Groupe N : 20

ÉCOLE CENTRALE CASABLANCA

PROJET INTRAPRENDRE UNE SPIN-OFF

Functional Specifications Document

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1 Context

The history of industry, from ancient manual craftsmanship to the transformative Industrial Revolution, signifies a progression marked by innovation and technological leaps. As factories emerged, altering societal structures and fostering urbanization, maintenance evolved as a crucial element ensuring sustainable operations. Initially reactive, addressing issues post-failure, it incurred high costs due to downtimes and inefficient resource use.

Over time, maintenance transformed from a reactive stance to proactive methodologies, with preventive measures aiming to anticipate failures. However, limitations persisted, leading to unforeseen breakdowns. The advent of Industry 4.0 ushered in a paradigm shift, integrating IoT, AI, machine learning, and big data analytics to empower predictive maintenance. This approach revolutionized industries, optimizing schedules and resource allocation while minimizing downtime.

In Morocco, the embrace of Industry 4.0 technologies signifies a stride towards enhanced operational efficiency. The integration of predictive maintenance across sectors like manufacturing, energy, and transportation emphasizes data-driven decision-making. Challenges in implementation, including infrastructure readiness and skill availability, have influenced adoption rates. Yet, initiatives by governmental bodies and technology providers have been pivotal in raising awareness, providing training, and facilitating the transition to predictive maintenance practices.

2 Problematic

The implementation of AI-driven predictive maintenance in Morocco faces a significant challenge due to the archaic nature of many manufacturing systems in our country. Moroccan industry, characterized by its reliance on traditional methods and older machinery, confronts a problematic gap when it comes to integrating modern, AI-based technologies. Many manufacturing plants in Morocco still operate with outdated machinery and infrastructure, which are not equipped for integration with advanced AI and IoT technologies. This older equipment often lacks the necessary sensors and connectivity options required for data collection and analysis, essential for predictive maintenance.

This gap in predictive maintenance not only leads to operational inefficiencies but also poses a risk to the entire supply chain's stability and reliability. The repercussions are multifaceted : unforeseen equipment failures incur hefty repair costs and revenue losses due to production halts, particularly impacting businesses with limited financial resilience.

Furthermore, the lack of predictive maintenance can erode a company's reputation, a cornerstone in maintaining competitive advantage and client trust. Consistent failures and inability to meet commitments can lead to a loss of confidence among partners and customers, potentially resulting in long-term business setbacks.

These challenges underline the need for a strategic approach that not only incorporates technological solutions but also addresses infrastructural upgrades, workforce training, financial support mechanisms, and policy reforms. Overcoming these obstacles is crucial for Moroccan industries to harness the full potential of AI in predictive maintenance, thereby enhancing efficiency, reducing downtime, and staying competitive in the global market.

The central problematic, can be rephrased as follows : **In what ways can the implementation of predictive maintenance practices be strategically introduced within Morocco's industrial landscape to effectively address the economic losses and operational disruptions caused by prolonged downtime due to equipment malfunctions and anomalies ? Additionally, how**

can the accurate prediction of machinery lifespan be leveraged to optimize machine efficiency, minimize interruptions, and boost overall production output ?

3 Project overview and objectives

The core of our project revolves around the integration of Artificial Intelligence (AI) capabilities into real time IoT data platforms to transform the landscape of industrial operations. This initiative is rooted in the concept of harnessing the power of AI to significantly enhance the predictive maintenance capabilities within the industrial sector.

Our solution intitled "PredictA" stands at the forefront of industrial maintenance technology, revolutionizing how industries approach machine health and maintenance. Our cutting-edge solution ingeniously blends two critical components : a comprehensive dashboard and an advanced alerting system. This dual approach empowers industries to not only monitor but proactively manage their machinery with unprecedented precision and efficiency.

At its core, PredictA is designed to seamlessly integrate with industrial environments and supply chains, leveraging the latest in IoT and machine learning technologies. The solution comprises two main elements :

- **Dashboard for Real-Time Monitoring and Analysis :**

  - The dashboard component of PredictA is a powerful tool for visualizing the health and performance of industrial machines. It offers real-time data visualization, enabling users to see the operational status of their machinery at a glance.

