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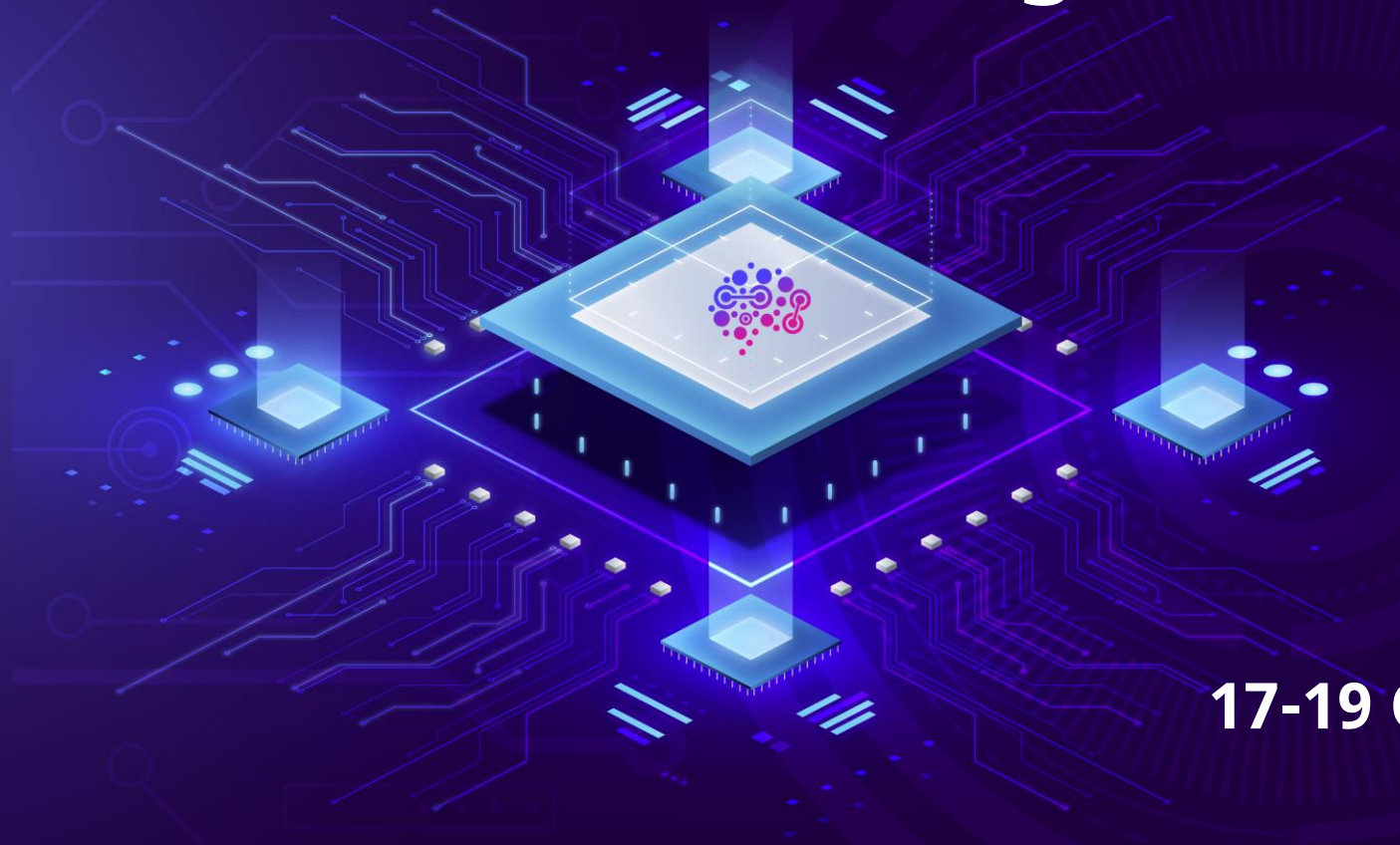

Advancing emerging edge AI technologies and driving next generation intelligent applications.

17-19 October 2023, Athens, Greece

European Conference on EDGE AI Technologies and Applications - EEAI

An Overview of the Automated Optical InspectionEdge AI Inference System Solutions

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Alberto Faro, Deepsensing Srl, Italy

17-19 October 2023 Athens, Greece

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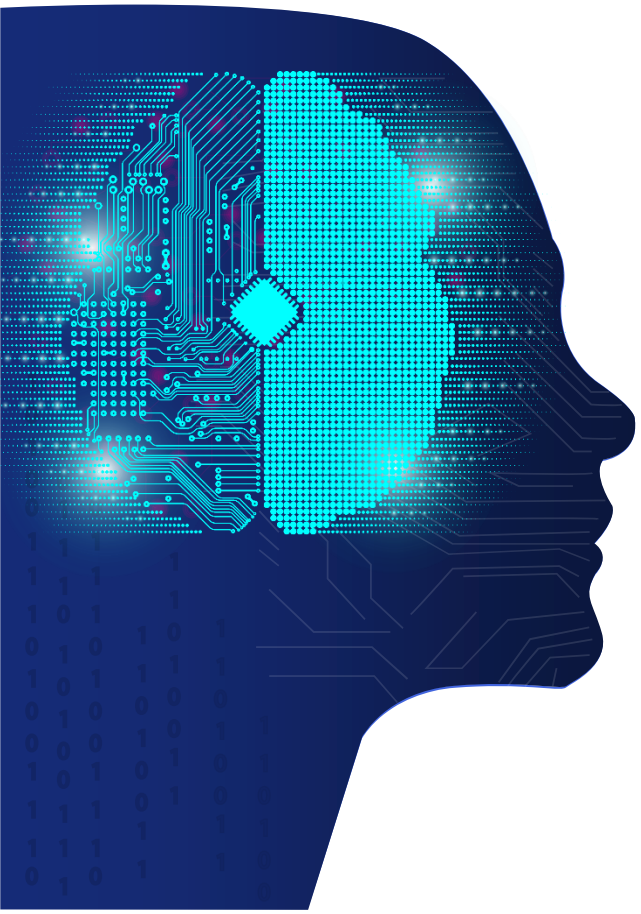
Presentation Outline



