

1. Operational Scenarios:

Deployment or Adaptation Phase

1. System Configurations and calibrations
2. Configure the system according to the product being used.

Operation Phase

3. Product/item detected.
4. System Start.
5. Pick Product/item.
6. Translate the product/item.
7. Place the Product/item.
8. Return to home position.
9. Stand by.
10. Emergency Stop.

1.1 Description of Operational Scenarios

<i>Deployment or Adaptation Phase</i>	<i>S1 System configuration and calibration</i>
Preconditions	<ul style="list-style-type: none">• The System should arrive at the destination of set up without any damages.• An empty space should be made available for the system set up.• The specified space should be a leveled surface.• The power supply should be available.
Triggering Event	The system should be bought by a customer.
Description	The system is bought by the customer and it is our duty to set up, configure and calibrate off-line for the customer.
Post-Conditions	The system is configured and calibrated.

<i>Operational Scenario</i>	<i>S2 Configure new product</i>
Preconditions	<ul style="list-style-type: none">• The system should be well set up.• The system should be configured and calibrated.• The product to be sorted should be labelled with QR code
Triggering Event	Dimensional analysis of product.
Description	We add new products labelled with QR code, possibly of different sizes and configure the system with new products.
Post-Conditions	Now, the product is placed on the conveyor, and it can be detected by the system.

<i>Operational Scenario</i>	<i>S3 Product/item Detected.</i>
Preconditions	<ul style="list-style-type: none"> • The power supply should be available. • The robot should be configured and ready to use. • The product/item should be on the conveyor.
Triggering Event	The product placed on the conveyor is sensed and a signal is sent that the product has arrived.
Description	The product is detected and helps to activate the system.
Post-Conditions	<ul style="list-style-type: none"> • System is started.

<i>Operational Scenario</i>	<i>S4 System Start.</i>
Preconditions	<ul style="list-style-type: none"> • The power supply should be available. • The sensors should detect the product/item.
Triggering Event	Product/item is detected in the previous scenario.
Description	Initializes the operational parameters required to complete a single cycle process.
Post-Conditions	The QR code is scanned and is then matched with the prerequisite data available in the database.

<i>Operational Scenario</i>	<i>S5 Pick Product/item.</i>
Preconditions	<ul style="list-style-type: none"> • The product/item should be within reach of the delta robot. • The weight of the product should be within the range of the robot's payload capacity. • The dimensions of the product shouldn't be the same as those of the dimensions saved in the database.
Triggering Event	The dimensions of the product/item do not match the dimensions recorded in the database.
Description	In this process the Delta robot picks up the products/items which do not match the dimensions.
Post-Conditions	<ul style="list-style-type: none"> • The product/item is picked up by the end effector ready to be translated by the bot.

<i>Operational Scenario</i>	<i>S6 Translate the product/item.</i>
Preconditions	<ul style="list-style-type: none"> • The product/item should already be held by the grippers. • It needs to be ensured that the location where the product/item is to be relocated is empty/free.
Triggering Event	The defective product/item is detected and is already picked up by the Delta Robot.
Description	This is the stage in which the product/item is transported to another location (segregated) from the main production line.
Post-Conditions	<ul style="list-style-type: none"> • The translated product is ready to be placed.

<i>Operational Scenario</i>	<i>S7 Place the Product/item.</i>
Preconditions	<ul style="list-style-type: none"> The product/item should already be translated to the desired place and ready to be placed.
Triggering Event	The Delta Robot has translated and reached the desired place where the defective piece can be placed/dropped.
Description	The Delta Robot has picked and translated (product/item) a certain distance from the main conveyer and is now ready to place the defective product/item on an empty surface.
Post-Conditions	<ul style="list-style-type: none"> The defective product has now been segregated from the main conveyer. The robot can then return to its home position.

<i>Operational Scenario</i>	<i>S8 Return to home position.</i>
Preconditions	<ul style="list-style-type: none"> All the operations involved in the completion of a single process cycle must be completed. Gripper should not have any product attached to it.
Triggering Event	Completion of a single operation cycle.
Description	This is the stage where the robot returns to its home position after completing one cycle of operation and is ready to execute the next.
Post-Conditions	<ul style="list-style-type: none"> Robot returns to home position and proceeds to go in STANDBY state after a set duration.

