Automatic Adaptation of Mixed Reality User Interfaces

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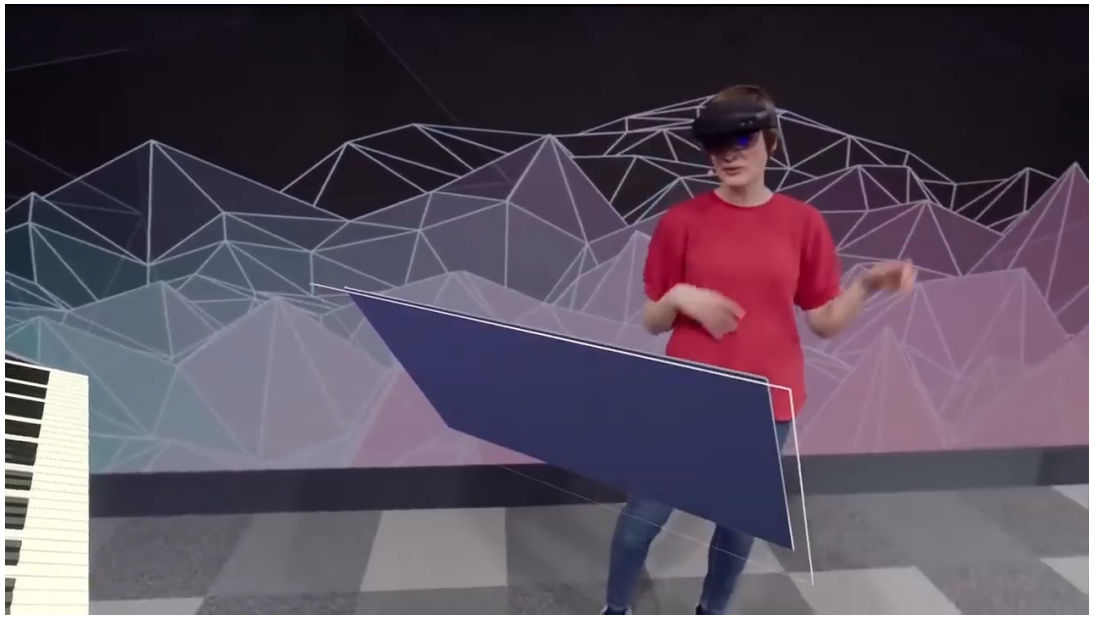
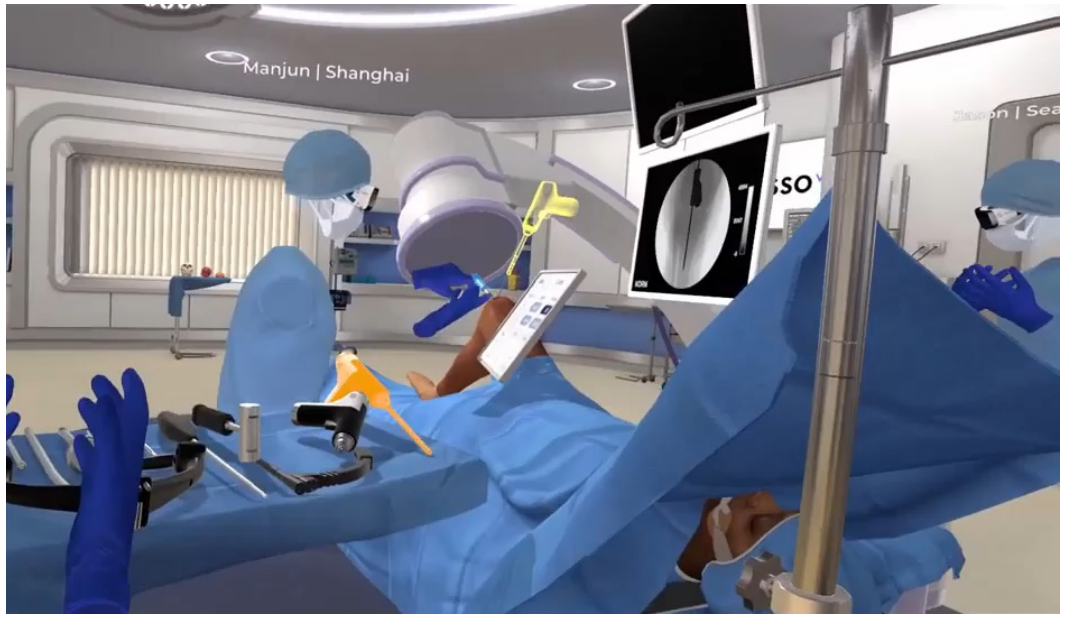
Some definitions

AR



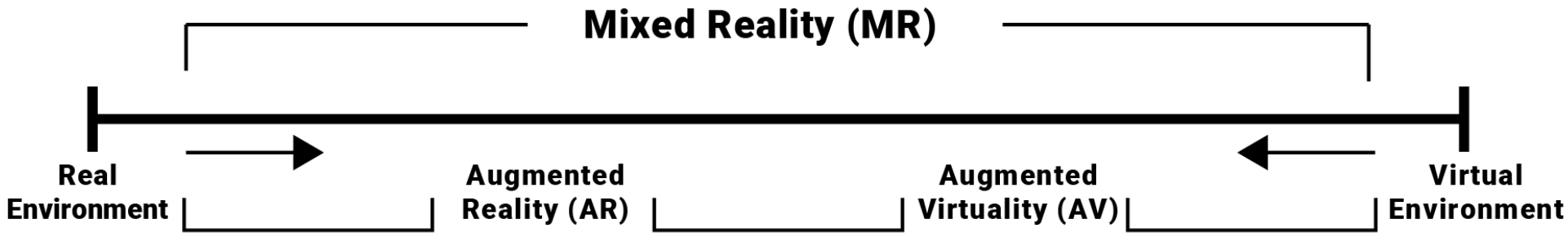
Julia Schwartz, Microsoft HoloLens demo

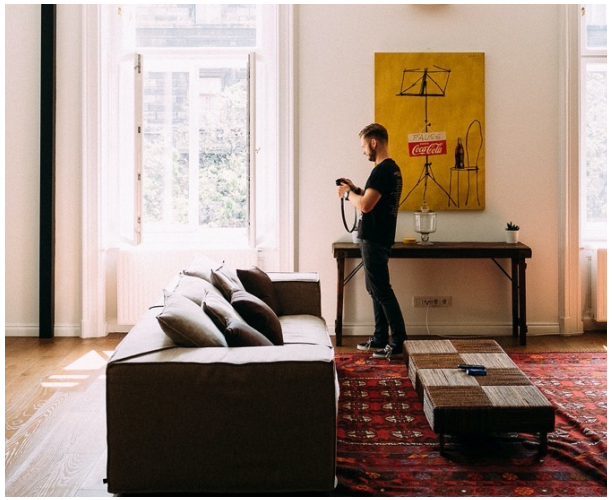
VR

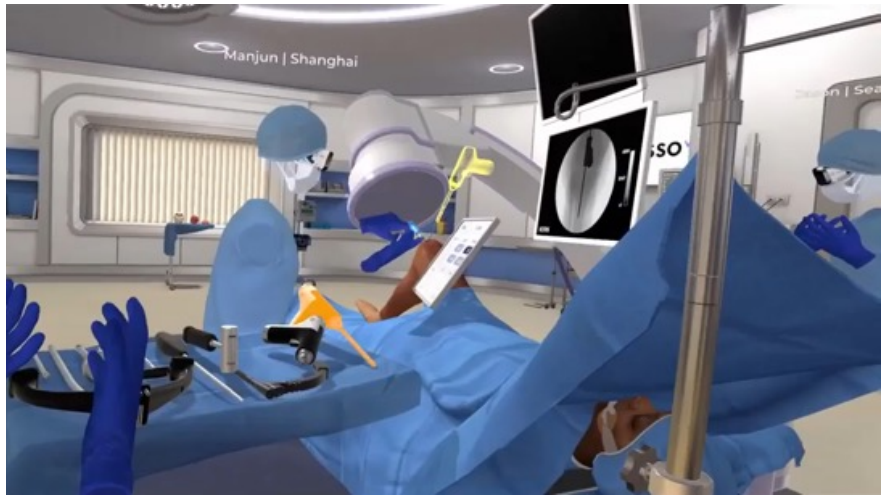


OSSO VR

Further reading: Speicher et al., What is Mixed Reality?, CHI 2019







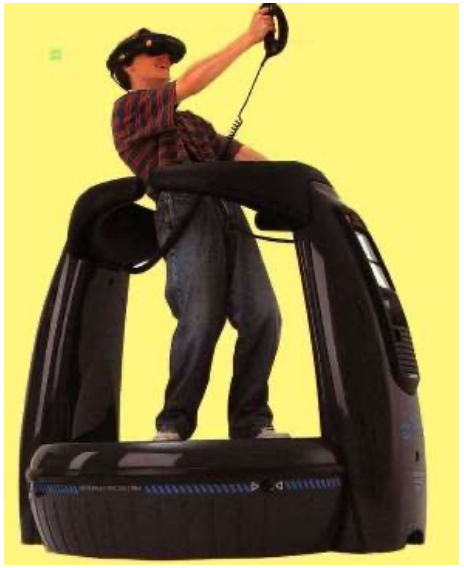
[Milgram & Kishino, IEICE TIS 77 (12)]

The Past

Sensorama
Steinhaus, 1960s

3D head-mounted display
Sutherland, 1968

DataGlove, EyePhone
VPL Research (1980s)



1000SU Elysium
Virtuality Group, 1990s

Oculus Rift
Oculus, 2013

Devices

Smartphones

HTC Vive Pro 2

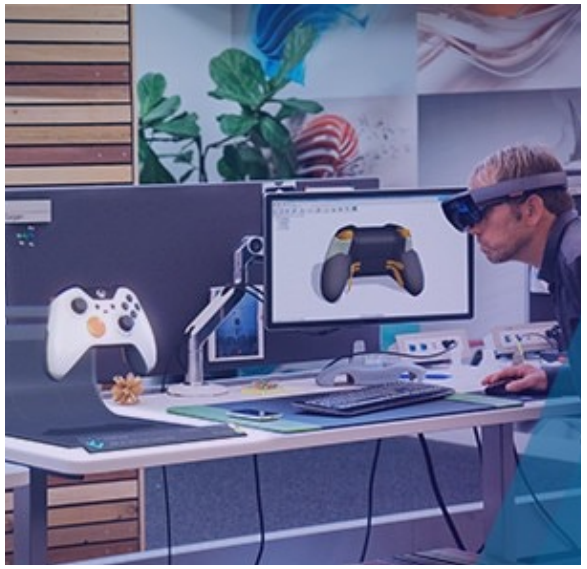
Oculus Quest 2

Microsoft HoloLens 2

Magic Leap

Varjo XR-3

Applications



Productivity

Casual

Health

Military

Virtual Reality is here to stay!

ESA approved flight training for helicopters

image source: varjo.com

Meta Quest 2
15 mio devices sold

image source: engadget.com

VR successful in RCT for pain relieve, PTSD & therapy

image source: engadget.com

What about Mixed Reality?

image source: thestreet.com

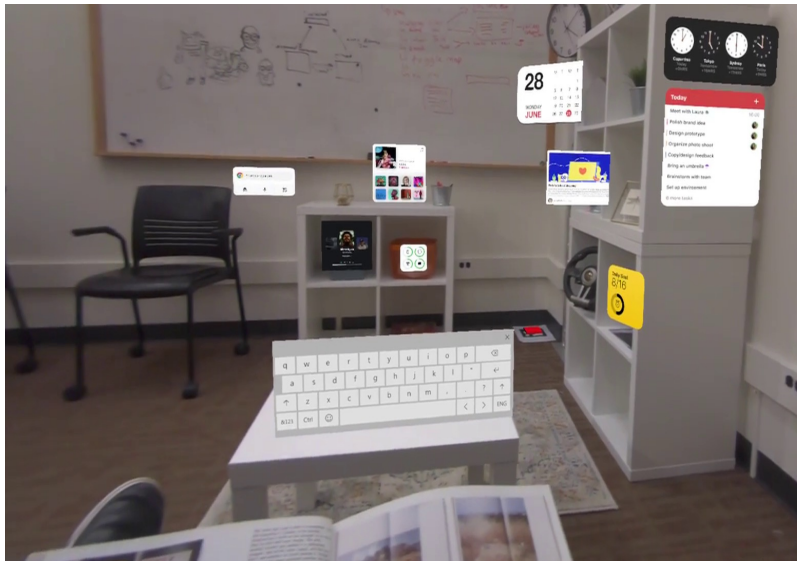


image source: forbes.com

What parts do we need to get right?

