Augmented reality and intelligent systems in Industry 4.0

A. Benassi, A. Carboni, S. Colantonio, S. Coscetti, D. Germanese, B. Jalil, R. Leone, J. Magnavacca, M. Magrini, M. Martinelli, F. Matarese, D. Moroni, P. Paradisi, F. Pardini, M.A. Pascali, G. Pieri, M. Reggiannini, M. Righi, O. Salvetti, M. Tampucci

http://si.isti.cnr.it

Seminari ARTES 4.0

12 NOVEMBRE 2020

Multidisciplinarietà

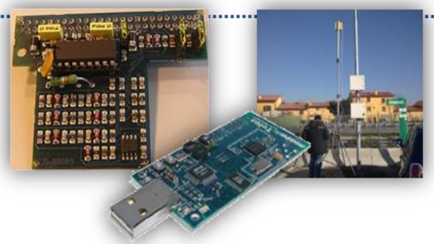
http://si.isti.cnr.it

a copertura dell'intero ciclo multimediale

Acquisizione & Produzione

Smart Camera & Sistemi embedded

Piattaforme multimodali di acquisizione

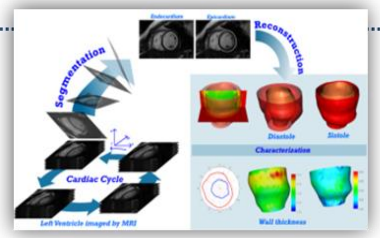


Elaborazione e Comprensione

Elaborazione a basso livello

Descrizione del contenuto

Comprensione e annotazione

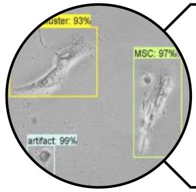


Stoccaggio e distribuzione

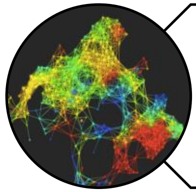
Sistemi Informativi

Ambienti Virtuali 3D

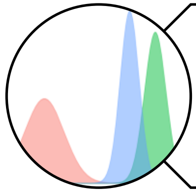
Competences and Applications fields



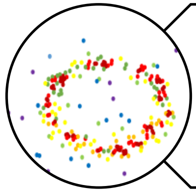
Computer vision



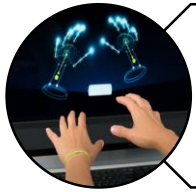
Artificial intelligence & intelligent systems



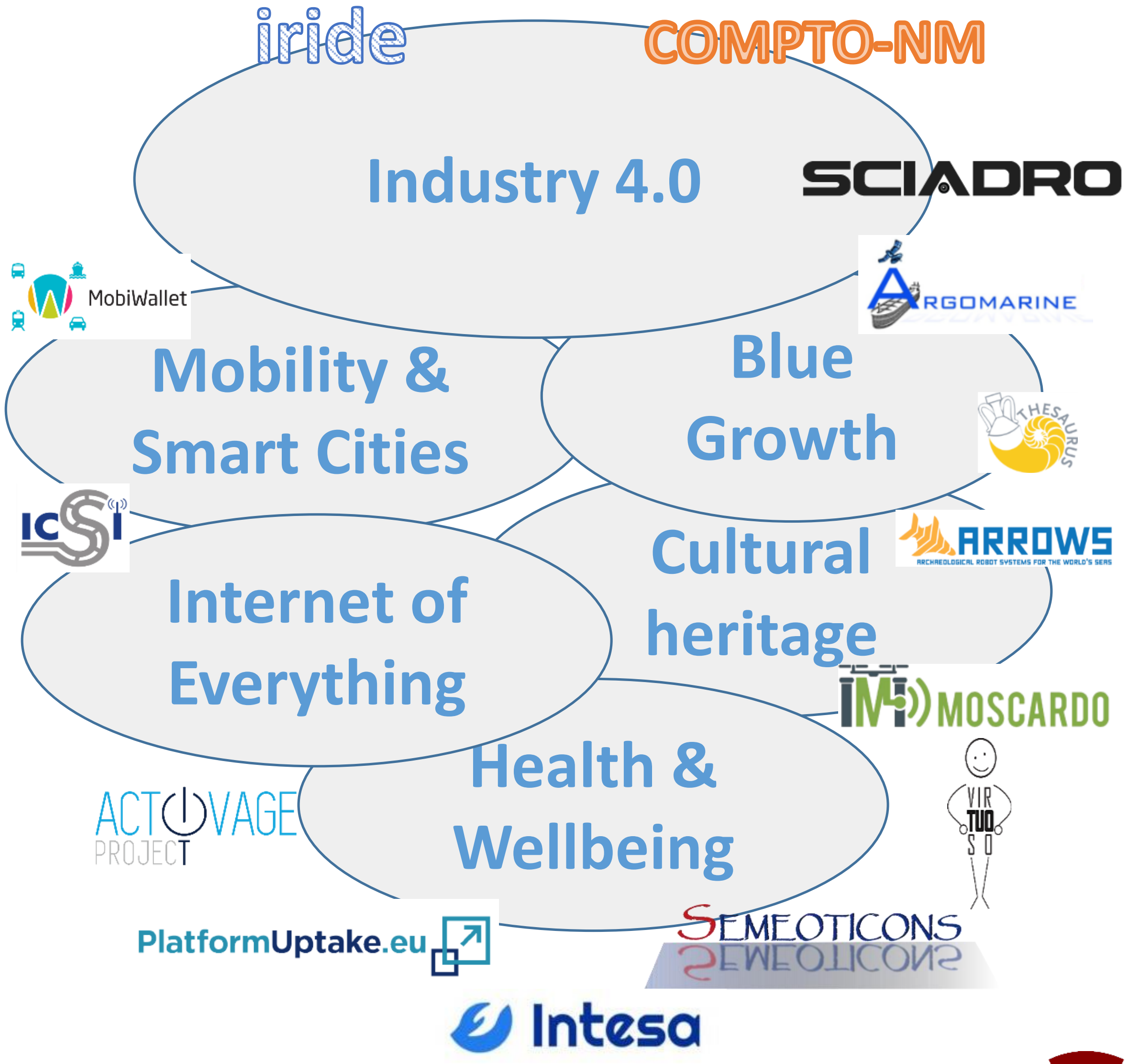
Statistical signal processing



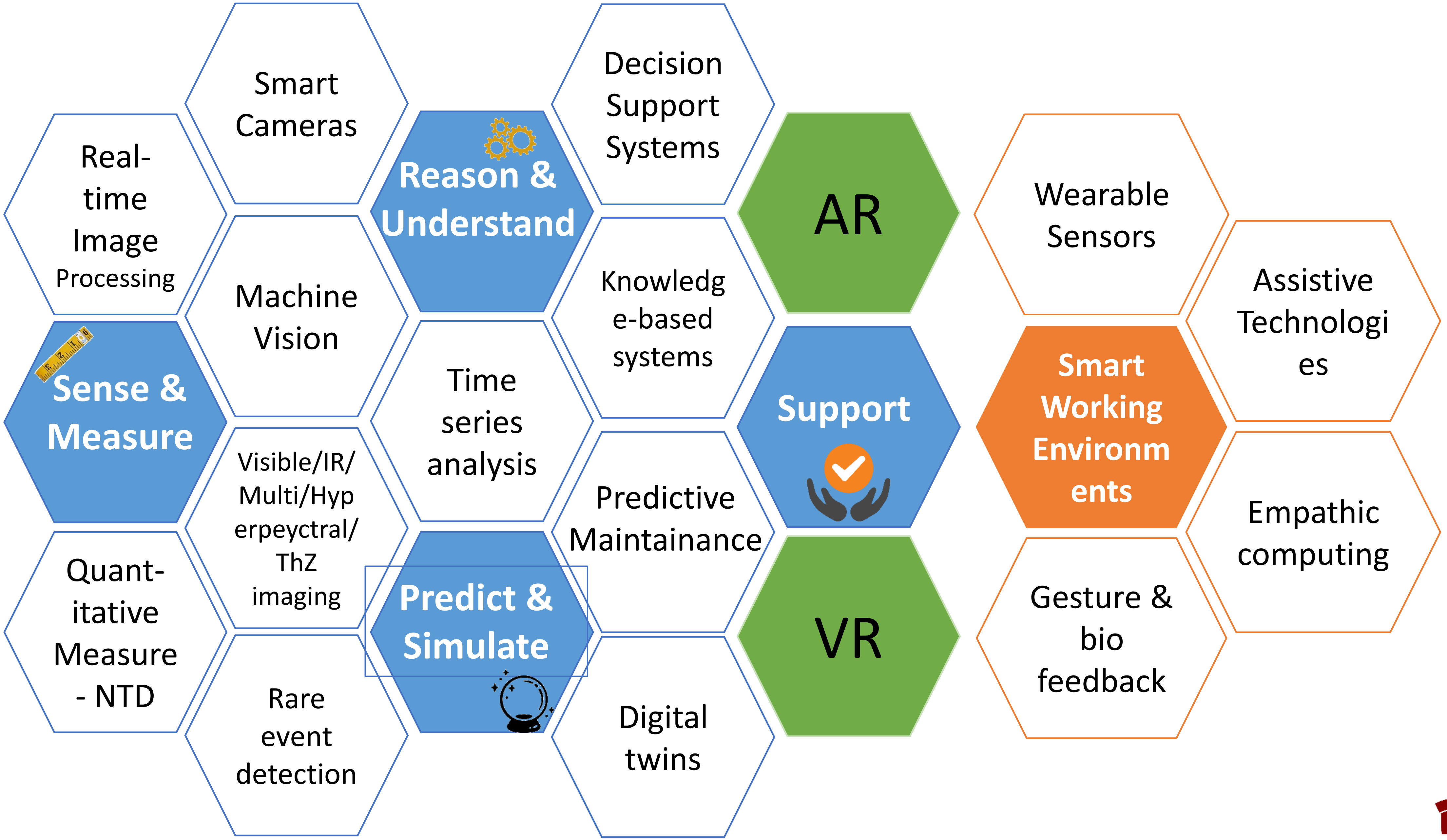
Topological data analysis



Human-computer interaction



SiLab for ARTES 4.0



Outline

XR Continuum

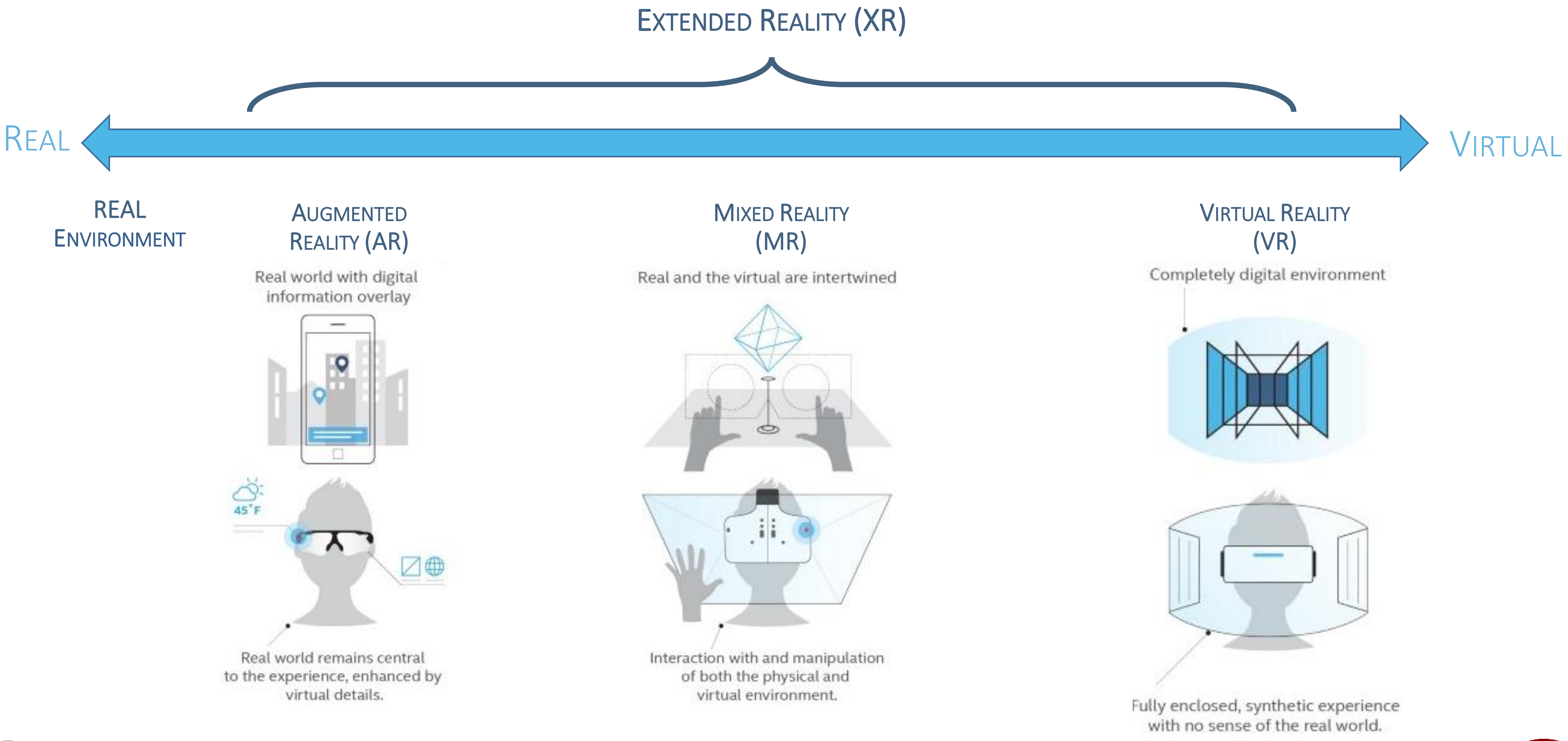
XR in Industry 4.0

XR in action:

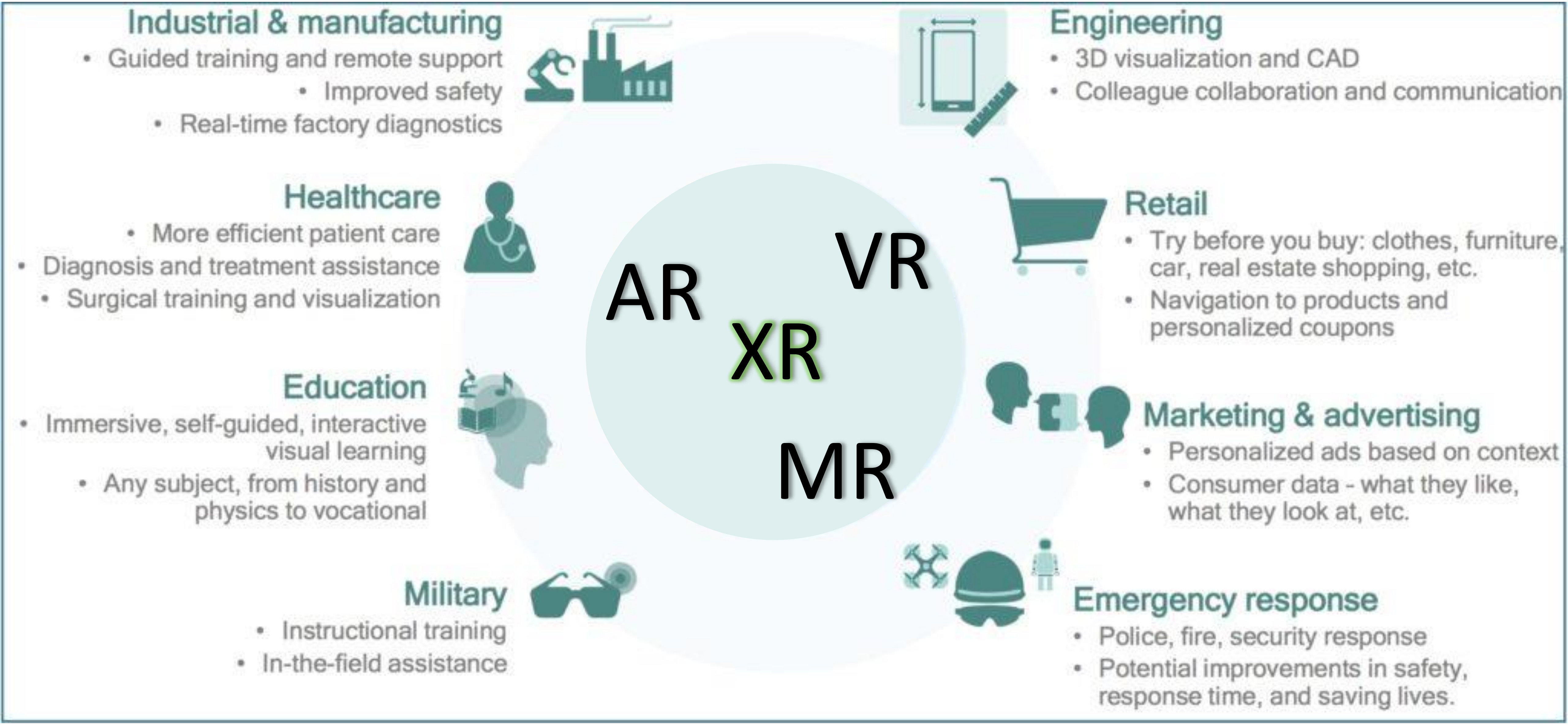
- Monitoring and maintenance of production facilities
- AUV-based Inspections
  - Structural health monitoring
  - Powerline analysis
- eHealth: treatment and rehabilitation
- Cultural heritage: enhanced experience in sightseeing and augmented exhibitions

XR Continuum & AR in I4.0

Extended Reality Continuum



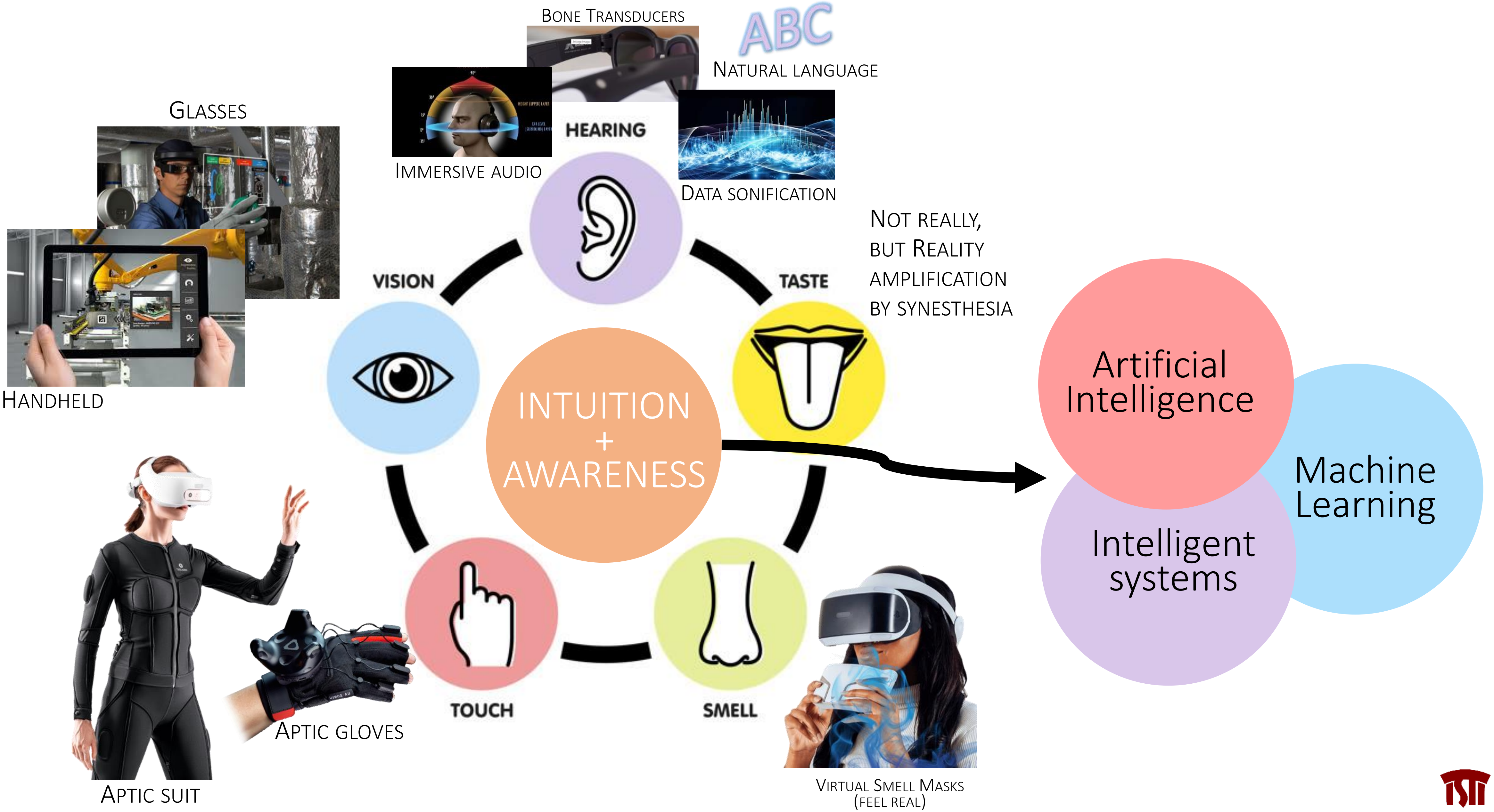
XR Application domains



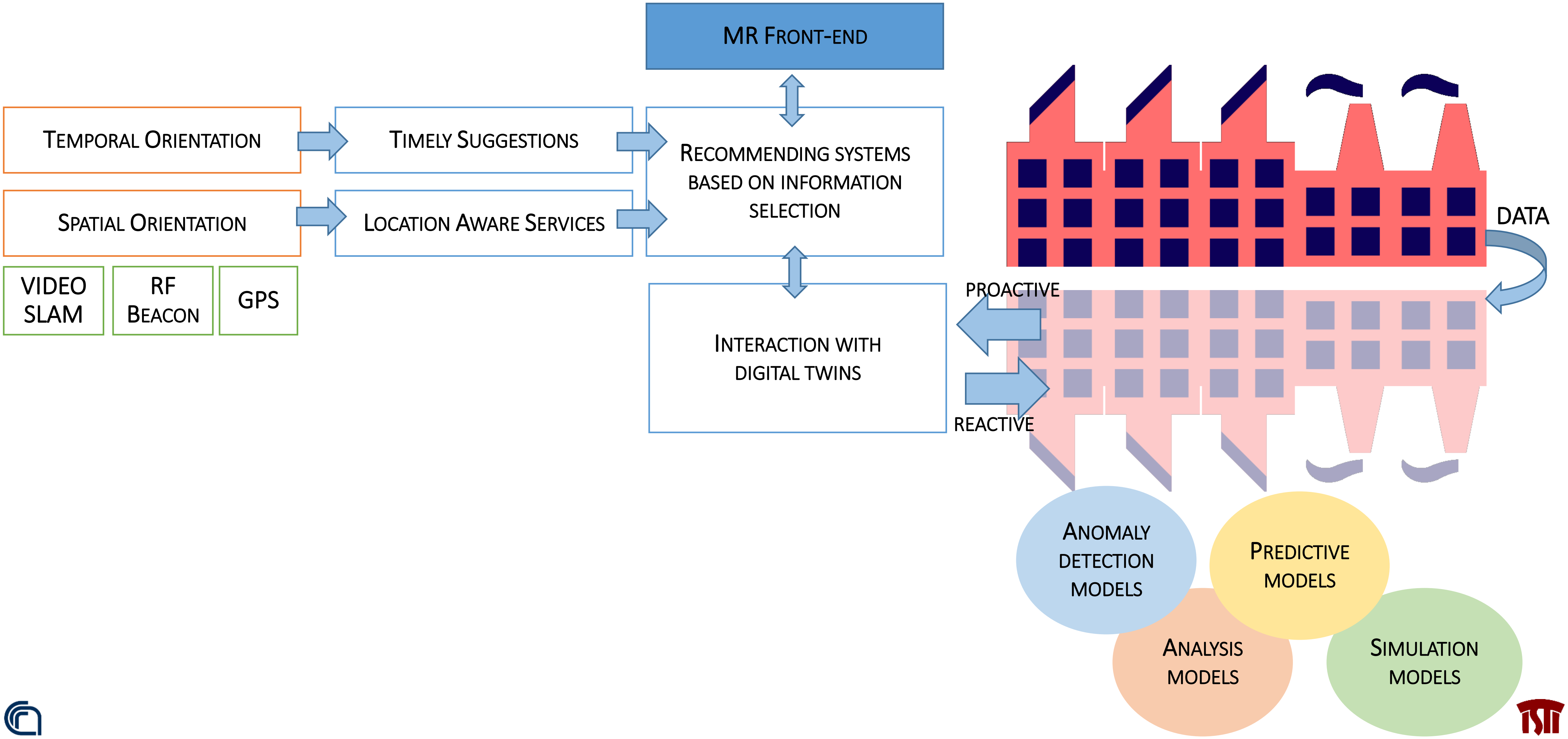
Extended Reality across Industry 4.0

SERVICE	MANUFACTURING	SALES & MARKETING	DESIGN	OPERATIONS	TRAINING
• Manuals & Instruction • Service inspection &verifications • Remote expert guidance • Improved service & Self service	• Quality Assurance • Maintenance work instructions • Performance dashboards • Assembly work Instructions	• Displays & Demos • Logistics • Retails space optimization • Augmented brand experience • Augmented advertising	• Collaborative CAE / CAD / CAM • Inspection of digital prototypes • Error diagnosis	• Head-up displays • Digital product control • Augmented operator manuals	• Job specific training • Safety & Security training • Expert coaching