<i>Operational Scenario</i>	<i>S9 Stand by.</i>
Preconditions	<ul style="list-style-type: none"> There shouldn't be any products/items arriving on the conveyor for a certain duration of time. Previous cycle should have been completed
Triggering Event	Set threshold time to go into standby mode is exceeded.
Description	The Home position is maintained.
Post-Conditions	The robot in standby mode is ready for actuation in case a product is detected.

<i>Operational Scenario</i>	<i>S10 Emergency Stop.</i>
Preconditions	<ul style="list-style-type: none"> The system should be running.
Triggering Event	When the emergency switch is closed.
Description	In this scenario, irrespective of what process is running the whole system is forcefully turned off in real-time.
Post-Conditions	<ul style="list-style-type: none"> The whole system operations are suspended. The power supply to all the electrical components are cut-out.

1.2. Operational Needs from Operational Scenarios

S3 Product/item Detected:

- **ON3_1:** The system shall identify the product on the conveyor line and notify the subsequent processes about its arrival.
- **ON3_2:** The system shall be able to visually perceive and differentiate between a moving conveyor and an object on a moving conveyor.
- **ON3_3:** The response time must be instantaneous or as minimal as possible.
- **ON3_4:**

S4 System Start:

- **ON4_1:** The system shall indicate the beginning of the operation.
- **ON4_2:** The system shall transmit activation signals to all its subsystems.
- **ON4_3:** The system status shall be logged into the database for diagnostics in case of any contingency.
- **ON4_4:**

S5 Pick Product/item:

- **ON5_1:** The system shall be able to pick products of cylinder or box shape, with a maximum dimension of 5 cm^3 and a minimum dimension of 0.5 cm^3 and a maximum weight of 100 g.
- **ON5_2:** The system shall complete the pick task in less than 2 seconds. if there are no potential collisions while performing.
- **ON5_3:** The system shall pick the item safely as per ISO 14539:2000.
- **ON5_4:** The moving parts of the system shall not present any sharp edges, and the robot arm and the gripper to handle the parts shall be lightweight.

S6 Translate the product/item:

- **ON6_1:** The system shall change its position and orientation without dropping/damaging the product in the gripper.
- **ON6_2:** The system shall translate to the required location with minimal deviation.
- **ON6_3:** The system shall finish the repositioning in under 2 seconds.
- **ON6_4:**

S7 Place the Product/item:

- **ON7_1:** The system shall place the products in the desired location (whether it's a conveyor or box)
- **ON7_2:** The system shall place the product with not more than 0.05 mm of clearance between the product and the surface.
- **ON7_3:** The system shall ensure that the release of the gripper and the product being placed on the surface are nearly simultaneous.
- **ON7_4:** The system shall ensure that the entire operation takes not more than 1.5 seconds to complete and move on to the subsequent process.
- **ON7_5:** The system shall place the item safely as per ISO 14539:2000.

S8 Return to home position:

- **ON8_1:** The system shall return all actuators and the end effector back to a certain predetermined configuration (home configuration).
- **ON8_2:** The system shall ensure that no product is currently being held by the gripper, unless the emergency STOP function has been engaged.
- **ON8_3:**
- **ON8_4:**

S9 Stand by:

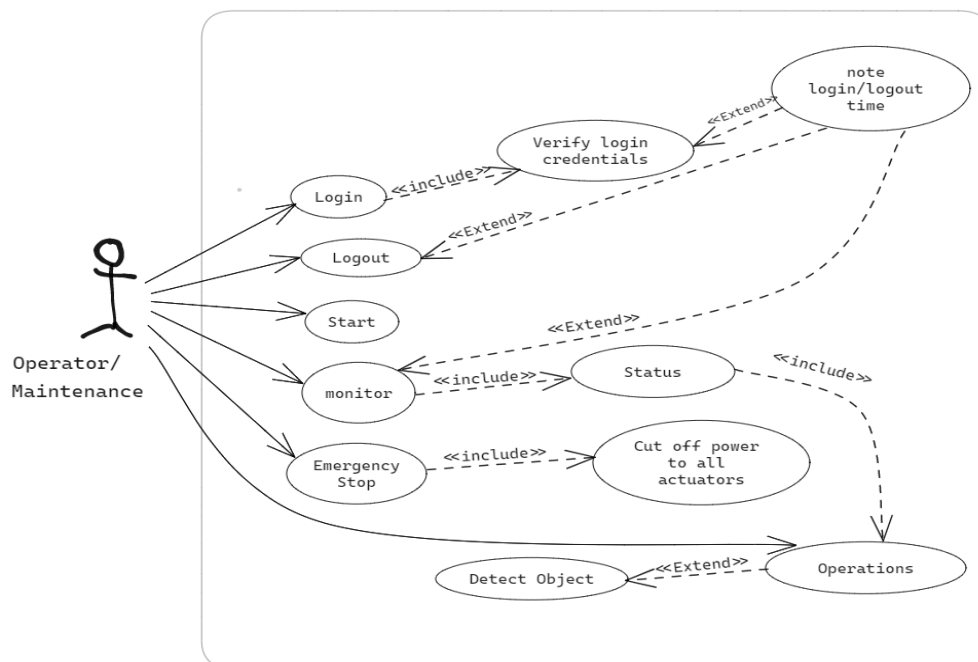
- **ON9_1:** The system shall hold the relative positioning and orientation of the actuators and the end effector in the predetermined 'Home' configuration unless indicated otherwise by any other process.
- **ON9_2:** the system shall release the actuators and end effector from the home configuration when an appropriate trigger event occurs in the system (i.e., a faulty product is identified on the main conveyor).
- **ON9_3:** The transition of actuator states from 'home' configuration to the required configuration shall happen almost instantaneously and shall not take more than 2 seconds.
- **ON9_4:**

