ENABLED ROBOTICS

ER-FLEX 250 User Manual

Document version 3.0.0

Hardware version 2.0
Software version 2.x
MiR software version 2.x

CONTENTS

Copyright specification

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Definitions

Table 1: Definitions table

Name:	Description:
UR	Universal Robots arm.
MiR	The mobile robot from Mobile Industrial Robots.
ER	The company Enabled-Robotics A/S
ER-Flex hardware [hardware]	The physical parts in between the MiR and the UR.
ER-Flex robot [robot]	The combination of the er-flex hardware, Ability software, UR and MiR.
ER-Flex tower [tower]	The rear area of the er-flex hardware on which the UR is mounted and electronics are inside
ER-Flex front platform [platform]	The front area of the er-flex hardware, where a module or other configurations of tools/adapters can be attached onto.
ER-Flex High Module [module]	An accessory, fixed to the platform. Used for mounting fixtures or other applications.
Ability software [Ability]	The software provided enabling control and programming of the robot.
ER-Cam [camera]	Camera used by vision system included in ability
Ability user interface [user interface]	The graphical interface, used for programming and setup, provided by Enabled Robotics.
Calibration board	Included 10x13 checkerboard marker, defined as CH7 marker.Used to calibrate the camera.
Visual Marker [marker]	Included checkerboard markers, defined as CH1 and CH3 to be used as landmarks for the vision system
Integrator	Trained individual(s) responsible for the commissioning of the robot and integration of tools, fixtures etc. The Integrator has the necessary qualifications to evaluate safety in relation to the application in which the robot is used.
Robot Programmer	Trained individual responsible for programming the robot. The Robot programmer has the necessary safety qualifications in relation to the programs developed.
Operator	Trained individual responsible for the daily use of the robot.

CHAPTER

ONE

PREFACE

1.1 About

This manual describes the er-flex robot developed by Enabled Robotics. The solution provides functionality for combining robots from Universal Robots (UR) and Mobile Industrial Robots (MiR).

This document provides information on how to start and operate the robot, typical applications, maintenance of the product and general safety notes and precautions.

1.2 Target audience

This manual is intended for system Integrators who develop and program robot installations. The audience are expected to have knowledge on:

- How to set up and program robots from Universal Robots.
- How to set up and program robots from Mobile Industrial Robots
- Electronic and electrical systems.
- Mounting of tools and sensors.

1.3 Safety notice

The er-flex robot is a generic system on which different applications can be developed. A dedicated risk assessment for the system solving the specific application is therefore required.

When integrating the robot into an application, points of awareness of the Integrator includes, but are not limited to:

- That all risks associated with whichever tools that are mounted on the UR are dealt with.
- That all risks associated with mounting additional equipment on the er-flex module are dealt with.
- That the mounting of sensors and cables does not create danger for persons or properties. This includes, but is not limited to whether body parts or equipment can be trapped in cables or whether the additions give rise to sharp edges and corners.
- That all parts are securely mounted.
- That proper precautions are taken to prevent dangerous situations in case of sensor failure.
- That operators are properly instructed on the behavior of the robot, including the variations that may occur due to the use of sensors.

The robot always needs to be approved in accordance with the standards and regulations of the country in which it is installed.

CHAPTER

TWO

SAFETY

2.1 Safety message types

In this manual the following safety message types are used

Danger:

Indicates a potentially hazardous situation that could result in death or serious injury.

Take proper precautions to avoid damage or injury.

Warning:

Indicates a potentially hazardous situation that could result in minor or moderate injury. Alerts against unsafe practices.

2.2 General safety precautions

Danger:

Make sure that the Universal Robot, tools, fixtures and any other items on the robot are securely mounted before operating the robot.

Danger:

Never use the robot if it is partly or completely damaged, including missing protection plates and if cables show signs of wear and tear.

Danger:

The robot may drive over the feet of personnel and cause injury.

All personnel should wear safety shoes when near an operating robot and be informed about the risk and how to avoid it.

Danger:

Contact with live electrical parts of the MiR, UR or er-flex module can cause electric shocks.

The robot should only be turned on when all covers are closed and the electronics are not accessible.

Danger:

Electrical components may heat up during operation and could cause injuries if touched before they had time to cool down.

Be careful when touching components inside the robot and give it sufficient time to cool off before touching anything.

Danger:

The robot may drive into ladders, scaffolds and similar equipment resulting in hazards from persons falling or falling objects hitting persons.

Do not place ladders, scaffolds and similar equipment in the working area of the robot. If such cannot be avoided it is recommended to physically block the areas (e.g. by tight rows of safety cones) preventing the robot from reaching the equipment.

Danger:

Overloading the robot and failing to comply with load specifications within this manual may cause the robot to:

- Fall over with the risk of crushing people.
- May increase the braking distance resulting in the robot not stopping before collision with humans or obstacles.

Always load the robot according to specification and inform relevant staff (e.g. Operators and Robot Programmers) on the load requirements.

Danger:

The robot is equipped with a Lithium battery pack that may get hot, explode or ignite and cause serious injury to personnel and equipment if the batteries are misused electrically or mechanically.

Always follow the precautions listed below:

- Do not short-circuit or attempt to recharge with false polarity
- Do not expose to temperatures outside the specified temperature range of the battery.
- Do not crush, puncture or disassemble the battery. The battery has safety and protective measures that if damaged may cause the battery to heat up, explode or ignite.
- Do not get the battery wet.
- If the battery leaks fluids and it gets into the eyes of someone do not rub it. Rinse with water and immediately seek medical care. If untreated the battery fluid could cause damage to the eyes.
- Only use an original MiR charger (cable charger or charging station) and follow the instructions of the charger and battery manufacturer.
- Do not touch damaged batteries with bare hands. Use suited personal protective equipment (PPE) and tools for handling.
- Isolate the battery and keep clear if any of the following events occurs:
  - The battery exhibits abnormally high temperatures.
  - The battery emits abnormal odors.
  - The battery changes color.

- The battery case is deformed or otherwise differs from the normal electrical or mechanical conditions.

- Attempts to modify or manipulate with the batteries may lead to considerable safety risks and are prohibited.
- Do not use the battery on anything other than the MiR robots for which it is intended.

Danger:

Robot malfunctioning can lead to an electrical fire, causing danger to personnel and equipment.

Warning:

If the software prompts an error, bring the robot to a halt and reset to a safe state from where the program can be restarted. If the problem remains, contact your local supplier.

Warning:

Personnel might be trapped or stumble over the robot if not paying attention to the robot.

Personnel operating near the robot must be informed on the risks and instructed on how to engage the Emergency stop to halt the robot in case of a dangerous event.

2.3 Intended use

The robot is intended for indoor use in an industrial environment where only qualified personnel are allowed access. Details of the operating conditions can be found in Section 3.4.

The commission and initial setup of the robot is to be performed by an Integrator qualified to identify and mitigate potential hazards and ensure that the robot can operate safely in the environment and in accordance with relevant standards and local legislation.

The subsequent programming of the robot is intended for trained Robot Programmers who can identify and mitigate hazards related to the specific program, ensuring that the application is safe and complies with relevant standards and local legislation. The er-flex robot is not intended for simultaneously moving the MiR and UR. The risk assessment of the robot assumes a strictly sequential operation of the MiR and UR and that when the MiR is driving, the UR, including its tool and objects therein, is completely within the foot-print of the MiR.

The er-flex robot can be used as partly completed machinery in accordance with the EU Machinery Directive 2006/42/ec. If in any way modified, for example by, but not limited to, the adding of tools or fixtures, it is the obligation of the individual(s) undertaking the modifications, that the robot is safe and complies to the relevant safety standards.

2.4 Foreseeable misuse

Any use of the robot besides the intended use is deemed as misuse. This includes, but are not limited to, the foreseeable misuses listed below:

2.5 Risk assessment

The er-flex robot is a generic system on which different applications can be developed. A dedicated risk assessment (EU Machinery Directive 2006/42/ec) for the system solving the specific application is therefore required. It is recommended to do the risk assessment in accordance with ISO 12100-1. For the mobile robot consult ISO 3691-4:2020 and ISO 10218-2 for the robot arm. In addition, the risk assessment can consider to use the Technical Specification ISO/TS 15066 as guidance.

When integrating the robot into an application, points of awareness of the Integrator includes, but are not limited to:

- That all risks associated with whichever tools that are mounted on the UR are dealt with.
- That all risks associated with mounting additional equipment on the robot is dealt with.
- That the mounting of sensors and cables does not create danger for persons or properties. This includes but is not limited to whether body parts or equipment can be trapped in wires or whether the additions give rise to sharp edges and corners.
- That all parts are securely mounted.
- That proper precautions are taken to prevent dangerous situations in case of sensor failure.
- That operators are properly instructed on the behavior of the robot, including the variations that may occur due to the use of sensors.

At all times consult the MiR User Guide Chapter 4 and the UR User Manual Chapter 1 for details on the safety for the individual components.

CHAPTER

THREE

PRODUCT PRESENTATION

The er-flex robot is a combination of a MiR mobile robot and an Universal Robots (UR) robot arm. The robot is intended for autonomous pick and place operations of objects and transportation in an industrial indoor environment. The integration of MiR and UR consists of a mechanical integration, an electrical integration and a software integration enabling the two entities to be operated as one.

The er-flex robot includes a vision package which using a camera (denoted the ER-cam) can calibrate to visual markers in the environment, locate parts and read QR codes and barcodes.

The primary user interface is web-based and can be accessed as described in the Section 4.3.

The user interface allows for programming of both the mobile robot and the robot arm.

The initial mapping of the environment for the MiR to navigate needs to be done using the MiR interface. For navigation between locations the robot fully relies on the localization and navigation of the MiR robot.

3.1 System overview

An overview of the system can be seen in Fig. 3.1.

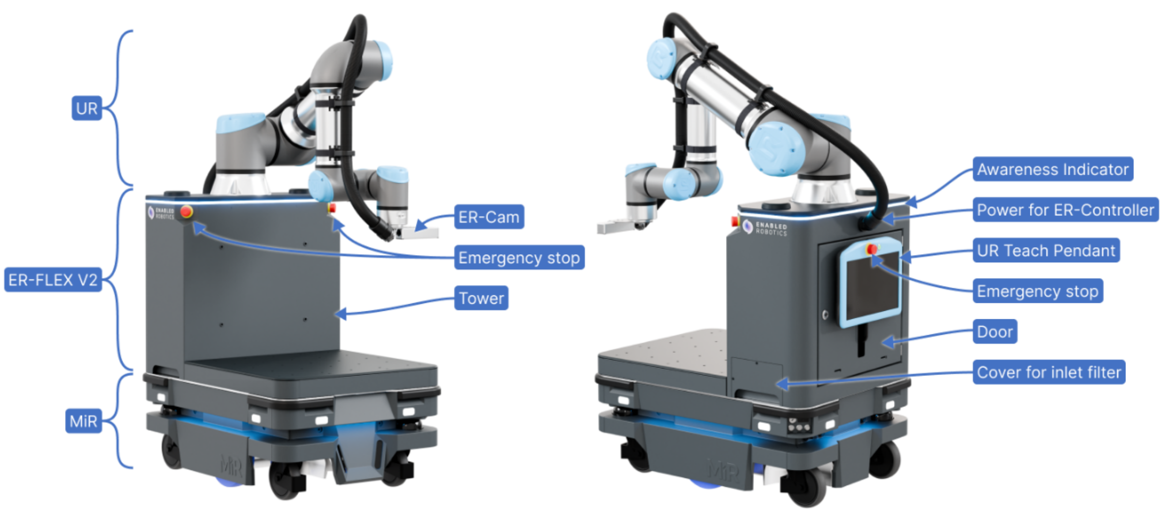


Fig. 3.1: Main parts and features of the er-flex robot.

The ER-Flex hardware consists of a tower, where the UR is mounted, and a platform at the front area where a standard high module or other applications can be fixed onto. The platform is equipped with a thick stainless steel top plate with M6 threads for mounting fixtures, tools or other applications, and always with a Black ESD finish.

The standard front module can be purchased as an accessory and exists only as a high version.

3.2 Components inside the tower

The components listed below are placed inside the tower, and are those that users should be familiar with. The remaining components are listed in the Electrical documentation.

Table 3.1: Component table

Component	Description	Location
Safety switch MiR-ER	Disconnects all power to ER-Flex hardware from MiR.	F1:Left hand side of DIN-rail
Switch	Switch for internal network connections	K3:Right hand side of DIN-rail
24V fuse	Fuse for 24V output	F2:Right hand side of DIN-rail
24V auxiliary connection points	Output for user to install further applications (24V, 0V & GND)	X3:Right hand side of DIN-rail
UR Controller	OEM DC controller for the UR	Mounted in the top of the tower, above the DIN-rail
DFI	ER-Flex System controller	Mounted in the bottom of the tower, below the DIN-Rail

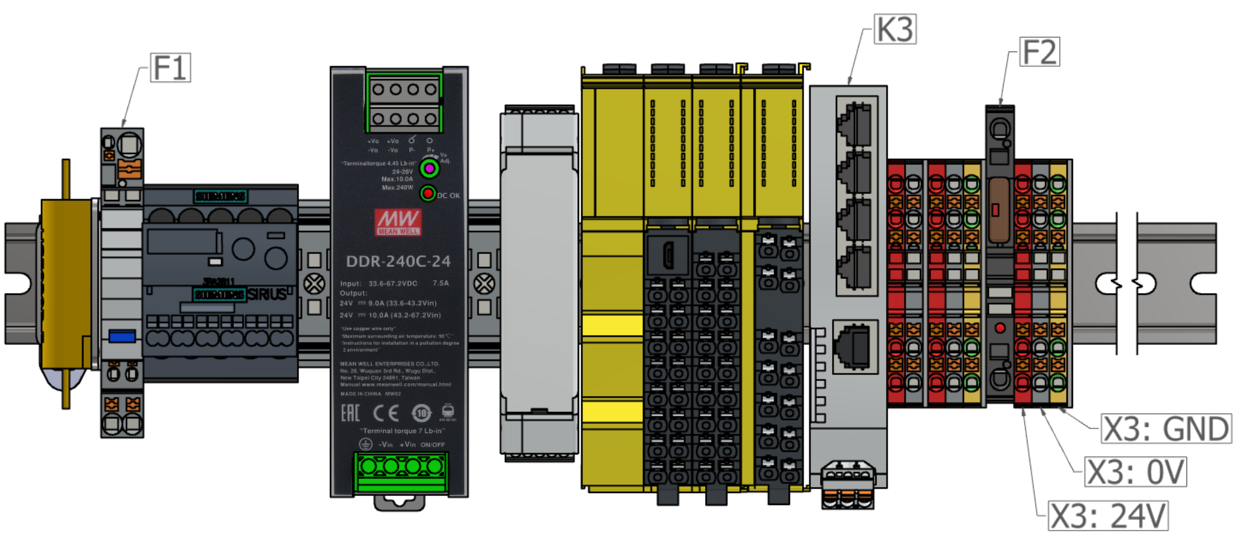


Fig. 3.2: Components on the DIN-rail

3.3 Safety system

The safety systems of the MiR and the UR are connected such that they both go into emergency stop when an arbitrary emergency stop button is pressed and both return to operational mode when the emergency stop has been released and a reset button pressed.

3.4 Environment

The robot is intended for use in indoor industrial environments where only trained personnel and persons with appropriate safety instructions are allowed access.

Operating Conditions

- Indoor
- Ambient Temperature: +5^{0}C to +40^{0}C
- Humidity: 10%-95% non-condensing

Overall IP Rating: IP21

Detailed rating for the subcomponents:

- MiR250: IP21
- er-flex Hardware: IP54
- UR: IP54
- er-cam: IP54

The er-cam is protected against particles entering, but particles collecting on the lens of the camera may impact its ability to work.

3.5 Awareness indicators

The er-flex robot uses light as awareness indicators to inform people in its environment of its current behavior.

The following figure describes the different states of the robot and their corresponding colors.

Fig. 3.3: States of the robot and their corresponding colors

The MiR itself also has light indicators signaling its own state. Consult the MiR user guide for details of these colors.