- Introduction
- State-of-the-art
- Research Goal
- Methodology
- Design and Implementation
- Experimental Results
- Future Research
- Conclusion

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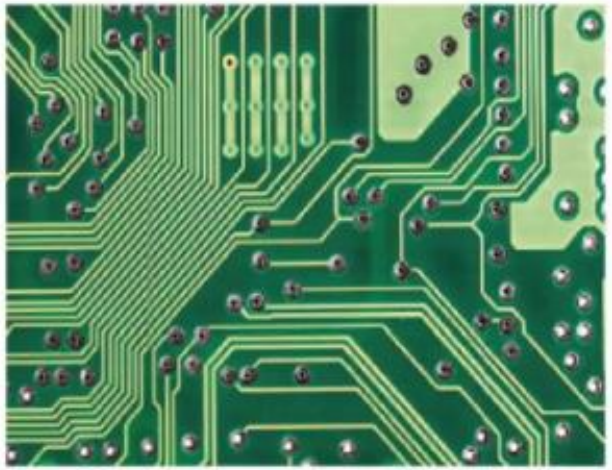
Introduction: AOI=Automatic Optical Inspection

• AIM OF THE PAPER

- The aim of the paper is to provide an overview of the AOI edge AI inference system solutions for detecting defects related to digital boards by discussing if, and how, they allow manufacturers to reach a satisfactory balance between customer needs (product quality and on-time delivery) and production costs.
- The AOI checks point out defects of either PCB, i.e., empty printed circuit boards, or PCBA, i.e., fully functional boards filled with all the needed components.

PCB  vs PCBA

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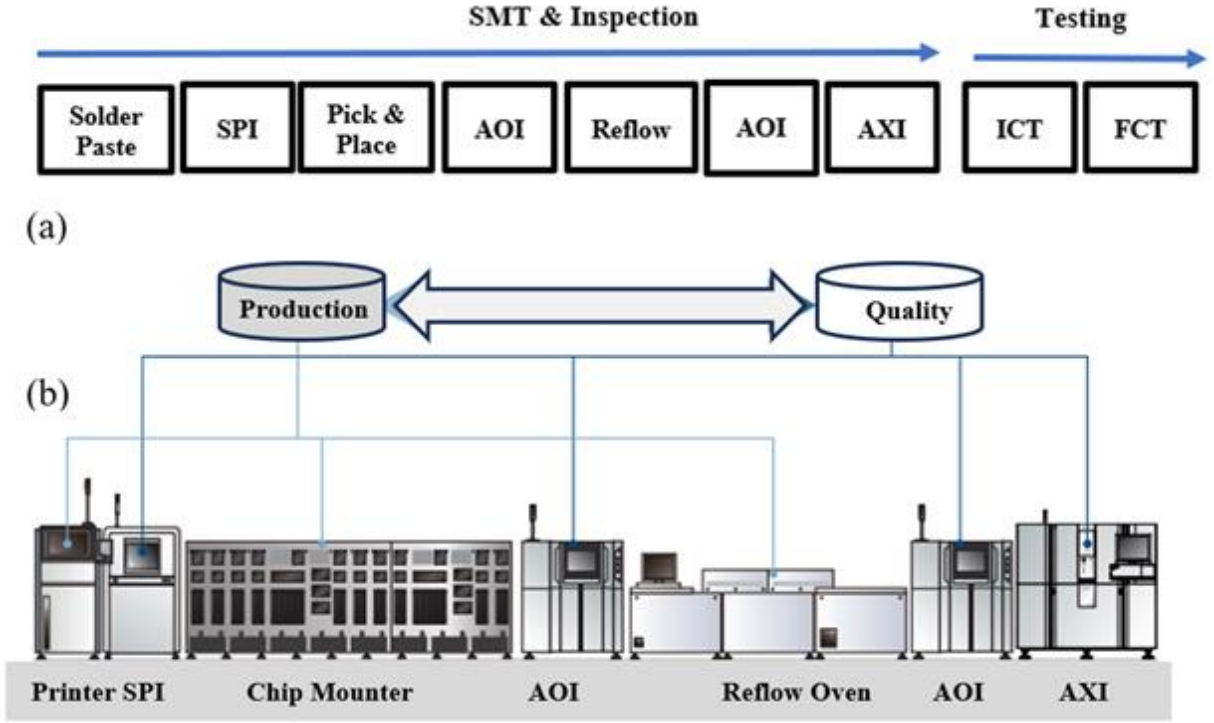
State-of-the-art: the standard Assembly Line config.

- Traditional AOI machines were designed to support the Surface Mount Technology (SMT) and the Pin Through Hole Technology (PTH), for mounting and interconnecting electronic components on Printed Circuit Boards (PCB). They are used at the output of the Pick and Place process and/or at the output of the Reflow Oven, to discover PCBA defects and making Coordinate Mounting Measurements (CMM), to indicate the defect location. Some times only one AOI is placed at the output of the Reflow Oven.



