D5.9 – i4Q Prescriptive Analysis Tools

WP5 – BUILD: Rapid Manufacturing Line Qualification and Reconfiguration

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ABSTRACT	This document is a Technical Specification document about the development of the i4Q Prescriptive Analysis Tools (i4Q^{PA}). This document 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. This document i4Q D5.9 v2 is an update of v1 of D5.3., for this reason it contains information of the 1st version together with the updates developed in this 2nd version.		

Document History

VERSION	ISSUE DATE	STAGE	DESCRIPTION	CONTRIBUTOR
0.1	07-Nov-2022	ToC	ToC created and sent for review	IKERLAN
0.2	25-Nov-2022	1st Draft	First draft sent for internal review	IKERLAN
0.3	02-Dec-2022	Internal review	Internal review	AIMPLAS, CERTH
0.4	09-Dec-2022	2nd Draft	Addressing the comments from the internal review. Updated draft sent to the coordinator.	IKERLAN
1.0	30-Dec-2022	Final doc	Final quality check and issue of final document	CERTH

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ABBREVIATIONS/ACRONYMS

API	Application Programming Interface
DT	Digital Twin
FMI	Functional Mock-up Interface
FMU	Functional Mock-Up
i4Q	Industrial data services for Quality Control in Smart Manufacturing
IoT	Internet of Things
IT	Information Technology
KPI	Key Performance Indicator
PA	Prescriptive Analysis
PDF	Portable Document Format
RestAPI	RESTful Application Programming Interface
OF	Optimization Function

Executive summary

This document presents an executive explanation of the **i4Q Prescriptive Analysis Tool** (i4Q^{PA}) Solution providing the general description, the technical specifications and the implementation status. The deliverable **D5.9** is the Source Code of the i4Q^{PA} Solution that is in a private repository of Gitlab: https://gitlab.com/i4q.

The documentation associated to the i4Q^{PA} 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^{PA} Solution documentation is http://i4q.upv.es/19_i4Q_PA/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 Prescriptive Analysis Tool**, 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 Prescriptive Analysis Tool**, providing an overview and its architecture diagram. It is addressed to software developers.

Section 3: Details the implementation status of the **i4Q Prescriptive Analysis Tool**, explaining the current status, next steps and summarizing the implementation history.

Section 4: Provides the conclusions.

APPENDIX I: Provides the PDF version of the **i4Q Prescriptive Analysis Tool** web documentation, which can be accessed online at: **http://i4q.upv.es/19_i4Q_PA/index.html.**

1. General Description

1.1 Overview

i4Q[PA] will allow the user to launch a wide range of simulations of a model, even if the model has been generated in the i4Q[DT] solution or not. These simulations will be evaluated according to some metrics and evaluation criteria that a user can define in the solution. Thus, the i4Q[PA] will provide a ranking for the different configurations defined for the simulations, providing a prescription based on the evaluation criteria [1].

1.2 Features

- Providing the capability of defining several scenarios to run simulations of the Digital Twin [1].
- Providing the capability of defining custom optimization functions for evaluation and prescription of simulations' results [1].
- Providing the capability of defining the optimization functions and its inputs [1].
- Providing tables and graph for an easy analysis of evaluation and prescription results [1].

2. Technical Specifications

2.1 Overview

i4Q^{PA} is mapped to the Digital Twin Services sub-component of the Platform Tier, providing the capability of defining several scenarios to run simulations of the Digital Twin [1].

It is also related to the Data Analytic and Services subcomponent to evaluate the performance of each simulation run, and the Orchestration management to efficiently handle the execution of the defined simulations, both from the same Tier and the Simulation and Optimisation sub-component of the Enterprise Tier performing exhaustive simulation to identify the best scenario proposed [1].

The i4Q^{PA} will use single or compound, physic-based or data-driven models, and time series as inputs to perform the simulations. Apart from that, once the simulation results are obtained from the i4Q^{DT}, the i4Q^{PA} will use performance evaluation algorithms in order to rank all the simulations. Thus, different evaluation criteria will be defined based on the KPIs or the time series that the i4Q^{DT} results provide [1].

