AGILEHAND

D3.2 – AGILEHAND Usage, Functional & Technical Specifications

WP3 – DESIGN: AGILEHAND Architecture and Integration

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ABSTRACT	This deliverable tries to explain the AGILEHAND system's structure, its component parts, and how the system interacts with its surroundings. The Business View, Usage View, Functional View, and Implementation View are the four key pertinent viewpoints analysed in this deliverable in the context of the AGILEHAND Architectural Framework.		

Document History

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0.1	04/10/2023	ToC	ToC created and sent for review	UPM and KBZ
0.2	11/10/2023	Working version	Executive Summary, Document structure, Context, 1° draft of Functional and Technical Specification	UPM and all AGILEHAND partners
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0.8	16/12/2023	Final version	Final version	UPM

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ABBREVIATIONS/ACRONYMS

AI	Artificial Intelligence
AF	Architecture Framework
API	Application Programming Interface
CORS	Cross-Origin Resource
CR^{Hand}	Collaborative Robot Handling
DS^{Sense}	Data Sets Sensing
DT^{Agile}	Data Driven Digital Twin
ETA	Estimated time of arrival
FaaS	Functions as a Service
GQ^{sense}	Grade the Quality Sensing
IoT	Internet of Things
ICT	Information and Communication Technologies
IDS	International Data Spaces
KER	Key Exploitable Result
KPI	Key Performance Indicator
MES	Manufacturing Execution System
ML	Machine Learning
OER	Other Exploitable Result
OPC/UA	Open Platform Communications/Unified Architecture
PE^{Agile}	Production Execution Optimization Toolkit
PLC	Programmable Logic Controller
PR^{Agile}	Production Reconfiguration
PT^{Agile}	Product Oriented Traceability
RGB	Red Green Blue
RGBD	depth (D) and color (RGB)
ROS	Robot Operating System
RR^{Hand}	Robot Robot Handling
SC^{sense}	Self-Calibrating Sensing
SDKs	Software Development Kits

SMED	Single Minute Exchange of Dies
SQL	Structured query language
SSO	Single-Sign-On
ST^{hand}	Self-Adaptable Transportation System
SUS	System Usability Scale
UI	User Interface
UX	User Experience
WP	Work Package

Executive summary

This deliverable aims at explaining the structure of the AGILEHAND system and its constituent elements, as well as how the system interacts with its surroundings.

The creation of the AGILEHAND Architecture as a strategic tool using cutting-edge and industry-specific technologies as a base is one of the challenges in implementing the various solutions to be developed.

The definition of usage, functional & technical specifications will be of paramount important during the use case implementation in terms of: • a common lexicon that facilitates communication; • a common architectural vision that focuses the efforts of numerous people and teams; • modularization, which separates the work and fosters an atmosphere favorable to later integration; • the conceptualization and manifestation of the domain.

Deliverable's architecture for AGILEHAND Solutions is based on the use of several concurrent views. The management of functional and non-functional needs independently, as well as the worries of the multiple AGILEHAND project stakeholders, technical and business partners, is made possible by the diversity of viewpoints.

In terms of perspectives, the various stakeholders that may engage with the solutions are examined, related to the roles that have been defined, and associated with how a company's data flows. After that, the applications of the solutions, their features, the specification of technologies, and the requirements for their implementation are examined.

The Architecture Framework (AF), a set of standards, techniques, and guidelines, is used to explain architectures that have been built within a particular application area or group of stakeholders. This AF takes into account a set of standards for the creation, understanding, and application of an AGILEHAND architectural perspective that frames one or more stakeholder issues. There might be a correspondence rule in the AF that names or identifies connections between two or more architectural description elements.

Document structure

Section 1. AGILEHAND Context: This section presents the AGILEHAND Suites and Business Viewpoint. In particular, the business perspective addresses issues that are specifically related to the operation of the firm, with a particular emphasis on business strategy, financial issues, and anticipated returns on investment.

Section 2. AGILEHAND Functional and Technical Specification: This section offers crucial details about the environment in which the project will be created. The important components that aid in understanding the situation now and the variables affecting the project are presented. Important data is gathered on the issue or requirement that has to be resolved, the project's justification, its scope, restrictions, and assumptions, the industrial context, the environment's analysis, and the framework of the industrial ecosystem. For the project's proper planning and execution, this information helps to consolidate the project and its objectives.

Section 3. AGILEHAND Usage Models & Mock-ups: This section describes tools and methodologies used and applied in the design process of the Agilehand platform. It presents a prototype mock-up for a common platform to incorporate all solutions of Agilehand ecosystem. This also includes results, findings and recommendations analysed during the usability testing performed with select audience.

Section 4. Conclusions: conclusions and final considerations.

1. AGILEHAND Context

1.1. AGILEHAND Suites

The AGILEHAND project intends to create innovative solutions for three essential components of a workpiece handling system:

- the "**grading**" aspect, or knowledge of the qualities and state of the workpiece. The project focuses in particular on a self-calibrating sensing approach for generating a mesh of interconnected and overlapping sensors that will enhance the traceability, agility, and reconfigurability of manufacturing lines. The key benefits will be a quick, precise, and affordable way to grade delicate and perishable goods with finer precision.
- The **sorting**, **handling**, and **packaging** stages' of soft and deformable items. The AGILEHAND project deals with the issues associated with robotic manipulation in a situation that is more conducive to human interaction and where the objects are varied, malleable, and sensitive.
- Manufacturing line **agility**, **adaptability**, and **reconfigurability** aspects, to create a collection of approaches for agile production line reconfiguration in a mixed-model manufacturing environment. These artificial intelligence (AI) based solutions will enable monitoring, adaptive control, and synchronization of production and logistics flows in a factory, even in the face of product, production mix, or new market variability, ensuring high performance in customer response time and efficient resource use.

In order to reach the objectives AGILEHAND Project will create three **AGILEHAND SUITES** as **Key Exploitable Results (KERs)** that concern **Smart Sensing Technologies** (WP4), **Self-Adaptive Handling, Sorting and Packaging Technologies** (WP5) and **Agile, Flexible and Rapid Reconfigurable Technologies** (WP6). These SUITES are made up of 10 new technological solutions (**Other Exploitable Results - OERs)** as highlighted in Table 1. These 10 OERs are specific technological solutions that can also be exploited individually. Table 1 provides a description of each SUITE, the OERs within each Suite and the Specific Objective they aim to achieve.

Table 1. AGILEHAND SUITEs and solutions.

KER	Smart Sensing SUITE		Description
OERs	AGILEHAND Grade the Quality	GQ^{SENS}	A cost-effective, accurate and fast solution to grade the quality (both interior and exterior) of delicate objects
	AGILEHAND Self-Calibrating	SC^{SENS}	A self-calibrating solution for producing networks of sensors to improve production-line traceability
	AGILEHAND Data-Sets	DS^{SENS}	Data-sets containing scans of delicate objects in a real-environment with ground-truth data
KER	Self-Adaptive Handling, Sorting and Packaging SUITE		Description
OERs	AGILEHAND Self-Adaptable Transportation systems	ST^{HAND}	An intelligent platform capable of performing transportation, inspection, sorting and value addition processes to delicate products, and capable of being cross functional to handle a variety of product types.
	AGILEHAND Collaborative Robot	CR^{HAND}	A safe collaborative environment where man and machine can work together and perform product handling tasks along various stages of production.
	AGILEHAND Robot-Robot	RR^{HAND}	Synergistic cooperation between the various robots and intelligent machinery across the line to exchange product relevant information amongst themselves and a Production Execution Optimization Toolkit to create ever evolving production models.
KER	Agile, Flexible and Rapid Reconfigurable SUITE		Description
OERs	AGILEHAND Product-Oriented Traceability	PT^{AGILE}	Product-oriented traceability solution to collect and store production and logistics operations data linked to product orders.
	AGILEHAND Data-Driven Digital Twin	DT^{AGILE}	Multi-layer toolkit Data-Driven Digital Twin for the real-time/near-real time monitor and synchronization of production and logistics systems.
	AGILEHAND Production Reconfiguration	PR^{AGILE}	Optimisation library implementing algorithms to optimize production lay-out and machine set-up.
	AGILEHAND Production Execution Optimization Toolkit	PE^{AGILE}	Optimisation library implementing algorithms to optimize production execution: planning, scheduling, startup optimization, and process control considering collaborative (human-in-the-middle) approaches.

Each suite contains a distinct sort of information, and because of this diversity, enabling interoperability and seamless data flow between the many suites within an organization can be very difficult. Data flow and integration are hampered by the separate suites' inability to properly communicate in the absence of a unified framework. The creation of a platform that guarantees the data can endure across the suites so that it can be utilized in any type of system looks to be one of the primary demands to be fulfilled by this architecture. Thus, the four needs that this platform must prioritize are as follows:

Openness and transparency: All parties involved in the manufacturing process must have access to the technology specs, architecture, and documentation. Given that these technologies are developing and open to future improvements and standards, decisions will be made on their use to promote the distribution of cooperatively produced artifacts under open-source licenses.

Interoperability: Everyone who is a part of the reference architecture will be able to communicate with everyone else in a clear and specified way. Because of this, the AGILEHAND solutions

will outline the technical methods to accomplish this using various implementation, communication, and data management standards.

Federated systems: A federated system made up of autonomous providers will control communication between entities. These service providers will follow a predetermined set of guidelines, frameworks, and laws, assuring a unified strategy.

Authenticity and trust: A mutual authentication, selective disclosure, and trust revocation-based identity management system is necessary to create a safe digital ecosystem. This system will foster confidence and guarantee the sincerity of ecosystem interactions.

1.2. AGILEHAND Business Viewpoint

The business perspective addresses issues that are specifically related to the operation of the firm, with a particular emphasis on business strategy, financial issues, and anticipated returns on investment. These participants set the strategic direction for the company and make decisions on important players, actions, information flow, and interactions between processes. This view essentially identifies the primary actors, goals, and fundamental skills that inform it. The AGILEHAND business viewpoint offers a representation of business operations that may be applied to many firms, highlighting shared processes and potential opportunities for information exchange and reuse, as indicated in the sections below.

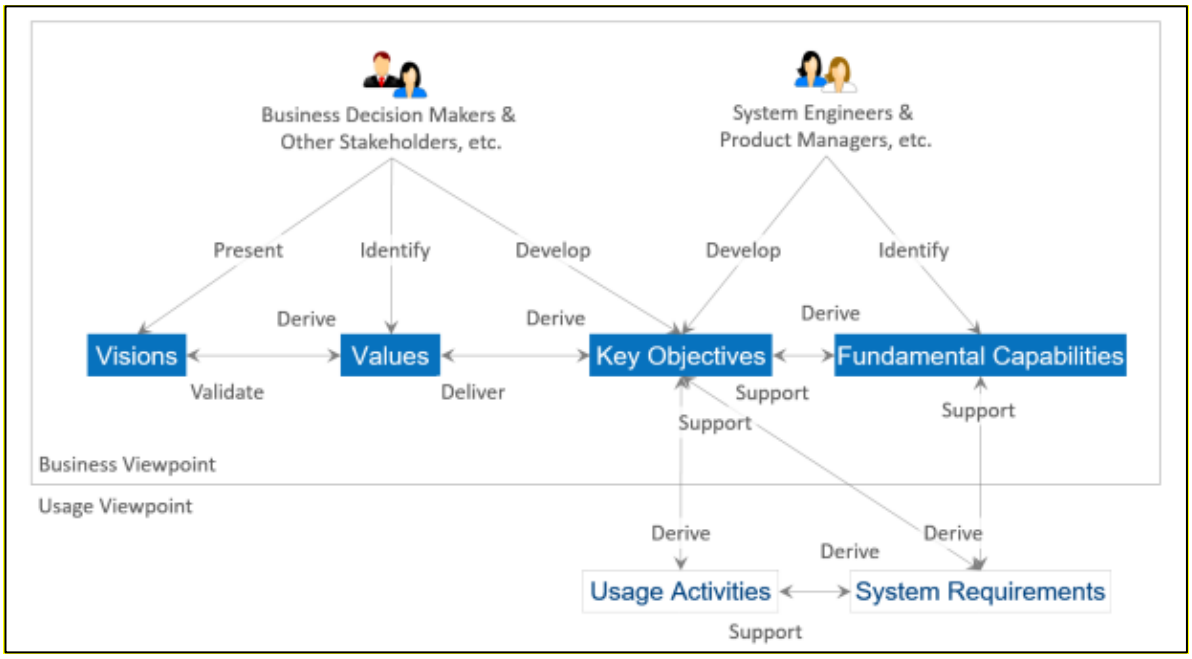

Figure 1. A Vision and Value-Driven Model.

The following key components will be taken into account for the business viewpoint definition:

• The stakeholder's business direction in relation to the organization is described in this part, along with how the stakeholder may interpret that direction.

• Values: In this section, we learn how stakeholders view the company's mission and how they get involved in putting AGILEHAND solutions into practice.

• The quantifiable technical tools known as key objectives enable the business level to understand what is anticipated from AGILEHAND solutions in the context of values. Time-bound and quantifiable goals are best.

• Basic capabilities; this section will give a high-level overview of the ability of AGILEHAND solutions to achieve important business goals.

1.2.1 Stakeholder's classification

Consider each stage of the solutions' life cycle when determining where the major stakeholders, or those with a direct stake in the organization, are located. From designers to maintenance workers, various types of profiles can be found in each stage of the life cycle. Primary stakeholders are categorized in the following table (Table 2). This classification takes into account both the level they are at (High/Medium/Low Level) and the suite they are involved in (Smart Sensing/Self-Adaptive Handling Sorting and Packaging/Agile Flexible and Rapid Reconfigurable). The type of stakeholder according to the suite stage is described first to help you comprehend the table:

- **Smart Sensing**: Stakeholders in charge of the Smart Sensoring tasks. This type of profile must have technical knowledge related to smart sensing solutions design and operation of the machine.
- **Self-Adaptive Handling, Sorting and Packaging**: Stakeholders in charge of developing new designs for handling, sorting and packaging equipment, altering existing designs, developing design criteria, working with other teams, etc. Technical expertise pertaining to the machine's design and operation is required for this type of profile.
- **Agile Flexible and Rapid Reconfigurable**: Stakeholders in charge of the tasks of supplying, manufacturing, and delivering the product. Within this phase, there are both strategic and operational profiles, as this phase requires a long- and short-term vision.

The degree of the role is then described in relation to the responsibilities of each position.

i) **High-Level**: This level of management is in charge of determining the organization's course, making strategic choices, and ensuring that the company's objectives and core values are in line. To ensure the success of the business, top executives interact with the board of directors and shareholders.

ii) **Middle-Level**: Middle-level management is made up of department heads, managers, and supervisors. They convert the top-level management's strategic objectives into workable assignments for their teams. They are in charge of conveying the company's vision to lower-level employees while ensuring that their departments achieve their goals on schedule and within budget.

iii) **Low-Level**: The first-line management or supervisory level is made up of team leaders and managers. They keep an eye on everyday employee activities, offering direction, encouragement, and workload management to make sure workers hit their goals. They are essential to the success of the organization because they guarantee efficient and effective functioning.

