DEPLOYMENT GUIDE

PALLETIZING

Workcell Design 1

Single Conveyor + Fixed Robot Mounting + Single Pallet

UNIVERSAL ROBOTS

UNIVERSAL ROBOTS

DEPLOYMENT GUIDE OVERVIEW

This application deployment guide is intended to provide users with appropriate information to assist with the deployment of Universal Robots with minimal external support. This guide has been developed based on our experiences of deploying collaborative robots and guides the user through the analysis of an existing manual process, followed by the design, deployment of a collaborative robot application to automate the task.

This guide is intended as a reference only, Universal Robots takes no responsibility as to the success or safety of the solution deployed using this guide.

This guide addresses Palletizing applications. This is the process of preparing packaged goods for transportation by stacking, in a layered pattern, on pallets. The layer patterns depend on the packaged goods dimensions, pallet dimensions, stack stability, and a user's preference. This packaging process is also known as tertiary or transportation packaging.

RECOMMENDED PREREQUISITES

Before going any further into this application deployment guide, it is recommended that you complete the following tasks to ensure you have the required knowledge to progress with the deployment:

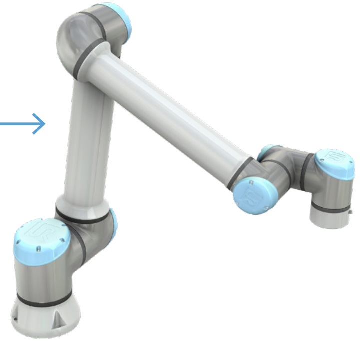
UR Academy
This free-of-charge online training course consists of a number of interactive modules to equip you with all the knowledge you need to program your first Universal Robot. The complete course is estimated to require approximately 1.5 hours to complete and is available on the UR website here:
https://www.universal-robots.com/academy/

Application Builder
This tool provides a high level overview of the configuration options for an application, providing information on each stage of a process to help the user decide on the configuration that's most suitable for them. Upon completion of the application build, the user is presented with a simulation of the application and the option to download a program template and explanation of how to use it.
https://www.universal-robots.com/builder/

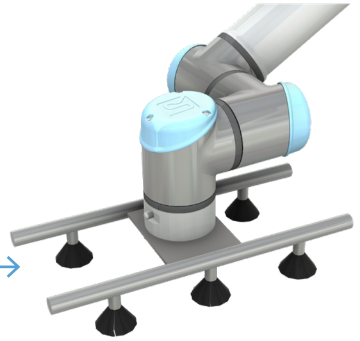
Classroom Trainings
In addition to the online resources listed above, face to face classroom trainings are available in our Universal Robots Authorized Training Centers around the world. These offer the user the option to take their knowledge of Universal Robots to the next level and potentially further reduce deployment times. Find the schedule for your nearest training center here:
https://www.universal-robots.com/academy/

GLOSSARY

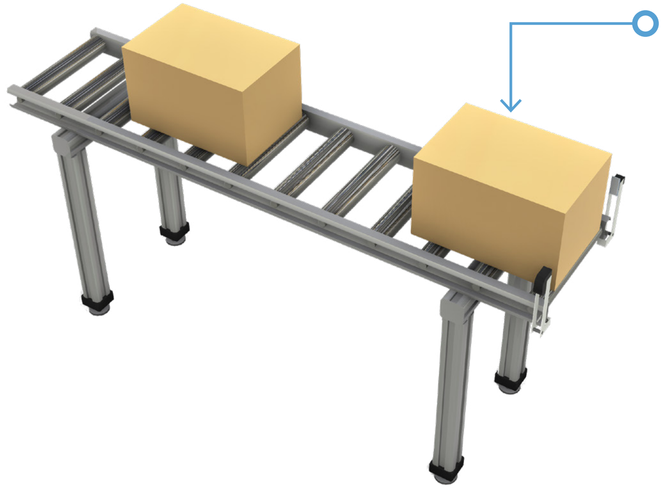
Here some of the common terms related to collaborative robot palletizing applications are introduced:



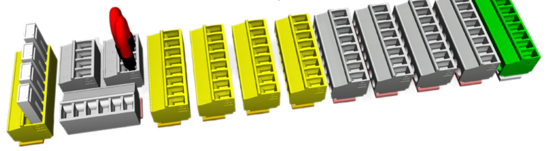
Cobot is short for Collaborative Robot – a type of Industrial Robot with features that generally make it more flexible, easier to program, safer to work around and more affordable than traditional industrial robot solutions.



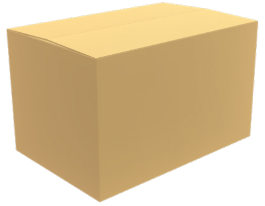
End Effector is the application specific tool mounted at the end of the robot, that interacts directly with the workpiece. This is also referred to as End of Arm Tooling (EOAT), gripper, manipulator or simply robot tool and is usually electrically or pneumatically powered



Infeed describes how the workpieces or components enter the robot process. Infeed can be manual or automated, and is generally easier to work with if the workpieces arrive in a uniform predictable position and orientation.



I/O stands for Input/Output and refers to how the robot talks to other devices. In industrial automation the term I/O usually describes discreet 24V digital signals hard wired between devices but can also refer to signals exchanged over a fieldbus such as Modbus, Profinet or Ethernet/IP.



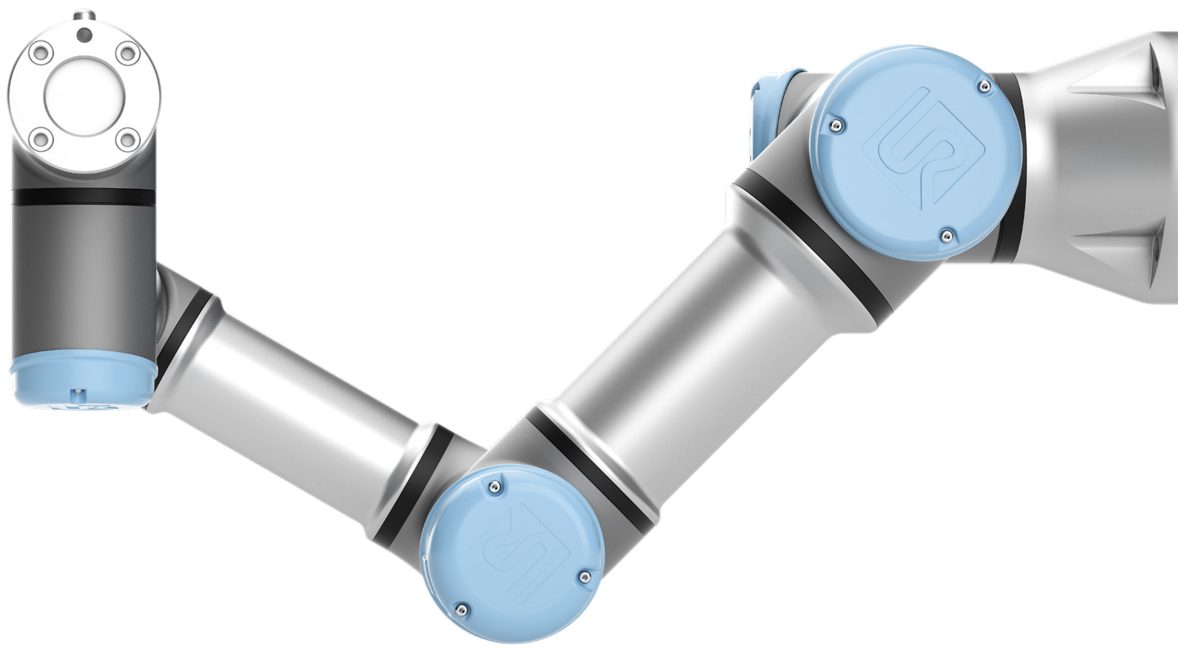
Workpiece is the object that the robot manipulates as part of the application process. In various scenarios it may also be referred to as the part, product, component, but here we'll call it a workpiece.

Pattern describes the position and orientation of an array of workpieces in the infeed or outfeed of a process. This can be a simple uniform grid or can include various product positions and orientations that give the most space efficient or stable result.

Process describes the main task that the robot completes with the workpiece once it has been fed into the workspace. In the case of a palletizing application this is the process of picking up the boxes and placing them onto the pallet in the desired pattern.

PROCESS TO AUTOMATE

The major steps required to automate a process with collaborative robots are:



ANALYSIS

A thorough analysis of the existing manual process is critical to successful development of an automated solution. All of the stages, details and potential variations in the existing process must be analyzed to ensure that the resulting solution can handle the full range of possible scenarios presented to it.

DESIGN

This stage involves identifying suitable approaches to automating the processes analysed in the first stage. Appropriate peripheral components will be selected to allow the cobot to interact with it's environment and complete the task.

DEPLOYMENT

Once the required components have all been acquired they must be integrated together to form a complete solution. This includes mechanical installations, electrical connections and programming of devices.

OPERATION

When the deployment is completed it is important to establish guidelines around the operation of the system to ensure that it runs smoothly. This will include training on running the system, minimizing downtime and extracting any required productivity data.

