



# AGILEHAND

## D5.1 – AGILEHAND Self-Adaptive Handling, Sorting and Packaging SUITE v1

WP5 – BUILD: Self-Adapting  
Handling, Sorting and  
Packaging SUITE



## Document Information

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ABSTRACT	<p>The scope of D5.1 is to showcase the progress made so far within WP5 which regards four pilots. The Key Exploitable Result of this WP is to develop the Self-Adaptive Handling, Sorting and Packaging suite for AGILEHAND. This constitutes 3 Other Exploitable Results, namely, Self-Adaptable Transportation Systems, Collaborative Robot, and Robot-Robot.</p>			

## Document History

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2.0	27-12-2024	Document finalized	Addressed comments of UNINOVA and FBK	TAU

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## ABBREVIATIONS/ACRONYMS

<b>ACE</b>	Automation Control Environment
<b>IOU</b>	Intersection Over Union
<b>IPC</b>	Industrial PC
<b>KER</b>	Key Exploitable Result
<b>MV</b>	Machine Vision
<b>OER</b>	Other Exploitable Result
<b>PPM</b>	Parts Per Million
<b>ROS</b>	Robot Operating System
<b>RL</b>	Reinforcement Learning
<b>TCP/IP</b>	Transmission Control Protocol/Internet Protocol
<b>WP</b>	Work Package
<b>ST<sup>HAND</sup></b>	Self-Adaptable Transportation systems
<b>CR<sup>HAND</sup></b>	Collaborative Robot
<b>RR<sup>HAND</sup></b>	Robot-Robot

## 1. Executive summary

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This deliverable describes the activities carried out within WP5 for the various **AGILEHAND** pilots, namely MULTISCAN, Sant'ORSOLA, PRODUMAR and MARELEC. The following technologies- self-Adaptable Transportation Systems, Collaborative Robot, Product Oriented Traceability are described in the following sections.

## 2. Document structure

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**Section 1** describes the work on the “**AGILEHAND Self-Adaptable Transportation Systems**” solution developed in Tasks 5.1, and 5.2. Its scope is to create an intelligent platform capable of performing transportation, inspection, sorting and value addition processes to delicate products, while being capable of handling a variety of products- with minimal hardware modifications.

**Section 2** describes the work on the “**AGILEHAND Collaborative Robot**” solution, which has elements from Tasks 5.2, and 5.3. Its scope is to create manipulation solutions, where man and machine can work together and perform product handling tasks along various stages of production.

**Section 3** describes the work on the “**AGILEHAND Robot-Robot**” solution, which is based on the solutions developed in all the Tasks, but with special inputs received from Task 5.4. Its scope is to propose a framework to all the solution developers, to define a synergistic cooperation between the various robots and machinery, involved at the various stages of product’s primary processing.

**Section 4** concludes the document and summarizes the work performed in the various tasks of WP5.



## 4. AGILEHAND Self-Adaptable Transportation Systems (ST<sup>HAND</sup>)

### 1.1 Overview

AGILEHAND is developing intelligent platforms which can perform the necessary product transportation, inspection, sorting, and value addition processes. The products from whom the production process is being automated and optimized, exhibit complex physical and biological properties. Hence the focus of this OER is to perform delicate but rapid manipulations and transportation, while keeping the structural integrity of the product intact and maintaining hygienic work conditions.

In the context of addressing the various pilot use cases, the handling and value addition processes primarily utilize Machine Vision (MV) as sensor feedback to track the real time locations of the various instances of the object, and to provide feedback to the robotic manipulators while they are performing material handling or value addition processes. MV solutions being developed in WP4 are predominantly intended for product classification, and location tracking of the individual instances while they are being conveyed between various processing stations. However, certain MV solutions are further developed in WP5 for getting process feedback on the material handling, packaging and value addition processes performed by the robot/cobot manipulators. An abstract system overview of an integrated MV and robotic system is shown in Figure 2, depicting a MV system that provides individual product identification, grading, and location information to the robotic system to perform the corresponding manipulation operation.

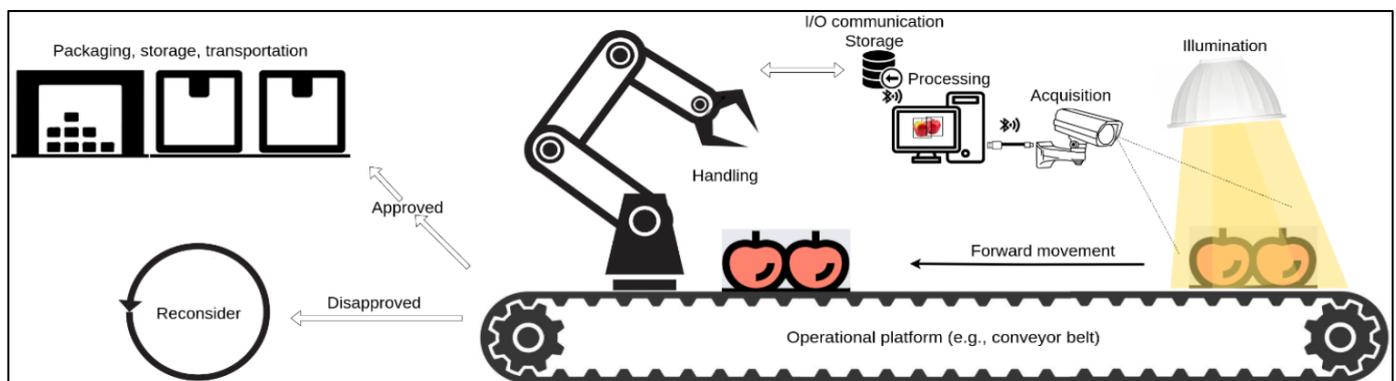


Figure 2. Abstract overview of the robotic and transportation system utilizing MV data as the sensor input and feedback

This section will focus on describing the various solutions developed for performing the physical transportation and manipulation operations performed on the various products, the various physical platforms developed to address the concerns of each pilot’s product, the integration of MV solutions developed dedicatedly in WP5 and integrating with the developments (MV) made in WP4.

### 1.2 Implementation Status

The pilot requirements and the exact phases in the production processes to be optimized were identified and finalized, through dedicated workshops and pilot visits from March 2023 to March 2024. These workshops and pilot visits helped narrow down the scope of the solutions to be

implemented and identify most the critical challenges to be addressed. Furthermore, it helps to identify the logistics and the main partner responsible for being the solutions developer for a given pilot. The scopes of the pilots were identified, however, as mentioned earlier not all pilots require the same TRLs of developed technologies across all the OERs, and this sub-section will reflect that.

## 1.2.1 Current Implementation

This section describes how the implementation of Self-Adaptable Transportation Systems in the pilots was defined, and how the various solution developers have progressed with the demonstrator.

