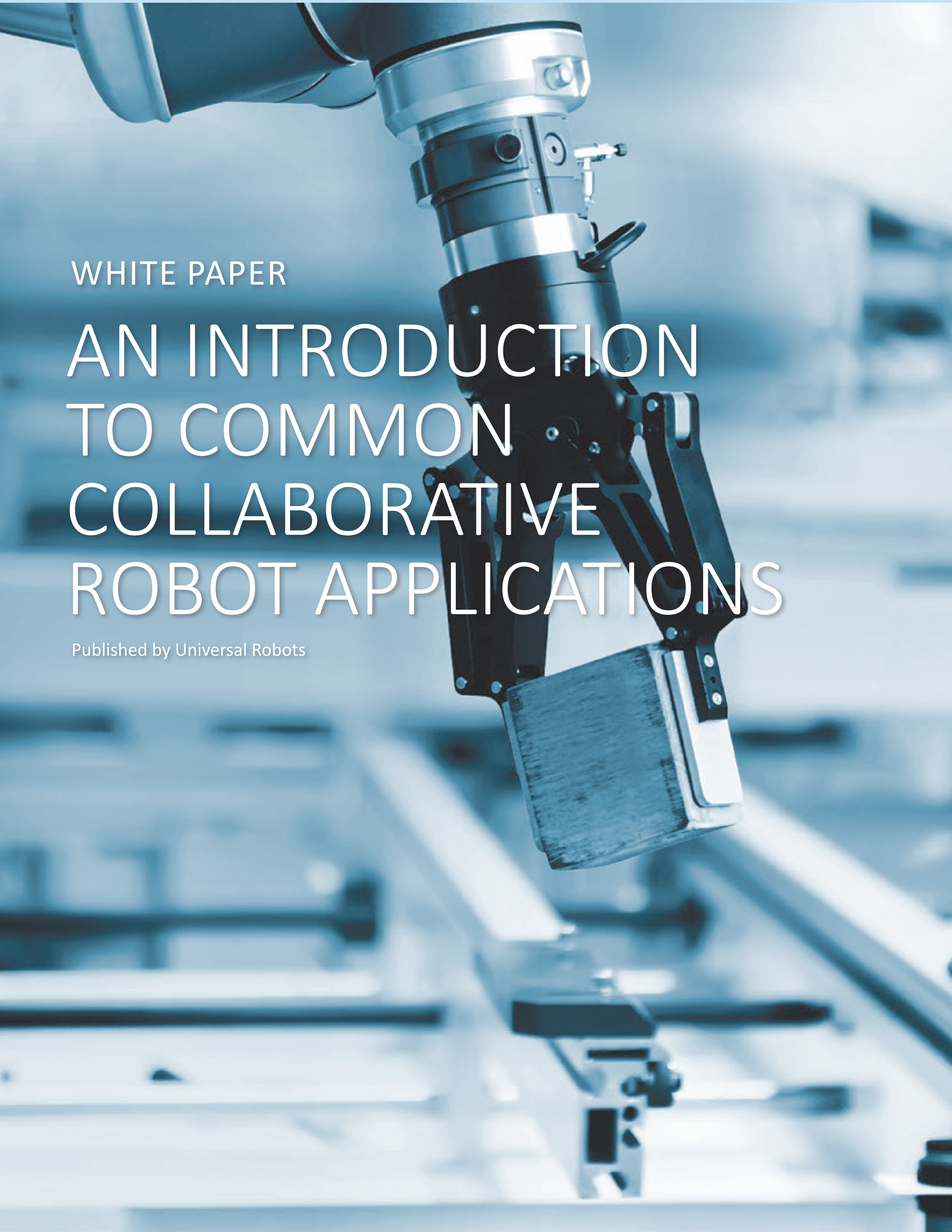
UNIVERSAL ROBOTS



WHITE PAPER

AN INTRODUCTION TO COMMON COLLABORATIVE ROBOT APPLICATIONS

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EXECUTIVE SUMMARY

This document is intended to give an overview of collaborative robot technology, and how it can be integrated into common industrial applications to improve manufacturing processes. Six application areas will be discussed, with an overview of each application, how the robot handles the process, plus the common accessories required to be integrated with the robot to successfully complete the task. The benefits of using collaborative robots in each type of application will also be presented.

INTRODUCTION TO COLLABORATIVE ROBOTS

The field of collaborative robotics has expanded significantly over the past ten years, and is now by far the fastest growing segment of the global industrial robotics market.