Table 2. Classification of primary stakeholders.

Smart Sensing (Enterprise site)		
High-Level	**Medium-Level**	
Product/Line Manager	Smart Sensing Design Engineer	
	Mechanical Engineer	
	Automation Engineering	
Self-Adaptive Handling, Sorting and Packaging (Enterprise site)		
High-Level	**Medium-Level**	
Product/Line Manager	Handling, Sorting and Packaging Design Engineer	
	Robotic Engineer	
	Machinery and Robot Configurators	
Agile Flexible and Rapid Reconfigurable (Enterprise site)		
High-Level	**Medium-Level**	**Low-Level**
Purchasing Manager	Material Planner	Assembler
Planning Manager	Process support engineer	Processing operators
Processing Manager	Production Schedulers	
Director of Operations		
Supply Chain Manager		

1.2.2 Roles

Effective data management and exploitation have become essential for enterprises across a range of industries in the constantly changing digital landscape. An ecosystem with clearly defined roles has been created to enable smooth data sharing and utilization. Owners, providers, consumers, users, and service providers of data are among them. Each is essential to guaranteeing the classification, security, integrity, and restricted access to priceless data sets. These are those that the AGILEHAND project has specified, as seen here.

• **Data Owner**: The Data Owner is a senior-level person who is in charge of classifying, safeguarding, and maintaining the integrity of one or more data sets. The Data Owner must decide on the price structure for providing this data to third-party users as well as the data usage guidelines and contracts.

• **Data Provider**: The Data Owner gives the Data Provider authorization to make the data available to Data Consumers. The International Data Spaces reference architecture model must be followed in the interchange of data and the dissemination of metadata.

• **Data Consumer**: Receiving data from the Data Provider, the Data Consumer. Most of the time, the Data Customer asks the Data Provider for specific datasets directly, but if the Data Customer wants to get data from multiple data suppliers, they must contact a data intermediary, which gives them the metadata they need to connect to a data provider.

• **Data User**: In line with the established data usage policy, the Data User is the legal entity that has the right to utilize and exploit the data provided by the Data Owner. The duties of the Data User and the Data Consumer might occasionally overlap.

• **Service Provider**: A member of the International Data Spaces (IDS) framework, the service provider provides services such as data analysis, integration, cleansing, and enrichment. The same business or a specific recipient receives data, they carry out activities, and they deliver results. They are able to add applications to their IDS connection and take on the role of a Service Broker, supplying other participants with metadata about services that are available.

Following an explanation of each type of current role, it is required to determine the sort of role that each stakeholder described in the previous section performs inside each project suit. The Smart Sensing (Enterprise site) suite is represented by Table 3, the Self-Adaptive Handling, Sorting and Packaging (Enterprise site) suite by Table 4, and the Agile Flexible and Rapid Reconfigurable (Enterprise site) suite by Table 5. In Tables 3-5 it is indicated with X the primary stakeholders: those ultimately most affected, either positively or negatively by an organization's actions. Secondary stakeholders: the "intermediaries," that is, persons or organizations who are indirectly affected by an organization's actions are indicated with (X).

Table 3. Mapping data roles with stakeholders from the Smart Sensing suite.

	Product/ Line Manager	Smart Sensing Design Engineer	Mechanical Engineer	Purchasing Manager	Material Planner	Assembler
Data Owner	X	(X)	(X)	(X)	(X)	X
Data Provider	X	(X)	X	X	X	(X)
Data Consumer	-	X	X	(X)	X	-
Data User	(X)	X	X	(X)	X	(X)
Service Provider	-	X	X	-	X	X

Table 4. Mapping data roles with stakeholders from the Self-Adaptive Handling, Sorting and Packaging suite.

	Product/ Line Manager	Handling, Sorting and Packaging Design Engineer	Robotic Engineer	Machinery and Robot Configurators	Purchasing Manager	Material Planner	Assembler
Data Owner	X	(X)	(X)	(X)	(X)	(X)	X
Data Provider	X	(X)	X	X	X	X	(X)
Data Consumer	-	X	X	X	(X)	X	-
Data User	(X)	X	X	X	(X)	X	(X)

Service Provider	-	X	X	X	-	X	X

Table 5. Mapping data roles with stakeholders from the Agile Flexible and Rapid Reconfigurable suite.

	Planning Manager	Process support engineer	Processing operators	Processing Manager	Production Schedulers	Director of Operations
Data Owner	(X)	-	-	(X)	(X)	-
Data Provider	X	X	-	(X)	X	X
Data Consumer	-	X	(X)	X	(X)	(X)
Data User	(X)	(X)	X	X	-	X
Service Provider	(X)	-	X	(X)	(X)	X

2. AGILEHAND Functional and Technical Specification

2.1. User technical specification

This section provides a detailed description of each AGILEHAND pilot use case (expectation), defining, for each Smart Sensing suite, Self-Adaptive Handling, Sorting and Packaging suite and Agile Flexible and Rapid Reconfigurable suite, the following information:

- **Objective** and the **use case code**. The use cases are code as follows: ToBe-P**X.y** (where: **'X'** is the number of the concerned Pilot; **'y'** identified the addressed suite.
- **AGILEHAND-solution** that is applied to address the above use case to bring improvement.
- **Input variables** that Pilot currently manages, describing the nature of data, as data type: "T" as a textual feature, "N" as a numerical feature), "V" as Video data, "P" as Picture/Figures/photos.
- **Source of Input data/variables**: "S"=Sensors signals not yet stored in DB or files; "S-DB" = Sensors signals streamed and stored in DB or files, "C" = Video /photo Cameras data not yet stored in DB or files, "C-DB"= Video/photo cameras data streamed and stored in DB, "A-DB" = other data/info automatically collected and stored in DB or files, "D" = Drawings/cad files", "L"=Legacy historical data, e.g. included in files, reports/documents of the user company, "NA"= data not yet available.
- **Output variables** (results) & **Technologies:** in these parts the output that the solution aims at achieving and the technologies to be used to reach the objective are highlighted.

All the AGILEHAND solutions will be validated at the end by at least one Pilot.

2.1.1. Pilot 1 – MULTISCAN

The AGILEHAND solution maps for Pilot 1 – MULTISCAN to assess the user needs are listed for the SMART SENSING suite in table 6, for SELF-ADAPTIVE HANDLING, SORTING AND PACKAGING suite in table 7 and for AGILE FLEXIBLE AND RAPID RECONFIGURABLE suite in table 8.

Table 6. Solution Map - Pilot 1 (Multiscan) for SMART SENSING suite.

	Smart Sensing SUITE Solutions		
	GQ^{SENS}	SC^{SENS}	DS^{SENS}
Pilot 1 (MULTISCAN)	A cost-effective, accurate and fast solution to grade the quality (both interior and exterior) of delicate objects	A self-calibrating solution for producing networks of sensors to improve production-line traceability	Data-sets containing scans of delicate objects in a real-environment with ground-truth data
Objective ToBe-P1.SmartSensing:	Identify the type of fruit and grade its external quality (for example: Persian limes, grade 3, or Avocado, grade 1) and send it through OPC/UA to the machine		
Input variables *(that Pilot can make available) (data type: "T" as textual feature, "N" as numerical feature), "V" as Video data, "P" as Picture/Figures/photos, ... etc; please add other pertinent acronyms that fit your case, if any)*	Product photo (P), Variety of vegetable and fruits and their annotations/grades (T), Collection of Machine Recipes - Configurations (N), Level of customer satisfaction (N), Type of market to which the classified product is delivered (T)		
Source of Input data/variables *(from: "S"=Sensors signals not yey strored in DB or files; "S-DB" = Sensors signals streamed and stored in DB or files, "C" = Video /photo Cameras data not yet stored in DB or files, "C-DB"= Video/photo cameras data streamed and stored in DB, "A-DB" = other data/info automatically collected and stored in DB or files, "D" = Drawings/cad files", "L"=Legacy historical data, e.g. included in files, reports/documents of the user company, "NA"= data not yet available , ... etc; please add other pertinent acronyms that fit your case, if any)*	Product photo acquired with multispectral cameras and stored as files (C-DB), Variety of vegetables and fruits (L), Recipes - Configurations (L), Level of customer satisfaction (L), Type of market to wich the classified product is delivered (L)		
Output variables (results)	Solutions to set the appropiate recipe in the software for the product running (this includes sorting parameters, AI/ML model, transport speed and rotation, ...), reducing operator adjustments		Annotated images with information tags what will be used for trainning the other solutions algorithms.
Technologies	RGB, Multispectral	Apply object tracking algorithms	Acquisition of image datasets, and image annotation by use-case providers. We will provide a tool for the labeling task.

Table 7. Solution Map - Pilot 1 (Multiscan) for HANDLING SORTING AND PACKAGING suite.

	Self-Adaptive Handling, Sorting and Packaging SUITE Solutions		
	ST[HAND]	CR[HAND]	RR[HAND]
Pilot 1 (MULTISCAN)	An intelligent platform capable of performing transportation, inspection, sorting and value addition processes to delicate products, and capable of being cross functional to handle a variety of product types.	A safe collaborative environment where man and machine can work together and perform product handling tasks along various stages of production.	Synergistic cooperation between the various robots and intelligent machinery across the line to exchange product relevant information amongst themselves and a Production Execution Optimization Toolkit to create ever evolving production models.
Objective ToBe-P1.Handling, Sorting and Packaging:	Conveyor system with variable speed and in-position product rotation; delta robots to perform the bad fruit removal with specialized trajectories to perform compensated grasping.		Multi robot solution required to handle the high volume of fruits; and coordination between robots, vision system and the conveyor system.
Input variables *(that Pilot can make available)* *(data type: "T" as textual feature, "N" as numerical feature), "V" as Video data, "P" as Picture/Figures/photos, "F" as Flag... etc; please add other pertinent acronyms that fit your case, if any)*	Product photo (P), Collection of Machine Recipes - Configurations (N), mass and size of fruits (N), real-time object positions (N), speed of rollers (T), robot to robot status (F), robot target (N), robot speed control (N), Object grasp point (N)		Product photo (P), Collection of Machine Recipes - Configurations (N), mass and size of fruits (N), real-time object positions (N), speed of rollers (T), robot to robot status (F), robot target (N), robot speed control (N), Object grasp point (N)
Source of Input data/variables *(from: "S"=Sensors signals not yey strored in DB or files; "S-DB" = Sensors signals streamed and stored in DB or files, "C" = Video /photo Cameras data not yet stored in DB or files, "C-DB"= Video/photo cameras data streamed and stored in DB, "A-DB" = other data/info automatically collected and stored in DB or files, "D" = Drawings/cad files", "L"=Legacy historical data, e.g. included in files, reports/documents of the user company, "NA"= data not yet available, "R"= ROS simulation environment/ messages/ services/ actions,... etc; please add other pertinent acronyms that fit your case, if any)*	Product photo (C-DB), Recipes - Configurations (L), mass and size of fruits (S), speed of rollers (S), real-time object positions (C-DB/ A-DB), Object grasp point (C-DB), robot to robot status (R), robot target (C-DB/ A-DB), robot speed control (R)		Product photo (C-DB), Recipes - Configurations (L), mass and size of fruits (S), speed of rollers (S), real-time object positions (C-DB/ A-DB), Object grasp point (C-DB), robot to robot status (R), robot target (C-DB/ A-DB), robot speed control (R)
Output variables (results)	Develop a new manipulation system that replace flippers with delta robots (or similar). The product will be sorted avoiding product fall that might affect second grade qualities of delicate products (avocados, peaches, ...).		Robot and conveyor system which are interconnected; and multi-robot coordination
Technologies	Delta robot manipulator system; conveyor with speed control capabilities; suction cup and ejector end effector technology		Common framework for intercommunication and task planning (ROS)

Table 8. Solution Map - Pilot 1 (Multiscan) for RAPID RECONFIGURABLE suite.

	Agile, Flexible and Rapid Reconfigurable SUITE Solutions			
	PT[AGILE]	DT[AGILE]	PR[AGILE]	PE[AGILE]
Pilot 1 (MULTISCAN)	Product-oriented traceability solution to collect and store production and logistics operations data linked to product orders.	Multi-layer toolkit Data-Driven Digital Twin for the real-time/near-real time monitor and synchronisation of production and logistics systems.	Optimisation library implementing algorithms to optimise production lay-out and machine set-up.	Optimisation library implementing algorithms to optimise production execution: advanced scheduling, startup optimisation, and process control considering collaborative (human-in-the-middle) approaches.
Objective ToBe-P1.Rapid Reconfigurable:			Support production line operations with Algorithms to optimize machine set-up adjustments and frequencies. In case that a machine set up is needed, they operator will be supported by the solution to proceed with the changes	Control the grading machine parameters during production according to characteristics of the batch to match the quality requirements of the order
Input variables *(that Pilot can make available)* *(data type: "T" as textual feature, "N" as numerical feature), "V" as Video data, "P" as Picture/Figures/photos, ... etc; please add other pertinent acronyms that fit your case, if any)*			Ongoing Order (N) Set-Up Times (N), Operations Dependencies (T), Production Time (N), Production constraints (N), Start and due dates(N), Resources capabilities(N), Resources availabilities (N), Master production plan (N)	Ongoing Order (N), Batch grading Estimation (N), Target Quality (N), Current Set-up Parameters (N), Production Data (N), CAT A quality estimation (N)
Source of Input data/variables *(from: "S"=Sensors signals not yey strored in DB or files; "S-DB" = Sensors signals streamed and stored in DB or files, "C" = Video /photo Cameras data not yet stored in DB or files, "C-DB"= Video/photo cameras data streamed and stored in DB, "A-DB" = other data/info automatically collected and stored in DB or files, "D" = Drawings/cad files", "L"=Legacy historical data, e.g. included in files, reports/documents of the user company, "NA"= data not yet available , ... etc; please add other pertinent acronyms that fit your case, if any)*			Ongoing Order (L), Set-Up Times (L), Operations Dependencies (L), Production Time (L), Production constraints (L), Start and due dates(L), Resources capabilities(L), Resources availabilities (L), Lot-size restrictions (L), Master production plan (L)	Ongoing Order (NA), Batch grading Estimation (S), Target Quality (NA), Current Set-up Parameters (S), Production Data (S), CAT A quality estimation (S)
Output variables (results)			Pre Line set up: Optimize batch handling by calculating the ideal sequence of batches to reduce machine set up.	In-line set-up adjustments: Change the set-up parameters depending on the characteristics of the product to achieve a target quality
Technologies			Reconfigurable Manufacturing Systems	(Micro)-Service stack to deploy algorithms and apps to support production line operations; Rescheduling / Adaptive Control Algorithms; Process standardization

2.1.2. Pilot 2 – SANTORSOLA

The AGILEHAND solution maps for Pilot 2 – SANTORSOLA to assess the user needs are listed for the SMART SENSING suite in table 9, for SELF-ADAPTIVE HANDLING, SORTING AND PACKAGING suite in table 10 and for AGILE FLEXIBLE AND RAPID RECONFIGURABLE suite in table 11.

