National Science Foundation
Where Discoveries Begin

Real-Time Detection of Product Defects using Camera-Based AI/ML Algorithms

Nima Mahmoodi (UA)[1], Cheng Chen (UAH)[2], Hwan Yoon (UA)[1], Dan Fonseca (UA)[1], and Jackey Gong (UA)[1]

[1]Mechanical Engineering Department
[2]Industrial & Systems Engineering and Engineering Management Department

IUCRC
Industry-University Research Partnership

Why AI-Enabled Smart Factories?

People + Processes + Technology

Smart Factory

- **Predictive Maintenance**: Reduce downtime by up to 15%, according to Deloitte's 2023 report, boosting asset utilization and operational efficiency
- AI Quality Control: AI-based visual inspection based on image recognition may increase defect detection rates by up to 90% as compared to human inspection.
- **Agile Supply Chains**: AI-enhanced forecasting can optimize inbound logistics, manufacturing, efficiency and inventory.

Project Goals

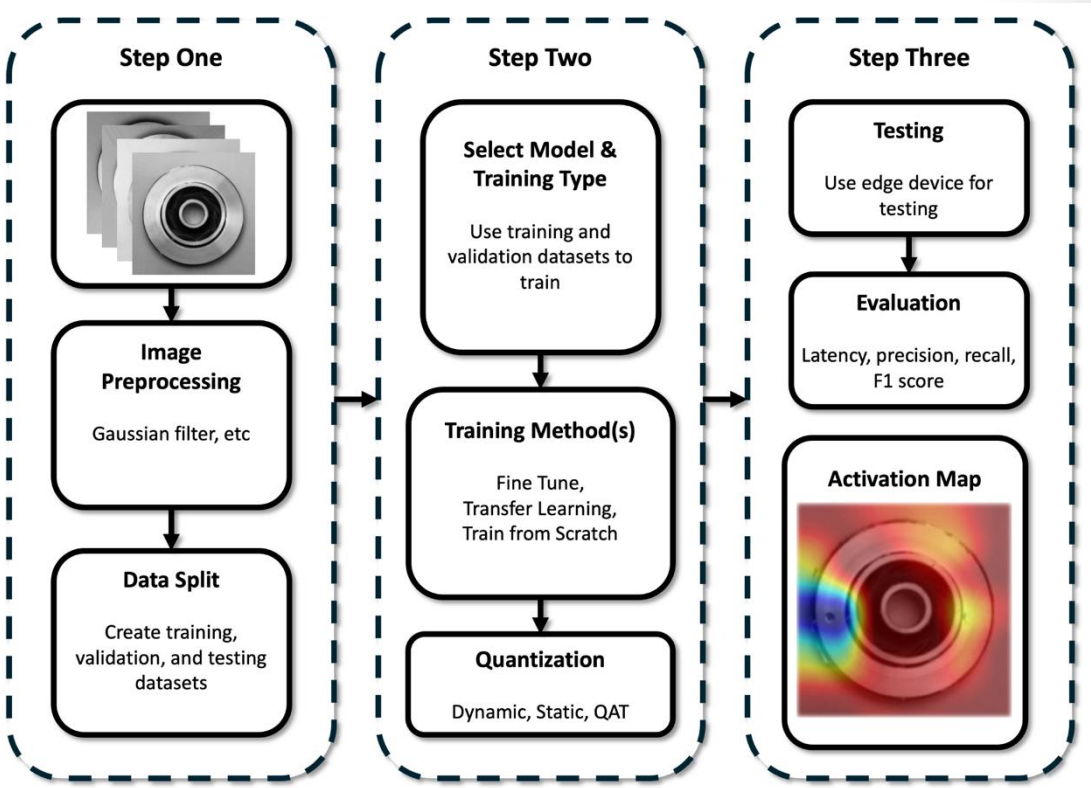
- Establish a unified smart factory vision that aligns operational efficiency, sustainability, and innovation objectives across leadership, IT, OT, and executive stakeholders.
- Deploy a scalable edge-first infrastructure to enable real-time data processing at the source, reducing latency and making AI-driven insights immediately actionable.
- Empower the workforce through targeted upskilling programs that enable employees to effectively leverage AI tools and foster a culture of continuous innovation.
- Scale validated AI and edge computing solutions across facilities to create a connected, intelligent enterprise with measurable ROI and operational optimization.

