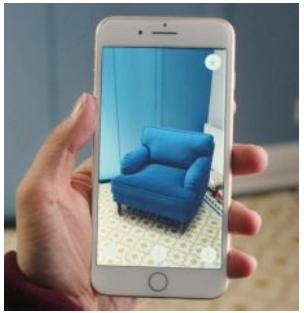
Secure Multi-User Content Sharing for Augmented Reality Applications

Kimberly Ruth, Tadayoshi Kohno, Franziska Roesner

University of Washington

Emerging AR/MR Technologies



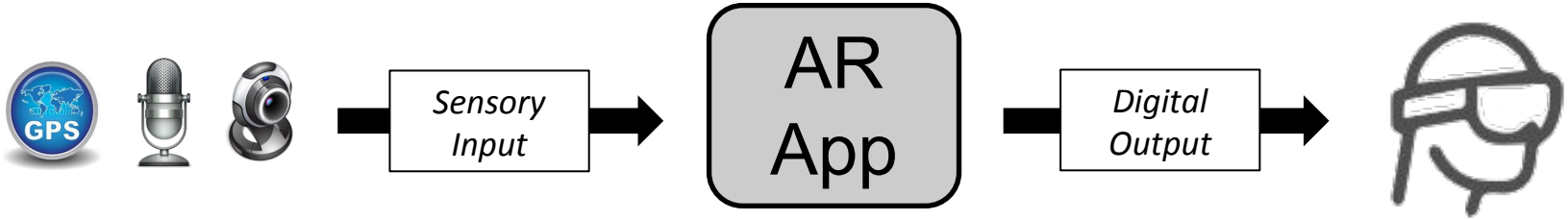
ARCore

Emerging AR/MR Technologies

Technologies that ***continuously process sensory input*** from the user's surroundings and ***overlay digital content*** on top of the user's perception of the world.

ARCore

AR Security Research Context



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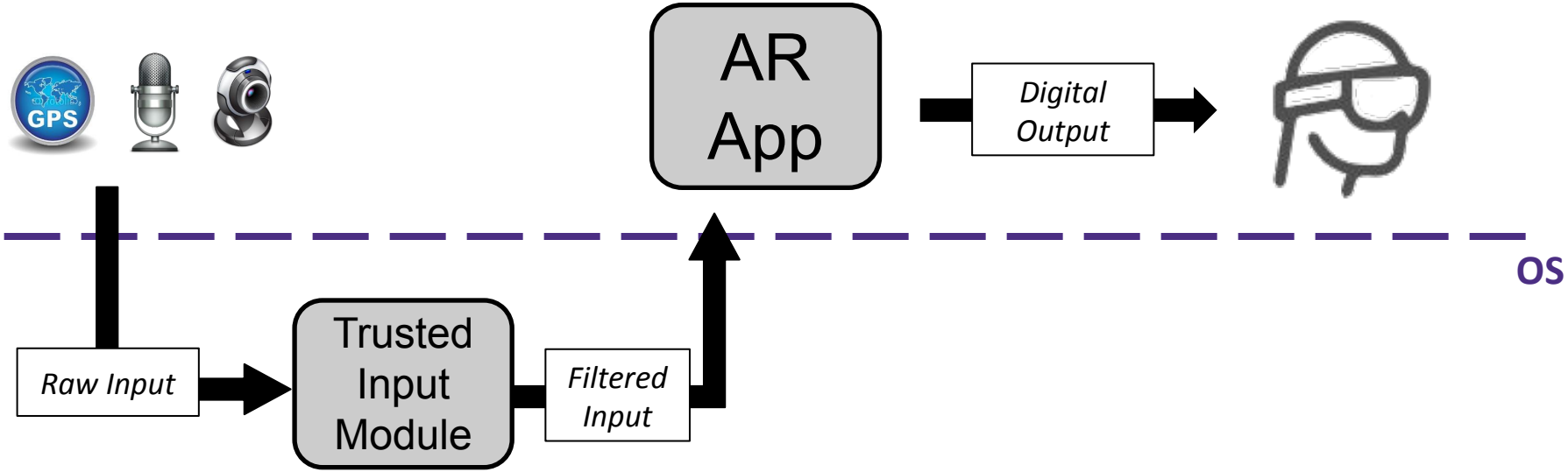

[Jana, Molnar, Moshchuk, Dunn, Livshits, Wang, & Ofek, 2013]
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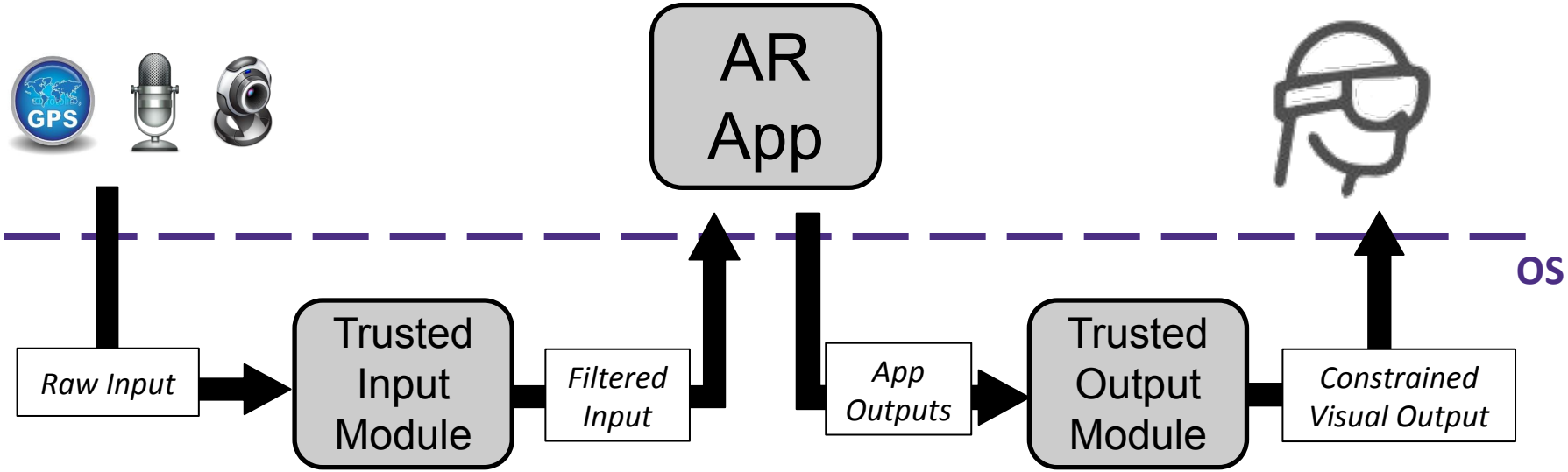

