Vision System Tutorial

v1.7.4

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1. Introduction to the Vision System

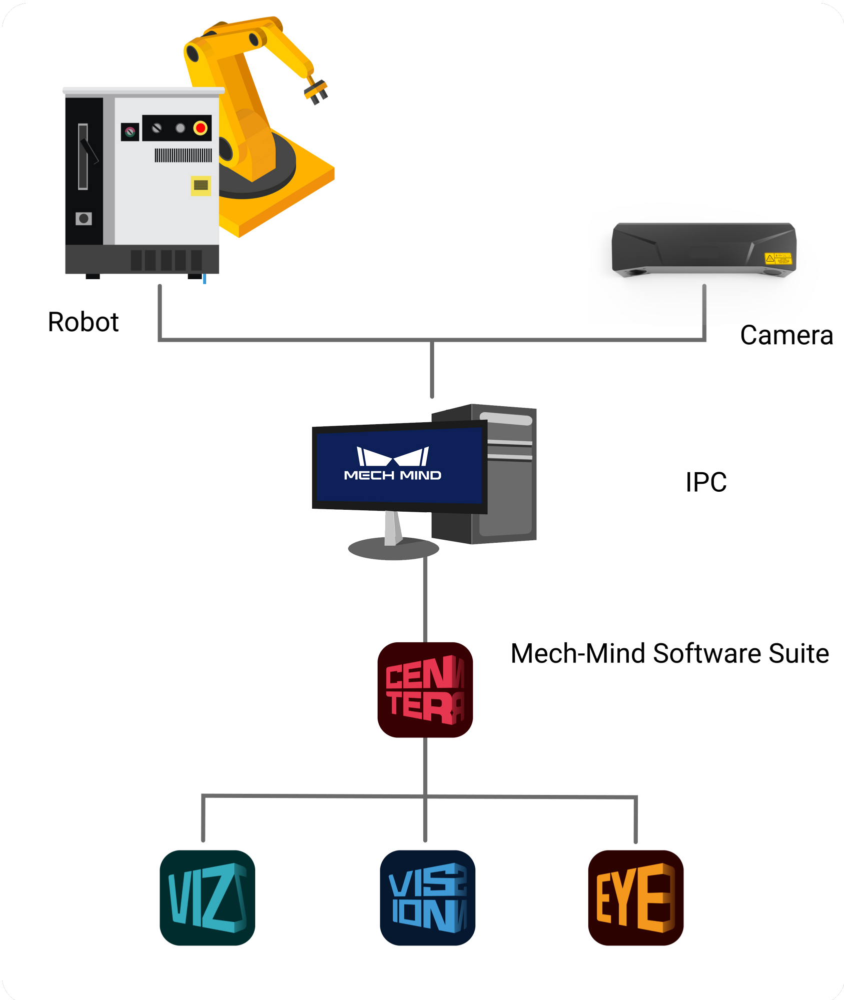
What Is the Mech-Mind Vision System?

The Mech-Mind Vision System is a comprehensive 3D vision solution from Mech-Mind for various industries, including automotive, logistics, supermarkets, and heavy industry. It offers a wide range of applications such as workpiece loading, depalletizing and palletizing, locating and assembly, piece picking, and quality inspection.

The Mech-Mind Vision System is usually used together with industrial robots and collaborative robots.

Components of the Vision System

The Mech-Mind Vision System usually consists of the camera, Mech-Mind Software Suite, IPC (industrial personal computer), and the robot, as shown below.



Camera

It is the Mech-Eye industrial 3D camera developed by Mech-Mind, which is used to capture image and location information of the objects.

Mech-Mind Software Suite

The Mech-Mind Software Suite performs vision processing based on image and location information captured by the camera, and outputs the location and orientation of the objects and the planned motion path of the robot, thus guiding the robots to complete intelligent tasks, such as picking, depalletizing and palletizing, gluing, sorting, etc.

IPC (Industrial Personal Computer)

It refers to the computer that provides the operating environment for the Mech-Mind Software Suite.

Robot

A robot is a programmable multi-purpose handling device with some autonomy that can perform tasks such as movement, manipulation or positioning. In the Mech-Mind Vision System, it performs intelligent tasks based on the results output by the vision system.

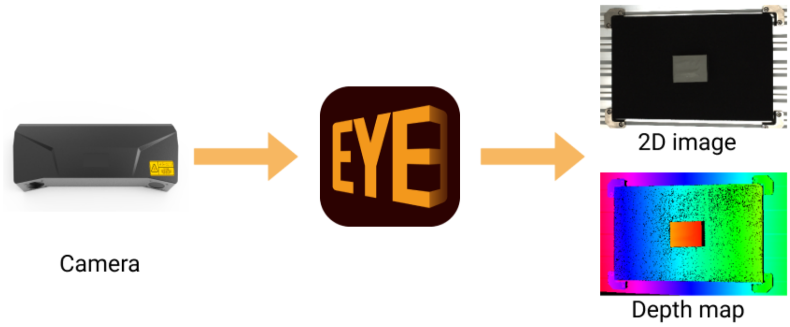
- A robot cell usually consists of a robot body, a controller, and a teach pendant.
- In industrial applications that require a high level of automation, a PLC (programmable logic controller) can be used to control the motion and operation of the robot. If a higher level of control and monitoring is required, a host computer can also be used to perform more complex programming and control of the robot, such as path planning, task planning, and motion control. The Mech-Mind Vision System can be used together with the PLC and host computer.
- In this article, "robot side" is used as a generic term for the robot, PLC, or host computer, and "vision side" to refer to the camera and the Mech-Mind Software Suite.

Introduction to the Mech-Mind Software Suite

The Mech-Mind Software Suite is developed by Mech-Mind and provides 3D vision solutions for robots and peripherals. It mainly includes the following software:

- Mech-Eye Viewer

  Mech-Eye Viewer allows users to adjust the parameters of the Mech-Eye industrial 3D camera according to the characteristics of the target object, and obtain high-quality 2D images, depth maps, and point clouds.



- Mech-Vision

  Mech-Vision is a state-of-the-art machine vision software. With its fully graphical interface, advanced machine vision applications such as piece picking, high-precision positioning, assembly, industrial inspection/measurement, and automatic path planning can be completed without writing codes.

Based on the image data captured on site, this software performs a series of vision processing and outputs the vision results (such as the position and orientation of the target object). In addition, based on the vision results, this software can perform collision-free path planning for the robot, and output the planned path.

- Mech-Viz

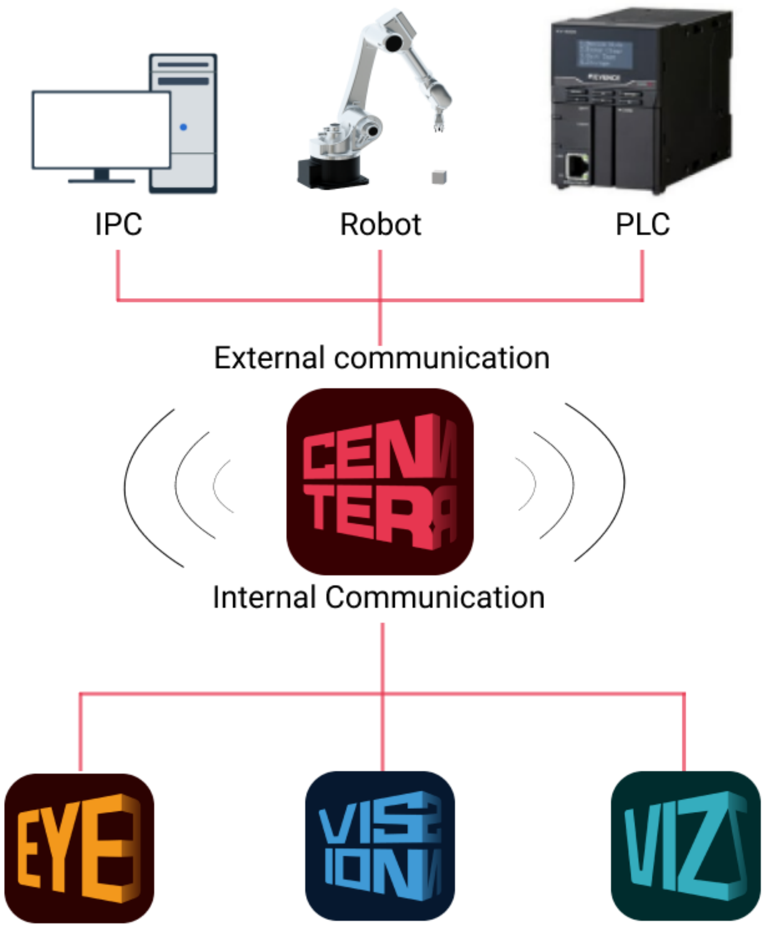
  Mech-Viz is a robot path planning software. It uses the information provided by Mech-Vision, including the point clouds and workpiece positions, to intelligently plan the robot path for picking, carrying, and palletizing and other complex application scenarios.

  This software allows users to build a workflow for the robot in a visualized manner and provides a 3D simulation function for validation before using the real robot. It has already been adapted to many major robot brands around the world.

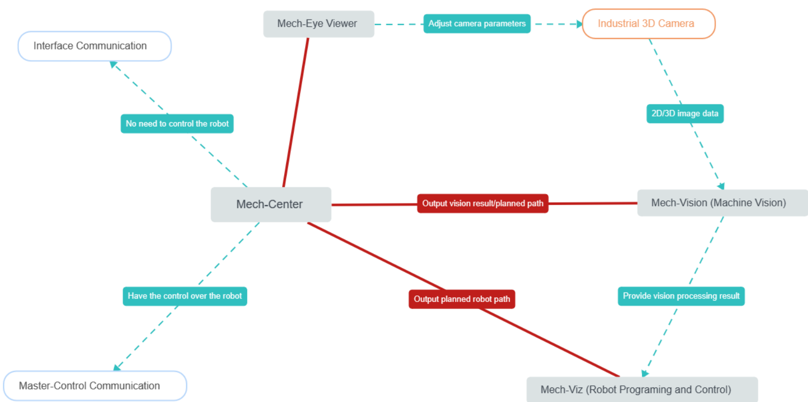
- Mech-Center

  Mech-Center is the communication hub and control center. It provides standard interface protocols and can help customers customize communication services, thus implementing communication with external devices and jointly completing smart manufacturing tasks with vision-guided robots.

  Within the Software Suite, Mech-Center is responsible for internal communication between the software. For example, it sends the vision result output from Mech-Vision to Mech-Viz for planning the robot's collision-free path. When Mech-Center communicates with external devices, it sends the vision result from Mech-Vision or the planned collision-free path output from Mech-Vision or Mech-Viz to the robot, PLC, or host computer. More information about the communication between the {company} Software Suite and external devices will be discussed in the following section.



The relationship between the individual software of the Mech-Mind Software Suite is shown in the following figure.



Communication with the Robot Side

To ensure that the vision result (output by Mech-Vision) or the planned robot picking path (output by Mech-Vision or Mech-Viz) can be successfully sent to the robot side, the Mech-Mind Vision System should be able to communicate with the robot side.

The Mech-Mind Vision System supports the following communication modes:

- Master-Control communication

  In this mode, the vision side has control over the robot, i.e., the vision side acts as the master device, while the robot slave device. The vision side controls the robot to perform tasks based on the planned path, such as workpiece loading or depalletizing/palletizing.

  When this mode is used, the robot can be controlled by loading a master-control program to the robot or by using the robot's SDK (Software Development Kit). This mode does not support communication with the PLC or host computer.

- Interface communication

  In this mode, the vision side does not need to take control of the robot. Typically, the robot side acts as the master device, while the vision side is the slave device. The robot side and the vision side use the same standard communication protocol to communicate (such TCP socket). The robot side sends requests while the vision side processes them and sends responses back. Depending on the request, the vision side returns either the vision result or the planned picking path. The robot makes further decisions or performs the appropriate tasks according to the responses returned from the vision side.

  When this mode is used, you should load the Mech-Mind robot interface program (for communicating with the vision side and for receiving the data returned from the vision side) to the robot controller. The robot controller should be configured to use the Mech-Mind robot interface program. Furthermore, it is necessary to write a robot program (routine) for controlling the robot to perform tasks, using the data from the vision side. This mode supports communication with the robot, the PLC, and the host computer.

For more information about the communication modes, refer to the section Communication Basics.

2. Getting Started Tutorial: Vision-Guided Robotic Picking (Master-Control Communication)

In this tutorial, you will learn how to deploy a simple 3D vision-guided robotic application of picking small metal parts in the Master-Control communication mode.

Application Overview

- Camera: Mech-Eye PRO M camera, mounted in Eye to Hand mode
- Robot: ABB_IRB_1300_11_0_9
- Workpiece: chain links (made of metal)

> For this application, you are required to prepare a model file in CAD format for the workpiece, which will be used to generate the point cloud matching model.

- End tool: gripper

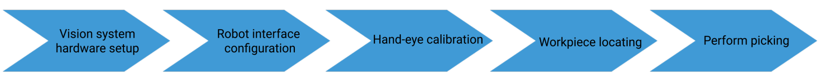
> For this application, you are required to prepare a model file in OBJ format for the gripper, which will be used for collision detection during path planning.

- Used software: Mech-Vision 1.7.2, Mech-Viz 1.7.2, Mech-Center 1.7.2, and Mech-Eye Viewer 2.1.0
- Communication mode: Master-Control communication

> If you are using a different camera model, robot brand, or workpiece than in this example, please refer to the reference information provided in the corresponding steps to make adjustments.

How to Deploy a Vision Application?

The deployment of the vision application can be divided into five phases, as shown in the figure below:



The following table describes the five phases of deploying a vision application.

No.	Phase	Description
1	Vision system hardware setup	Install and connect hardware of the Mech-Mind Vision System.
2	Robot communication setup	Load the robot master-control program and the configuration files to the robot system and set up the communication between the vision side and the robot, thus helping the Mech-Mind Software Suite obtain control over the robot.

No.	Phase	Description
3	Hand-eye calibration	Perform the automatic hand-eye calibration in the Eye-to-Hand setup, to establish the transformation relationship between the camera reference frame and the robot reference frame.
4	Workpiece locating	Use the "General Workpiece Recognition" case project to calculate the workpiece poses and output the vision result.
5	Perform picking	Use Mech-Viz to create a workflow that can guide the robot to repeatedly pick and place workpieces.

Next, follow subsequent sections to complete the application deployment.

2.1. Vision System Hardware Setup

In this tutorial, you will learn how to build the Mech-Mind Vision System.

Follow the steps below to build the Mech-Mind Vision System: **Check the contents of the package** → **Install the hardware** → **Connect the network** → **Upgrade the software (optional)** → **Confirm that the vision system can capture images normally**.

▶ https://www.youtube.com/watch?v=Utnjo0l0UAU/PLVcMd7cW2rXVtrAejMyVQni2dUDv8bxje *(YouTube video)*

Video Tutorial: Vision System Hardware Setup

Check the Contents of the Package

1. Make sure that the package is intact when you receive it.
2. Check the contents against the "packing list" in the package to ensure that no devices or accessories are missing or damaged.

The following figure shows the devices and accessories included in a vision system shipment. The table below is for reference only. Please take the "packing list" in the package as final.

No.	Category	Name	Function
1	IPC and accessories	IPC (Industrial Personal Computer)	Provision of the Mech-Mind Software Suite
2		IPC accessories	Provision of IPC accessories, such as antennas for WIFI connection
3		IPC power cable and adapter	Supplies power to IPC
4	Camera and accessories	Mech-Eye Industrial 3D Camera	Captures images
5		User manual	Mech-Eye Industrial 3D Camera User Manual and datasheet
6		Camera accessory box	Mounts the camera
7	Project accessories	License dongle	License for the Software Suite
8		Calibration board	Calibrates the camera
9		Flange adapter	Connects the calibration board to the robot flange
10		Camera DC power cable (standard: 20 meters)	Connects the camera and the DIN rail power supply; Longer power cables are an option
11		Camera Ethernet cable (standard: 20 meters)	Connects the camera and the IPC; longer camera Ethernet cables are an option
12		DIN rail power supply (standard)	Supplies power to Mech-Eye Industrial 3D Camera; The camera power adaptor is an option
13	Packing list		List of all the devices and accessories in the package

Contact Mech-Mind if any items are missing or damaged.

Prepare Other Materials

In this tutorial, besides the items in the package, you still need to prepare the materials shown in the following table by yourself.

Item	Function
Monitor	Provides display for the IPC
HDMI cable	Connects the monitor and the IPC
RJ45-to-RJ45 Ethernet cable	Connects the IPC and the robot controller

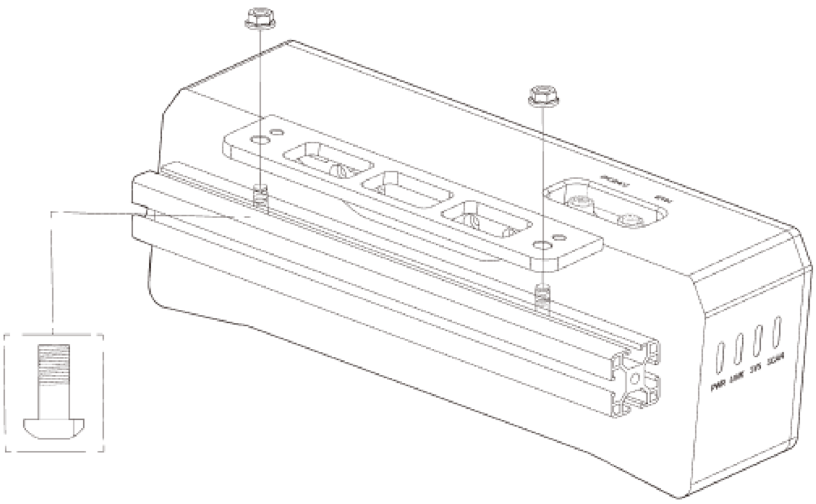
In this tutorial, the IPC and robot controller are directly connected through an RJ45-to-RJ45 Ethernet cable, and the IPC and the camera are directly connected through the camera Ethernet cable. Alternatively, you can use a router to connect the IPC and the robot controller, and the IPC and the camera, which is not covered in this topic.

Install Hardware

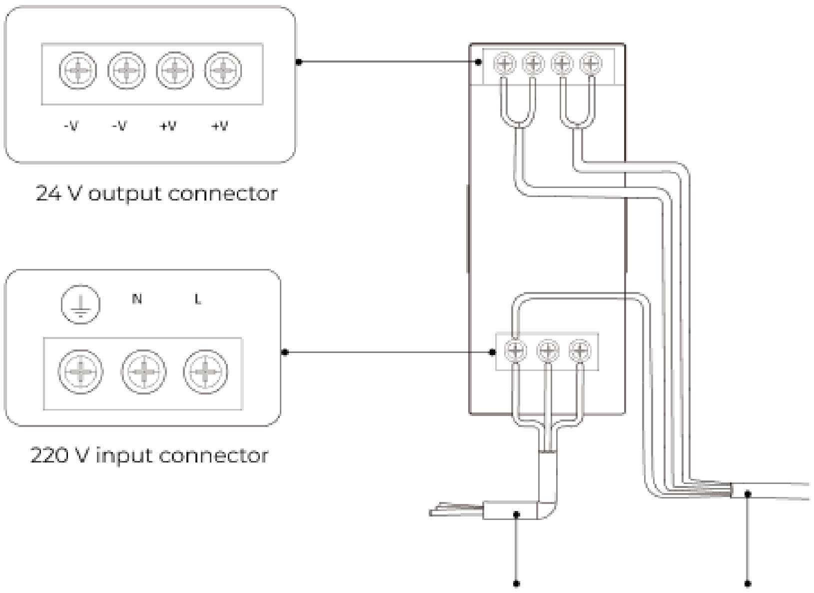
Mount the Camera

> In this tutorial, the camera is mounted on the camera mounting frame (that is the Eye to Hand mounting mode). In addition, the camera can also be mounted onto the end terminal of the robot (that is the Eye in Hand mounting mode).

1. Get the camera mounting bolts and wrench from the camera accessory box.
2. Tighten the two bolts with the wrench as shown below.

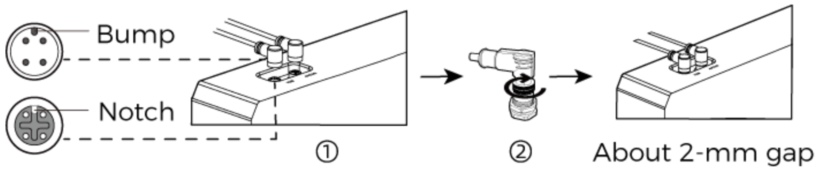


3. Please remove the lens protection film after mounting the camera.
4. Power the camera with the DIN rail power supply.
   - Connect the DC power cable:
     - Connect the +V wire to the +V connectors of the 24 V output connectors;
     - Connect the -V wire to the -V connectors of the 24 V output connectors;
     - Connect the PE wire to the 220 V input connector ⏚.



5. Install the Ethernet cable of the camera.

   Make sure the bump of the M12 connector and the notch of the ETH port, and tighten the nut after plugging in the cable.

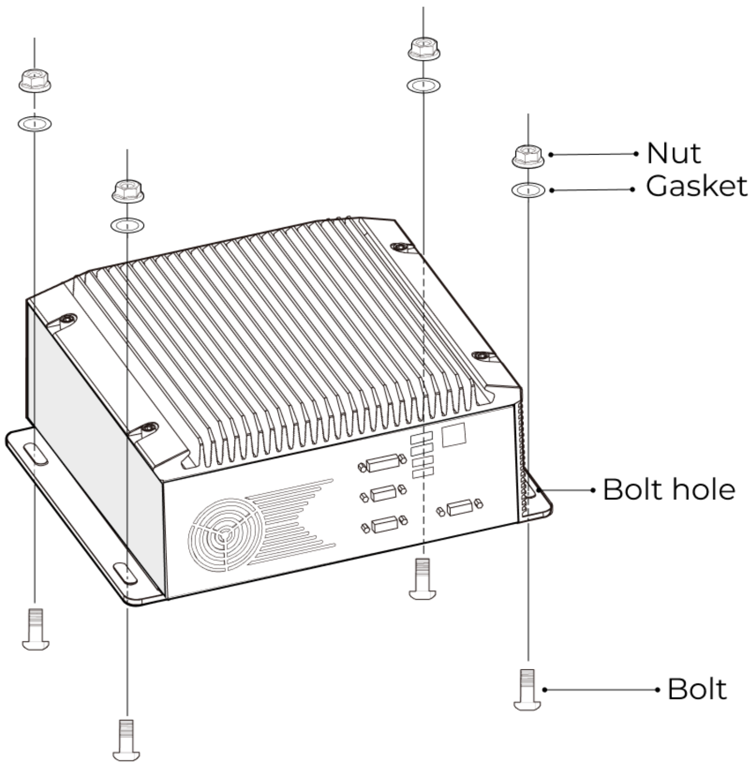


Mount the IPC

> The IPC is normally mounted in the control cabinet of the robot. The environment in which the IPC is mounted requires good heat dissipation, ventilation, and dust protection. It should be mounted at a location where Ethernet cables, HDMI cable, and USB ports can be easily mounted and serviced.

To mount the IPC, follow these steps:

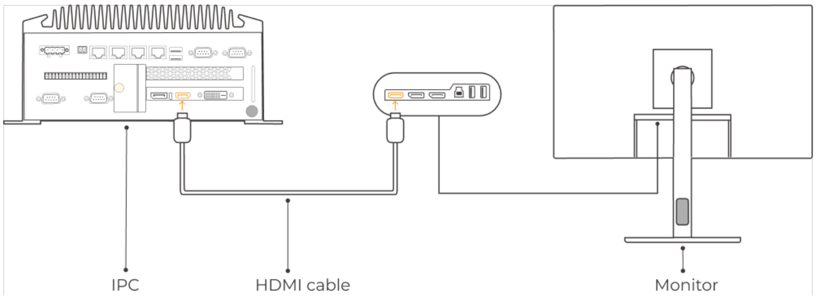
1. Prepare the wrench, bolts, nuts, and gaskets that are not included in the package beforehand.
2. If the robot controller is designed with mounting holes for the IPC in it, secure the IPC in the controller: place the bolt, gasket, and nut one by one, and tighten the two bolts with a wrench, as shown below.



> If the location of the robot controller is already fixed, skip this step and just place the IPC inside the controller.

3. Connect the IPC and the monitor with the HDMI cable.

Plug one end of the HDMI cable into the HDMI port of the monitor, and the other end into the HDMI port of the IPC, as shown below.



4. Connect the IPC to the power supply unit with the power adaptor.

   Plug the power cable of the power adaptor into the power connector of the IPC. Connect the adaptor to the power supply on the other end.

5. Insert the license dongle.

   Plug the license dongle into a USB port of the IPC.

6. After the IPC is connected to the power supply, switch on the IPC.
   - If the IPC is started normally, the power indicator should be solid on.
   - If the IPC cannot be started, contact Mech-Mind Technical Support.

Connect the Network

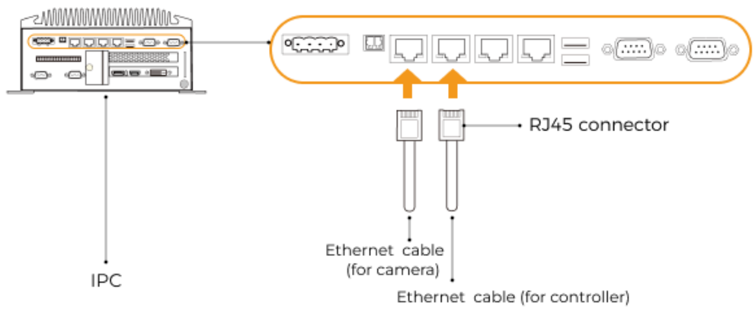
In this section, you will learn how to connect the network between the IPC and the camera, and between the IPC and the robot.

In the following sections, the following IP addresses will be used for network settings. Please adjust the network settings according to your actual network environment.

Device		IP address
IPC	Ethernet port connecting to the camera	192.168.100.10
	Ethernet port connecting to the robot controller	192.168.200.10
Camera		192.168.100.20
Robot		192.168.200.20 (already set on the robot)

Connect the IPC and the Camera, and the IPC and the Robot Controller

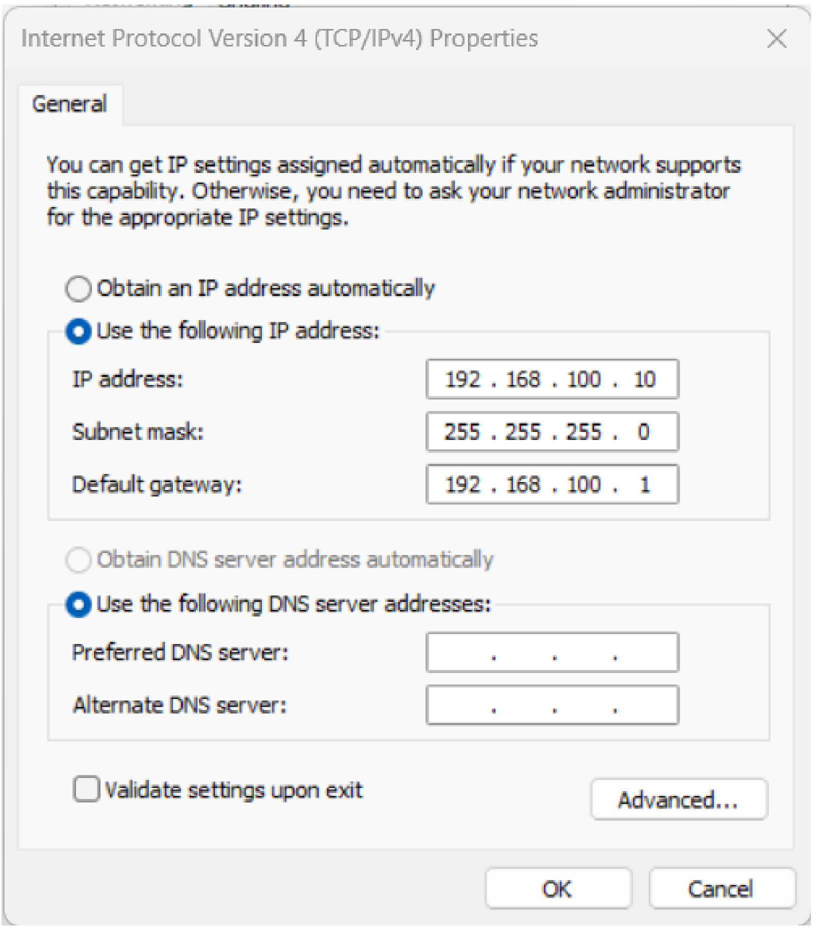
1. Plug the other end of the Ethernet cable connected to the camera into an Ethernet port of the IPC.



2. Use an RJ45-to-RJ45 Ethernet cable to plug one end into the Ethernet port of the robot controller and the other end into an Ethernet port of the IPC.

