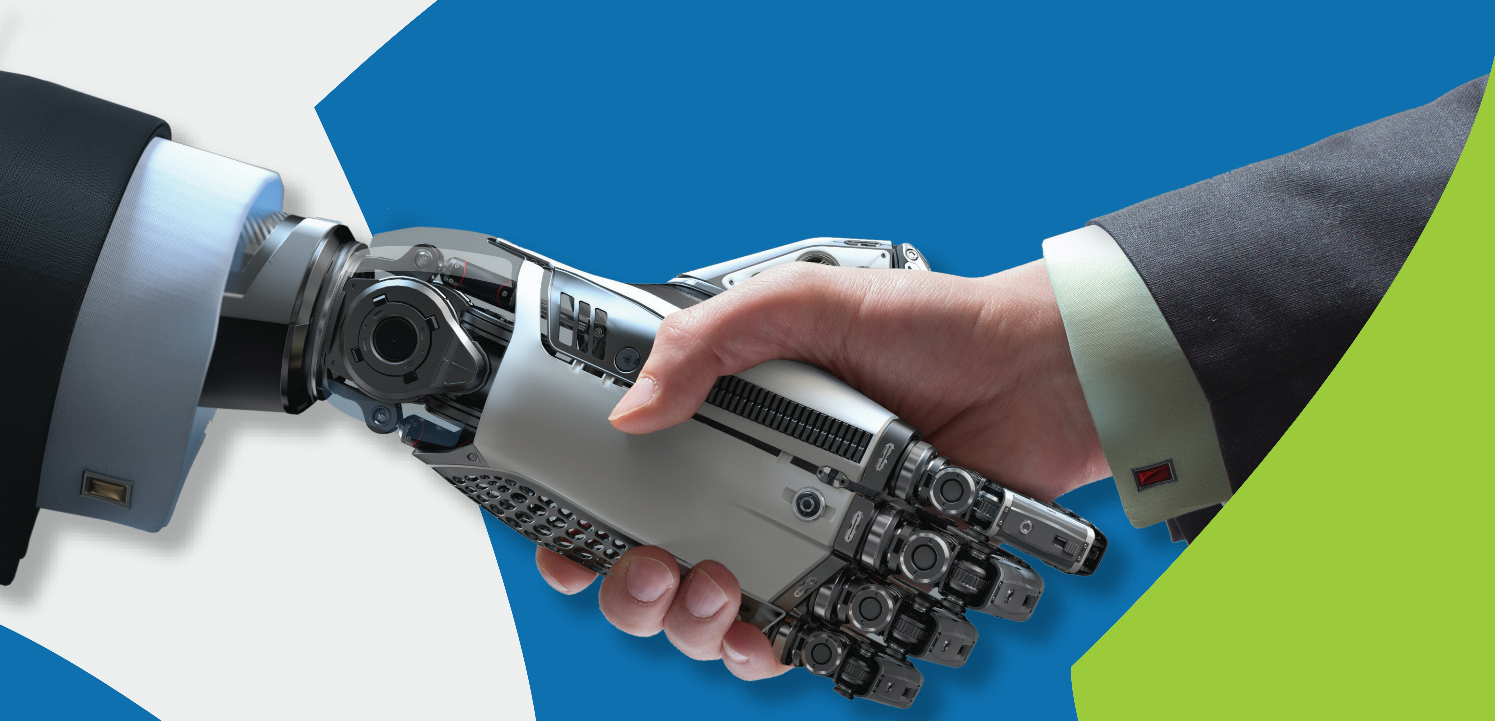
Next generation testing with

COLLABORATIVE ROBOTS

Using collaborative robots to automate the last leg of the testing lifecycle



Robotics in testing: An emerging technology trend

The testing process can be very interactive and multitasked, involving the simultaneous operation of more than one actuation point to trigger and resulting in a large number of combinations. For example, testing an instrument cluster may require actuation of touch points on screen, push button pressing, knob adjustment, listening to an alarm/chime, observing visual indication, and detecting audio response.

As the number of test cases or use case combinations increase, it is difficult to cope with the complexity while maintaining the pace and accuracy of the testing process. Hence, there is a need to automate the testing process and gain more time for humans to analyze the results.

