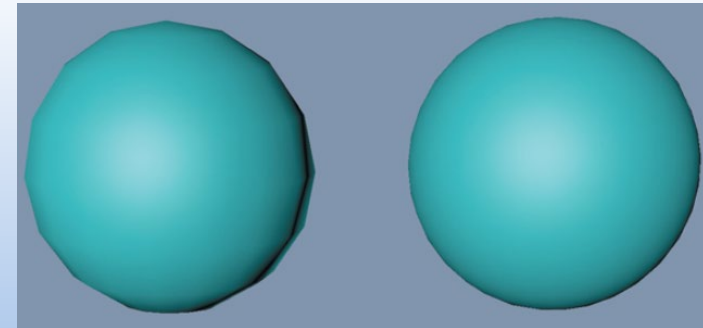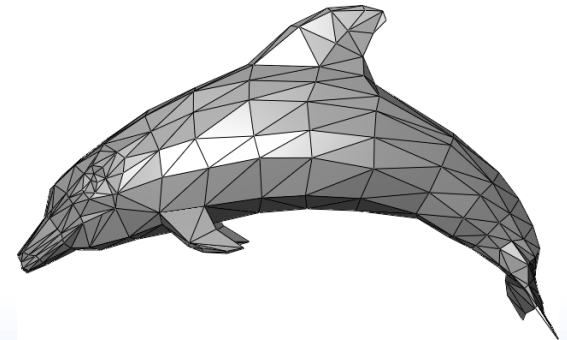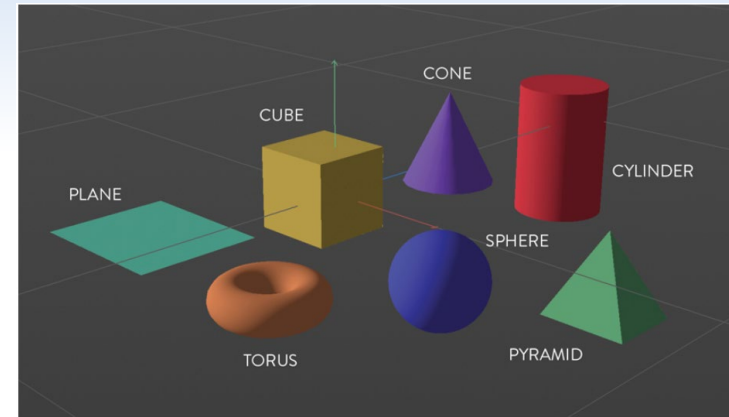# Virtual Content

# 3D Objects

- ## Primitives
  - ➤ 3D geometric shapes that can be added, subtracted and combined to make more complex shapes

- ## Mesh
  - ➤ Collection of points, edges and faces that make up an object
  - ➤ Polygon
    - Where multiple points and edges close to form a complete shape
    - Polygon count

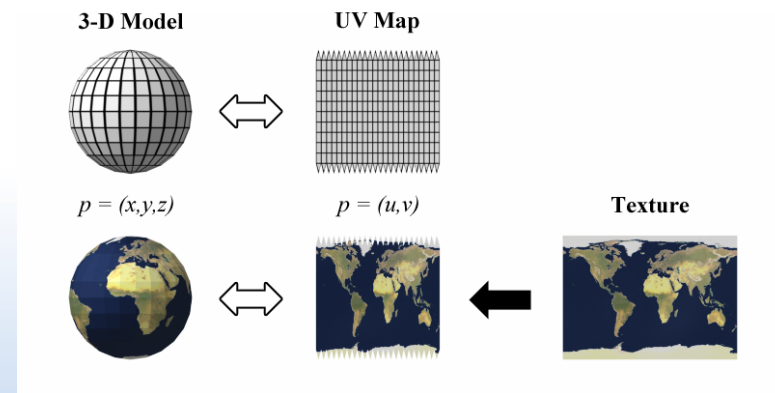# 3D Objects

➢ Elements of polygonal object representations



a) Vertices  b) Edges  c) Faces  d) Triangles  e) Object
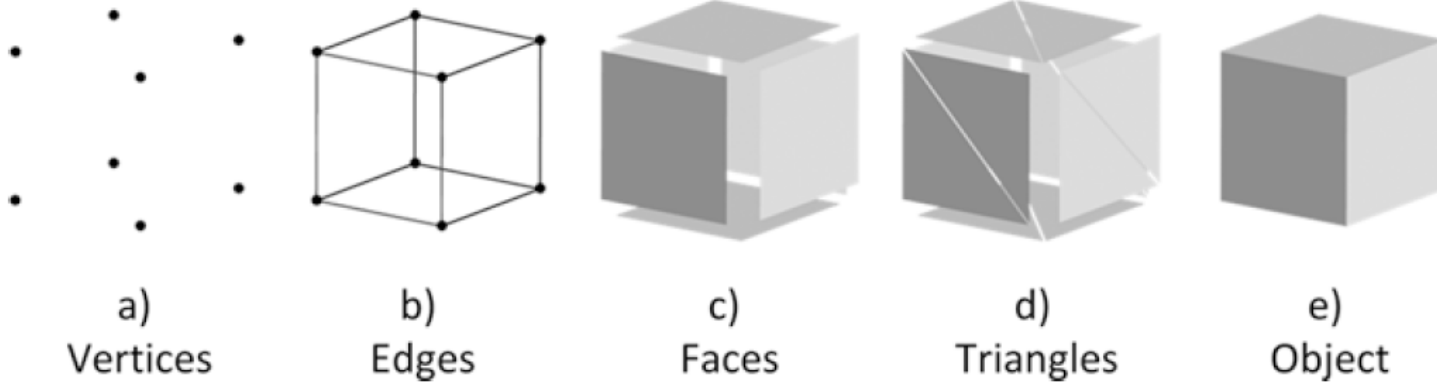
# 3D Objects

- Material
  - ➤ Surface properties added to an object to determine how it will appear
  - ➤ Offers more detail on a model versus creating a more completed polygon shape and has faster load time
  - ➤ Texture
    - An image applied on an object using a material
    - UV mapping
      - – The processes of projecting a 3D model's surface into a 2D image