Set the IP Addresses on the IPC

1. Select Control Panel › Network and Internet › Network and Sharing Center › Change adapter settings on the IPC. The **Network Connections** page will be displayed.
2. Right-click the Ethernet port connected to the camera, and select **Rename** to rename the Ethernet port, such as “To_camera”.
3. Right-click the Ethernet port connected to the camera, and select **Properties** to enter the **Ethernet Properties** page.
4. Select the **Internet Protocol Version 4 (TCP/IPv4)** checkbox, and then click the **[Property]** button to enter the **Internet Protocol Version 4 (TCP/IPv4) Properties** page.
5. Select the **Use the following IP address** radio button, set the **IP address** parameter to “192.168.100.10”, **Subnet mask** to “255.255.255.0”, and **Default gateway** to “192.168.100.1”, and then click the **[OK]** button.

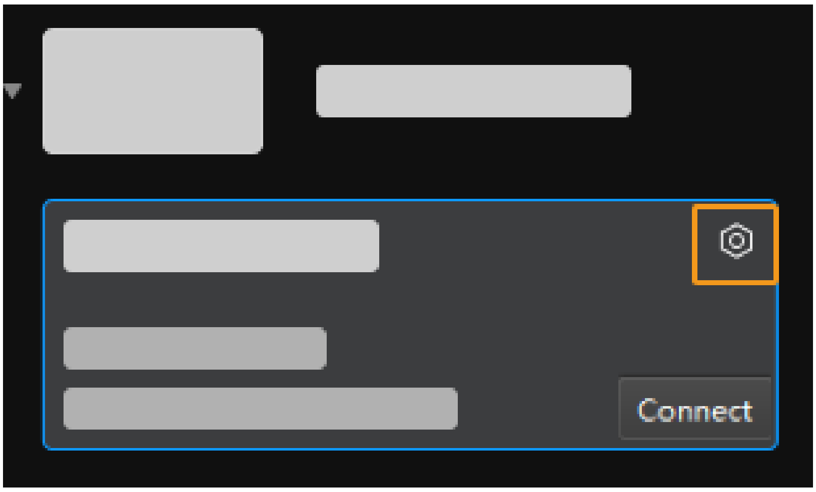


6. Repeat steps 2 to 5 to rename the Ethernet port connected to the robot controller (for example, “To_robot”), and set the IP address for this Ethernet port. For example, set the IP address of this Ethernet port to “192.168.200.10”.

> The IP address of the robot and that of the IPC Ethernet port connected to the robot controller must be on the same subnet.

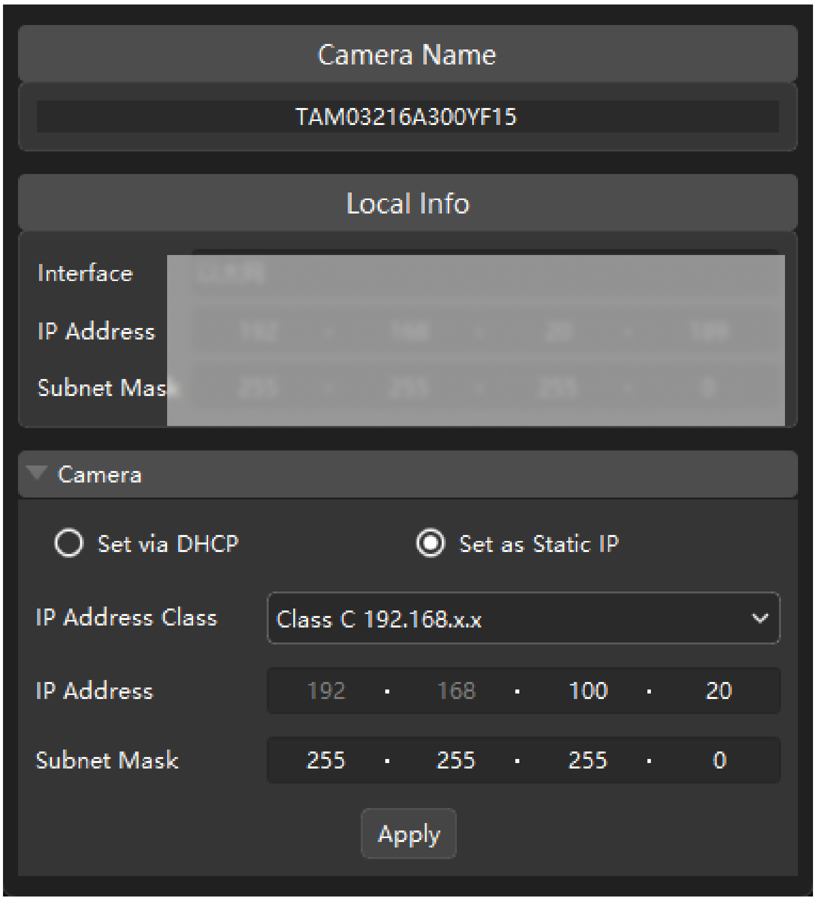
Set the Camera IP Address

1. Double-click on the desktop of the IPC to open and run Mech-Eye Viewer.
2. Select the camera in the camera list, and hover the cursor on the camera. Click to open the **Config Camera Network** dialog box.



If the camera cannot be found or connected, please refer to Camera Troubleshooting.

3. In the **Camera** area, select the **Set as Static IP** radio button, set **IP Address Class** to "Class C 192.168.x.x", **IP Address** to **192.168.100.20**, and **Subnet Mask** to "255.255.255.0" and then click [**Apply**].



The IP address of the camera and that of the IPC Ethernet port connected to the camera must be on the same subnet.

Test the Network Connectivity

1. Press `Win` + `R` to open the **Run** dialog box.

2. Type cmd in the **Run** dialog box, and then click **[OK]**.
3. Type **ping XXX.XXX.XX.XX** in the command prompt window and press **[Enter]** to execute the command.

> Replace XXX.XXX.XX.XX with the actual IP address of the camera/robot.

If the network connectivity is normal, you should receive the following response:

```
Pinging XXX.XXX.XX.XX with 32 bytes of data:
Reply from XXX.XXX.XX.XX: bytes=32 time<1ms TTL=128
Reply from XXX.XXX.XX.XX: bytes=32 time<1ms TTL=128
Reply from XXX.XXX.XX.XX: bytes=32 time<1ms TTL=128
Reply from XXX.XXX.XX.XX: bytes=32 time<1ms TTL=128
```

Upgrade the Software (Optional)

The IPC purchased from Mech-Mind already has the latest version of Mech-Mind Software Suite installed.

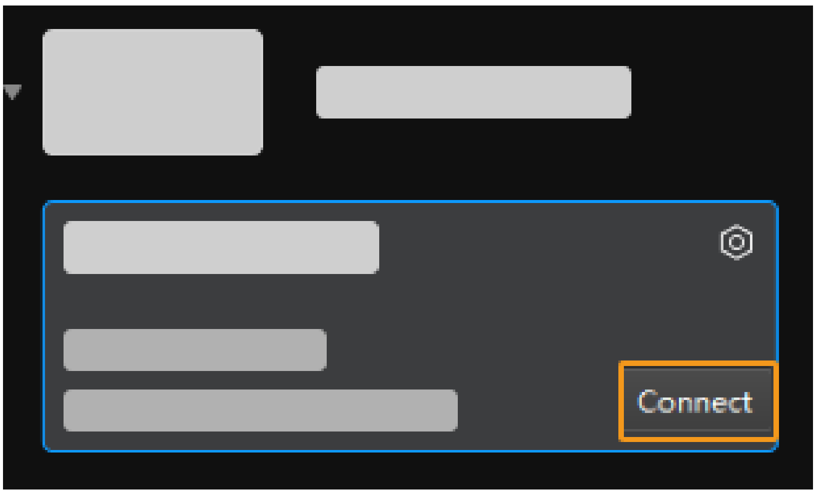
Please check if all software on the IPC is running with the latest version. If so, skip this section; if not, follow the sections below to update the software to the latest versions.

- Downloading and installing Mech-Eye SDK
- Downloading and installing Mech-Vision, Mech-Viz and Mech-Center

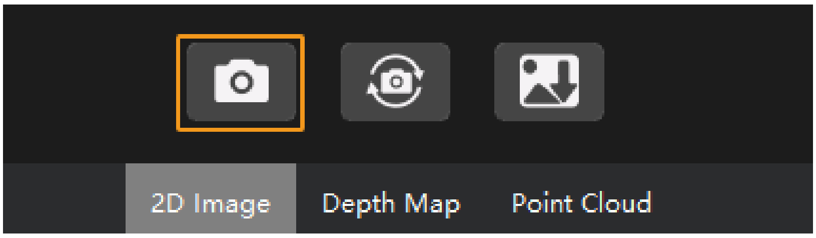
Confirm That the Vision System Can Capture Images Normally

After testing the network connectivity between the IPC and the camera/robot, please confirm that the vision system can capture images normally:

1. Place workpieces at the center of the camera's field of view (FOV), and make sure that the workpieces on the edge and top are all within the FOV.
2. Open and start Mech-Eye Viewer by double-clicking on the desktop of the IPC.
3. Select the camera in the camera list and click **[Connect]**.

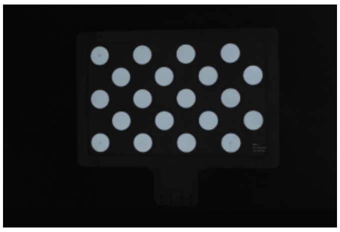
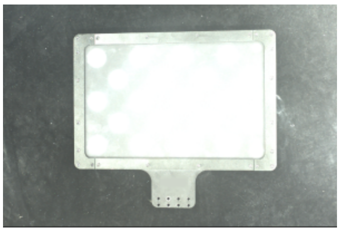
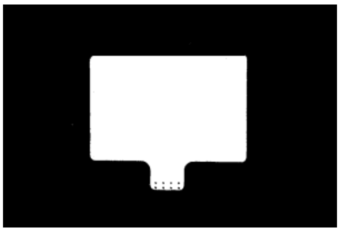
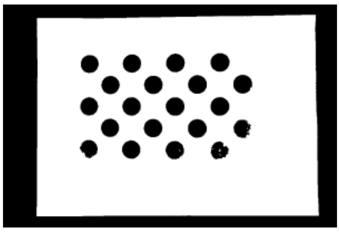
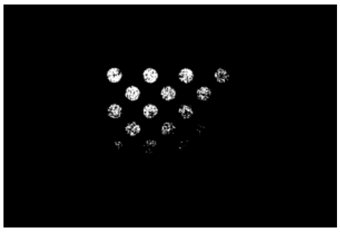


4. After the camera is connected, click **[Capture once]**.



5. Make sure that the captured images meet the following standard.

   - 2D image: the captured 2D image is not significantly overexposed (too white to recognize objects) or underexposed (too dark to recognize object details).
   - Depth map and point cloud: All relevant parts of the object can be recognized.

	Normal	Overexposed	Underexposed
2D image			
Point cloud			

If the captured images do not meet the required standard, please use Mech-Eye Viewer to adjust camera parameters.

Up to now, you have learned how to build the vision system.

2.2. Robot Interface Configuration

In this tutorial, you will learn how to load the Master-Control program files to the ABB robot and configure the Master-Control communication.

- In this section, you will load the robot Master-Control program and the configuration files to the robot system to establish the communication between the vision side and the robot, thus helping the Mech-Mind Software Suite obtain control over the robot.
- If you are using the robots of other brands, you can find instructions on setting up the Master-Control communication configuration with the desired robot from the section Master-Control Communication.

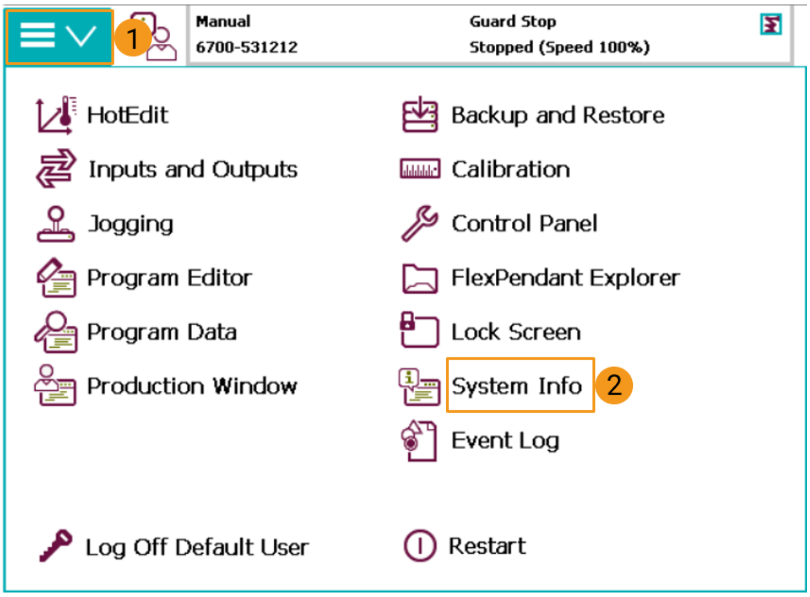
▶ https://www.youtube.com/watch?v=jyZYv4cK090/PLVcMd7cW2rXVtrAejMyVQni2dUDv8bxje *(YouTube video)*

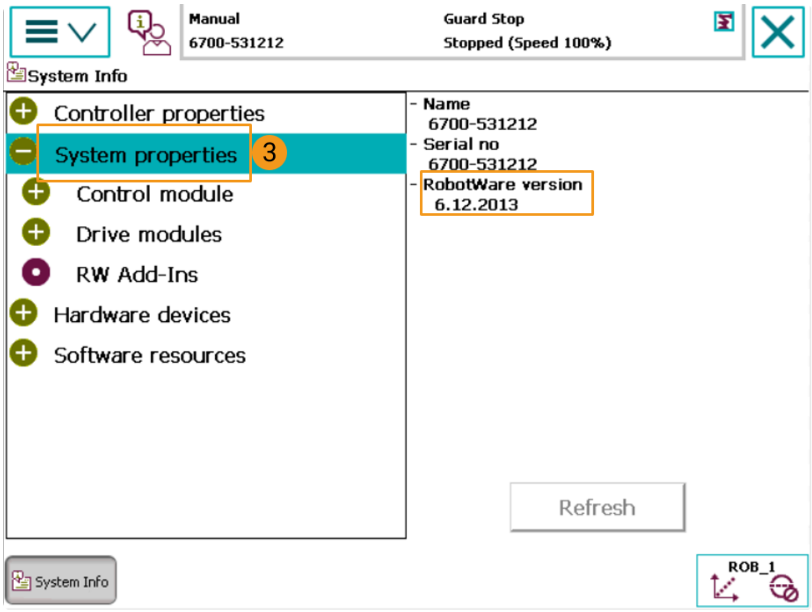
Video Tutorial: Robot Interface Configuration

Preparation

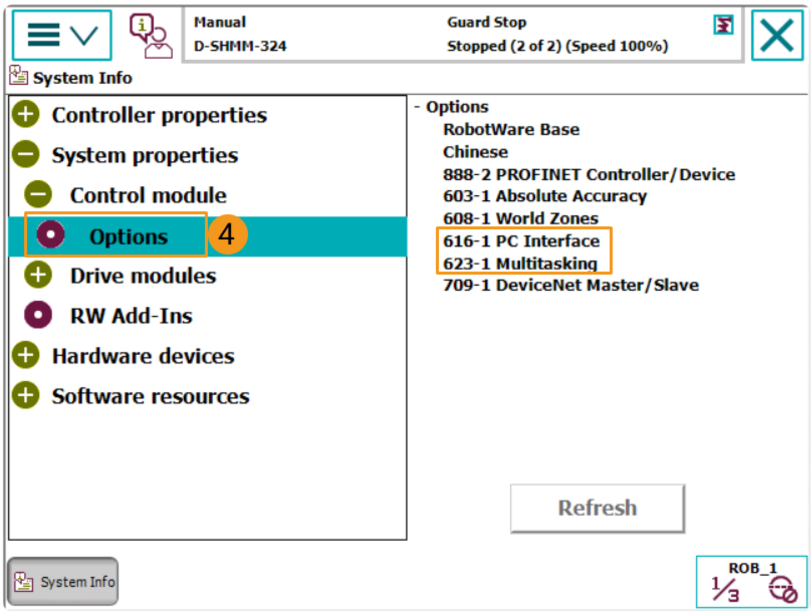
Check the Controller and RobotWare Version

1. Make sure that D652 or DSQC1030 IO board has been installed on the robot controller.
2. Confirm that the RobotWare version is 6.0 or above on the teach pendant.





3. Confirm that the following control modules have been installed on the teach pendant.
    - 623-1 Multitasking
    - 616-1 PCInterface



If the preceding conditions cannot be met, the vision side cannot communicate with the robot through the master-control mode. Please contact the vendor of your robot.

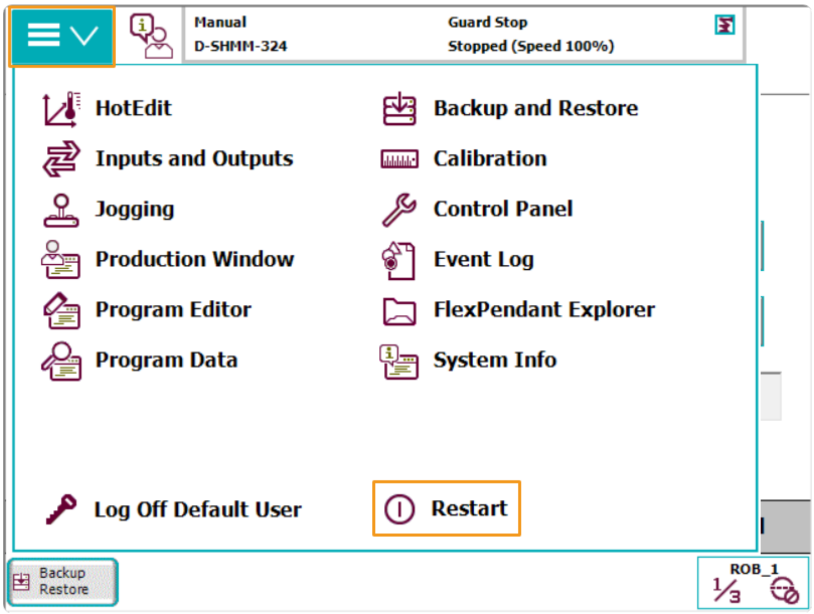
Reset the Robot System

After checking the software and hardware status of the controller, reset the robot system. If you are using a new robot, skip this section.

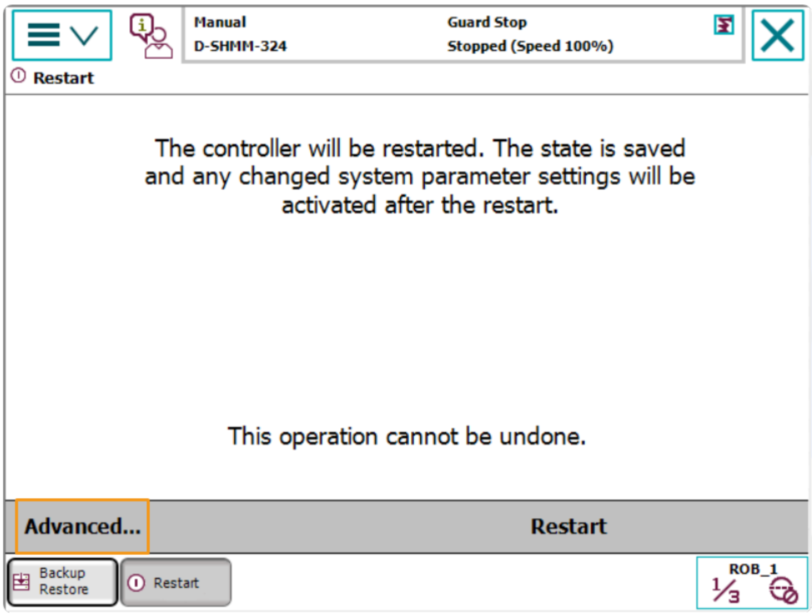
Resetting the system will restore the factory settings. Please make sure that you have completed the backup operation.

To reset the robot system, follow these steps:

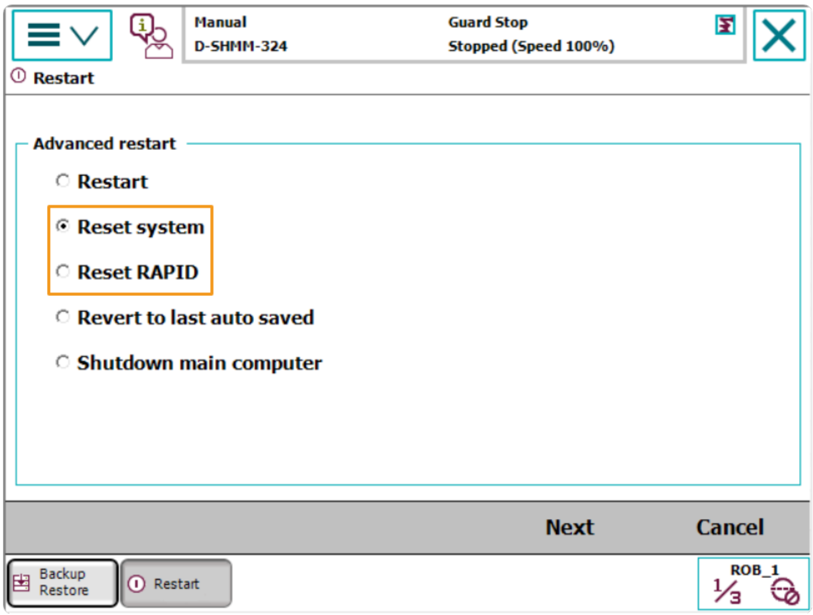
1. On the teach pendant, go to the home page using the menu in the upper-left corner, and then press [Restart].



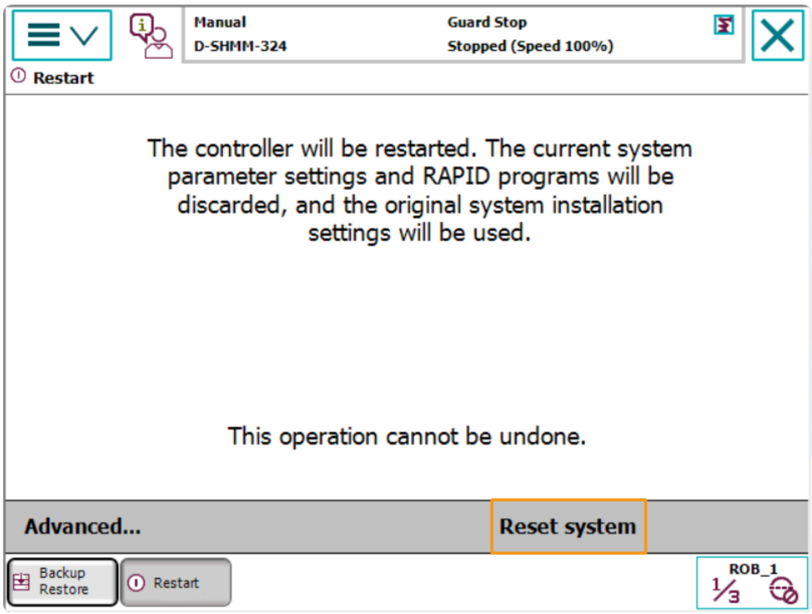
2. Press [Advanced...].



3. Select **Reset system** and then press [**Next**].



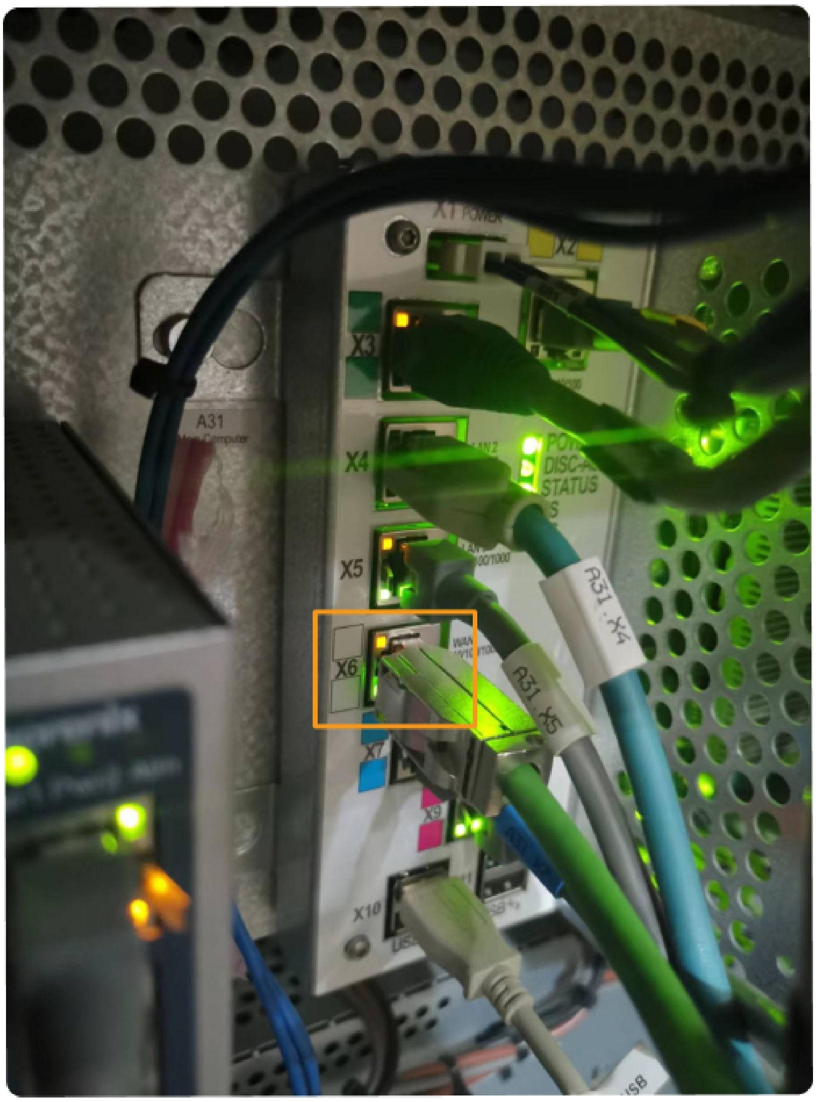
4. Press [**Reset system**].



Resetting the system takes 1 to 2 minutes. Resetting is completed when the home page is displayed again on the teach pendant.

Connect the Network

1. Connect the IPC Ethernet Cable to the **X6 (WAN)** port on the robot controller, as shown below.



2. Make sure that the IP address of the ABB robot and that of the IPC are in the same subnet.

Prepare the Program Files

1. On the IPC, open the `Mech-Center/Robot_Server/Robot_FullControl/abb/server on ABB` folder of the Mech-Mind Software Suite's installation directory.
2. Copy this folder to the USB flash drive, and insert it into the computer installing the RobotStudio software.

> RobotStudio is the simulation and offline programming software for ABB robots. This software can be installed on the IPC or another computer. In this example, RobotStudio is installed on another computer.

File description:

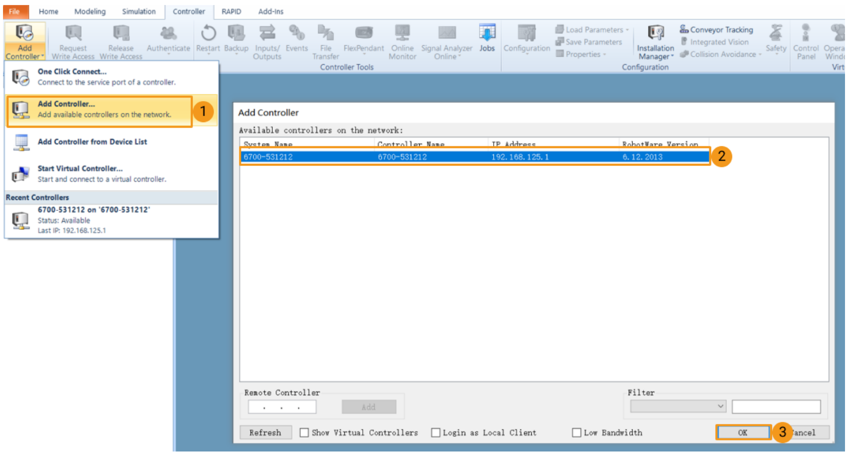
- "MM" folder: includes the robot program modules.
- "config": robot configuration files.
  - If the D652 IO board is used on site, you should use the D652.cfg and SYS.cfg files.
  - If the DSQC1030 IO board is used on site, you should use the DSQC1030.cfg and SYS.cfg files.

- If neither the D652 IO board nor the DSQC1030 IO board is used on site, you should use the EIO.cfg and SYS.cfg files.

Load the Program Files to the Robot

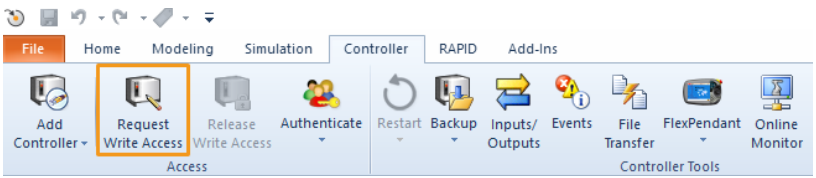
Open RobotStudio and Connect to the Controller

Click the **Controller** menu of RobotStudio, and select Add Controller › Add Controller on the toolbar. In the prompted **Add Controller** dialog box, select the controller, and click the **[OK]** button.