XR: extending sensing and the 6th sense



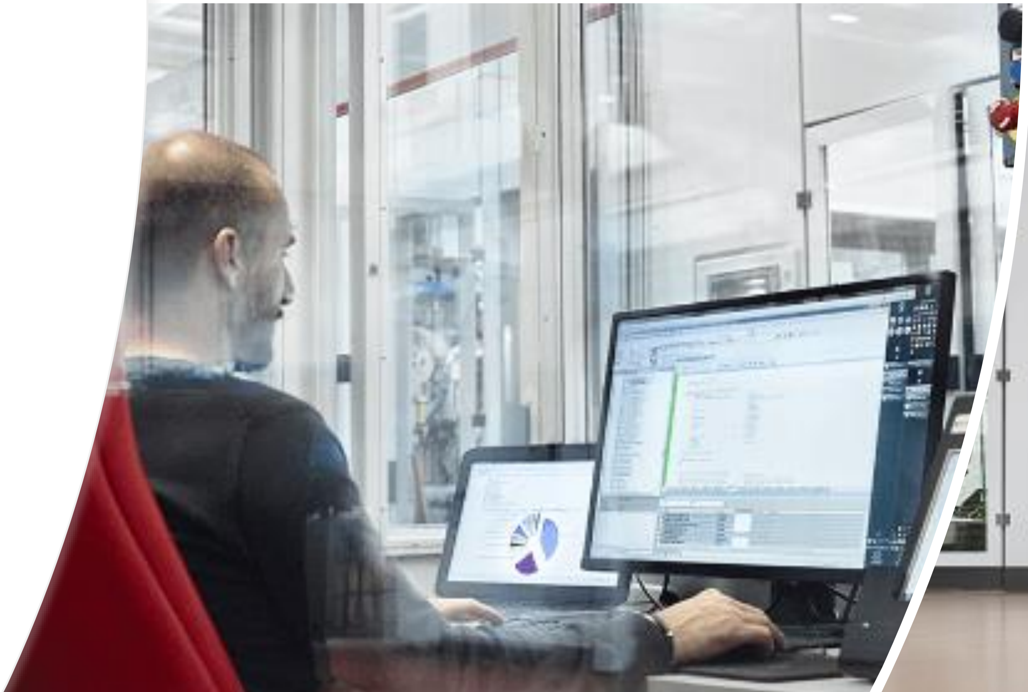
Extending sensing with intelligent services



The tissue converting scenario

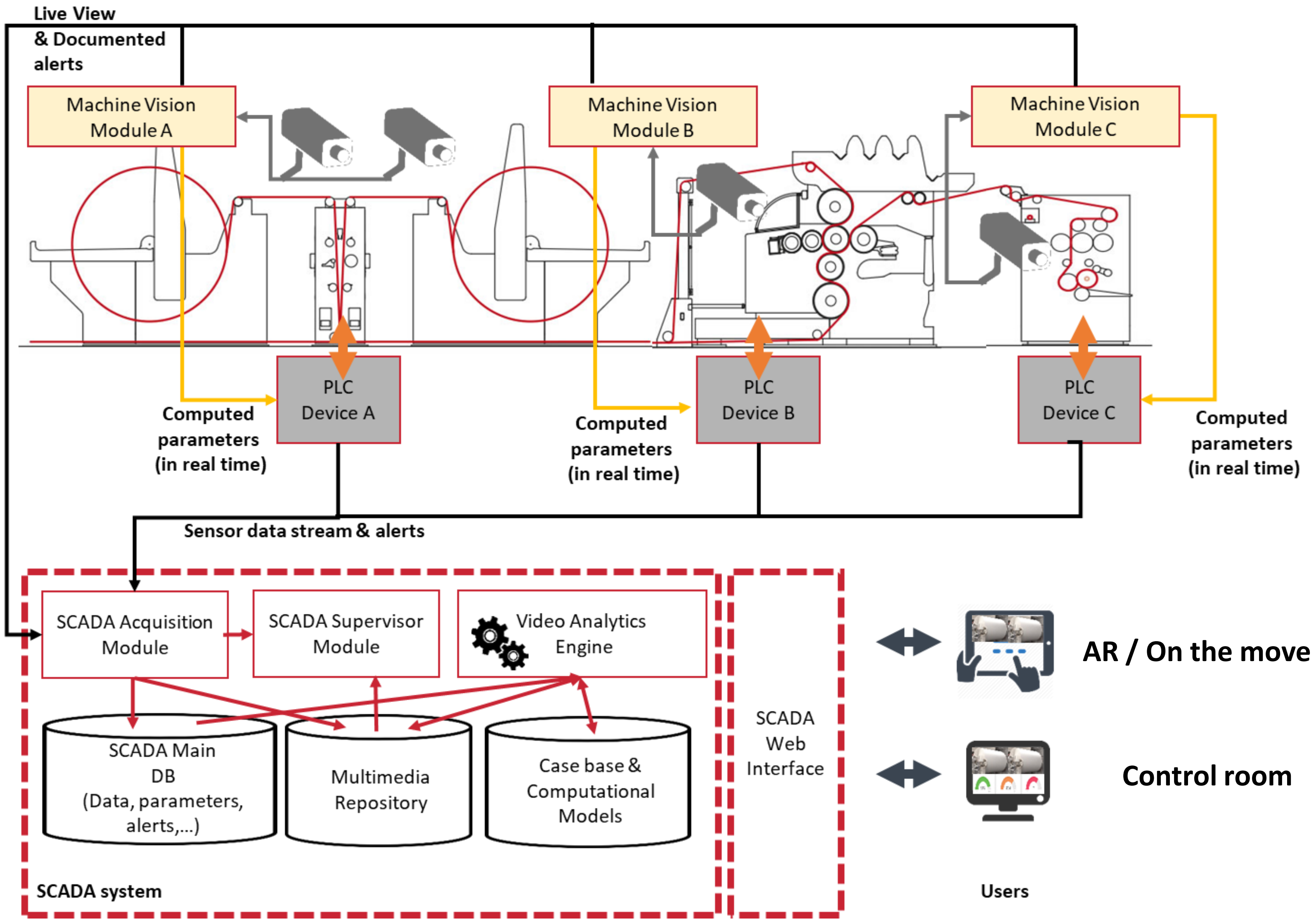
- 10k+ components
  - Ordinary and extraordinary maintenance
  - High-level skills required

- AR technologies to support the operator and the remote assistance center.



Pictures sources: https://www.paperindustryworld.com/high-performance-tissue-converting-technology-for-resolute/futura-andromeda/; https://www.futuraconverting.com/it/impianti-di-produzione-professionali/linee-consumer/andromeda-system/

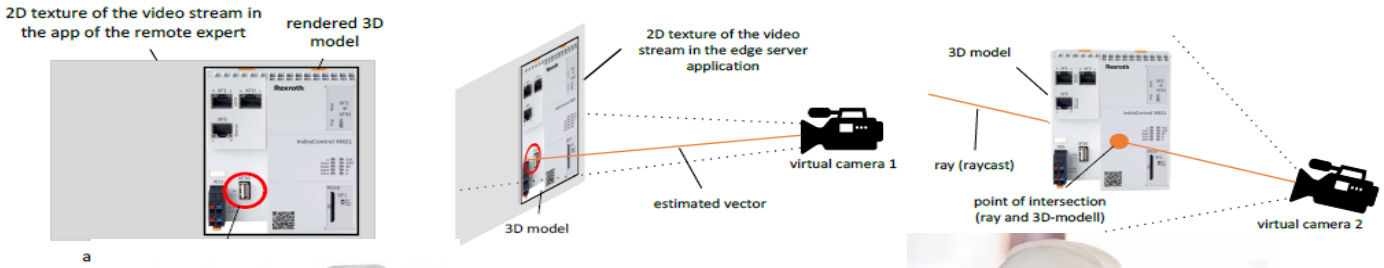
Machine Vision and Video Analytics in Industry 4.0



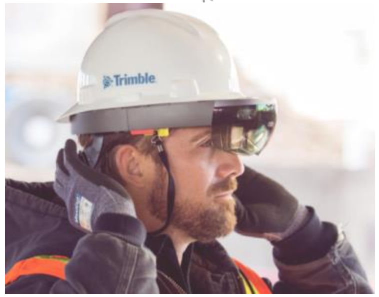
- Real-time local image processing for control
  - Adaptation at single machine level
- Real-time global video analytics for
  - Adaptation at line level
  - Failure prediction
  - Maximize uptime
- Long term monitoring and machine learning for predictive maintenance
- Live view and real time operational monitoring through AR

Adding Content to Reality in the Factory

- **Markerless** system based on **Natural Feature Tracking**
- Dust and dirt: Activating elements cannot be based only on appearance
- 2D/3D Mapping combined with location based services (RF)
- Interfaces based on smart glasses for factory environment
- Troubleshooting and **proactive functionalities**



Epson Moverio BT 2200



Hololens & Hard Hat

AR frameworks

- Many SDKs for Augmented Reality in the market
  - Apps development for mobile devices and smart glasses
  - Image and Object recognition and identification
  - Tracking through SLAM and NFT technologies
  - Marker- and location-based

- Many SDKs released under license (free or commercial), few open-source projects too.
- Due to the features and support offered, we've chosen a licensed framework.

