The Manufacturing Partnership Day
26/9/2023, Brussels, Belgium

OPTIMAI Industry 5.0 through the lens of AI and XR

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https://optimai.eu/

OPTIMAI

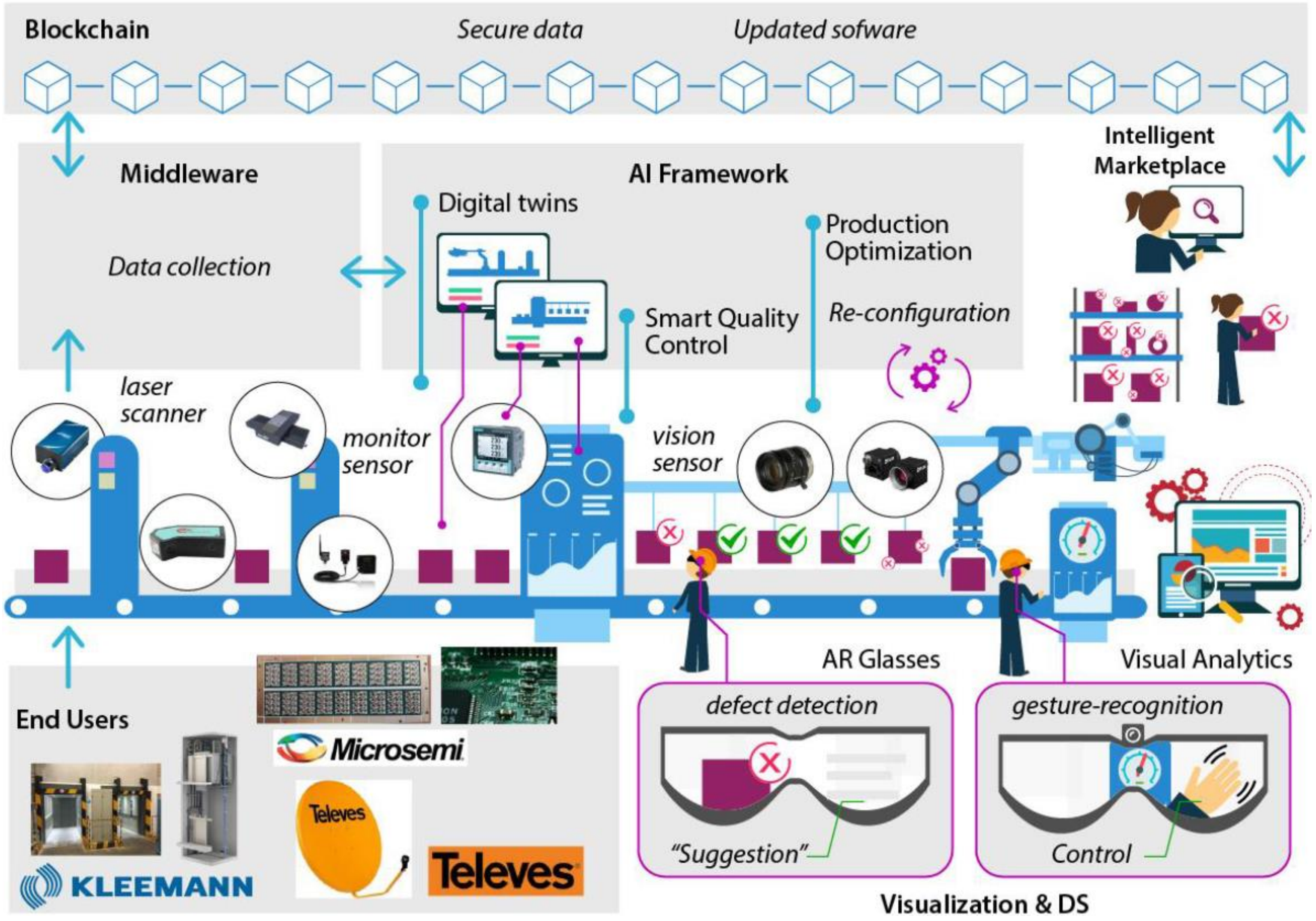
Presentation outline

- Project overview
- ZDM technologies in OPTIMAI
- OPTIMAI Industry 5.0
- Conclusions