3-D Model     UV Map

$p = (x,y,z)$     $p = (u,v)$     Texture

# 3D Objects

- Assets
  - ➢ Create using 3D Digital Content Creation (DCC) tools
    - Maya, 3ds Max, LightWave 3D, ZBrush, Blender
  - ➢ Prefab
    - Reusable asset
      - – Template of a GameObject
        - » Allows you to create, configure, and store a GameObject complete with all its components, property values
      - – Can create multiple *instances* of a prefab
  - ➢ Unity asset store (https://assetstore.unity.com/)
    - A library of free and commercial assets
      - – Created by Unity Technologies or the community
        - » E.g., textures, models, animations, entire project examples, tutorials, and Editor extensions
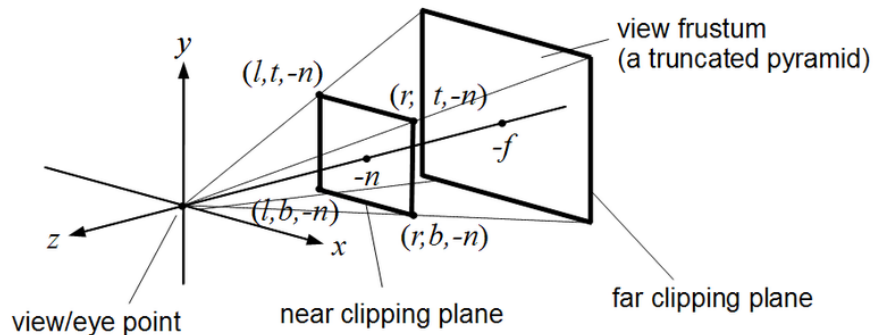
# 3D Objects

- Camera
  - ➢ Perspective
    - Objects look smaller the further they are from the point of view
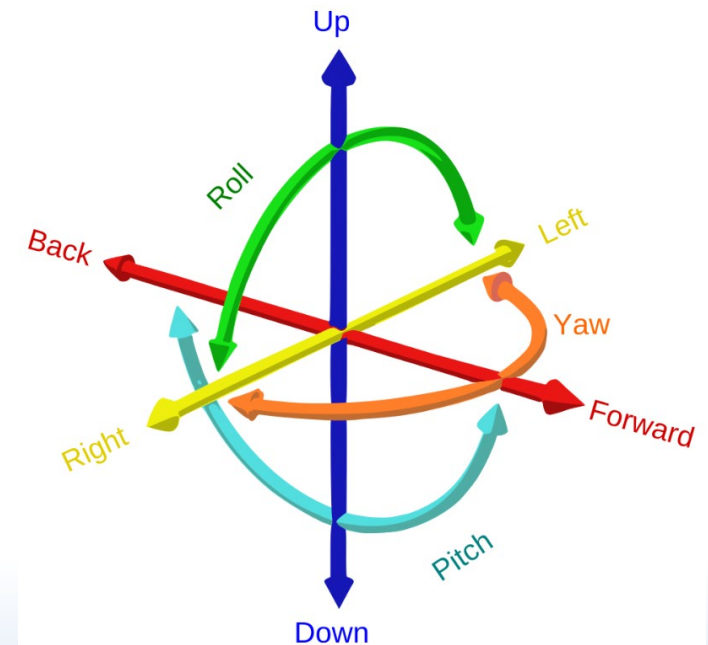    - Field of view
  - ➢ Orthographic
    - Size of objects does not change with distance

# 3D Objects

- Degrees of freedom (DOF)
  - ➢ Mechanical degrees of freedom of movement in 3D space
    - Tracking HMD or controllers
    - Movement of objects in 3D space
  - ➢ 6 DOF
    - Position
      - x, y, z
    - Rotation
      - yaw, pitch, roll
  - ➢ 3 DOF
    - In VR, typically refers to tracking rotational motion only

# Lighting

- Lighting
  - ➢ Essential part of a scene
    - Believable immersion relies on the use of light and its accompanying shadow
    - Determines overall emotion and mood of the scene
  - ➢ Illuminance
    - The amount of light that falls onto a surface
  - ➢ Luminance
    - The amount of light that comes from, passes through and reflects off a surface
      - E.g., amount of light passing through a lightbulb

# Lighting

➢ Types of light
- Point light
  - Emits light in all directions
- Spot light
  - Emits light in a cone shape
- Parallel/directional light
  - Parallel rays that mimic the sun
- Area light
  - Light source confined within a single object, often a rectangle or sphere
- Ambient light
  - Applies to the full scene
    » Changes its overall brightness
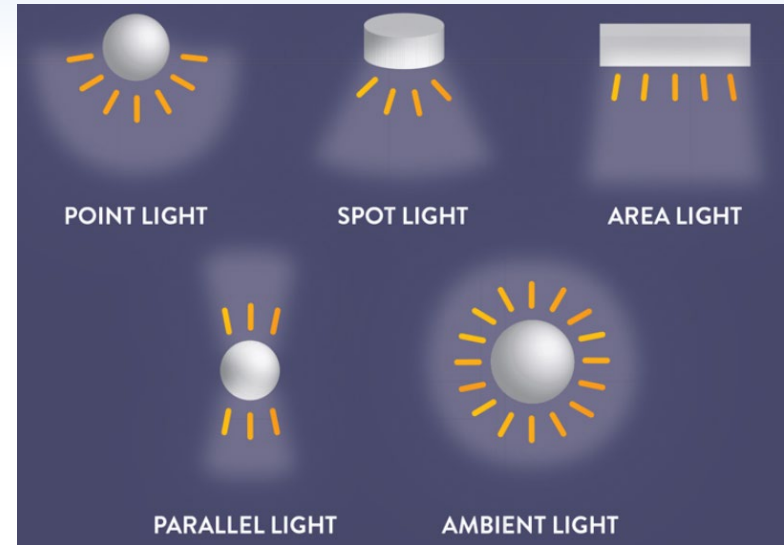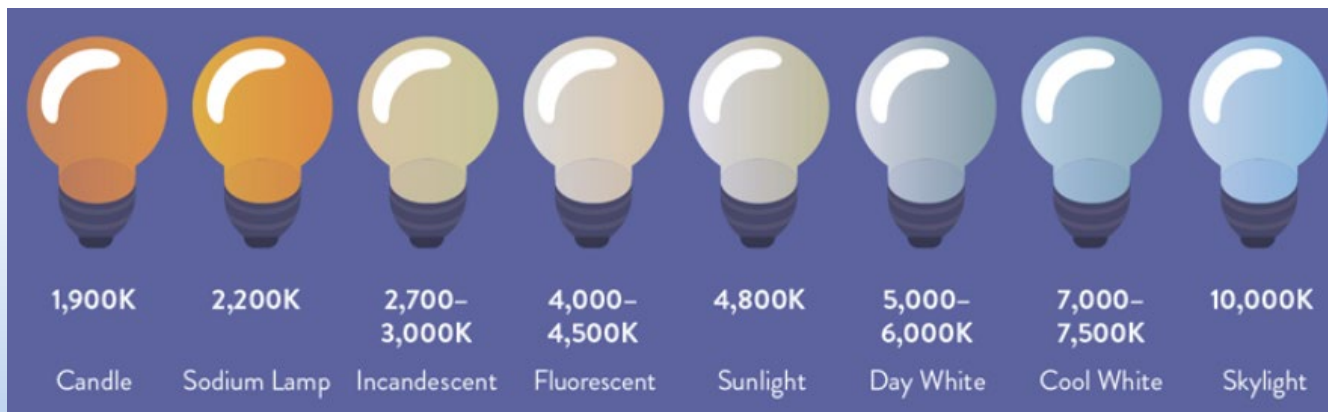
# Lighting