Obtain Write Access to the Robot

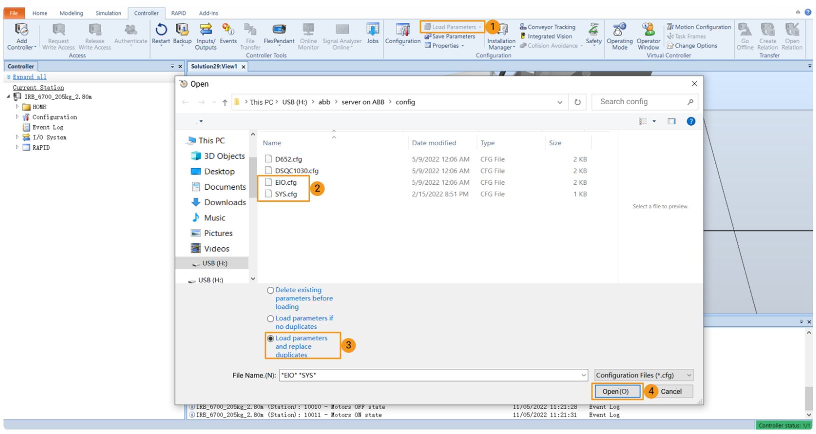
1. On the toolbar, click **Request Write Access** to request the write access to the teach pendant.



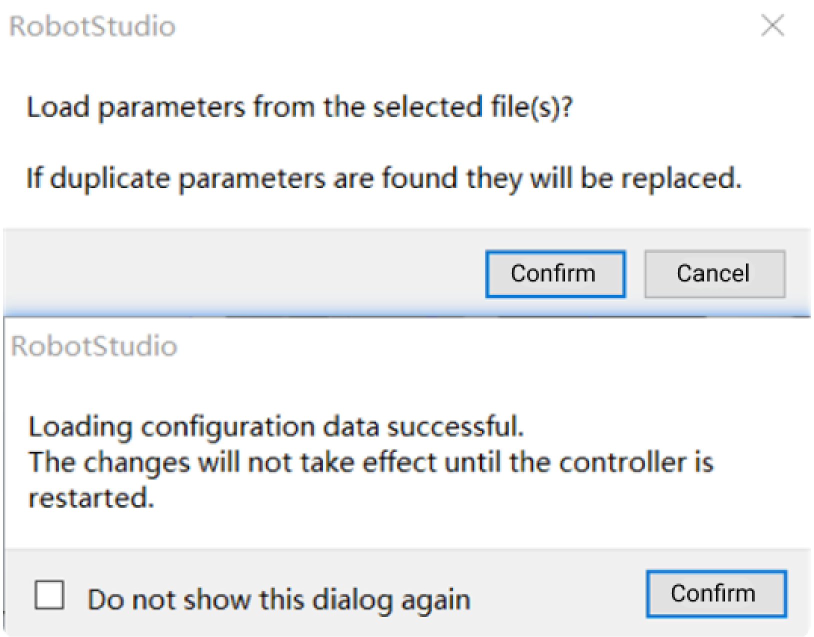
2. In the prompted **Request for Write Access** dialog box on the teach pendant, tap **[Grant]**.

Load the Robot Configuration Files

1. Click the **Controller** menu of RobotStudio, and select Load Parameters on the toolbar. Select the configuration files to import from the USB flash drive, select the **Load parameters and replace duplicates** radio button, and then click the **[Open]** button.

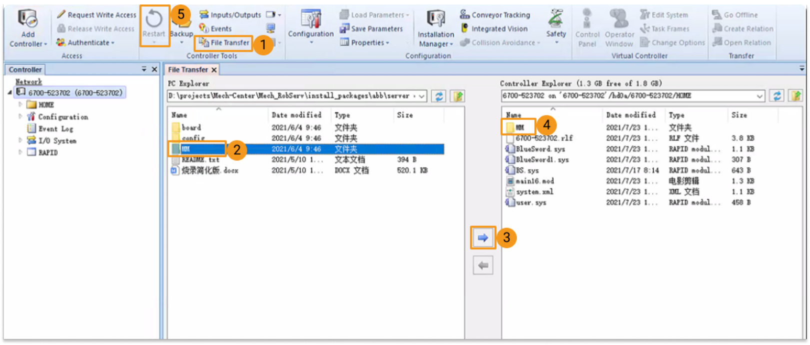


2. In the prompted dialog boxes, click **[Confirm]**.



Load the Robot Program Modules

1. Click the **Controller** menu of RobotStudio, and select **File Transfer** on the toolbar. On the left panel of the **File Transfer** interface, select the “MM” folder, and then click the **Transfer** button to transfer this folder to the HOME directory of the robot system.



2. Click the **Controller** menu of RobotStudio, and select **Restart** on the toolbar to restart the robot system.

Till now, you have loaded the master-control program and the configuration files to the robot.

Test Whether Master-Control Communication Can Be Established

After the robot system has been rebooted, perform the following steps to test whether the master-control communication can be established with the robot:

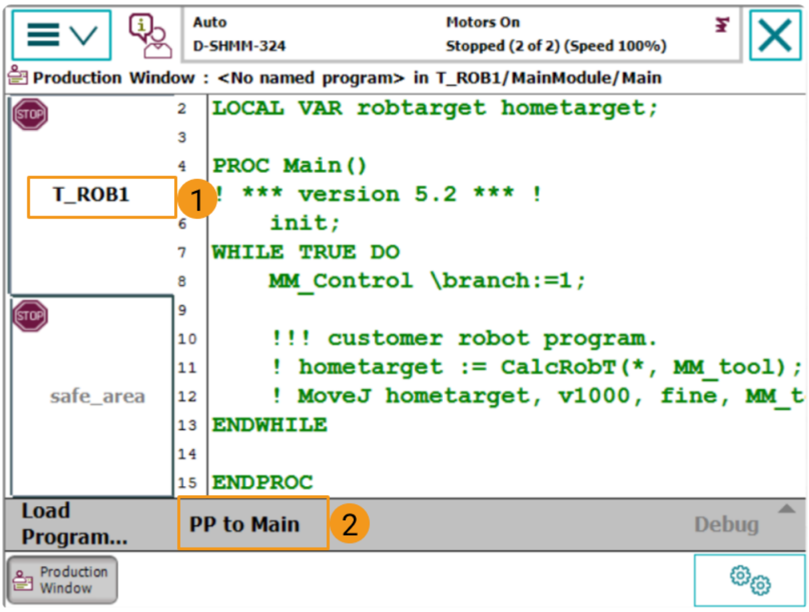
Switch the Robot to Automatic Mode

1. In the robot controller, switch the robot to the automatic mode by using the switch key.
2. In the prompted dialog box on the teach pendant, tap **[Confirm]**.
3. In the robot controller, press the motor power button to power up the robot. When the robot is

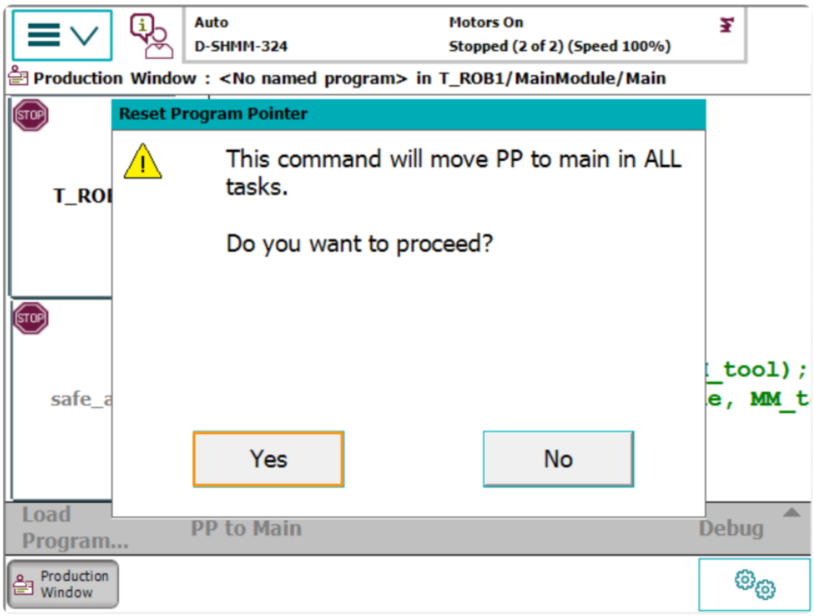
powered on, this button is solid on.

Run the Main Program

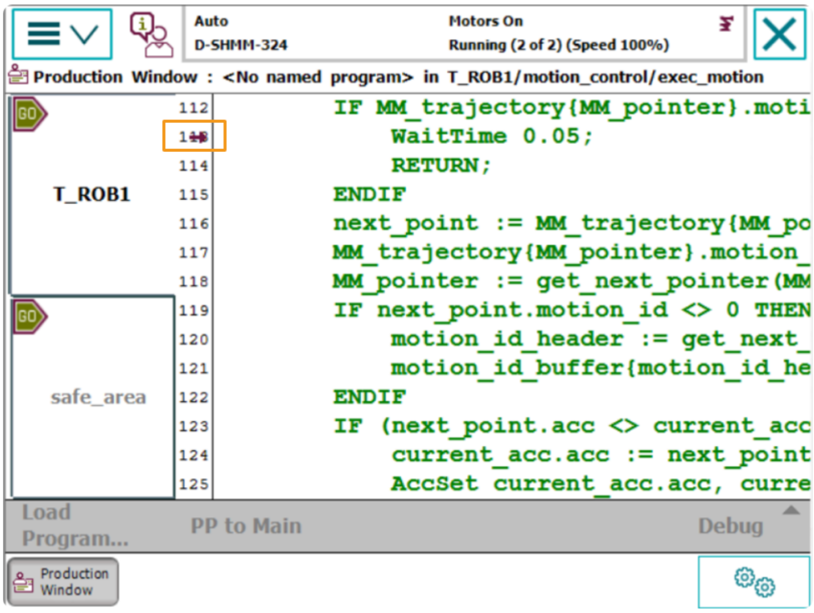
1. On the teach pendant, move the PP of tasks T_ROB1 to main, and tap [PP to Main].



2. In the prompted dialog box, click [Yes].

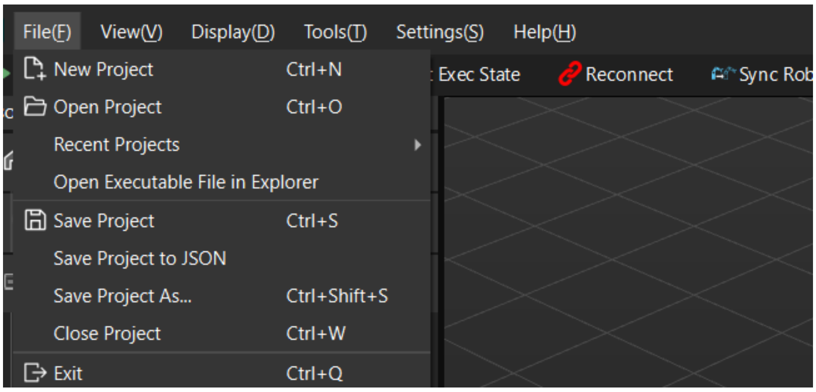


3. Press the run button on the right of the teach pendant.

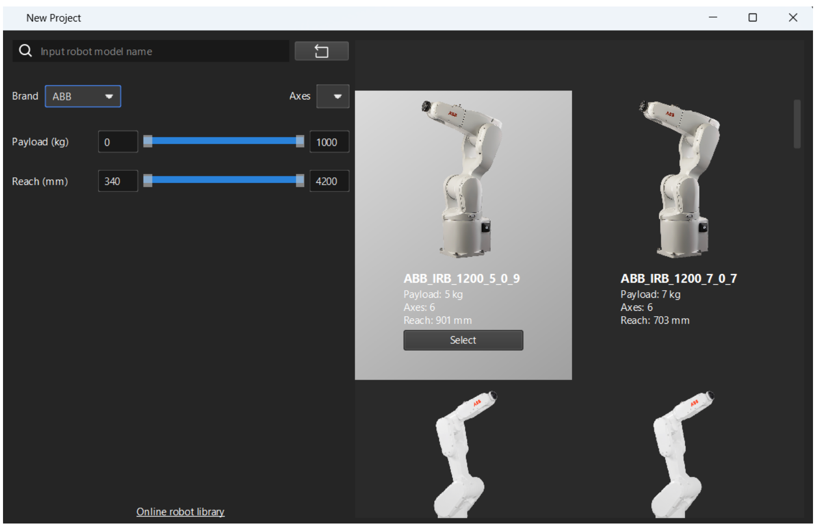


Create a Mech-Viz Project

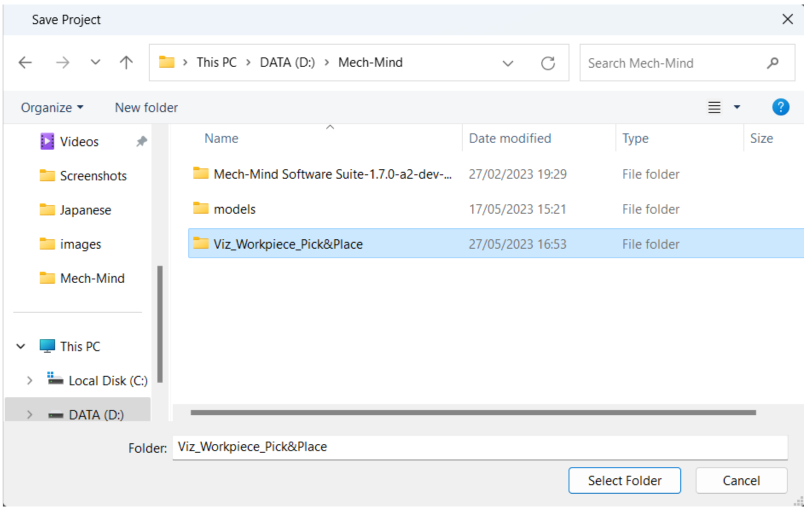
1. Open Mech-Viz, select File › New Project.



2. Set **Brand** to “ABB”, select the robot model “ABB_IRB_1300_11_0_9” on the right panel, and then click **[Select]**.

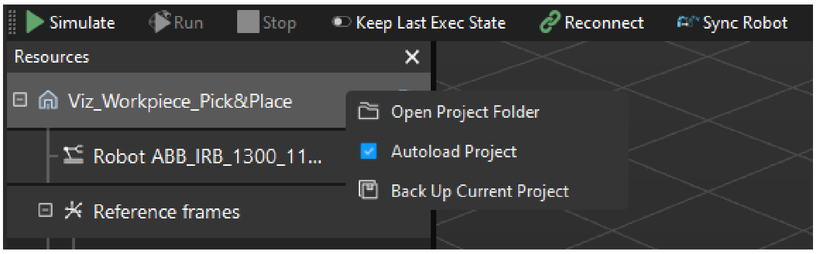


3. Press Ctrl + S, create a new folder named “Viz_Workpiece_Pick&Place”, select it, and then click [Select folder].

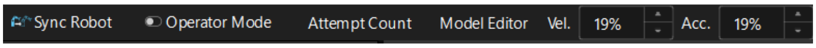


After the Mech-Viz project is saved successfully, in the **Resources** panel, the project name is displayed as “Viz_Workpiece_Pick&Place”.

4. Right-click the project name, and select **Autoload project** checkbox.



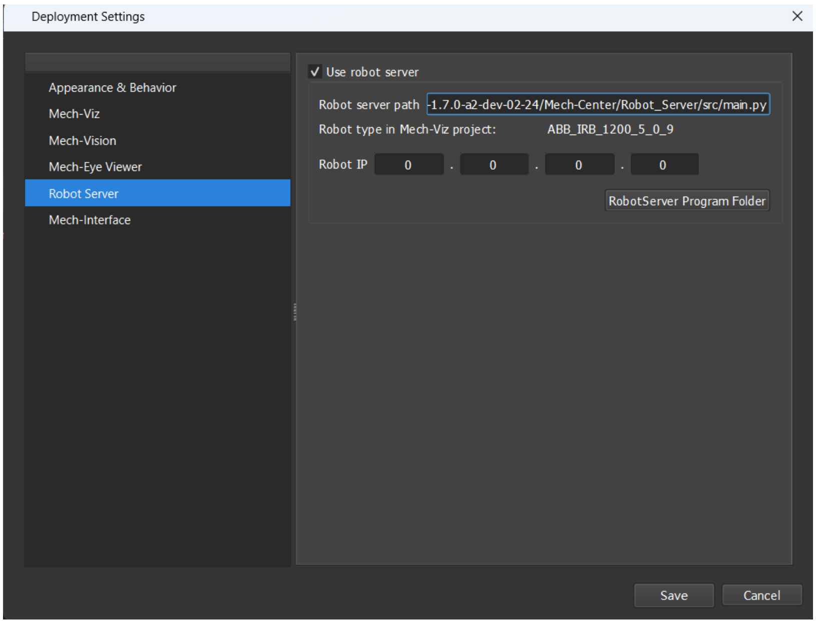
1. For the robot motion safety, on the toolbar, set **Vel.** (velocity) and **Acc.** (acceleration) to a small value, such as 5%.



2. Press Ctrl + S to save the project.

Configure Master-Control Communication Settings on Mech-Center

1. Open Mech-Center, select Deployment Settings › Robot Server, and then select **Enable Robot Server** checkbox.
2. Make sure that the robot model matches the real robot, set **Robot IP** to the IP address of the real robot, and then click [**Save**].



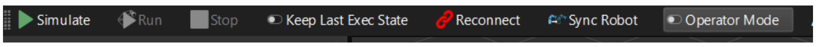
Connect to the Robot

In Mech-Center, click **Connect Robot** on the toolbar.

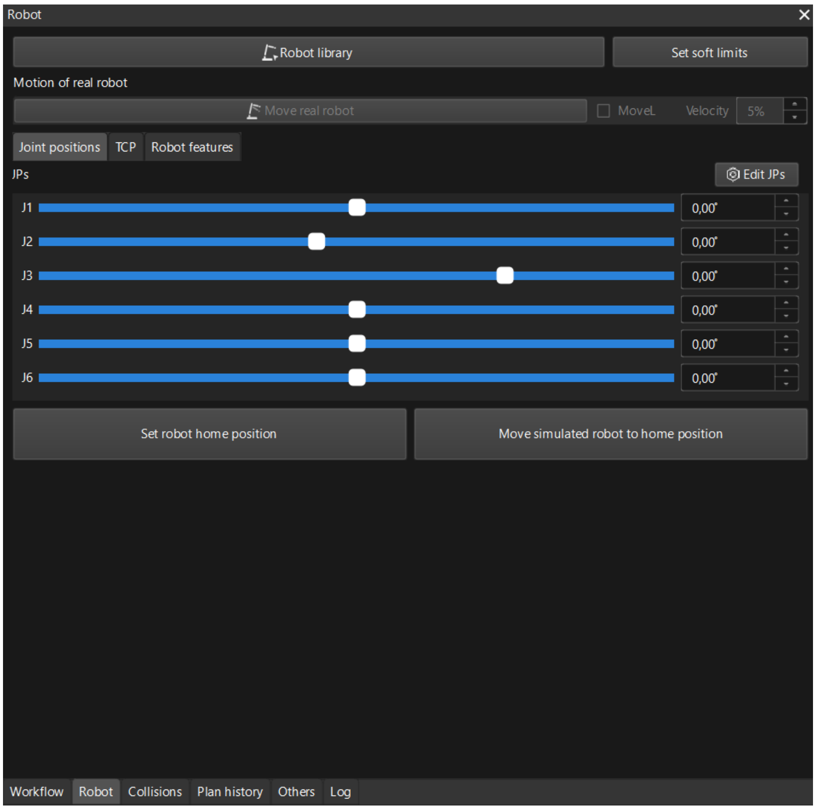
- If the robot is successfully connected, a robot icon with the robot model will be displayed in the Service Status bar, and the corresponding message is printed in the Log panel.
- If the connection fails, please check if any of the operations so far was incorrect.

Move the Robot

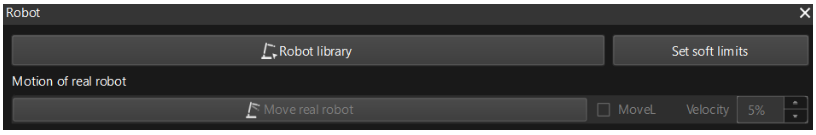
1. In Mech-Viz, click **Sync Robot** in the toolbar to synchronize the pose of the simulated robot to that of the real robot. Then, click **Sync Robot** again to disable the synchronization.



2. On the **Robot** tab, change the joint position of J1 slightly (for example, from 0° to 3°). The simulated robot will move accordingly.



3. Click [**Move real robot**].



When moving the robot, please ensure the safety of personnel. In the case of an emergency, press the emergency stop button on the teach pendant!

If you observe that the real robot moves to the pose of the simulated robot, the master-control communication has been established successfully.

2.3. Hand-Eye Calibration (Master-Control)

In this tutorial, you will perform the automatic hand-eye calibration in the Eye-To-Hand setup.

The hand-eye calibration establishes **the transformation relationship between the camera and robot reference frames (that is camera extrinsic parameters)**. With this relationship, the object pose determined by the vision system can be transformed into that in the robot reference frame, which guides the robot in performing its tasks.

▶ https://www.youtube.com/watch?v=oMG6fCJFUYQ/PLVcMd7cW2rXVtrAejMyVQni2dUDv8bxje *(YouTube video)*

Video Tutorial: Hand-Eye Calibration (Master-Control)

Preparation before Calibration

In this section, you will mount the calibration board, adjust the camera parameters, and complete the pre-calibration configuration.

Mount the Calibration Board

> In the Eye to Hand scenario, the calibration board needs to be mounted to the robot flange adapter.

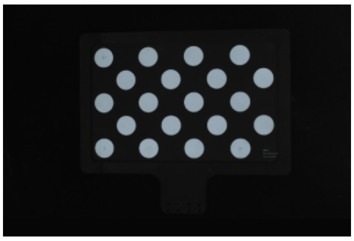
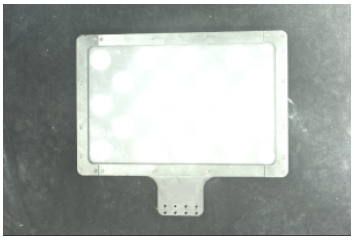
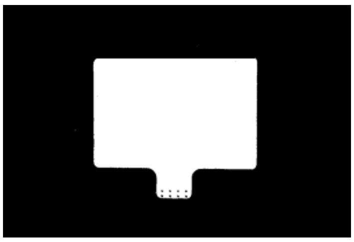
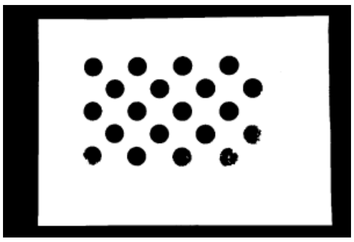
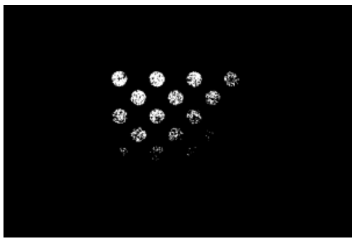
Follow these steps:

1. Take the calibration board and flange adapter out of the system delivery package.
2. Use screws, gaskets, and nuts to fasten the flange adapter to the flange adapter.
3. Use screws, gaskets, and nuts to secure the calibration board to the flange adapter.
4. After mounting the calibration board, move the robot to the top of the lowest workpiece in the work area and into the camera FOV.

Adjust Camera Parameters

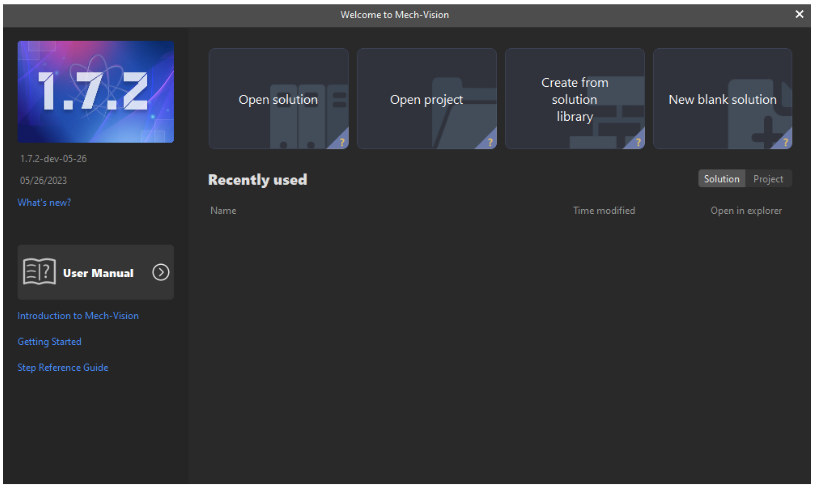
1. In Mech-Eye Viewer, connect to the camera, and then set **Parameter Group** to “calib”.

2. Adjust the 2D parameters to make sure that the 2D image of the calibration board is clear and neither overexposed nor underexposed.
3. Adjust 3D parameters to make sure that the obtained point clouds of the circles on the calibration board are complete and have clear contours. It is recommended to set the **Surface Smoothing** and **Outlier Removal** parameters of **Point Cloud Processing** to **Normal** to reduce point cloud fluctuation.

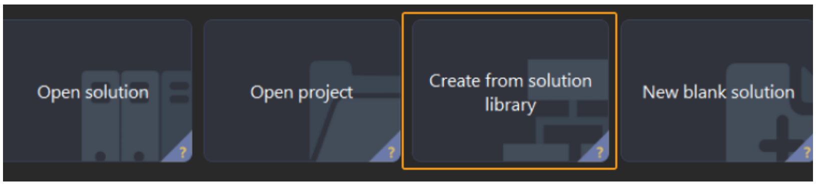
	Normal	Overexposed	Underexposed
2D image			
Point cloud			

Create a Mech-Vision Project and Save It

1. Open Mech-Vision. If the welcome interface as shown below is displayed, it indicates that Mech-Vision is started successfully.

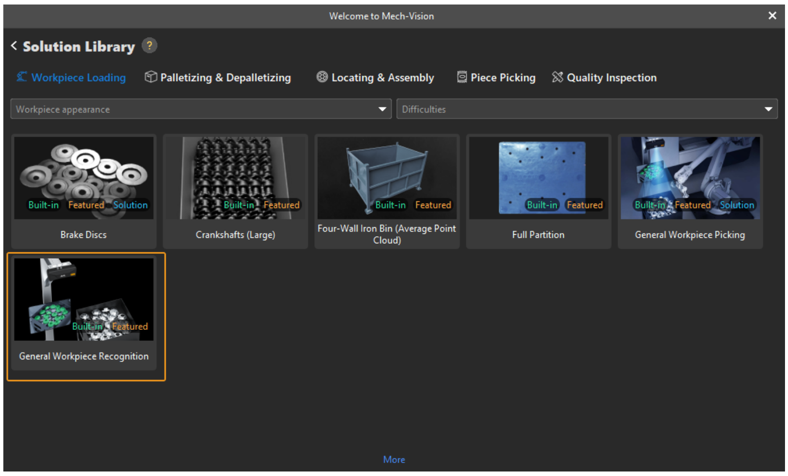


2. In the Welcome interface of Mech-Vision, click [**Create from solution library**] to open the Solution Library.



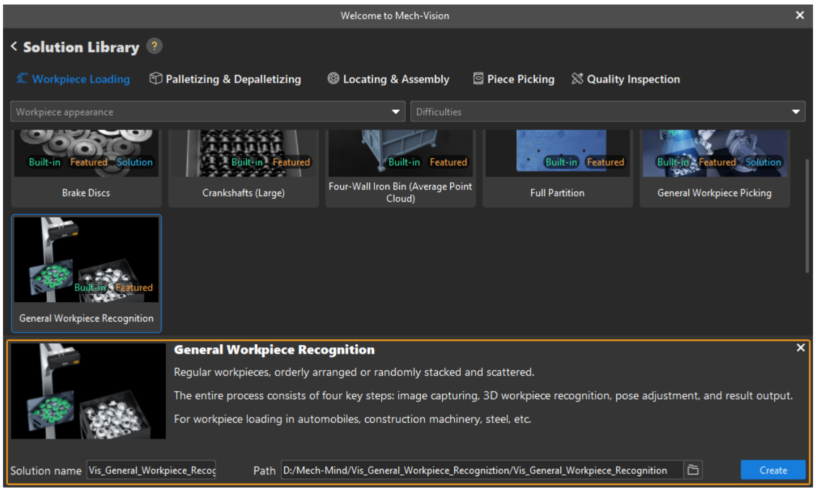
The Solution Library is a resource library that provides typical solutions or projects (with sample data) from various application scenarios.

3. Select the **General Workpiece Recognition** project from the Solution Library.



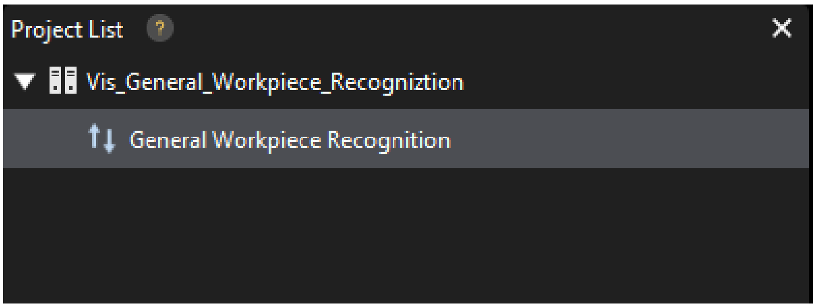
If you cannot find this project in the Solution Library, click [**More**] at the bottom of the Solution Library interface.