CURRENT PROCESS

Prior to starting the design of the automated solution, the current process must be closely observed with every small detail documented as these can be crucial to the overall success of the automation deployment.

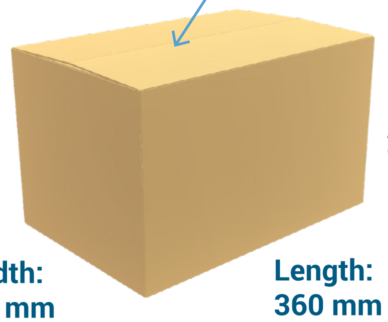
Operator Process – thoroughly analyze and record all of the actions performed by the operator to complete the task effectively and efficiently. Pay attention to all seemingly small steps that could have large impacts on the performance of the task. Record detailed specifications for product and pattern, plus any additional steps such as adding a slip-sheet between layers or applying labels to boxes.

Infeed – document how the workpiece boxes are presented to the current palletizing operation. Do they arrive on a conveyor? Are they always in the same orientation? Does the operator pick up multiple boxes at once?

Workpiece Evaluation – make a thorough analysis of the workpiece boxes being palletized. What is the size/weight of the boxes and does this change often? What type of box is picked up?

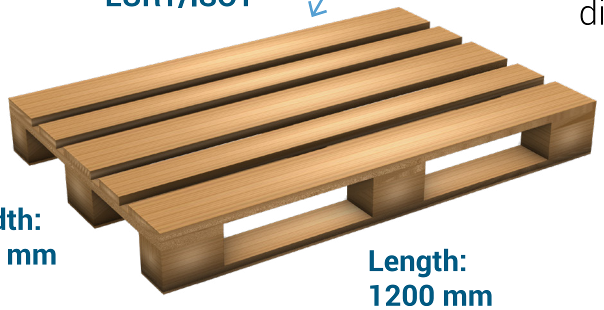
Layout – consider the layout of the key aspects of the current process. Are there any obstructions, physical constraints or obstacles within the work cell footprint? Will the automated cell occupy the same footprint, or should it be reduced if possible?

CURRENT PROCESS DETAILS



Workpiece

Record dimensions and weight of box along with any other relevant information such as orientation requirements

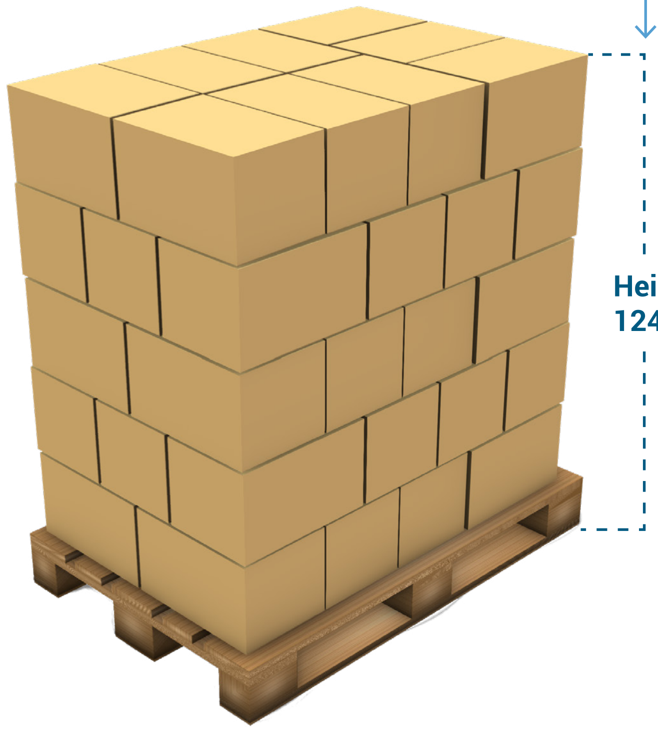


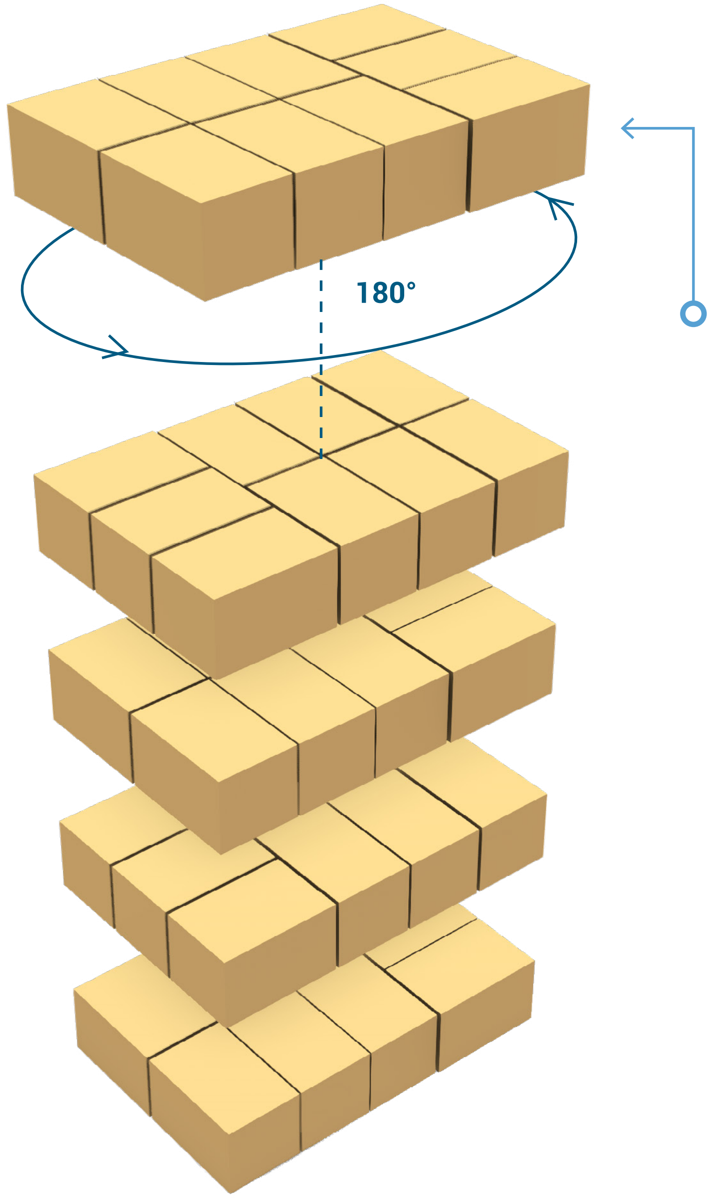
Pallet

Record type/ specifications of pallet along with dimensions

Full Pallet Height

Record the height of the full pallet once the process is complete, including height of the pallet itself and all of the layers of boxes.





Layer Pattern

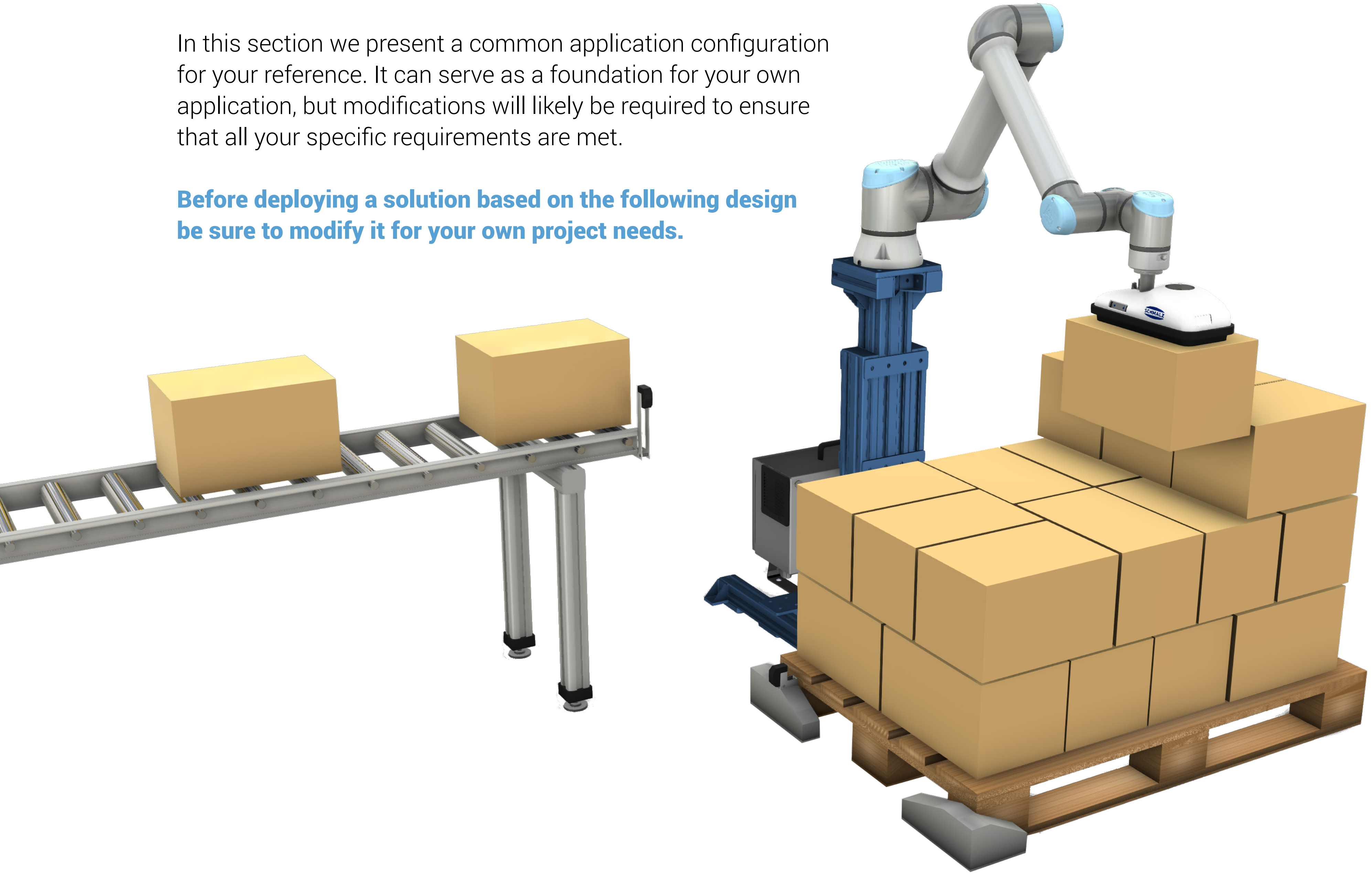
Record the number of boxes per layer, their positions/orientations, the total number of layers and any rotation between layers. These are most likely all already optimized for stability and space efficiency in the manual process and does not need to be adjusted.