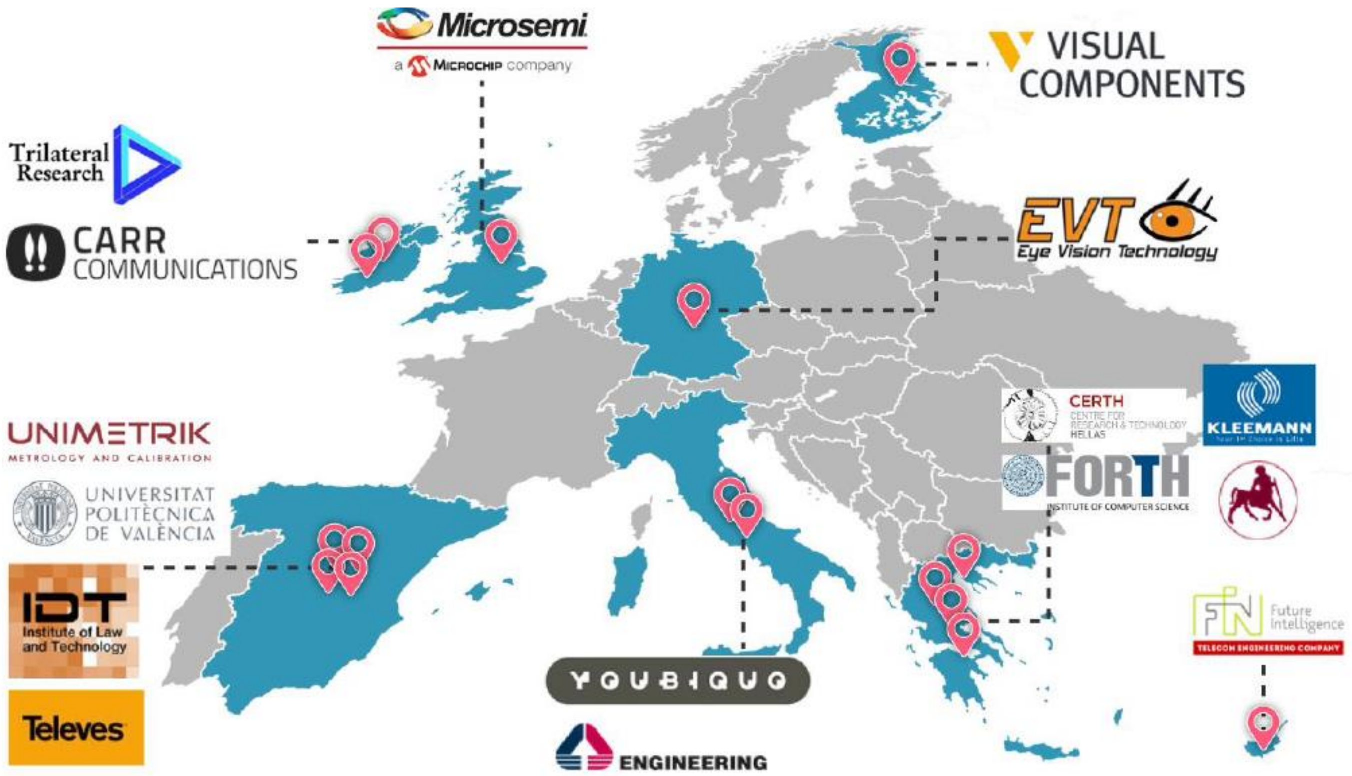
Project overview

OPTIMAI Concept

- Instrumentation of production line with smart sensors
- Real-time monitoring and data collection employing a middleware layer
- Using AI methods to detect defects early in production
- Virtualization of the manufacturing process using digital twins
- Speed up line qualification and reconfiguration utilizing a context-aware AR environment



The Consortium



Grant Number	**958264**
H2020 Call	H2020-NMBP-TR-IND-2020-singlestage
Duration	36 Months
Starting Date	**1 January 2021**
Countries	Greece, Cyprus, Germany, Finland, Italy, Spain, Ireland, United Kingdom

- 16 Partners
- 8 European Countries

PROJECT PARTNERS

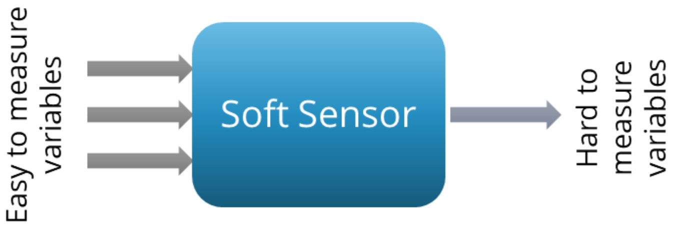
ZDM technologies in OPTIMAI

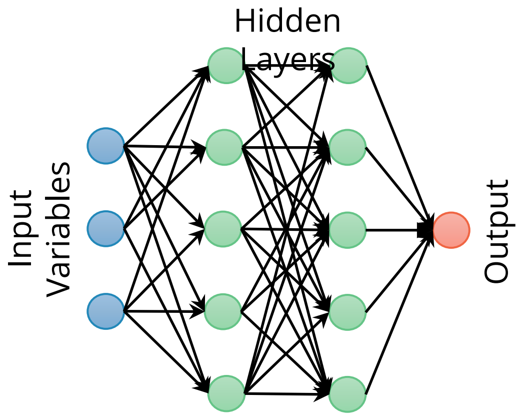
Defect Detection

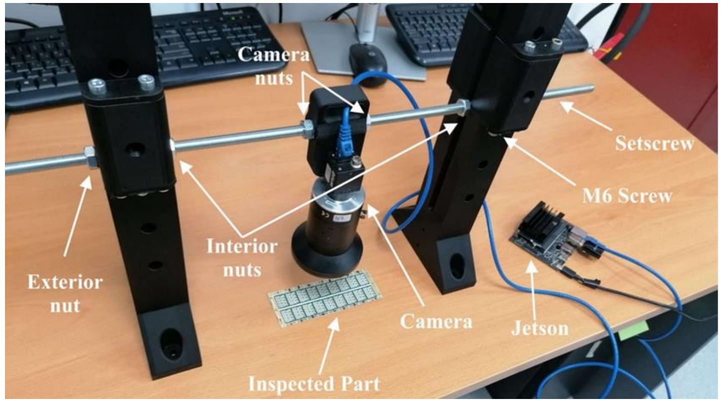
Applied in Microelectronics

Defect Detection
Applied in Microelectronics

- DL applications involve the development of **Soft Sensors (SS)** for the indirect monitoring of hidden variables during production.
- **What we do: a soft sensor which uses DL to detect defects**
  - Instead of using a 3D laser sensor, we use **a 2D sensor to capture an RGB image of the product**
  - Analyse the **2D RGB image** with DL to **estimate a 3D measurement such as volume**





