Smart mooring dampers

Build new products based on AI and IoT technologies.

The Challenge

The company produces sea dampers for the marine industry. They want to innovate their product including IoT technology.

Main Requirements

N/A

Other Requirements

- Scalability;
- Low maintenance requirements;
- Edge software deployment must be supported by platforms that allow the necessary updates or applications of patches automatically;
- Edge hardware must be designed for critical environments: low energy, high resistance to shock, vibration, temperature, etc.

Key Performance Indicators

- Add always-on data visualization;
- Perform data analytics and take data-driven decisions;
- Increase revenues based on sales;
- Track assets indoor or outdoor;
- Cut operational costs.

Industry Sector:
IIoT

Challenge classification:
Smart products

Time for Project Completion:
3 months

Other informations

The company expects to deploy 25 devices.

Need for device management operations (such as managing or updating the software remotely)?
Yes

Strict deadlines in device operations for doing the tasks?
Yes

Research Phase

Taking into account the challenge description, its requirements and its information, elaborate at least 5 questions that can lead your research for a solution.

Research questions:

1. Will production managers do decision-making, or should it be automated?
2. Does the company still rely on legacy systems?
3. Is the replacement of industrial equipment allowed?
4. Do you want to verify continuously whether the published data are correct and up to date?
5. Can the manufacturing system be stopped to perform the retrofitting process?

Given the questions and the main requirements of the challenge previously listed:

- *identify possible technologies using the Planet4 Taxonomy Explorer;*
- *identify and analyze the sources (papers, articles, etc.) of those technologies that best suit the challenge;*

Technologies identified in the taxonomy:

- Edge Computing
- Data Visualization Tools and Platforms
- Data Analytics
- Machine Learning
- Federated Learning
- Industrial Gateways and Data Acquisition Devices
- Cybersecurity Technologies
- RFID
- Industrial IoT
- Sensors (hardware)

Sources of those technologies that best suit the challenge:

1. Šulyová, D.; Koman, G. The Significance of IoT Technology in Improving Logistical Processes and Enhancing Competitiveness: A Case Study on the World's and Slovakia's Wood-Processing Enterprises. Sustainability 2020, 12, 7804. https://doi.org/10.3390/su12187804
2. Silva, N.; Barros, J.; Santos, M.Y.; Costa, C.; Cortez, P.; Carvalho, M.S.; Gonçalves, J.N.C. Advancing Logistics 4.0 with the Implementation of a Big Data Warehouse: A Demonstration Case for the Automotive Industry. Electronics 2021, 10, 2221. https://doi.org/10.3390/electronics10182221

3. Rupprecht, B.; Trunzer, E.; König, S.; Vogel-Heuser, B. Concepts for Retrofitting Industrial Programmable Logic Controllers for Industrie 4.0 Scenarios. In Proceedings of the 2021 22nd IEEE International Conference on Industrial Technology (ICIT); March 2021; Vol. 1, pp. 1034–1041.
4. Review: Digital Product Factory #2. Smart Systems Hub GmbH 2021. https://smart-systems-hub.de/review-digital-product-factory-2-en

In light of the discoveries made:

- *report the answers for the questions above;*
- *compare 2-3 of the more common solutions identified in the sources (how would they change the approach to the solution? What are the possible benefits/issues in such a use of these technologies?);*
- *draw initial conclusions on which path you want to take in proposing a solution.*

Answers:

1. Automated decision-making can boost the company's growth by eliminating mistakes and biases and speeding up the process as much as possible since it can almost instantly process vast amounts of data.
2. Yes. The factory is not IoT-ready since it consists of mechanical and analog devices, outdated Programmable Logic Controllers (PLCs), and obsolete industrial machines.
3. No.
4. Yes.
5. The manufacturing system has to be retrofitted without stopping its program execution.

