EECE5698
Networked XR Systems

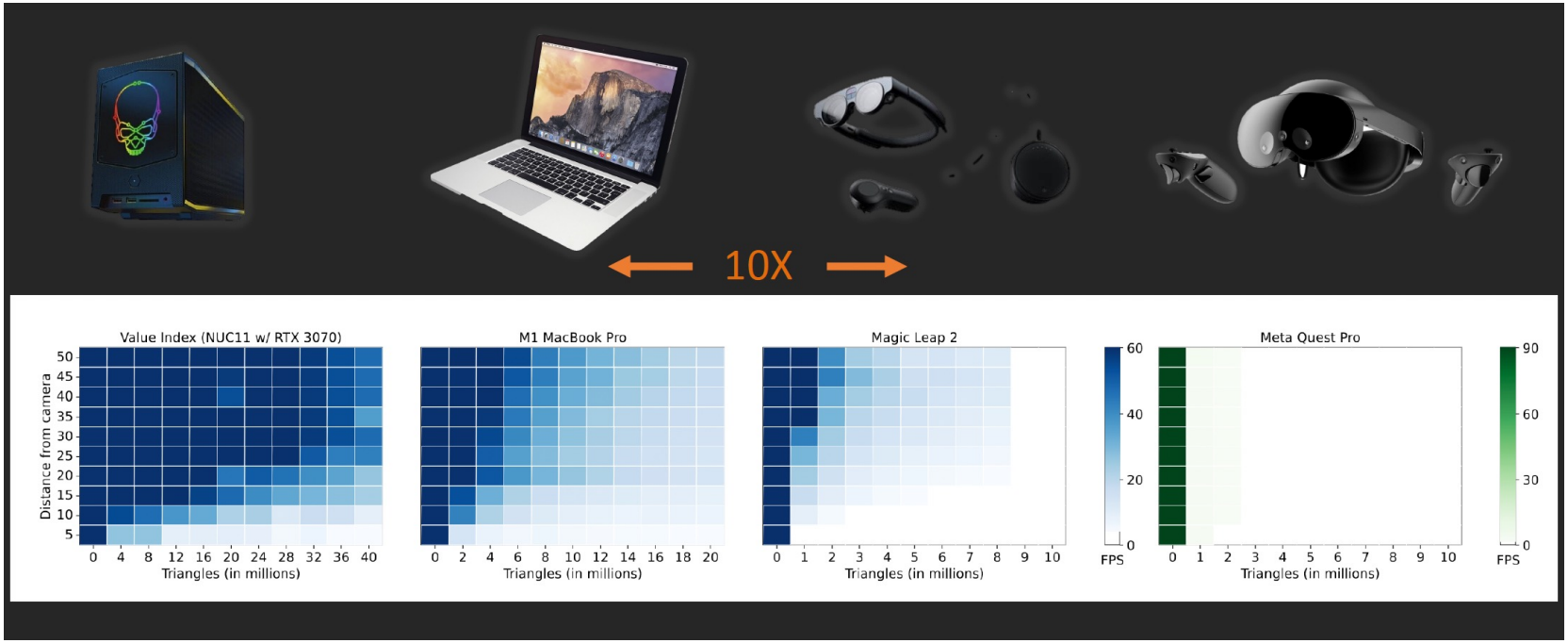
Slide credits: Edward Lu, CMU

Lecture Outline for Today

- Quiz3 Discussion
- Rendering Performance
- Hybrid or Split Rendering
- Scheduling Objects for Local and Remote Rendering
- Compute and Network Adaptation

