A vision on eXtended Reality from the SUN XR project (Social and hUman ceNtered XR)

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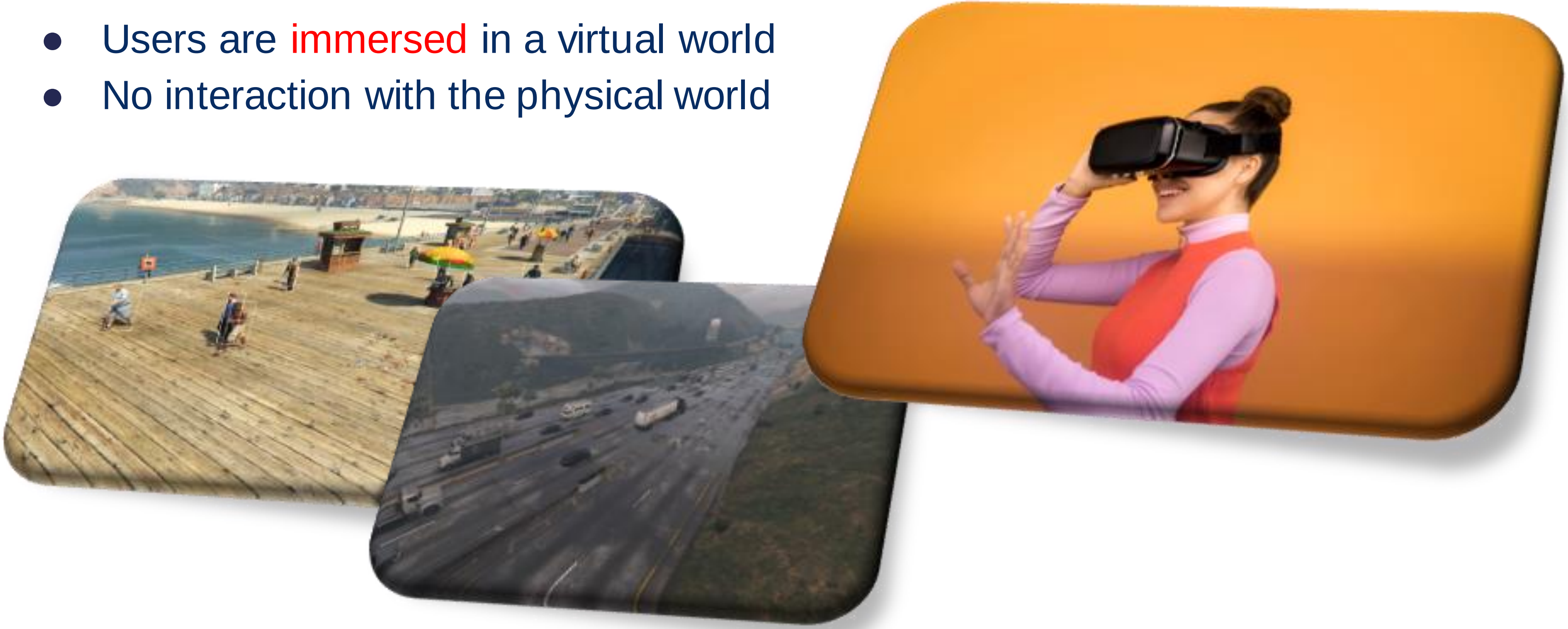
Extended Reality …

- Extended Reality builds on top of
- Augmented and Mixed Reality builds on top of
- Virtual Reality

Virtual Reality

- Users are immersed in a virtual world
- No interaction with the physical world

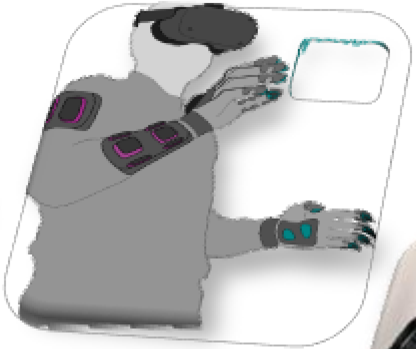


Augmented and Mixed Reality

- Virtual world is fused (overlayed) with physical world
- Mixed Reality users can interact with physical and virtual objects

Extended Reality

- Users can feel (e.g. touch) physical and virtual objects in the two fused worlds
- Virtual objects have physical properties (material/weight/temperature…)
- Sensors transfer data from physical to virtual world



SUN XR Project idea in two sentences

- Overcome limitations in XR to build concrete applications that integrate the physical and the virtual world in a convincing way, from a human and social perspective.