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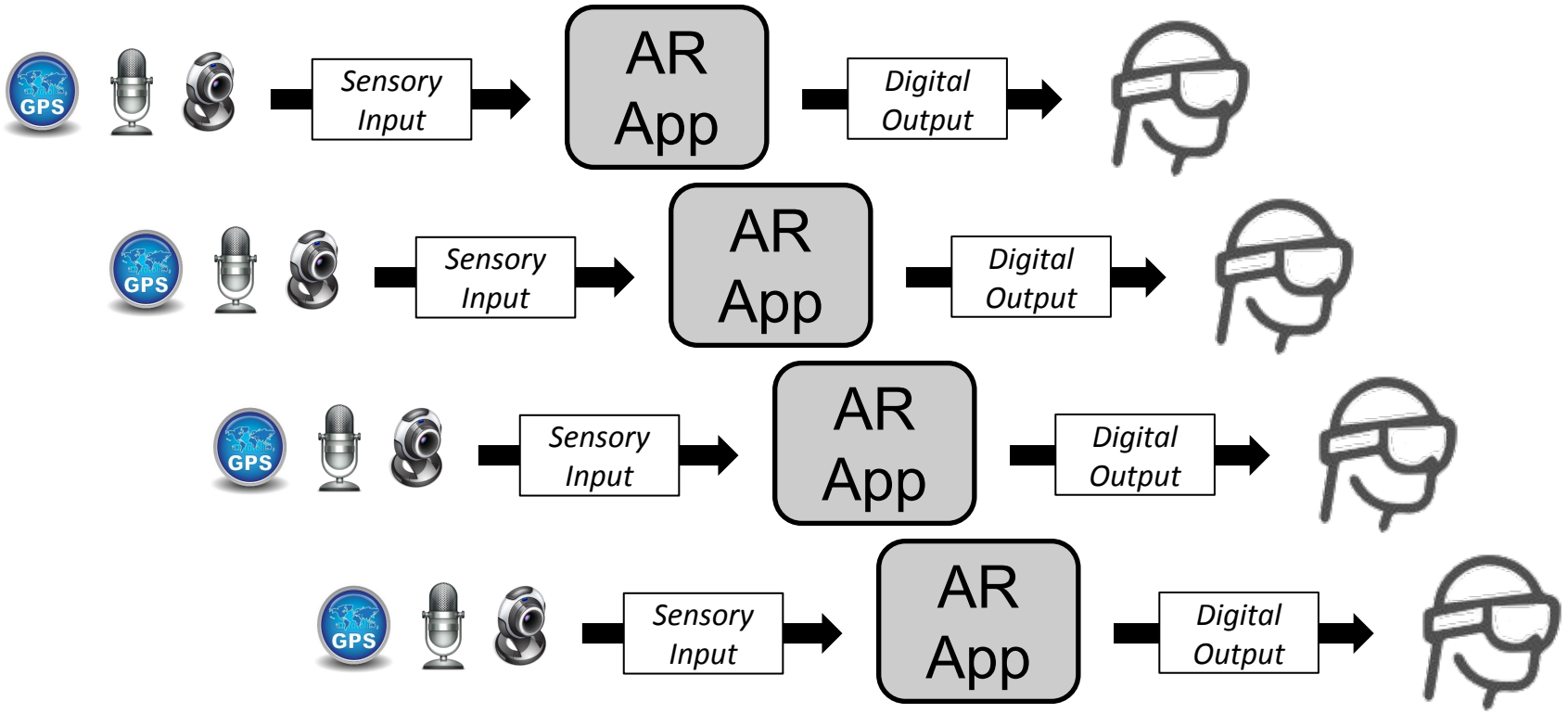
[Lebeck, Ruth, Kohno, & Roesner, 2017]
[Ahn, Gorlatova, Naghizadeh, Chiang, & Mittal, 2018]