Table 9. Solution Map - Pilot 2 (Santorsola) for SMART SENSING suite.

	Smart Sensing SUITE Solutions		
	GQ^{SENS}	SC^{SENS}	DS^{SENS}
Pilot 2 (SANT'ORSOLA)	A cost-effective, accurate and fast solution to grade the quality (both interior and exterior) of delicate objects	A self-calibrating solution for producing networks of sensors to improve production-line traceability	Data-sets containing scans of delicate objects in a real-environment with ground-truth data
Objective ToBe-P2.SmartSensing:	Automatically classify the raspberry into 5 classes		
Input variables *(that Pilot can make available) (data type: "T" as textual feature, "N" as numerical feature), "V" as Video data, "P" as Picture/Figures/photos, ... etc; please add other pertinent acronyms that fit your case, if any)*	Product photo (P), Fruit-level annotation (T indicating the class name, or N indicating the grade class), Level of customer satisfaction (N), Type of market to which the classified product is delivered (T)		
Source of Input data/variables *(from: "S"=Sensors signals not yey strored in DB or files; "S-DB" = Sensors signals streamed and stored in DB or files, "C" = Video /photo Cameras data not yet stored in DB or files, "C-DB"= Video/photo cameras data streamed and stored in DB, "A-DB" = other data/info automatically collected and stored in DB or files, "D" = Drawings/cad files", "L"=Legacy historical data, e.g. included in files, reports/documents of the user company, "NA"= data not yet available , ... etc; please add other pertinent acronyms that fit your case, if any)*	Product photo acquired with RGBD cameras (C-DB), Level of customer satisfaction (L), Type of market to wich the classified product is delivered (L)		
Output variables (results)	Solutions able to classify fruits/punnets per color in categories (dark, medium, light) and detects waste (defects to be defined).	Every batch will have a quality report and the system will be track all the batches in/out of the machine for traceability.	Annotated images with information tags what will be used for trainning the other solutions algorithms.
Technologies	RGBD	Apply object tracking algorithms	Acquisition of image datasets, and image annotation by use-case providers. We will provide a tool for the labeling task.

Table 10. Solution Map - Pilot 2 (Santorsola) for HANDLING SORTING AND PACKAGING suite.

	Self-Adaptive Handling, Sorting and Packaging SUITE Solutions		
	ST[HAND]	CR[HAND]	RR[HAND]
Pilot 2 (SANT'ORSOLA)	An intelligent platform capable of performing transportation, inspection, sorting and value addition processes to delicate products, and capable of being cross functional to handle a variety of product types.	A safe collaborative environment where man and machine can work together and perform product handling tasks along various stages of production.	Synergistic cooperation between the various robots and intelligent machinery across the line to exchange product relevant information amongst themselves and a Production Execution Optimization Toolkit to create ever evolving production models.
Objective ToBe-P2.Handling, Sorting and Packaging:	Remove bad fruits from punnet, and replace good fruits to the correct punnet with the correct weight. Integration between the conveyor, vision-system, robotic manipulator and feeder mechanism. Proceed to the packaging machine	Refilling the buffer station where robotic refilling is to be performed.	Multi robot solution required to handle the high volume of fruits; and coordination between robots, vision system and the conveyor system.
Input variables *(that Pilot can make available)* *(data type: "T" as textual feature, "N" as numerical feature, "V" as Video data, "P" as Picture/Figures/photos, "F" as Flag... etc; please add other pertinent acronyms that fit your case, if any)*	Product photo (P), mass and size of fruits (N), speed of rollers (T), real-time object positions (N), Object grasp point (N), robot to robot status (F), robot target (N), robot speed control (N)	Statistical estimation for refill fequency (N)	Product photo (P), Collection of Machine Recipes - Configurations (N), mass and size of fruits (N), real-time object positions (N), speed of rollers (N), robot to robot status (F), robot target (N), robot speed control (N), Object grasp point (N)
Source of Input data/variables *(from: "S"=Sensors signals not yey strored in DB or files; "S-DB" = Sensors signals streamed and stored in DB or files, "C" = Video /photo Cameras data not yet stored in DB or files, "C-DB"= Video/photo cameras data streamed and stored in DB, "A-DB" = other data/info automatically collected and stored in DB or files, "D" = Drawings/cad files", "L"=Legacy historical data, e.g. included in files, reports/documents of the user company, "NA"= data not yet available, "R"= ROS simulation environment/ messages/ services/ actions, ... etc; please add other pertinent acronyms that fit your case, if any)*	Product photo (C-DB), mass and size of fruits (L), speed of rollers (S), real-time object positions (C-DB/ A-DB), Object grasp point (C-DB), robot to robot status (R), robot target (C-DB/ A-DB), robot speed control (R)	Number of berries remaining in buffer (S), Recipes - Configurations (L), mass and size of fruits (L), speed of rollers (L)	Product photo (C-DB), Recipes - Configurations (L), mass and size of fruits (L), speed of rollers (S), real-time object positions (C-DB/ A-DB), Object grasp point (C-DB), robot to robot status (R), robot target (C-DB/ A-DB), robot speed control (R)
Output variables (results)	Robotic manipulation solution to remove the bad fruits and replacing the weight using robotic/automation solution.	Refilling setup for the buffer station	Robot and conveyor system which are interconnected; and multi-robot coordination
Technologies	Cobot for performing bad raspberry removal; delta robot or special mechanism for re-filling the punnets; flipping the punnet to access the bottom layer; Cleaning the suction tube for the raspberry removal.	Explore possibility of using a delta robot to remove the bad fruit or feeder mechanism which utilizies gravity to reload punnets	Common framework for intercommunication and task planning (ROS-MQTT)

Table 11. Solution Map - Pilot 2 (Santorsola) for RAPID RECONFIGURABLE suite.

	Agile, Flexible and Rapid Reconfigurable SUITE Solutions			
	PT AGILE	DT AGILE	PR AGILE	PE AGILE
Pilot 2 (SANT'ORSOLA)	Product-oriented traceability solution to collect and store production and logistics operations data linked to product orders.	Multi-layer toolkit Data-Driven Digital Twin for the real-time/near-real time monitor and synchronisation of production and logistics systems.	Optimisation library implementing algorithms to optimise production lay-out and machine set-up.	Optimisation library implementing algorithms to optimise production execution: planning, scheduling, startup optimisation, and process control considering collaborative (human-in-the-middle) approaches.
Objective ToBe-P2.Rapid Reconfigurable:		Digital Twin to simulate the production process to helps the improvement of forecasted production demand	Development of a tool to support the line set up process by providing predictions.	
Input variables *(that Pilot can make available) (data type: "T" as textual feature, "N" as numerical feature), "V" as Video data, "P" as Picture/Figures/photos, ... etc; please add other pertinent acronyms that fit your case, if any)*		Production Layout (P), Logistic Layout (P), Ongoing Order (N), Set-Up Times (N), Operations Dependencies (T), Production Time (N), Production constraints (N), Resources capabilities(N), Resources availabilities (N), Master production plan (N)	Production Layout (P), Logistic Layout (P), Ongoing Order (N), Set-Up Times (N), Operations Dependencies (T), Production Time (N), Production constraints (N), Resources capabilities(N), Resources availabilities (N), Master production plan (N)	
Source of Input data/variables *(from: "S"=Sensors signals not yey strored in DB or files; "S-DB" = Sensors signals streamed and stored in DB or files, "C" = Video /photo Cameras data not yet stored in DB or files, "C-DB"= Video/photo cameras data streamed and stored in DB, "A-DB" = other data/info automatically collected and stored in DB or files, "D" = Drawings/cad files", "L"=Legacy historical data, e.g. included in files, reports/documents of the user company, "NA"= data not yet available , ... etc; please add other pertinent acronyms that fit your case, if any)*		Production Layout (A-DB), Logistic Layout (A-DB), Ongoing Order (L), Set-Up Times (L), Operations Dependencies (L), Production Time (L), Production constraints (L), Resources capabilities(L), Resources availabilities (L), Lot-size restrictions (L), Master production plan (L)	Production Layout (A-DB), Logistic Layout (A-DB), Ongoing Order (L), Set-Up Times (L), Operations Dependencies (L), Production Time (L), Production constraints (L), Resources capabilities(L), Resources availabilities (L), Lot-size restrictions (L), Master production plan (L)	
Output variables (results)		New toolkit for helping Production Manager to know in advance how many staff we'll need at any given time and simulate the result of production after choosing a defined production line.	Based on historical data and feedback from the user the system supports the line set up process and predicts the possible deliveries from the supplier with different criteria's (field location, weather conditions the last month and more).	
Technologies		Data-Driven Digital Twin for Production and Logistic System Synchronisation	Algorithms and apps to support production reconfiguration system	

2.1.3. Pilot 3 – PRODUMAR

The AGILEHAND solution maps for Pilot 3 – PRODUMAR to assess the user needs are listed for the SMART SENSING suite in table 12, for SELF-ADAPTIVE HANDLING, SORTING AND PACKAGING suite in table 13 and for AGILE FLEXIBLE AND RAPID RECONFIGURABLE suite in table 14.

Table 12. Solution Map - Pilot 3 (Produmar) for SMART SENSING suite.

	Smart Sensing SUITE Solutions		
	GQ^{SENS}	SC^{SENS}	DS^{SENS}
Pilot 3 (PRODUMAR)	A cost-effective, accurate and fast solution to grade the quality (both interior and exterior) of delicate objects	A self-calibrating solution for producing networks of sensors to improve production-line traceability	Data-sets containing scans of delicate objects in a real-environment with ground-truth data
Objective ToBe-P3.SmartSensing:	Sorting of the fish steaks regarding their diameter, allowing to distinguish them in category A and B (A would have higher value). Product will be also graded according to the color.	Automatic identification of the optimal cutting points (optimizing the use of the fish body and the quantity of high value products)	Create annotations of the steaks samples for defect identification, and information about the type of defect taking into consideration GQ-sens and SC-sens
Input variables *(that Pilot can make available)* *(data type: "T" as textual feature, "N" as numerical feature), "V" as Video data, "P" as Picture/Figures/photos, ... etc; please add other pertinent acronyms that fit your case, if any)*	Product photo (P), Variety of fishes (T), Annotation of quality of fish steak according to diameter (T), Level of customer satisfaction (N), Type of market to which the classified product is delivered (T)	Product photo (P), Annotation of parts of fish obtained from cutting procedure (head, body and tail) (T), Level of customer satisfaction (N), Type of market to which the classified product is delivered (T)	Product photo (P), Annotation of quality of fish steak according to diameter (T), Annotation of parts of fish obtained from cutting procedure (head, body and tail) (T), Level of customer satisfaction (N), Type of market to which the classified product is delivered (T)
Source of Input data/variables *(from: "S"=Sensors signals not yey strored in DB or files; "S-DB" = Sensors signals streamed and stored in DB or files, "C" = Video /photo Cameras data not yet stored in DB or files, "C-DB"= Video/photo cameras data streamed and stored in DB, "A-DB" = other data/info automatically collected and stored in DB or files, "D" = Drawings/cad files", "L"=Legacy historical data, e.g. included in files, reports/documents of the user company, "NA"= data not yet available , ... etc; please add other pertinent acronyms that fit your case, if any)*	Product photo acquired with RGBD sensors (C-DB), Variety of fishes (L), Annotation of quality of fish steak according to diameter (L), Level of customer satisfaction (L), Type of market to wich the classified product is delivered (L)	Product photo (C-DB), Annotation of parts of fish obtained from cutting procedure (head, body and tail) (L), Level of customer satisfaction (L), Type of market to wich the classified product is delivered (L)	Product photo (C-DB), Annotation of quality of fish steak according to diameter (L) Annotation of parts of fish obtained from cutting procedure (head, body and tail) (L), Level of customer satisfaction (L), Type of market to wich the classified product is delivered (L)
Output variables (results)	Solution able to reduce the product grading cost by automating human operations	Smart cutting process, where, for each fish, it is indicated the points to cut; heads, body and tail, ensuring the best index of fish body to be cut in steaks	Annotated images with information tags what will be used for trainning the other solutions algorithms.
Technologies	RGBD	Apply object tracking algorithms and system able to mark starting and ending points.	Acquisition of image datasets, and image annotation by use-case providers. We will provide a tool for the labeling task.

Table 13. Solution Map - Pilot 3 (Produmar) for HANDLING SORTING AND PACKAGING suite.

	Self-Adaptive Handling, Sorting and Packaging SUITE Solutions		
	ST^HAND	CR^HAND	RR^HAND
Pilot 3 (PRODUMAR)	An intelligent platform capable of performing transportation, inspection, sorting and value addition processes to delicate products, and capable of being cross functional to handle a variety of product types.	A safe collaborative environment where man and machine can work together and perform product handling tasks along various stages of production.	Synergistic cooperation between the various robots and intelligent machinery across the line to exchange product relevant information amongst themselves and a Production Execution Optimization Toolkit to create ever evolving production models.
Objective ToBe-P3.Handling, Sorting and Packaging:	Automate the feeding of the film wrapping line, according to size and format of the fish pieces that are being handled. A conveyor line with proximity sensors/actuator-based gates to control supply into the packaging machine. Or implement a robotic solution with suitable tooling and smart vision classification.		Intercommunication between the conveyor, the sealing oven, the blade position of plastic cutter, the fish being input
Input variables *(that Pilot can make available) (data type: "T" as textual feature, "N" as numerical feature), "V" as Video data, "P" as Picture/Figures/photos, "F" as flag ... etc; please add other pertinent acronyms that fit your case, if any)*	Variety of fishes (T), mass and size of fishes (N), speed of conveyor (N), speed of the plastic wrap blade (T), ovenReady status for packing and fish available (F)		Mass and size of fishes (N), speed of conveyor (T), speed of the plastic wrap blade (T), ovenReady status for packing and fish available (F)
Source of Input data/variables *(from: "S"=Sensors signals not yey strored in DB or files; "S-DB" = Sensors signals streamed and stored in DB or files, "C" = Video /photo Cameras data not yet stored in DB or files, "C-DB"= Video/photo cameras data streamed and stored in DB, "A-DB" = other data/info automatically collected and stored in DB or files, "D" = Drawings/cad files", "L"=Legacy historical data, e.g. included in files, reports/documents of the user company, "NA"= data not yet available , ... etc; please add other pertinent acronyms that fit your case, if any)*	Product photo (C-DB), Variety of fishes (L), mass and size of fishes (S-DB), speed of conveyor (S), speed of the plastic wrap blade (A-DB), ovenReady for packing and fish available (S)		Product photo (C-DB), Variety of fishes (L), mass and size of fishes (S-DB), speed of conveyor (S), speed of the plastic wrap blade (A-DB), ovenReady for packing and fish available (S)
Output variables (results)	Automate feeding of the fish (to maintain rate of feeding) into the packaging line and optimize cutting of the plastic wrap		Coneyor system, the sealing oven, the cutter blade position, and proximity sensors for fish being introduced are synchronized and integrated
Technologies	Vision based robotic system with suitable tooling/ OR utilizing a conveyor based approach with suitable sensors and actuators		Common framework for intercommunication (i.e. ROS)

Table 14. Solution Map - Pilot 3 (Produmar) for RAPID RECONFIGURABLE suite.

