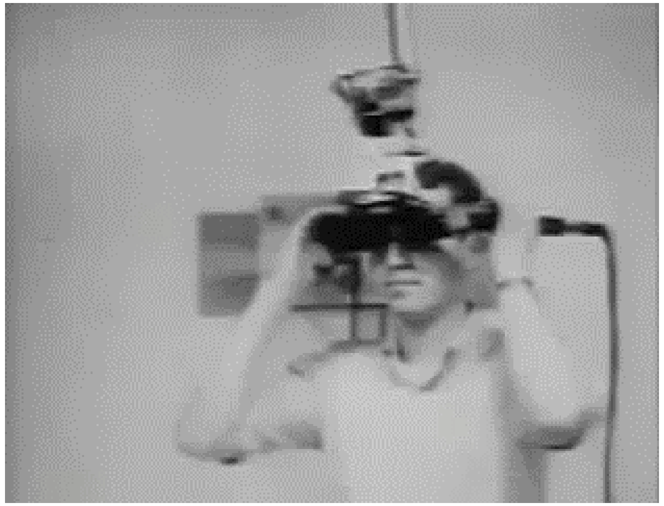
Helge Rhodin

CPSC 427
Video Game Programming

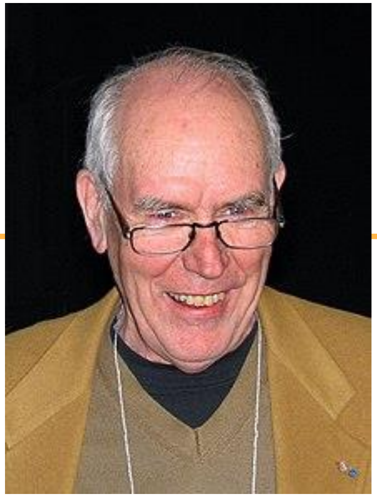
History and Future of Game Technology



Today

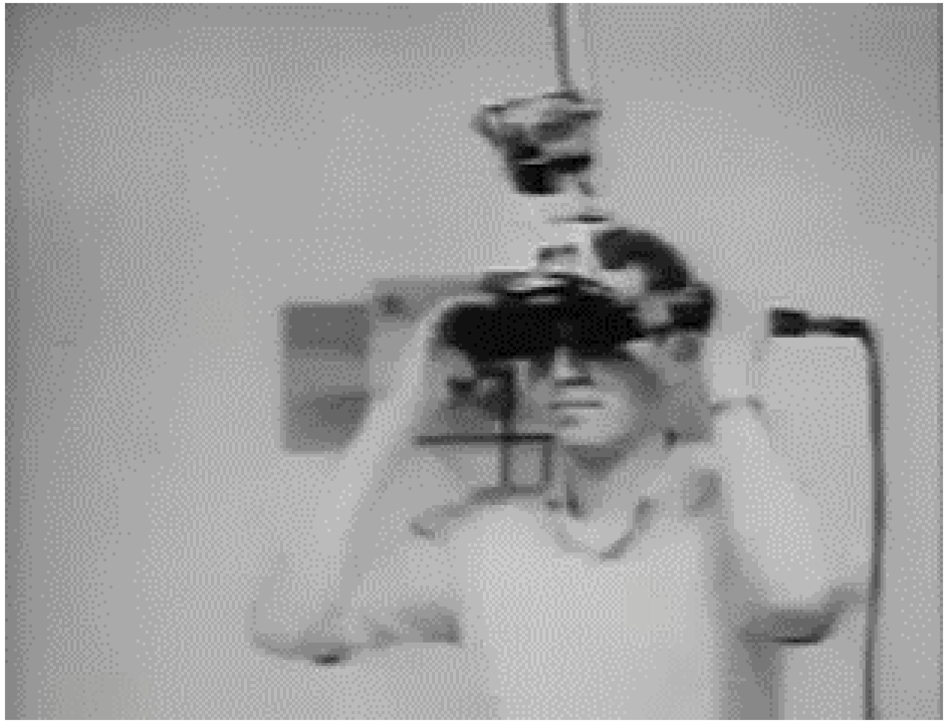
- ***Technical highlights in game history***
- ***Relations to computer science advances***
  - *computer graphics*
  - *computer vision*
  - *optics …*
- ***Course Summary***
- ***The future of gaming?***

The Sword of Damocles (1968)



- ***By Ivan Sutherland***

- ***First augmented reality head-mounted display (HMD)***



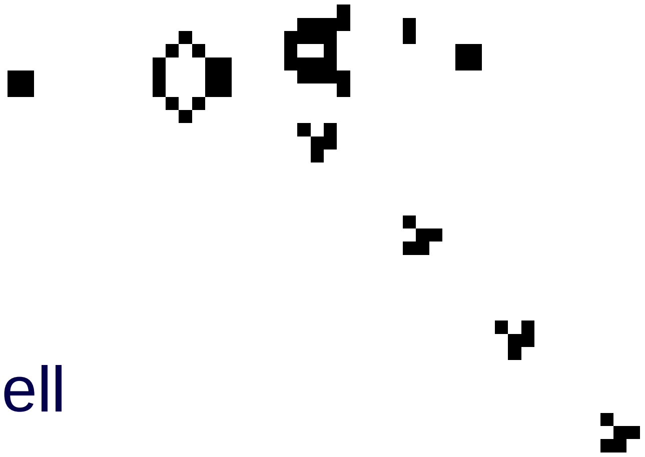
- stereoscopic display
  - *see-through technology!*
- viewpoint-dependent rendering
  - *required 6 DOF head tracking*
  - *some versions used ultrasound!*

LIFE (1970)

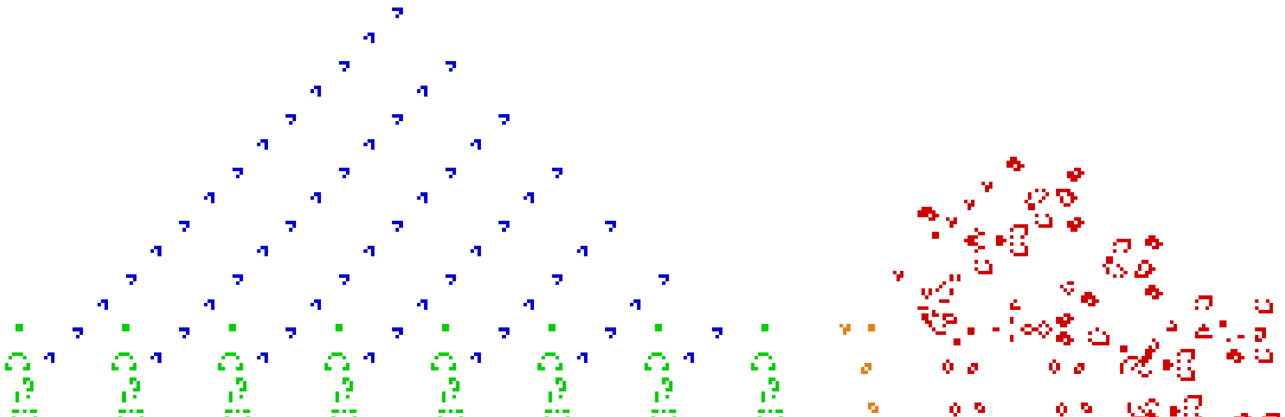
By John Horton Conway

Rules:

- A pixel grid of active/live and inactive/dead cells
- Any live cell with two or three live neighbours survives
- Any dead cell with three live neighbours becomes a live cell
- All other live cells die in the next generation



The seed (initial condition) determines the evolution



Perlin noise (1983)

Ken Perlin
https://mrl.cs.nyu.edu/~perlin/
NYU

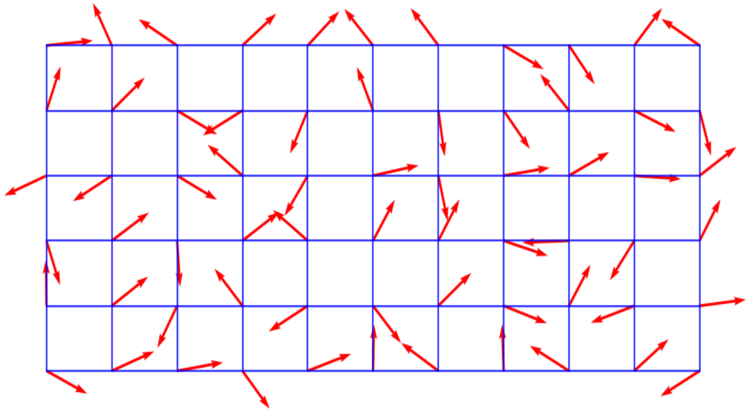
Check out his website!