To address these challenges, the adoption of next-generation technologies such as robotics to improve the efficiency and reliability of product and system testing is our way of enabling the ***Intelligent Industry***. The new-generation robots can sense, plan and act to perform tasks, resulting in a new range of robotics applications.

This point of view presents the role of robots in device testing applications, the evolution of collaborative robots in testing, their ability to achieve the desired role in testing, and the parameters to define types of robots and their specifications.

Black-box testing

Black-box testing is a testing method where the input and output combinations are defined without getting deeper into the details of implementation. This type of testing cascades into user testing or end-to-end testing of the system under test (SUT), device under test (DUT), or unit under test (UUT). We will henceforth refer to them all as DUT.

What type of robots are suitable?

The types of robots that can be considered for commercial applications are broadly classified as:

1.Service robots – Assist humans in various routine tasks with defined scope of work and dedicated functionality (e.g. robots in warehouses, packaging, inspection, and home assistance).

2.Custom robots – Special mechatronic designed robots to execute a dedicated task (e.g. robots for push/pull systems).

3.Industrial robots – Specialized service robots that are fast and performance oriented. These can be used best for stand-alone or clustered units (e.g. robots for manufacturing lines).

4.Cobots – Smaller robots capable of working in a collaborative environment alongside human operators.

While the first two categories are too specialized, traditional industrial robots are best suited for demanding tasks in terms of power/speed/exposure and similar parameters that are beyond human capacity. The use of such robots may be a surfeit in a testing environment, which mostly likely is a lab or back-end of a shop floor. Also, these machines come with a set of precautions and prerequisites due to their intimidating power and speed, which can be perceived as a threat to human and equipment safety if made to coexist and co-work.