- The virtual world will be a means to augment the physical world with new opportunities for social and human interaction.

Limitations:

Poor scala
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- Starting fr
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- Significant
high cost

Solutions:

Scalable a
cost-effec

- Use AI to in
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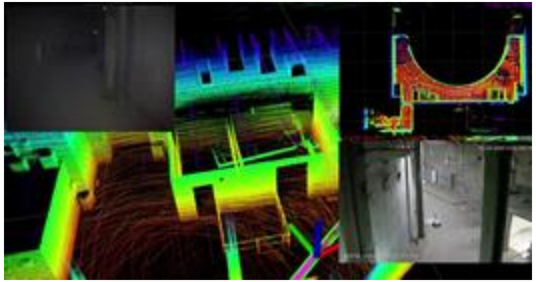
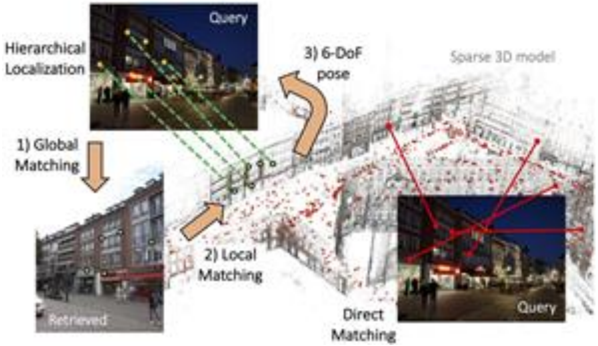
Scalable and cost-effective

- Use AI to incrementally learn and acquire from the physical world
- Learned items should be maintained in a platform and made reusable

Environment Exploration (CNR)

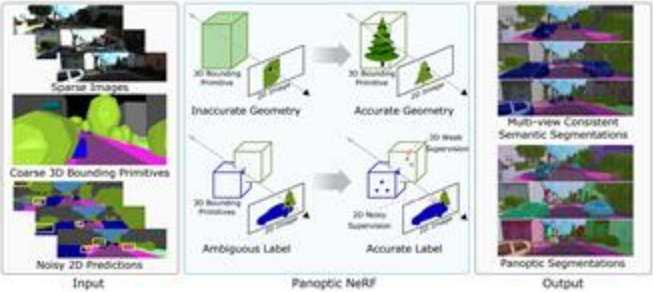
- Dynamic Exploration of Unknown Environments
  - Discovery strategy based on Reinforcement Learning
    - Learn on pre-built 3D architectural plants
    - Learn to build occlusion maps
    - Discover probability maps
  - Coarse Scene Reconstruction
    - Monocular / Stereo / Depth SLAM
    - Handle dynamic scenarios
    - Remote / On-Board
  - Map Localization
    - Based on few images
    - Sensor assisted positioning





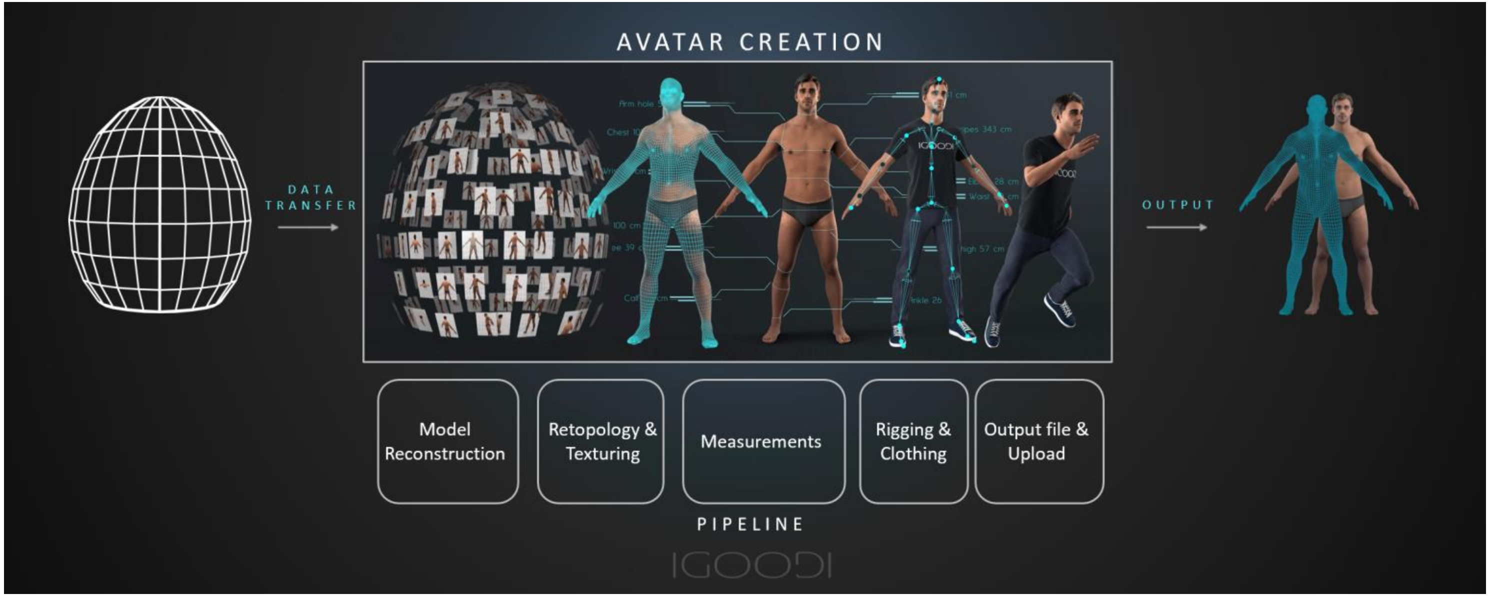
Exploit Semantic Priors (CNR)