### 1.2.1.1 Pilot- MULTISCAN

UPV has installed a set of rolls to simulate specific picking and placing positions. Our problem was that our conveyor belt has issues and cannot have a smooth speed. Because of that, we had to place the oranges on different point to avoid collision and this resulted in a poor optimization of the movement.



*Figure 3. Rolls for the picking position*

Now that the rolls have been placed, we know exactly where to pick and where to place the oranges. The idea is also to make the rolls on the placing position move to simulate a conveyor belt.

### 1.2.1.2 Pilot- SANT'ORSOLA

In the Sant'Orsola pilot (raspberry quality control pilot), quality control takes place over several processes, the first process involves a vision system that identifies the position within the tray of the discarded fruit. The second process involves the extraction of the fruit using an Omron TM12 cobot. The third process performs an overturning of the tray and a re-sending of the tray to the first two processes, this to check the lower state of raspberries. Finally, the process involves re-filling the tray with fruit to bring it up to weight.

As things stand, the first process has mostly been accomplished although it still needs to be completed, this process is carried out by our FBK colleagues. The second process has been completed by managing to extract the fruit correctly. This module is related to the previous

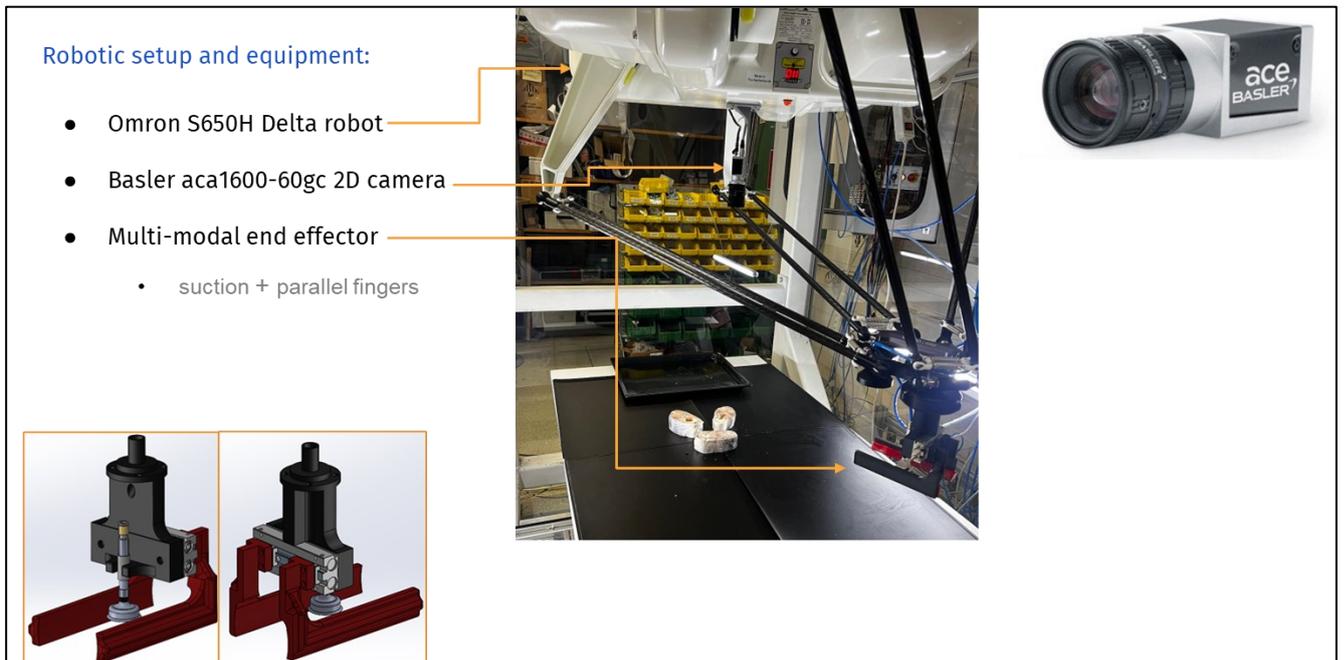
module, i.e. it is only possible to extract the fruit if the xyz coordinates are known, which are provided by the vision system encisioned in WP4.

For the flipping machine, we are in a study phase for the integration of the machine into the production line for quality control and the creation of the machine setup, and finally for the last process we did the CAD for the machine realization.

### 1.2.1.3 Pilot- PRODUMAR

For PRODUMAR, the initial version of the demonstrator has been developed in the laboratory of TAU. The requirements are quite straightforward from the robotic manipulation point of view, as the objective is to feed the fish (fillets and steaks) into the conveyor of a packaging machine with uniform frequency, depending on the machine availability. The objects handled are frozen fish which behave as rigid objects (predictable physical properties and behavior), making traditional robot manipulation approaches to be sufficient for performing the requirements of the pilot.

TAU demonstrated the capability of performing the pick and place application by utilizing the Omron Quattro 650H delta robot (Quattro 650H / HS, 2024), fitted with the Basler acA1600-60gc (acA1600-60gc, 2024) 2D camera. Furthermore, it employs a multi-modal end-effector (SMC Pneumatics, 2024), which performs pneumatic suction (for providing the lifting force) and pneumatically actuated parallel fingers (for providing support during pick and place tasks). The devices utilized in robotic system of the demonstrator can be seen in Figure 4.



**Figure 4.** The robotic system with the end-effectors and the camera

The vision system utilizes color filter segmentation (different from the solution developed in WP4, however, for internally testing the robotic system- we developed a rudimentary vision system) to identify the fish fillets and to estimate the centroids, which are the target points utilized by the end-effector to grasp the product. The results of the analyzed image with the estimated centroids can be viewed in Figure 5.



**Figure 5.** The color filter-based segmentation and centroid estimation

For demonstration purposes the fish pieces are currently stationary, and the picked products were dropped in a common bin, which is representative of the static drop off point in the conveyor of the packaging machine. The current tests have a system performance of 87%- where individual fish were properly segmented, picked and placed. The system could improve the current segmentation strategy and the design of the tool to improve the system performance.

#### **1.2.1.4 Pilot- MARELEC**

In MARELEC (chicken breast packaging pilot), **AGILEHAND**'s scope in the packaging process optimization takes place in two stages. The first phase involves bulk packaging operations performed by a delta robot, which picks up individual chicken breasts (ideally from a conveyor, but currently from a stationary surface) and places it in a box (which will be moving, but currently stationary).

The delta robot utilized for performing the bulk pick and place operation is the Quattro 650H (Quattro 650H / HS, 2024), which is fitted with an internally developed pneumatic tool mounted on the P34 platform, with individually controlled suction elements. The physical robotic setup is shown in Figure 6, and the utilized hardware is also listed. The main camera is the Basler acA1600-60gc (acA1600-60gc, 2024), which is a 2D camera generating the centroids on the chicken breast. Cameras 1 and 2 are the OAK1 model (Luxonis, 2024), and they are used to record the scene for documentation purposes. The Basler is integrated with an external workstation using the EtherNet/IP protocol, and the oak cameras are connected to the workstation using the USB protocol.