WORKCELL DESIGN 1

Single Conveyor + Fixed Robot Mounting + Single Pallet

In this section we present a common application configuration for your reference. It can serve as a foundation for your own application, but modifications will likely be required to ensure that all your specific requirements are met.

Before deploying a solution based on the following design be sure to modify it for your own project needs.



List of Components

Robot: UR10e

Mounting base: VENTION designed based on height and reach requirements https://www.universal-robots.com/plus/accessories/3d-machinebuilder/

Infeed: Conveyor configuration selected based on workpiece specifications

Tool: Schmalz Vacuum Area Gripping Systems FXCB https://www.universal-robots.com/plus/end-effectors/vacuum-area-gripping-systems-fxcb/

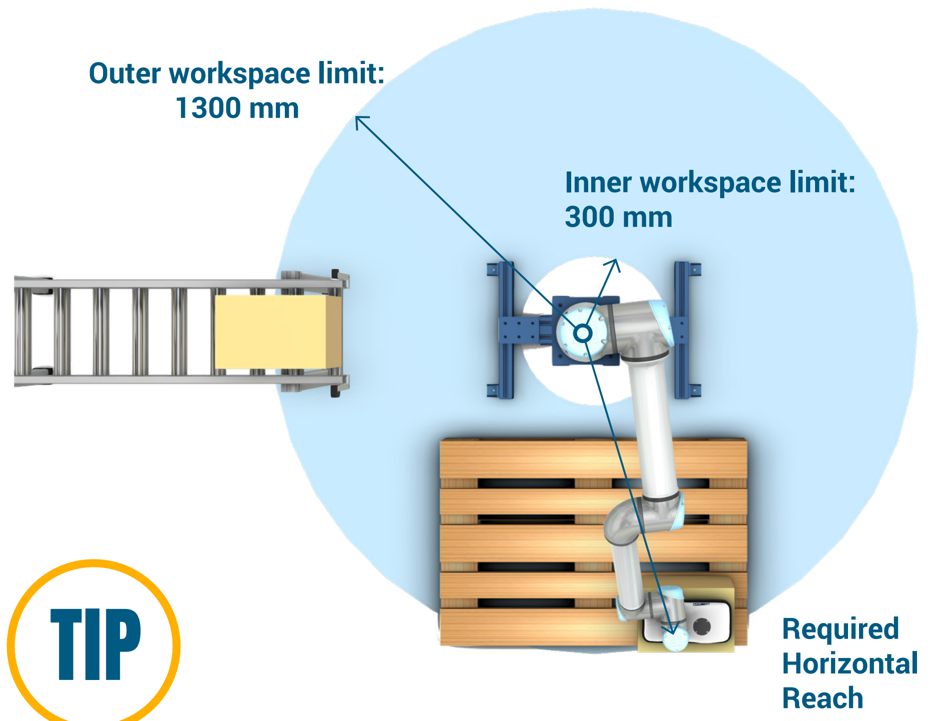
Peripheral equipment: Fixtures to locate pallet reliably, sensors to detect incoming products on infeed etc.

Cycle - 6 Boxes per minute
This cycle time estimate is based on default movement speeds generally safe for collaborative operation, and a tool engage/disengage delay of 0.5 second. Shorter cycle times are achievable but may required additional measures to ensure safe operation (see safety tips section).

WORKCELL DESIGN ①

Positioning the Robot within the Workspace

The UR10e has a working radius of 1300 mm and can reach almost any position within this space. Take this into consideration when deciding where to mount the robot within the workspace, ensuring that the infeed pick position and furthest box place positions on the pallet can be reached. It's fine for the far corners of the pallet to be outside the robot's working area if the above conditions are met.



TIP

"The Robot working Area Drawing" can be found on the UR support website
www.universal-robots.com/support/

Robot Mounting Height

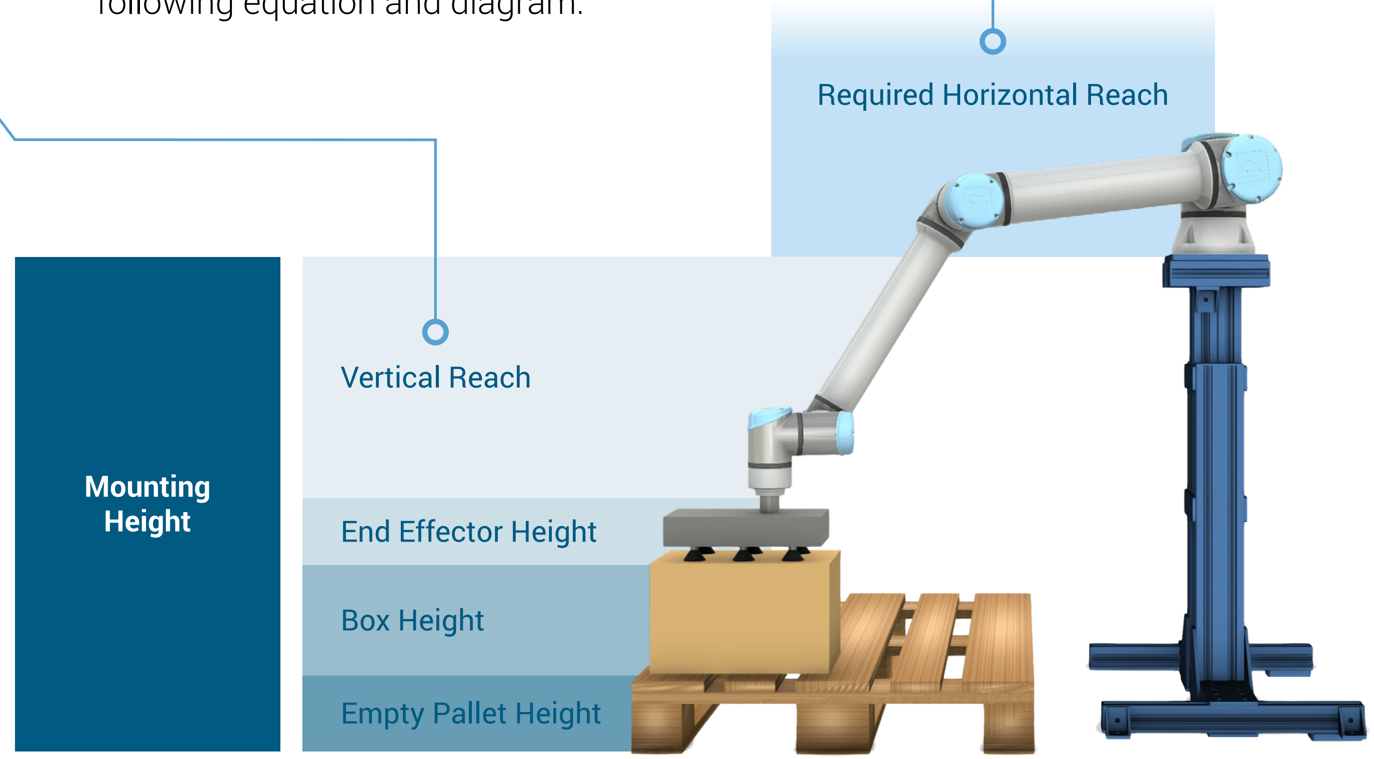
The optimal height at which to mount the robot is determined by several factors. First of all calculate the maximum required horizontal reach of the robot when placing boxes in the furthest corner of the bottom layer of the pallet. This is measured horizontally from center of robot base to center of robot tool flange. Next look up the maximum vertical reach below the robot base that is possible at that horizontal reach in the table below.