3.6 User instructions

The instructions on how to use and program the robot are organized in a number of sections.

Section 4: Getting Started: Unboxing, Powering up, Connection to the ability Interface, Moving MiR and UR in manual mode, Powering down.

Section 5: Commissioning: Camera Calibration, Mapping of the environment, Setting up network interfaces, Configuring a Setup, Setting up the Ability URCap, Charging the robot.

Section 6: General Control: Introduction to programming with the ability interface, Camera view, Joystick control, UR Teach Pendant view and Create program.

Section 7: Load specification: Details on how to load the robot

Section 8: Maintenance: Maintenance instructions, Software updates

Section 9: Transportation: Details on how to transport the robot

Section 11: Decommissioning: Disassembling and disposing instructions

CHAPTER

FOUR

GETTING STARTED

This section describes how to get started with the er-flex robot.

4.1 Unboxing

This section describes the contents of the box as well as how to unbox the robot.

4.1.1 In the box

The box contains the following items:

- The ER-FLEX 250 robot.
- 1 x Key (For the tower door).
- 1 x CH7 marker.
- 3 x CH3 markers.
- 1 x USB flash drive containing the Enabled Robotics URCap.
- 1 x ER-FLEX 250 Manual.
- Documents that are delivered with the UR.
- Documents that are delivered with the MiR (Includes the password needed for connecting to the robot WiFi hotspot).
- Accessories that are delivered with the MiR (E.g.: E-Stop, antennas, cloth, Customer optional WiFi access point dongle)

4.1.2 Unpacking

Warning:

Exercise caution when handling the pallet frames, as there is a risk of fingers and hands getting pinched while collapsing them.

Important: Unpacking the er-flex is a two person task.

Important: The robot is delivered fully assembled. No assembly is required from the user.

To unbox the robot follow the steps below:

1. Remove the lid and all but the last two frames of the pallet.
2. Remove the foam fixating the robot.
3. Remove the last two frames of the pallet.
4. Place the lid as a ramp for driving the robot down the pallet.
5. Place support material (use the folded pallet frames) under the ramp to support the load while the robot is driving on it.

4.1.3 Waste from packaging

After unboxing, the only waste materials are from the cargo box and the wrapping material. These materials are considered common waste with no disposal risk and should be sorted into categories such as plastic, wood, paper, and metal.

Note: Consider recycling the packaging materials or saving them for later transportation of the robot.

4.2 Powering on the robot

Warning:

Before powering on the robot, make sure that all people and objects are in a safe distance from the robot.

The er-controller, UR and MiR are all powered by the same battery located inside the MiR. To power on the robot, follow these steps.

1. For safety reasons the robot is shipped with the battery disconnected. To connect the battery follow the steps below: (See the MiR250 Quick Start Guide version 2.0 section 7.3. for additional details and illustrations)
   a. Remove the rear cover of the MiR. Do this by simultaneously pressing the two white circular buttons and gently wiggle the cover to remove it.
   b. Pull the battery lock pin out to release the battery lever.
   c. Pull up the battery lever to connect the battery connector.
   d. The battery pin will lock into place once the battery has been connected

   e. Reattach the rear cover.

2. Power on the MiR by pushing the power button for three seconds. The power button is located as the rightmost button in the left rear corner of the MiR see, Fig. 4.1.

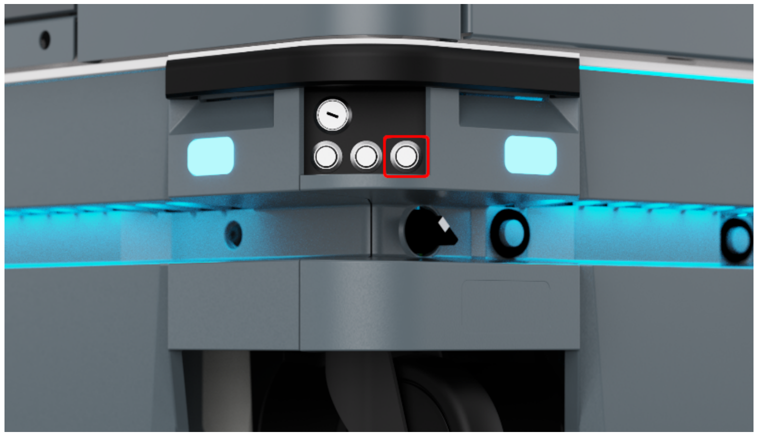


Fig. 4.1: MiR power button is located at the far right

3. Wait for the button to turn green (takes 10-15 seconds) and then turn on the UR by pushing the power button on the UR teach pendant, see Fig. 4.2.

Fig. 4.2: UR power button is located to the right of the emergency stop

4. Release the robot from emergency stops.

   a. Release the two emergency stops on the tower and on the UR teach pendant, see Fig. 4.3.

   b. When all three emergency buttons have been released (and the MiR and UR are fully started) the reset button on the backside of the tower and on the MiR will start flashing. Press either button to reset the robot from the emergency stop state, see Fig. 4.4.

   c. Note that the emergency stop state will not be released by the safety system until both the MiR and the UR are fully started, which will take a few minutes.

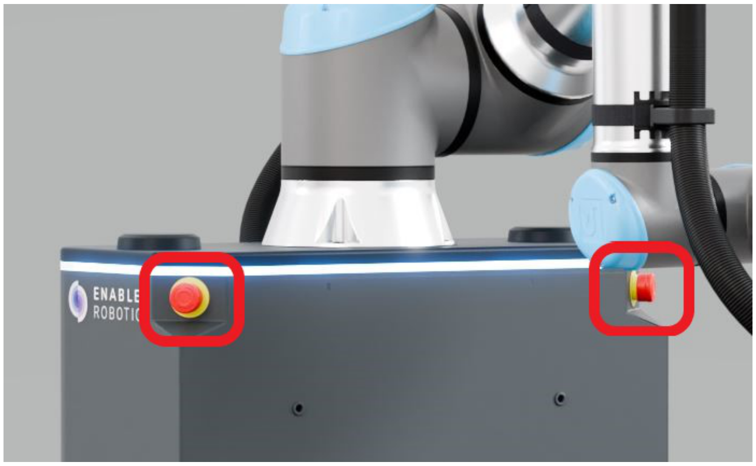


Fig. 4.3: An emergency stop is located on each side of the robot

Fig. 4.4: The reset button is located on the rear of the robot

5. If all systems have been started correctly, and a reset button has been pressed, the robot awareness indicator should be yellow. See Section 3.5 for a detailed description of the awareness indicator.

4.3 Connecting to the Ability interface

When the robot is powered on, you can connect to the robot's internal network via the RJ45 Ethernet port on the back of the robot. Once connected, you can configure the robot's settings and connect it to a wireless network.

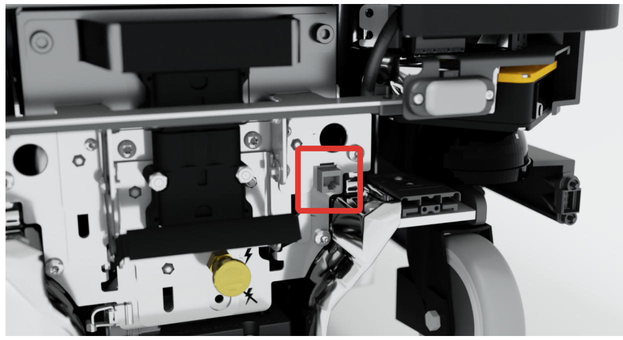


Fig. 4.5: The RJ45 ethernet port is located on the back of the robot. To access it, remove the MiR back cover by simultaneously pressing the two white circular buttons and gently wiggling the cover to remove it.

You can connect to the robot using an Ethernet cable or the provided access point. (See the MiR250 Quick Start Guide version 2.0 section 7.5. for additional details about using the provided access point)

If using the access point, a wireless network interface is set up named ER-FLEX-XXXXX, where XXXXX is a five-digit number identifying the robot. See the accompanying page with details for the robot and password for the wireless network.

When connected to the accesspoint open a browser and go to www.er.com.

Note: If using an ethernet cable, or using an access point that was not provided by Enabled Robotics, please use the ip address 192.168.12.30 instead of www.er.com to connect to the Ability user interface and 192.168.12.20 to access the MiR user interface.

The default login for the webinterface is *username*: **admin**, *password*: **admin**. This can later be changed through the system settings.

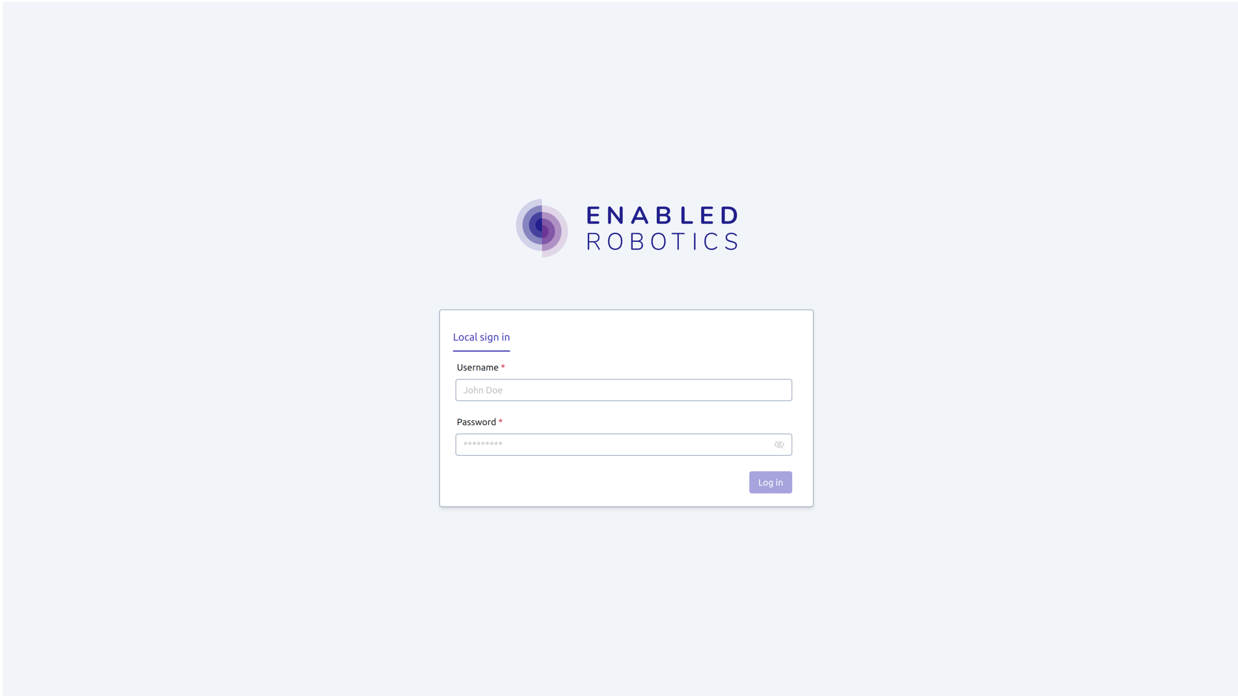


Fig. 4.6: Ability login page

When logged in, the dashboard will be shown.

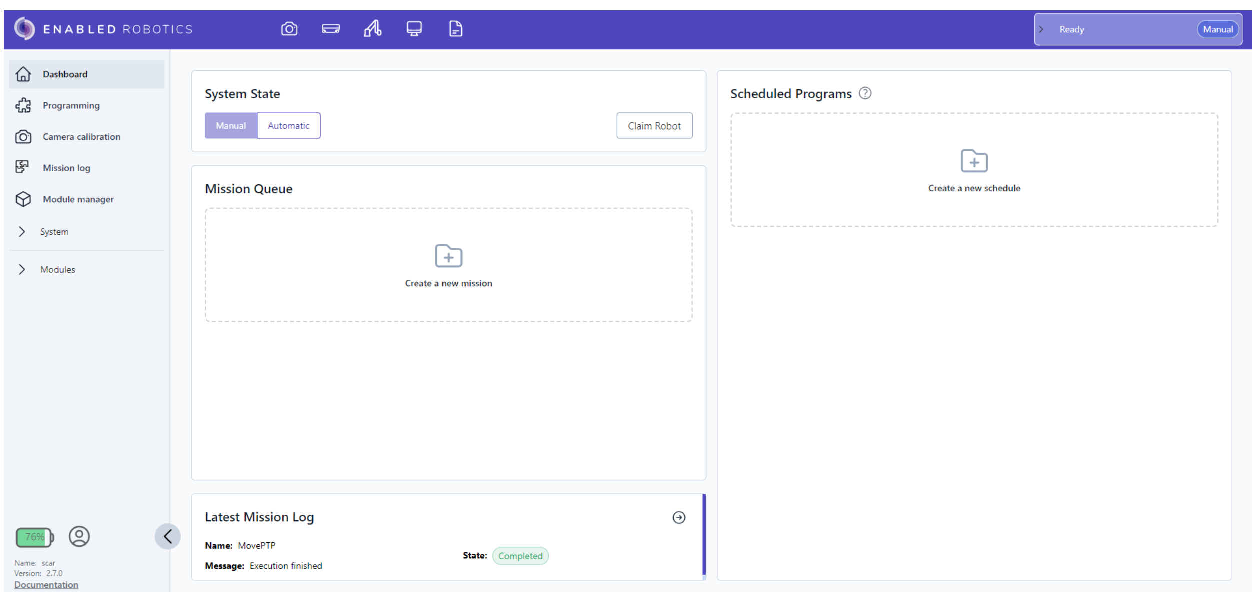


Fig. 4.7: Ability Dashboard

The state should show 'Ready'. If the state is showing 'No Connection', the topbar is red, or the screen is greyed out, it indicates that the system is still starting up. If the system fails to connect, contact the supplier for help with troubleshooting.

4.4 Moving the MiR and UR in manual mode

4.4.1 Moving the MiR

1. On the MiR, turn the operating mode key into manual mode (turn it to the right), see Fig. 4.8.

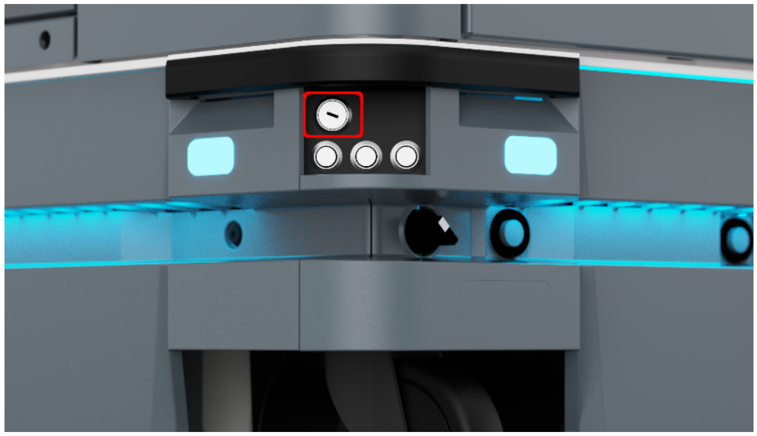


Fig. 4.8: Operating mode key hole is located above the leftmost button

2. Select the icon on the top bar in the interface to open the joystick control of the MiR.
3. Press the 'Activate Joystick' button to activate the joystick control of the MiR.
4. When notified press the reset button on the tower, or on the MiR, to initiate the MiR joystick control.

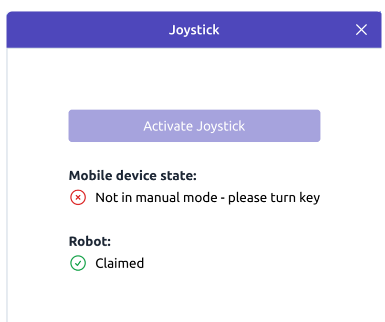


Fig. 4.9: MiR joystick in the Ability interface

Warning:

When driving down the pallet take care not to drive over the sides of the ramp and avoid high accelerations and decelerations.