Rendering Performance - Recap

Across different XR devices

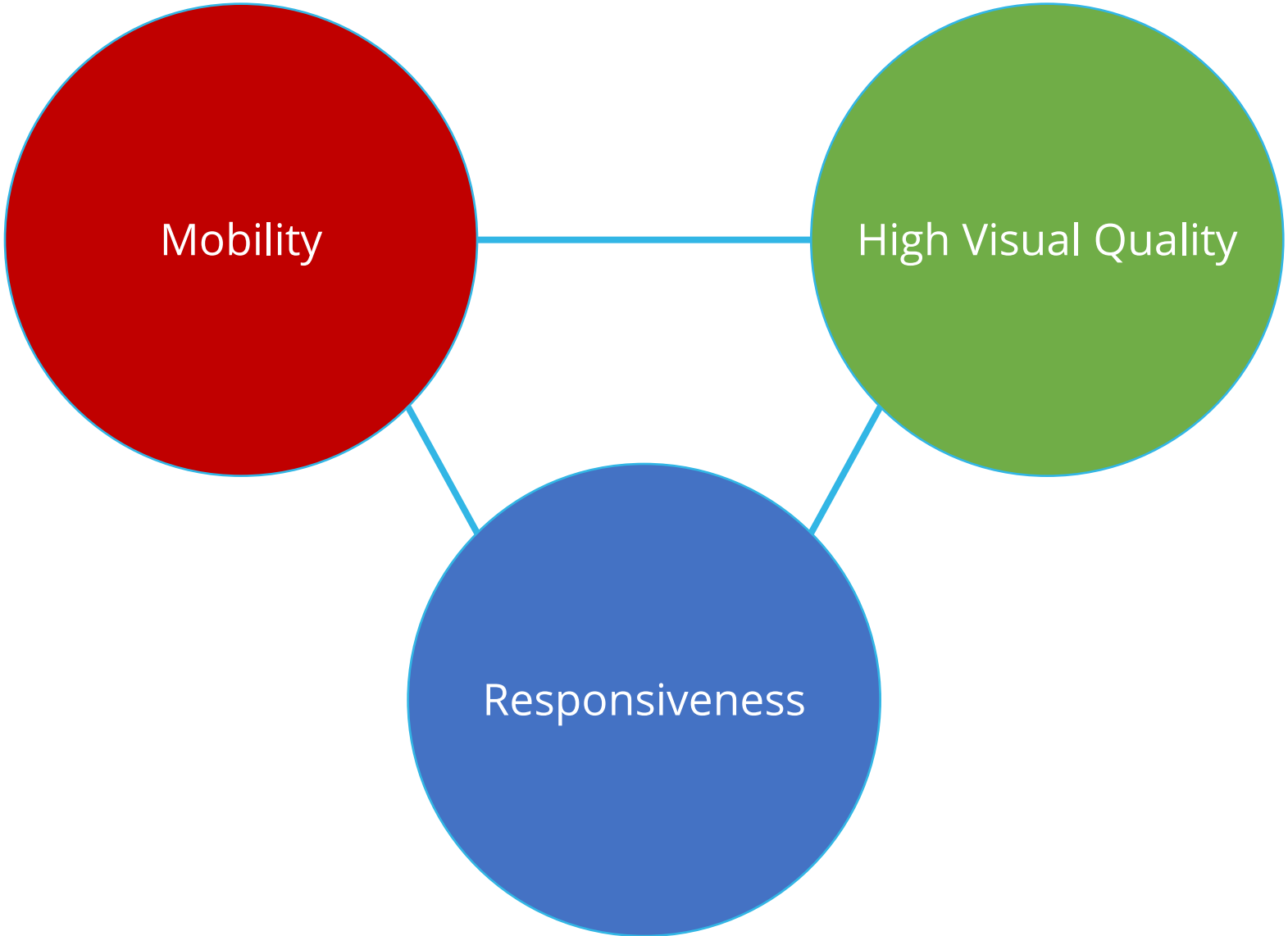


Types of Rendering

- Remote Rendering
  - Edge Rendering
  - Cloud Rendering
  - Distributed Rendering
- Local Rendering

- How about Hybrid Rendering?

