CS3001- CS3606 Advanced Topics in Computer Science and Business Computing

Topic 4 - Mixed Reality

Nadine Aburumman

Immersive Technologies

Virtual Environment

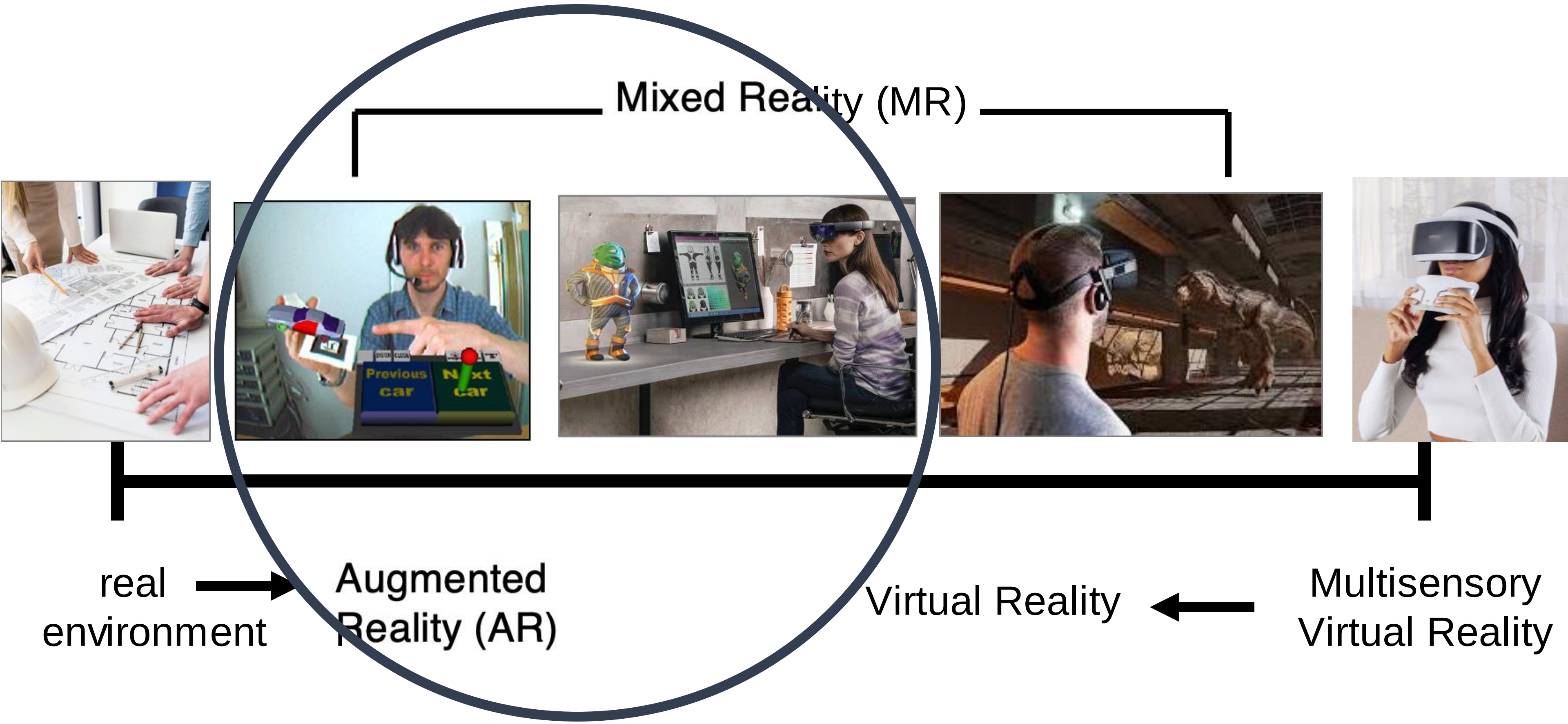
Augmented Reality (AR)

Virtual Reality (VR)

Mixed Reality (MR)

Introductory video can be found (here)

Mixed Reality



Milgram *et al*., "A Taxonomy of Mixed Reality Visual Displays", 1994
IEICE Trans. Information Systems

What will we cover in this Lecture?

(1)

Marker-based Augmented Reality (AR)

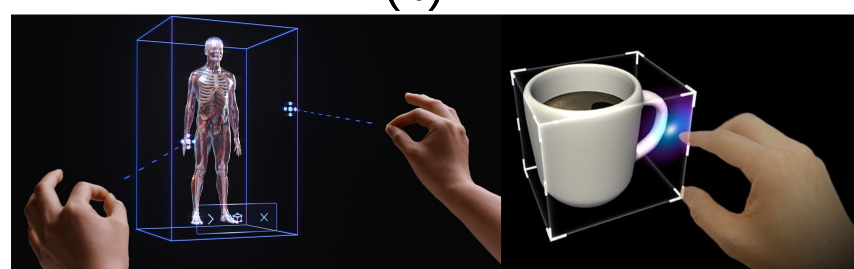
(2)

Markerless-Augmented Reality (AR)

(3)

VisualSLAM

(4)



Mixed Reality (MR)

Marker-based Augmented Reality

video stream from camera

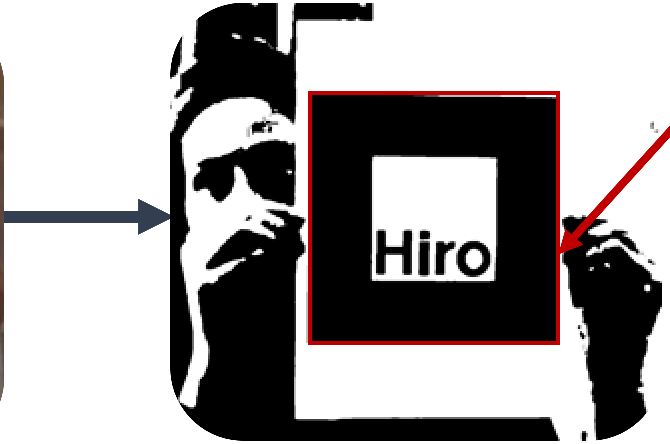
Marker-based Augmented Reality

why is it easy to detect the marker?

video stream from camera

image is converted to binary image and black marker is identified

Marker-based Augmented Reality



why is it easy to detect the marker?

simple computation relies on edge and corner detection

video stream from camera

image is converted to binary image and black marker is identified

Marker-based Augmented Reality

why is it easy to detect the marker?

edge and corner detection:

- surface color discontinuity
- illumination discontinuity

video stream from camera

image is converted to binary image and black marker is identified

Marker-based Augmented Reality

T= {P, R}

3D Transformation =

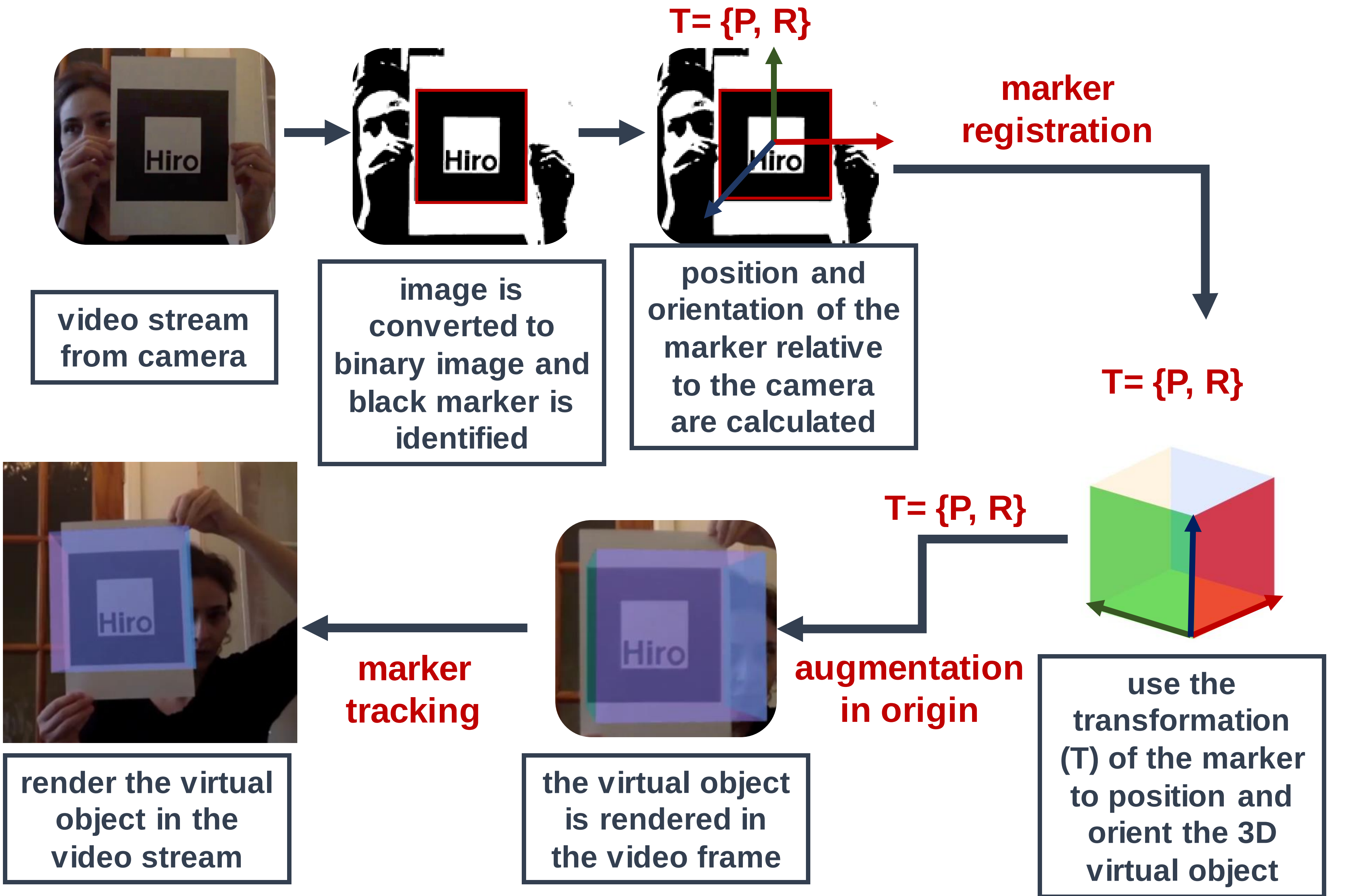
{position and orientation}

video stream from camera

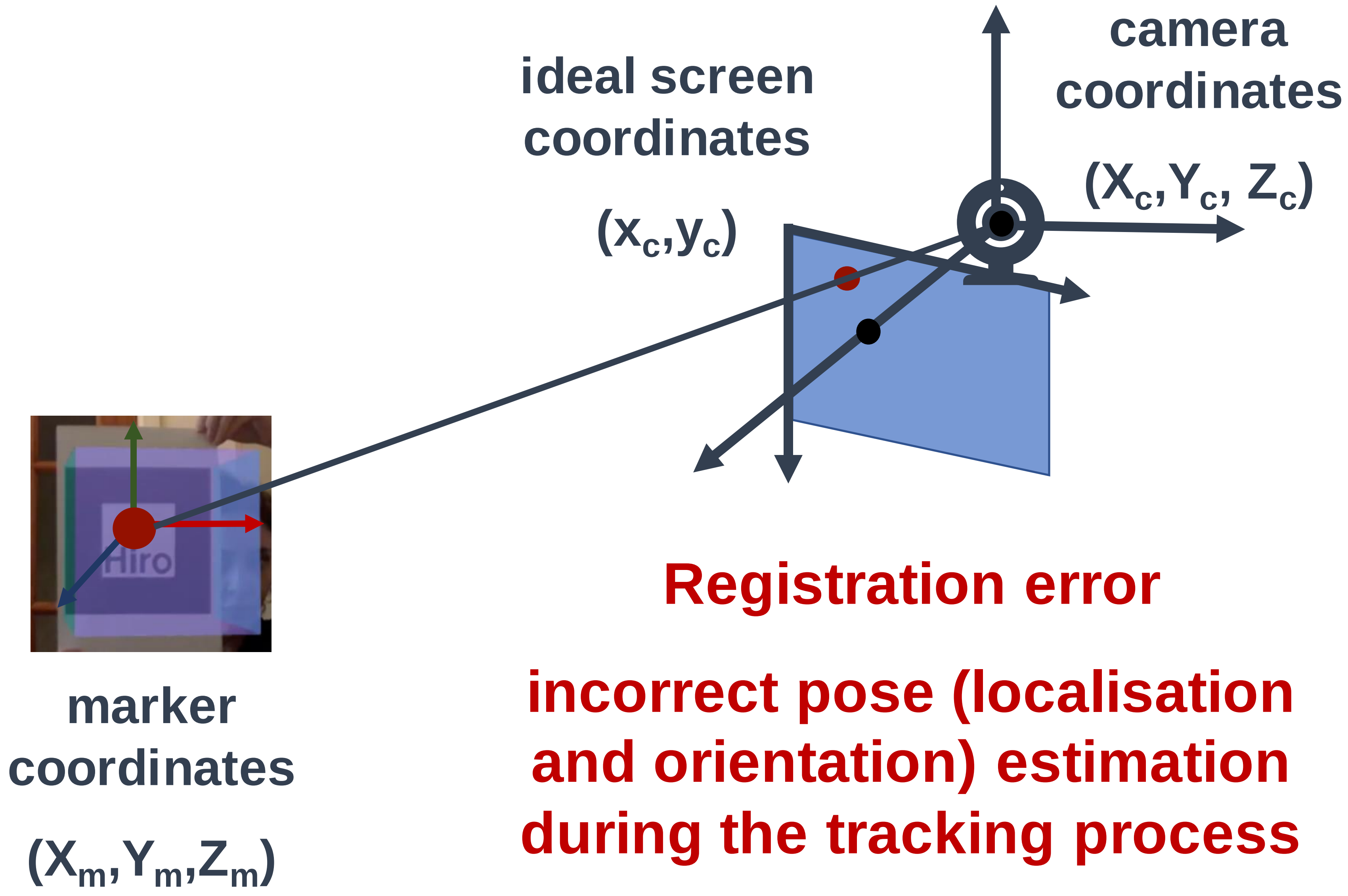
image is converted to binary image and black marker is identified

