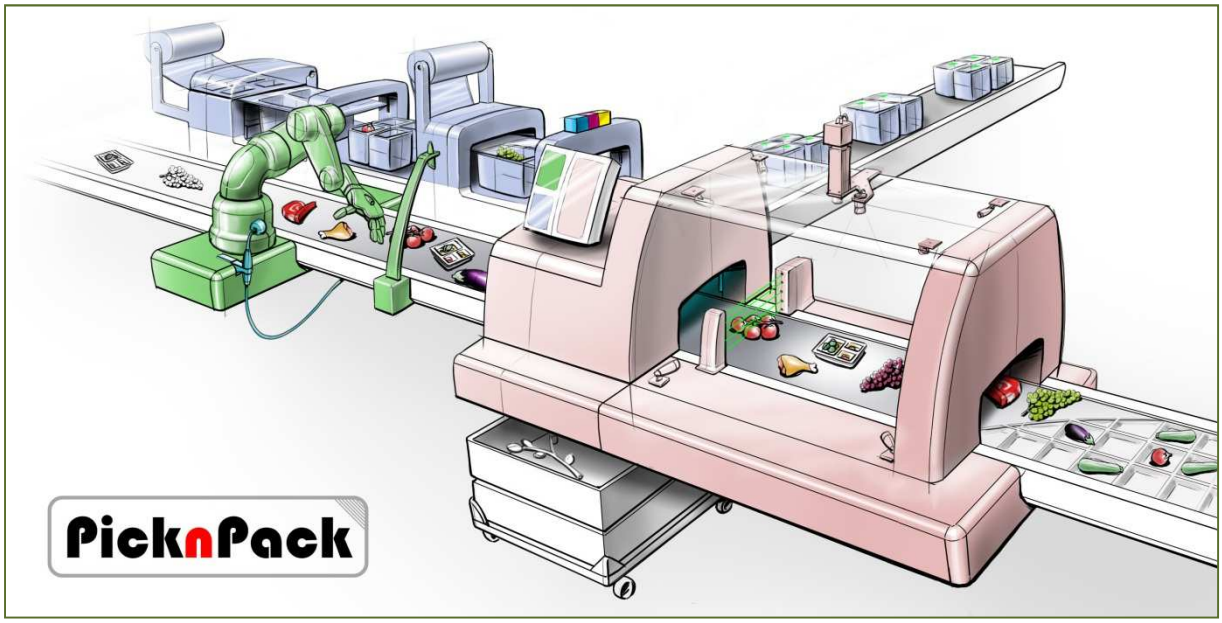
D5.1 – Report on system requirements

Version 1.1

Tecnalia

1/31/2013



Flexible robotic systems for automated adaptive packaging of fresh and processed food products

The research leading to these results has received funding from the European Union Seventh Framework Programme under grant agreement n° 311987.

Dissemination level		
PU	Public	X
PR	Restricted to other programme participants (including the EC Services)	
RE	Restricted to a group specified by the consortium (including the EC Services)	
CO	Confidential, only for members of the consortium (including the EC Services)	

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1 CONSTRAINTS

All WP5 partners have done and sent to all project partners a questionnaire to fulfil the necessary information for the definition of robotic module specifications.

The structure of the questionnaire is divided into two parts:

- The constraints listed by WP5 partners related their knowledge and equipment.
- The feedback of the rest of the PicknPack partners, related to a general description of the products, process, layout, communications, etc.

This information, combined with email exchanged and the conclusions of the issues discussed in the forum of the website have been used to define the robotic module specifications.

Below are the most relevant contributions (for more detailed information, see Annex: PicknPack Questionnaire_all_bloqued.xlsx).

1.1 Product specifications

Kind of product to be handled in each line

- **Contributions of other WP partners:**
  - Fresh food: Vine tomatoes and grapes (potentially avocados and mangos).
  - Processed food: Cottage Pie and Pizza (ingredients not defined yet)
  - See minutes of the meeting in London

Maximum weight of each kind of product [kg] Maximum weight of the gripper [kg]

- **Constraints listed by WP5 partners:**
  - Novel robot to be developed by Tecnalia: Less than 2kg of total payload
  - Available robot of Marel (Delta robot): Less than 1.5 kg for product + gripper weight below 2kg=less than 3.5kg.
- **Contributions of other WP partners:**
  - Some packages with multiple trusses of vine tomatoes go up to 1 kg.
  - It could be that an additional carrier to handle the vine tomatoes that increase the total weight.
  - Weight per truss could be between 410—710 gram.
  - Gripper weight: 1.1kg. Truss tomatoes: 0.55kg

Maximum and minimum dimensions (LxWxH) of each family samples

- **Constraints listed by WP5 partners:**
    - Novel robot to be developed by Tecnalia: Difference in height between all kind of products should not be more than 100 mm.
    - Available robot of Marel (Delta Marel Robot): Difference in height between all kind of products should not be more than 250 mm.
    - Differences in width and length should not be more than 80 mm between products during operation. For larger differences manual adaptations to the gripper are a possible solution.
- **Contributions of other WP partners:**
    - 100 mm height difference between members of the each family sample could be enough, though more is preferred. It could happen that due to product dynamics that parts of a truss are hanging and that higher elevation is needed to properly move the product. It also depends on the packaging height.
    - Pizza maximum diameter is 300mm

Shape of the products to be handled

- **Contributions of other WP partners:**
    - The vine tomatoes have dimensions in the order of 180 (length) x 110 (width) x 70 (height) mm (+- 20mm), with 5-6 tomatoes per truss. The tomatoes have a diameter of 50-60mm.
- No relevant information has been obtained for the other products.