The framework for integrating the various devices across the various subsystems (vision module, robotic module, and the developed software application), will eventually be performed using the Robot Operating System (ROS) (ROS, 2024). Since the Quattro does not have official ROS support and packages for directly interfacing with the physical robot, we utilize Omron's proprietary software platform 'Automation Control Environment' (ACE) for computing the motion planning and executing it on the physical robot (ACE, 2024). The ACE environment is installed on the Industrial PC (IPC) and is integrated with the robot controller.

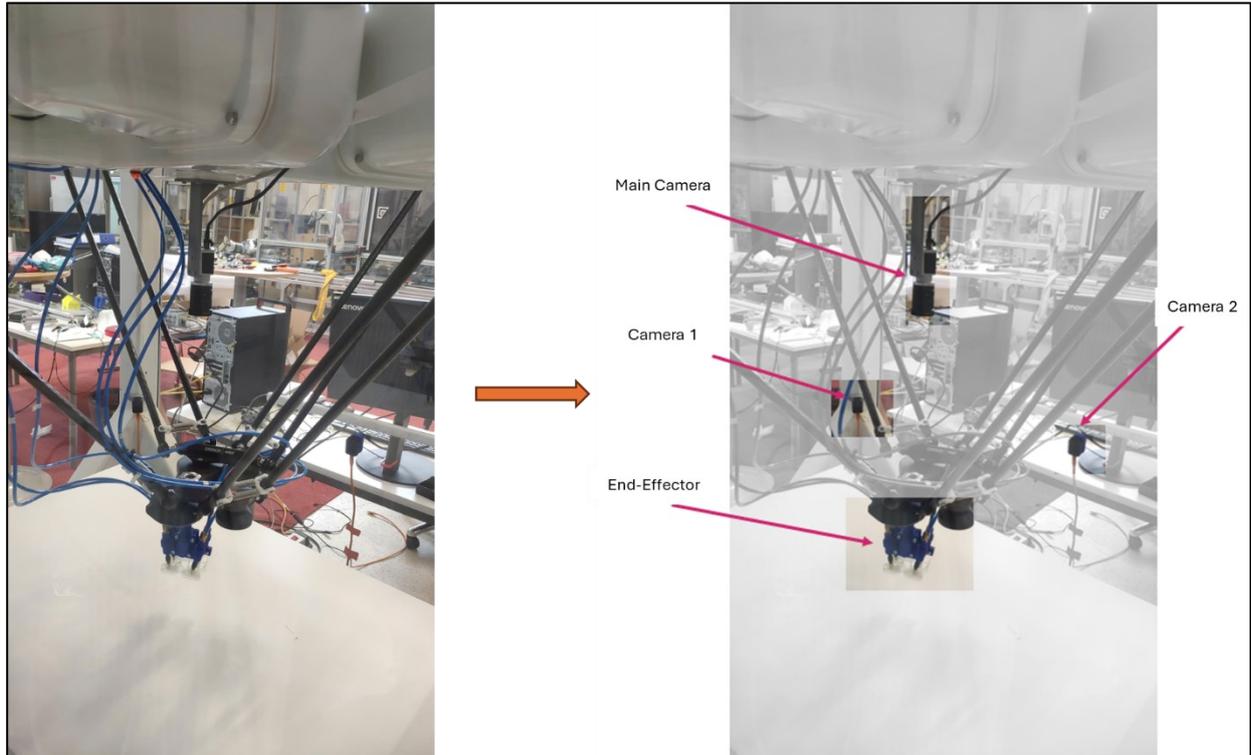


Figure 6. Delta robot hardware setup

Therefore, for the development and testing period, and because the sub-systems (delta robot and cobot) are currently isolated, we are interfacing the devices using sockets based on the TCP/IP protocol. The Figure 7 depicts a high-level visualization of the interaction and intercommunication between the various devices in the delta robot sub-system.

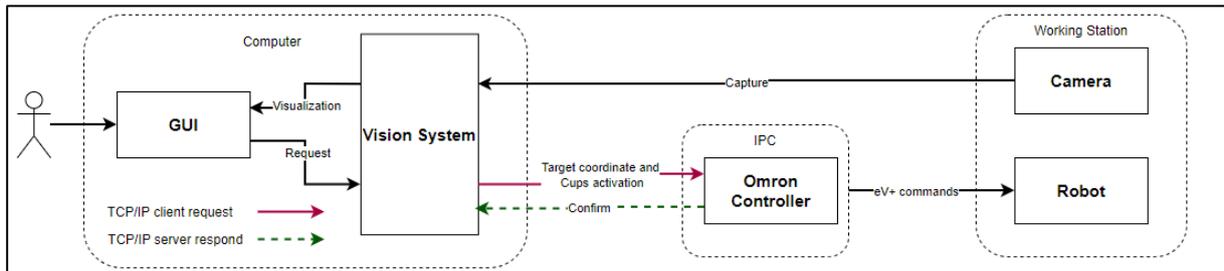
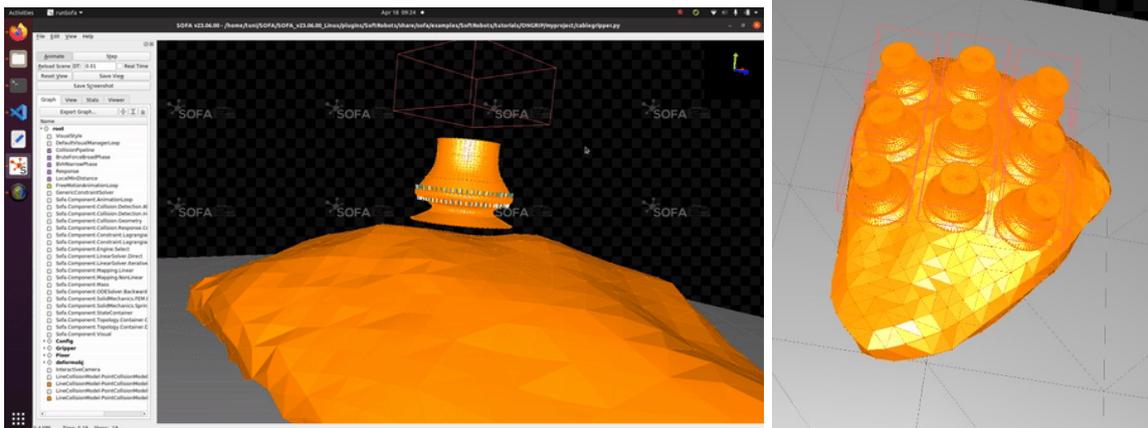


Figure 7. Systems Interaction Block Diagram

The vision system (Basler) captures the scene and utilizes color detection filters to identify the chicken breast from the background and estimate the centroid. This information is sent to the Omron controller as the robot target, which is computed and executed by the robot controller and consequently, the robot manipulator.