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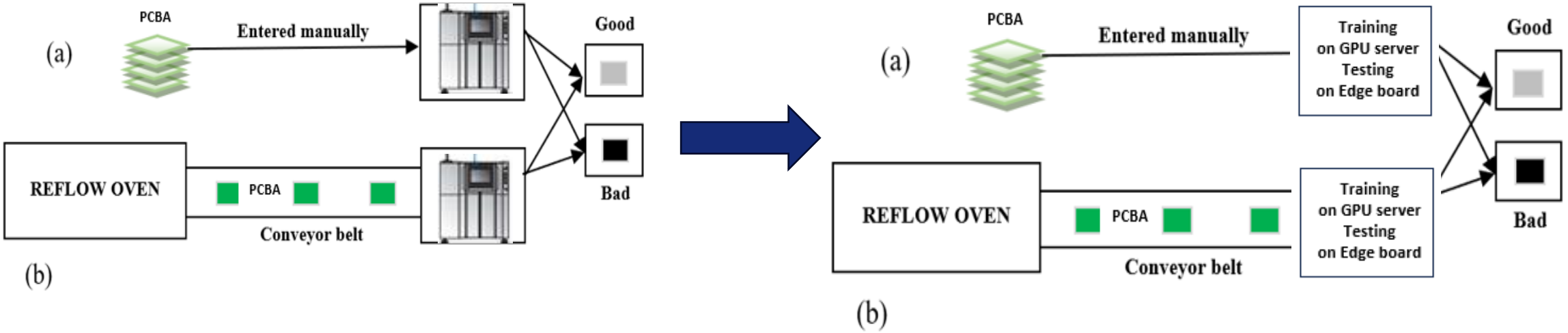
Research Goal:the tradeoff between Traditional Vs. EdgeAI AOI

The research goal is to evaluate the feasibility of replacing or complementing the traditional AOI machines to discover PCBA defects (on the left) by a low cost AI-based AOI solution consisting of a SW implemented on edge boards (on the right) under the condition that the latter solution should guarantee Zero-defect productions featured by KPIs similar to ones of the former solution.



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Methodology

1. To carry out an overview of the emerging EdgeAI based AOI solutions for evaluating under what conditions the alternative solutions may replace the traditional ones.

2. To identify the Key Performance Indicators (KPIs), Functional and Non Functional Requirements (FRs and NFRs) to meet customer orders, usually zero-defect productions delivered in a given time.

3. To verify theoretically if the alternative solutions may meet such KPIs, FRs and NFRs to provide zero-defect productions at a suitable production cycle time.

4. To point out a demonstrator platform to prove experimentally the feasibility of using alternative solutions depending on the customer needs that might be satisfied by lower performance and fewer requirements.

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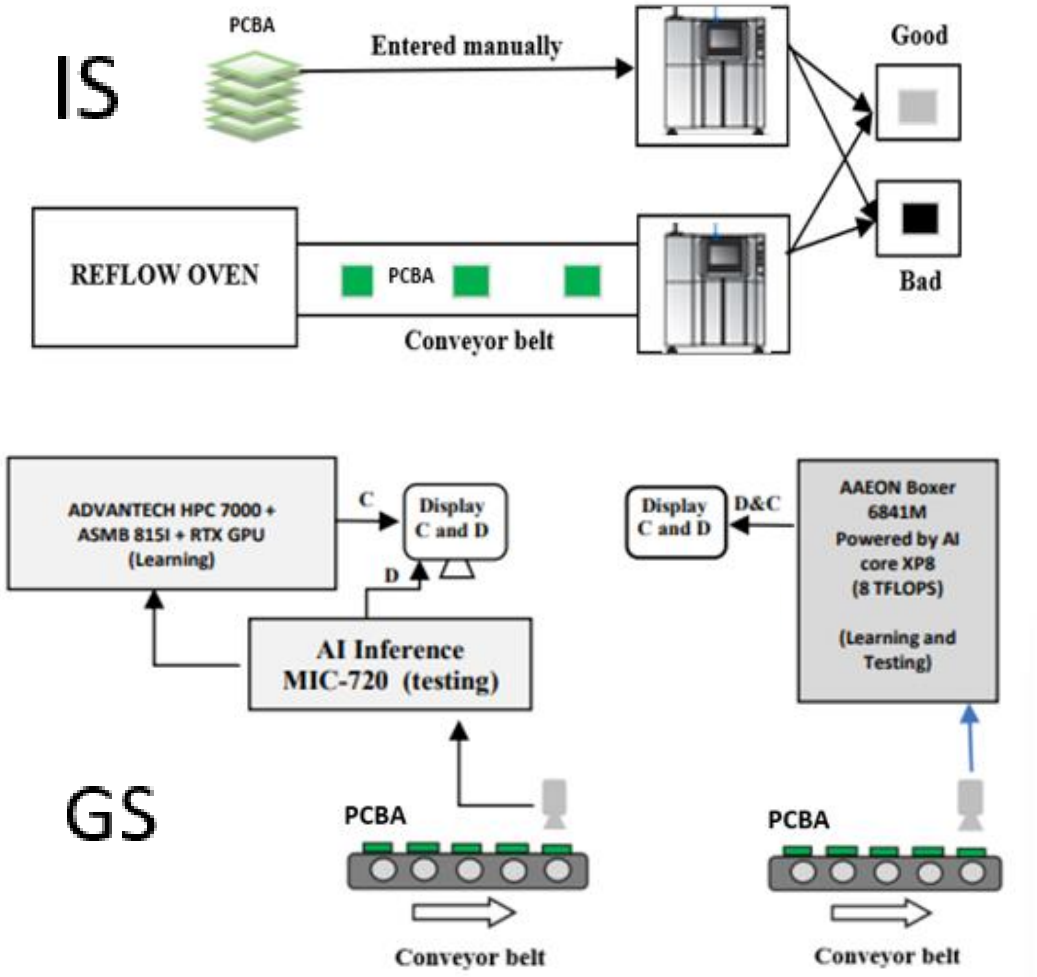
Design and Implementation: 4 main AOI configurations

- Four main AOI configurations were found by considering the AOI solutions available on market or outlined recently in the literature:

1. the one based on an inspection machine, called IS
2. the one that makes use of a GPU workstation equipped with high-precision cameras, called GS
3. The one based on a test board near the conveyor belt that sends images to the cloud server for online and continual learning, called ES
4. The one consisting of cameras sending images to a cloud server for testing and learning, called CS.