Objectives

- Develop and deploy an edge-based AI framework that integrates real-time PLC data (machine states, cycle times, alarms, and sensor signals) into a unified architecture for predictive analytics and process optimization.
- Design and implement AI-driven models for anomaly detection, predictive maintenance, and performance optimization, enabling closed-loop interaction between AI inference engines and PLC systems for adaptive machine control.
- Establish a secure, scalable industrial data infrastructure that connects PLCs, SCADA, and MES systems while supporting low-latency edge deployment and industrial communication protocols.
- Validate the integrated PLC-AI system through pilot implementation and quantify measurable improvements in OEE, downtime reduction, cycle time efficiency, and energy optimization.

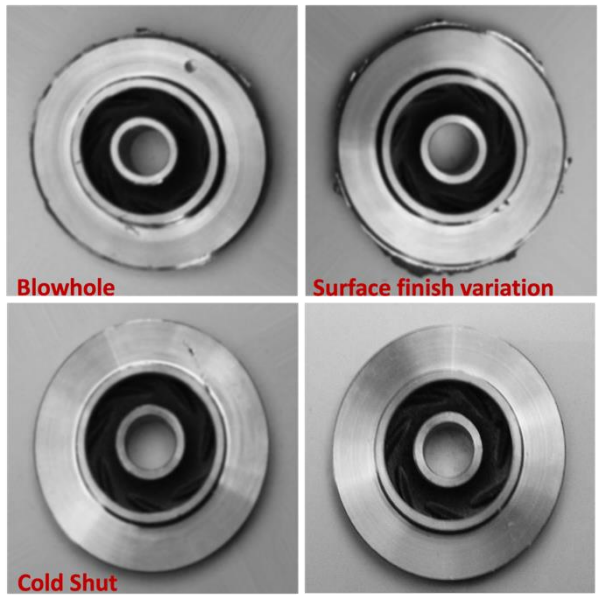
Approach / Research Methods (1/2)

- **Real-Time Inference**
  - Deploy edge-based AI models to process PLC and sensor data in real time
- **Latency vs. Accuracy**
  - Optimize model architectures to balance inference speed and prediction accuracy based on operational and safety requirements
- **Low Cost and Easy Deployment for Legacy Machines**
  - Develop non-intrusive integration methods to connect legacy PLC systems using standard industrial communication protocols without hardware replacement.