- Semantic Priors for Fine Reconstruction and Interaction
  - Pre-Built Library for 3D Objects
    - 3D Dataset Creation
  - Object Identification
  - Pose Detection
  - Real-Time Visualization & Interaction



Mass scale Avatar production (IGOODI)

- Mass scale Avatar production with proprietary bodyscanner
- Semiautomated pipeline with minimal human artistic intervention



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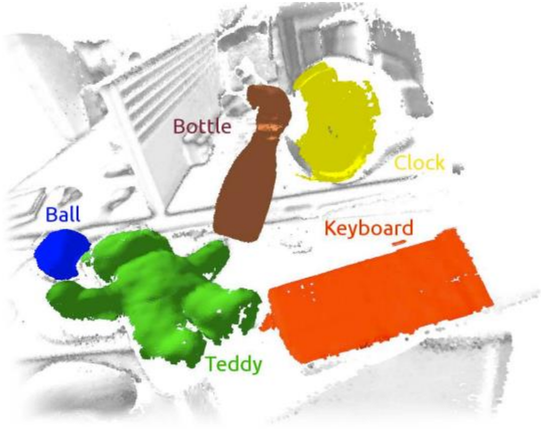
Convincing mixing of physical and virtual world

- Objects in the physical world should have digital twins with physical and semantic properties
- AI to give virtual objects the same behaviour than the physical ones

AI to Learn Objects from the Physical World (CNR)

- Main idea: Employ AI to **incrementally**
  1. find/detect/segment
  2. learn/recognize/describe

  objects in data streams in the most **unsupervised** way.
- Build an incremental DB of object descriptors
- End-to-end Continual/Lifelong Object Learning



- Challenges addressed:
  - Open-vocabulary object detection/segmentation: improve on fine-grain queries
  - Multi-modal fusion for semantic 3D understanding: go towards real-time usage

Acquisition of physical properties for 3D objects (CNR and SSSA)

- Innovative techniques to acquire or estimate the physical properties (like mass distribution or stiffness/softness) of 3D objects

- Creation of 3D objects with phisical/semantic properties to insert in the environment, for recreating convincing interaction experiences.

Acquisition of physical properties for 3D objects (CNR and SSSA)

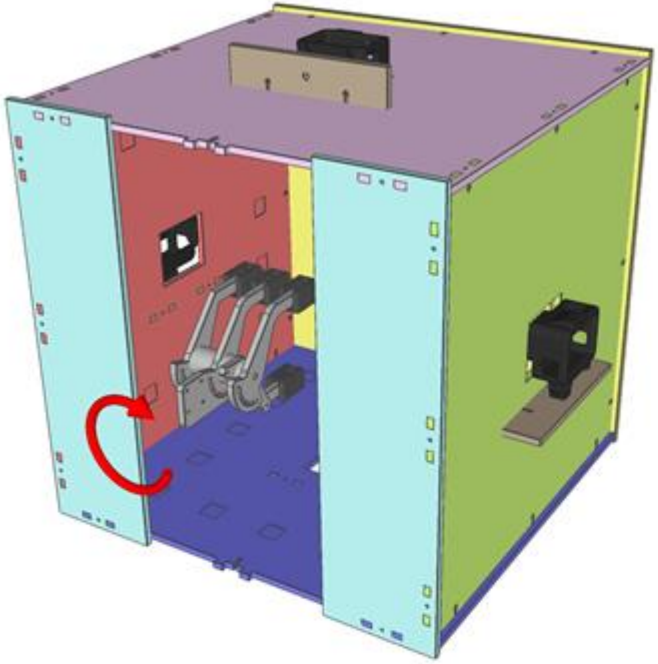
Sensorized passive gripper (SSSA)