Components

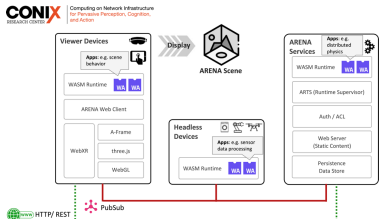
FRL, Holographic Optics

Displays

OpenPose

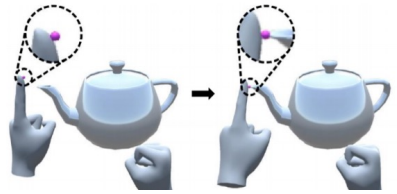
Tracking

ARENA



Communication

Gloumeau et al., PinNPivot



Interaction techniques

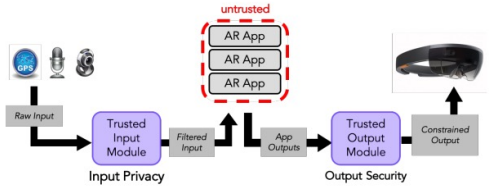
MSR, Capstan Crunch

Haptics & multimodality

Mask R-CNN

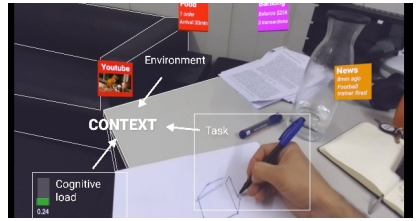
Scene understanding

Roesner & Kohno



Security & Privacy

Context-aware MR



Adaptive interfaces

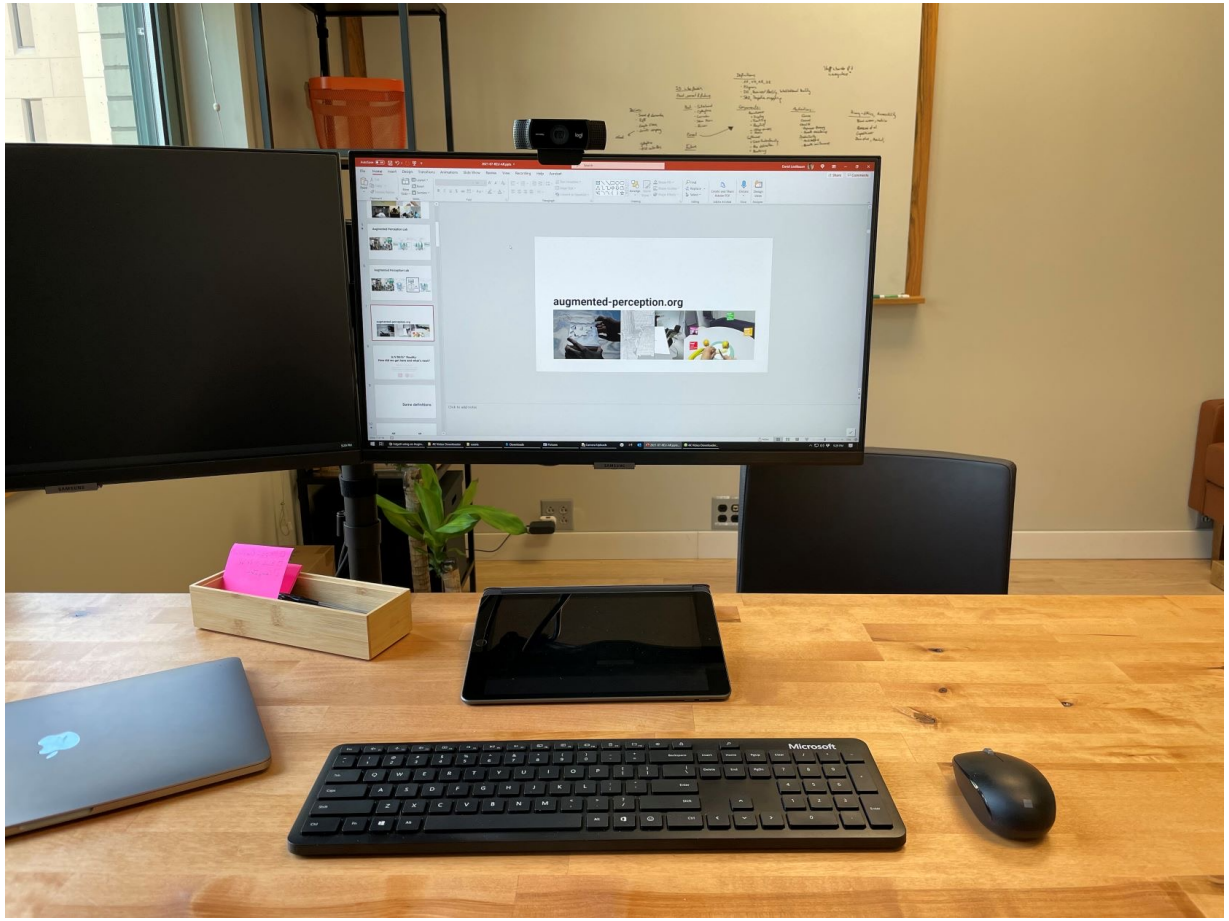
Hardware

Sensing

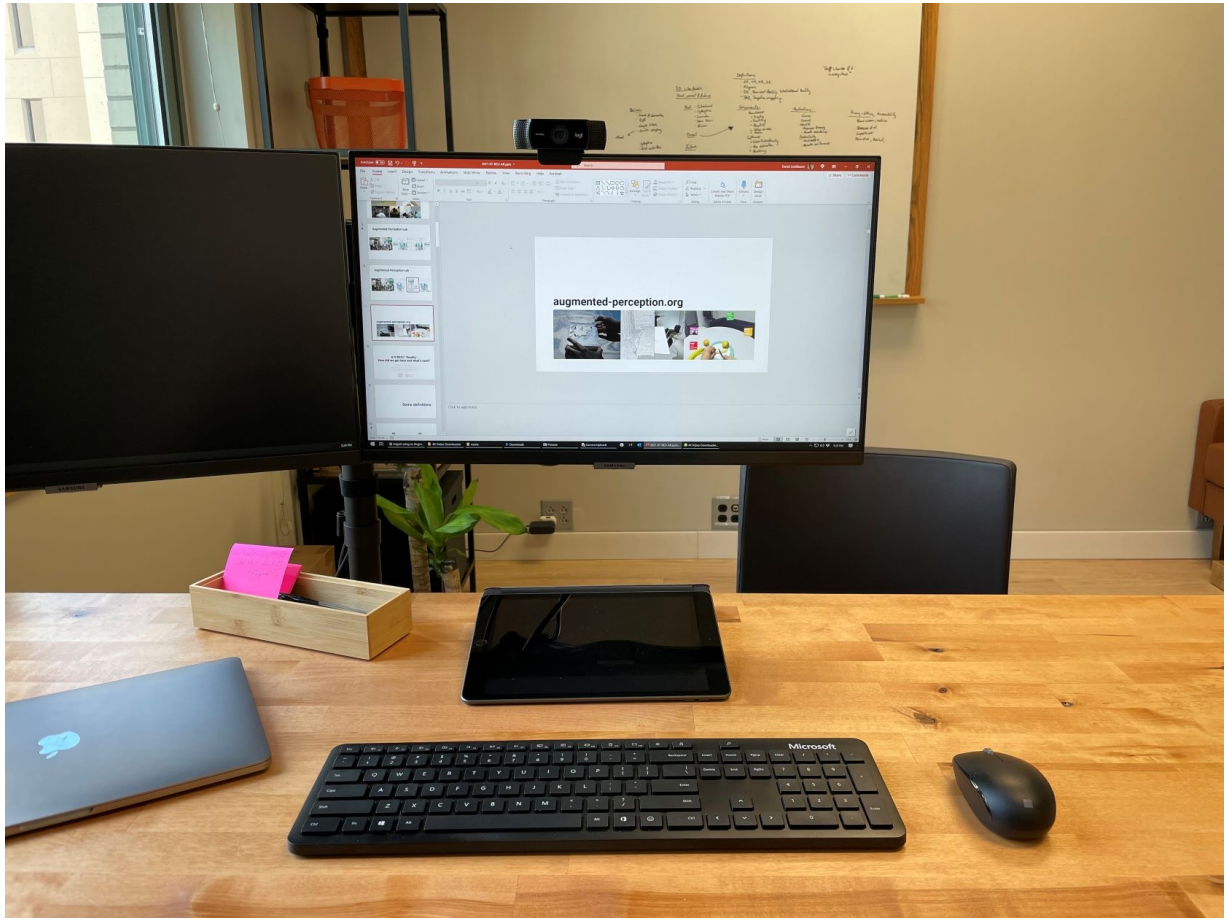
Systems

Interaction

3D user interfaces are challenging to create



3D user interfaces are challenging to create



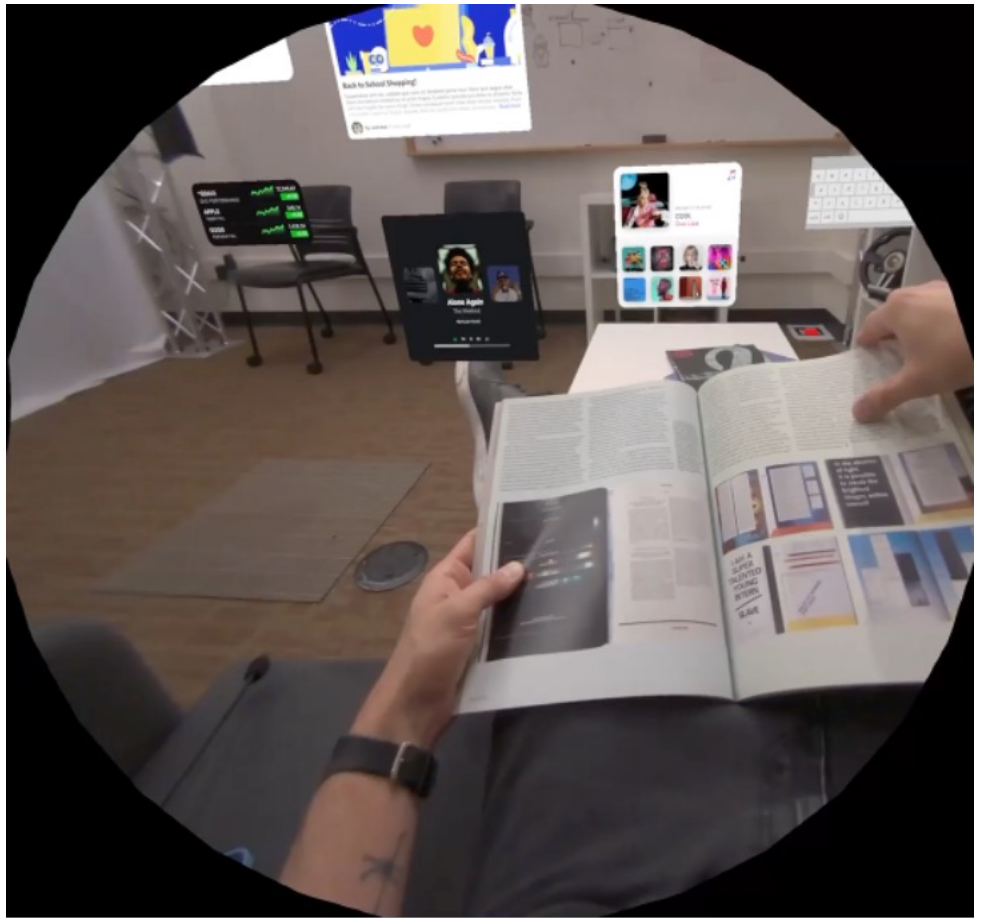
2D user interfaces

- constrained by 2D screens
- input always availabe
- independent of surrounding

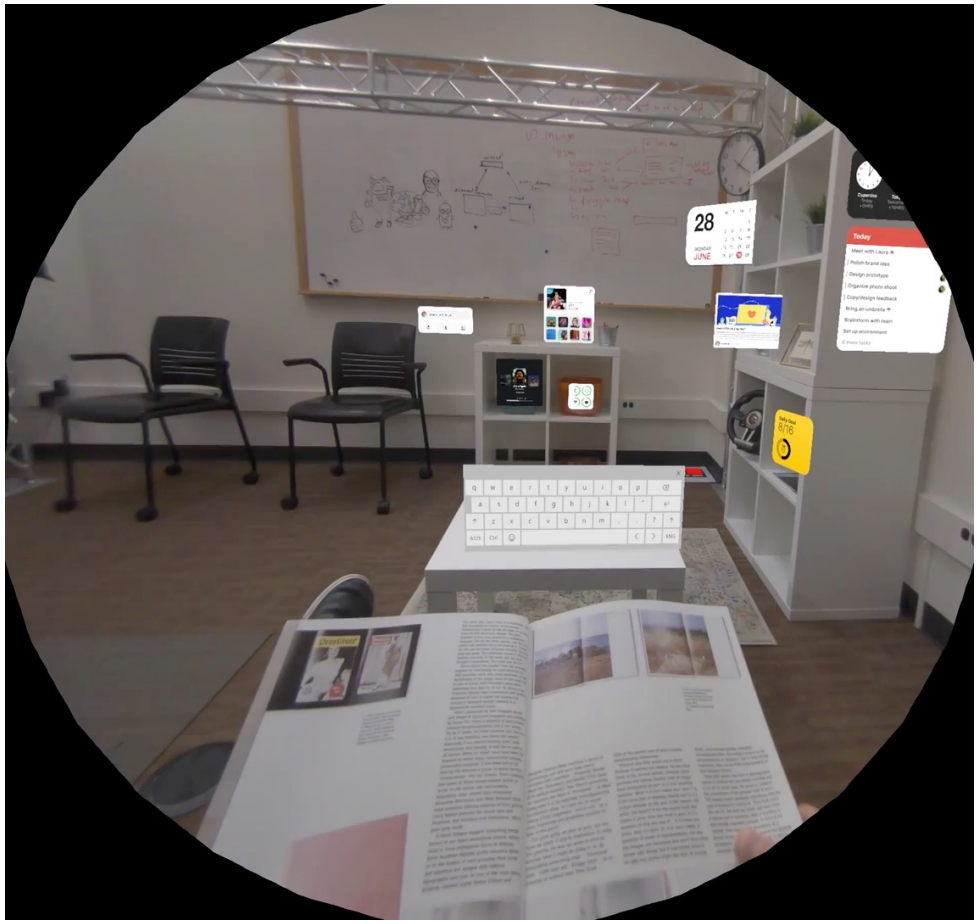
3D user interfaces are challenging to create