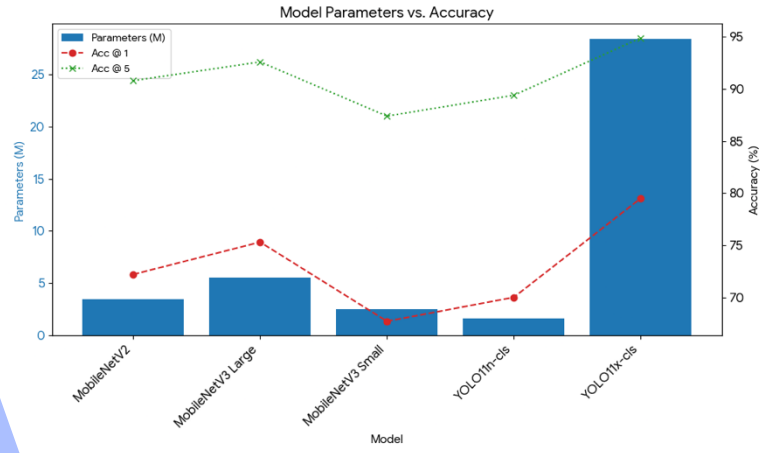


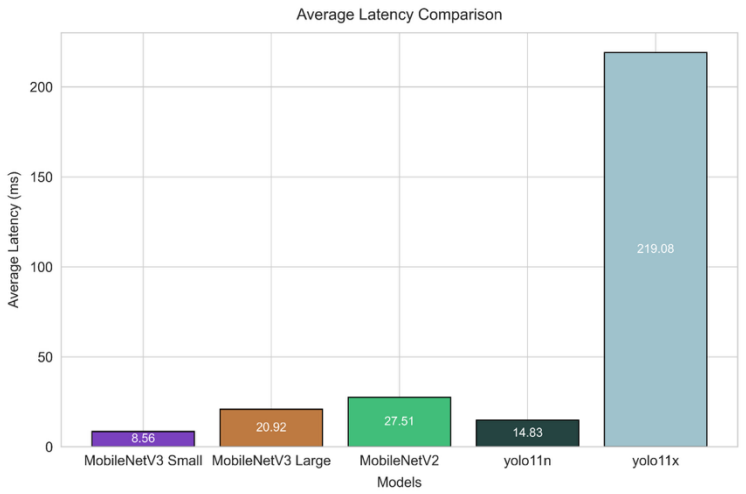
Data Pipeline

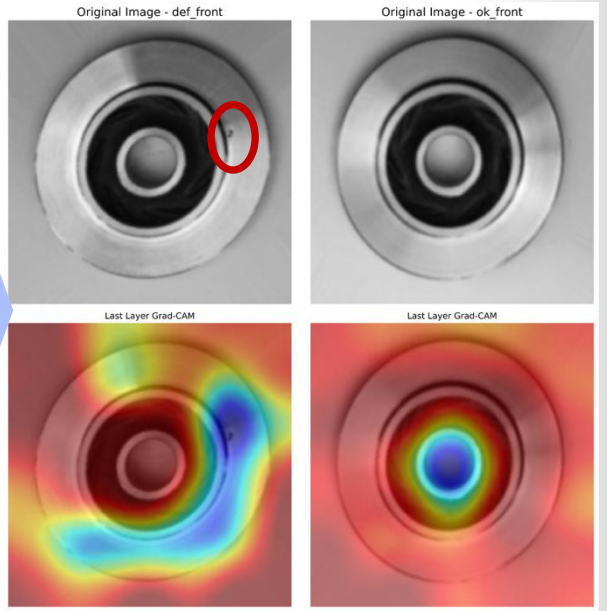
Outcomes / Research Methods (2/2)