Required Horizontal Reach [mm]	Max Vertical Reach [mm]
800	850
850	800
900	750
1000	650
1050	580
1100	510
1150	425
1200	320

The optimal mounting height for the robot is then calculated using the following equation and diagram:

Empty Pallet Height
\+ Box Height
\+ End Effector Height
\+ Vertical Reach

= Mounting Height



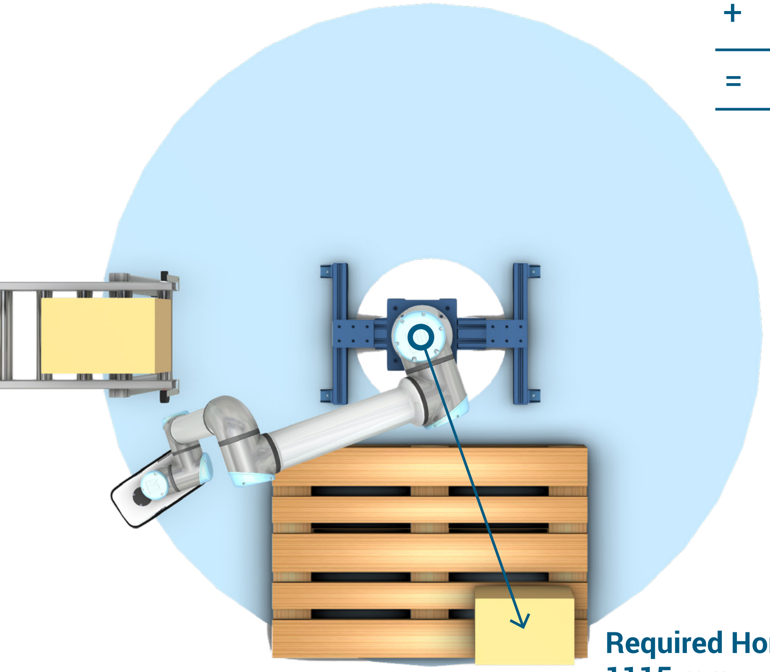
WORKCELL DESIGN 1

Robot Mounting Height Calculation Example:
Required horizontal reach for workcell design 1 is 1115 mm, we round this to 1100 mm in the lookup table that gives us a max vertical reach of **510 mm**.

Box height **220 mm** and pallet height **145 mm** are taken from the current manual process section. End effector height can be taken from product documentation or measured directly on the product. The value for the Schmalz gripper used here is **131 mm**.

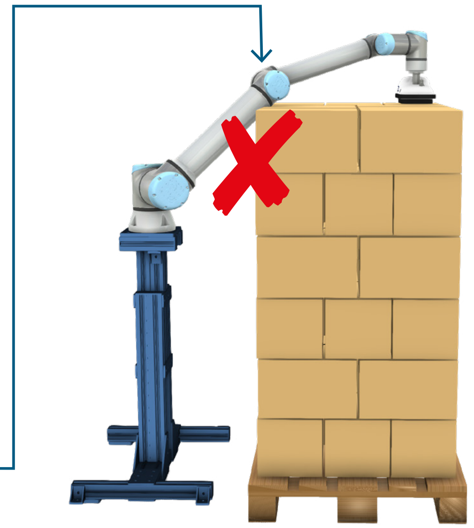
These values give us the following mounting height:

	145 mm	Empty Pallet Height
+	220 mm	Box Height
+	131mm	End Effector Height
+	510 mm	Vertical Reach
=	1006 mm	**Mounting Height**



Required Horizontal Reach: 1115 mm

Maximum Full Pallet Height
Next we calculate the how high the robot can stack the pallet while mounted at this height. If the calculated max full pallet height is less than that defined in the current process, a 7th axis will be required to expand the robot workspace (download workcell design 2 for further details). This formula also ensures that the arm itself will not collide with the stack while completing the upper layers.

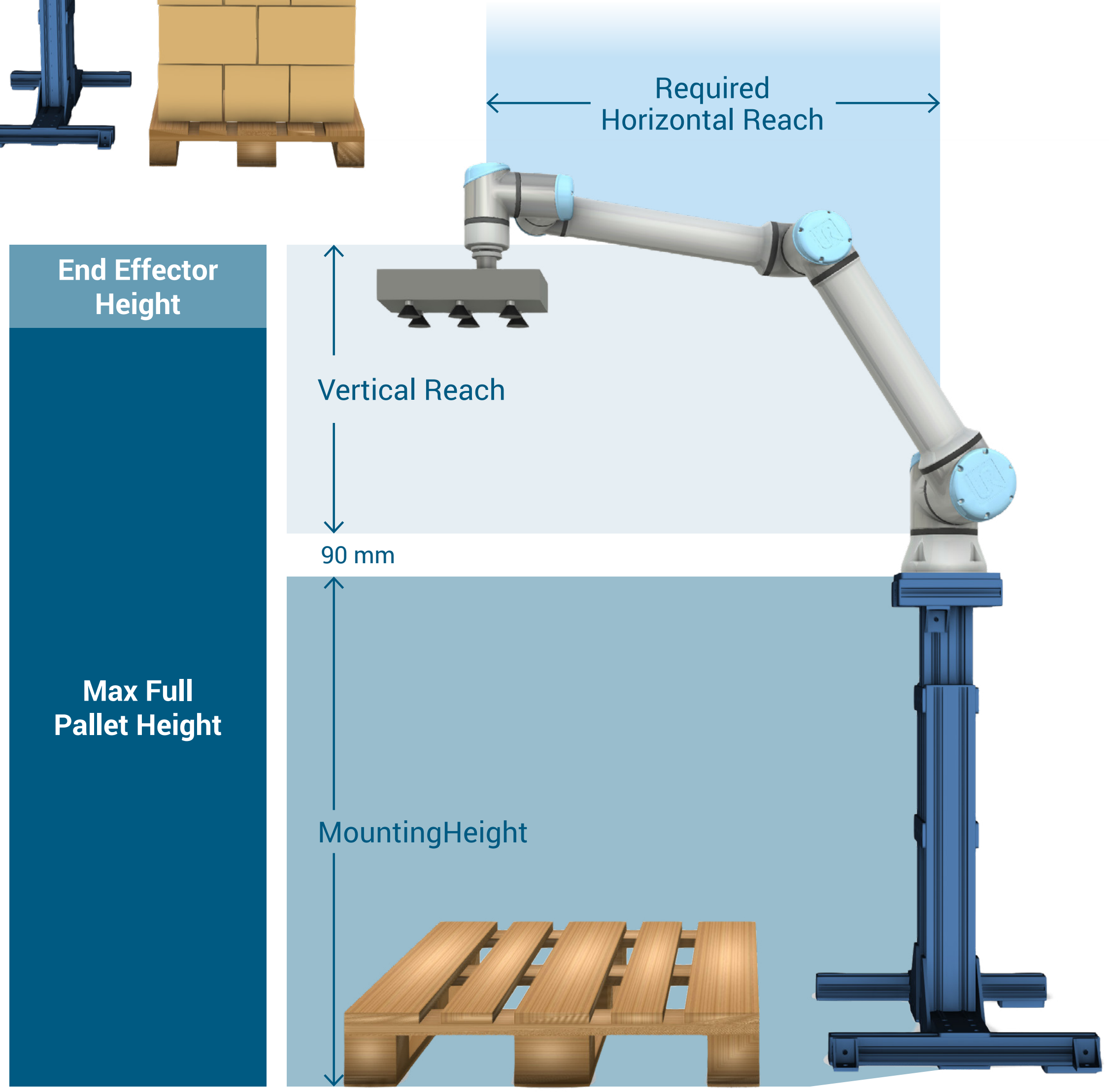


Maximum full pallet height can also be calculated from the values used in the mounting height calculation:

90 mm is added to the value because the robot has a larger vertical reach above the robot base than below it. Plugging in our sample values gives a maximum full pallet height of:

	1006 mm	Mounting Height
+	90 mm	
+	510 mm	Vertical Reach
-	131 mm	End Effector Height
=	1475 mm	**Max Full Pallet Height**