A collaborative robot, also known as a cobot, in its most basic definition is a robot which has the ability to safely work directly alongside human workers to complete a task. At Universal Robots (UR), however, we believe the accessibility of the technology through ease of deployment is similarly integral to the cobot definition. A robot that can operate directly alongside and interact with its co-workers does open up a huge number of new possibilities for task automation, but many of these possibilities could go unfulfilled if the robot system is not easy to program, affordable, and flexible enough that it can be re-deployed to different tasks at very short notice.

For this reason, we strive to make UR cobots safe and collaborative, easy to program and deploy at an affordable price, to make robotic automation technology truly accessible to everyone.

So why should your company deploy a cobot? What benefits could you expect to see? This will inevitably vary from case to case, but here are some of the common benefits:

Productivity

There are still many things that a human can do faster than a robot, due to our immense dexterity and ability to handle variations in our environment. However, for highly repetitive tasks, involving objects that are predictable in both size/shape and the orientation in which they are presented, a robot that can work for 24 hours a day without needing breaks in between is likely to result in a significant productivity gain.

Often a worker's job will consist only partially of these repetitive, easy to automate tasks, so the optimal configuration can be to have the person continue doing the variable parts of the task and make use of the robot as a smart tool to speed up the repetitive parts to increase his/her overall output. This only really works if you can stand right next to the robot, passing objects back and forth.

The productivity of an automated solution is also inherently easier to monitor than a manual solution, as data on the number of cycles completed by a cobot can be conveniently extracted over a network and incorporated into overall production data.

Quality

If one in every 20 products has to be scrapped due to a lapse in concentration from a tired worker, costs can rise significantly. The outcome is potentially even worse if the person inspecting the output of the process misses a defect only for it to be noticed by the end consumer.

The repetitive reliable operation of a collaborative robot can ensure that these critical steps in the manufacturing process go off without a hitch. From putting on those final labels in perfect orientation every time, to moving an inspection camera through 15 different positions around the product to make sure everything is just right.

Cost

A UR collaborative robot solution is often far more affordable than a traditional robot or fixed automation solution. The ease of programming and integration with certified accessories will reduce the implementation costs, both due to the reduced expertise and time required to complete the deployment.

The UR integrated adjustable safety system can completely negate the need for any fixed safety equipment such as fencing or additional sensing around the robot (subject to risk assessment), which can often contribute roughly a third of the overall project cost.

The human mind is a wondrous thing, and it makes sense to challenge employees with interesting tasks wherever possible and put more cost-effective automated solutions into the mind-numbing repetitive tasks.

Flexibility

There is simply less risk in investing in a flexible, re-deployable piece of automation equipment such as a collaborative robot. In the event of the company losing a production contract or discontinuing a product, the same cobot can easily be moved from one task to another due to its lightweight nature and easy reprogramming.

Understanding the versatility of the Universal Robots system makes business owners' decision to automate even more straightforward.

Health and Safety

The fact of the matter is that most of the tasks that are commonly automated with collaborative robots are not the ones that people enjoy doing. They are often extremely repetitive, monotonous and sometimes dangerous.

Regardless of whether avoiding a repetitive strain injury or improving morale by moving to a more varied and interesting task, bringing in a cobot really can improve conditions for employees in the workplace.

APPLICATIONS

The flexibility of the Universal Robots system has led to UR cobots being deployed in a huge range of applications and industries around the world. Here we will discuss 6 common application areas, how to implement a UR cobot into the application and what accessories would be required.

Glossary

To save repeating ourselves, we will first go through some of the common terms relating to collaborative robot applications and what they mean.

Workpiece – The object of interest that the robot will manipulate, generally a product or component.

I/O Interface – Inputs and Outputs used by the robot to communicate with its surroundings. Sensors are connected to inputs to detect signals representing things such as a product arriving, or a machine being ready for the next operation. Outputs typically are used to actuate devices such as valves, or to tell another machine that an operation is complete.

Polyscope – Universal Robots' touchscreen graphical user interface used to program the robots.

Universal Robots+ (or UR+)[1] – Universal Robots+ is a showroom of UR compatible accessories allowing applications to be built with increased speed/simplicity and reduced cost.

End-effector – The tool mounted on the end of the robot that allows it to interact with the workpiece, this could be anything from a simple gripper to a screwdriver or glue dispenser.

Pneumatic Gripper – A simple gripper powered by compressed air, this is inexpensive but not necessarily good at handling a range of different sized/shaped parts.