To drive the robot down the pallet:

1. Ensure that the ramp is correctly placed and supported underneath as explained in Section 4.1.
2. Place your foot on the lower part of the ramp to prevent it from sliding when the robot drives on to the ramp.
3. Slowly drive the robot in the forward direction down the ramp and be careful not to drive over the sides of the ramp.

When driving down the ramp the UR should be folded to have the center of gravity as low as possible.

Note: The MiR can also be moved by activating the brake release switch and pushing the robot around. Push on the ER-FLEX tower. Avoid pushing on the UR joints.

4.4.2 Moving the UR

Move the UR arm to different configurations as needed by following the instructions:

1. Select the  icon on the top bar in the interface to open the joystick control of the UR.

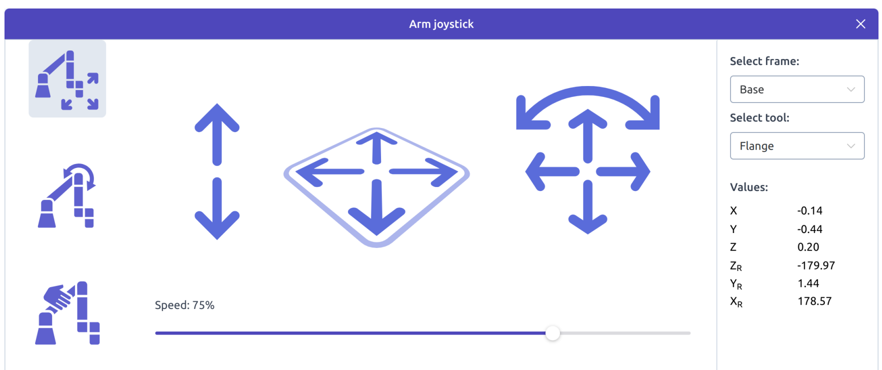


Fig. 4.10: UR joystick in the Ability interface

2. Either:
   a. Press the arrows to move the UR.
   b. Activate freedrive mode by pressing and holding the  icon for 3 seconds. You can now move the UR by pulling on the joints or end-effector.

4.5 Powering down the robot

To power down the robot follow the steps below:

1. Power down the UR: Press the power button on the UR teach pendant and select shutdown when asked on the screen.

Fig. 4.11: UR power button is located to the right of the emergency stop

2. Power off the MiR: Press and hold the power button for three seconds. The light in the button will start flashing red, while the MiR is shutting down.

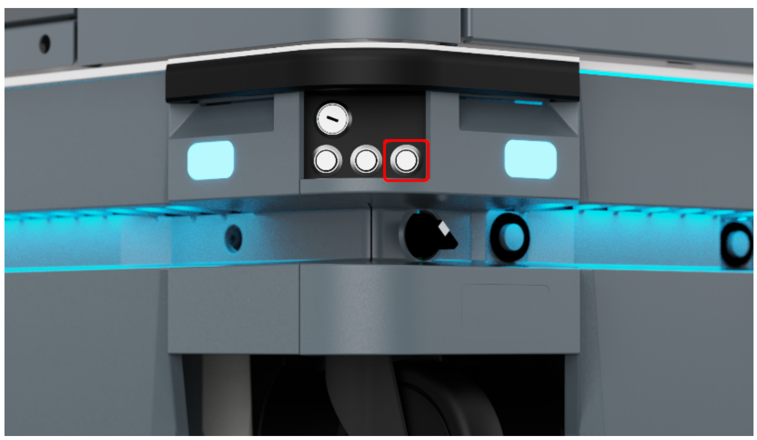


Fig. 4.12: MiR power button is located at the far right

Warning:

Always turn off the UR first. If the MiR is powered off first, it will cut power to the UR, which will shut down incorrectly and may produce an error message when restarted.

3. If required, disconnect the battery by following the steps below: (See the MiR250 User Guide section 8.2 "Disconnecting the battery". for additional details and illustrations)

   a. Remove the rear cover of the MiR. Do this by simultaneously pressing the two white circular buttons and gently wiggle the cover to remove it.

   b. Pull the battery lock pin out to release the battery lever.

c. Pull down the battery lever to disconnect the battery connector.
d. The battery pin will lock into place once the battery lever has been pushed all the way down.
e. Reattach the rear cover.

CHAPTER

FIVE

COMMISSIONING

Several steps need to be performed when installing the robot at a new location. In this chapter these steps are explained in detail.

5.1 Camera calibration

Before using the vision package, the camera needs to be calibrated. This calibration includes both the intrinsic calibration of the camera parameters as well as the robot to camera calibration.

Note: Every time the location of the camera on the arm changes, it should be calibrated again to function properly. Even small changes may impact the accuracy of the results.

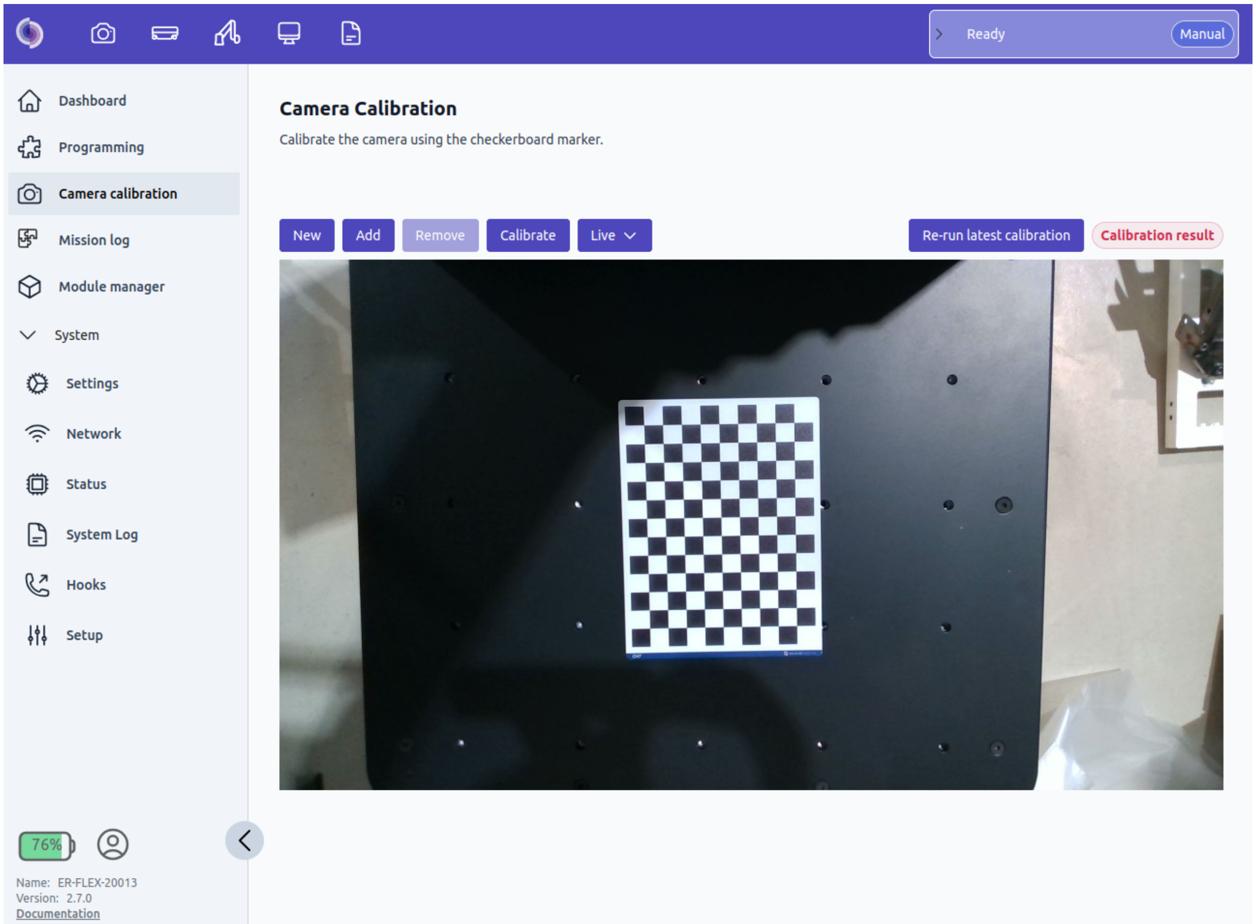
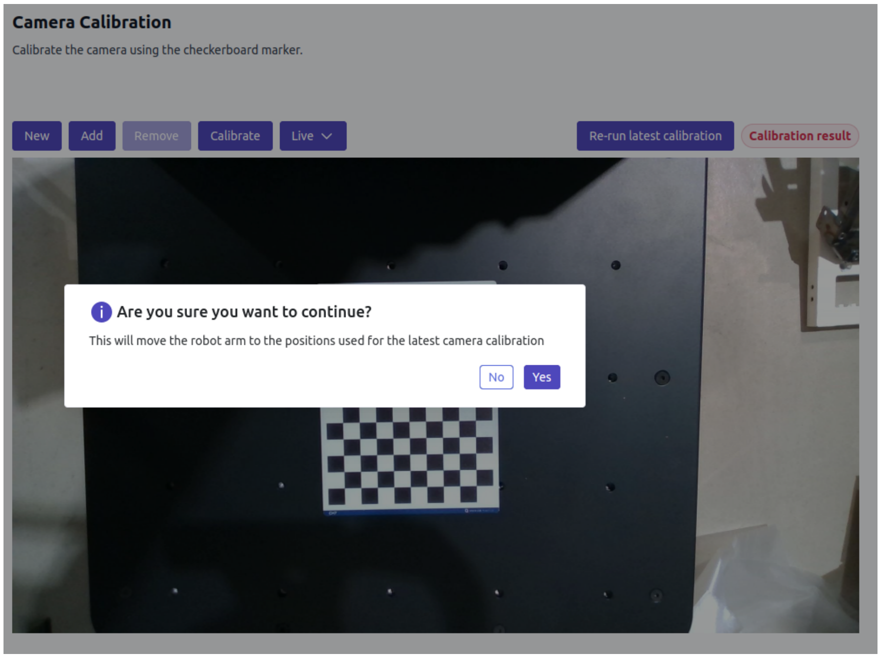


Fig. 5.1: Camera calibration page

To collect calibration measurements, follow the steps:

1. Place the calibration board in a stable position where it is possible for the camera to see it from many different angles (e.g. on top of the module).
2. Press 'New' to create a new calibration
3. Move the robot to a configuration where the complete calibration board is within the camera view and press 'Add'. If the calibration board was detected the screen displays the recognition result for 2 seconds, before returning to the live view. You can always click the dropdown box to view the individual recognition results and check the current measurement count.
4. Repeat until 15 or more measurements are added. It is important to vary both the camera's rotation and position relative to the marker. The maximum recommended angle between camera image plane and calibration board is 45°.
5. Press 'Calibrate'. Once calibrated you will see the calibration result displayed in the upper right part of the screen. The icon in the upper right corner of the screen will change color indicating the quality of the calibration (Green=Good, Yellow = Fair, Red = Poor). Under normal conditions the intrinsic error should be less than 0.5 and the extrinsic less than 1.5.

Re-run latest camera calibration If you need to re-calibrate the camera, you can press the "Re-run latest calibration" button. This will repeat the latest calibration by moving to the same robot arm positions, capturing new marker images and finally updating the intrinsic and extrinsic camera calibration. Before using this feature, make sure that it is safe to move the robot arm and that the marker is placed at the same position as last time the calibration was done.



Troubleshooting

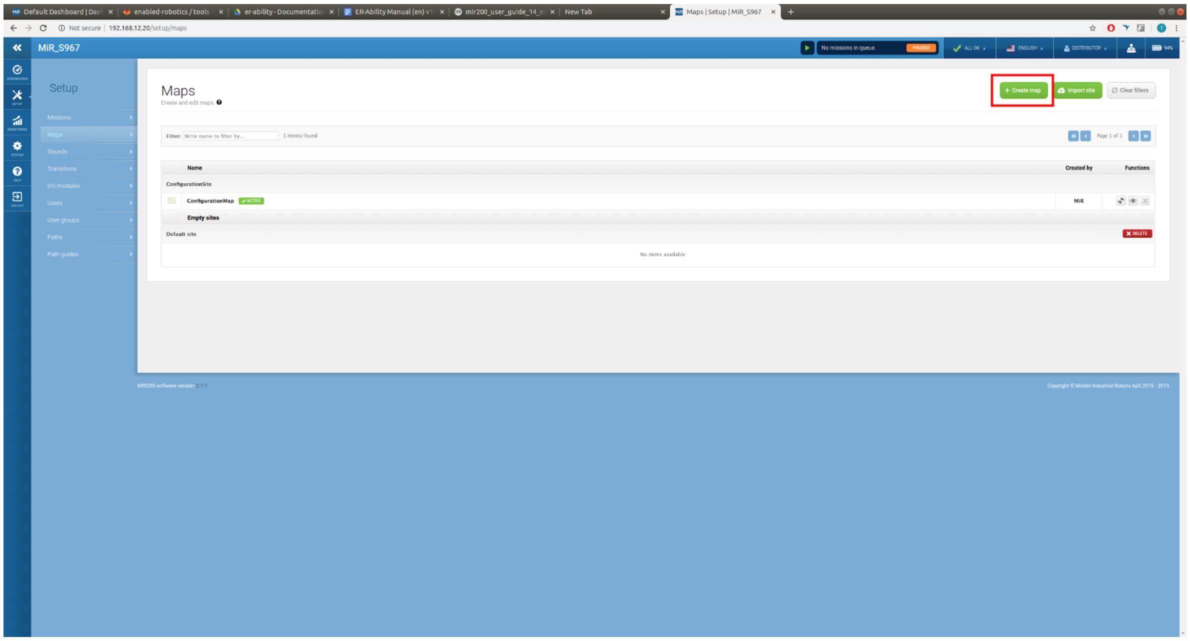
If the calibration does not show a satisfactory result it may be due to

1. Too many measurements with very steep angles between the calibration board and the camera or too large distance between camera and calibration board.
2. Too little variation in the orientation of the camera relative to the calibration board.
3. Too little variation in the position of the camera relative to the calibration board.
4. That the camera is out of focus.
5. The calibration board has moved relative to the robot during calibration.

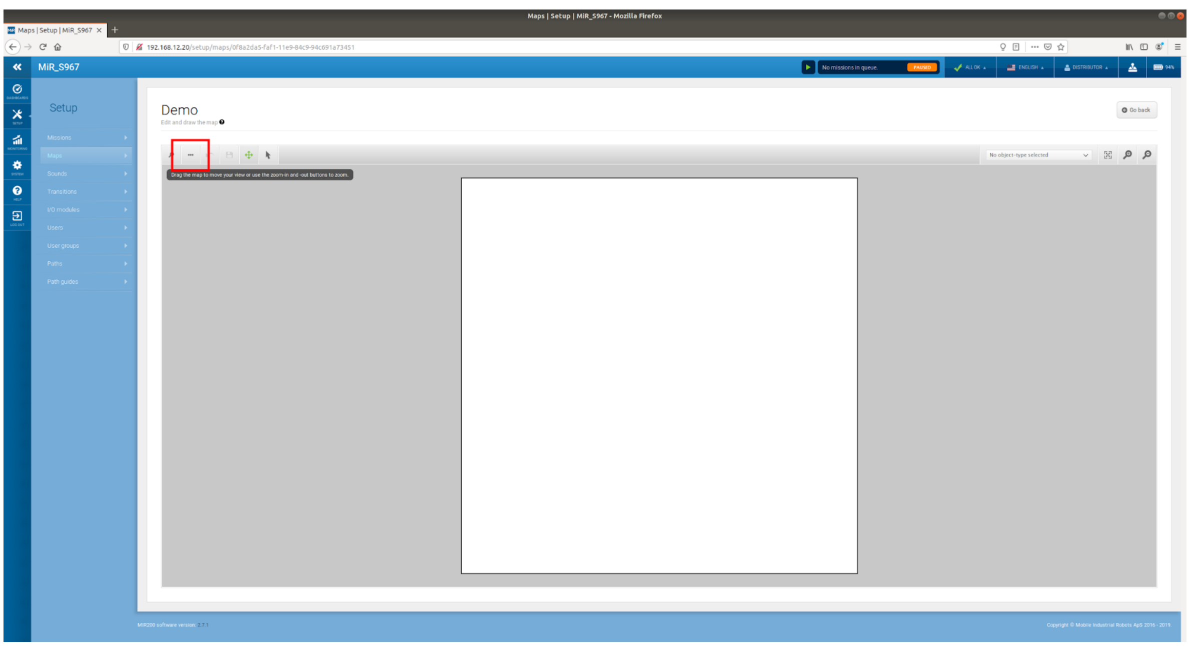
5.2 Mapping of the environment

As the er-flex robot depends on the mapping and localization or the MiR, the space in which the robot will work has to be mapped. This is done entirely in the MiR web interface. For a thorough introduction please refer to the MiR User Guide. Underneath is a short description of how the mapping is done.