GPS
Sensory Input
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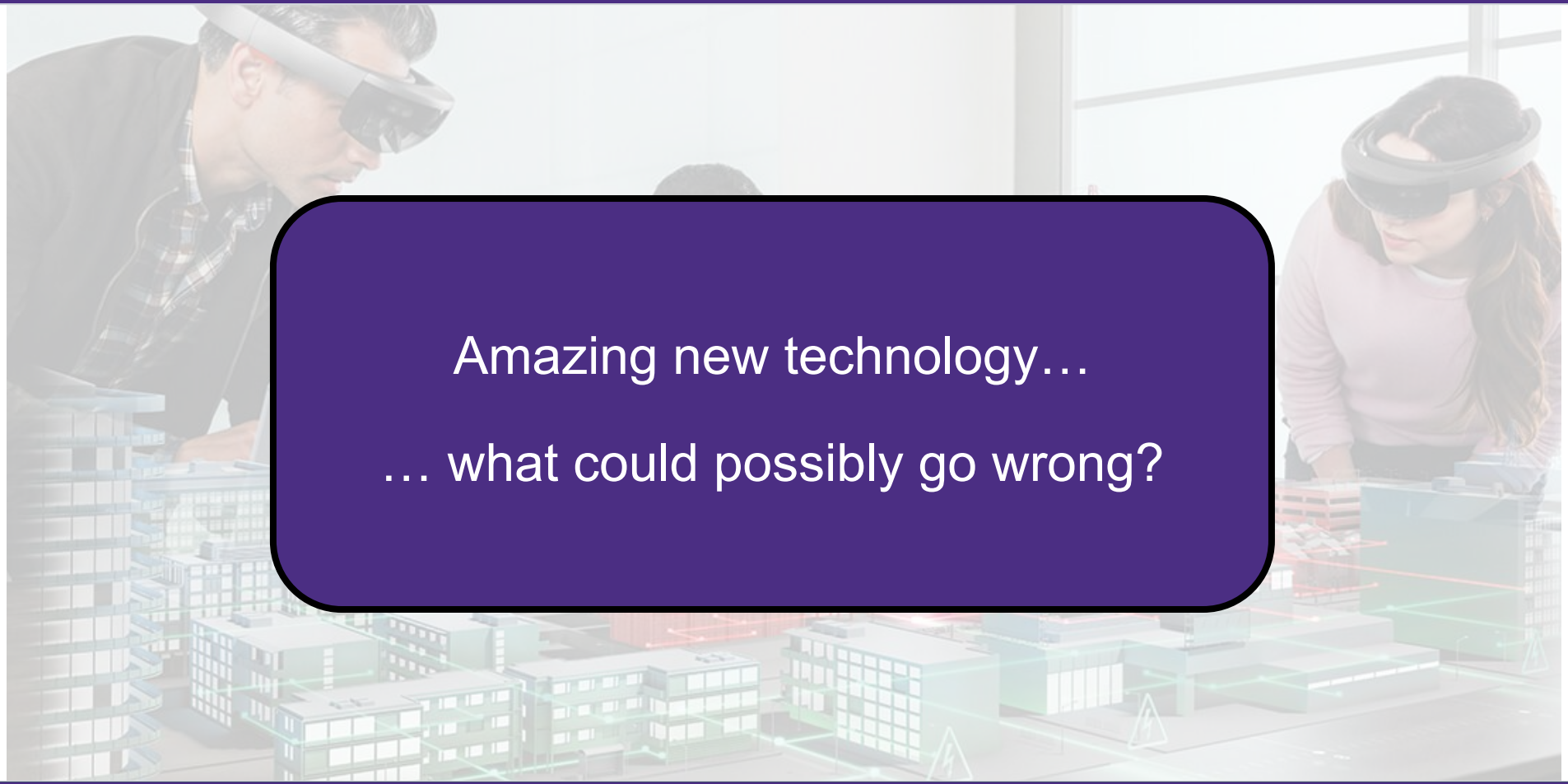
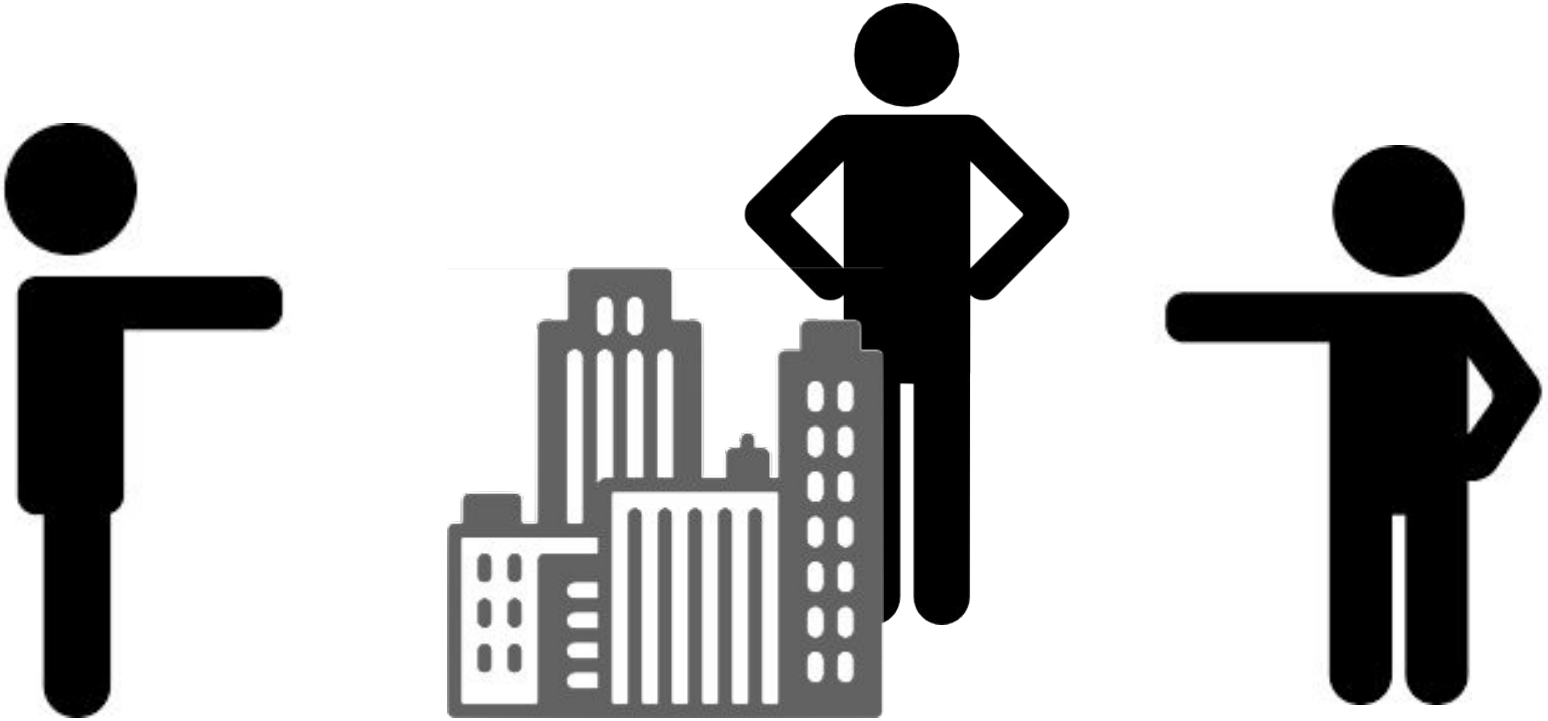