Real-Time Rendering for XR

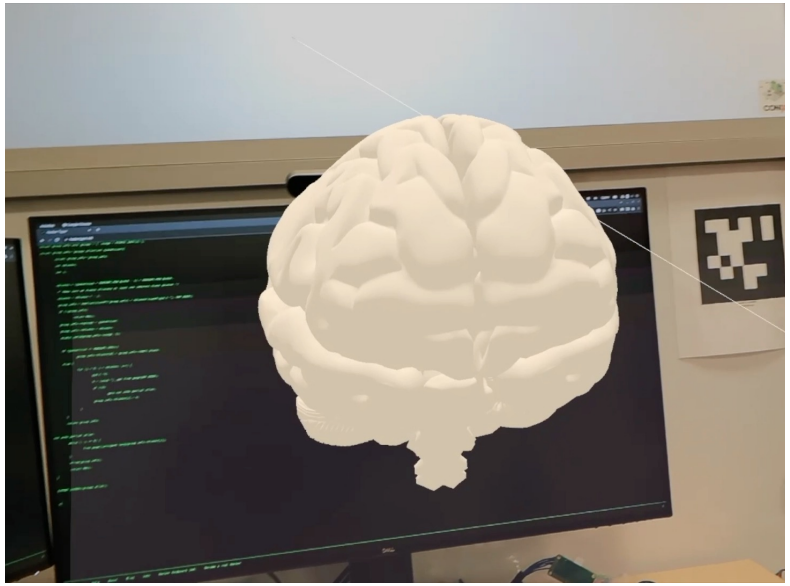


Local Rendering

✓ Low latency interactions

X Low object complexity

Recorded on Magic Leap 2



50K triangles

Local Rendering

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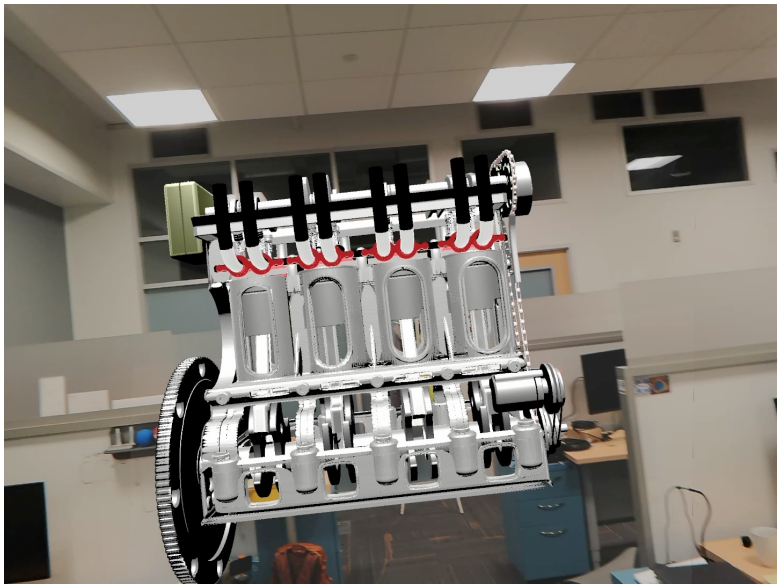
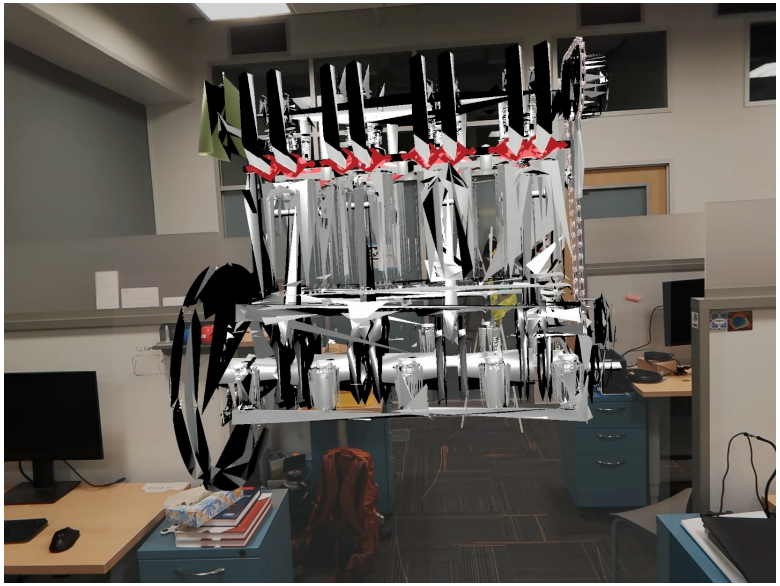
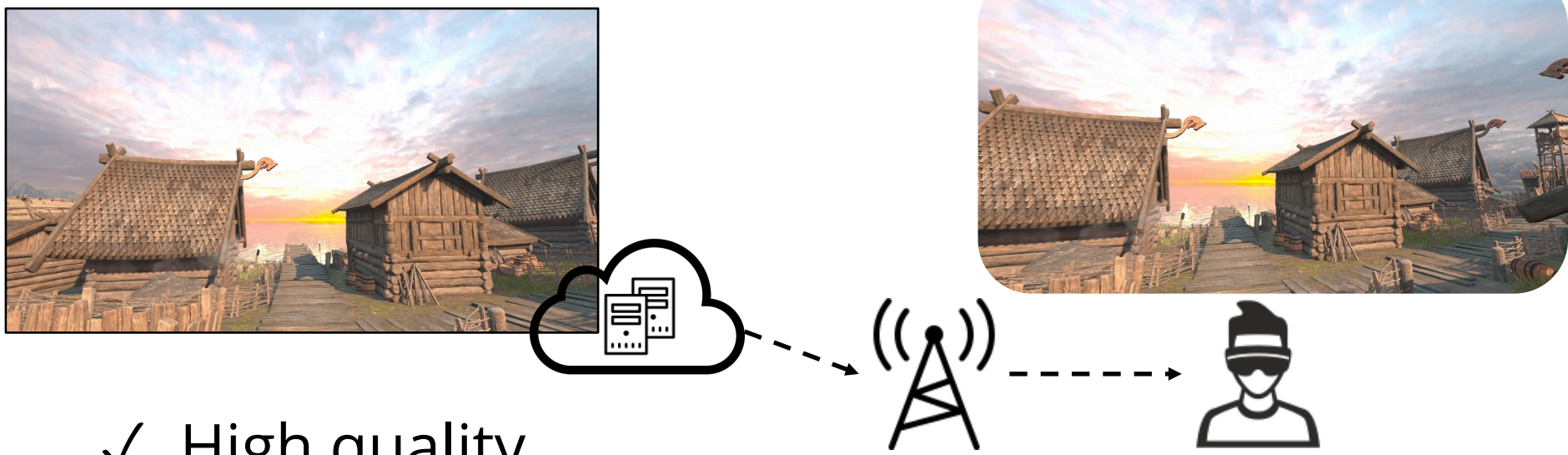


11M triangles



50K triangles

Remote Rendering

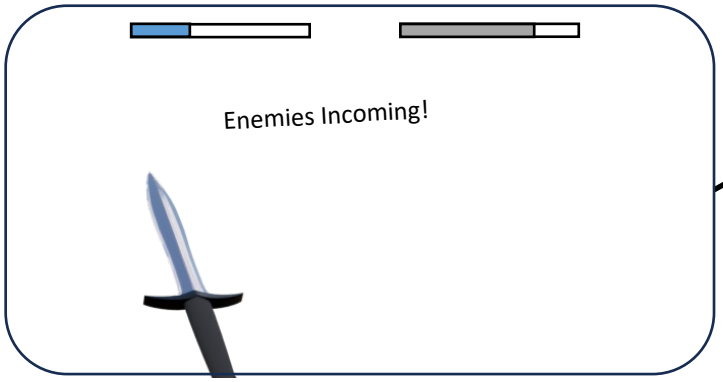


- ✓ High quality
- X High latency
  (Device→Network→Server→Network→Device)
- X Reprojection needed to mask latency
- X Networks can be unreliable

Split Rendering

Split scene into **local** and **remote** portions

Remote Render (high quality)



Local Render (low latency)