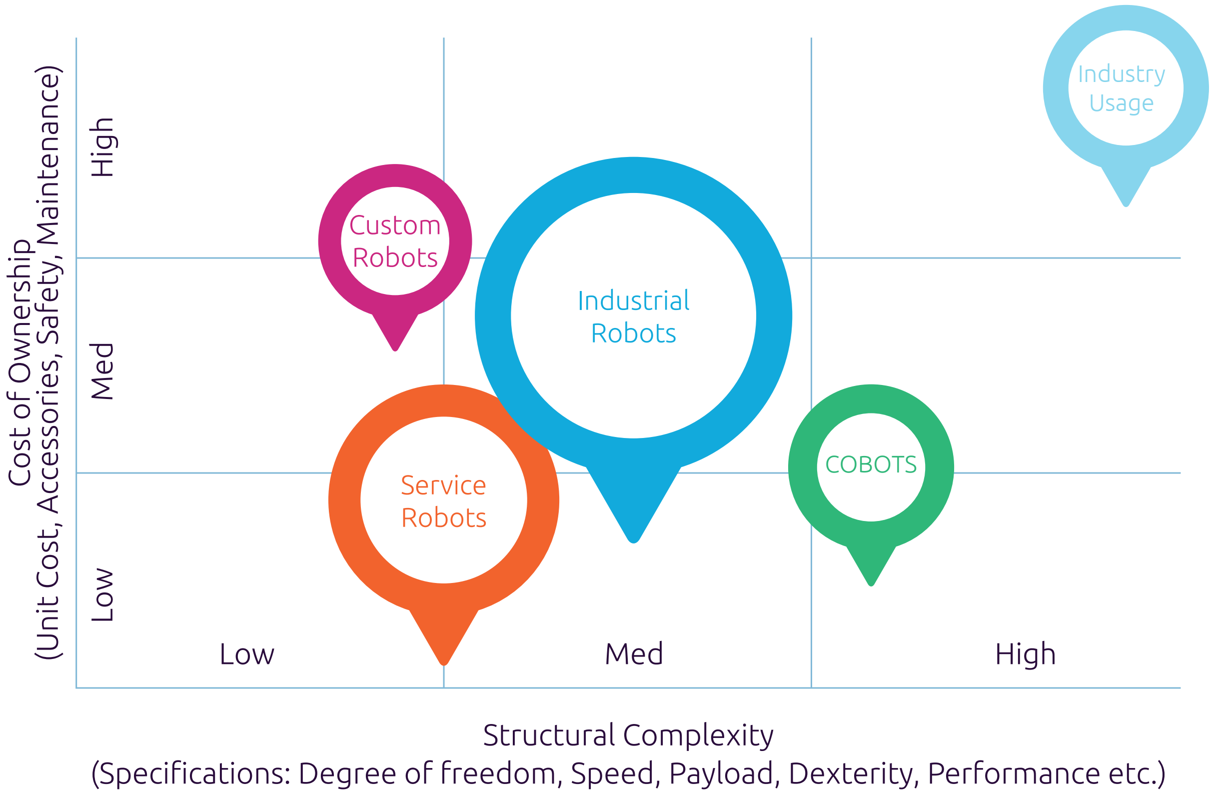


Figure 1: Qualitative comparison of robots in industry and their usage patterns

The new era of robotics: cobots

Cobots are collaborative robots that are enabled with constructional and operational mechanisms to qualify as safe companions for co-working with human operators. Inherent safety features, limited speed and force, as well as virtual safety limits all make them an ideal choice for a lab setup. Due to these parameters, cobots are more relevant than industrial robots.

They are light, small, mobile, and energy efficient as well as re-deployable to multiple locations without causing any changes to the production layout. They require very little programming to start work and do not require prior programming expertise for deployment from the cobot operators – unlike traditional robots, which can take weeks to set up before they are operational.

Some examples of cobots are: Universal Robots UR5, ABB YuMi, Fanuc CR-35iA, KUKA LBR iiwa, Kinova JACO.

Challenges for testing with cobots

The biggest challenge is to bring a consensus to the table that a cobot is needed to test a specific DUT. The factors could be investment, effort, and safety. While safety is mostly taken care of by cobot specifications, other factors are application specific and need a thorough study of the DUT.

Some simple dexterous operations can find a cobot implementation surplus and can be achieved by simpler mechanisms. For example, simple applications where only a few push/touch operations are required on a flat, effortlessly reachable surface, can be carried out by a simple solenoid or a cartesian (X-Y-Z) robot. However, when the operations are arduous and heterogeneous, a six-degrees-of-freedom (6DoF) robotic arm becomes the more obvious choice.

Parameters to access while defining the cobot specifications

Factors to consider from the DUT

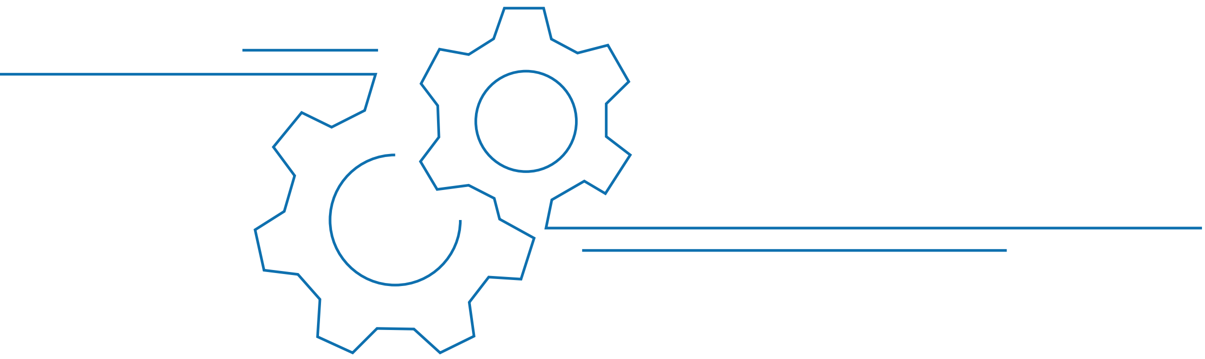
The DUT or its peripheral parameters are important factors to consider which play a crucial role while defining the cobot specifications.