- Equipped with flat pressure sensors
- Fixed grasping pressure and and contact points during the acquisition
  - Spring loaded thumb
  - Tunable offset finger positions

Acquisition of physical properties for 3D objects (CNR and SSSA)

Image based acquisition device

- Plywood box with 4 action cams for marker based acquisition of the manipulation of the object with the gripper
- Manipulation by rotation of the gripper with a stepper motor
- Synchronization of the cam acquisition with the stepper motor and the pressure sensor reading



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Plausible human interaction

- Wearable haptic interfaces
- Multisensory feedback with 3D objects
- Gaze and gesture based interaction via AI and computer vision

Haptic devices (SSSA)

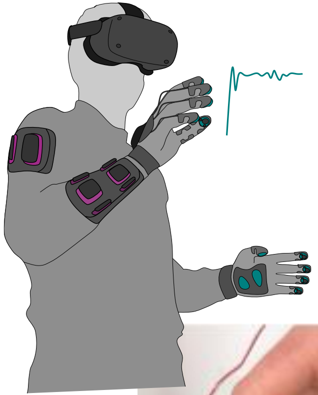
Development of highly wearable and miniaturized devices to deliver high quality haptic feedback to the user. Development of the Brain-Body-Machine-Interface.

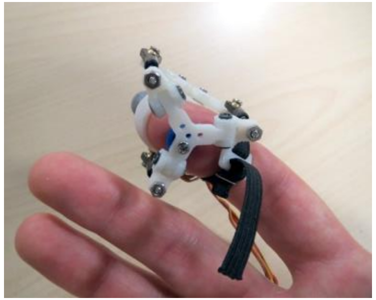
Proposed research/activity direction

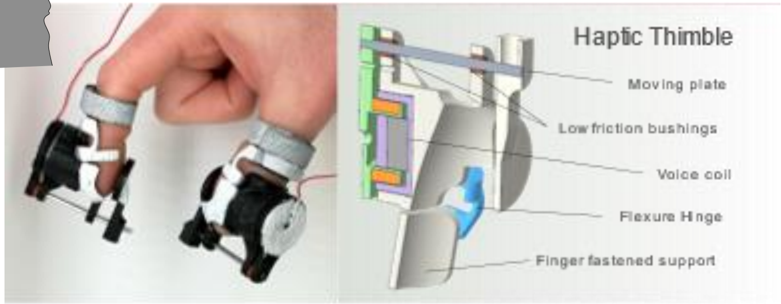
- Orienting the research and design towards wearability and quality of signals rather than bare intensity
- Reducing dimensions /increasing ergonomy with mixed soft and rigid materials (SLA printing)

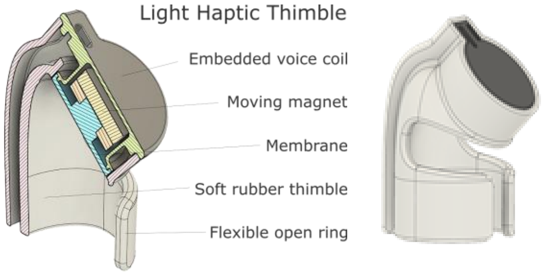
Challenges

- Trade-off between the complexity of haptic feedback and wearability/comfort of the haptic device (hand and fingerpads)
- Adaptability to different users







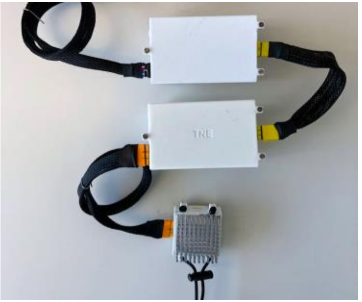


Haptic Interfaces: thermal feedback (EPFL)

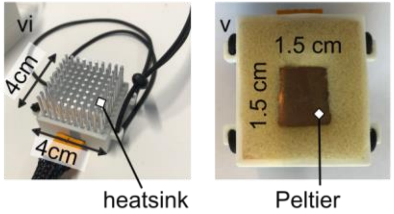
- Goal: provide realistic temperature sensations
- Development of a portable prototype
  - Heating/cooling the skin of the user in a non-painful range (15°C-40°C)
  - Mounted on the arm of the wearer

