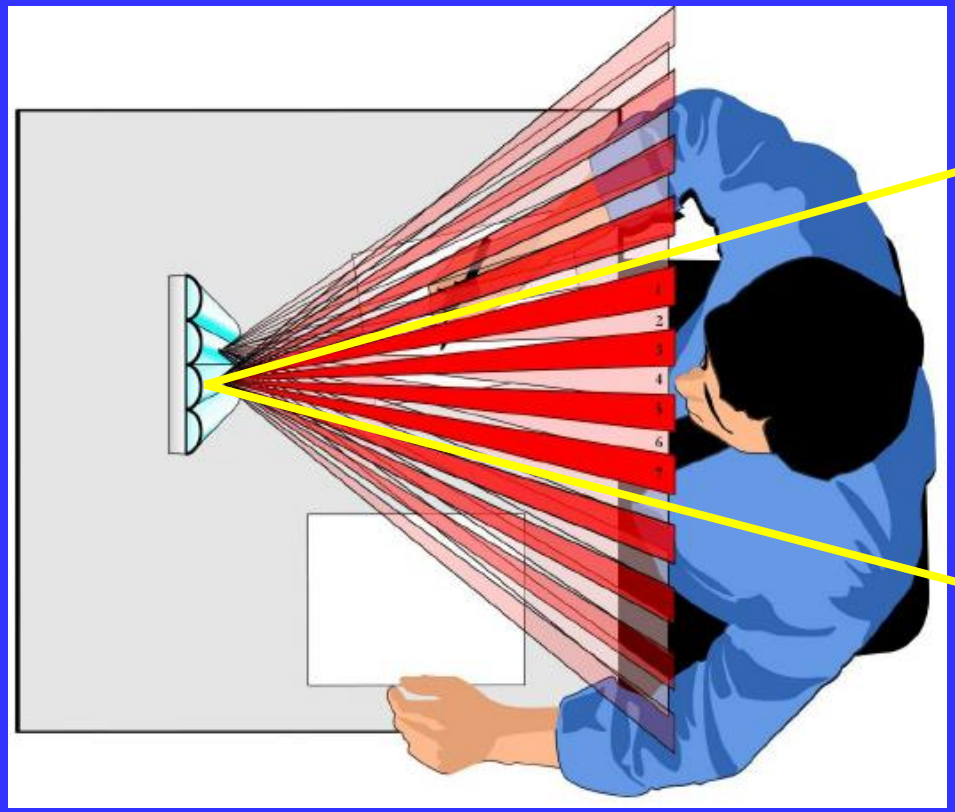
- Auto-stereoscopic displays usually (if not eye tracked) show more than two images at the same time on a single display.
- 5 - 9 view displays are the most common ones.





Auto-Stereoscopic Displays

- Images are blended to pixels (even RGB leds) with a special computation based on the physical structure of the surface and barrier or lense.