➤ Falloff
- Illumination decreases with distance from the light source

➤ Intensity
- The brightness of light

➤ Colour temperature
- Warm or cool depending on the proportional mix of colours
- Light temperatures measured in Kelvin

| 1,900K | 2,200K | 2,700–3,000K | 4,000–4,500K | 4,800K | 5,000–6,000K | 7,000–7,500K | 10,000K |
|---|---|---|---|---|---|---|---|
| Candle | Sodium Lamp | Incandescent | Fluorescent | Sunlight | Day White | Cool White | Skylight |

# Lighting

➢ **Lighting design**

- Likely to use more than one light in a scene
- Need a role for each light
    - May individually change light intensity
- General guideline
    - Create lighting design before adding materials and textures
        » Can see what light looks like

➢ **Shadows**

- Soft light
    - Creates **soft shadows** with a fuzzy edge
- Hard light
    - Creates **hard shadows** with sharp edges
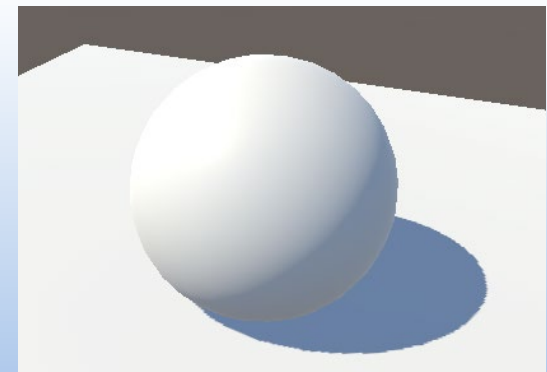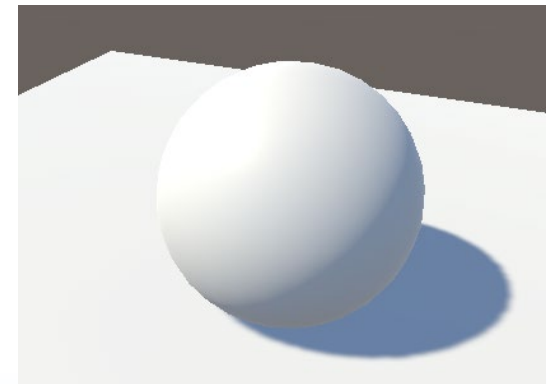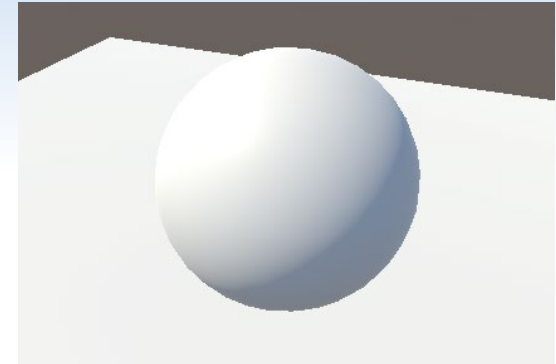
# Visual Cues

- Sensory cues
  - A piece of information that is derived from sensory stimulation and is relevant to perception
- Monocular depth cues
  - Not dependent on both eyes
  - Monocular depth cues are strong
    - Misconception that depth perception enabled by stereo cues alone
  - Divided between
    - Viewer motion
      - Requiring movement of light patterns across the retina
    - Fixed viewing position
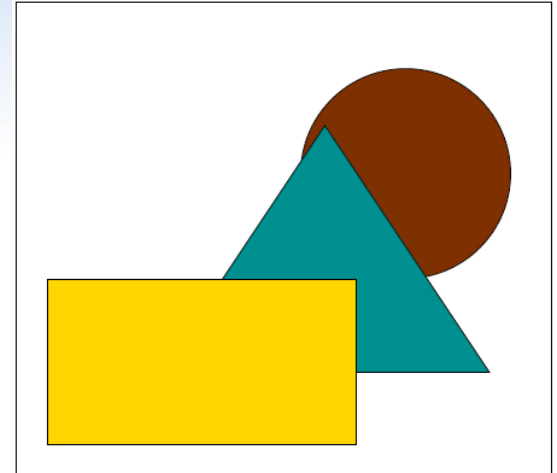
# Visual Cues

➤ **Motion parallax**

- Objects closer to a moving observer appear to move faster than objects further away

- Physiological perspective
  - The result of the speed at which an image moves across the retina