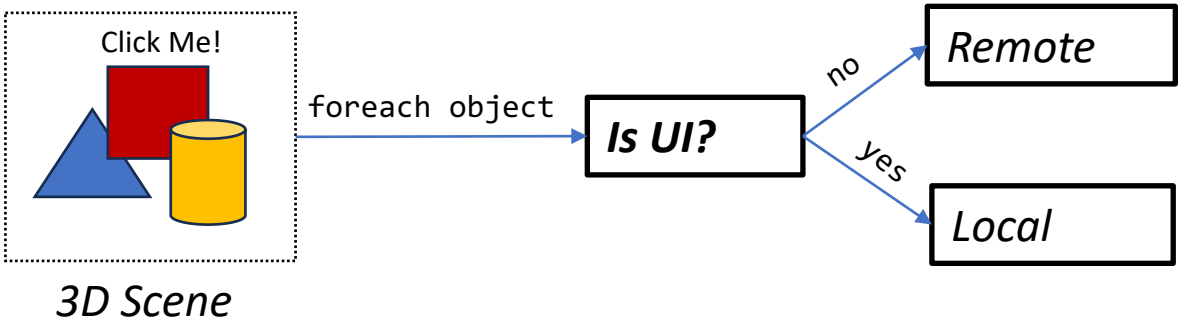
Recorded on Valve Index

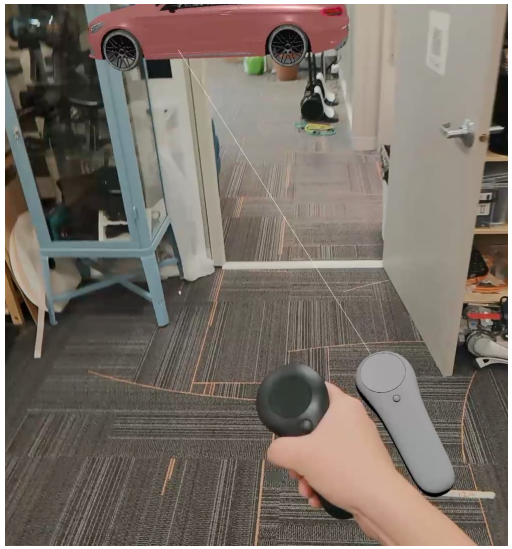
Split Render (best of both!)

State-of-the-art Split Rendering

(1) Static determination of what gets rendered where:

(*Azure Hybrid Rendering*)

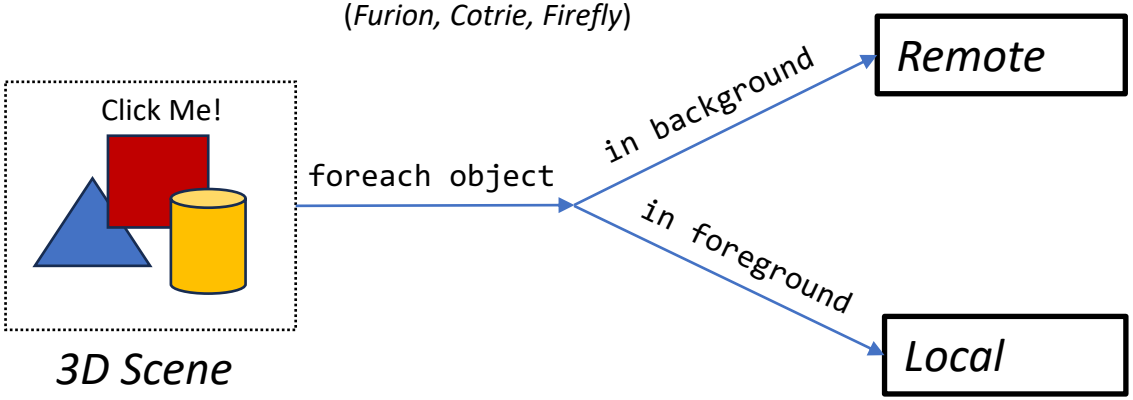




Recorded on Magic Leap 2

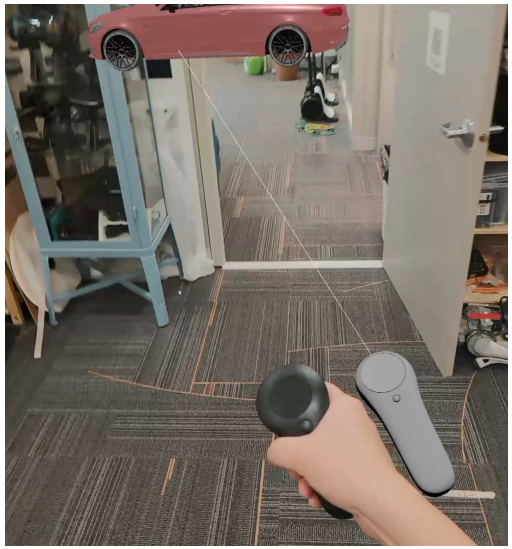
(2) Distance-based determination of what gets rendered where:

(*Furion, Cotrie, Firefly*)