Texture and glossiness of the objects to be handled

- **Constraints listed by WP5 partners:**
    - For glossy objects, diffuse lighting is necessary to prevent specular reflections. For low-textured objects, structured light is necessary.
- **Contributions of other WP partners:**
    - Objects will definitely be glossy. This is typical for spherical objects like tomatoes and grapes. Diffuse light will be necessary.

Graspable and non-graspable parts of each kind of product

- **Contributions of other WP partners:**

- Vine fruits will have to be picked by a combination of stem picking and power grasp on some of the fruits.

Deformability of each kind of products (i.e. Rigid or deformable)

- **Constraints listed by WP5 partners:**
  - If the product is deformable, it might change shape during transportation belt. If this is the case, the information of the sensing module (WP4) cannot be used, as it is outdated.
- **Contributions of other WP partners:**
  - The products are deformable. Shapes will change, millimetre accuracy will not be guaranteed between sensing module and handling module. The truss/vine typed products need rotation to be properly positioned in the package.

Product delicacy (max contact forces, normal and shear)

- **Contributions of other WP partners:**
  - Delicacy has to be determined by WP4 sensing. Some parameters are known on beforehand from the type of fruit and cultivar. This information should be available in the database and it must be transmitted to the robotic module.

Will the product be wet when grasped? Are they washed in the process? Additional comments

- **Contributions of other WP partners:**
  - At this moment products are not wet. Though it could be that grapevine, mango or avocado, when imported, they have to be washed before handling. Because of condensation, products might be a bit wet.

Are there substances that can clog or stick after time? (i.e. sugar, proteins…)

- **Contributions of other WP partners:**
  - Yes. Occasionally tomatoes will have cracks or bursts through which juice comes out. These have to be removed from the belt by the handling unit. Also loose parts of stems are in the surroundings of the tomatoes.

Necessary actions to pick and place each kind of products (grasping/scooping/pouring)

- **Constraints listed by WP5 partners:**
  - The vine fruits will need to be grasped. The peas and carrots for the cottage pie need to be scooped (spooned).
- **Contributions of other WP partners:**

- Different actions will be required. We still have to visit the factory where they produce the ready meals in UK. That will give more information on the composition and construction of the ready meals.

Individual or multiple picking for each kind of product. If multiple picking, how many products per picking?

Contributions of other WP partners:

- Multiple picks should be possible. To get the correct weight in the package most of the time one vine / truss is put in the package, and an additional single product is added to reach the right weight.
- In this process, trusses are cut in smaller pieces to get to the appropriate weight. It would be great if our robot could do that, but perhaps outside the scope of this project.
- The robotic module will not cut products to obtain the right weight. It is outside the scope of this project.

1.2 Process specifications

Required picks per minutes for each kind of product

- **Constraints listed by WP5 partners:**
  - Less than 30 picks/minute
- **Contributions of other WP partners:**
  - In the function diagrams being developed in WP7 the number of picks of 30 products per minute is consider as a fixed requirement.

Conveyor tracking or fixed grasping point (conveyor step by step)?

- **Constraints listed by WP5 partners:**
  - Preferable step by step. Advantages of step by step are that it makes the grasping somewhat easier. Disadvantages are that the product might change shape during (de-) acceleration. Furthermore, in the sensing module, we need a continuous movement, as the hyper-spectral camera and the 3D laser-triangulation sensor scan line by line.
- **Contributions of other WP partners:**
  - We go and aim for conveyor tracking. Continuous movement is preferred for a smooth stable product flow. Most system suppliers use conveyor tracking nowadays and we have to show that our systems can work in a continuous workflow.

Product orientation

- **Constraints listed by WP5 partners:**
    - Tecnalia and Marel robots have 4 degrees of freedom (X, Y, Z and Zº (vertical picking)). So, the product could arrive to the robot module face up, horizontally (shortest dimension vertically i.e. Z-direction), and 360º in Z.
- **Contributions of other WP partners:**
    - 4 DOF is minimum. Probably more is required to reach a good grip quality and to properly insert the vine fruit into the package. Though that extra DOF could be inserted in the gripper, and not in the robot arm.

Minimal distance between products [x,y] mm?

- **Contributions of other WP partners:**
    - The smaller the better. Though, the gripper determines the minimum distance. If distance is larger, belt speed will increase. You should tell to us what the minimum distance should be. We can determine the belt speed and we know how to put the products on the belt at the beginning of the line.

Is visual evaluation of the success of the pick and place action necessary?

- **Constraints listed by WP5 partners:**
    - If so, additional methods (and potentially hardware) need to be implemented to check whether the object has been picked and placed successfully.
- **Contributions of other WP partners:**
    - Yes it is. The sensing module checks the subassembly of the product, and for the ready meals, the packed product. I think that visual evaluation in the handling area is required to determine the success rate and control the process.
    - Grasp success can potentially also be sensed with a (touch) sensor in the gripper.

Is it necessary to localize objects for collision-free path planning?

