D5.11 – i4Q Manufacturing Line Reconfiguration Toolkit v2

WP5 – Rapid Manufacturing Line Qualification and Reconfiguration

Document Information

GRANT AGREEMENT NUMBER	958205	ACRONYM		i4Q	
FULL TITLE	Industrial Data Services for Quality Control in Smart Manufacturing				
START DATE	01-01-2021	DURATION		36 months	
PROJECT URL	https://www.i4q-project.eu/				
DELIVERABLE	D5.11 – Manufacturing Line Reconfiguration Toolkit v2				
WORK PACKAGE	WP5 – Rapid Manufacturing Line Qualification and Reconfiguration				
DATE OF DELIVERY	CONTRACTUAL	31-Dec-2022	ACTUAL		30-Dec-2022
NATURE	Report		DISSEMINATION LEVEL		Public
LEAD BENEFICIARY	UPV				
RESPONSIBLE AUTHOR	Miguel A. Mateo-Casali (UPV)				
CONTRIBUTIONS FROM	UPV				
TARGET AUDIENCE	1) i4Q Project partners; 2) industrial community; 3) other H2020 funded projects; 4) scientific community				
DELIVERABLE CONTEXT/ DEPENDENCIES	This document presents a technical overview of the Manufacturing Liner Reconfiguration Toolkit solution (i4Q LRT). This document is an update with respect to the previous version D5.5 Manufacturing Line Reconfiguration Toolikt.				
EXTERNAL ANNEXES/ SUPPORTING DOCUMENTS	None				
READING NOTES	None				
ABSTRACT	This document is a Technical Specification document about the development of the i4Q Manufacturing Line Reconfiguration Toolkit (i4Q^{LRT}). This document is an update to deliverable 5.5 Manufacturing Line Reconfiguring Toolkit. This document which provides a thorough description and analysis of the functionalities, features, and the current implementation status. It provides an in-depth technical overview of the principal functional sub-components (i.e., features) of the Solution.				

Disclaimer

Copyright message

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS/ACRONYMS

AI	Artificial intelligence
API	Application Programming Interface
CI/CD	Continuous integration and delivery
CSV	Comma Separated Values
CVE	Common vulnerabilities and Exposures
DIT	Data Integration and Transformation
DR	Data Repository
HTTP	HyperTextTransfer Protocol
i4Q	Industrial data services for Quality Control in Smart Manufacturing
IT	Information Technology
LRT	Manufacturing Line Reconfiguration Toolkit
MQTT	Message Queuing Telemetry Transport
PDF	Portable Document Format

Executive summary

This document presents an executive explanation of the **i4Q Manufacturing Line Reconfiguration Toolkit** (i4Q^{LRT}) Solution providing the general description, the technical specifications and the implementation status. It is an updated deliverable with respect to its previous version D5.4 Manufacturing Line Reconfiguration Toolkit. The deliverable **D5.11** is the Source Code of the i4Q^{LRT} Solution that is in a private repository of Gitlab: https://gitlab.com/i4q.

The documentation associated to the i4Q^{LRT} Solution is deployed on the website http://i4q.upv.es. This website contains the information of all the i4Q Solutions developed in the project "Industrial Data Services for Quality Control in Smart Manufacturing" (i4Q). The direct link to the i4Q^{LRT} Solution documentation is http://i4q.upv.es/21_i4Q_LRT/index.html.

Such documentation is structured according to:

- General description
- Features
- Images
- Authors
- Licensing
- Pricing
- Installation requirements
- Installation Instructions
- Technical specifications of the solution
- User manual

Document structure

Section 1: Contains a general description of the **i4Q Manufacturing Line Reconfiguration Toolkit**, (i4Q^{LRT}) providing an overview and the list of features. It is addressed to final users of the i4Q Solution.

Section 2: Contains the technical specifications of the **i4Q Manufacturing Line Reconfiguration Toolkit** (i4Q^{LRT}), providing an overview and its architecture diagram. It is addressed to software developers.

Section 3: Details the implementation status of the **i4Q Manufacturing Line Reconfiguration Toolkit** (i4Q^{LRT}), explaining the status, next steps and summarizing the implementation history.

Section 4: Provides the conclusions.

APPENDIX I: Provides the PDF version of the **i4Q Manufacturing Line Reconfiguration Toolkit** (i4Q^{LRT}) web documentation, which can be accessed online at:
http://i4q.upv.es/21_i4Q_LRT/index.html

1 General Description

1.1 Overview

The **i4Q Manufacturing Line Reconfiguration Toolkit** (i4Q^{LRT}) is a collection of optimisation micro-services that use optimisation algorithms and simulation to evaluate different possible scenarios and propose changes in the configuration parameters of the manufacturing line to achieve the quality targets. i4Q^{LRT} AI learning algorithms develop strategies for machine parameters calibration, line setup and line reconfiguration.