State-of-the-art Split Rendering

Coterie, Asplos'20



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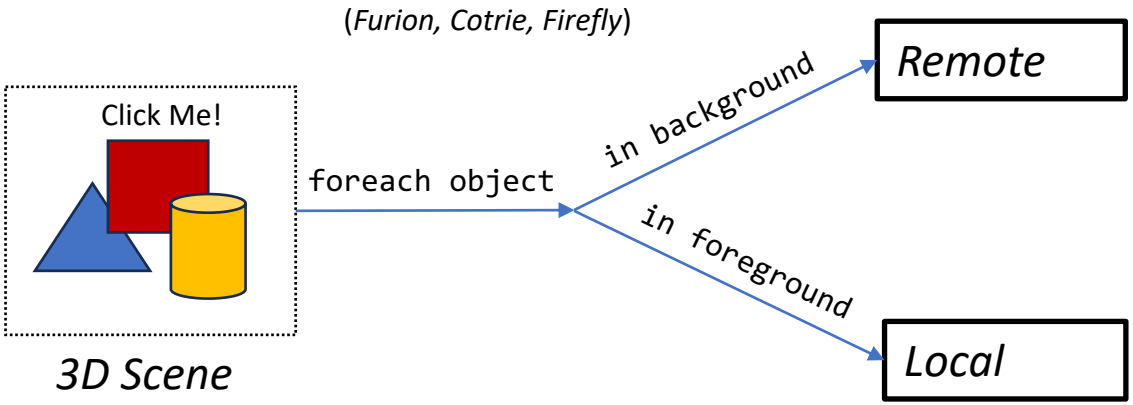
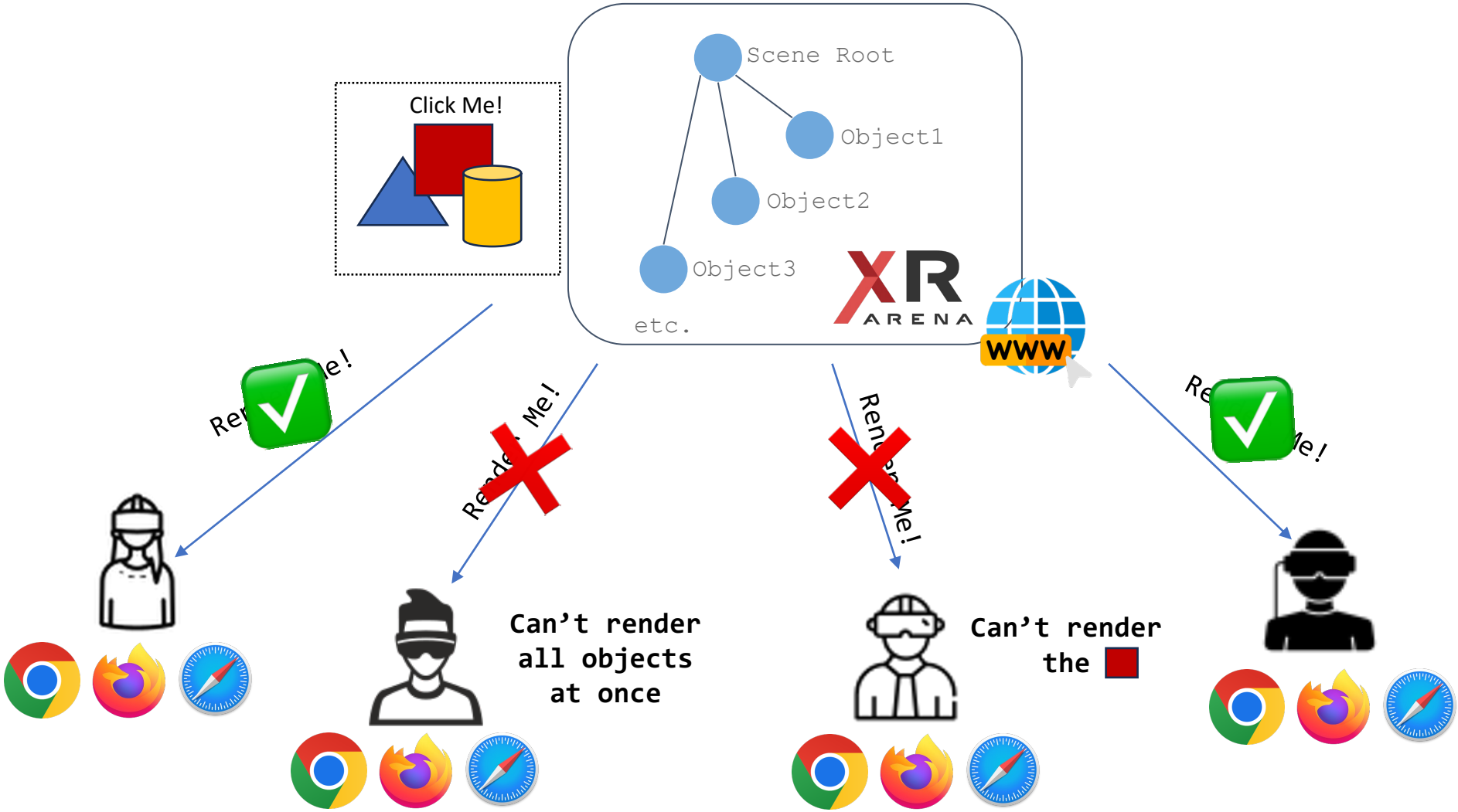
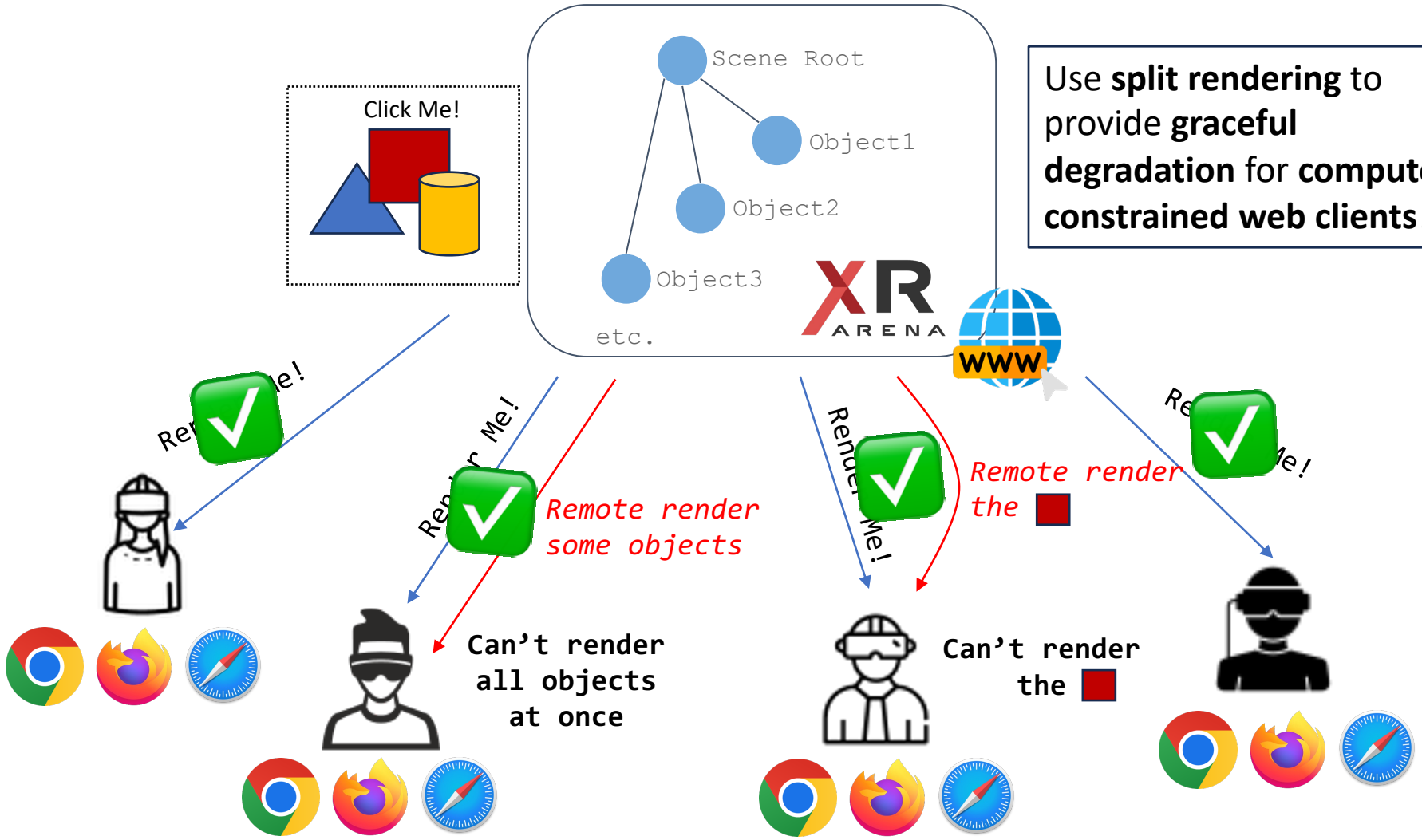