Shape	The contour of physical operations, accessibility of interface points, all define the DoF of cobot and the end effector geometry.
Size	It is important to define the reach of the cobot required to cover area of interest.
Sensitivity	The sensitivity of interface points to any outer pressure/force is important to define the fine specifications such as minimum or maximum applicable force, spatial resolution of the tool point, approach speed, or retract speed for interface point.
Sophistication	The operational sophistication of a physical operation, for instance holding knobs, non-uniform shapes to hold, soft or hard objects to grip – all such aspects could pose challenges on the dexterity of the cobot.

Factors to consider from a technology perspective

The concurrent and future technology factors that can be considered for a cobot implementation in testing applications are:

Screen type	Nature of touch- capacitive/resistive, multi-touch; determines the type of end effector required for performing desired operations on the DUT and any additional DoF requirement.
Speed	The speed required for reaching out to the DUT and performing action can have a huge impact on cobot selection. Acceleration, force and inertia are also important factors that must be optimized in application development.
Envelope	The structure of cobot is defined by the path it takes to reach the DUT and cover the operational space. (e.g. arm-manipulator, SCARA, cartesian or parallel robots.
Environment	It is important to consider the DUT application and testing environment for factors that are hazardous to human and cobot safety.
Risk	Risk analysis or additional safety measures for application considering end-effectors, DUT, accessories, and defined tasks.
Repeatability	It is necessary to ensure the accuracy of operations with consistency in results.
Payload	Payload is an important paramenter in deciding the size and mounting preferences of the cobot. Generally, for testing the payload is only the end effector since no additional heavy load has to be picked up.



Cobot-based test framework: Programming and integration capabilities

Cobots are more flexible than industrial robots as they allow remote programming via APIs. They are also driven by third-party applications running on a PC. Many cobots comply with ROS standards and hence can be directly run with any ROS-based application. This gives an advantage to the user to leverage the interchangeability of cobots from different vendors. Robots are rarely used as stand-alone devices in testing like manufacturing or assembly line applications, they must have interface with:

Camera vision systems	Cobots provide built-in PLCs that can trigger smart vision systems and their output can be utilized to perform actions. If a vision system is PC based, then the cobot can be indirectly controlled via the PC-based application using TCP/IP commands.
Sensors and actuators	Cobots provide a set of digital and analog I/Os though which sensors can be read, and actuators can be driven. These I/Os are accessible via APIs from any remote controller and can be directly driven from the main application.
Simulators, DUT, environment, protocol, voice, plant models	Cobots provide in-built support for some standard protocols such as Modbus. Peripherals or other controllers can be interfaced to a cobot to achieve master-slave functionality. Simulators or application which support these protocols can communicate with cobot for a seamless exchange of data. Cobot simulators are available which can be used for a software development and initial testing of application, validating the cobot feasibility into a simulator, or model with APIs.

