

# ECE 590/COMPSI 590

## Special Topics: Edge Computing

### Augmented and Virtual Reality and Edge Computing

Wednesday September 12th, 2018

## Last Class: Recap

- Edge helping cloud
  - Why edge makes sense for the cloud
  - Background: latency and jitter
  - Challenges in supporting low-latency low-jitter solutions with modern cloud architectures
- Telecom and the edge
  - An infrastructure view of edge computing
  - 5G and ETSI MEC

# This Lecture

- AR and edge computing: an introduction
- Mobile devices for AR
- Edge for AR: promising directions

3

# Quiz

4

## This Lecture

- AR and edge computing: an introduction
- Mobile devices for AR
- Edge for AR: promising directions

5

## Augmented Reality: A Definition

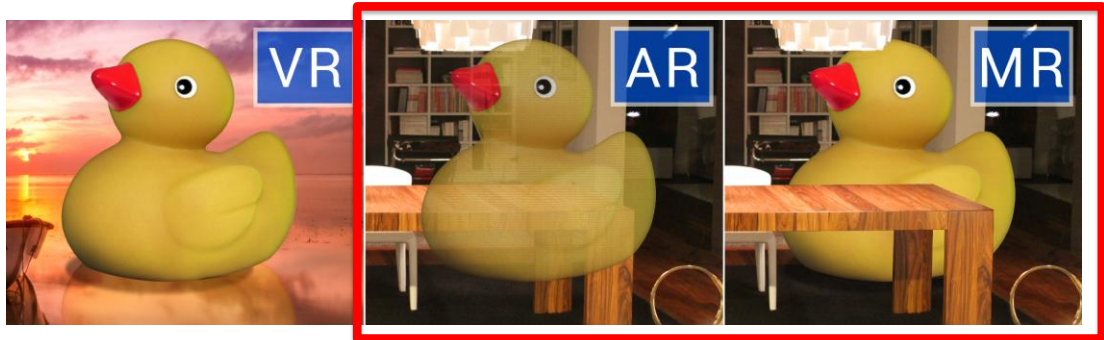
- The [virtual] content is laid out around a user **in the same spatial coordinates as the physical objects surrounding her/him**, and with interaction techniques that approximate interactions with physical-world objects (e.g., grabbing and moving them).

From: Baldassi et al, Challenges and New Directions in Augmented Reality, Computer Security, and Neuroscience, June 2018.

6

# Virtual, Augmented, Mixed Reality: Are They The Same?

- Focus on AR/MR in this lecture



7

## Where Does Edge Computing Fit In? (1/3)

- Same principles as for other high-end mobile devices
- **Latency, bandwidth** requirements among the most demanding for consumer mobile applications
  - Edge computing as means for achieving these
- Conflicting needs:
  - Experience complexity
  - Speed of operation

8

## Where Does Edge Computing Fit In? (2/3)

- Ultra-low-latency is critical for high-quality experiences
  - High latency **literally** makes you sick
- Popular use case in telecom edge computing deployments

AT&T begins testing AR, VR at new edge computing site

[in LinkedIn](#)
[Twitter](#)
[f Facebook](#)
[G+ Google+](#)
[+ More 1](#)

🕒 20 FEB 2018  
AUTHOR

9

## Where Does Edge Computing Fit In? (3/3)

- Opportunities for helping **multiple** co-located AR devices
  - Supporting experiences that are similar, but not identical

10

# This Lecture

- AR and edge computing: an introduction
- Mobile devices for AR
- Edge for AR: promising directions

11

## Augmented Reality: On Existing Mobile Devices

- On mobile phones and tablets
  - Pokemon Go, tattoo application, constellation demonstration, ghost snap, Google Translate