4. After this project is selected, the information introducing this project will be displayed on the lower part of the Solution Library interface. Set the solution name and path, and then click [**Create**].

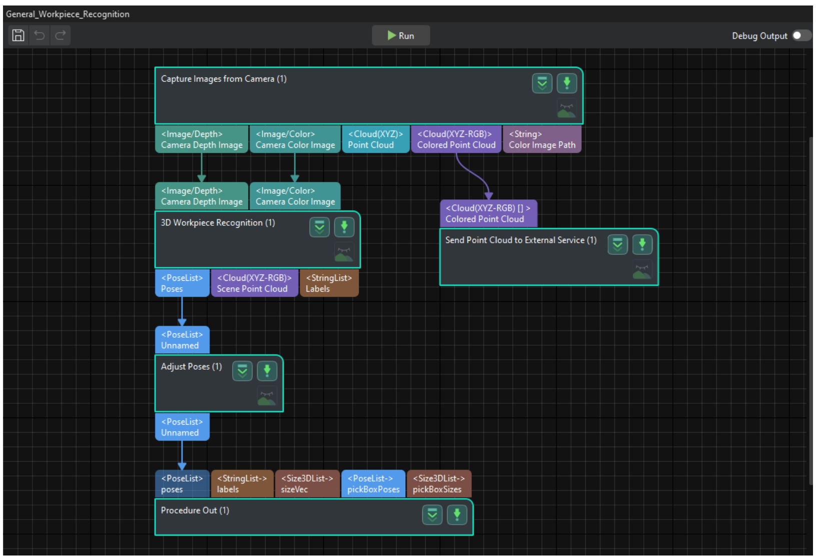


After the project is created, the created solution and project will be displayed in the project list in the upper-left corner of the Mech-Vision main interface.

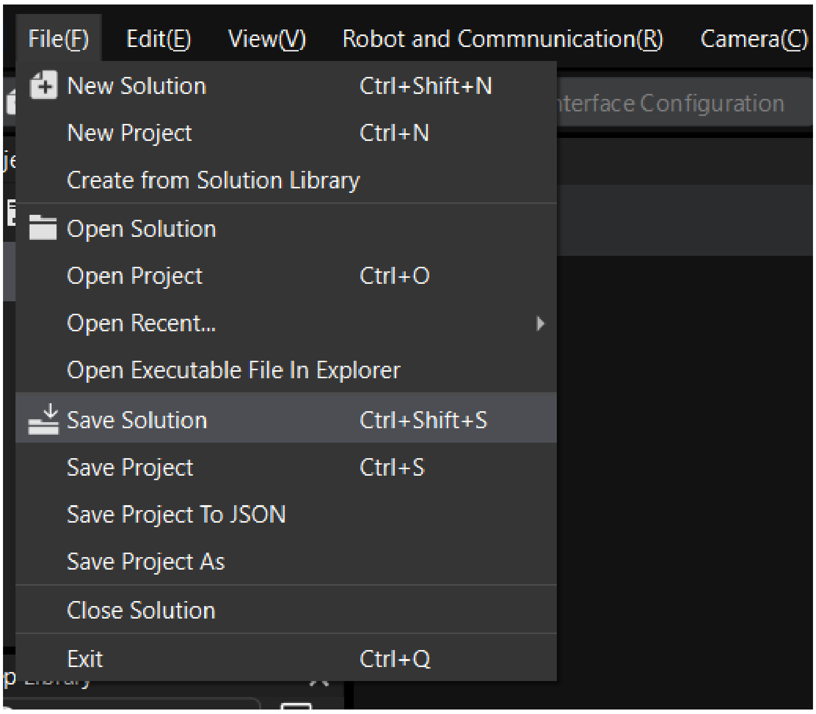
- A **solution** is a set of configurations and data related to robots and robot communication, vision processing, path planning, etc. that are required for the machine vision application.
- A **project** is a workflow of vision processing in the solution. Normally, a solution only contains one project, but it may contain more than one project in complex application scenarios. In this tutorial, the solution requires only one project.



In the Graphical Programming Workspace of the main interface, the workflow of the "General Workpiece Recognition" project will be displayed.

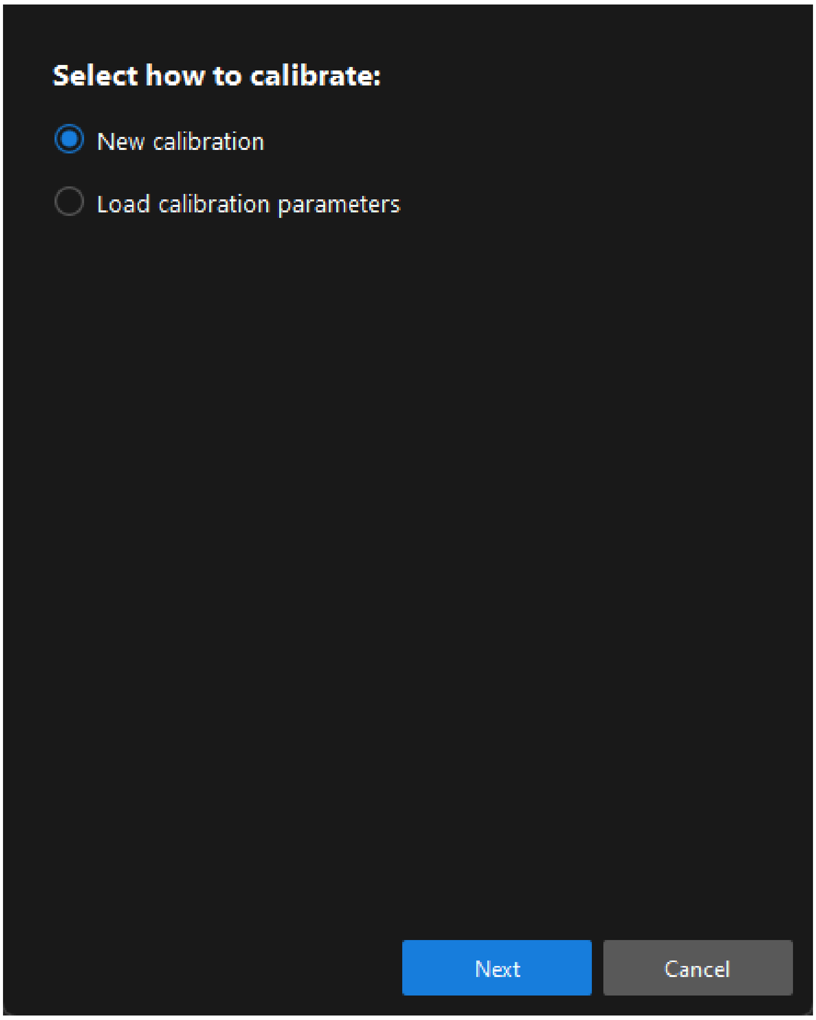


5. On the menu bar, select File › Save Solution.

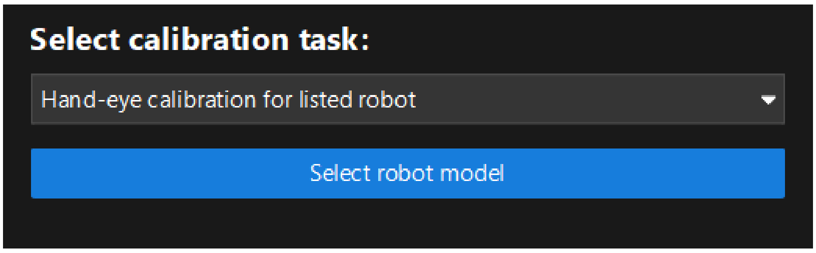


Pre-calibration Configuration

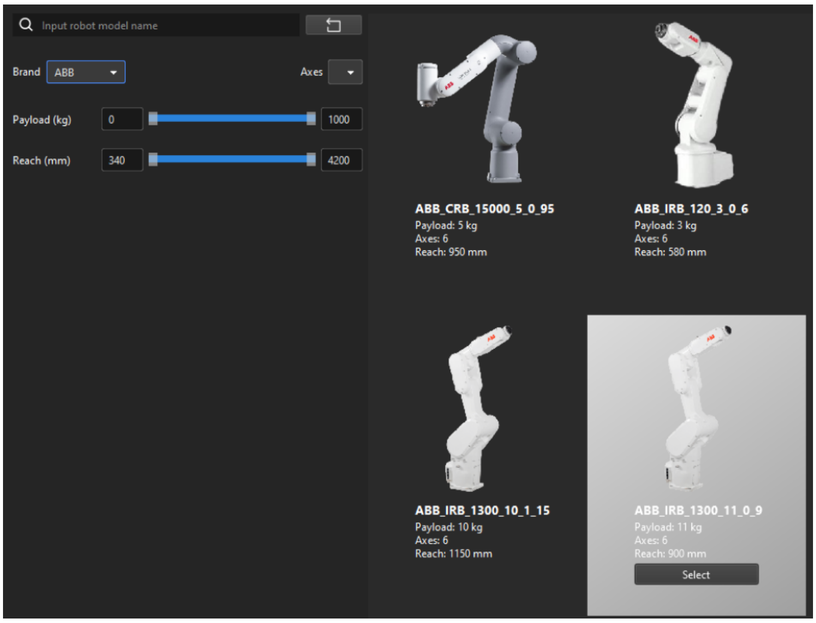
1. In Mech-Vision, click the **[Camera Calibration (Standard)]** on the toolbar. The **Configuration before Calibration** window will be prompted.
2. In the **Select how to calibrate** window, select the **New calibration** radio button, and then click the **[Next]** button.



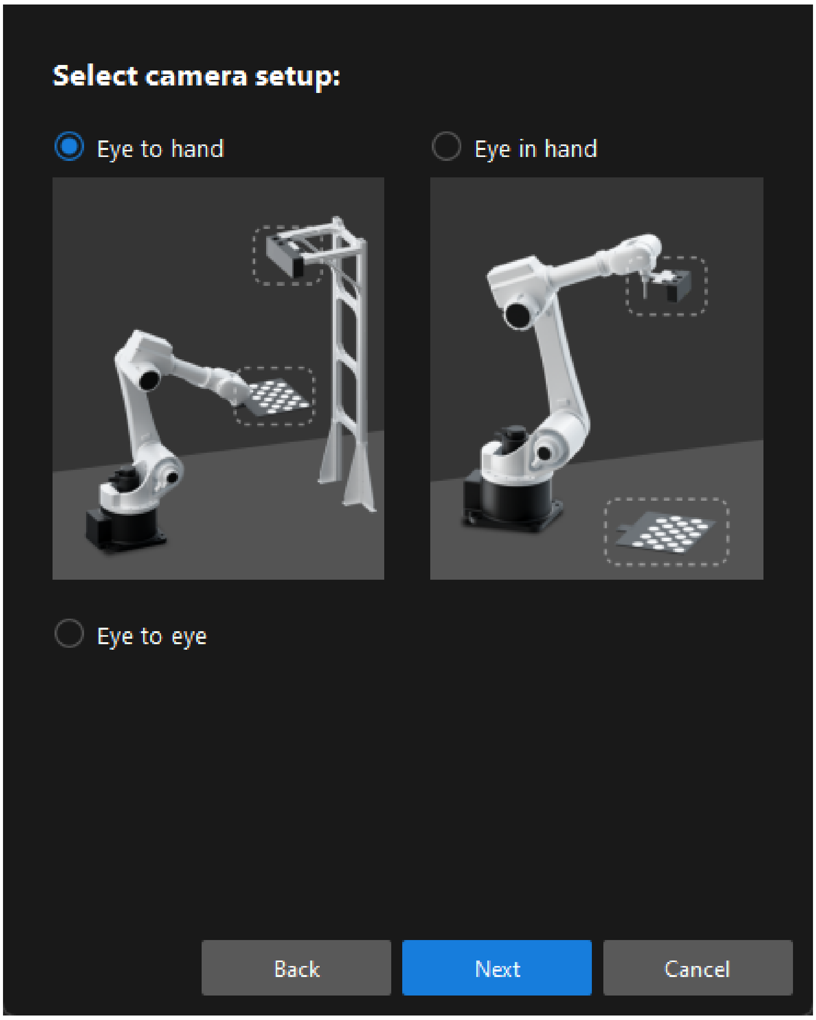
3. In the **Select calibration task** window, select **Hand-eye calibration for listed robot** from the drop-down list box, and click the **[Select robot model]** button.



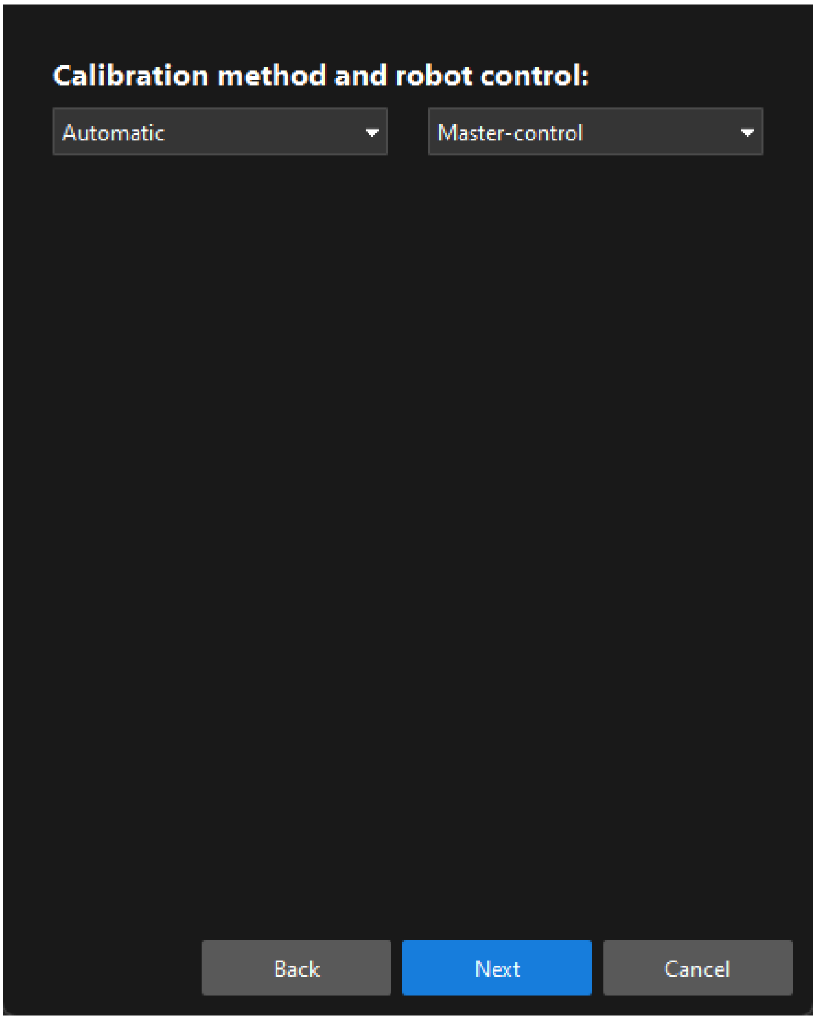
4. Click the **Brand** dropdown box, and select “ABB”. Then, at the right panel, select model “ABB_IRB_1300_11_0_9”, click the **[Select]** button, and then click the **[Next]** button.



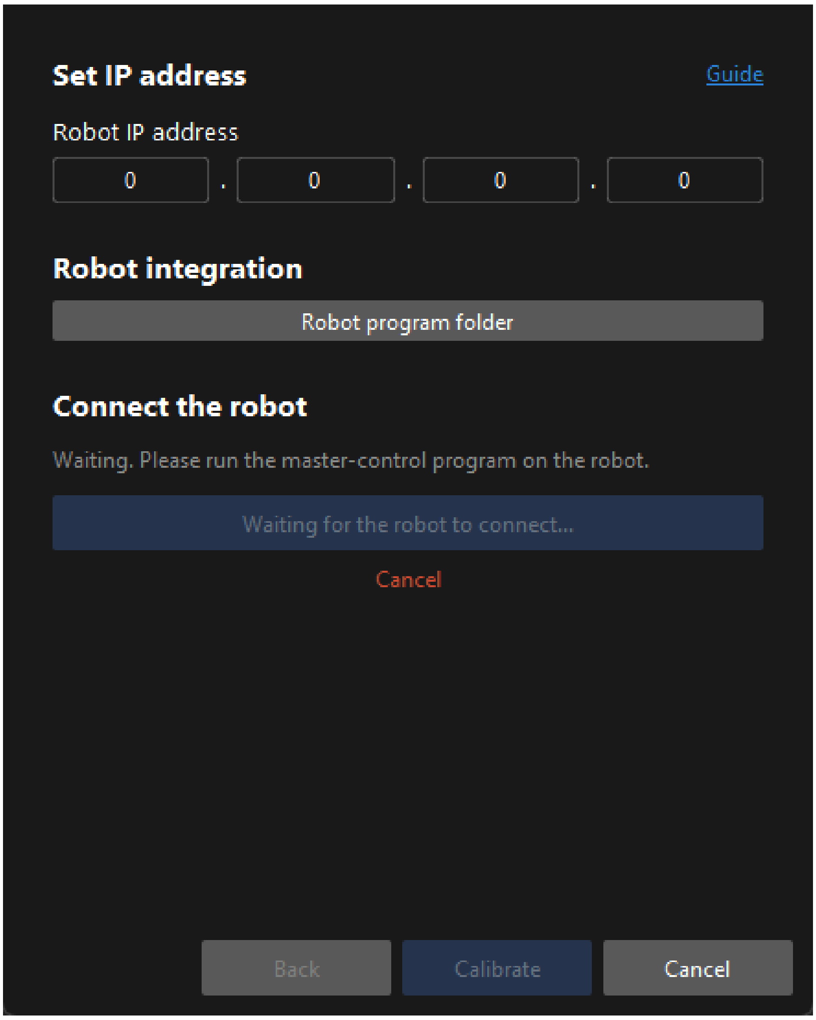
5. In the **Select camera setup** window, select the **Eye to hand** radio button, and then click the **[Next]** button.



6. In the **Calibration method and robot control** window, select **Automatic** and **Master-control**, and then click the **[Next]** button.



7. In the **Communication Settings** window, set the **Robot IP address** parameter to the real robot's IP address.

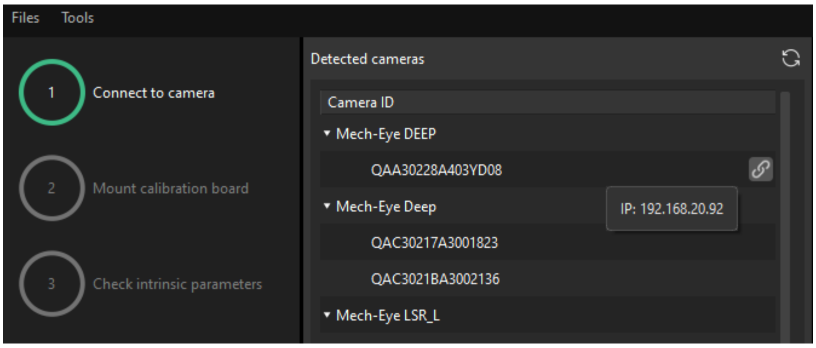


8. On the robot teach pendant, confirm that the MM main program has been started.
9. Return to Mech-Vision, and click the [**Connect the robot**] button in the **Connect the robot** area. The button will turn into **Waiting for the robot to connect...**
10. Wait until the "Connected" status message is displayed in the **Connect the robot** area, and then click the [**Calibrate**] button. The **Calibration (Eye to Hand)** window will be prompted.

Calibration Procedure

Connect to the Camera

1. In the **Connect to Camera** step, find the camera to connect in the **Detected Cameras** list, and click the button.

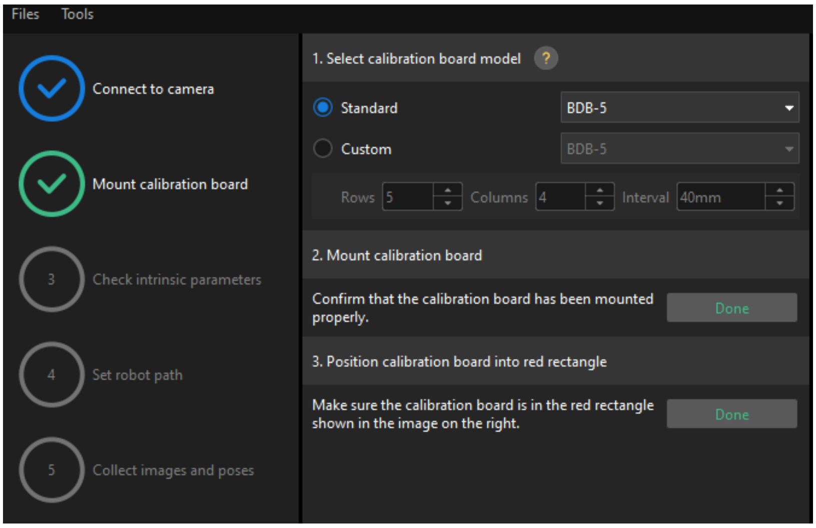


2. After the camera is connected, click the **[Capture once]** or **[Capture live]** button.
3. In the right **Image viewer** panel, ensure that the captured 2D image and depth map meet the calibration requirements and click the **[Next]** button on the bottom bar.

> If the captured image does not meet the calibration requirements, you need to open the Mech-Eye Viewer software to adjust the 2D and 3D exposure parameters and re-capture images.

Mount the Calibration Board

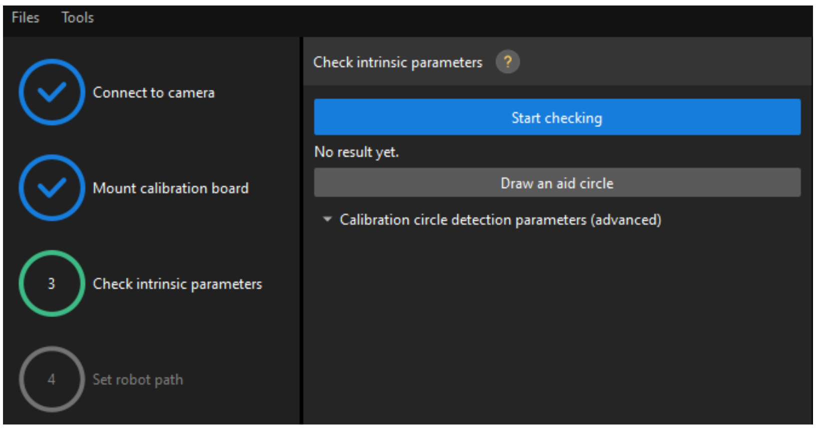
1. In the **Mount calibration board** step, select the **Standard** radio button and select the calibration board model according to its model nameplate in the **1. Select calibration board type** area.
2. Make sure that the calibration board has been attached to the robot flange securely, and then click the **[Confirm]** button in the **2. Mount calibration board** area.
3. Confirm that the calibration board is in the center of the camera's field of view (the red rectangle), and then click the **[Confirm]** button in the **3. Position calibration board into red rectangle** area.



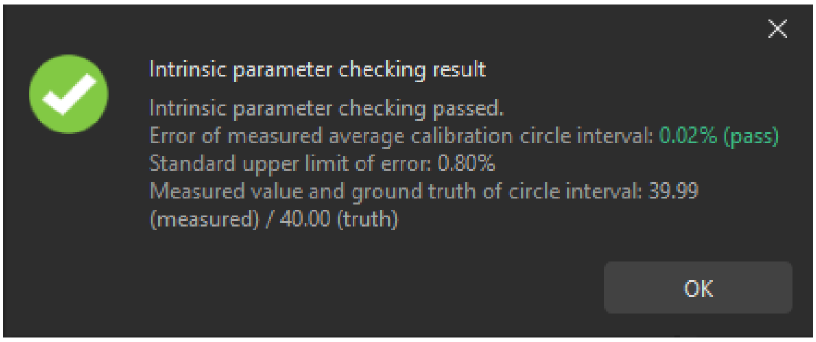
4. After all the operations related to the calibration board are completed, click the **[Next]** button on the bottom bar.

Check Intrinsic Parameters

1. In the **Check intrinsic parameters** step, click the **[Start checking]** button.



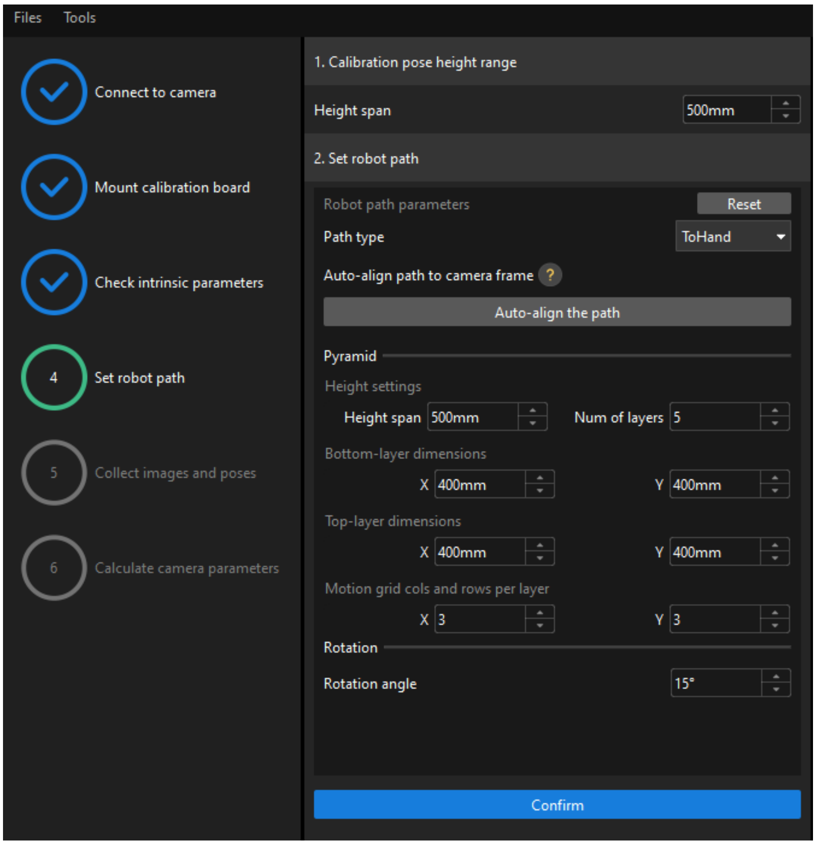
2. Confirm that the camera intrinsic parameters check passes, and then click the **[Next]** button on the bottom bar.



If the camera intrinsic parameter check fails, adjust detection parameters by drawing aid circles or manually adjusting the calibration circle detection parameters.

Set Robot Path

1. In the **Set robot path** step, specify the **Height span** parameter. Please set this parameter according to the working distance range of the calibration board in the camera height direction.



2. Set the **Path type** to **ToHand**, specify the pyramid parameters **Height span**, **Num of layers**, **Bottom-layer dimensions X/Y**, **Top-layer dimensions X/Y**, and **Motion grid cols and rows per layer**, specify the satellite parameter **Rotation angle**, and then click the **[Confirm]** button.

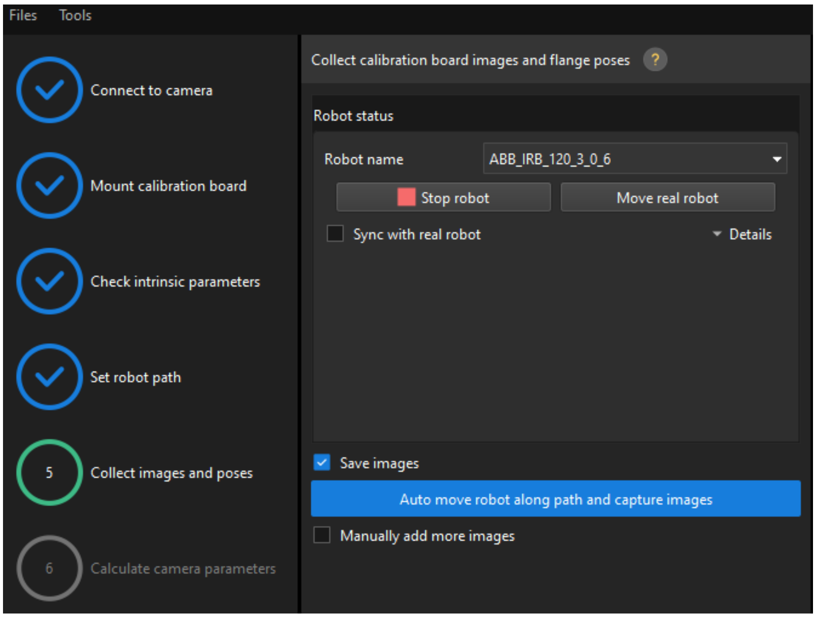
The set robot path should cover the work area.