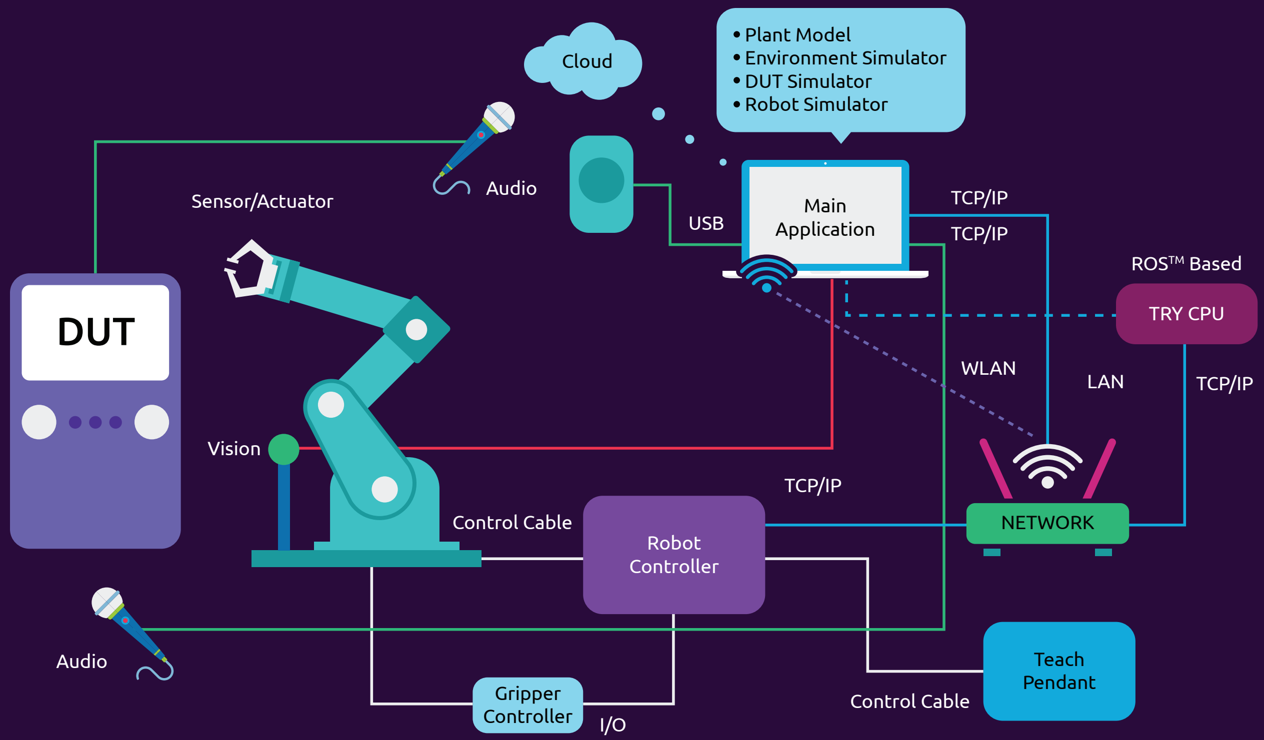
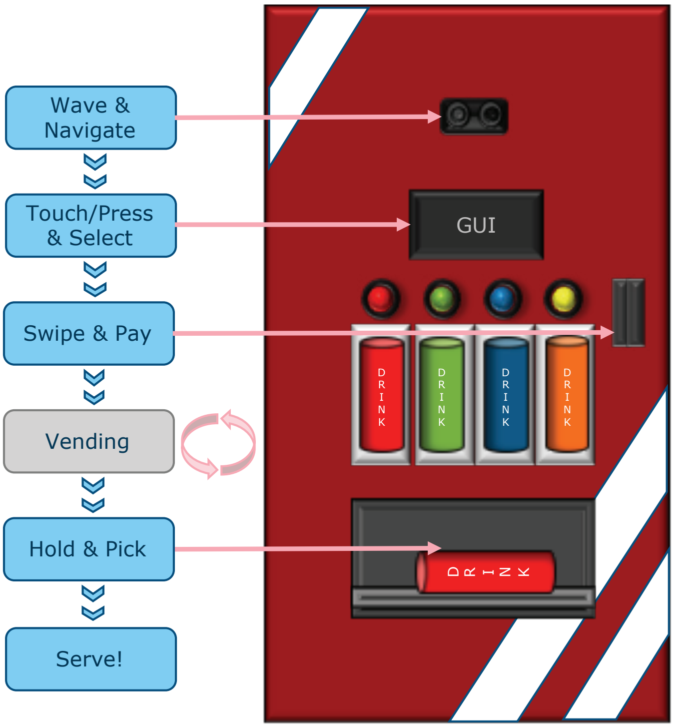


