

Original Notice

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Robotiq Force Copilot



Instruction Manual

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Table of Contents

Revisions	5
1. General Presentation	7
1.1. Main features	7
1.1.1. Force Copilot	7
2. Safety	8
2.1. Warning	9
2.2. Intended Use	10
3. Installation	11
3.1. Scope of Delivery	11
3.2. Software Installation for Universal Robots	12
Installation	12
Uninstalling the URCap Package	14
License Agreement	16
4. Software	20
4.1. Control with Universal Robots	20
4.1.1. ActiveDrive Toolbar	21
Overview	21
Toolbar collapsed	21
Toolbar expanded	21
Features	22
Error Messages Overview	24
4.1.2. Using the force and torque values	26
4.1.3. Path Recording	28
Overview	29
Features*	31
4.1.4. Insertion nodes	32
Child nodes	33
Features (Spiral)	34
Features (Rotational)	35
Features (Linear)	36



4.1.5. Find Surface node	37
4.1.6. Force Control Node	39
Overview	39
Features	40
Reference frame	40
Parameters	40
Current vs targeted position	42
Motion Frame	43
Test	45
4.1.7. Force Event	46
Features (Click Detection)	46
Features (Wait for Force)	48
4.1.8. Collision Detection	49
4.1.9. Multipoint Path Node	50
How to set up a Multipoint Path	51
Step 1	51
Step 2	52
5. Troubleshooting	55
5.1. Troubleshooting on Universal Robots	55
5.1.1. Monitoring the Sensor state	55
6. Warranty	56
6.1. Exclusions	56
7. Contact	57
Appendix A – Applied Standards	59



Revisions

Robotiq may modify this product without notice, when necessary, due to product improvements, modifications or changes in specifications. If such modification is made, the manual will also be revised, see revision information. See the latest version of this manual online at: support.robotiq.com.

Revision 2019/05/22

Updated Software section to include the "current vs targeted position" and "motion frame"

Updated section Signals Specification section and Environmental and Operating Conditions section

Revision 2019/03/13

Updated mechanical specifications (section 5.2)

Updated signal specifications (section 5.3)

Revision 2019/02/26

Updated Software section to include Force Event (Click Detection and Wait for Force feature) and Collision Detection

Revision 2018/10/09

Initial release



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Information provided by Robotiq in this document is believed to be accurate and reliable. However, no responsibility is assumed by Robotiq for its use. There may be some differences between the manual and the product if the product has been modified after the edition date.

The information contained in this document is subject to change without notice.



1. General Presentation

The term "Force Copilot" used in the following manual refer to the Robotiq Force Copilot unless otherwise specified. The Robotiq Force Copilot is a software package designed for using the force and torque values read by a force torque sensor in the framework of robotic applications. The software interface provides force and torque feedback that can be used for robot hand guiding, force control processes, assembly tasks, product testing, and much more.

Info

The following manual uses the metric system. Unless specified, **all dimensions are in millimeters.**

1.1. Main features

1.1.1. Force Copilot

The hardware counterpart of Force Copilot is the license dongle, a USB storage device hosting the product license.

The Force Copilot software is used for the implementation of a force torque sensor operational commands in a user interface.

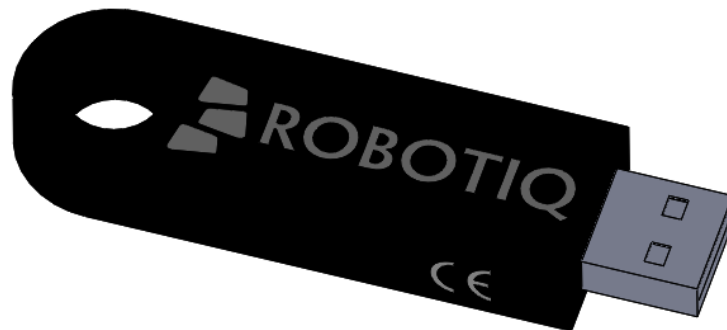


Fig. 1.1: Force Copilot License Dongle.



2. Safety

Warning

The operator must have read and understood all the instructions in this manual before using Force Copilot.

Info

The term "operator" refers to anyone responsible for:

Any of the following usage of Force Copilot the and the associated operational commands:

- Installation
- Control
- Calibration
- Programming

The drawings and photos in this documentation are representative examples and differences may exist between them and the delivered product.



2.1. Warning

Info

Any use of Force Copilot in noncompliance of these warnings is inappropriate and may cause injury or damage.

Warning

A force torque sensor used in human-robot collaboration must not be considered a complete safety measure, additional dedicated safety device(s) must be considered. Sensor failure can occur and result in danger for workers or machinery. See local or international safety measure for human-robot collaboration.



2.2. Intended Use

Info

Always comply with local and/or national laws, regulations and directives on automation safety and general machine safety.

The unit may be used only within the range of its technical specifications. Any other use of the product is deemed improper and unintended use. Robotiq will not be liable for any damages resulting from any improper or unintended use.



3. Installation

Warning

Be sure to read and understand the safety instructions related to the Robotiq Force Copilot prior to installation.

3.1. Scope of Delivery

Standard delivery for a Force Copilot kit

Force Copilot
Robotiq Force Copilot License Dongle
Axes labelling decals
Stylus for touch screen



3.2. Software Installation for Universal Robots

Info

The robot PolyScope version must be 5.0 and later to install and use Force Copilot.

Installation

Follow this procedure to install Force Copilot on Universal Robots.



URCap

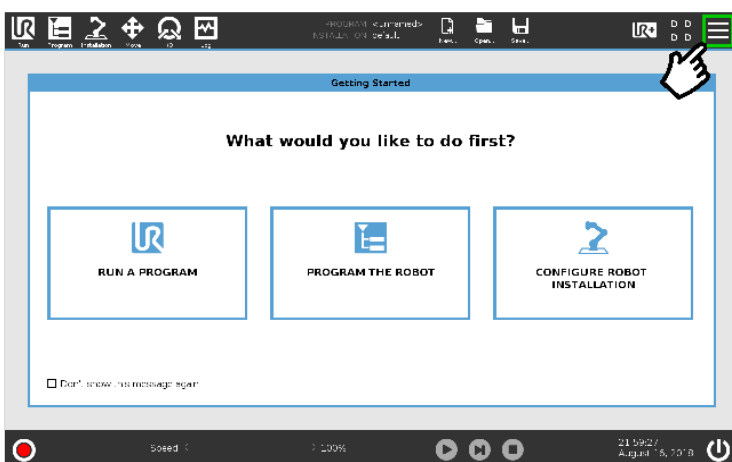


Force Copilot version XXX-X.X.X

- Browse to support.robotiq.com
- Select Force Copilot
- Download UCS-X.X.X.urcap
- Decompress the file on the USB license dongle
- Insert the USB license dongle in the robot teach pendant, robot controller, or USB hub connected to the robot controller

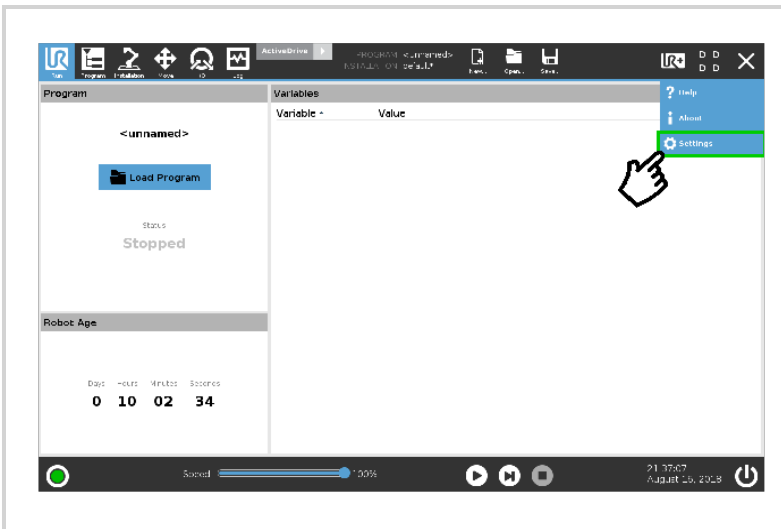
Caution

Make sure that the license dongle stays connected to the robot.



- Make sure that your PolyScope version is up-to-date.
- On the teach pendant, tap the **triple bar icon** in the upper right corner of the screen.
- Select **Settings**.
- Tap **System** in the navigation pane on the left and select URCaps.



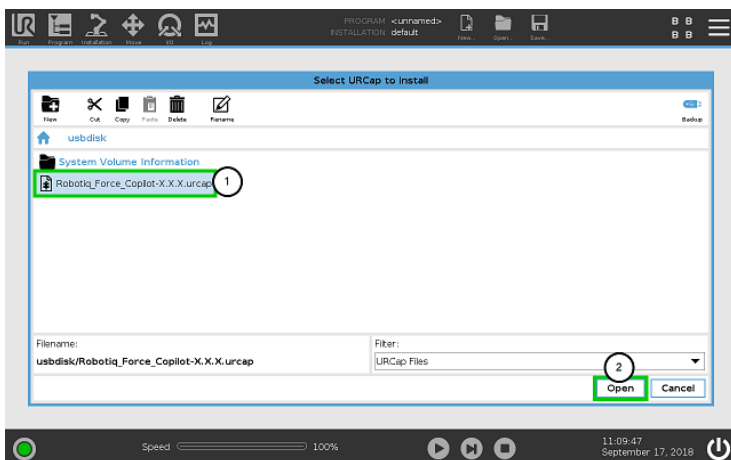


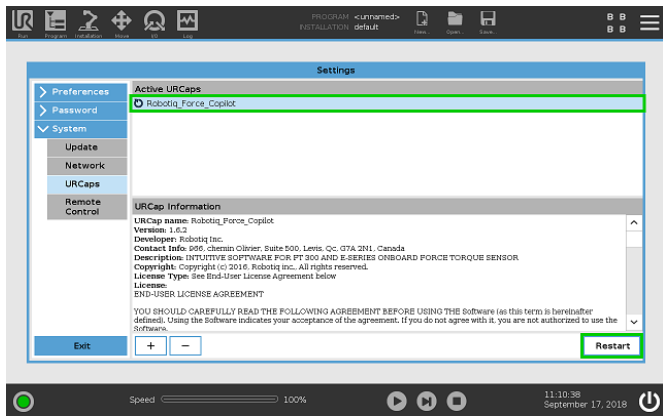
Tip

Tap the triple bar icon in the upper right corner of the teach pendant screen and select **About**. A window containing the Universal Robots software version will pop up.

- 1 Tap **System** in the navigation pane on the left.
- 2 Select **URCaps**.
- 3 Tap the **Plus (+)** button to display the storage devices and browse for the URCap file.

- 1 Tap **Robotiq_Force_Copilot-X.X.X.urcap** to select it.
- 2 Tap the **Open** button.

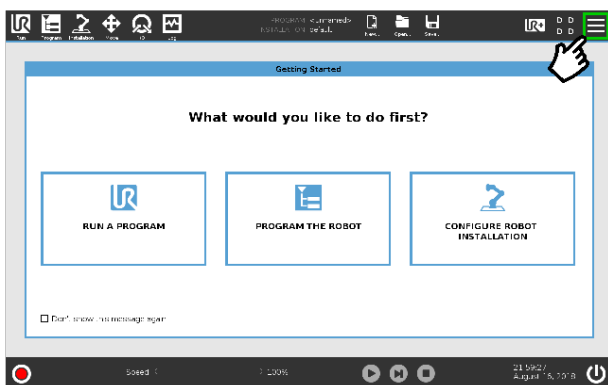




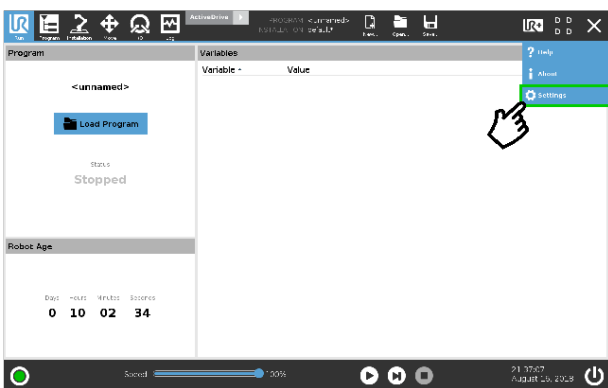
- Tap the Restart button to complete the URCap installation. By doing so, you accept the license agreement detailed in the URCap information textbox.