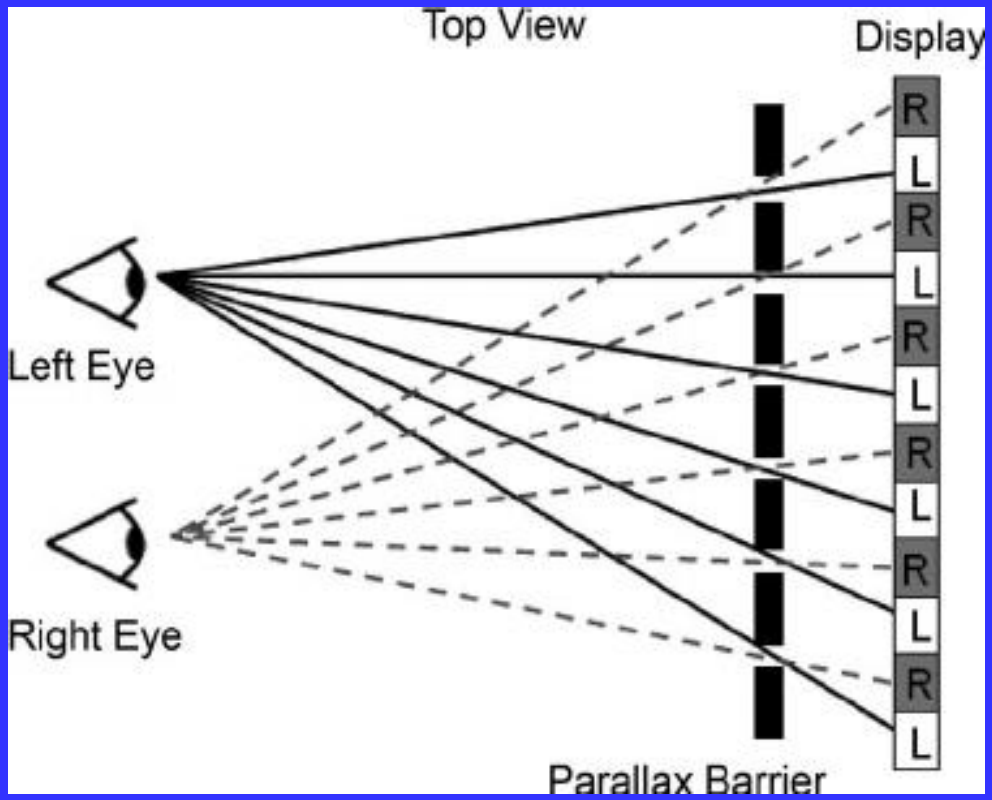


7-views are directed to different zones.

Shall be watched inside this viewing region

Parallax Barriers

- Pixels of different viewing zones are blocked in order to prevent being seen from other viewing zones.

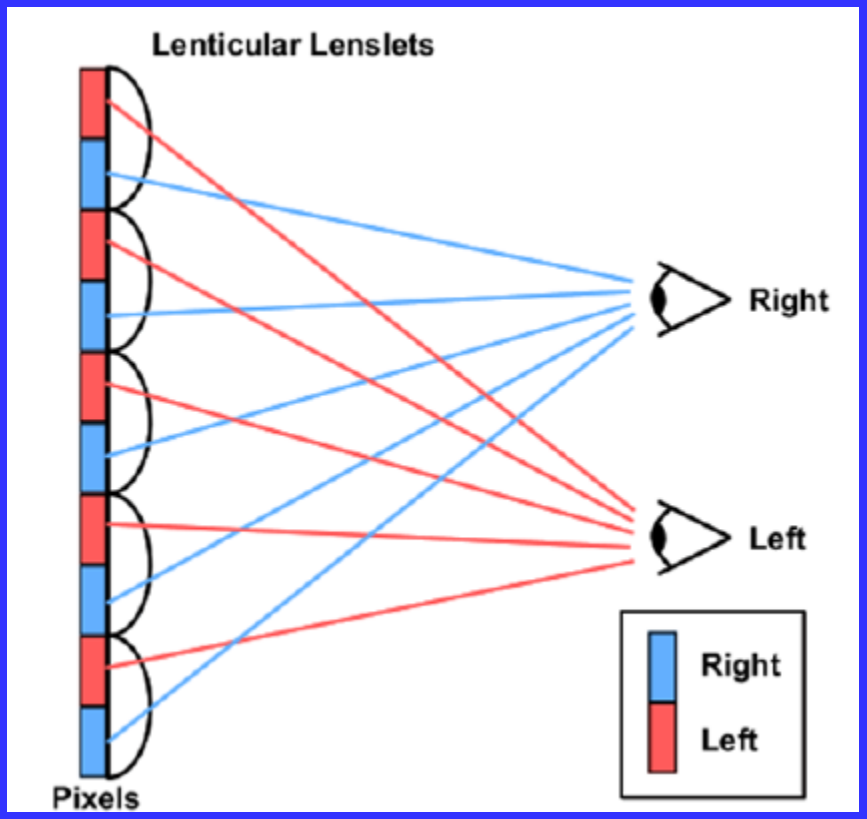


2-view display sample.

Pixels of display are filtered such that some pixels are seen by left eye and some other pixels are seen by right eye.