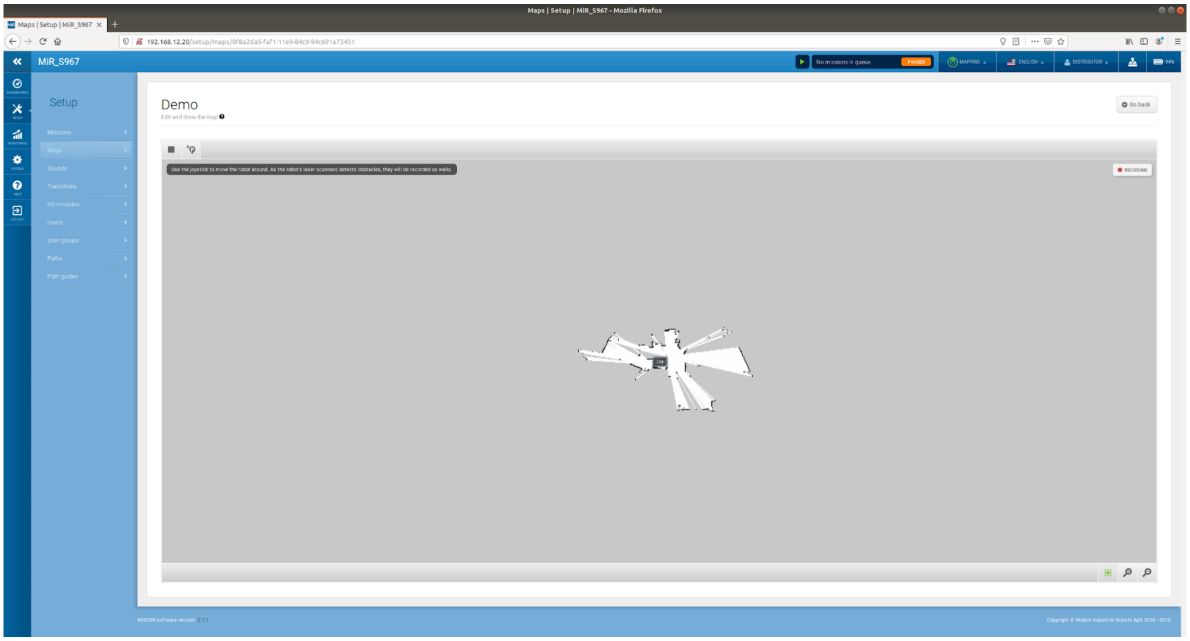
1. Connect to the wireless network and go to mir.com.
2. Login using the credentials for the MiR. See document accompanying the robot.
3. Go to SETUP -> Maps and press 'Create Map'.



4. Enter name, and press 'Create Map'
5. Press the menu button and 'Record and overwrite'



6. Press 'Start Mapping'



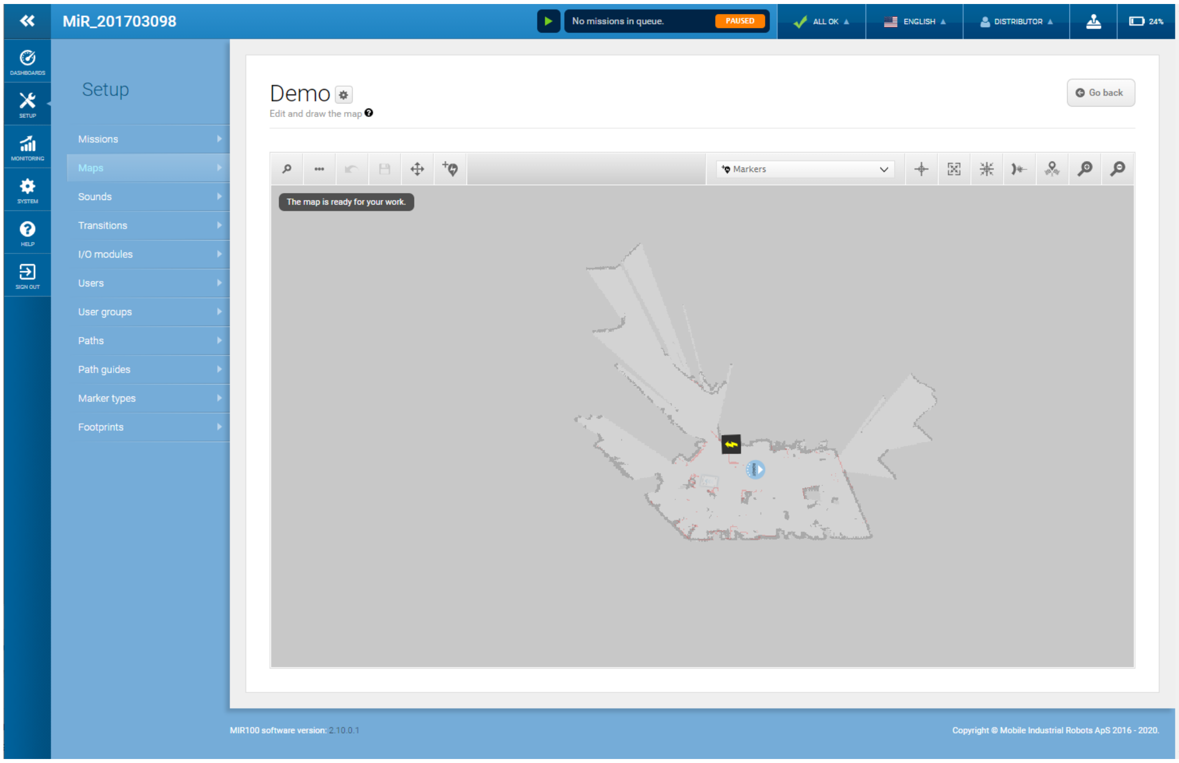
7. Move the robot around with the joystick in the MiR interface, until the required space has been mapped.
8. Press the stop button.
9. Press the apply button.

Having recorded the map it can be post-processed using the map editing functionalities in the MiR interface. During this process it is possible to define forbidden zones the robot is not allowed to enter, preferred pathways, landmarks, charging stations etc. For details on how to define the elements consult the MiR user guide. Details on how to define charging stations are outlined below.

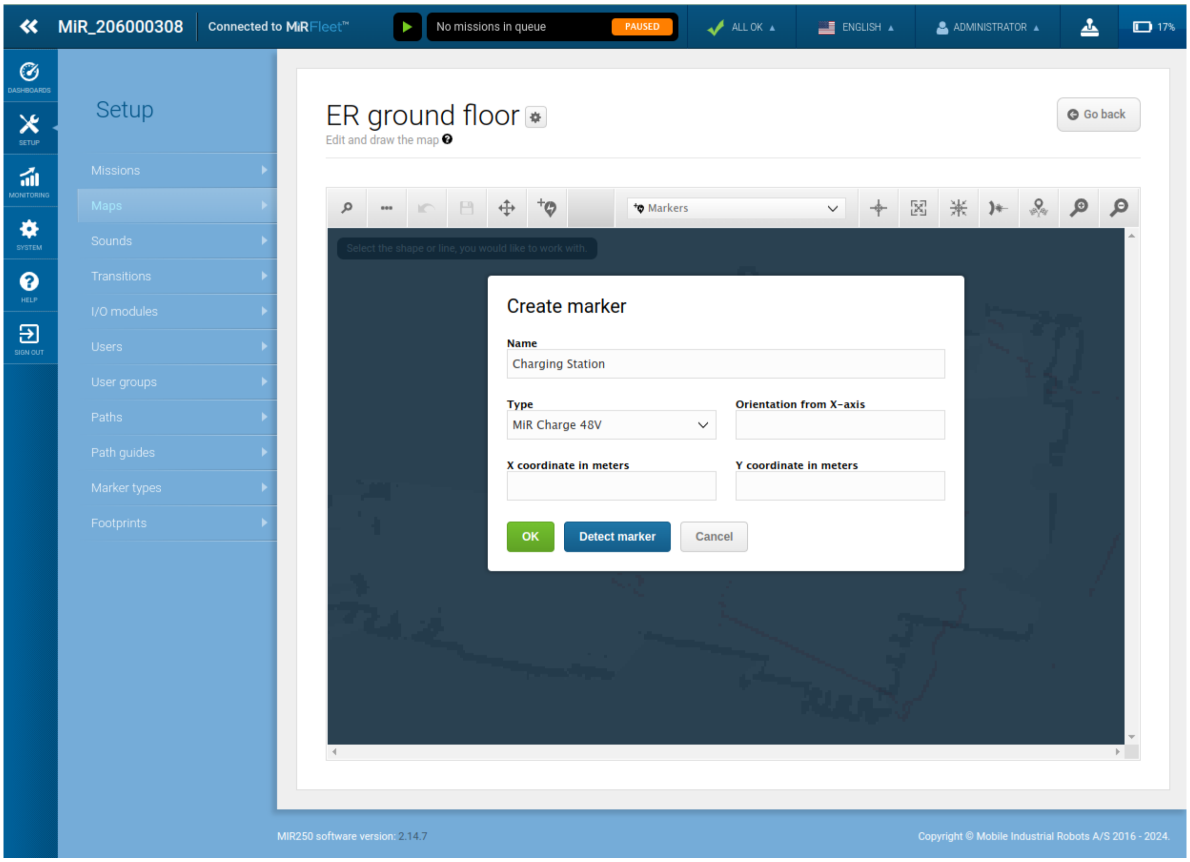
5.2.1 Defining charging stations

To have the robot automatically drive to a charging station it needs to be defined within the map. To add a charging station, do the following:

1. Position the robot 1 meter in front of the charging station facing straight towards it.
2. In the interface of the MiR choose *Setup* > *Maps* and select the map for editing.
3. In the drop-down box on the menu bar select ‘Markers’.



4. Press the 'Draw new marker' Button
5. Type a name for the marker and select the 'MiR Charge 48V' for the 48V charger used with the MiR250. Select 'MiR Charge 24V' if using a 24V charger with the MiR100 or MiR200.
6. Press 'Detect marker' for the robot to detect the marker.



For details on installing the charging station consult the mir_charge_48v_operating_guide provided with the charging station.

5.3 Network

5.3.1 Connection to Wi-Fi hotspot

The er-flex robot can be connected to an existing wireless network. To connect go to *Network* and press ‘New connection’ to get the screen shown in Fig. 5.2.

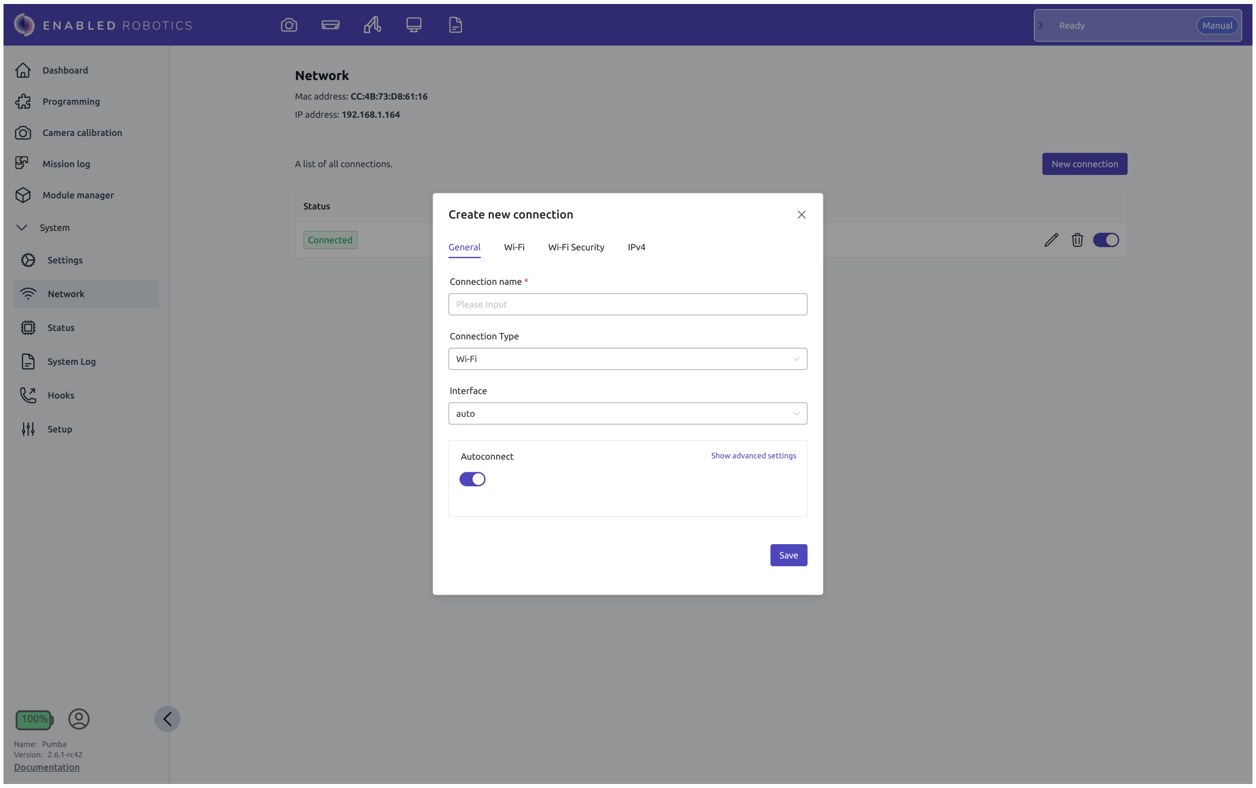


Fig. 5.2: Setup connection to a network.

Name the connection and select 'Connection Type'. Autoconnect can be selected if you want the robot to automatically connect to the given network whenever available.

In the 'Wi-Fi' tab, select your network from the list of available SSIDs. Go to the 'Wifi Security' tab, select security type and enter relevant information. Press 'Submit' to have the robot connect to the network. Once connected, the connectivity status will be displayed to the left on the new connection.

Note: When editing a connection, the security details must be filled out again.

5.3.2 Ports

The ports listed below need to be open for their corresponding services to be available on the network. Notice, that if the service is not required, the port does not have to be open.

- 22 - SSH: Used for remote support sessions.
- 80 - HTTP: Web server used to serve the web interface.
- 443 - HTTPS: Used for software updates.
- 4840 - OPC-UA: Used to expose the OPC-UA Interface.
- 8082 - REST: Used to expose the REST API.
- 8090 - Video stream: Used to show camera view in web interface.
- 9090 - Websocket: Used for communication between web interface and the robot.

5.4 Setting up the ER-Ability URCap

When using the er-ability user interface we need to have a program on the UR controller with a specific URCap running. This URCap is called “EnabledRobotics - ER-Ability” and makes a bridge between the ability software running on the er-controller and the UR. This URCap adds a node called ER-Ability which is used in a UR Program. If this URCap is not running on the UR Controller a dialog will appear in the user interface asking for permission to restart the program on the UR.

A default program with the ER-Ability URCap is installed on the UR controller when the er-flex robot is delivered. Which program to start on the UR can be defined in the Setup as the URAbilityProgram.

An example of a UR program with the ER-Ability URCap is shown in Fig. 5.3.