Uninstalling the URCap Package

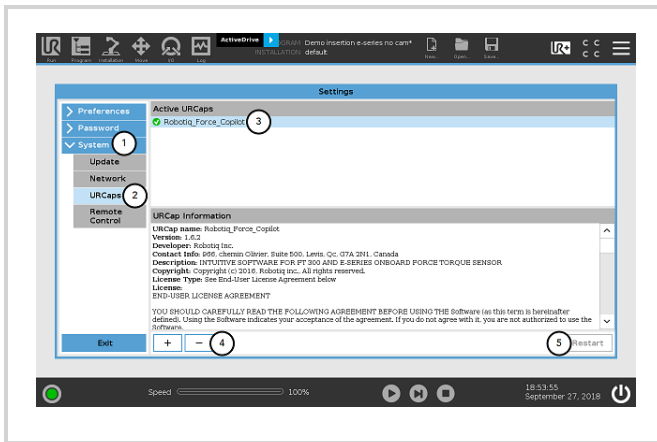
If you wish to uninstall the Force Copilot URCap, follow this procedure:



On the teach pendant, tap the **triple bar** icon.



Select **Settings**.



- 1 Select **System** in the navigation pane on the left.
- 2 Tap **URCaps**.
- 3 In the **Active URCaps** box, tap the **Robotiq_Force_Copilot** URCap; the URCap should be highlighted.
- 4 Tap the **minus (-)** button to uninstall the URCap.
- 5 **Restart** PolyScope to complete the uninstallation process.



License Agreement

END-USER LICENSE AGREEMENT

YOU SHOULD CAREFULLY READ THE FOLLOWING AGREEMENT BEFORE USING THE SOFTWARE (as this term is hereinafter defined). Using the Software indicates your acceptance of the agreement. If you do not agree with it, you are not authorized to use the Software.

IMPORTANT, READ CAREFULLY: This End-User License Agreement (the "Agreement") is a legal agreement between you and the Licensor (as this term is hereinafter defined), the licensor of the Software. This Agreement covers the Software. The Software includes any "on-line" or electronic documentation and all modifications and upgrades related thereto. By downloading, installing, or otherwise using the Software, you agree to be bound by the terms of this Agreement. If you do not agree to the terms of this Agreement, the Licensor cannot and does not license the Software to you. In such event, you must not download, use or install the Software.

1. Definition.

- 1.1. "**UR**" means Universal Robots A/S, a corporation incorporated under the laws of Denmark, having its registered office at Energivej 25, DK-5260 Odense S, which specializes into the conception, advanced manufacturing and sale of robotic products (the "UR's Business");
- 1.2. "**Software**" means any of the Licensor's software provided to its customers for the purposes mentioned in sub-section 2.2 hereof including their modifications and upgrades and their related materials;
- 1.3. "**Licensor**" means Robotiq inc., a corporation incorporated under the laws of Quebec, having its registered office at 500-966 chemin Olivier, Lévis, Québec, Canada, G7A 2N1, which specializes into the conception, advanced manufacturing and sale of robotic products (the "Licensor's Business");
- 1.4. "**End-User**" means a customer authorized pursuant to this Agreement to install or use the Software with a specific product of the UR's Products;
- 1.5. "**Licensor's Products**" means those robotic products developed by the Licensor in the course of the Licensor's Business;
- 1.6. "**UR's Products**" means those products developed by UR in the course of the UR's Business;
- 1.7. "**Licensor's Authorized Representatives**" means and includes the Licensor and Licensor's authorized vendors, resellers, distributors and licensors;
- 1.8. "**Designated Equipment**" means a personal computer that has a functional USB port and an operating system that is an equivalent or a more recent version of one of the following:
 - Windows 7;
 - Mac OSX;
 - Linux Ubuntu 16.
- 1.9. "**Purchase Agreement**" means an agreement between the End-User and the Licensor pursuant to which the End-User purchased one or more of the Licensor's Products;
- 1.10. "**Trial Period**" means the limited period during which the Software may be installed on the UR's Product and used without any charge by the End-User in order to be used without a Licensor's Product.

2. License and Object of the Agreement.

- 2.1. **License.** Subject to the terms and conditions hereof, the Licensor grants to the End-User a personal, temporary, non-exclusive, non-assignable and non-transferable and revocable license to use the Software in accordance with the terms and conditions hereof.
- 2.2. **Object of the Agreement.** The object of this Agreement is the grant of a license for the use of software that enables control functionalities of UR's Products devices or Licensor's Products (the "Purpose").



3. Software and Documentation.

3.1. **Download.** The Software shall be downloaded from the Licensor's website or provided to the End-User through a USB flash drive, according to the instructions set forth in the order summary sent to the End-User by email or by other means of communication, as decided by the Licensor (the "Order Summary"). The download of the Software shall be made with the End-User's Designated Equipment.

3.2. **Installation.** The installation on the UR's Product shall be done with a USB flash drive inserted into the UR's Product. If the Software was downloaded from the Licensor's website, it shall be uploaded on a USB flash drive device for the purpose of installation on the UR's Product.

3.3. **Utilisation.** Two scenarios are possible according to the modalities set forth in the Order Summary:

a) The use of the Software is made with a Licensor's Product. In this case, the End-User may start using the Software upon completed installation.

b) The use of the Software is made without a Licensor's product. In this case, a Trial Period is granted to the End-User. At the end of the Trial Period, which shall be set forth in the Order Summary, the use of the Software requires the software protection dongle (the "Dongle"). The Dongle will be provided to the End-User for a fee as per section 5 of this Agreement, either by the Licensor or by a Licensor's Authorized Representative.

3.4. **Documentation.** The Licensor may provide, if applicable, all documentation containing the detailed specifications for operation and use of the Software, which Software shall be used in accordance with such documentation. This documentation, if applicable, will be provided, wholly or in part, within (i) this Agreement, (ii) the Licensor's Web site <http://robotiq.com/> (iii) the Licensor's Products and the Purchase Agreement therewith, or (iv) any other agreement, document, support, whatsoever decided by the Licensor.

4. **Modifications and Upgrades.** The Licensor shall be under no obligation to provide any upgrade, modification or patch to the Software. However, the End-User shall be entitled to receive free of charge the upgrades and patches of the Software provided by the Licensor if, at such time, the End-User is not in default in respect of any of its obligations contained herein. Modifications that create new functionalities may be offered to the End-User at a price set by the Licensor at its sole discretion.

Such modifications, upgrades and patches of the Software shall be installed by the End-User itself by consulting the Licensor's website <http://robotiq.com/> where a link to proceed to such installation will be made available thereof.

5. **Fees.** The End-User shall pay the Licensor for using the software as per the Order Summary. The fees shall cover upgrades and patches of the Software provided by the Licensor if, at the time of the upgrade or patch, the End-User is not in default in respect of any of its obligations contained herein.

New End-Users not using the Licensor's Products will be entitled to a Trial Period, which shall begin on the date of the first installation on the UR's Product and which shall end after the Trial Period as determined in the Order Summary.

6. **Maintenance.** During the term of this Agreement, the Licensor will maintain the Software in an operable condition and will make available any corrections and improvements as are generally incorporated in the Software by the Licensor without additional charge to the End-User.

7. **Title to Software.** The licensed Software is composed of confidential data and trade secrets and is proprietary to and constitutes trade secret information and intellectual property of the Licensor. Title and ownership rights to the Software, including the intellectual property rights related thereto, shall remain with the Licensor. The End-User agrees to maintain the confidential nature of the source code and libraries.

The license granted herein does not include the right to sublicense to others, and may not be assigned to others, in whole or in part, without the prior written consent of the Licensor. The End-User may not or allow others to modify or prepare derivative works, copy (except for normal backups for recovery purposes), reproduce, republish, reverse engineer, upload, post, transmit, or distribute, in any manner, the Software.

8. **Restricted Use.** The Software shall be used solely and exclusively by the End-User and its employees for the Purpose mentioned in sub-section 2.2 hereof. Any other use of the Software, including resell derivative modifications or extensions, is expressly prohibited.

9. **Audit.** During the term of this Agreement and for six (6) months after the termination, the Licensor shall have the right, during normal business hours and upon reasonable advance notice to the End-User, to visit the End-User's premises for the purpose of



auditing the End-User's use of the Software to confirm that such use is in accordance with this Agreement or to confirm that the End-User has ceased the use of the Software after the termination of the Agreement. The costs of such audit shall be borne by the Licensor unless it determines that the End-User has underpaid it for any twelve-month period by five per cent (5%) or more or that the use of the Software is not in accordance with the Agreement; in such case, the End-User shall pay the costs of the audit and such underpayment.

10. **Exclusion of Warranty on Software.** The End-User expressly acknowledges and agrees that use of the Software is at the End-User sole risk. The Software is provided "as is". The Licensor warrants that, during the term of this Agreement and except if modified by the End-User, the Software will meet in all material respects the specifications provided for in the Licensor's website.

11. **Limitation of liability.** To the maximum extent permitted by law, the Licensor and Licensor's Authorized Representatives shall not be liable for any indirect, incidental or consequential damages for breach of any express or implied warranty, breach of contract, negligence, strict liability or any other legal theory related to the Software. Such damages include, but are not limited to, loss of profits, loss of revenue, loss of data, loss of use of the product or any associated equipment, down time and user's time, even if the Licensor has been advised of the possibility of such damages. In any case, the Licensor's entire liability under any provision of this agreement shall be limited to the amount actually paid in respect of the Licensor's products purchased by the end-user pursuant to a purchase agreement.

12. **Indemnification.** The End-User shall indemnify and hold the Licensor harmless from any liability, loss, claim and from any judgment, damage and cost (including, without limitation, the costs and fees of a dispute and reasonable legal fees), fine, penalty and interest whatsoever arising from any defence, dispute, compensation, claim or counterclaim as a result of the use of the Software by any third party authorized by the End-User.

13. **Training, Maintenance and Support.** There is no entitlement to training, maintenance and support under this license unless otherwise specified in the Purchase Agreement or any other written agreement between the End-User and the Licensor. The End-User may provide the Licensor with details regarding any bug, defect or failure in the Software promptly and with no delay from such event; the End-User shall comply with the Licensor's request for information regarding bugs, defects or failures and furnish him with information, screenshots and try to reproduce such bugs, defects or failures upon Licensor's demand.

14. **Expiration and Termination.** The Licensor may terminate this Agreement for default by the End-User by sending a ten (10) day notice to the End-User.

Upon the termination of this Agreement for any reason, the End-User shall promptly uninstall the Software on any UR's Products and Licensor's Products, computer, or server on which it has been installed, deliver to the Licensor all CDs, DVDs, USB flash drives, and other tangible items and materials embodying the Software, and return to the Licensor all copies thereof or destroy such copies and warrant in writing that all copies thereof have been destroyed or deleted. In the event of the termination of this Agreement, all obligations of the parties under this Agreement due for performance on the date of termination shall survive the termination, and the party terminating shall not be liable to the other party for any damages arising out of the termination.

15. **Miscellaneous.**

15.1. This Agreement constitutes the entire understanding and agreement between the Licensor and the End-User and replaces any prior agreement relating to the same subject matter.

15.2. This Agreement shall be governed and construed in accordance with the laws of the province of Quebec and the federal laws of Canada applicable therein. Any legal action or proceeding between the Licensor and the End-User for any purpose concerning this Agreement or the parties' obligations hereunder shall be brought exclusively in a court of competent jurisdiction sitting in the judicial district of Québec, Québec.