position and orientation of the marker relative to the camera are calculated

Marker-based Augmented Reality



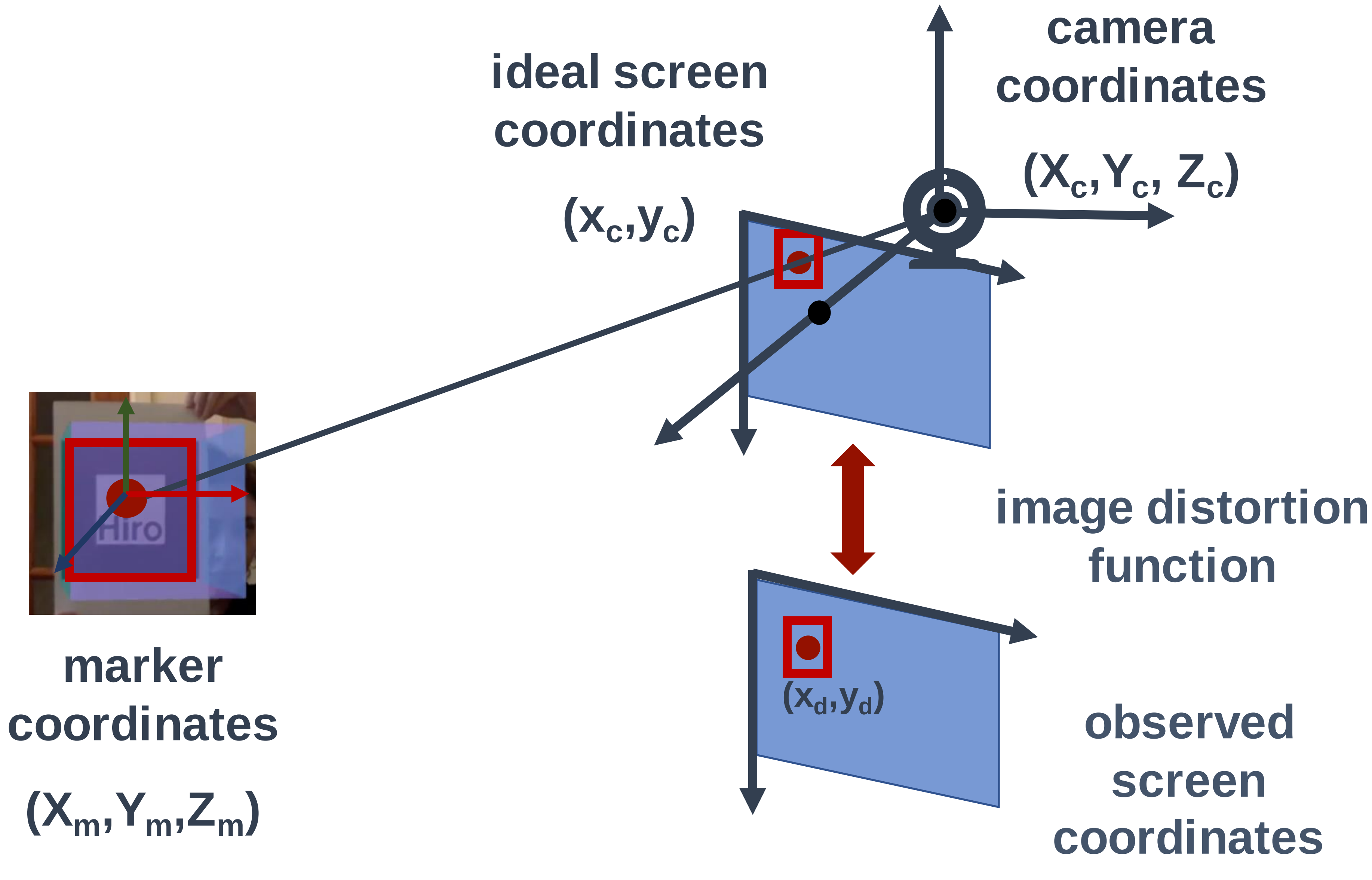
Coordinates for Marker Tracking



Registration error

incorrect pose (localisation and orientation) estimation during the tracking process

Coordinates for Marker Tracking



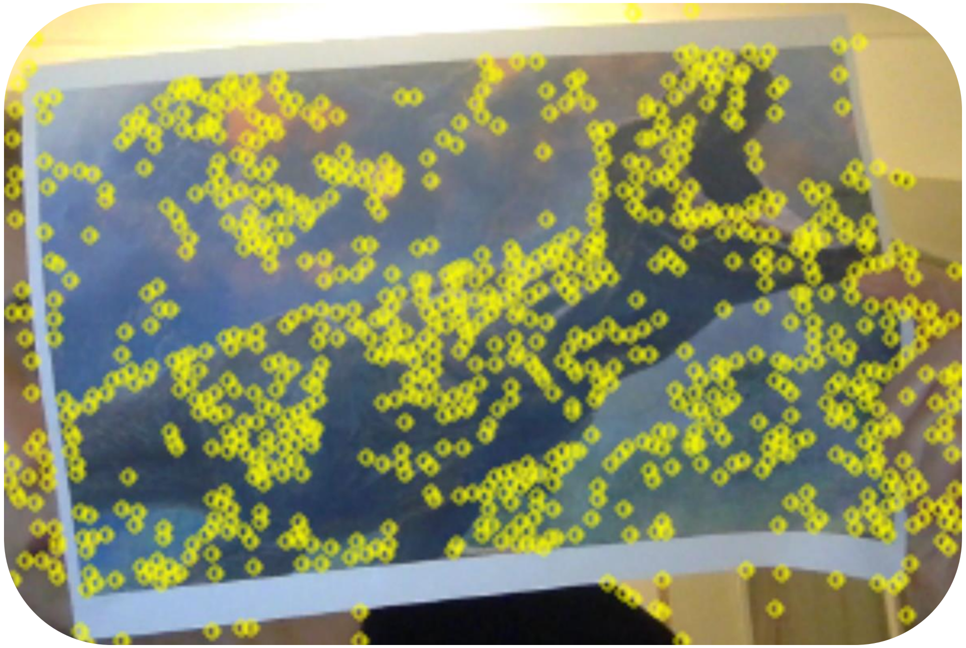
Marker-based Augmented Reality

+

+	−
easy to use and implement	if the camera moves away from the marker, the virtual content disappears
efficient and real-time performance (low latency)	marker must have strong borders and contrast
feature-based tracking, which is very stable	does not work with reflected light
	does not work with occlusion

Marker-based Augmented Reality (Revisited)

Image-based Augmented Reality

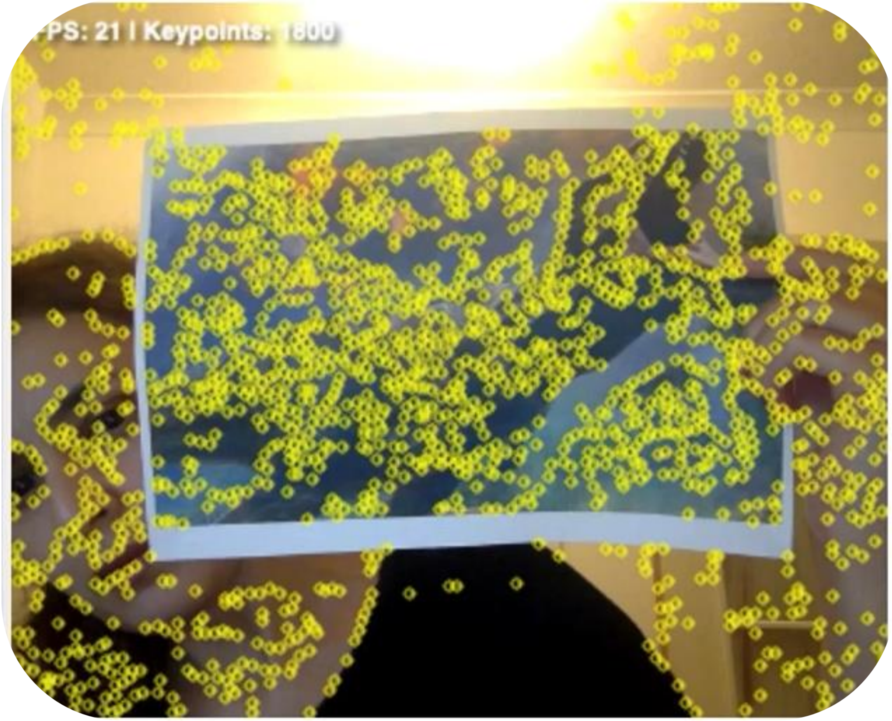


marker as an image

feature detection algorithm

Marker-based Augmented Reality (Revisited)