- **Constraints listed by WP5 partners:**
    - It is too hard to implement an online collision-free path planning. It is like an entire project. So, we assume that the working area of the robot module is free of unexpected objects.
    - Fully agree. However, something basic to avoid collision of the product with the package is necessary.
- **Contributions of other WP partners:**

- Fully Agree

Accuracy necessary to pick and place the object (x,y,z) mm

- **Constraints listed by WP5 partners:**
  - If very precise, open-loop control might not be sufficiently accurate and visual servoing is necessary to guide the gripper with visual feedback.
  - Conveyer belt has typical accuracy of +/-1mm, repeatability of +/-1mm over the full speed range up to 200mm/sec and +/- 1.5mm up to 800mm/sec ".
  - Robots have typical accuracy of +/-1mm, repeatability of +/-1mm over the full speed range
- **Contributions of other WP partners:**
  - 1mm accuracy is fine. I propose to use visual servoing for handling, as the product changes of shape when it is elevated from the belt (think of lifting a grapevine truss or a truss of tomatoes). Some go hanging when you lift; visual information is required to properly position it in the package.

Pick operation: Is there a conveyor with one product at a time, or are there several products in parallel? Which is the picking sequence?

- **Contributions of other WP partners:**
  - Sorting to achieve the desired weight will not be carried out during this project, because it needs a lot more hardware and space.
  - There are products in parallel. It could be that large trusses are placed on one side, and smaller parts on the other side to put correct weights in one package. Same counts for the ready meals. Different products will be on the belt.

Place operation: Is visual inspection necessary to check correct packaging? Will the robotic module put all the products in the same position and the packaging system will put it in the appropriate tray and position? Or will the packaging system send to the robotic module the point and orientation to place the product in the appropriate tray?

- **Constraints listed by WP5 partners:**
  - The information of the position to place the product should be sent by packaging module and the visual guidance sense should not sense that place position.
- **Contributions of other WP partners:**
  - The trays to put the product majority will only have one compartment.
  - Packaging must be max. 300 x 300 x H mm.

- I need to ask for in the coordination. I think just now the best solution will be that WP6 are present two places in the PicknPack line. First we produce a tray unit working as follows: 1. Plastic film on a roll, 2. Ink-jet printing direct on the un-formed film, 3. Thermo forming (decoration and active inks must be changed after the floating index). After a section open for filling in food components the tray is ready for sealing/cutting unit. The filling area can be with trays still un-cut or already cut in the first unit. The last unit 1. Print first the top film, 2. Seal the tray and top film, 3. cut the package, 4. Inspect integrity.

What is the minimum required opening and closing times for the gripping operation? (seg)

- Not relevant information has been obtained.

Are there any additional functions required during the time that the product is inside the gripper?

- **Contributions of other WP partners:**
  - Try to develop a method to measure the firmness of the fresh fruit
  - Possibly, the mass will be measured in the QAS-module instead of during the grasping.

Maximum cost and power consumption

- **Contributions of other WP partners:**
  - It would be interesting to establish an emissions target based on the energy consumption of the machine.

1.3 Layout

Complete draft of the layout including all the peripherals on the food processing

- **Contributions of other WP partners:**
  - There is a difference in layout between the fresh fruit line and the processed foods line. For the fresh fruit, the QAS-module is before the robotic handling, but for the processed food, the QAS-module is behind the robotic handling. This is something that has to be confirmed by the coordinator of the project.
  - This is not known yet

Detailed layout and dimensions of the robot picking area

- **Constraints listed by WP5 partners:**
  - Novel robot to be developed by Tecnalia: Range less than 1200mm X-Y
  - Available robot of Marel: Range of 1250mm X-Y
  - The width of the conveyor belt is desired to be less than 300mm. A smaller belt requires a smaller field of view, which increases the resolution and thus the accuracy.
- **Contributions of other WP partners:**
  - Pizzas have typically a diameter of 300mm, so 300mm for the conveyor belt is a little bit small.

Constraints on the workspace of the robot

- **Constraints listed by WP5 partners:**
  - We are thinking of a robot with 4 Degrees of freedom. It does not have singular points, so, the workspace is a complete prism. All the points of its range could be reached.

1.4 Hygienic constraints

Materials constraints for robotic and handling module

- **Contributions of other WP partners:**
  - All articles, fittings and equipment with which food comes into contact are to be so constructed, of such materials, in good order, repair and condition, as to minimize any risk of food contamination.
  - Materials and equipment shall be selected so that, under normal or foreseeable conditions of use, they do not transfer their constituents to food in quantities which could: endanger human health or bring about an unacceptable change in the composition of the food or bring about deterioration in the organoleptic characteristics thereof.

Design constraints of food contact surfaces

- **Contributions of other WP partners:**
  - Smooth surfaces-hygienic welding, no crevices (metal to metal contact), no protrusions, no sharp corners, no dead areas, accessible for cleaning and inspection, drainability, and food grace of ancillary liquids.

Contamination constraints

- **Constraints listed by WP5 partners:**
  - It should be measured physical contamination (solid, dirt, pest), microbial contamination (Is the amount of undesirable microorganisms on the product too high for further processing?) and chemical contamination.
- **Contributions of other WP partners:**
  - The QAS-module will only measure physical contaminations. We assume that the microbial and chemical contaminations are predefined.
  - Contamination should be feedback to the operator/system. Cleaning is then required.

List of hygienic requirements for hygienic manipulation

- **Contributions of other WP partners:**
  - General requirements will be addressed and discussed in a workshop.

Automatic cleaning and or disinfection procedure? Observation of the hygienic status of the equipment?

- **Contributions of other WP partners:**

- In the system integration process we have included this as a function "Determine cleaning interval, call operator".