Amazing new technology…

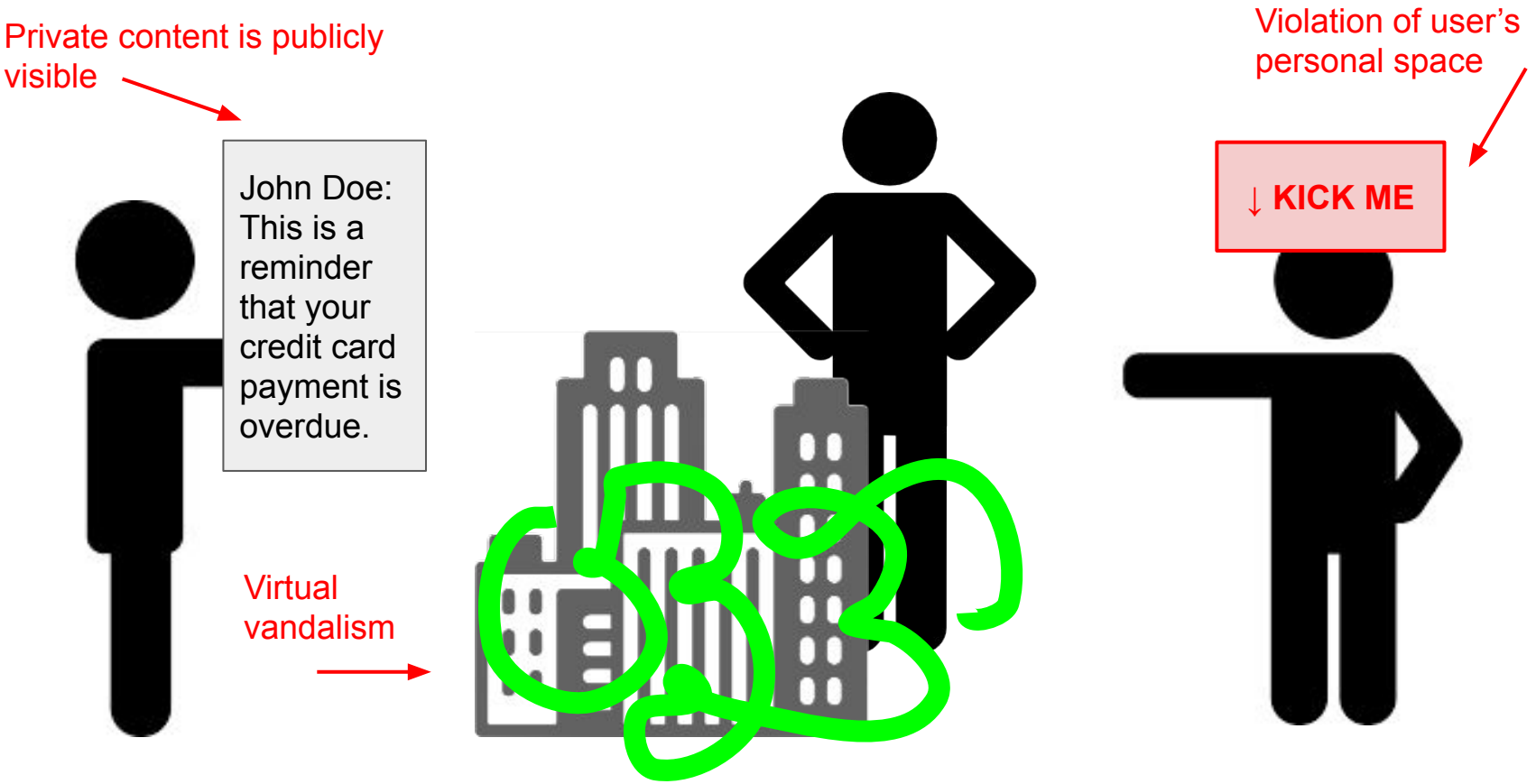
… what could possibly go wrong?



Private content is publicly visible

Private content is publicly visible

Virtual vandalism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John Doe: This is a reminder that your credit card payment is overdue.
Virtual vandalism
Violation of user's personal space
↓ KICK ME

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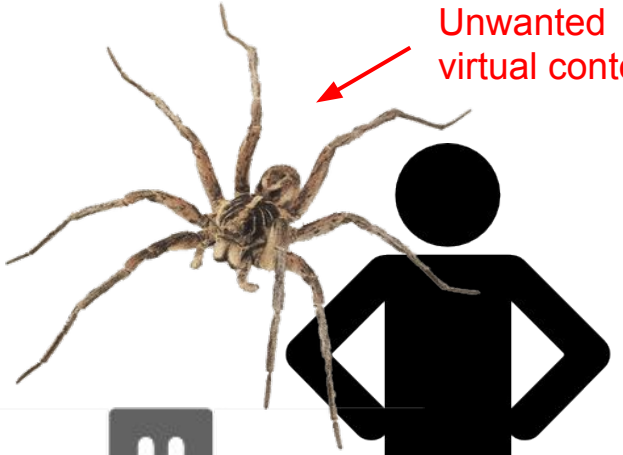
Unwanted virtual content



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Precursors Today

In VR:

- Sexual harassment occurs between player avatars
- Offensive remarks and standing in personal space is a meme

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In smartphone AR:

- Virtual “Balloon Dog” sculpture vandalized in Snapchat
- Unauthorized AR content in MoMA Picasso exhibit

Goal: Design multi-user AR security and privacy primitives

Case Studies as Design Development Tool

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Opt-in, co-located: **Paintball**

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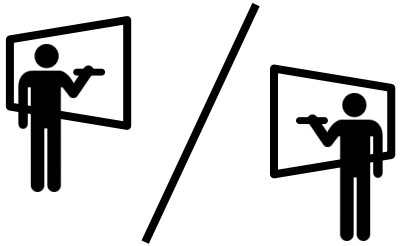
Opt-in, not co-located: **Multi-Team Whiteboards**



Case Studies as Design Development Tool

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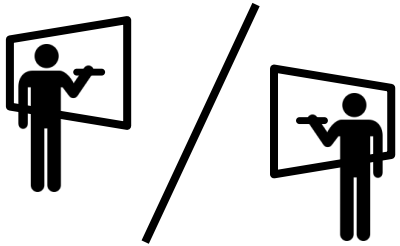
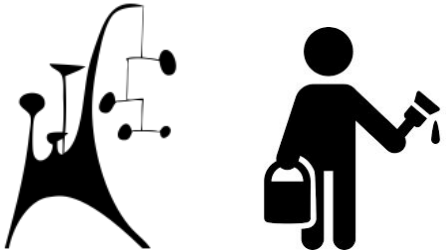


Opt-out, co-located: **Community Art**



Threat Model

Scope: multiple users of a single application

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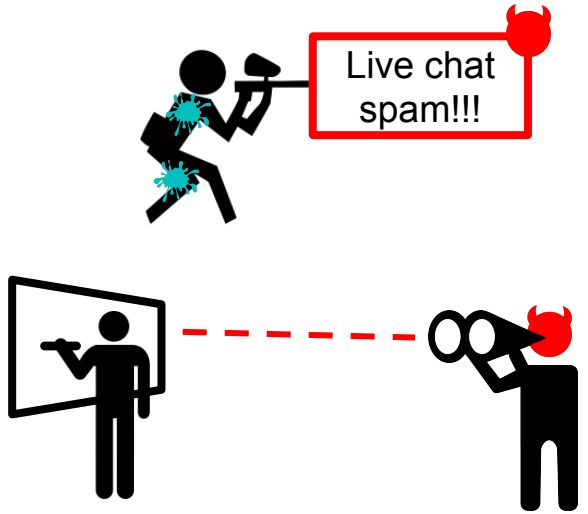


