# Augmented reality and intelligent systems in Industry 4.0

Davide Moroni

http://si.isti.cnr.it

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# SILab in a nutshell

## The Team

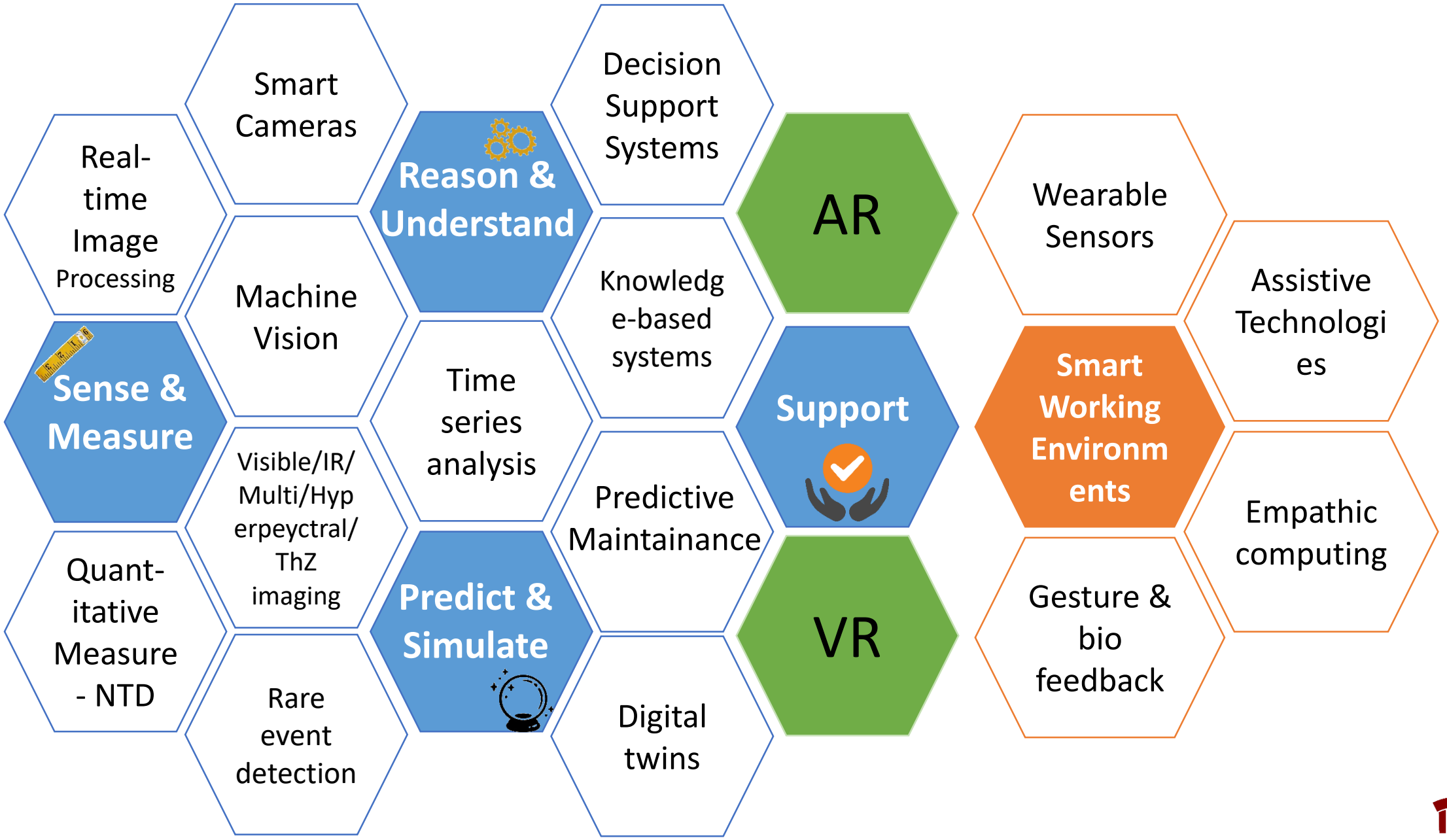

## Competences

- Computer vision
- Artificial intelligence & intelligent systems
- Statistical signal processing
- Topological data analysis
- Human-computer interaction
- Inclusion & Accessibility

## Application fields

- Industry 4.0 — Smart Converting 4.0, COMPTO-NIM
- Blue Growth — NAUTILOS
- Mobility & Smart Cities — MobiWallet, space, ICSI, SCIADRO
- Cultural Heritage — MOSCARDO, ARROWS
- Internet of Everything — PlatformUptake.eu
- Health & Wellbeing — ProCAncer-I, ACTIVAGE PROJECT, NAVIGATOR, SEMEOTICONS

# Signals and Images Lab for Industry 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

# XR Continuum & AR in I4.0

# Extended Reality Continuum

EXTENDED REALITY (XR)

REAL ⟷ VIRTUAL

## REAL ENVIRONMENT

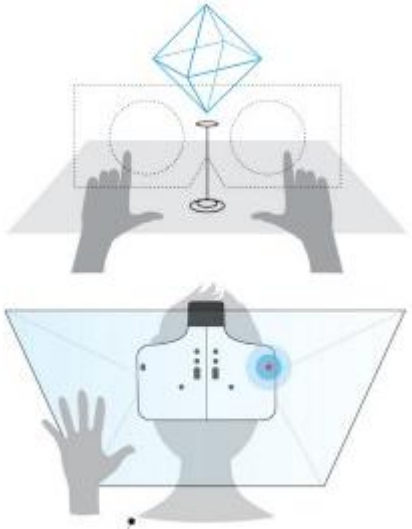
## AUGMENTED REALITY (AR)

Real world with digital information overlay


Real world remains central to the experience, enhanced by virtual details.

## MIXED REALITY (MR)

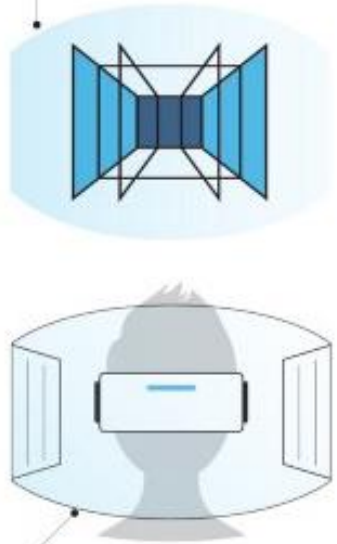
Real and the virtual are intertwined



Interaction with and manipulation of both the physical and virtual environment.

## VIRTUAL REALITY (VR)

Completely digital environment



Fully enclosed, synthetic experience with no sense of the real world.