Two-dimensional slice through 3D Perlin noise at z=0

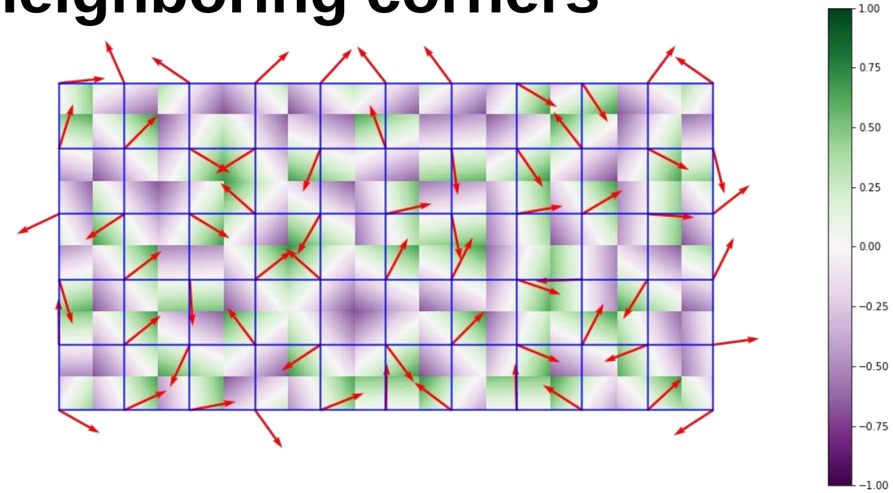
Landscape by Perlin noise

Perlin noise

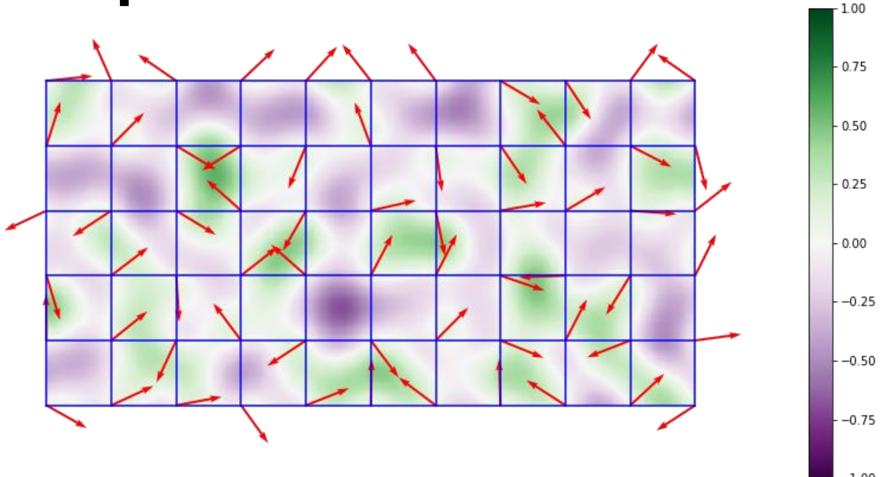
1. Generate random vectors



2. Dot product of rnd. vec. and offset to neighboring corners



3. Interpolate based on distance



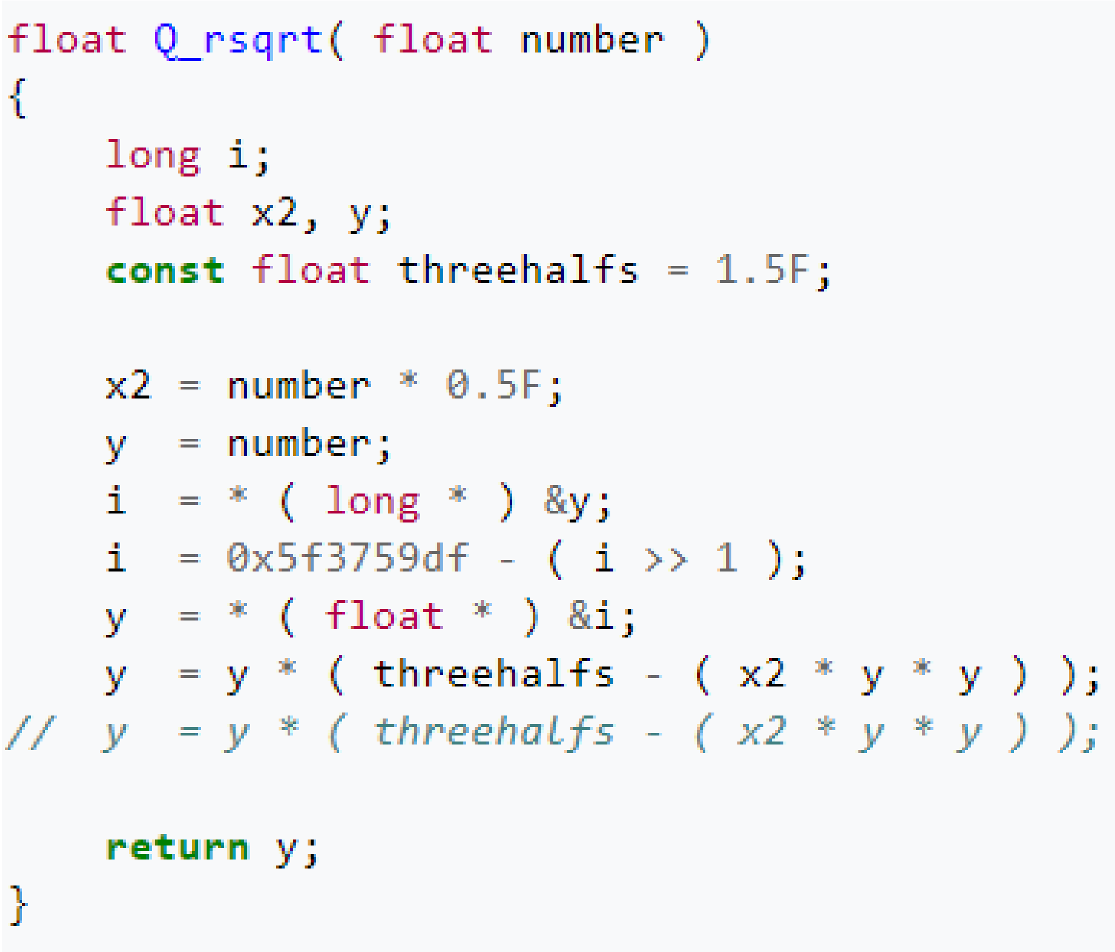
4. Repeat at different resolutions and add displacements

WASD

- 1997: Dennis “Thresh” Fong, *the greatest Quake player in the universe*
  - *What’s your config?*

- ***Quake 2, Half-Life, Starsiege Tribes, and other games then picked it up as default configs***

Code in Quake 3 (1999) – what??

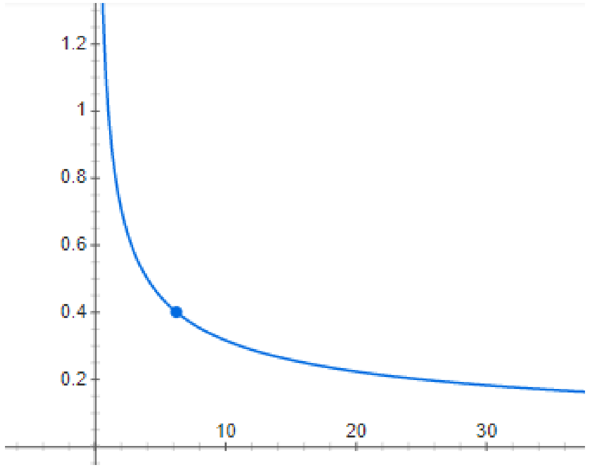


```
float Q_rsqrt( float number )
{
    long i;
    float x2, y;
    const float threehalfs = 1.5F;

    x2 = number * 0.5F;
    y  = number;
    i  = * ( long * ) &y;
    i  = 0x5f3759df - ( i >> 1 );
    y  = * ( float * ) &i;
    y  = y * ( threehalfs - ( x2 * y * y ) );
//  y  = y * ( threehalfs - ( x2 * y * y ) );

    return y;
}
```

OpenArena (open source version of the original)

Fast inverse sqrt

- *1/sqrt(x)*



- *For normalizing a vector*

$$\hat{v} = \frac{v}{\|v\|}$$

- *For lighting and reflectance*
- ***How to speed it up?***

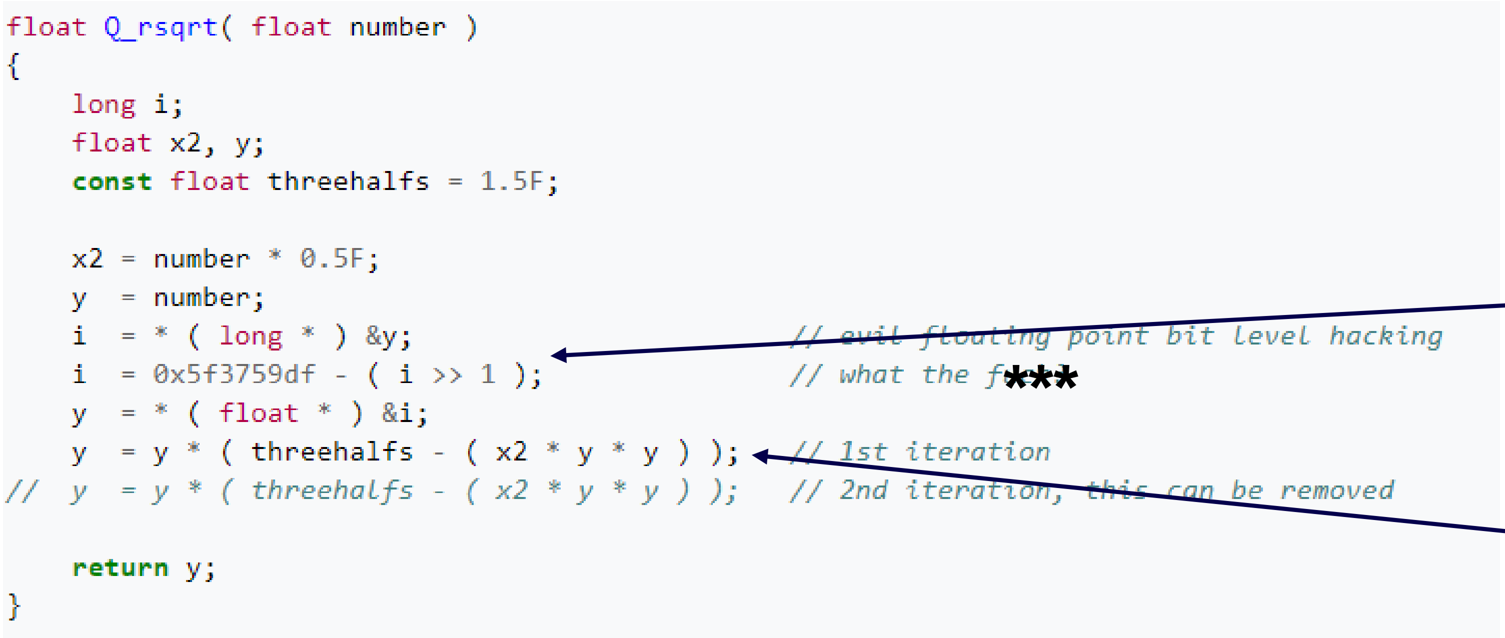
Light effects

Fast inverse sqrt

- ***How to speed it up?***
- *Only use addition and multiplication (at the time, division was very expensive)*