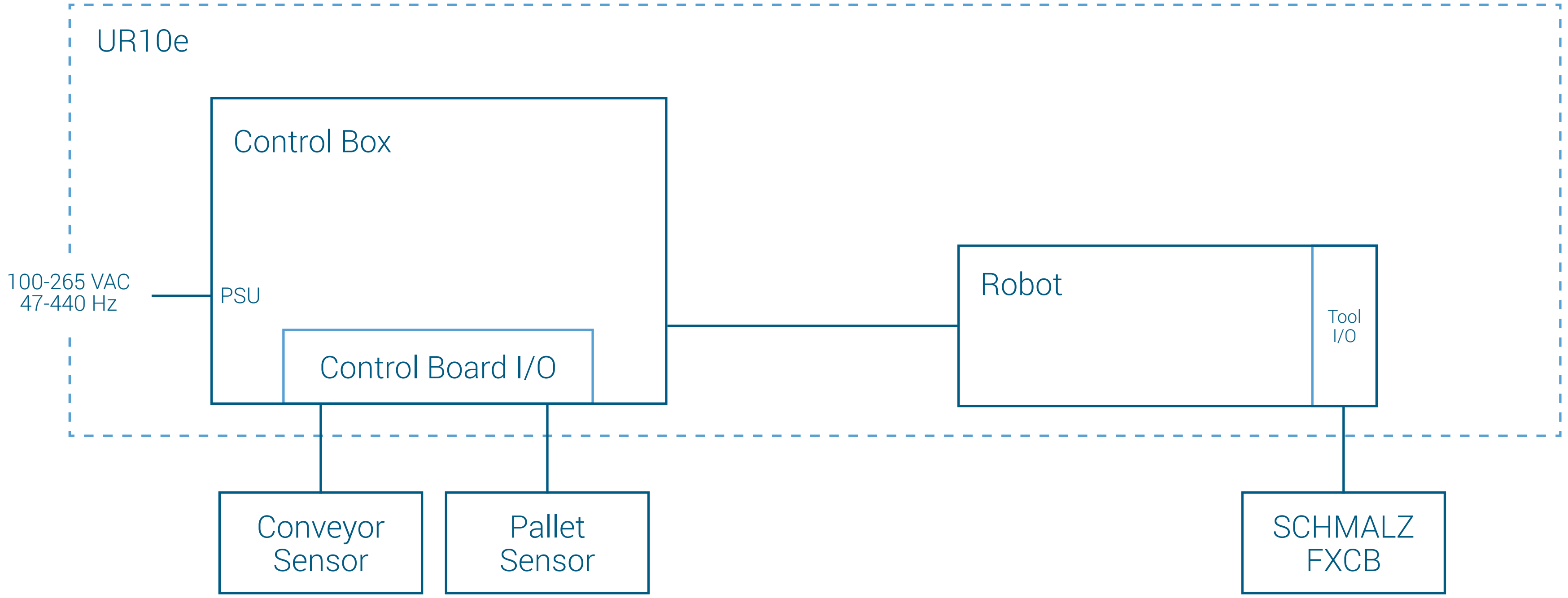
Our current process analysis gives a full pallet height of 1245 mm, less than the 1475 mm calculated here, and therefore entirely achievable.



WORKCELL DESIGN ①

Sensors
The sensors used here to detect boxes on the infeed conveyor and whether the pallet is in the correct position are photoelectric sensors. These typically emit infra red light and detect changes in reflected light levels to determine whether an object is present in the detection area or not.

These photoelectric sensors come in a wide range of shapes and sizes from many different manufacturers. If you're not sure where to get them from or how to select an appropriate one, your UR distributor will almost certainly be able to help.



Controller I/O Connections
3 wires will usually be connected between photoelectric sensor and robot controller, although 2 and 4 wire versions, or even ethernet fieldbus versions do exist.

In a 3 wire configuration these are for Power (+24 VDC), Ground (0 VDC), and one PNP digital input signal. A change in this signal indicates the detection of an object, and in the sample robot program on the next page they are integrated into logic under the names Infeed_Ready and Pallet_Ready.

Tool I/O Connections
The Schmalz FXCB is a UR+ approved product that is supplied with a cable that allows it to connect to and communicate through the I/O connector at the robot tool flange. To pick a workpiece box turn on tool output 0 (enable vacuum) and turn off tool output 1 (disable blow off air). Do the reverse to release a workpiece box.

The FXCB has an integrated vacuum generator so the user only needs to provide a compressed air supply into the 10 mm pushfit connector on the gripper housing.

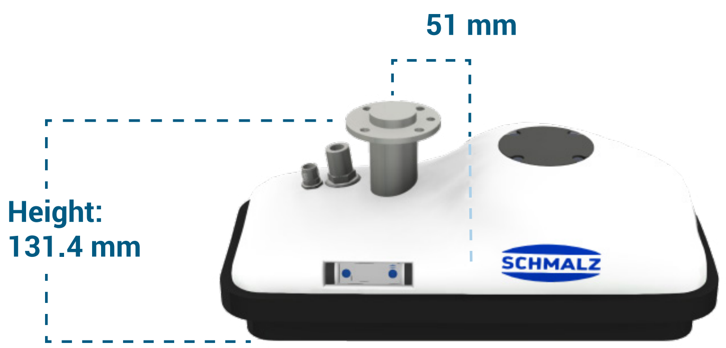
PROGRAMMING

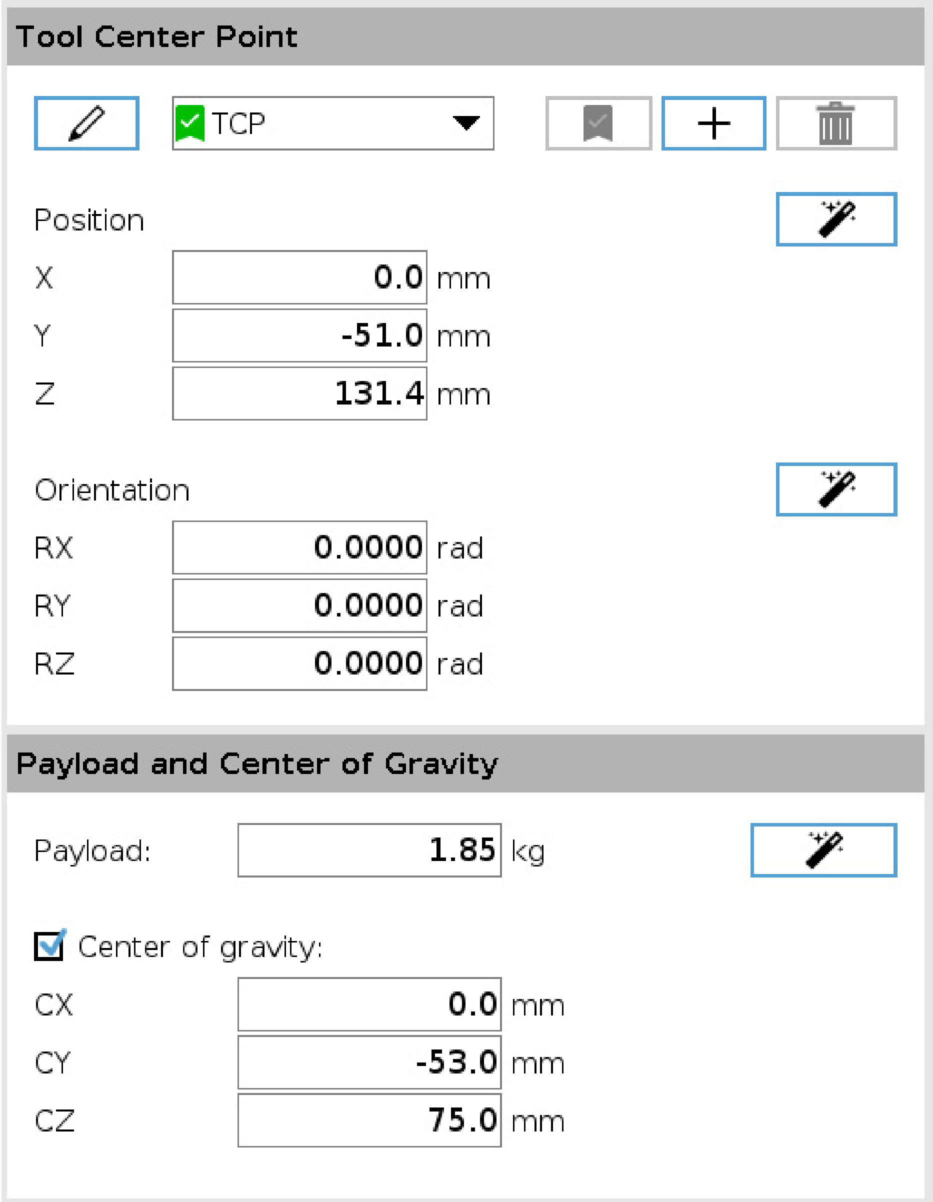
Installation

Before starting to set up your application on the robot teach pendant it's a good idea to first complete UR Academy online training, to familiarize yourself with how each of these concepts works on the UR system.