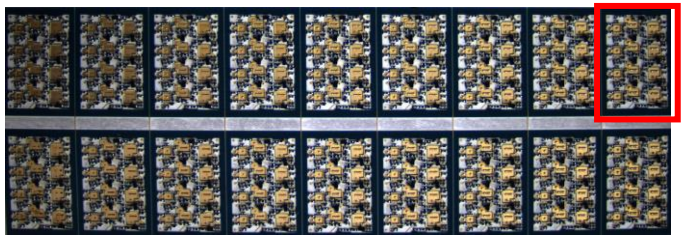


✓ Lower cost
✓ Easy to use & install

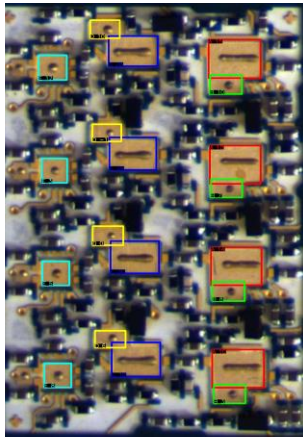
A. Evangelidis, N. Dimitriou, L. Leontaris, D. Ioannidis, G. Tinker and D. Tzovaras, "A Deep Regression Framework Toward Laboratory Accuracy in the Shop Floor of Microelectronics," in IEEE Transactions on Industrial Informatics, vol. 19, no. 3, pp. 2652-2661, March 2023.

Use Case Description
Overview

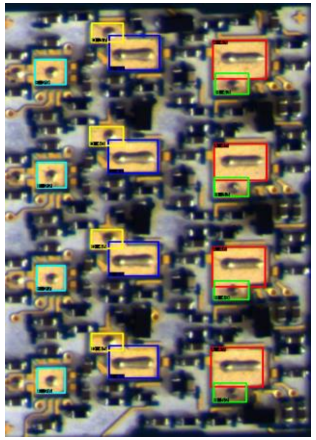
- An industrial process that generates defects is the dispensing of glue on **Printed Circuit Boards (PCBs)**
- The defects are the dispensing of insufficient or excessive amount of glue
- **Problem:** The identification of such defects required manual inspection which is a time-consuming and a process with errors



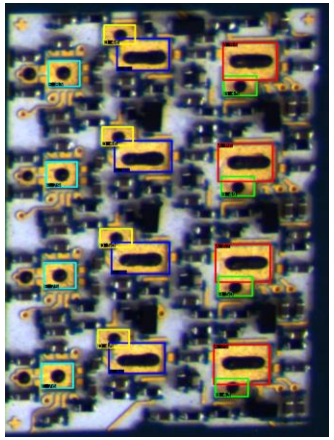
Printed Circuit Board (PCB) with 18 circuit modules