Vacuum Tool (or Cup) – Objects with a flat surface on the top can be easily picked up with a vacuum tool (or vacuum cup), but not suitable when the product need to be rotated from the pick position and placed upside down. A compressed air supply is needed for this method, but many industrial environments have this readily available so it is not necessarily a concern.

Adaptive Gripper – An adaptive gripper, while more expensive than a vacuum cup or pneumatic gripper solution, gives the flexibility of picking assorted sizes of objects and the ability to limit the force of the grasp. This is a convenient choice as often the end-effector will not need to be replaced when redeploying the robot to another application similar task.

TCP – Tool Centre Point. The part of the end-effector that comes into contact with the workpiece, and therefore the point that we are most interested in controlling the position of.

Waypoint – A position in the robot's workspace that it will move the tool to.

Blend Radius – Sometimes the robot does not need to go to the exact position of a waypoint and stop. If the waypoint is just a rough guide as to the path the robot should take, it can get within a certain distance of that point and then start to curve toward the following point, allowing for reduced cycle time and smoother movements.

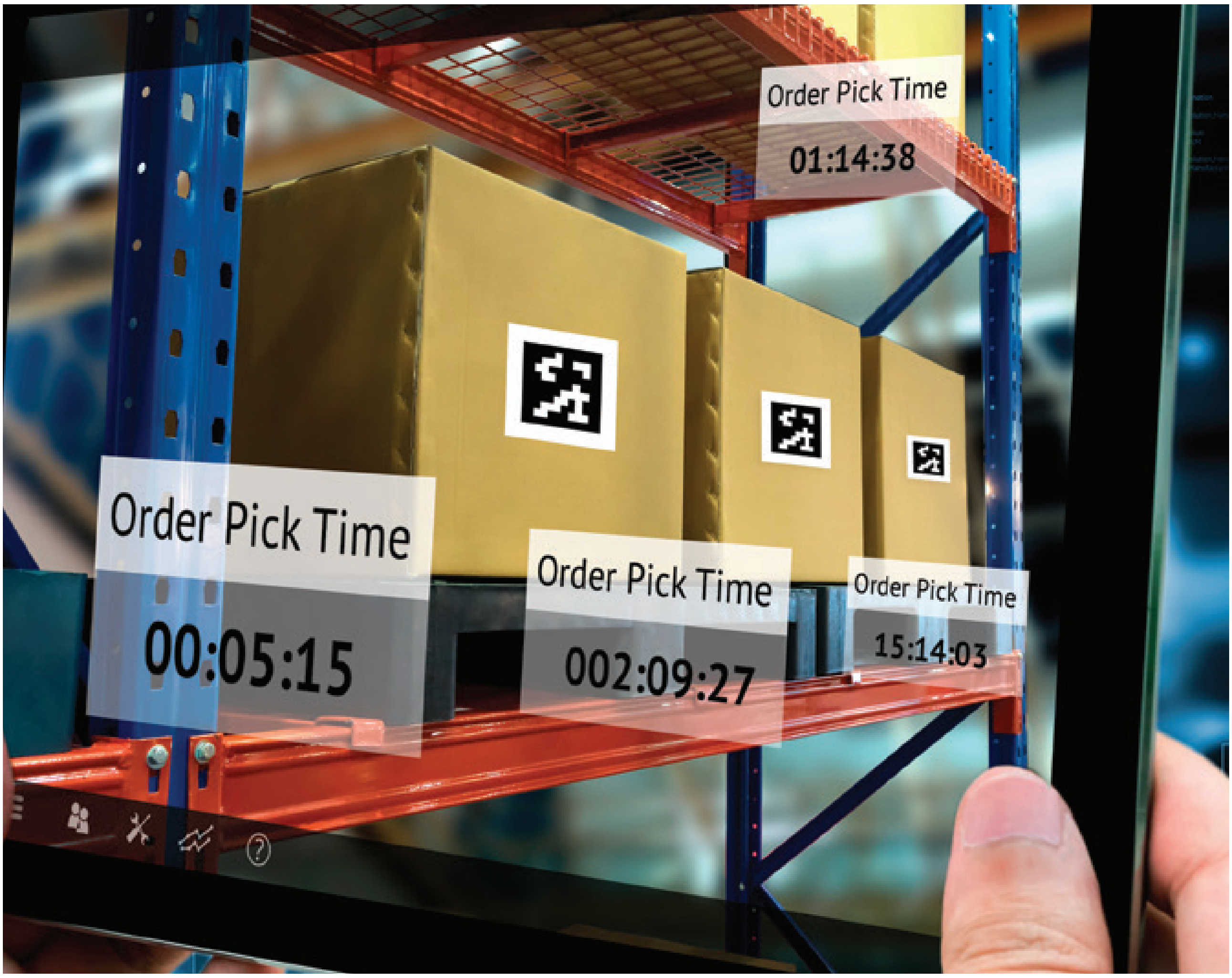
Vision System – Situations where the workpieces to be picked are presented to the robot in a non-standard position or orientation may require a vision system to tell the robot the precise pick parameters. Vision systems are becoming increasingly affordable and easy to install, and add flexibility, but also complexity to a solution. With that in mind, a mechanical guide to force the workpiece into a fixed location where feasible, is a valid and usually more cost-effective alternative to using vision.