Comparison:

Using the taxonomy, we identified two possible technological solutions for improving the manufacturing process phases. As the company suggested, the proposed solution has to employ specific technologies: ***Internet of Things***, ***Edge Computing*** and ***Big Data & Analytics*** (*e.g.* ***Data Visualization Tools and Platforms***). Moreover, according to the other requirements, the industry wants to monitor the products and industrial assets in real-time. Therefore, with the taxonomy's help, technologies such as ***RFID*** for monitoring the movement of materials/products and localizing their exact position inside the industrial plant, as well as advanced ***sensors*** (i.e., with communication capabilities) for measuring different process parameters such as temperature, pressure, humidity, etc., were identified.
The difference in the proposed solutions concerns the architecture of the edge layer. The first one concerns the integration of edge computing capabilities directly into a module intended for industrial automation, such as a Programmable Logic Controller to create an industrial edge controller. This single system can

perform various tasks such as industrial control, monitoring, data acquisition and communication, operator interface, edge data processing, and analytical functions. In addition, it can be programmed using familiar automation tools like flowcharting and IEC 61131-3 languages or higher-level languages such as C / C ++, Java, and Python. The advantage of this approach is that it reduces installation and hardware maintenance costs as no additional hardware is required. However, it is only feasible if the production process can shortly be stopped to reconfigure the controller or replace the PLC with a modern Edge Programmable Industrial Controller (in case the controller used is outdated). In replacing existing industrial units, it should be borne in mind that the existing configurations and control codes can often only be transferred between PLCs of the same vendor or even PLC series due to the vendor-dependent nature of these devices.
In contrast, the second solution concerns installing a hardware ***IIoT Edge Gateway*** and directly connecting it to the PLC. This approach has several advantages since it can be implemented without stopping the manufacturing system, and it is feasible even if industries are still based on legacy systems. These gateway devices have multi-protocol translation capabilities and can collect and aggregate data from various I/O devices and controllers and communicate the data in local data centers or the cloud through IoT protocols. However, the solution's cost is higher than the former as it requires the installation of new devices on the shop floor. Finally, we can employ ***Machine Learning*** techniques which automate decision-making and predictions based on production data and ***Cybersecurity Technologies*** such as Blockchain to enhance IoT safety.

Conclusions:

The final choice of the solution is based on the comparison made before, the industry's requirements and the answers to the questions asked. Initially, we chose the architecture of the edge layer. Regarding the industry requirement that edge hardware has to be designed for critical environments, both solutions satisfy it. However, the fact that the factory consists of legacy industrial components prevents us from choosing the first solution as the existing controllers do not have the necessary processing capabilities to integrate edge computing inside them. Also, the enterprise does not want to replace its controllers due to reliability concerns and vendor restrictions. Another reason that prevents us from adopting the first solution is the requirement not to stop the system's operation. A loss of control can lead to serious safety threats, unacceptable productivity losses, unexpected downtimes, and behavior. So to achieve networking on the shop floor, it is recommended to use ***IIoT Edge Gateways***.