	Agile, Flexible and Rapid Reconfigurable SUITE Solutions			
	PT AGILE	DT AGILE	PR AGILE	PE AGILE
Pilot 3 (PRODUMAR)	Product-oriented traceability solution to collect and store production and logistics operations data linked to product orders.	Multi-layer toolkit Data-Driven Digital Twin for the real-time/near-real time monitor and synchronisation of production and logistics systems.	Optimisation library implementing algorithms to optimise production lay-out and machine set-up.	Optimisation library implementing algorithms to optimise production execution: planning, scheduling, startup optimisation, and process control considering collaborative (human-in-the-middle) approaches.
Objective ToBe-P3.Rapid Reconfigurable:	Storing and provision of relvant product and process data for tracing products. That inculdes measurement data of quality control indicators (e.g. room or bath temperatures). Support the user by provision of Indicators of production phases for improvement on specific steps (ex: time on glazing pool) Storing the data in a Central Data Storage (Single Source of Truth)			Production analysis and forecast based on production history (raw and packing materials needed, production and lead times, among others)
Input variables *(that Pilot can make available)* *(data type: "T" as textual feature, "N" as numerical feature), "V" as Video data, "P" as Picture/Figures/photos, ... etc; please add other pertinent acronyms that fit your case, if any)*	Room or bath temperatures (N), production phases (T), Production and quality control record sheet (T)			Ongoing Order (N) Set-Up Times (N), Operations Dependencies (T), Production Time (N), Production constraints (N), Start and due dates(N), Resources capabilities(N), Resources availabilities (N), Master production plan (N)
Source of Input data/variables *(from: "S"=Sensors signals not yey strored in DB or files; "S-DB" = Sensors signals streamed and stored in DB or files, "C" = Video /photo Cameras data not yet stored in DB or files, "C-DB"= Video/photo cameras data streamed and stored in DB, "A-DB" = other data/info automatically collected and stored in DB or files, "D" = Drawings/cad files", "L"=Legacy historical data, e.g. included in files, reports/documents of the user company, "NA"= data not yet available , ... etc; please add other pertinent acronyms that fit your case, if any)*	Room or bath temperatures (S), production phases (L), Production and quality control record sheet (L)			Ongoing Order (L), Set-Up Times (L), Operations Dependencies (L), Production Time (L), Production constraints (L), Start and due dates(L), Resources capabilities(L), Resources availabilities (L), Lot-size restrictions (L), Master production plan (L)
Output variables (results)	Storing relevant product and process data in a database and provision of the data to the user over the developed suite. That includes parameters e.g. production time, produced quantities. Products can be trace back and forward.			Production data for better management (supply and production forecast; correction/adjustment of production values; etc).
Technologies	Tracing products along the production line. Digitalization and provision of relevant product and process parameter. Development of a central data storage.			Algorithms and apps to support production line operations; Rescheduling / Adaptive Control Algorithms

2.1.4. Pilot 4 – MARELEC

The AGILEHAND solution maps for Pilot 4 – MARELEC to assess the user needs are listed for the SMART SENSING suite in table 15, for SELF-ADAPTIVE HANDLING, SORTING AND PACKAGING suite in table 16 and for AGILE FLEXIBLE AND RAPID RECONFIGURABLE suite in table 17.

Table 15. Solution Map - Pilot 4 (Marelec) for SMART SENSING suite.

	Smart Sensing SUITE Solutions		
	GQ^{SENS}	SC^{SENS}	DS^{SENS}
Pilot 4 (MARELEC)	A cost-effective, accurate and fast solution to grade the quality (both interior and exterior) of delicate objects	A self-calibrating solution for producing networks of sensors to improve production-line traceability	Data-sets containing scans of delicate objects in a real-environment with ground-truth data
Objective ToBe-P4.SmartSensing:	Assess extra raw product properties on the fly: quality, freshness and fat content		
Input variables *(that Pilot can make available) (data type: "T" as textual feature, "N" as numerical feature), "V" as Video data, "P" as Picture/Figures/photos, ... etc; please add other pertinent acronyms that fit your case, if any)*	Product photo (P), weight distribution and quality of the incoming raw material (N), Variety of poultry filets (T), Annotation of quality of poultry filets (T), Level of customer satisfaction (N), Type of market to which the classified product is delivered (T)		
Source of Input data/variables *(from: "S"=Sensors signals not yey strored in DB or files; "S-DB" = Sensors signals streamed and stored in DB or files, "C" = Video /photo Cameras data not yet stored in DB or files, "C-DB"= Video/photo cameras data streamed and stored in DB, "A-DB" = other data/info automatically collected and stored in DB or files, "D" = Drawings/cad files", "L"=Legacy historical data, e.g. included in files, reports/documents of the user company, "NA"= data not yet available , ... etc; please add other pertinent acronyms that fit your case, if any)*	Product photo acquired with RGBD sensors (C-DB), weight distribution and quality of the incoming raw material (L), Variety of poultry filets (L), Annotation of quality of poultry filets according to diameter (L), Level of customer satisfaction (L), Type of market to wich the classified product is delivered (L)		
Output variables (results)	Solutions that can be used for grading and steering the production towards an optimal solution to fulfil the customer production orders.	Real-time quality assesment e.g. of each fillet fed to a grading line	Annotated images with information tags what will be used for trainning the other solutions algorithms.
Technologies	RGBD	Use of (new) smart sensors makes it possible to acquire extra data on incoming raw materials. Additional info regarding breed, feeding products and other chemical compositions could be translated in an objective quality assessment.	Acquisition of image datasets, and image annotation by use-case providers. We will provide a tool for the labeling task.

Table 16. Solution Map - Pilot 4 (Marelec) for HANDLING SORTING AND PACKAGING suite.

	Self-Adaptive Handling, Sorting and Packaging SUITE Solutions		
	ST[HAND]	CR[HAND]	RR[HAND]
Pilot 4 (MARELEC)	An intelligent platform capable of performing transportation, inspection, sorting and value addition processes to delicate products, and capable of being cross functional to handle a variety of product types.	A safe collaborative environment where man and machine can work together and perform product handling tasks along various stages of production.	Synergistic cooperation between the various robots and intelligent machinery across the line to exchange product relevant information amongst themselves and a Production Execution Optimization Toolkit to create ever evolving production models.
Objective ToBe-P4.Handling, Sorting and Packaging:	By means of a robot-grader, poultry filets with or without inner filets can be packed in a unified way, shorter makespan, smaller footprint in production area. Main goal here is to develop a gripper which is fast (>=80 picks/min) and grips the fillets firmly without damaging or losing them. The grasped product is then positioned in a visually leasing manner into the box.	Study to re-arrange the parts in the punnet in collaboration with or without humans. Parts needs to be moved in the properly possition for a nice presentation	Multi robot solution required to handle the high volume of fillets; and coordination between robots, vision system and the conveyor system.
Input variables *(that Pilot can make available)* *(data type: "T" as textual feature, "N" as numerical feature), "V" as Video data, "P" as Picture/Figures/photos, "F" as Flag ... etc; please add other pertinent acronyms that fit your case, if any)*	Product photo/3D image (P), Variety of poultry filets (N), mass and size of poultry filets (N), speed of conveyor (T), Position and rotation of product on the conveyor belt (N), conveyor belt speed (N), Object grasp point (N), robot to robot status (F), robot target (N), robot speed control (N)	Product photo/3D image (P), Variety of poultry filets (N), mass and size of poultry filets (N), Object contacts (N)robot target (N), robot speed control (N), robot control force (N)	Product photo/3D image (P), Variety of poultry filets (N), mass and size of poultry filets (N), speed of conveyor (T), Position and rotation of product on the conveyor belt (N), conveyor belt speed (N), Object grasp point (N), robot to robot status (F), robot target (N), robot speed control (N)
Source of Input data/variables *(from: "S"=Sensors signals not yey strored in DB or files; "S-DB" = Sensors signals streamed and stored in DB or files, "C" = Video /photo Cameras data not yet stored in DB or files, "C-DB"= Video/photo cameras data streamed and stored in DB, "A-DB" = other data/info automatically collected and stored in DB or files, "D" = Drawings/cad files", "L"=Legacy historical data, e.g. included in files, reports/documents of the user company, "NA"= data not yet available, "R"= ROS simulation environment/ messages/ services/ actions, ... etc; please add other pertinent acronyms that fit your case, if any)*	Product photo (C-DB), Variety of poultry filets (S), mass and size of poultry filets (L), speed of conveyor (S), real-time object positions (C-DB/ A-DB), Object grasp point (C-DB), robot to robot status (R), robot target (C-DB/ A-DB), robot speed control (R)	Product photo (C-DB), Variety of poultry filets (S), mass and size of poultry filets (L), speed of conveyor (S), real-time object positions (C-DB/ A-DB), Object location (C-DB), robot target (C-DB/ A-DB)	Product photo (C-DB), Variety of poultry filets (S), mass and size of poultry filets (L), speed of conveyor (S), real-time object positions (C-DB/ A-DB), Object grasp point (C-DB), robot to robot status (R), robot target (C-DB/ A-DB), robot speed control (R)
Output variables (results)	Lower contamination risks. Smaller footprint which leads to shorter makespan and longer shelf-life. Reduce packaging costs. Robot picking up fillets and placing them in trays nicely ordered with a good presentation.	Reorder trays with a good presentation. Reduce human work. Avoid repetitive work.	Robot and conveyor system which are interconnected; and multi-robot coordination
Technologies	Parallel link robot based grading/ separation. Robotic system to neatly place (top row) the products into the box	Collaborative robot, robot control force, vision system	Inter-communication between the vision system, the conveyor, the robot manipulators (ROS)

Table 17. Solution Map - Pilot 4 (Marelec) for RAPID RECONFIGURABLE suite.

	Agile, Flexible and Rapid Reconfigurable SUITE Solutions			
	PTAGILE	DTAGILE	PRAGILE	PEAGILE
Pilot 4 (MARELEC)	Product-oriented traceability solution to collect and store production and logistics operations data linked to product orders.	Multi-layer toolkit Data-Driven Digital Twin for the real-time/near-real time monitor and synchronisation of production and logistics systems.	Optimisation library implementing algorithms to optimise production lay-out and machine set-up.	Optimisation library implementing algorithms to optimise production execution: planning, scheduling, startup optimisation, and process control considering collaborative (human-in-the-middle) approaches.
Objective ToBe-P4.Rapid Reconfigurable:		Digital Twin to simulate the production process to helps the evaluation of the order ETA offline and online to improve the order decision making process	Matching the quality of the identifed chicken to the suitable order, which required different quality classes. Prediction of the day planning according to the needed order quantities, based on historic data of quality and yield of the different suppliers.	Recommend changes in the order (sourcing material used) when the target quality can be compromised
Input variables *(that Pilot can make available)* *(data type: "T" as textual feature, "N" as numerical feature), "V" as Video data, "P" as Picture/Figures/photos, ... etc; please add other pertinent acronyms that fit your case, if any)*		Production Layout (P), Logistic Layout (P), Ongoing Order (N), Set-Up Times (N), Operations Dependencies (T), Production Time (N), Production constraints (N), Resources capabilities(N), Resources availabilities (N), Master production plan (N)	Suppliers characteristics (T), Production Layout (P), Logistic Layout (P), Ongoing Order (N), Set-Up Times (N), Operations Dependencies (T), Production Time (N), Production constraints (N), Resources capabilities(N), Resources availabilities (N), Master production plan (N)	Ongoing Order (N) Set-Up Times (N), Operations Dependencies (T), Production Time (N), Production constraints (N), Start and due dates(N), Resources capabilities(N), Resources availabilities (N), Master production plan (N)
Source of Input data/variables *(from: "S"=Sensors signals not yey stored in DB or files; "S-DB" = Sensors signals streamed and stored in DB or files, "C" = Video /photo Cameras data not yet stored in DB or files, "C-DB"= Video/photo cameras data streamed and stored in DB, "A-DB" = other data/info automatically collected and stored in DB or files, "D" = Drawings/cad files", "L"=Legacy historical data, e.g. included in files, reports/documents of the user company, "NA"= data not yet available , ... etc; please add other pertinent acronyms that fit your case, if any)*		Production Layout (A-DB), Logistic Layout (A-DB), Ongoing Order (L), Set-Up Times (L), Operations Dependencies (L), Production Time (L), Production constraints (L), Resources capabilities(L), Resources availabilities (L), Lot-size restrictions (L), Master production plan (L)	Suppliers characteristics (L), Production Layout (A-DB), Logistic Layout (A-DB), Ongoing Order (L), Set-Up Times (L), Operations Dependencies (L), Production Time (L), Production constraints (L), Resources capabilities(L), Resources availabilities (L), Lot-size restrictions (L), Master production plan (L)	Ongoing Order (L), Set-Up Times (L), Operations Dependencies (L), Production Time (L), Production constraints (L), Start and due dates(L), Resources capabilities(L), Resources availabilities (L), Lot-size restrictions (L), Master production plan (L)
Output variables (results)		Predict the ETA when continuing the production with active raw material quality & yield	Suggest the needed raw material quantities and from which suppliers to order from, to meet the next order quantities.	Suggest the production manager to switch over from raw material (when available in stock) when a better end result can be achieved (ETA/Yield/give-away)
Technologies		By aid of a Digital-Twin software suite, the production can be continuously monitored on product quality and order ETA by making simulation runs on the Digital-Twin.	Algorithms and apps to support production line set up	Algorithms and apps to support production line operations; Rescheduling / Adaptive Control Algorithms

Figure 2 shows the defined AGILEHAND solution matrix that synthesize the selected solutions Vs Pilots use cases (for implementation, demonstration and validation).