End effector: Change over procedure: Manual or automatic?

- **Contributions of other WP partners:**
  - Consider hygienic design criteria: Avoid sources of cross contamination (batch to batch).
  - Manual change over for mechanical parts is foreseen. Changeover procedure should take minutes, not five minutes (from grapevine to truss tomato). To change to ready meals is not required in minutes; this will be in a different factory.

1.5 Communication specifications

Communication between robot submodule and gripper

- **Contributions of other WP partners:**
  - As the gripper and the robot manipulator must work together as the same unit, communication through a centralized or clustered server configuration is not desirable. It is highly recommended to locate both controllers in the same location and also develop a deep cooperation between partners in order to facilitate the integration.

Communication between vision guidance submodule and quality/sensing module

- **Constraints listed by WP5 partners:**
  - The 3D information of the product as recorded by the sensing module can be used by the robot module if accurate high-resolution 3D information is necessary. The 3D information should be stored as either a 3D point cloud, a voxel representation, or a triangulated mesh. This information can come from both the 3D-vision unit and the X-ray sensor. Efficient communication protocols need to be used to transfer these relatively large data packages.
  - The transformation between the coordinate systems of the sensor system and the robot system need to be known. This requires a calibration phase, and information from the tick encoder of the conveyer belt.
  - WUR prefer ROS as middleware.
- **Contributions of other WP partners:**
  - Middelware definition is required. Due the quality/sensing module will be food/product oriented and It will provide semantic information, the used middelware must be compatible with the added intelligence of the system but it will be balancing flexibility and complexity. Proposed middelwares are OPC_UA and DDS, but further suggestions are accepted in this phase of the project. Further study is necessary.

Communication between robot submodule and vision guidance submodule

- **Constraints listed by WP5 partners:**
  - The vision-guidance submodule will communicate the position and orientation of the handling point in the robot coordinate system. The position is a 3D vector and the orientation of the TCP in 3D space is represented by a quaternion vector. The transformation between the coordinate systems of the vision-guidance and robot submodules need to be established through a calibration procedure.

- Additional product information relevant for the pick-and-place procedure can be communicated from vision-guidance to robot submodule, such as the weight and dimensions.
- If high-speed closed-loop control is desired, latencies in the communication between vision-guidance and robot submodule should be as low as possible.
- WUR prefer ROS as middelware
- Ethernet based protocol exists in Marel robot.
- Tecnalia development will be based on ROS (Robot Operating System).

- **Contributions of other WP partners:**
  - Middelware should respond to the specific requirements, depending on the information exchange, the requirements of this exchange can vary. If the vision guidance submodule provides information for visual servoing to the robot/gripper system, the data flow has different requirements that when the visual system gives only the initial grasping position. The proposed middelwares for the integration of PicknPack signals related with modules communications could be: ROS (Robot Operating System), OPC_UA (OPC Unified Architecture) or DDS (Data Distribution Service), but DLO input is needed.

Communication between robot submodule and quality inspection submodule

- **Constraints listed by WP5 partners:**
  - Online exchange information: Sample id (identifier with the type of product to be handled, e.g. 1: grapes, 2: tomatoes …), Quality inspection results (very good/ good/ moderate/ no good or as defined semantically), weight, dimensions and if applicable, optimal point to pick the product (to maintain the quality properties) and estimated delicacy of the picking.

- **Contributions of other WP partners:**
  - Middelware provides the signal information for the quality programmed actions, when the system detects some differences in the quality of the product require a defined action programmed in the robot. The quality inspection will have defined activities that the robot should perform when a particular situation occurs, this information should be sent to the robot controller in the shape of basic operations. The proposed middelwares for the integration of PicknPack signals related with the robot could be: ROS (Robot Operating System), OPC_UA (OPC Unified Architecture) and DDS (Data Distribution Service).

Communication between robot submodule and packaging system

- **Constraints listed by WP5 partners:**
    - Online exchange information: Location of packaging point [X,Y,Z and RZ] and Location of the rejected point [X,Y,Z] or rejected area.
- **Contributions of other WP partners:**
    - Middelware should respond to the requirements, depending on the information exchange and the capability of the robot in the activity, the requirements of this task can vary. If the packaging system is highly flexible, then the robot/gripper system needs to place properly the products inside the changing conditions. The proposed middelwares for the integration of PicknPack signals related with the robot could be: ROS (Robot Operating System), OPC_UA (OPC Unified Architecture) or DDS (Data Distribution Service), further suggestions are accepted.

Communication between robot submodule and master for working modules

- **Constraints listed by WP5 partners:**
    - Online exchange information: Working control (on/off/clean option or disinfection), Working modes (automatic/ step by step, reduced speed, 100% speed…), Speed of the conveyor (if conveyor tracking).
- **Contributions of other WP partners:**
    - The master for working modules should be very well documented and it needs to provide examples for all the module designers in order to guarantee a good flow of information. Depending on the selected middelware, each design (including the master module) must provide the required information. The robotic module will communicate with the master through the selected middelware.
    - The proposed middelwares for the integration of PicknPack signals related with the robot could be: ROS (Robot Operating System), OPC_UA (OPC Unified Architecture) or DDS (Data Distribution Service). WP2 should study the advantages of each of them and then select the most adapted to the Picknpack requirements.