# XR Application domains

## Industrial & manufacturing

- Guided training and remote support
- Improved safety
- Real-time factory diagnostics

## Engineering

- 3D visualization and CAD
- Colleague collaboration and communication

## Healthcare

- More efficient patient care
- Diagnosis and treatment assistance
- Surgical training and visualization

## Retail

- Try before you buy: clothes, furniture, car, real estate shopping, etc.
- Navigation to products and personalized coupons

AR VR XR MR

## Education

- Immersive, self-guided, interactive visual learning
- Any subject, from history and physics to vocational

## Marketing & advertising

- Personalized ads based on context
- Consumer data - what they like, what they look at, etc.

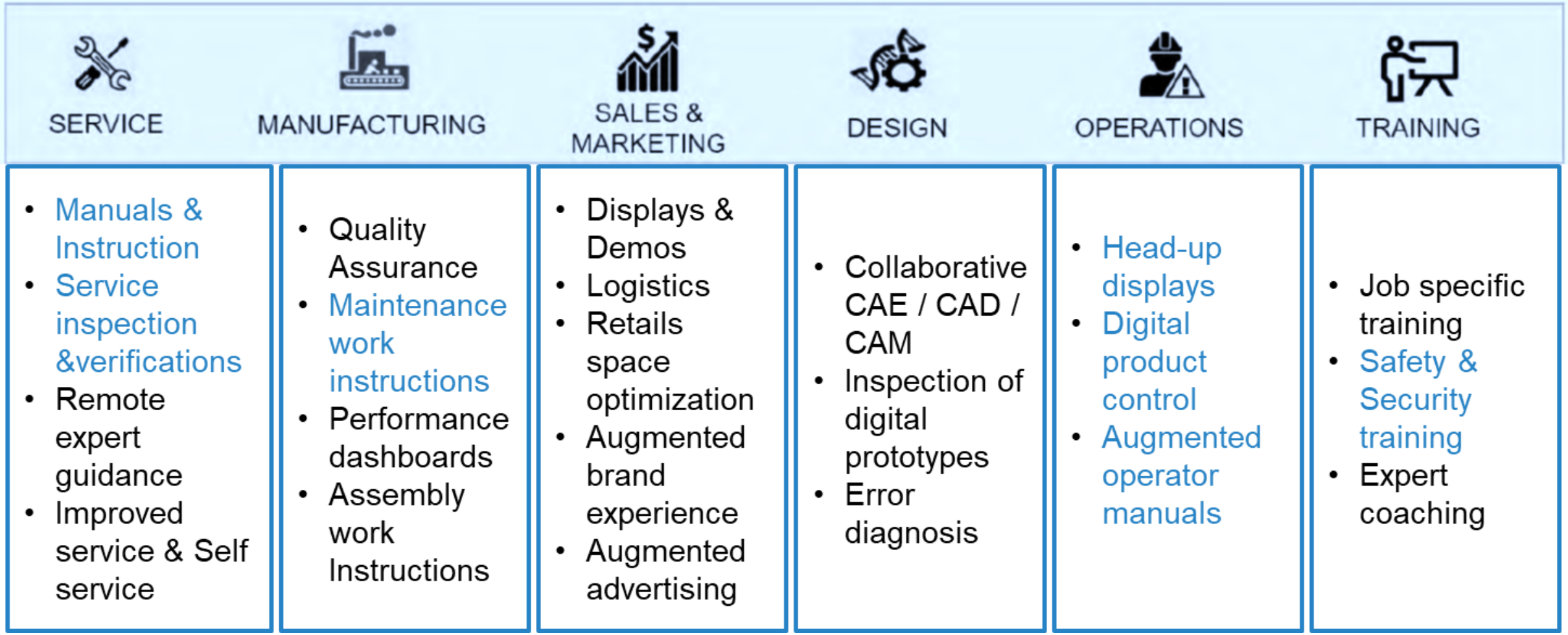
## Military

- Instructional training
- In-the-field assistance

## Emergency response

- Police, fire, security response
- Potential improvements in safety, response time, and saving lives.