	Smart Sensing			Handling, Sorting and Packaging			Agile, Flexible and Rapid Reconfigurable				
Solutions	GQSENS	SCSENS	DSSENS	STHAND	CRHAND	RRHAND	PTAGILE	DTAGILE	PRAGILE	PEAGILE	TOT
PILOT 1 (MULTISCAN)	1	1	1	1		1			1	1	7
PILOT 2 (SANT'ORSOLA)	1	1	1	1	1	1		1	1		8
PILOT 3 (PRODUMAR)	1	1	1	1		1	1			1	7
PILOT 4 (MARELEC)	1	1	1	1	1	1		1	1	1	9
TOT	4	4	4	4	2	4	1	2	3	3	

Figure 2. AGILEHAND solution matrix (Suite-Solution-Pilot)

All the AGILEHAND solutions will be validated at the end by at least one Pilot. Moreover, there is a work balance regarding the number of solutions per pilot. More solutions will be validated by Marelec (9 solutions) and less by Multiscan and Produmar (7 solutions).

2.2. Functional Viewpoint

The AGILEHAND architecture for project solutions comprises physical devices, software on a PC desktop, functions in a users' on-premises data centre, and functions in the cloud.
In particular:

- **Physical Devices** - These are the hardware components situated at various physical locations. They could include IoT devices, sensors, mobile devices, or any other physical equipment relevant to the solution. They are responsible for data collection, monitoring, and interaction with the environment.
- **Software on PC Desktop** – A PC desktop within an organization's office may serve as a central control or management point for the solution. This desktop software can be a user interface for monitoring and controlling the physical devices, processing data, and providing real-time feedback. It may also have specific software components or applications that manage local tasks or data processing.
- **Software On-Premises Data Centre** – The users' on-premises data centre is a local computing environment within the organization's premises. This may include a dedicated server room or data centre facility. It hosts functions or services that require low-latency processing, house critical data, or are subject to strict security and compliance requirements. These on-premises functions may include data storage,

databases, authentication services, or other applications that are not suitable for the cloud or need to be closely integrated with physical devices.

- **Software Cloud-Based**– Cloud-based functions and services are hosted in remote data centres by a cloud service provider. These services can include machine learning models, data analytics, large-scale data storage, and global-scale services that leverage the cloud's scalability and accessibility. The cloud serves as a highly scalable, resilient, and geographically distributed platform for functions that do not require on-premises processing.

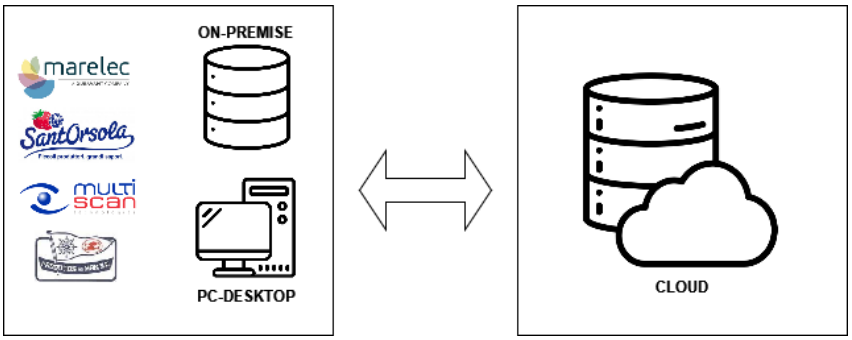

Figure 3. Components of a solution architecture

The architecture is designed to accommodate scalability and redundancy requirements, both locally and in the cloud, to ensure high availability and fault tolerance. Thus, it could offer flexibility, enabling organizations to balance local processing, data control, and security with the advantages of cloud scalability and remote data analysis. However, the specific implementation will depend on the nature of the solution and the organization's requirements.

According to this specification, Agilehand Solution Components represent fundamental building blocks that come together to create a robust and adaptable system. These components play distinct roles in the functioning of Agilehand solutions, catering to a wide array of requirements and scenarios. Let's delve into each type to better understand their unique characteristics and significance:

1. **Component** – A part of an Agilehand solution. At the core of the Agilehand ecosystem, a "component" is the elemental unit that collectively forms a holistic solution. Each component serves a specific purpose, contributing to the overall functionality of the solution. These components can vary in form and function, from software modules to hardware devices, each playing a crucial role in achieving the desired outcomes.
2. **Native Component** – Within the Agilehand solution, a "Native Component" stands out as a software element designed to harness the resources of a specific physical device. This could be a robot, a desktop computer, or any other dedicated hardware. Native components are closely integrated with their host devices, allowing them to tap into local resources, process data, and perform operations in real-time or with low-latency precision.

3. **Cloud Component** – On the other end of the spectrum, the "Cloud Component" is a software module that capitalizes on the expansive computing resources offered by cloud infrastructure. These components reside in remote data centers operated by cloud service providers. They are engineered to benefit from the scalability, reliability, and global accessibility that the cloud environment provides. Cloud components excel in tasks demanding significant computational power, extensive data storage, and seamless scalability to meet varying demands.
4. **On-Prem Component** – The "On-Prem Component" is a software element strategically designed to utilize the computing resources of on-premise infrastructure. These resources are typically located within an organization's physical premises, such as a local data center or server room. On-prem components are selected for tasks where data security, regulatory compliance, or low-latency processing are paramount. They offer organizations direct control over their infrastructure and data, ensuring that sensitive information remains in-house.

In conclusion, Agilehand Solution Components exemplify versatility and adaptability. Their varying functionalities and resource utilization methods empower organizations to tailor their solutions to specific needs, balancing factors like data control, scalability, and performance, all within the context of the ever-evolving technological landscape. Understanding these components is the first step in harnessing the full potential of Agilehand solutions for a myriad of applications and industries.

In the realm of user interface design and software accessibility, User Interface (UI) Components within Agilehand Solutions offer users a dynamic and interactive experience. These components are integral to the way individuals interact with software and the data it manages. Let's explore two fundamental types of UI Components: the Native User Interface and the Web Interface, each tailored to deliver a unique user experience.

- **Native User Interface** – It is a specific type of UI Component within the Agilehand Solution that brings the user experience to life through a graphic interface. It is designed as a native component that is closely integrated with a particular device or platform. This user interface is optimized for the device it resides on, offering a seamless and responsive interaction between the user and the software. Users can expect a consistent and efficient experience when interacting with the software on their device, be it a desktop computer, a mobile device, or any other native platform.
- **Web User Interface** - It is a Cloud and On-Prem Component that extends the user experience to a broader, more versatile audience. This UI component provides a graphic user interface that can be accessed via a standard web browser on various native devices, including desktop computers and mobile devices. The web interface serves as a universal access point, making the software accessible from virtually anywhere, as long as there is an internet connection. Users can enjoy the freedom to engage with the software on their preferred devices, regardless of the underlying operating system or hardware.

In summary, as shown in Figure 4, Agilehand User Interface Components cater to a diverse range of user needs and preferences. The Native User Interface is ideal for ensuring a seamless, platform-specific experience, while the Web Interface expands accessibility, making the software

available to users across different devices and locations. Understanding and implementing these UI components empowers organizations to offer engaging, responsive, and user-friendly interactions, enhancing the overall usability and accessibility of their solutions.

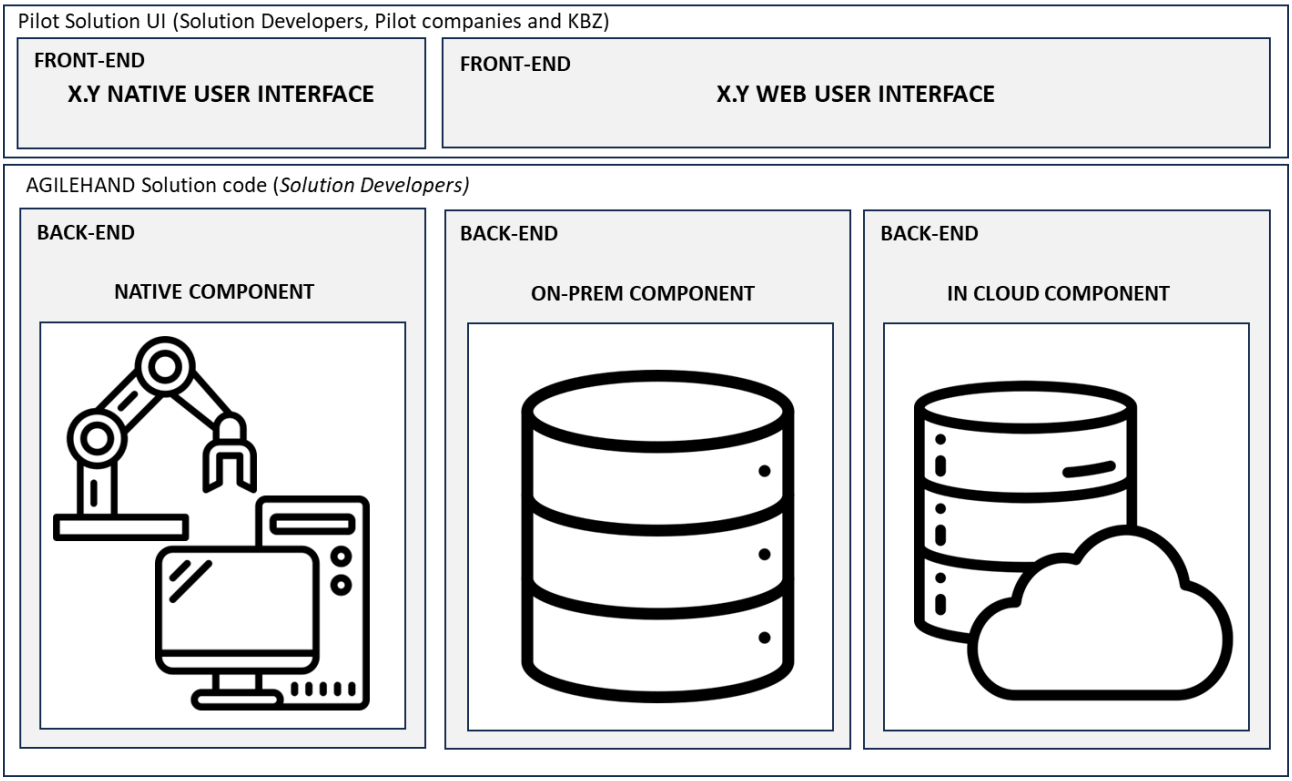

Figure 4. Solution composition

It becomes apparent that the solution component functionalities can be comprehensively understood by delineating them into two primary classes: core functions and interconnectivity with other solutions and devices, as shown in Figure 5. The core functions serve as the backbone, embodying the fundamental capabilities that define the essence of each solution. Whether it be data collection, storage, retrieval, or processing, these core functions encapsulate the essential operations that contribute to the efficacy of the overall system. On the other hand, the functionalities related to solution connectivity with external entities, solutions, and devices play a pivotal role in enhancing the holistic effectiveness of each solution. This class encompasses the mechanisms through which the solution seamlessly integrates with other components of the software ecosystem, facilitating a harmonious exchange of data and insights. From interoperability with external databases to real-time communication with peripheral devices, these interconnectivity functions contribute to the solution's versatility and adaptability within a broader technological landscape. Despite the unique contexts and purposes of the two solutions under consideration, the analogy drawn between these two functional classes illuminates the shared essence of their operational paradigms, highlighting the universal importance of both core

functions and interconnectivity in shaping the comprehensive functionality of contemporary software solutions.

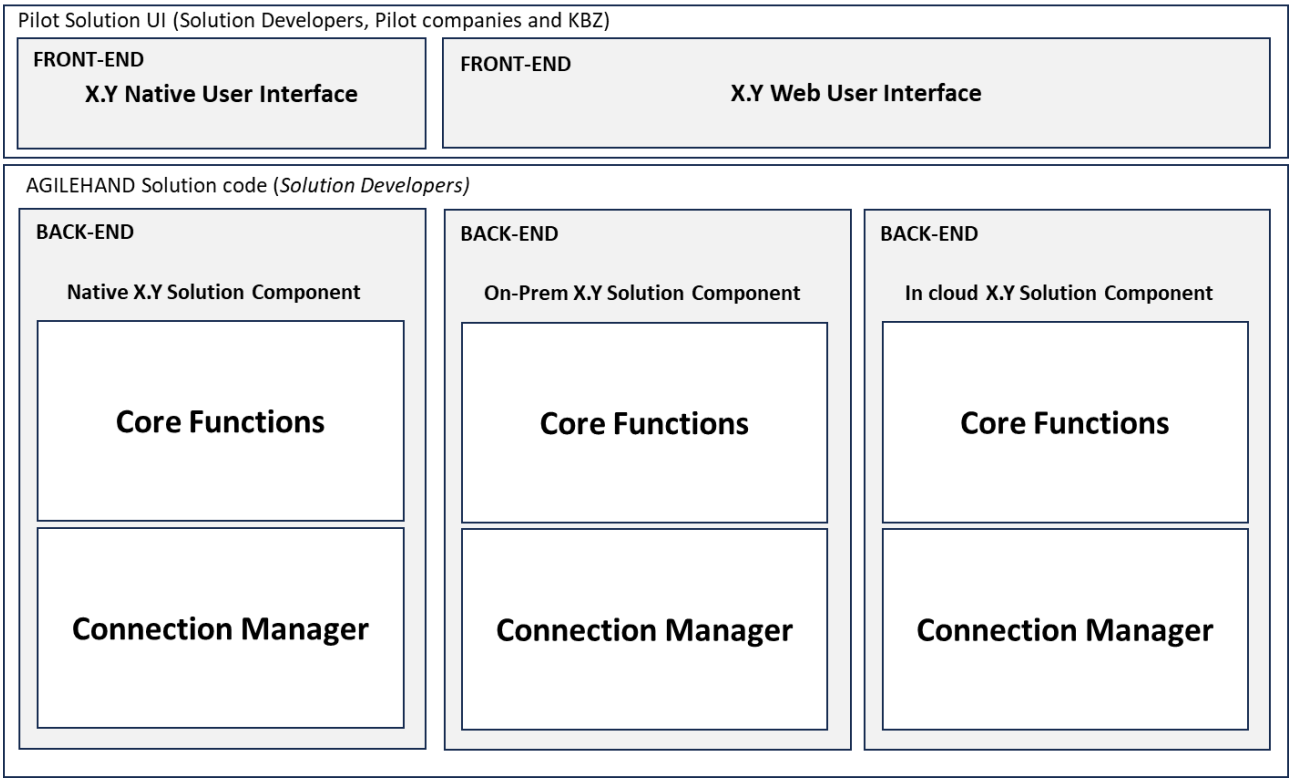

Figure 5. Macro classification of AGILEHAND solutions component

In particular, Figures 6 and 7 highlight, within a general structure, the fundamental characteristics of each function block.