Photoelectric Sensor – In order for the robot to know when a product is present and ready to be picked, additional sensing is sometimes required. Inexpensive photoelectric or photo-sensors (light based) can be installed to detect a product arriving on a conveyor or when a tray of products is placed down into a known location, without significantly impacting the overall cost of the project.

External Jig – In applications where the robot is required to place the workpiece into a precise location an external jig may be used, which could either be active or passive. In a passive jig the workpiece will automatically centre itself when placed due to the mechanical properties of the jig, whereas an active jig can close around the work piece securing it in a fixed location.

1) https://www.universal-robots.com/plus

PICK AND PLACE



A pick and place task is one in which the robot is required to pick up a workpiece and place into another location and or orientation. Here the handling of the workpiece is the key action rather than any other process being carried out on it. Tasks such as machine tending and packaging/palletizing could also be considered as pick and place, but they are more specific cases that will be discussed in the later sections. In the simplest instance products will be presented to the robot in a uniform layout tray/ pallet or on a conveyor in predictable position, where in more complex cases a vision system may be required to determine product orientation.

"Implementing a UR cobot into a pick and place application can be done with minimal cost and disruption to production, as it can often slot straight into an existing set-up."

Manual pick and place tasks are often the most repetitive and mundane tasks in a production environment, with the dull nature of the task often leading to mistakes or decreased efficiency if workers are not frequently rotated. These are generally some of the least enjoyable tasks that can also entail a risk of repetitive strain or other injury if the object is of substantial weight. When selecting a first task for cobot automation, a pick and place task is an excellent choice as the highly repetitive nature and simple movements make it very easy to set up.

Accessories

End-effector – Either a vacuum cup based solution or a gripper could be suitable, depending on the size and shape of the work-piece. If it has a smooth, flat upper surface and will be placed in the same orientation that it was picked, a vacuum based solution is a good choice. If it has no flat surfaces, or needs to be placed in a different orientation, then an adaptive gripper may be required.

Vision System – If the products arriving for the robot to pick are in a non-standard position/orientation then it may be necessary to integrate a simple vision system to detect the orientation of the part.

Protective Suit – If the machining process is particularly damp or dirty, additional protection for the robot may be required, in the form of a protective suit, available from UR+.

Programming

Programming of a pick and place application is generally very straightforward - move to a pick location, activate the end-effector, then move to a place location and deactivate the end-effector. In the simplest case both pick and place locations could be fixed, but often one or both positions would need to be adjusted each cycle, as they are in a grid or stack orientation (conveniently achieved using palletizing or seek Wizard functionality in Polyscope), or vision guided (achieved using a third party vision plugin from UR+).

Typical Programming Time – Less than 1 hour

Benefits

Implementing a UR cobot into a pick and place application can be done with minimal cost and disruption to production, as it can often slot straight into an existing set-up. Companies will often have to rotate workers on a monotonous pick and place task every couple of hours as productivity starts to drop, where as a cobot allows productivity rates to be maintained across multiple shifts.

MACHINE TENDING

Machine tending is another task very widely executed by Universal Robots around the world, where the machine being tended could be anything from a CNC to an injection moulding machine, a laser engraver to a metal stamping press.

As a manual process, machine tending requires workers to stand for hours on end, placing individual parts into a potentially dangerous machine. With the addition of a robot, however, the same employee can handle a far greater number of machines, being able

"The cost of a cobot is usually significantly lower than the machine it is tending. By allowing the machine to run 24 hours of back to back cycles, this will likely pay for the cobot tending it in a very short period."

to supply products in large batches instead of individually, thus increasing productivity. The robot will pick a blank unprocessed product from a tray, stack, conveyor or some other feeder configuration, and place it into a fixed location in a machine. Once the machine cycle completes, the robot will take out the completed part and put in another blank. If the machine cycle is long enough to allow it, one robot can tend multiple machines simultaneously, accelerating the return on investment.