- Strong relative motion cue

- Important information on relative depth differences



Credit: Illustration elements by sergeiminsk and Ginko © *123RF.com*
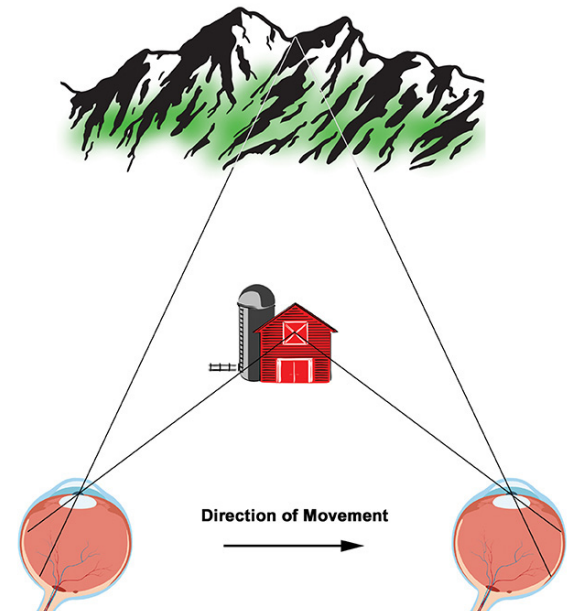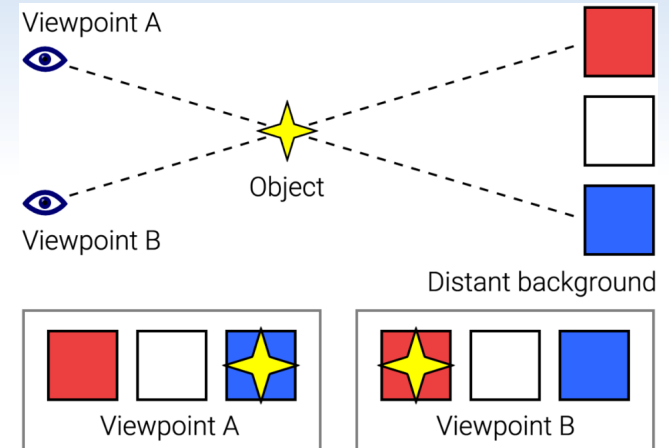
# Visual Cues

➢ Occlusion
- Also known as interposition
- Generated when one object blocks and observer's view of another object
  - Blocking object perceived as being closer to the observer
- Indicates relative, as opposed to absolute, distance
- Two components when moving
  - Deletion (hiding)
  - Accretion (revealing)





*Credit: Illustration by joyfull / Depositphotos.com*
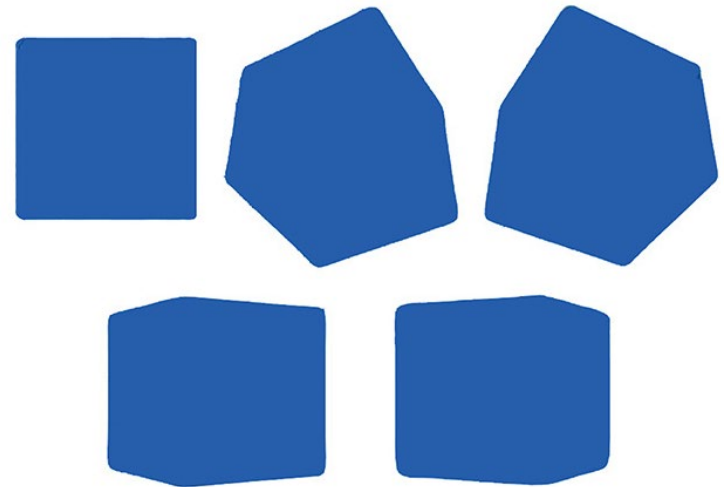
# Visual Cues

➢ Linear perspective

- Convergence of lines towards a single point in the distance

➢ Kinetic depth effect

- Structure from motion

- Perception of an object's complex, 3D structure from that object's motion

- Perceived based on
    - Changes in the pattern on the retina as the object moves
    - Previous experience



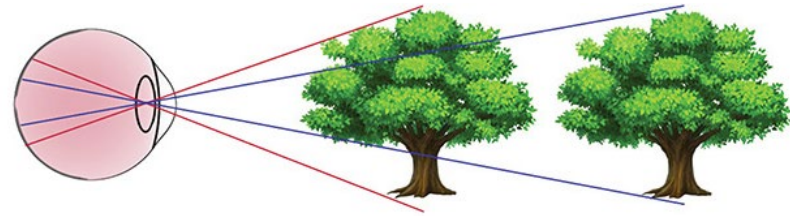Credit: Image by Warren R.M. Stuart via Flickr under a CC 2.0 license



Credit: Illustration by S. Aukstakalnis
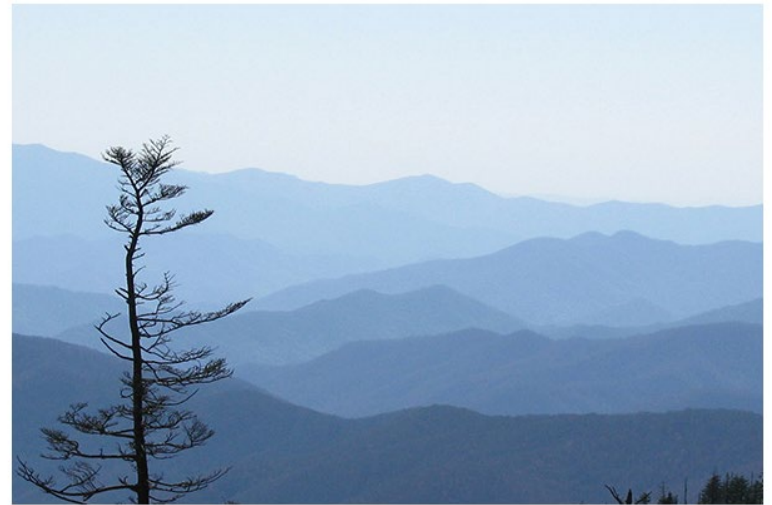
# Visual Cues