In addition to this, we are modeling the physical and mathematical properties of the chicken breast in a virtual environment, to perform necessary tests in simulation to observe the behavior of the chicken breasts. The simulation environment that we identified is SOFA (SOFA , 2024), which is an interactive mechanical simulation environment for biomechanics and robotics, the SOFA environment also enables training models for performing Reinforcement Learning (RL).



**Figure 8.** Simulation on SOFA for the chicken breast

However, we need to measure and quantify the various mechanical properties of the chicken breasts, for working with the specific plugin “SofaViscoElastic” on SOFA. These quantities include the Youngs Moduli  $E_i$ , Relaxation times  $\tau_i$ , and the Poisson Ratio  $\nu$ . However, due to the anisotropic property of the chicken breasts, these quantities are difficult to physically measure, and we are relying on an external organization to quantify these values for us.

As we were facing difficulties with setting up a virtual simulation, we proceeded to improve the pick and place process along with the product flipping using RL, but with physical iterations. The system specifications will be updated in the next deliverable (D5.2), after proper dissemination of the results in the form of a patent and publications.

## 1.2.2 Future Implementation

### 1.2.2.1 Pilot- MULTISCAN

UPV will be working on improving the speed of the process. To achieve that, a single point placing operation will be used. A ramp, allowing the product to roll out of the way will be installed. UPV will also make tests with tomatoes to see how many ppm are possible to get, without damaging the product, as it is more fragile than oranges. UPV is waiting for MULTISCAN to validate to layout to adapt to their equipment.

### 1.2.2.2 Pilot- SANT'ORSOLA

In the future, the depth estimation part of the computer vision module must be completed in order to be able to complete all the tasks to be turned over. Once this is done, we enter a phase of testing and fine-tuning the computer vision system and fruit extraction.

In addition, we need to create the production line for the flipping machine system, either by adding diverters or by replicating the computer vision and extraction fruit modules, in order to carry out the actual installation of the flipping machine and evaluate its operation.

Finally, we have to study and create the filling station with an integrated weighing system.

### **1.2.2.3 Pilot- PRODUMAR**

TAU will be receiving the ACOPOS 6D (ACOPOS 6D, 2024) conveyor system from B&R to demonstrate moving fish pieces. Furthermore, it would update the vision-based product classification and tracking system by integrating the pick and place sub-system to the vision pipeline developed by FBK. The end-effector design also requires some upgrades, as the footprint of the current tool is quite large, and it would cause collisions with the fish pieces which are lying close to each other.

We will finalize the exact scope of the final demonstrator and the feasibility to build a demonstrator for PRODUMAR.

### **1.2.2.4 Pilot- MARELEC**

Currently, the development of the vision system utilizes a 2D camera, with grade A quality chicken breasts to identify the centroid and the target coordinate for the robot. In the coming months, the vision system developed in WP4 to classify, track, and provide the target coordinates will be integrated with the delta robot station. Furthermore, TAU will be employing the ACOPOS 6D (ACOPOS 6D, 2024) conveyor from B&R, which will be operating on the principle of magnetic levitation. The delta robot station will also be integrated with the cobot station.

Discussions are ongoing with the pilot company to build their demonstrators. We suggest using near-identical hardware for robots and cobot manipulation.

## 2. AGILEHAND Collaborative Robot (CR<sup>HAND</sup>)

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### 2.1 Overview

**AGILEHAND** aims at developing cobot solutions where the process optimization is implemented in a shared space on the work floor, including manipulators and human workers. This includes the development of collaborative (working together with human workers) solutions and standalone (cobot performing the operations independently) solutions, to perform product handling tasks along the various stages of production.

The solutions development for the OER also involves the development of dedicated tooling, compatible with cobots, while attempting to offset the slow cycle times of contemporary cobots. The cobot stations are dependent on product information such as location, product category, etc. which is provided in advance by MV solutions developed in WP4. In addition to this, MV solutions are developed in WP5 to provide process feedback in real-time to augment the cobot manipulation.

This section will focus on the solution developers' progress with developing cobot platforms for addressing the requirements of the relevant pilots, while developing their own tooling and sensor feedback approach.

### 2.2 Implementation Status

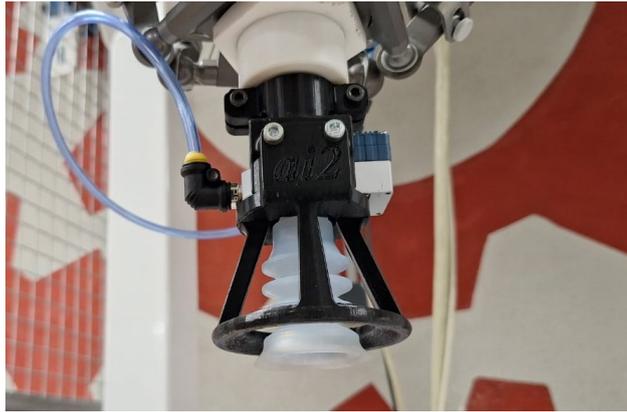
The pilot requirements and the exact phases in the production processes to be optimized were identified and finalized, through dedicated workshops and pilot visits from March 2023 to March 2024. These workshops and pilot visits helped narrow down the scope of the solutions to be implemented and identify most the critical challenges to be addressed. Furthermore, it helps to identify the logistics and the main partner responsible for being the solutions developer for a given pilot. The scopes of the pilots were identified, however, as mentioned earlier not all pilots require the same TRLs of developed technologies across all the OERs, and this sub-section will reflect that.

#### 2.2.1 Current Implementation

This section describes how the implementation of Collaborative Robots in the pilots was defined, and how the various solution developers have progressed with the demonstrator.

##### 2.2.1.1 MULTISCAN

Currently, UPV is working on the optimization of the picking process of the oranges. For that, the first step was to create a robust gripper, able to grasp the oranges in a fast and reliable way. The gripper developed is using a vacuum pump and a stopper to avoid any unwanted vibration during fast operations, see Figure 9.



**Figure 9.** Suction end-effector for orange picking

The actual setup has fixed positions, but the goal is to measure the maximal speed achievable. The actual speed is 60 pieces per minutes, but the goal is to improve that by 10ppm.

Moreover, a gripper made to grab tomatoes has been developed, using a compliant mechanism to avoid damaging the tomatoes.