  - Detailed historical data analysis is also available, providing insights into long-term trends and patterns in machine performance. This feature aids in making informed decisions regarding maintenance and operations.

  - The dashboard is highly customizable, allowing users, employees and managers to tailor views and settings to their specific monitoring needs, thereby enhancing user experience and engagement.

- **Advanced Alerting System :**

  - The alerting system in PredictA is a robust mechanism designed to provide timely notifications about the health of machines. It leverages sophisticated algorithms to predict and detect anomalies and potential issues in machine performance. This system proactively triggers alerts in anticipation of problems, ensuring issues are addressed before they manifest.

  - Alerts are delivered through various channels like message and dashboard notifications, ensuring that key stakeholders are promptly informed about any concerns.

  - This predictive approach to maintenance alerts helps prevent unplanned downtimes and costly repairs. PredictA does predict as well the remaining useful life of the machine.

- **Recommendation system :**

  - PredictA's recommendation system acts as a smart assistant, guiding maintenance teams with precision and foresight. It offers actionable recommendations in response to detected malfunctions and anomalies.

By combining the comprehensive monitoring capabilities of the dashboard with the predictive alerting system, PredictA delivers a holistic solution for predictive maintenance. This synergy allows industries to not only track the real time status of their machinery but also anticipate and address potential issues before they escalate. The result is a significant reduction in downtime, optimized maintenance schedules, and improved overall operational efficiency.

PredictA is more than just a predictive maintenance tool ; it's a complete ecosystem designed to enhance the reliability and longevity of industrial machinery. With its intuitive dashboard and sophisticated alerting system, PredictA stands as an invaluable asset for any industry looking to embrace the future of machine maintenance.

4 Functional requirements

- **Estimation of Remaining Useful Life (RUL) of Machines :**

  PredictA System Functionality : PredictA will accurately calculate the Remaining Useful Life (RUL) of industrial machines using advanced algorithms and models.

  Data Requirements : The system will require various data inputs such as machine usage data, maintenance history, and operational parameters to perform RUL estimations.

  Output Specifications : PredictA will present the RUL information through a user-friendly dashboard, offering detailed reports and visualizations for easy interpretation.
- **Anomaly Detection :**

  PredictA Detection Mechanism : The system will utilize sophisticated machine learning algorithms and threshold-based alerts to detect anomalies in machine performance.

  Anomaly Reporting : PredictA will report identified anomalies through various channels like email alerts and dashboard notifications, ensuring prompt and effective communication.
- **Dashboard for Monitoring Machine Performance :**

  Dashboard Features : PredictA's dashboard will feature real-time data visualization, historical data analysis, and customizable views for comprehensive monitoring.

  User Interaction : Users will have the ability to interact with the dashboard, customizing views and settings to suit their specific monitoring needs.
- **Alert and Recommendation Messages :**

  Alert System : PredictA will offer a nuanced alert system, categorizing alerts as critical, warning, or informational, and prioritizing them accordingly.

  Recommendation Engine : The system will generate actionable recommendations for performance improvement based on data analysis and machine learning insights.
- **System Integration and Compatibility :**

  Integration with Existing Systems : PredictA will seamlessly integrate with existing industrial systems and protocols, ensuring smooth operation and data exchange.

  Compatibility Requirements : The solution will be compatible with a range of hardware and software, accommodating various industrial environments.
- **Security and Data Privacy :**

  Data Protection : PredictA will implement robust measures to secure sensitive data and ensure user privacy, adhering to industry standards like GDPR.

  Compliance Standards : The system will comply with relevant industry standards and regulations to maintain data integrity and security.
- **User Roles and Access Control :**

  Different User Roles : PredictA will feature distinct user roles with specific access levels to the system, ensuring proper data access and system usage.

  Access Management : The solution will have a comprehensive access management system to enforce and manage user roles and permissions.

— **Performance and Scalability :**

Performance Metrics : PredictA will be designed to meet high-performance benchmarks, ensuring reliability and efficiency in its operations.