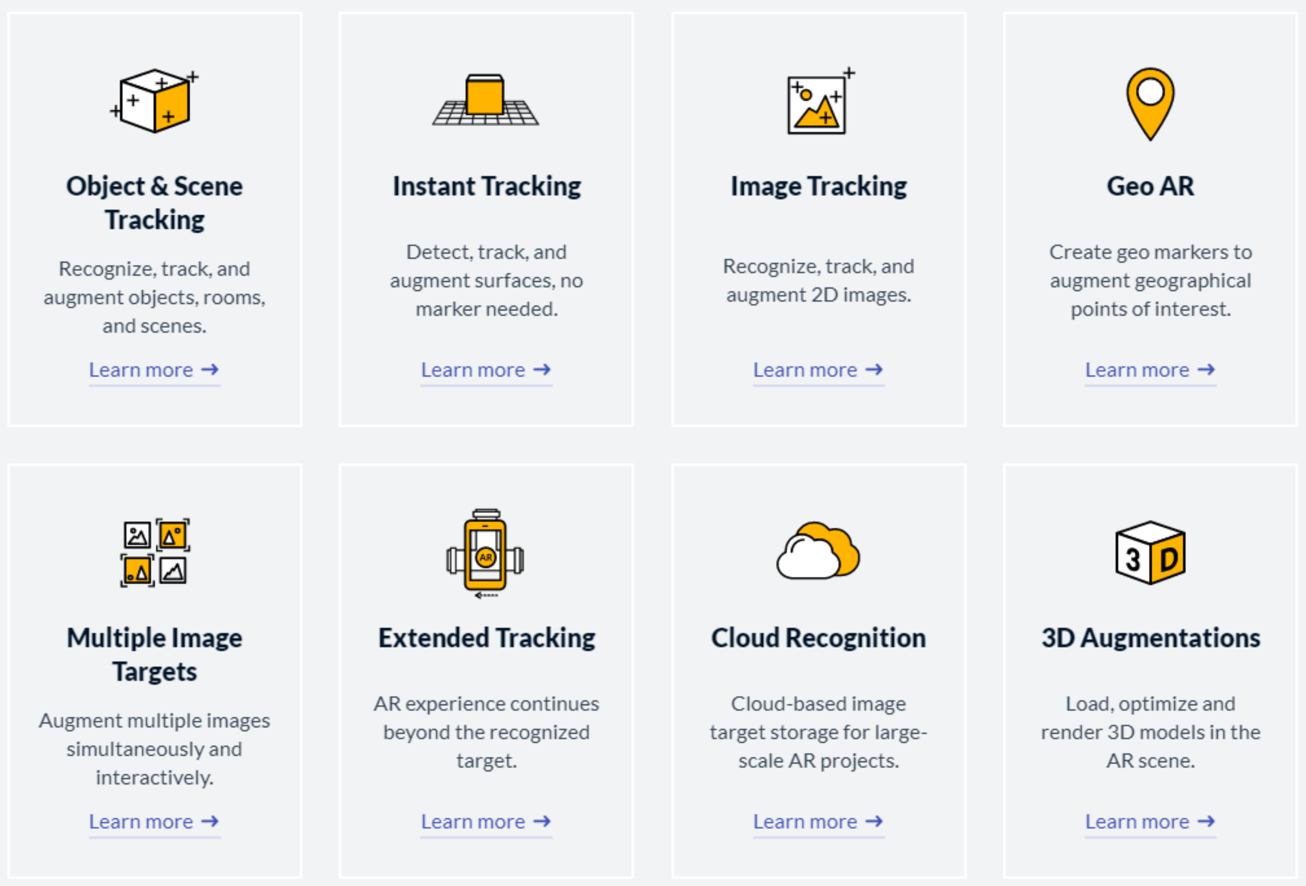
ARKit ARCore

vuforia™

wikitude

Wikitude SDK

- Company active since 2008 - SDK developed since 2012



- SLAM based technology, no needs of markers.
- Available for Android, iOS and Windows
- Optimized for some smart glasses models.
- Wikitude Studio: simplified development procedures.
- Commercial solution, with a full trial version available.

- Scene recognition – not present in the other SDKs

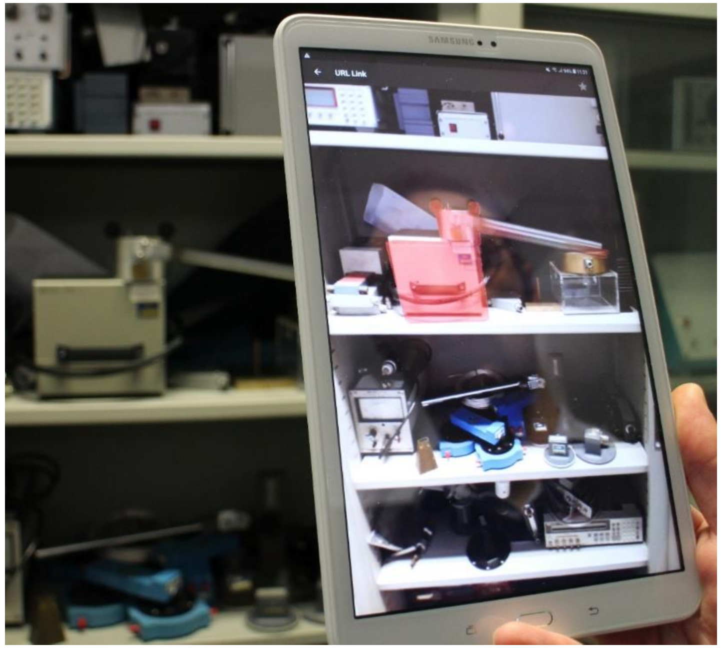
Devices

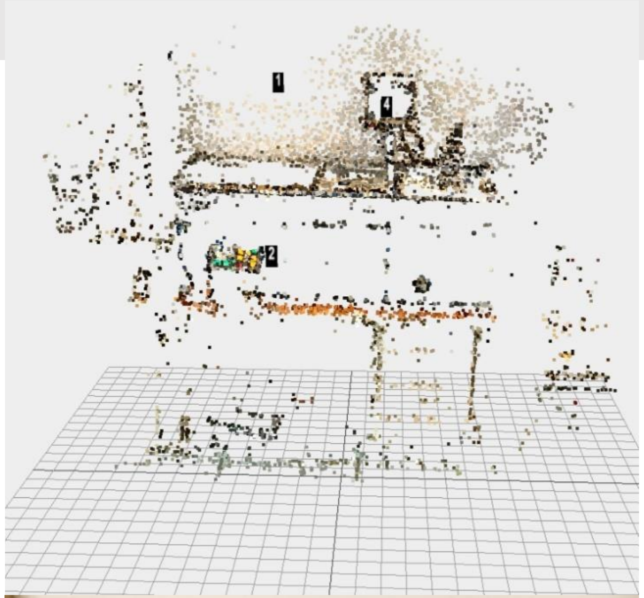
- Many devices useful for Augmented Reality activities:
  - Smartphones, tablets, smart glasses.
- Today, a typical configuration of a mid-range smartphone is suitable for AR applications.
  - Quad/octa-core CPU
  - 4GB+ RAM
  - Rear camera with 12+ Megapixel resolution.
  - Still some battery capacity limitations

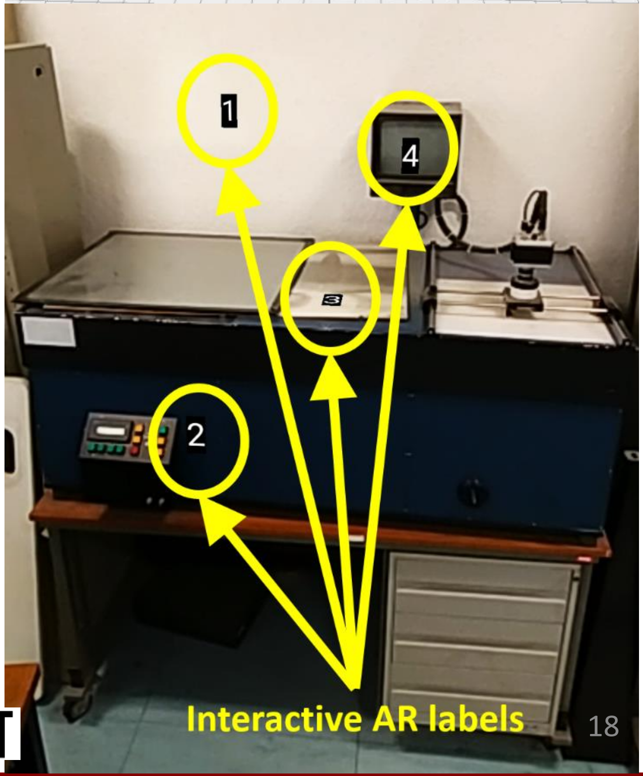
- Tablets are not so widespread. Mid-range models h end models are expensive.
- See-through smart glasses: Microsoft Hololens (1-2), Meta 2, Epson Moverio

The Prototype

- Controlled laboratory environment
- Two main components:
  - Recognize the target (Wikitude);
  - Retrieve remote data (i.e. Android).
- A tool for recognizing features of target objects and providing a set of AR content:
  - Interactive label;
  - Multimedia files (videos, images, documents);
  - Real-time data.

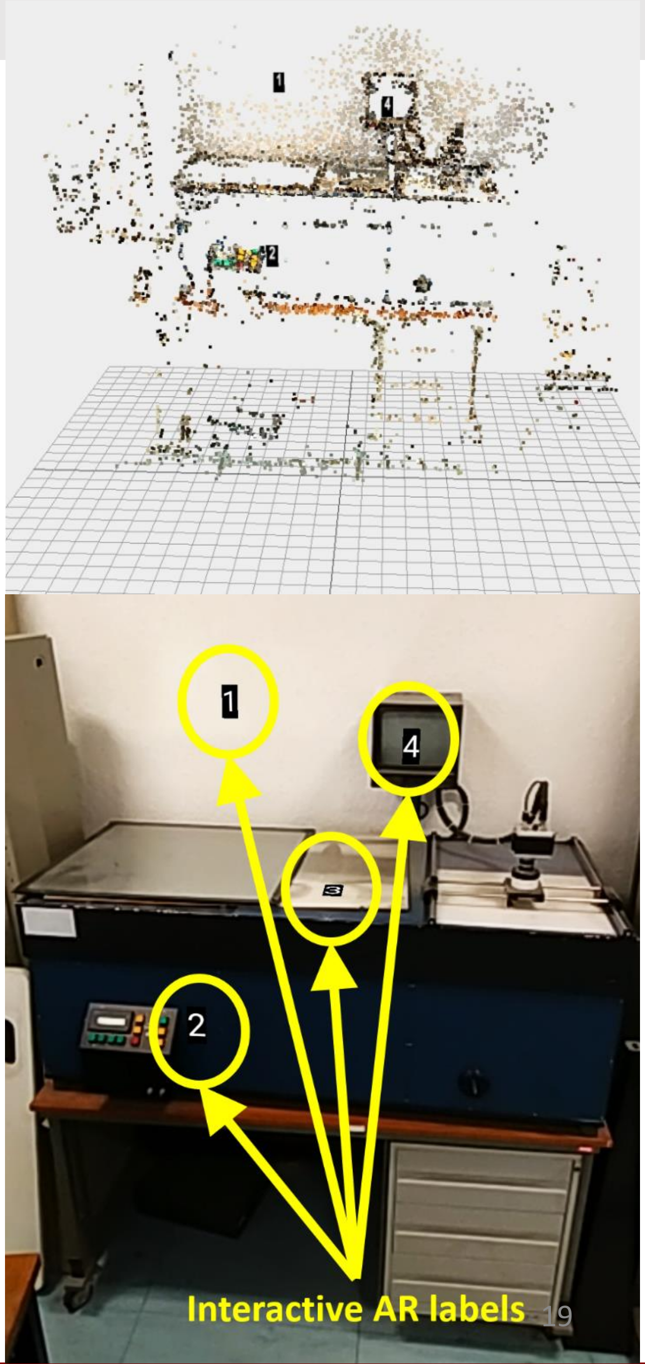






The Prototype

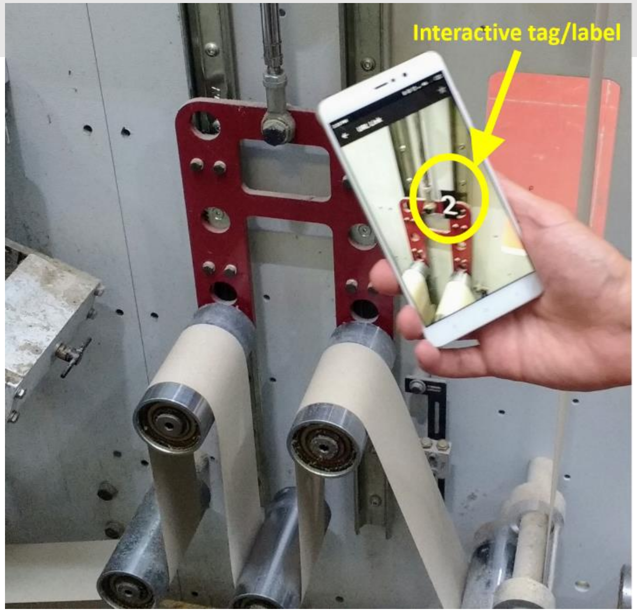
- The AR scene is built from pictures acquired by a smartphone, via Wikitude Studio.
- From the pictures, a point cloud of the scene is generated.
- Once the point cloud is generated, the user can place AR objects directly on it.
  - Types of AR content: images, videos, 3D objects, labels, buttons.
- Then, the AR scene created can be downloaded and integrated in a mobile application for the remote data recovery.
- The AR contents can be edited for monitor and maintenance:
  - Labels can report real-time data;
  - Interactive buttons can retrieve documents or maintenance assistance videos.



Use Cases

- Three main macro-categories of intervention:
  - Monitoring line parameters and live view of the cameras.
  - Ordinary maintenance with documentation and video access.
  - Troubleshooting.