Image-based Augmented Reality

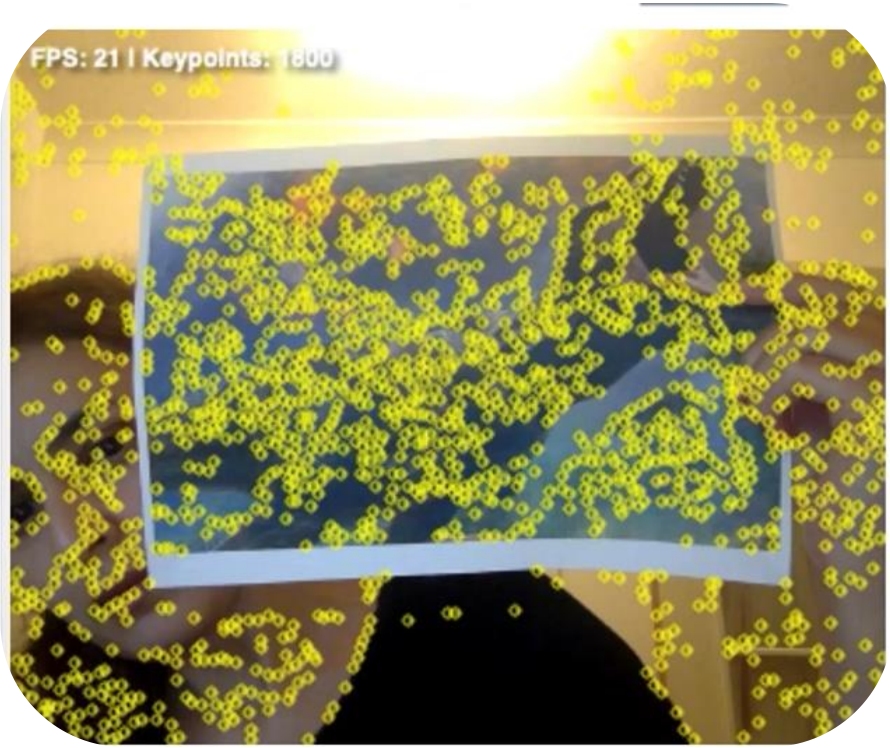


marker as an image

feature detection algorithm (continuous tracking and tracking stability)

Marker-based Augmented Reality (Revisited)

Image-based Augmented Reality



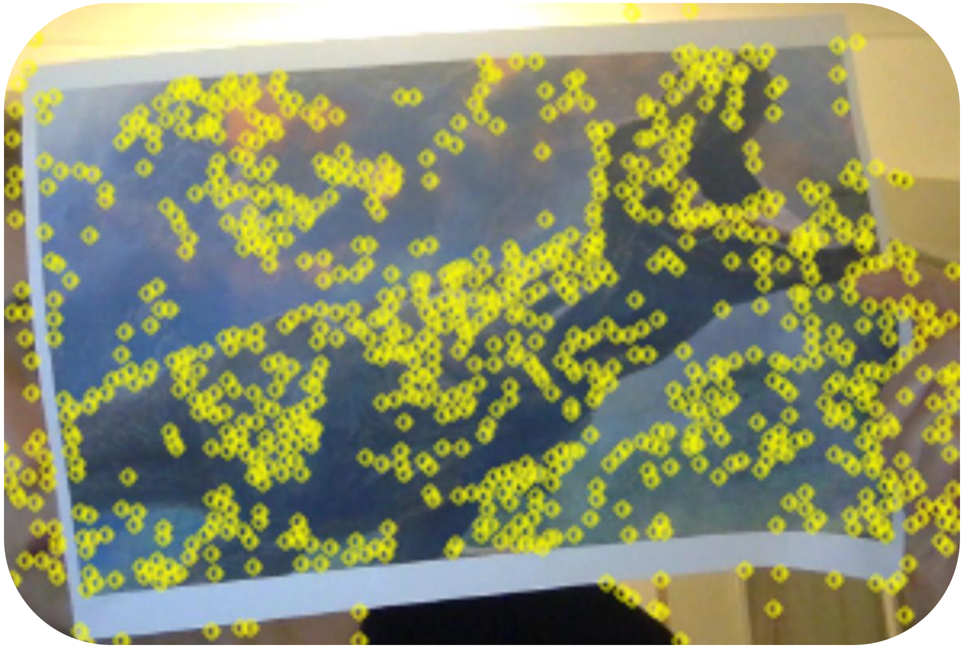
continuous tracking and tracking stability

Challenging, why?

Marker-based Augmented Reality (Revisited)

Image-based Augmented Reality

continuous tracking and tracking stability



Challenging, why?

- keeps continuous track of feature points in each frame with respect to next frame
- keeps continuous track of image pose over time, thus detects outliers (pose calculation/pose estimation)
- frame rate should be slow, the pose may change significantly between frames (augmentation “jumps”)

Marker-based Augmented Reality (Revisited)

Image-based Augmented Reality

continuous tracking and tracking stability

Challenging, why?

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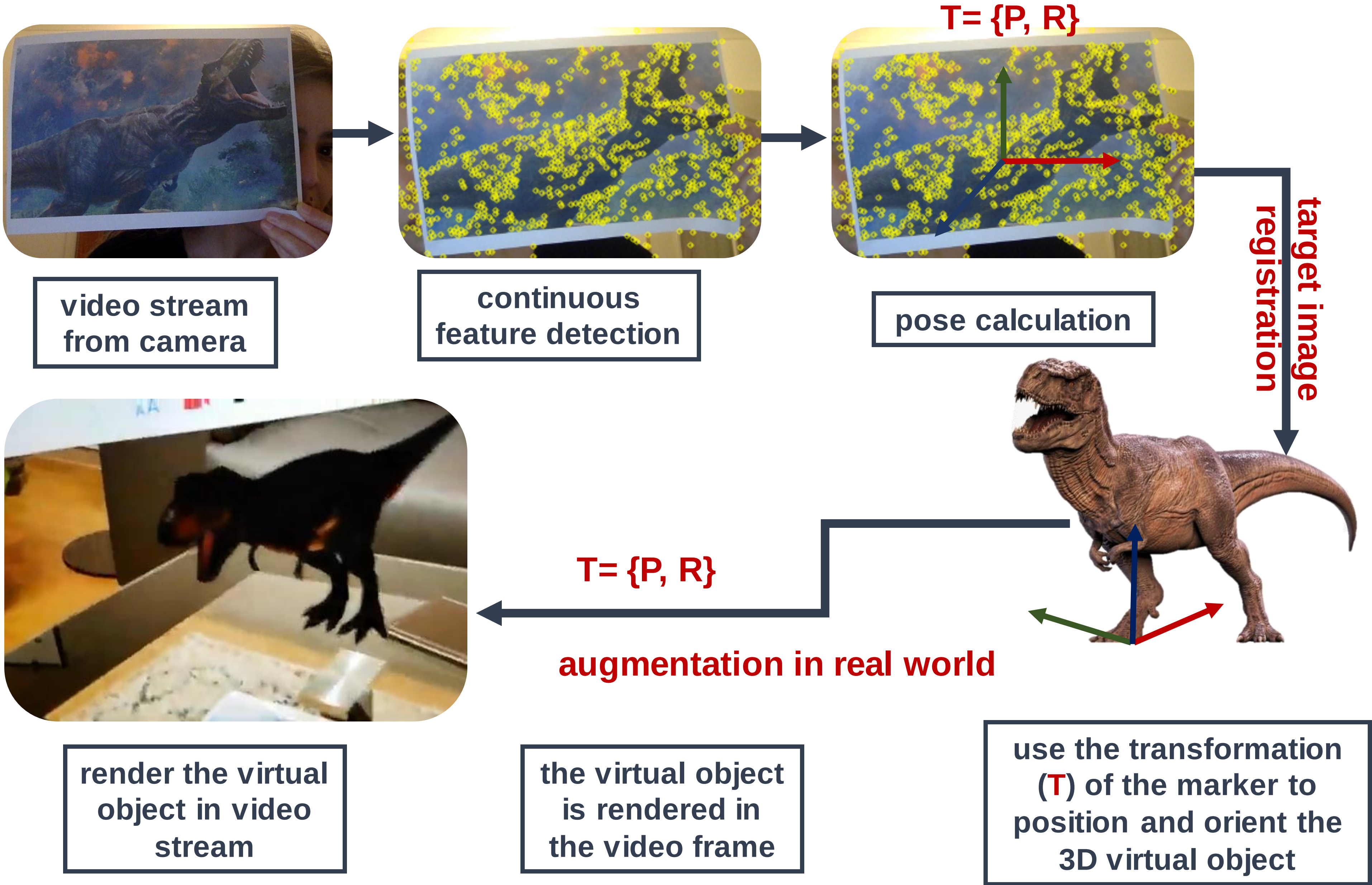
Marker-based Augmented Reality (Revisited)