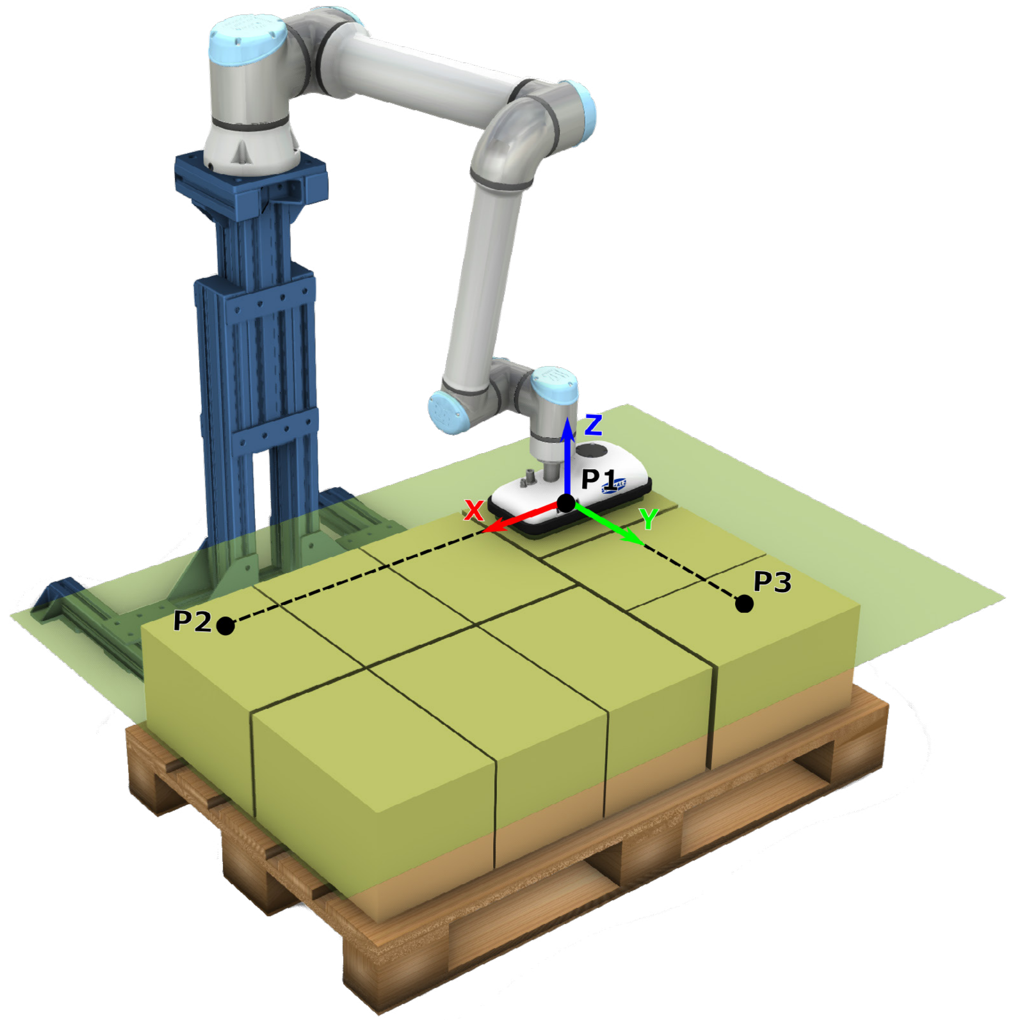
We start under the installation tab, where we can configure how the robot is set up in its environment and its connections to other devices.

TCP Configuration
Define the correct Tool Center Point, Payload and Center of Gravity configurations based on the end-effector used.





Feature Plane
Next create a Feature Plane to represent the position of the Pallet, which essentially links all of the positions of the boxes to the coordinate system of this pallet feature. So if once the program is complete the pallet position, height or orientation needs to be adjusted, this feature can be adjusted and all box placement positions will move with it. Keep in mind that the Plane's +Z direction needs to point upwards in the direction that the layers will be stacked.



PROGRAMMING

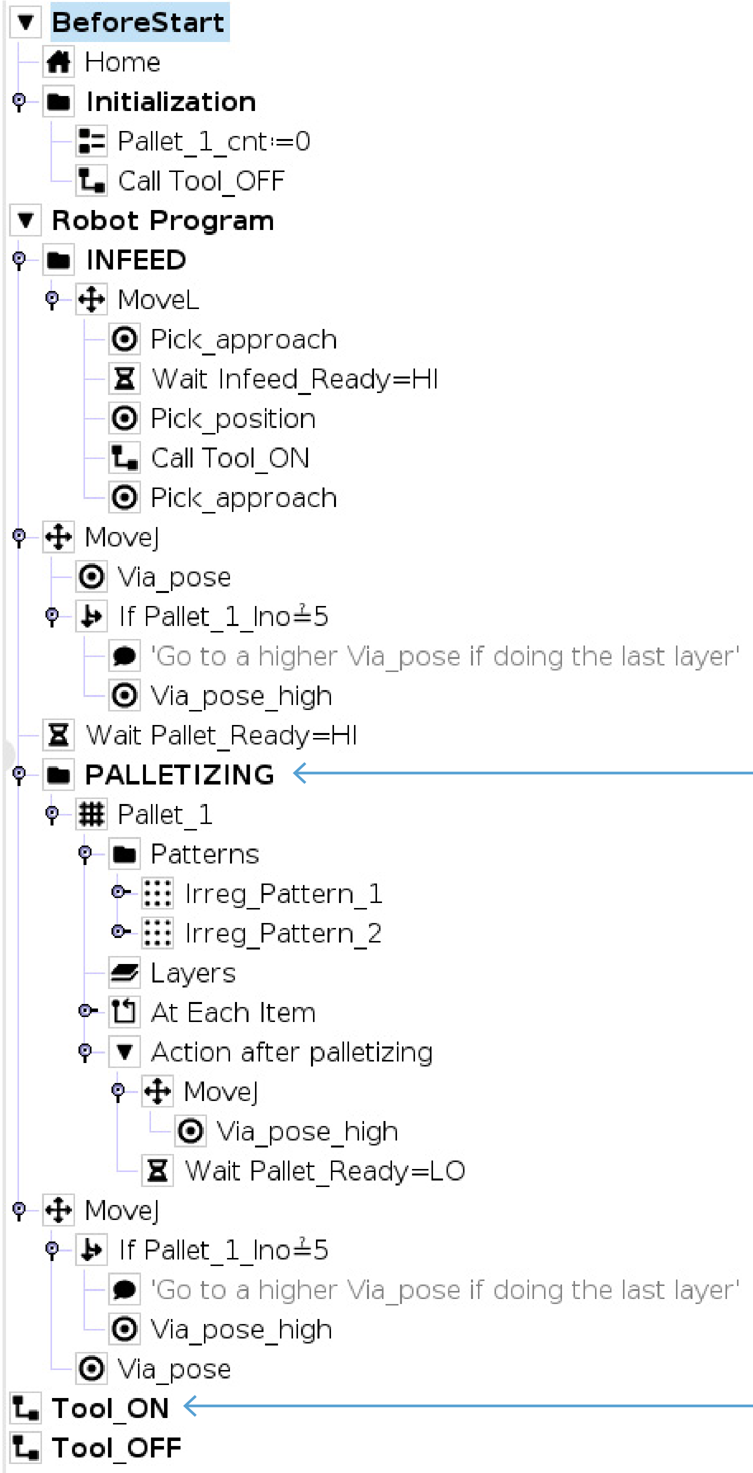
Program

The **BeforeStart** section is executed once before entering the main program loop. Here the robot is moved to the starting position and the status the gripper and pallet counter are reset. In each loop of the main **Robot Program**, the robot first picks a box from the infeed conveyor and then places it in the next position in the pallet pattern.

INFEED

Here the robot moves to a position above the conveyor, waits for a sensor signal indicating a box has arrived, then moves down to the pick position, calls the Tool_ON subprogram to grasp the box then moves back up to the approach position.

Next the robot moves to a Via position between the conveyor and pallet and checks that the pallet sensor has detected that there is a pallet in place. If not the robot will wait here until the pallet is ready.



PALLETIZING

This section is built using the new UR Palletizing wizard software released in software v5.3. You can see more on how to configure this process on the next page.

We use this wizard to teach the patterns which the robot should use to place the boxes in each layer, and then configure actions that need to be executed at each item, such as approach position, signals to release the box and exit position.

After each box placement is complete the robot moves back to the Via position next to the pallet before moving to the infeed to pick the next box.

After the full pallet is complete the robot moves to the Via position and waits for the pallet sensor to indicate that the full pallet has been removed.

TOOL_ON/OFF

These subprograms contain commands to turn on and off the vacuum gripper, small delays to allow the actions to take effect, plus commands to update the active robot payload (gripper weight only or gripper and box weight combined).

!

Together with this deployment guide you will receive the full UR program shown on this page and a template to form the foundation of your own program. The template structure is the same as the program shown here, but without specifics such as predefined input/output channel numbers and waypoint positions, which will need to be defined for your unique setup.