- Real-time access to the machine parameters;
- Monitoring performances;
- Data can only be obtained through the PLC.



Results

- Test have been carried out with a smartphone (Xiaomi Mi5s Plus) and a tablet (Samsung Galaxy Tab 5Se)
- Application performance depending on the number of images acquired – with a clear scene and in presence of an occluder.

Number of images	Point cloud dim. (kB)	Eff. (%)		Eff. w/ occl. (%)	
		S	T	S	T
20	339	50	20	70	30
30	825	55	25	75	30
40	1548	75	50	80	50
50	2207	85	60	85	60
60	2280	90	80	95	80
70	2795	100	90	100	90

- Application stability – after the scene recognition, the user moves along a predefined path through the scene. The stability refers to how many times the targets are not lost .

Number of images	Stability (%)	
	S	T
20	0	20
30	20	35
40	75	80
50	85	90
60	90	95
70	90	95

Lesson learnt and on-going activities

- A software prototype to perform scene recognition in an Augmented Reality system, to support the maintenance and control of a tissue converting factory line.
- A first prototype to perform laboratory tests.
- Then, an extended implementation in the real factory environment.
- The performance and robustness of the prototype has been analyzed.

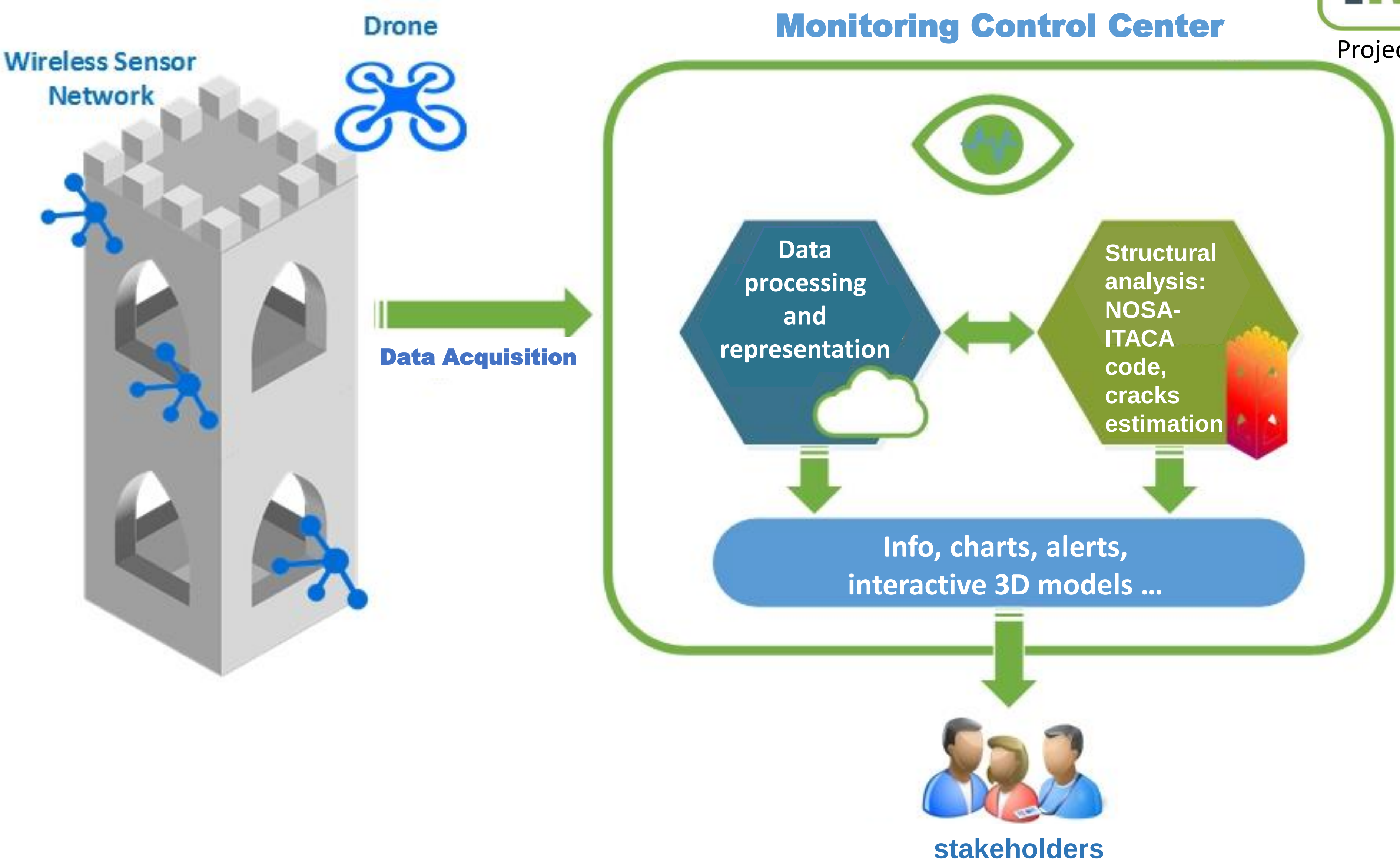
On going:

- Big Data analysis integration for predictive maintenance.
- Machine vision for live monitoring of the production process and predictive maintenance.
- Proactive system for troubleshooting.

AUV-Based Inspections

Structural Health Monitoring: MOSCARDO system

Project website http://www.moscardo.it/



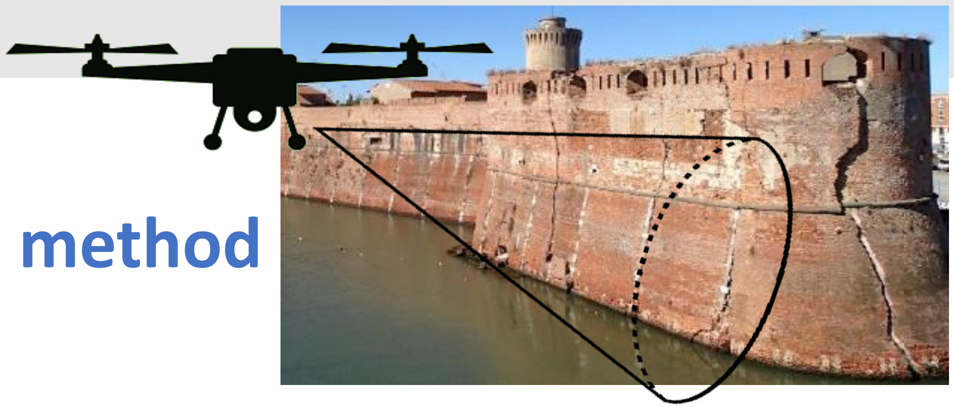
Infomobility SRL
Partner & Capofila

CNR ISTI
Partner

UniFI DICEA
Partner

EIS Srl
Partner

UAV + MARKER-BASED SLAM method

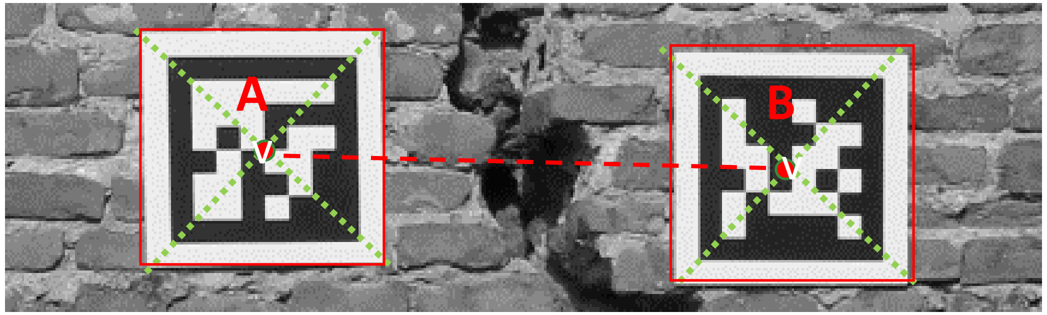


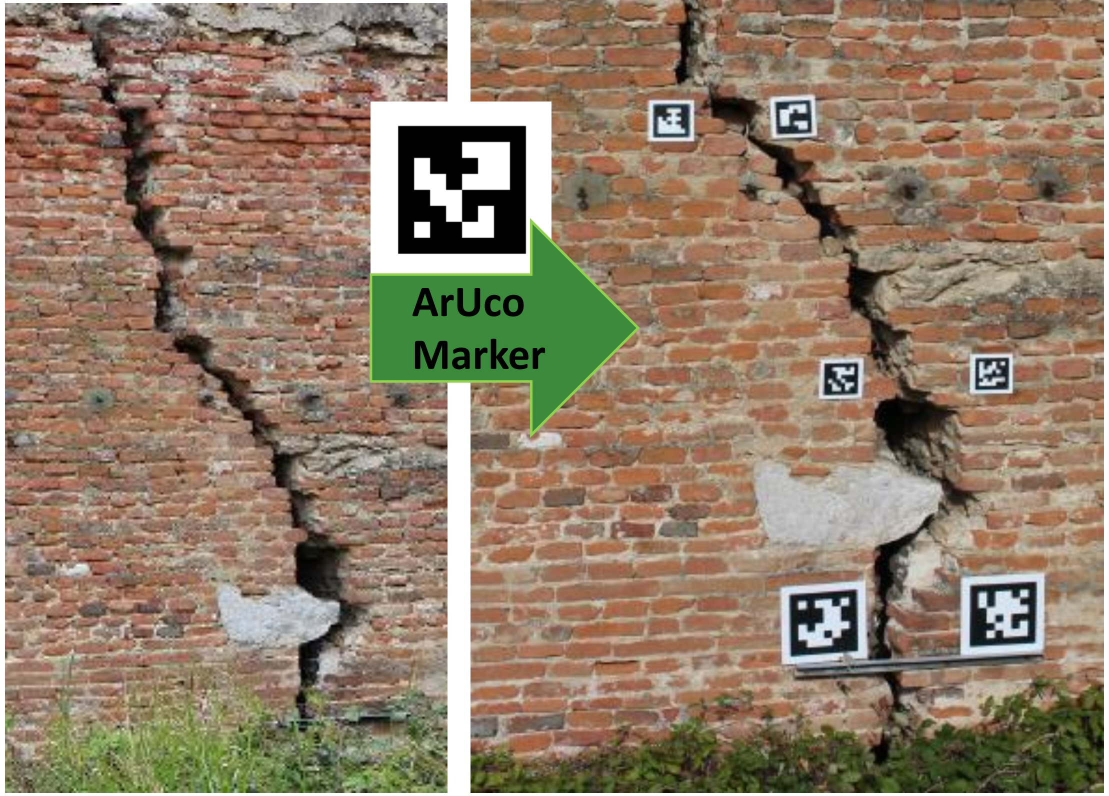
Evaluation of cracks features using:

- Image processing
- Suitable ArUco marker configurations for achieving sub-millimetric accuracy

Images acquired by UAV allows for:

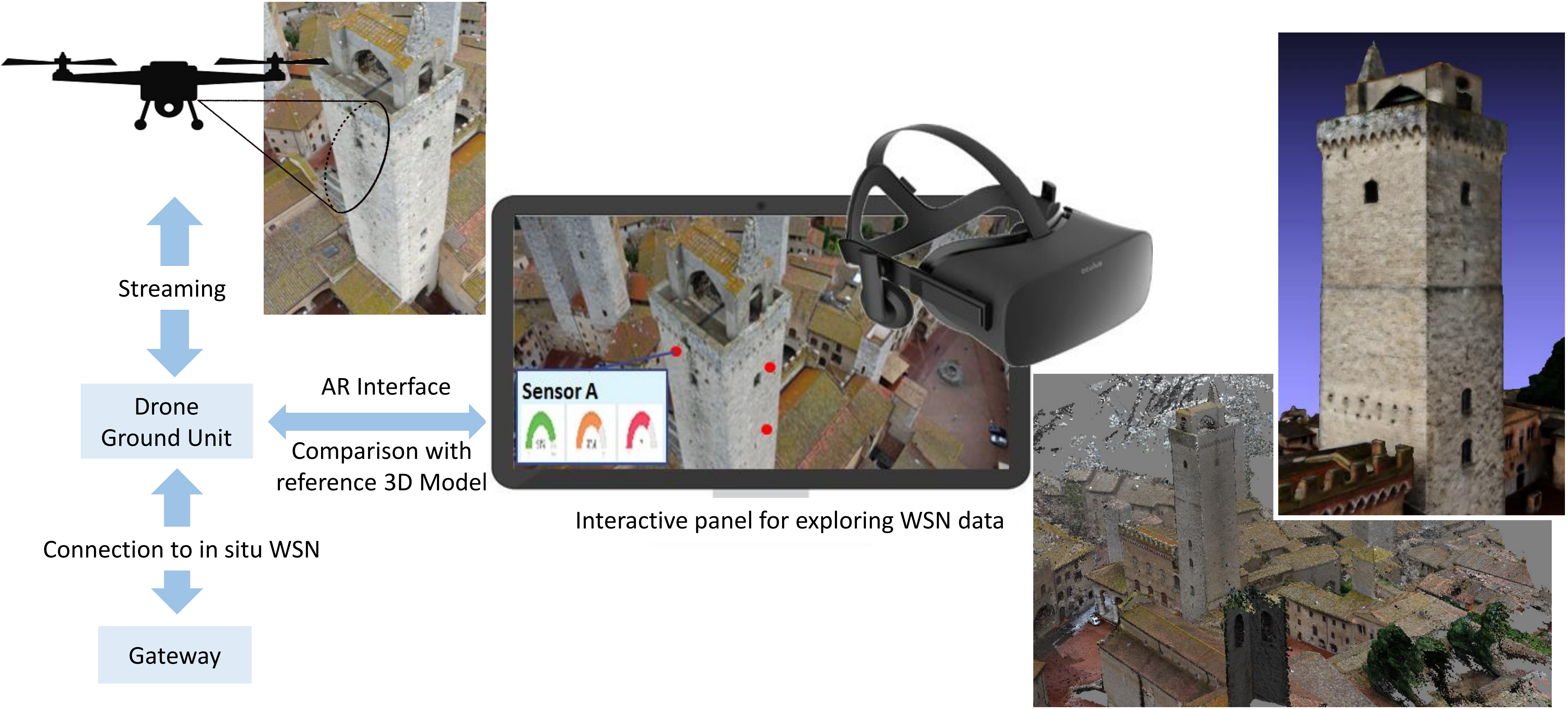
- Accessing cracks also in difficult areas
- Capturing cracks from optimal locations
- Fast data acquisition of the whole structure, to get a 3D model





Bacco, M., Barsocchi, P., Cassará, P., Germanese, D., Gotta, A., Leone, G. R., Pascali M.A., Moroni, D. & Tampucci, M. (2020). Monitoring Ancient Buildings: Real Deployment of an IoT System Enhanced by UAVs and Virtual Reality. IEEE Access, 8, 50131-50148 (https://doi.org/10.1109/ACCESS.2020.2980359).

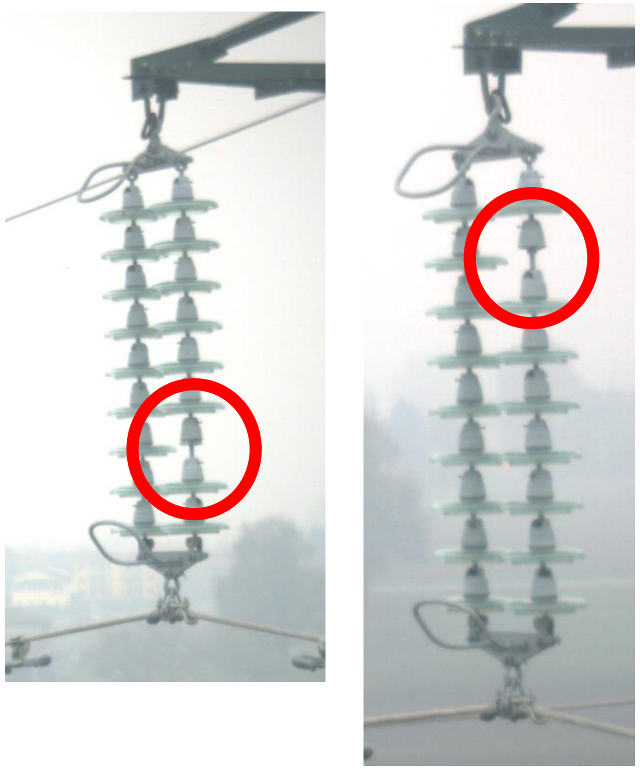
VR: the inspection



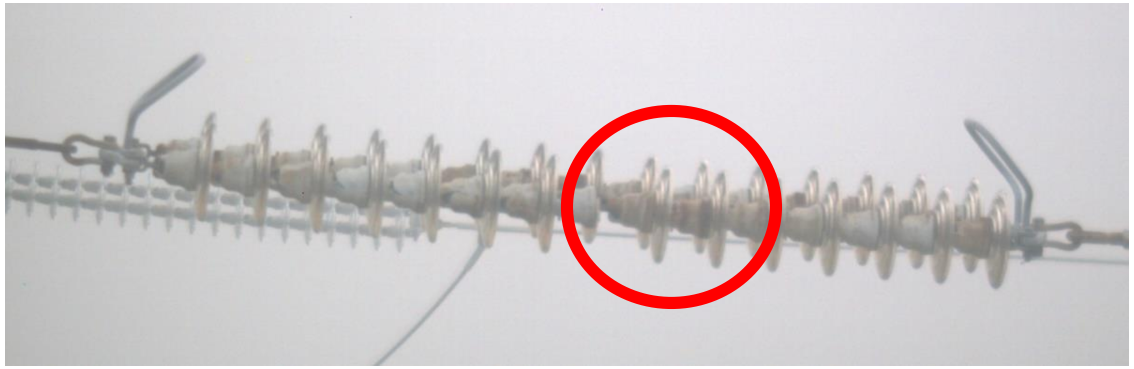
VR: 3D Front-end

LIVE VR DEMO: http://moscardo.isti.cnr.it/

Inspection of aerial power lines

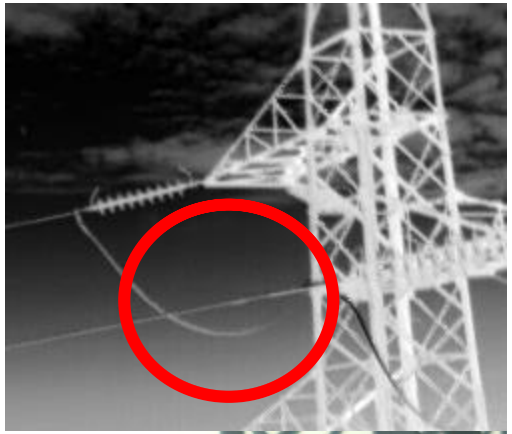


Missing insulator #1



Rust and missing insulator

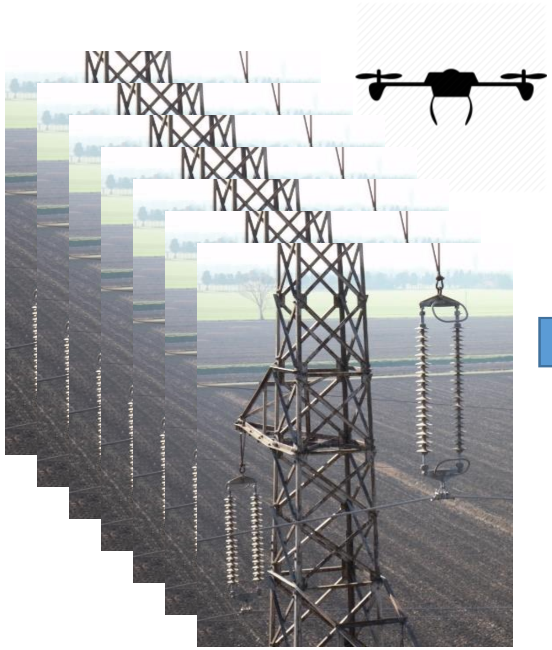
Strefolatura – Broken strands



Infiascatura

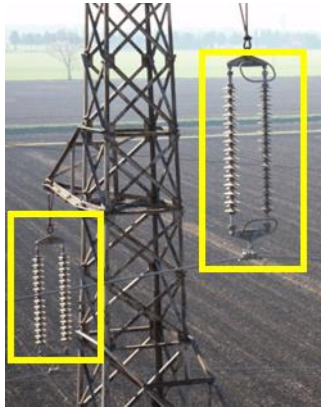
Inspection of aerial power lines: Object detection pipeline

UAV Video Stream



Object detection

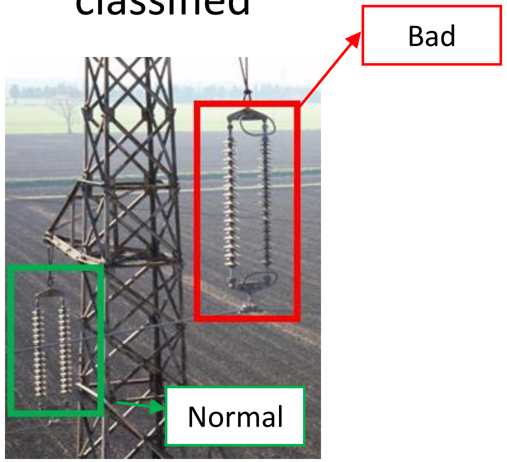
Objects of interest detected



Example: insulator detector detects Regions of Interest (ROI)

Object classification

Object of interest classified



Example: a classifiers takes in input detected insulators ROI and assign class labels, such as *rust*, *no rust*, *missing disk*, *deformed*

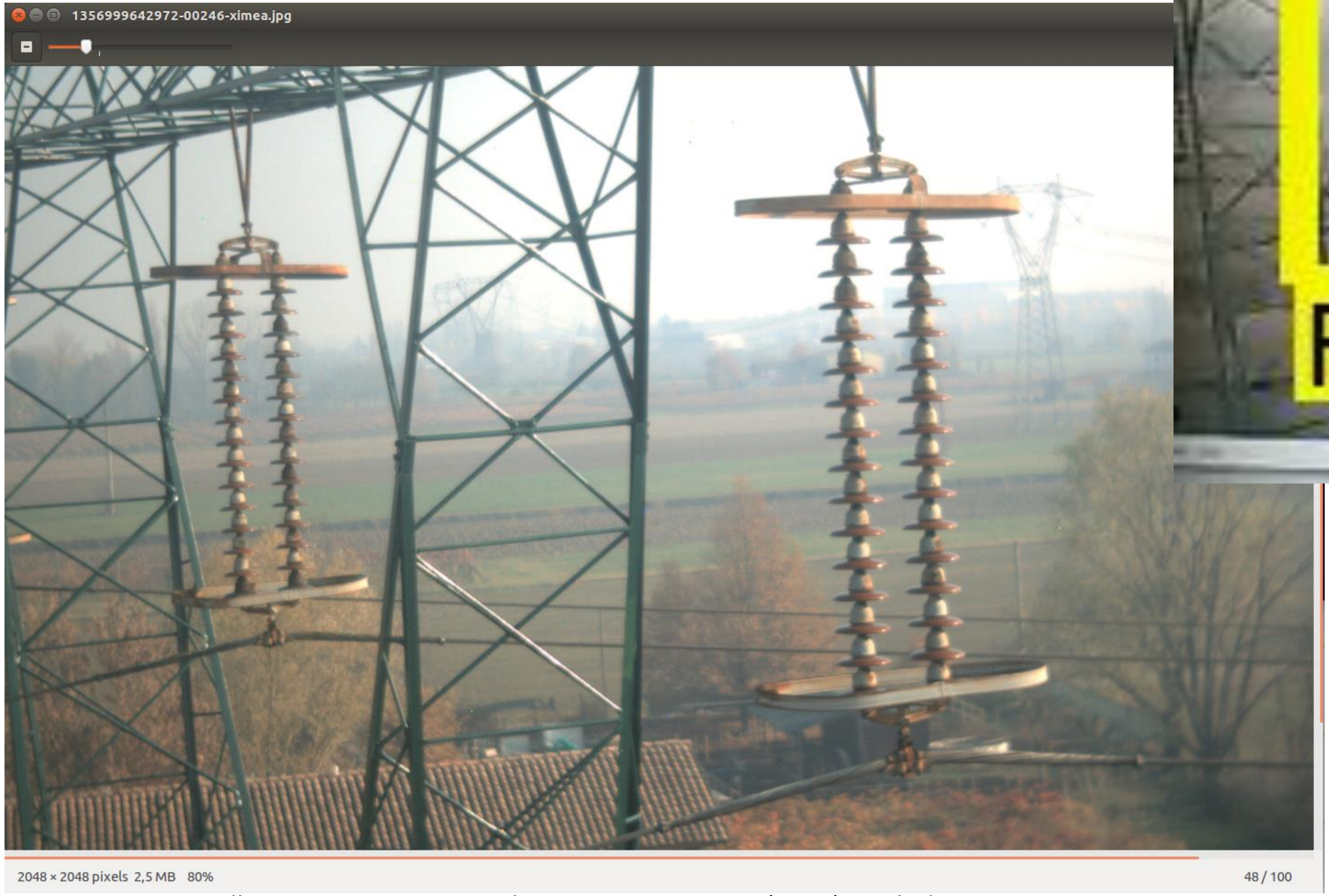
Inspection of aerial power lines: Deep Learning