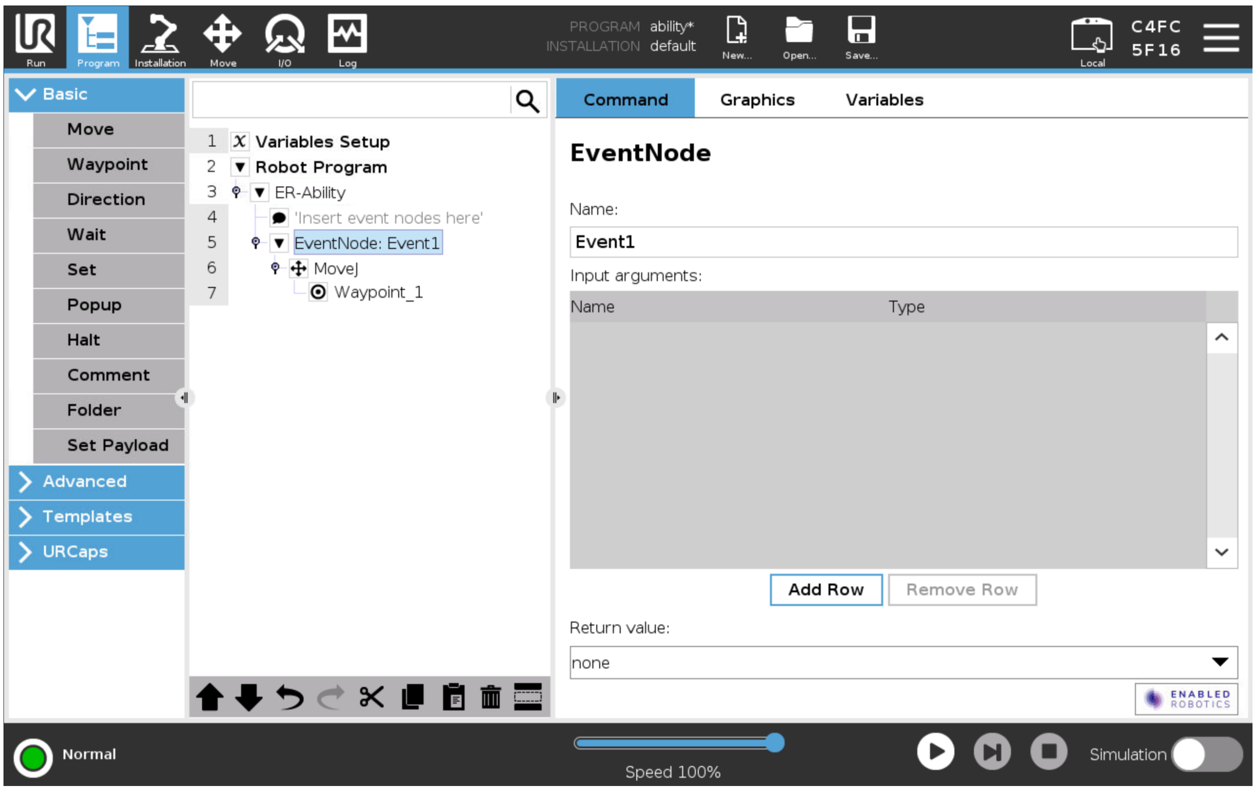
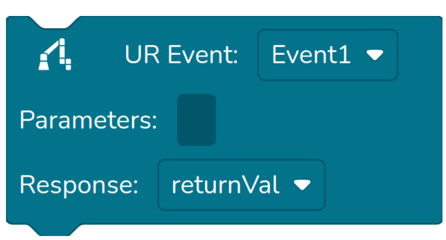


Fig. 5.3: Example UR Program using ER-Ability URCap

In the ER-Ability URCap it is possible to define event nodes, which are subprograms for the UR created in the UR Polyscope interface. The definition of an event node in the UR Polyscope interface can be seen in the example above. These event nodes can be called from the er-ability user interface using the ‘UR Event’ block.



In the block, the user can select between the events defined in the ER-Ability URCap and provide parameters which are available in the event node as a local array, called *localVariables*.

Note: Only events defined as sub-nodes to the ER-Ability URCap can be selected and activated from the 'UR Event' block.

5.5 Charging the robot

The robot can be charged using a MiR charging station or using the MiR cable charger.

For details on how to use the cable charger consult the MiR user guide.

To use the MiR charging station, the station needs to be defined in the map of the MiR. See Section 5.2 for how to add a charging station.

To manually instruct the robot to charge, press the battery icon in the bottom left corner of the user interface and select which charging station to go to.

Within a program you can ask the robot to drive to a charging station using the 'Drive to Charging Station' block which can be found under the 'Mobile Platform' category.

CHAPTER

SIX

GENERAL CONTROL

To access the Ability interface, first connect to the robots WiFi hotspot, then open a browser and go to www.er.com. See Section Section 4.3 for details on how to connect.

There are two modes for controlling the robot, a manual mode and an automatic mode. The manual mode is used when a user wants to control the robot, such as when programming the robot or moving the robot. The automatic mode is used when the robot is to run automatically and enables the use of missions, such as when running in production or running long-term programs.

6.1 Manual Mode

The manual mode is the default mode of the robot and it is used when programming or moving the robot.

6.1.1 Programming Dashboard

The programming dashboard gives an overview of all available programs.

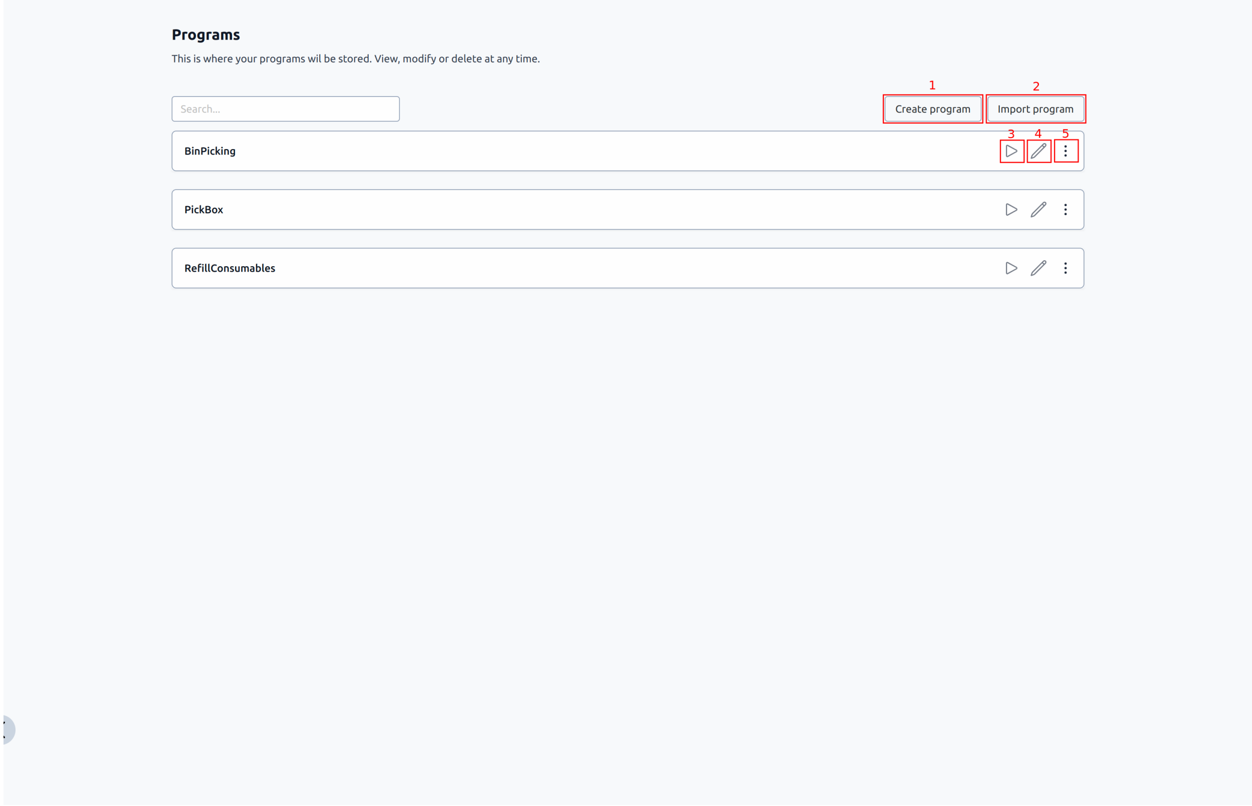


Fig. 6.1: Programming Dashboard

From the programming dashboard it is possible to create a new program (1), import a program from disk (2), play a program (3), edit a program (4), download a program and delete a program (5).

6.1.1.1 Import and export of programs

Pressing the export button (5) will download a compressed '.tar.gz' archive containing all data related to the program.

It may also contain other files or folders if certain blocks are used.

Pressing the "Import a program" button (2), lets the user choose a program (packed in a '.tar.gz' archive) from their device storage. Once chosen, the program is uploaded and validated. The name of the imported program will be equal to the folder-name inside the archive. If another program with the same name already exists, a pop-up will ask the user whether to overwrite the existing program or cancel the import.

When importing a program that has been created on another robot, please make sure that the configurations of the manipulators and mobile devices are similar. If the program makes use of any user defined entities such as custom tools or markers, the setup-file needs to be imported as well. This is done from the Setup-page under 'System'.

6.1.2 Navigating the programming interface

To find the programming view choose the 'Programming' item in the side menu.

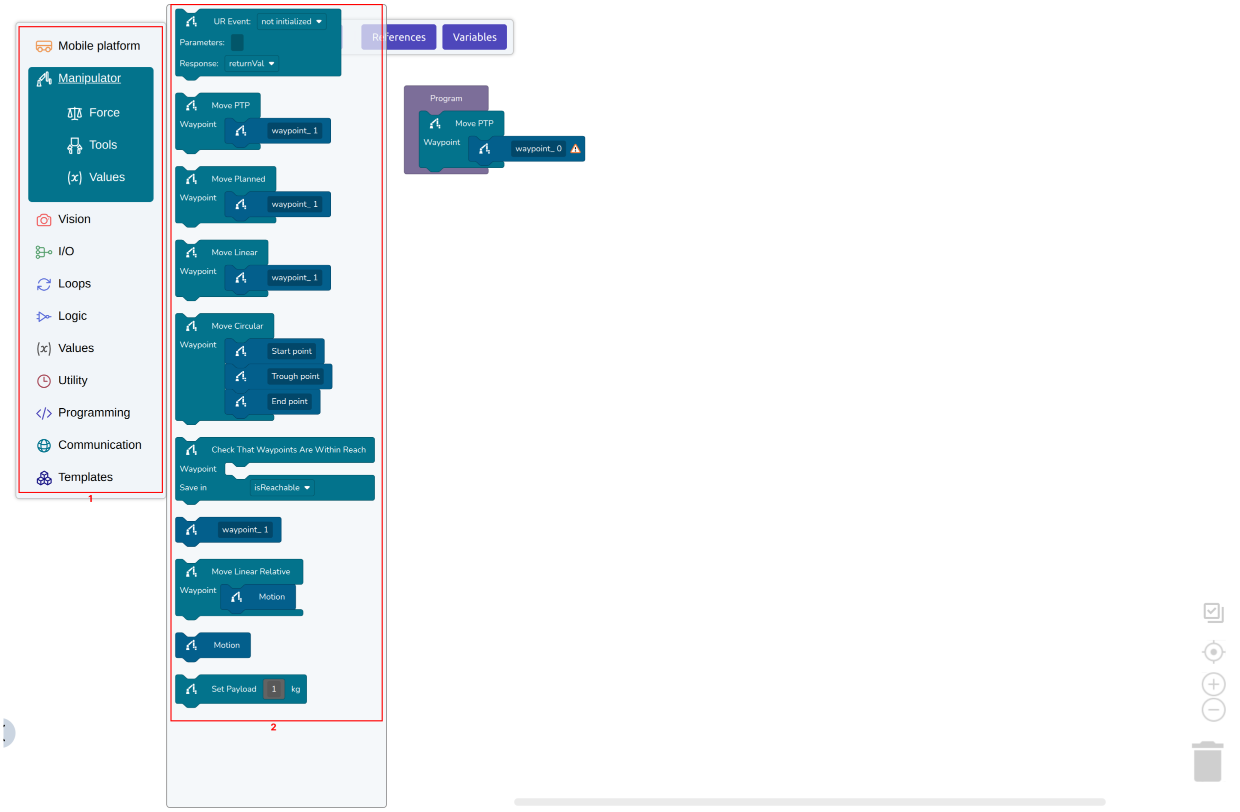


Fig. 6.2: Overview of the programming interface. (1): Block categories. (2): Blocks

6.1.2.1 The camera view

Pressing the camera view allows the user to get a camera view from the onboard camera. It functions as an overlay of the user interface and can therefore be kept open when e.g. programming the robot.

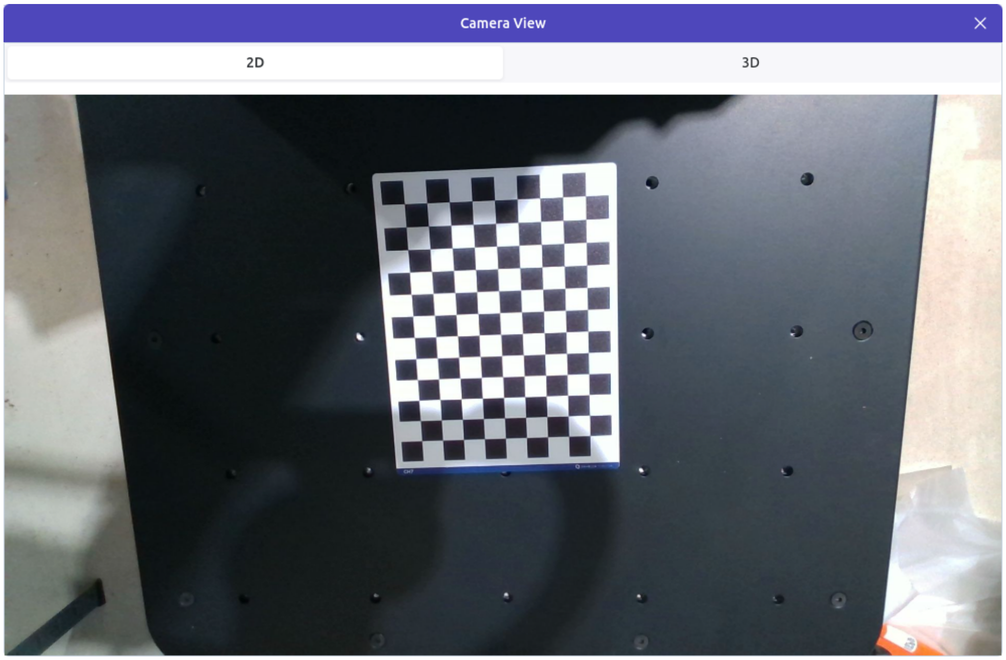


Fig. 6.3: Camera view

If the Vision 3D module is enabled, it is possible to inspect a point cloud of the current scene. The visualization includes the coordinate system of the current camera-location, but it is possible to select any available frame or tool.