3D user interfaces

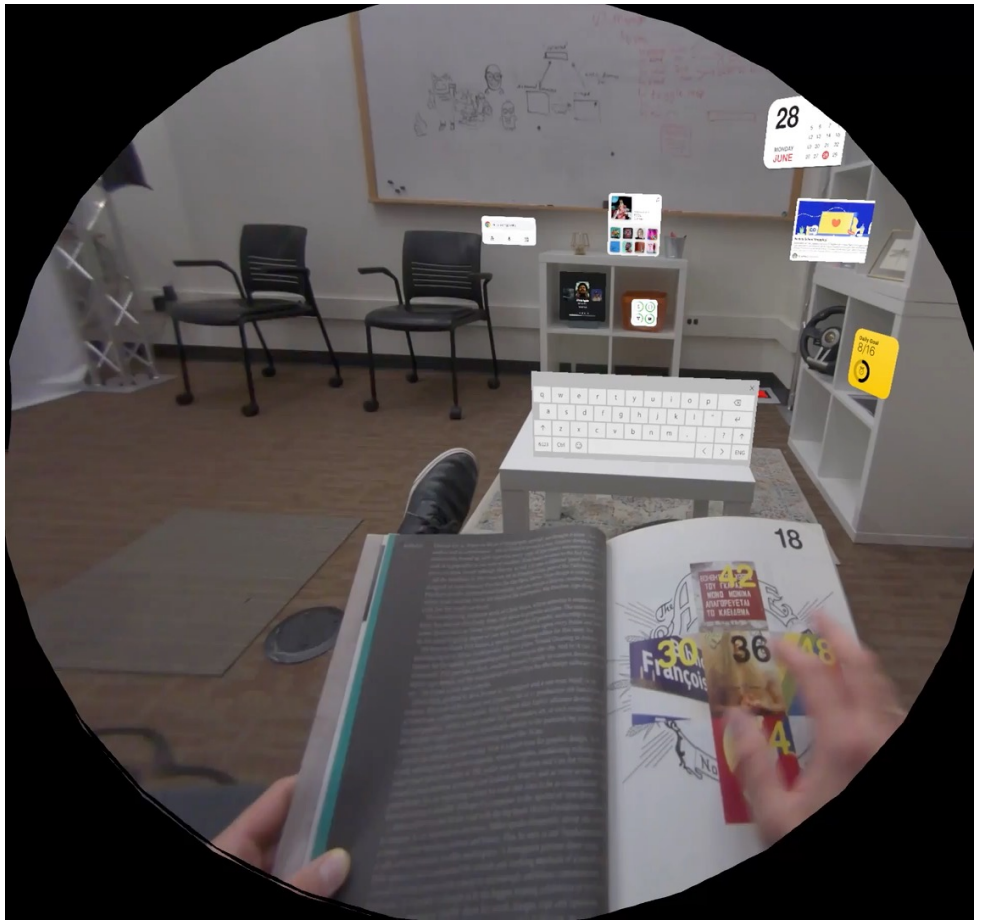
- Take up arbitrary portion of users' field of view
- Spatially distributed
- Influenced by surrounding environment



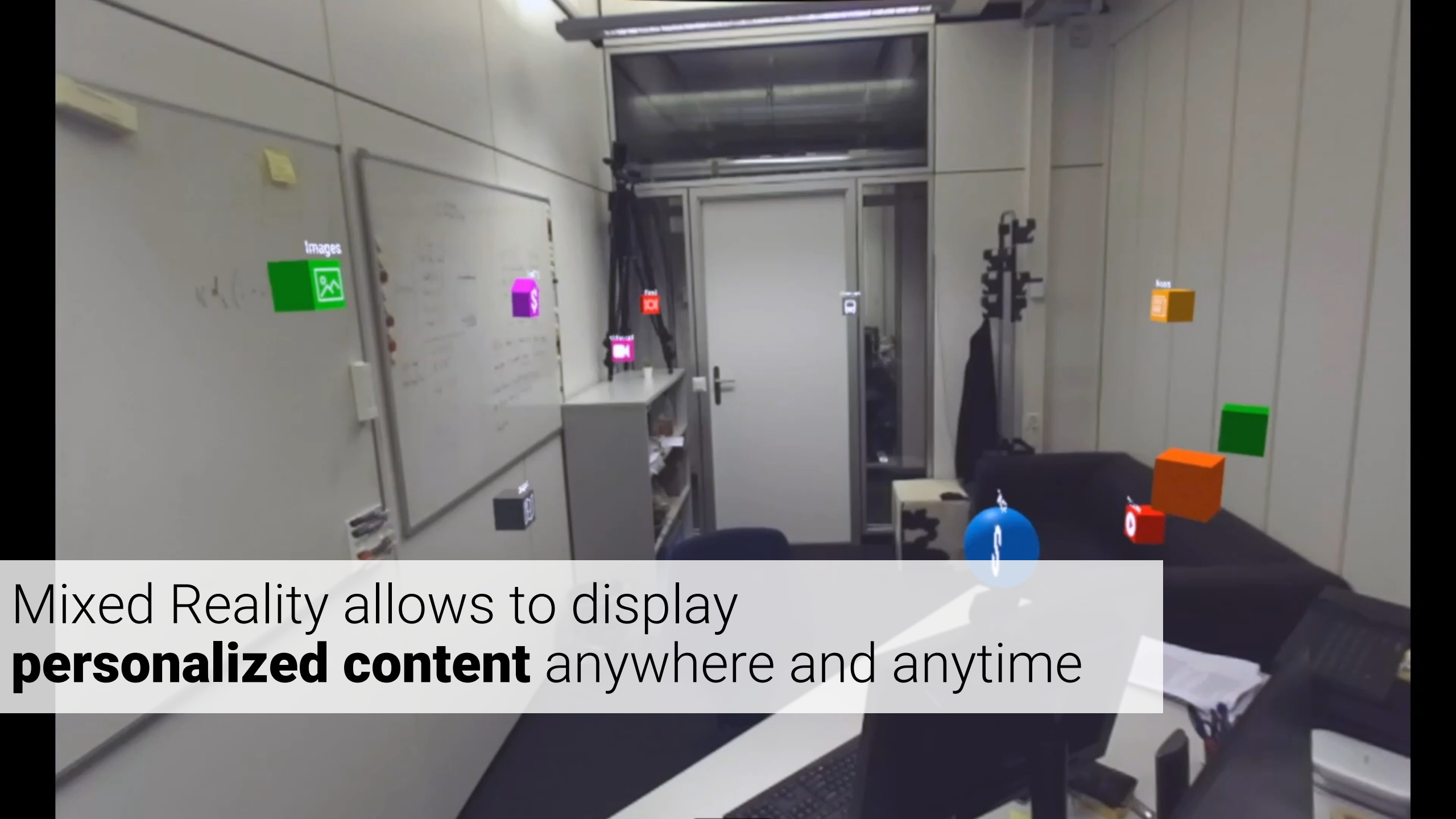
3D user interfaces are challenging to create



Spatial distribution & embedding

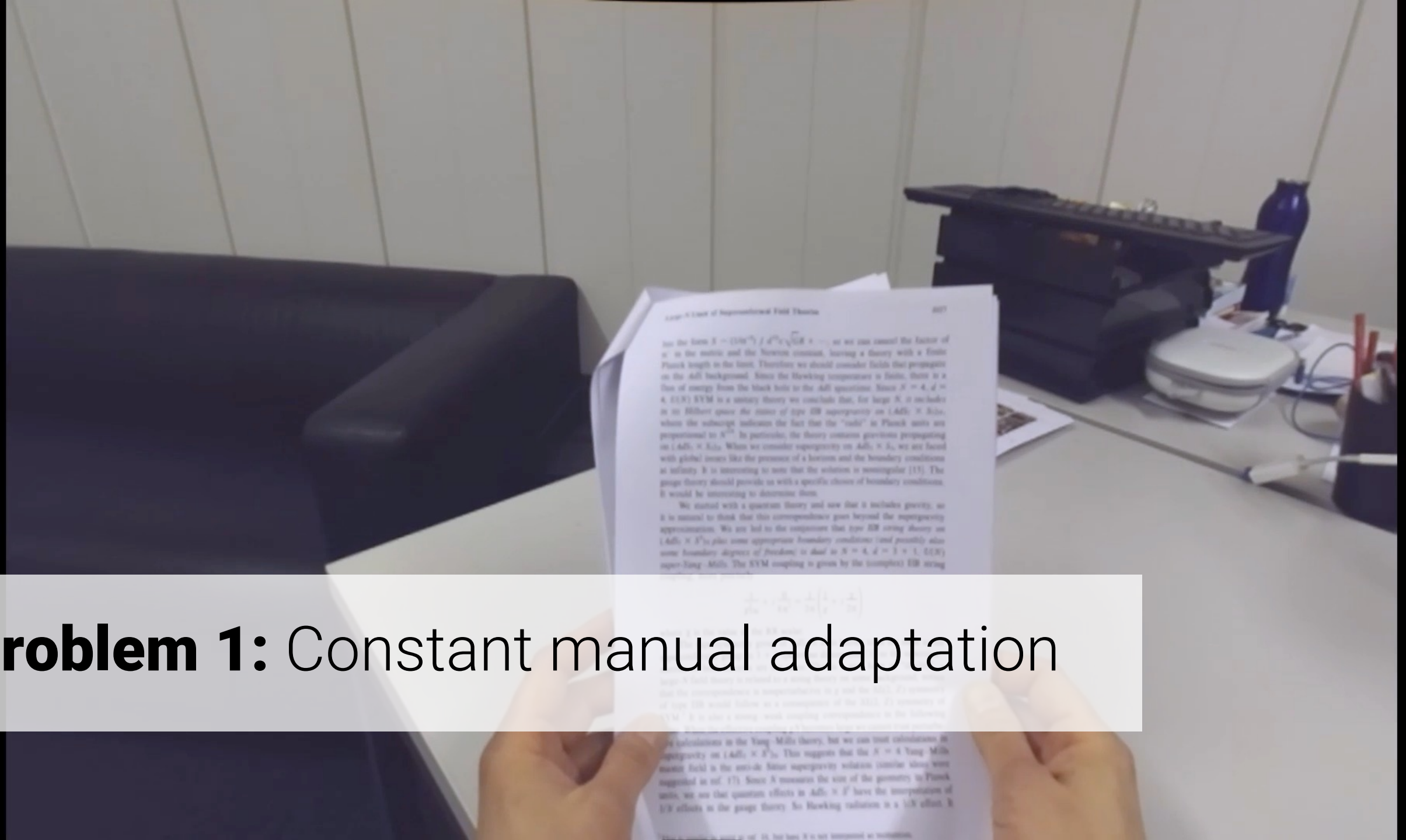


Interaction range



Mixed Reality allows to display
personalized content anywhere and anytime

MR has to be **context sensitive**.



Problem 1: Constant manual adaptation

Problem 2: Information overload

How do we present the **right information** with the **right appearance** at the **right position** at the **right time**?

Key components

Understanding & predicting humans

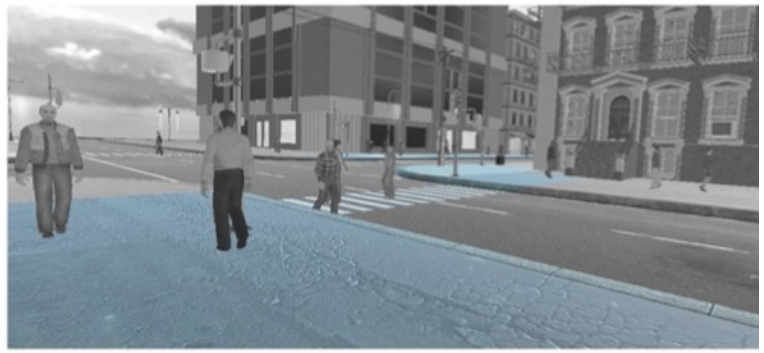
Deep learning saliency + depth.
Karlie Li, Andong Jing, David Lindlbauer.

Understanding & predicting humans

Arrows

Avatar

Call Outs



Desaturation

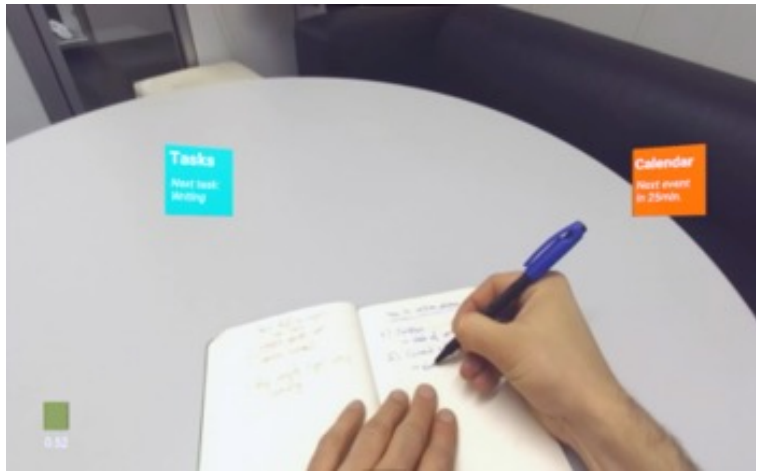
User Preference for Navigation Instructions in Mixed Reality
Jaewook Lee, Fanjie Jin, Younsoo Kim, David Lindlbauer, IEEE VR 2022

Understanding & predicting humans

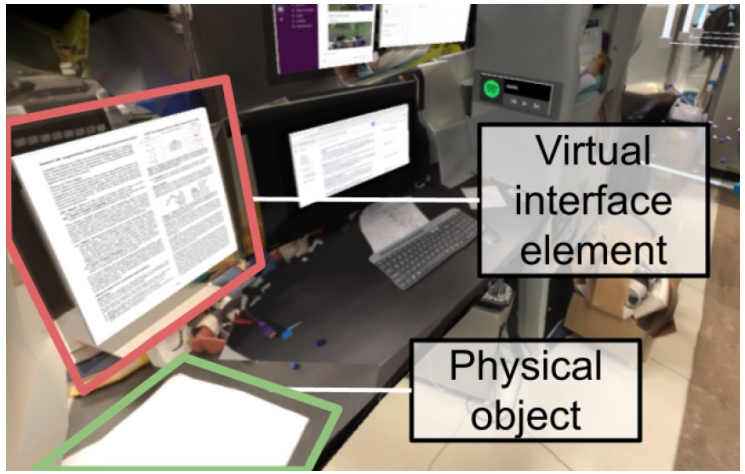
Towards Understanding Diminished Reality.
Yi Fei Chen, Hang Yin, Yukang Yan, Jan Gugenheimer, David Lindlbauer. CHI 2022