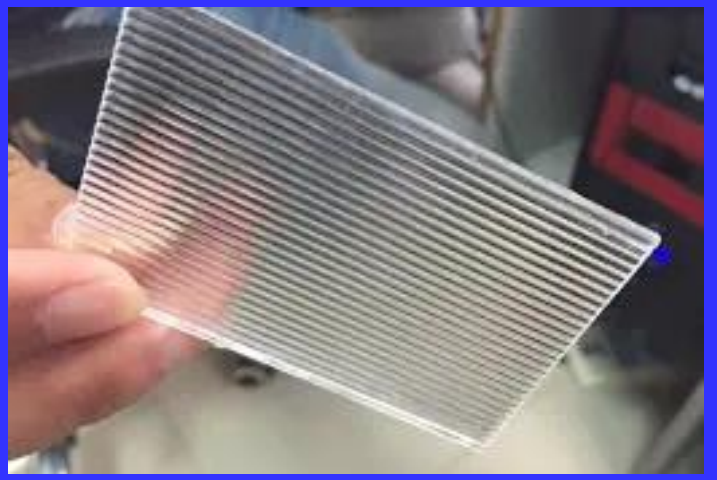
Lenticular Lenses

- Pixels of different viewing zones are directed to different directions via tiny lenses on top of pixels.



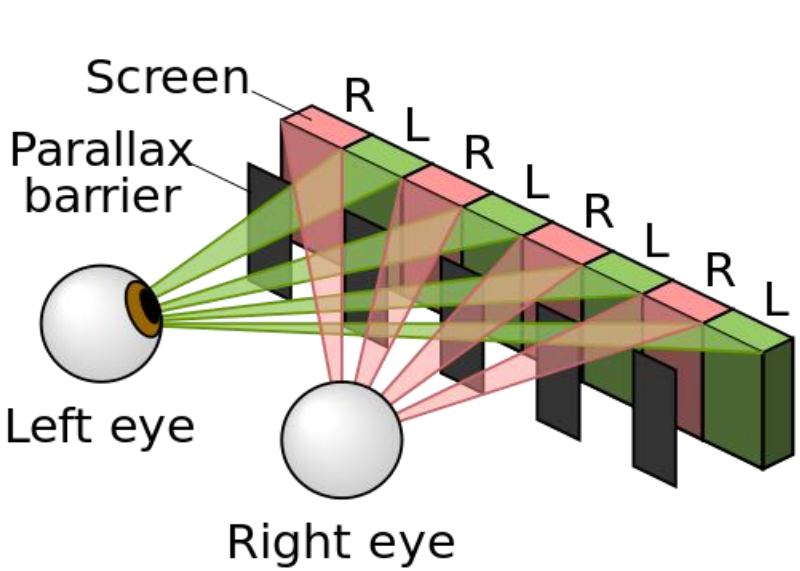
2-view display sample.

Pixels of display are directed such that odd pixels are sent to left eye and even pixels sent to right eye.



a lenticular sheet

Barriers vs Lenticular Lenses



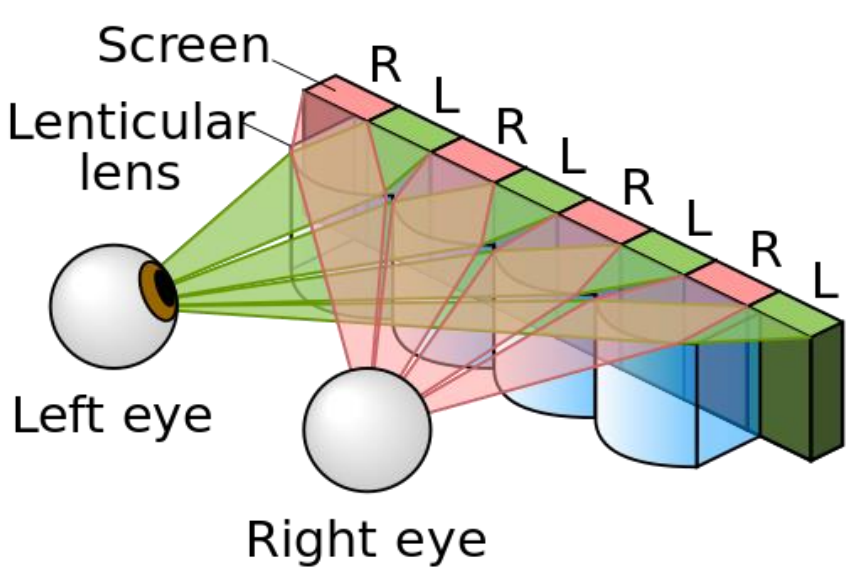


Image is sharper but, brightness of display is lower.