Due to the small footprint of a UR cobot, it can often be installed without adjusting factory layout, and leaving enough space that an operator can still access the machines if required.

Accessories

End-effector – A machine tending application will often utilize a dual gripper configuration, with one gripper picking and placing the blank and one the completed part. This results in a reduction in cycle time, with the robot being able to handle both parts in a single movement inside the machine.

Vision System – If the products arriving for the robot to pick are in a non-standard position/orientation then it may be necessary to integrate a simple vision system to detect the orientation of the part.

Programming

Robot movements for a machine tending application are generally very simple, moving between ingoing/outgoing product positions and the fixed machine position.

Some I/O interfacing is usually required for the robot to tell the machine when the part is in place and the cycle can begin, then for the machine to tell the robot that the cycle has finished and it is ready for the next part. For machines like CNC or injection moulding, additional signals will be required to synchronize the handover of the part and to let the machine know when the robot is outside the machine so the door can be closed.

If the robot is tending multiple machines, some additional logic will likely be necessary to decide which machine to tend to next in the case that they do not have identical cycle times.

Typical Programming Time – Less than 0.5 days

Benefits

The cost of a cobot is usually significantly lower than the machine it is tending. By allowing the machine to run 24 hours of back to back cycles, this will likely pay for the cobot tending it in a very short period, even faster if the cobot is tending multiple machines.

The small footprint of a UR cobot means that machine layout does not need to be adjusted, often on larger machines. The robot could even be mounted onto the side of the machine, requiring zero footprint.

PACKAGING AND PALLETIZING

“The benefits of automating a packaging task are similar to generic pick and place – increased productivity over multiple shifts.”

Before any product leaves a factory, it is highly likely that it needs to undergo some form of packaging ready to be shipped onto its next destination. The packaging and palletizing task could involve packaging a product by placing it into a shrink-wrapping machine, picking packaged products from a conveyor and collating them into boxes, or placing these boxes onto a pallet ready for shipping.

Such tasks are all extremely repetitive and generally involve small payloads making them ideal for automation with Universal Robots. Rigid products arriving in standard orientation are extremely easy to handle, though a simple vision system may be required to detect orientation of parts if not uniform. If less rigid products such as sachets are presented, and need to be tightly packed into boxes, extra consideration on the handling method is required, but still entirely possible.

For business running high mix low volume production, rapid product changeover is key, so the easy programming interface provided by Universal Robots is perfect for this, allowing for reconfiguration of an application within a matter of minutes.

Accessories

End-effector – Packaging and palletizing tasks are commonly handled with an array of vacuum cups to pick up and release the products. In the simplest form, these can be attached to a single flat plate, but can also be set up so that their positions are reconfigurable, allowing a range of different sized products to be picked with the same tool.

Conveyor Tracking – Synchronizing the movement of the robot with a conveyor to pick products on the fly is simple with the UR conveyor tracking wizard. Simply connect a position sensing encoder to input channels in the controller (or via Modbus fieldbus), configure the direction and speed ratio, and the robot is ready to track the movements of a variable speed conveyor. Note that if this is an end of line conveyor, where the products hit a mechanical stop at the end, it is not necessary to track the movement of the conveyor as the pick position is fixed.

Vision System – If the products arriving for the robot to pick are in a non-standard position/orientation then it may be necessary to integrate a simple vision system to detect the orientation of the part.

I/O Interfacing – A few inexpensive light sensors (photoelectric) connected directly into the controller will allow the robot to detect the presence of arriving products and the box into which they are to be placed.

Programming

For the most part, setting up the program for this type of application is very similar to a pick and place, with the pick usually from a fixed position, triggered by a sensor input. The place positions will likely vary for packing into boxes or palletizing, with either a horizontal offset within a layer, or a vertical offset between layers, both of which are straightforward to set up within Polyscope. For a more complex palletizing pattern, it may make more sense to enter the dimensions and locations of the place positions parametrically instead of teaching/offsetting them manually.

Typical Programming Time – Less than 0.5 days.