-> 4x speedup compared to division

*Used elsewhere before but best known for its use in **Quake III Arena!***



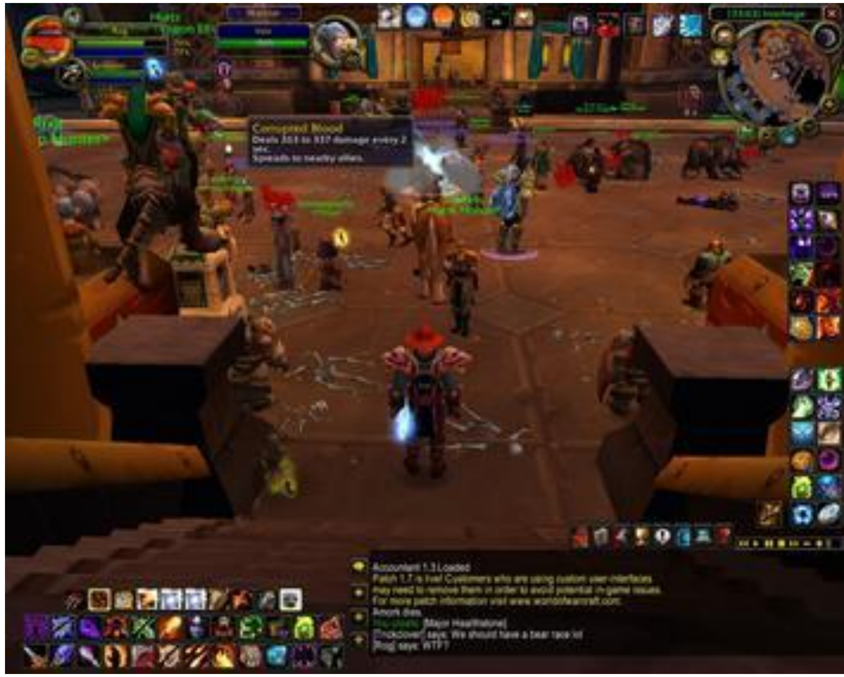
```
float Q_rsqrt( float number )
{
    long i;
    float x2, y;
    const float threehalfs = 1.5F;

    x2 = number * 0.5F;
    y  = number;
    i  = * ( long * ) &y;                       // evil floating point bit level hacking
    i  = 0x5f3759df - ( i >> 1 );               // what the f***
    y  = * ( float * ) &i;
    y  = y * ( threehalfs - ( x2 * y * y ) );   // 1st iteration
//  y  = y * ( threehalfs - ( x2 * y * y ) );   // 2nd iteration, this can be removed

    return y;
}
```

Magic exploiting floating point representation and $\log(\frac{1}{\sqrt{x}}) = -\frac{\log(x)}{2}$

One step of Newton's method (root finding)

World of Warcraft - Corrupted Blood Incident

- *virtual pandemic*
- *spread by end boss Hakkar (intended to be local to a single dungeon)*
- *spread by pets and minions*
- *lasted one week*
- programmer-imposed quarantines
- players' abandoning of densely populated cities
- *Model for epidemic research*
  [Balicer, Ran (2005). "Modeling Infectious Diseases Dissemination Through Online Role-Playing Games". Epidemiology. 18 (2): 260–261.]



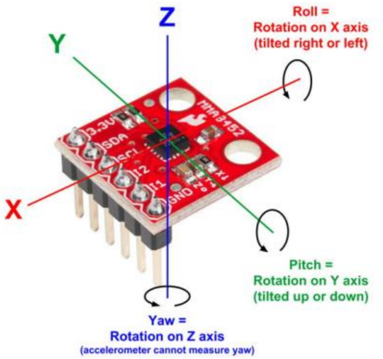
Corrupted Blood
Deals 263 to 317 damage every 2 sec.
Spreads to nearby allies.

Accountant 1.3 Loaded
Patch 1.7 is live! Customers who are using custom user-interfaces may need to remove them in order to avoid potential in-game issues. For more patch information visit www.worldofwarcraft.com.
Amorii dies.
[illegible] [Major Healthstone]
[Thickclover] says: We should have a bear race lol
[Brog] says: WTF?

WoW, September 13, 2005

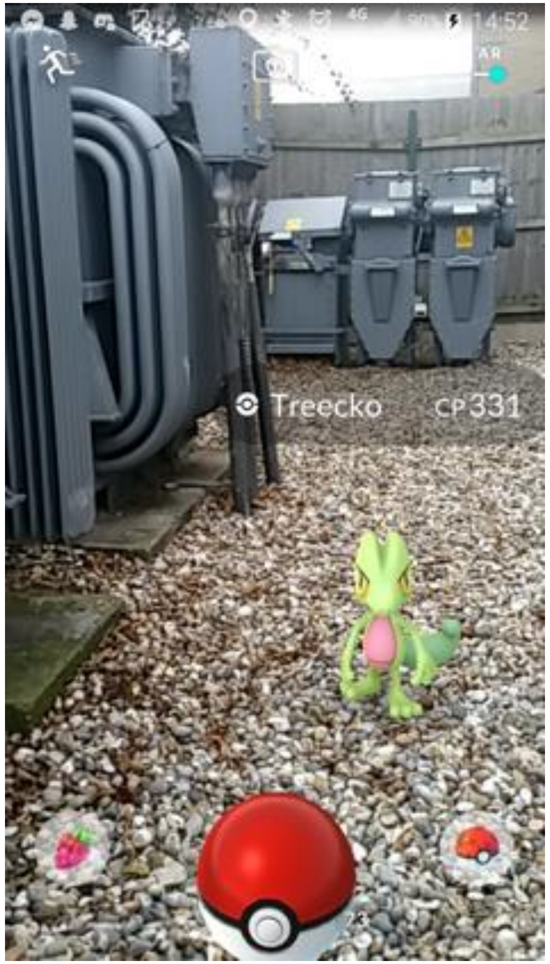
Pokemon Go (2016)

- ***Augmented reality***
    - *requires tracking of the real world*
        - 6 DOF (3D position and 3D rotation)


Z
Y
X
Roll = Rotation on X axis (tilted right or left)
Pitch = Rotation on Y axis (tilted up or down)
Yaw = Rotation on Z axis (accelerometer cannot measure yaw)

Options:

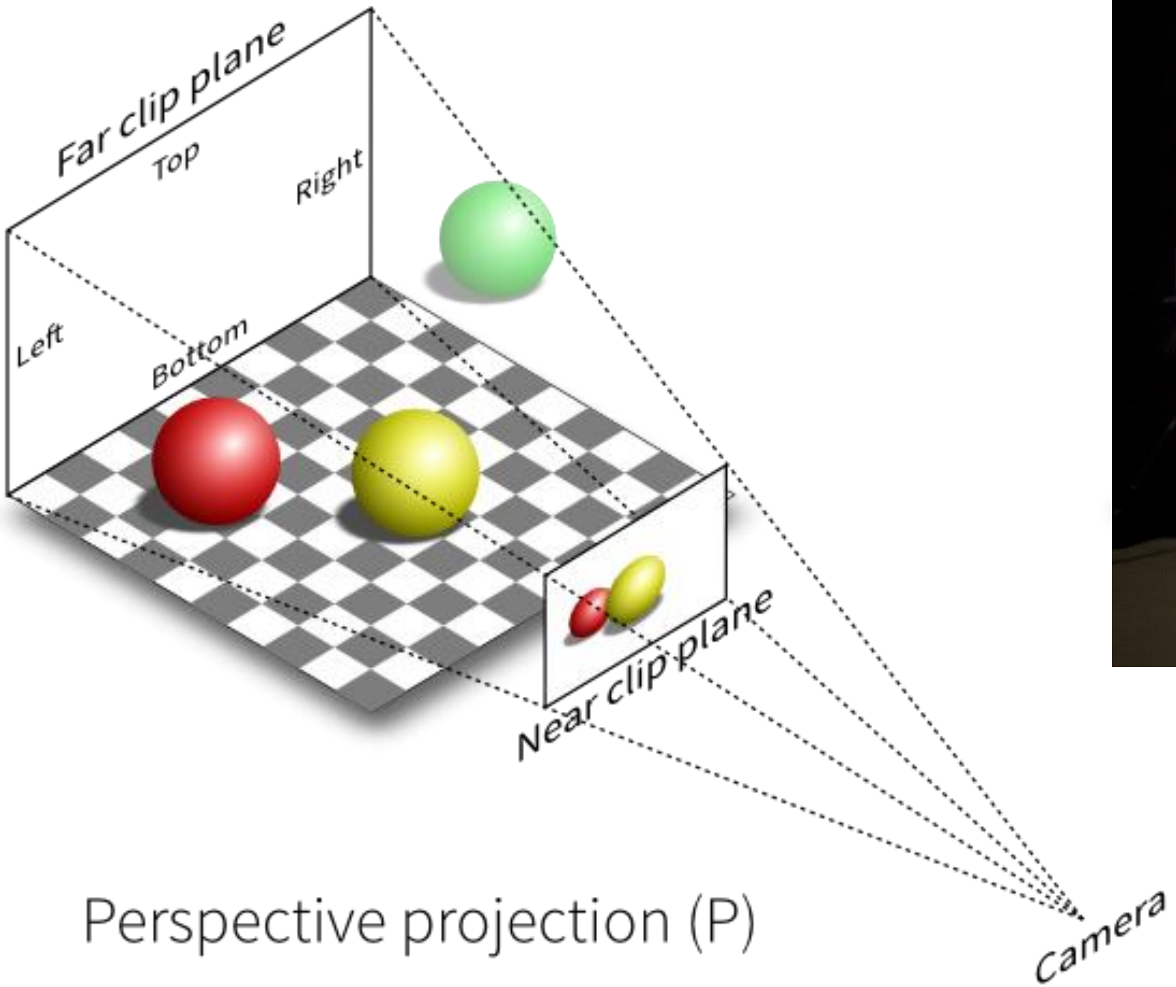
- Use device accelerometers
    - *Advantage: simple*
    - *Disadvantage: drift & no relation to the real world*
- Estimate camera angle relative to real objects



Which one is done in Pokemon Go?