Marker-less Augmented Reality

my living room

my living room with a T-Rex in it

Marker-less Augmented Reality

Optical Tracking

- marker tracking (e.g. ARToolKit square markers or known features in an image)

my living room

Marker-less Augmented Reality

Optical Tracking

- marker track[illegible]g. ARToolKit square mark[illegible]known features in a[illegible]ma[illegible])

available for more than 10 years

my living room

Marker-less Augmented Reality

Optical Tracking

- **unprepared tracking: tracking in unknown environment (e.g. visual SLAM tracking)**

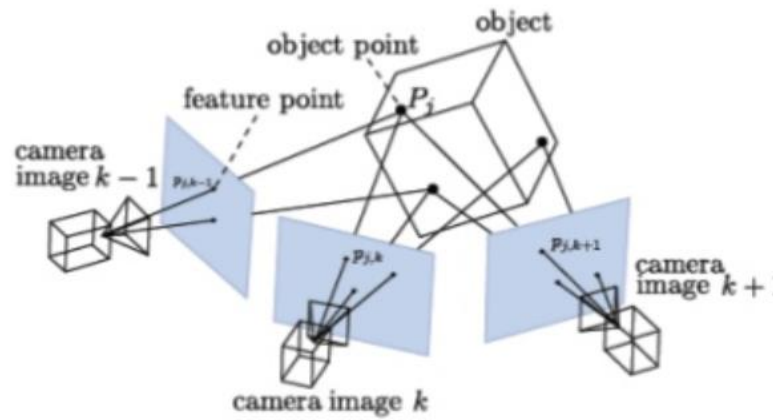
- **SLAM (Simultaneous Localization and Mapping): this is a very important problem in mobile robotics**

my living room

Marker-less Augmented Reality

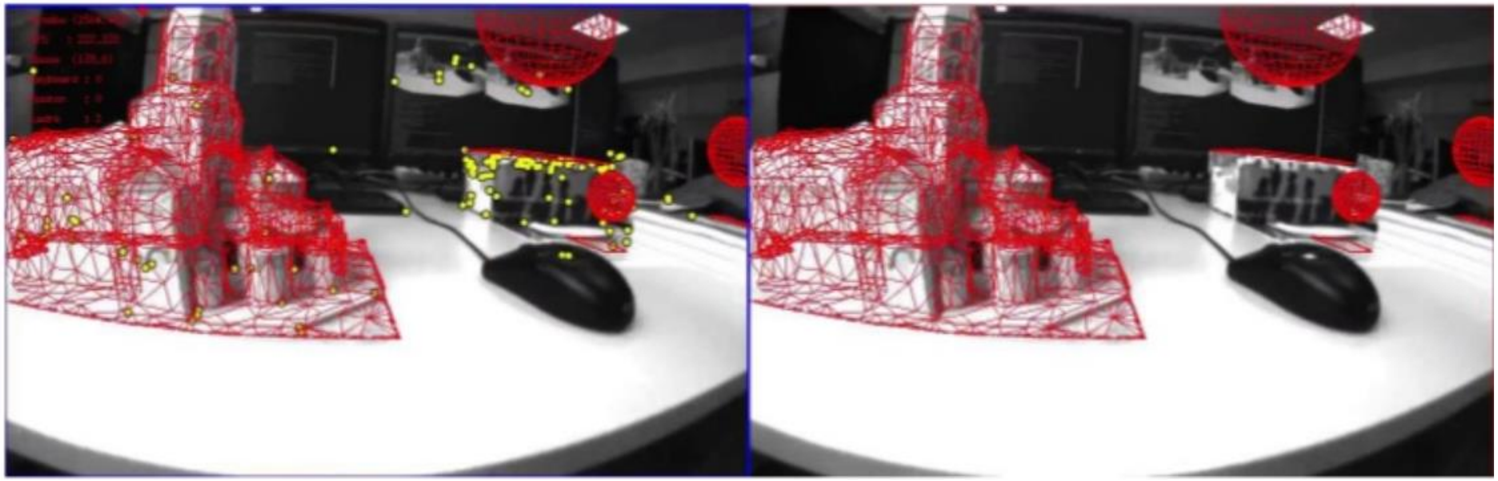
Visual SLAM

- early SLAM system (1986-now)
    - computer vison and sensor
- using cameras only, such as stereo view
- MonoSLAM (single camera) developed in 2007



Marker-less Augmented Reality

Visual SLAM



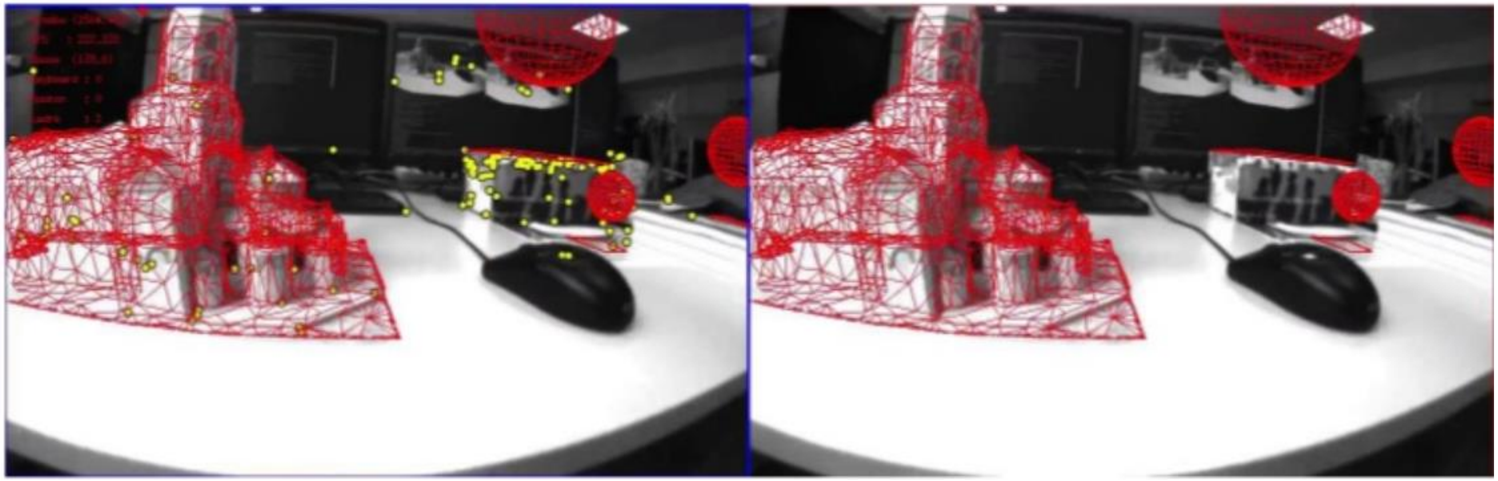
Step 1: tracking a set of points through camera frames

Step 2: using these tracks to triangulate their 3D position

Step 3: simultaneously use the estimated point location to calculate the camera which could have observed them