Solution on the left is in between GS and ES, whereas solution on the right belongs to GS

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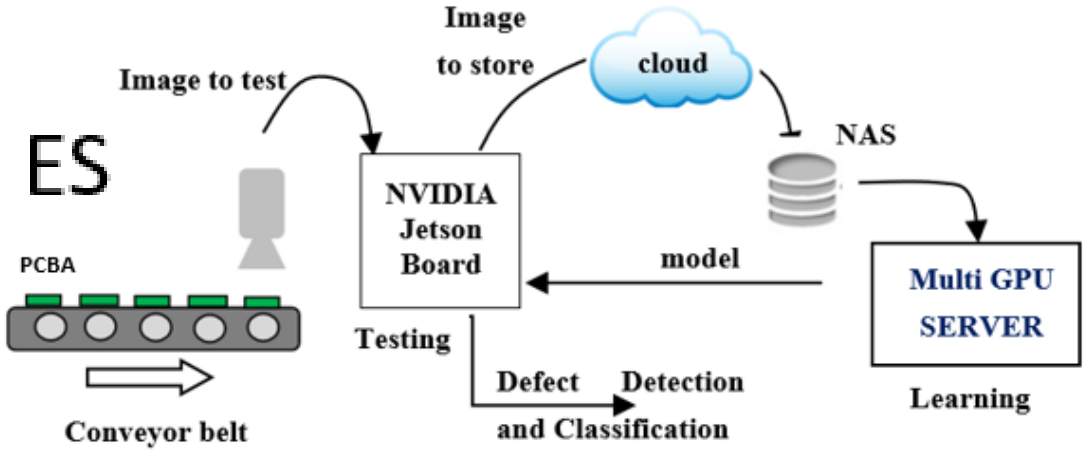