HoloLens - Augmented Reality done right

Virtual Camera



Perspective projection (P)

Virtual camera registered in the real world
(using marker-based motion capture)

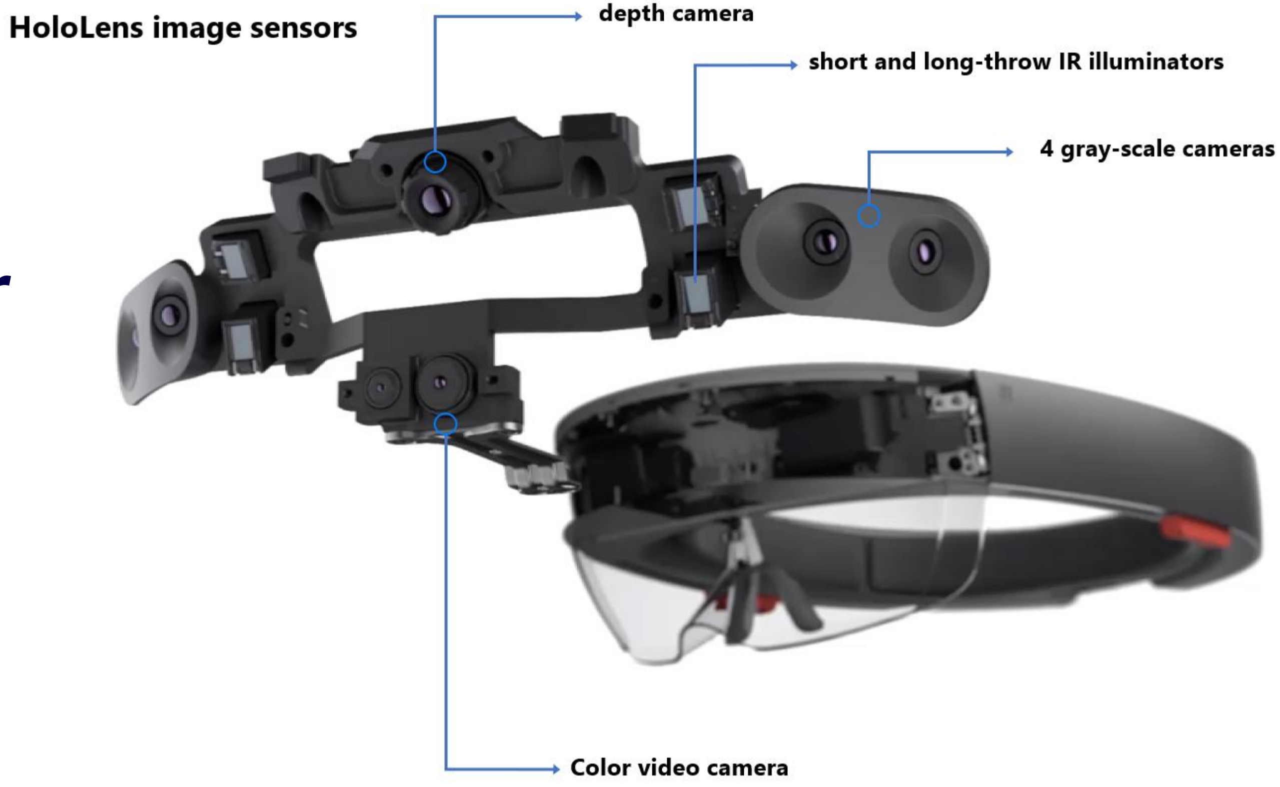
Spatial mapping and tracking

HoloLens --- Augmented Reality done right

Input: gray-scale fisheye cameras (paired with accelerometers)

Method: track image features with on-board processor

Output: reconstruct the 3D scene and camera pose



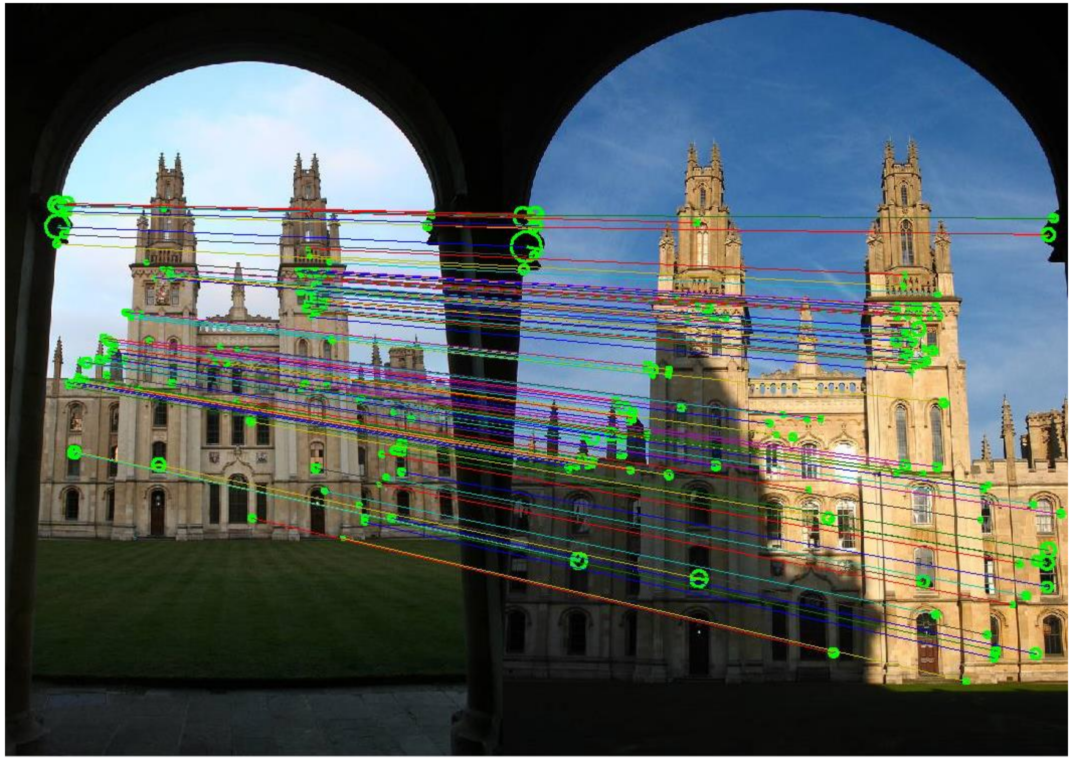
Related computer vision concepts

- ***Feature detection***

- ***Feature tracking and re-identification***

- ***Perspective projection***

- ***Hand Gesture recognition (as input)***



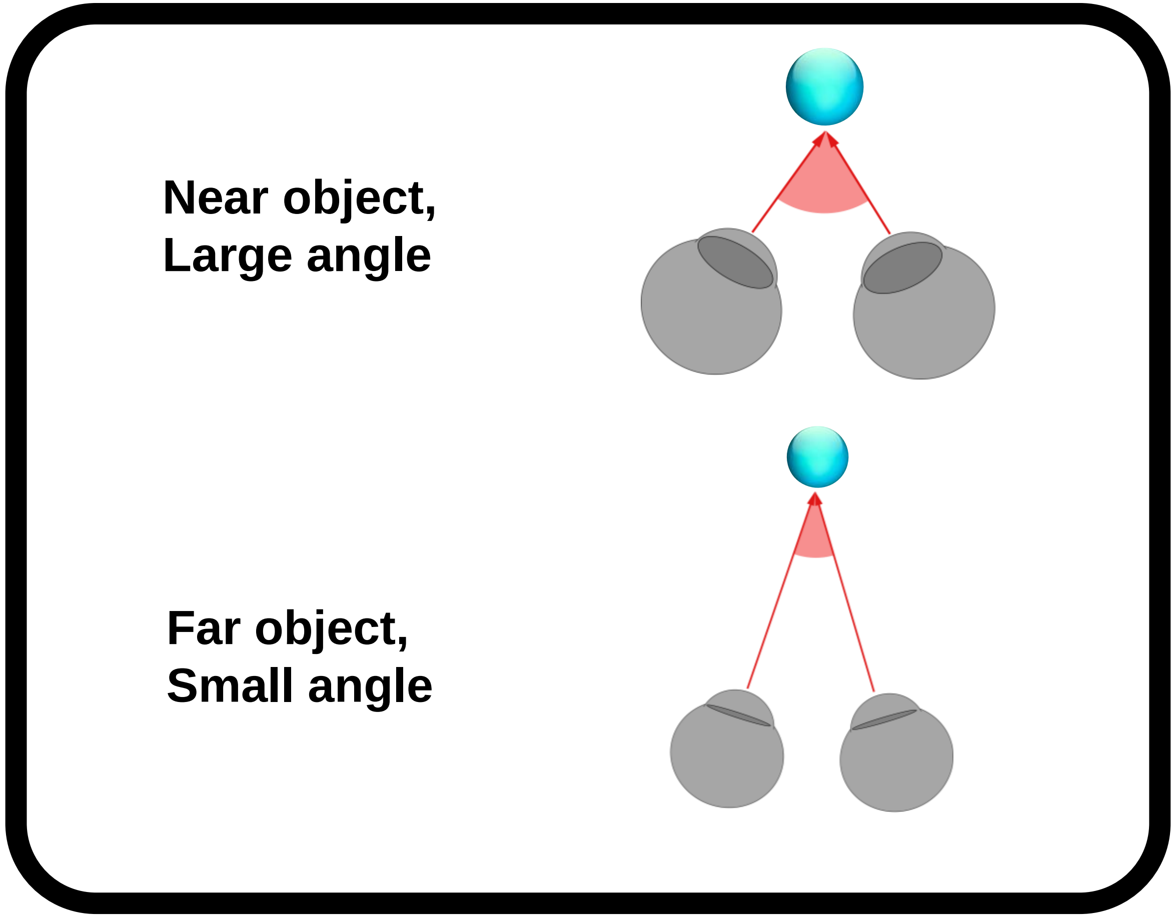
Virtual and Augmented Reality Issues

Open questions:

- ***Why are headsets so bulky?***
- ***Why do I get motion sick or perceive discomfort?***
- ***Why is the field of view (FOV) and resolution so low?***

3D perception — Binocular

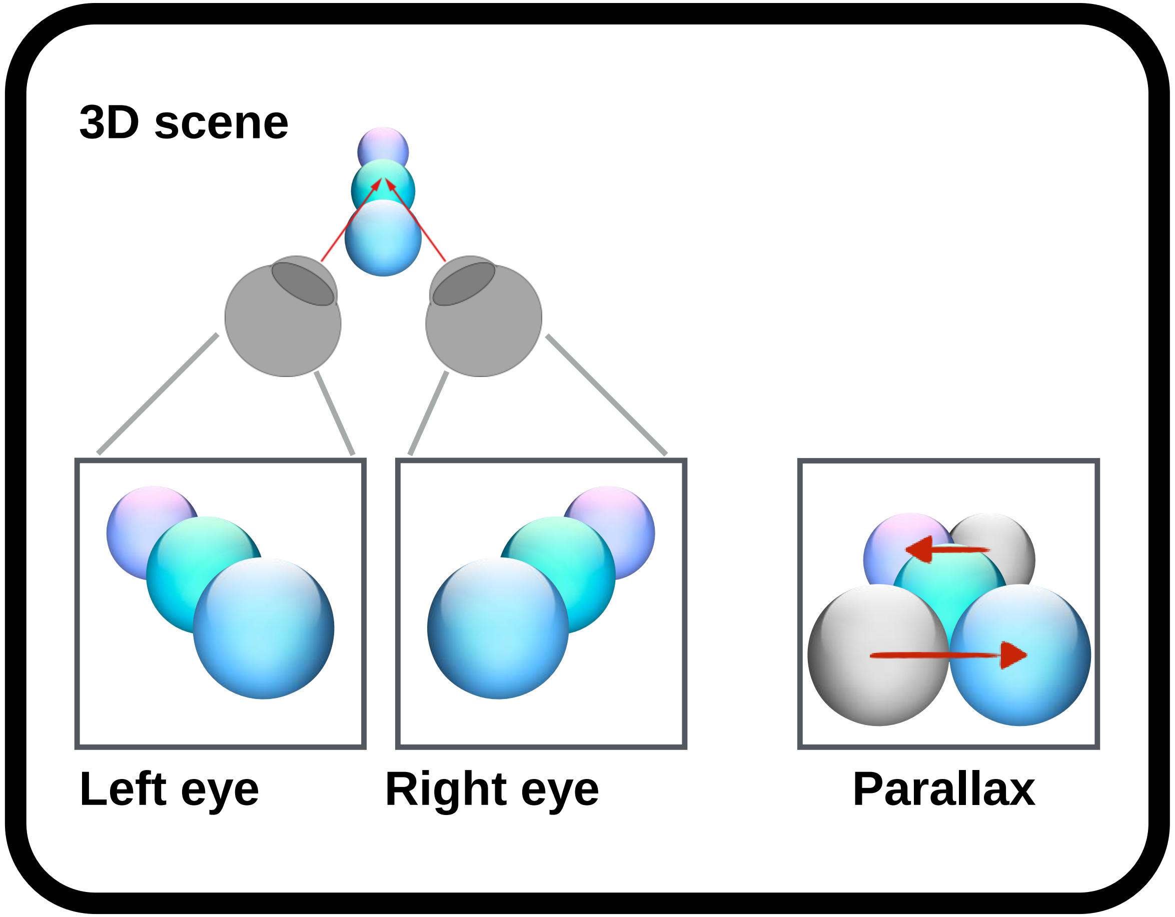
Convergence and accommodation



Near object,
Large angle

Far object,
Small angle

Binocular parallax



3D scene

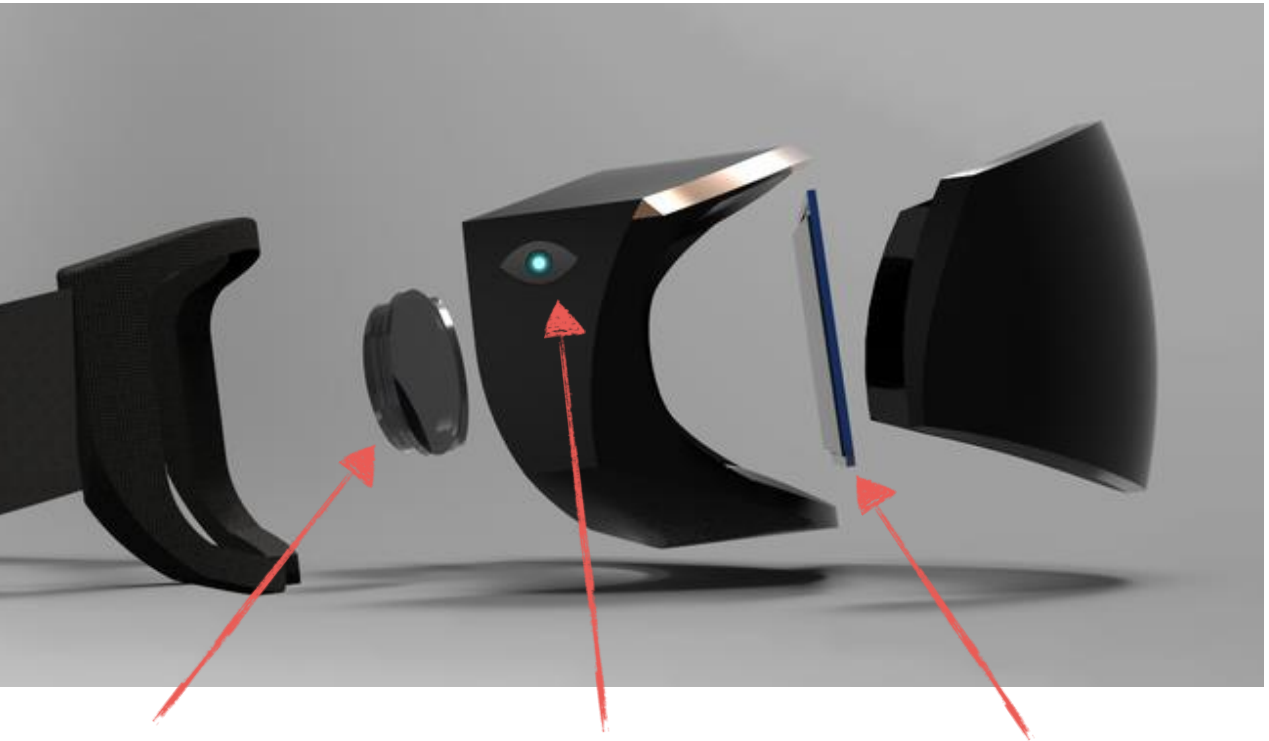
Left eye

Right eye

Parallax

Head-Mounted Display

Head-Mounted Display (HMD)