3. In the right **Scene Viewer** panel, confirm that the waypoints of the automatically generated

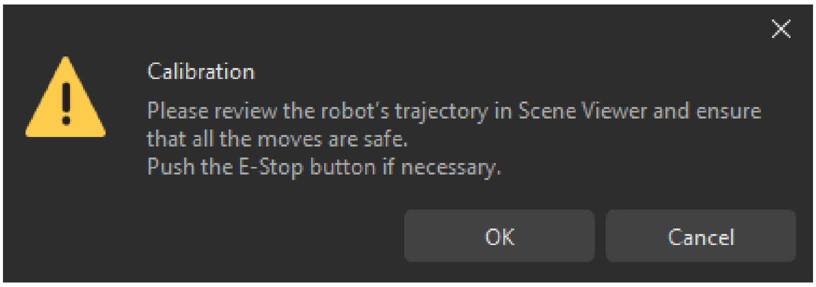
motion path will not collide with obstacles in the environment, and then click the [Next] button.

Collect Images and Poses

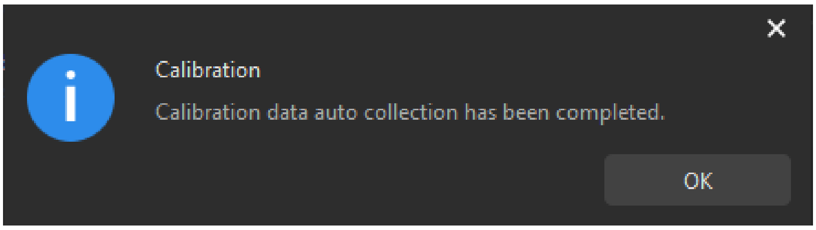
1. In the **Collect images and poses** step, select the **Save images** checkbox.



2. Click the **[Control robot to auto move along path and capture images]** button.
3. Read the safety window carefully and click the **[OK]** button.

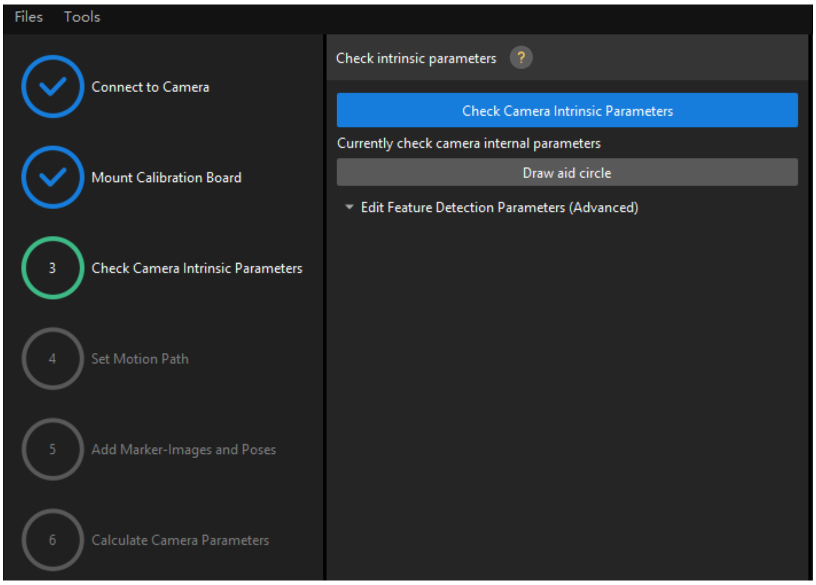


4. Wait until the robot finishes moving along the preset path and the camera finishes capturing images on all waypoints. Captured images can be seen in the right **Marker Image and Pose List** panel during this process.
5. After the automatic image capturing finishes, click the **[OK]** button, and then click the **[Next]** button on the bottom bar.



Calculate Camera Parameters

1. In the **Calculate camera parameters** step, click the **[Calculate camera extrinsic parameters]** button.

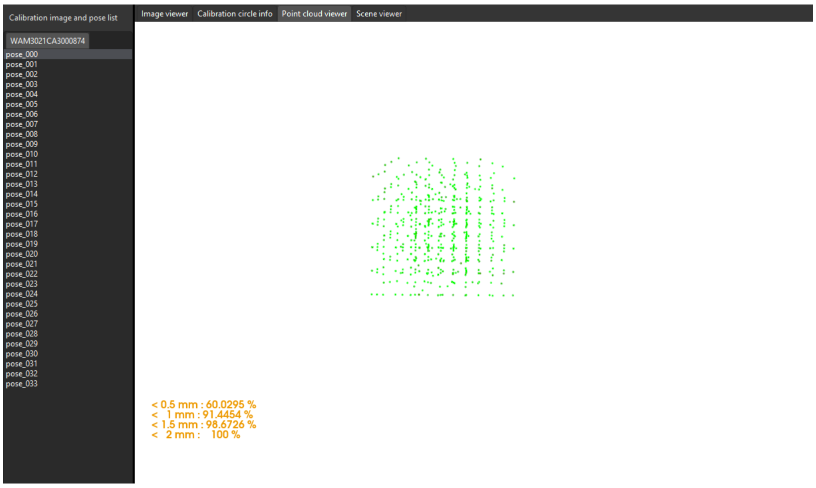


2. In the prompted window indicating calibration success, click the **[OK]** button.
3. View the calibration error of the point cloud in the right **Point cloud viewer** panel.

> The error point cloud shows the deviation between the calculated value and the actual value of the circles on the calibration board.

4. Confirm that the calibration accuracy meets the project requirements.

   Determine the error value with 100% to obtain the rough calibration accuracy. For example, the calibration accuracy in the following figure is within 2 mm.

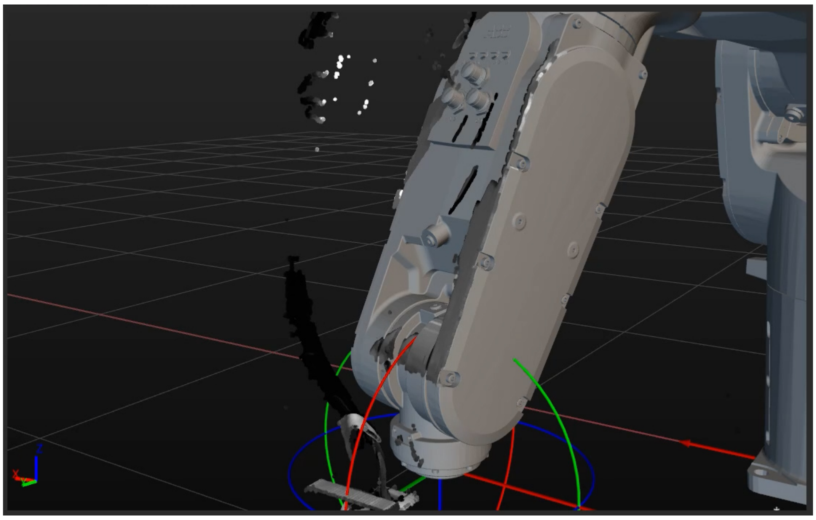


   To improve the calibration accuracy, please refer to the section Calibration Result Check and Analysis.

Validate and Save the Calibration Result

1. After calibration, move the robot arms into the FOV of the camera.
2. In the **Calculate camera parameters** step, click the **[Calculate camera extrinsic parameters]** button. This operation triggers the camera to capture images.
3. Click **Scene viewer** to check the coincidence degree between the point cloud of the robot and the robot model.

   If the point cloud of the robot approximately coincides with the robot model, the calibration is successful.



4. Click the **[Save]** button on the bottom bar. In the prompted **Save Calibration Files** dialog box, click the **[OK]** button. The camera calibration result will be automatically saved in the "calibration" directory of the project.

2.4. Workpiece Locating

Before using this tutorial, you should have created a Mech-Vision solution using the "General Workpiece Recognition" case project in the "Hand-Eye Calibration" section.

In this tutorial, you will first learn the project workflow, and then deploy the project by adjusting the Step parameters to recognize the workpiece poses and output the vision result.

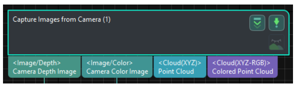
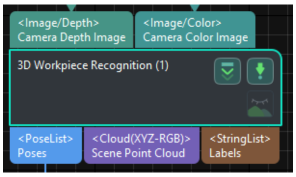
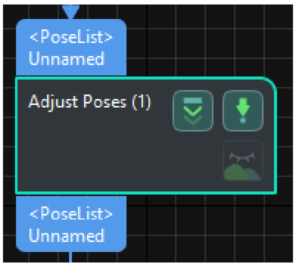
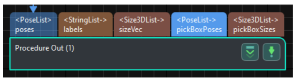
> In this tutorial, you will need to convert the model file of the workpiece in the CAD format into a point cloud matching model. Since it takes a long time to prepare the CAD model file, you are recommended to prepare the CAD model file of the workpiece before using this tutorial.

▶ https://www.youtube.com/watch?v=D3On5xx14F4/PLVcMd7cW2rXVtrAejMyVQni2dUDv8bxje *(YouTube video)*

Video Tutorial: Workpiece Locating

Introduction to the Project Workflow

The following table describes each Step in the project workflow.

No.	Phase	Step	Image	Description
1	Capture images	Capture Images from Camera		Connect to the camera and capture images
2	Recognize workpieces	3D Workpiece Recognition		Use 3D matching algorithms to calculate the workpieces' poses (as pick points)
3	Adjust poses	Adjust Poses		Transform the pick points from the camera reference frame to the robot reference frame
4	Output the vision result	Procedure Out		Output the workpieces' poses for the robot to pick

A pick point refers to a point on the workpiece on which the robot can pick the object.

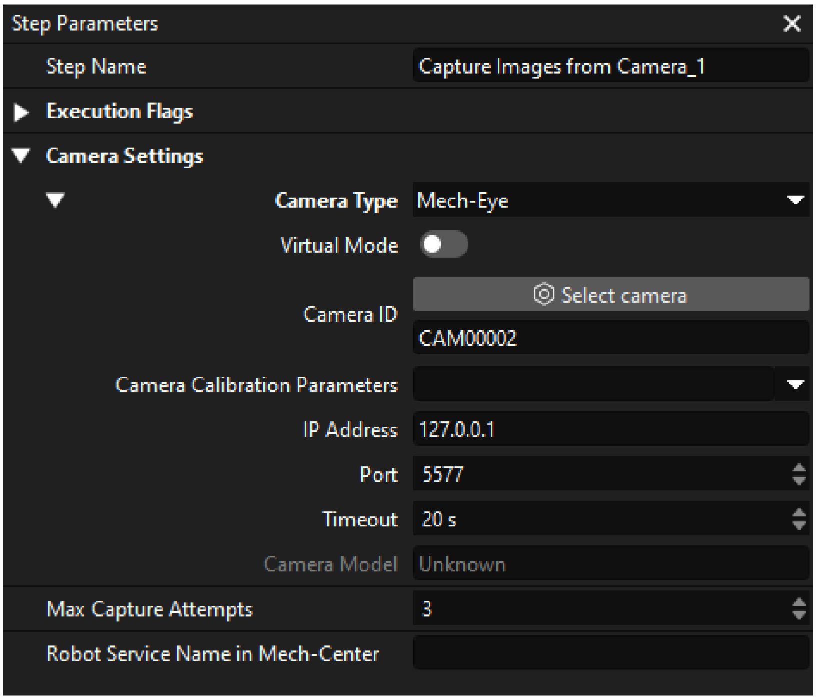
Adjust Step Parameters

In this section, you will deploy the project by adjusting the parameters of each Step.

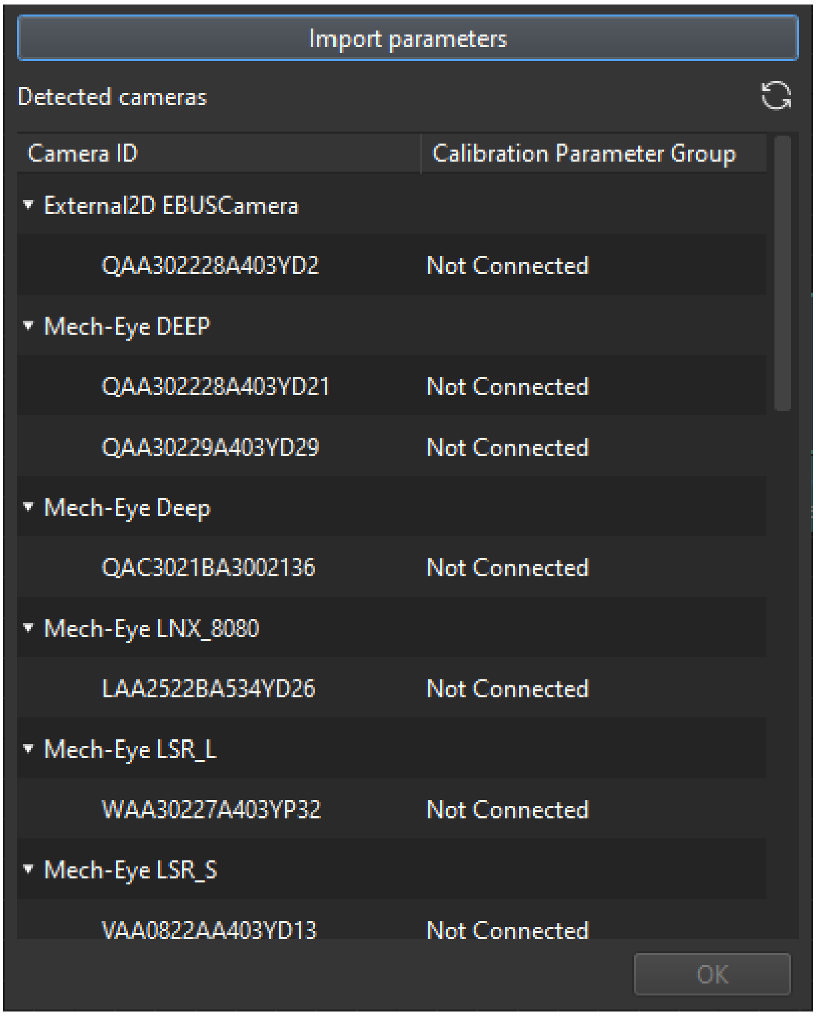
Capture Images from Camera

You should adjust the parameters of the "Capture Images from Camera" Step to connect to the camera.

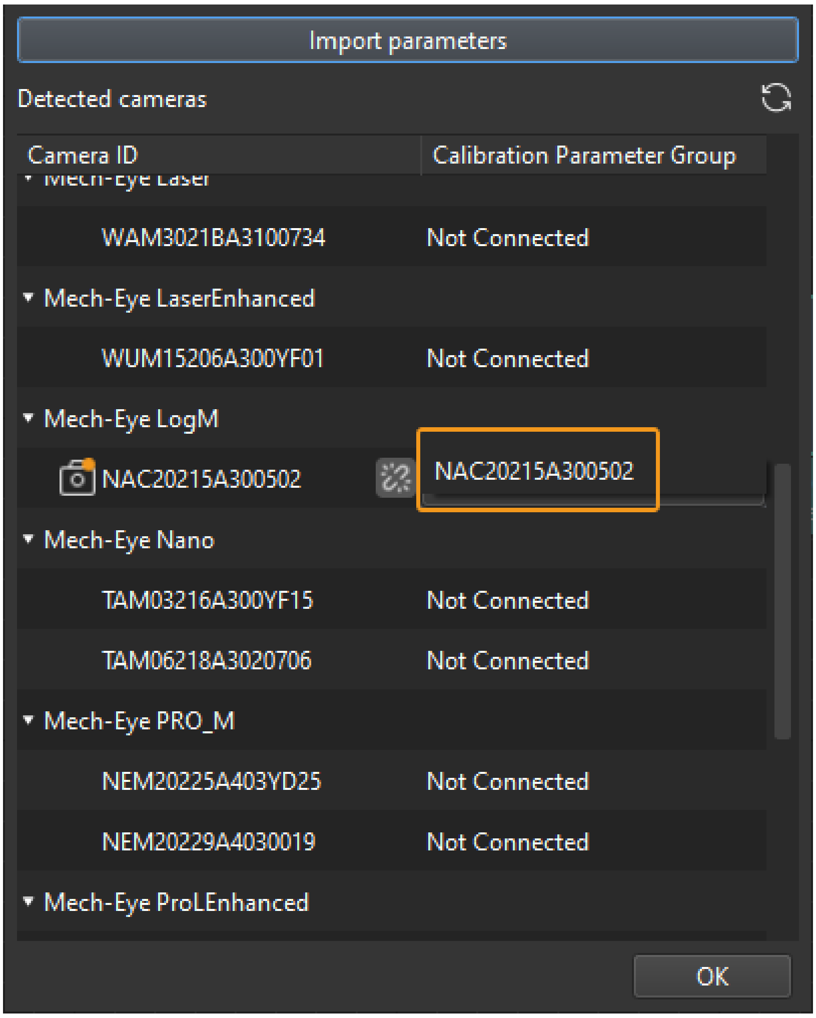
1. Select the "Capture Images from Camera" Step, and click **[Select camera]** on the Step parameters tab.



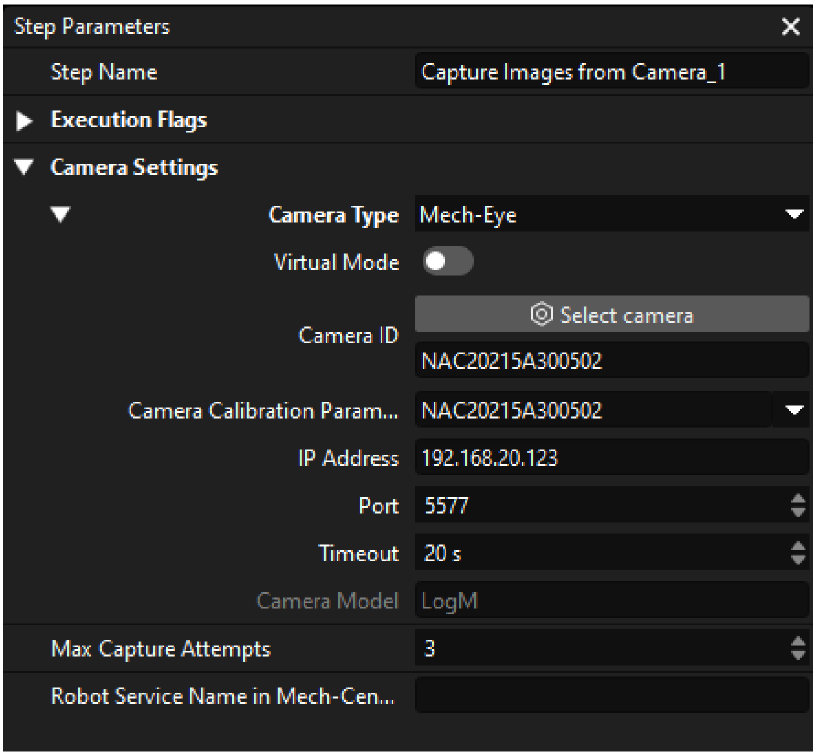
2. In the prompted window, click on the right of the camera serial No. to connect the camera. After the camera is connected, the icon will turn into .



After the camera is connected, select the parameter group. Click **[Select from]** and select the displayed parameter group.



3. After the camera is connected and the parameter group is selected, the calibration parameter group, IP address, and ports of the camera will be obtained automatically. Just keep the default settings of the other parameters.

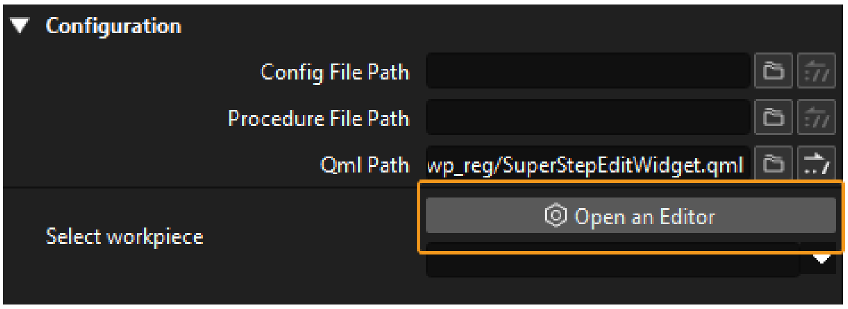


Now, you have connected the software to the camera.

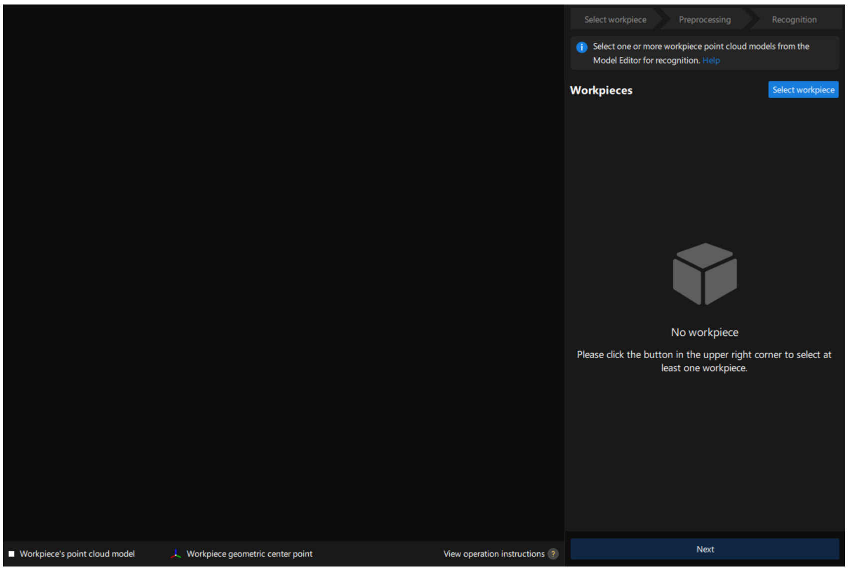
3D Workpiece Recognition

The “3D Workpiece Recognition” Step has integrated a 3D Workpiece Recognition visualized configurator, which provides point cloud preprocessing, model-based matching, and pose (pick point) calculation.

Select the “3D Workpiece Recognition” Step, and click **[Open an Editor]** on the Step parameters tab.



The 3D Workpiece Recognition visualized configurator is shown below.



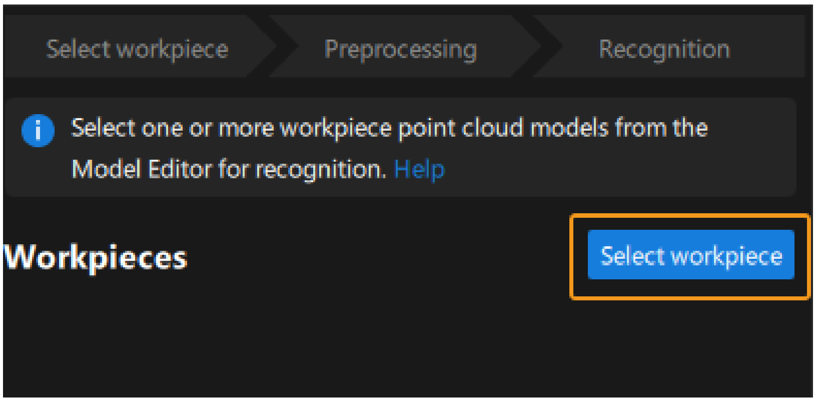
Then follow the procedure to recognize workpieces.

Select workpiece

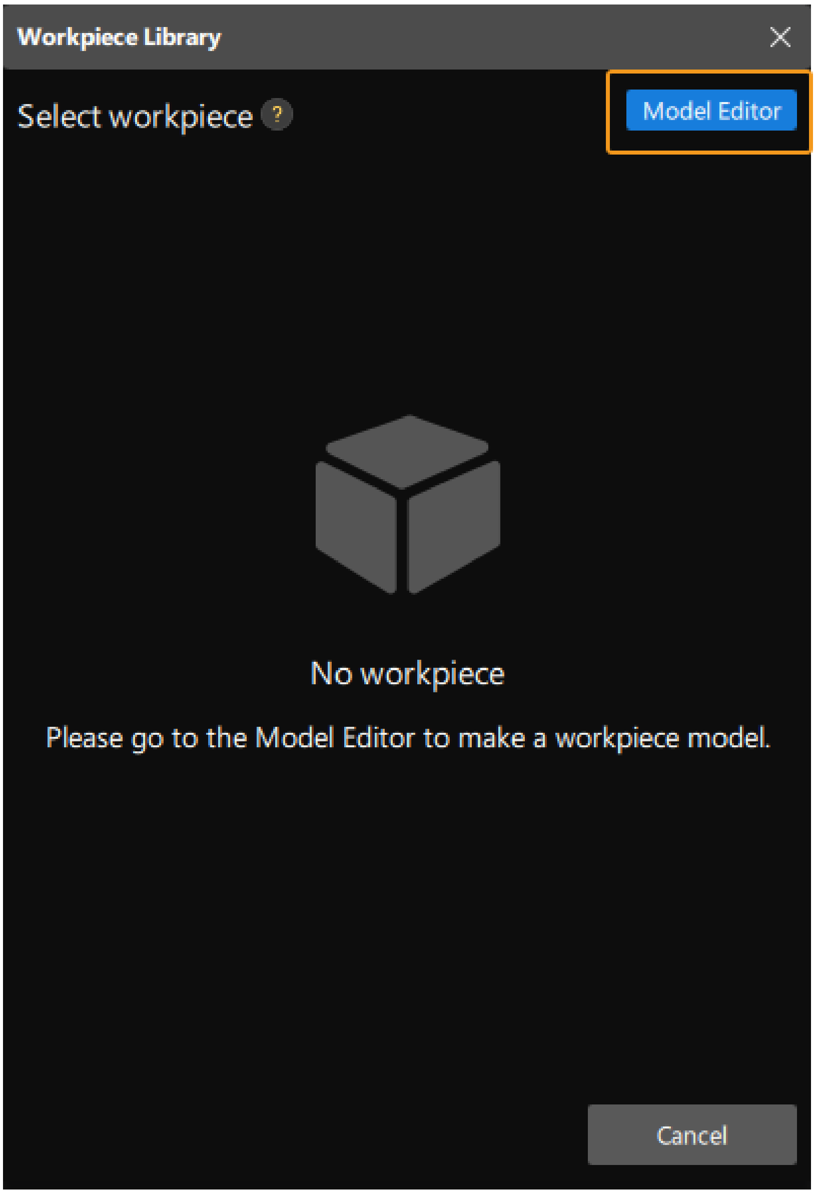
After entering the 3D Workpiece Recognition visualized configurator, you need to make the point cloud model for the workpieces to recognize.

1. Open the Model Editor.

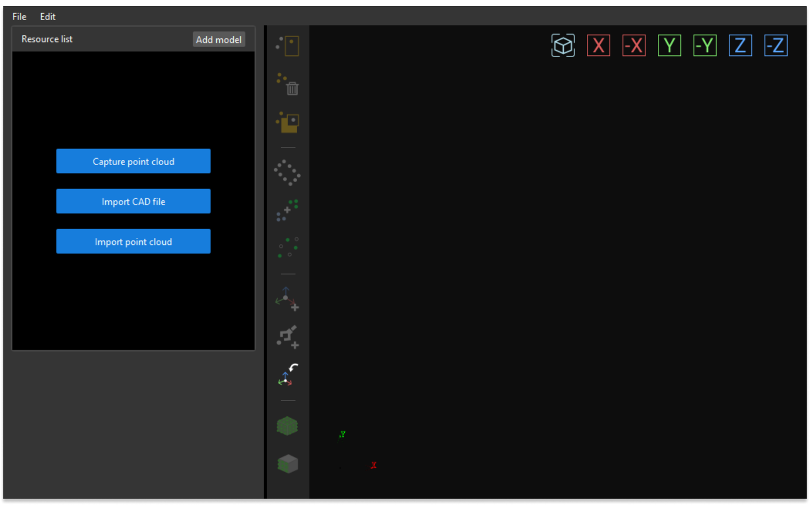
   On the upper part of the 3D Workpiece Recognition visualized configurator. click **[Select workpiece]**.



   In the prompted Workpiece Library window, click **[Model Editor]**.

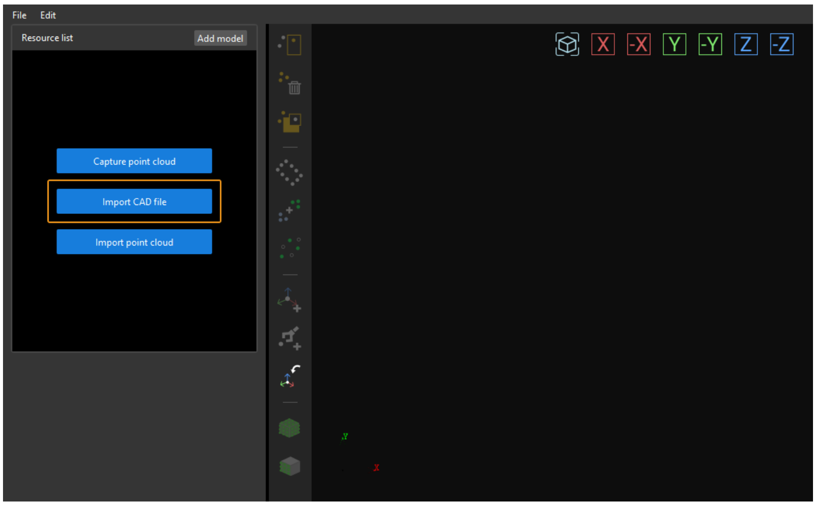


The following figure shows the Model Editor.