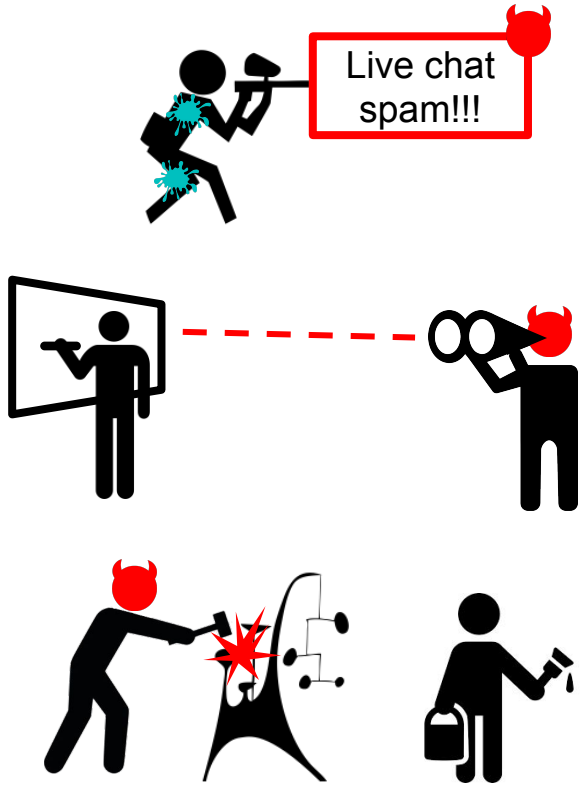
Threat Model

Scope: multiple users of a single application
Untrustworthy users may attempt to:

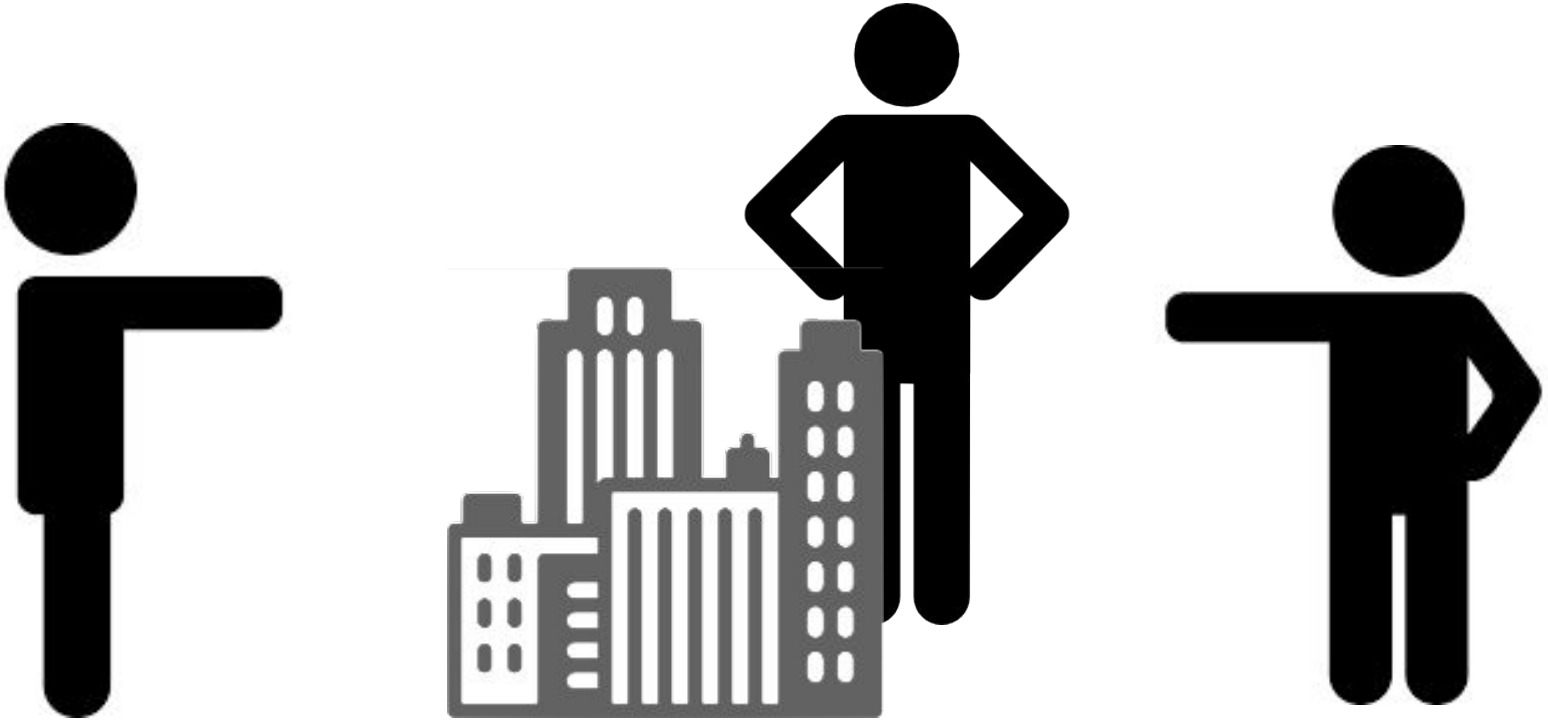
1. **Share unwanted AR content** with other users

2. **See private AR content** belonging to another user

3. **Perform unwanted manipulations on AR content** belonging to another user

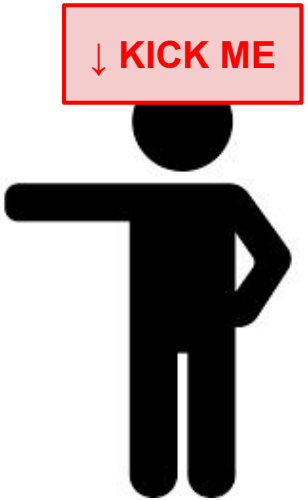


Goal: Design multi-user AR security and privacy primitives that *protect users from each other*



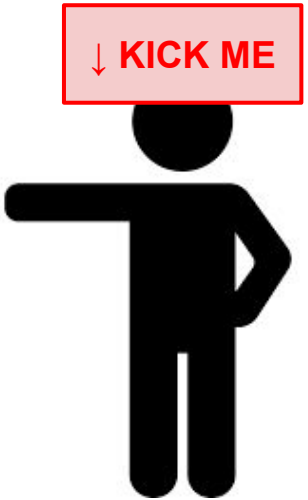
Goal: Design *functionality-friendly* multi-user AR security and privacy primitives that protect users from each other

One Size Does Not Fit All



VS.