Communication between robot submodule and traceability modules

- **Constraints listed by WP5 partners:**
    - Online exchange information: Is needed to sense and send information for traceability task? Which are the information and their protocol communication? (e.g. successfully handling, successfully package)
- **Contributions of other WP partners:**
    - No relevant information has been obtained.

2 REQUIREMENTS

According to the information obtained in chapter 1 “CONSTRAINTS”, each of the modules of WP5 must fulfil following requirements

2.1.1 Submodule 5.A Robotics

REQUIREMENTS	COMMENTS
Degrees of freedom	The degrees of freedom must allow grasp samples from a conveyor and place them in the packaging system.
Payload	The payload must be high enough to grasp all kind of samples (max. estimated 3 Kg).
Speed	The speed of this module must reach 30 picks per minute
Accuracy	The handling system including the visual guidance system should allow grasp samples in conveyor tracking mode.
Repeatability	Not known till analyse the behaviour of the novel robots.
Actuators	The actuators must be clean (according to food handling standards) and must me suitable for the dynamics needs of the manipulator
Kinematics configuration	To be defined by the designer to reach the rest of requirements
Robot mounted	Any configuration that could take samples from a conveyor
Envelope	To be defined according to the final layout
Environment	Electric Supply: 400V (3P+PE), I<32A Pneumatic supply: 6 Bar. Lighting: More than 500 lux. Mounting: On floor (flat and dry)
Hygienic	See table on page 18
Safety	The robotic module will fulfill following normative: EN-ISO 12100, UNE-EN ISO 13849-1, UNE-EN 60204-1, EN-ISO-TR 14121-2, EN-ISO 13857, EN –ISO 10218-1
Other	The robot must fulfil other requirements regarding to defined communication protocols and hygienic issues

2.1.2 Submodule 5.B Machine vision

REQUIREMENTS	VALUE
Machine vision	3D perception is necessary to determine the 3D position and orientation of the grasp point. A low-cost system based on the Microsoft Kinect and/or stereo vision can be used onsite to provide the necessary information. If higher-resolution 3D data is needed, the 3D sensing module developed in WP4 can be used.
Calibration	The transformation between the different submodules needs to be known through a calibration procedure. This concerns the vision system, the robot's workspace, and the sensing module if its information is used.
Picking process	The target pose of the end effector needs to be determined, based on the boundaries/surfaces of the object and taking product information into account (graspable and non-graspable parts). Depending on the weight, payload, and the gripper, it might be necessary to find the optimal grasp configuration by optimizing the (task) wrench space.
Scooping process	The target pose of the end effector needs to be determined, based on the geometry of the supply in the bin. The geometry of the supply might also determine the scooping action. The required quantity and the shape of the scoop are input as well. After scooping, the tray needs to be inspected to see if the right quantity is added to the tray. If not, additional scooping actions might be necessary.
Placing process	The food products, especially the vine fruits, will change shape during grasping and transportation. It might therefore be necessary to inspect the current state of the product prior to placing. It might be necessary to visually inspect the package to determine free space to put the ingredient.
Quality estimation	The amount of berries disconnecting from the truss is an indication of the (over)ripeness of the product. If this needs to be observed, the belt should be inspected after picking up the product
	If water leaves fruit products, it is an indication of rot. If this needs to be observed, the belt should be inspected after picking up the product

2.1.3 Submodule 5.C Equipment

REQUIREMENTS	VALUE
Conveyor width	The product must move without interferences on the conveyor. Usually 3-5 cm border on each side of the (largest) product going through is enough.
Conveyor speed	The speed of the conveyor must allow the handling module to reach 30 picks per minute. Large product inertia could limit the speed of handling.
Conveyor accuracy	The belt should allow grasp samples in conveyor tracking mode.
Buffers	Usually the upstream process is continuous (there is a steady flow of product coming into the line). To handle inconsistent flow or bursts - buffering may be needed.
Hygienic	The equipment must fulfil the requirements defined in WP8

2.1.4 Submodule 5.D Grasping

REQUIREMENTS	COMMENTS
Degrees of freedom	The gripper has multiple DOF actuated by 1 actuator for opening and closing of the gripper. Option: An extra, actuated, DOF for extra product and gripper orientation capabilities.
Mass	Total of gripper and product can't exceed 2 kg.
Payload	The gripper must be capable of handling payloads of up to 1 kg.
Moving speed	The gripper can be moved with 30 picks/min without product loss.
Opening and closing time	If product dimensions are known on forehand to have a variation of maximally 40 mm, the gripper closes and opens within 0.1 second.
Accuracy	The gripper can cope with 20 mm position accuracy. Placing accuracy therefore also has 20 mm accuracy.
Hygienic	• The gripper must be made of foodgrade materials and is cleanable with spray water. • The gripper has an open design for cleaning purposes. • Product juice does not interact with gripper material and can be easily removed.
Gripper replacing	A gripper can be manually replaced within 1 minute.
Product conditions	The gripper can cope with: • deformable products • wet products • vine products that contain a variable number of 'units'
Picking strategy	• vine products of different sizes can be combined to reach a certain container mass. The gripper can grasp vine products of different sizes and combine them in one container. • Vine tomatoes are grasped by a combination of stem picking (holding the stem) and a power grasp (holding the tomatoes on one side of the vine).