- Required developments
  - Miniaturization of the system
  - Improvement of the software interface

Thermal feedback system

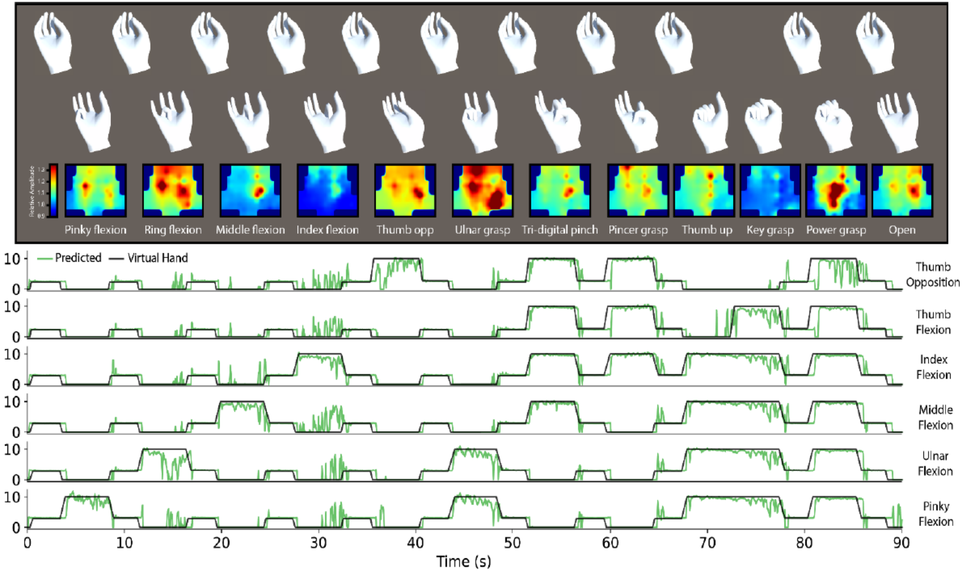


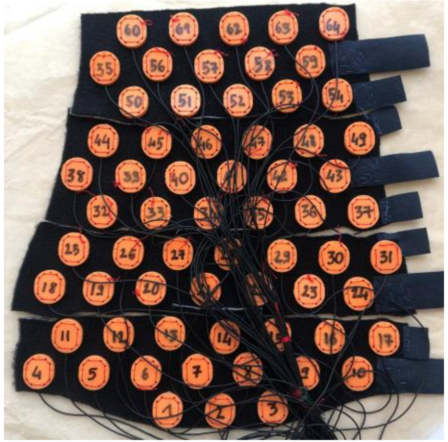
Thermal display



Haptic Interfaces: EMG Decoding (EPFL)

- Characterization of Medium Density EMG setup
- Higher performance than standard EMG systems



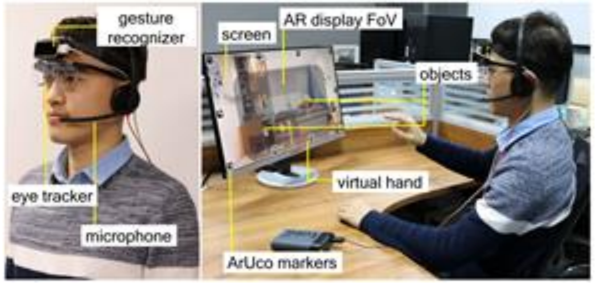


XR Multimodalities (TSI)

- A gaze-gesture-speech tracking AR system (via AR glasses, Leap Motion controller and microphone), **single-modal, double-modal, and triple-modal interaction modalities**

- **Results**
    - Gaze+Gesture+Speech multimodal setting is superior to other modality combinations in terms of task performance
    - Eye gaze-based interaction more efficient than other modalities although vulnerable to inaccuracies

- **Derived design considerations**
    - Use gaze to conduct swift actions such as selecting targets
    - Verbal commands for confirmation operations
    - hand gesture for skilled actions



Wang, Z., Yu, H., Wang, H., Wang, Z. and Lu, F., 2020, November. Comparing single-modal and multimodal interaction in an augmented reality system. In 2020 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct) (pp. 165-166). IEEE.
Wang, Z., Wang, H., Yu, H. and Lu, F., 2021. Interaction with gaze, gesture, and speech in a flexibly configurable augmented reality system. IEEE Transactions on Human-Machine Systems, 51(5), pp.524-534.