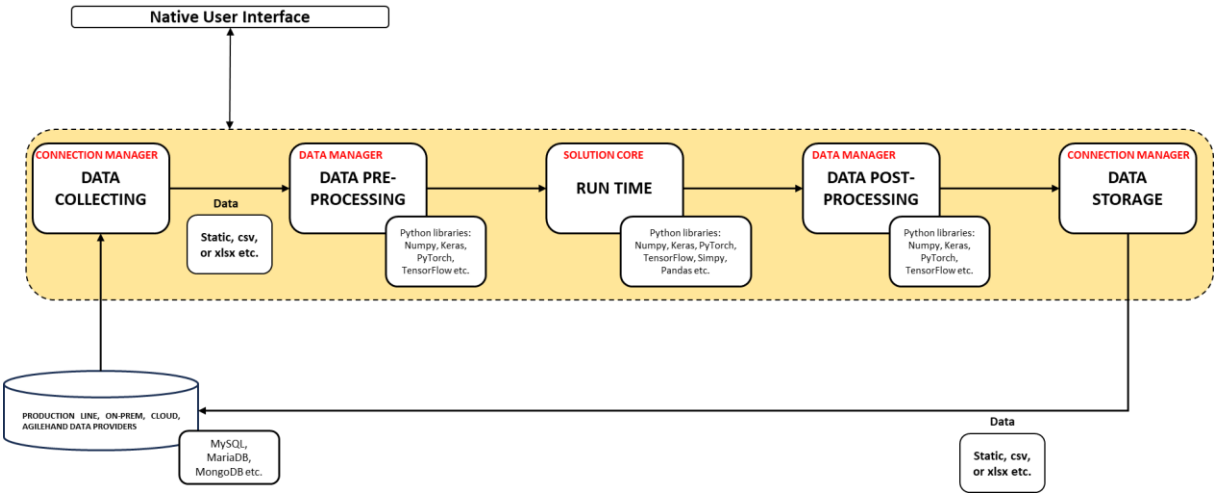

Figure 6. AGILEHAND Native solution general structure

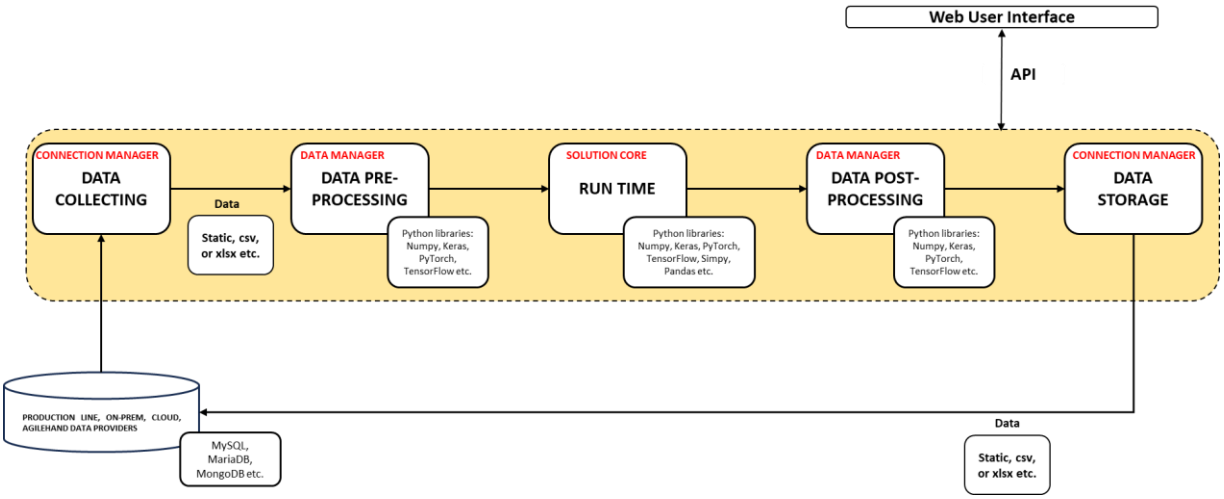

Figure 7. AGILEHAND On-prem/Cloud solution general structure

2.2.1. AGILEHAND architectural blueprint

The diagram in Figure 8 delineates the architectural framework of AGILEHAND software solutions, portraying the intricate integration across diverse environments, encompassing corporate devices such as desktop PCs or embedded devices, and on-premises/cloud infrastructure. The overarching goal is to ensure the autonomy of each solution, allowing them to be deployed independently, while concurrently fostering their integration into a cohesive system. This amalgamation aims to deliver a unified user experience and seamless interoperability. The conceptual foundation of this proposal rests upon two integration layers employing cloud services and infrastructure, fostering communication among solution components, and fostering a unified system experience. This diagram serves as a complementary document to the reference architecture, providing a concrete set of technologies and a development roadmap tailored specifically for AGILEHAND solutions.

The architectural blueprint articulates a systematic approach to constructing solutions characterized by modularity and seamless integration. The emphasis is on delineating specific layers, each assigned distinct roles within the overall framework:

1. **UI Components**: Encompassing all user-facing elements of the solutions, UI Components include individual UI controls and navigation components. Crafted from a shared UI template, these components ensure a unified and consistent user experience across diverse solutions. This uniformity extends to the look and feel, behaviour, and overall usability of the interfaces.
2. **Internal Backend Components**: Handling critical aspects such as business logic, data processing, and decision-making algorithms, Internal Backend Components operate behind the scenes, not directly exposed to external interfaces but indispensable for the solutions' functionality. These components seamlessly interact with the Data Integration layer to retrieve essential data.
3. **Externally Available Backend Components**: These components serve as the gateway for external systems or solutions to interface with the solution through well-defined APIs, providing a standardized means of interaction and data exchange.

4. **Integration Components**: Specifically engineered to manage interactions between the solution and other solutions or external systems, Integration Components play a pivotal role in tasks such as data ingestion (capturing data within the application context and transferring it to the Data Integration layer) and orchestrating workflows across the integrated environment. Leveraging APIs and event-driven architectures such as message queues or service buses (e.g., Kafka), these components facilitate real-time data exchange and seamless process integration, enhancing the overall interoperability of the solution within a connected environment.

The architectural blueprint key aspects include:

1. **Consistency in User Interface (UI):** Both native and web solutions ensure a uniform User Interface (UI) experience by providing UI components that maintain a consistent look and feel. Additionally, a single-sign-on experience is implemented, emphasizing the importance of a seamless user journey across diverse solutions. Cross-Origin Resource (CORS) configurations further enhance these interfaces by enabling the request of resources from domains outside the origin domain, facilitating the integration of services hosted on external domains.
2. **Common Integration Strategy:** A unified integration strategy is employed across both native and cloud solutions through the utilization of service definitions and Software Development Kits (SDKs). This standardized approach is instrumental in ensuring consistent and interoperable interactions among components, promoting a cohesive system architecture.
3. **Data Storage and Messaging:** The system leverages various types of databases, including file, time series, and relational databases. Simultaneously, a unified message bus is implemented for real-time data handling. This dual strategy ensures that all solutions within the ecosystem benefit from a robust and scalable data management infrastructure, enhancing communication across the platform.

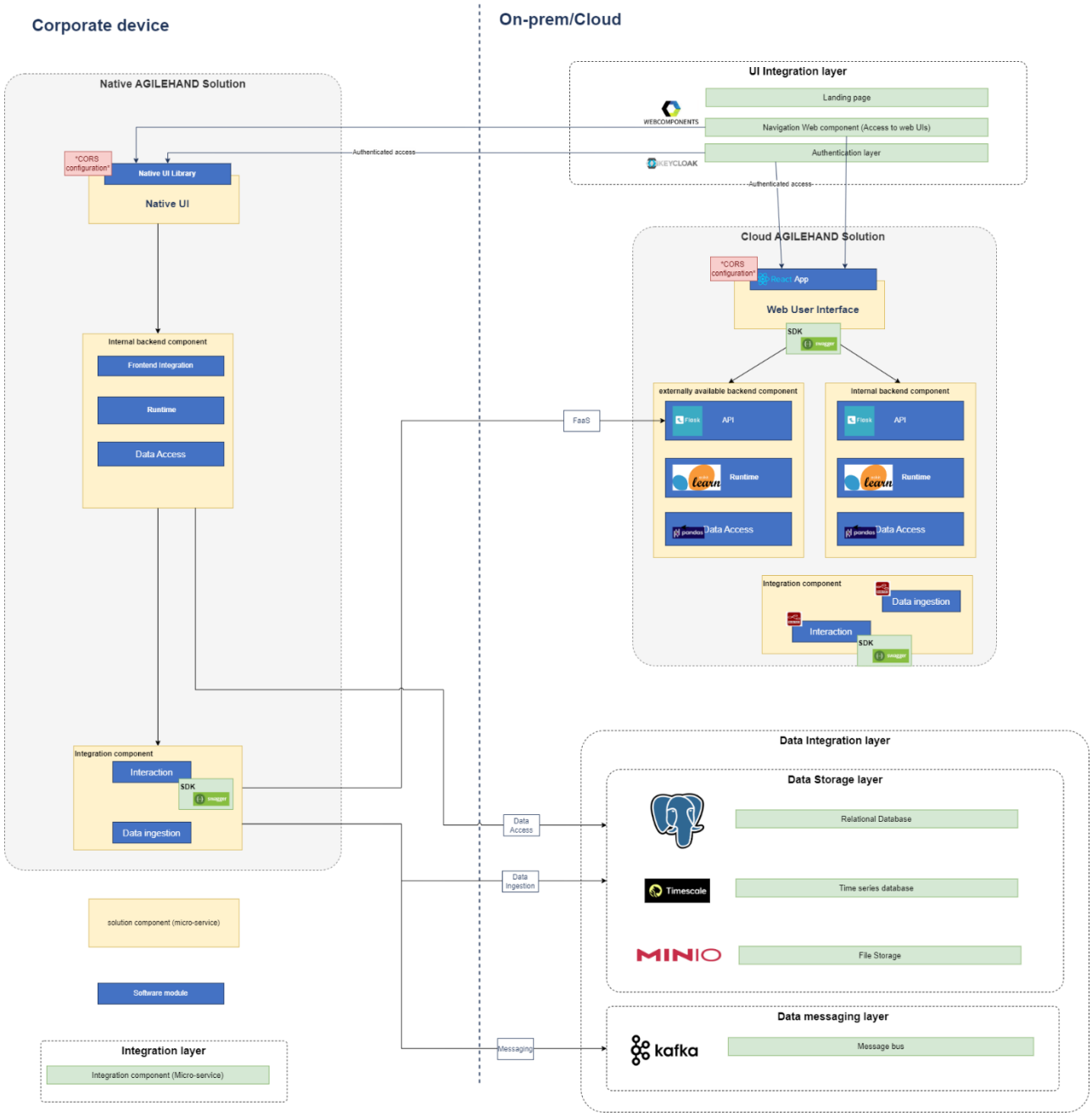

Figure 8. AGILEHAND architectural blueprint

UI Integration layer

The UI Integration Hub, an exemplar of meticulous craftsmanship, must be purposefully designed to act as the central nexus, seamlessly facilitating user interactions across the spectrum of AGILEHAND solutions. With careful attention to detail and precision, this hub stands out as a sophisticated orchestrator, unifying and streamlining the user experience throughout AGILEHAND's diverse solution landscape. At its core, the UI Integration Hub comprises essential components that play pivotal roles in enhancing connectivity and coherence across the AGILEHAND ecosystem. These primary components not only ensure a harmonious user journey but also contribute to the overall efficiency and effectiveness of the AGILEHAND solutions. These components include:

1. **Landing Page:** Serving as a universal entry point, the landing page ensures a consistent starting experience for users engaging with various interfaces. Beyond initiating user interactions, it may feature access to static documentation about AGILEHAND, offering valuable information.
2. **Navigation Web Component:** This dynamic component operates as a navigational powerhouse, furnishing links to user interfaces within different cloud-based solutions. Loaded post a successful login, it functions as a menu button or navigation bar tailored to the user's permissions and roles. This strategic design enables users to seamlessly access multiple solutions without the inconvenience of repeated logins or disjointed interfaces.
3. **Single-Sign-On (SSO) via Keycloak:** Integrated into the system for authentication, Keycloak, an open-source identity and access management solution, facilitates Single-Sign-On (SSO). This means users authenticate once and gain access to all solutions without the need for repetitive authentication. This not only streamlines the user experience but also bolsters security by centralizing user authentication and authorization. Beyond login management, Keycloak boasts capabilities in user identity management, federation with other identity providers, and customization for various protocols like OpenID Connect or SAML, adding a layer of versatility to its functionality.

Ax example of Integration Strategy

While each solution maintains its autonomy, certain solutions have the potential to augment the value proposition of others by exposing internal functionalities through APIs (Application Programming Interfaces). It's important to note that this envisaged synergy is specifically applicable to cloud solutions, as illustrated in the accompanying diagram.

The proposed methodology hinges on standards-driven practices to expose functionalities of cloud solutions via REST APIs, aiming to foster interoperability and simplify integration processes. A possible strategy could unfolds through the following sequential steps:

1. **OpenAPI Specification:** A language-agnostic standard, the OpenAPI specification serves as a comprehensive framework for defining REST APIs. Its pre-defined YAML syntax enables the explicit description of every endpoint aspect, establishing a transparent contract that can be shared among stakeholders. This specification serves a dual purpose, functioning as both documentation and a development guide.
2. **Swagger SDKs:** Leveraging Swagger's suite of open-source tools, notably the Swagger Codegen, this step facilitates the implementation of the OpenAPI specification. The Swagger Codegen proves instrumental by generating client libraries (SDKs) for diverse platforms such as Java, Python, and Go. This not only expedites the development process but also ensures the creation and maintenance of multi-platform SDKs. These SDKs can be seamlessly integrated into the internal components of other solutions, enabling them to interact and integrate with each other effortlessly.

This meticulous approach guarantees that the functionalities exposed by cloud solutions through their REST APIs are accessible across a diverse range of environments, aligning with the concept

of Functions as a Service (FaaS). This not only enhances the overall flexibility of the solutions but also lays the foundation for a cohesive and interoperable cloud ecosystem.

Data Integration Layer

The Data Integration Layer stands as the cornerstone for comprehensive data management across the entirety of AGILEHAND solutions. Tailored to adeptly handle diverse data types, it offers indispensable services that encompass data persistence, retrieval, and real-time processing. This layer functions as a centralized data hub, orchestrating all interactions related to data within AGILEHAND. By consolidating data operations in this strategic layer, we not only ensure and enhance the consistency, availability, and integrity of data but also address critical aspects such as security, scalability, and overall system performance.