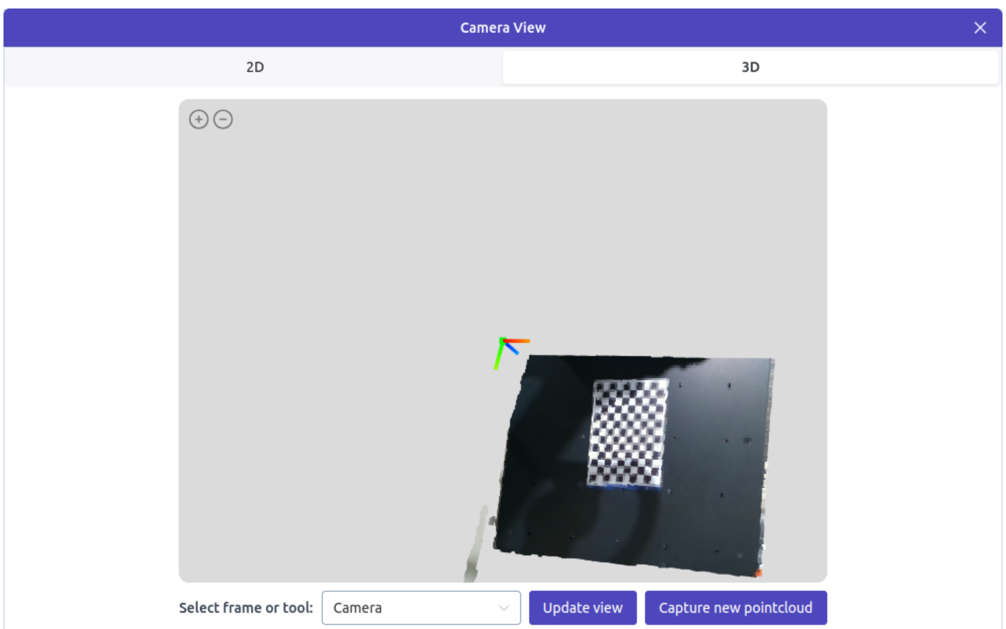


Fig. 6.4: Pointcloud view

6.1.2.2 The joystick control

> **Warning:**
>
> As the entire robot is moved with the joystick, make sure that no objects or humans are close to the robot before using this feature

Pressing the mobile joystick in the top bar, allows the user to control the MiR robot with an on-screen joystick. The joystick can be activated when the user has claimed the robot token and the MiR is in manual mode.

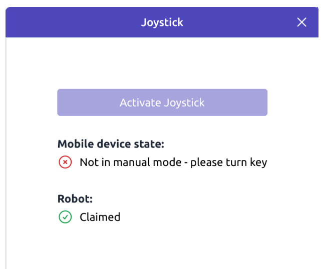


Fig. 6.5: Joystick for manually moving the MiR

Pressing the manipulator joystick opens a view with three modes of arm control. Default, shown in Fig. 6.6, enables cartesian movements of the tool. Pressing the middle button to the left enables moving the individual joints. Finally, holding the bottom button down for 2 seconds puts the robot into teach mode for 100 seconds, or until the button is pressed again.

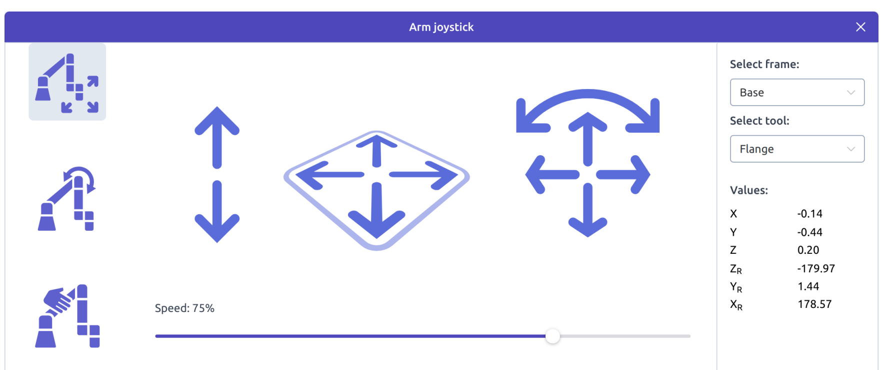


Fig. 6.6: Joystick for manually moving the UR

Whenever the teach mode is enabled all axes are free by default. It is possible to constrain the tool movement to specified axes. An example is shown in Fig. 6.7 where the Flange is constrained to translational movement in the Base frame.

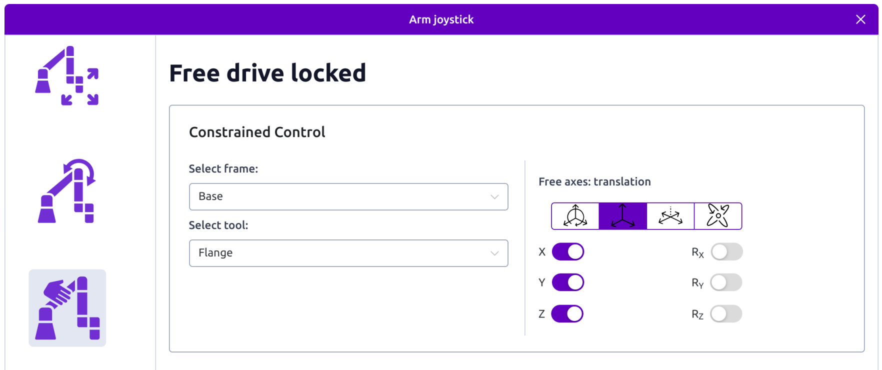


Fig. 6.7: Constrained free drive control

6.1.2.3 UR teach pendant view

The UR teach pendant view ( ) gives access to the content of the UR teach pendant within the er-ability interface. This functionality is intended for giving experts easy access to configuring the arm and to define custom subroutines (events) within the UR Polyscope interface, which can then be activated by inserting a block in the er-ability programming interface.

See Section 5.4 for details on how to define events.

The UR teach pendant view is shown in Fig. 6.8.

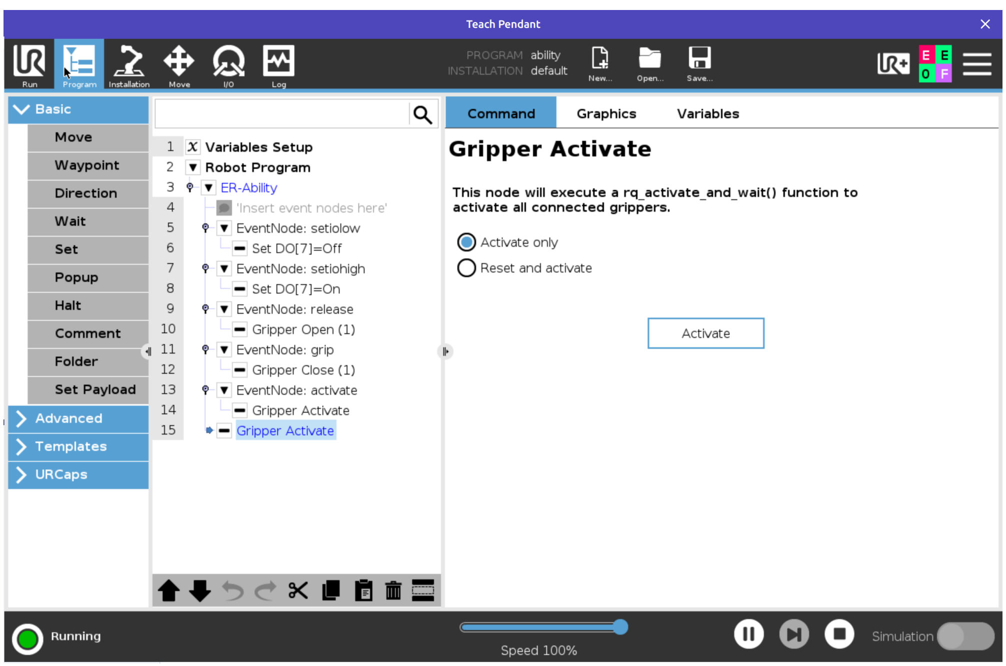


Fig. 6.8: UR Teach pendant view

6.1.2.4 Creating a reference

User defined references can be created through the Reference menu. Clicking 'Update' will update the default transform values based on the current location of the selected tool in the selected parent coordinate system. The values defined here are stored with the program data. Blocks may update the current transform of selected references during program execution, but every time the program is loaded, the current transform is reset to the default transform.

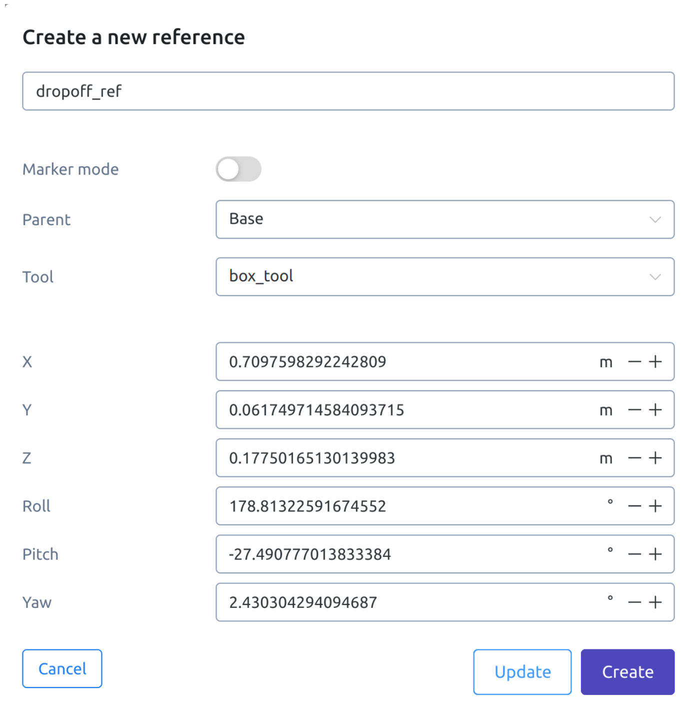


Fig. 6.9: Menu for creating a new reference

If ‘Marker mode’ is toggled, the default transform is computed automatically based on a marker detection. References created by the ‘Calibrate To Marker’ block are initialized in marker mode.

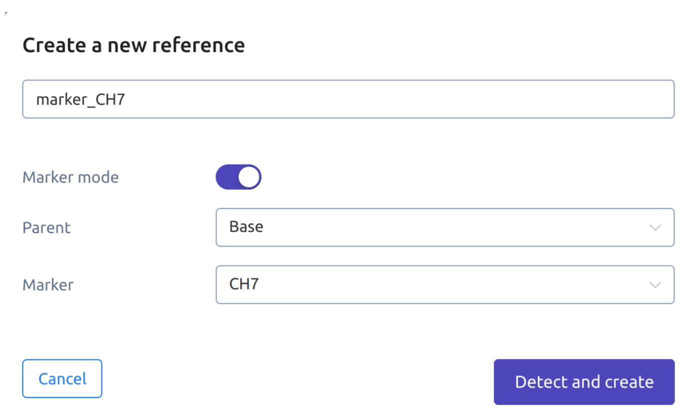


Fig. 6.10: Menu for creating a new marker reference

6.1.2.5 Inspecting current values of references and variables

The current values of references and variables can be inspected through the ‘Runtime Info modal’. Whenever a program is loaded the references are reset and all variables are cleared.

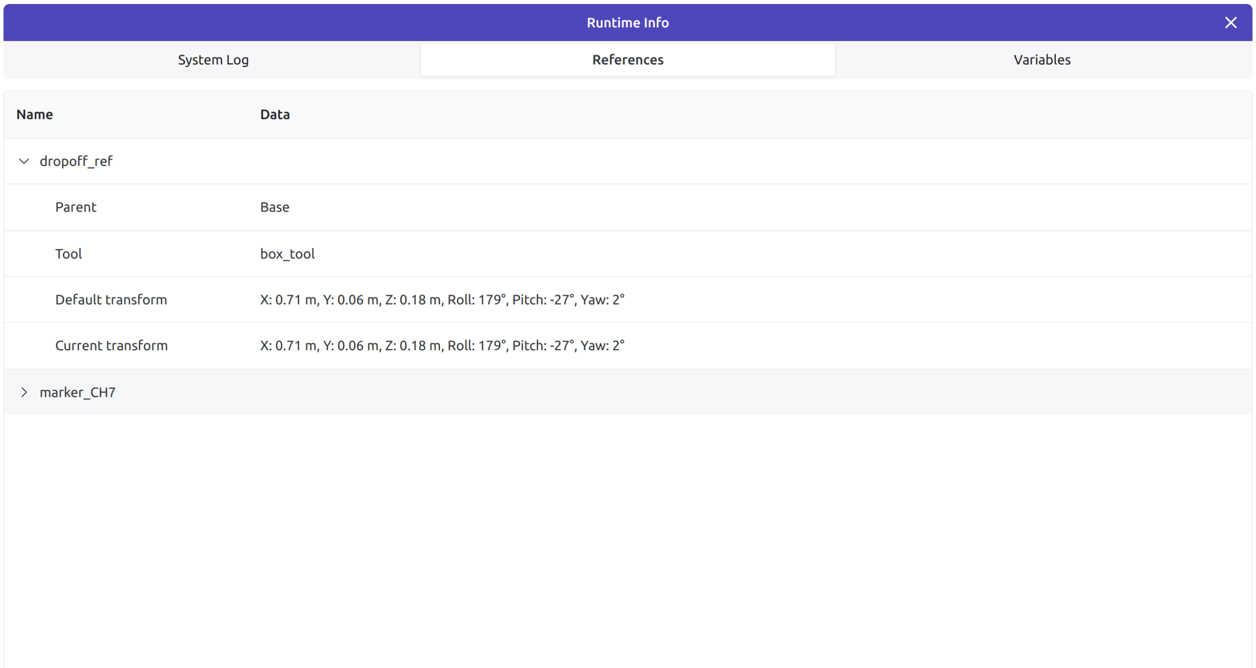


Fig. 6.11: Reference info tab

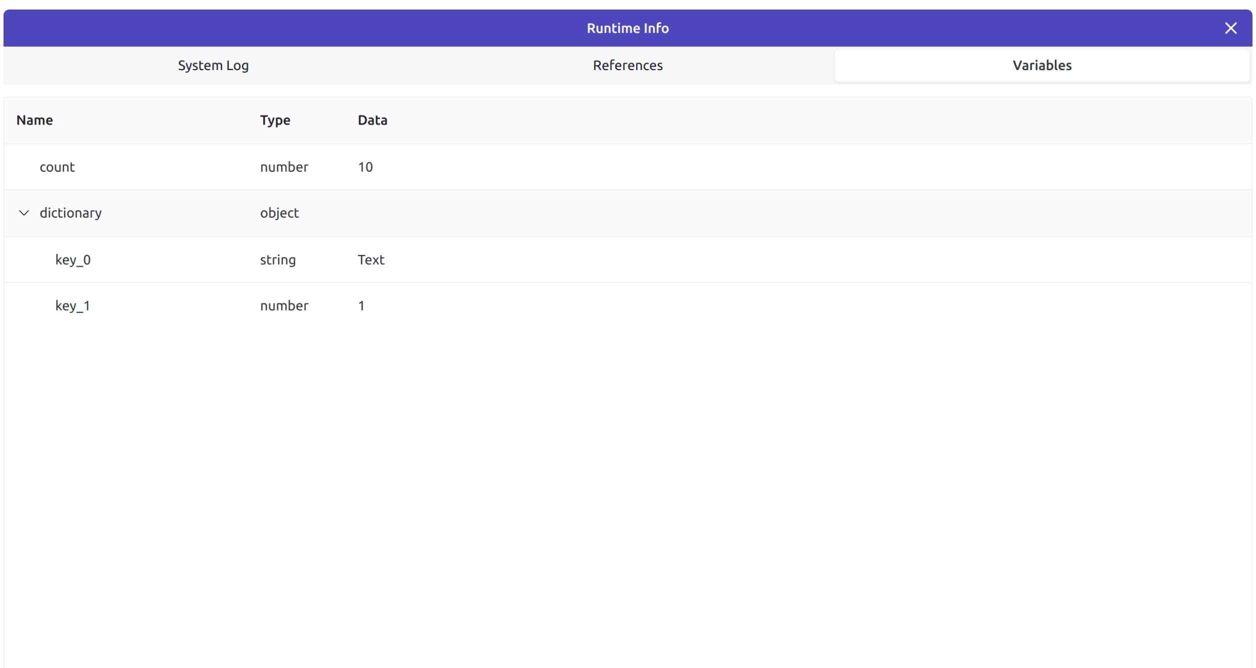


Fig. 6.12: Variable info tab

6.1.3 Programming basics

The robot can be programmed from the Ability user interface. The interface provides a block-based programming interface for fast and easy programming of the robot. To create a program do the following:

1. Press the 'Programming' item in the side menu.
2. Press 'New' to create a new program and enter a name.

An empty program will now appear. A program always contains the 'Program' block, into which further blocks can be inserted. Only blocks added inside of the 'Program' block will be executed. The only exceptions are the 'Function' and 'Error function' blocks that can be found under the Programming block category. Code inside a 'Function' block will be executed when a corresponding 'Call Function' block has been added in the main programming block. Similarly, code inside an 'Error function' block can be executed by a related block if it encounters an error.