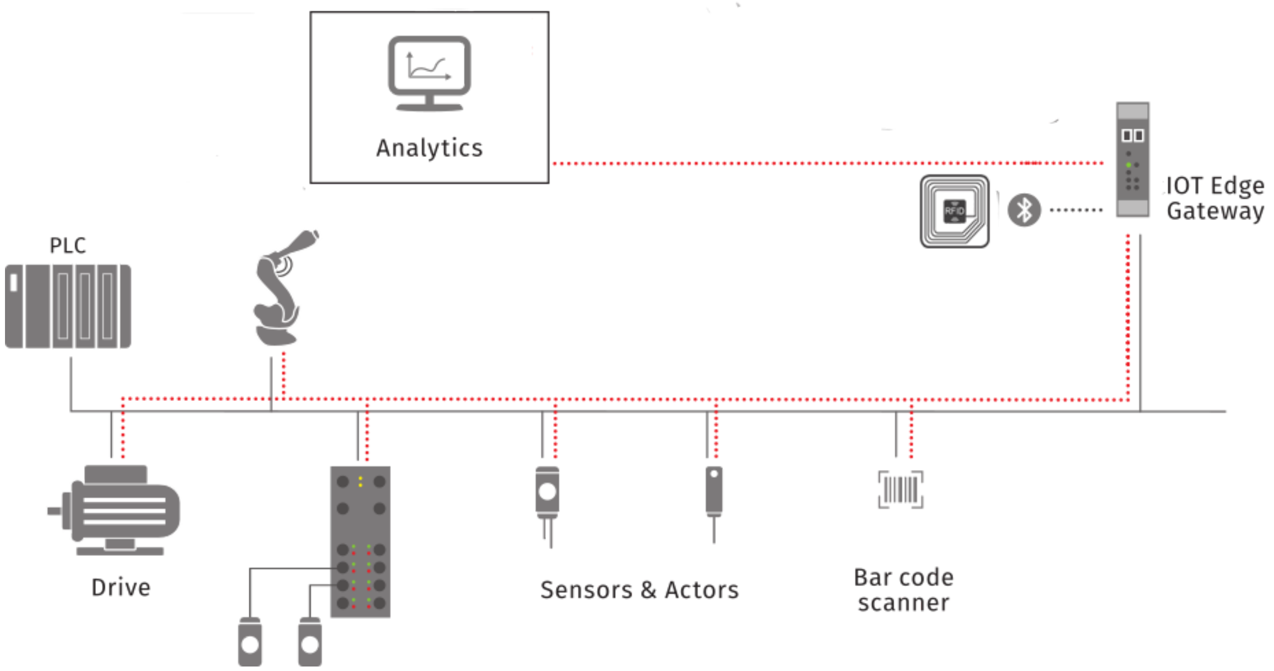
Proposed Solution

Making use of the technologies identified after the analysis of the sources, describe a possible solution to the challenge. Also, do not forget the constraints (time, number of devices to produce/connect, etc.): the solution must be applicable to the real context of the company that commissioned the challenge.

Solution Summary

Brief description of the solution (1-2 paragraph + 1 image)

Based on the analysis made in the previous two sections, the following solution is proposed:



The solution allows us to collect data from different industrial units like sensors, PLCs, and industrial engines and run applications such as event processing, predictive analytics, and ***machine learning*** models closer to the data sources (i.e. on ***edge***). This solution reduces latency since the data does not have to be sent back and forth to the cloud, thus ensuring real-time responsiveness of the manufacturing process. In addition, the proposed solution employs ***RFID*** tags and readers for optimizing various industrial operations. Finally, ***blockchain*** technology is exploited to create a secure and immutable database of assets or products.

Solution Description

Describe the solution and its details

As mentioned, the proposed solution's critical element is the ***IIoT Edge Gateway***. Since the manufacturing system consists of mechanical and analog devices, outdated Programmable Logic Controllers (PLCs), and obsolete industrial machines, the connection between the gateway and the industrial assets is established through ***Industrial Communication Protocols***. Once the connection is established, production data (e.g. sensor data) are collected, stored, and fed to edge computing data analytics processes for making data-driven decisions. These are ***Machine Learning*** algorithms that can predict consumer demands, detect anomalies in production processes in real-time, control products' quality, assess the equipment's health status and predict when the assets' next failure is likely to occur. The outcome of the AI models can be presented in dashboards, thus helping the operator to understand in an intuitive way what is happening on the factory floor in real-time.
Furthermore, through ***RFID***, managers and employees can access real-time data on an individual's (e.g., raw materials, finished products, etc.) movement and position across the facility by tagging it with passive RFID tags and then setting up numerous reader "checkpoints" at crucial points in the industrial environment. At the same time, the written data onto an RFID tag are encrypted and published through ***blockchain*** technology. In addition, the company can record other information such as price, date, location, quality, and certification to manage its supply chains effectively. Therefore, merging the blockchain technology with RFID lets the company, its suppliers, distributors, transporters, and customers create a single source of trusted information mechanism in the supply chain, thus enhancing transparency.