One Size Does Not Fit All



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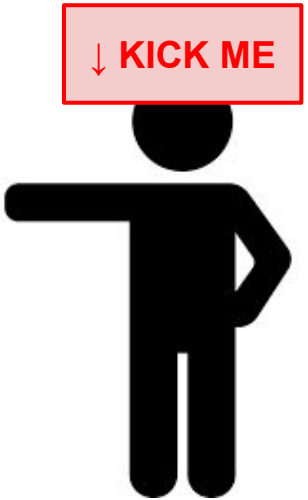

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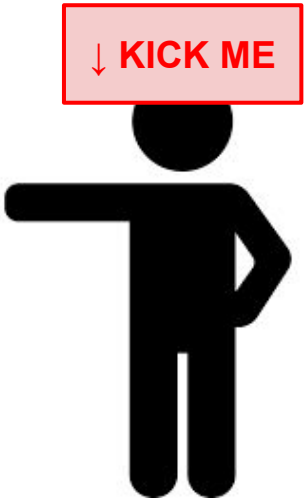

- Both involve attaching virtual content to users
- Bad vs. good is dependent on application semantics
- Cannot distinguish these in a general-purpose solution

Goal: Design functionality-friendly multi-user AR security and privacy primitives that *help developers* to protect users from each other

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Approach: App-Level Developer Toolkit

- Benefit: packaging controls behind an API reduces developer burden
- Benefit: lack of reliance on OS support facilitates ease of deployment in practice
- Benefit: opens possibility of cross-platform compatibility
- Limitation: cannot protect against misuse or abuse by app developer

Design Components

	Outbound sharing controls	Inbound sharing controls
What and with whom?		
Where?		
How much?		

Design Components

	Outbound sharing controls	**Inbound sharing controls**
What and with whom?	Permission management	Two-party sharing consent
Where?	Location coupling	Personal space
How much?	Private content in a shared world	Clutter management

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Key challenge: integration with physical 3D space

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Key challenge: integration with physical 3D space

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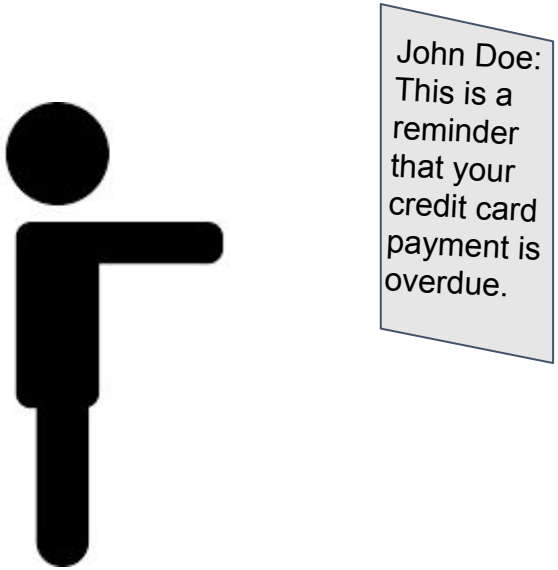

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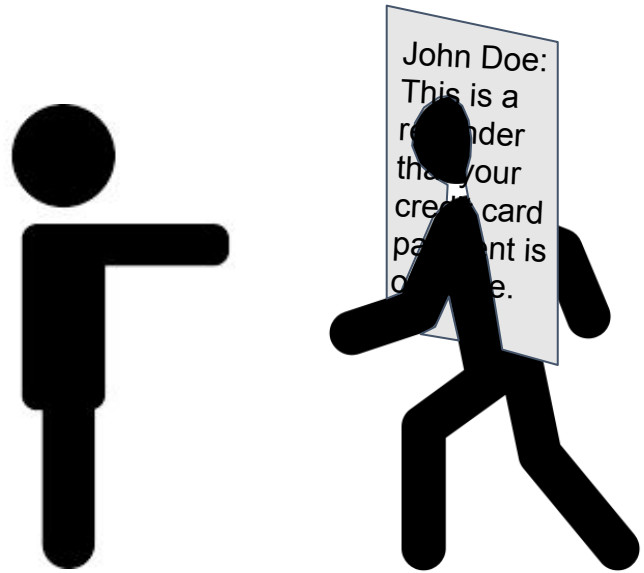
Left user's view: virtual content obscured



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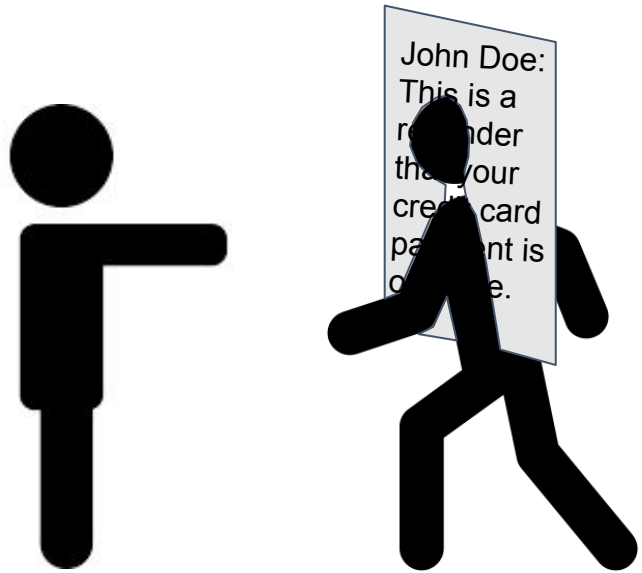
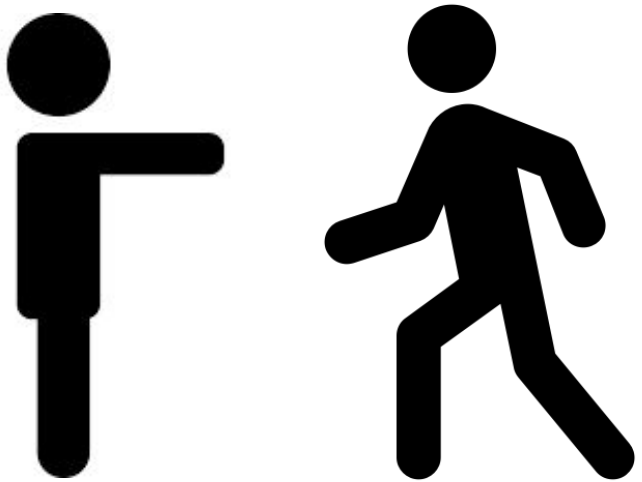