The objective of the i4Q Manufacturing Line Reconfiguration Toolkit is to increase productivity and reduce the efforts for manufacturing line reconfiguration through AI. This tool consists of a set of analytical components (e.g., optimisation algorithms, machine learning models) to solve known optimisation problems in the manufacturing process quality domain, finding the optimal configuration for the modules and parameters of the manufacturing line. Some examples of the problems that the i4Q^{LRT} can solve for manufacturing companies are the fine-tuning of the configuration parameters of the machines along the line to improve quality standards or improving the manufacturing line set-up time.

1.2 Features

I4Q$^{LRT:}$

- Provides the possibility to deploy algorithms as micro-services at the edge of the network, via distributable files.
- Provides information necessary to understand the use, characteristics and needs of the algorithm.
- Offers the ability to instantiate optimization algorithms as standalone (micro-)services that can be deployed and managed at Edge.
- Allows algorithms to be instantiated and run at the edge of the network, obtaining information directly from the production line, by configuring the data source. This way, the algorithms can optimise the production line by providing a correct configuration.

2 Technical Specifications

2.1 Overview

The **i4Q Manufacturing Line Reconfiguration Toolkit** (i4Q^{LRT}) is mapped to the Simulation and Optimisation sub-component of the Enterprise tier. To facilitate the interconnection between processes and to scale the deployment of solutions across different industries and sectors, it is important that the algorithms are semantically interoperable and that all use the i4Q digital models and ontologies. Also, to ease integration and interoperability with other i4Q solutions, they all must use the same services to access data at rest and data in motion for model instantiation and execution. To address this, the strategy is to wrap algorithms into an interoperability layer that will implement the different cross-cutting functions (clients to data services, security and compliance services, libraries for digital models and vocabularies). The interoperability layer will also provide endpoints so that other solutions can instantiate and run the algorithms in complex workflows.

Some of these workflows may require that models are executed at the edge tier, close to the data source, to minimise latency. Therefore, the interoperability layer must ensure that the algorithms are deployable at the edge, through the Distributed Computing sub-component, and manageable by the Orchestration Management Sub-component.

Finally, to enable the digital twinning of models and algorithms with the underlying physical architecture, they should be regarded as (virtual) assets. For instance, an algorithm to optimise (i.e., fine tune) the configuration parameters of a machine should be regarded as a feature of its digital twin, and in that sense, the services provided by the interoperability layer should be mappable as features of the digital twin.

2.2 Architecture Diagram

i4Q^{LRT} includes different processes, functions and AI models which are mapped to the Enterprise Tier and to the Edge Tier of the i4Q Reference Architecture. Considering that it is a solution found at various levels of the architecture:

- **Enterprise Tier:** The i4Q^{LRT} mapping to "Simulation and Optimization" sub-component enables the effective monitoring of multiple analytical solutions from Enterprise Tier. This ensures the comprehensive analysis of possible simulations.
- **Platform Tier:** One of the sub-components not foreseen at the beginning, which is currently one of the most important, is "Data Brokering and storage". Thanks to the solutions hosted in this sub-component, such as i4Q^{DR} or i4Q^{DIT}, it will be able to work directly with different clients located in the Edge Tier from the application. Either to test or validate, or simply run some algorithms to see their result using the stored data to train them.