2.1.5 Submodule 5.E Hygiene

REQUIREMENTS	COMMENTS
Choice of materials of construction	All articles, fittings and equipment with which food comes into contact are to be so constructed, of such materials, in good order, repair and condition, as to minimize any risk of food contamination. Materials and equipment shall be selected so that, under normal or foreseeable conditions of use, they do not transfer their constituents to food in quantities which could: • Endanger human health or • Bring about an unacceptable change in the composition of the food or • Bring about deterioration in the organoleptic characteristics thereof.
Design constraints for food contact surfaces	• Smooth surfaces (hygienic welding) • No crevices (metal to metal contact) • No protrusions • No sharp corners • No dead areas • Accessible for cleaning and inspection • Drainability • Ancillary liquids: Food grade
Contamination constraints'	It could be measured physical contamination (solid, dirt, pest), microbial contamination (Is the amount of undesirable microorganisms) and chemical contamination.
Cleaning and / or disinfection	All articles, fittings and equipment with which food comes into contact are to be effectively cleaned and, where necessary disinfected.
Change over procedure	Consider hygienic design criteria Avoid sources of cross contamination (batch to batch)

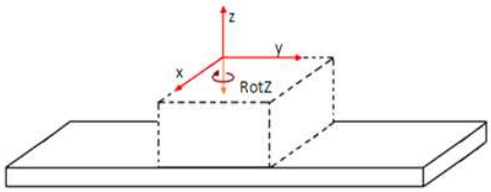
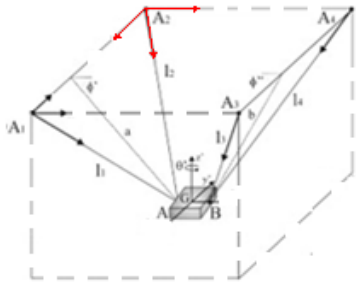
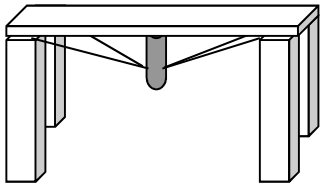
3 TECHNICAL SPECIFICATIONS FOR THE ROBOTIC MODULE

3.1.1 Submodule 5.A Robotics

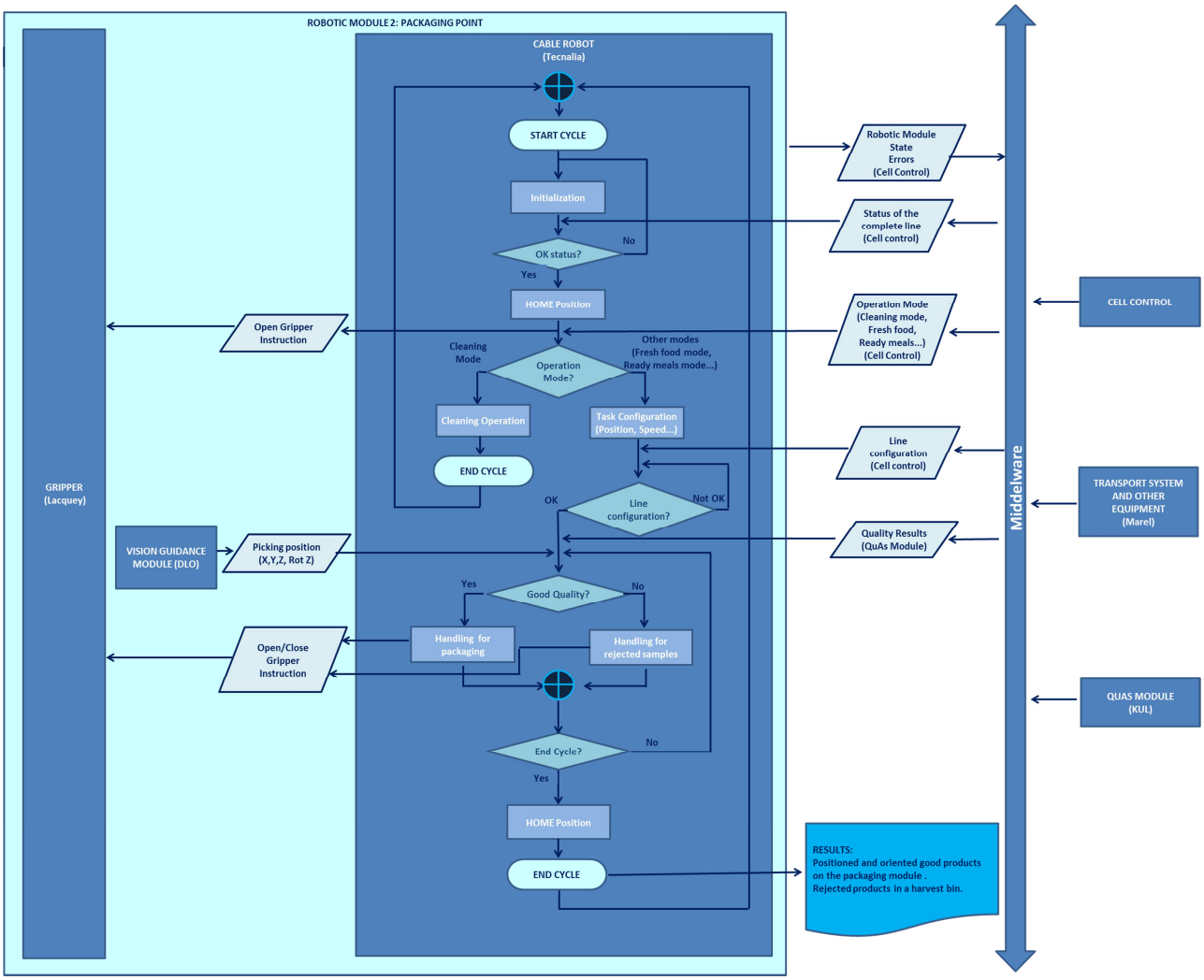
Following table includes the technical specifications that should fulfil the two robotic modules.