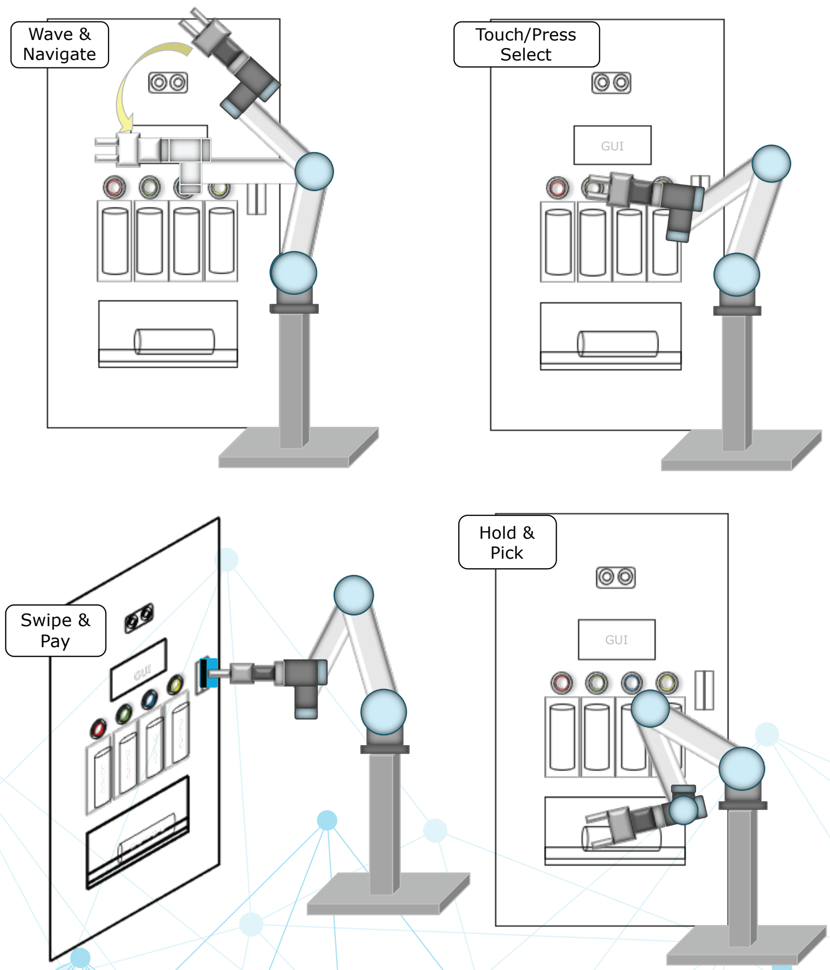
Figure 2: A cobot-based test setup

Use case: Testing smart drink dispenser with a cobot



The illustrations showcase a testing use case for a smart drink dispenser also generally known as a vending machine (VM). Usual actions performed on the VM are shown in the flow chart. The size of the vending machine is about 6–7ft height and 4ft wide. The actuation points are distributed well along the boundaries. For a cobot to perform these actions, a very flexible structure and fine dexterity is essential. The subsequent diagrams show possible poses of the cobot which can be used to perform the actions effectively.

The load capacity, touch precision, and movement accuracy, while maintaining flexibility of poses and adequate reach (almost 360° in horizontal as well as vertical plane), are more practical to achieve with a six-degrees-of- freedom cobot than a traditional industrial robot. With force and speed limiting features, virtual safety planes, joint angle restrictions and other safety features, the cobot is a better choice as this is a collaborative workspace where the user will be working in close proximity to the robot.



The cobotization roadmap

Collaborative robots are enhanced with visual, sound, and sensor capabilities for performing end-to-end testing use cases from actuation to detection and verification.

To help companies understand the robotics journey in testing, Capgemini has illustrated well-defined steps to incorporate cobot-based testing in a verification and validation ecosystem.

Exploration
- Understanding of device under test
- Study of user interface
- Study of test lifecycle
- Assessment of robot type
- Assessment of sensor need
- Choice of end effectors

Proof of concept
- Robot, stylus, gripper selection
- Selection of sensors
- Defining the need of software components
- Robot stimulations for envelope
- Arrangement and movement profile
- Timing of actions on DUT
- Calculation of execution cycle timings

First Implementation
- Application development
- Test case development & execution
- Timing and verification effectiveness

Diffusion
- Design reassessment
- Application deployment
- Calibration & customization
- Scalability analysis
- Production deployment
- Value monitoring

Production
- Robotics analytics
- Project managemnt
- Production log analysis
- Setup and process fine tuning
- Upgrade and maintenance strategy
- Downtime investigation
- Value monitoring

Scope of cobots in testing

- Functional testing: Testing of physical action-based features of a device or module
- Performance testing: Consistent and rigorous testing of device inputs and responses
- User testing: Limitation of maximum possible user actions to cover DUT functionality
- System testing: Testing in tough or hazardous environment for end usage
- Assisted testing: Robot assisting human to perform repetitive tasks.