2.2 Architecture Diagram

The processes and services that are being included in the i4Q^{PA} software tool are mapped to two tiers in the i4Q Reference Architecture:

- **Enterprise Tier:** The i4Q^{PA} mapping to "Simulation and Optimization" sub-component enables the capability of obtaining prescriptions after the execution of multiple simulations in order to identify best and worse scenarios, as well as a full ranking, and establishing some thresholds in certain variables.
- **Platform Tier:** the Digital Twin services is providing the capability of simulating a model under some specific conditions which is the core of this solution, whereas the Orchestration management will allow the correct handling of all the simulations to be launched, Data Analytics and Services will be providing the capability to evaluate the performance of each model.

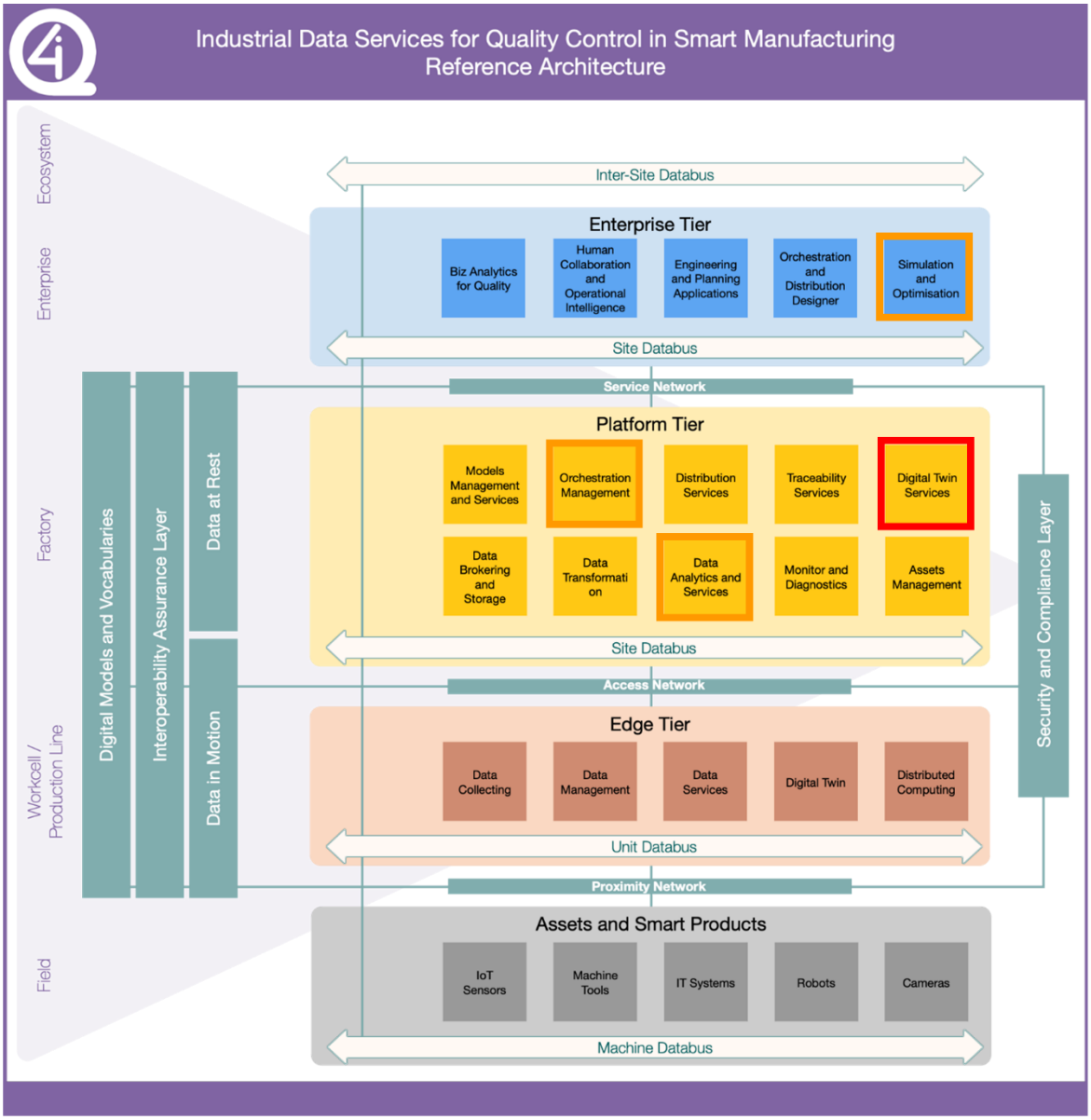

Figure 1. i4Q[PA] Solution Architecture

3. Implementation Status

3.1 Current implementation

During M12-M18 of the project, the first version of the solution i4Q^{PA} was developed. These are the followed steps or added functionalities:

- Development of an internal road mapping of the task.
- Development of a mock-up with all i4Q^{PA} solution's basic functionalities: model reading, simulation, evaluation and prescription.
- Mock-up code adaptation to new application structure, composed of a frontend, a backend and a RestAPI. Every frontend widget, or backend table or dictionary has its own isolated request function, therefore, a global class had to be created to communicate all request functions.
- The frontend was designed taking the i4Q web template as starting point and customizing it to meet the specific needs of the i4Q^{PA} solution. These are the functionalities or features added to the frontend:
    - Implementation of 4 main tabs (home, simulation, evaluation/prescription, and help) and some secondary tabs within the main ones.
    - Redux addition to all tabs, a predictable state container for JavaScript apps.
- The mock-up code was the starting point of the backend, therefore it had to be adapted to the RestAPI. Functionalities or features added to the backend:
    - Single and compound model reading and simulation.
    - Development of an evaluation library composed of metrics and optimization functions (OFs). The library is able to read and run custom or predefined OFs.
- Functionalities or features added to the i4Q^{PA} solution:
    - Model selection, model's internal parameters range configuration and simulation configuration.
    - Simulations results filtering through two filtering layers. In the first input the user can define which outputs and simulations they want to plot. And in the second filter individual signals can be selected from a signal table.
    - Simulations results plotting.
    - Simulations results' evaluation configuration.
    - Simulations results' evaluation.
    - Prescription of the optimum model configuration according to the selected evaluations.