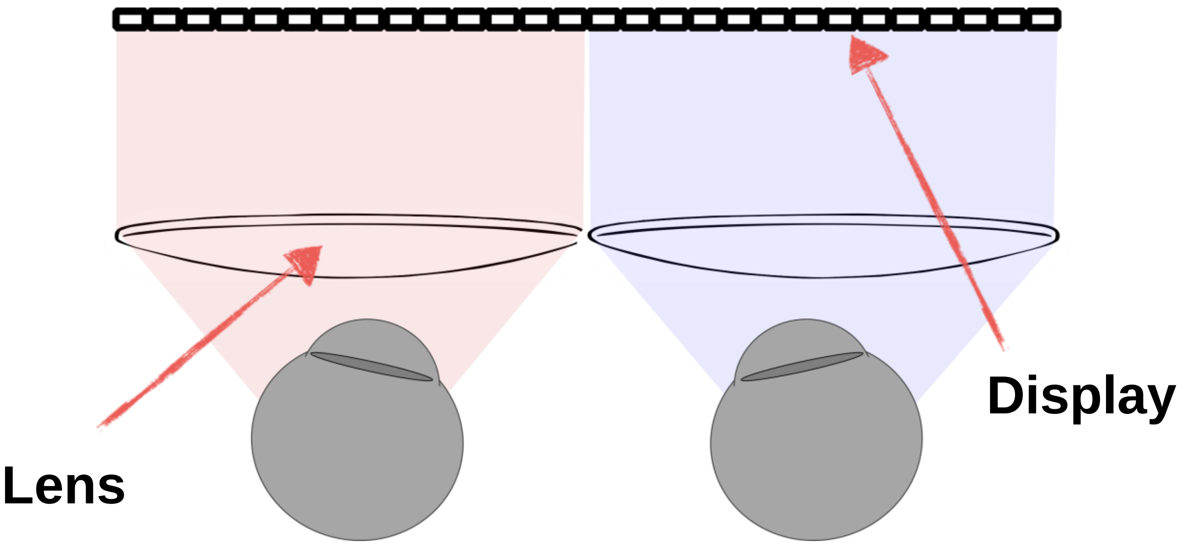


Lens

Tracking sensor

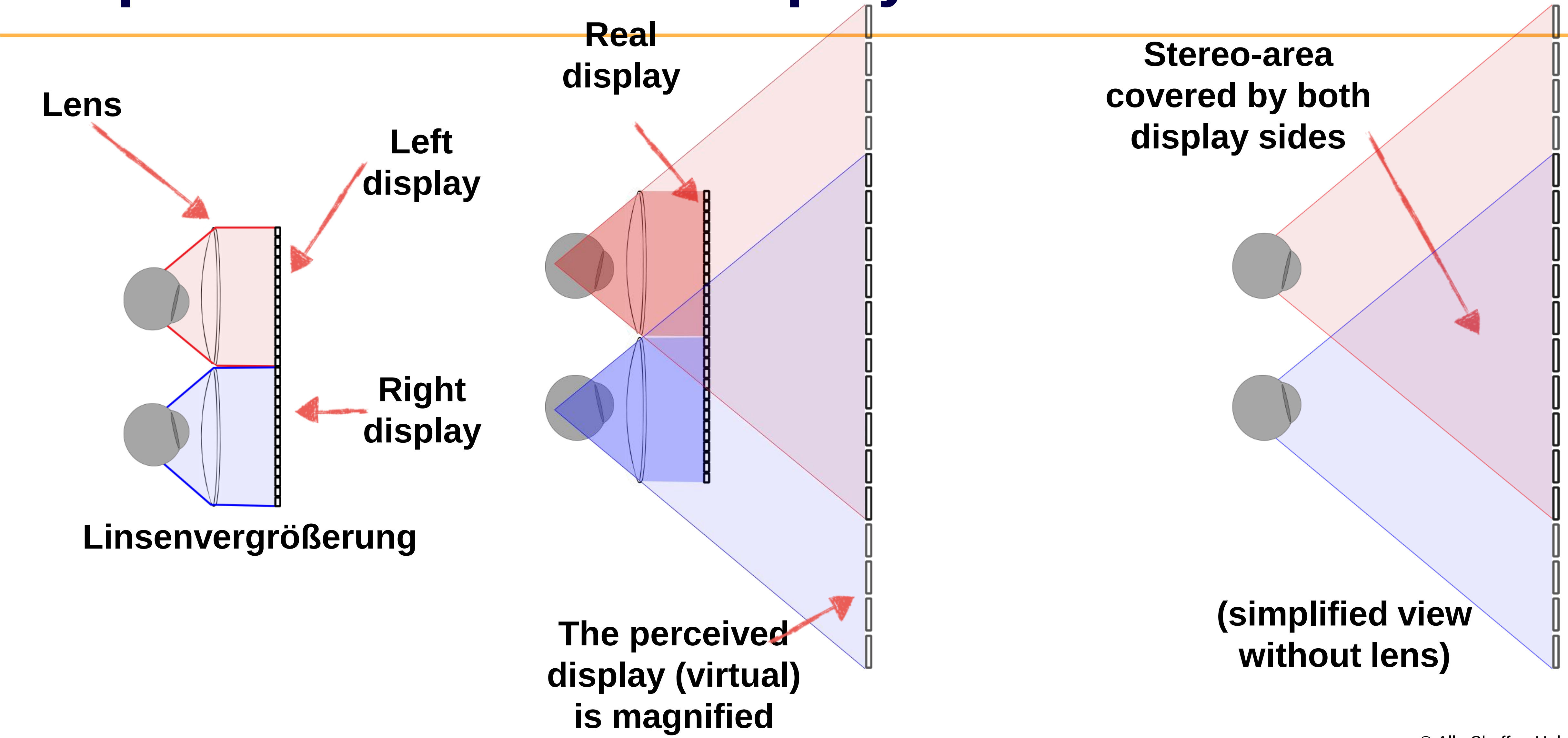
Display

Optical setup



[HMD Aufbau: minimalicity.com]

Optik und Virtuelles Display



Lens

Left display

Right display

Linsenvergrößerung

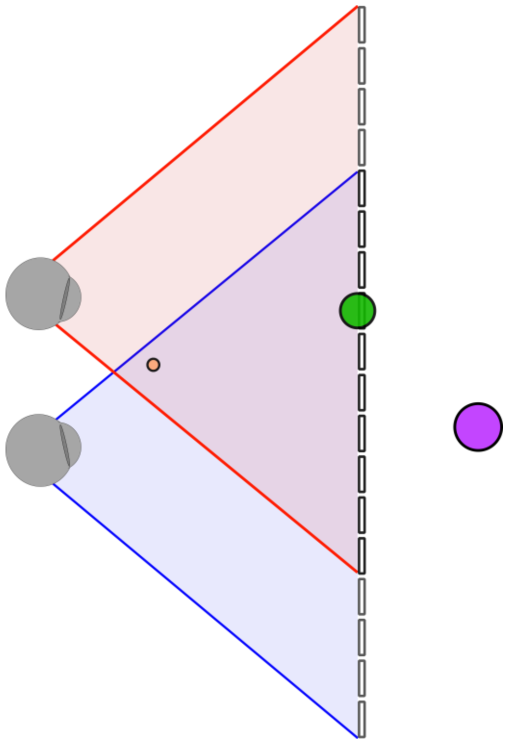
Real display

The perceived display (virtual) is magnified

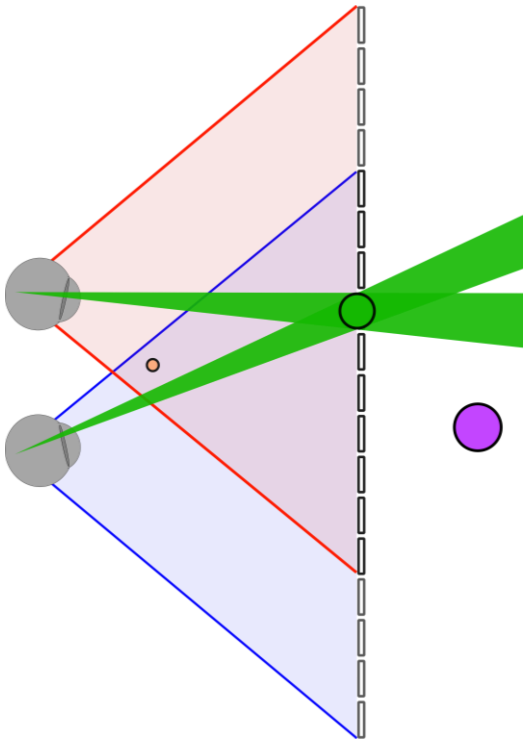
Stereo-area covered by both display sides

(simplified view without lens)

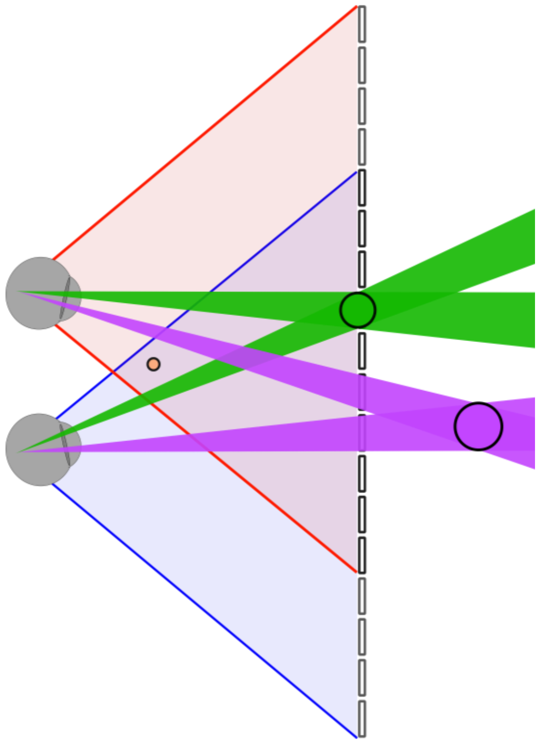
Stereo-Display



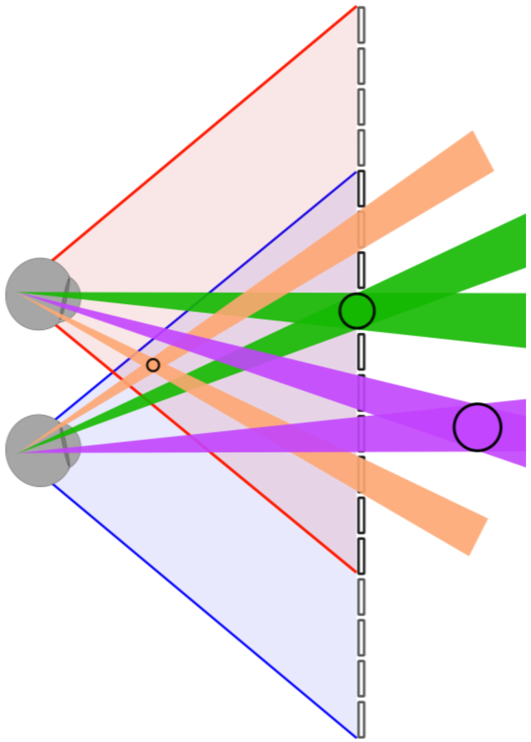
Desired/real object positions



Case I: Object projected on display



Case II: Object is behind the screen



Case III: Object is in front of screen

Issues of VR?