# Extended Reality across Industry 4.0



# XR: extending sensing and the 6th sense

GLASSES

HANDHELD

IMMERSIVE AUDIO

BONE TRANSDUCERS

DATA SONIFICATION

ABC

NATURAL LANGUAGE

HEARING

VISION

TASTE

TOUCH

SMELL

INTUITION + AWARENESS

NOT REALLY, BUT REALITY AMPLIFICATION BY SYNESTHESIA

Artificial Intelligence

Machine Learning

Intelligent systems

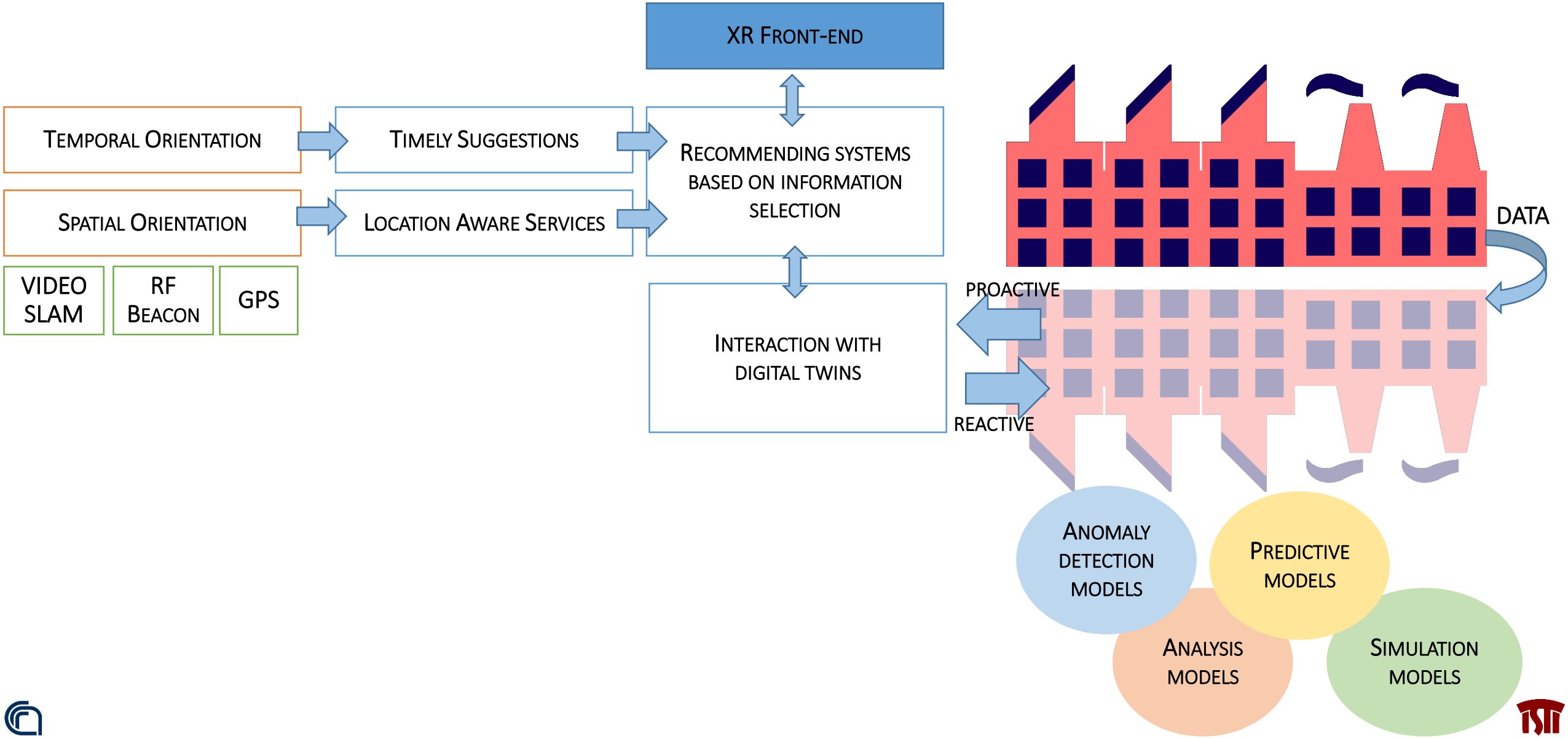
APTIC SUIT



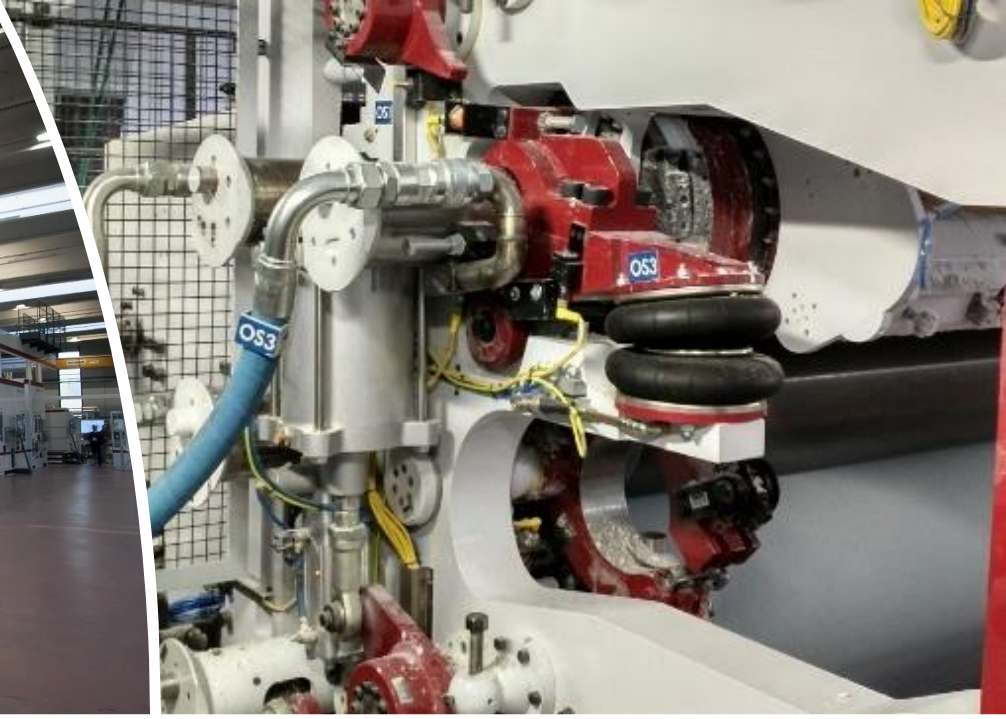
APTIC GLOVES

VIRTUAL SMELL MASKS (FEEL REAL)

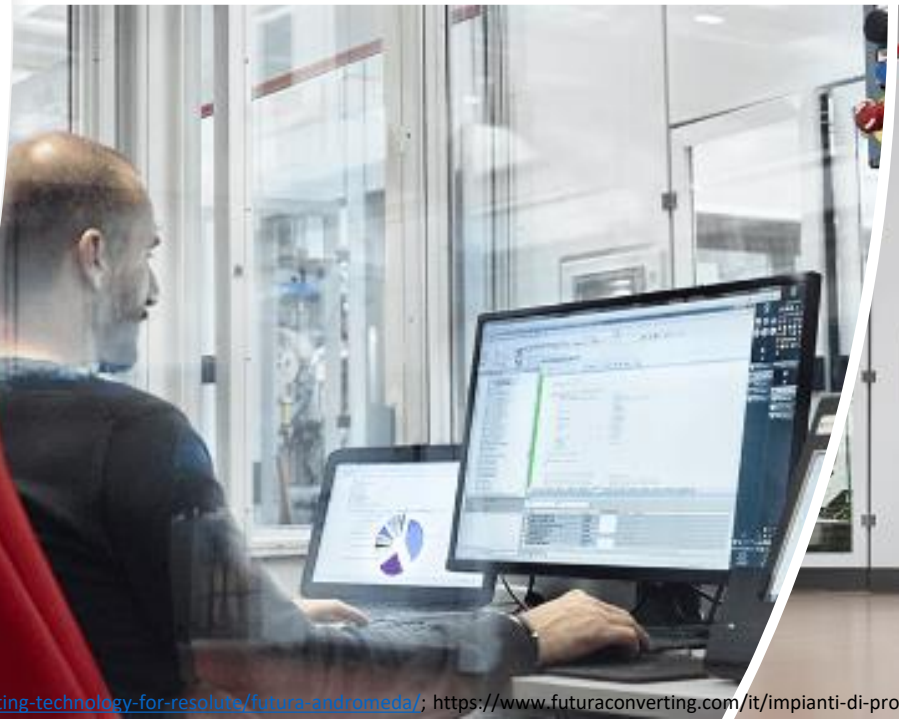
# Extending sensing with intelligent services