This integral component permits a standardized and streamlined approach to data management, significantly simplifying development, integration, and maintenance processes. Through the centralization of data services, it becomes more straightforward to uphold high availability, adhere to security and regulatory requirements, and ensure efficient recovery mechanisms, making it an essential element for the seamless functioning of the integrated AGILEHAND ecosystem. In particular, the Data Integration Layer is further categorized into specific services providing several database services meticulously adapted to the distinct data requirements of various AGILEHAND solutions. This multi-database strategy empowers each solution to choose the most fitting storage mechanism for its unique data needs. Data services within this layer encompass:

a) **Relational Databases (e.g., PostgreSQL):** Engineered to manage structured data with defined relationships, relational databases utilize a schema to articulate tables, fields, and their interconnections. PostgreSQL, a renowned open-source relational database, is favored for its robustness, performance, and adherence to SQL standards.
b) **Time-Series Databases (e.g., Timescale):** Optimized for time-series data, where data points are indexed chronologically, TimescaleDB proves invaluable for IoT and monitoring applications that involve data collection over distinct time intervals.
c) **File Storage Services (e.g., MinIO):** Serving as a high-performance distributed object storage system designed for extensive data storage, MinIO is compatible with Amazon S3 APIs. It finds utility in storing unstructured data such as photos, videos, log files, backups, or software packages.

3. AGILEHAND Usage Models & Mock-ups

3.1. Design Tool and Methodology

3.1.1. Figma

Designing good user interfaces is often a challenging process which comprises consideration of several factors such as good functional and systematic requirement analysis. To cover all aspects of design process a fully functional tool is a necessity which can support all kind of design process needs. One of such tools that supports a wide variety of such functionalities and openly accepted in enterprise practices is a cloud-based design tool called Figma. This tool allows designing mock-ups for user interfaces with the ability to add interaction to them by prototyping feature. A brief visual look of Figma in workflow is presented in Figure 9.

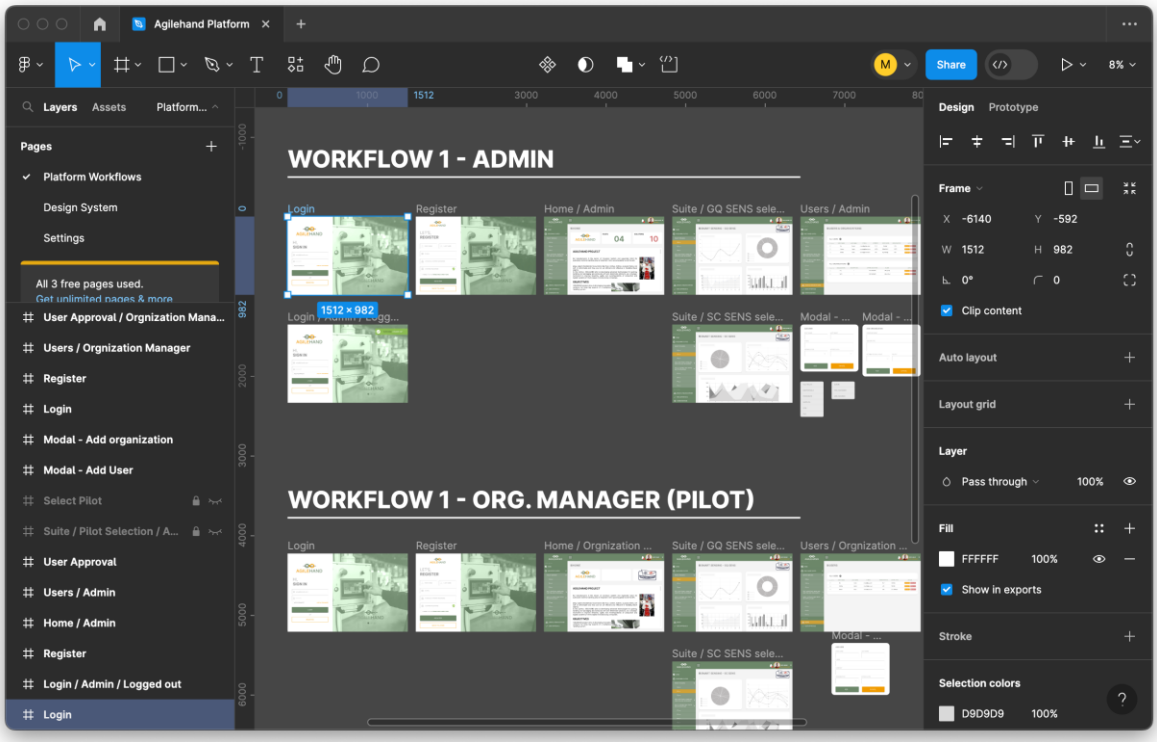

Figure 9. Figma tool interface

Figma is prominently known for its real-time collaboration feature which not only allows designers to work on same design simultaneously but also allows stakeholders to view and give feedback directly on the design as it evolves throughout the design process.

3.1.2. Prototyping

Figma offers prototyping functionality to simulate application workflows. Prototypes provide screen to screen navigation, individually interactable animated components and responsive design to ensure consistency of user experience across multiple devices and screen sizes.

3.1.3. Co-Creation Approach

A good user interface must incorporate user feedback to have accessible, user friendly and highly interactive design. A high-quality user experience largely depends on user-friendliness of UI.
One way to achieve user-friendliness is through co-creation approach, which involves continuous collaboration and participation of end-users to gather feedback and insights which can be used to refine the product design. Agilehand common platform mock-up is designed using this approach of active participation from involved end-users to assure a final system that is built on user expectations.

3.2. Mock-ups and Testing framework

Mock-up designs serve as an integral system development process providing a first look of expected product. The mock-up for Agilehand common platform is designed in a dashboard like UI which acts as an overall template for all solutions developed under Agilehand Suites.
Agilehand Common Platform acts as a central dashboard that offers analytics and recommendations presented by different Agilehand solutions. This platform accommodates distinct user types based on roles and permissions, each with their unique workflow and requirements. Three basic user types exist in common platform namely Admin, Organization Manager and Organization Member.

Admin: This user type is mainly responsible for overall management of the common platform. Which includes managing solutions, adding, and managing organizations and their managers etc.

Organization Manager: Within each organization exists and Organization Manager. This user is responsible for solely managing their associated organization and its members. An Organization may be assigned one or more general or specifically tailored solutions depending on the Organization needs, Organization can not only include Pilot companies but also Other member partners of the project where needed.

Organization Member: This user type offers bare minimum features on the dashboard and is meant to be used by members of the Organization who only need to use the solutions of the Organization.

Each page is designed to be presented differently depending on the user type and the Pilot it is assigned to. Each pilot comes with different needs addressed in different AGILEHAND solutions. These solutions are customizable to comply with the specific needs of pilots.

The first page in mock-up is the login page shown in Figure 10. On this page, registered users are provided with the functionality to input their email address and password, facilitating access to login interface. The login page also provides access to registration page for organization members and a password recovery option.

Figure 10. Login page

Regarding account registration (Figure 11), organization members without an existing account can proceed with registration by providing the requested information, including first name, last name, email address and chosen password. After completing this registration process, user should expect to be approved by the respective organization manager to gain adequate access to optimally utilize the services available on platform.

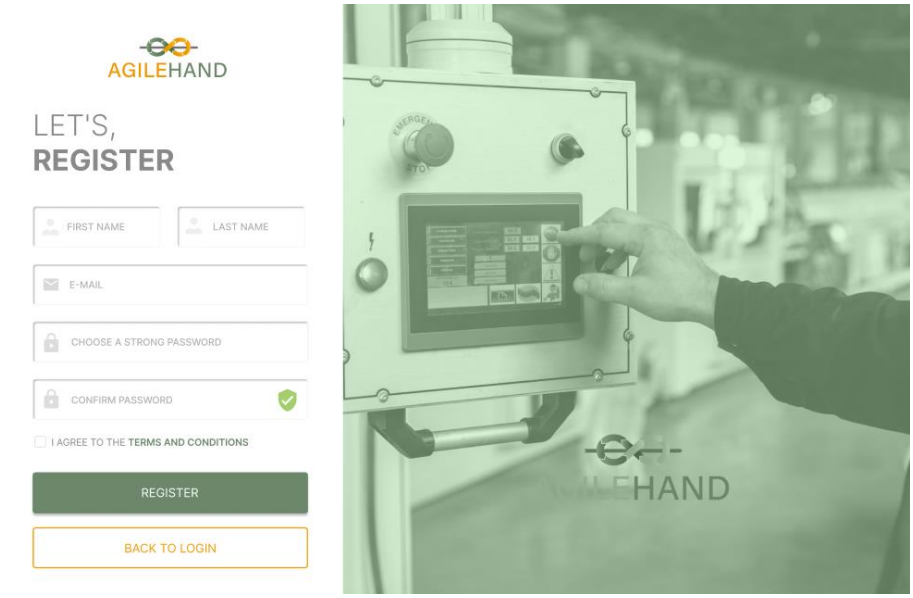

Figure 11. Registration Page

Upon accessing the interface, users will be directed to the primary navigation panel featuring selections including 'AGILEHAND Suites', 'Smart Sensing', 'Self-Adapting Handling', 'Sorting and Packaging', 'Agile, Flexible, and Rapid Reconfiguration', and 'Settings'. Within the 'Home' section, users will encounter an extensive exposition elucidating the AGILEHAND project alongside its delineated objectives. This section additionally encapsulating the count of conducted pilot studies and resultant solutions within the AGILEHAND project framework. The intent of this

interface is to afford a comprehensive portrayal of the project's facets, facilitating streamlined access to its fundamental constituents.

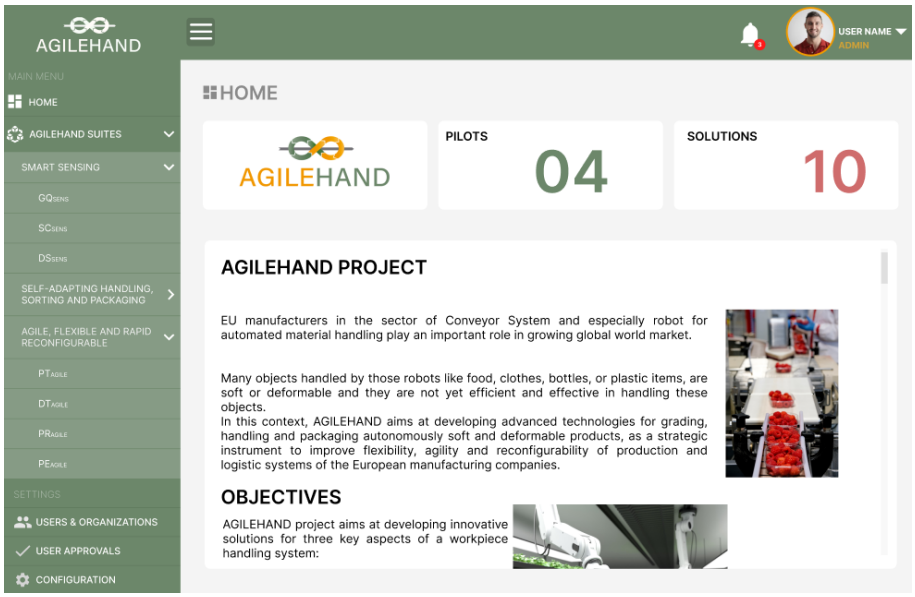

Figure 12. Homepage

In any Agilehand Suite such as the Smart Sensing Suite, each of the submenus represent an Agilehand solution such as GQsens, SGsens, and DSsens. Each of these solutions are meant to present content relating to the functionality concerned to that specific solution and also in relation to the pilot associated.

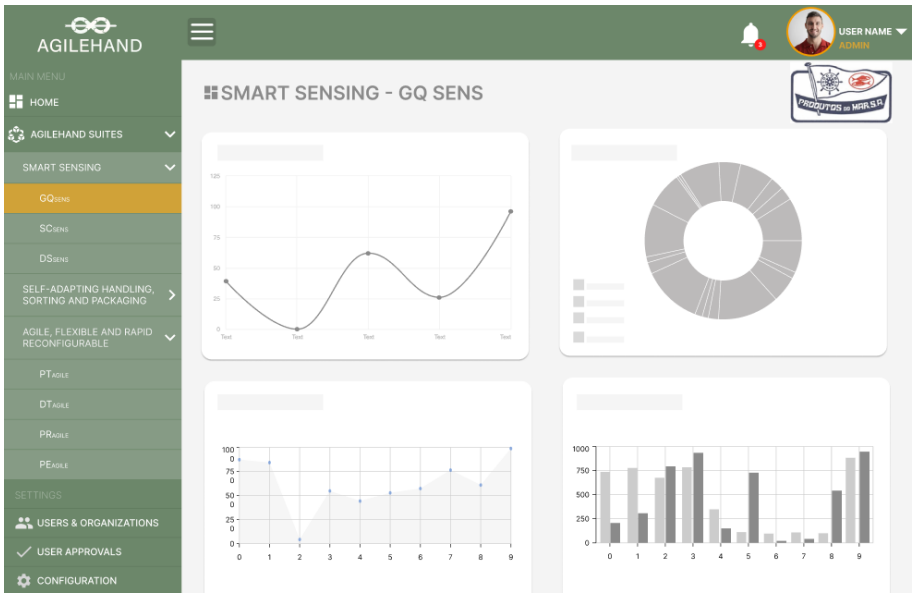

Figure 13. GQ SENS Smart Sensing solution

For admin users have the capability to regulate access privileges, dictating permissions regarding feature utilization and activity execution within the provided solution, for both individual users and organization accessing the platform.
Basically, admin user controls who is permitted to perform certain actions on the platform, whether individual users or organizational groups, by granting access permissions appropriate to their roles or responsibilities and associating individual solutions.