S10 Emergency Stop:

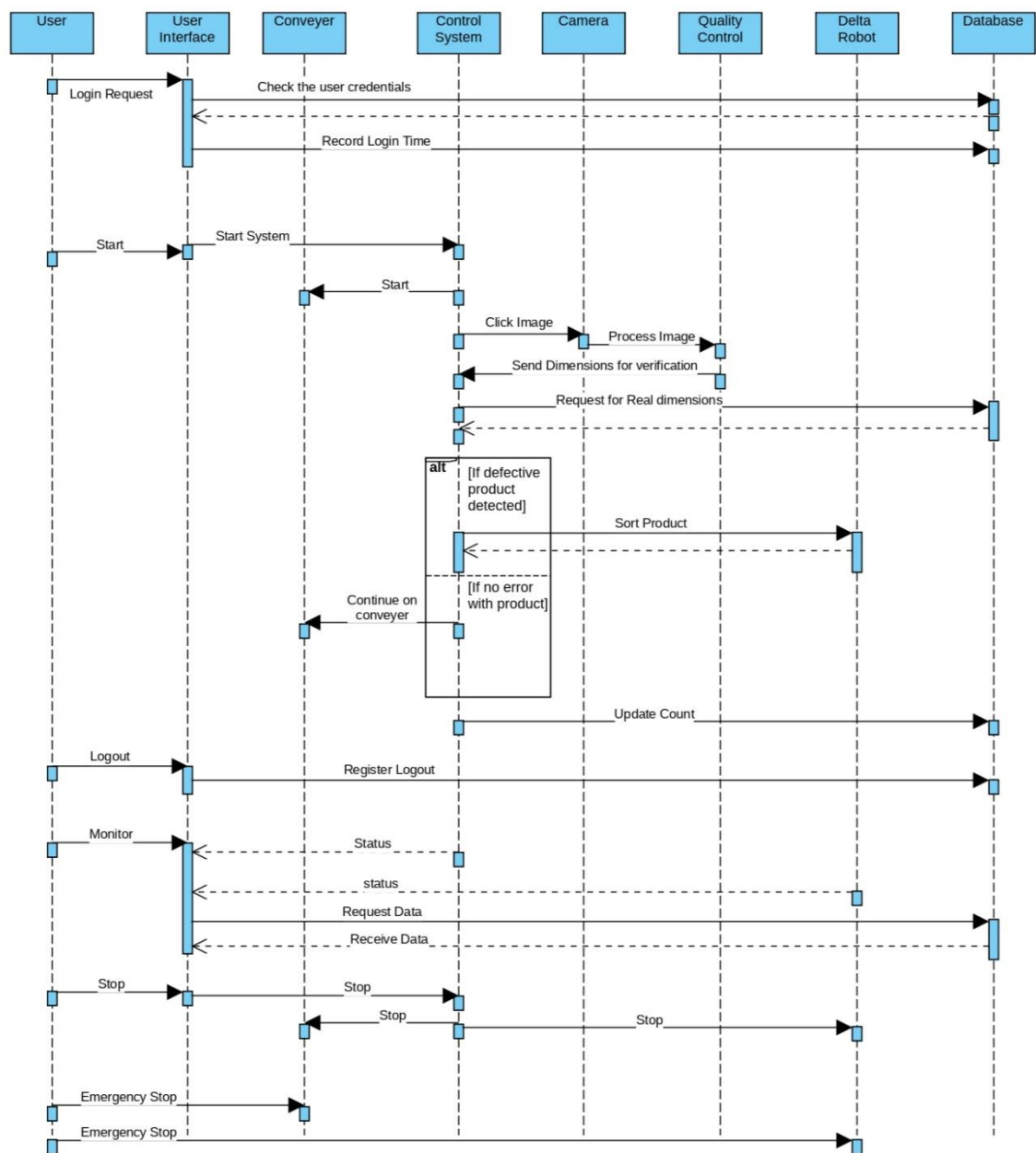
- **ON10_1:** The system shall terminate all currently ongoing operations.
- **ON10_2:** The actuators and the end effector shall halt their current actuation processes and hold their current position and orientation so as to not cause further damage.
- **ON10_3:** The state of the system shall be logged into the system as well as indicated to the operator.
- **ON10_4:** There shall be minimal delay between the trigger input and the triggering of the appropriate response. This shall not take more than 1 second.