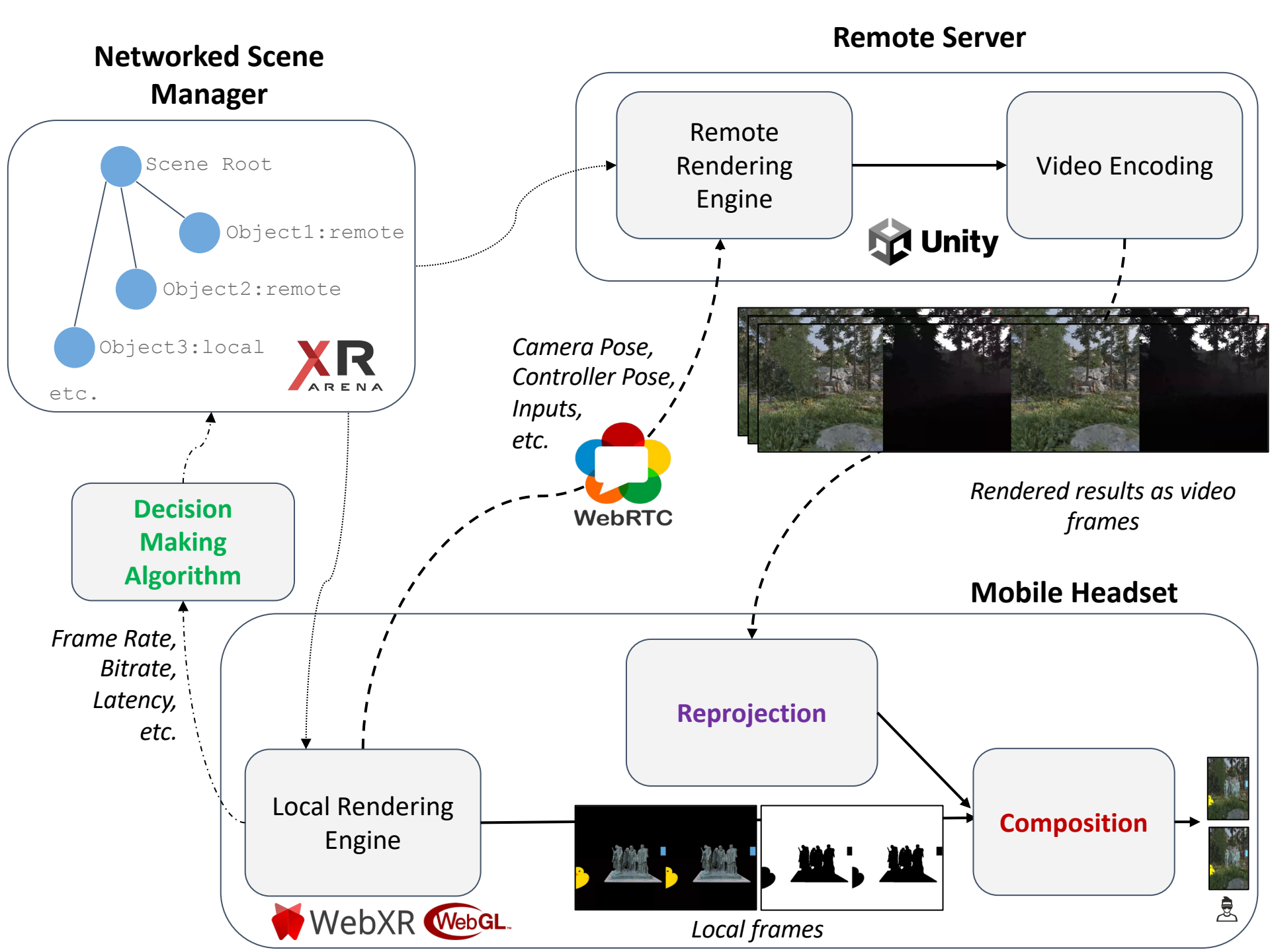
3D Scene

Split Rendering for ARENA

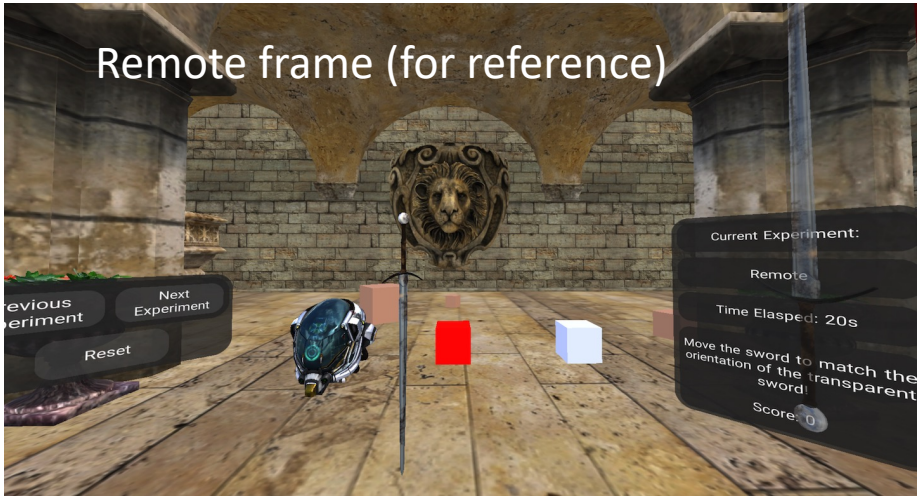


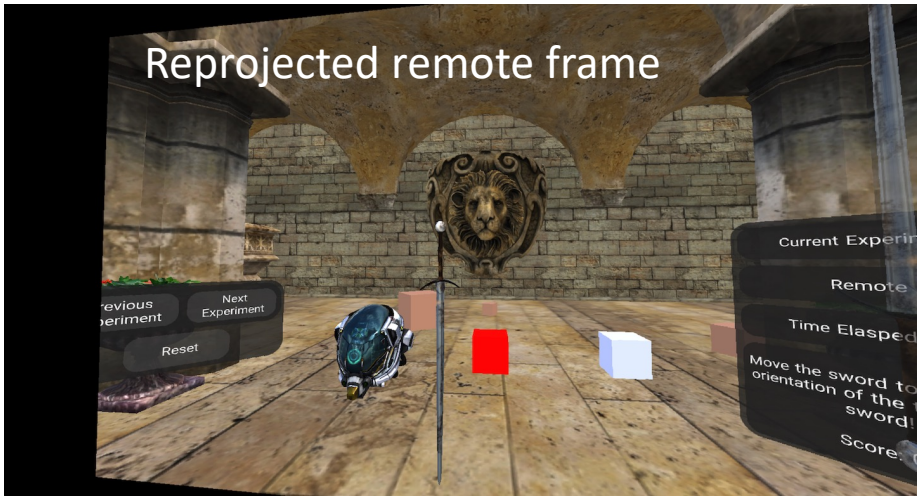
Split Rendering for ARENA

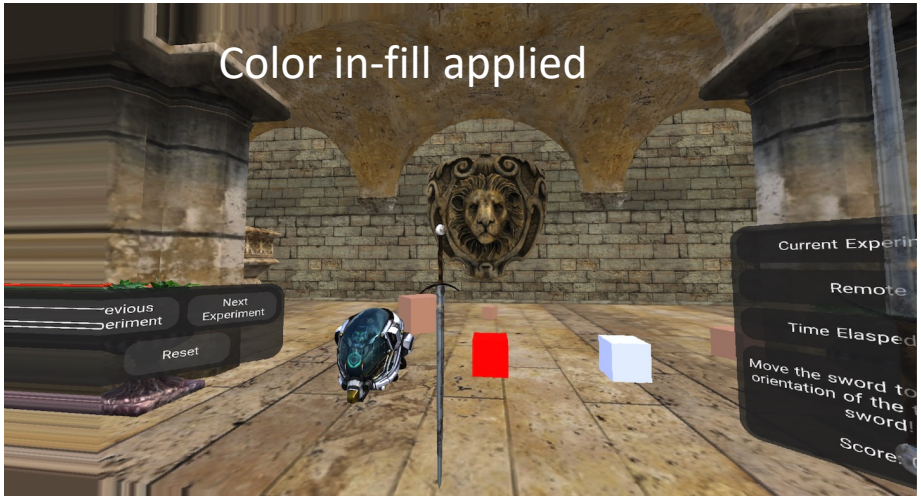



Networked Scene Manager
Scene Root
Object1:remote
Object2:remote
Object3:local
etc.
XR ARENA
Remote Server
Remote Rendering Engine
Video Encoding
Unity
Camera Pose, Controller Pose, Inputs, etc.
WebRTC
Rendered results as video frames
Decision Making Algorithm
Frame Rate, Bitrate, Latency, etc.
Mobile Headset
Reprojection
Local Rendering Engine
Composition
WebXR
WebGL
Local frames

Reprojection with ATW







Object Rendering Mediums

(a) r = *HL* (b) r = *LL* (c) r = *R* (under low bitrate)

In RenderFusion, an object could be one of three representations, *r*:

Representation	Local Resource Usage	Visual Quality	Response Latency
Highpoly Locally Rendered (HL)	High	High	Low
Lowpoly Locally Rendered (LL)	Low	Low	Low
Remotely Rendered (R)	Very Low	High (under good bitrates)	High

Decision Making Algorithm

Which representation (*r*) is best?