➤ Relative size

- Two objects similar in size offset in terms of distances from the observer

- Smaller object perceived as a further away



Credit: Illustration by S. Aukstakalnis

➤ Aerial perspective

- Also known as atmospheric perspective

- Effect of light scattered by particles in the atmosphere

  – As distance increases, contrast decreases



Credit: Image by WSilver via Flickr under a CC 2.0 license

# Visual Cues

➢ **Texture gradient**

- Strong cue
- Gradual change in appearance of textures and patterns of objects with distance
- Less distinguishable with distance
- Three key features
  - Perspective gradient
    - » Decrease in separation of texture elements
  - Compression gradient
    - » Decrease in apparent height of texture elements
  - Density gradient
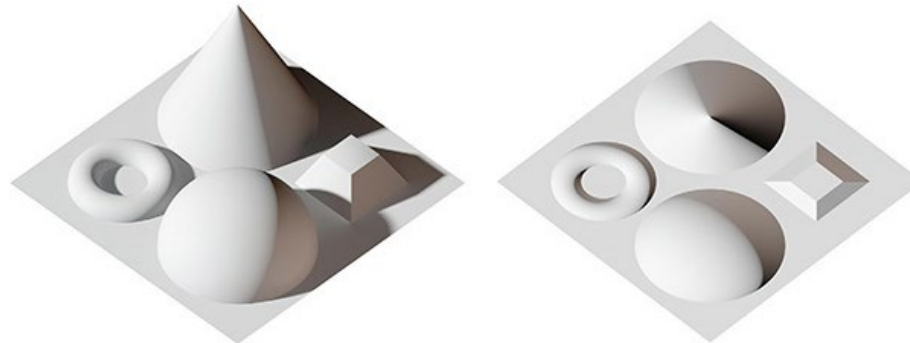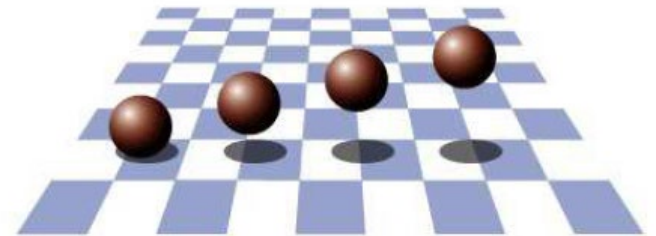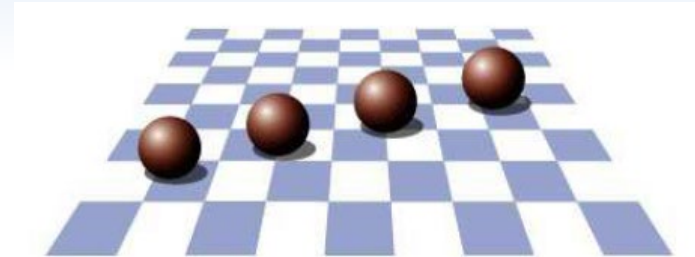    - » Increase in number of elements per unit area



*Credit: Image by Jeremy Keith via Flickr under a CC 2.0 license*

# Visual Cues

➢ Lighting/shading/shadows
- How light interacts with irregular surfaces reveals information about geometry
- Angle and sharpness of shadows influence perceived depth and positioning
- Shadows resolve ambiguous depth

Credit: Illustration by Julian Herzog via Wikimedia under a CC 4.0 license

# Visual Cues

➢ Optical expansion

- Increase in size as object comes close, increases occlusion of background
- Observer perceives object movement and its distance



Credit: Illustration by S. Aukstakalnis

# Visual Cues



"Paris Street, Rainy Day," Gustave Caillebotte, 1877. Art Institute of Chicago.

# Unity

- Component system
  - ➢ Different approach to object-oriented programming
  - ➢ Composition rather than inheritance
    - Objects exist on a flat hierarchy instead of a hierarchy of classes
    - Facilitates rapid prototyping
      - Mix and match components rather than refactor the inheritance chain when objects change
    - Have the option to use inheritance in code
  - ➢ GameObjects
    - Built up as a collection of components
  - ➢ Components
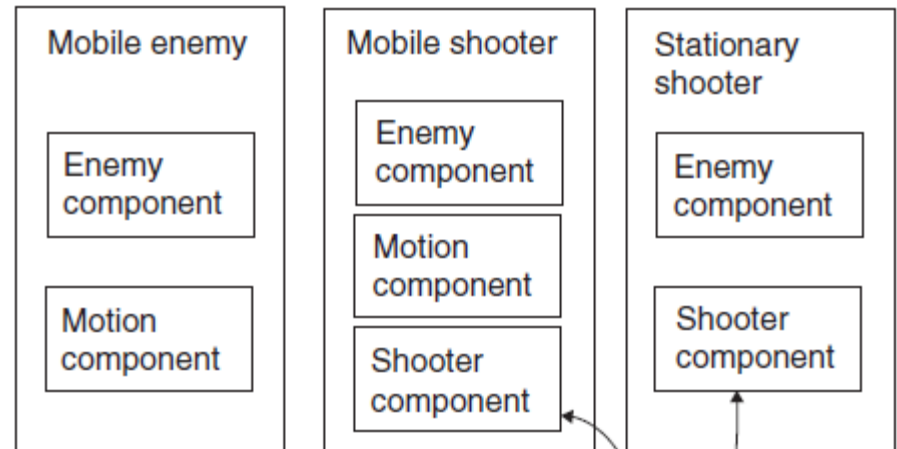    - Packets of functionality
    - Can mix and match

# Unity

➤ Inheritance versus composition



**Inheritance**

Enemy
Mobile enemy
Mobile shooter
Stationary shooter
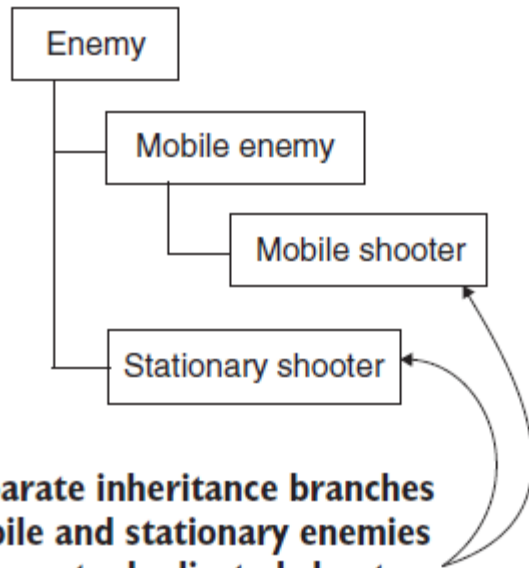
The separate inheritance branches for mobile and stationary enemies need separate duplicated shooter classes. Every behavior change and new enemy type requires a lot of refactoring.