# The tissue converting scenario

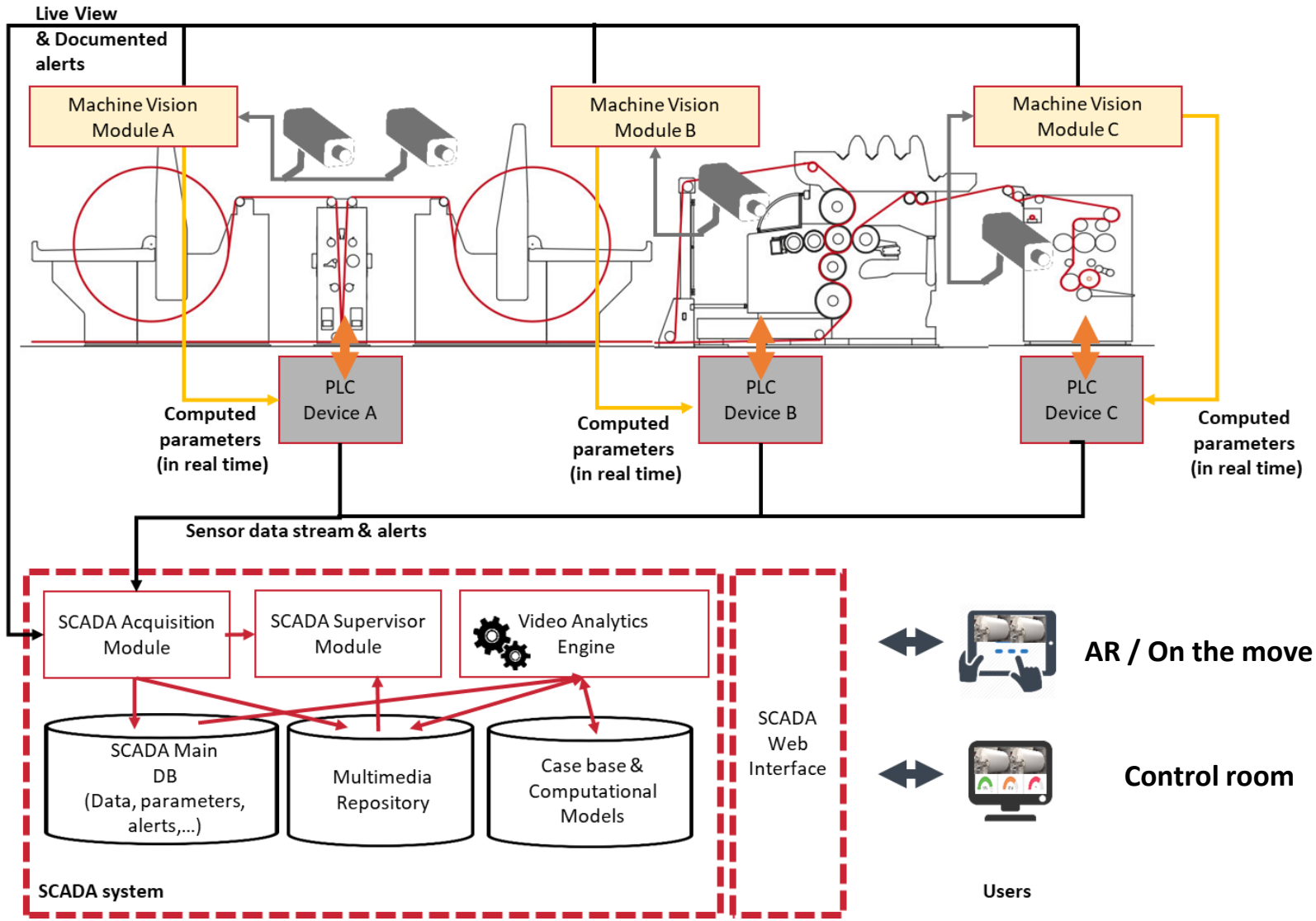

- 10k+ components
  - Ordinary and extraordinary maintenance
  - High-level skills required



- 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/

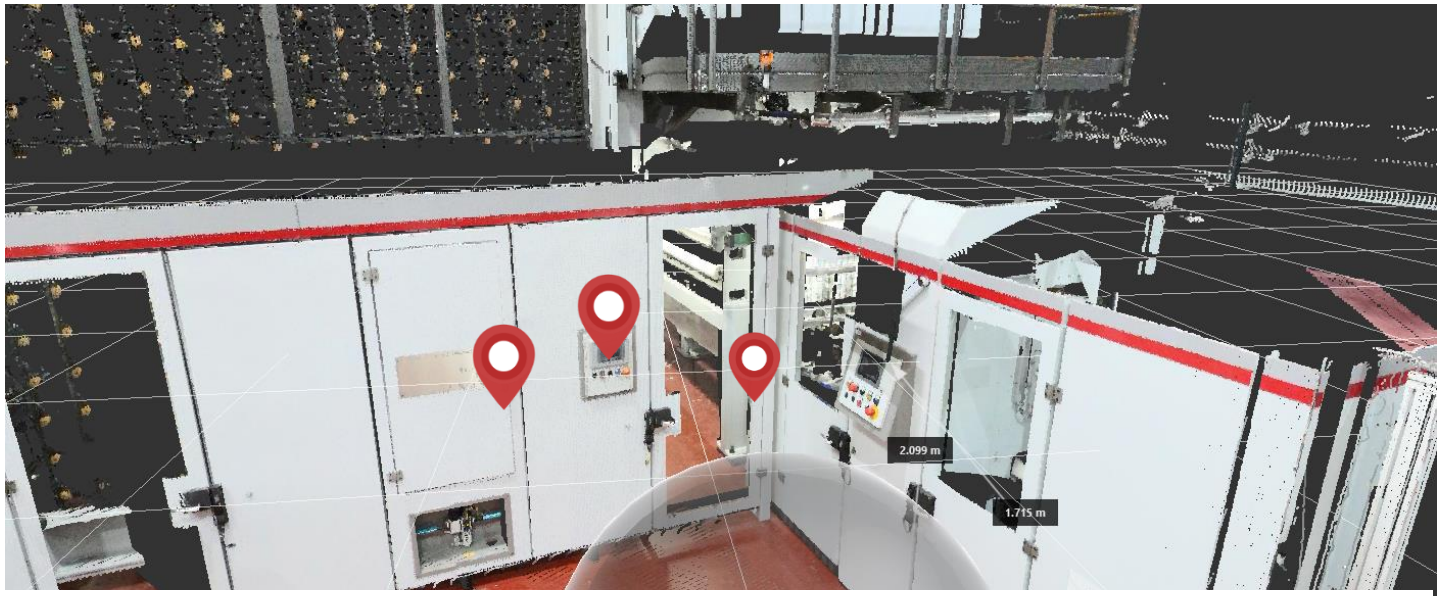
# Machine Vision and Video Analytics in Industry 4.0