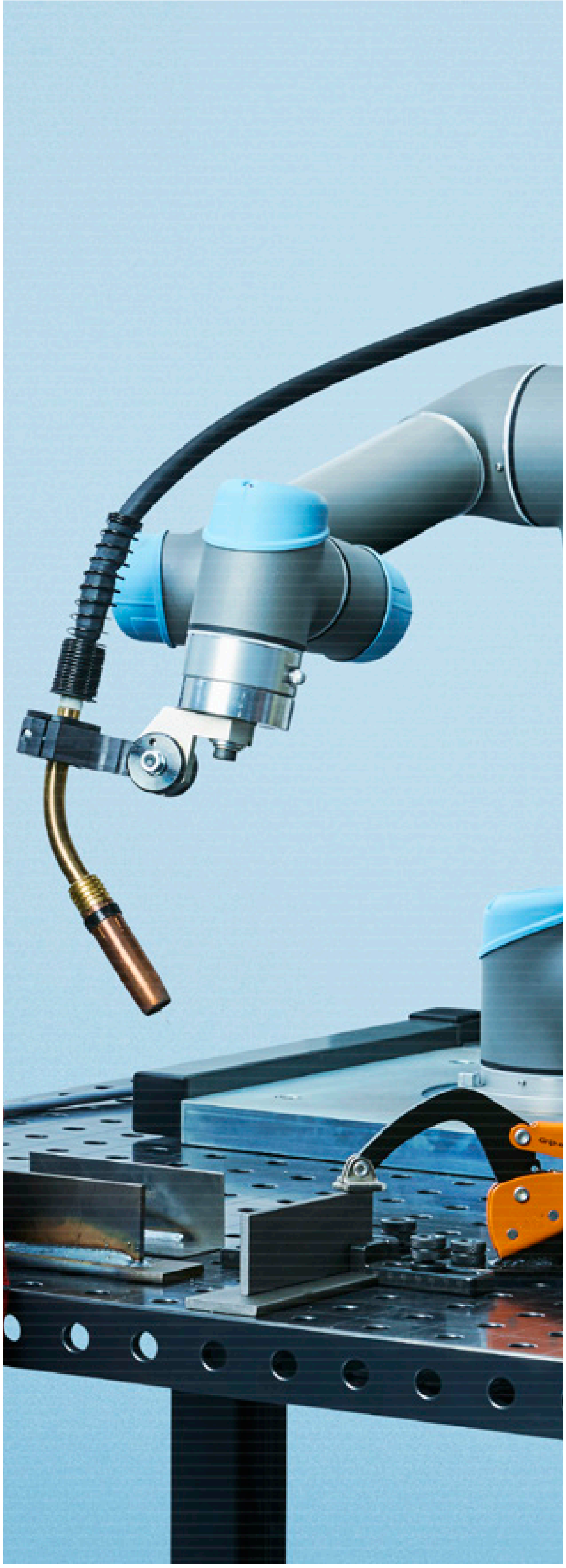
Benefits

The benefits of automating a packaging task are similar to generic pick and place – increased productivity over multiple shifts. The Universal Robots system comes fully equipped with interfaces to integrate with existing production lines out of the box, without the need to pay for additional add on features, reducing costs of implementation.

PROCESS TASKS (GLUING, DISPENSING OR WELDING)

In a process task, whether it's gluing, dispensing or welding, the key details are the same: the robot moves a tool through a fixed path while the tool interacts with the workpiece. In each of these process tasks, it takes a significant amount of time to train up a new employee to be able to control the numerous variables required to attain an excellent quality finish. If this control can instead be copied directly from one robot to another, it becomes a considerably more straightforward process. It is also potentially very challenging for a human worker to dispense a repeatable amount of material across a fixed path with minimal variation cross a whole shift, whereas a robot can control the required variables relatively easily.

A traditional robot welding system for example, requires both significant welding and robot programming expertise to set up, and is usually far more expensive than a welding torch alone. If the difficulty of the robot programming aspect can be simplified, anyone who knows how to weld can set up an automated robot welding cell.



"Increased productivity and quality can be expected with Universal Robots carrying out a process task with a consistently accurate output over tens of thousands of cycles and more."

Accessories

End-effector – A process tool is required, which could be a welding torch, sealant, glue or solder paste dispenser to name but a few. Often the tool does not need to be specifically designed for robotic operation, potentially reducing integration costs. Turning on and off the tool is normally achieved using standard digital I/O signals, with the potential addition of an analogue signal to control deposition rate.

Programming

Polyscope programming interface includes a process move option, which maintains a constant TCP speed, meaning that if the robot tool is depositing material at a constant rate, the system achieved constant coverage throughout the programmed path. The simplest method of programming a process task is to define the key waypoints within a process move, along with blend radii allowing the robot to curve around the corners in the path.

If the system is required to deal with a large number of rapidly changing parts, for which the CAD models and CAM process paths are readily available then it may be more convenient to import these paths directly into the robot program rather than teaching them manually. This can be achieved easily with a number of different third party software packages, outputting programs from the CADCAM data that can be directly executed on the UR system.