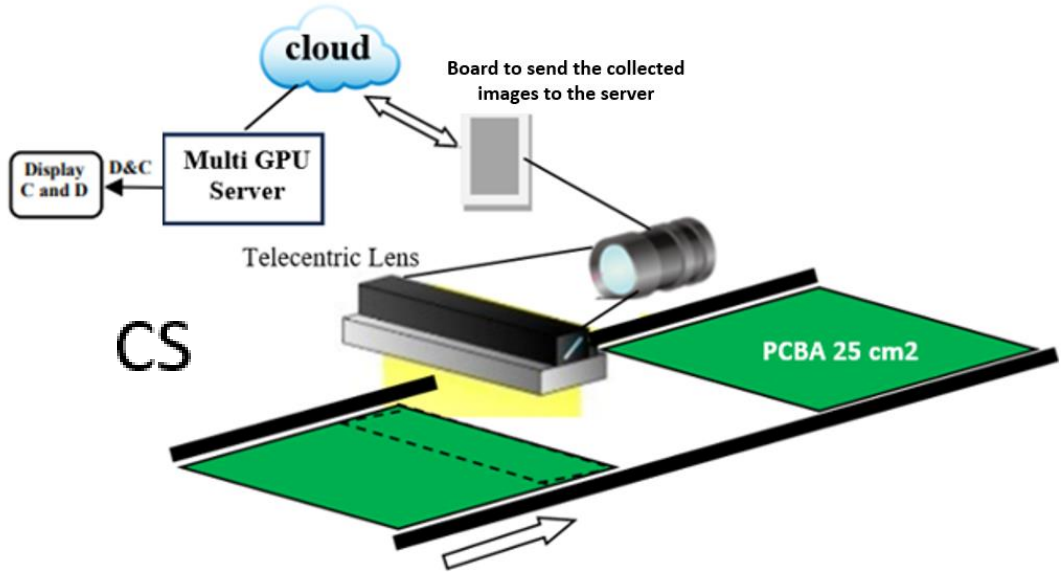

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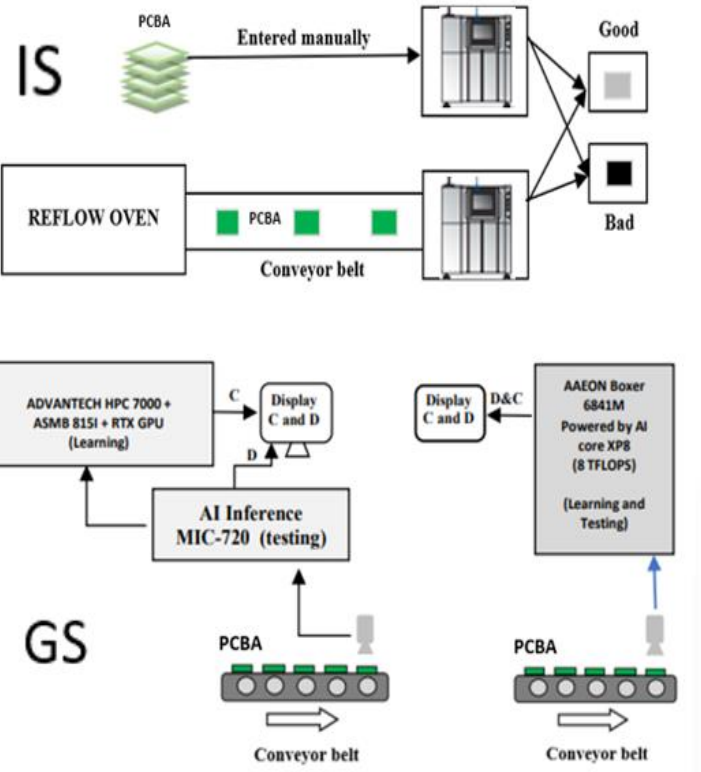
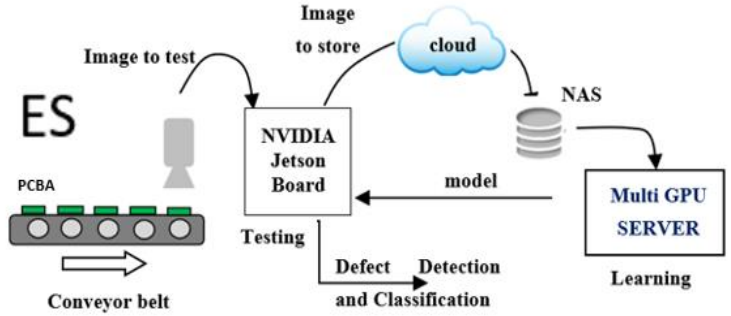
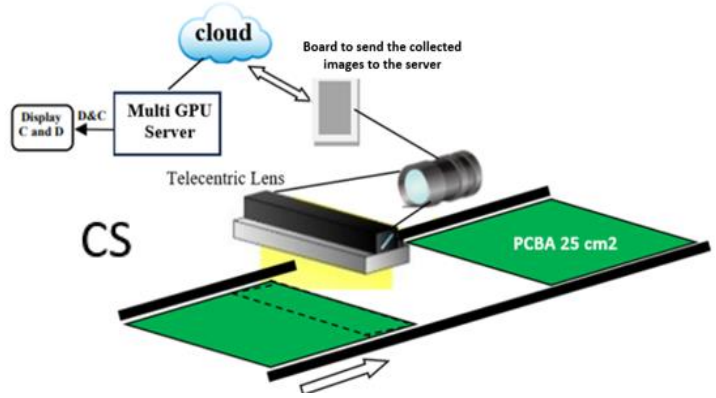
Design and Implementation: Weaknesses and Strenths



	Test and Classification	Learning	Weaknesses and Strengths
IS	local	no OL and CL	CLOSED SYSTEM
	HR CAMERA		GOOD ANALYTICS TOOLS
GS	local	OL and CL	TOO EXPENSIVE
	HR CAMERA	GPU WS	HIGH PRECISION
ES	local	OL and CL	FEW IND. APPLICATIONS
	HR CAMERA	CLOUD SERVER	HIGH POTENTIAL
CS	cloud	OL and CL	TOO SLOW
	HR CAMERA	CLOUD SERVER	INEXPENSIVE





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Theoretical Results

	FR and NFR	KPI	Target Value	IS	GS	ES	CS	Comments (note TD = To be Developed)
FR	**Precision**	mAP	> 99 % by DL-YOLO algorithms	Y	Y	TD (>98 % by DL YOLO alg.)	Y	Target value allows the AI-AOI to meet the value of Cpk = 1,33 featuring HQ factories in digital industry
	Inspection Throughput	BPH	3000-4000 bph	Y (4000 bph)	Y	Y (3500 bph)	N	All solutions are able to meet the inspection throughput of about 3500 bph (Boards Per Hour)
	Takt Time	TT	Better than traditional AOI	TD	TD	Y (by parallel EdgeAI AOIs)	TD	If TT is too low it could be not possible to meet FR unless parallelizing inspection lines as allowed by ES
NFR	**On Line Learning**	OL	> 0,1 % per month	TD	Y	Y	Y	GS, ES and CS are able to carry out on line learning. IS may not meet such FR since it is usually not conceived to re-train a local learning model
	Continual or Literature Learning	-	Discovering new defects without forgetting previous ones	N	Y	Y	Y	GS, ES and CS are able to carry out CL or LL. IS is a closed solution not able to use external datasets
	Working Time Saving	-	Decrease of the cycle time	Y	TD	TD	TD	Only IS is provided with managemet tools able to reduce the working time.
	Defect Explanation	-	Expected value is >50%	Y	Y	Y	Y	All solutions are able to provide defect explanation usualy done using the GPU server