- **Edge Tier:** The i4Q^{LRT} mapping to "Distributed Computing" subcomponent. This allows to deploy and run workloads of the different algorithms deployed on the edge. This enables efficient analysis and fast action when reconfiguring the production line.
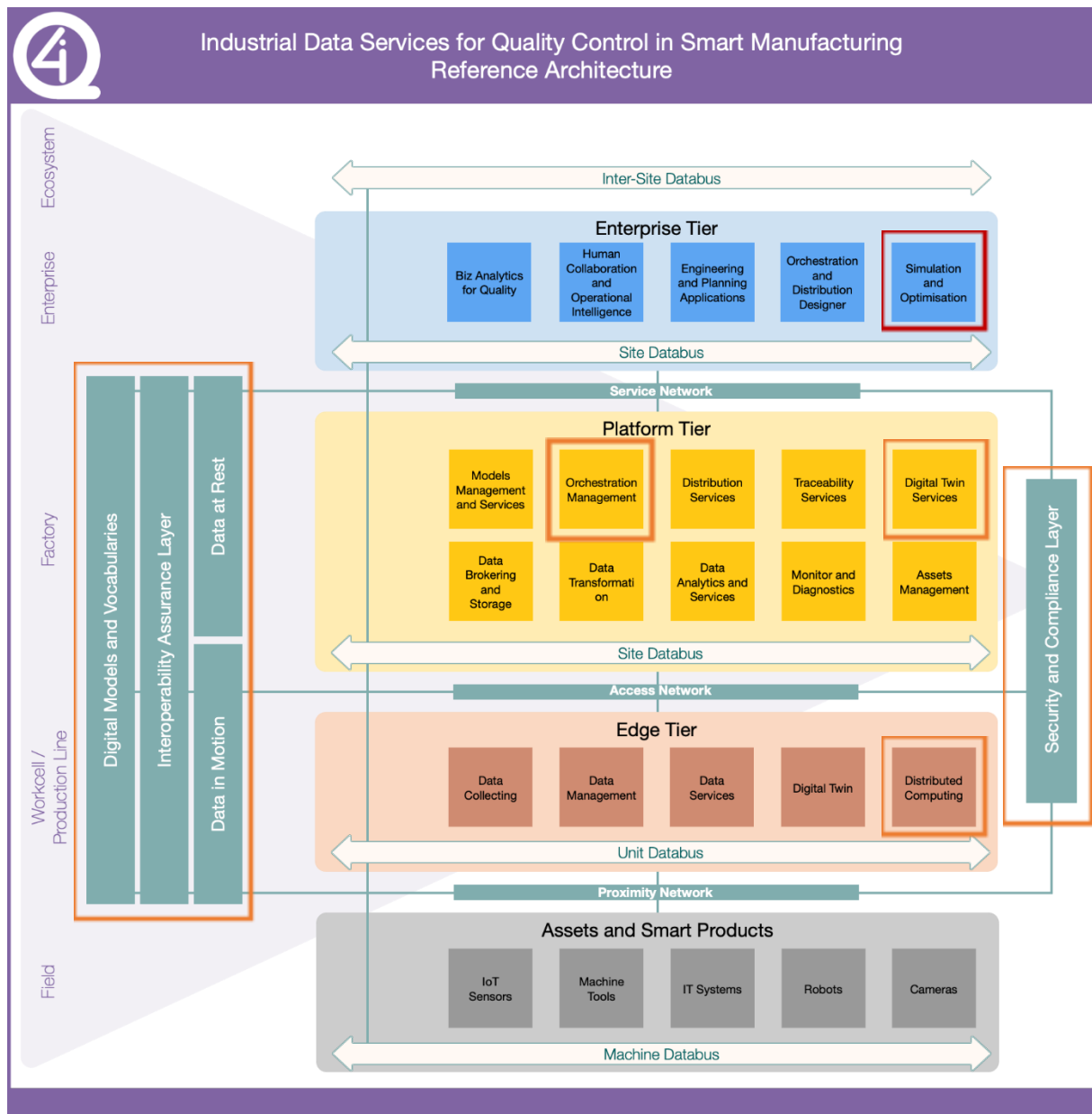

Figure 1. i4Q^{LRT} Solution Architecture

3 Implementation Status

3.1 Current implementation

The **i4Q Manufacturing Line Reconfiguration Toolkit** (i4Q^{LRT}) adopts a microservice approach where each optimization algorithm is a standalone (micro-)service that can be deployed and managed at Edge. The deployment strategy relies on containerization technology, specifically using Docker Layers (that allow create a distributable object specifically to instantiate and run an algorithm).

The current implementation of the i4Q^{LRT} Solution is:

- We provide a dockerized solution that allows algorithms to be deployed as services.
- The solution has been developed with the Helm Chart standard to allow deployment in Kubernetes environments.
- Implemented the possibility for this service to interoperate with Kubernetes such as Mongodb, MQTT and HTTP.
- An API has been defined to launch the algorithms.
- A template has been created to allow IT managers to easily deploy the algorithm as a service.
- A form has been implemented through HelmCharts for the deployment of solutions in a Rancher K3S environment.
- The necessary continuous integration files have been implemented to automate the quality analysis and the dockerized encapsulation of the algorithms as services.
- The possibility of obtaining information about the deployed algorithm through the metadata.json file has been implemented.
- The possibility of solving the algorithms by passing the values with an http call has been developed.
- Several optimization algorithms have been implemented and will be provided with the solution.
- The possibility to interpret .CSV files has been implemented.
- A specific machine learning model has been developed for Pilot 4 "FACTOR".
- The possibility of connecting to a message broker to continuously collect data from a Kafka client has been implemented.
- A graphical client has been implemented to easily configure the connections between the different data flows to the solution.
- A graphical client has been implemented to allow easy interpretation of the results of the algorithms.