**Component system**

Mobile enemy
Enemy component
Motion component

Mobile shooter
Enemy component
Motion component
Shooter component

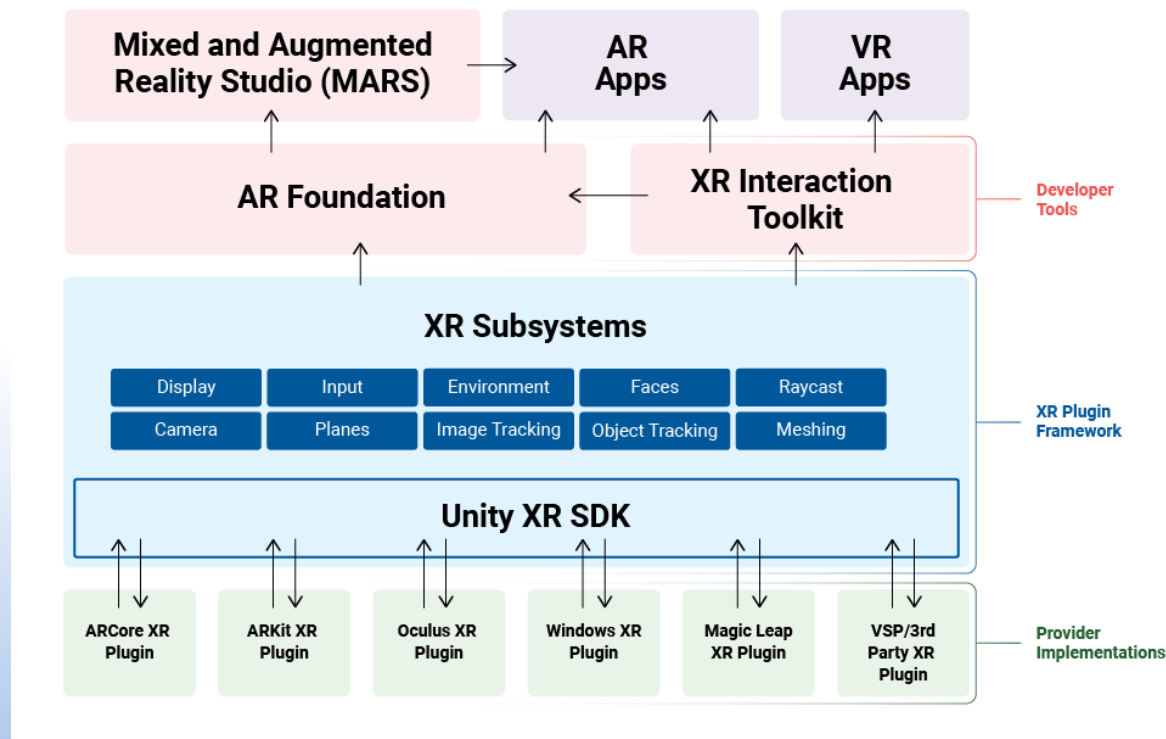Stationary shooter
Enemy component
Shooter component

The mix-and-match components enable a single shooter component to be added anywhere it's needed, on both mobile and stationary enemies.

# Unity

- Unity XR plugin framework
  - ➢ Exposes common functionalities across supported platforms