12

## Google Translate Examples: Real-Time Processing



13

## Augmented Reality: On Specialized Hardware

- Head-mounted displays



Microsoft HoloLens



Magic Leap headset

14

# Holographic Experience Examples



15

Duke UNIVERSITY

# Specialized AR Hardware: Origins

- Ivan Sutherland's research group, 1968: Sword of Damocles



Duke UNIVERSITY



# Battlefield Augmented Reality Systems

- From late 1990s



Duke UNIVERSITY

## Smart Glasses

- A wide range at CES every year



18

Duke UNIVERSITY

# Holograms in Black Mirror



19

## Specialized Hardware: Advantages

- More immersive experience
  - Very different qualitatively: AR (almost) everywhere you look
  - Almost everywhere: subject to field of view restrictions
- Higher-quality components, device specialization leading to better experiences



20

## Specialized Hardware: Challenges (1/2)

- Heavy, bulky, uncomfortable
- Currently expensive to the point of being impractical
  - Microsoft Hololens: \$3,000
  - Magic Leap: \$2,300
- Technology in the making



21

## Cars as a Promising AR Use Case



- Already looking through a fixed display
- Cost, bulkiness can be hidden

22

## Specialized Hardware Challenges: Motion Sickness

- Can be a major issue
- Mismatch between what you see and what your body perceives
  - Complex associated phenomena
- Latency one of major causes
  - **Motion-to-photon** latency



23

## Specialized Hardware Challenges: Safety and Security

- Completely new interface category. Threats include:
  - Blocking your view
  - Motion
  - Binocular disconnections
  - Multisensory disconnections

From: Baldassi et al, Challenges and New Directions in Augmented Reality, Computer Security, and Neuroscience, June 2018.

24

# This Lecture

- AR and edge computing: an introduction
- Mobile devices for AR
- Edge for AR: promising directions

25

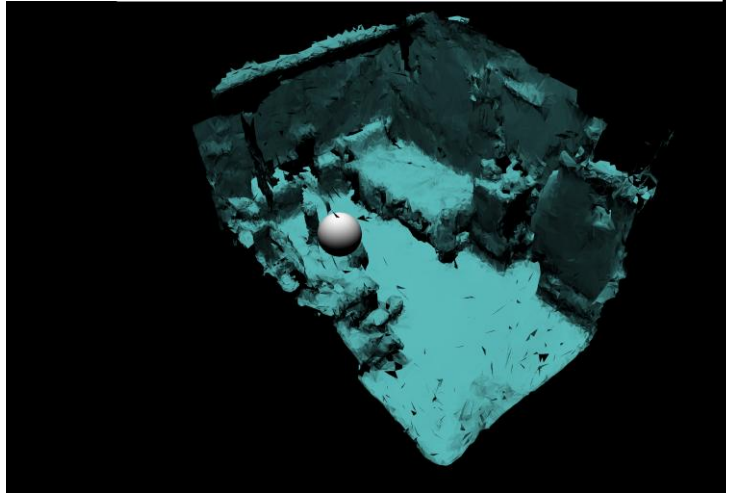
## Edge for AR: Mobile Offloading

- Can be to the point of full **wireless tethering**
- Semi-independent modes are potentially promising:
  - Low-quality experiences: on the device
  - Higher-quality experiences: with edge support where available
    - Requires re-thinking AR application design

26

## Edge for AR: Local Awareness

- Maps
- Persistent knowledge of environmental properties
- Interfacing with **smart objects**

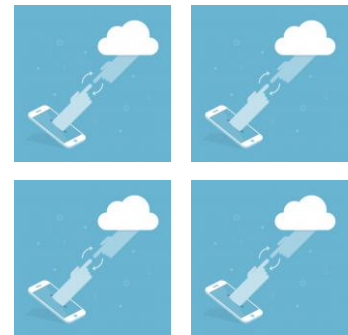


Mesh representing a student dorm room

27

## Edge for AR: Content Delivery

- Current approach: stovepiped applications
  - Does not scale
- Most promising: edge for delivering similar but not identical experiences



28

## Recap

- AR and edge computing: an introduction
- Mobile devices for AR
- Edge for AR: promising directions

29

## Next Class

- A closer look into mobile offloading:
  - Making Smartphones Last Longer with Code Offload
- Automating system decisions:
  - Resource Management with Deep Reinforcement Learning

30