Scalability Provisions : The system will be scalable, capable of adapting to increasing industrial demands and expanding operational needs.

— **Model Retraining and Updates :**

Retraining Frequency : PredictA's predictive models for estimating Remaining Useful Life (RUL) and anomaly detection will undergo retraining twice per year.

Data Utilization for Retraining : The retraining process will use new data collected from the machines to enhance accuracy and efficiency, the types of data used (operational data, new maintenance records).

Performance Improvement Tracking : The system will monitor and report the improvements in model performance post-retraining, to ensure continuous enhancement of the predictive capabilities.

User Notification : Users will be informed about the retraining schedule and any changes or improvements in the system post-retraining.

5 Technical requirements and specifications

Table 1 – Technical Requirements and Technologies for PredictA

Functionality	**Technology/Tool**	**Purpose/Use**
RUL Estimation	Scikit-learn's LinearRegression	Calculate Remaining Useful Life of machines
Data Collection	AWS IoT Core	Collect data from IoT sensors
Data Preprocessing	Apache Spark, Kafka	Clean and prepare data for analysis
Anomaly Detection	Isolation Forest (Scikit-learn)	Identify anomalies in sensor data
Feature Engineering	Pandas, NumPy, Scikit-learn	Extract and manipulate relevant features
Machine Learning Models	Scikit-learn	Implement ML algorithms for RUL and anomaly detection
Model Training	Scikit-learn's classes	Fit models to prepared datasets
Model Evaluation	Precision, Recall, F1-Score, RMSE, MAE, R^2	Assess model performance
Dashboard	Grafana	Visualize data, historical analysis, user interaction
Alert System and Recommendations	Slack, Dashboard Notifications	Communicate critical information and alerts
Data Security	GDPR Compliance	Ensure data protection and privacy
System Integration	Compatibility with Industrial Systems	Seamless operation and data exchange
User Access Control	Access Management System	Manage user roles and permissions
Scalability	PredictA's Architecture	Adapt to increasing demands and needs
Model Retraining	Biannual Retraining Process	Update models with new data
Sensor Technology	Vibration, Temperature, Pressure Sensors	Monitor various physical parameters
Data Transmission	MQTT, HTTP	Facilitate data transfer between devices and systems
Micro-controllers for Data Collection	Raspberry Pi, Arduino	Acquire and process sensor data
Data Storage	Amazon S3	Securely store large volumes of data in the cloud
Model Deployment	AWS SageMaker	Deploy machine learning models for production use
Real-time Model Training	Airflow	Continuously train models with incoming data
Cybersecurity Measures	Data Encryption, Access Controls	Protect data integrity and privacy

6 Algorithms

-Anomaly Detection with Sensor Data : When it comes to spotting anomalies in sensor data for predictive maintenance, quality matters most. Cleaning up unreliable readings and choosing the right features that reflect machinery health is key. Time matters, too ; capturing patterns over time and handling imbalanced data can't be overlooked. Making sense of the model's decisions and adapting in real time ensures quick action. Integrating this seamlessly into the maintenance flow and staying vigilant with validation keeps things running smoothly.

Isolation Forest is an algorithm designed for anomaly detection that works on the principle that anomalies are less frequent and can be isolated faster than normal instances in a dataset. It constructs a random forest by recursively partitioning data until anomalies are isolated into individual trees, requiring fewer partitions for anomalies than normal points.

- Data Preprocessing : cleaning and preparing your dataset. Python's Pandas library is useful for data cleaning and manipulation.
- Feature Engineering : Extracting relevant features from your dataset that can help identify anomalies. NumPy or Scikit-learn for feature extraction and manipulation.
- Model Training : Implementing Isolation Forest using Scikit-learn's IsolationForest class. Fitting the model to the prepared dataset.
- Evaluation : Evaluating the model's performance using metrics like precision, recall, or F1-score.

-Remaining Useful Life (RUL) Prediction with Sensor Data : Estimating a machine's Remaining Useful Life using sensor data is about precision. Starting with spotless data and picking out the most telling features are crucial. Tracking how things change over time and handling imbalances in data ensures accurate predictions. Making sense of these predictions in real time and integrating seamlessly into maintenance workflows keeps everything on track, saving time and resources in the long run.