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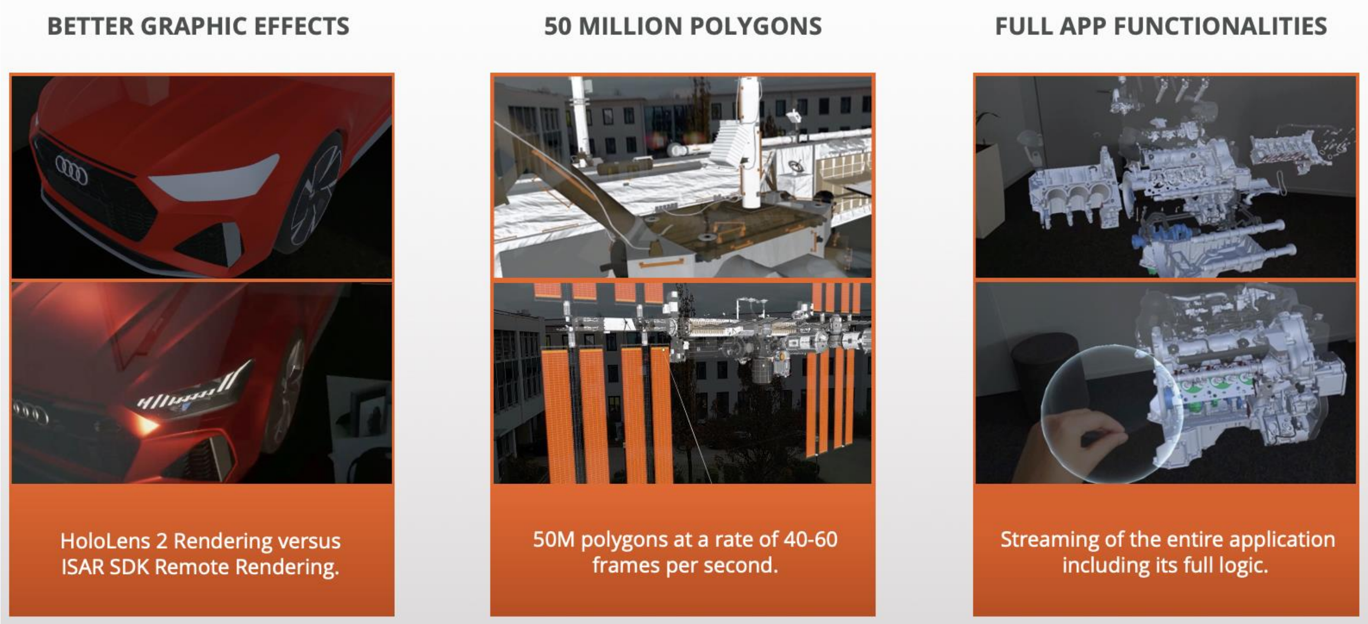
Surpass device resource constraints

- AI and generative solutions to provide high-quality rendering also in presence of coarse-grained, low-resolution and missing parts

High quality real time rendering (HOLOLight)

- Paradigm shift for high quality real time rendering
- Integration of bandwidth control to change value on run time



Improving photogrammetry using AI (CNR)

- Quality and completeness of 3D models is affected by problems in the input images. E.G. view-dependant artifacts, like specular reflections are a major problem