- Dockerization of solution.

And for the M19-M24, the second version of the solution i4Q^{PA} was developed, a more complete and polished solution. These are the changes done to the solution:

- Addition of the functionality to simulate models with just external inputs sets, instead of with the variation of the values of the internal parameters of the model.
- Addition of the whole prescription process of data-driven models.
- Addition of the possibility to add custom metrics.
- Addition of the evaluation functions and metrics developed by EXOS.
- Addition of message broker.
- Addition of simulations requests to the DT. The PA carries out half of the simulations and the DT the other half. When the DT's feedback is received, the PA makes sure that all simulations results are received before processing them.
- Simulations and evaluations' results storing in Excels.
- Simulations and evaluations' results are made available through message broker.
- Bugs corrections.
- Code cleaning.
- Frontend visual improvement.
- Addition of information to the frontend to help the user.
- Docker improvement.

3.1.1 Solution features analysed and mapping with user requirements

A set of features has already been developed for i4Q^{PA}, based on the set of user requirements referring to i4Q^{PA} (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^{PA} solution.

- PC4r8.3.1 “Define the evaluation criteria to be performed among variables, e.g. if vibrations are rising, check the roughness of the part” is covered by the feature of providing the capability of defining custom OFs for the evaluation and prescription of the simulations' results. Therefore, any evaluation criteria can be defined.
- PC4r8.3.2 “Establish the limited values where the variables should keep. E.g. if you are machining aluminium in summer, do not go over 100 ºC” is covered by the feature of providing the capability of defining the OF and its inputs. All defined inputs' values are defined through the frontend. Therefore, the user can program the OF so that if the signal goes beyond the introduced input, the result of the evaluation is 0, for instance.
- PC4r8.3.3 “The system shall perform simulations that isolate a single variable in order to detect the independent variables that lead to changes in dependent variables” is covered by the feature of providing the capability of defining several scenarios to run simulations of the DT. The solution allows the user to select which internal parameters of the model to vary and how.
- PC4r8.3.4 “The solution should evaluate and learn from the results of the simulations and establish the thresholds of the variables. E.g. if you are machining aluminium over 100ºC, you have quality issues” is covered by the feature of providing tables and graph for an easy analysis of evaluation and prescription results. The information displayed in tables and graphs give the user the required information to establish thresholds of variables.