Key components

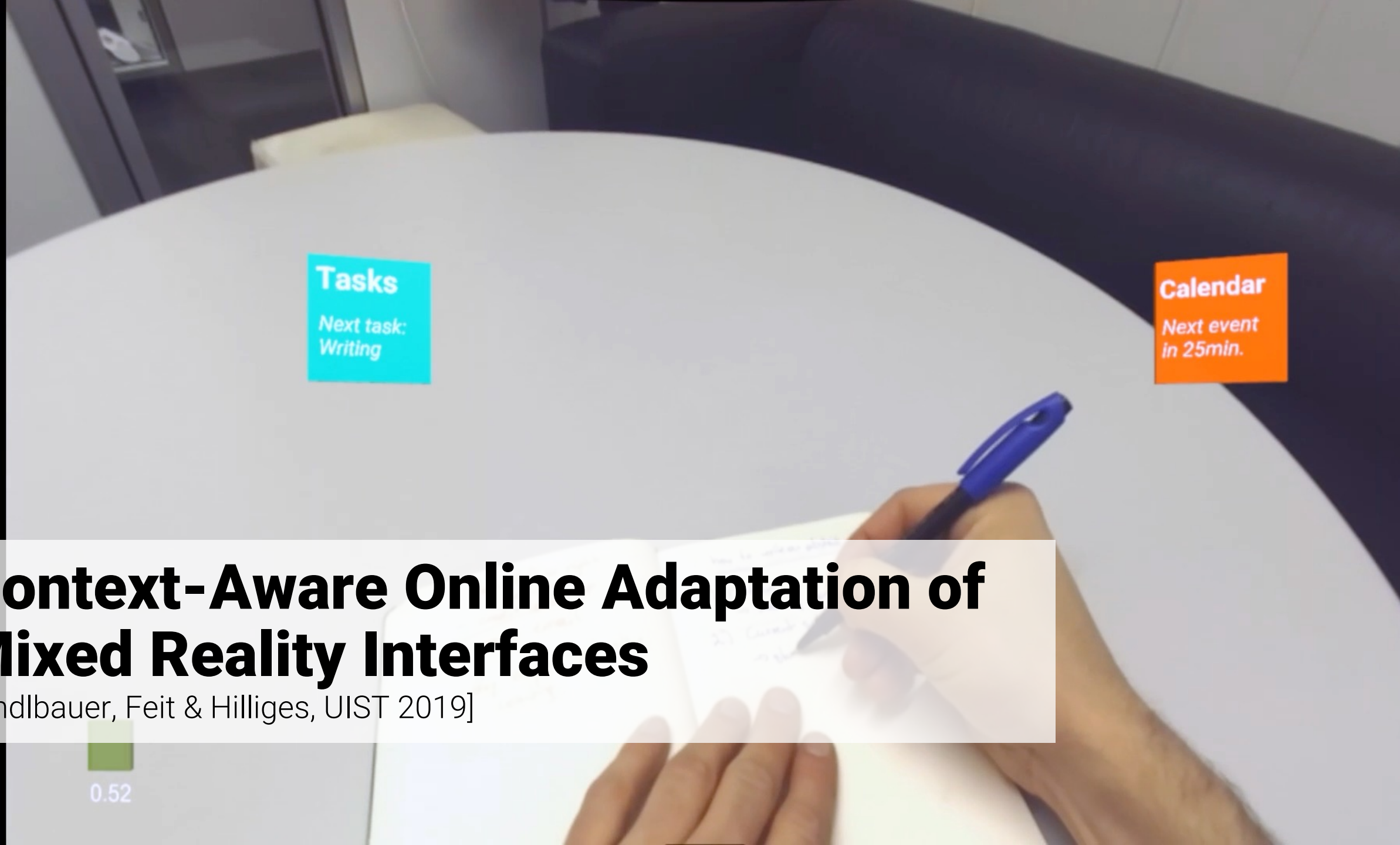
Computational approaches for MR



Context-aware MR [UIST 2019]



SemanticAdapt [UIST 2021]



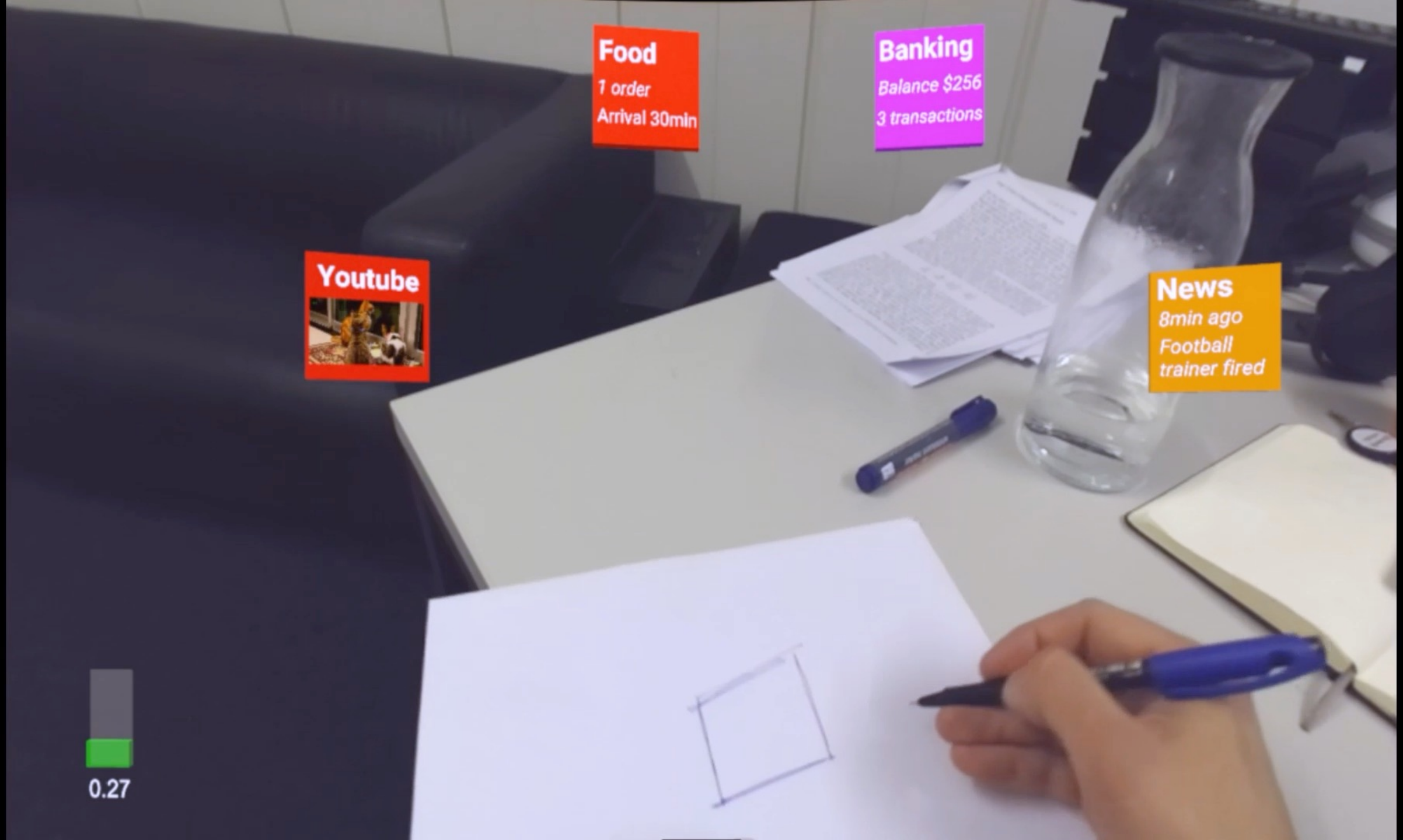
Context-Aware Online Adaptation of Mixed Reality Interfaces

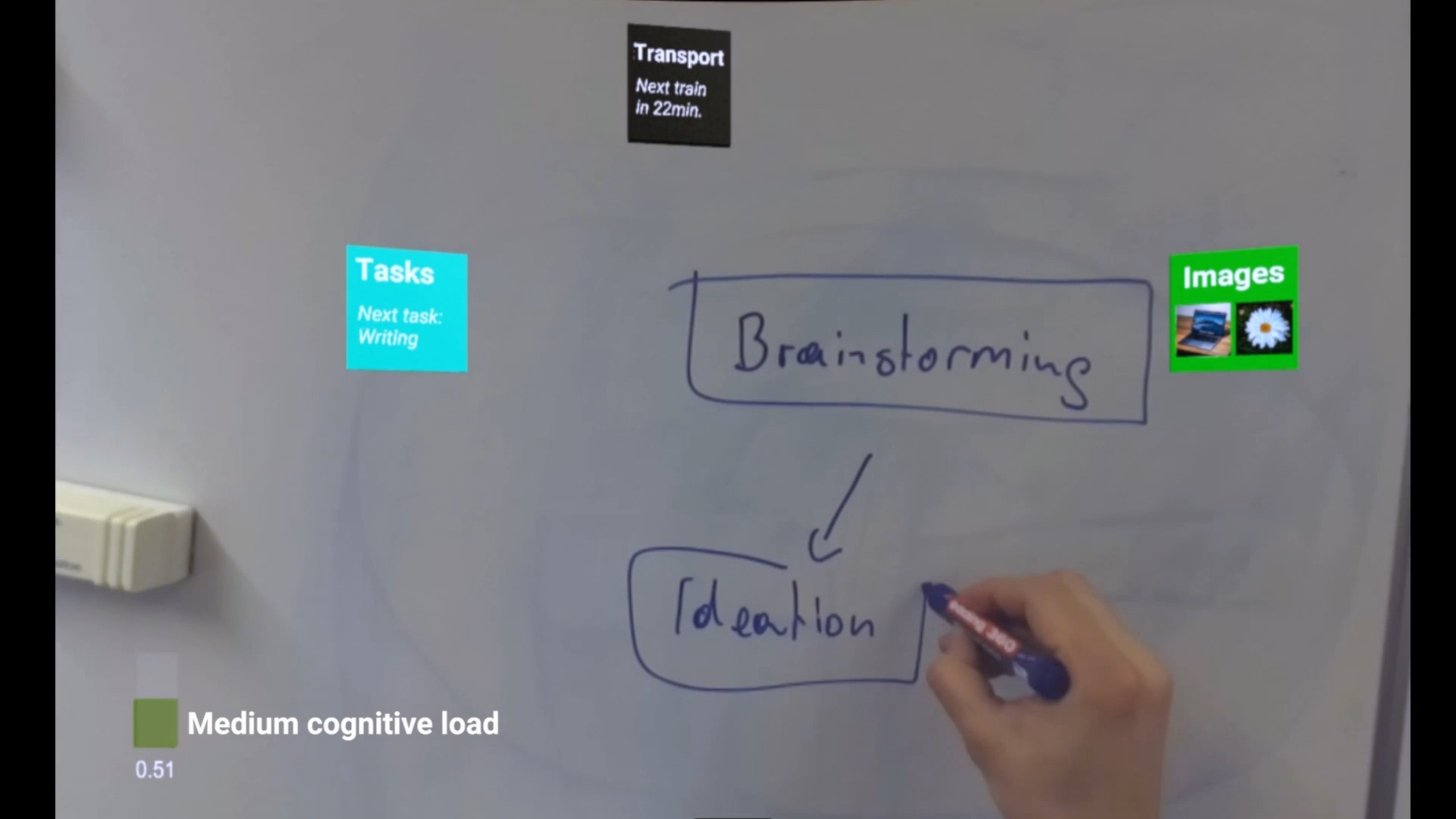
[Lindlbauer, Feit & Hilliges, UIST 2019]

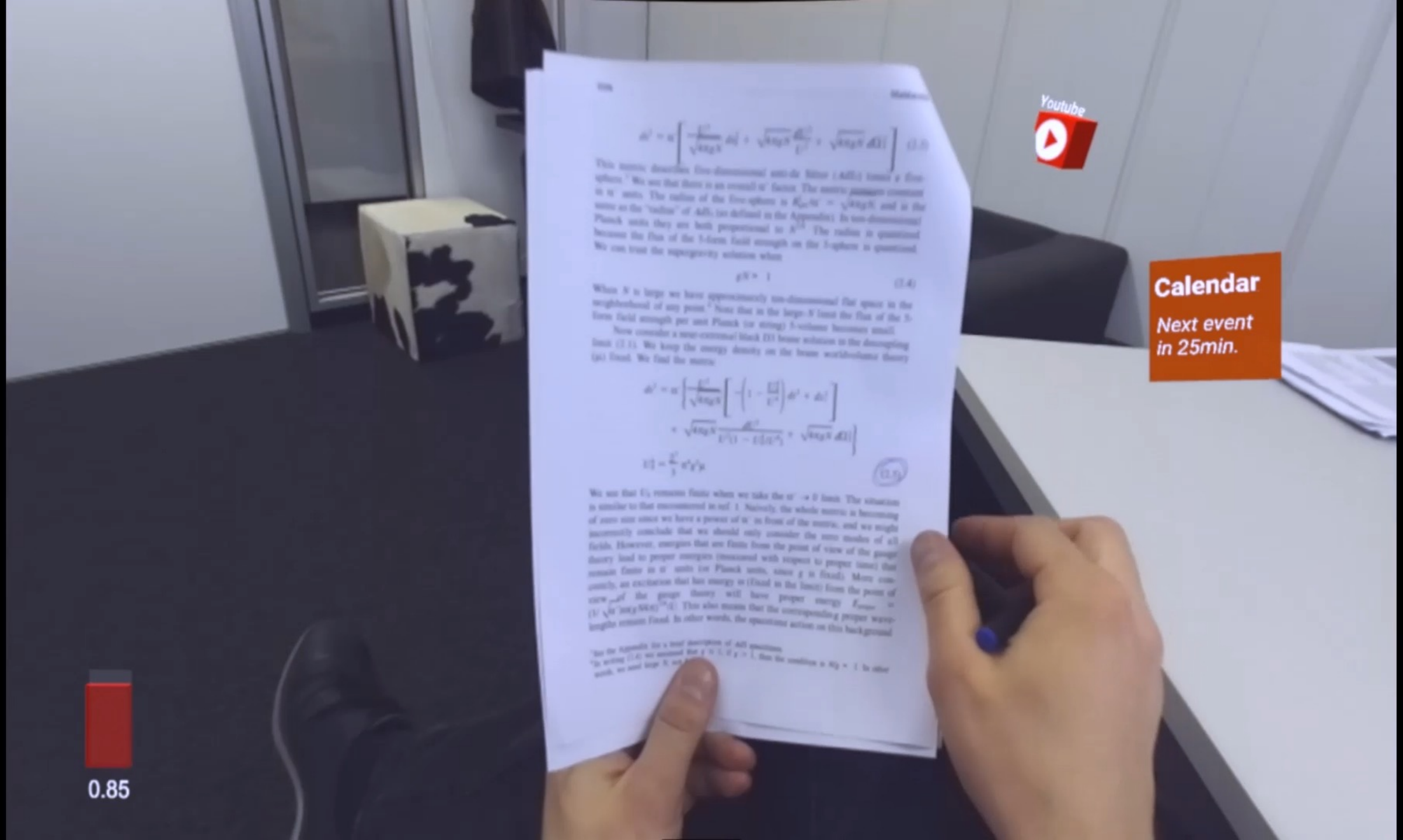
We want to **jointly optimize** an interface for **user's current context**