Marker-less Augmented Reality

Visual SLAM



observing enough points can solve both structure and motion (camera path and scene structure)

Marker-less Augmented Reality

Challenges for Visual SLAM

- camera moves through an unchanged scene
- not suitable for person tracking, gesture tracking
- outdoor tracking

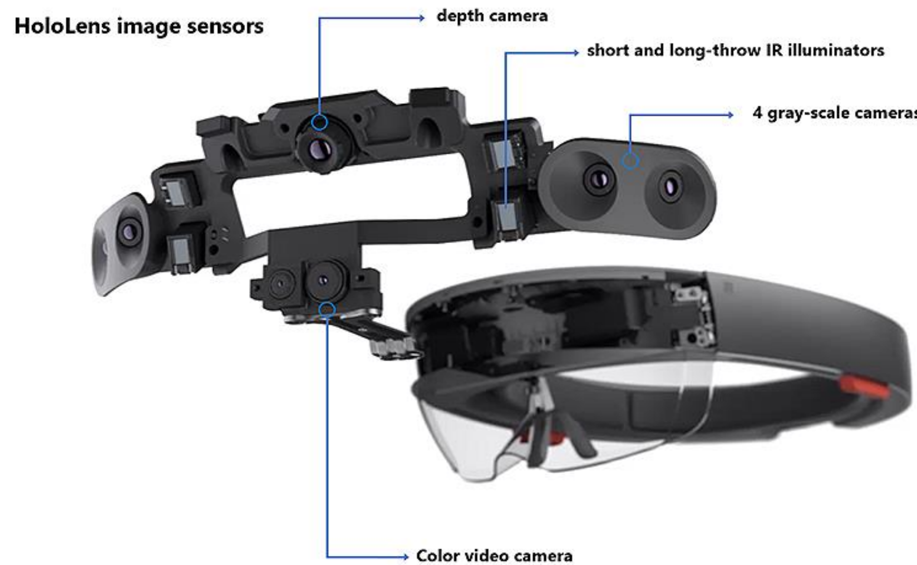
Marker-less Augmented Reality

Visual SLAM

scene understanding

Mixed Reality

See-through display



Aspect Ratio: **3:2**

Resolution: **2K**

Display Rate:**120 - 240Hz**

Mixed Reality

Sensors Calibration

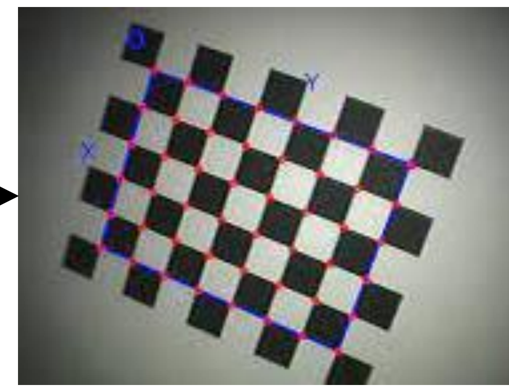
$$\begin{bmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix}$$

Intrinsic properties
(Optical Centre, scaling)

estimates the camera parameters

Mixed Reality

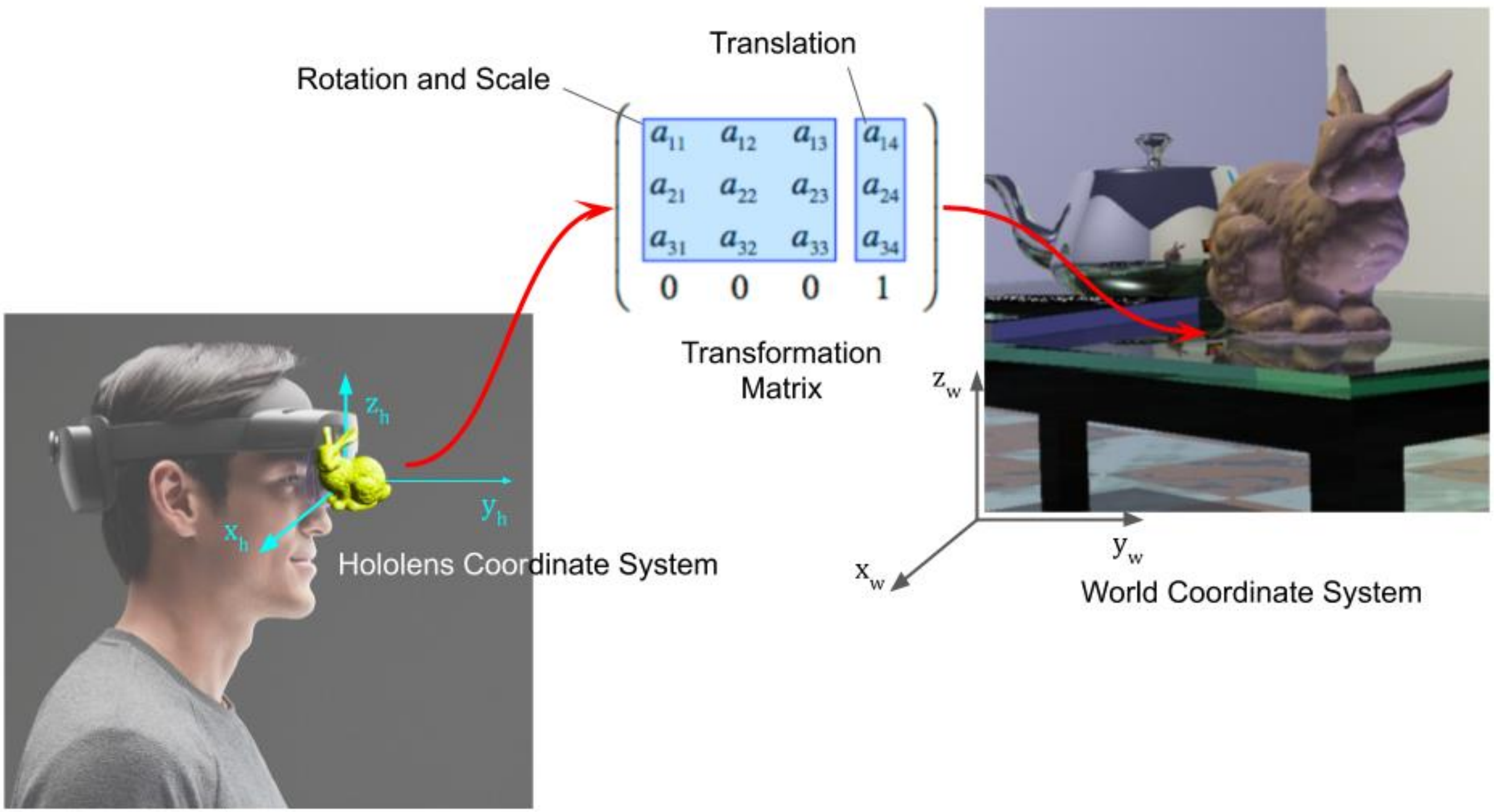
Sensors Calibration



$$\begin{bmatrix} r_{11} & r_{12} & r_{13} & t_1 \\ r_{21} & r_{22} & r_{23} & t_2 \\ r_{31} & r_{32} & r_{33} & t_3 \end{bmatrix}$$

Extrinsic properties
(Camera Rotation
and translation)