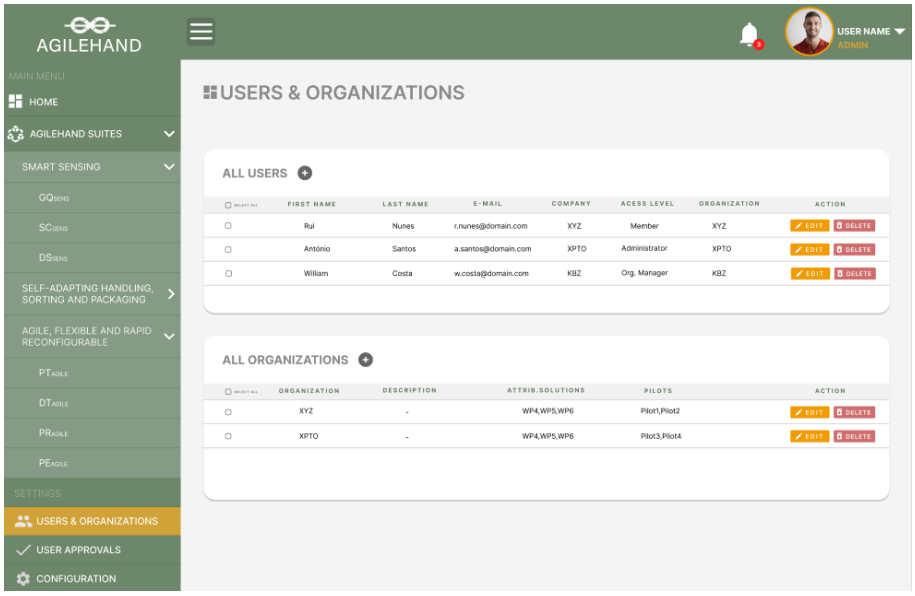

Figure 14. Users & Organizations page

In the registration part, once a new user successfully creates an account, immediate access to AGILEHAND is not granted without approval from the administrator or organization manager. This step is taken to ensure tighter control of access into the AGILEHAND platform. With this approach, admins have the power to review and approve new user access, ensuring that the access rights granted are in line with existing needs and responsibilities. Consent from the organization manager is an additional step in access security management which often uses role-based access management principles. This allows organization manager to assess the role or position of a new user and determine the appropriate level of access within AGILEHAND platform. With this approach, the AGILEHAND platform can ensure that each user has access according to the tasks or roles they have in the environment. This functionality is handled in User Approvals page shown in Figure 15

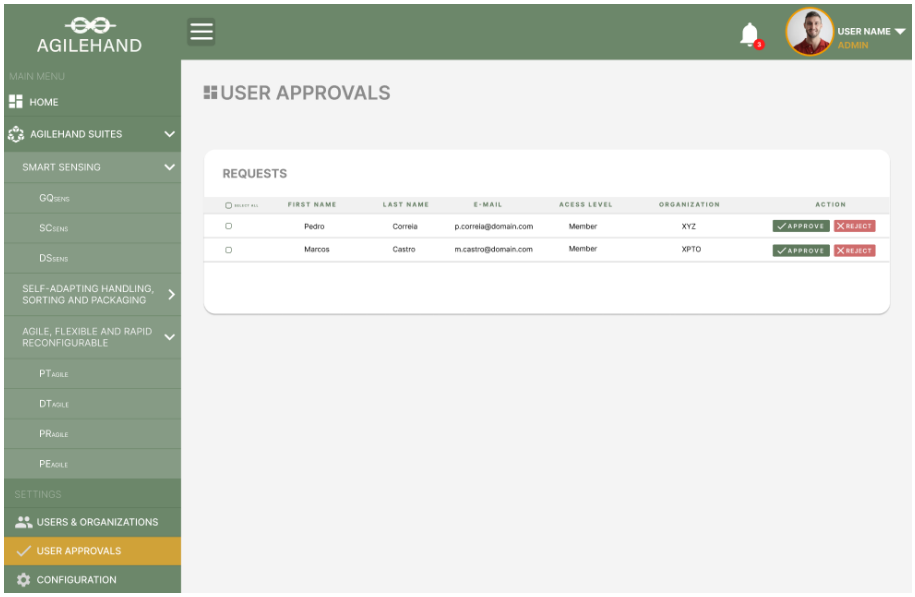

Figure 15. User Approvals page

3.2.1. Usability Testing

Usability testing is a systematic evaluation of ease of use and user friendliness in a product or system which is usually performed through direct participation from stakeholder and end-users by providing relevant observation and feedback on the experience. The goal of usability is to pinpoint design issues and make improvements to ultimately enhance overall user experience (UX). User-centred design in software development has grown in recent years which is why usability testing has become an essential in the design process. Following in figure 16 is the proposed recycling model for Agilehand platform usability testing.

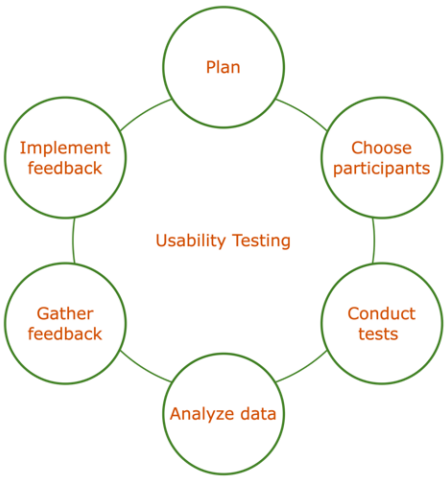

Figure 16. Usability testing model

System Usability Scale (SUS) is a widely adopted user interface usability testing standard and provides a rigorous framework to assess UI/UX through quantitative metrics. Following SUS derived measures were adopted to evaluate usability of Agilehand platform UI:

- **Task Success Rate:** This metric outputs the proportion of participants who completed given set of tasks. Higher rate of this metric indicates ease of use.
- **Time of Task:** Measures the time taken by participants to complete each task. It can help identify potential issues that may arise during interaction with the system design.
- **Error Rate:** Errors occurred during any task such as deviation due to miss clicks or incomplete task.
- **Test Completion Time:** Overall completion time combined from individual task completion time. This metric offers a comprehensive look of how long it actually took users to complete the whole usability test.
- **Click Heatmaps and User Flow Patterns:** User click tracking and navigation patterns allow identification of common behaviours, user expectations and facilitate optimization of UX.
- **Questionnaires and Surveys:** Qualitative feedback through this metric gives valuable information regarding perception of the UI, overall satisfaction, preferences, and suggestions for improvement.

3.2.2. Test Scenarios

In the context of useability assessment of Agilehand common platform prototype, a series of test scenarios are included in the evaluation through systematic and structured approach. These scenarios include brief instruction within each task. Participants are asked to perform 11 actions on the prototype followed by a set of 6 open-ended question designed to bring forth qualitative feedback from users regarding over satisfaction with the presented platform user interface.

Following is the list of tasks included in the test scenario:

Task 1: Navigate from login page to homepage

Task 2: Select GQ SENS solution from Agilehand Suites Menu

Task 3: Select SC SENS solution from AGILEHAND SUITES

Task 4: Open and Close notification panel

Task 5: Open and Close Profile dropdown

Task 6: Navigate to USERS & ORGANIZATIONS

Task 7: Open ADD USER form

Task 8: Open dropdown options in ADD USER form

Task 9: Open ADD ORGANIZATION form

Task 10: Navigate to User Approvals page

Task 11: Navigate back to Home page

Following set of questions are asked to participants after performing prototype tasks:

Question 1: On a scale of 1 to 5, how easy was it to navigate through the dashboard?

Question 2: How long did it take you to complete all the tasks using the dashboard?

Question 3: On a scale of 1 to 5, how many clicks were required to access different sections of the dashboard?

Question 4: How satisfied are you with the overall design and layout of the dashboard?

Question 5: Were there any specific elements or features that you found confusing.

Question 6: Can you provide any suggestions for improving the overall user experience of the dashboard?

At the end of this questionnaire the test scenario ends with an optional access to design file to open in Figma where any future feedback can be left directly on the design. Which may be addressed by the designers shortly.

The test scenario described above has been created and shared through an online testing platform called Useberry. This online platform allows to conduct usability testing for digital prototypes for web and mobile apps. Useberry can be integrated with variety of design tools including Figma. Useberry allow to collect rich insights and user feedback right from the prototype through a streamlined step by step workflow. During the test, Useberry platform also allows collecting data such as session recordings, click tracking and user flows.

3.3. Results analysis, Findings and Recommendations

A total of 8 Agilehand partners were invited to participate in the usability of common platform. The usability test gave us insights into many useful findings. Leveraging the Metrics provided by System Usability Scale gave useful information to understand user behaviours. The feedback provided by participants was analysed, focusing on metrics such as completion time, completion rate and user ratings.

The following image is a click heatmap of login page, giving us insights on what parts of the page user expect to be interactive and should give user visual feedback when they click on it.

Figure 17 User click heatmap on login page

Similarly, on the homepage in figure 18, user click map reveals that there are parts in the design that could be improved in terms of UI flexibility and interaction with different components of the page.

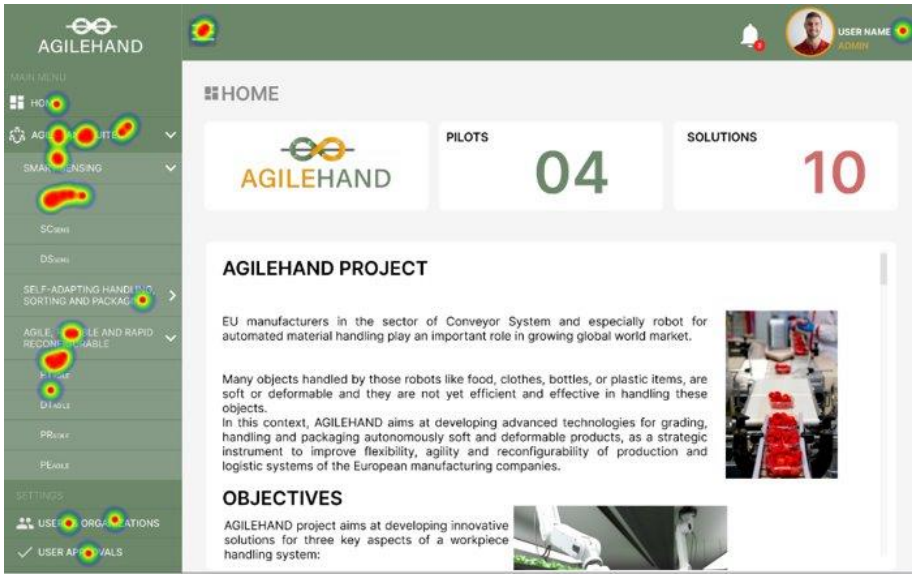

Figure 18 User click heatmap on home page

Analyzing the user flows recorded during prototype navigation tasks for example in the task "Select GQ SENS solution from AGILEHAND SUITES" It is shown that users took different approaches to complete the task while majority of participants were successfully able to complete the task some participants deviated to a different page and were not able to complete the task as described, which led to abandonment of the task.

Figure 19 User navigation flows

The graph 1 (Figure 20) shows the number of total attempts for each task in the Usability test. It can be observed that maximum of 7 attempts were recorded for the first task which concludes that the task was completed by all the participants who attempted this task. Only the task 2 and task 10 were not completed by 1 participant.

The completion rate per task depicted in Graph 1 shows cumulative attempts by participants during the usability testing process across various tasks. A prominent observation is that the most proportion of participants (i.e., 7) successfully completed Task 1, indicating that the Task 1 was

easy to accomplish, and instructions provided were comprehensible. Furthermore, it is worth mentioning that only two tasks (i.e., Task 2 and Task 10) did not meet full completion rate, highlighting potential issues that could be linked to task instructions or design elements.

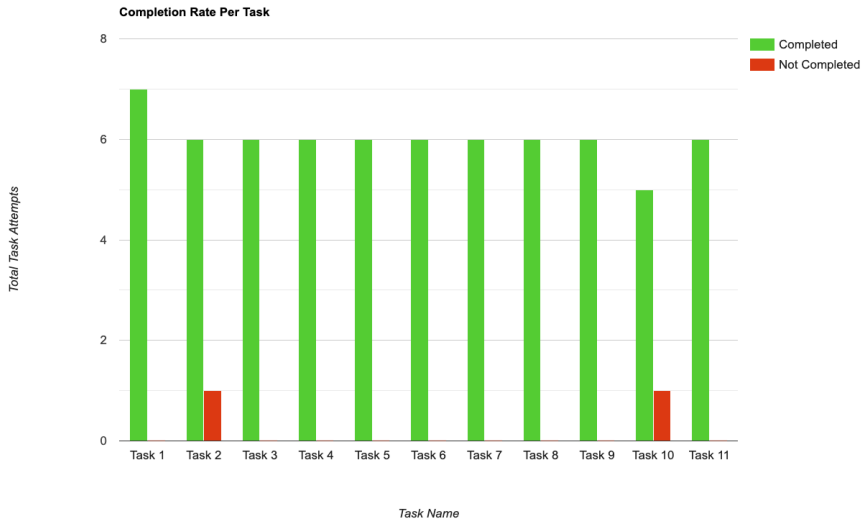

Figure 20 Graph 1. Task completion rate

Similarly in the graph 2 (Figure 21) the Average time of completion per task indicates that most of the tasks attempted took adequate time for majority of participants who completed the task. This metric indicates that completion time was within expected time intervals.

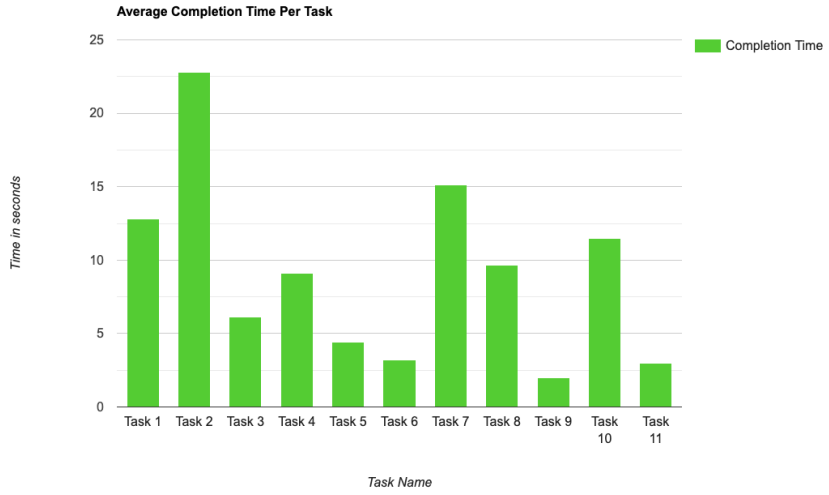

Figure 21 Graph 2. Average completion time per task

In conclusion, the usability testing revealed that overall proposed design has good user experience while there is room for improvement in parts of the design which users found unreachable or not interactable.

4. Conclusion

Deliverable D3.2 provides the description of the finally selected pilots use cases, the mapping of AGILEHAND solutions related to the specific pilots' needs, usage, technical and functional specifications. The present industry needs as stated by the pilots have been aligned with the feasibility approval of AGILEHAND solution developers through an iterative method that has been completed.
The results will include inputs from the business perspective, such as stakeholder views, regulations, and business considerations. The tasks, roles, or activities that have to be performed within the framework will be identified from the usage perspective. We will break down the architecture into its domains from a functional point of view.

The defined functional architecture is a well-founded structure that supports all the components required to enable seamless operability at various layers as it is derived from the needs of the project. It also helps teams and stakeholders work together more easily by creating a common language and understanding of the project structure.

The AGILEHAND platform design process makes use of tools and processes that are described in the Usage Models & Mock-ups section. It displays a mock-up prototype for a shared platform that will house every AGILEHAND ecosystem offering. This also includes results, findings, and suggestions from the usability test that was conducted with a chosen audience.