Typical Programming Time – Less than 0.5 days

Benefits

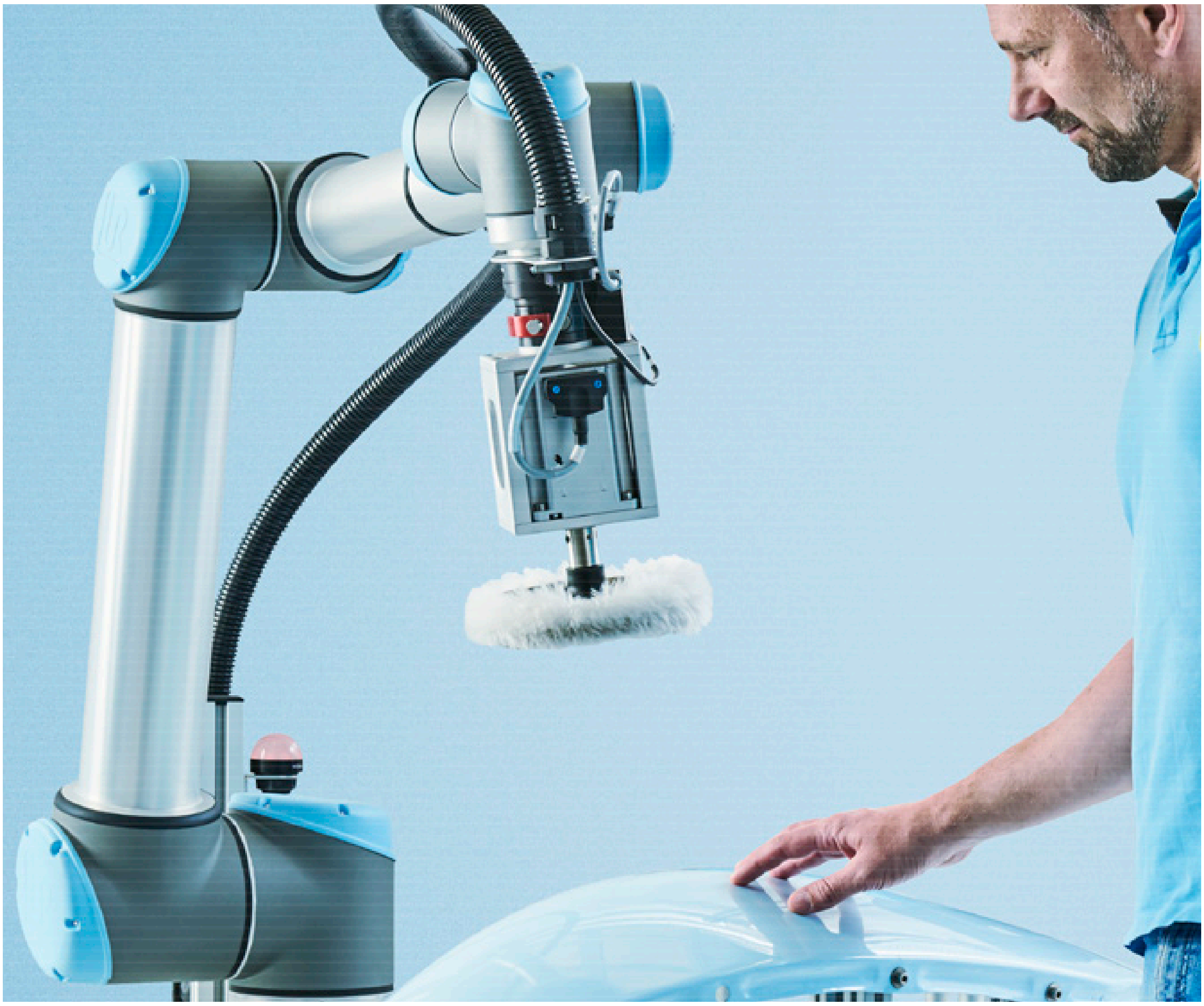
Increased productivity and quality can be expected with Universal Robots carrying out a process task with a consistently accurate output over tens of thousands of cycles and more. The flexibility and easy programming of the robot mean updating a program to handle a new workpiece is possible in a matter of minutes.

FINISHING TASKS (POLISHING, GRINDING OR DEBURRING)

"As with a process task, the possibility for sharp productivity and quality improvements are immediately clear when automating a finishing task with a UR cobot."