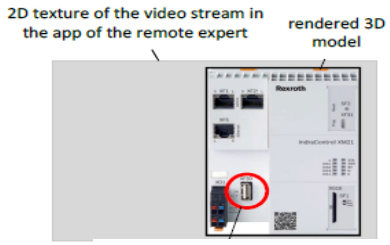


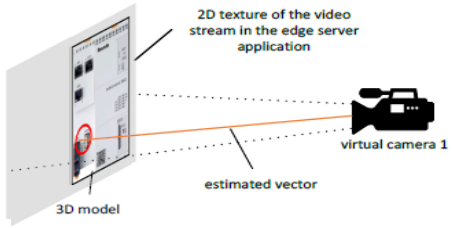

- Real-time local image processing for control
  - Adaptation at single machine level
- Real-time global video analytics for
  - Adaptation at line level
  - Failure prediction
  - Maximize uptime
- Long term monitoring and machine learning for predictive maintenance
- Live view and real time operational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

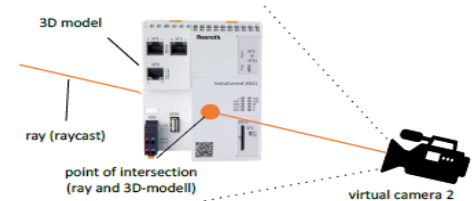
# Adding Content to Reality in the Factory

- 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

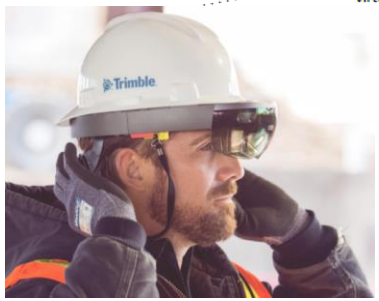



Epson Moverio BT 2200




Hololens & Hard Hat

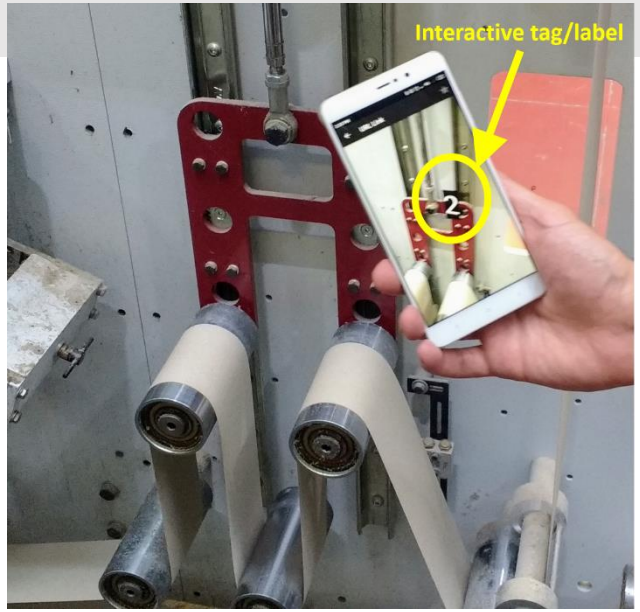
# Devices

- 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

# 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.




# Use Cases

Video available at: https://tinyurl.com/68u2nn2v

# 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:

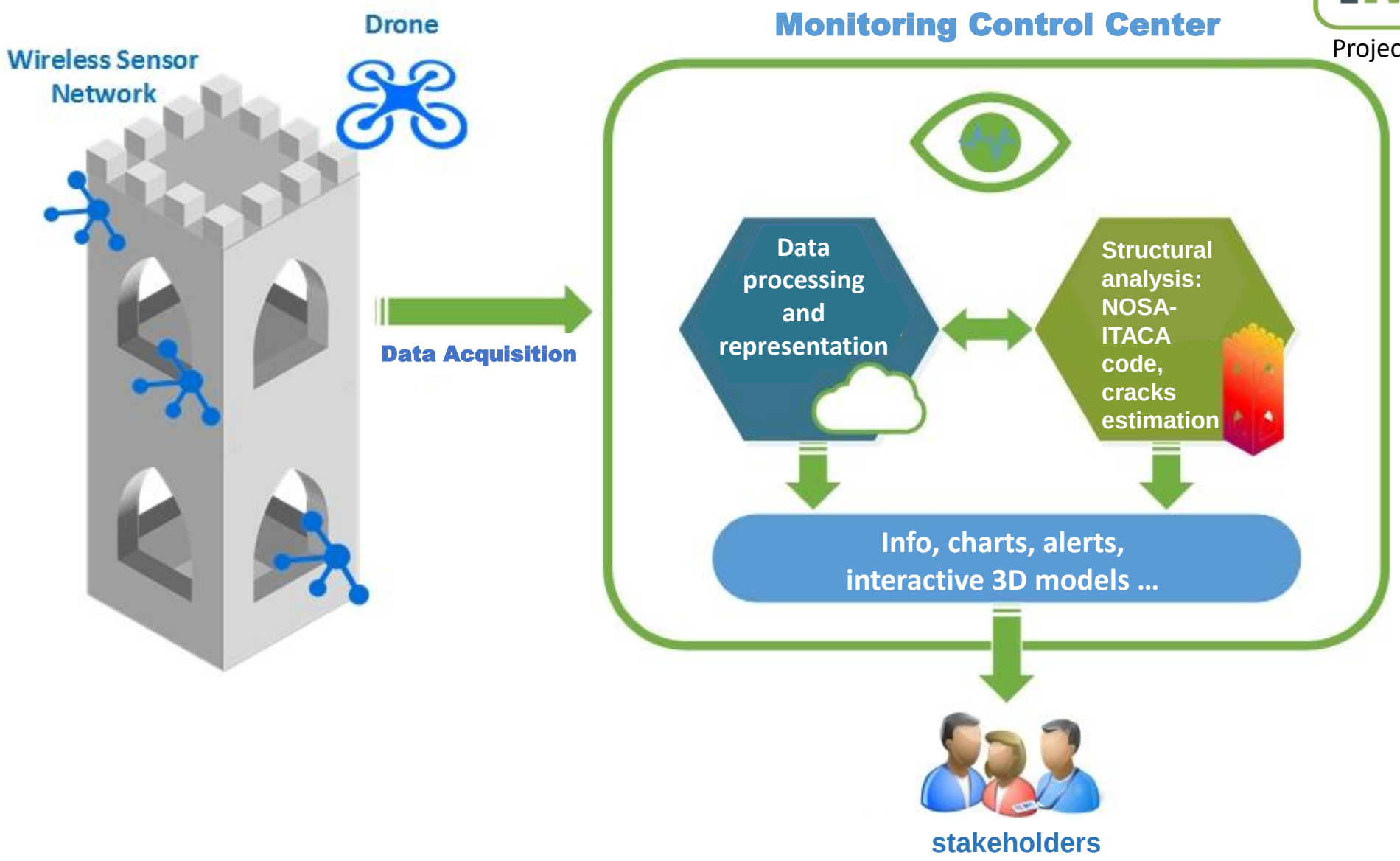
- Big Data analysis integration for predictive maintenance.
- Machine vision for live monitoring of the production process and predictive maintenance.
- Proactive system for troubleshooting.