Industry domains of testing applications

- Aerospace: Cockpit operation, user testing
- Medical: Bench-top instrument testing, motion profiling for robotic surgery
- Industrial automation: Machine tending, quality inspection
- CPRD: User testing of DUT, performance testing, GUI testing.

Pitfalls to avoid

Choice of overkill BOM	The selection of robot ideally should be just sufficient to achieve the degree of scalability, but the application must have modularity to allow gradation of BOM. E.g. For a smartphone testing application, an x-y-z type of robot may be a better choice than a 6DoF robotic arm.
Ignoring risk	Cobots are inherently safe but their applications are not. If the end effector is not safe, the cobot is no longer safer. E.g. any screwdriver, laser pointer/engraver and knife could pose risk to user and equipment. An adequate risk assessment should be done to avoid accidents.
Payload dilemma	The type of actuators used on cobot further determine the what the payload should be. Apart from this, there will be mounts, fixtures, cables, etc. to add to the weight.
Actual speed of operation	The specified speed of operation and actual speed of operation for the cobot could be different for different poses, path and predefined movement profiles. E.g. Joint movement is faster than the linear movement.
Path planning	Defining exact waypoints is important in testing applications for accurate movement of stylus. The maximum acceleration, speed, force limits, angle limits, all need to be carefully planned to achieve desired profile.
Repeatability	It is important to ensure the accuracy of operations with consistency in results.
Vibrations	Testing application requires that the cobot follow many sharp turns, discontinuous paths, abrupt speed/acceleration variations, and frequent hits. These all can cause vibrations while it is at operation and pose challenges in accuracy, aesthetics, and maintenance.

Approach to determine the ROI

Manual Vs automated equations	The automation effect of testing can be calculated by determining the operations performed by the cobot and the proportion of those actions in the overall test execution cycle. The other aspects that can be considered are speed, accuracy of operations, and repeatability of results.
Considering scalability and reusability	A cobot-based test solution is scalable as more similar or non-similar cobots can be added to it with incremental efforts and preventing the re-training of testers for each new application. Most of the applications can be reused in case of change or upgrade of components, and change of DUT features.
Development time for solution	Overall solution development time is important from the point of view of how much utilization would be compared to the time spent for development. How likely are the DUT features to evolve while the solution is under development; and, the shelf life and active life of the components. Cobots are evolving every day and we can expect very dynamic market conditions in the future, with new vendors coming in and older ones phasing out.
Implementation efforts and cost	For a small team of testers or a low throughput shop-floor, an automation solution may be underutilized resulting in a poorer ROI than a pipelined manufacturing unit where testing is actually a bottleneck for the production output. Hence, the efforts and cost to develop a customized solution may not rationalize into a profitable outcome. ROI in short term may not be achievable and the long-term ROI may be decimated by the maintenance or the up-gradation cost.
Savings in maintenance	Manpower maintenance has social-economic factors contributing to the cost. Maintaining a trained testing team with consistent output and quality is challenging. It is always beneficial to rationally divide the testing tasks in human and machine to achieve a tangible ROI. Cobots are by themselves lower in maintenance than other robots and hence more economical.

Need and role of TRY

For efficient cobot-based automation testing solutions, it is important to consider interchangeability from different vendors. Ease of programming and developing a solution quickly always adds up to the confidence and contribute to better ROI.
TRY – "Teach Robot Yourself" is such a solution from Capgemini

TRY is
- Software Platform for Robotic Services
- Offers simple usage for collaborative robots
- Highly flexible and easily reprogrammable
- Sharing knowledge between robots

TRY Offers
- Robot task as a Service
- Easy-to-use development platform
- Robot and Services connectivity
- Content from the ROS community

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Conclusion

Cobots are finding wide-ranging acceptance in end-to-end automation testing. As technological advancements encourage robot and human co-working, the testing arena is changing rapidly and cobots are proving crucial to speed up the testing channel to cope with the overall product lifecycle challenges. Introducing cobots in the testing space is a specialized task that requires domain understanding of robots as well as verification and validation. To help companies understand this journey, Capgemini helps with a methodical approach to achieve maximum automation and sustainability, while maintaining a safe collaborative testing environment.

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