A finishing task requires the robot end-effector to apply a force across the surface of a work-piece to remove a certain amount of material. Polishing, Grinding and Deburring are different in amount, form and location of material to be removed, but the requirements of the robot are essentially the same.

When a person completes a finishing task with a manual tool, this often requires the worker to apply a large amount of force to the workpiece, generating a significant amount of vibration which over time can lead to injury which could be avoided with robotic operation.



Finishing tasks often utilize the process move command mentioned in the processing task and a robot can either be manually taught the path to complete the task, or it can be exported from CADCAM data directly to a UR program.

Utilising force control can also potentially make the robot more robust when dealing with parts of different dimensions. This can either be achieved with the robots internal force sensing capabilities or a wrist mounted external force torque sensor depending on the sensitivity required.

Accessories

End-effector – A finishing tool is required for this type of application, which could either be designed for general purposes (manual) or specifically robotic purposes. While manual tools are generally cheaper, and can be powered on and off by the robot, their fine controls are generally controlled by push buttons, while robot tools include an I/O interface for direct control.

Force Torque Sensor – If the task at hand requires force control in the sub-Newton range (phone case polishing for example) then you may want to consider adding additional sensing to the robot for finer scale force control.

Programming

The program logic for a finishing task in its simplest form is very straightforward, simply navigating along a fixed path and activating the tool at the relevant points.

Typical Programming Time – Less than 0.5 days

Benefits

As with a process task, the possibility for sharp productivity and quality improvements are immediately clear when automating a finishing task with a UR cobot. If done manually, these tasks also require the worker to apply a force with a hand tool repeatedly over many hours potentially leading to repetitive strain injuries, so health and safety benefits can also be expected.

QUALITY INSPECTION

Quality Inspection involves full inspection of a finished product, especially one that is the result of a precision engineering process, often requiring high-resolution images to be captured from many different angles to confirm that all of the surfaces and dimensions conform to the required specifications. The cameras capturing these high-resolution images are commonly costly, so requiring say 10 cameras to fully inspect a product is not cheap. If a single camera is mounted on a robot and moved around the product to all of the fixed capture positions, however, the costs of this type of automated inspection system drop significantly.

"A machine vision system will usually have a faster, more consistent output than a person inspecting a product, leading to improved quality and productivity."

In order to make the system solution fully autonomous the robot may also be equipped to move the parts in and out of the inspection jig, either from a tray or conveyor therefore requiring minimal supervision.

Accessories

Vision Systems – The main accessory involved in a quality inspection application is the vision system, including the camera and software to process the images. Often the system required will be a more high-end system than the sort of system required to simply locate a part for the robot to pick it, but with increasingly capable vision processing algorithms, configuration doesn't necessarily have to be super complicated.

End-effector – If the robot is also required to handle the part in and out of the inspection location then a gripper should also be mounted on the robot alongside the camera to move the part.

External Jig – Once the robot places a part it may need to be clamped in place in a jig to fix the position.

Programming

Setting up this type of application is generally very straightforward. In the instance that the robot does not need to handle the part directly, the program will simply consist of moving to fixed waypoints then triggering the camera via digital I/O or Ethernet communications.

A pick and place operation may also be added to this in the case that the robot handles the part, but this is again a very straightforward process.

Typical Programming Time – Less than 2 hours (excluding vision system)

Benefits

A machine vision system will usually have a faster, more consistent output than a person inspecting a product leading to improved quality and productivity. As mentioned above, compared to mounting multiple cameras around an inspection cell, a cobot based solution can potentially be significantly cheaper while fitting into the same compact workspace.

CONCLUSION

For a newcomer to robotic automation, this paper provides basic insights into how collaborative robots can be implemented in common tasks and the benefits of doing this. The common applications discussed above can be rolled out in a very short period, especially when utilizing the huge range of plug & play accessories available in the UR+ showroom.

At Universal Robots, we want to create an ecosystem whereby automation is made accessible for all. Beside content in this white paper, first-time adopters can learn a lot of the required skills for implementing a UR cobot from **Universal Robots Academy** [2], which is Universal Robots' e-learning program offering a free, interactive online training course aimed specifically at newcomers to robotic automation. To complement this, UR channel partners around the world are also capable of delivering standard UR face-to-face technical training programs to guide existing technical staff so they can implement robot applications on their own. Affording existing staff the opportunity to operate and even program a collaborative robot system makes for a much more rewarding experience, and a more attractive workplace environment for new staff.

By putting automation in the hands of operators, we allow small companies with low volume production to join larger companies in automating their processes without the need for high initial investment and extensive automation experience.

2) https://www.universal-robots.com/academy

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