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A Collaborative Automated Cell to Enhance Digital Maturity in SMT Assembly Lines

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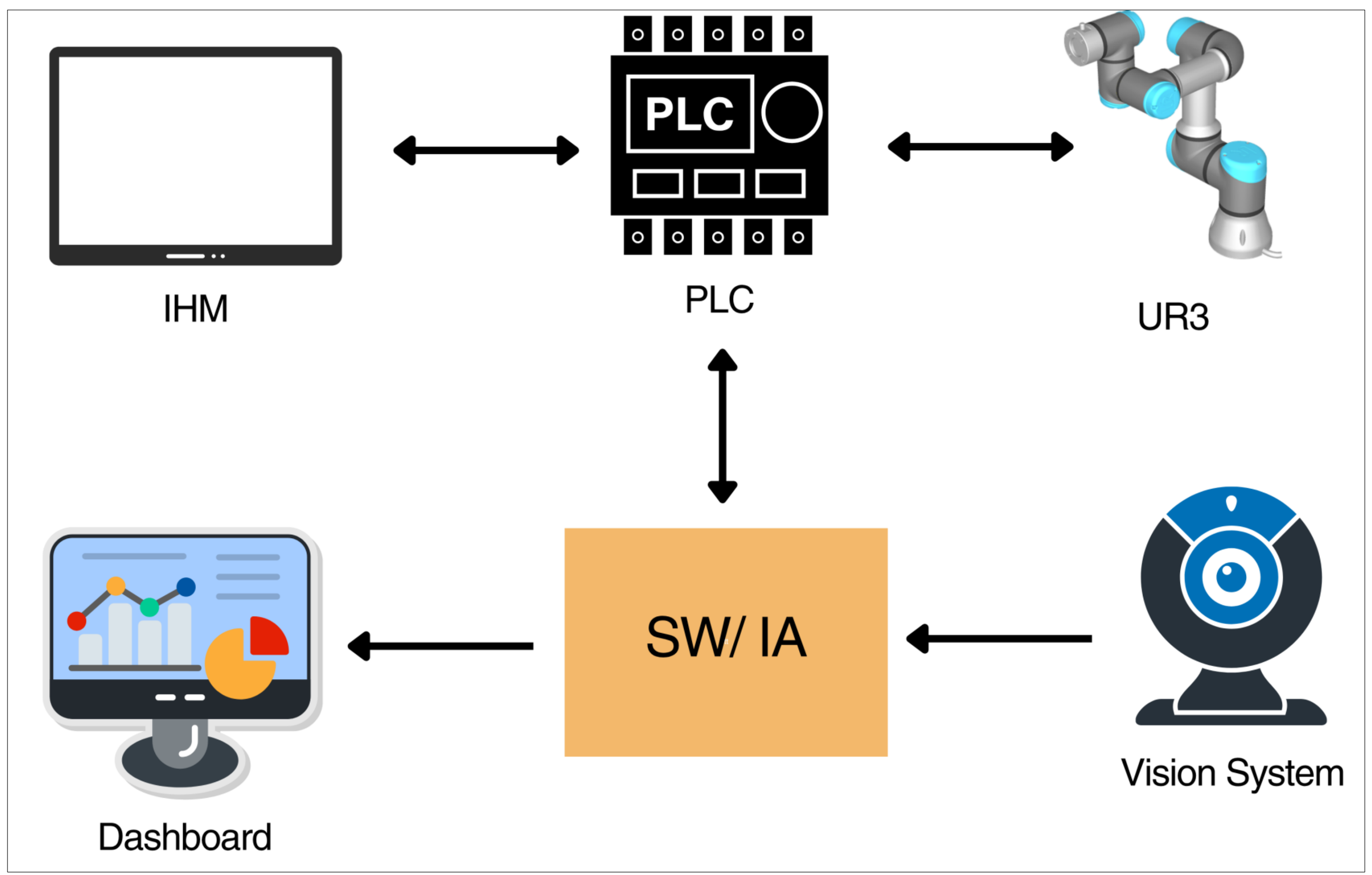
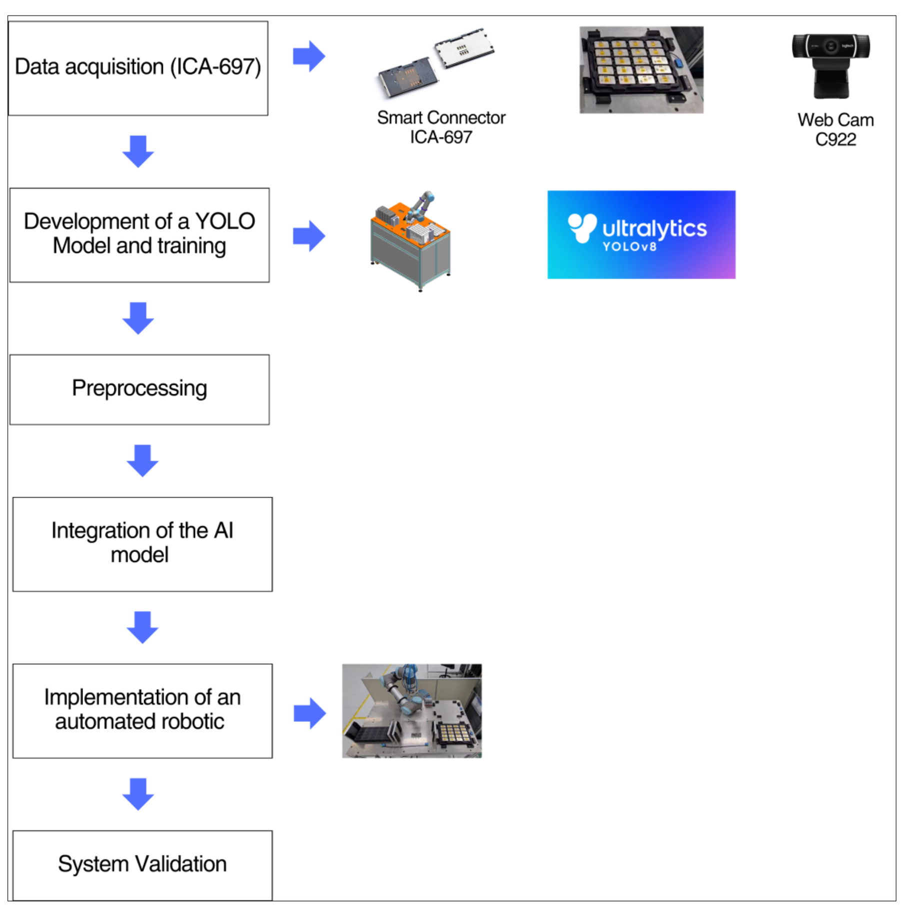
INTRODUCTION & AIM