3.1.1 Solution features analysed and mapping with user requirements

A set of features has already been developed for i4Q^{LRT}, based on the set of user requirements referring to i4Q^{LRT} (Deliverable 1.9) and in line with the functional viewpoints (Deliverable 2.6). Similar requirements have been assigned into common categories of tasks based on an

extensive technical study conducted on user requirements, available datasets, etc., introduced to ensure the generalization abilities of the i4Q^{LRT} solution.

- PC1r5.4 "Capability to propose alternative processing parameters to remove chatter presence during the execution of the process" is covered by the feature of being able to get the result of the algorithm. This function runs the algorithm with the input configuration and the defined data taken in the request.
- PC1r6.3 Capability to propose alternative processing parameters to reduce specific equipment components degradation rate" is covered by the feature of being able to get the result of the algorithm. This functionality is responsible for executing the algorithm. All input data shall be considered for the configuration with the different data clients.
- PC2r11 "For each algorithm define in which way the data must be recorded, in terms of sampling frequency, resolution" is covered by the feature of being able to provide metadata about the algorithm. This function provides information about the algorithm, including a description of inputs and outputs.
- PC4r3.4.1 "Acting before a quality deviation happens" is covered by the feature of being able to execute the algorithm. In addition, because sensors will be installed to collect information directly, the action may be taken before the failure occurs.
- PC4r3.4.2 "Improve the process". The improvement of the process is implicit in the functionality when implementing the solution. It will be possible to access the data, train the models and obtain the best possible configurations.
- PC6r4.1 "Optimization procedure should be converted to autonomous to improve injection machine performance and OEE" is covered by the feature of being able to get the result of the algorithm. This functionality is part of the objective of the algorithm execution. Thanks to the input data, the best decision will be made to improve the process.
- PC6r4.2 "Standardize the solution independently of the equipment that is going to be used" is covered since the solution is developed to be interoperable and to be implemented in any environment.

3.2 History

Version	Release date	New features
V0.1	30/11/2021	Backend OpenApi
V0.2	20/12/2021	Generated continuous integration files for the automatic build of docker images.
V0.3	21/12/2021	Documentation
V0.4	24/12/2021	Tools for automatic quality and safety analysis have been implemented to automatically analyse software quality, safety, and security requirements.
V0.5	31/01/2022	Update backend base image and add first algorithm as a micro-service (manpower scheduling)

Version	Release date	New features
V0.6	01/02/2022	Update Backend Imagen Security – CVE-2018-0269
V0.7	07/02/2022	Add mjanaive algorithm
V0.8	14/02/2022	Add Kubernetes environment with Helm Charts
V0.9	01/04/2022	Refactoring and add Update backend Image. A core with multiple clients has been implemented so that the solution can be used individually in Kubernetes.
V0.10	16/04/2022	Add a specific machine learning model
V1.0	13/05/2022	Add connection with broker message (kafka consumer)
V1.1	10/10/2022	Add Client Node-Red and Grafana.
V1.2	15/11/2022	Refactoring Helm Charts
V1.3	30/11/2022	Added new algorithms to the catalog
V2.0	15/11/2022	New release

Table 1. i4Q^{LRT} Version history

4 Conclusions

Deliverable D5.11 Manufacturing Reconfiguration Toolkit is a technical specification document, providing an in-depth technical overview of the i4Q^{LRT} solution. It describes in detail the role, the functionalities, and the conceptual architecture of i4Q^{LRT}. It presents a study detailing the main features of the solution to clarify the key functionalities and objectives of the i4Q^{LRT} solution, describing its architecture diagram with respect to i4Q Reference Architecture.

The current implementation status of i4Q^{LRT} is detailed thoroughly, presenting the significant progress of this overall development. This document presents these approaches which include 1) the pilots requirements analysis and engineering to clarify the technical specifications, 2) the technical studies conducted to define the solution's abstract level architecture 3) the input and output definition of the solution, 4) the objectives of i4Q^{LRT}.

5 Appendix I

The PDF version of the **i4Q Manufacturing Line Reconfiguration Toolkit** (i4Q^{LRT}) web documentation can be accessed online at: http://i4q.upv.es/21_i4Q_LRT/index.html