For all objects in the scene

$$\max \sum_{o \in O} A(o)B(o,r)$$

$$\text{s.t.} \sum_{o \in O_L} \text{Polycount}(o) \leq \text{MaxLocalPolycount}$$

Goal: **Find *r* for each object to maximize sum of total *benefit*, *B(o,r)*, scaled by object size relative to viewport, *A(o)***

Decision Making Algorithm

Which representation (*r*) is best?

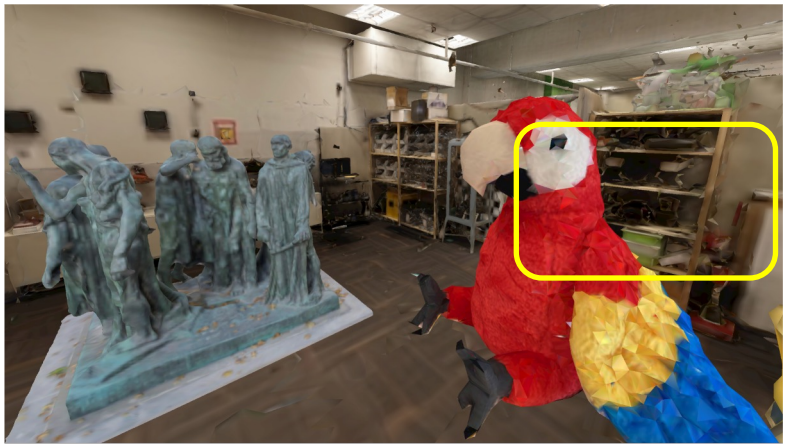
is less than the max polygons that can be rendered locally within a target frame rate

$$\max \quad \sum_{o \in O} A(o)B(o,r)$$

$$\text{s.t.} \quad \sum_{o \in O_L} \text{Polycount}(o) \leq \text{MaxLocalPolycount}$$

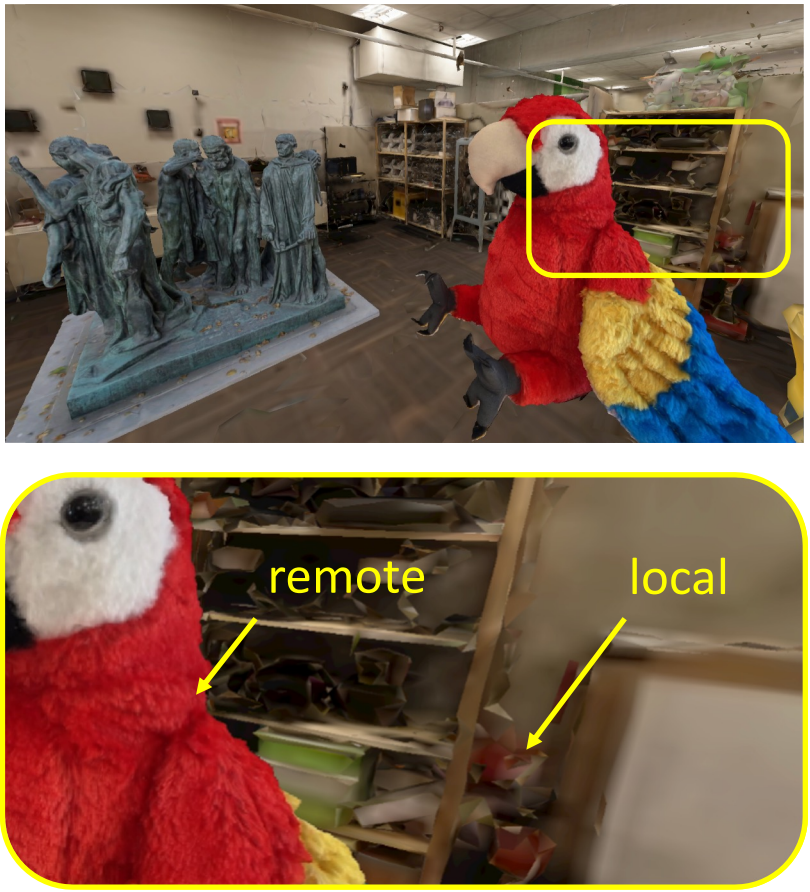
Ensuring that total polycount of all locally rendered objects…

Perceptual Study: Quality



Pure Local

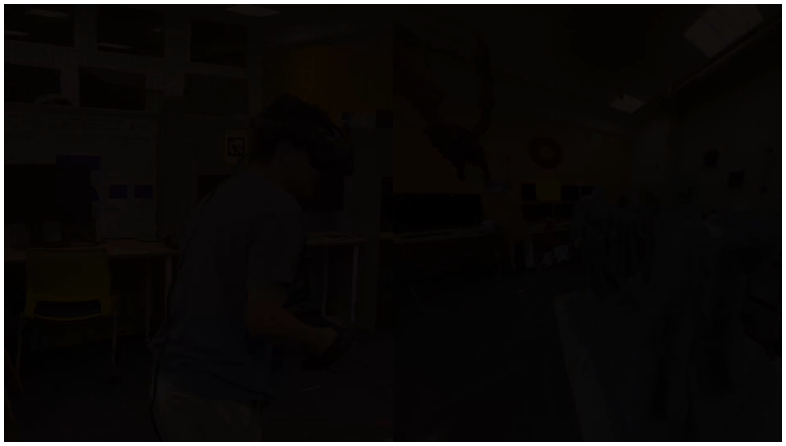
Perceptual Study: Quality



Pure Remote

Perceptual Study: Latency

Pure Local



Pure Remote

Perceptual Study: Latency

RenderFusion

Summary of the Lecture

- Rendering Performance
- Hybrid or Split Rendering
- Scheduling Objects for Local and Remote Rendering
- Compute and Network Adaptation

Next up: Tracking algorithms