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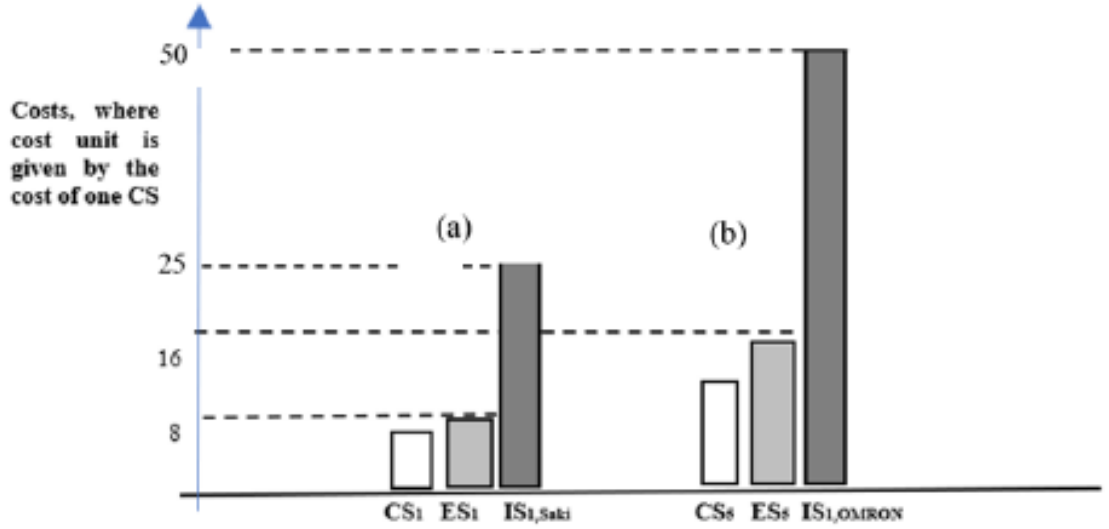
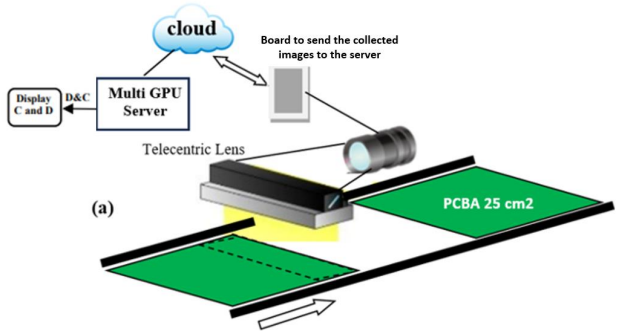
Theoretical Results

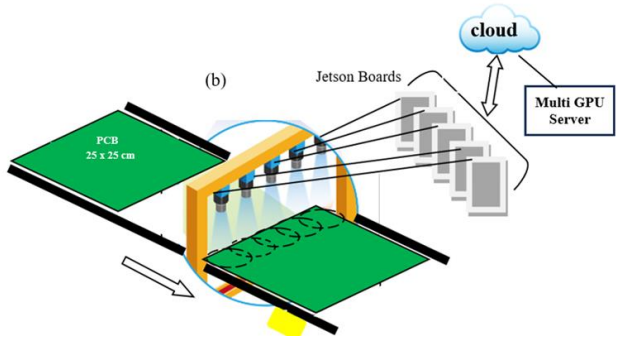
The previous table illustrated the feasibility of replacing or complementing the traditional AOI machines (denoted as IS) by an EdgeAI-based AOI solution consisting of a SW implemented on edge boards (denoted as ES) since the latter solution is able to guarantee KPIs FRs and NFRs similar to ones of the former solution.

- **The figure on the right reports our purchase evaluation. It points out that ES has a lower purchase cost of the IS comparing ES with both low cost and professional ISs.**

- Also, parallel ESs have a reasonable cost. This makes possible to decrease TT and increase Thoughput (bph) by using more than one EdgeAI AOIs in parallel







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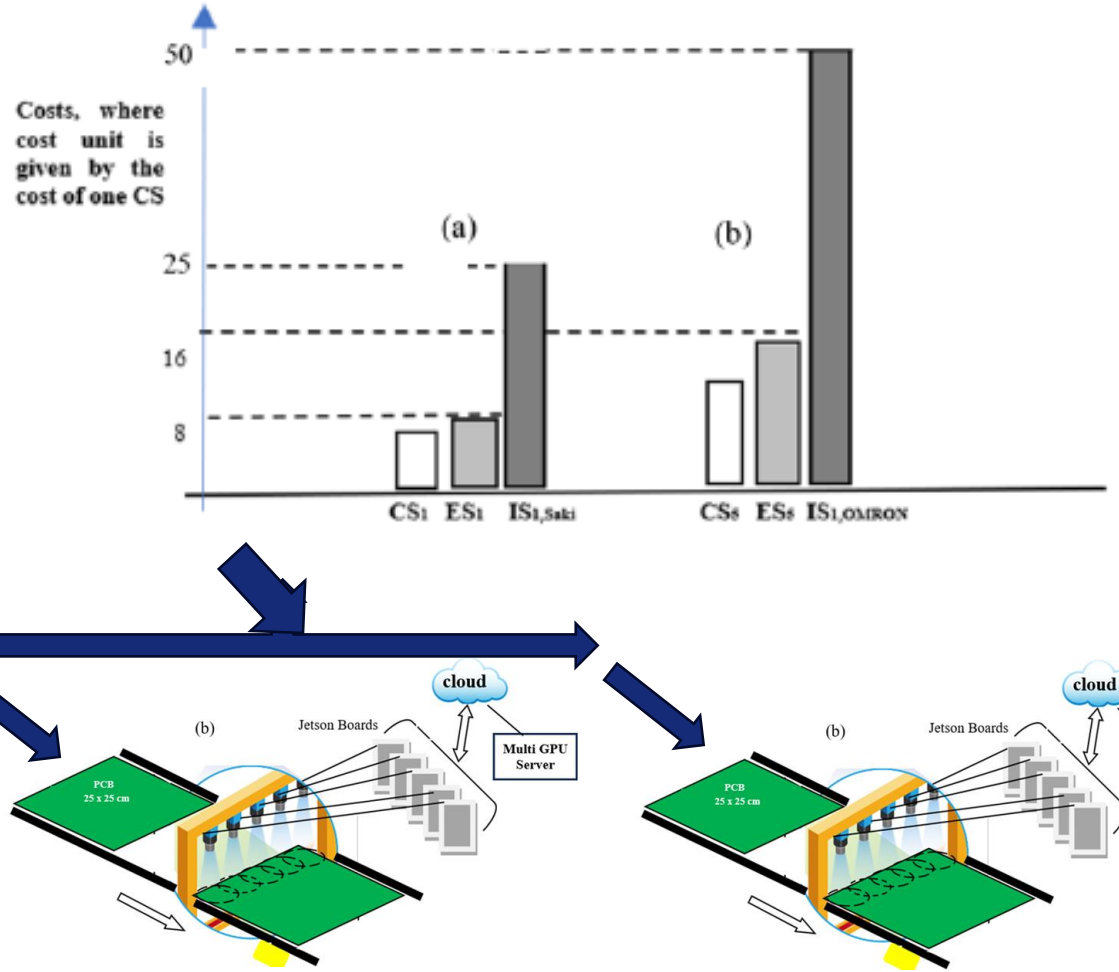