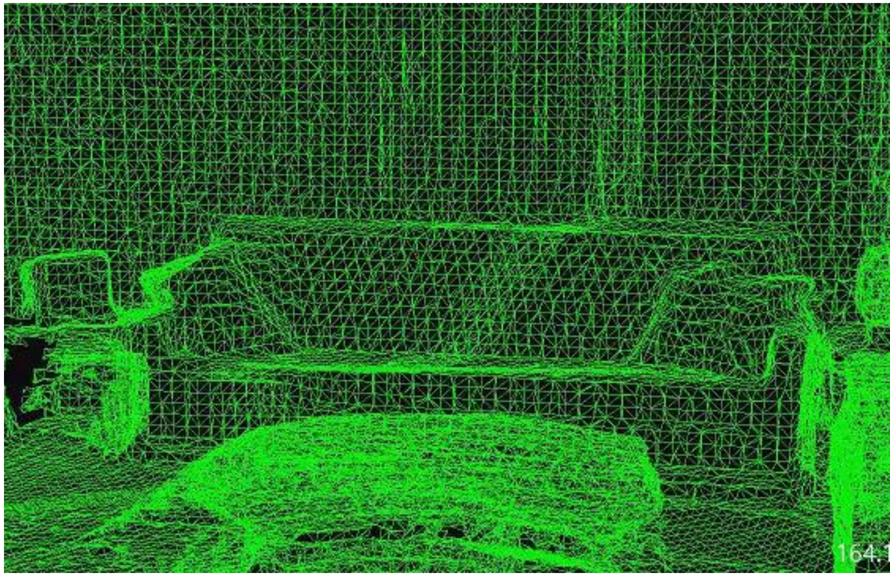
Mixed Reality



Mixed Reality

Spatial Mapping

- **the process of a mixed reality device mapping the real space, for the device to create an understanding of it**
- **a mesh is created that lays over the real environment. A mesh looks like a series of triangles placed together, like a fishing net**



this is done through computational geometry and computer vision (visual SLAM).

Mixed Reality

Spatial Mapping

- **visualisation and navigation**

to position and display the virtual object correctly and grant the virtual object/agent/character the ability to navigate around

Mixed Reality

Spatial Mapping

- **physics and occlusion**

to perform physics simulation, e.g. the virtual object can bounce across the floor

Mixed Reality

Spatial Mapping

https://www.youtube.com/watch?v=zff2aQ1RaVo

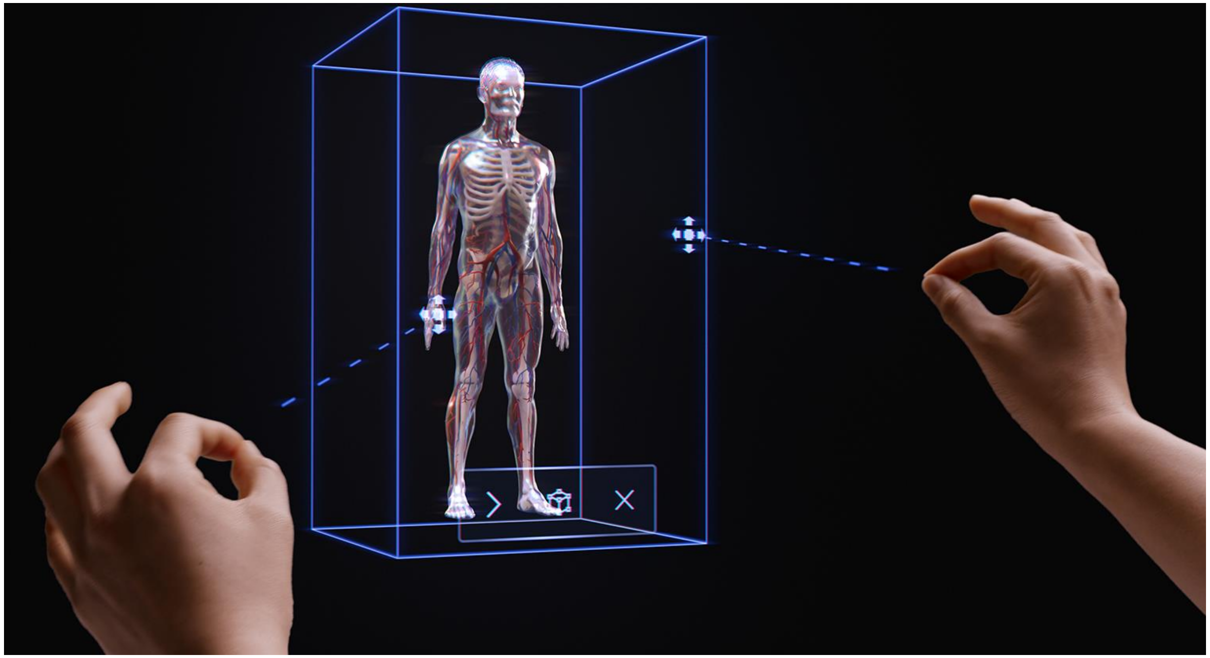
Mixed Reality

Interaction Models

now that you can see spatially registered virtual content in real world, how can you interact with it?

https://www.youtube.com/watch?v=qfONlUCSWdg

Mixed Reality



Mapping Recognition

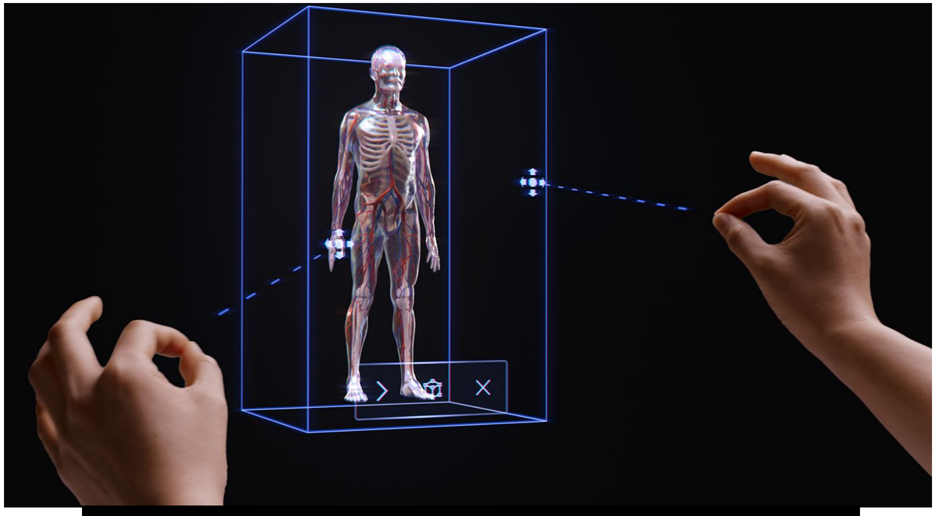
The process of mapping, registration, and recognition of non-static elements of the real world, which allows one to communicate between the real world and virtual objects.

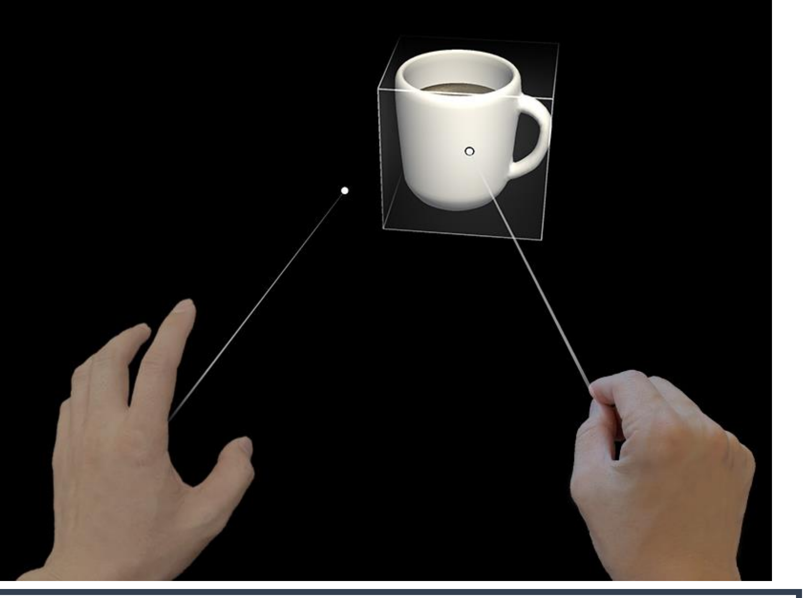
Mixed Reality

Mapping Recognition

- the user's hands are recognised and interpreted as left and right-hand skeletal models