3. Insert instructions. The different blocks are categorized and placed in different submenus. The blocks are color coded based on the category. For example, orange blocks refer to the Mobile Platform, while blue to the Manipulator and purple to Programming structures.
4. Configuring blocks. When a block has been inserted it can be configured. Click the block and a menu will appear to the right with the different settings available on the block. This is called the 'block menu'. For configuration, positions etc. the block menu will contain a button for reading in the current values of the robot. Remember to press 'Apply' to store the result before leaving the menu.
5. Click 'Save' to save the program.
6. Click the 'Play' button in the upper right corner to execute the program.

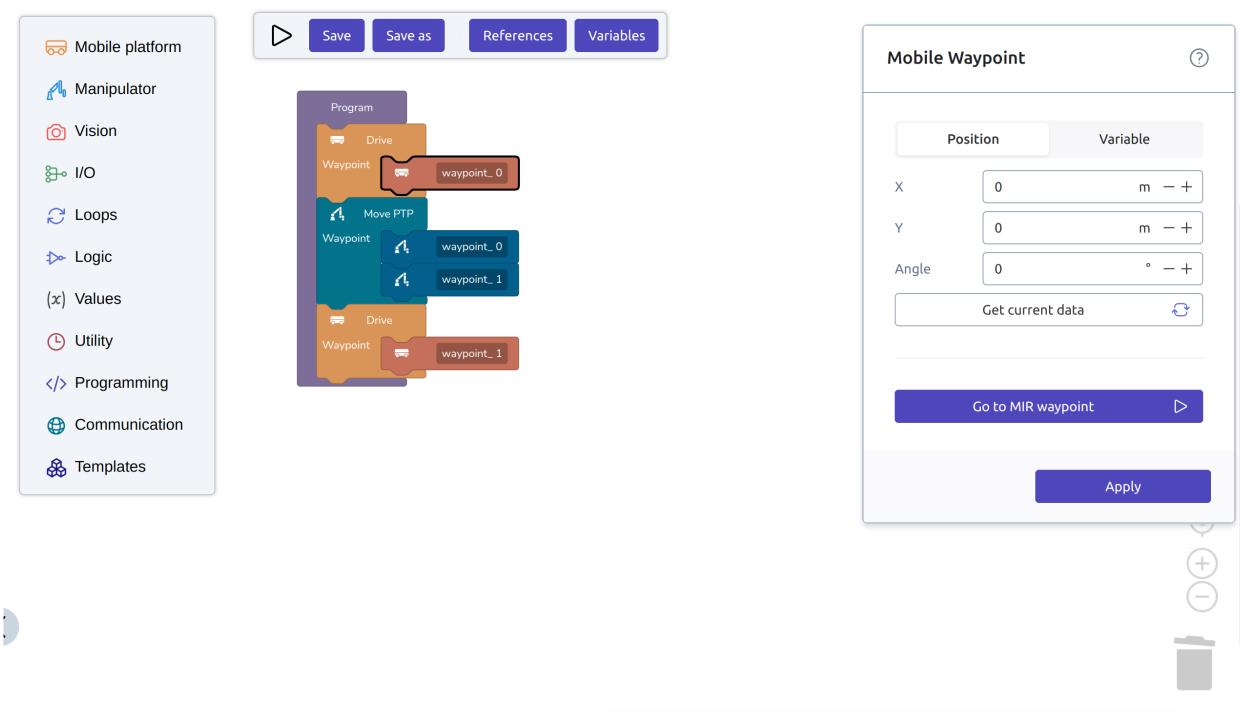


Fig. 6.13: Ability sample program

Danger:

When driving with the MiR always ensure that the UR and its tool is completely inside the footprint of the MiR. Failure to do so may cause hazardous situations as the MiR is unaware of the configuration of the UR and tool while driving.

Warning:

When using the vision system, movements of the arm may change based on the results of the vision system. It is therefore important to ensure that the robot has enough clearance to obstacles to avoid collision.

A detailed guide on how to program the robot can be found in the Ability User Documentation available through the "Help" menu in the web interface or at enabled-robotics.com.

6.2 Automatic Mode

The dashboard page offers functionality to control the robot's mode, add missions to the queue, and schedule programs.

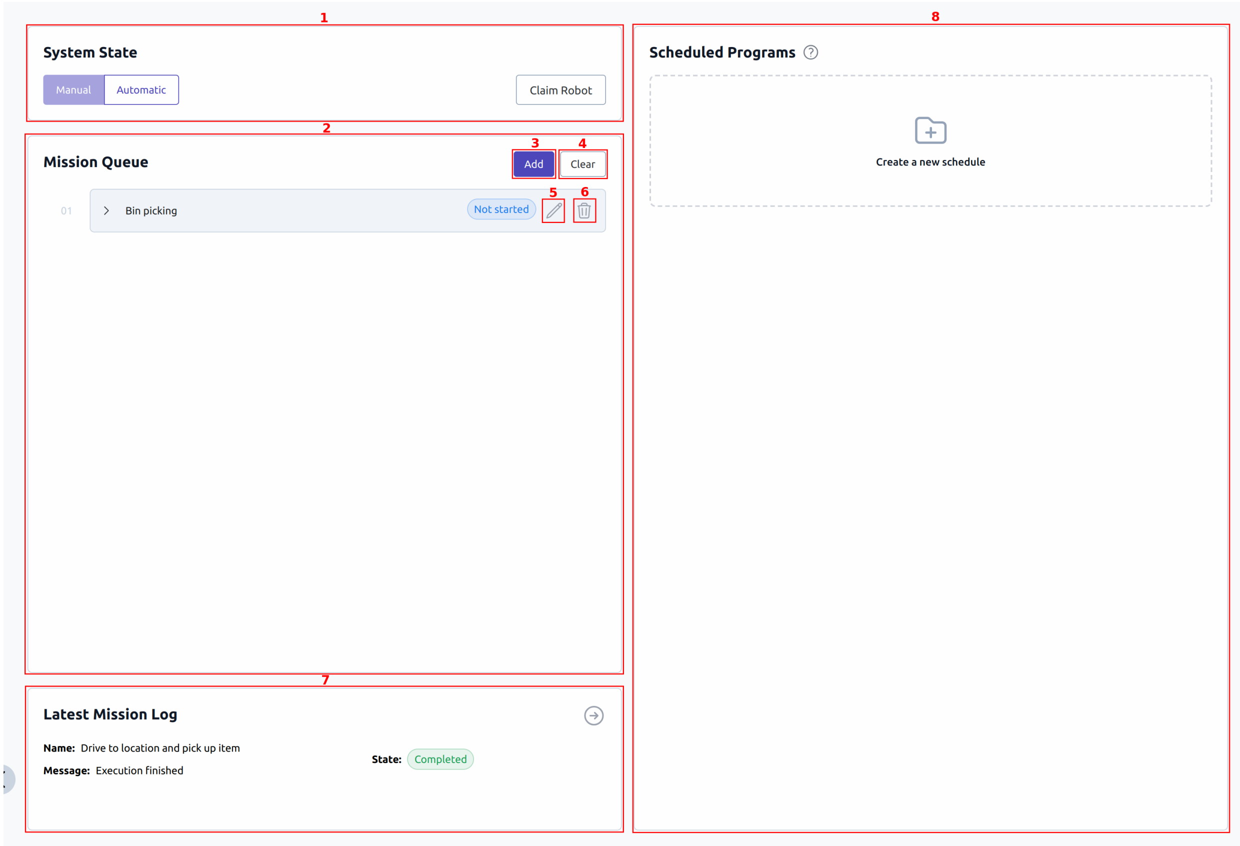


Fig. 6.14: Dashboard

- The 'System State' provides a visual representation of the robot's current mode and allows users to switch between modes using the switch (1).
- The 'Mission Queue' offers a comprehensive view of queued missions awaiting execution (2). Users can add new missions to the queue (3), clear the entire queue (4), and modify (5) or delete (6) individual missions. When the robot is in automatic mode, the queued missions are executed sequentially. Each mission may consist of multiple programs, allowing a series of programs to run in a predefined order.
- The 'Latest Mission Log' maintains a record of the last executed or canceled mission from the queue (7).
- The 'Scheduled Programs' provides an overview of upcoming scheduled programs (8) and enables users to schedule additional programs to be added to the mission queue. This feature enhances the planning and automation capabilities of the robot.

6.2.1 Mission builder

The mission builder allows users to create missions complete with programs and associated arguments, seamlessly adding them to the queue. Accessing the mission builder can be done by adding a new mission to the queue.

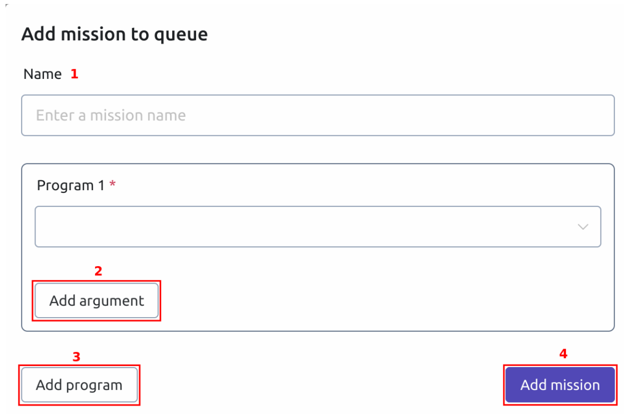


Fig. 6.15: Mission Builder

The mission can be given a name for identification (1), add as many programs as needed (3) and arguments to each program (2). By pressing the 'Add mission' button (4), the mission is add to the queue. The mission is executed if the robot is in automatic mode and the mission is next in line.

6.2.2 Scheduled Program

The program schedualer can be used if a program is to be executed at a spefic time in the future.

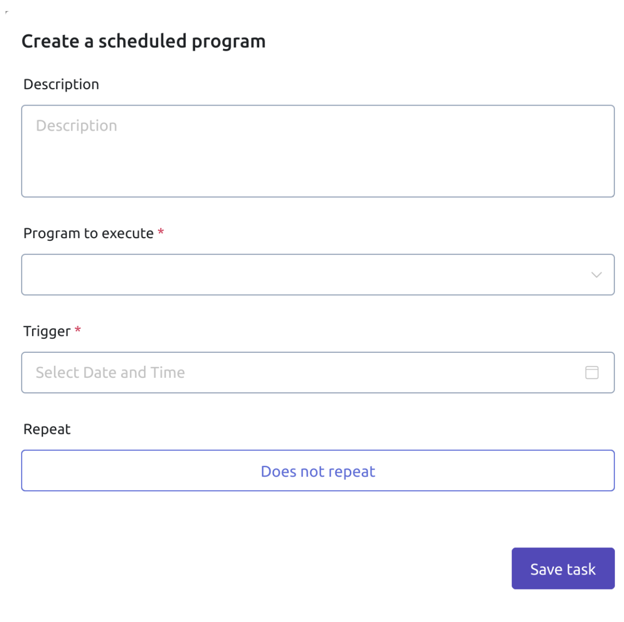


Fig. 6.16: Scheduled Program

When adding a new scheduled program, the configuration includes options to provide a description, specify the program for execution, and define a trigger. The trigger dictates the scheduling of the program, with an added repeat functionality to determine its frequency of schedulation. Upon the scheduled time, the program is added to the queue as part of a mission and executed when the robot is in automatic mode and the mission is next in line.

CHAPTER SEVEN

LOAD SPECIFICATION

Danger:

Always ensure that objects are placed securely while driving. Failing to do so may result in hazardous situations.

Danger:

Always ensure that the payload of the robot fulfills the requirements specified in this manual. Failing to do so may cause the robot to lose stability and fall over.

7.1 Mounting

The front platform uses M6 threads for mounting fixtures, tools or other applications.

Never insert bolts more than 20mm below the surface of the top plate.

7.2 Payload placement

The drawings below illustrate where the center of mass (CoM) of the payload are to be placed to ensure safe driving with the MiR. The volumes illustrated are for the given configuration of the UR with different payloads.

7.2.1 ER-FLEX 250 with UR5e

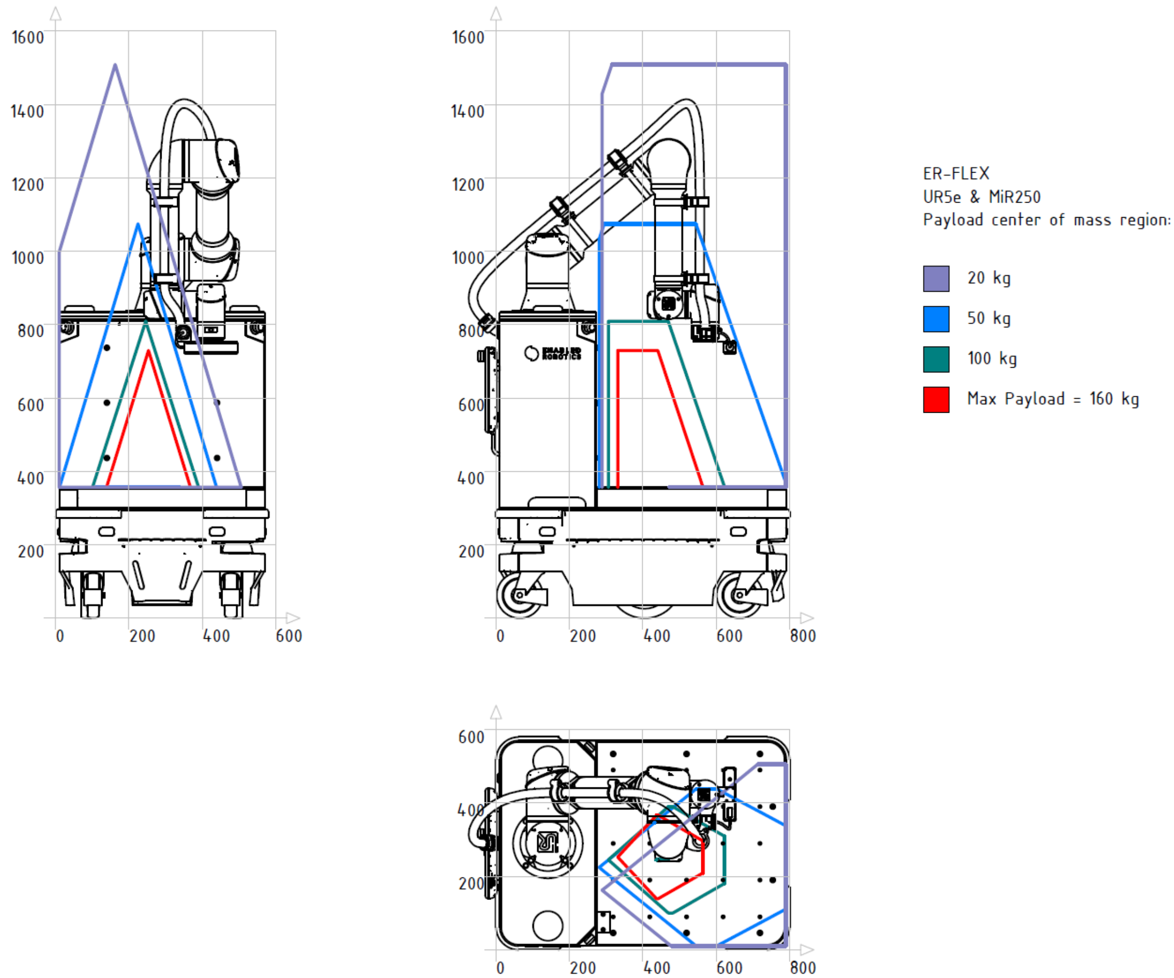


Fig. 7.1: Payload specification for ER-FLEX 250 with UR5e.