→ cognitive load, task & environment

IMPLEMENTED SCENARIOS


Food
1 order
Arrival 30min
Banking
Balance $256
3 transactions
Youtube
News
8min ago
Football
trainer fired
0.27


Transport
Next train in 22min.
Tasks
Next task: Writing
Brainstorming
Images
Ideation
Medium cognitive load
0.51


Youtube
Calendar
Next event
in 25min.
0.85

APPROACH

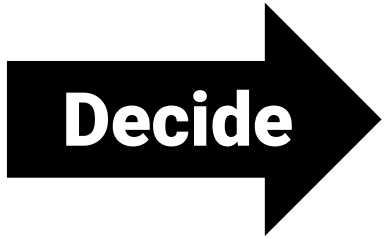
Approach

Current context

Cognitive load

Task

Environment



Visibility

Placement

Level of detail

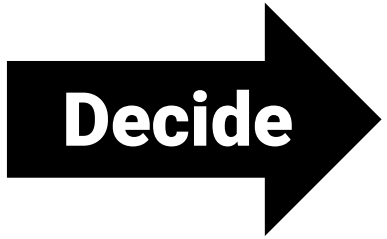
Approach

Current context

Cognitive load

Task

Environment

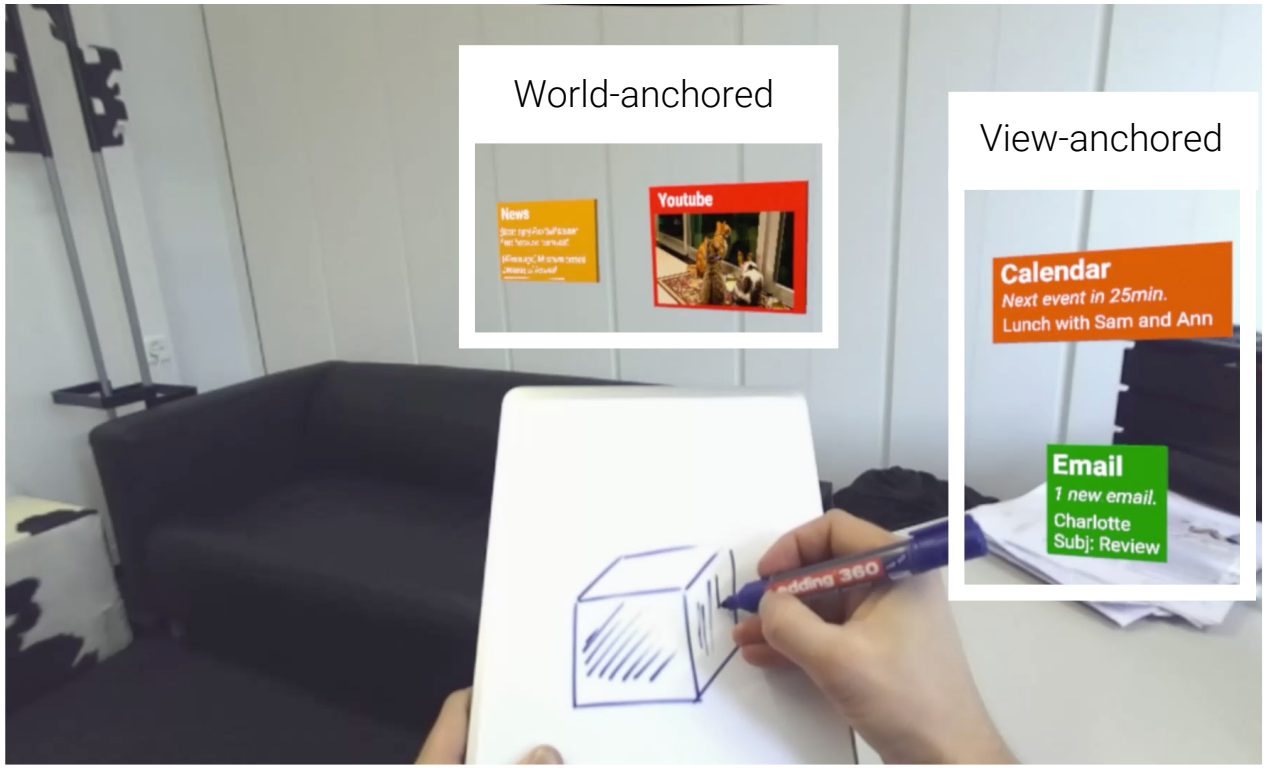


Visibility

Placement

Level of detail

Approach

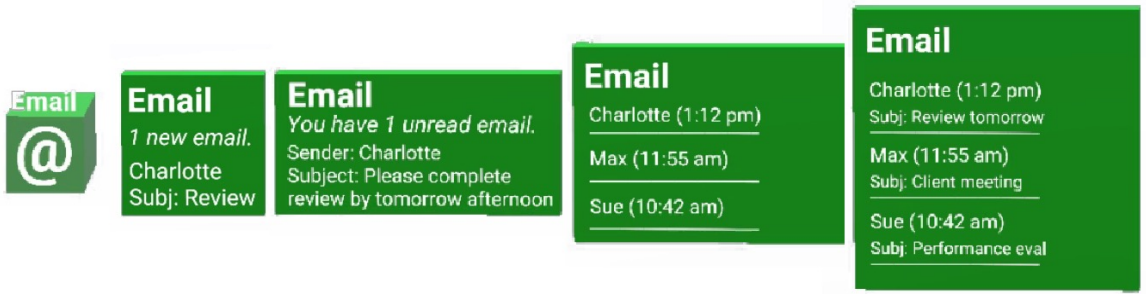


Visibility

Placement

Level of detail

Approach



Visibility

Placement

Level of detail

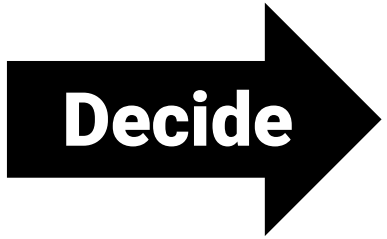
Approach

Current context

Cognitive load

Task

Environment



Visibility

Placement

Level of detail

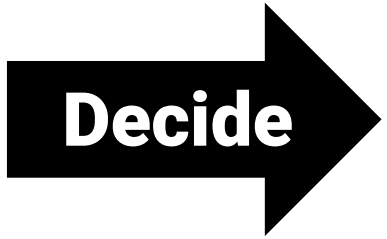
Approach

Current context

Cognitive load

Task

Environment



Visibility

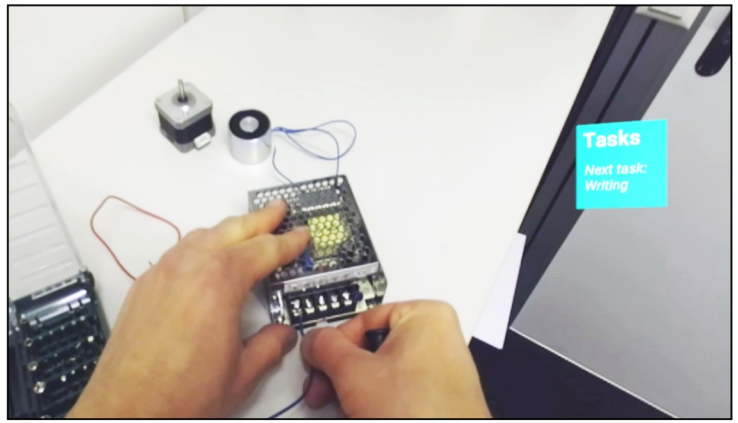
Placement

Level of detail

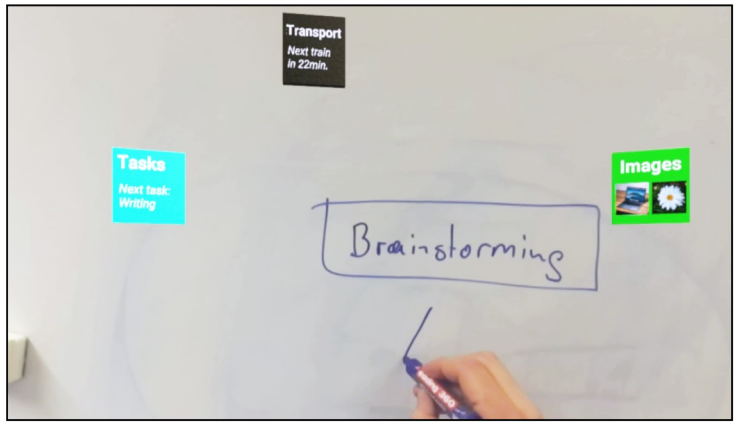
Rule-based decision making +
Combinatorial optimization

Increasing cognitive load

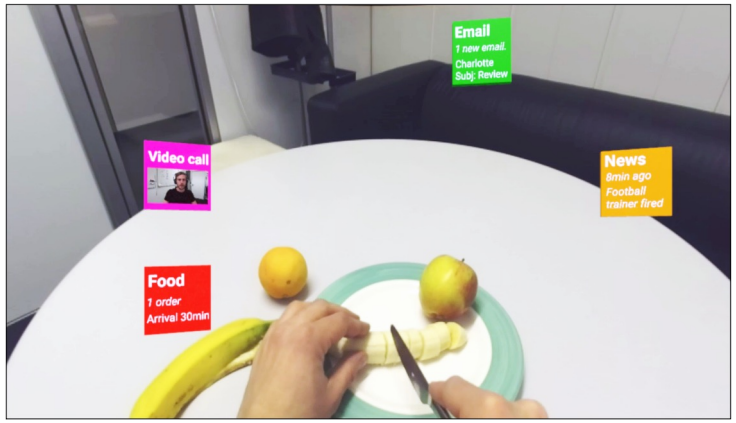
HIGH cognitive load



MEDIUM cognitive load



LOW cognitive load



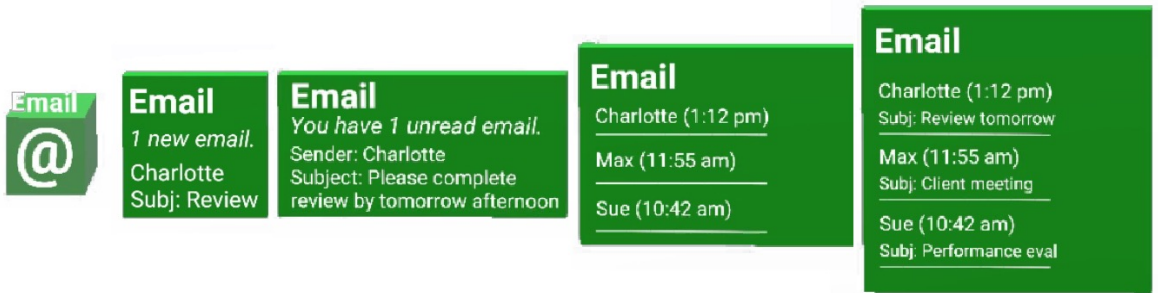
Show **less elements** based on **task** and **environment**