Brightness of display is higher, but image is more blurred.

Extended Reality

- eXtended Reality (XR) is an umbrella term that encompasses
  - Virtual Reality (VR),
  - Augmented Reality (AR),
  - Augmented Virtuality (AV),
  - Mixed Reality (MR)

Virtual Reality

- Virtual Reality (VR) is a computer technology that uses headsets to
  - Fully immerse users in a computer simulated reality
  - By generating realistic images and sounds
  - To replicate a real world
  - Or to create an imaginary world.

- VR is an artificial digital environment that completely replaces the real world.

Virtual Reality

- In VR, the person is submerged in a digitally created world,
- Hearing, vision, and sometimes even other senses are completely created by a digital device
- Delivered to the person via a headset.

Virtual Reality

- Two of the popular headsets are HTC and Oculus series.
- Oculus is now renamed as Meta.

Tracking with Base Stations

HTC Vive Pro

Inside Out Tracking

HTC Vive Cosmos

Meta Quest 2

Augmented Reality

- Augmented Reality (AR) is a computer technology that uses headsets, glasses or mobile devices to
  - Merge the real and virtual worlds
  - By overlaying virtual objects onto the real world.

- Unlike VR, which replaces the real world with a totally computer-simulated virtual world,
- AR only adds overlays onto the real world.

Augmented Reality

- Pokémon Go and Snapchat filters are two examples of mobile phone AR.
- These mobile devices overlay virtual objects onto camera images in real-time.

Augmented Reality

- Marker trackers (Vuforia, ARKit, etc.) are very commonly used with augmented reality applications to find where to locate virtual objects on the real world image

Augmented Reality

- There are also augmented reality headsets on the market.
- But AR does not necessarily need a headset.
- AR can be delivered through smart glasses also.

- There are two types of AR glasses:
  - Video See-through
  - Optical See-through

Video See-Through AR

- Video See-through devices shows the real-world using a camera.
- The real-world can only be seen through the image of a stereo camera device put on the glasses.
- Virtual objects are drawn onto camera images.

Video See-Through AR

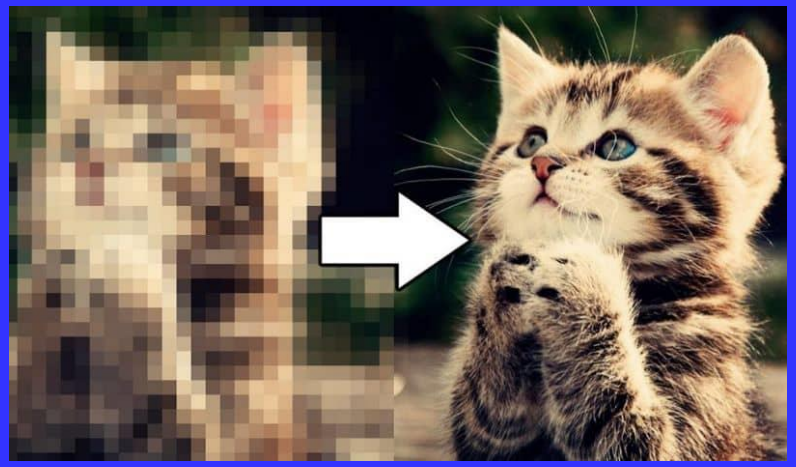
- There are 2 types of Video See-Through AR Glasses.
  - Glasses Produced with Camera
  - Glasses Integrated with Camera

Varjo XR-3

Zed Mini integrated Occulus

Video See-Through AR

- The main problem with video see-through devices is the pixelation effect.
- The outside world is seen through a camera,
- Unless camera resolution is higher than eye resolution, outside will be seen pixelated.