PROGRAMMING

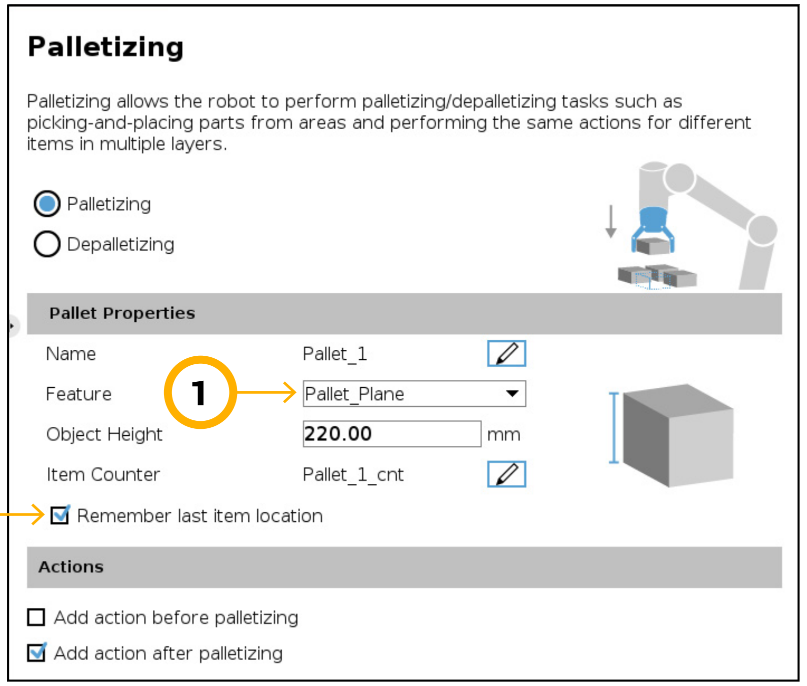
Palletizing Template

Palletizing - Configuration

1 Select the previously created Pallet plane feature

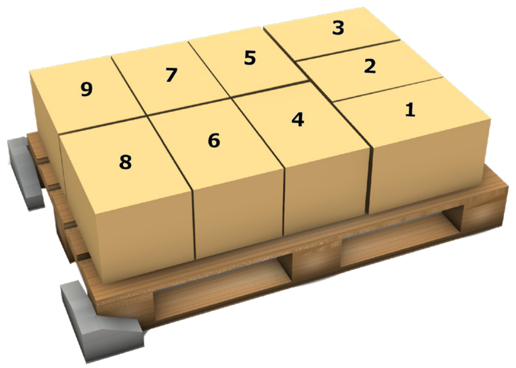
2 Check “Remember last item location”

- Stores the variable value between program executions and Controller restarts.
- Gives the possibility to manually change the starting position of the pallet by changing the variable value. E.g. If you change the Installation variable value to 10, the robot will start palletizing from the 2nd layer.

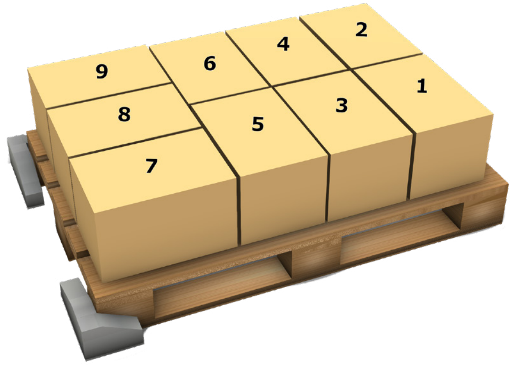


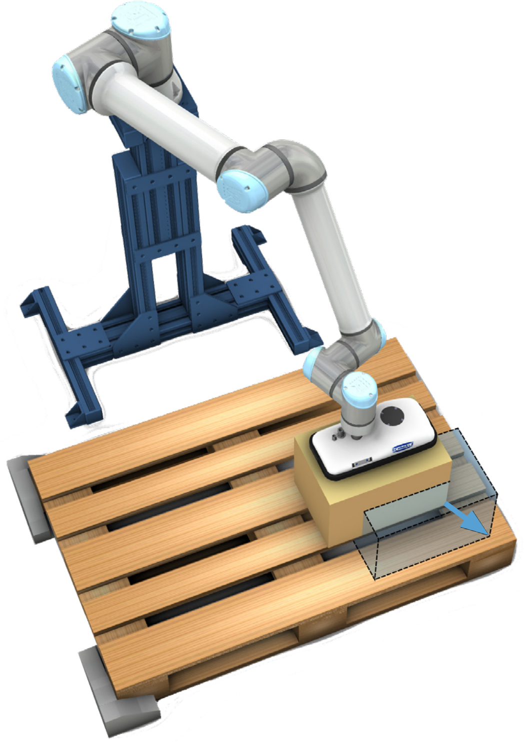
Palletizing – Patterns

Pattern 1:
Place the first layer of boxes on the pallet and teach all 9 item positions as shown here. The robot will palletize following the item number.



Pattern 2:
Rearrange your first layer of boxes on the pallet into the pattern for the second layer, which in our reference case is rotated 180 degrees from the first layer pattern. Now add a second pattern to your program and teach the item positions in sequence as you did previously.

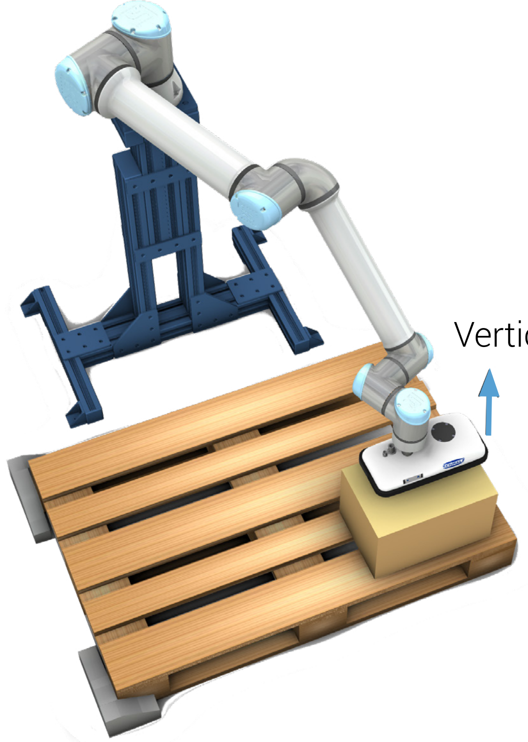




Palletizing – Actions performed at each item

Use the wizard to define how to approach to and exit from your item positions. The Approach and Exit directions are defined relative to the pallet feature. The robot will ignore the box orientation and always approach/exit them with the same direction. We use a diagonal approach and a straight vertical exit.

Diagonal Approach



Vertical Exit

SAFETY TIPS

In this section we discuss common safety risks in the workcell design case along with recommendations on how to reduce them. For further details on how to complete a full risk assessment, please refer to the Universal Robots risk assessment guide. As with all above content, but especially regarding robot safety, it is very important to conduct a full risk assessment according to own installation and requirements before completing the deployment of the application.

RISK 1

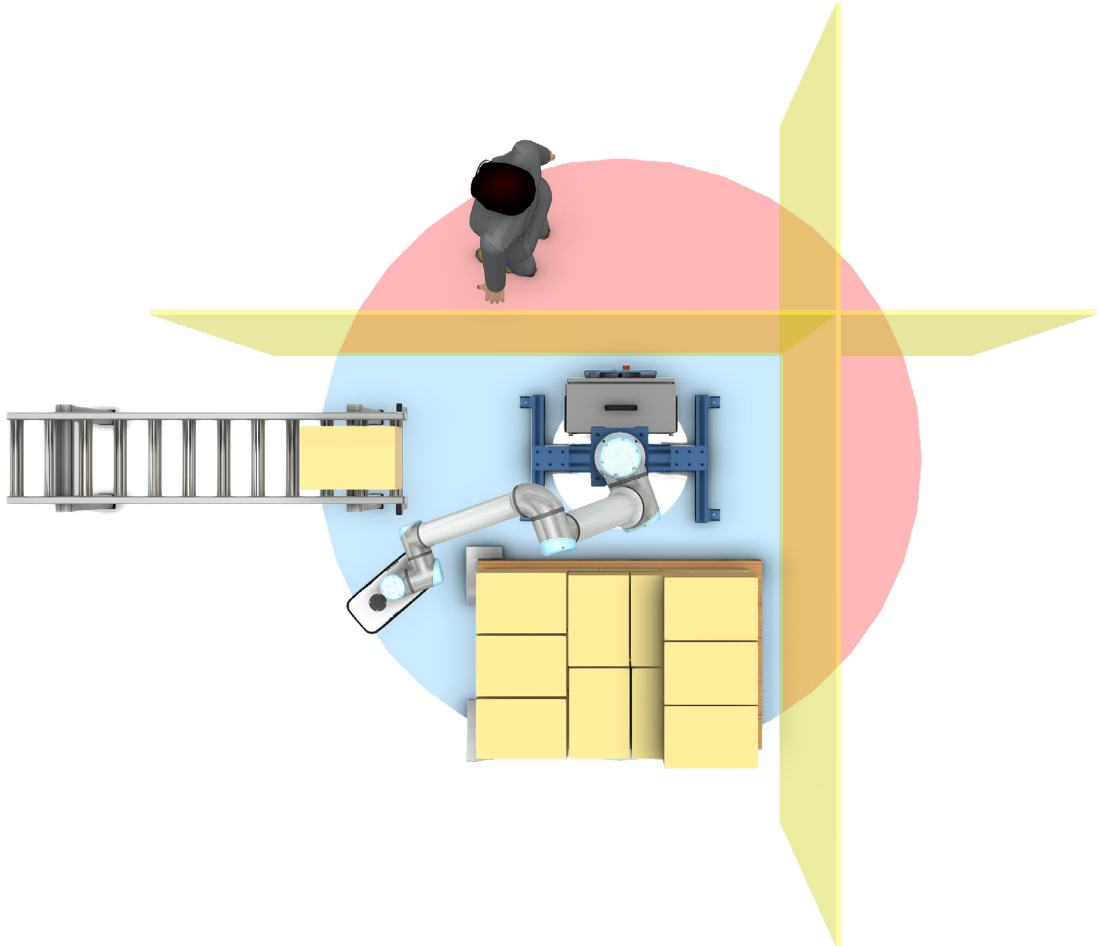
Collision outside of expected robot working area

Risk description

During the palletizing operation, the robot's expected working area is between the infeed and pallet areas. Without suitable safety system configuration there is a risk that the user program may command the robot to move outside of this expected working area and into the human operator working area, causing a collision.