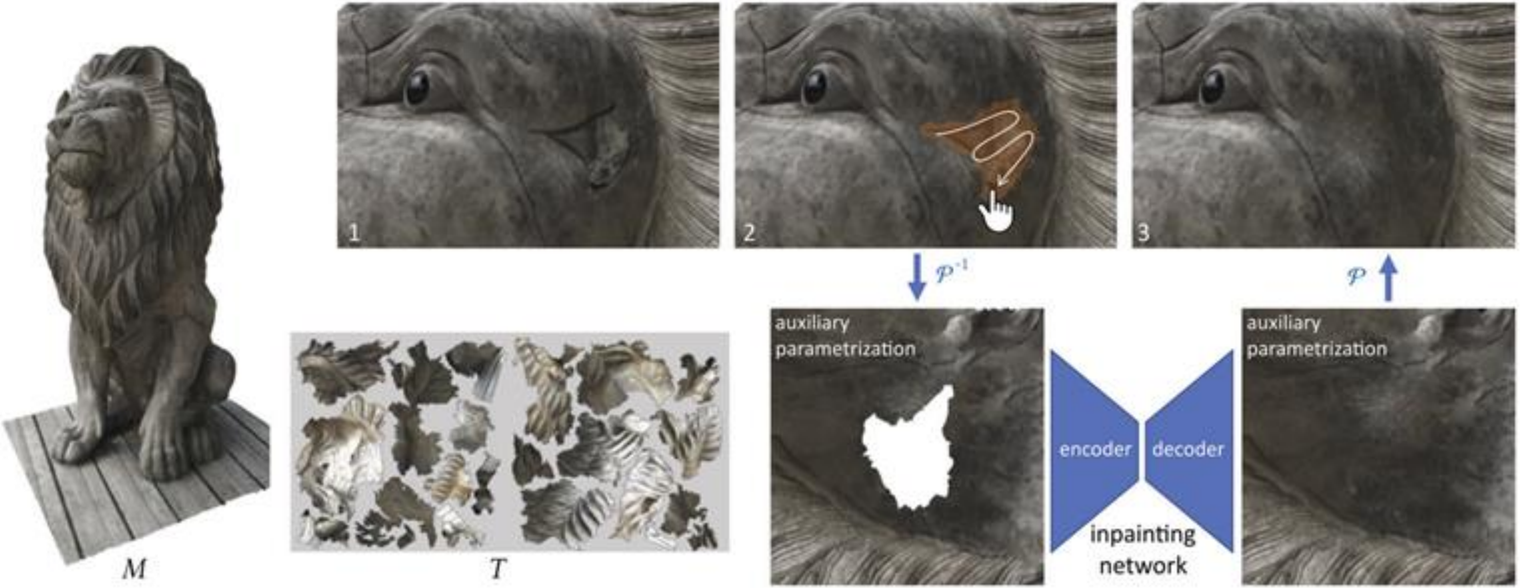
- Pre-processing the input images to remove / correct / mask-out the problems will result in better and more complete reconstructions.

- First experiments carried out with a synthetic dataset.

Improving photogrammetry using AI (CNR)

Improving photogrammetry using AI (CNR)

AI-based automatic correction of errors caused by atlas parametrization, plus an assisted editing tool to manually correct specific areas



Pilots

- P1: Extended reality for Rehabilitation
  - **Target Users**: Persons who need rehabilitation
  - **Main Technology partners**: **THING (Lead)**, TSI, IG
  - **End User Partners**: **ASL-NO (Lead)**, OAC, CRR-Suva

- P2: Extended reality for safety and social interaction at work
  - **Target users**: industry workers
  - **Main Technology partners**: **HOLO (Lead)**, UPV, IG
  - **End User partners**: **FACT (Lead)**

- P3: Extended reality for people with serious mobility and verbal communication diseases
  - **Target users**: Disadvantaged persons
  - **Main Technology partners**: **EPFL (Lead)**, SSSA
  - **End User Partners**: **CRR-Suva (Lead)**, ASL-NO, KPRF

Pilot 1: XR 4 rehabilitation

- to assist and **monitor the individual motor learning** in the context of a **supervised personalised remote exercise rehabilitation program** for the management of injuries/pathologies
- The main goal of this scenario is to **improve compliance to the physiotherapy protocol**, **increase patient engagement**, **monitor physiological conditions** and **provide immediate feedback** to the patient by classifying an exercise in real-time as correctly or incorrectly executed.

Technical challenges:

- Real Physical Haptic Perception Interfaces
- Non-invasive bidirectional body-machine interfaces
- Wearable sensors in XR
- Low latency gaze and gesture-based interaction in XR
- 3D acquisition with physical properties
- AI-assisted 3D acquisition of unknown environments with semantic priors
- AI-based convincing XR presentation in limited resources setups
- Hyper-realistic avatar

Sensors used to monitor the status of the subject.

Hololens for XR technology and audiovisual feedback.

Smartwatch technology for HR, SpO2, blood pressure monitoring.

S-EMG wireless wearables to record the muscle activation levels. Inertial Meas

Pilot 2: XR for safety and social interaction at work

- **prevent serious accidents** provoked by the co-occurrences of different causes, which can be **avoided by conscious collaboration**
- **XR can create more immersive experiences** for people at work in order to make **their job safer**, by providing **new ways to be aware of possible hazards and receive more effective, engaging and entertaining training on safety procedures**.
- Features that will be exploited in the scenario include:
  - **High Quality 3D Content i**n XR: To securely import and view all your design files for AM in XR. Visualize and manipulate even data-intensive 3D content.
  - **Merge the Real and Virtual**: Place your CAD/engineering designs in the real world. Manipulate projected assemblies directly at their envisaged destination.
  - **Work on Complex Holograms**: Fully manipulate your designs and assemblies. Place, rotate, adjust, resize, slice and dice. Save your work.
  - **Share the Experience**: Collaborate with your colleagues, partners, or customers in AR. Set up local and global meetings in an XR environment.