Submersible Pump Impellers







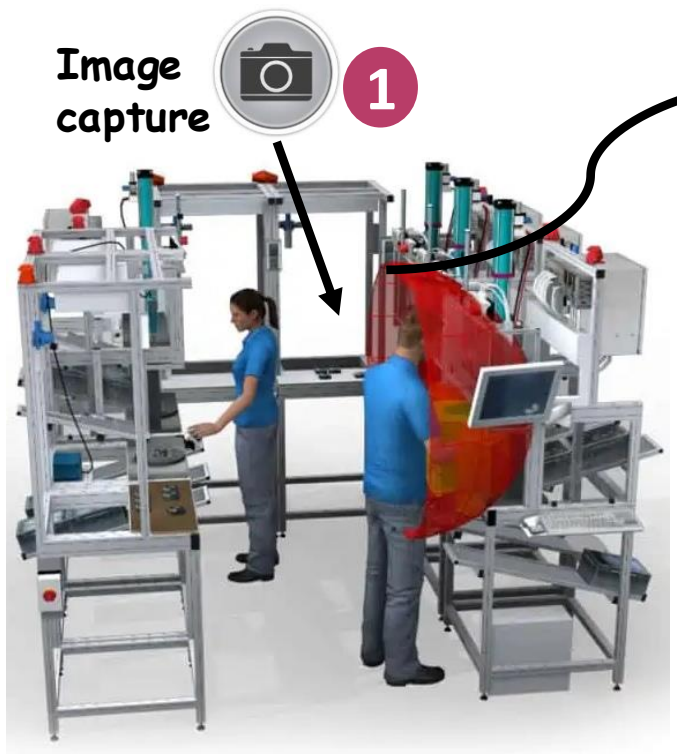
Feature map

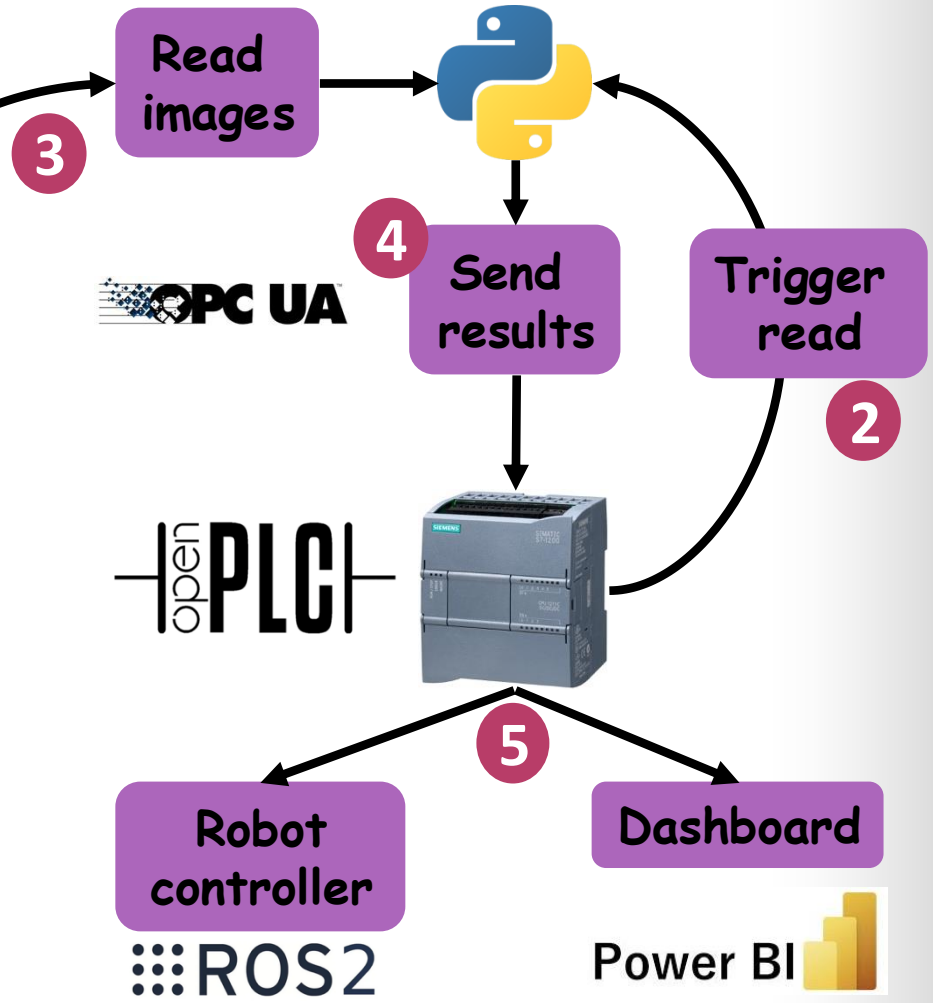
National Science Foundation
Where Discoveries Begin

IUCRC
Industry-University Research Partnership

Opportunities

- **Cyber-Informed Machine Learning**
  - Develop AI models that incorporate cybersecurity awareness by detecting abnormal network traffic, unauthorized PLC commands, and anomalous control behavior.
- **PLC–AI Integration**
  - Design a bidirectional interface between AI inference engines and PLC controllers to enable real-time data exchange and adaptive process control.
- **Dynamic Dashboard**
  - Develop a real-time visualization platform that aggregates PLC, AI, and system-level metrics into actionable operational insights.



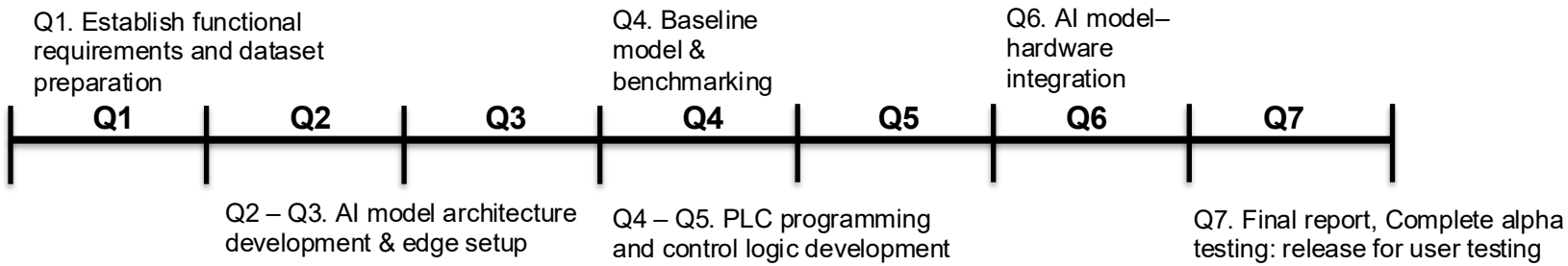


Project Administration

Budget

Item	Year 1	Year 2	Total
Salaries and Stipends			
Faculty – H. Yoon	3,000	3,000	6,000
Faculty – D. Fonseca	3,000	3,000	6,000
Graduate Research Assistant	31,200		62,400
Fringe Benefits			0
Faculty and Staff (32%)	1,920	1,920	3,840
Student Research Assistants	1,664	1,664	3,328
Other Direct Costs			
Supplies, Software, and Equipment			
Travel	3,416	3,416	6,832
Total Direct Costs	44,200	44,200	88,400
Indirect Costs (10% Request)	4,420	4,420	8,840
Items Not Charged F&A			
GRA Tuition	11,380	11,380	22,760
Budget Totals	**$60,000**	**$60,000**	**120,000**

Duration: 12 Months



National Science Foundation
Where Discoveries Begin

Questions?

IUCRC
Industry-University Research Partnership