Right user's view: no behavioral cue



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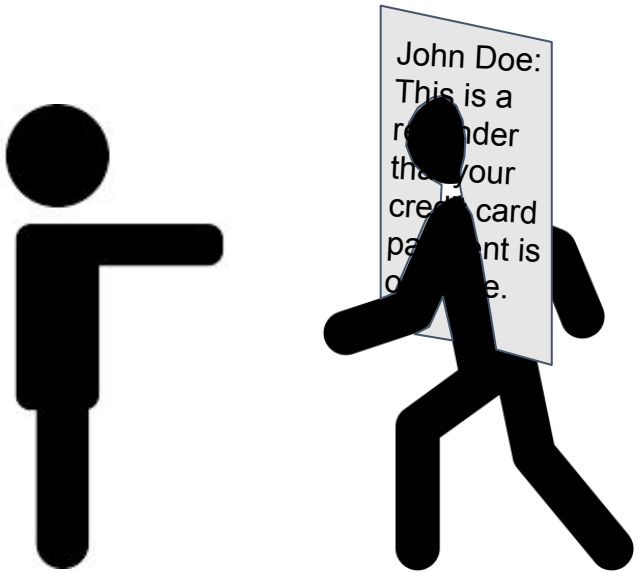

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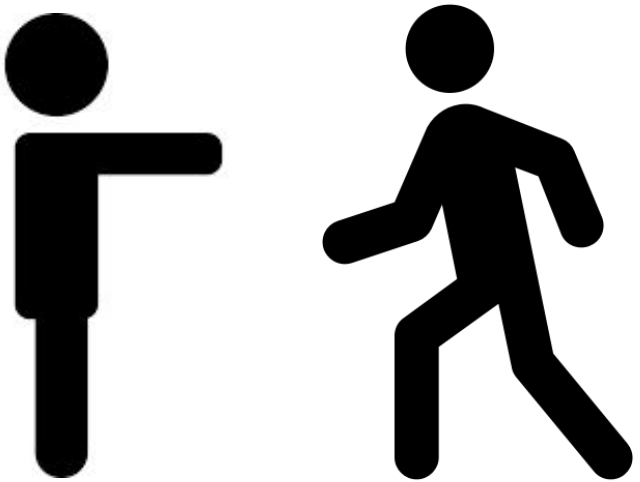


Solution: Ghosting

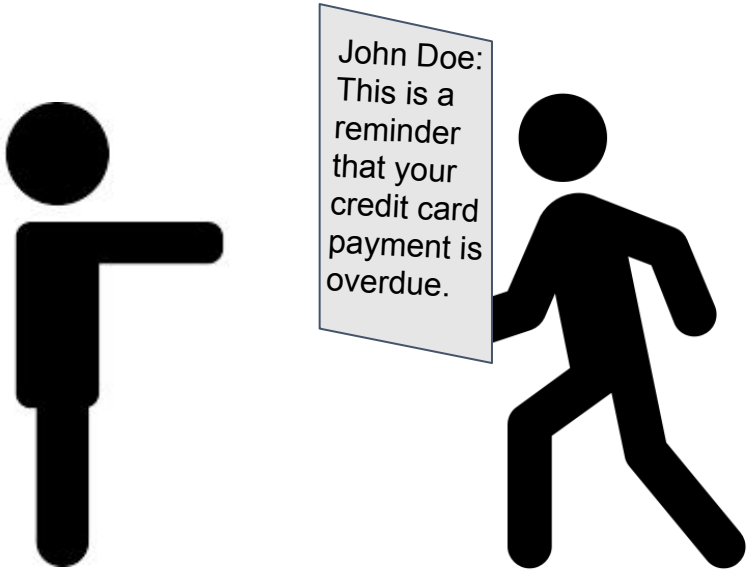
User's view:

John Doe:
This is a reminder that your credit card payment is overdue.

Others' view:

Solution: Ghosting

Left user's view: full virtual content



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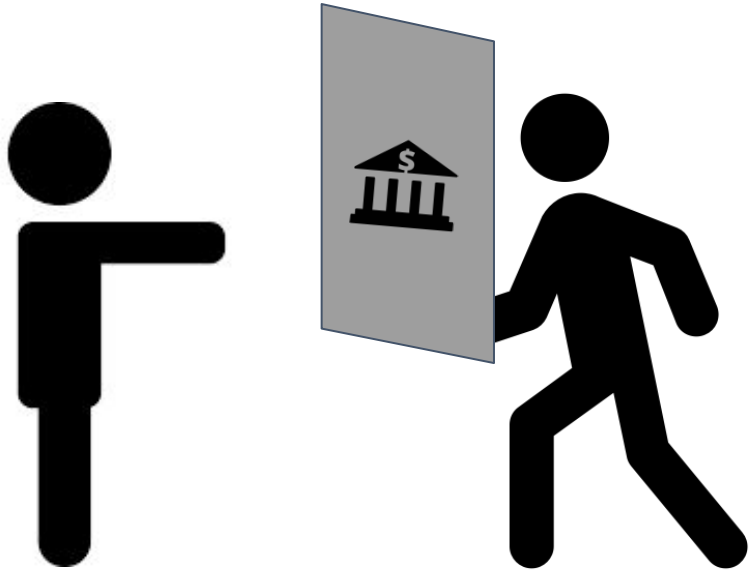
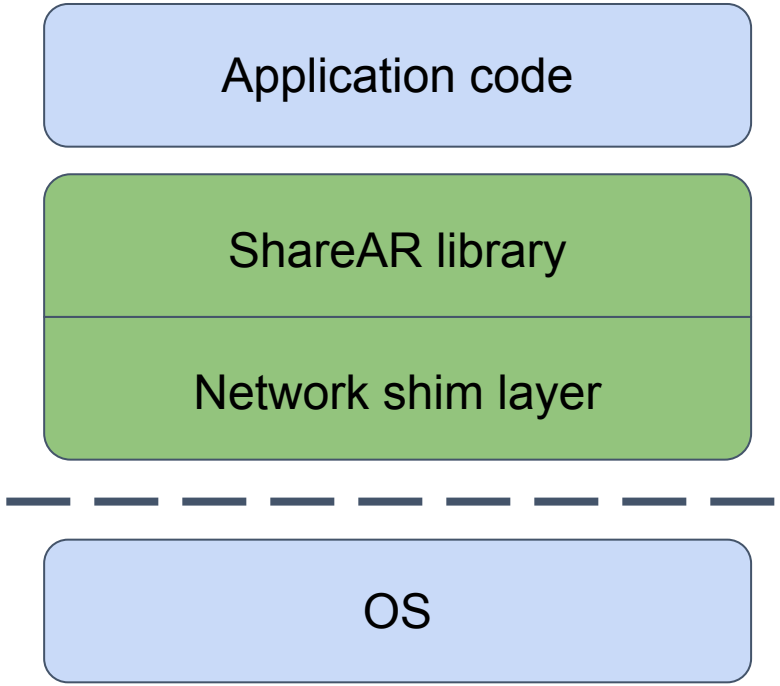