3.2 History

Version	Release date	New features
v0.1	09/12/2021	Adaptation of fmpy library to carry out multiple simulations.
v0.2	14/12/2021	Mock up – Model reading, configuration, simulation and prescription.
v0.3	17/12/2021	Mock up – First version of evaluation process.
v0.4	11/01/2022	Created i4Q^{PA} solution's structure: frontend, backend and web framework.
v0.5	27/01/2022	Web framework – Addition of Flask app. Backend – Adaptation of mock up to frontend-backend i4Q^{PA} structure: model reading, configuration and simulation. Frontend – Adaptation of i4Q frontend template to i4Q^{PA} solution's needs (tab's structure). Development of model selection, configuration and simulation. Addition of simulations' progress bar. General visual improvement.
v0.6	10/02/2022	Bug fix. Addition of simulations' results first filter.
v0.7	22/02/2022	Addition of simulations' results second filtering and display.
v0.8	08/04/2022	Added evaluation function class and class initialization. fmisim library's first version.

Version	Release date	New features
v0.10	12/04/2022	Multiple simulation function added to fmisim library. Backend – Adaptation of code to fmisim library. Frontend – Merge of model selection and simulations' results' visualization tabs. Addition of type of simulation (serial/parallel) selector.
v0.11	25/04/2022	Backend – Evaluation structure added and tested. Evaluation library is composed by a single metric and evaluation function.
v0.12	04/05/2022	Frontend – Added evaluation configuration widgets
v0.13	09/05/2022	Added evaluations and evaluations' parameters description. Frontend – Added evaluation selection and evaluation results bar graph.
v0.14	24/05/2022	Frontend – Added a widget to define parallel simulations' core number. Backend – Added data-driven models to the whole prescription process. Added CERTH metrics.
v0.15	30/05/2022	Frontend – Added a widget to select and upload input signals. Backend – Added input signals management. Added compound models' management. Added Docker files templates. Documentation update.
v0.16	12/06/2022	Backend – Added message broker and all required libraries. Frontend – Added an external file uploading widget for evaluations.
v0.17	27/06/2022	Backend – Added i4Q^{DT} simulation request and feedback management. Added external file for evaluation management.
v1.0	19/08/2022	Frontend – Multiple visual improvements. Backend – Bug corrections.
v1.1	13/09/2022	Backend – Added custom metrics. Improvement of data-driven models management and prescription. Bug corrections.
v1.2	20/09/2022	Frontend – Added input signals to simulations results graph. Bug corrections.
v1.3	05/10/2022	Solution's configuration split: user config and internal config. Backend – Added simulations and evaluations results Excel storing. Frontend – Minor visual improvements.
v1.4	19/10/2022	Backend – Updated message broker to be able to send bigger messages.

Version	Release date	New features
v1.5	15/11/2022	Docker file improvement. Minor changes.

Table 1. i4Q[PA] Version history

4. Conclusions

Deliverable D5.3 Prescriptive Analysis Tools is a technical specification document, providing an in-depth technical overview of the i4Q^{PA} solution. It describes in detail the role, the functionalities, and the conceptual architecture of i4Q^{PA}. It presents a study detailing the main features of the solution to clarify the key functionalities and objectives of the i4Q^{PA} solution, describing its architecture diagram with respect to i4Q Reference Architecture.

The current implementation status of i4Q^{PA} 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^{PA}.

References

[1] ‘i4Q Prescriptive Analysis Tools — i4Q RIDS’. https://i4q.upv.es/19_i4Q_PA/index.html (accessed Nov. 29, 2022).

Appendix

APPENDIX I: Provides the PDF version of the **i4Q < Prescriptive Analysis Tools >** web documentation, which can be accessed online at: **http://i4q.upv.es/19_i4Q_PA/index.html.**