× Insufficient



✓ Normal

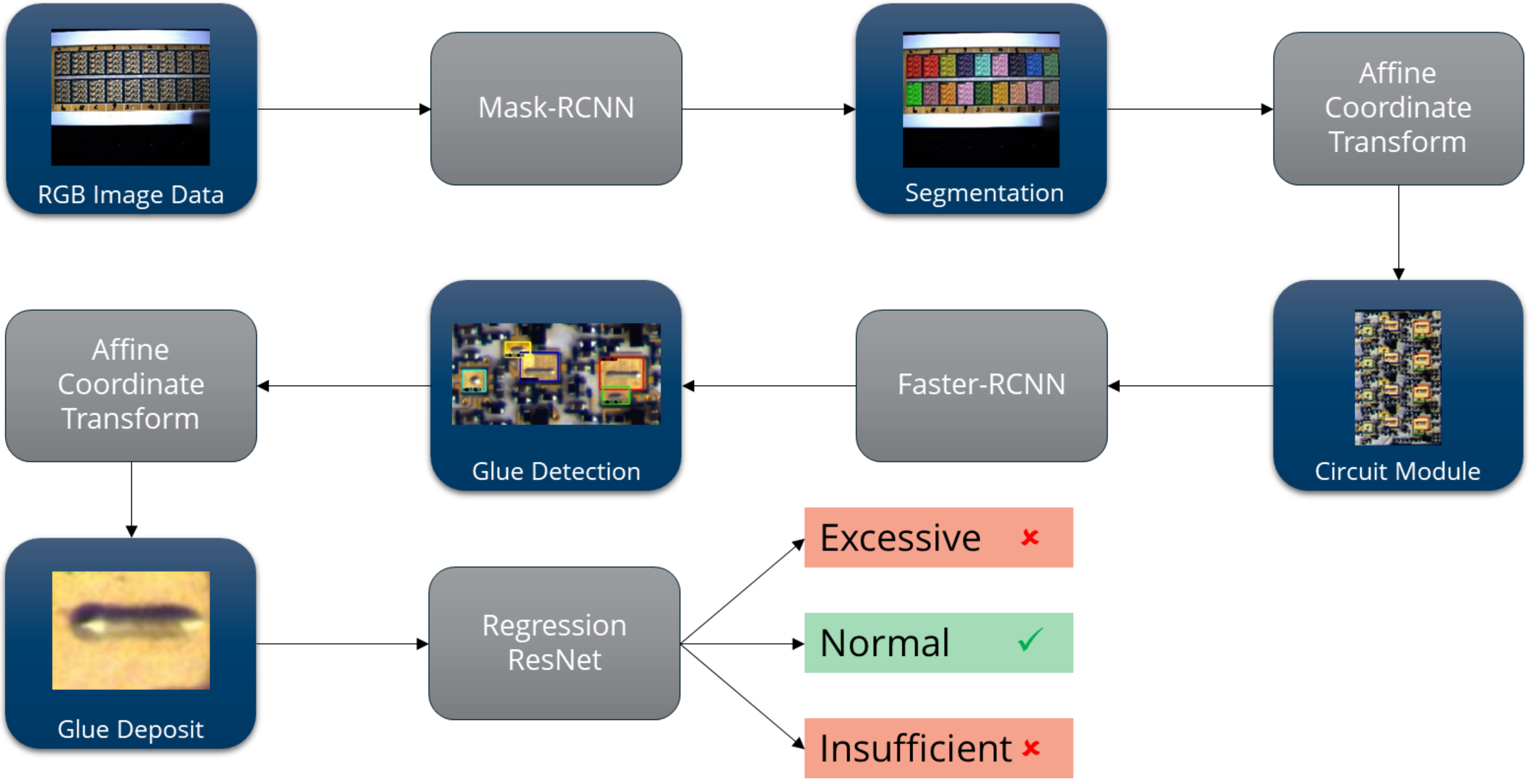


× Excessive

- **Solution:** Developed an automatic inspection system that uses RGB images of the inspected PCBs - **reducing inspection time and increasing the accuracy**

A. Evangelidis, N. Dimitriou, L. Leontaris, D. Ioannidis, G. Tinker and D. Tzovaras, "A Deep Regression Framework Toward Laboratory Accuracy in the Shop Floor of Microelectronics," in IEEE Transactions on Industrial Informatics, vol. 19, no. 3, pp. 2652-2661, March 2023.

Defect Detection Framework



Solution Highlights

- ✓ **Soft sensor:**
  - ✓ Use of a **2D sensor to measure a 3D** measurement, replacing 3D laser sensor. Any 2D sensor can be used e.g. smartphone camera
  - ✓ **Lower cost**
  - ✓ **Easy to use/install**
- ✓ Drastically **reduces inspection time**
- ✓ **Instance segmentation** simplifies data acquisition: there is no need to put the product on specific position – the product and interested areas are automatically detected

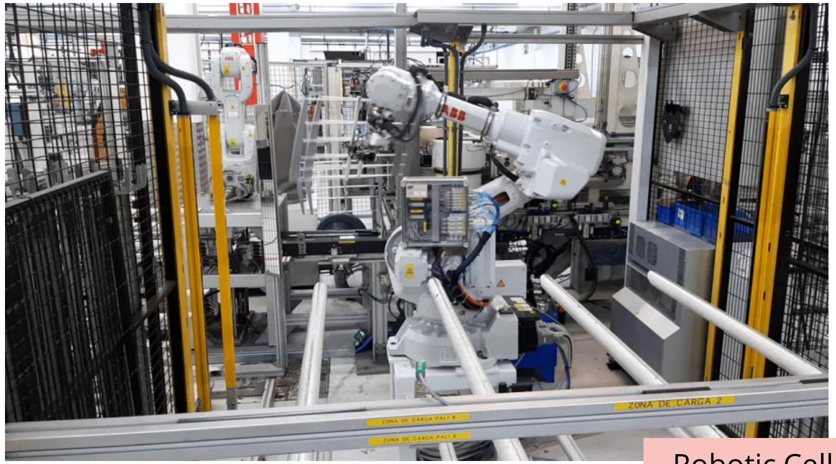
Defect Detection

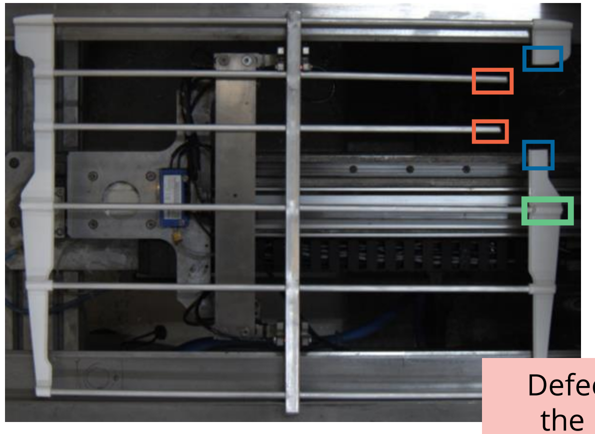
Applied in Antenna Manufacturing

OPTIMAI

Defect Detection
Applied in Antenna Manufacturing

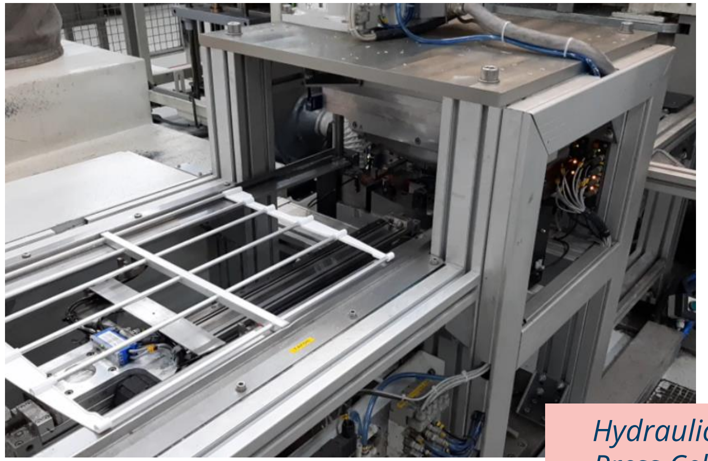
- An **antenna** production line consists of robotic cells
- **Problem:** In the robotic cell of a hydraulic press, the inspection is conducted manually by the operator and un-synchronously, at a later time
- **Solution:** Run the inspection **automatically in near real time** to avoid defect propagation with a machine vision camera integrated in the existing robotic cell.