15.3. The Licensor's failure to insist upon or enforce strict performance of any provision of this Agreement shall not be construed as a waiver of any provision or right. Neither the course of conduct between the parties nor trade practice shall act to modify any provision of this Agreement.

15.4. The Licensor may assign its rights and duties under this Agreement to any party at any time without notice to the End-User. The End-User may not assign this Agreement without the prior written consent of the Licensor.

15.5. If any part of this Agreement is null, illegal or non-enforceable, this Agreement shall be interpreted as if this part was never part of this Agreement.

15.6. The provisions of this Agreement are for the benefit of the Licensor and its officers, directors, employees, agents, licensors and suppliers. Each of these individuals or entities shall have the right to assert and enforce those provisions directly against the



End-User on its own behalf. This Agreement is also for the benefit of, and binds, the End-User and its heirs, successors, legal representatives and permitted assigns.

15.7. The Licensor hereby confirms that there is no relationship of agency between the Licensor and UR, and that they are independent contractors.

15.8. Any rights not expressly granted herein are reserved.

15.9. The parties confirm that they have agreed that this Agreement and all related documents be drafted in English only. Les parties aux présentes confirment qu'elles ont accepté que la présente convention et tous les documents y afférents soient rédigés en anglais seulement.



4. Software

The following subsections provide instructions for the installation of the Force Copilot software package. This lets you receive input from a Force Torque Sensor.

4.1. Control with Universal Robots

Force Copilot contains many features to program and control the robot arm using a sensor force and torque readings. The package provides:

- ActiveDrive toolbar
- Path recording node
- Zero FT Sensor node
- Insertion node
- Find Surface node
- Force Control node
- Force Event node
- Collision Detection node
- Multipoint Path node



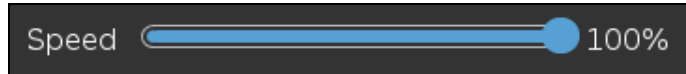
4.1.1. ActiveDrive Toolbar

The ActiveDrive Toolbar is automatically installed with the Force Copilot software package. It enhances the guiding mode on Universal Robots by allowing the robot to be hand-guided smoothly and easily towards a waypoint. The ActiveDrive feature is a great way to assist the Path recording described in the **Path Recording** section, by hand-guiding the robot while recording a path.

Info

The Force Copilot software Package contains the ActiveDrive Toolbar. Therefore, the toolbar is automatically installed with the URCap Package.

The robot speed set with the Speed slider will affect the speed at which the robot moves in the ActiveDrive mode. Verify and adjust the speed slider to the desired speed. It has to be greater than 50%.



Overview

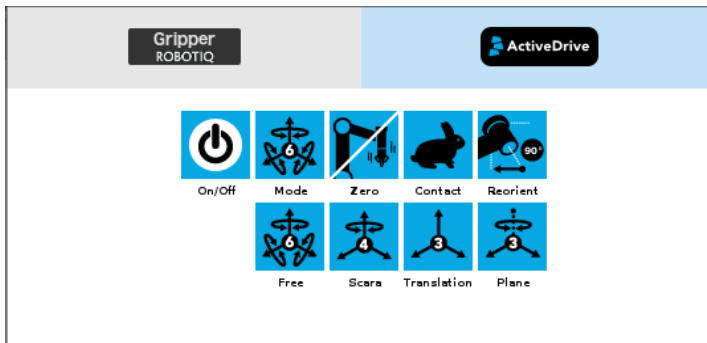
Toolbar collapsed



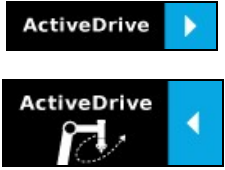







Tap the UR+ button to expand the toolbar.

Toolbar expanded




(Tap the mode selector to expand.)



Features

Primary icon	Functionality name	Description
	ActiveDrive	Tap to toggle between the expanded and collapsed ActiveDrive Toolbar. When grey, the functionality is not available. Tap the button to see why it is not available.
	Start / Stop	<p>Tap to start or stop ActiveDrive. ActiveDrive will automatically turn off after 30s of inactivity.</p> <p>When started, ActiveDrive allows you to move the robot freely by applying forces on robot's end-effector. This is different from the Free Drive feature on the robot, where you can move the robot arm.</p>
	Modes	Shows the current ActiveDrive mode. When tapping the icon, the available modes will appear and you can change to a different mode. ActiveDrive modes allow you to restrain the robot to specific movements.
	Free	Free motion: all translations and rotations are allowed.
	Scara	SCARA-style motion: all translations and horizontal rotation (twist) are allowed.
	Translation	Translation motion: only translations are allowed. No rotation of the robot is possible in this mode.
	Plane	Plane motion: horizontal translations and horizontal rotations (twist) are allowed (no vertical motions are allowed).
	Drift Control	Tap this button to stop the robot from drifting (resets the sensor's offset).

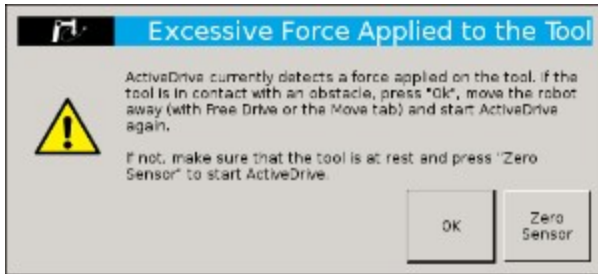


Primary icon	Functionality name	Description
 	Speed	<p>Motion speed control is toggled between fast and slow, allowing precise movement in slow motion.</p> <p>The force torque sensor will switch to slow speed automatically whenever high forces are detected, for example, during an impact with an object.</p>
	Square robot	<p>Aligns the tool center point (TCP) orientation with the robot base. Tap and hold this button to automatically move the end-effector to the closest orthogonal orientation of the base axis system (just try it, you will see!).</p>

Error Messages Overview

The ActiveDrive Toolbar will be automatically collapsed and be grayed whenever one of the following situations occurs. In such cases, by tapping the ActiveDrive button, the following messages will appear:

- Message:



- Solution:

- Starting ActiveDrive while an excessive force is applied to the tool:
 - Determine if an external force is applied to the end-effector. If it is the case, tap **OK** and move the robot away from the obstacle (with Free Drive or Move tab), or remove any external forces and start ActiveDrive again.
 - If no external forces are applied, tap **Zero Sensor**.

- Message:



- Solution:

- The robot is not initialized: Tap **OK** and go to PolyScope's home page. Tap **Setup Robot** and go to **Initialize Robot** to start the robot.



- Message:



- Solution:

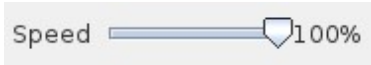
- A program is already running: The ActiveDrive Toolbar cannot be used while a program is running. Stop the program to enable the ActiveDrive feature.

- Message:



- Solution:

- The speed setting of the robot is lower than 50%: The robot's speed setting should be greater than 50%. Modify the speed setting in the robot program using the slider.



- Message:



- Solution:

- If the Freedrive button is pressed: The ActiveDrive mode cannot be used when the Free Drive mode is ON. Make sure you are not pressing on the teach pendant's Teach button when trying to use the ActiveDrive toolbar.

4.1.2. Using the force and torque values

Force Torque Sensor functions are made available in the Universal Robots functions drop-down menu.

- The `rq_zero_sensor()` function can be called at any point in a robot program to zero the force and torque values of the Force Torque Sensor.
- The `get_sensor_Fx()`, `get_sensor_Fy()`, `get_sensor_Fz()`, `get_sensor_Mx()`, `get_sensor_My()`, `get_sensor_Mz()` functions allow the user to assign the sensor values to any variable.
- The `get_applied_tcp_force(<index>)` function returns the current wrench (force and torque vector) value currently applied at the tool center point (TCP).
- The `get_applied_base_force(<index>)` function returns the current wrench (force and torque vector) value applied at the robot arm base.
- The `express_force_in_frame(<T_from_to>,<wrench_from>)` function is used to convert the wrench (force and torque vector) reading in a given reference frame into another (end-effector to robot base, and vice-versa, for example).
 - `T_from_to` = relative pose of the reference frame into which the wrench reading is converted
 - `wrench_from` = wrench to transform in pose or list format (Fx, Fy, Fz, Mx, My, Mz)

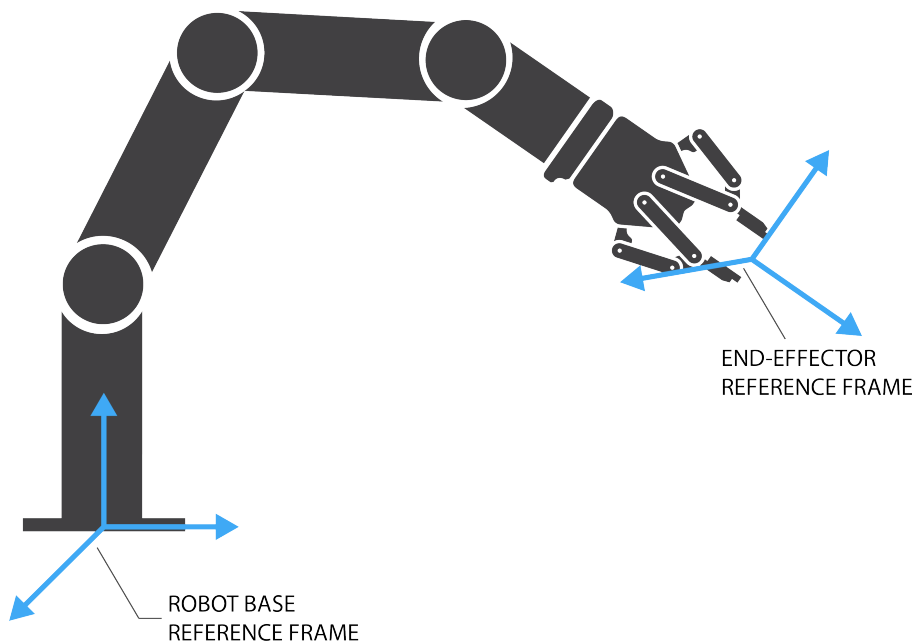


Fig. 4.1: Example of two reference frames for the `express_force_in_frame(<T_from_to>,<wrench_from>)` function

Info

Although displayed in real time in the Variables tab, the force and torque values can be seen in the Force Copilot Dashboard.