Pixelation effect

Varjo XR-3 (No pixelation)

Video See-Through AR

- Varjo XR-3 vs other standard glasses
- Expensive > $5995 or $1495/year

Optical See-Through AR

- Optical See-through devices shows the real-world using an optical lens that shows outside world as it is.
- The real-world can be seen by the user naked eyes as it is (no pixelation effect).
- Virtual objects are drawn onto a black image.

Hololens 2

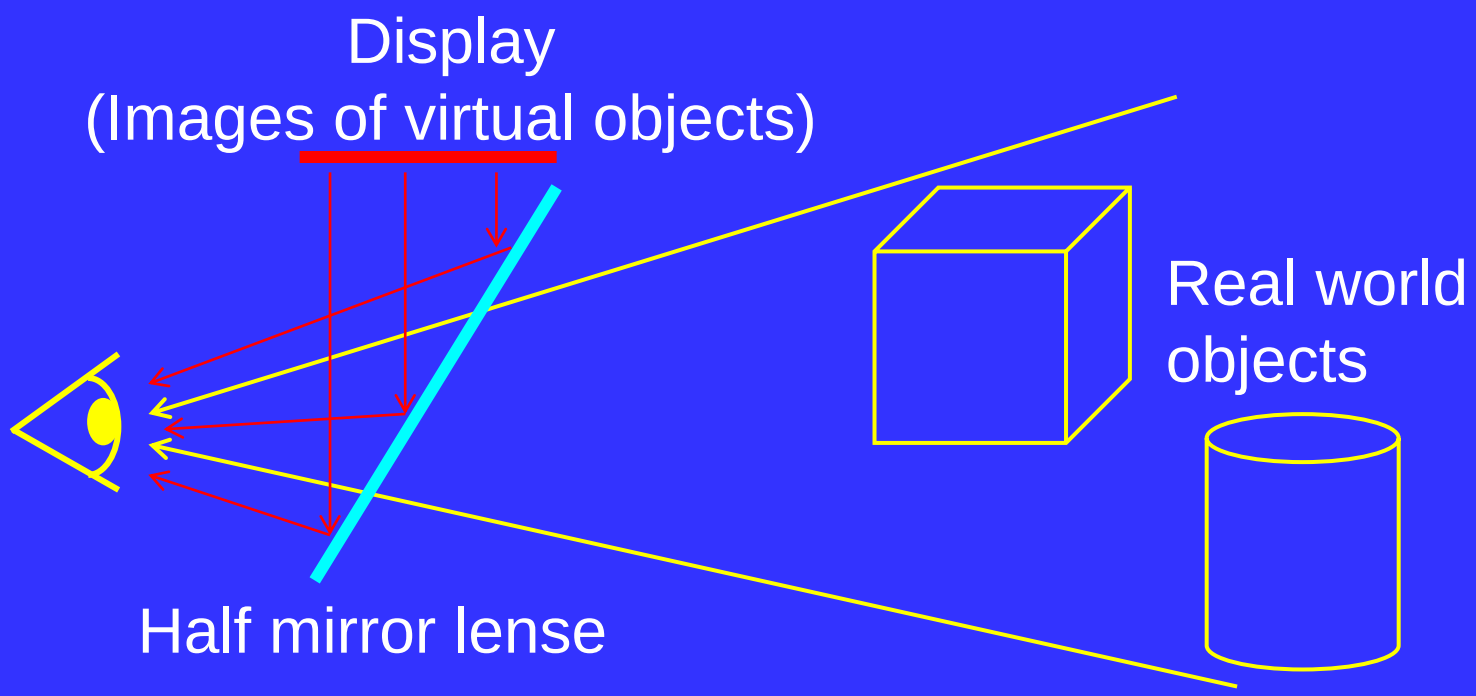
NReal

Optical See-Through AR

- Optical See-through devices cannot show fully opaque virtual objects since virtual objects are drawn over real-world semi-transparently.
- Light from real-world is directly comming to eyes of user as it is,
- So outside lighting cannot be blocked,
- But may be lowered by just using a darker glasses like sun glasses.
- Therefore showing a black virtual object is not possible unless outside is dark or black

Optical See-Through AR

- In princible virtual image is not totally overlaped but summed to light comming from outside world.
- The most simplest technique is to use a half mirror.
- Black color means no light so means transparent



Augmented Virtuality

- Augmented Virtuality (AV) is very similar to Augmented Reality, just the concept of image generation is inversed to
  - Merge the real and virtual worlds
  - By overlaying real world objects onto a virtual world.