Protective measure

Safety planes should be configured to prevent the robot from moving outside of its expected working area. Configuring these in the UR safety system means that they are Performance Level D rated functions monitored by dedicated redundant dual safety processors, and therefore highly reliable. If the robot program commands the robot to move through one of the safety planes, it will be stopped by the safety system.



SAFETY TIPS

RISK 2

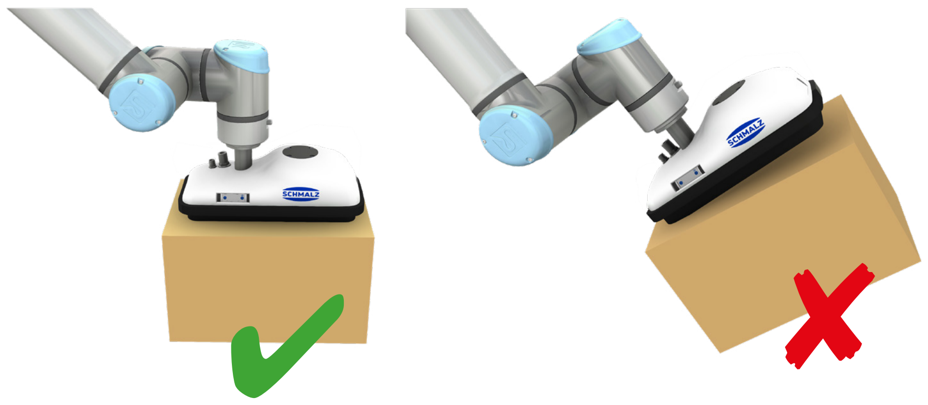
Dropping a box workpiece

Risk description

The suction force from the vacuum gripper used in this workcell design acts perpendicular to the gripping surface, so is most effective when the payload weight is acting directly opposite to this, with gripping surface facing down and the box beneath it. If the tool orientation changes, especially with high acceleration, there is an increased risk of dropping the box, potentially injuring nearby operators.

Protective measure

The majority of palletizing operations are completed with the tool always facing downwards, therefore the tool direction should be restricted close to this direction in the UR safety settings to reduce the risk of dropping a box workpiece.



RISK 3

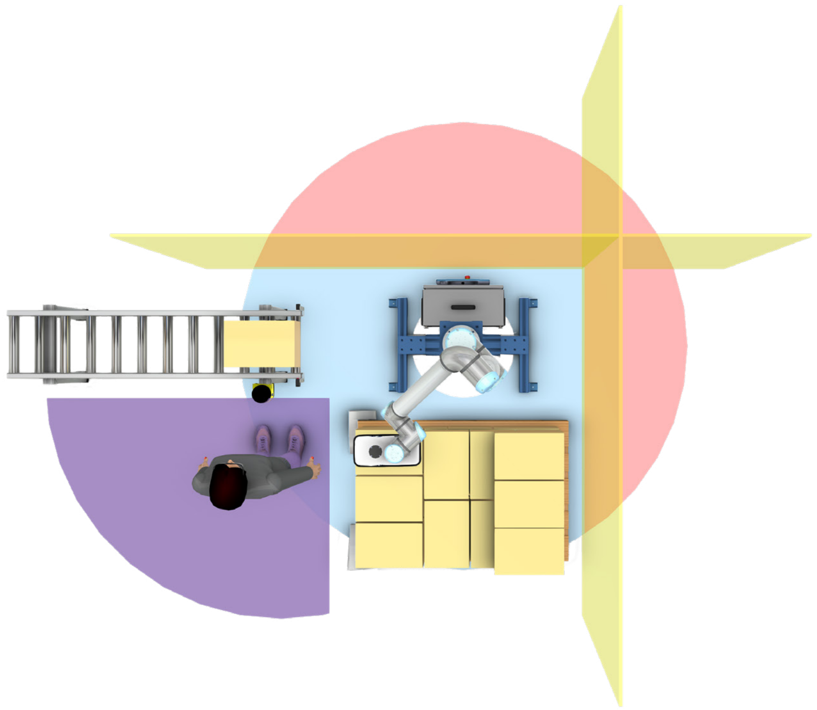
Collision within expected robot working area

Risk description

It may be possible for a human operator to enter the expected working area of the robot while it is palletizing, leading to a transient contact collision between robot and operator.

Protective measure

Appropriate force and speed limits should be selected in the UR safety system to reduce impact force and pressure with the body region in question to an acceptable level. A reduction in speed will also increase the likelihood of the operator avoiding the collision before it happens. Additionally, lightweight barriers and warning signs can also be added around the workspace, along with appropriate training for operators can all reduce risk of injury further.



If the speed selected after the risk assessment is too slow to meet production cycle time requirements, a safety scanner configuration can be considered. This is integrated with the UR safety system to allow the robot to move at a higher speed in normal mode when the surrounding area is clear but then switch into a reduced mode operating at lower speed when an operator enters the robot workspace.

DEPLOYMENT

Once the application design has been finalized, and everything from the list of components has been purchased and delivered, it's time to begin the application build. This will roughly follow these steps:

1. ROBOT SET UP

Set up robot and other mechanical equipment according to layout design, do a rough robot reach test using freedrive mode to make sure there are no unforeseen difficulties.

2. COMPONENT CONNECTIONS

Wire up all components as specified in design, testing each component individually to ensure correct functionality.

3. PROGRAMMING

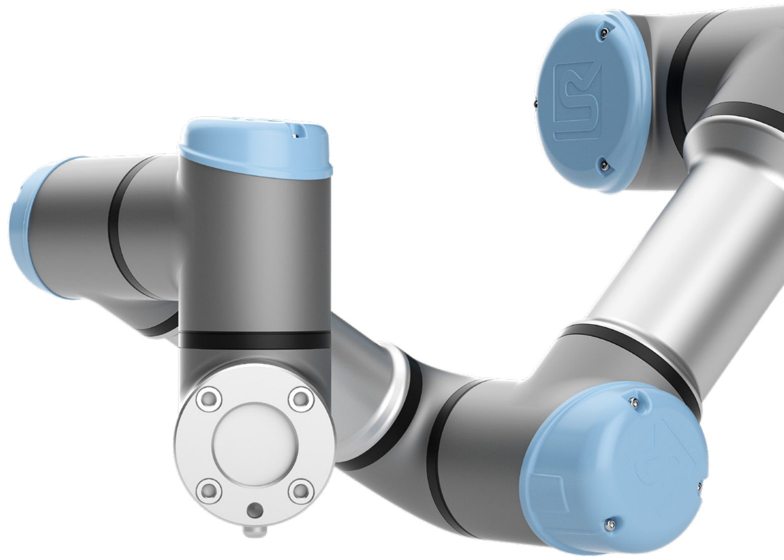
Start from the reference program template and begin to set up the robot installation and program. Test each part of the program individually by suppressing other parts before testing the complete work cell.

4. OPTIMIZATION

Optimize robot movements, by adding blend radii, removing unnecessary waits and adjusting move profiles. For acceleration, minimum possible values that allow the robot to complete the task within the required cycle time should be selected to minimize wear on robot joints.

5. FINAL TEST

Perform a final test, monitoring the system running in the production environment for at least one full shift, testing any potential failure modes and recovery methods.



OPERATION

The role of the operator must be clearly defined for them to be trained on their responsibilities. What they should do under normal conditions and how they should handle any faults that occur. Additionally they must be aware of any remaining minor hazards identified by the risk assessment but not fully mitigated and how to avoid them. Once this has been defined a training should be performed to educate operators on the system, and a quick start guide provided to give a quick refresher on training details during operation.

Protective stops may occasionally occur while an application is running, and it is important to train operators on how to recover from and report these. If the frequency of unexpected protective stops increases, it could point to an issue with the robot application that could adversely affect the performance or lifetime of the robot and should therefore be promptly escalated to the appropriate person responsible for application configuration.

If you would like to monitor the productivity and status of the robot while it is in operation, there are a number of third-party solutions available in the software section of our UR+ showroom that allow full integration of a UR robot into an industry 4.0 manufacturing environment.

Support Resources
If you experience any challenges during or after deploying your Universal Robots application, the following resources are available to support you:

- Universal Robots support site contains many how-to articles to help resolve common issues.

- The Universal Robots service manual is available from the downloads section of the support site and includes such useful resources as an inspection plan to minimize the chances of issues with the robot, and explanation of error codes that could appear in the robot log file.

If the above online resources are not enough to resolve the issue, contact the UR partner from whom you purchased your robot to request support.