# AUV-Based Inspections

# Structural Health Monitoring: MOSCARDO system

MOSCARDO

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




infomobility
Infomobility SRL
Partner & Capofila

CNR ISTI
Partner

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UniFI DICEA
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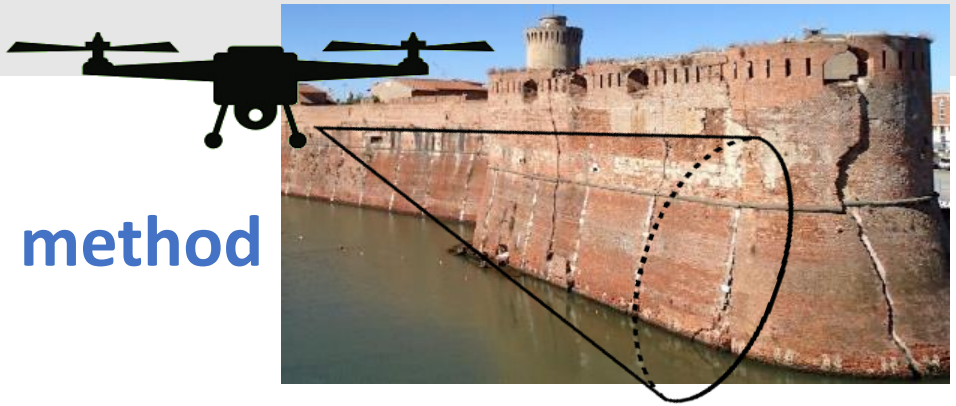


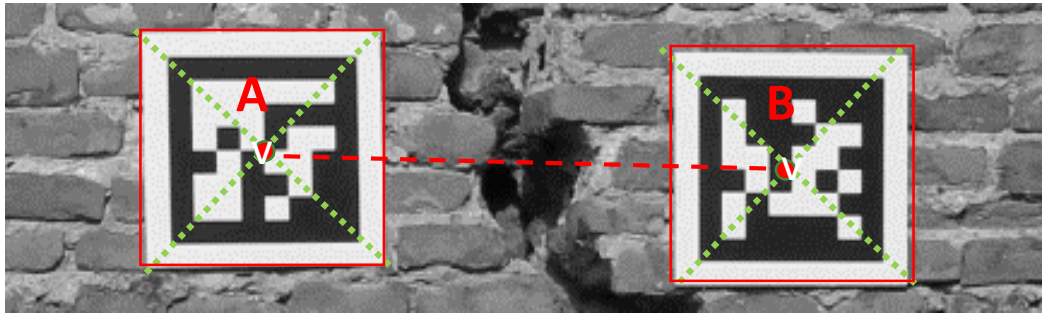
# UAV + MARKER-BASED SLAM method

**Evaluation of cracks features using:**

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

**Images acquired by UAV allows for:**

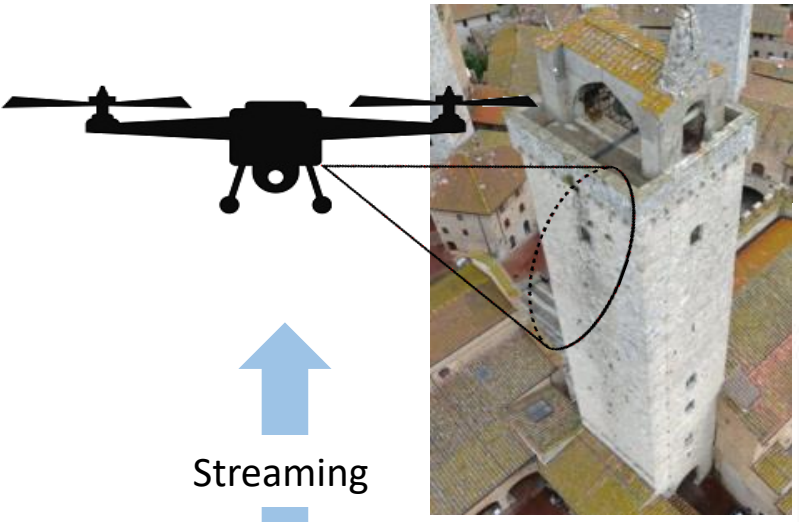
- Accessing cracks also in difficult areas
- Capturing cracks from optimal locations
- Fast data acquisition of the whole structure, to get a 3D model





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



Streaming

Drone
Ground Unit

AR Interface

Comparison with
reference 3D Model


Interactive panel for exploring WSN data

Connection to in situ WSN

Gateway

With the contribution of Fly&Sense, Area della Ricerca CNR (Coordinator: Andrea Berton)

# VR: 3D Front-end

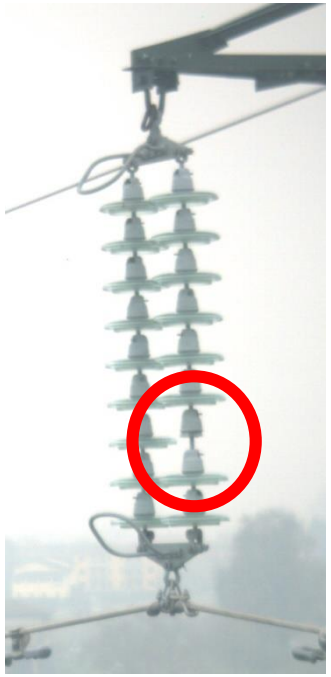

LIVE VR DEMO: http://moscardo.isti.cnr.it/

# MOSCARDO Video

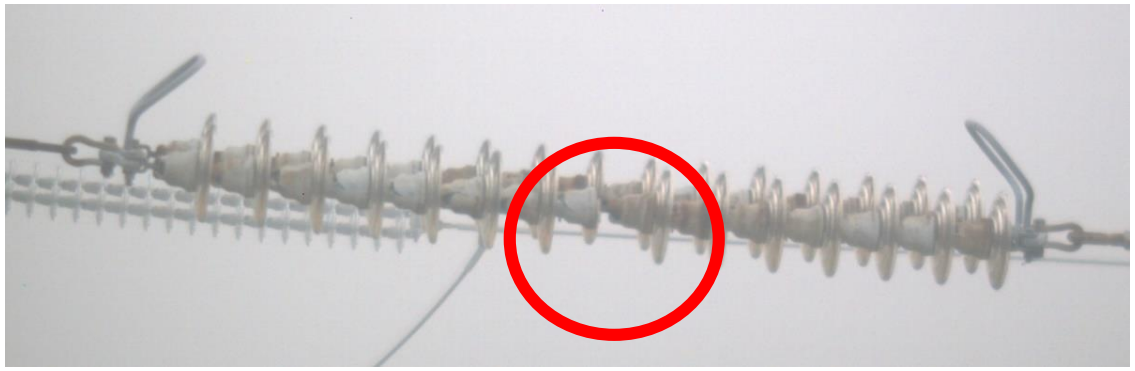
Video available at: https://youtu.be/WHATS9Voyt4