- We have a virtual world as a background, and real world objects are drawn onto virtual world.

Augmented Virtuality

- AV is more difficult than AR
- Since real-world objects shall be determined from the camera via image processing
- And cut from their borders to paste on to virtual environment.

Augmented Virtuality

- Our augmented virtuality car driving simulator.

Mixed Reality

- Mixed Reality (MR) is a hybrid of VR and AR technologies.
- Sometimes referred to as hybrid reality,
- MR merges the real world with the virtual world,
  - Where real and digital objects can co-exist and interact with each other in real-time.

Mixed Reality

- Similar to AR, MR superimposes virtual objects on top of the real world.
- Similar to VR, these overlaid virtual objects are interactive and enable users to manipulate the virtual objects.

- An example of MR is HoloLens and Nreal glasses, which are also AR glasses.
- So MR glasses are not different from AR glasses.
- If glasses have an interaction mechanism, any AR glasses is also a MR glasses.

HoloLens 2

- HoloLens 2 provides a hand interaction to the user.
- You can also open any 2D windows application as a plane window in the air.

Nreal Devkit / Light / Air

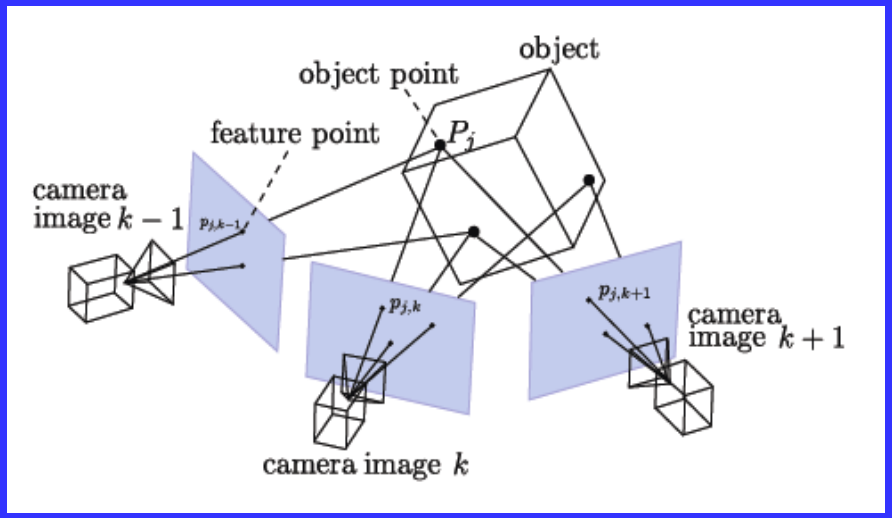
- Nreal Devkit provides both a controller device and hand interaction to the user.
- It has an external computer, but also it can be connected to some mobile phones (NReal Light).

Inside Out Tracking

- Some VR, AR, MR devices (HTC Cosmos, Meta Quest 2, Hololens, etc.) uses inside out tracking
  - To find and track their 3D location in real world.
- A common technique used for inside out traking is
  - Simultaneous Localization and Mapping (SLAM)
- SLAM is used with one or more camera devices attached on the headset.

Inside Out Tracking

- SLAM extracts the 3D model of the environment in time using feature points detected from cameras.
- When a feature point is detected
  - With two different cameras or
  - With one camera but from different directions,
- 3D depth can be computed and point clouds can be generated.