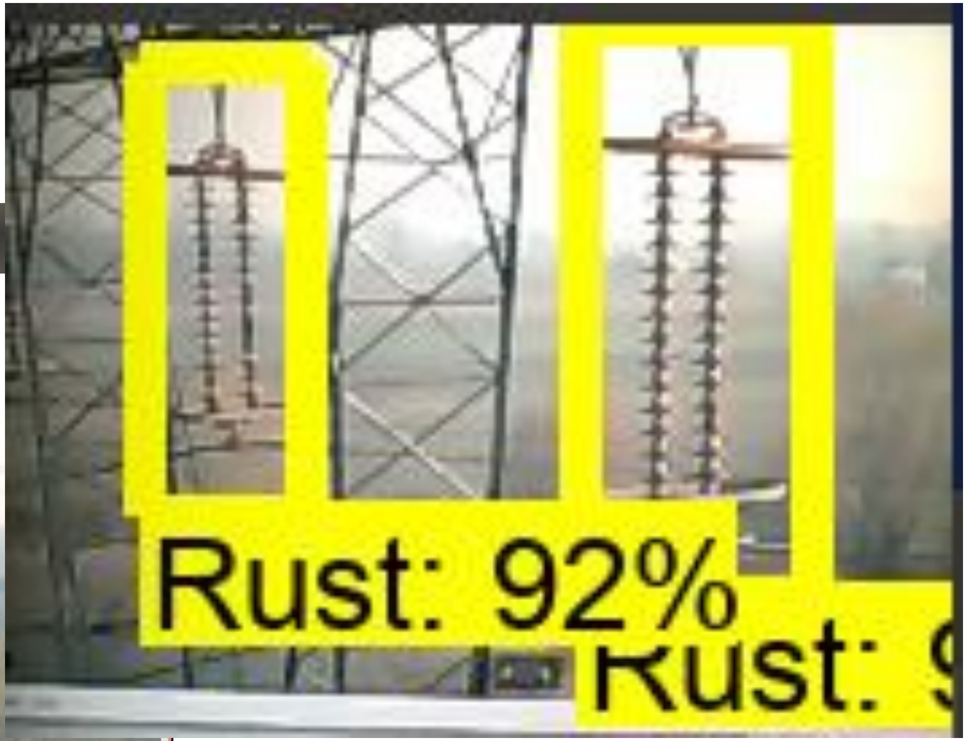
- Used 2 Convolutional Neural Network (CNN - Deep Learning)
  1. Detection: State of the art R-CNN trained for insulator detection
  2. Classification
     - New CNN trained on only 2 classes (Rust / No Rust)
       - Train accuracy = 100.0%
       - Validation accuracy = 90% (N=110)
       - Final test accuracy = 97% (N=110)

- Encouraging results
  - Good performance, suitable for on board processing
- But:
  - Limited dataset
    - Need more data and examples from several sites to perform proper validation
    - Interest in incrementing the number of classes to detect also missing parts and other faults

Jalil, B., Leone, G. R., Martinelli, M., Moroni, D., Pascali, M. A., & Berton, A. (2019). Fault detection in power equipment via an unmanned aerial system using multi modal data. Sensors, 19(13), 3014. (https://doi.org/10.3390/s19133014).

Inspection of aerial power lines: Deep Learning





Jalil, B., Leone, G. R., Martinelli, M., Moroni, D., Pascali, M. A., & Berton, A. (2019). Fault detection in power equipment via an unmanned aerial system using multi modal data. Sensors, 19(13), 3014. (https://doi.org/10.3390/s19133014).

Wire detection and thermal analysis

Visible Images:

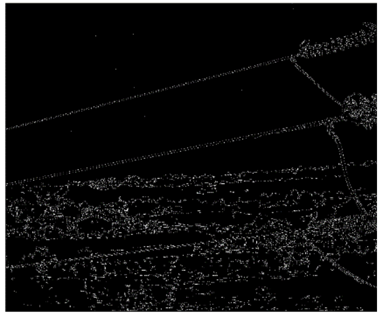
- Image Enhancement
- Edge detection (canny edge detection with threshold adjustment)
- Hough Transform
- Mask generation
    - Identification of clusters of peaks corresponding to nearly parallel lines

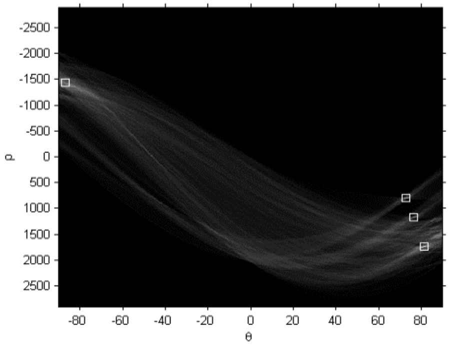
Infrared Image:

- Cables inspection and fault detection

On Larger perspective:

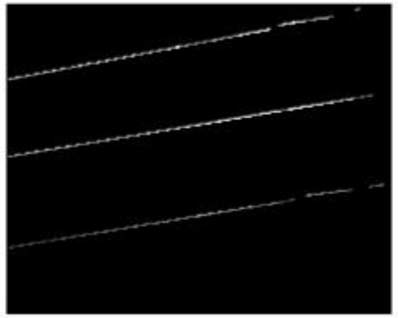
- Image registration both visible and Infrared images
- Fully automatic algorithm
- Fast algorithm





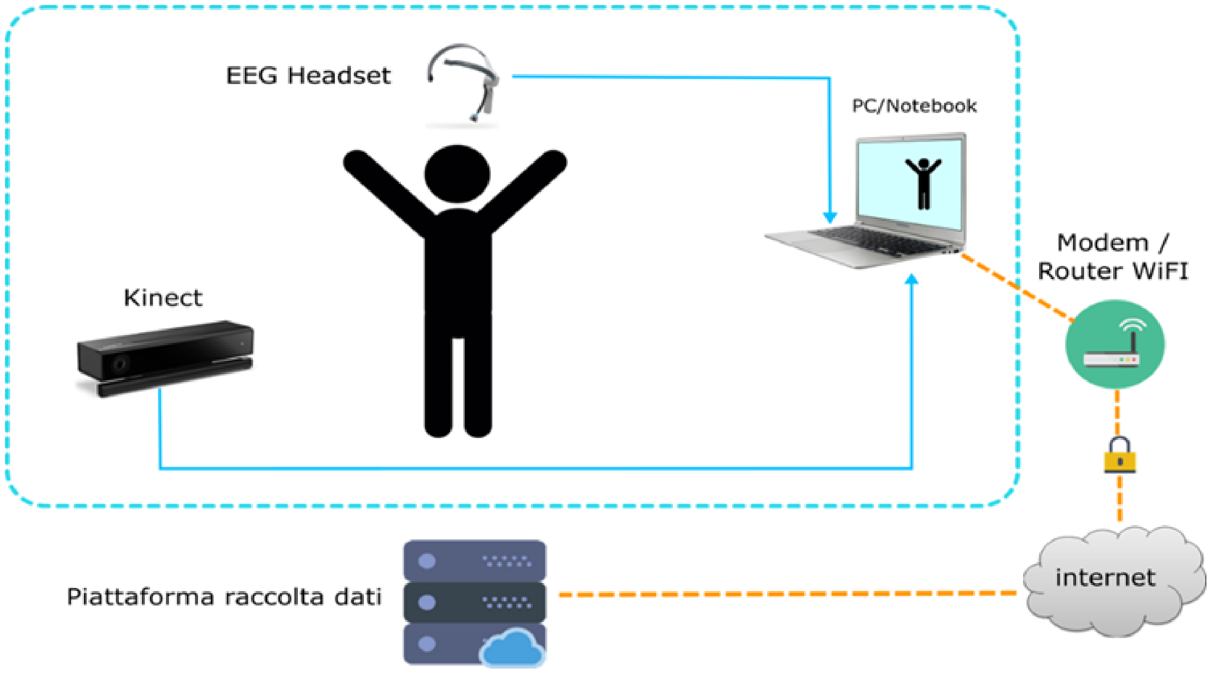
Hough trasform detection in Images

Detected power lines in Images



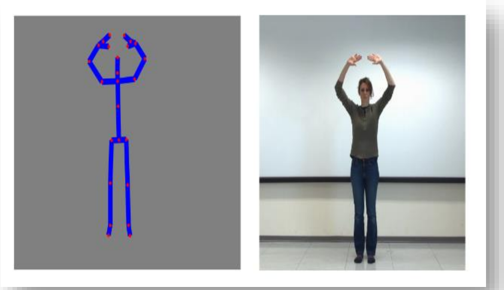
Other applications: Rehabilitation and enhanced experience

Guided motor and cognitive activity

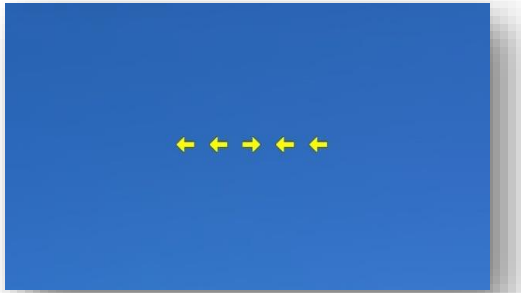


Microsoft Kinect
Gestural interaction device able to accurately detect movements of the whole figure or of the hands

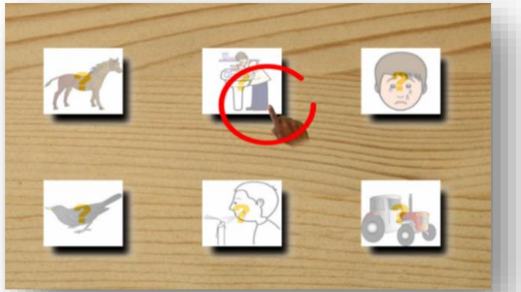
EEG wireless helmet
It detects brain activity with easy use, not requiring assembly with conductive gels.



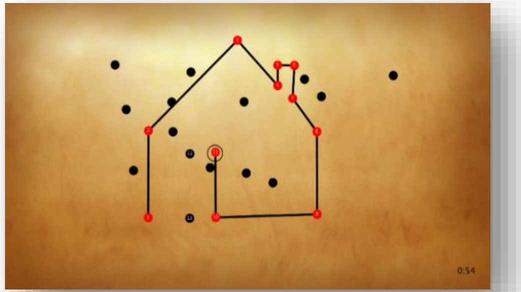
Physical Activity
guided and monitored automatically



Attention test (ANT)
Gesture-controlled with EEG monitoring



Gesture-controlled exergame
"Select the tile corresponding to the sound"



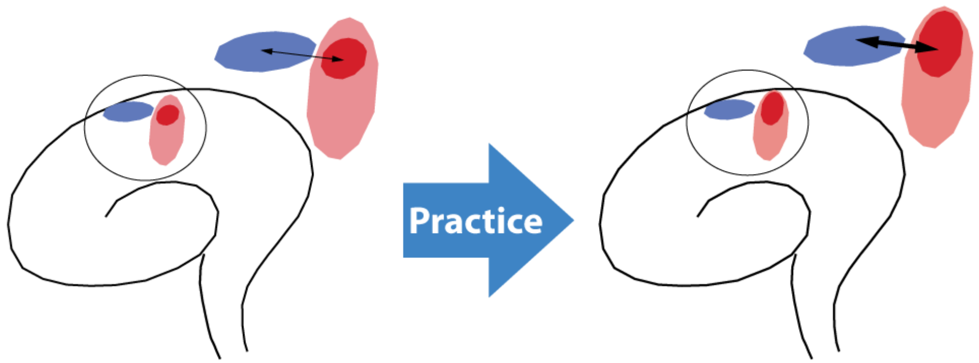
Gesture-controlled exergame
"Connect the dots and discover the figure"

Track-Hold: A system for neuromotor rehabilitation based on a passive robotic aid

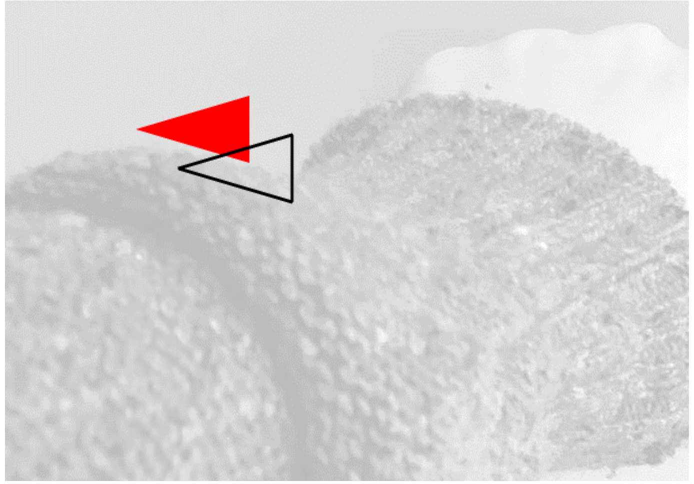
15 million people are affected by cardiovascular pathologies 10-20% of the cases had experience of cerebrovascular disease or cerebral stroke.