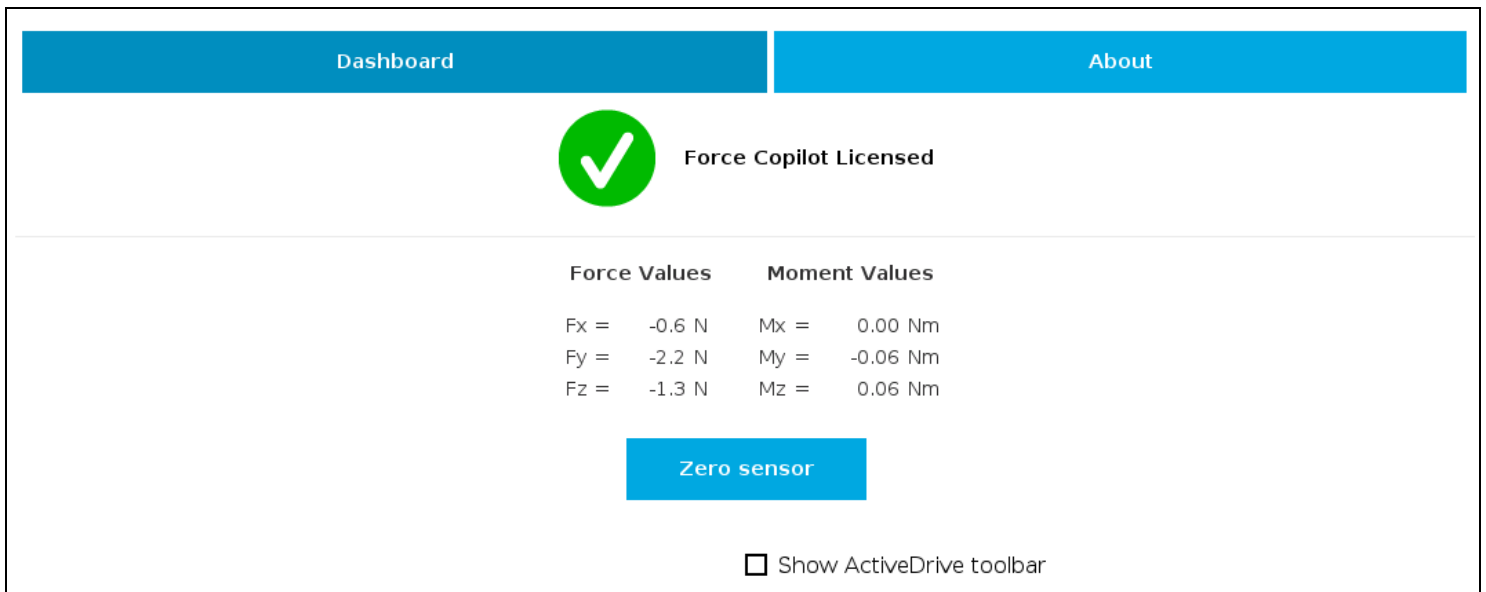
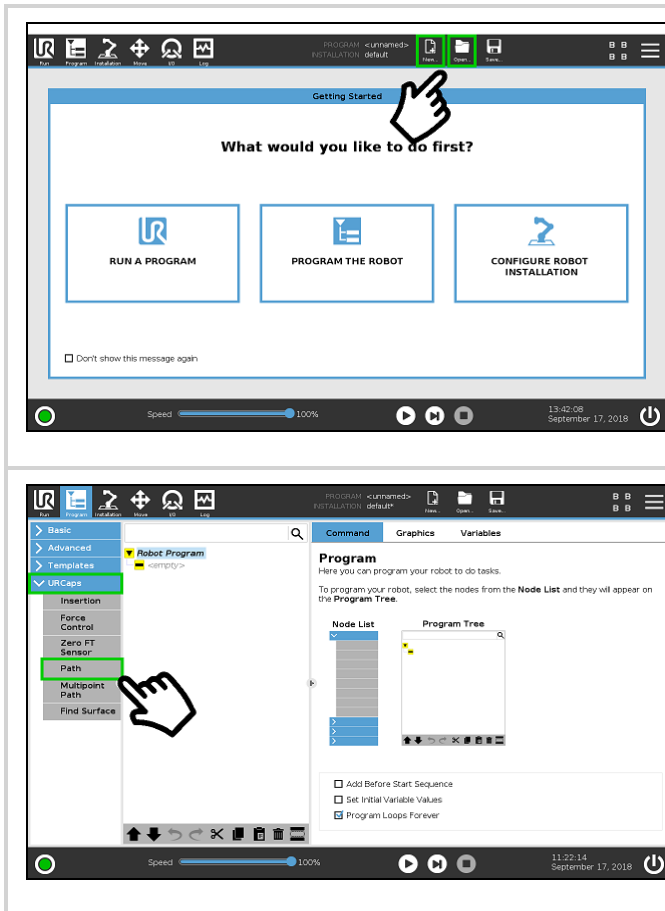


Fig. 4.2: Force Copilot Dashboard with force and torque values displayed in real time.

4.1.3. Path Recording

The Force Copilot software package adds a Path feature inPolyscope which can be used to record paths directly by moving the robot. The ActiveDrive Toolbar is a great tool to use while recording a path, as it is an easy way to hand guide the robot end-effector. Path recording can be used for specific processes requiring complex paths (polishing, gluing, etc.) or more generally, for any task otherwise requiring programming many waypoints. The Path node offers options to modify the recorded path to change its speed and play the path backwards or relative to a variable starting position.

How to add and record a path

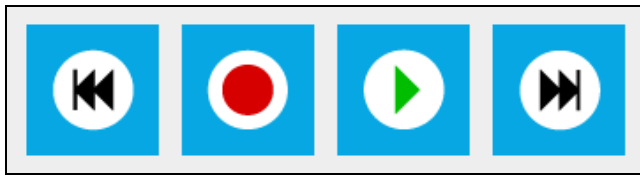


- In the ribbon at the top of thePolyscope interface, tap the **New** button to create a program or tap the **Open** button to load an existing program.

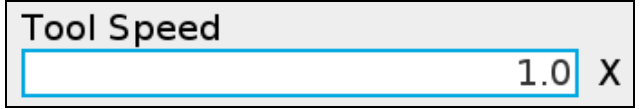
- Select the **URCaps** menu.
- Tap the **Path** button.



Overview



Path recording and visualization.



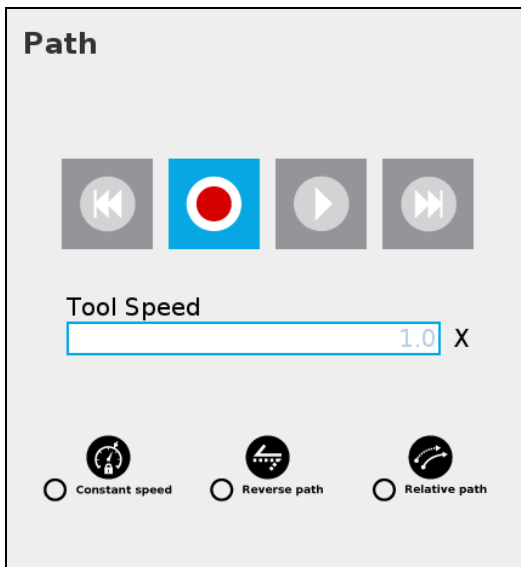
Path speed box.



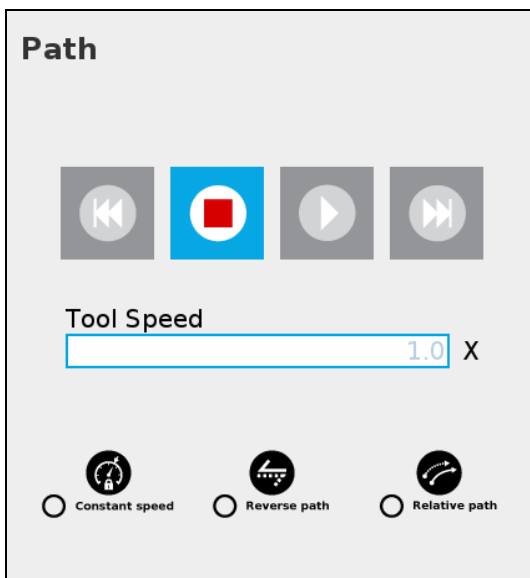
Path options.



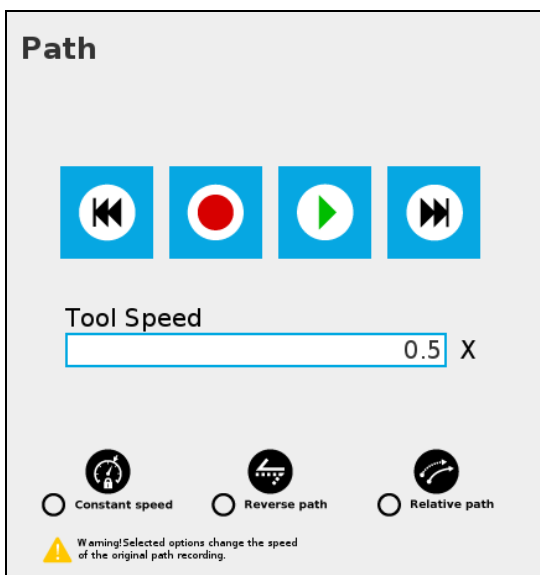
Warning section. Displayed whenever a setting results in a duration different than the original path duration.



When a Path node is empty (no path recorded), the only available button is the record button.











While recording a path, the only available button is the stop button.



When the speed of the original recording is modified using the speed slider, a warning message appears and the path time and speed information is updated.



Features*

Primary icon	Description
	Starts and stops the path recording.
	Press and hold in order to move the robot at the path's start.
	Press and hold in order to move the robot at the path's end.
	Press and hold to move the robot to starting point, and play the path as run in the program.
	If selected, the path is modified to play at a constant tool speed (linear speed at the tool center point). With this option, all pauses and hesitations (dead times) in the path will be removed.
	If selected, the recorded path will be played backwards in the program. It can be useful if a path is copied and played backwards, resulting in a path played back and forth.
	<p>If selected, the path will be played relative to the current robot position when the program enters the path instruction.</p> <p>This effectively offsets all the recorded path.</p>
	Displayed whenever a setting results in a duration different than the original path duration.

* When an icon is greyed, it means it is unavailable.

If you tap the record button when a path is already recorded in a node, a warning pop-up will ask if you want to overwrite the path (tap **OK**) or keep the previously recorded path (tap **Cancel**).

4.1.4. Insertion nodes

The Force Copilot software Package includes Insertion nodes, which can be used to perform spiral, rotational and linear movements to insert objects in holes or bores, or to make contact with a surface. It is an essential integration resource for streamlining robot programs in the framework of precise assembly applications.

When the task is performed by a human operator, the operator's fingers provide valuable feedback through the sense of touch, thus allowing the human to detect any resistance when trying to insert a pin in a hole, for instance. To a certain extent, Force Copilot gives that kind of sensitivity to the end effector.

How to add an Insertion node

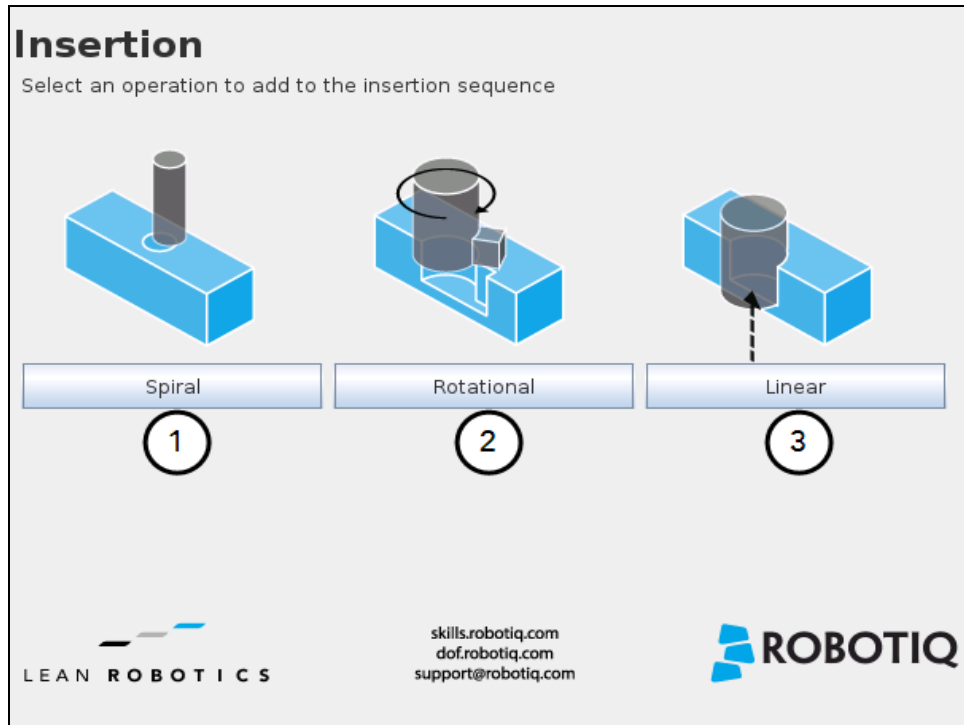
- On the teach pendant, tap the **New** button to create a program or the **Open** button to load a program
- Tap the **URCaps** button in the navigation pane on the left
- Select **Insertion**
- Tap the **Insertion** node in the robot program to edit it

Info

The parent **Insertion** node is automatically followed by a **Zero Sensor** child node.