3.1.1.1.1 Tecnalia robot

Due to the innovative target of this EU funded project, a novel cable robot will be developed by Tecnalia for handling products, instead of buying or releasing a commercial one.

SPECIFICATION	VALUE	COMMENTS
Degrees of freedom	3 translation + 1 rotation	
Payload	1-3 Kg.	Depending on final product requirements and productivity
Speed	1 kg – 0.3 secs. 3 Kg – 0.54secs.	Standard Cycle: (25 – 300 – 25)
Accuracy	+/- 0.5 mm.	
Repeatability	-	Not known till analyse the behaviour of the first prototype
Actuators	Electrical	
Kinematics configuration	Cables for planar control of X,Y movement. Z and Rotation(z) embedded in the platform	
Robot mounted	4 pillars attached to the floor and one upper base to support the platform	
Envelope	X-Y: 1600 x 400 mm. Z: 150 mm. Rot Z: 180º	Due to the characteristics of the cable robot, its range can be easily modified
Other	Communications GUI	Regarding to these issues, the robot must fulfil the requirements defined in WP2

3.1.1.1.2 Function Scheme

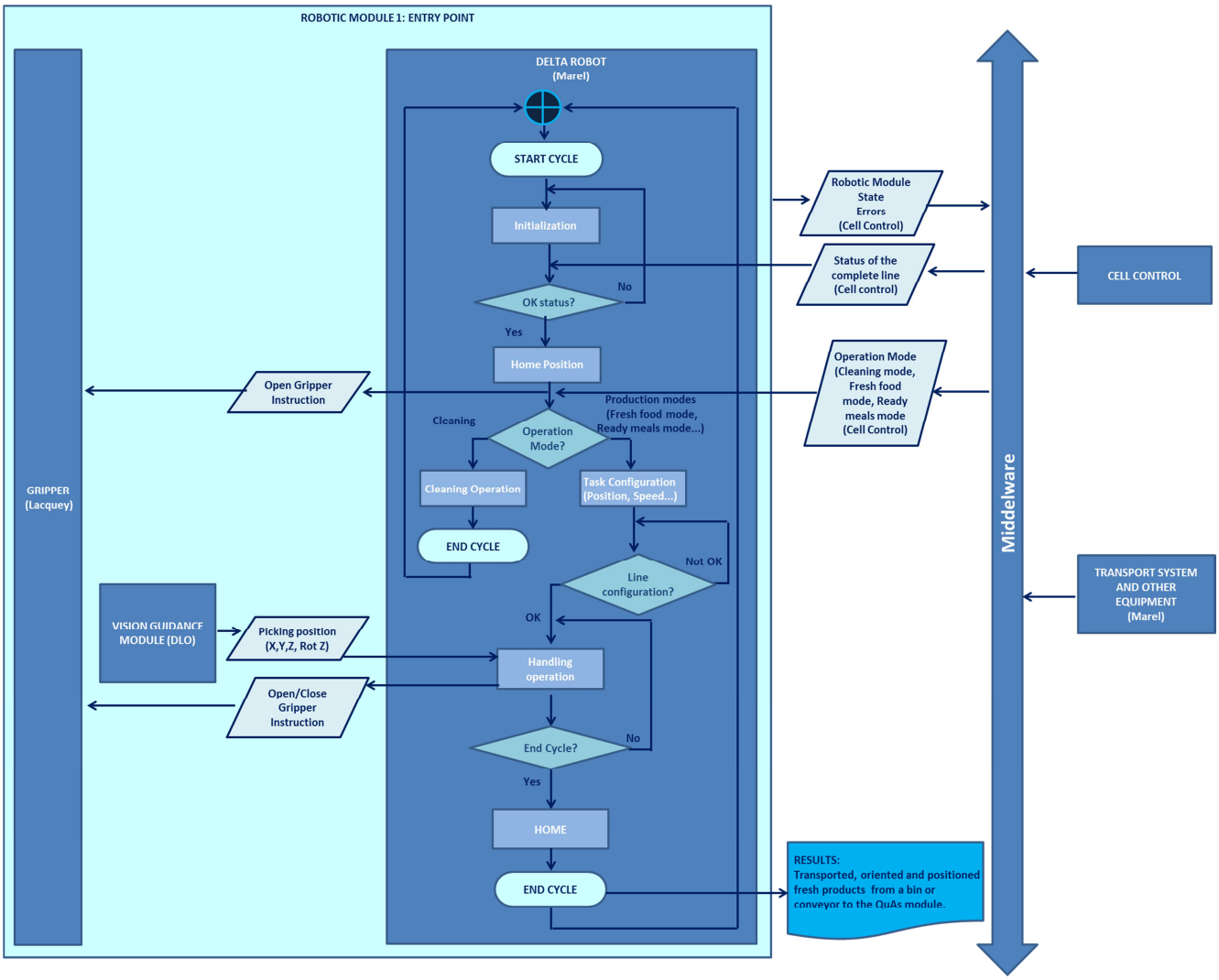


3.1.1.1.3 Marel robot

Marel will use a novel self-designed Delta robot that will test during the project.