Robotic Cell



Broken Rod
Broken End
Folding Error

Defect Antenna from the production line


Hydraulic Press Cell

Results

- Quantitative analysis of defect inspection
  - The proposed methodology **achieved 10% better performance** while having **2.2 lower latency compared** to existing learning methods.

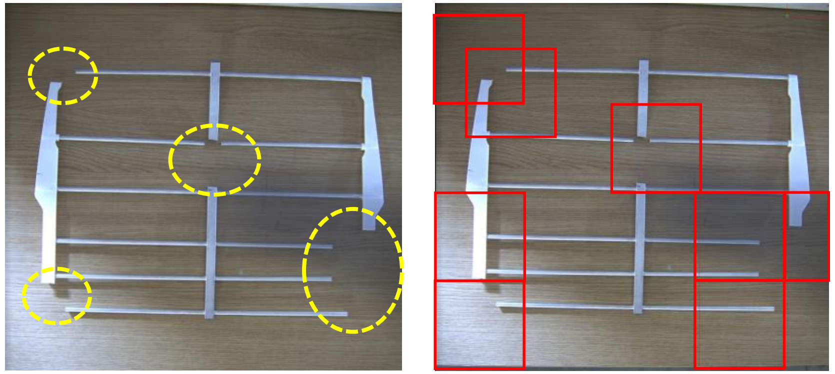
	Model	Precision %	Recall %	F1-score %	MCC
baseline learning methods	ResNet6-1	39.1	17.1	23.8	0.093
	ResNet6-2	86.4	47.9	61.6	0.558
	ResNet6-3	94.3	56.8	70.9	0.666
	ResNet6-4	100	61.6	76.2	0.732
complex network	ResNet6-5	97.1	69.1	80.8	0.768
	ResNet18	95.0	78.7	86.1	0.821

10% better performance (compared to ResNet6-3)

proposed

2.2x lower latency (compared to ResNet18)

- Qualitative analysis of defect inspection
  - On the left, the defect regions on the antenna image
  - On the right, the patch-based defect detections



Leontaris, L., Mitsiaki, A., Charalampous, P., Dimitriou, N., Leivaditou, E., Karamanidis, A., ... & Papageorgiou, E. (2023). A blockchain-enabled deep residual architecture for accountable, in-situ quality control in industry 4.0 with minimal latency. Computers in Industry, 149, 103919.

Solution Highlights

- **Inspection in synchronization** with the production line
- **Near real time** inspection, below ½ of a second
- **Easy to install** in existing infrastructure
- Executed **automatically**
- Receives signal from **the robot**