### **2.2.1.2 SANT'ORSOLA**

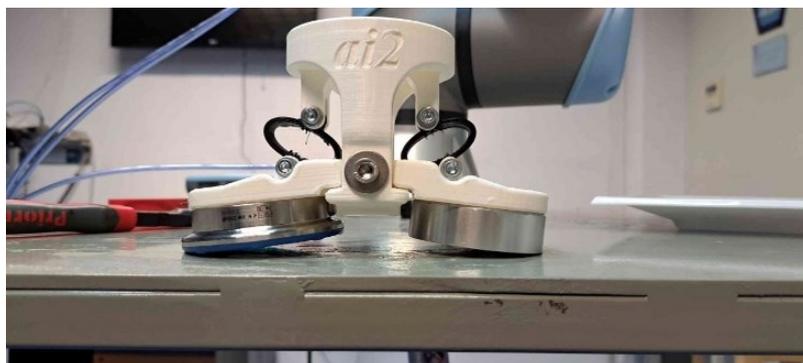
Initially, the project defined the use of a collaborative robot, which could extract the target fruit without causing damage to the surrounding fruit.

This was successfully implemented, using a tray tracking function, based on determining the speed of the conveyor belt with an encoder and identifying the tray with a photocell trig.

The collaborative robot tracks the target fruit and as soon as it engages the target it performs a pick-in in which the fruit is sucked in, then performs a pick-out to exit the tray with the tool.

### **2.2.1.3 PRODUMAR**

UPV developed two new grippers for the PRODUMAR pilot. The first one is a gripper containing 2 Bernoulli grippers (see Figure 10).

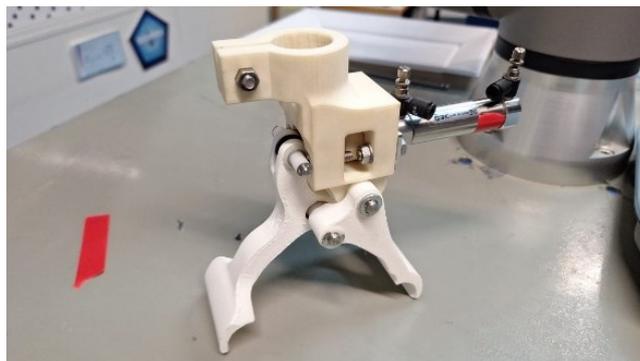


**Figure 10.** Bernoulli grippers for fish grasping

However, this setup brings a new issue. Each Bernoulli gripper can lift a small fish steak on its own, but due to the gripper configuration, the gripper unsticks to the big fishes. The springs, seen in black, put the gripper back to the original position, which is slightly angled. This feature has been implemented to have a fixed position during fast robot movement and avoid vibration of the Bernoulli grippers.

However, the springs are too strong and create an opposite force of the suction force. Because of that, the gripper can't lay flat on the surface without the robot pushing towards the fish. Therefore, during movement, the fish unsticks from the gripper and falls.

We also created another gripper, working with a pneumatic system, as seen in **Figure 11**.



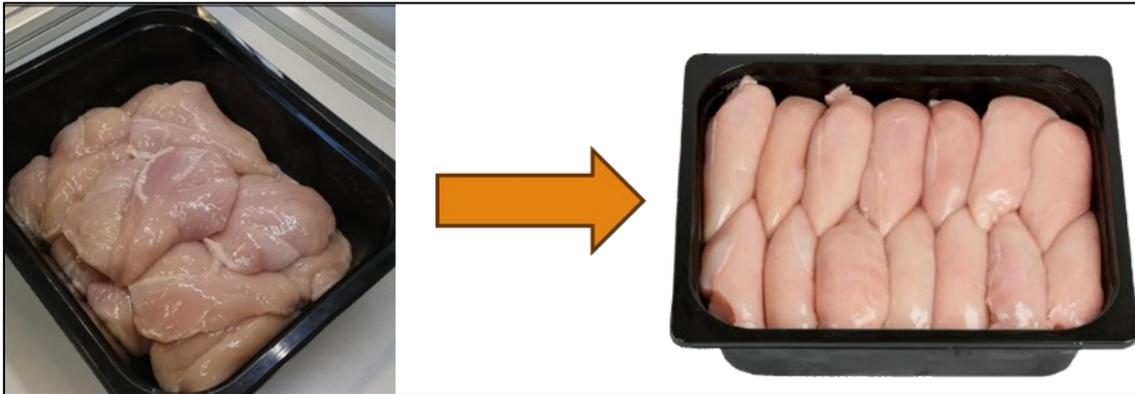
**Figure 11.** Pneumatic end-effector for fish grasping

This gripper also has a flaw that the opening range is too small for some of the fishes produced. It can grip smaller fishes with uneven gripping surfaces, due to a degree of freedom around the gripper axis. Our goal is to work on a new grip that has a wider range of opening.

TAU has developed a multi-modal gripper for PRODUMAR which utilizes the pneumatic parallel gripper SMC mh2-12d2-x636 (SMC Pneumatics, 2024) as the major body, which has two fingers attached to it. The gripper adapter also has provisions to mount a single suction cup. The suction cup is utilized to provide the lifting force necessary to grasp and hold the object, while the parallel fingers are utilized to hold the product in place while it is being moved around. The end-effector is shown in Figure 4.

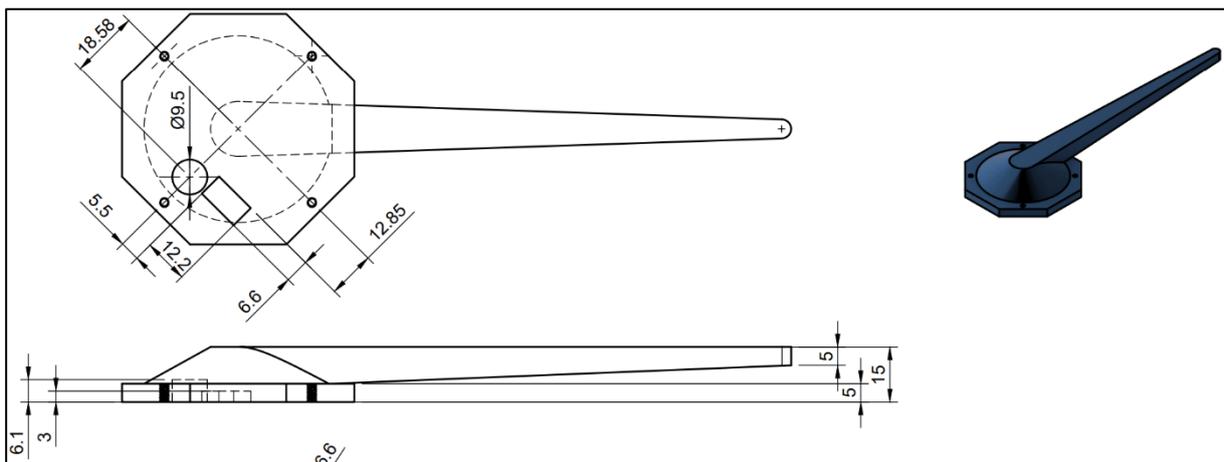
#### **2.2.1.4 MARELEC**

The cobot solution developed at the solution developers' end is intended to perform the final adjustments and beautification operations, on the top layer of the chicken breasts. The cobot station is the final stage (check Figure 17 to see an illustration of the whole system) of the solution proposed. The Figure 12 represents an example of the initial state of the chicken breast's layout and the ideal end condition which is currently being arranged by human workers.