Child nodes



- 1 **Spiral** button to insert a **Spiral** child node
- 2 **Rotational** button to insert a **Rotational** child node
- 3 **Linear** button to insert a **Linear** child node

Spiral

Following a contact established between the object grasped by the end effector (or the end effector itself) and the corresponding mating part or surface, a spiral motion is engaged on a specific plane to find the path of least resistance according to the direction, speed, force, radius increment per turn and maximum radius parameters set by the user.

Rotational

Following a contact established between the object grasped by the end effector (or the effector itself) and the corresponding mating part or surface, a rotational motion is engaged on a specific plane to find the path of least resistance, according to the direction, speed, force, maximum torque and maximum rotation angle parameters set by the user.

Linear

Following the successful spiral, rotational or fortuitous location of a mating hole or bore, a linear motion is engaged at a certain speed until the force threshold or maximum travel distance is reached.

Features (Spiral)

The Spiral child node is packaged with an **On error** condition line to be populated with a program instruction when/if the error condition occurs. The potential sequence after the Spiral instruction is followed by a program halt, by default.

Spiral

Function used to insert an object in a hole and to perform a spiral search if an obstacle is found.

Motion

Destination (A) Teach position 1

Direction (B) Tool 2 Z+ 3

Advanced parameters 4

Speed (C) mm/s 5

Force initiating spiral move (D) N 6

Force initiating insertion (G) N 7

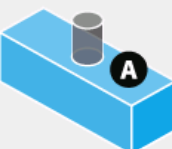
Radius increment per turn (E) mm 8

Enable peck mode

9 **Tool retraction between points of contact**

Error condition

Maximum radius (F) mm 10



- 1 **Teach position** button (Destination): Tapping this button saves the object's destination as a waypoint in the robot program
- 2 **Reference frame** dropdown menu (Direction): Menu used to select the frame according to which the tool will move in space
- 3 **Axis** dropdown menu (Direction): Menu used to select the direction in which the tool will go to reach the destination
- 4 **Advanced parameters** box: Box that expands the advanced parameters menu when ticked
- 5 **Speed** parameter: Textbox for the user to enter a speed value
- 6 **Force initiating spiral move** parameter: Textbox for the user to enter a force threshold value that triggers the spiral move, after the part/tool has established contact with the mating part/surface
- 7 **Force initiating insertion** parameter: Textbox for the user to enter a force drop value indicating that the part/tool has found the path of least resistance, prior to completing the insertion process
- 8 **Radius increment per turn** parameter: Textbox for the user to enter the distance between each spiral turn on the spiral radius
- 9 **Enable peck mode** box: Box that enables the retraction of the tool between points of contact
- 10 **Maximum radius** (Error condition): Textbox for the user to enter the maximum radius of the spiral, considering that no path of least resistance has been found

Default values and units of measurement

Parameter	Unit of measurement	Default value
Reference frame (Direction)	N/A	Tool
Axis (Direction)	N/A	Z+
Speed	mm/s	5
Force initiating spiral move	N	10



Parameter	Unit of measurement	Default value
Force initiating insertion	N	3
Radius increment per turn	mm	0.7
Maximum radius (Error condition)	mm	5

Features (Rotational)

Rotational

Function used to insert an object in a hole and to rotate on a given tool axis if an obstacle is found.

Motion

Destination (A) Teach position 1

Direction (B) Tool Z+ 2 3

Advanced parameters 4

Linear speed (C) 5 mm/s 5

Force initiating rotation (D) 10 N 6

Rotation speed 5 °/s 7

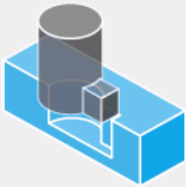
Maximum torque 1 Nm 8

Enable peck mode

9 **Tool retraction between points of contact**

Error condition

Maximum rotation angle (E) 45 ° 10



- 1 **Teach position** button (Destination): Tapping this button saves the object's destination as a waypoint in the robot program
- 2 **Reference frame** dropdown menu (Direction): Menu used to select the frame according to which the tool will move in space
- 3 **Axis** dropdown menu (Direction): Menu used to select the direction in which the tool will go to reach the destination
- 4 **Advanced parameters** box: Box that expands the advanced parameters menu when ticked
- 5 **Linear speed** parameter: Textbox for the user to enter a speed value for the approach motion towards the destination
- 6 **Force initiating rotation** parameter: Textbox for the user to enter a force threshold value that triggers the rotation move, after the part/tool has established contact with the mating part/surface
- 7 **Rotation speed** parameter: Textbox for the user to enter a speed value for the rotational (indexing) motion
- 8 **Maximum torque** parameter: Textbox for the user to enter a torque threshold value used to prevent potential collision with objects during the rotational motion
- 9 **Enable peck mode** box: Box that enables the retraction of the tool between points of contact
- 10 **Maximum rotation angle** (Error condition): Textbox for the user to enter the maximum angle of the rotation motion, considering that no path of least resistance has been found

Default values and units of measurement

Parameter	Unit of measurement	Default value
Reference frame (Direction)	N/A	Tool
Axis (Direction)	N/A	Z+
Linear speed	mm/s	5
Force initiating rotation	N	10
Rotation speed	°/s	5
Maximum torque	Nm	1
Maximum rotation angle (Error condition)	°	45

Features (Linear)

Linear

Function used to reach the bottom of a hole by travelling in a linear manner

Motion

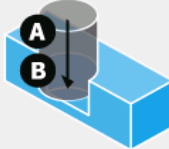
Direction (A) Tool Z+

① ②

Advanced parameters

③ **Speed (B)** ④ 5 mm/s

Force threshold (C) ⑤ 10 N



Error condition

Maximum travel distance (D) 100 mm ⑥

- 1 **Reference frame** dropdown menu (Direction): Menu used to select the frame according to which the tool will move in space
- 2 **Axis** dropdown menu (Direction): Menu used to select the direction in which the tool will go to reach the destination
- 3 **Advanced parameters** box: Box that expands the advanced parameters menu when ticked
- 4 **Speed** parameter: Textbox for the user to enter a speed value for the approach motion towards the destination
- 5 **Force threshold** parameter: Textbox for the user to enter a force threshold value that completes the linear motion
- 6 **Maximum travel distance** (Error condition): Textbox for the user to enter the maximum distance value which, upon being reached, means the force threshold has never been reached in the linear motion



Parameter	Unit of measurement	Default value
Reference frame (Direction)	N/A	Tool
Axis (Direction)	N/A	Z+
Speed	mm/s	5
Force threshold	N	10
Maximum travel distance (Error condition)	mm	100

4.1.5. Find Surface node

The Force Copilot software package includes the Find Surface node, which is a great tool for machine tending and various other applications that require repeated accurate positioning of objects.

The default parameters of the function allow for a versatile demo or a quick test of the features while the advanced parameters make it a more customizable asset.

How to add a Find Surface node

- On the teach pendant, tap the **New** button to create a program or the **Open** button to load a program
- Tap the **URCaps** button in the navigation pane on the left
- Select **Find Surface**
- Tap the **Find Surface** node in the robot program to edit it

|

- 1 Direction relative to the tool** dropdown menu: Menu used to select the direction of the linear motion, relative to the tool
- 2 Zero Sensor Before Execution** box: Box that inserts a Zero FT Sensor command right before the Find Surface instructions
- 3 Advanced parameters** box: Box that expands the advanced parameters menu when ticked
- 4 Motion speed** parameter: Textbox for the user to enter a speed value for the approach motion towards the destination
- 5 Maximum distance traveled (Stop condition)**: Textbox for the user to enter the maximum distance value which, upon being reached, means the force threshold has never been reached in the linear motion
- 6 Insert instruction textbox**: Checkbox that inserts the corresponding stop condition in the robot program when ticked; its main function is to facilitate the programming and improve the user experience
- 7 Force threshold (Stop condition)**: Textbox for the user to enter a force threshold value that completes the linear motion
- 8 Insert instruction textbox**: Checkbox that inserts the corresponding stop condition in the robot program when ticked; its main function is to facilitate the programming and improve the user experience

Parameter	Unit of measurement	Default value
Direction relative to the tool	N/A	Z+
Motion speed	mm/s	5
Maximum distance traveled (Stop condition)	mm	100
Force threshold (Stop condition)	N	10



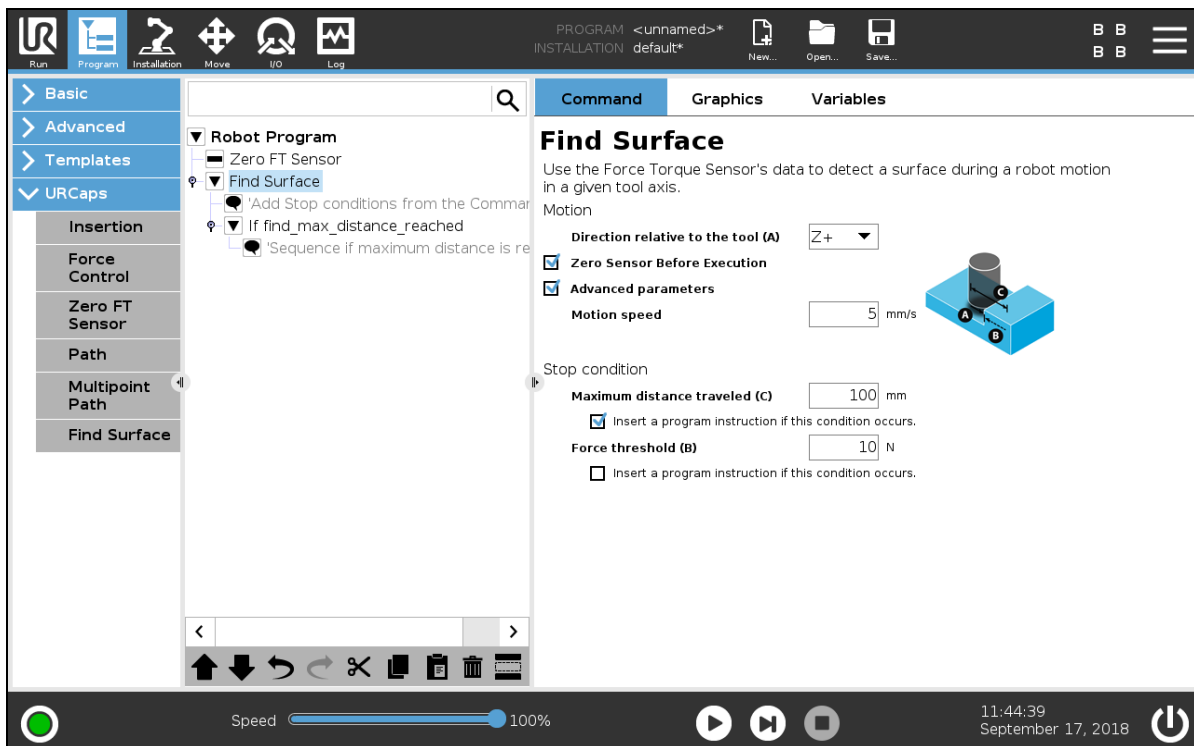


Fig. 4.3: Find Surface node with stop condition(s)



4.1.6. Force Control Node

Overview

The Robotiq Force Control node is used to apply force and torque values along and around axes.

How to add a Force Control node

- On the teach pendant, tap the **New** button to create a program or the **Open** button to load a program
- Tap the **URCaps** button in the navigation pane on the left
- Select **Force Control**
- Tap the **Force Control** node in the robot program to edit it

Warning

UR Move nodes (MoveL, MoveJ, MoveP) and Force nodes cannot be executed as child of the Robotiq Force Control node.

Tip

Where a UR Move node would normally be used, the user shall record a Robotiq Path emulating the desired Move.

In a situation where the user wants to make contact with a surface in accordance with the user-defined settings, a Wait instruction can be inserted as child of the Robotiq Force Control.