Implementation Plan

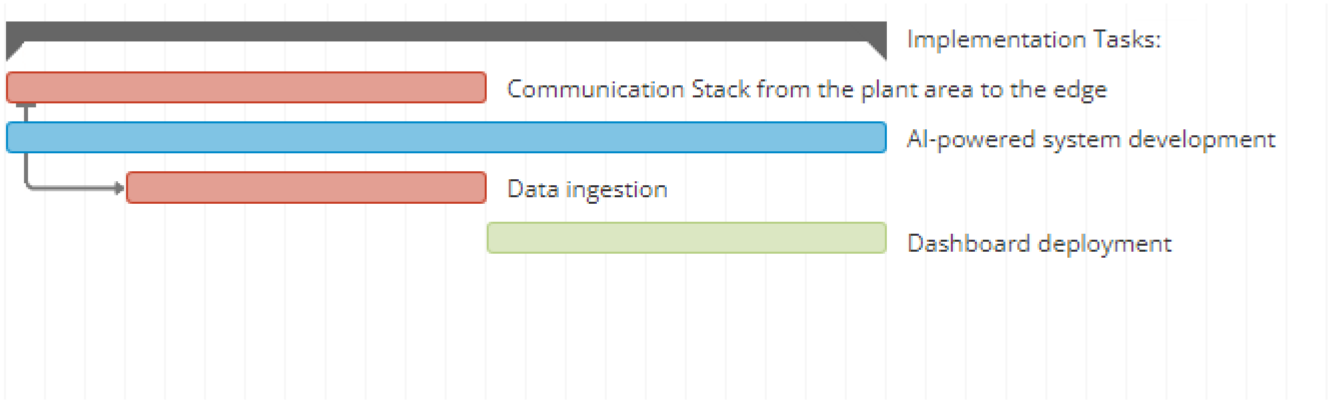
Describe the solution implementation plan considering among other things: gantt chart with milestones, high-level cost analysis, possible difficulties (at least 3 major issues or difficulties) and additional opportunities (at least 2 extra benefits).

The developers of the solution must start from scratch to implement the proposed technological solution. The implementation plan is composed of 4 stages:

- Data ingestion: Production data from sensors, mechanical and analog devices, Programmable Logic Controllers (PLCs), and industrial machines are collected, and stored in the edge devices
- The complete communication stack from the plant area to the edge,
- The edge computing data analytics (AI models)
- The deployment of a dashboard to display the AI model's results

Based on the results of other similar implemented projects, it can be implemented within **three months** [4].

Gantt chart:



High-level cost analysis

Regarding the proposed solution's cost, there is no established methodology for pricing, but only estimations are available. Edge computing costs vary greatly depending on the scale, data, location, and expertise. Overall expenses may rise or fall based on the infrastructure in place in the industrial environment [5].

Infrastructure expenses

The hardware and sensors are among the first concerns for deploying AI applications to the edge. Sensors, computation systems, and networks are the most prevalent components of edge infrastructure.

AI application expenses

The work required to construct a model determines the cost of a custom AI project. AI development work is often separated into six stages [6]:

1. Discovery & Analysis Phase
2. Prototype Implementation and Evaluation Phase
3. Minimum Viable Product (MVP)
4. Product Release
5. Maintenance and Support

Prices for each stage individually are often:

1. Prototype development begins at **$2.500**.
2. MVP development begins at **$8.000** and often costs up to **$15.000** (depending on project size, complexity, and participating team).
3. The final solution may cost from **$20.000**

Taking into account all this analysis as well as the pricing of companies that offer such solutions, the final cost of an All-in-One Edge-to-Cloud Solution for connecting industrial assets ranges from **$202,5K** to **$450K** [7].

Benefits:

1. Faster response time.
2. Operational Efficiency.
3. Enhanced Security.
4. Interoperability between legacy and modern devices.

Difficulties [8,9]:

1. Edge networks are not simple to build and can be expensive.
2. The edge device may be directed to discard information to save costs.
3. Most production facilities cannot keep temperature and humidity levels within the acceptable ranges for reliable IT equipment performance. IT equipment protection also necessitates dust-protected or sealed IT racks or enclosures that prevent unfiltered outside air from accessing the equipment and dedicated cooling.

5. Building an Edge Strategy: Cost Factors Available online: https://developer.nvidia.com/blog/building-an-edge-strategy-cost-factors/ (accessed on 10 August 2022).
6. How Much Does Artificial Intelligence (AI) Cost in 2020? Azati: Uniting experts to fulfil important projects 2020.
7. Octave. *Sierra Wireless.* https://www.sierrawireless.com/octave/ (accessed on 10 August 2022)
8. Weighing the Risks - and Rewards - of Edge AI Technology Available online: https://www.weforum.org/agenda/2022/05/at-the-edge-of-innovation-what-can-edge-ai-do-for-you/ (accessed on 10 August 2022).
9. The Core Challenges of Edge Computing in Industrial Environments Available online: https://www.manufacturing.net/industry40/blog/21796310/the-core-challenges-of-edge-computing-in-industrial-environments (accessed on 10 August 2022).