Linear Regression is a fundamental predictive modeling technique used to establish the relationship between independent variables and a dependent variable by fitting a linear equation. In the context of RUL prediction, it can estimate the remaining lifespan of a machine or component based on historical data.

- Data Preprocessing : Cleaning and preparing the dataset, handle missing values, and scale features if necessary, using Pandas for data cleaning and Scikit-learn for scaling.
- Feature Engineering : Extracting relevant features that can help predict RUL. Ensuring temporal sequencing if dealing with time-series data.
- Model Training : Implementing Linear Regression using Scikit-learn's LinearRegression class. Fitting the model to your prepared dataset.
- Evaluation : Assessing the model's performance using evaluation metrics like RMSE, MAE, or R^2.

7 Our solution's architecture

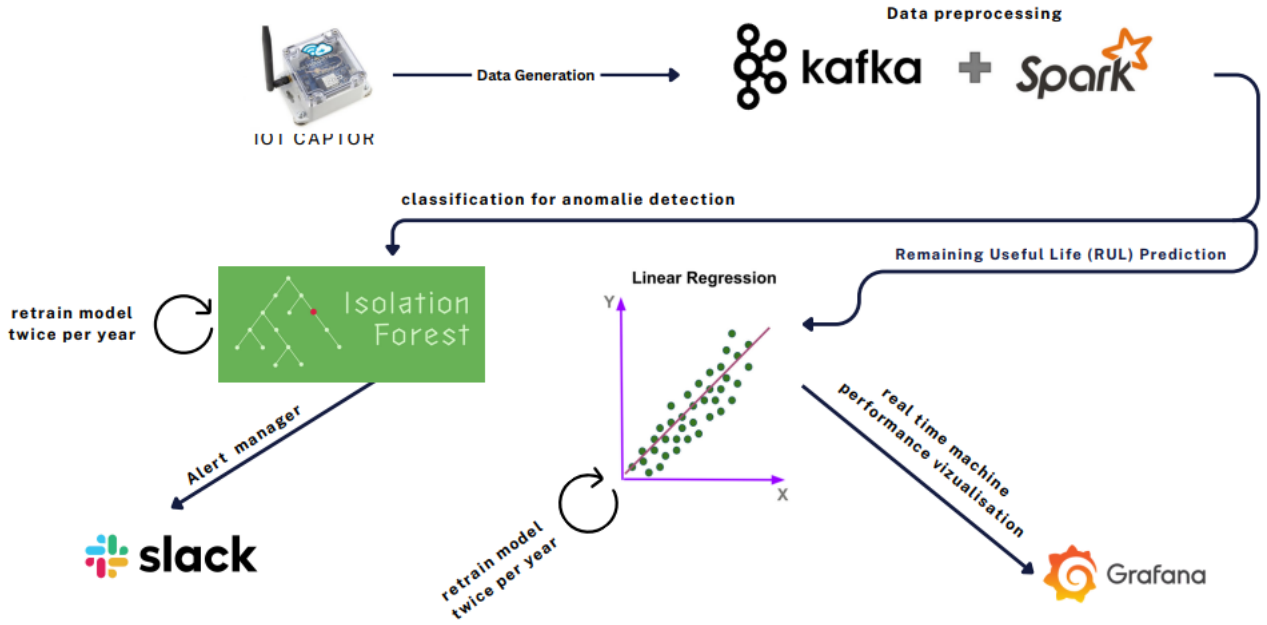

Figure 1 : PredictA's simplified Architecture

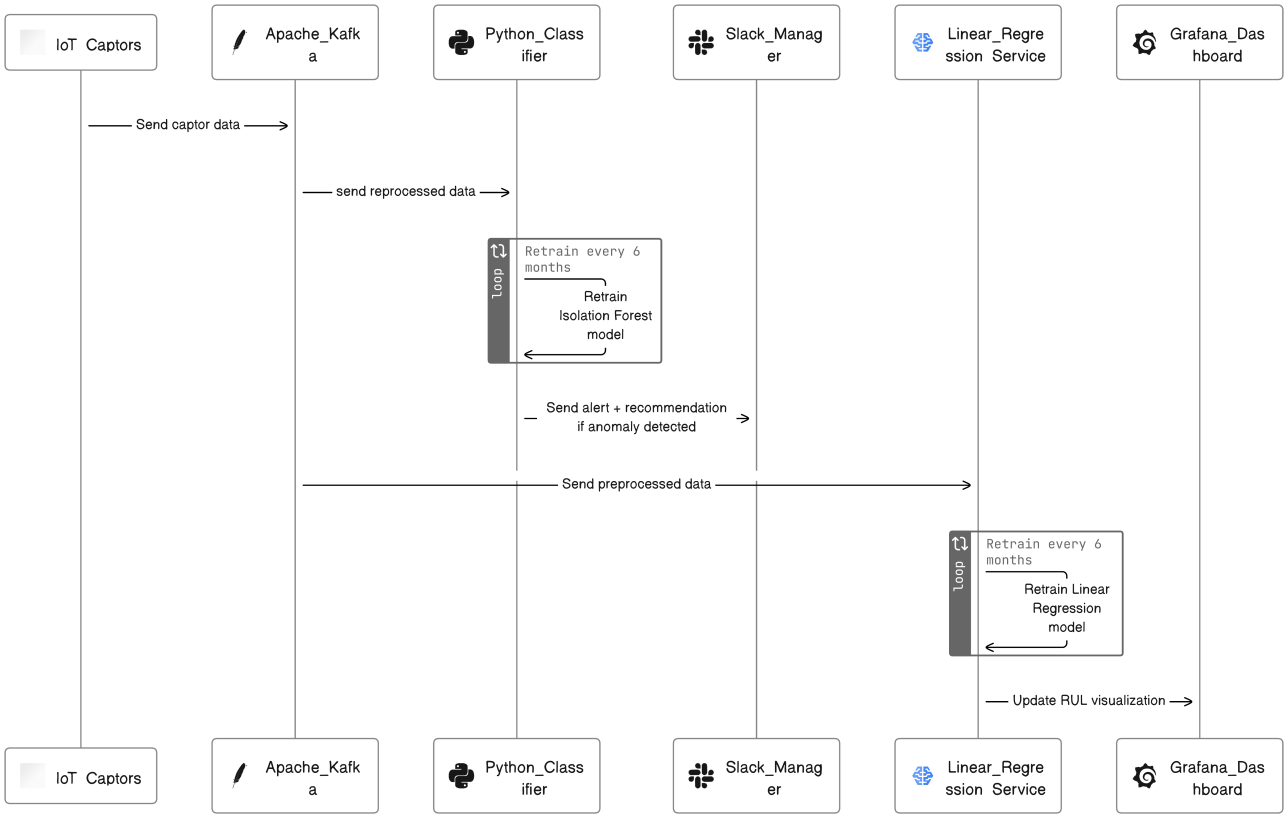

Figure 2 : Sequential Diagram of the solution

8 Clients

Our target market is Morocco, a coutry brimming with opportunities. Currently, the country is experiencing rapid growth in various industrial sectors, increasing the demand for advanced predictive maintenance solutions like PredictA. Our potential clients include businesses in manufacturing, energy, transportation, and heavy machinery - all sectors that stand to benefit significantly from PredictA's ability to enhance operational efficiency and reduce maintenance costs. With Morocco's industrial expansion, PredictA is positioned to become an essential tool for companies aiming to modernize their maintenance practices and embrace technological advancements.

Significantly, we have already initiated contact with ONEE, as a major player in the energy and utilities sector in Morocco. They have expressed interest in PredictA. This development underscores the market's readiness for advanced predictive maintenance solutions and positions PredictA as a frontrunner in transforming industrial maintenance practices in Morocco.