- ***What does this imply for us (video game programming)?***

Light field displays (3D without glasses)

Sony

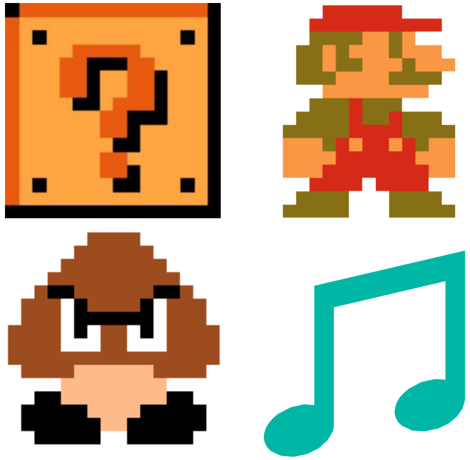
Principle: a diplay that emits a different color dependent on the view direction

Difficulty: i) Render an independent image for each view direction (and position).

ii) hardware realization.

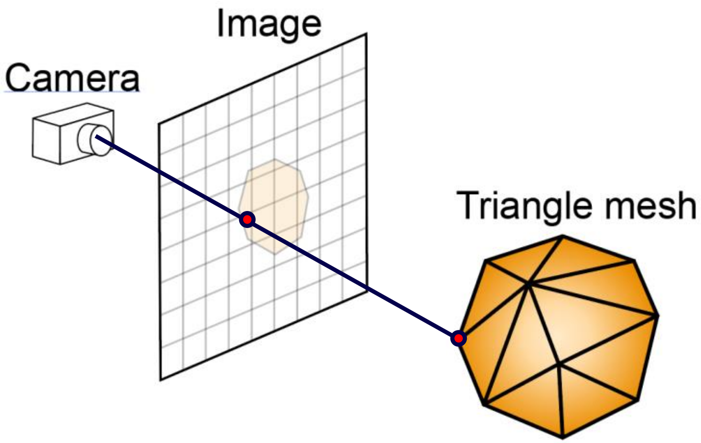
Course Summary

1. Intro

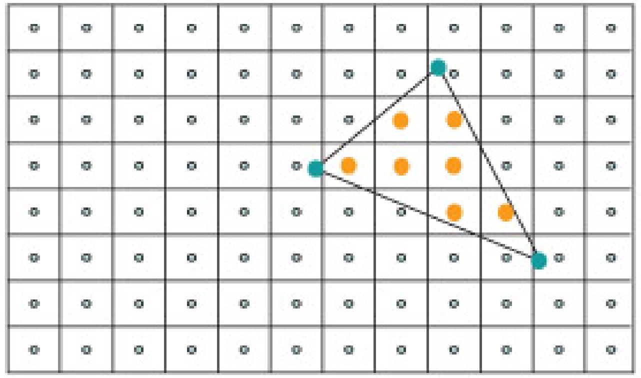


2. ECS

3. User Interfaces



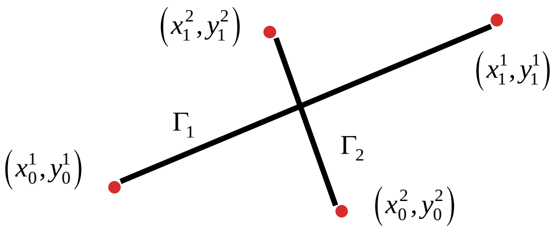
4. Rendering



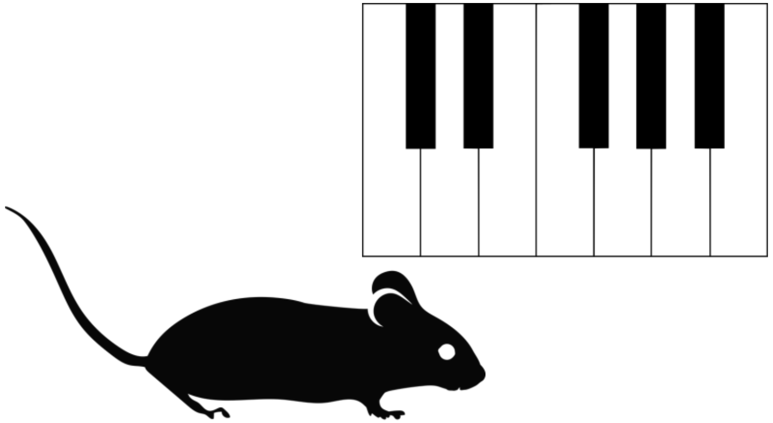
5. Rendering Pipeline

6. Advanced OpenGL

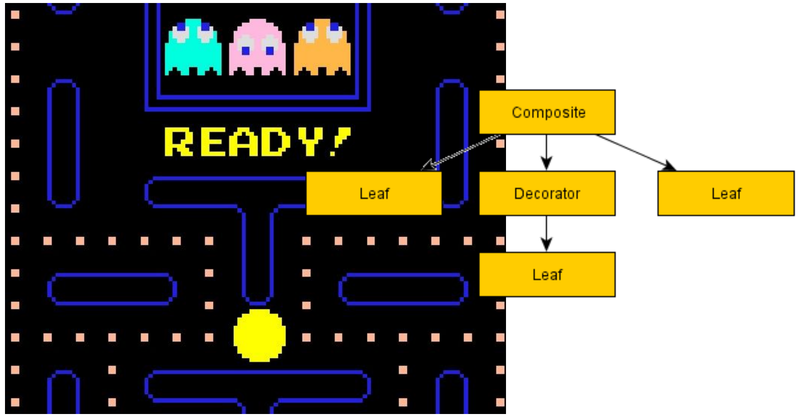
Course Summary



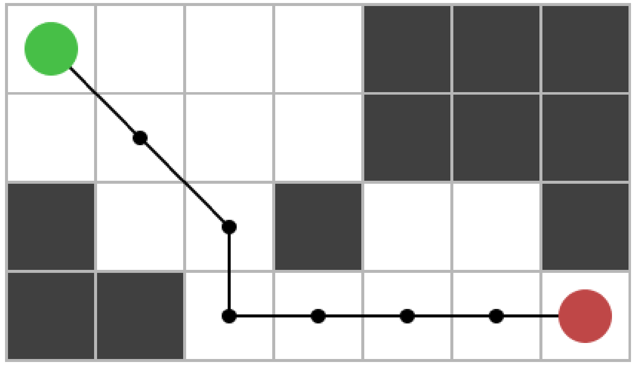
7. Collisions



8. IO & Observer Pattern

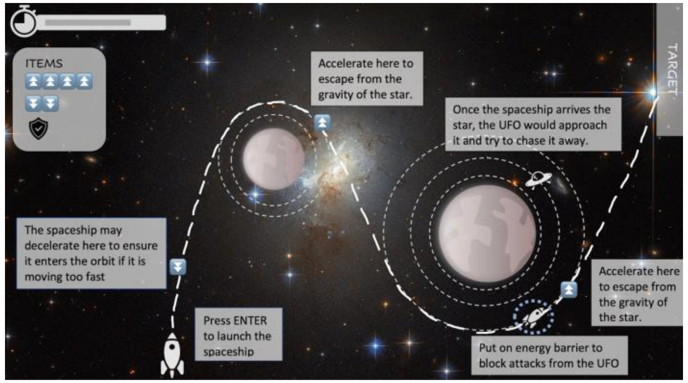


9. AI with states



10. AI with strategy

11. AI two players / Simulation



Accelerate here to escape from the gravity of the star.

Once the spaceship arrives the star, the UFO would approach it and try to chase it away.

The spaceship may decelerate here to ensure it enters the orbit if it is moving too fast

Press ENTER to launch the spaceship

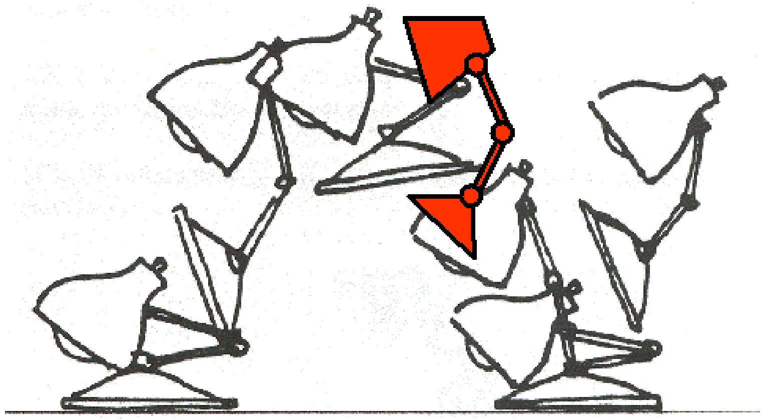
Accelerate here to escape from the gravity of the star.