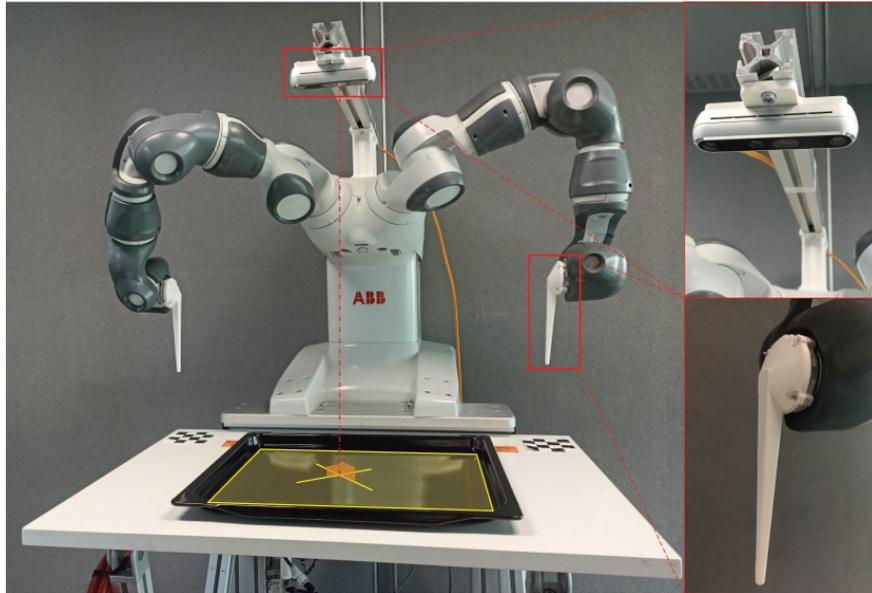
**Figure 12.** Initial state of chicken breasts (left) and expected final state of chicken breasts (right)

The cobot used to build the preliminary solution is the Dual arm YuMi – IRB 14000 (Dual-arm YuMi- IRB 14000, 2024), fitted with passive end-effectors that are similar in appearance and functionality to chopsticks. These passive-type end-effectors were selected for their low physical footprint (enabling easy entry between overlapping pieces of chicken), hygiene and ease of cleaning, and reduced overall cycle times as the tool does not need additional time for actuation (Figure 13 showcases the tooling used by the cobot).



**Figure 13.** Chopstick end-effector design used on the YuMi

Furthermore, we use feedforward and feedback information from a local vision system, which uses the RealSense D455 camera (Intel RealSense Depth Camera D455, 2024) to collect RGB and depth data of the individual chicken breast (current advancement). The current workstation is shown in Figure 14, and there is no conveyor setup integrated yet.



**Figure 14.** Cobot Station uses the chopstick end-effectors and RealSense camera

Currently, the cobot platform has developed reliably executable motion primitives (Rotation and Translation), for manipulating individual viscoelastic objects having biological muscle tissues. An image processing algorithm was developed to define sub-centroids and a theoretical ‘As rigid as Possible’ zone, which is the point at which the chicken breast stops deforming with an external stimulus and starts behaving like a rigid object. The object’s final position can be given as the target condition to be reached and the result is verified using Intersection over Union (IOU), centroid error, and orientation deviation metrics. Further details regarding the manipulation primitives can be seen here: <https://www.youtube.com/watch?v=LrDr1uEfs58>. The proposed manipulation primitive yielded consistently positive results and can be seen from the image. A summary of the performance of the system and the measured performance metrics are presented in Table 1, which shows reasonable values, thereby increasing confidence in the system. A journal article has been submitted to the IEEE journal- Robotics and Automation Letters (RA-L), entitled “*Bimanual Motion Primitives for Manipulating 3D Deformable Objects having Biological Tissues on a Planar Surface with Passive End-effectors*”.

**Table 1.** Summary of Quantitative Experiment Results on chicken breasts (180 experiments) and pork loin steaks (36 experiments)

Evaluation Metrics		Quantitative Experiments			
		Translation		Rotation	
		Chicken	Pork	Chicken	Pork
IoU (%)	min.	69.07	73.81	71.78	73.47
	avg.	85.46	79.02	83.81	83.49
	max.	94.70	90.02	93.29	92.47
Centroid Error (mm)	min.	1.50	1.02	0.60	0.70
	avg.	5.49	6.13	4.11	5.08
	max.	13.50	10.04	11.80	9.90
Orientation Deviation (°)	min.	0.03	0.97	0.35	0.47
	avg.	6.39	3.52	7.42	3.98
	max.	23.72	8.26	21.84	8.80

An additional instance segmentation pipeline was developed to enable real-time identification of the various instances of chicken breasts. To effectively arrange the chicken breasts inside the package, it is necessary to identify the different instances. TAU has trained a YOLO-v8 Deep-Learning model to accomplish this task. Additionally, alternative dataset generation techniques have been explored to reduce the burden of capturing and annotating large amounts of chicken breast images. These techniques include: i) crawling internet images of chicken breasts, ii) a semi-automatic annotation tool, and iii) the synthetic generation of chicken breast images. This last approach leverages the power of the Blender computer graphics software to generate photorealistic scenes and Python to apply random variations on the generated images. All these developments have been presented at APM&JAS 2024 conference, in the paper entitled: “*Exploring Dataset Generation Methods for Instance Segmentation: Application for Stacked Meat Products*”. We will update further details regarding the results, once we have published the results in the relevant journals.

## 2.2.2 Future Implementation

### 2.2.2.1 MULTISCAN

UPV is working on the optimization of the movement, to try to upgrade the process and make it viable. We are doing tests and new optimizations of the path to get better results. We will film the process in slow motion to try to find at which point we could optimize further.

### 2.2.2.2 SANT'ORSOLA

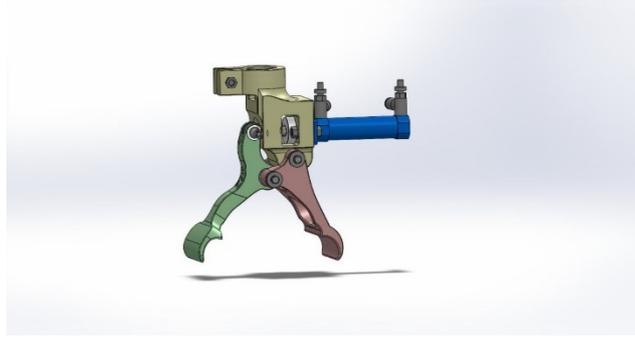
Currently, we are able to extract the fruit on the moving punnet by knowing the coordinates of the target inside it. But we do not have tests on a tray full of raspberries, checking that they are not damaged by the extraction process.