9 Business Model Canvas

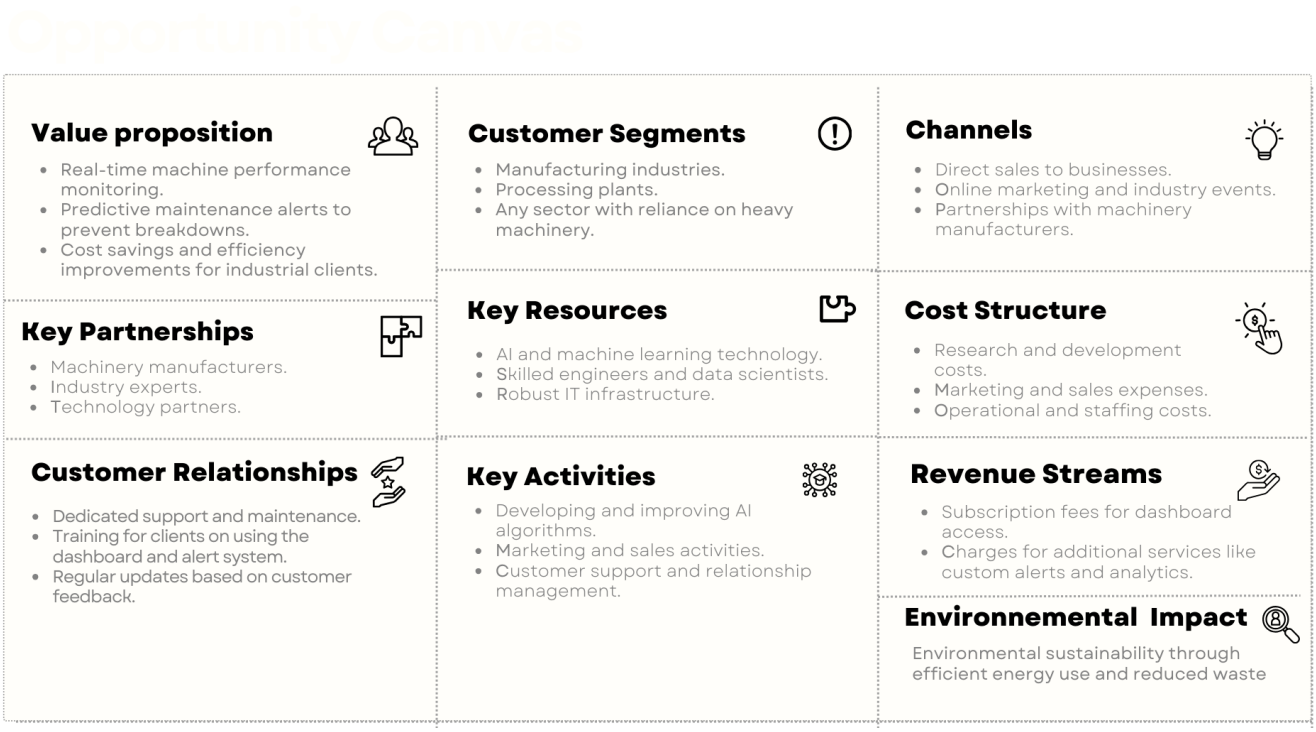

Figure 3 : PredictA's BMC

10 Perspectives and conclusion

As PredictA progresses, it stands at the threshold of transformative impact within Morocco's industrial landscape. The future outlook for this project is marked by significant potential for expansion and innovation. PredictA's advanced predictive maintenance capabilities, embodied in its intuitive dashboard and alerting system, are poised to set a new standard in industrial machinery management. The integration with key players like ONEE opens avenues for further collaborations and endorsements from major industry leaders.

Looking ahead, PredictA has the opportunity to not only solidify its presence in Morocco but also to explore expansion into neighboring regions, adapting to various industrial needs and environments. Continuous technological advancement, in alignment with evolving industry requirements, will be crucial. This involves integrating emerging technologies like AI and IoT more deeply, enhancing data analytics capabilities, and improving user experience.

In conclusion, PredictA represents a significant step forward in the realm of industrial maintenance. With its innovative approach to predictive maintenance, the project not only addresses the current needs of the Moroccan industrial sector but also lays the foundation for future growth and expansion. The journey of PredictA is a testament to the power of technology in transforming traditional industries and paving the way for a more efficient, reliable, and sustainable future.