## Unity XR Tech Stack
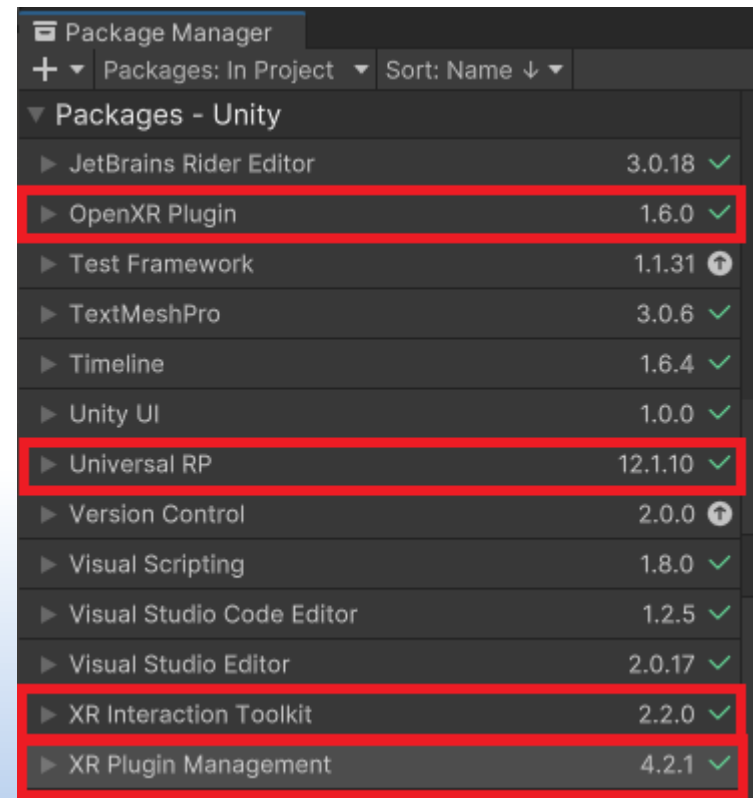
# Unity

- Packages
  - ➢ Contains features to fit the various needs of a project
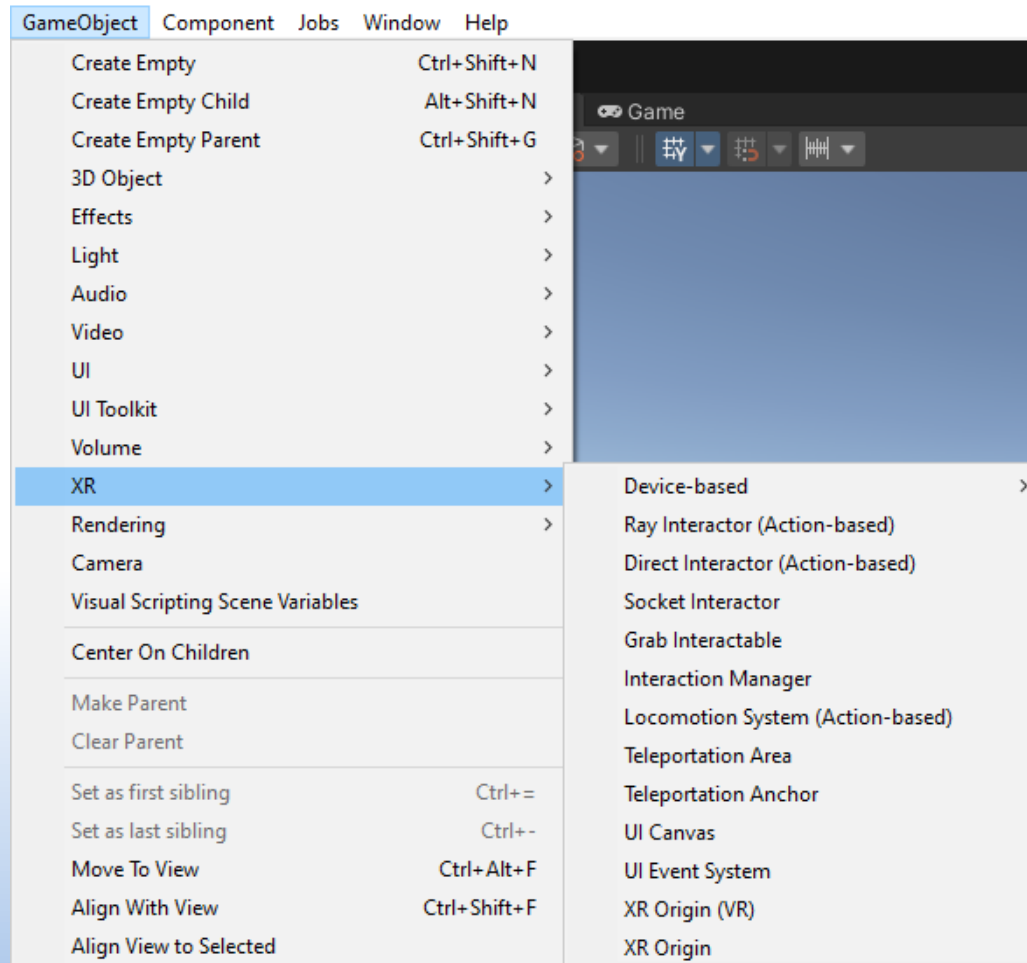  - ➢ Need to setup and configure
  - ➢ For XR projects
    - XR Plugin Management
    - XR Interaction Toolkit
    - OpenXR Plugin
    - Universal RP (Render Pipeline)
      - – Optimised for mobile
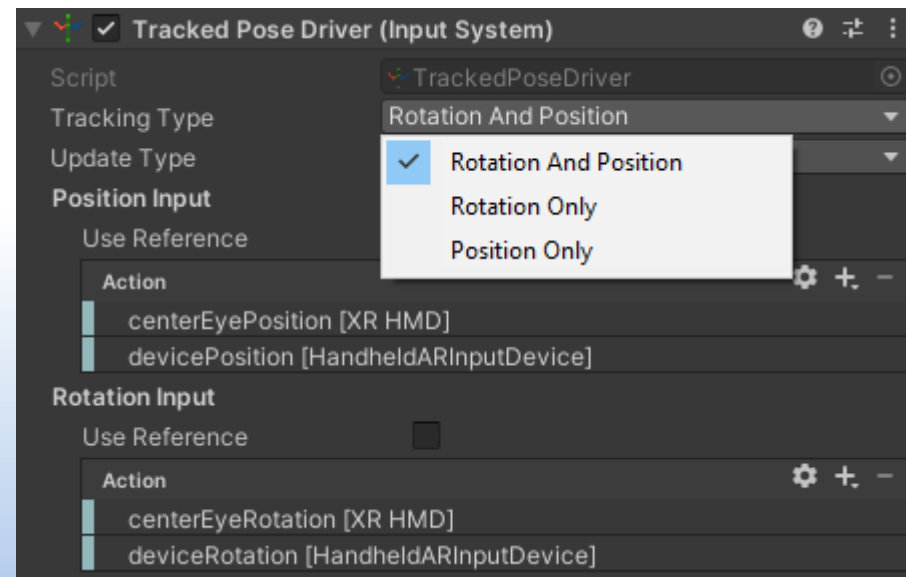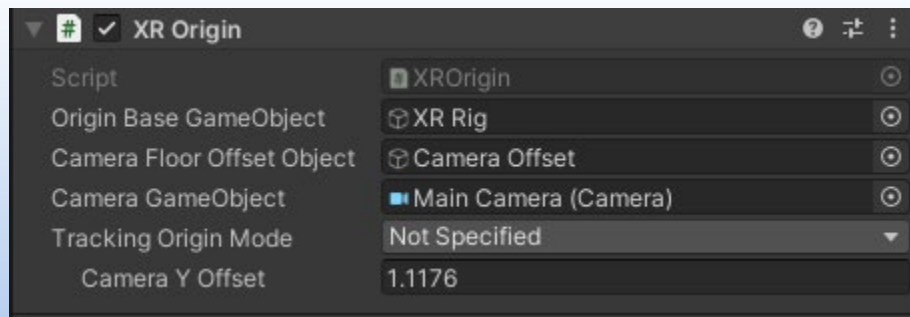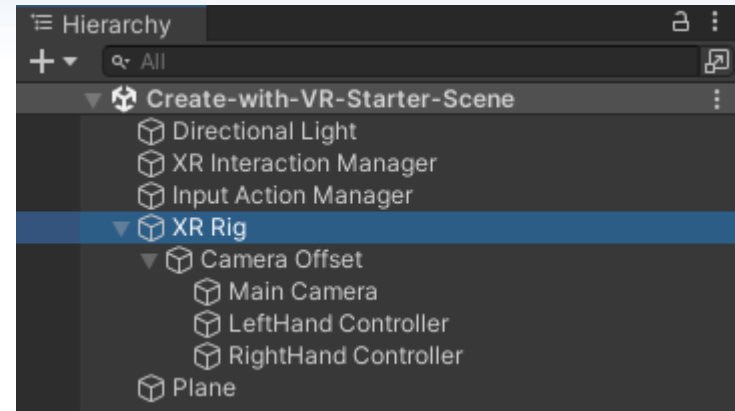
# Unity