2. UML Charts

2.1. Use Case Diagram

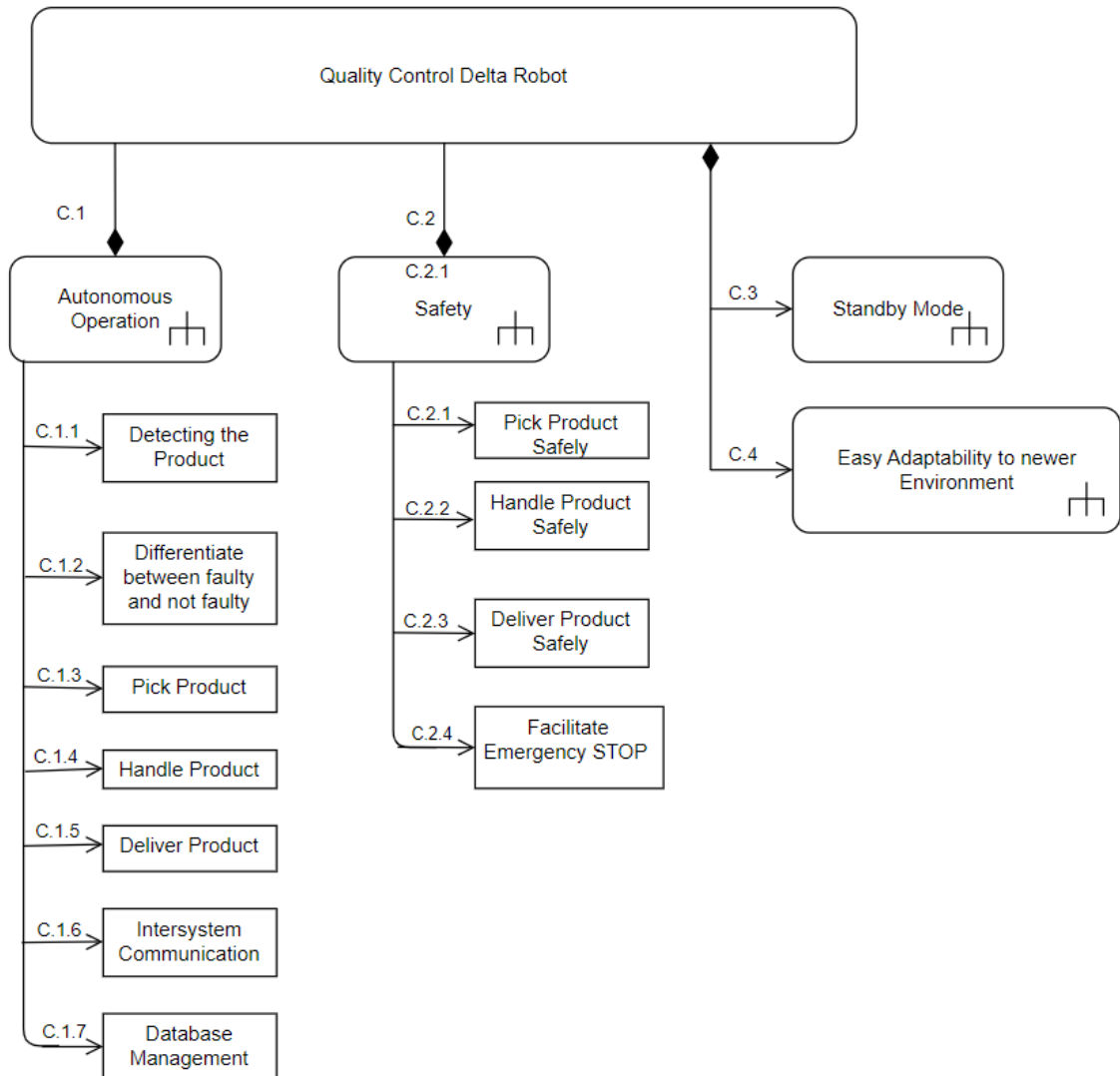


2.2. Sequence Diagram



3. Capabilities

3.1. sysML Chart



3.2. Capabilities

<i>Capability</i>	<i>Description</i>
C.1 Autonomous Operation	The robotic system should be able to identify and segregate faulty products from an ongoing production line autonomously.
C.1.1 Detecting the Product	The system should be able to detect the arrival of a product on a conveyor.
C.1.2 Differentiate between faulty and non-faulty	The system should be able to tell apart a faulty product from a conveyor line.
C.1.3 Determining the position of the product w.r.t the conveyor	The system should be able to determine the position of the product on the conveyor.

C.1.4 Pick Product	The robot can pick a product from the conveyer.
C.1.5 Handle Product	The robot can move holding any product without dropping it.
C.1.6 Deliver Product	The robot can deliver the products by placing them on to the desired location.
C.1.7 Intersystem Communication	The system should be able to communicate between the various subsystems so as to allow synchronization of processes.
C.1.8 Database Management	The system should have the ability to read, write and manipulate the database, whenever the need may arise.
C.2 Safety	The system and all its constituent subsystems must not cause harm to its surroundings with a priority to not cause any casualties to the operator.
C.2.1 Pick Product Safely	The robot picks the product while avoiding undesired collisions with any part of the product.
C.2.2 Handle Product Safely	The robot moves holding a product without losing grip on it or colliding with any obstacles.
C.2.3 Place Product Safely	The robot places the products in the desired location without inflicting any damage to the product.
C.2.4 Facilitates emergency STOP feature	In case of emergency, when indicated by the operator the system must terminate all operations instantaneously.
C.3 Standby Mode	After Initialisation or completion of an operation cycle, the system should have the ability to HOLD its position and wait for an appropriate trigger to begin operation.