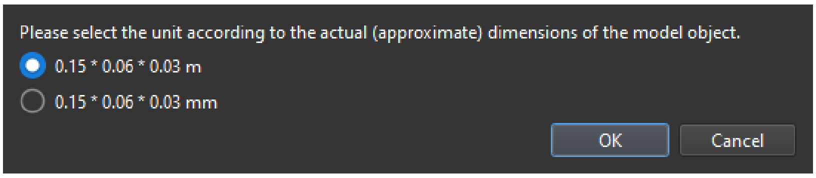


2. Import the CAD file.

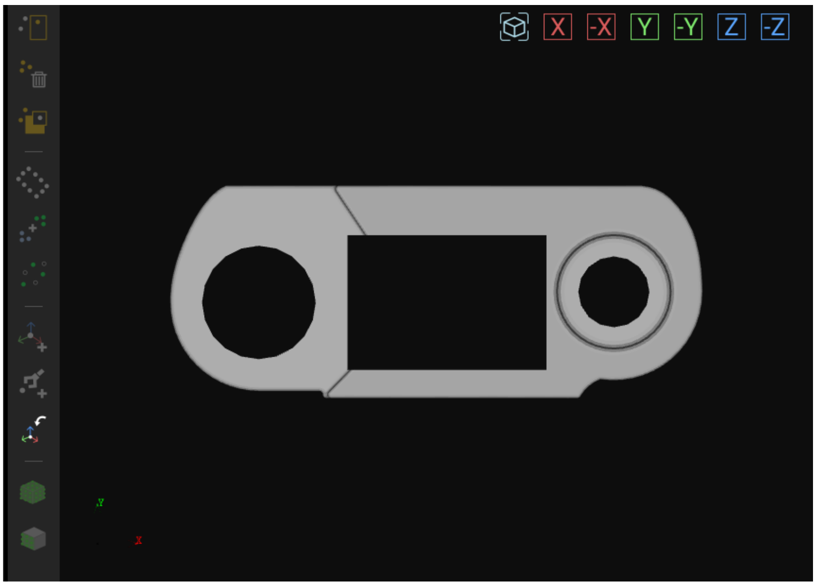
On the Matching Model and Pick Point Editor interface, click [**Import CAD file**].



Import the prepared workpiece model in STL format, select the unit of measurement of the model object with which the workpiece was created, and click [**OK**].

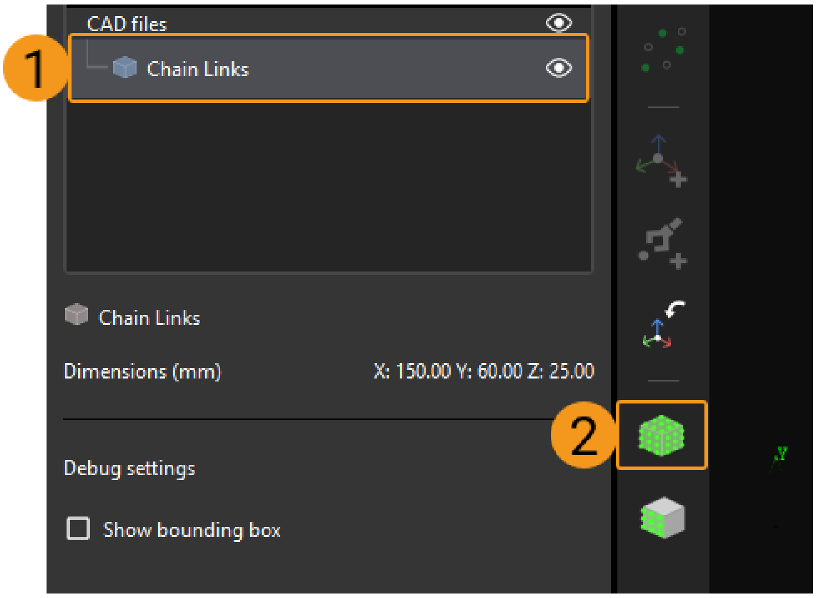


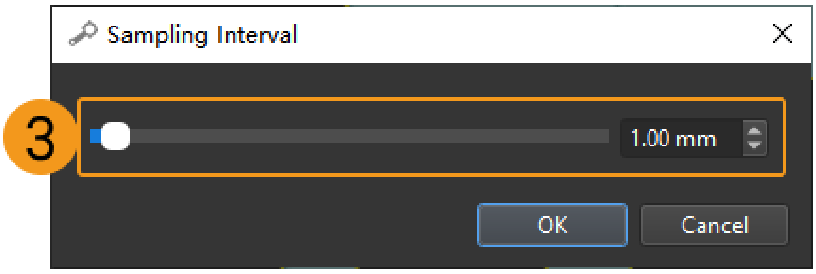
After the CAD file is imported, it will be displayed in the visualization area of the Matching Model and Pick Point Editor interface.



3. Use the CAD file to make the point cloud model.

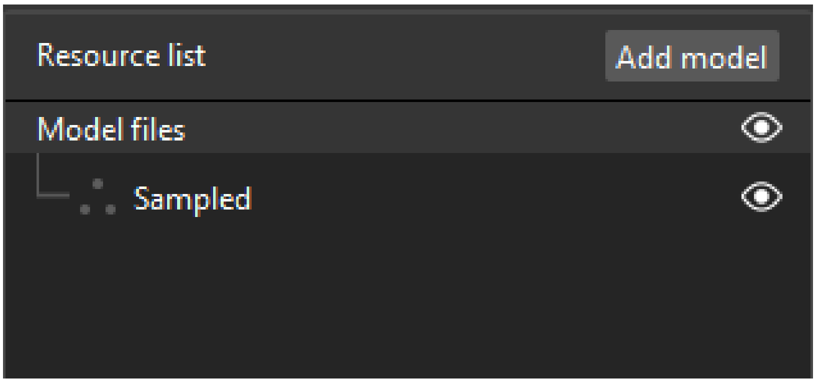
On the left resource list of the Matching Model and Pick Point Editor interface, select the CAD file, and click the  button on the toolbar. Then, set the sampling interval on the prompted window to generate the point cloud outside the exterior surface of the CAD model.



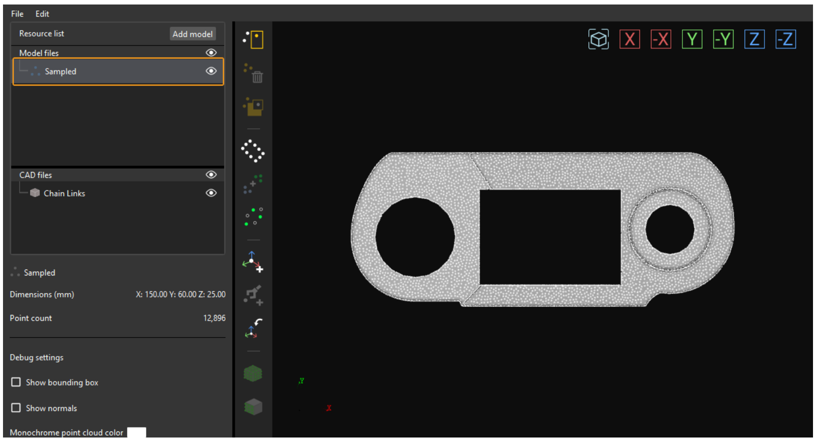


4. View the generated point cloud model.

   The point cloud model generated based on the CAD file will be displayed in the resource list.

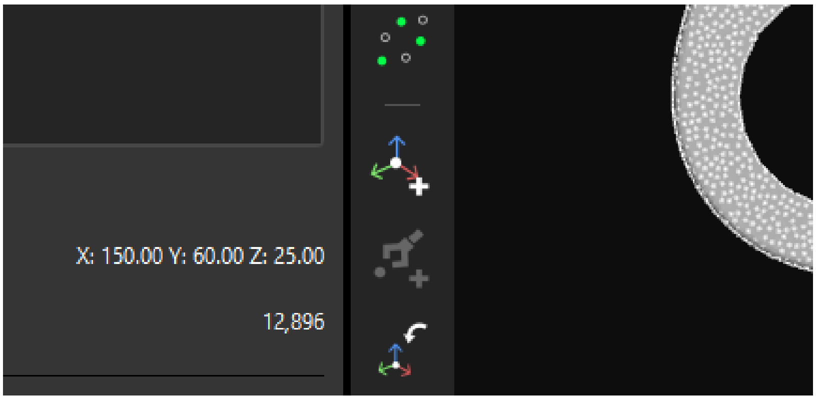


   Select the point cloud model file and you will see the point cloud model in the visualization area of the Matching Model and Pick Point Editor interface.

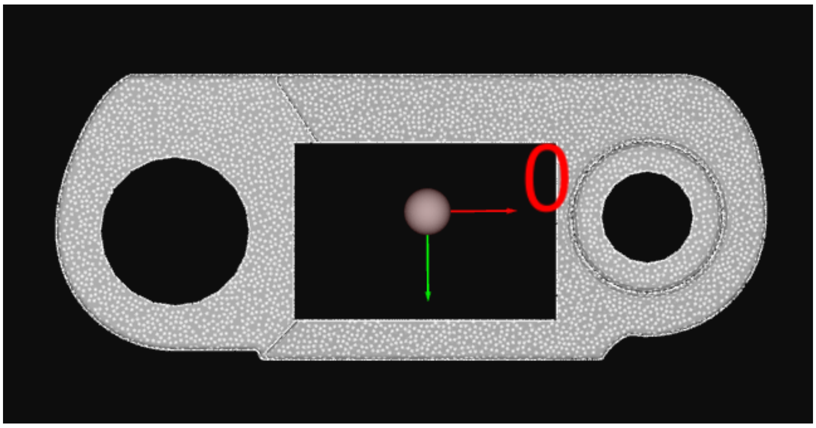


5. Add a pick point.

   Click the button on the toolbar to add a pose as a pick point to the point cloud model of the workpiece.

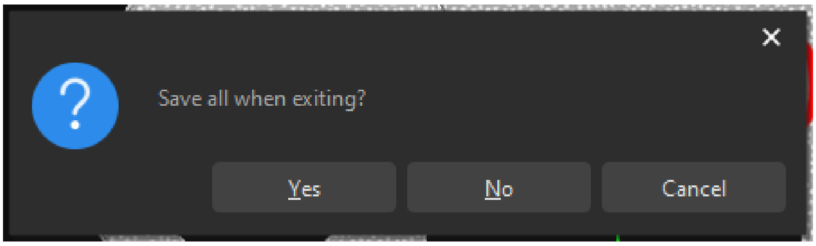


   The following figure shows the added pick point.



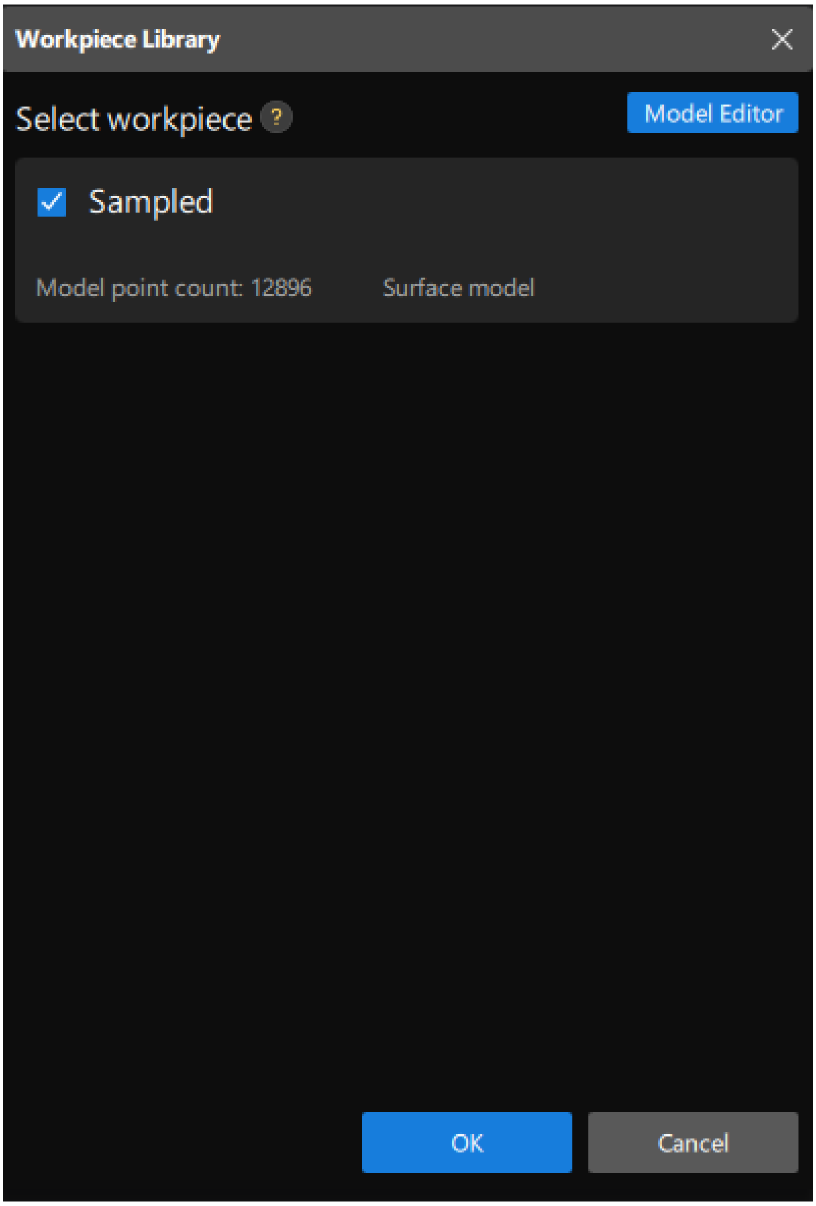
6. Save the model and the pick point.

   Close the Matching Model and Pick Point Editor, and click **[Yes]** in the prompted window.

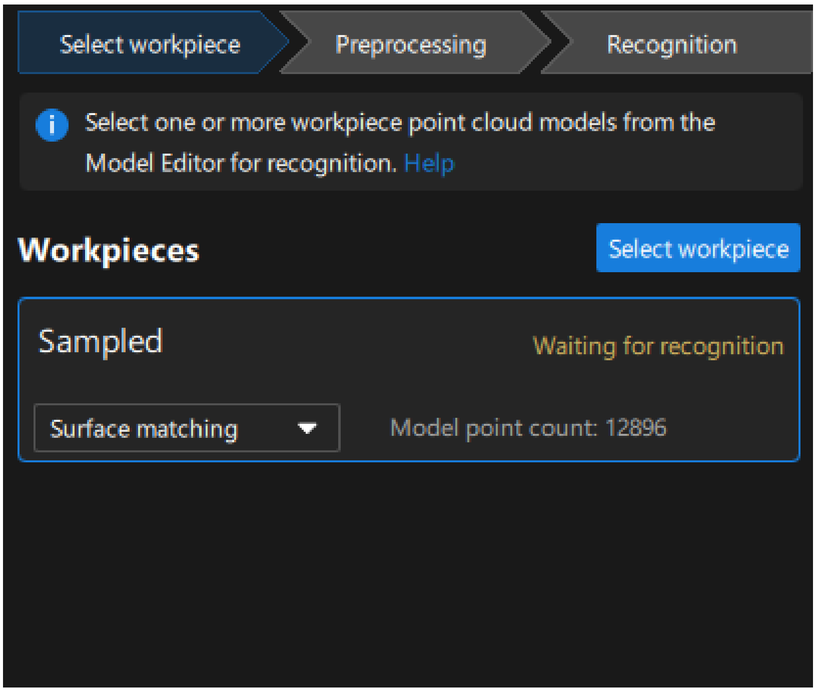


7. Select this workpiece from the Workpiece Library.

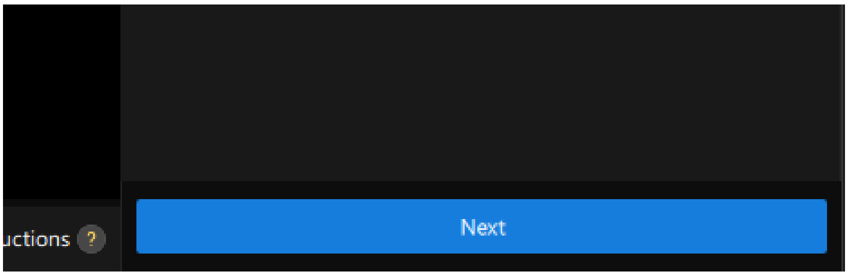
   After closing the Matching Model and Pick Point Editor, select the saved point cloud model of the workpiece, and click [OK].



   Subsequently, the target workpiece to recognize is displayed in the upper-right corner of the 3D Workpiece Recognition visualized configurator.



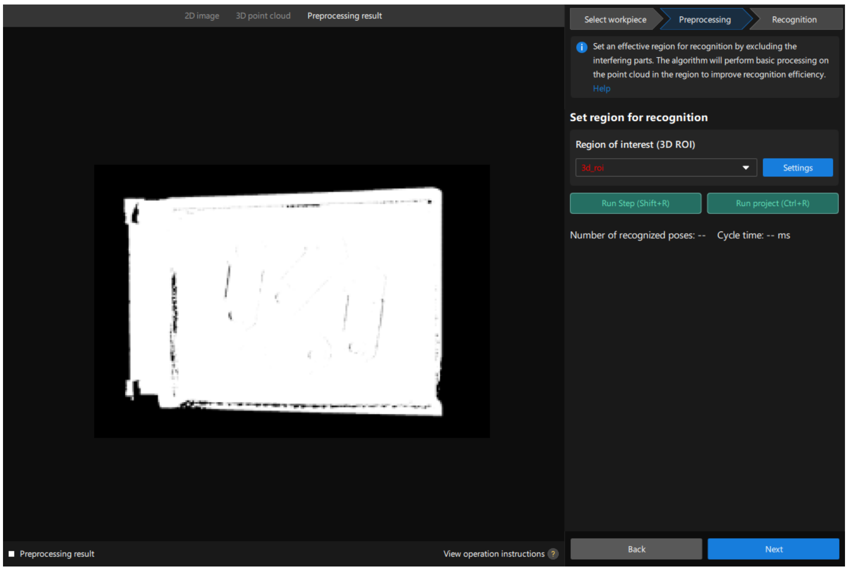
Now, you have selected the workpiece. Click **[Next]** on the bottom of the 3D Workpiece Recognition visualized configurator.



Preprocessing

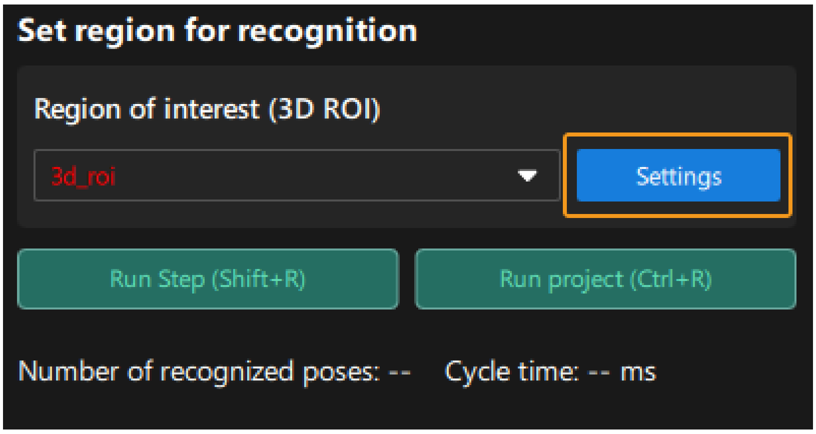
Preprocessing is used to set an effective region for recognition to exclude the point cloud of unnecessary parts and keep only the point cloud of the workpiece, thus improving recognition efficiency.

The following figure displays the Preprocessing interface.

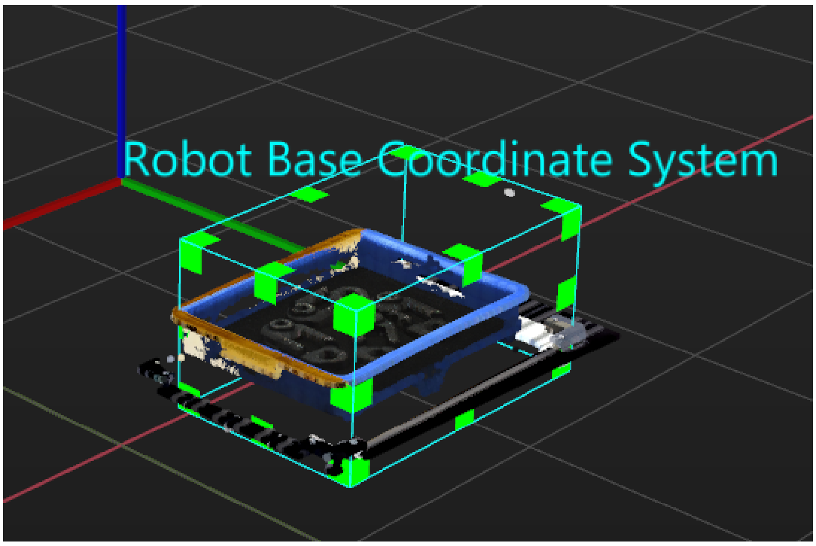


1. Set the region for recognition.

   Click **[Settings]**.

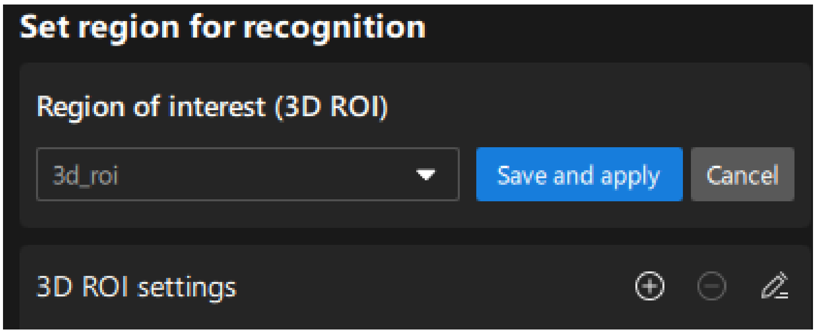
   

   In visualized interface, set the region for recognition (3D ROI). Press and hold the `Ctrl` key, select the vertices of the 3D ROI, and drag the 3D ROI to the proper size. The following figure displays the set 3D ROI.

2. Save the region for recognition.

   Click **[Save and apply]** to save the region for recognition.

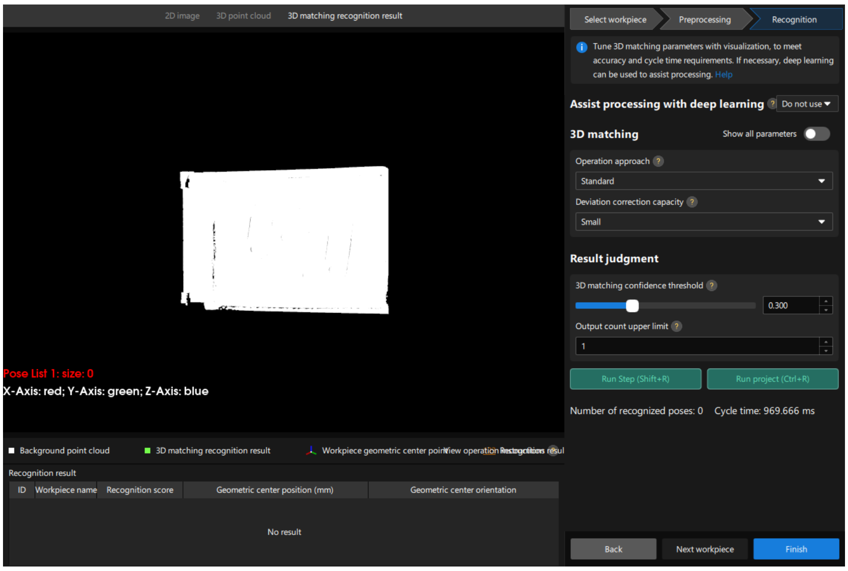


Now, you have finished the preprocessing procedure. Click **[Next]** on the bottom of the 3D Workpiece Recognition visualized configurator to enter the recognition procedure.

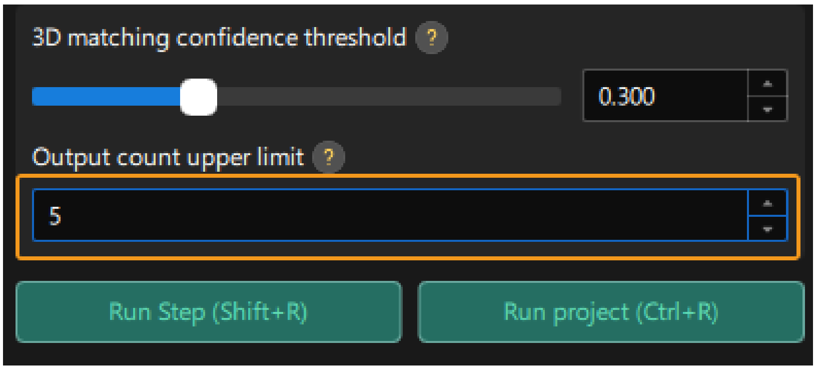
Recognize workpieces

In this procedure, you can adjust the 3D matching related parameters in a visualized manner, and output the workpieces' poses.

The following figure displays the Recognition interface.

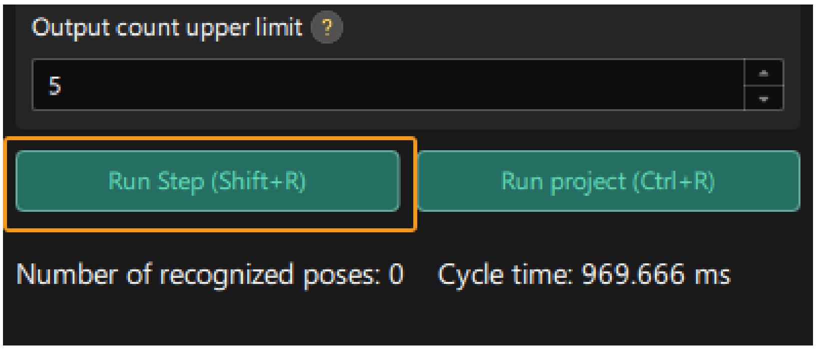


1. Since this project needs to recognize a maximum of five workpieces, set the **Output count upper limit** to 5.

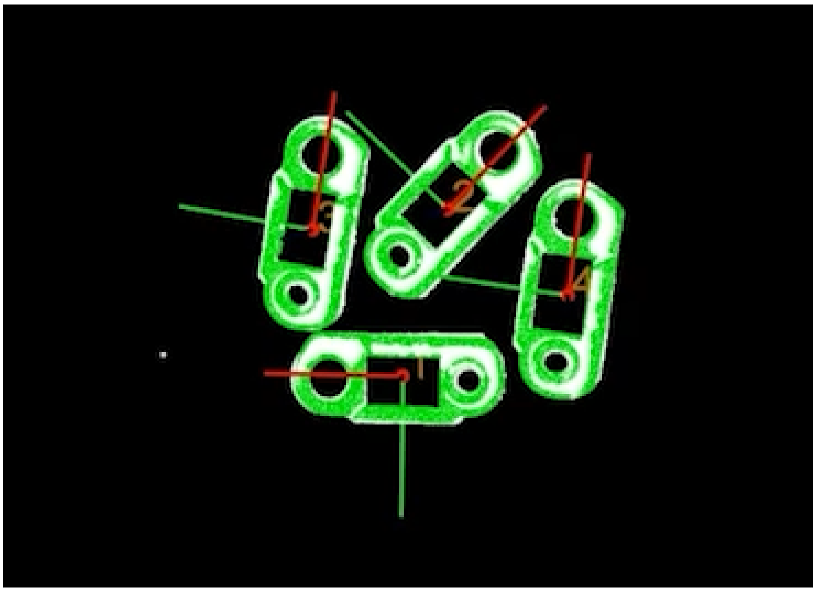


2. View the visualized output result.

   Click [Run Step].

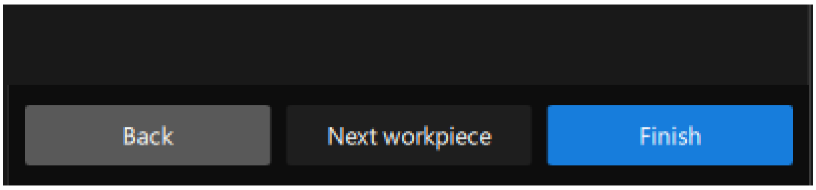


   You can view the visualized output result in the visualized area. As the figure below, the poses of four workpieces are output.

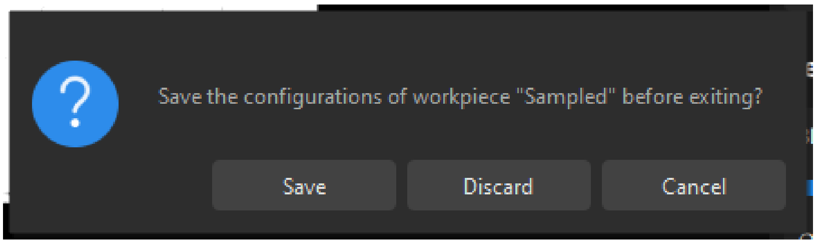


3. Save the configuration.

   Click the [Finish] button on the bottom of the 3D Workpiece Recognition visualized configurator.