Input

Provided by content creators

Measured by system

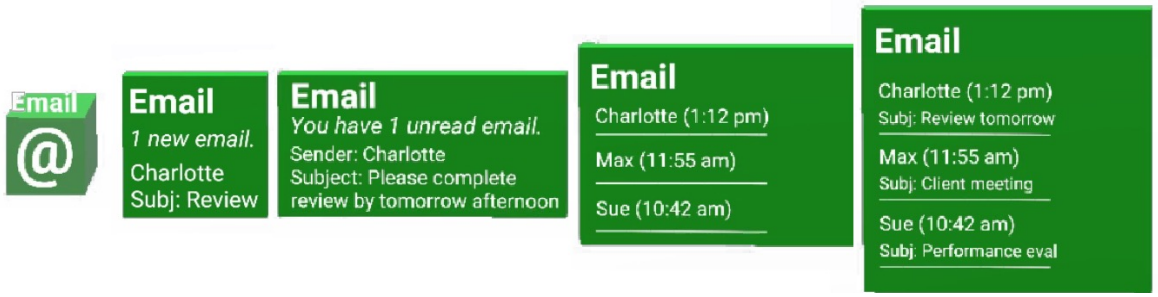
Input



Provided by content creators

Measured by system

Input

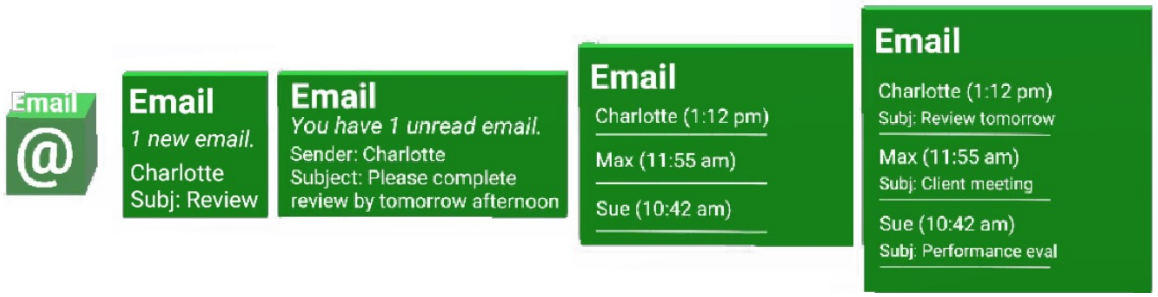


Cognitive cost
of element $\in [0, 1]$

Provided by content creators

Measured by system

Input



Cognitive cost of element $\in [0, 1]$

Task t

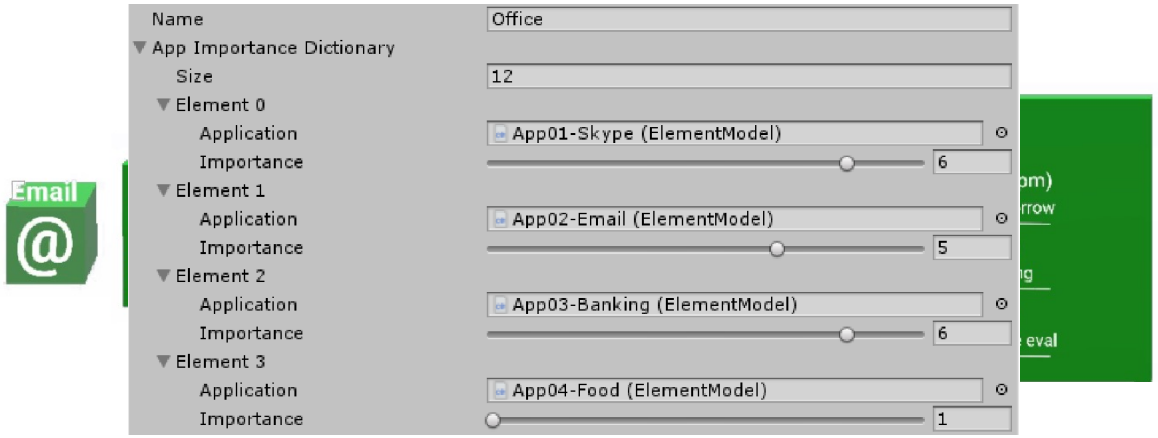
Utility for $t \in [0, 1]$

Usage frequency during $t \in [0, 1]$

Provided by content creators

Measured by system

Input



Cognitive cost of element $\in [0, 1]$

Task t

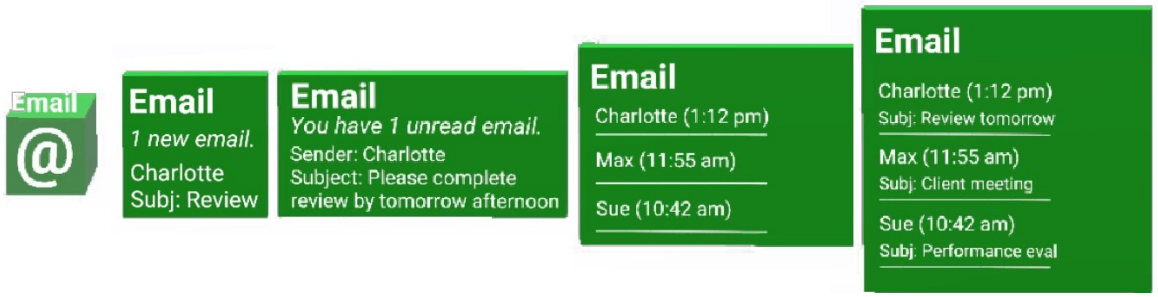
Utility for $t \in [0, 1]$

Usage frequency during $t \in [0, 1]$

Provided by content creators

Measured by system

Input



Cognitive cost of element $\in [0, 1]$

Task t

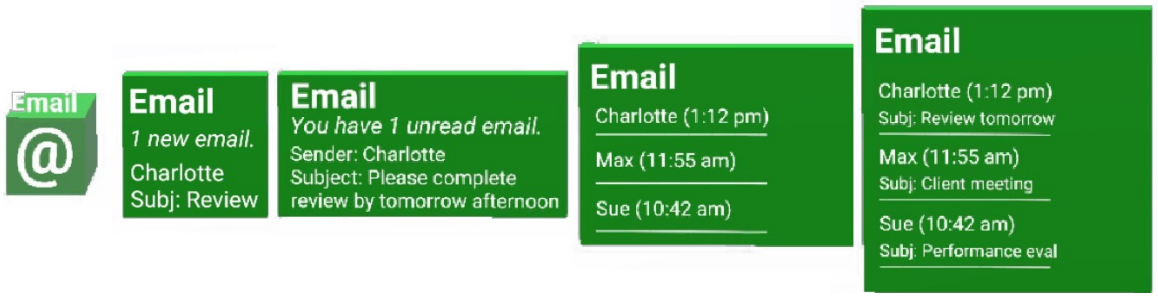
Utility for $t \in [0, 1]$

Usage frequency during $t \in [0, 1]$

Provided by content creators

Measured by system

Input



Cognitive cost of element $\in [0, 1]$

Task t

Utility for $t \in [0, 1]$

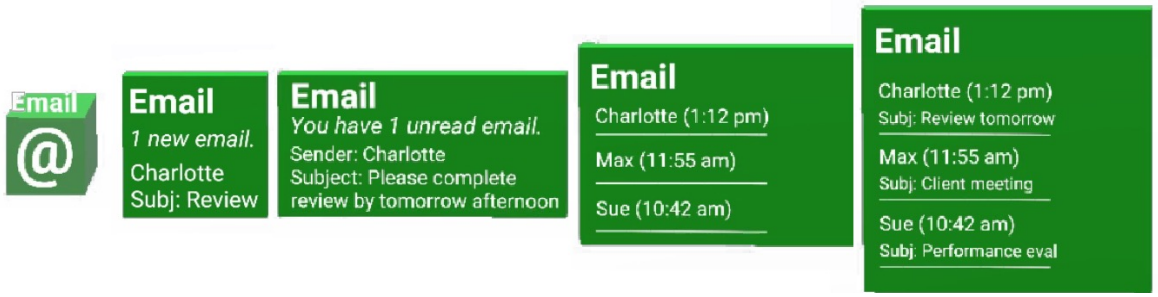
Usage frequency during $t \in [0, 1]$

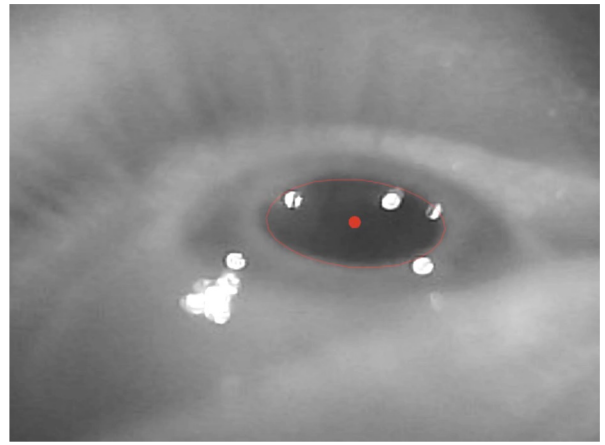
Visibility of element $e \in \{0, 1\}$

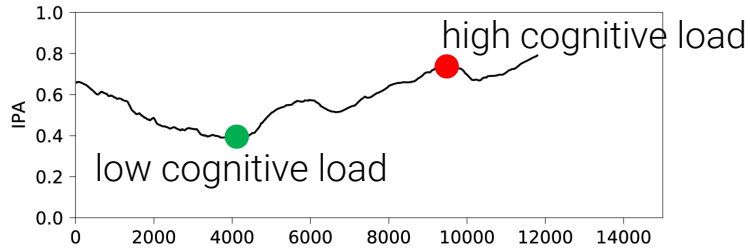
Provided by content creators

Measured by system

Input







[Duchowski et al. 2018. *The Index of Pupillary Activity*]

Cognitive cost of element $\in [0, 1]$

Task t

Utility for $t \in [0, 1]$

Usage frequency during $t \in [0, 1]$

Visibility of element e $\in \{0, 1\}$

Cognitive load estimation $\in [0, 1]$

Provided by content creators

Measured by system

Method

3 step process

1) World-anchored or view-anchored
2) Visibility & level of detail
3) Placement in field-of-view

1) World-anchored or view-anchored

Use knowledge of environment (depth cameras)

World-anchored if elements are visible to users

- Element in field of view
- Element not occluded by other geometry

2) Visibility and level of detail

Integer linear programming to find solution

$$max \sum_{e=1}^{n} \sum_{d_e=1}^{m_e} x_e y_{e,d_e} (p_e + u_{e,d_e})$$

element $x_e \in \{0, 1\}$
level of detail $y_{e,d_e} \in \{0, 1\}$
frequency of use $p_e \in [0, 1]$
utility $u_{e,d_e} \in [0, 1]$

subject to

1) Cognitive load constraint $L_{ext} + L_{vir} \leq L_{max} - \alpha$
2) LoD constraint $\sum_{d_e=1}^{m_e} y_{e,d_e} = 1 \quad \forall e \in 1, \ldots, n$

2) Visibility and level of detail

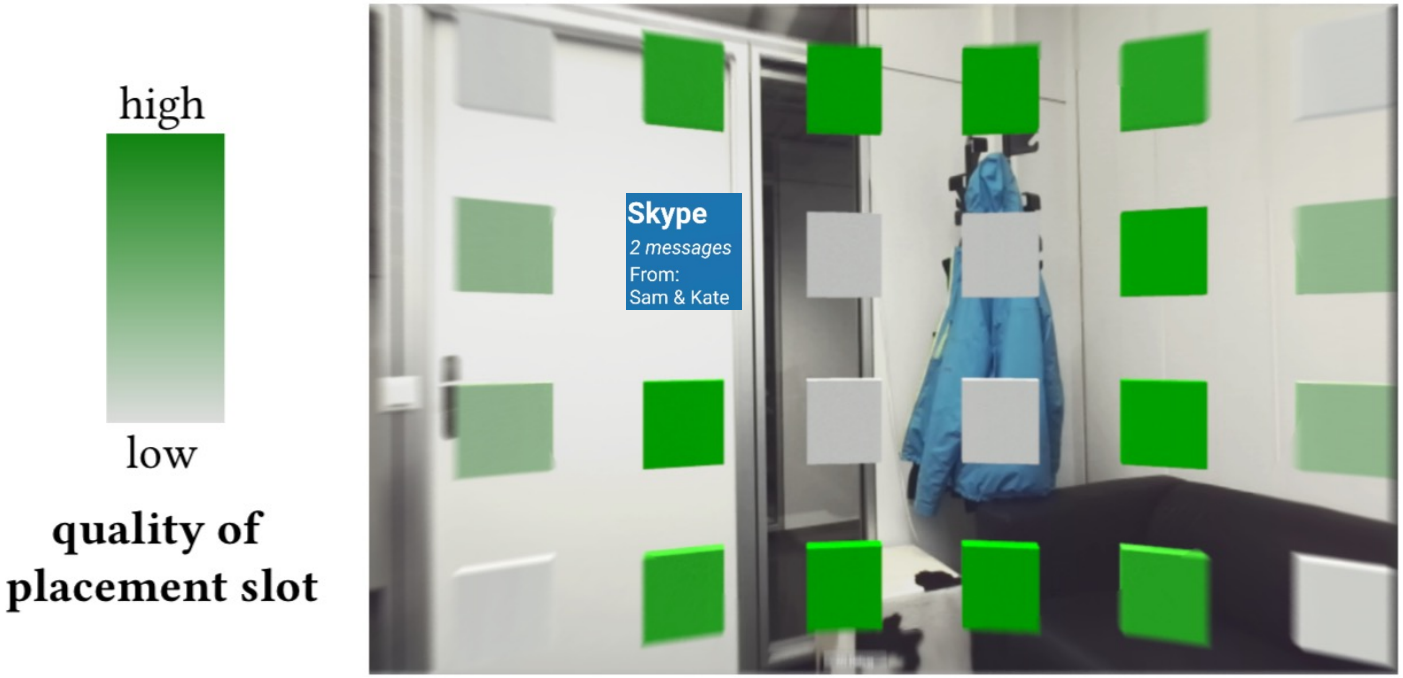
Integer linear programming to find solution

$$max \sum_{e=1}^{n} \sum_{d_e=1}^{m_e} x_{ey_{e,d_e}} (p_e + u_e d_e)$$

Display as many elements with
the highest level of detail
while not exceeding the cognitive load of user.