A Sample Mixed Reality App

- We are developing an interactive content development tool with Unity for creation of;
  - Interactive presentations
  - Interactive trainings
  - Interactive planning
  - Interactive map applications
  - Interactive Operations, Maintenance and Repair
  - Remote assistance
  - Virtual meetings
  - Development of augmented scenes
  - Development of Metaverse environments

A Sample from Maintenance

- Interactive Maintenance and Repair of a Computer

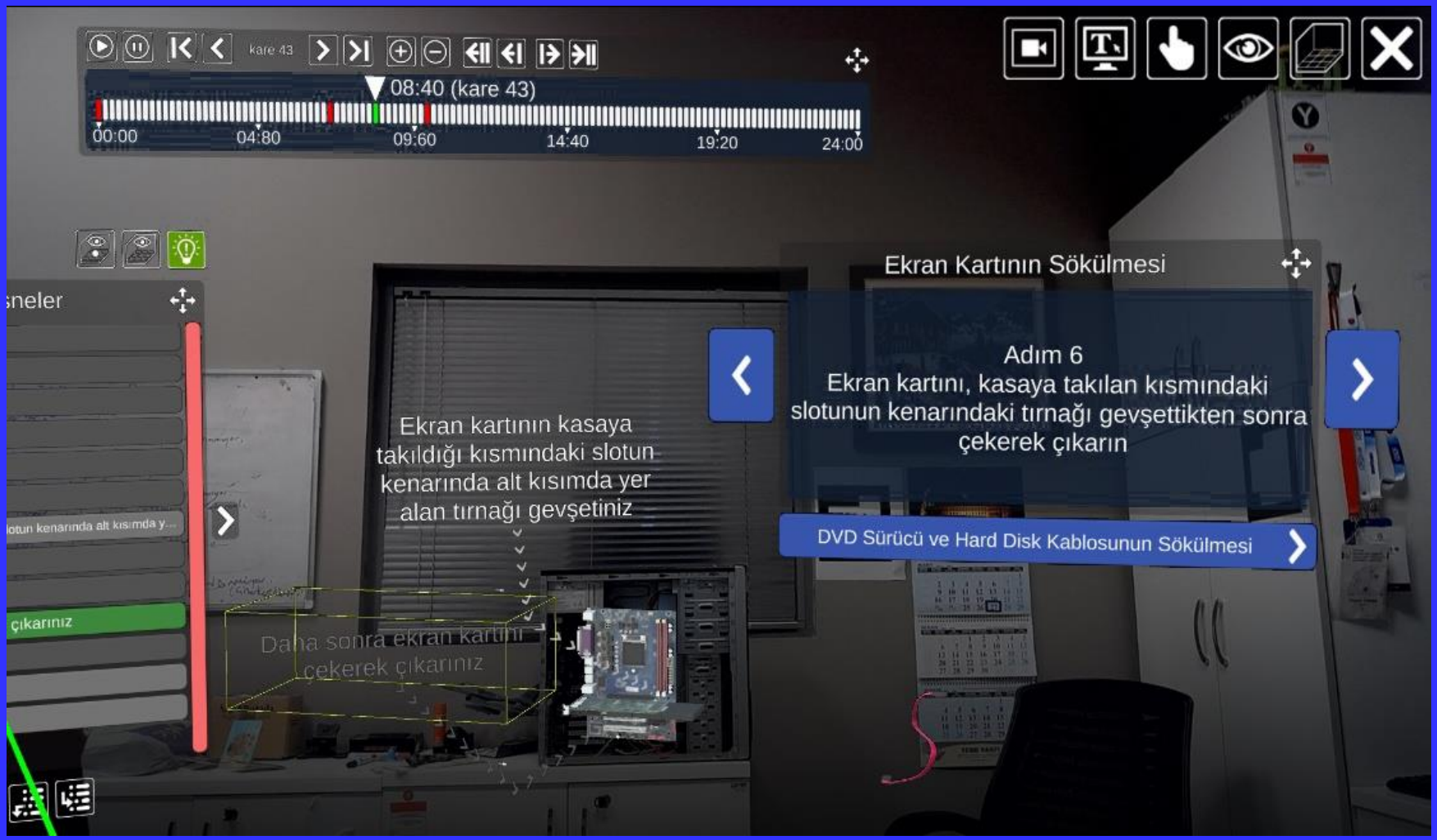
Generating Table of Contents

Creating Maintenance Steps

Creating Virtual Objects

Preparing Keyframe Animations

Guidance of Operators about Steps



A Sample from Anatomy Training

- Interactive Human Anatomy