PhD in Computer and Control Engineering
XXXV cycle

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A management framework for smart manufacturing applications in Industry 4.0

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1. Introduction

In recent years, Industry 4.0 focused on new smart processes, like **Additive Manufacturing** (AM), that require more sophisticated control and management infrastructures.

2. Research Goals

Creation of a **management framework** for smart manufacturing environment in order to address industry 4.0 demands.

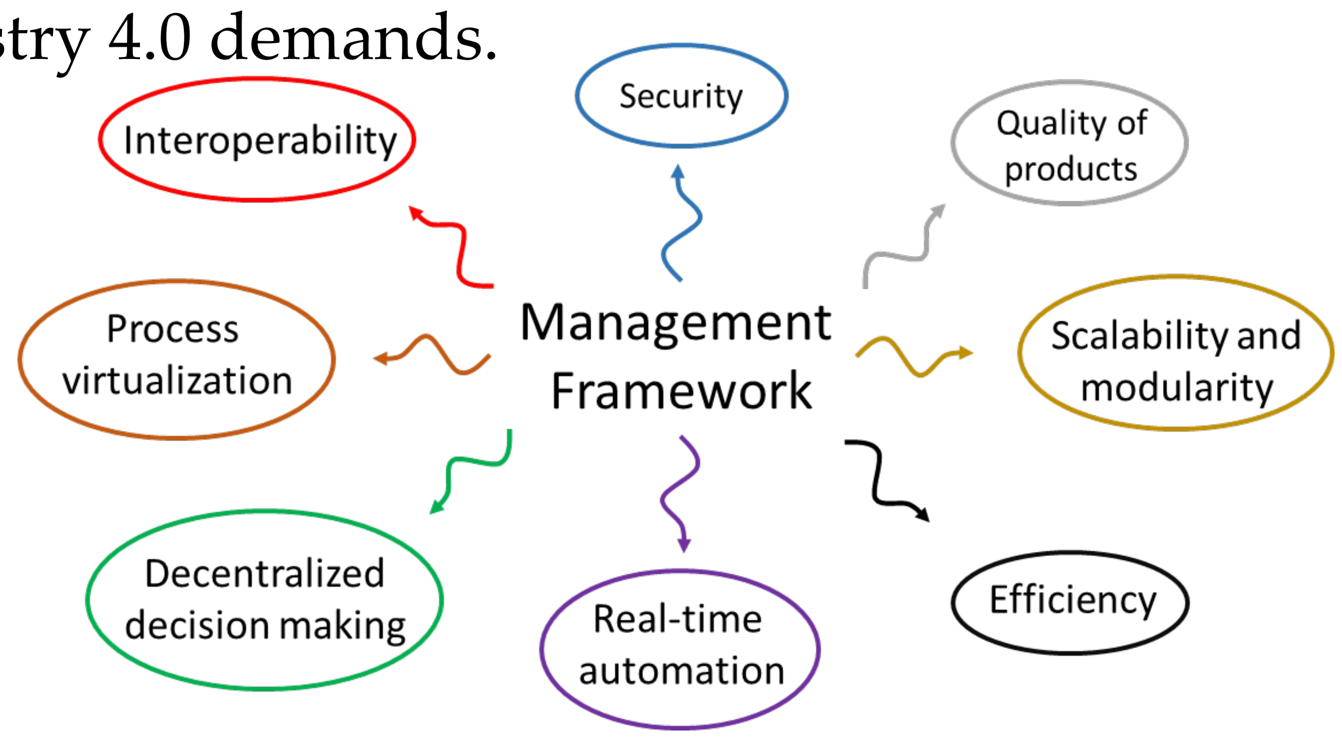

Figure 1: Industry 4.0 demands

3. Management framework for smart manufacturing

To respond to the industry 4.0 needs, I propose a general-purpose platform able to manage several **smart manufacturing use cases** [1]. The platform is developed based on state-of-art open-source software (DeviceHive, PostgreSQL, React) to **guarantee the process quality, efficiency and security standards and interoperability** with the machines and software already present. Using machine learning techniques, a set of custom services are integrated in the platform to face several critical issues in AM: **product defects detection** [2], **synthetic image generation** [2], **visual inspection and process control** [3], and **process anomaly detection**.