C.4 Easy adaptability to newer environment	The system must be versatile enough to accommodate any work environment and operate optimally.

3.3 Traceability Matrix

Scenarios/Capabilities	C.1.1 Detecting the product	C.1.2 Differentiate between faulty and not faulty	C.1.3 Determining the position of the product w.r.t to conveyor	C.1.4 Pick Product	C.1.5 Handle Product	C.1.6 Deliver Product	C.1.7 Intersystem Communication
S1: System Configurations and calibrations							X
S2: Configure the system according to the product being used.							X
S3: ProductItem detected.	X						X
S4: System Start.		X	X				
S5: Pick ProductItem.			X	X			
S6: Translate the productItem.					X		X
S7: Place the ProductItem.						X	
S8: Return to home position.							X
S9: Stand by.							
S10: Emergency STOP							

Scenarios/Capabilities	C.1.8 Database Management	C.2.1 Pick product safely	C.2.2 Handle product safely	C.2.3 Place product safely	C.2.4 Facilitates emergency STOP feature	C.3 Stand-by Mode	C.4 Easy adaptability to newer environment
S1: System Configurations and calibrations					X		
S2: Configure the system according to the product being used.	X				X		X
S3: ProductItem detected.					X		
S4: System Start.	X				X		
S5: Pick ProductItem.		X			X		
S6: Translate the productItem.			X		X		
S7: Place the ProductItem.				X	X		
S8: Return to home position.	X				X		
S9: Stand by.					X	X	
S10: Emergency STOP					X		

3.4 High Level Functions

High level Functions	Description
Manage Operation (From C1.1, C1.2, C3)	The system plans and executes the required operation based on the product categorisation.
Calibrate (from C4)	The system must be able to operate and adjust to different environments
Pick Product (from C1.4, C2.1, C2.2)	The system must pick the product in a safe manner without damaging the product.
Translate robot (from C2.2)	The system should translate the product without colliding with its operator or immediate environment.
Place Product (from C1.6, C2.2, C2.3)	The system places the product to the required location.
Handle Contingencies (from C2.4)	The system must stop all operations immediately when indicated by the user.