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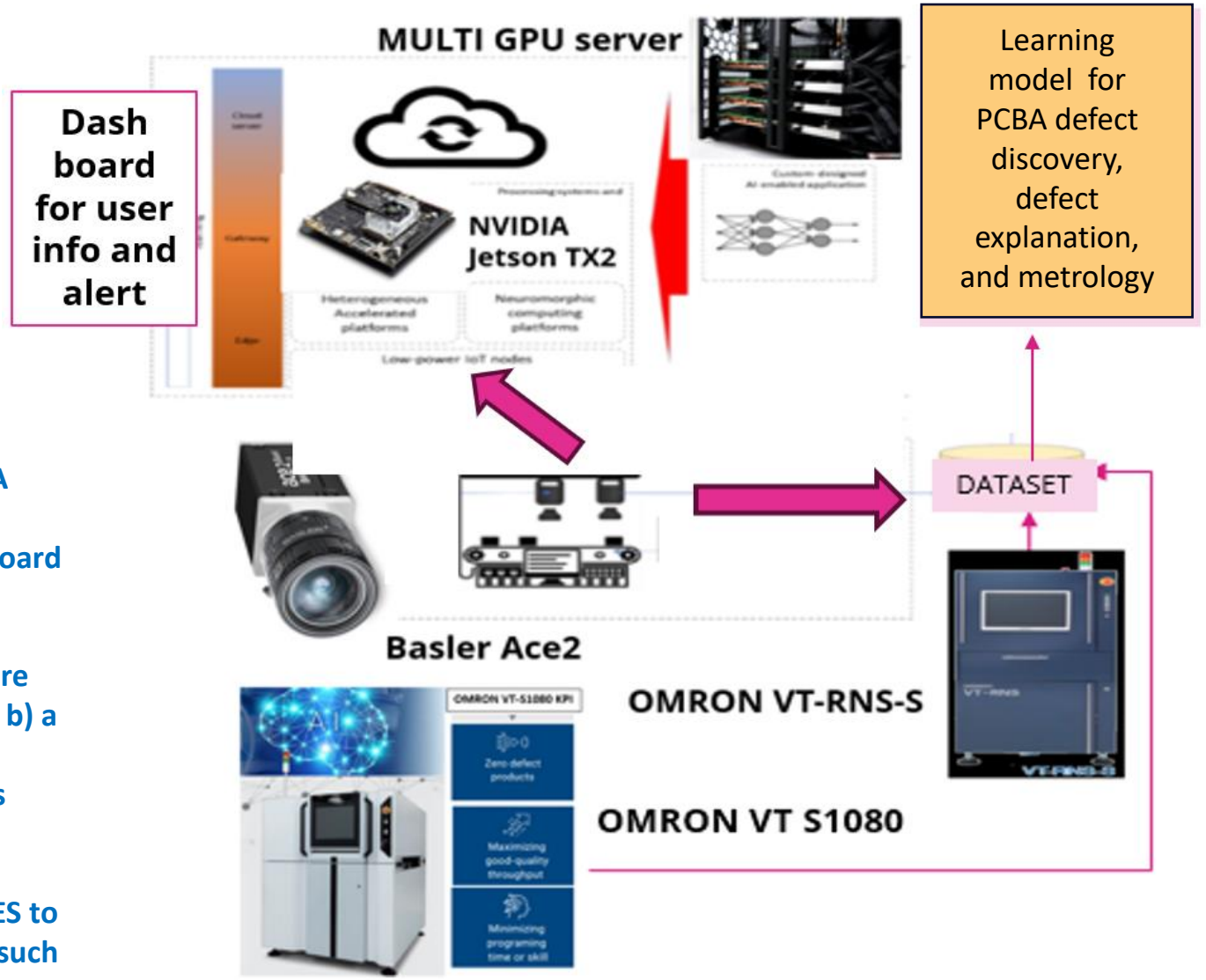
Future Research

Confirmation of the theoretical results using an experimental platform, e.g., the one shown on the right, is needed to prove in practice the advantages of adopting ES instead of IS, GS and CS and under what conditions this is really feasible and convenient.

Such platform should be used for carrying out the following tasks:

- OFFLINE
  - Acquisiton of the PCBA images from different sources to train a neural network implemented on a multi GPU server to find PCBA defects and explaining defect causes
  - Deployment of the trained model for defect discovery on edge board for testing
- ONLINE
  - Testing the PCBA using the images taken by the cameras which are sent to: a) the Edge board for testing the PCBAs in real time and b) a dataset stored on a NAS system on the cloud for OL and CL.
  - Implementing an alert system to inform operators and managers about the defected PCBAs and defect causes

- Validation of ES will be obtained by proving that the KPIs achieved by ES to find PCBA defects are similar to the ones of relevant IS on the market, such as OMRON VT S1080