(with English subtitles)

# Inspection of aerial power lines

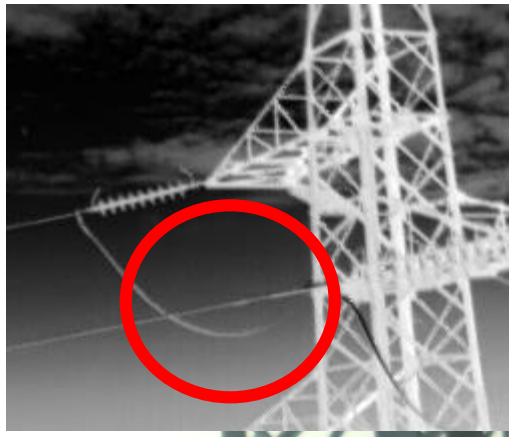


Missing insulator #1



Rust and missing insulator

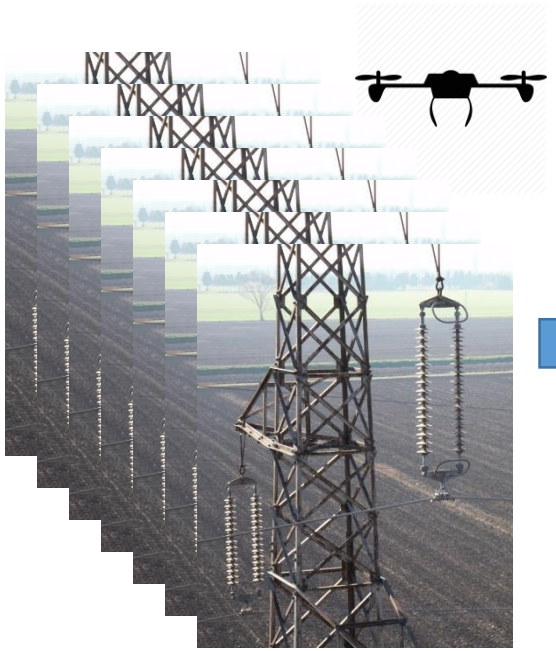
Strefolatura – Broken strands



Infiascatura

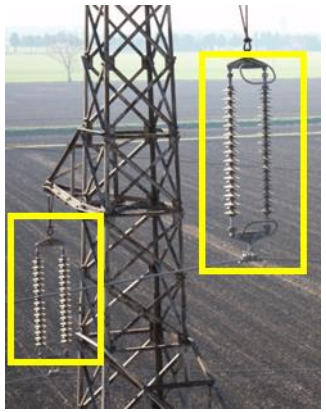
# Inspection of aerial power lines: Object detection pipeline

UAV Video Stream



Object detection

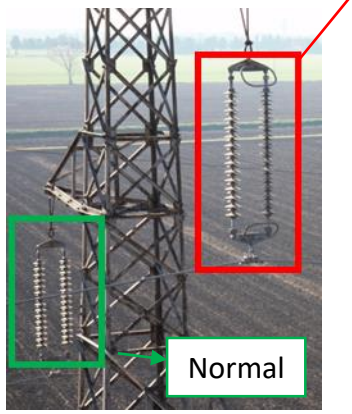
Objects of interest detected



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).

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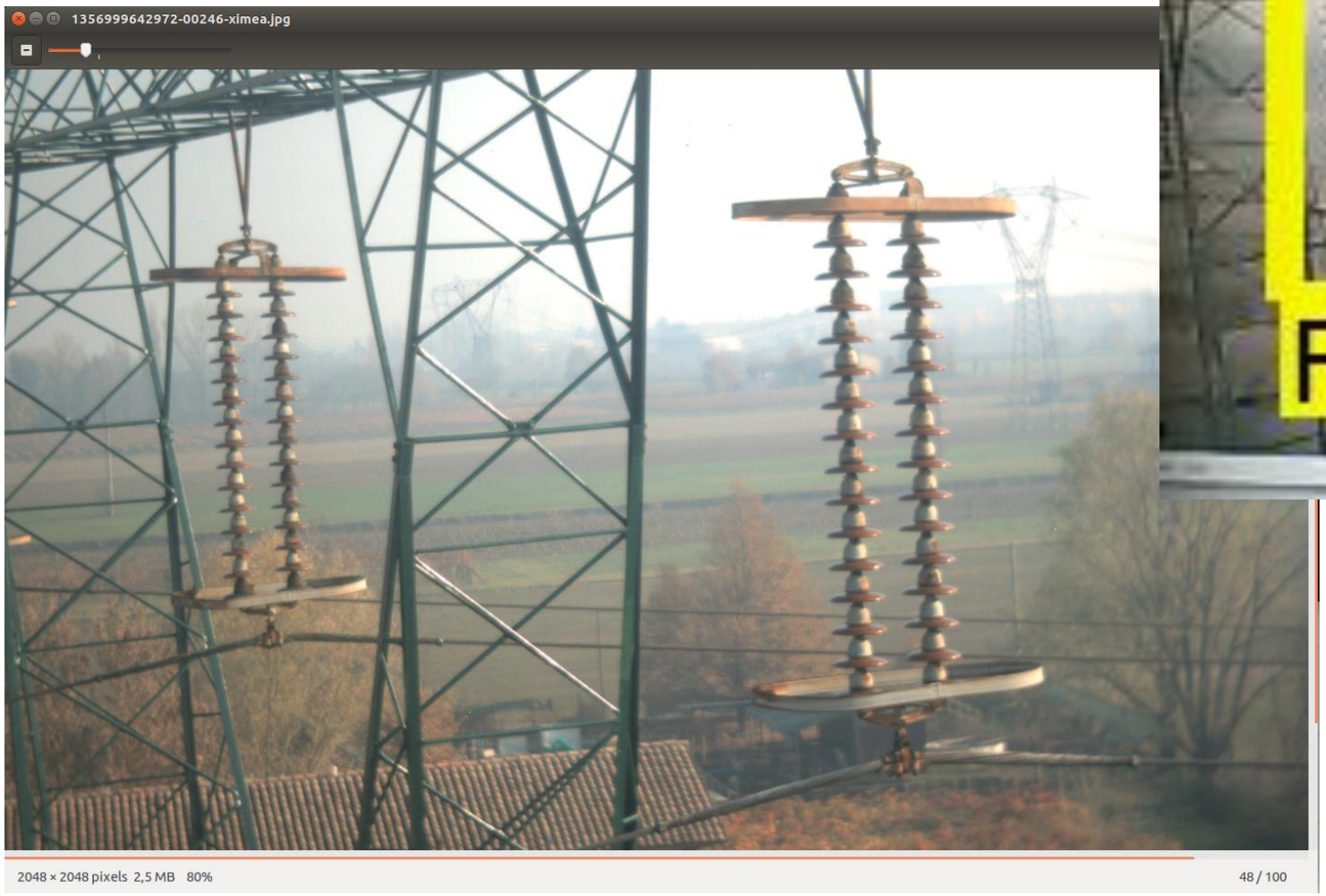