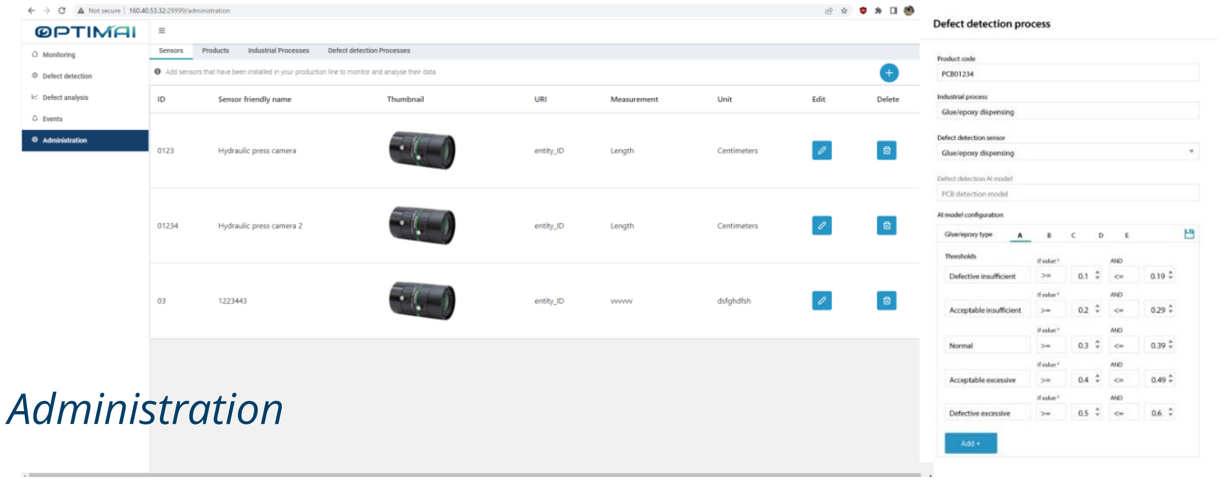
Industry 5.0

OPTIMAI technologies

Decision Support System

DSS interfaces

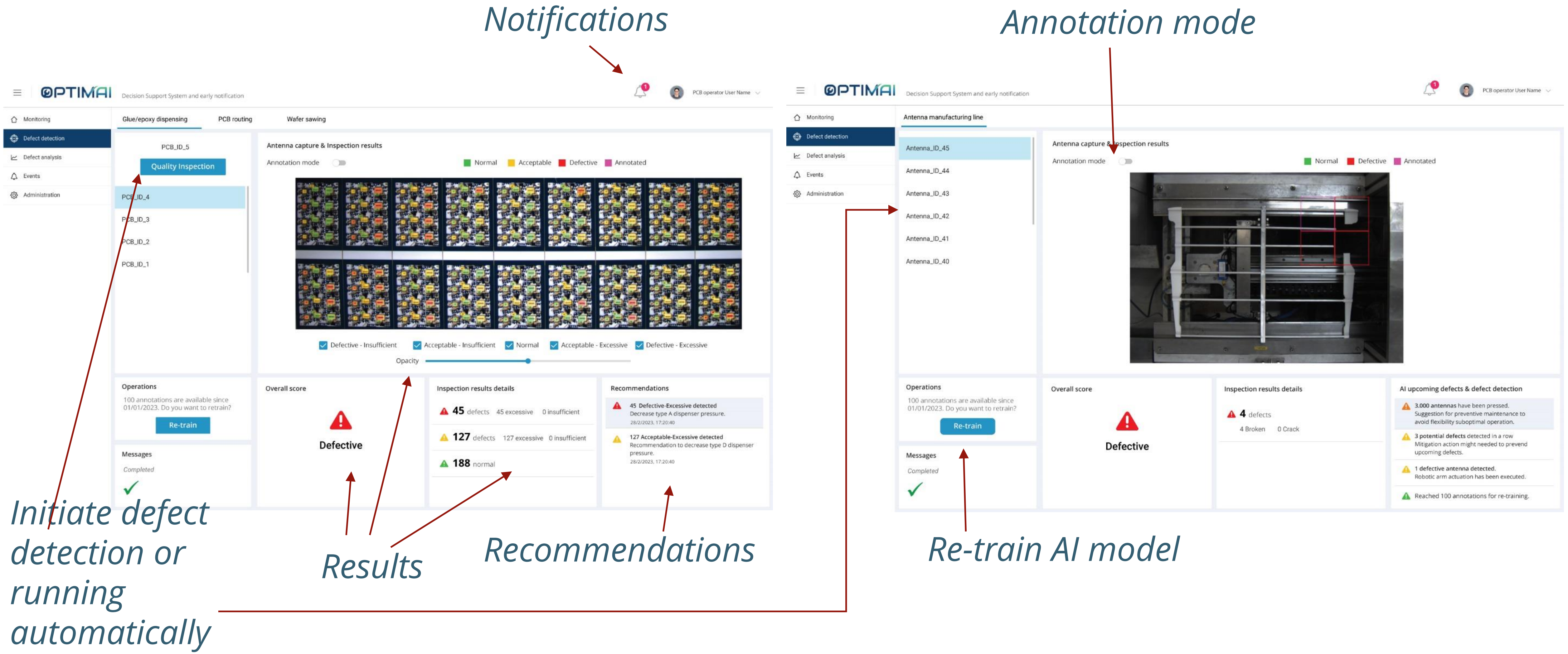
- **Administration:** manage sensors & processes such as defect detection processes
- **Defect detection** operation & results
- **Monitoring & Prediction** of defects & suboptimal operations: support quick decisions for mitigation actions to avoid defect generation and propagation
- **Historical data analysis:** support time consuming decisions to optimize the production line
- **Events** (blockchain etc.)