In the prompted window, click [Save].



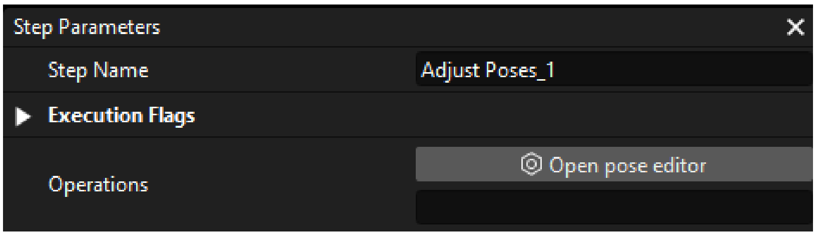
Now, you have recognized the workpieces and calculated their pick points.

Adjust Poses

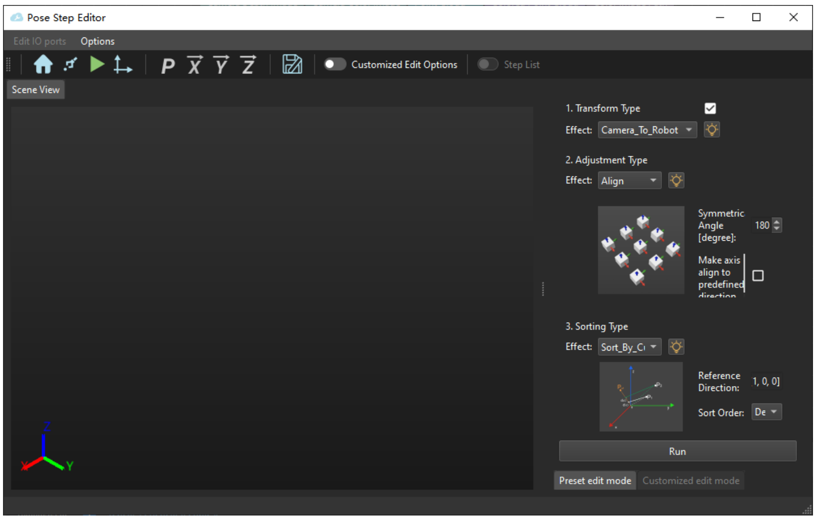
The pick points output by the “3D Workpiece Recognition” Step is in the camera reference frame. To facilitate robot picking, you need to adjust the workpieces’ poses to transform them from the camera reference frame to the robot reference frame.

1. Open the pose editor.

   Select the “Adjust Poses” Step, and click **[Open pose editor]** on the Step Parameters tab.

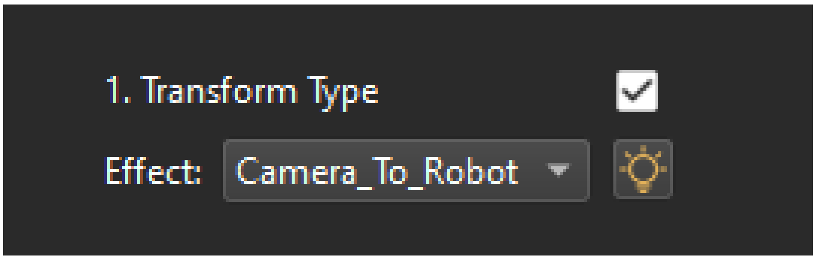


   The following figure shows the pose editor.



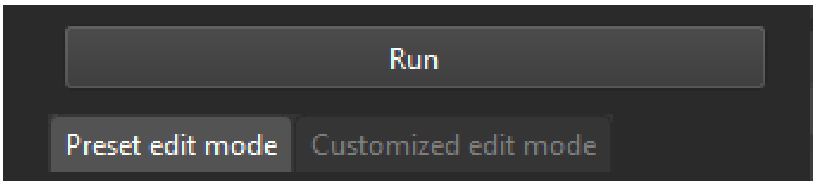
2. Adjust the reference frame.

On the upper-left corner of the pose editor, set Effect to **Camera_To_Robot**.

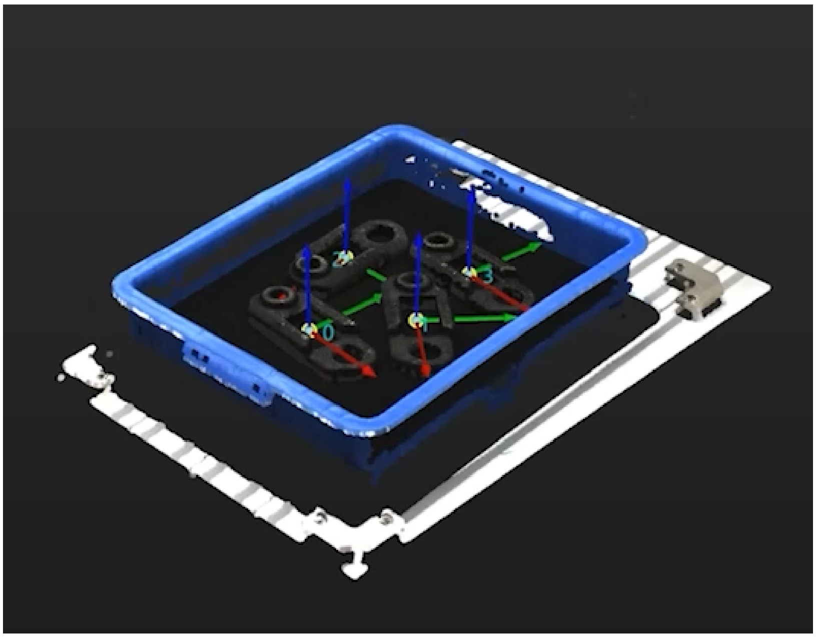


3. View the reference frame transformation result.

   On the bottom of the pose editor, click the **[Run]** button.

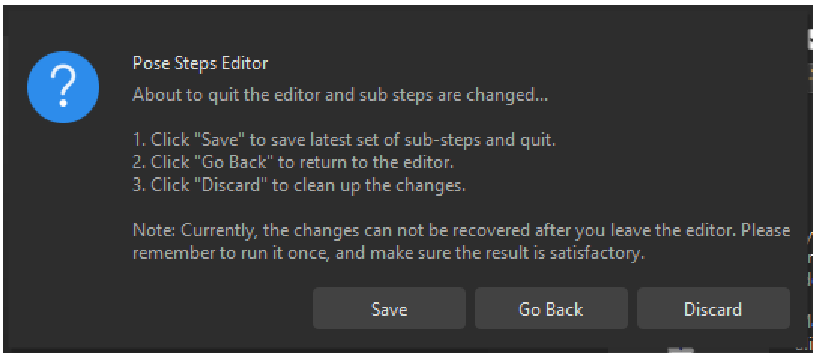


   You can see the transformed pick points in the Scene View of the pose editor.



4. Save the configuration.

   Close the pose editor, and click **[Save]** in the prompted window.



Now, the reference frame of the pick points has been transformed.

Procedure Out

The "Procedure Out" Step sends the results of the current project to the backend service.

Up to now, you have deployed the Mech-Vision project.

2.5. Perform Picking

After having obtained the poses of workpieces using a Mech-Vision case project, you can then build a workflow for the Mech-Viz project to guide the robot to repeatedly pick and place workpieces.

In this tutorial, the model file of the end tool in the OBJ format is required for collision detection. Please prepare the OBJ model file of the end tool before using this tutorial.

▶ https://www.youtube.com/watch?v=at95dOGIRcg/PLVcMd7cW2rXVtrAejMyVQni2dUDv8bxje *(YouTube video)*

Video tutorial: Perform Picking

The following figure shows the process of building a project.

Configure the Robot and Scene

To avoid collision with surrounding objects during robot picking and placing, you should add the tool model, scene model, and bin models to the project for collision detection.

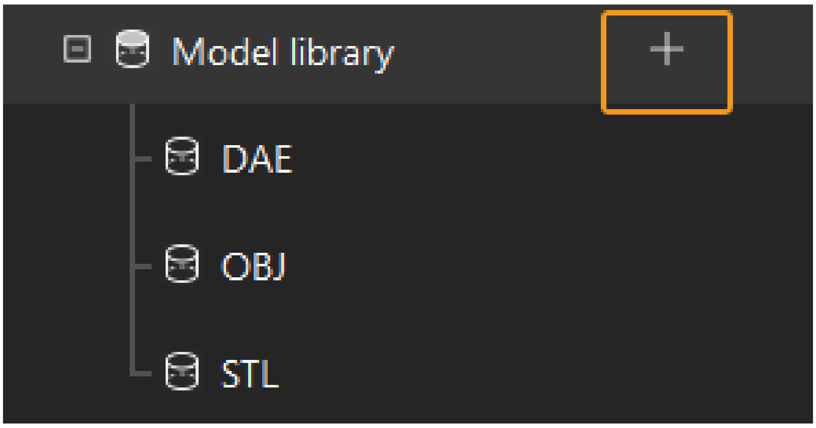
Import and Configure the Tool Model

Tool refers to the device mounted on the robot end that performs processing/picking jobs.

The end tool should be imported and configured so that its model can be displayed in the 3D simulation space and used for collision detection.

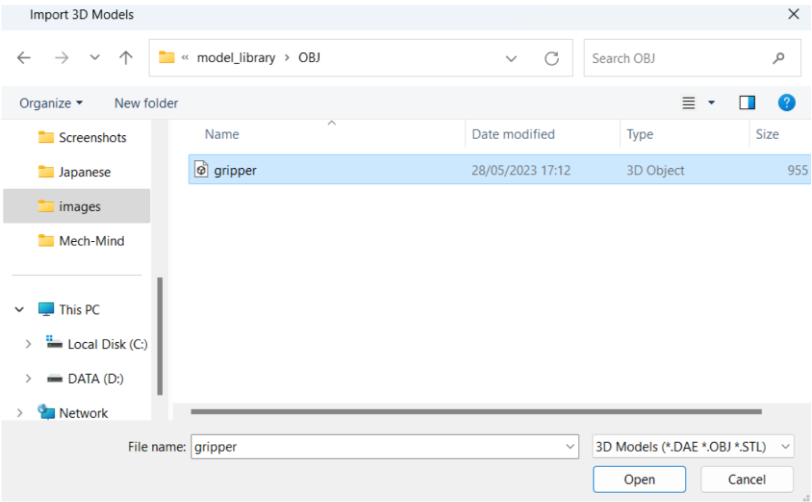
Import the Tool Model

1. Click [+] in Resources › Model Library.

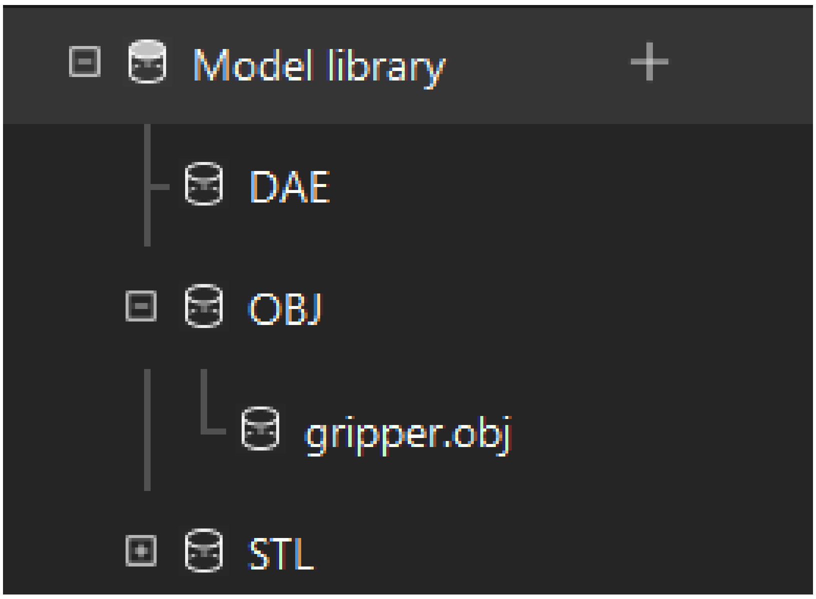


Project resources refer to various basic resources used in the project, including the robot, tools, workpieces, and scene objects.

2. In the prompted window, select the collision model file in .obj format, and then click [Open].

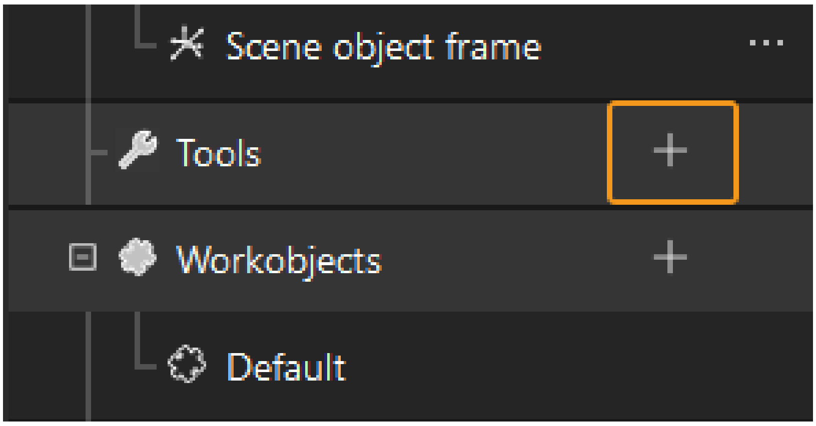


3. After the model is imported, you can see the imported model in the model library.

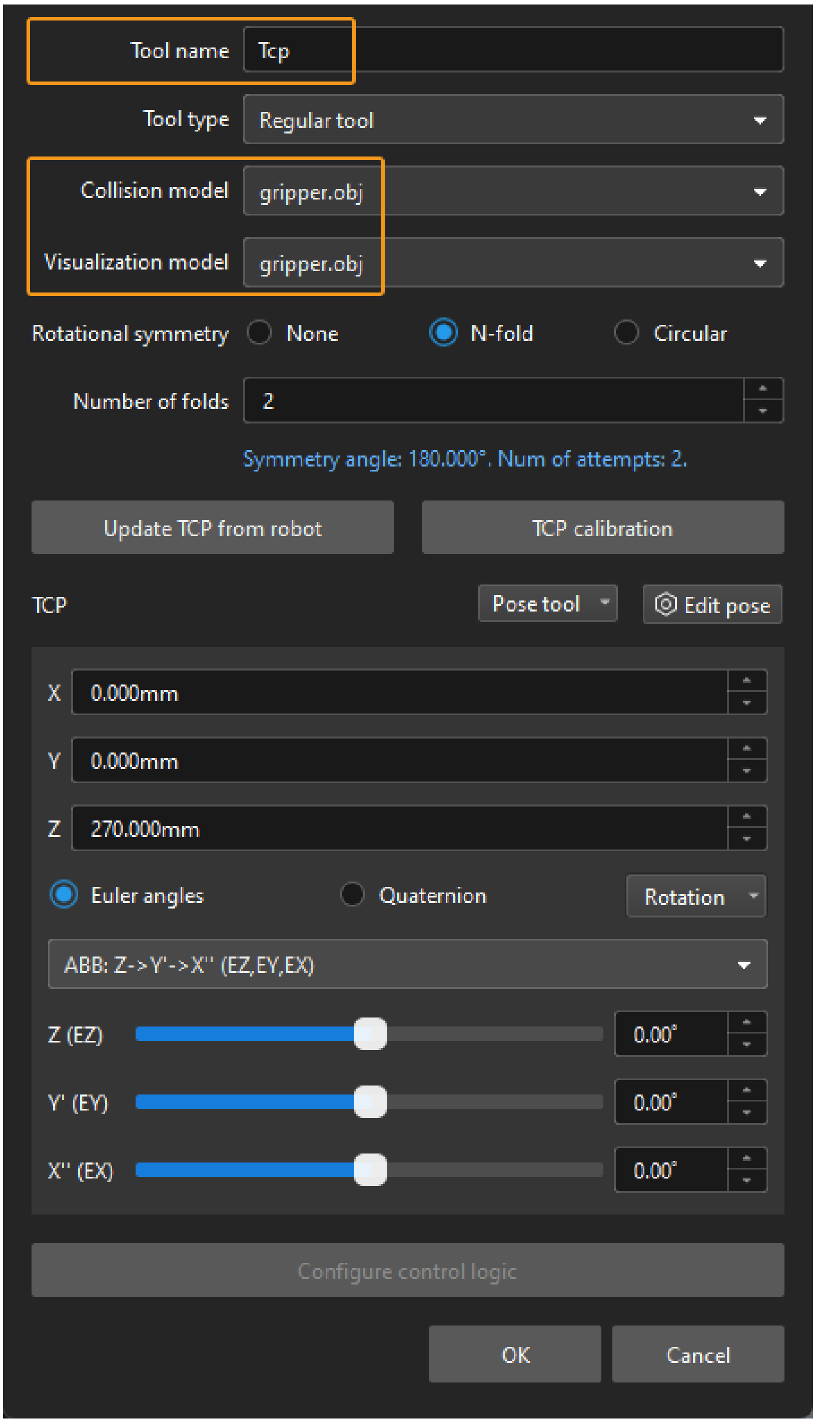


Configure the Tool

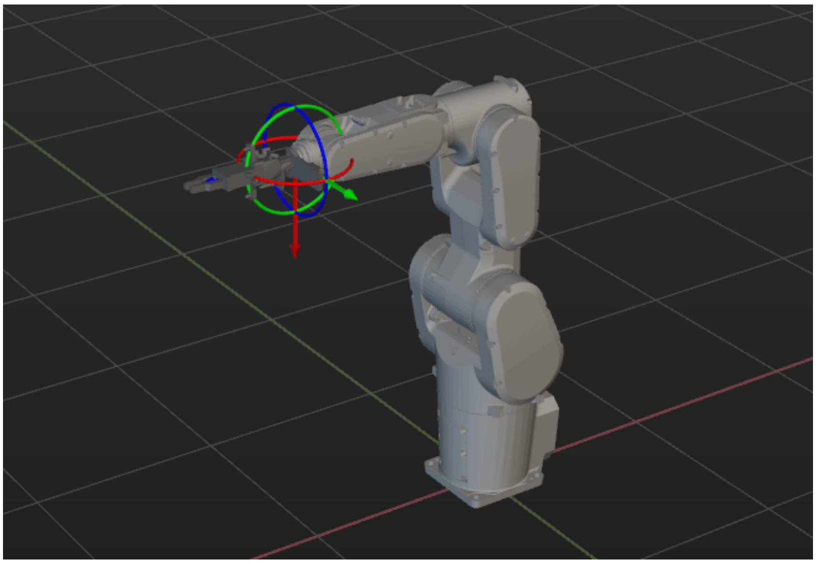
1. Click [+] in Resources › Tools.



2. In the prompted window, enter the tool name, select the imported tool model as the collision model and visualization model, and then click [OK].



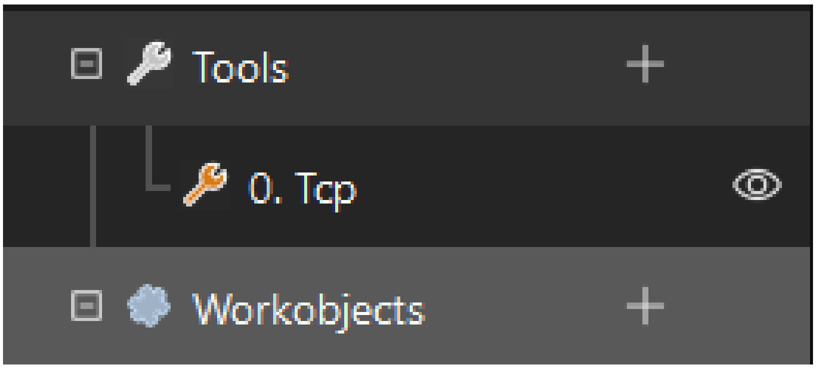
3. After the tool is configured, you can view the configured tool in the 3D simulation space, as shown below.



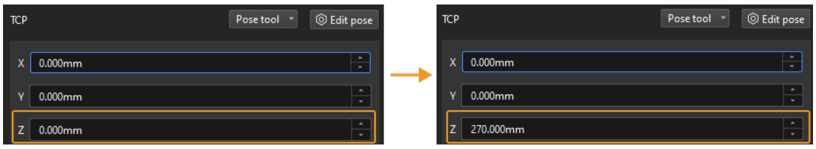
Adjust the Tool

As shown above, the position of the Tool Center Point (TCP) in relation to the robot is obviously wrong. So, you should adjust the position of the TCP so that it is at the tip of the tool.

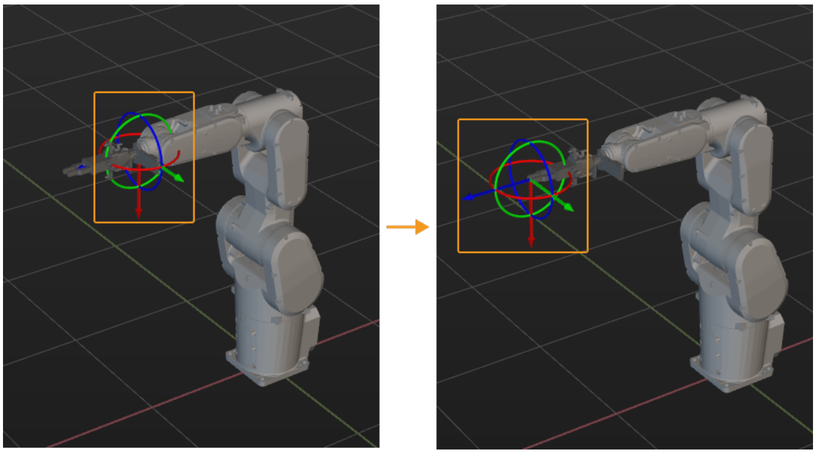
1. Double-click the tool model in the model library.



2. In the prompted windows, adjust the settings as shown below.



3. The poses of the tool before and after fitting are shown below.

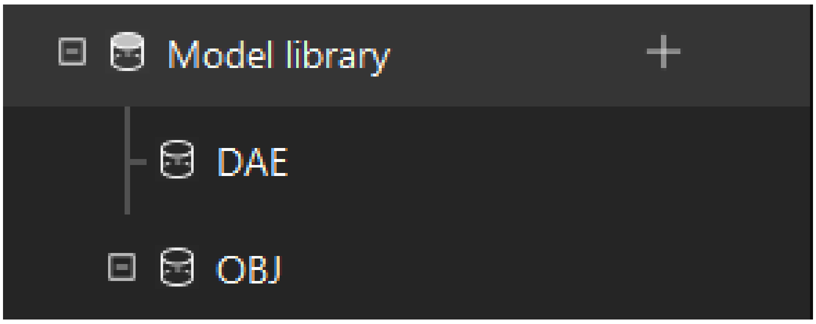


Import and Configure the Scene Model

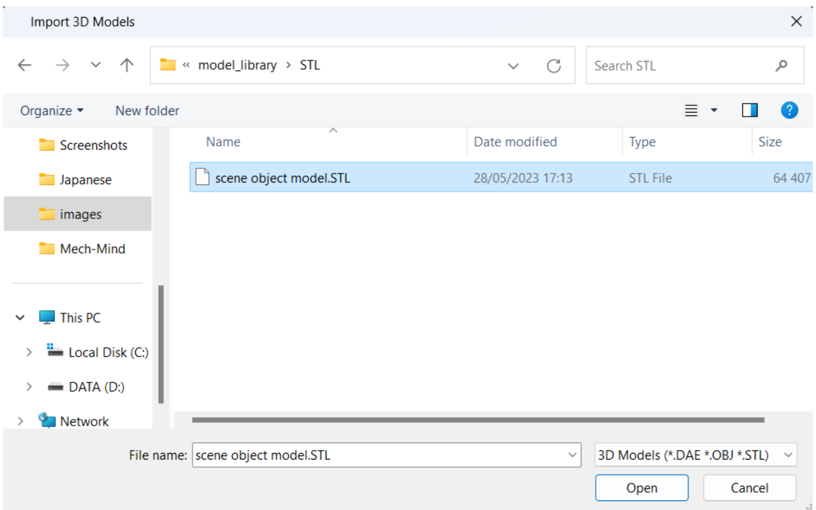
Scene objects are imported and configured to make the scene in the software closer to the real scenario, which facilitates the planning of the collision-free robot motion path.

Import the Scene Model

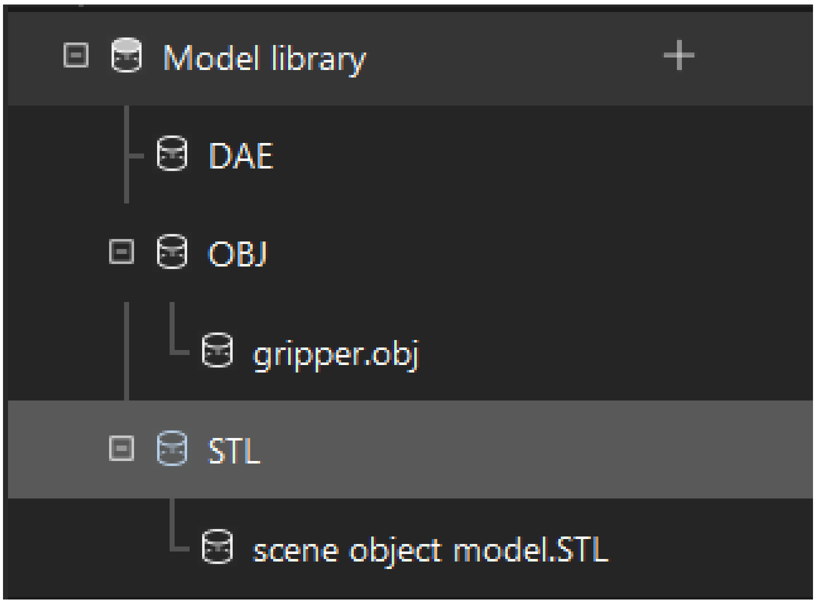
1. Click [+] in Resources › Model Library.



2. In the prompted window, select the scene object model file, and then click [Open].

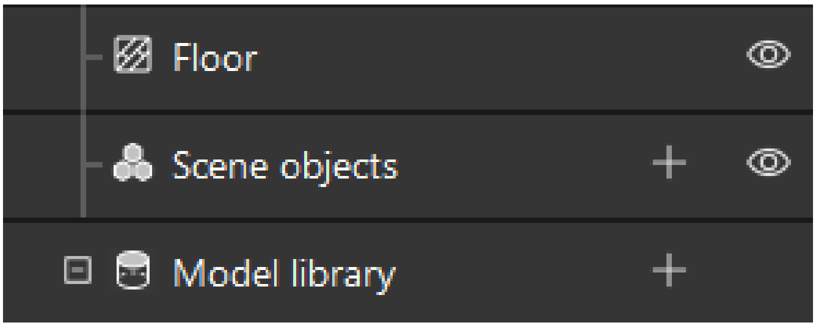


3. After the model is imported, you can see the imported model in the model library.

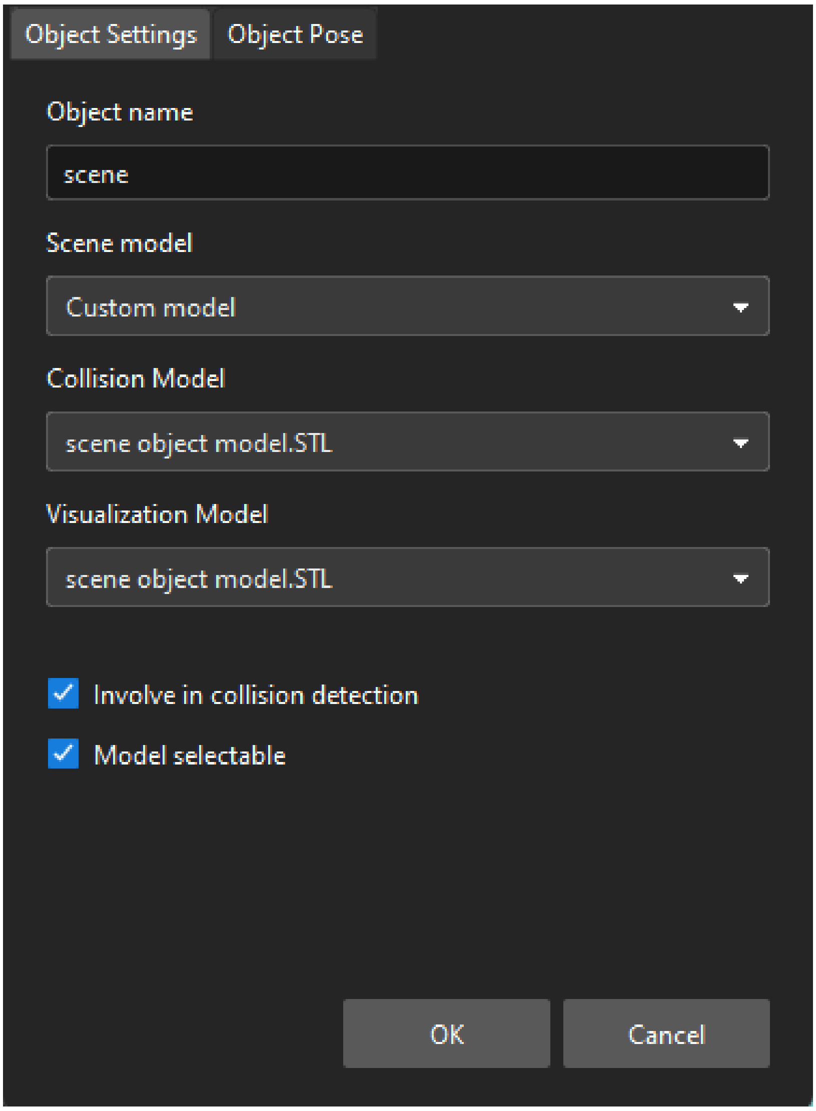


Configure the Scene Model

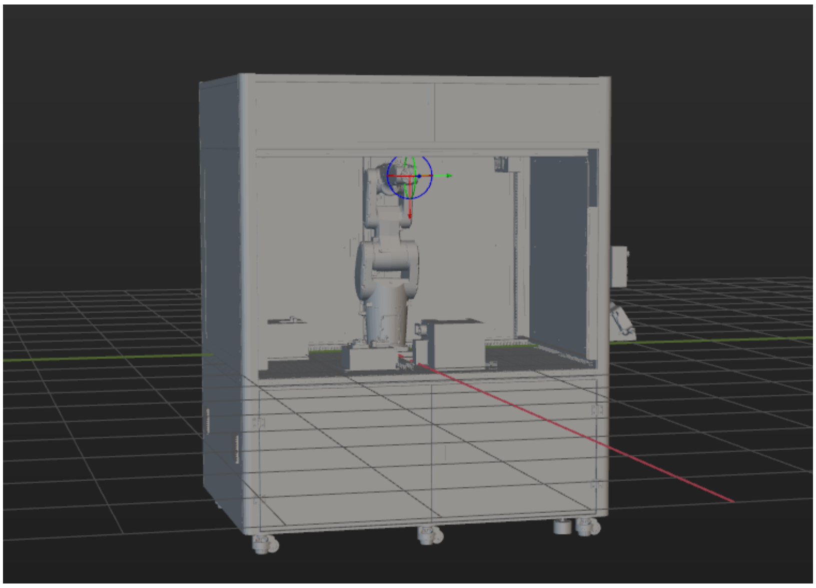
1. Click [+] in Resources › Scene Objects.