Stroke remains **the second leading cause of mortality** and the **first leading to disability.**

The physiological presupposition of neurorehabilitation is represented by the phenomenon of **Neuroplasticity** and the **consequent learning** and **motor control process:** the ability of the brain to modify its structure and functions according to the activities of its neurons, related for example to somato-sensory stimuli.



Track-Hold: A system for neuromotor rehabilitation based on a passive robotic aid



Track-Hold (by Wearable Robotics) is a passive robotic arm designed to record the movements of the upper limbs of human beings.
It allows the execution of exercises in a "weightless" mode: its mechanical configuration **compensate the weight of the arms** and **the weight of unit itself**, so that the exercise is purely neurological.

- **7 rotation sensors** placed in the joints
- **0.1 degree** precision
- **100 Hz** sampling rate

Exercises are dictated by a **functional basis**. *Daily life* movements, performed by manipulating the device, are broken down into sub-movements, which consist in **reaching a keypoint** characterized by a precise angle and 3D position.
Data collected:

- **Total time**
- **Distance overhead** (overall precision)
- **LF index, HF index**: they allows to detect some indications of tremors associated with neuromotor disorders based on their frequency.
- **Raw data (**for further analysis)

Explore Kandinsky

A portable virtual reality system for the treatment of subjects with Autism Spectrum Disorders

A **virtual environment** for Oculus GO, displaying **Kandinsky paintings** from the abstract period (1920–1930).

It shows an **interpretation of the tridimensional position** of the single graphical elements of the paintings, placing them in the virtual space.

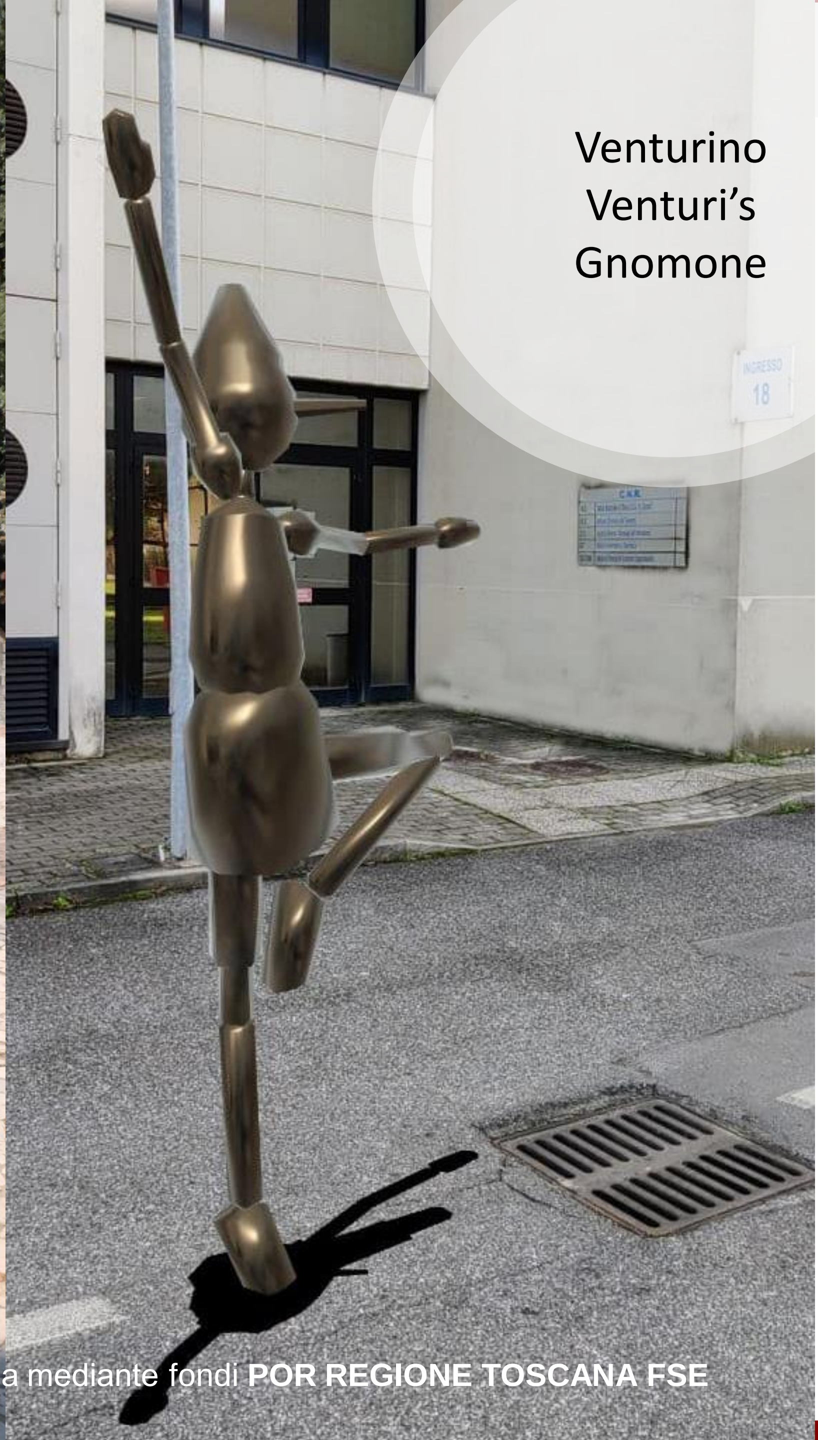
The user can interact with the individual elements, **moving them in space**. At the end of the manipulation it is possible to observe is **effects on the original painting**.

- The user **freely express himself** with the arrangement of the elements, in some way following the DIR Floortime paradigm (spontaneous interaction).
- The exercise requires **abstraction skill**, not trivial for subjects with ASD.
- Graphical object manipulation requires **a precise motor coordination**, so that useful because dyspraxia associated with ASD is very common.

VERO - Virtualità intErattiva nel paRco di pinOcchio

- Augmented reality applications will encourage the involvement and immersion of the visitors with an interactive audiovisual experience which can be playful and informative at the same time
- A version of the apps, dedicated to special AR see-through glasses, will allow a further degree of immersion, greatly enriching the visiting experience.
- Augmented reality features could be used with printed material containing photographic reproductions of the mosaics (such as brochures and books), so that the visitors can continue the interactive experience at home, too.
- The project involves the creation of mobile applications that will animate one of the most important works of art in the Pinocchio Park, the Piazzetta dei Mosaici created by the artist Venturino Venturi

Programma di Intervento denominato "CNR4C" Progetto Congiunto di Alta Formazione, cofinanziato dalla Regione Toscana mediante fondi **POR REGIONE TOSCANA FSE 2014/2020 Asse A Occupazionale** – nell'ambito di "**Giovanisì** (Progetto Regione Toscana per l'autonomia dei giovani)



Venturino Venturi's Gnomone

Programma di Intervento denominato "CNR4C" Progetto Congiunto di Alta Formazione, cofinanziato dalla Regione Toscana mediante fondi **POR REGIONE TOSCANA FSE 2014/2020 Asse A Occupazionale** – nell'ambito di "**Giovanisì** (Progetto Regione Toscana per l'autonomia dei giovani)

THANK YOU

Davide Moroni
davide.moroni@cnr.it
http://si.isti.cnr.it

References

1. Coscetti, S., Moroni, D., Pieri, G., & Tampucci, M. (2019, November). Augmented Reality for Tissue Converting Maintenance. In 2019 15th International Conference on Signal-Image Technology & Internet-Based Systems (SITIS) (pp. 585-590). IEEE.
2. Coscetti, S., Moroni, D., Pieri, G., & Tampucci, M. (2020, January). Factory Maintenance Application Using Augmented Reality. In Proceedings of the 3rd International Conference on Applications of Intelligent Systems (pp. 1-6).
3. Germanese, D., Leone, G. R., Moroni, D., Pascali, M. A., & Tampucci, M. (2018). Long-term monitoring of crack patterns in historic structures using UAVs and planar markers: a preliminary study. *Journal of Imaging*, *4*(8), 99.
4. Germanese, D., Pascali, M. A., Berton, A., Leone, G. R., Moroni, D., Jalil, B., ... & Benassi, A. (2019). Architectural Heritage: 3D Documentation and Structural Monitoring Using UAV. In *VIPERC@ IRCDL* (pp. 1-12).
5. Germanese, D., Leone, G. R., Moroni, D., Pascali, M. A., & Tampucci, M. (2018, September). Towards structural monitoring and 3d documentation of architectural heritage using UAV. In *International Conference on Multimedia and Network Information System* (pp. 332-342). Springer, Cham.
6. Bacco, M., Barsocchi, P., Cassará, P., Germanese, D., Gotta, A., Leone, G. R., ... & Tampucci, M. (2020). Monitoring Ancient Buildings: Real Deployment of an IoT System Enhanced by UAVs and Virtual Reality. *IEEE Access*, *8*, 50131-50148.
7. Bacco, M., Chessa, S., Di Benedetto, M., Fabbri, D., Girolami, M., Gotta, A., ... & Pellegrini, V. (2017, September). UAVs and UAV swarms for civilian applications: communications and image processing in the SCIADRO project. In International Conference on Wireless and Satellite Systems (pp. 115-124). Springer, Cham.
8. Jalil, B., Pascali, M. A., Leone, G. R., Martinelli, M., Moroni, D., & Salvetti, O. (2018, September). To identify hot spots in power lines using infrared and visible sensors. In International Conference on Multimedia and Network Information System (pp. 313-321). Springer, Cham.
9. Jalil, B., Pascali, M. A., Leone, G. R., Martinelli, M., Moroni, D., Salvetti, O., & Berton, A. (2019). Visible and Infrared imaging based inspection of power installation. *Pattern Recognition and Image Analysis*, *29*(1), 35-41.
10. Jalil, B., Leone, G. R., Martinelli, M., Moroni, D., Pascali, M. A., & Berton, A. (2019). Fault detection in power equipment via an unmanned aerial system using multi modal data. *Sensors*, *19*(13), 3014.
11. Delmastro, F., Dolciotti, C., La Rosa, D., Di Martino, F., Magrini, M., Coscetti, S., & Palumbo, F. (2019). Experimenting Mobile and e-Health Services with Frail MCI Older People. *Information*, *10*(8), 253.
12. Coscetti, S., & Magrini, M. (2019, November). An Interactive System for Motor and Cognitive Assisted Activities. In *2019 15th International Conference on Signal-Image Technology & Internet-Based Systems (SITIS)* (pp. 591-594). IEEE.
13. Magrini, M., Curzio, O., Carboni, A., Moroni, D., Salvetti, O., & Melani, A. (2019). Augmented Interaction Systems for Supporting Autistic Children. Evolution of a Multichannel Expressive Tool: The SEMI Project Feasibility Study. *Applied Sciences*, *9*(15), 3081.