Administration

Monitoring & Prediction

DSS Defect detection related operations



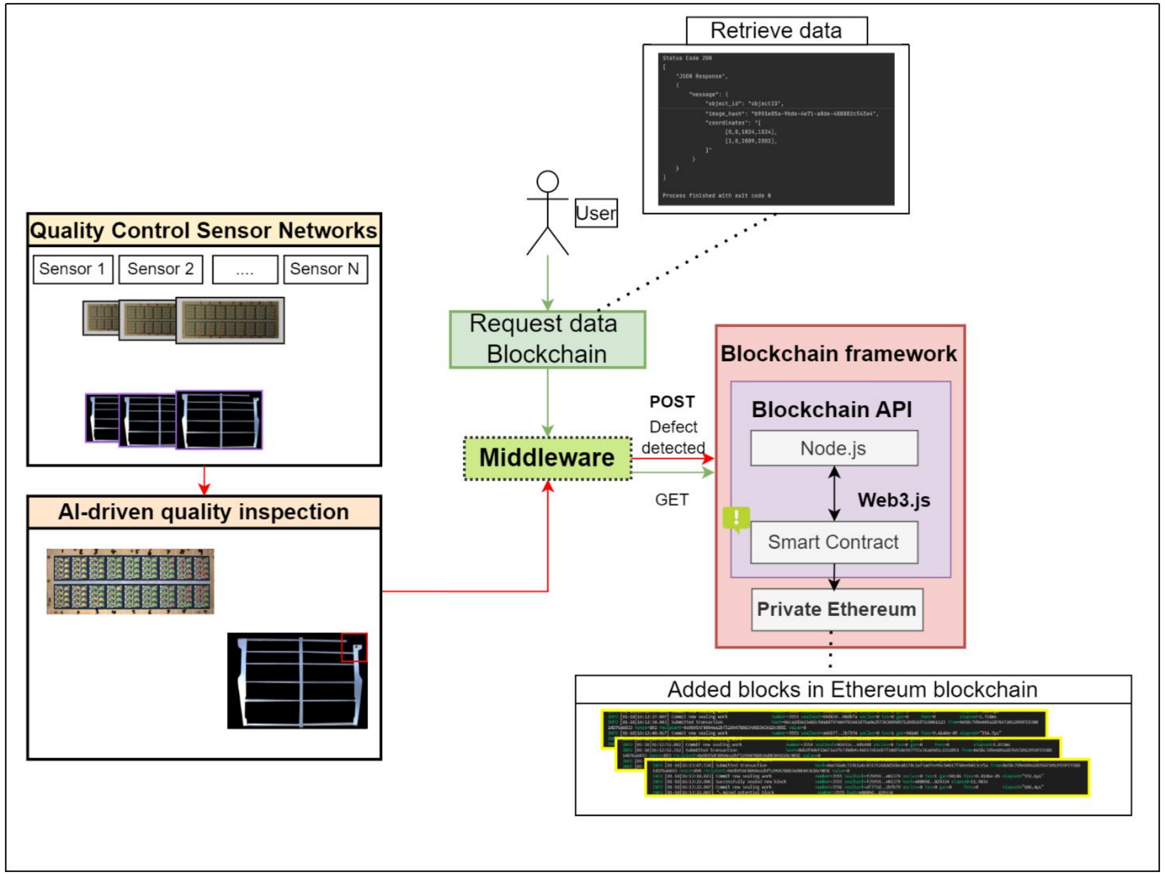
Blockchain Module

› Store information about defective products on the private blockchain for

✓ Transparent and immutable record of the defects,

✓ Providing users clear insights into the nature and extent of the defects.

- Private Ethereum blockchain for each pilot site
- Proof of Authority (PoA) as consensus mechanism
- Blockchain API to accept requests from the Middleware
- Smart Contracts have been developed to store the defective products' data



DSS defect detection highlights

- ✓ **Annotation** of defect detection results
- ✓ **Re-training of the AI models** to continuously optimize defect detection
- ✓ Initiation (manual) and monitoring (auto) of **defect detection operations**
- ✓ **Monitoring** defect detection (and prediction) **results**
- ✓ **Notifications & Recommendations** for quick response (manually-operator or automatic re-calibration)
- ✓ **Transparent and immutable record** of the defects through blockchain

Extended Reality (XR)

Perception techniques for operator-machine interaction

Use cases

- **Instance segmentation**:
  - Create segmentation masks for the quality inspection of produced Hydraulic Lift Power Units
  - Aim to identify any mismatch between the produced parts and the parts referred to the client’s order (BoM)
- **Object tracking:**
  - Detecting and Tracking the objects of Interest in the BoM

Detection list:

1. Valve Block
2. Junction Box
3. Release Valve
4. Emergency Button
5. Allen Tool 1
6. Allen Tool 2
7. Hydraulic Unit

Use cases

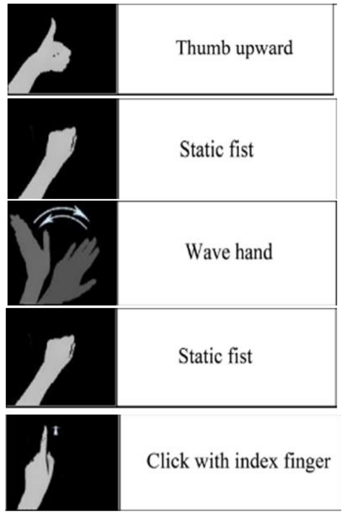
- **Pose estimation:**
  - Apply the Gen6d model for estimating the **6D pose** (location and orientation) of the valve block in the operator's field of view
  - **Input**: RGB image of the object of interest
  - **Output**: RGB image displaying the projected 3D bounding box