SPECIFICATION	VALUE	COMMENTS
Degrees of freedom	4DOF: 3 translation + 1 rotation	--
Payload	Up to 3.5 Kg.	e.g. 1.5kg for product and 2Kg for gripper
Speed	Less than 100 picks per minute	Standard Cycle: 25 – 305 – 25 + 90º rotation of total load 1.2kg
Accuracy	+/-1mm over the full speed range	Not checked till analyse its behaviour
Repeatability	+/-1mm over the full speed range	Not checked till analyse its behaviour
Kinematics configuration	Delta Robot: multiple kinematic chains interconnecting the base with the end-effector.	Much stronger and more powerful rotary axis, to reach higher speed with heavier grippers
Robot mounted	Suspended	--
Envelope	X-Y: 1250 x 1250 mm. Z: 250 mm. Rot Z: 360º	--
Control and communications	Open control system on IEC standard platform for complete control over the robot. Ethernet based protocol	Regarding to this issue, the robot must fulfil the requirements defined in WP2
GUI	User friendly display for set-up and programming	--

3.1.1.1.4 Function Scheme



3.1.2 Submodule 5.B Machine vision

SPECIFICATION	VALUE	COMMENTS
Sensor positioning	Top view	Preferably, the sensor is placed right above the product, viewing downwards. If visual servoing is required or the object needs to be observed during transportation by the robot, such a view will suffer from the occlusion by the gripper, in which case different angles will be necessary.
Dimensionality	2D or 3D	If the height of the product (z-coordinate of the grasping point) is constant and know, 2D information is sufficient to guide the robot. If the height varies, 3D information is necessary.
Field of view	Kinect: 57° (h) x 43° (v), 870x650mm Stereo: depending on lenses Gocater2040: 96-194mm Gocater2050: 158-365mm Gocater2070: 308-687mm	The required field of view depends on the products size. If visual servoing is required, the field of view should be large enough to observe the complete work space. One of the Gocater sensors will be used in the sensing module. The Kinect or stereo vision will be used in the robot module.
Viewing distance	Kinect: 0.6 – 3.0m Stereo: depending on lenses Gocater2040: 0.19-0.40m Gocater2050: 0.30-0.70m Gocater2070: 0.40-0.90m	--
Spatial resolution	Kinect: 1.0-1.5 mm Gocater2040: 0.19-0.34mm Gocater2050: 0.30-0.60mm Gocater2070: 0.55-1.1mm	The necessary resolution depends on the gripper and grasping method.
Depth resolution	Kinect: 1-5 mm Stereo: 0.5-5 mm Gocater2040: 0.02-0.05mm Gocater2050: 0.025-0.09mm Gocater2070: 0.07-0.27mm	The necessary resolution depends on the gripper and grasping method. For stereo: depends on baseline, focal length and image resolution. The accuracy hugely depends on the texture of the object. NB additional noise might apply.
Synchronization	Triggering	The sensor(s) should be triggered in concurrence with the conveyer belt encoder. This is especially critical when the conveyer belt continuously moves.
Illumination	Bright, diffuse illumination	The product needs to be properly illuminated to allow high shutter speed. Diffuse lightning is necessary to prevent specular reflections and shadows. The spectrum of the light is not important.
Additional equipment	Projector (potentially)	When stereo vision is used with non-textured objects, a (pico) projector needs to be mounted to cast a light pattern on the product.

3.1.3 Submodule 5.C Equipment

SPECIFICATIONS	VALUE
Conveyor Width	Depending on product size. Typical belt widths are 300mm, 400mm, 500mm, 600 and 900 mm. Belts widths of 300mm-400mm probably will be used.
Conveyor Speed	It is a tradeoff between belt speed and distance between products. Typical belt speeds are between 200mm/sec and 800mm/sec.
Conveyor accuracy	+/- 1mm at constant speed (not accelerations / decelerations) up to 200mm/sec and +/- 1.5mm up to 800mm/sec.
Buffers	Assume singulated flow. No input/output buffers required. This could be used an infeed conveyor.

3.1.4 Submodule 5.D Grasping

SPECIFICATIONS	VALUE
DOF	• multiple DOF, 1 actuator for opening and closing • Option:1 extra DOF for orientation
Gripper mass	< 1.5 kg
Payload	< 1 kg
Gripper + payload mass	<2 kg
Moving speed	Max 30 picks/min
Opening and closing time	2 x 0.1 second, when closing distance <40 mm
Accuracy	20 mm position accuracy
Hygienic	• Foodgrade • Cleanable • Juice resistant
Gripper replacing	< 1 minute
Power supply	• Opening and closing: 220 or 24 VDC • Option extra DOF: to be determined
Control	• Motor power on: 1 x DI • Opening and closing: 1 x DI • Option extra DOF: to be determined
Mount	• ISO 9409-1-a-50 (M6 bolts) OR • ISO 9409-1-a-31.5 (M5 bolts)
Degree of protection	IP 65
Ambient temperature	Between 5 en 40 degree Celsius

3.1.5 Submodule 5.E Hygiene

REQUIREMENTS	COMMENTS
Robot hygienic requirements	• No Carbon Fibre used. • Full wash down Titanium rods
Gripper hygienic requirements	• Foodgrade • Cleanable • Juice resistant
Equipment hygienic requirements	• Sealed belt edges • Juice resistant • Cleanable
Contamination constraints'	Physical contamination (solid, dirt, pest) will be measured

4 Annex

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