So in the future we should perform real tests, this is possible to do accurately when we would have accurate information from the computer vision module, also this will allow us to verify the motion and vacuumer check systems that we have implemented in order to have a verification of the correct execution; this is to simulate the quality control process.

### 2.2.2.3 PRODUMAR

UPV is now working on developing two new grippers, based on the flaws of the first ones. First, the new Bernoulli gripper will have weaker springs, and an equilibrium position that is flat, so that the return force of the spring doesn't act against the suction force.

Also, UPV is working on a new pneumatic gripper, that will have a wider range of motion, to pick bigger fish. The freedom axis will also be redesigned to adapt better to uneven surfaces, to avoid losing the fish during the movement, see Figure 15.

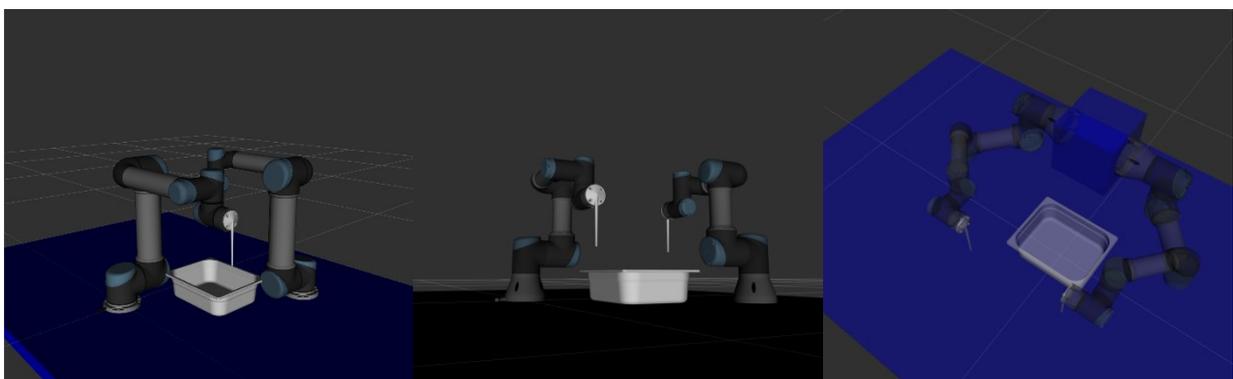


**Figure 15.** New gripper design

TAU will incorporate the designs made by UPV in their robot solution and conduct the necessary tests to evaluate their performance, especially to grasp fillets and the fish pieces which are close to each other. Another research area to be evaluated is the selection of the most optimal product to be picked by utilizing a vision-based application, developed with FBK, to determine in real time the most suitable product which can be picked- with minimal damage to the tooling and the piece. Furthermore, corrective robotic manipulation could be performed to move some pieces around to create more space for the tool to enter.

#### **2.2.2.4 MARELEC**

The developed primitives, which currently handle individual pieces of chicken on a flat surface will be extended- to handle multiple (adjacent) chicken breasts on an uneven surface. Furthermore, the solution will be extended to work with chicken breasts on a moving conveyor, and it will be integrated with the delta robot station which performs the bulk packaging operation. Coordination effort is also ongoing with the pilot company, to set up a physical demonstrator on their premise. The idea is to recreate a similar setup with a delta robot and a dual-armed cobot station to perform the bulk packaging and beautification. We have been making reachability tests with UR3s and UR5s with several configurations (as shown in Figure 16). We must test the setup with UR10s (UR10e, 2024) as these are the cobots easily available for rent.



**Figure 16.** Reachability tests conducted with different URs, with different configurations

## 3. AGILEHAND Robot-Robot (RR<sup>HAND</sup>)

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### 3.1 Overview

**AGILEHAND** aims to develop solutions that are hardware-agnostic, which could be integrated across similar production lines and effectively communicate with the existing machinery present in those production lines. This OER deals with developing guidelines for integrating the developed solutions with the existing machinery, regardless of the framework being utilized by the individual solutions developers. Furthermore, this OER will eventually handle the necessary integration of solutions developed in tasks across WP4, WP5, and WP6, to be utilized across the various stages of the production process and optimization.

This section will describe and document the work done in collecting the hardware information of the equipment used by the pilots and the solutions developers. It will also present the expected hardware to be utilized by the demonstrators built in the pilot premises towards the end of the project.

### 3.2 Implementation Status

Two surveys were conducted across the lifecycle of the project, till the current date, for all the pilot companies and the solution developers. The objective of the surveys was to document the hardware (actuators and sensors), input/output datatypes of their system, existing frameworks for integration and control, the availability of documentation and virtual models, and any issues faced with the hardware.

The first survey was conducted in October 2023, which was a bit premature for the solutions developers, especially since WP5 had just begun 3 months prior. Therefore, a second follow-up survey was conducted in September 2024 which provided more realistic information. Now the implementation status will be analyzed and in the final year of the project (when the demonstrators will be built at the pilots' location), suggestions will be made for the intercommunication and integration of the various devices and the control elements.

#### 3.2.1 Current Implementation

The link to surveys is provided below, however, the participant response contains confidential information which we can provide to the EU commission as a separate attachment, if requested.

The link to the survey conducted in September 2023: <https://forms.office.com/e/yYKcswKHij>

The link to the survey conducted in October 2024: <https://forms.office.com/e/YH7qdpSGiU>

##### 3.2.1.1 MULTISCAN

The solution UPV has created uses a list of hardware as:

- **ABB IRB340 Delta robot**
- **Vacuum ejector (VTM-20BA)**
- **3D printed stopper to secure the oranges**
- **Rolls sent by Multiscan**

We don't have an exact setup at the moment as we are still waiting for Multiscan's answer on this point.

### **3.2.1.2 SANT'ORSOLA**

The solution we have implemented for the fruit extraction module at present is several hardware components cooperating together to enable the system to function properly, a list at this time is:

- **Collaborative Robot OmronTM12**
- **several normal and fiber optic photocells**
- **vacuum sensor (pressure difference sensor)**
- **conveyor belt with its setup (motors, encoders, plc, etc.)**

The components of the flipping machine, which will also include photocells and high sensors, must be added to the list above, and we are currently also considering the use of either diverters to select the trays to be flipped or an on/off door to close and open the trays for flipping.

### **3.2.1.3 PRODUMAR**

The solution developed in TAU for PRODUMAR involves a delta robot, which receives the target coordinate of the fish steak/fillet to be picked from the MV system (developed in WP4). It then places the product on the conveyor line, which is part of the packaging machine. However, since we do not have access to the specific equipment related information from PRODUMAR, we are demonstrating their application in the laboratory of TAU.