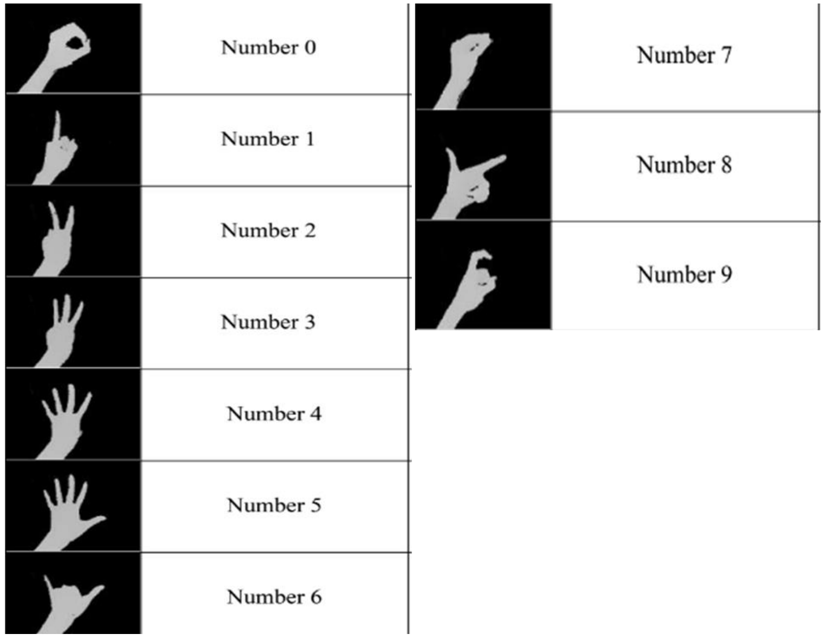
Input video

Estimated poses

Use cases

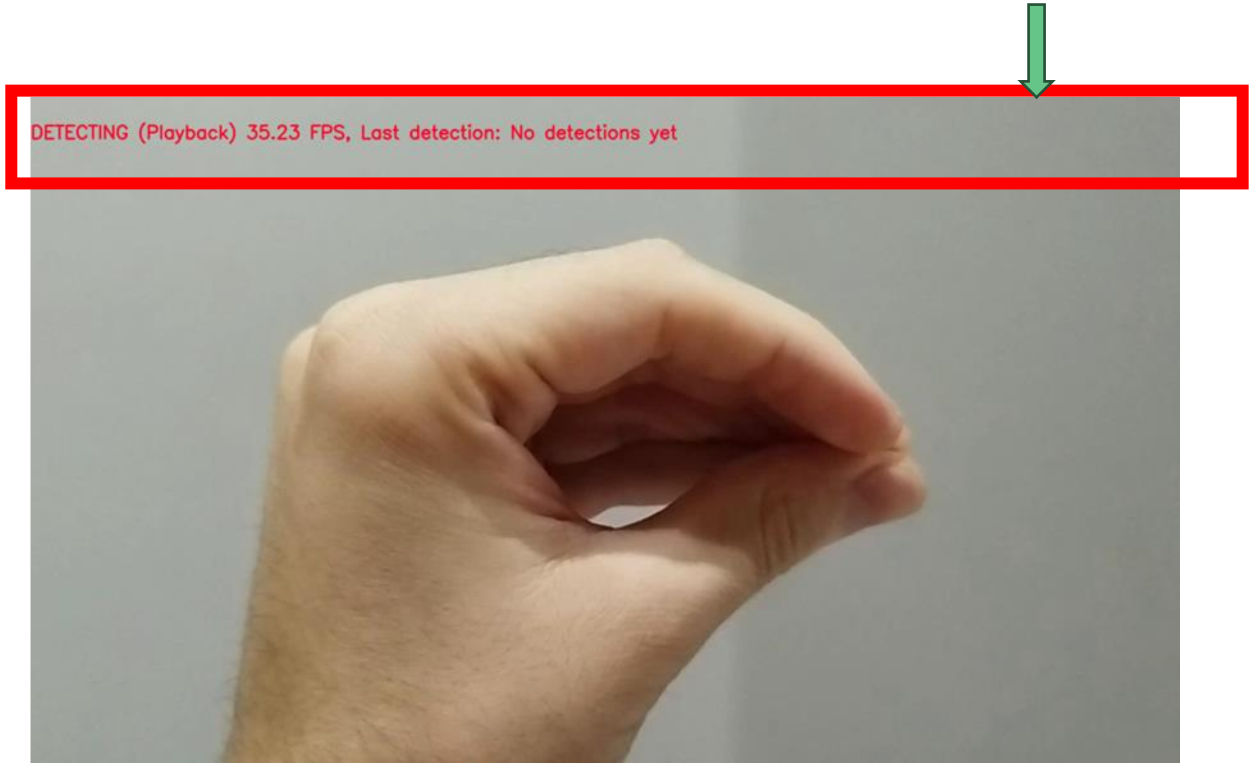
- **Gesture recognition:**
  - Deploy a real-time algorithm for recognizing the operator's gestures in the shop floor.
  - **Input**: frames from the live feed obtained from the AR glasses
  - **Output**: The identified gesture categories
    - Numbers from 0-9
    - Click with index finger
    - Thumbs up/down
    - Wave
    - Swipe up/down/left/right
    - Static fist





Use cases

- **Functionalities in AR application:**
  - Gesture vocabulary for the AR application:
    - Wave hand
    - Thumbs up/ down
    - Numbers 1-5
  - Functionality examples in the AR application:
    - Wave hand **:** Wake up
    - Thumbs up/down **:** Yes/ No
      - when checking if the parts are correct
    - Number 1: Check order
    - Number 2: Manual setup
    - Number 3: Unit testing



Conclusions

- **Challenges faced**
  - Integration between different modules
    - Practical difficulties due to continuous production
  - Difficult environmental conditions for hardware installation/operation
    - Machine vision systems must be maintained regularly to properly function in harsh environments
  - Training end users to engage in and improve automated defect inspection
  - Timing restrictions due to production deadlines
    - Deployment/updates/support of AI software must be completed in limited time windows
    - Inspection must be performed accurately and in real-time

Conclusions

- **Future steps**
  - Validation from end users and production workers during pilot studies
    - Kleemann: Manufacturing of lifts (Greece)
    - Televés: Manufacturing of antennas (Spain)
    - Microchip Technology Caldicot Ltd.: Assembly of microelectronics (UK)
  - Systematic evaluation of methodologies during the next months
  - Create questionnaires to collect feedback from end users
  - Record evaluation metrics and estimate KPI improvements
  - Build exploitation plan and explore commercialization potential

Project website	Twitter	LinkedIn	YouTube
https://optimai.eu/	@OPTIMAI_Project *https://twitter.com/OPTIMAI_Project*	OPTIMAI Project *https://www.linkedin.com/company/optimai-project/*	OPTIMAI H2020 *https://www.youtube.com/channel/UCgn6kut1if7_mAsDbSR0xMw*

Thank You

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