Put on energy barrier to block attacks from the UFO

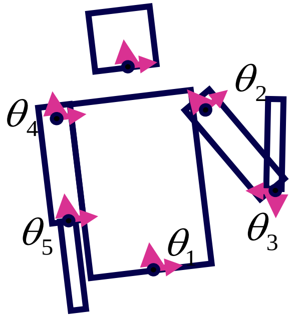
12. Simulation

13. Debugging

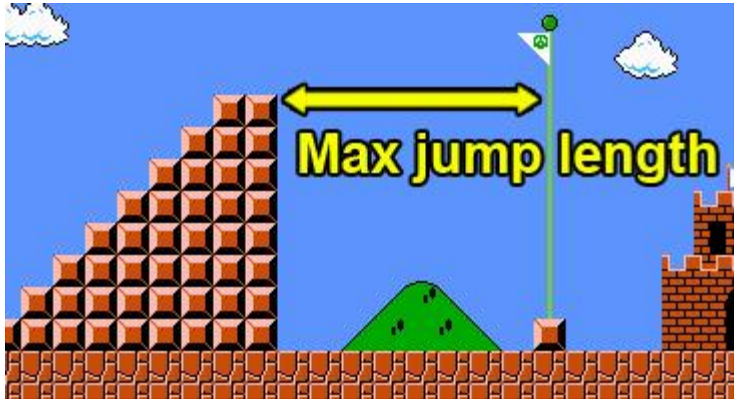
Course Summary



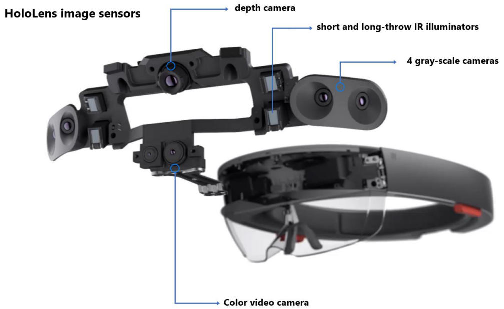
14. Curves & Animation



15. Skeleton Animation

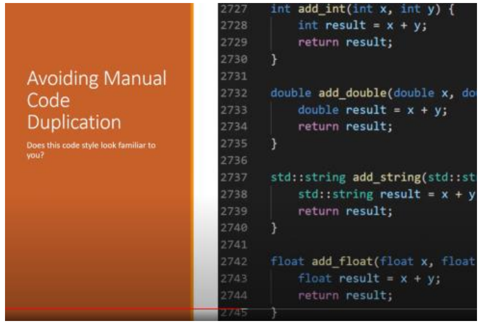


16. Game Balancing



17. Balancing + History & Future

Tutorials

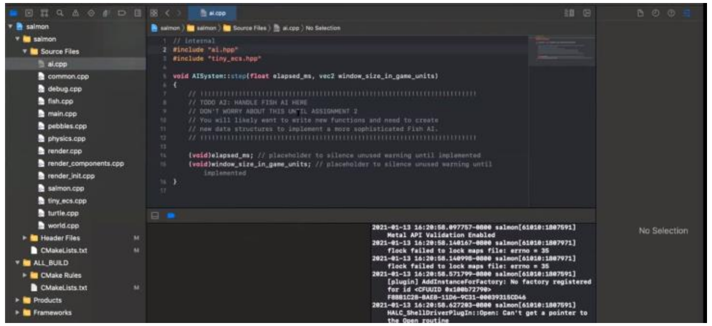


Avoiding Manual Code Duplication

Does this code style look familiar to you?

```
int add_int(int x, int y) {
    int result = x + y;
    return result;
}

double add_double(double x, do
    double result = x + y;
    return result;
}

std::string add_string(std::st
    std::string result = x + y
    return result;
}

float add_float(float x, float
    float result = x + y;
    return result;
}
```

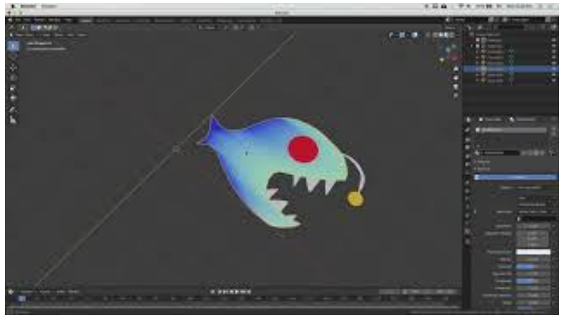
C++
by Tim



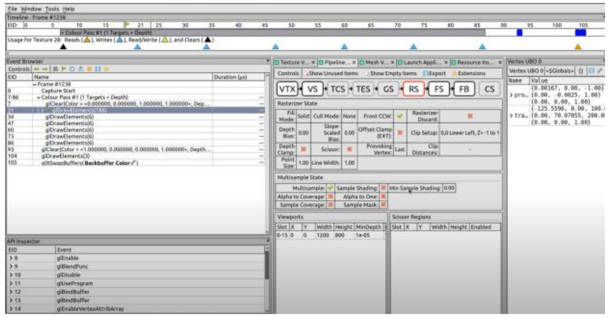
```
// internal
#include "ai.hpp"
#include "tiny_ecs.hpp"

void AISystem::step(float elapsed_ms, vec2 window_size_in_game_units)
{
    // !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
    // TODO A2: HANDLE FISH AI HERE
    // DON'T WORRY ABOUT THIS UNTIL ASSIGNMENT 2
    // You will likely want to write new functions and need to create
    // new data structures to implement a more sophisticated Fish AI.
    // !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

    (void)elapsed_ms; // placeholder to silence unused warning until implemented
    (void)window_size_in_game_units; // placeholder to silence unused warning until
        implemented
}
```

```
2021-01-13 16:20:58.097757-0800 salmon[61010:1807591]
    Metal API Validation Enabled
2021-01-13 16:20:58.140167-0800 salmon[61010:1807971]
    flock failed to lock maps file: errno = 35
2021-01-13 16:20:58.140998-0800 salmon[61010:1807971]
    flock failed to lock maps file: errno = 35
2021-01-13 16:20:58.571799-0800 salmon[61010:1807591]
    [plugin] AddInstanceForFactory: No factory registered
    for id <CFUUID 0x100b72790>
    F8881C28-BAE8-11D6-9C31-00039315CD46
2021-01-13 16:20:58.627203-0800 salmon[61010:1807591]
    HALC_ShellDriverPlugIn::Open: Can't get a pointer to
    the Open routine
```

Tools and
Game Framework
by Andrew



Mesh editing &
OpenGL integration by Dave



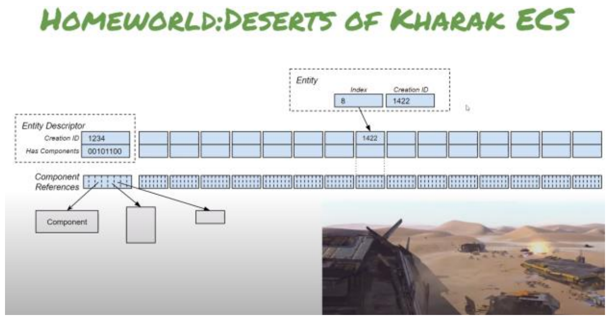
GPU debugging by
Camilo

3.216E+08 (12.4%) aggregated sample costs in RenderSystem::drawToScreen(glm::mat<3, 3, float, (glm::qualifier)0> const&) (salmon) and below.

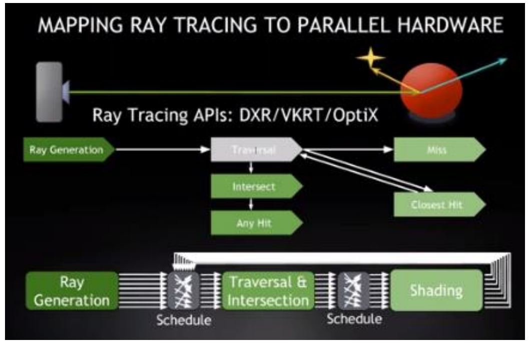
CPU profiling
by Camilo and Tim

Team feedback
by all TAs!

Guest Speakers

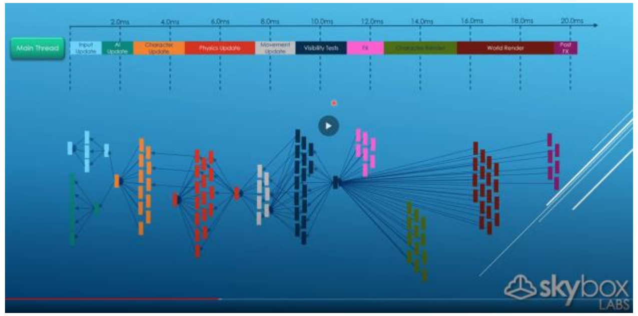

HOMEWORLD:DESERTS OF KHARAK ECS

ECS by Yggy King
(Blackbird Entertainment)


MAPPING RAY TRACING TO PARALLEL HARDWARE

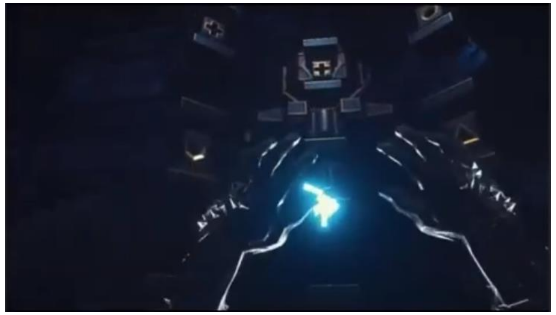
Ray Tracing APIs: DXR/VKRT/OptiX

Raytracing by Ralf Karrenberg
(NVIDIA)



Rendering by **Russell Gillette**
(Skybox)

Online Games and Behavior
by Kimberly Voll
(Fair Play Alliance, Stray-Bombay, ex. Riot Games)



VR by Dinos Tsiknis
(Charm Games)

The Future?

Streamed games?

- ***Cloud gaming (Stadia, GeForce Now, PlayStation Now, xCloud, Luna)***
- ***Streaming content at 60+ fps, up to 4k resolution***
- ***Can that work?***
  - *Multi-player games worked for decades now*
  - *Internet throughput has increased dramatically*
  - *Compression has improved too*
  - *Yes!*
- ***Minimal delay remains***
  - *Predictive input?*

AI

- AI characters

  “I do see a future where, within 10 years, whether it’s through mixed-reality headsets or looking at AR through our phones, we’ll have this concept of, ‘Oh, I hang out occasionally with this NPC who remembers me and who I have this conversation with.’” --Mitu Khandaker

- Infinite content creation
  - Worlds, quests, art, …
  - Interactive with user preferences / guidance

Natural Communication

- ***Body language***
  - Explicit gestures
  - Subtle emotions

- ***Voice control***

- ***Haptic feedback***

- ***Brain interfaces?***
  - *natural???*

How do you see the future?