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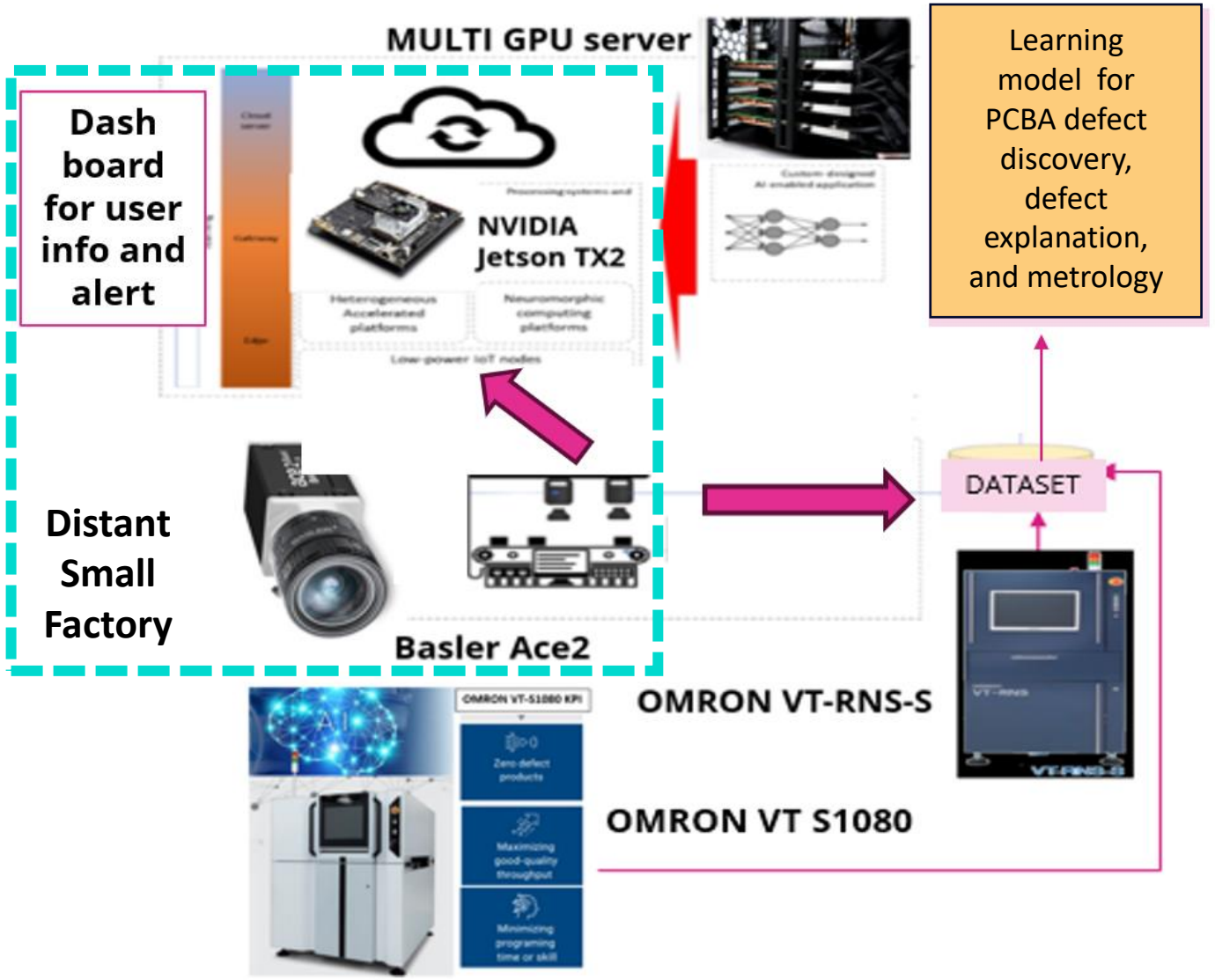
Future Research

EdegAI AOI opens the possibility to allow small factories to check their digital boards by using only the needed cameras and a testing board whereas the trained model and its optimization is carried out by a multi GPU server on the cloud.



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Conclusion

- **The contribution has demonstrated the feasibility of replacing or complementing the traditional AOI machines to discover PCBA defects by a low cost AI-based AOI solution consisting of a SW implemented on edge boards**

- **An experimental study is needed to confirm the theoretical considerations since several issues are still open that may impede to reach the envisaged performances.**

- **EdgeAI solutions could make possible to provide not only to medium factories but also small factories with effective AOI systems at a cost compatible with their budget.**

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EDGE AI

Thank You

For your attention

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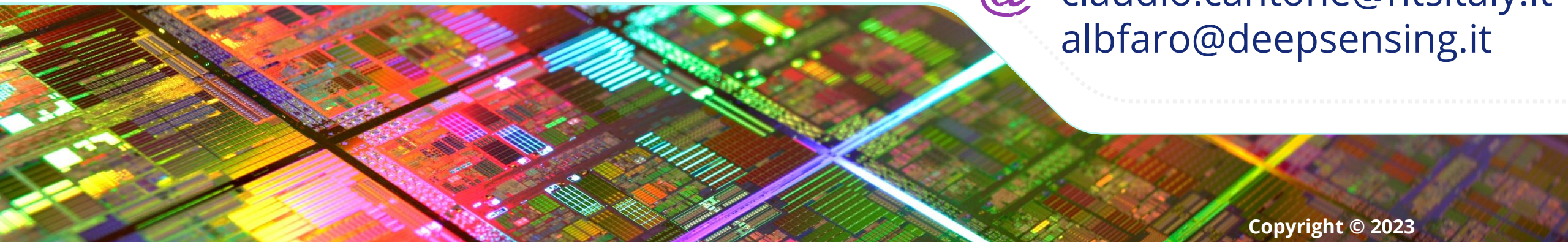

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