The Force Control node is primarily meant to be used with a Robotiq Path node.

With the various user-defined settings available, operators can use a force torque sensor to apply force/torque and thus follow irregular shapes and/or surfaces for applications such as polishing, deburring, finishing, dispensing, etc.



Features

Reference frame

The user can select a reference frame from a dropdown menu, as shown below.

The **Tool** reference frame uses the X, Y and Z axes of the **end-effector** to apply force and torque values in the appropriate direction.

On the other hand, the **Base** reference frame takes into consideration the X, Y and Z axes of the **robot arm base**.

Fig. 4.4: Force Control node with Reference Feature dropdown highlighted.

Parameters

- 1 **Enable control:** each checkbox corresponds to the enablement of force feeding along an axis (upper three options) or torque feeding around an axis (lower three options)
- 2 **Force/Torque:** depending on which options were checked at step 1, the corresponding textboxes here should be filled with the desired force/torque values
 - a Force values applied are in newtons (N) – the range allowed goes from -150 to +150 N
 - b Torque values applied are in newton-metre (Nm) – the range allowed goes from -50 to +50 N.

Info

Tapping the text boxes brings up a numpad used to enter the values.

- 3 **Stiffness:** the stiffness settings act directly on the Sensor's directional compliance depending on the orientation of the end-effector and the axes selected at step 1.
 - a A stiffness value closer to 0% will provide greater compliance along/around the corresponding axis
 - b A stiffness value of 100% offers no compliance along/around the corresponding axis
- 4 **Deviation range:** the deviation range limits the flexibility allowed along/around the corresponding axis.
 - a The deviation range **along** the X, Y and Z axes is measured in **millimeters (mm)** – the negative range allowed goes from -1000 mm to 0 mm while the positive range allowed goes from 0 mm to 1000 mm.
 - b The deviation range **around** the X, Y and Z axes is measured in **degrees (°)** – the negative range allowed goes from -179° to 0° while the positive range allowed goes from 0° to 179°.

Example

In a situation where **10 N** are applied exclusively along the **Z-axis**, with **20% stiffness** along the X and Y axes, and a deviation range that goes from **-50 mm to +50 mm** along all axes...

- The end-effector will systematically point towards its Z-axis
- The end-effector will not rotate around Rx, Ry and Rz (no torque feeding)
- The end-effector will be moderately flexible to move along the X and Y axes
- The movements along the X, Y and Z axes will be limited to -50 mm and +50 mm from the command position



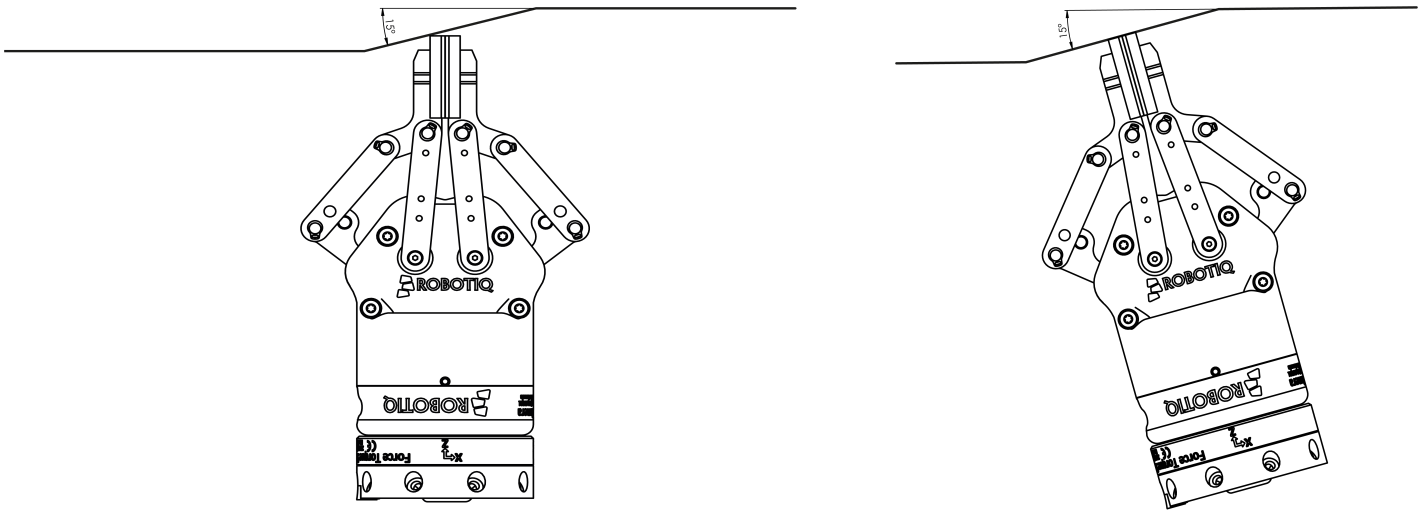


Fig. 4.5: Deviation range - On the left, no deviation range has been entered. On the right, a deviation range of at least 15 degrees has been entered around the corresponding axis.

- 5 Enable adaptive stiffness:** this checkbox greys out the stiffness values in the boxes at step 3 since the Force Control calculates the rigidity of the surface/object with which the end-effector comes in contact. Thus, constant force/torque values are applied to surfaces with variable rigidity (e.g.: long, bent, bending or folded sheets or parts).

When entering into contact with a surface for the first time, the end-effector will pull back for it has reached the force/torque value entered at steps 2a and/or 2b. It will then go back to the surface and apply the same force/torque values while pulling back less and less over time.

Current vs targeted position

From the Force Control node, you can choose to either:

- Apply force at the current position
- Apply force based on a targeted position

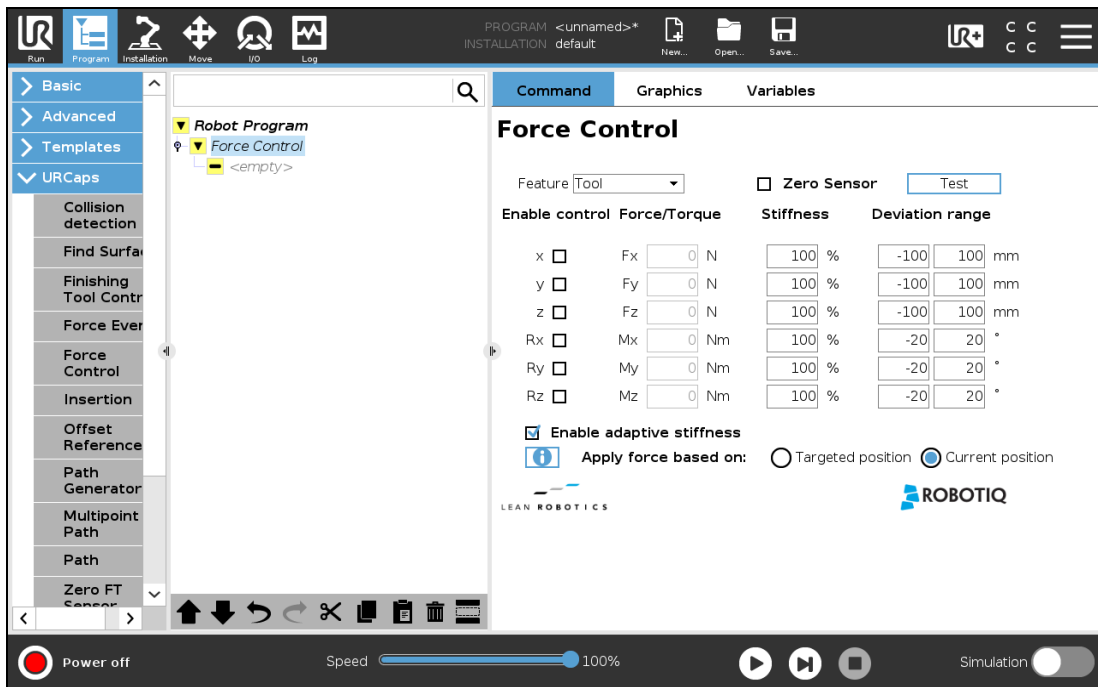


Fig. 4.6: Force Control for e-Series

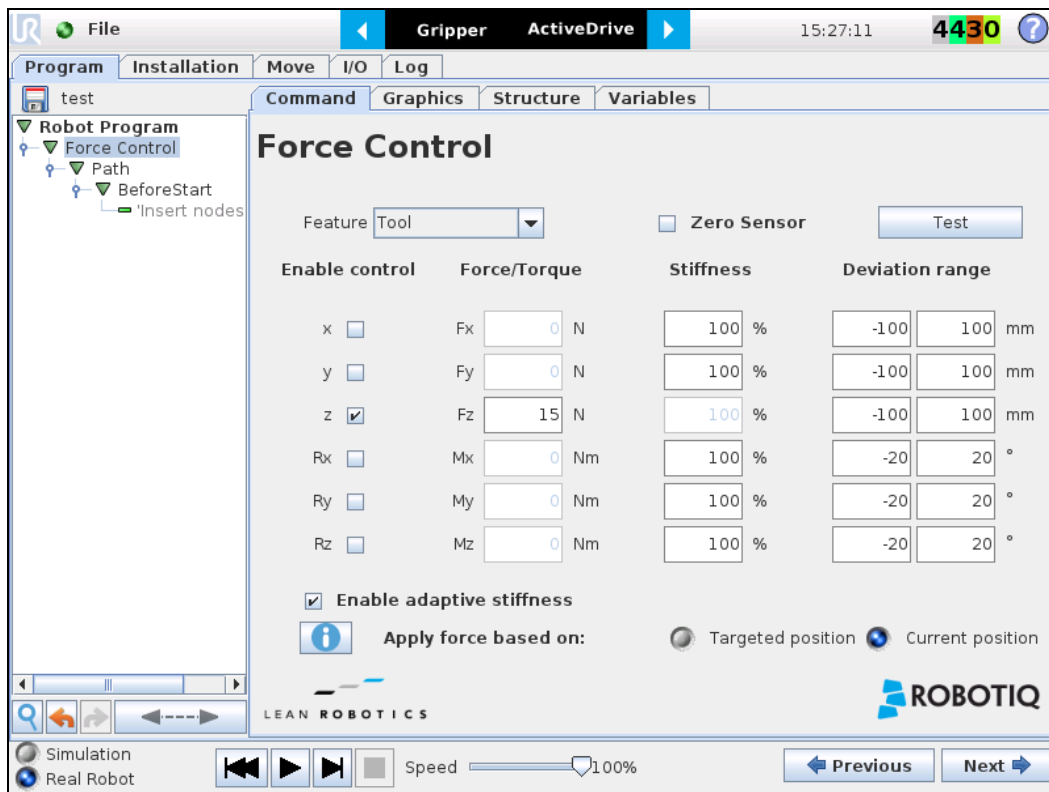
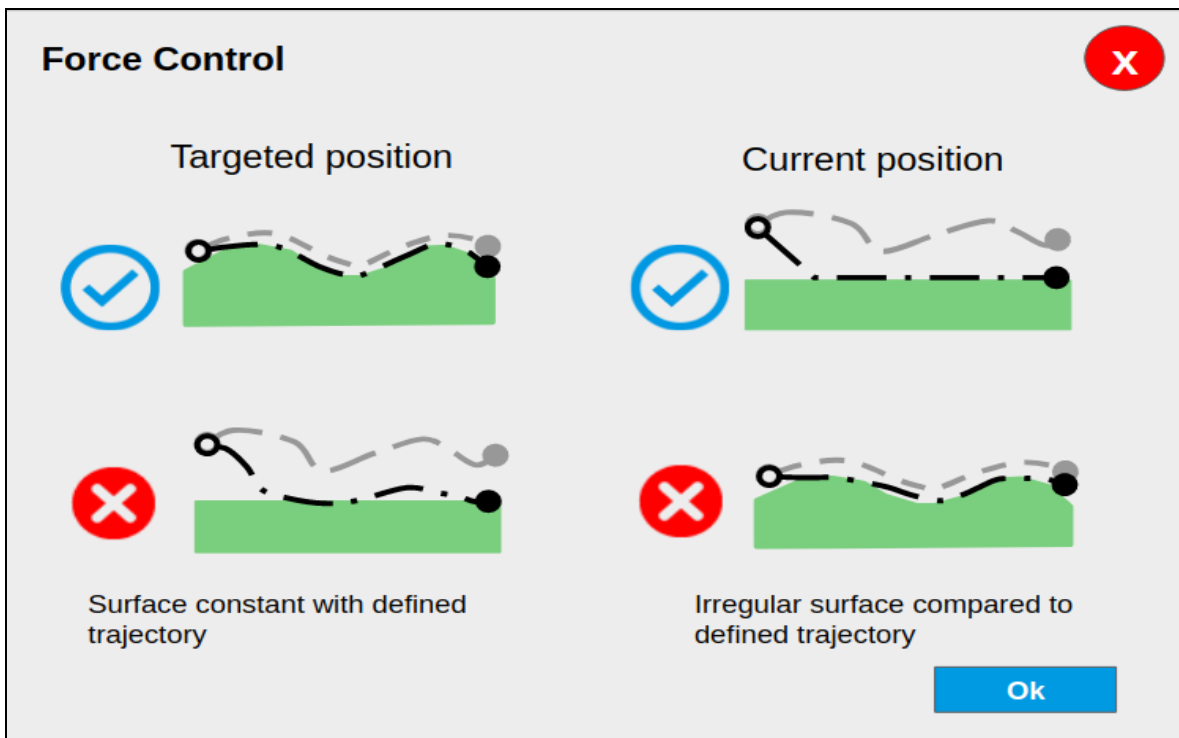