Hardware utilized to build the first iteration of the demonstrator for the pilot in the solution developer's (TAU) premises:

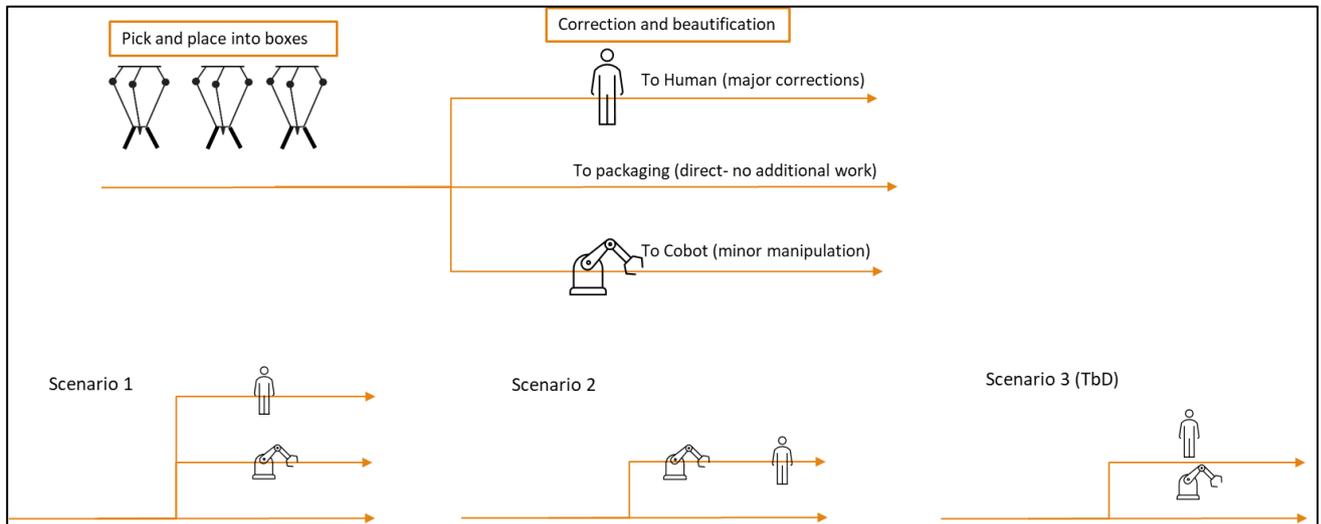
- **Delta robot to be utilized** – Omron Quattro S650H with P34 platform
- **Conveyor setup** – ABB ACOPOS 6D (to be physically installed in January 2025)
- **Cameras** – Basler camera (Quattro for centroid estimation); OAK-1 camera (capturing the scene); and RealSense D455 (used with the YuMi for centroid and depth estimation)
- **End effectors** – Multi-modal end-effector utilizing a food grade SMC suction cup and the pneumatic mh2-12d2-x636 parallel gripper.

### **3.2.1.4 MARELEC**

The developed solution will utilize delta robots for performing the bulk pick and place operation of placing the chicken breasts into the dedicated packaging box, with approximately 2 layers.

Then along the production line, there will be a dual arm cobot that performs minor adjustments to the top layer of the chicken breasts to beautify it and increase the visual appeal of the product to the end consumer.

The Figure 17 depicts a high-level schematic of the



**Figure 17.** A high-level overview of the process flow in chicken breast packaging

Hardware utilized to build the first iteration of the demonstrator for the pilot in the solution developer's (TAU) premises:

- **Delta robot to be utilized** – Omron Quattro S650H with P34 platform
- **Dual arm cobot setup** – ABB YuMi IRB - 14000
- **Conveyor setup** – ABB ACOPOS 6D (to be physically installed in January 2025)
- **Cameras** – Basler camera (Quattro for centroid estimation); OAK-1 camera (capturing the scene); and RealSense D455 (used with the YuMi for centroid and depth estimation)
- **End effectors** – Specialized end-effectors developed in-house. Quattro uses an I/O actuated multi-node suction cup; YuMi utilizes passive chopstick-like structures.

The delta robot and the cobot solutions are currently not integrated and are developed as standalone solutions, for the time being. ROS is the framework utilized for integrating the various subsystems, operating as the middleware communicating between the devices and across the various sub-systems.

## 3.2.2 Future Implementation

### 3.2.2.1 MULTISCAN

We are going to change the placing hardware, which is rollers at the moment, into a different solution, as a slope, to make the oranges naturally move out of the way, or rotating rollers, to also make the oranges move out of the way.

### **3.2.2.2 SANT'ORSOLA**

In the future we plan to integrate the hardware devices we currently have with conveyor belts leading to the flipping machine and the filling station.

We will need to add modules for sorting the trays into the correct conveyor belt in case we decide to use a loop to control the bottom layer. If we decide to maintain a sequential line without a recirculation loop, which involves installing two computer vision and extraction fruit modules sequentially, we will not need the deviators but will replicate the same hardware mentioned in the previous section.

### **3.2.2.3 PRODUMAR**

Currently, there is not any demonstrator planned in PRODUMAR premises. The technical innovation is minimal from the point of view of WP5, as it essentially involves a robot performing pick and place of a rigid (frozen fish) product, utilizing the location information provided by the MV system developed in WP4.

### **3.2.2.4 MARELEC**

The demonstrator is in the process of being finalized, for implementation in an actual production line. The hardware to be procured (rented) is being finalized by TAU and MARELEC. The equipment is being rented, as the infrastructure is currently unavailable in MARELEC premises and the idea is to utilize the most similar hardware, to recreate the demonstrator on the pilot side.

- **Delta robot to be utilized** – To be Decided (discussion in progress with renting company)
- **Dual arm cobot setup** – 2 x UR10 cobots (simulation pending)
- **Conveyor setup** – A VFD-controlled conveyor setup available
- **Cameras** – To be decided
- **End effectors** – To be decided

## 4. Conclusion

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The document presents the progress achieved in each of the OERs in the context of solutions developed for the individual pilots. The solution developers are in periodic contact with the pilot companies that they are responsible for. The final phase of the project (post D5.1) will be to finetune the developed solutions and to start building the final demonstrator at the Pilots' premise. The demonstrator for PRODUMAR will be built and showcased at TAU laboratory. And the MULTISCAN demonstrator will be showcased in the premises of UPV, as the pilot company as the pilot company is a technology developer who sells inspection and sorting machines to

food processing entities. The future steps are also specified for each OERs addressing the situation for each pilot. There will be emphasis placed on developing the required visualization of KPIs for each demonstrator, based on the template provided by the partners KBZ through WP3. Furthermore, the solutions developed will be attempting to comply with the ISO 22000 standard, which deals with ensuring food safety management across the production process.

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