- five colliders are attached to the five fingertips of each hand skeletal model





Microsoft HoloLens

Mixed Reality

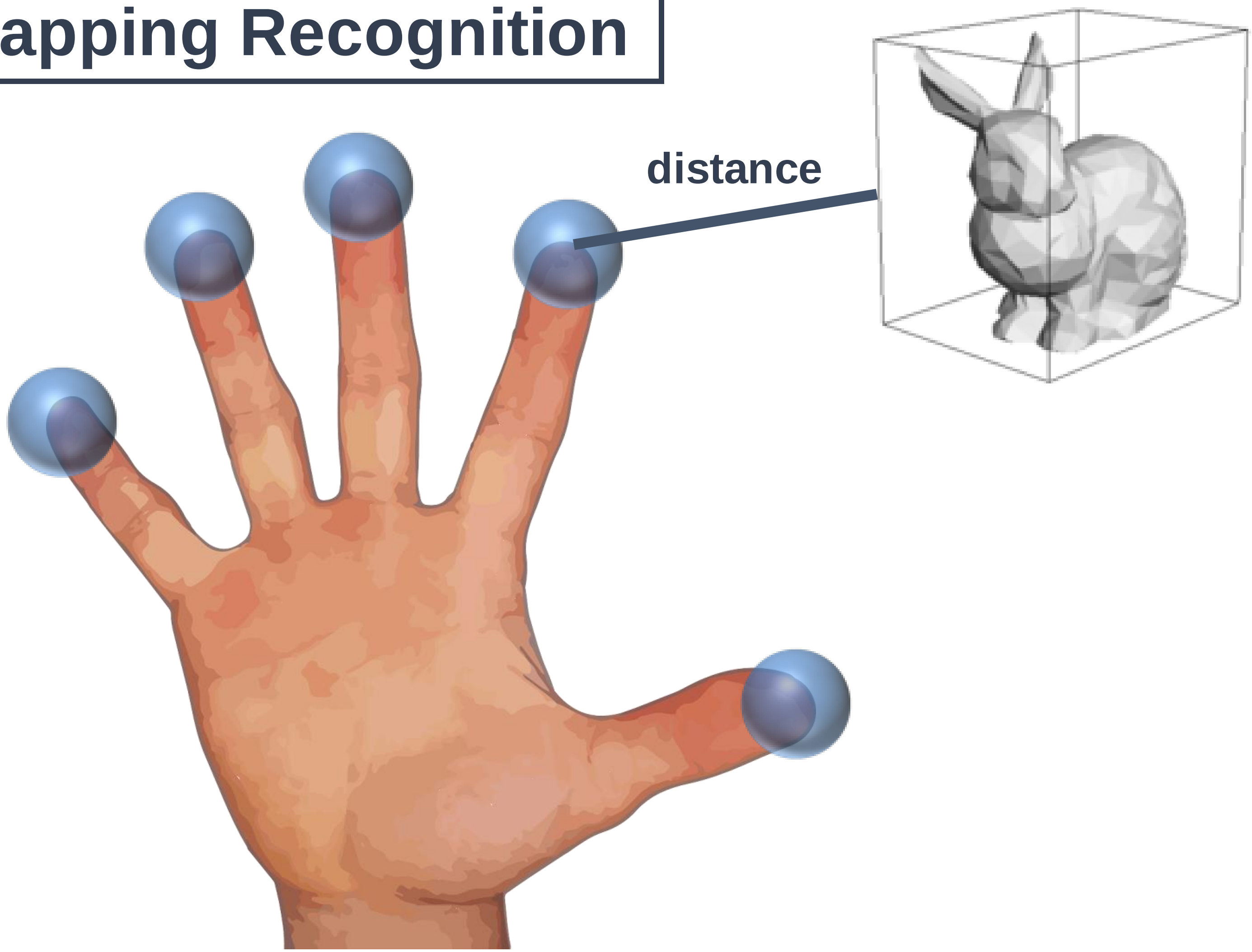
Mapping Recognition

- the collider is a sphere collider, which can be visually rendered to provide better cues for near targeting

- the sphere's diameter should match the thickness of the index finger to increase touch accuracy

Mixed Reality

Mapping Recognition



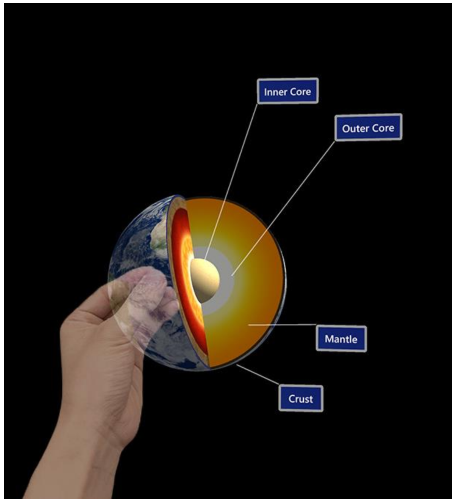
Mixed Reality

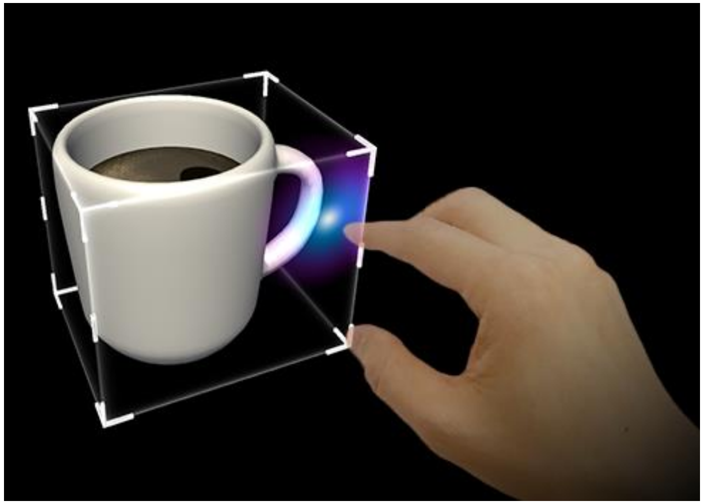
Interaction Models

- direct interaction, where 10 collidable fingertips are used can cause unexpected and unpredictable collisions

- 3D object manipulation using a bounding box

- bounding box provides better depth through its proximity shader





Microsoft HoloLens

Mixed Reality

Interaction Models

- gaze and head interactions (eye and head tracking)
- voice-based interaction

Microsoft HoloLens

Student Led Awards

- Nominations open until March 13th
- Recognise the staff who helped you out!
- Categories including Tutors, Lecturers, Support, Feedback and Diversity.
- https://brunelstudents.com/sla/

References

- Rokhsaritalemi, Somaiieh, Abolghasem Sadeghi-Niaraki, and Soo-Mi Choi. "A review on mixed reality: Current trends, challenges and prospects." *Applied Sciences* 10.2 (2020): 636.

- Speicher, Maximilian, Brian D. Hall, and Michael Nebeling. "What is mixed reality?." *Proceedings of the 2019 CHI conference on human factors in computing systems*. 2019.

- Kruijff, Ernst, J. Edward Swan, and Steven Feiner. "Perceptual issues in augmented reality revisited." *2010 IEEE International Symposium on Mixed and Augmented Reality*. IEEE, 2010.

Questions

Office hours: Monday 2:30 p.m. - 3:30 p.m.

Email: Nadine.Aburumman@brunel.ac.uk

Book an appointment:
https://nadineaburumman.youcanbook.me/