Fig. 4.7: Force Control for CB-Series





Tip

- Use the targeted position option when your defined trajectory is close to the actual part that will be processed within the Force Control node.
- Use the current position option when your defined trajectory may not resemble to the actual part that is being processed.

Motion Frame

From the Force Control node, it is possible to choose your feature among:

- Tool
- Base
- Motion Frame



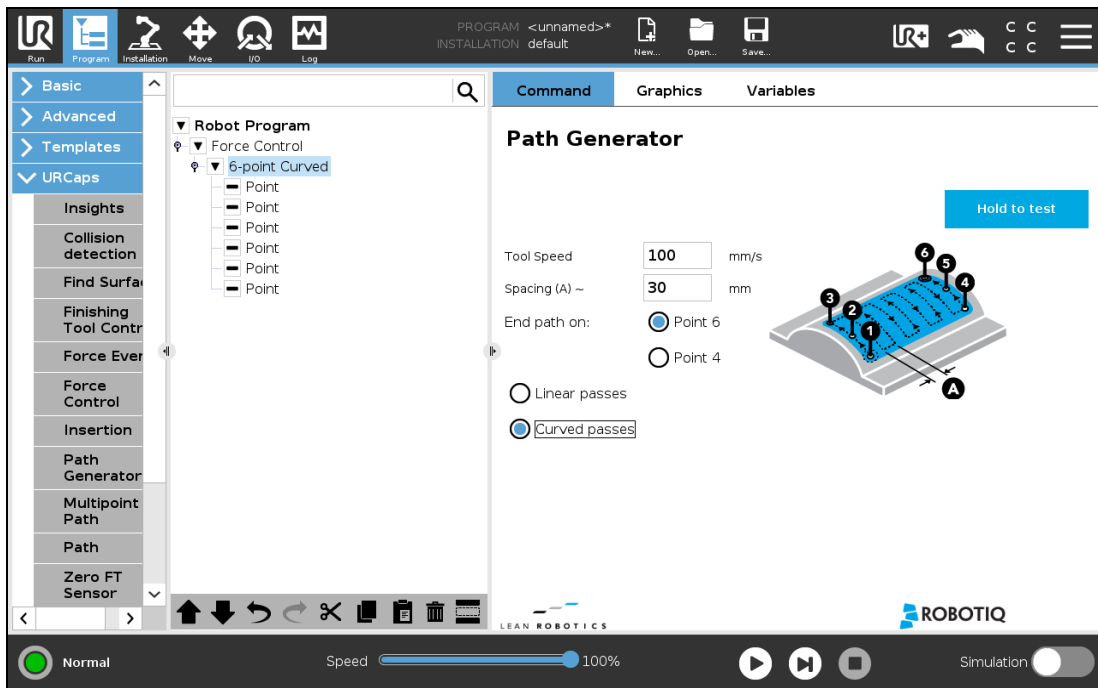


Fig. 4.8: Motion Frame for e-Series

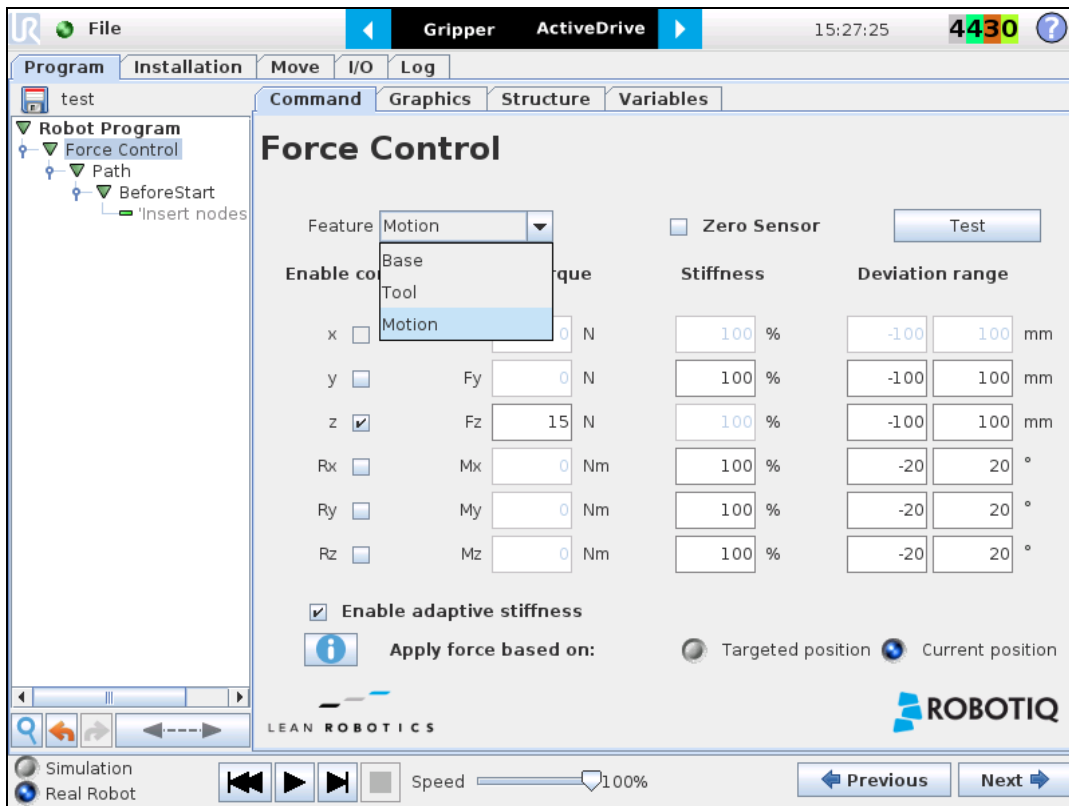
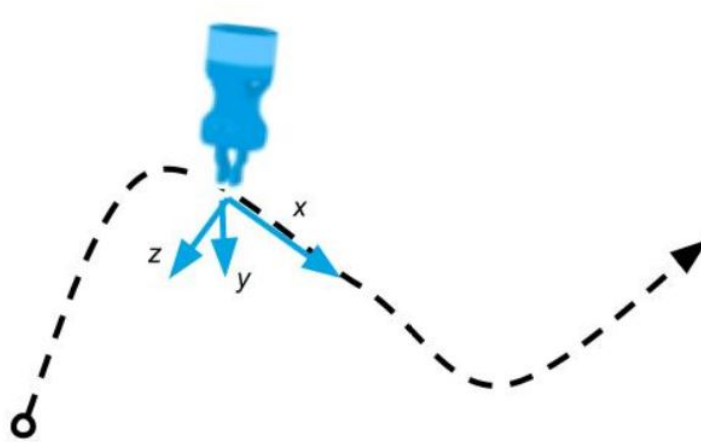


Fig. 4.9: Motion Frame for CB-Series

The motion frame option allows to apply constant forces and torques along a path. The X axis represents the motion direction, the Z axis is perpendicular to the X axis and is close to the robot's Z axis.





Test


The Test button applies the user-defined settings of the Force Control node to the sensor, therefore moving along/around the corresponding axes, if the control had been enabled for the latter, regardless of other instructions entered before or after the Force Control node in the program tree.

Force Control

Feature Tool Test


Enable control	Force/Torque	Stiffness	Deviation range
x <input checked="" type="checkbox"/>	Fx <input style="width: 40px;" type="text" value="5"/> N	<input style="width: 40px;" type="text" value="80"/> %	<input style="width: 40px;" type="text" value="-100"/> <input style="width: 40px;" type="text" value="100"/> mm
y <input type="checkbox"/>	Fy <input style="width: 40px;" type="text" value="0"/> N	<input style="width: 40px;" type="text" value="100"/> %	<input style="width: 40px;" type="text" value="-100"/> <input style="width: 40px;" type="text" value="100"/> mm
z <input type="checkbox"/>	Fz <input style="width: 40px;" type="text" value="0"/> N	<input style="width: 40px;" type="text" value="100"/> %	<input style="width: 40px;" type="text" value="-100"/> <input style="width: 40px;" type="text" value="100"/> mm
Rx <input checked="" type="checkbox"/>	Mx <input style="width: 40px;" type="text" value="10"/> Nm	<input style="width: 40px;" type="text" value="60"/> %	<input style="width: 40px;" type="text" value="-20"/> <input style="width: 40px;" type="text" value="20"/> °
Ry <input type="checkbox"/>	My <input style="width: 40px;" type="text" value="0"/> Nm	<input style="width: 40px;" type="text" value="100"/> %	<input style="width: 40px;" type="text" value="-20"/> <input style="width: 40px;" type="text" value="20"/> °
Rz <input type="checkbox"/>	Mz <input style="width: 40px;" type="text" value="0"/> Nm	<input style="width: 40px;" type="text" value="100"/> %	<input style="width: 40px;" type="text" value="-20"/> <input style="width: 40px;" type="text" value="20"/> °

Enable adaptive stiffness



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skills.robotiq.com
dof.robotiq.com
support@robotiq.com



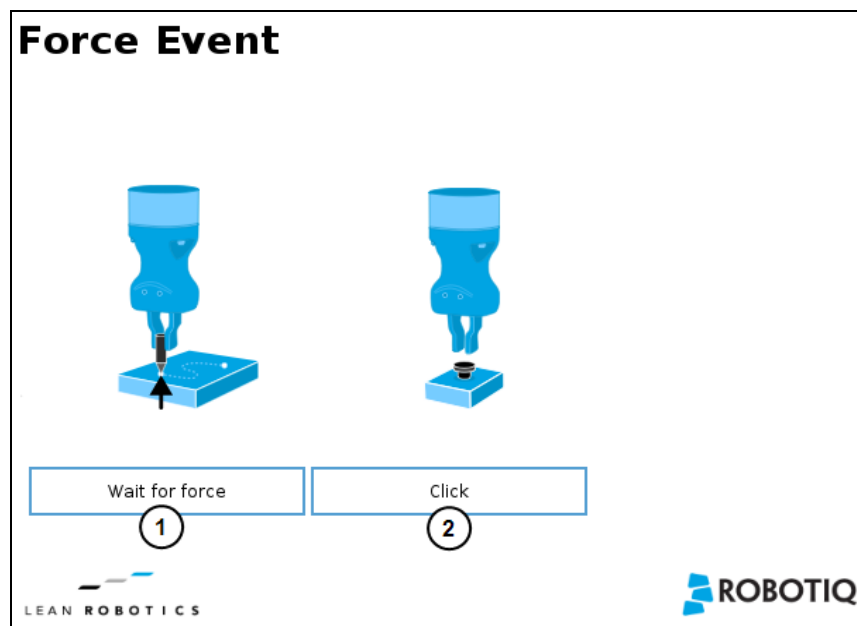
ROBOTIQ

4.1.7. Force Event

The Force Copilot software package includes Force Event, which can be used to perform a click detection or to wait for a specific force or torque.