7.2.2 ER-FLEX 250 with UR10e

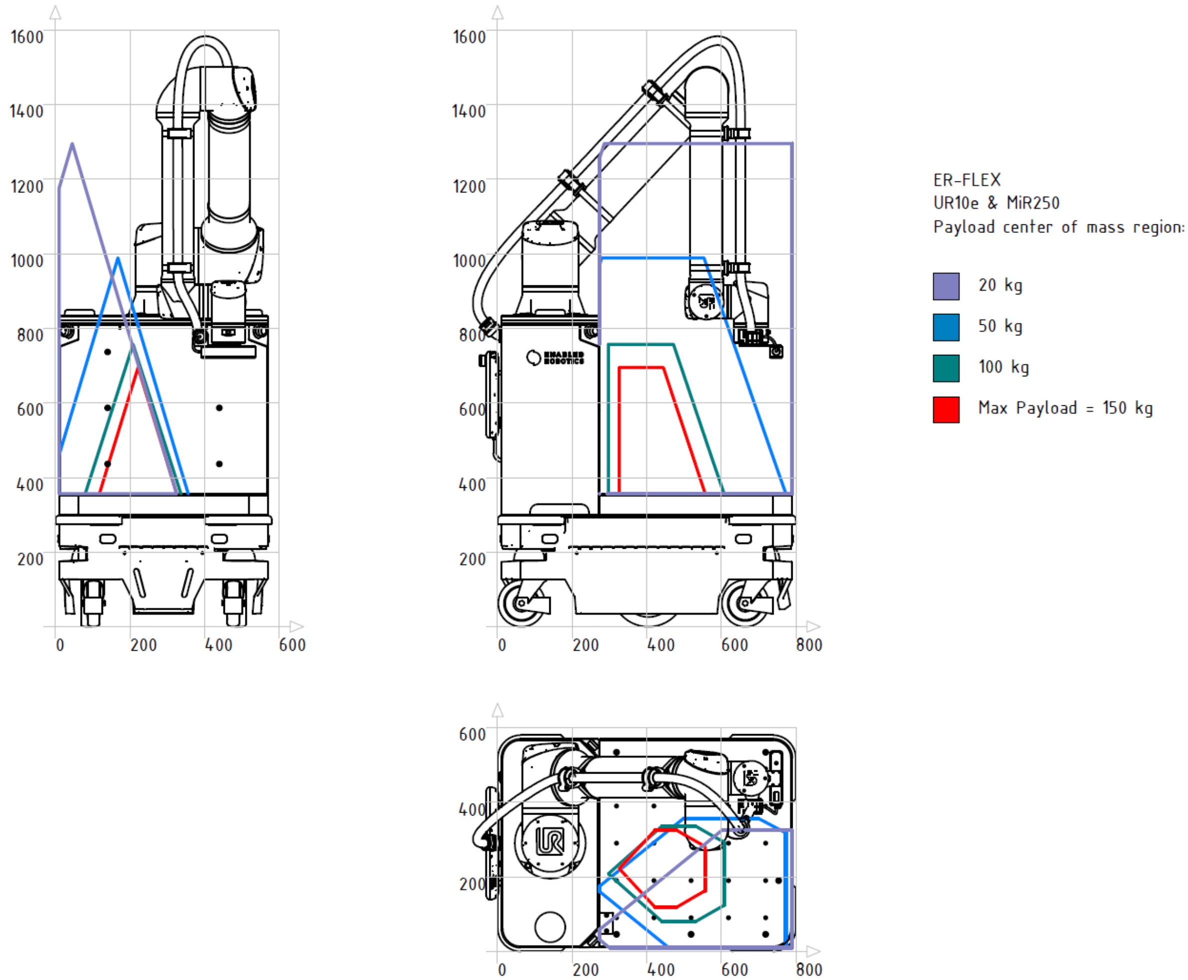


Fig. 7.2: Payload specification for ER-FLEX 250 with UR10e.

7.2.3 ER-FLEX 250 with UR16e

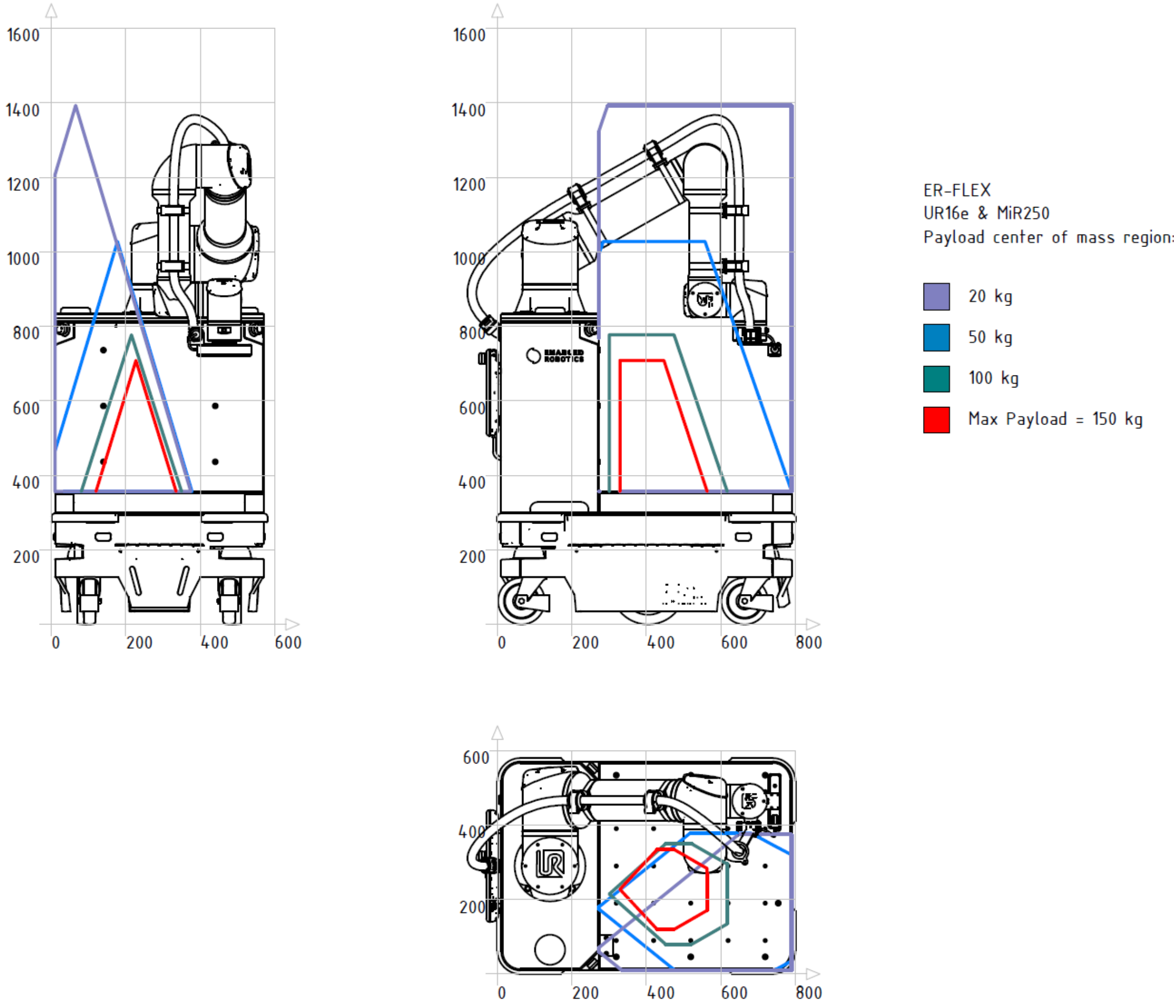


Fig. 7.3: Payload specification for ER-FLEX 250 with UR16e.

CHAPTER

EIGHT

MAINTENANCE

Warning:

Maintenance should be carried out by trained personnel only.

Warning:

Failing to shut down the robot when maintenance instructions state to do so, may lead to dangerous situations with risk of injury or damaging equipment.

Before performing any disassembly of the system:

1. Shut down the robot as described in Section 4.5.
2. Reverse the steps for connecting power specified in Section 4.2.

8.1 Maintenance of MiR

Follow the maintenance instructions of the MiR user guide.

8.2 Maintenance of UR

Follow the maintenance instructions of the UR user manual.

8.3 Maintenance of er-flex Hardware

Maintenance of the er-flex hardware should be performed according to the schedule below:

Table 8.1: Maintenance table

Part	Interval	Action
Emergency Stops(The two on the tower)	Three months following EN/ISO 13850 Safety of machinery - Emergency stop function	(1) Turn on the robot. (2) Press one of the two emergency stops located on the tower and check that both MiR and UR enter into emergency stop. (3) Release the emergency stop and press the reset button on the tower. (4) Press the other emergency stop located on the tower and check that both MiR and UR enter into emergency stop. (5) Release the emergency stop and press the reset button on the tower. (6) Replace if there are signs of wear or not functioning.
UR mounting	Three months	Ensure that the four M8 mounting bolts of the UR are fastened with 20Nm. Ensure that the O-ring between the UR base and the top plate is installed correctly (Press firmly down on O-ring all the way round the base). Replace if it has signs of wear.
ER-Flex hardware	Six months	(1) Turn off the robot. (2) Ensure that the four M8 bolts fixing the ER-Flex hardware to the MiR are tightened with 20Nm (two inside tower and two under the platform). (3) Remove the eight M6 bolts in the front platform, and remove platform and base of platform. (4) Robots with a high front module attached: Remove the four M4 bolts in the door and remove the door. Then remove the two M6 bolts inserted in the tower, and eight M6 bolts into the platform to be able to remove the front module and platform base. (5) Open the door on the tower to access the two bolts in the tower. (6) Ensure that the two rear M6 bolts fastening the UR Controller are fastened with 10Nm. (7) Ensure that the two M6 bolts fastening the DIN-rail are fastened with 10Nm. (8) Inspect all wires for wear and poor attachment.Replace if showing signs of wear. (9) Inspect wires going through the front of the tower towards MiR connections in the lower left and right corners. (10) Ensure the two antennas are secured to the top plate. (11) Close the door on the tower. (12) Remount front platform (and highmodule if present), tighten all M6 bolts with 10Nm. (13) High module: Remount the door and tighten the four M4 bolts with 2Nm. And then insert the rubber plugs in the holes.

Continued on next page

Table 8.1 – continued from previous page

Part	Interval	Action
ER-Cam	One Month	(1) Remove dust and dirt from the lens with a clean dry cloth. Be careful not to scratch the lens. (2) Ensure that the cable is securely held in place in the camera housing. (3) Ensure that the bolts mounting the camera are tightened with 0,9Nm of torque (threads/bolts has been secured with thread-locker from factory). (4) Ensure that the cable connecting the camera to the controller does not show signs of wear. (5) Ensure that the cable guide is attached firmly to the UR-arm. Replace cable guide or velcro bands if there are signs of wear.
Filters	One Month(Depending on environment)	Inlet filer: Remove the three M4 bolts on the left side of the tower, and remove the inlet filter cover. Inspect, and replace filter if needed. Outlet filter: Turn off the robot. Open the door in the tower. Remove the outlet filter cover in the right hand side by opening the quicklock handle holding it in place. Inspect, and replace filter if needed.

8.4 Software updates

New updates of the ability software running on the robot will become available periodically. Information about the latest release can be found at www.enabled-robotics.com.

Updating the robot is done from the web interface. Make sure the robot is connected to the internet, then navigate to *Settings* and open the 'Software Update' tab.

For a detailed description on how to update the system please check www.enabled-robotics.com or the *Documentation* menu found on the web interface.

Warning:

Do not turn off the robot while running the software update as this may leave the software in an undefined state.

CHAPTER

NINE

TRANSPORTATION

To pack the robot for transportation use the original packaging the robot was shipped in. There is no need to disassemble the robot system before packing it, provided that no additional hardware is mounted. However, if your robot does have additional hardware, please consult the transportation guidelines provided by the hardware manufacturer or integrator.

9.1 Packaging

1. Move the UR to a safe location with low center gravity and completely within the footprint of the MiR.
2. Perform the steps of unboxing, as described in Section 4.1, in reverse order. Remember to put additional support under the ramp of the box before driving the robot up onto the pallet.
    a. In the event that the original shipment pallet is unavailable, opt for a pallet that adheres to UIC 435-2 standards and measures 800x1200 mm
    b. Should the original pallet frame be inaccessible, employ six cargo suited pallet frames, each sized at 800x1200x195mm.
    c. Utilize the ramp in strict accordance with the instructions outlined in section Section 4.1. Take special caution regarding the possibility of the ramp gliding, as failure to follow the correct procedure may lead to hazardous circumstances.
3. Shut down the robot (see Section 4.5).
4. Disconnect the power reversing the steps described in Section 4.2.
5. Position the original foam pieces (or equivalents) in the location as observed during the unboxing process.
    a. By positioning the robot within the foam pieces, the center of gravity will be approximately centered within the transportation case.

Warning:

The lithium battery of the MiR is subject to specific transport regulations. Regulations may depend on the mode of transportation: land, sea, or air.

Always follow the safety instructions of the MiR and UR.

CHAPTER

TEN

STORAGE

When storing the robot, adhere to the guidelines of this section.

10.1 Long term storage

If it is deemed necessary to package the robot before storage, refer to section Section 9.1.

1. Charge or discharge the robot to 80% battery.
2. Shut down the robot (see Section 4.5).
3. Disconnect the power reversing the steps described in Section 4.2.

10.2 Storage conditions

The robot with disconnected or removed battery must be stored in an area at room temperature with a non-condensing relative air humidity of 10–95%.

The lithium battery of the MiR must be disconnected and stored at room temperature in a non-condensing relative air humidity of 10–95%. Temperatures and humidity below or above the specifications will shorten the service life of the battery.

Important: For battery storage times, consult *MiR 48V Battery Troubleshooting and Technical Guide*. Always adhere to MiR's guidelines regarding battery storage.

CHAPTER

ELEVEN

DECOMMISSIONING

11.1 Disassembly

Danger:

When disassembling the robot be sure to follow the steps specified. When dismounting parts, be sure these are securely held so that they do not fall down.

Failure to follow the specification may result in risks of electrical shock or crushing from components falling.

1. Power down the robot as described in Section Section 4.5.
2. Disconnect the power reversing the steps described in Section 4.2.
3. Remove the platform and its base.
4. Disconnect all cables between the MiR and the ER-Flex hardware.
5. Open the tower door, disconnect, and remove all components on the DIN Rail.
6. Dismount the UR OEM Controller and disconnect the cable going to the UR and DIN rail.
7. Unscrew the four M8 bolts fixing the UR to the tower, lift the UR and pull clear the cable from within the tower. When lifting the UR, use appropriate lifting equipment to support the weight of the UR and ensure that it does not fall or damage the ESD painted top plate.
8. To remove the awareness LED light inside the LED plate, pull the ESD painted top plate upwards. This top plate is held in place by strong magnets. Do not pull the LED plate upwards, this is glued in place to ensure a watertight seal. (replace the seal, if the LED has been removed, or pulled up)
9. Dismount the ER-Hardware from MiR, by removing the four M8 bolts fixing it onto the MiR. Use appropriate lifting equipment to support the weight of the ER-hardware and ensure that it does not fall or damage anything.

11.2 Disposing

The disassembled parts are to be disposed of in accordance with the national regulations and standards. Notice that the MiR robot contains lithium batteries which may be subject to special requirements. Always follow the specifications from MiR and UR on how to decommission the MiR and UR on their own.

Danger:

Lithium battery packs may cause serious injury (explode or ignite) if they are abused electrically or mechanically. Follow the below precautions when handling the lithium batteries:

- Do not short circuit, recharge or connect with false polarity.
- Do not expose to temperature beyond the specified temperature range or incinerate the battery.
- Do not crush, puncture or disassemble the battery. The battery contains safety and protection devices, which, if damaged, may cause the battery to generate heat, explode or ignite.
- Do not allow the battery to get wet.
- In the event the battery leaks and the fluid get into one's eye, do not rub the eye. Rinse well with water and immediately seek medical care. If left untreated, the battery fluid could cause damage to the eye.
- Use only the original charger (cable charger or charging station) and always follow the instructions from the battery manufacturer.