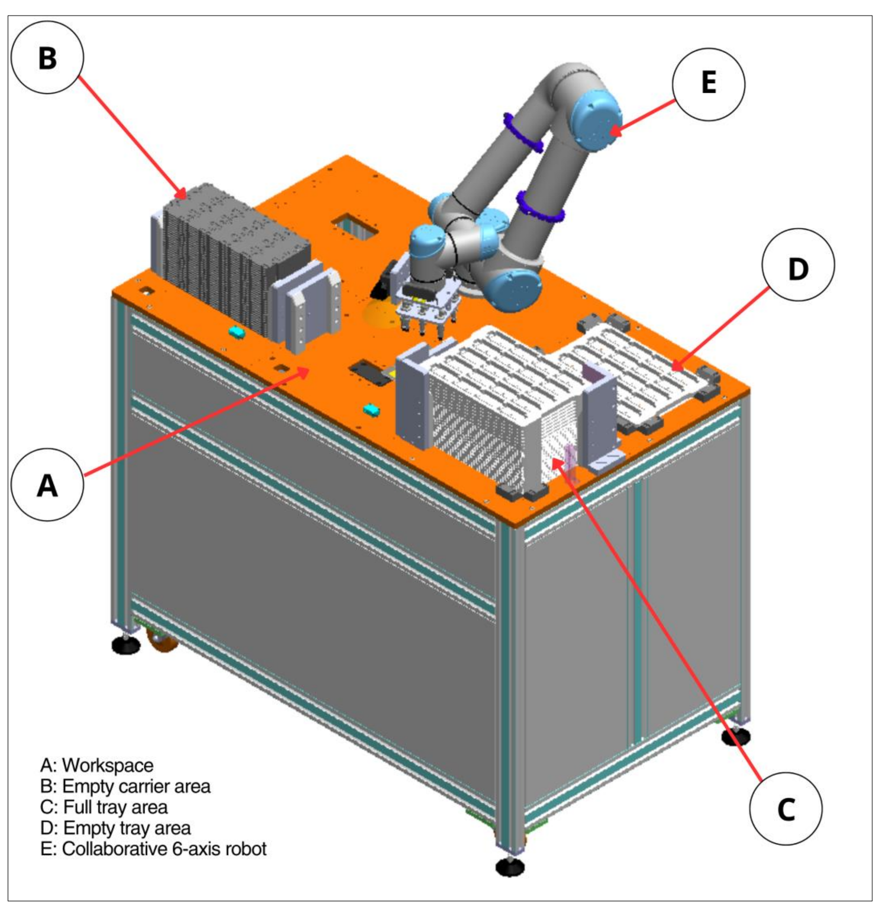
In Surface Mount Technology (SMT) production lines, the handling and feeding of electronic components, such as Smart Card connectors, are often performed manually due to equipment constraints, leading to variability in cycle time, ergonomic risks, and positioning errors that directly impact process efficiency and yield [1]. Additionally, existing industrial solutions do not fully address the need for integrated systems capable of combining robotic manipulation, real-time object detection, and adaptive positioning under non-structured conditions[2]. This work aims to develop and experimentally validate a collaborative robotic cell integrated with computer vision and artificial intelligence (YOLO-based model) for automated identification, manipulation, and repositioning of Smart Card connectors in SMT environments, improving positioning accuracy, reducing cycle time, and increasing production capacity while advancing the process toward Industry 4.0 digitalization and visibility levels.