Implementation: ShareAR

- App-level library written for Microsoft HoloLens
- Assumes Unity development environment
- Network shim layer uses Microsoft MixedRealityToolkit Sharing; can be swapped out to use another networking solution



Evaluation

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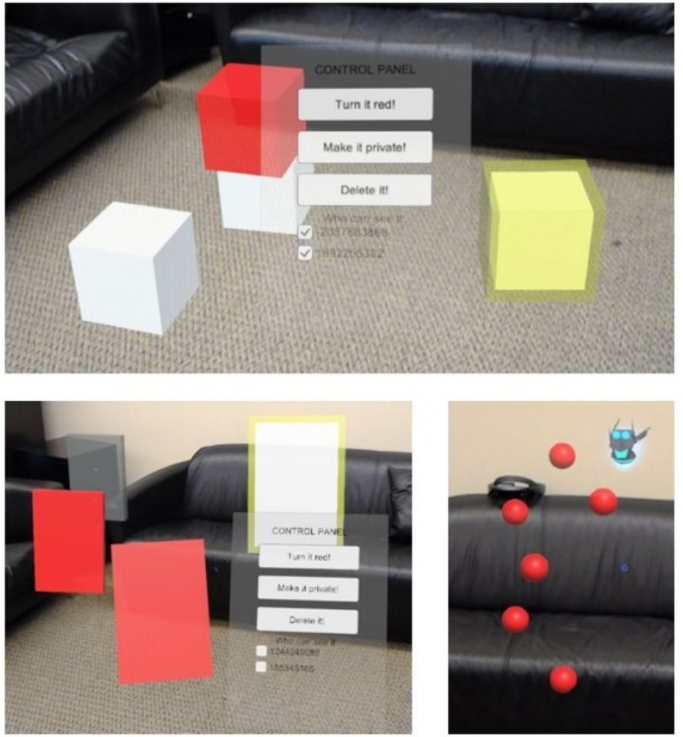

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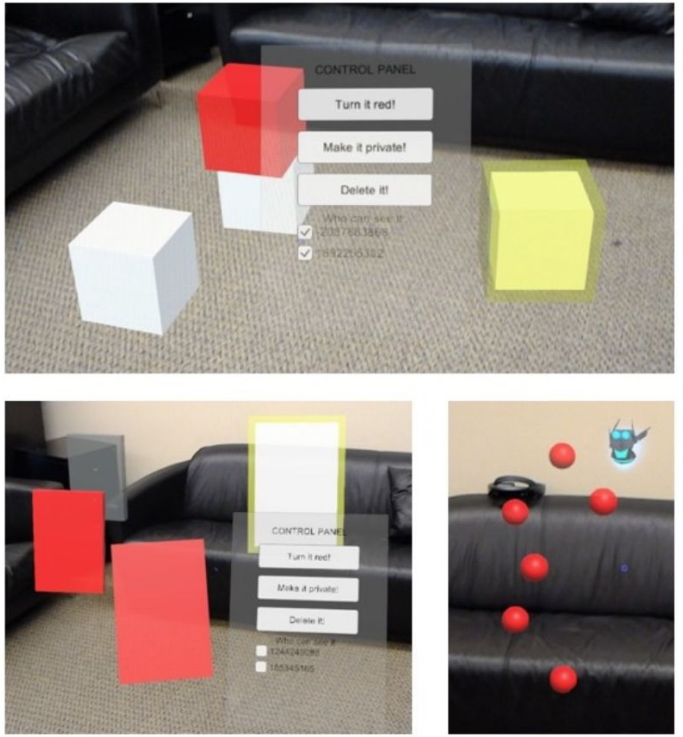

Evaluation

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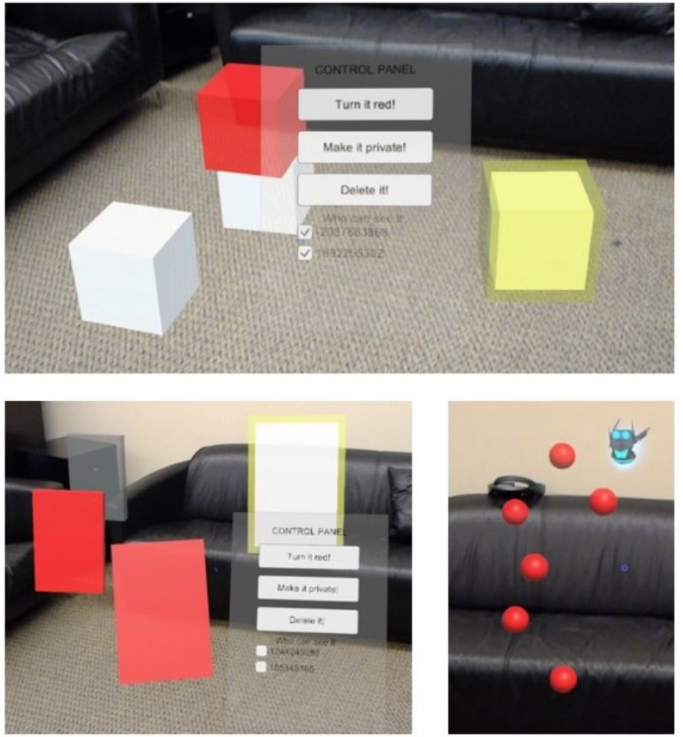
4. Performance measurement, scaling with number of users and number of objects



Evaluation

Continued evaluation in practice:

- 2 undergraduates this summer building apps using ShareAR
- Toolkit available for other developers and researchers to download; looking for further feedback from practical use
- Visit **arsharingtoolkit.com** to try it out

Henry Bowman

AJ Kruse

Summary

Multi-user AR security is a topic that warrants the attention of the security community.

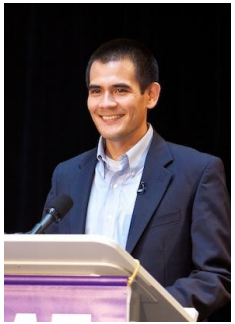
Security is not enough: practicality requires building security solutions based on functionality requirements.

This work contributes:

- A set of **goals** for a multi-user AR security framework,
- A **design** that meets those goals, and
- An **implementation** that helps multi-user AR app developers in practice to achieve functionality and security.

Acknowledgements

Franziska Roesner



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Security and Privacy Lab

NSF

Washington Research FOUNDATION

Funders

Project website: **arsharingtoolkit.com**

Questions? Kimberly Ruth – kcr32@cs.washington.edu