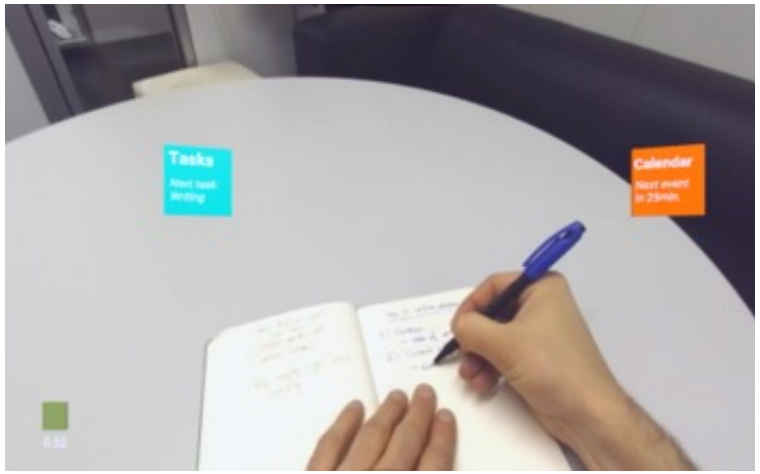
3) Placement in view

Place **view-anchored elements** greedily to best slots

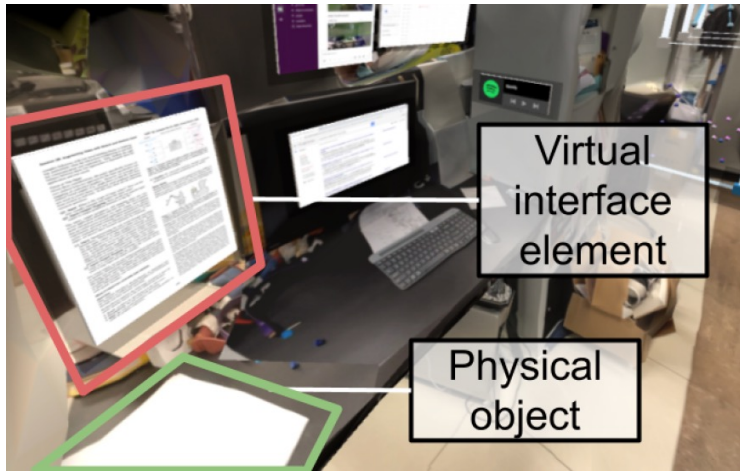


Visualization (debug view) of placement slots

Computational approaches for MR

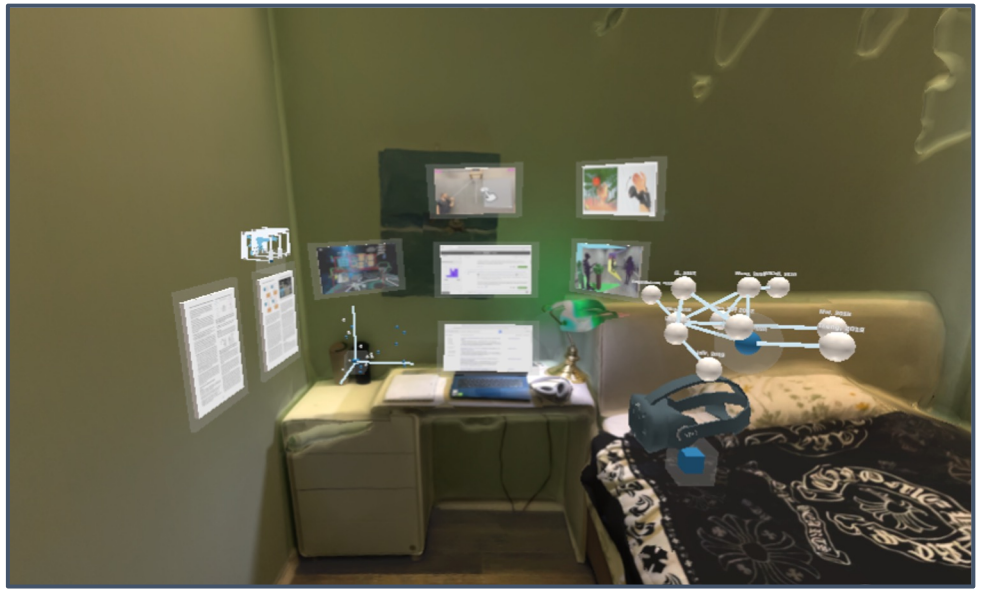


Context-aware MR [UIST 2019]



SemanticAdapt [UIST 2021]

SemanticAdapt

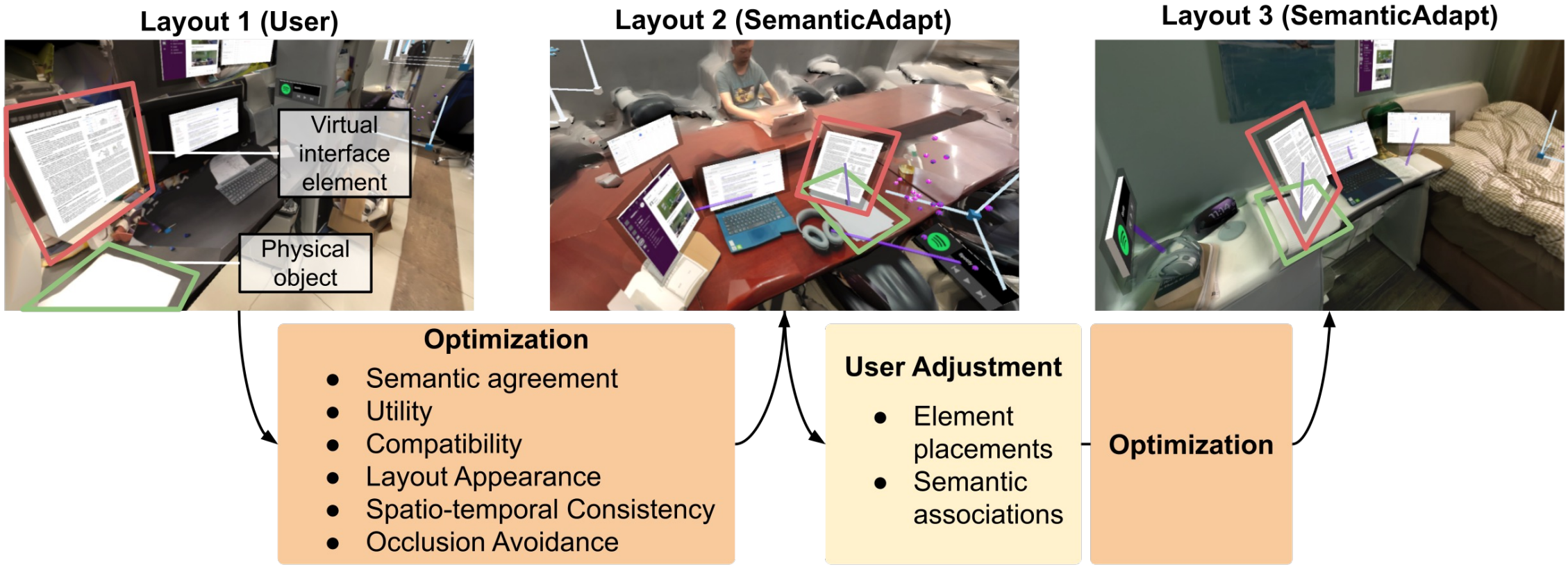


Environment 1

Environment 2

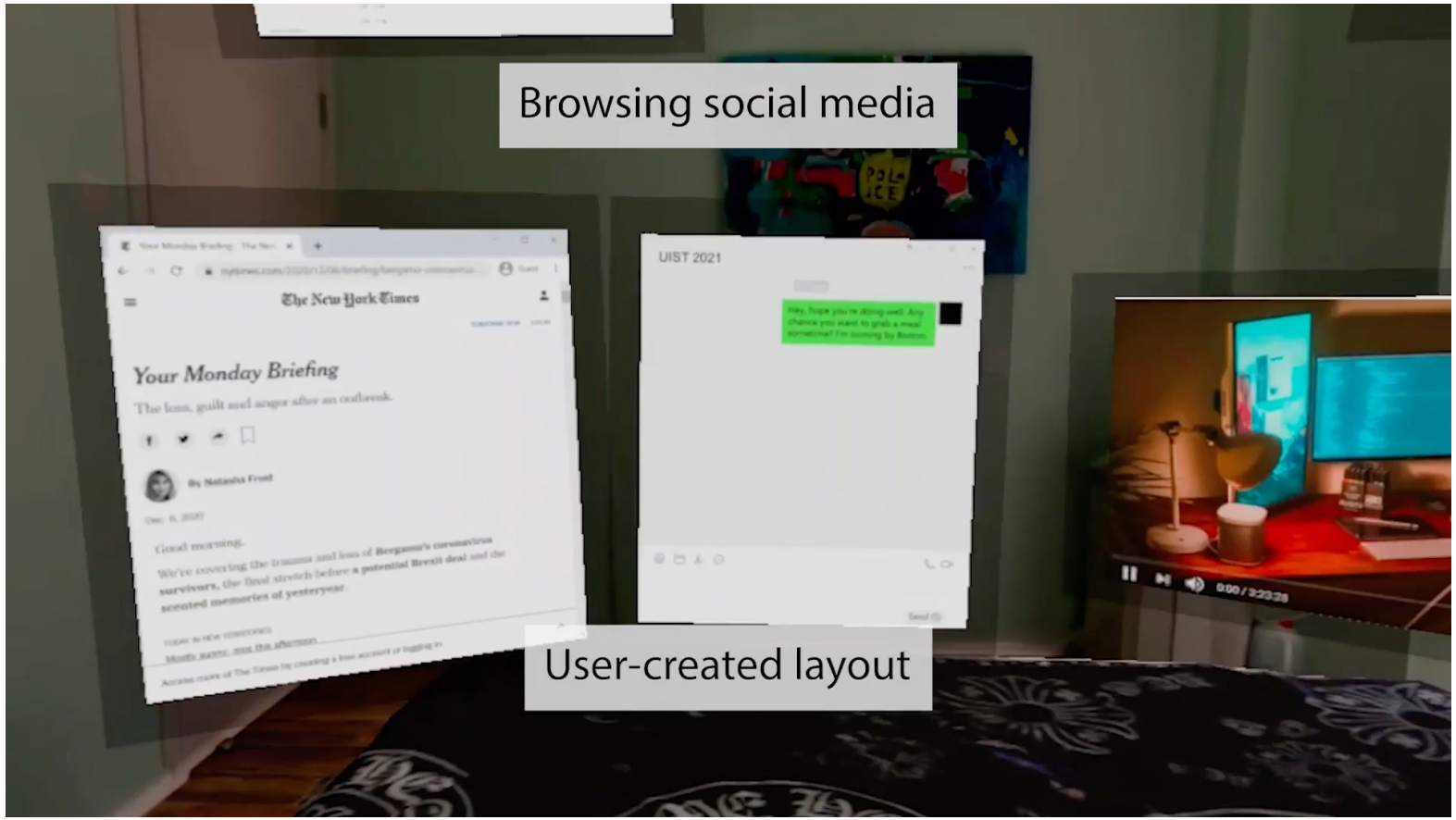
Yi Fei Cheng, Yukang Yan, Xin Yi, Yuanchun Shi, David Lindlbauer. *SemanticAdapt: Optimization-based Adaptation of Mixed Reality Layouts Leveraging Virtual-Physical Semantic Connections*. ACM UIST 2021

SemanticAdapt



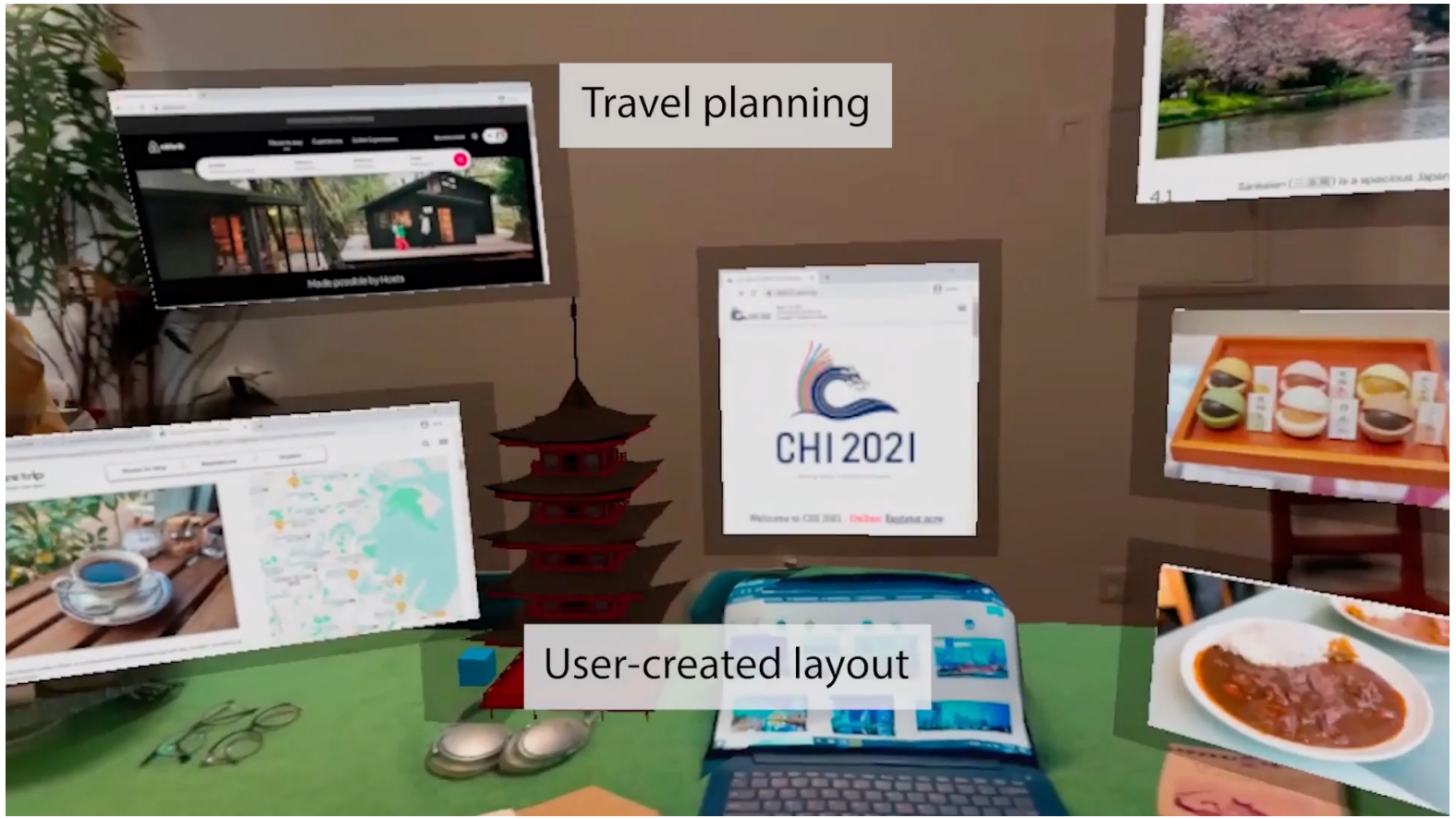
Yi Fei Cheng, Yukang Yan, Xin Yi, Yuanchun Shi, David Lindlbauer. *SemanticAdapt: Optimization-based Adaptation of Mixed Reality Layouts Leveraging Virtual-Physical Semantic Connections*. ACM UIST 2021