How to add a Force Event function

- On the teach pendant, tap the **New** button to create a program or the **Open** button to load a program
- Tap the **URCaps** button in the navigation pane on the left
- Select **Force Event**
- Tap the **Force Event** node in the robot program to edit it
- Select an operation to add to the **Force Event** sequence



1 Wait for Force function

2 Click detection function

Wait for Force

The Wait for force feature is used to detect a specific force or torque inside a Force Control node.

Click Detection

The Click Detection feature is used to detect a drop that is followed by a rise of a force or a torque.

Features (Click Detection)

The Click Detection feature monitors forces and torques throughout the nodes placed within it. This feature senses if a drop in the force or torque is then followed by a sudden rise, thus making a "click". If a click is detected within the Click detection node, the program then skips the remaining instruction lines that are included in the Click detection node. The program automatically goes to the following instruction.

Indeed, a program instruction can be added if no click is detected.



Force Event

Click

Use the force torque sensor data to detect a drop in force (click) when inserting a connector, pushing a button, etc.

Force drop : N

Torque drop : Nm

Insert a program instruction if no click were detected.



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Tip

To perform a click button action, as shown by the animated gif, a Find Surface function has to be added up in the Click detection node.



Features (Wait for Force)

The Wait for Force feature is used to detect a specific force or torque inside a Force Control node. The program waits until the force or torque is reached prior to the program continuation. The values are defined by the Force Control's force and torque parameters. To be sure the program is not incessantly running, a Timeout option is available.

Force Event


Wait for force



Wait until force and torque are reached.

Timeout sec.

Force/Torque

Fx	<input type="text" value="0"/>	N
Fy	<input type="text" value="0"/>	N
Fz	<input type="text" value="25"/>	N
Mx	<input type="text" value="0"/>	Nm
My	<input type="text" value="0"/>	Nm
Mz	<input type="text" value="0"/>	Nm





4.1.8. Collision Detection

The Collision Detection feature is used to stop a program when the forces and the torques, monitored by the embedded e-Series sensor, exceed the defined limits. By default, the program does not monitor forces and torques.

How to add a Collision Detection

- On the teach pendant, tap the **New** button to create a program or the **Open** button to load a program
- From the **Installation** tab:
 - Go to the **Installation** tab and tap the **URCaps** submenu
 - Select **Force Copilot**
 - Tap the **Configuration** tab to edit it

- From the **Program** tab:
 - Tap the **URCaps** button in the navigation pane on the left
 - Select **Collision Detection**
 - Tap the **Collision Detection** node to edit it

You can either choose to halt (stop) or suspend (pause) the program when a collision is detected. The forces and torques monitored in the collision detection node are the ones measured by the embedded sensor. Thus, any forces or torques applied to the robot arm will not be detected. Only those applied to the end-of-arm tooling are monitored.

The Collision Detection feature in the installation tab can be configured to start the monitoring upon every robot program start. On the other hand, the Collision Detection node in the Program tab starts a thread that runs in parallel with the rest of the robot



program. If the Stop monitoring option is selected in the Collision Detection node, the thread stops and the program continues without monitoring the force or the torque.

4.1.9. Multipoint Path Node

The Multipoint Path node is an advanced version of the Path node, combining complex trajectory recording and point-to-point teaching, with the option to define each segment as a **straight line** or as a **curve**.

Tip

Try inserting a Multipoint Path node in a Robotiq Force Control node. The former will perform the movements that were taught while taking into consideration the parameters set in the latter.

How to add a Multipoint Path node

- On the teach pendant, tap the **New** button to create a program or the **Open** button to load a program
- Tap the **URCaps** button in the navigation pane on the left
- Select **Multipoint Path**
- Tap the **Multipoint Path** node in the robot program to edit it

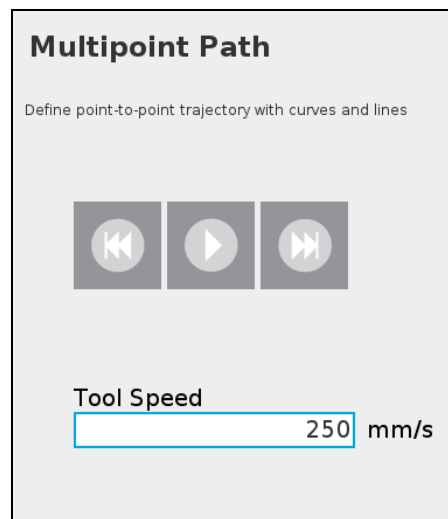
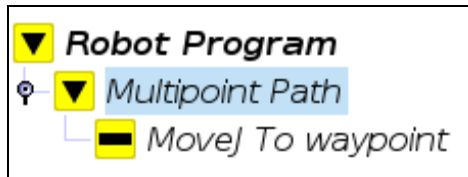


Fig. 4.10: Multipoint Path node (empty)

Info

Please note that a Multipoint Path parent node is **always** followed by a MoveJ command leading to the starting waypoint of the path sequence.





How to set up a Multipoint Path

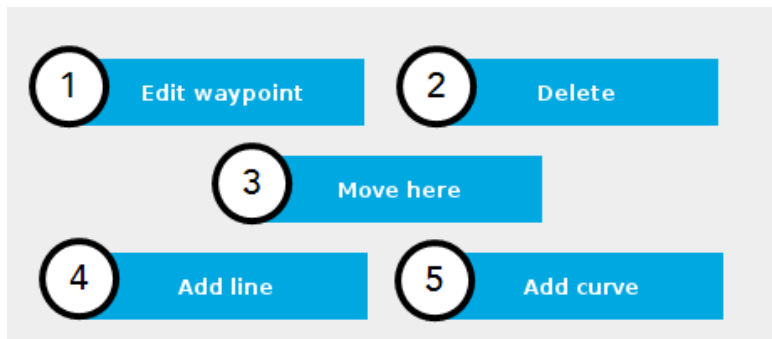
Step 1

- Select the **MoveJ To waypoint** child node in the program tree.
- A menu will display in the **Command** tab.
- Using the Freedrive mode or the UR Move menu, move the robot arm to the position you want to be the starting point of your Multipoint Path.

|

- Tap the **Set waypoint** button. The UR waypoint interface will pop up and ask you to define the waypoint.
- Adjust the position if needed, then press **OK**.

At this point, the interface will look like this:



- 1 Tap the **Edit** button to open the UR waypoint interface and adjust the position of the robot arm (this works for every waypoint of the Multipoint Path)
- 2 Tap the **Delete** button to cancel the waypoint (deleting the starting waypoint will turn it to unassigned)
- 3 Tap and hold the **Move here** button to make the robot arm travel to the corresponding waypoint
- 4 Tap the **Add line** button to let the system know that a **straight line** will be linking the current waypoint and the next waypoint
- 5 Tap the **Add curve** button to let the system know that a **curve** will be linking the current waypoint and the next waypoint

Important

Whether the path is made of straight lines, curves or a mix of both, it inevitably passes through each waypoint set by the user.

Important

The curve segments are not generated and/or represented according to a spline model; they are rather based on **Bézier curves**.



Info

For describing the continuity of the curves used in the Multipoint Path node, control points are generated on the bisector of each waypoint junction (angle). Curves are therefore tangent to those bisectors.

Step 2

- Using the Freedrive mode or the UR Move menu, move the robot arm to the next desired position.
- Add another waypoint in the program tree by tapping the **Add line** or **Add curve** button.

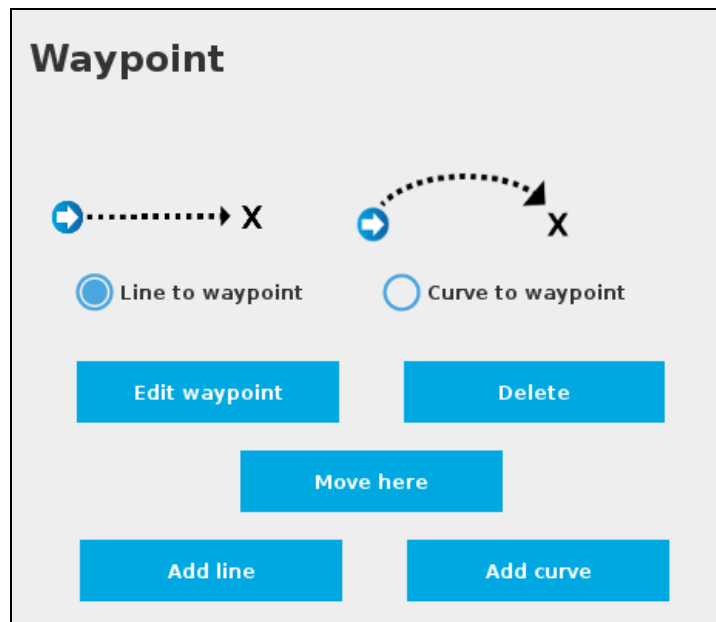


Fig. 4.11: Multipoint Path interface with Line/Curve options.



Caution

Adding several waypoints (lines or curves) without moving the robot in between them will result in the generation of identical waypoints.

In order to remedy this situation, the user can edit each waypoint created and adjust its position.

Tip

You can toggle at any time between the **Line to waypoint** and **Curve to waypoint** options.

Select the waypoint in the program tree and tap the appropriate radio button in the **Command** tab.

Repeat step 2 until you complete your Multipoint Path.

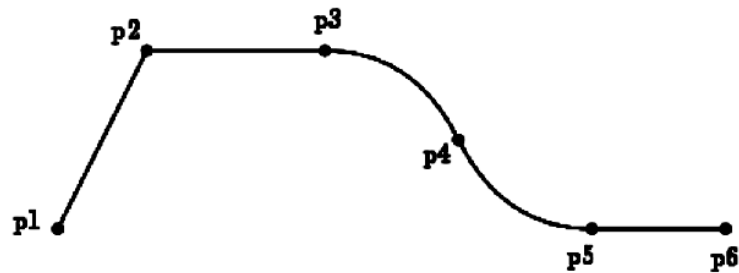


Fig. 4.12: Representation of a six-waypoint Multipoint Path with both curves and straight lines.



5. Troubleshooting

5.1. Troubleshooting on Universal Robots

5.1.1. Monitoring the Sensor state

In order to view the sensor status and verify the force and torque values:

- Tap the **Installation** button in the ribbon at the top of the screen
- Select the **URCaps** menu in the navigation pane on the left
- Tap **Copilot**
- Tap the **Dashboard** tab

Info

If needed, the user can tap the **About** tab to get further information regarding the force torque sensor.

Dashboard

About



Force Copilot Licensed

Force Values

Fx = -0.6 N
Fy = -2.2 N
Fz = -1.3 N

Moment Values

Mx = 0.00 Nm
My = -0.06 Nm
Mz = 0.06 Nm

Zero sensor

Show ActiveDrive toolbar



6. Warranty

Robotiq warrants the Force Copilot against defects in material and workmanship for a period of one year from the date of reception when utilized as intended

6.1. Exclusions

Robotiq reserves the right to make changes in the design or construction of any of its products at any time without incurring an obligation to make any changes whatsoever on units already purchased.

This warranty excludes failure resulting from: improper use or installation, normal wear and tear, accident, abuse, neglect, fire, water, lightning or other acts of nature, causes external to the product or other factors beyond Robotiq's control.



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Appendices

Appendix A – Applied Standards

Coming soon.