- ## XR GameObjects

# Unity

- ## XR Origin
  - ➢ Stand in for supported XR headset
  - ➢ Represents the user's camera and controllers
  - ➢ Tracks camera
    - Position and/or rotation

# VR Systems

- **VR Systems**
  - ➤ HMD and controllers
    - Untethered
      - Meta Quest 2
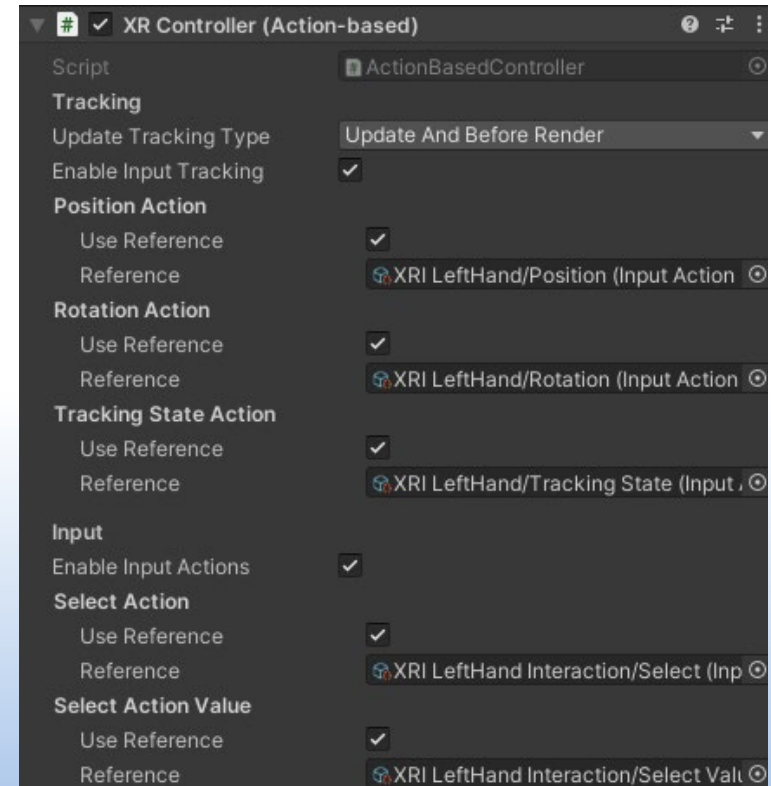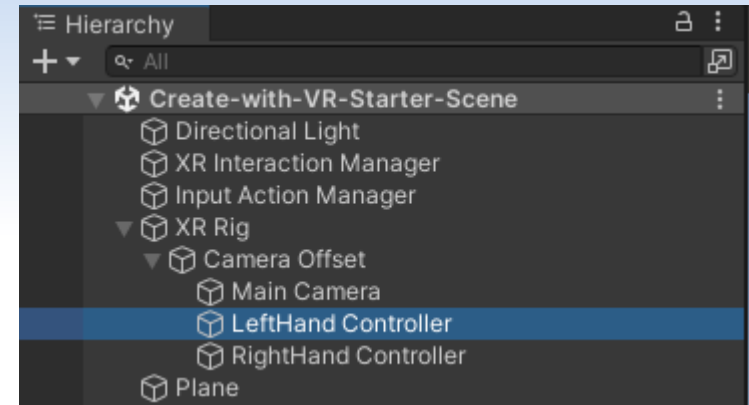    - Tethered
      - Valve Index
      - HTC Vive Pro 2
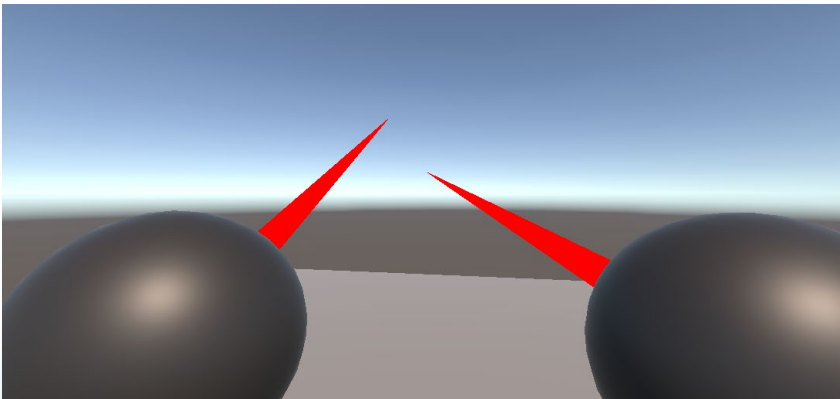
# Unity

- **XR Controllers**
  - ➢ Input
    - Position and rotation
    - Buttons, thumbsticks, triggers, grips/bumpers

# Unity

- ## XR Controllers
  - ➢ XR device simulator
    - Test using keyboard and mouse controls
      - – Operating 3 devices, with 6 DOF, with one mouse and keyboard



| ▶ | # | ✓ | XR Controller (Action-based) | ❷ | ⇌ | ⋮ |
| ▶ | # | ✓ | XR Ray Interactor | ❷ | ⇌ | ⋮ |
| ▶ | ⮂ | ✓ | Line Renderer | ❷ | ⇌ | ⋮ |
| ▶ | # | ✓ | XR Interactor Line Visual | ❷ | ⇌ | ⋮ |

# References

- Among others, material sourced from
  - S. Aukstakalnis, Practical Augmented Reality: A Guide to the Technologies, Applications, and Human Factors for AR and VR, Addison-Wesley
  - D. Schmalstieg and T. Hollerer, Augmented Reality: Principles and Practice, Addison-Wesley
    - www.augmentedrealitybook.org
  - R. C. Stevens, Designing Immersive 3D Experiences, New Riders
  - R. Doerner, W. Broll, P. Grimm, B. Jung, Virtual and Augmented Reality: Foundations and Methods of Extended Realities, Springer
  - S.M. LaValle, Virtual Reality, Cambridge University Press
  - J. Hocking, Unity in Action: Multiplatform Game Development in C#, 3rd Edition, Manning
  - https://learn.unity.com/tutorial/vr-project-setup/
  - http://en.wikipedia.org/wiki/
  - https://docs.unity3d.com/Manual/