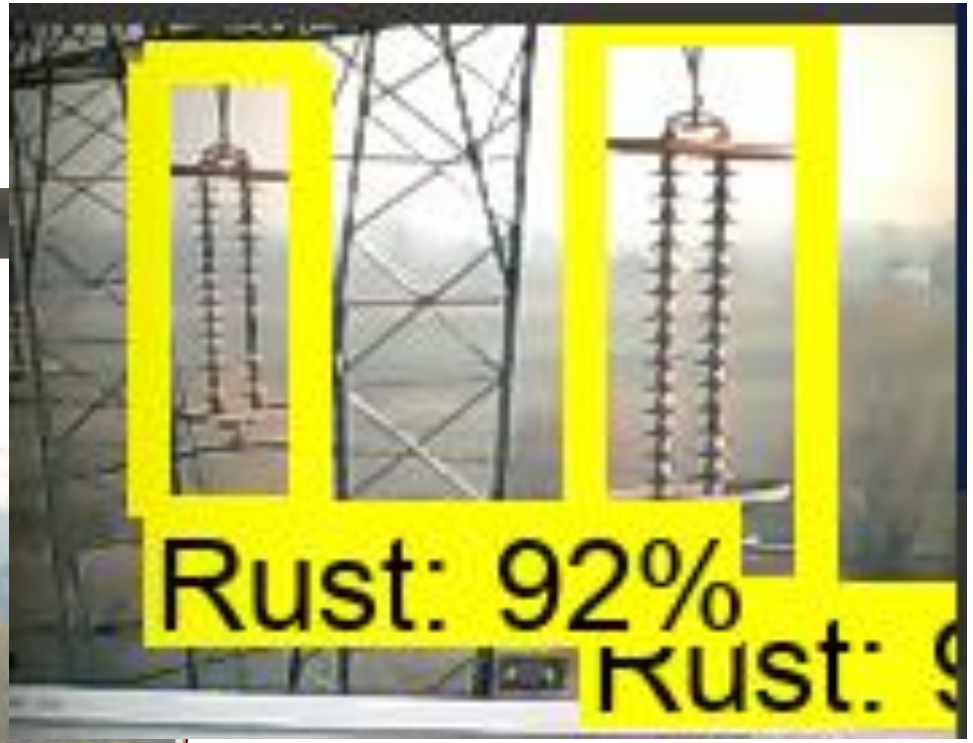


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# Wire detection and thermal analysis

## Visible Images:

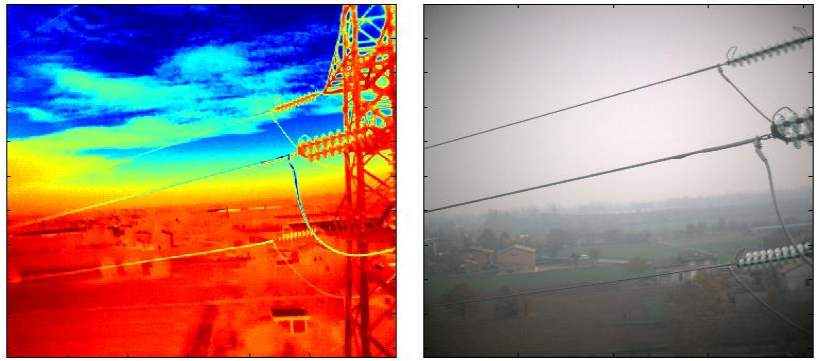
- Image Enhancement
- Edge detection (canny edge detection with threshold adjustment)
- Hough Transform
- Mask generation
    - Identification of clusters of  peaks corresponding to nearly parallel lines

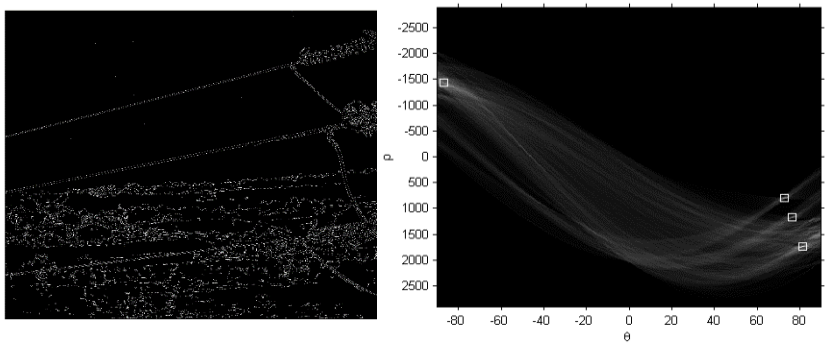
## Infrared Image:

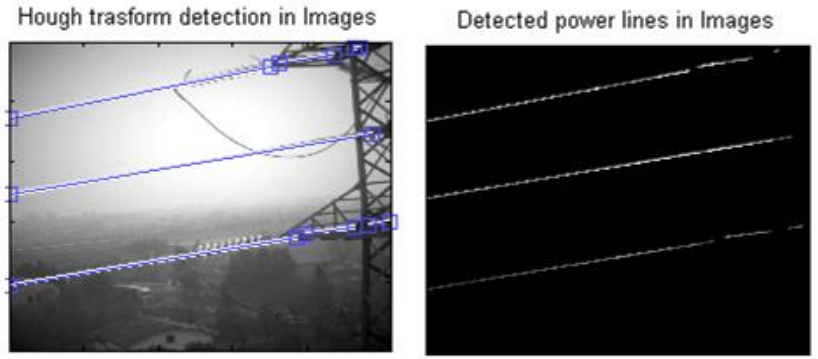
- Cables inspection and fault detection

## On Larger perspective:

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





# Conclusions

- XR has a great potential in Industry 4.0 that has not been fully unveiled
- Artificial Intelligence and Intelligent Systems represent a sixth-sense enabling even more applications
- Their combination has already been proven to be effective in disparate scenarios:
  - From production plants to aerial inspections

- Still, there exist a number of non-technological barriers that should be tore down:
  - Regulation issues
  - Data accessibility and shareability

# THANK YOU

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

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