Technical challenges:

- Wearable sensors in XR
- Low latency gaze and gesture-based interaction in XR
- Multimodal XR collaboration
- Semantic integration of virtual and physical world
- 3D acquisition with physical properties
- AI-assisted 3D acquisition of unknown environments with semantic priors
- AI-based convincing XR presentation in limited resources setups
- Hyper-realistic avatar
- Context aware avatars

Pilot 3: XR for people with serious mobility and verbal communication diseases

- To **allow people with communication and motor disabilities to interact with friends** and relatives, **meeting realistically in an extended (physical + virtual) environment**.
- The goal is to **count on residual abilities giving them a meaning in terms of communication supported by avatars in a virtual environment.**
- The person with communication and motor disabilities will be **represented by an avatar** which will **interact with other people staying in a physical augmented environment**.
  Simultaneously, the person with communication and motor disabilities will have the illusion to be also in the same physical environment with the other people, and can interact with the new interfaces

Technical challenges:

- Real Physical Haptic Perception Interfaces
- Non-invasive bidirectional body-machine interfaces
- Wearable sensors in XR
- Low latency gaze and gesture-based interaction in XR
- 3D acquisition with physical properties
- AI-assisted 3D acquisition of unknown environments with semantic priors
- AI-based convincing XR presentation in limited resources setups
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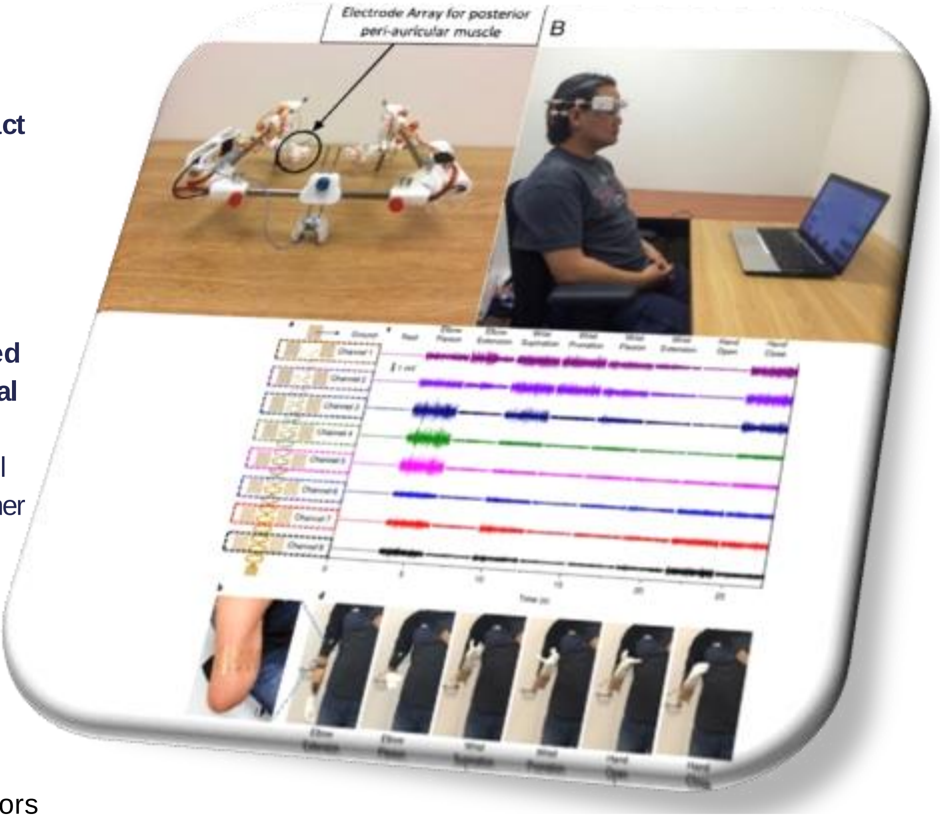

Examples of devices for auricular muscle recordings (top panel), and for EMG arrays (bottom panel)

SUN Consortium: https://www.sun-xr-project.eu/

- CNR
- Engineering
- Thingenious
- TSI
- Holo Light
- Igoodi
- Sant'Anna
- KPeople
- IN2
- CERT
- VUB
- ASL-Toscana
- OAC
- UPV
- Factor
- EPFL
- CRR-Suva
- UoG

SUN XR project
(Social and hUman ceNtered XR)

- *Visit us at:*
    - *https://www.sun-xr-project.eu/*

- *We are at M6 of a 36 months project -> Stay tuned!*

Thank You!

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