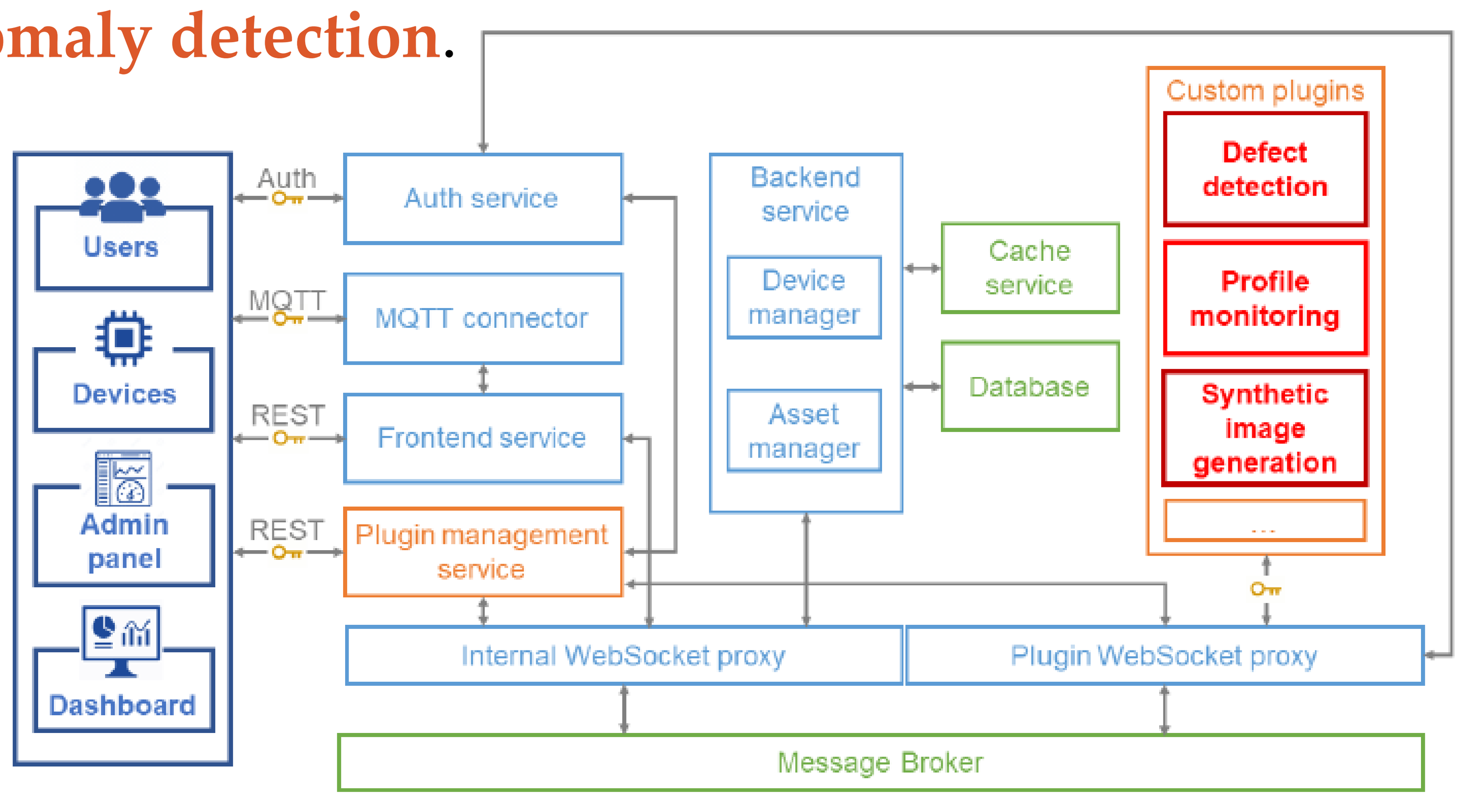

Figure 2: AM Management Framework

3.1. Product defects detection

One of the main technologies in AM is Powder Bed Fusion. In this process, several defects occurs (holes, spattering, etc.) so an **image analytics algorithm** service with a U-Net to detect defects was developed.

	Holes	Spatt.	Incand.	Horizontal	Vertical
Accuracy	91.3%	95.8%	79.2%	91.6%	91.6%
Precision	87.5%	95.6%	75.0%	91.6%	100.0%
Recall	100.0%	100.0%	100.0%	91.6%	75.0%
F-score	0.93	0.98	0.86	0.92	0.86

Table 1: Defects detection results

3.2. Synthetic image generation

In AM production, the **data available are limited** by time and costs. Therefore, a service with a ConSinGAN network to generate synthetic data is provided.

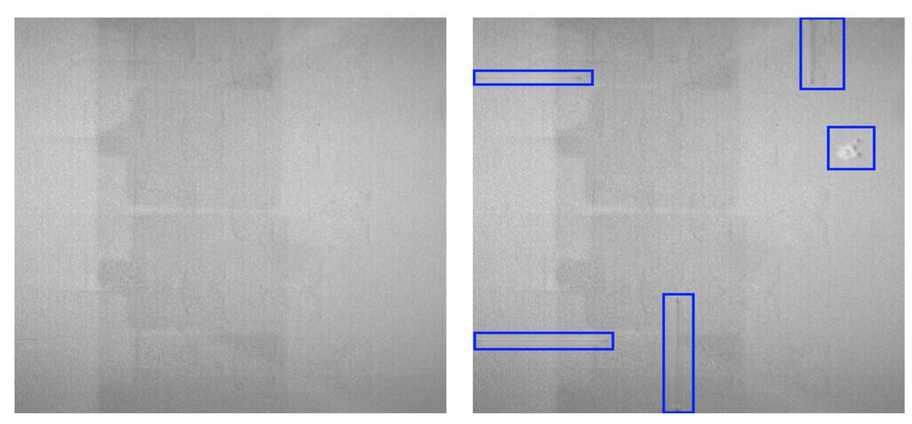

Figure 3: Synthetic image result (right) and original image (left)

3.3. Visual inspection

To guarantee the **quality of products in AM**, a visual inspection service with different computer vision techniques (thresholding, etc.), and a machine learning model (U-Net) is integrated in the platform.

	Accuracy	Sensitivity	Specificity
Laboratory	87.99 %	70.31 %	88.37 %
Industry	76.89 %	60.68 %	77.36 %

Table 2: Results of visual inspection in different environments

3.4. Process anomaly detection

A platform service for process anomaly detection of Electron Beam Melting processes was developed. An LSTM autoencoder is used to reconstruct the machine signals and **predict the future status of a job**.

	Precision	Recall	F1-score
Fail	86 %	75 %	80 %
Success	78 %	88 %	82 %

Table 3: Results of process anomaly detection

4. References

1. **Cannizzaro, D.**, et al., *"In-situ defect detection of metal Additive Manufacturing: an integrated framework"*, IEEE TETC, 2021.
2. **Cannizzaro, D.**, et al., *"Image analytics and machine learning for in-situ defects detection in Additive Manufacturing"*, Proc. DATE, 2021.
3. **Cannizzaro, D.**, et al., *"Quality inspection of critical aircraft engine components: towards full automation"*, Proc. ETFA, 2022.