METHOD

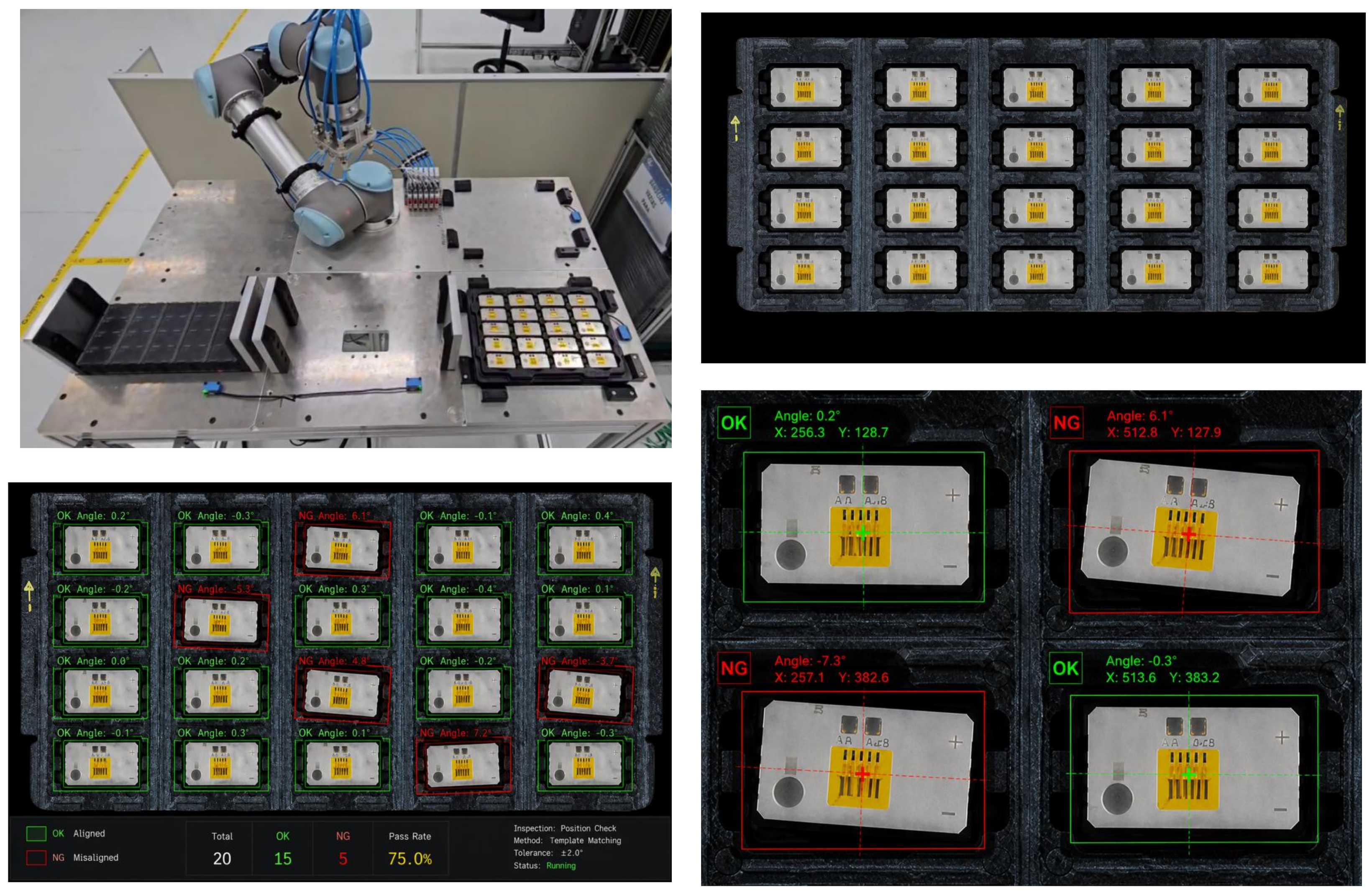
The proposed methodology was structured in sequential stages combining data-driven perception and robotic automation: (i) acquisition of visual data from Smart Card connectors (ICA-697) positioned in non-structured trays under real industrial conditions; (ii) development and training of a computer vision model based on the YOLO architecture for real-time detection of connector position and orientation, considering variability in lighting, reflections, and geometric misalignment; (iii) preprocessing and annotation of image datasets to ensure robustness and generalization of the model; (iv) integration of the vision system with a collaborative robot (UR3) equipped with a vacuum gripper, enabling precise pick-and-place operations; (v) implementation of industrial automation systems (CLP and HMI) to control synchronization, safety, and process flow; and (vi) validation of the complete system in a real SMT production environment (Line S4), including performance evaluation in terms of positioning accuracy, cycle time, and operational stability. The solution was also integrated with the Panasonic SMT feeder system, ensuring compatibility with existing equipment and enabling continuous operation within the production line.





RESULTS & DISCUSSION

The proposed system was successfully implemented and validated in a real SMT environment, achieving accurate detection and positioning of Smart Card connectors using a YOLO-based vision system integrated with a collaborative robot. The results showed a reduction in cycle time from 15 s to 5 s per connector and an increase in production capacity up to 5,000 connectors per shift, improving efficiency and reducing process variability. Additionally, the integration of AI, computer vision, and collaborative robotics proved effective in non-structured conditions, enhancing process reliability and enabling real-time monitoring through dashboards, advancing the system to Industry 4.0 maturity level 3 (Visibility).



CONCLUSION

This work presented the development and validation of a collaborative robotic cell integrated with computer vision and artificial intelligence for automated handling of Smart Card connectors in SMT environments. The proposed solution demonstrated significant improvements in productivity, accuracy, and process stability, reducing manual dependency and operational variability. Furthermore, the integration of AI-based perception with collaborative robotics proved to be an effective approach for industrial automation in non-structured scenarios [3][4], contributing to the advancement of manufacturing systems toward Industry 4.0 principles.

FUTURE WORK / REFERENCES

Future work includes expanding the solution to other types of electronic components, improving the robustness of the vision system under different industrial conditions, and incorporating advanced AI models for adaptive grasping and predictive process optimization[5]. Additionally, further integration with MES systems and real-time analytics platforms is expected to enhance traceability and support higher levels of Industry 4.0 maturity.

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