SemanticAdapt



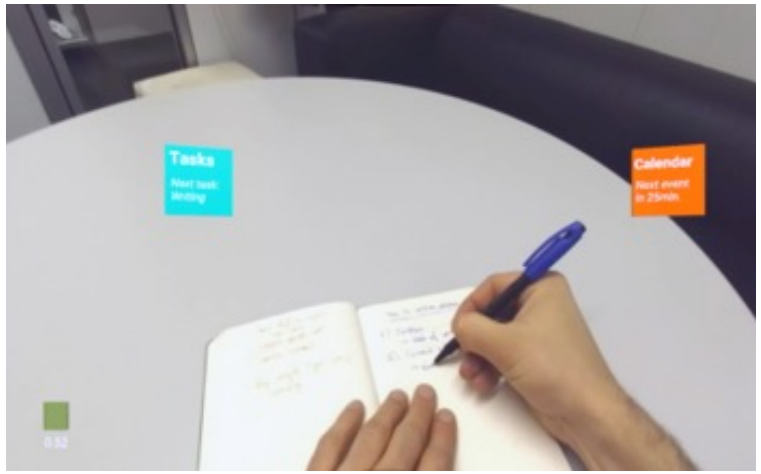
Yi Fei Cheng, Yukang Yan, Xin Yi, Yuanchun Shi, David Lindlbauer. *SemanticAdapt: Optimization-based Adaptation of Mixed Reality Layouts Leveraging Virtual-Physical Semantic Connections*. ACM UIST 2021

SemanticAdapt

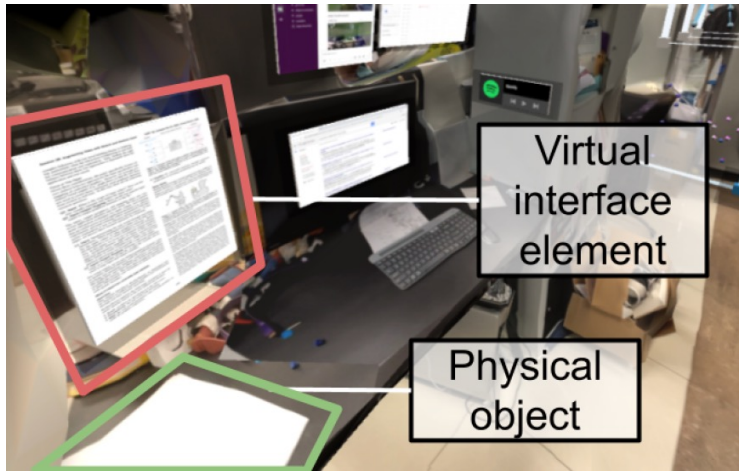


Yi Fei Cheng, Yukang Yan, Xin Yi, Yuanchun Shi, David Lindlbauer. *SemanticAdapt: Optimization-based Adaptation of Mixed Reality Layouts Leveraging Virtual-Physical Semantic Connections*. ACM UIST 2021

Context-aware interfaces



Context-aware MR [UIST 2019]



SemanticAdapt [UIST 2021]

Context-Aware Online Adaptation for MR

Manual design of MR interfaces is **not feasible**

- Jointly optimize MR interfaces for **current context**

User modeling & environment prediction

- Cognitive load estimation is challenging
- Semantic connections are challenging

Users' first

- Predictability is key
- Take preference, capabilities and constraints into account

Key components

Open challenges

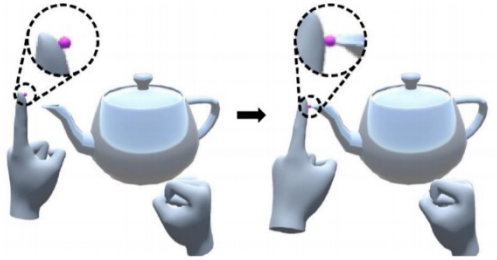
FRL, Holographic Optics

Displays

OpenPose

Tracking

FRL, Holographic Optics



Interaction techniques

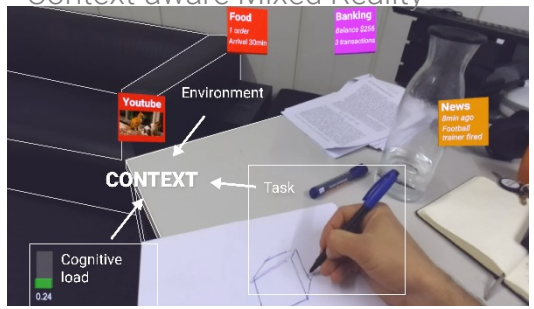
MSR, Capstan Crunch

Haptics & multimodality

Mask R-CNN

Scene understanding

Context-aware Mixed Reality



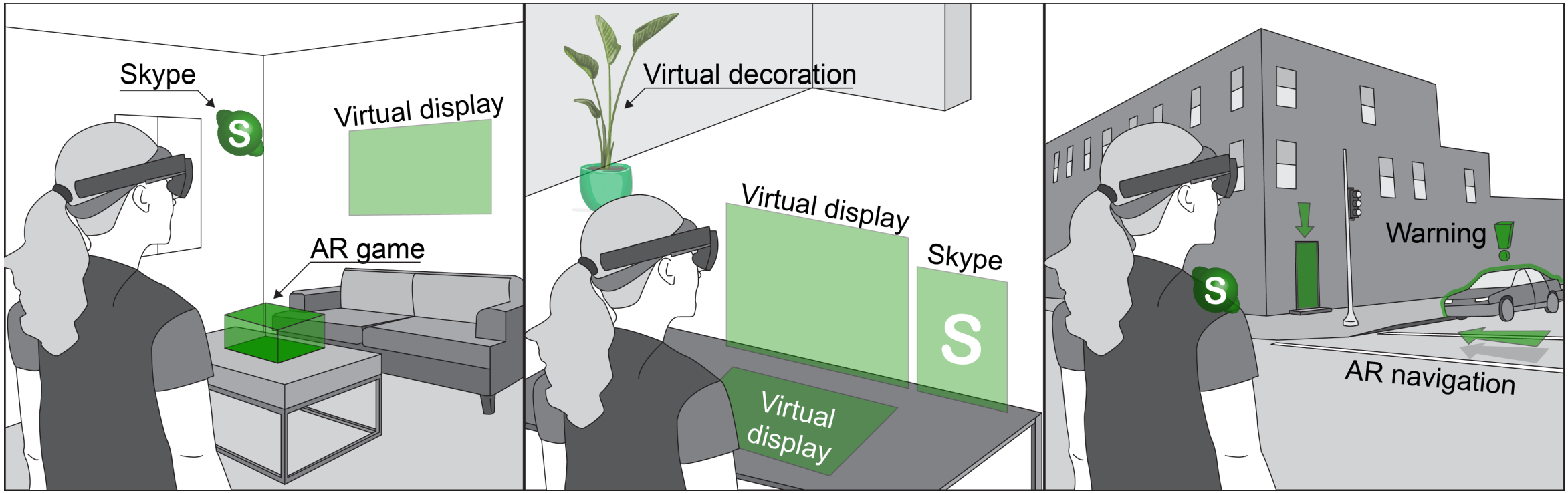
Context awareness

Hardware

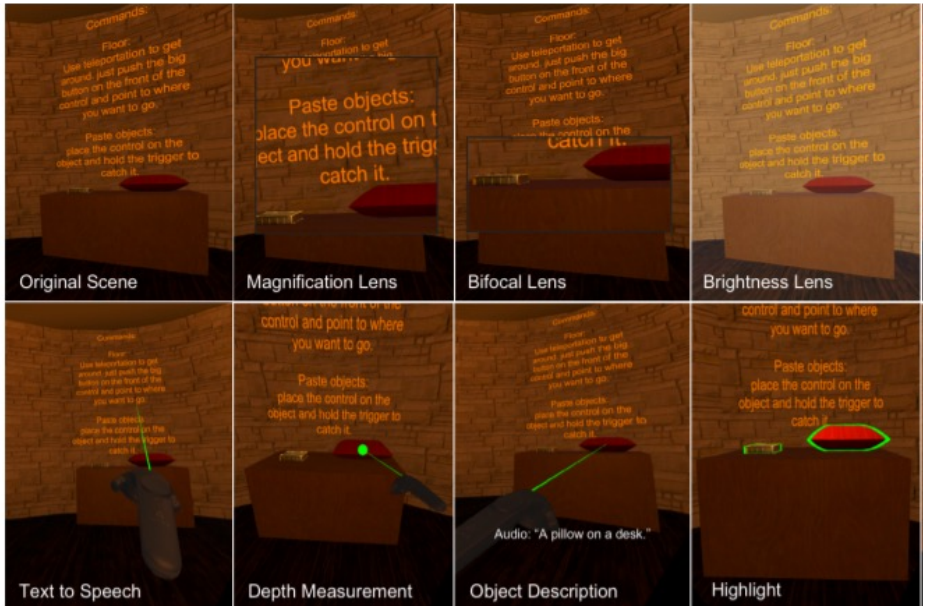
Tracking & sensing

Interaction

Large context changes



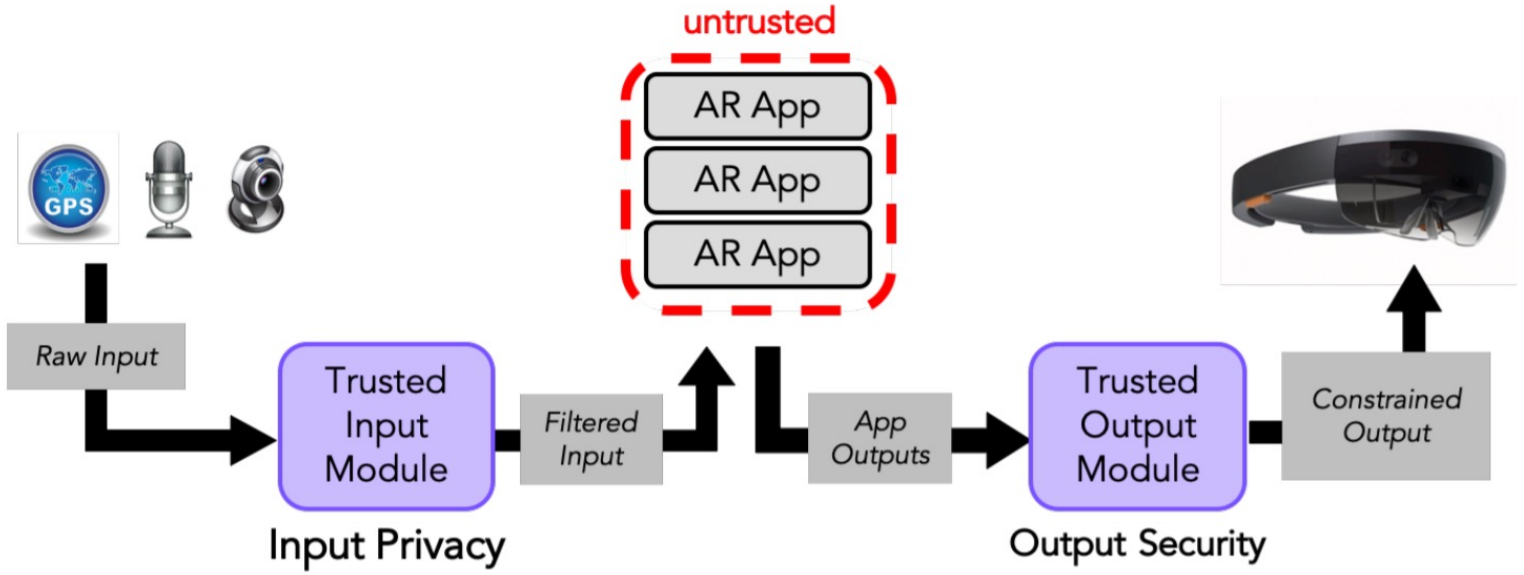
Accessibility + User modeling



Zhao et al., SeeingVR. CHI 2019

Zhao et al., AR Visualizations to Facilitate Stair Navigation. UIST 2019

Privacy



Roesner & Kohno. Security and Privacy for Augmented Reality: Our 10 Year Retrospective. VRSEC @ SOUPS 2021

Be careful what you wish for?

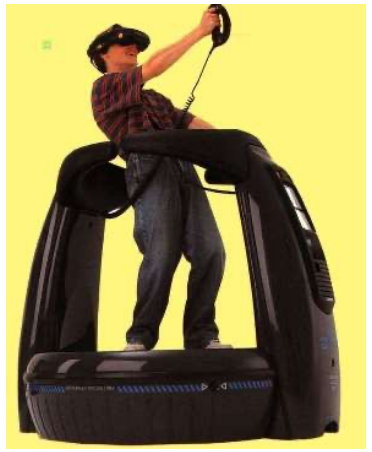
Times Square - Wikipedia

Keiichi Matsuda - Hyper Reality

Exciting times

t-50

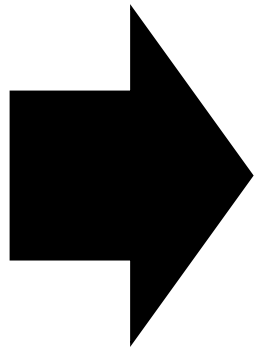
t-40



t-20

t-10

t-0



Automatic Adaptation of Mixed Reality User Interfaces

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