2. In the prompted window, enter the object name, select “custom model” as the “scene model”, select the imported scene object model as the collision model and visualization model, and then click [OK].



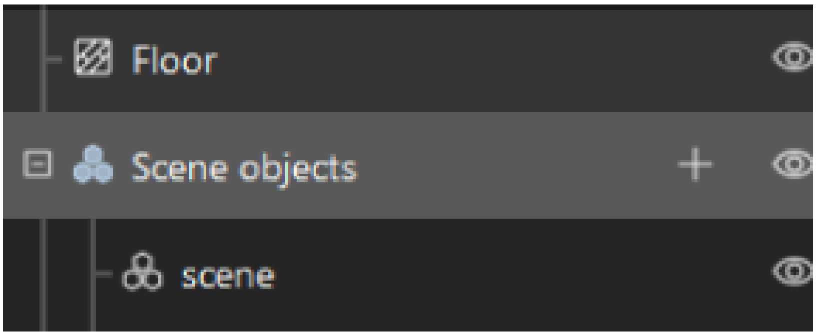
3. After configuration, the scene object is displayed in the 3D simulation space.



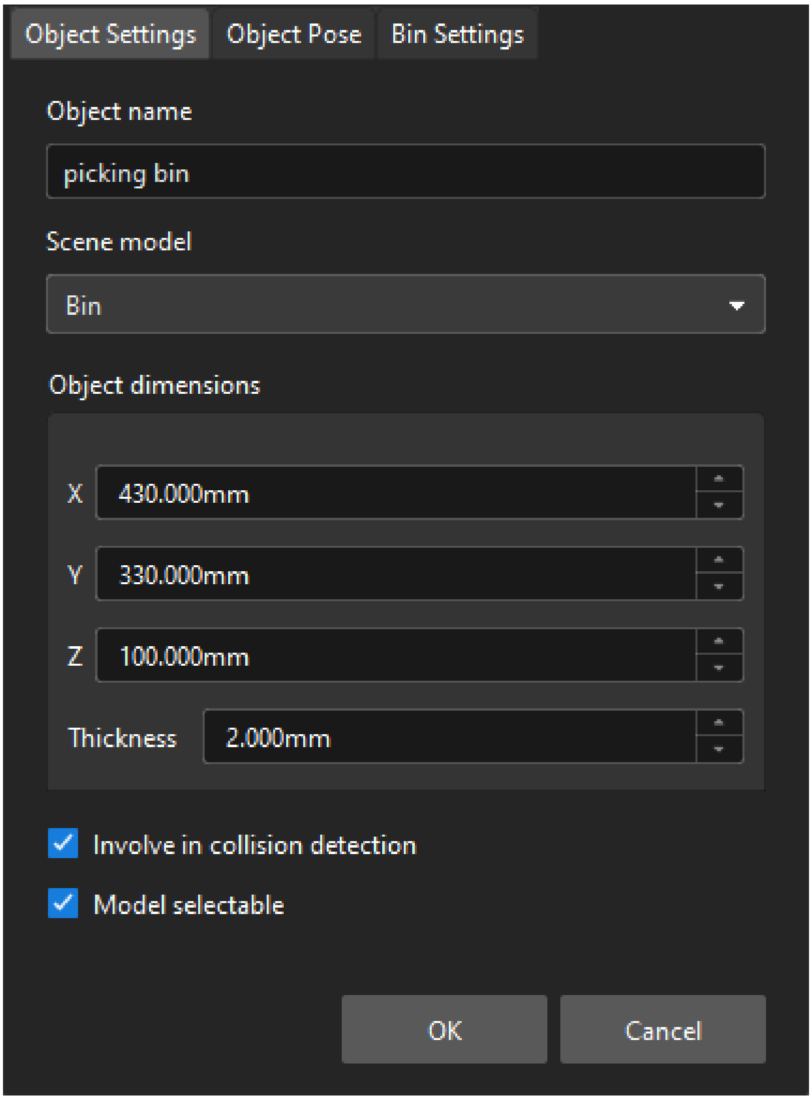
Add and Configure the Bin Models

1. Add the “picking bin” model.

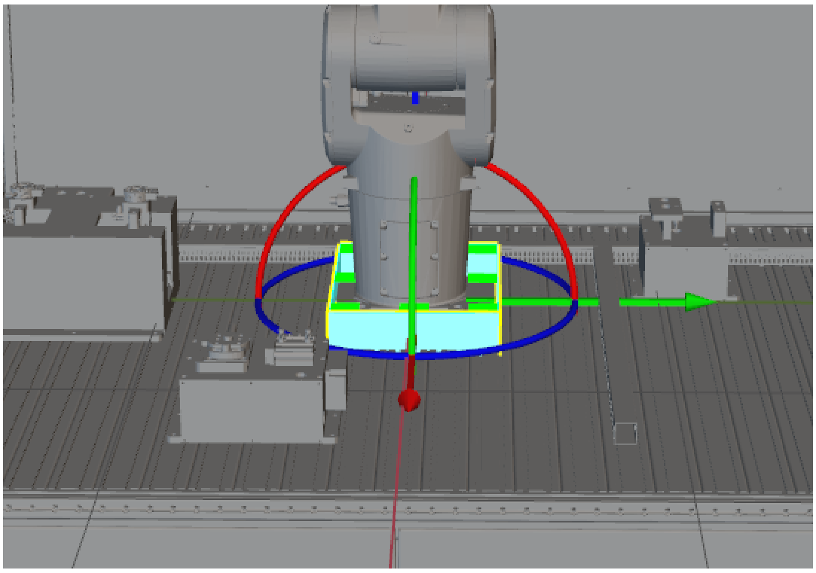
   Click [+] in Resources › Scene Objects.



   In the prompted window, set the “Object name” parameter to “picking bin”, and the “Scene model” parameter to “Bin”. Then set the “Object dimensions” parameter according to the measured size of the real bin, and then click [OK].



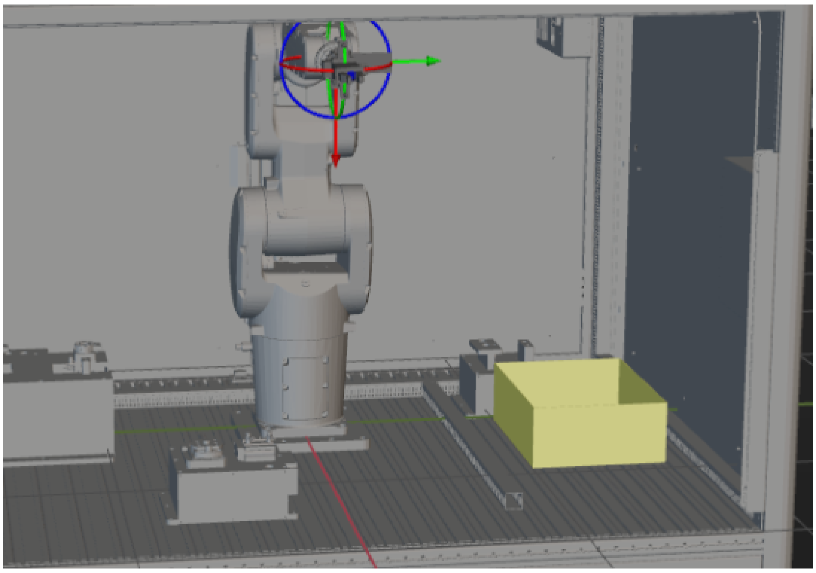
   After configuration, the “picking bin” model is displayed in the 3D simulation space.



2. Adjust the “picking bin” model.

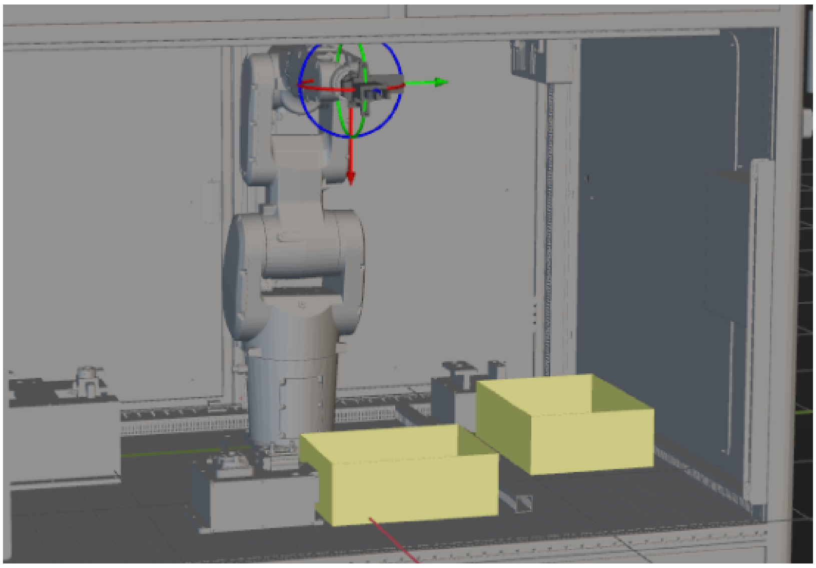
   To determine the position of the real bin, you can run the Mech-Vision project to send the point cloud of the real bin to Mech-Viz. Then, you can adjust the pose of the “picking bin” based on the point cloud position of the real bin.

   Press the `Ctrl` key and press the left mouse button to drag the “picking bin” model to coincide with the point cloud position of the real bin. The position of the “picking bin” model after adjustment is shown below.



3. Add and adjust the “placing bin” model.

   Use the same method to add and adjust the “placing bin” model, as shown below.



So far, you have added all the resources required by the Mech-Viz project.

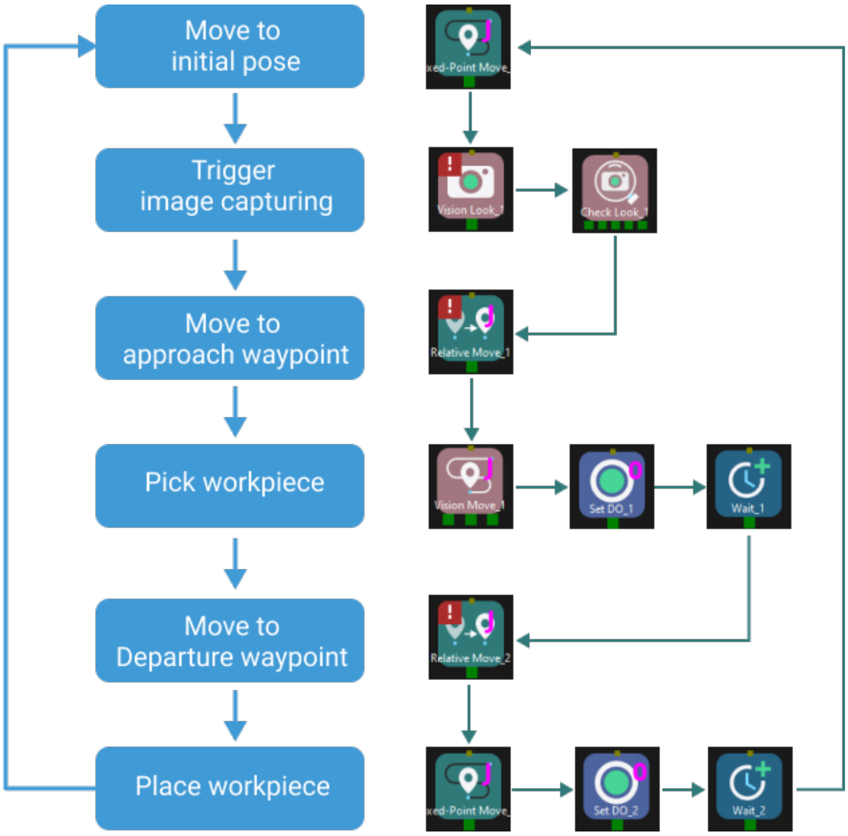
Create a Workflow

Now that you have configured the models, you can start creating a workflow. Drag a step from the step library to the graphical programming workspace, set the parameters of the Steps, and connect Steps to achieve preset program functions.

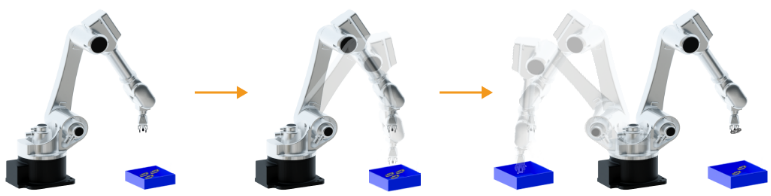
- The workflow refers to the robot motion control program created in Mech-Viz in the form of a flowchart.
- A Step refers to a function module of robot programming.

Introduction to the Project Workflow

The created workflow is shown below.



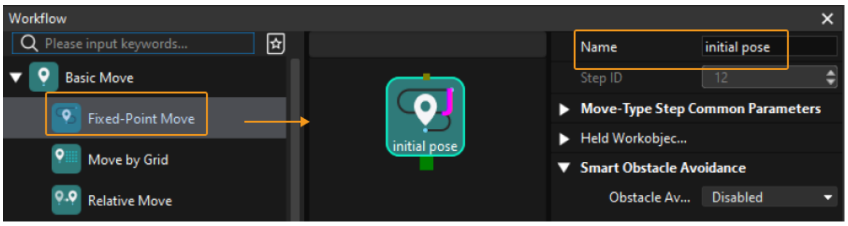
The created workflow can achieve the picking and placing as shown below.



Define the “Home Position”

The home position is the starting point of the robot movement and should also be a safe position. At this point, the robot should be away from the objects to pick and the surrounding devices, and should not block the camera’s FOV.

After the robot arrives at the self-defined home position, select **Fixed-Point Move** in the Step Library, and drag it to the graphical programming workspace, rename it as “initial pose”. Then click **[Sync Robot]** on the toolbar to record the current pose of the robot for this Step.



Trigger the Camera to Capture Images

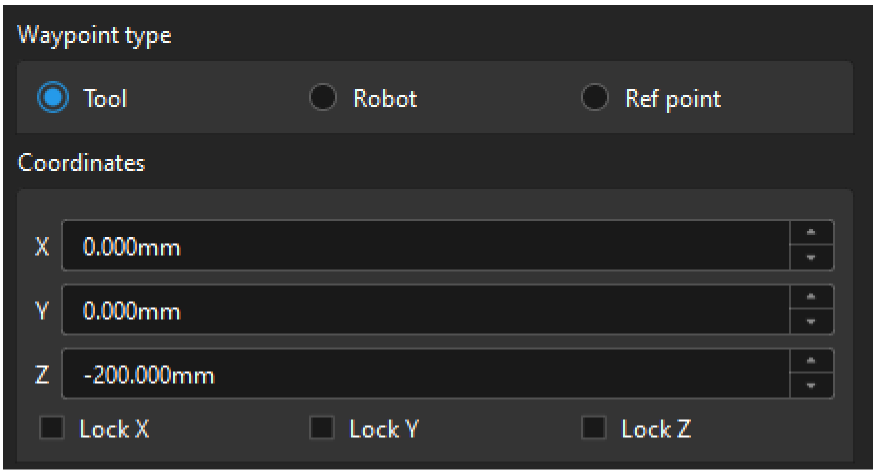
Step	Vision Look
Description	Start the Mech-Vision project to obtain the vision recognition result.
Operation	Find the "Vision Look" Step in the Step Library, and drag it to the graphical programming workspace.
Parameter Settings	Select **General_Workpiece_Recognition** from the **Vision Name** drop-down list.
Image	

After the "Vision Look" Step, add the **Check Look** Step to check whether there is any vision result.

Step	Check Look
Description	Check whether there is any vision result.
Operation	Find the "Check Look" Step in the Step Library, and drag it to the graphical programming workspace.
Parameter Settings	Keep the default parameter settings.

Move the Robot to the Approach Waypoint

After obtaining the vision recognition result, you can then use the **Relative Move** step to move the robot to the approach waypoint.

Step	Relative Move
Description	The robot moves according to the vision recognition result.
Operation	Find the "Relative Move" Step in the Step Library, drag it to the graphical programming workspace, and rename it as "approach waypoint".
Parameter Settings	Set **Relative Move Dependency** to **Next waypoint**; set **Waypoint type** to **Tool**, and set the **Z** coordinate to **-200mm**.
Image	

Pick the Workpiece

After the robot has arrived at the approach waypoint, you can control the robot the pick workpieces. The picking process can be divided into two steps.

1. Step 1: Use the **Vision Move** Step to control the robot to reach the picking waypoint of the workpiece.
2. Step 2: Use the **Set DO** Step to control the robot to expand the gripper to pick the workpiece.

See the following for details.

Step	Vision Move
Description	The robot moves according to the vision recognition result.
Operation	Find the "Vision Move" Step in the Step Library, and drag it to the graphical programming workspace.
Parameter Settings	Select **General_Workpiece_Recognition** from the **Vision Name** drop-down list.
Image	

Step	Set DO
Description	Control the robot to expand the gripper to pick the workpiece.
Operation	Find the "Set DO" Step in the Step Library, drag it to the graphical programming workspace, and rename it as "expand the gripper".
Parameter Settings	Set the **Digital Out Value** and **DO Port** parameters to **1**.
Image	

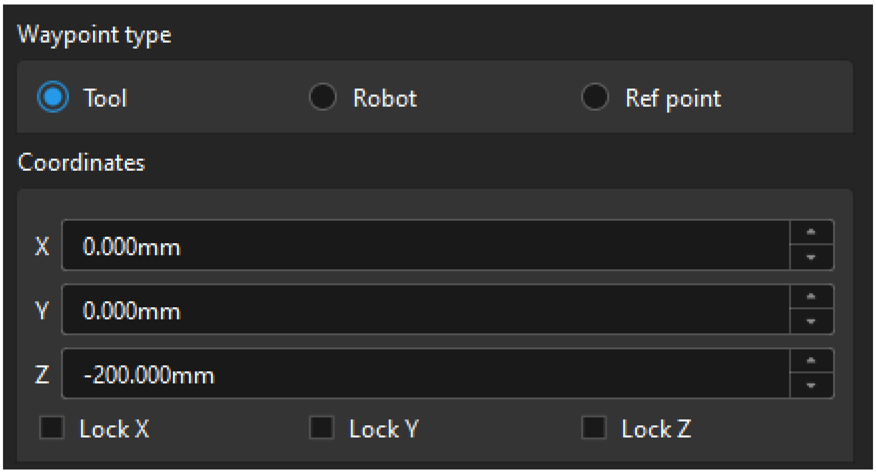
Since it takes time for the gripper to expand, you should add the **Wait** Step to avoid empty picking by the robot.

Step	Wait
Description	Avoid an empty pick by the robot.
Operation	Find the "Wait" Step in the Step Library, drag it to the graphical programming workspace, and rename it as "wait for firm gripping".
Parameter Settings	Set the **Wait Time** parameter to **1000ms**.
Image	

Move the Robot to the Departure Waypoint

After the robot picks the workpiece, you should add the **Relative Move** Step to control the robot to arrive at the departure waypoint.

<table>
<tr><td>Step</td><td>Relative Move</td></tr>
<tr><td>Description</td><td>The robot moves according to the vision recognition result.</td></tr>
<tr><td>Operation</td><td>Find the “Relative Move” Step in the Step Library, drag it to the graphical programming workspace, and rename it as “departure waypoint”.</td></tr>
<tr><td>Parameter Settings</td><td>Set Relative Move Dependency to Next waypoint; set Waypoint type to Tool, and set the Z coordinate to -200mm.</td></tr>
<tr><td>Image</td><td>


</td></tr>
</table>

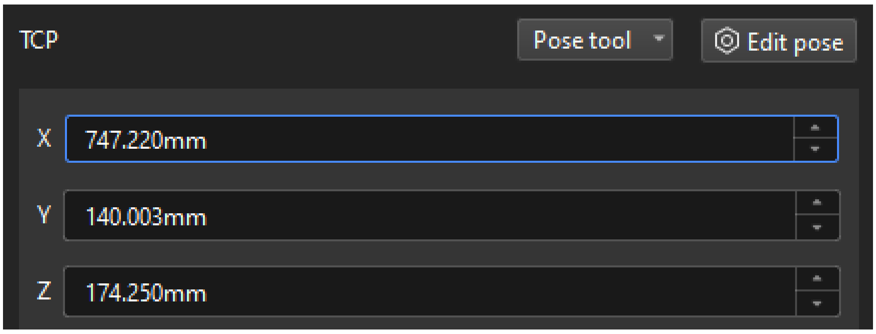
Place the Workpiece

After the robot picks the workpiece, the robot needs to place the workpiece into the placing bin. The placing process can be divided into two steps.

1. Step 1: Use the **Fixed-Point Move** Step to control the robot to arrive at the position of the placing bin.
2. Step 2: Use the **Set DO** Step to control the robot to close the gripper to place the workpiece.

See the following for details.

Step	Fixed-Point Move
Description	Control the robot to arrive at the position of the placing bin.
Operation	Find the “Fixed-Point Move” Step in the Step Library, drag it to the graphical programming workspace, and rename it as “placing waypoint”.
Parameter Settings	Set a suitable **TCP** as the placing waypoint.

Image	

Step	Set DO
Description	Control the robot to close the gripper to place the workpiece.
Operation	Find the “Set DO” Step in the Step Library, drag it to the graphical programming workspace, and rename it as “retract the gripper”.
Parameter Settings	Set the **Digital Out Value** parameter to **0** and the **DO Port** parameter to **1**.
Image	

Since it takes time for the gripper to close, you should add the **Wait** Step to avoid that the robot cannot place the workpiece.

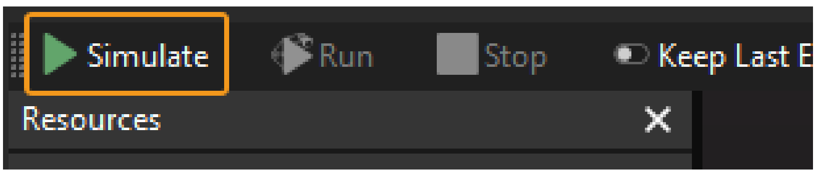
Step	Wait
Description	Avoid the failure of placing the workpiece by the robot.
Operation	Find the “Wait” Step in the Step Library, drag it to the graphical programming workspace, and rename it as “wait for release”.
Parameter Settings	Set the **Wait Time** parameter to **1000ms**.
Image	

Connect Steps

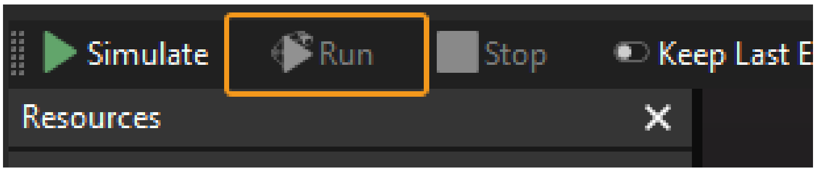
After adding the previous steps, connect them one by one. To control the robot to repeatedly pick up and place workpieces, you should connect the exit port of “Placing Wait” to the entry port of “Home Position”.

Simulate and Run the Project

1. After all the Steps are connected properly, click the [**Simulate**] button on the toolbar to simulate the Mech-Viz project.



2. If the project runs as expected in simulation, click the [Run] button on the Mech-Viz toolbar to run the project with the real robot.



It is recommended that the robot should move at a low speed and that you pay attention to the robot motion trajectory. In an emergency, press the emergency stop key on the teach pendant.

3. Getting Started Tutorial: Vision-Guided Robotic Depalletizing (Master-Control Communication)

In this tutorial, you will learn how to deploy a simple 3D vision-guided robotic application of depalletizing cartons in the Master-Control communication mode.

Application Overview

- Camera: Mech-Eye DEEP camera, mounted in Eye to Hand mode
- Robot: ABB_IRB_1300_11_0_9
- Workpiece: single-case cartons
- Used software: Mech-Vision 1.7.2, Mech-Viz 1.7.2, Mech-Center 1.7.2, and Mech-Eye Viewer 2.1.0
- Communication mode: Master-Control communication

If you are using a different camera model, robot brand, or workpiece than in this example, please refer to the reference information provided in the corresponding steps to make adjustments.

https://www.youtube.com/watch?v=9QrLGzeLI3Y/PLVcMd7cW2rXWbHhTQX8m2R1r6PhX6vrCI *(YouTube video)*

Getting Started Tutorial: Vision-Guided Robotic Depalletizing Overview

Explanation of Terms

Pallet	A platform device used to hold goods (such as cartons)
Depalletizing	A task that a robot performs to disassemble objects from a pallet as required under the vision guidance
Palletizing	A task that a robot performs to place objects at specified positions on a pallet under the vision guidance
Single-case depalletizing	Depalletize single-case cartons (with the same dimensions) from a pallet
Mixed-case depalletizing	Depalletize single-case cartons (with different dimensions) from a pallet

Single-case depalletizing

Mixed-case depalletizing

How to Deploy a Vision Application?

The deployment of the vision application can be divided into five phases, as shown in the figure below:

The following table describes the five phases of deploying a vision application.

No.	Phase	Description
1	Vision system hardware setup	Install and connect hardware of the Mech-Mind Vision System.
2	Robot communication setup	Load the robot master-control program and the configuration files to the robot system and set up the communication between the vision side and the robot, thus helping the Mech-Mind Software Suite obtain control over the robot.
3	Hand-eye calibration	Perform the automatic hand-eye calibration in the Eye-to-Hand setup, to establish the transformation relationship between the camera reference frame and the robot reference frame.
4	Carton locating	Use the case project “Single_Case_Cartons” to locate cartons and provide guidance for accurate robot picking.
5	Picking and placing	Build the workflow for a Mech-Viz project to plan a collision-free robot path for picking and placing cartons.

Next, follow subsequent sections to complete the application deployment.

3.1. Vision System Hardware Setup

In this tutorial, you will learn how to build the Mech-Mind Vision System.

Follow the steps below to build the Mech-Mind Vision System: **Check the contents of the package** → **Install the hardware** → **Connect the network** → **Upgrade the software (optional)** → **Confirm** that the vision system can capture images normally.

▶ https://www.youtube.com/watch?v=N8iwcoSjEdU/PLVcMd7cW2rXWbHhTQX8m2R1r6PhX6vrCI *(YouTube video)*

Video Tutorial: Vision System Hardware Setup

Check the Contents of the Package

1. Make sure that the package is intact when you receive it.
2. Check the contents against the "packing list" in the package to ensure that no devices or accessories are missing or damaged.

The following figure shows the devices and accessories included in a vision system shipment. The table below is for reference only. Please take the "packing list" in the package as final.

No.	Category	Name	Function
1	IPC and accessories	IPC (Industrial Personal Computer)	Provision of the Mech-Mind Software Suite
2		IPC accessories	Provision of IPC accessories, such as antennas for WIFI connection
3		IPC power cable and adapter	Supplies power to IPC
4	Camera and accessories	Mech-Eye Industrial 3D Camera	Captures images
5		User manual	Mech-Eye Industrial 3D Camera User Manual and datasheet
6		Camera accessory box	Mounts the camera

No.	Category	Name	Function
7	Project accessories	License dongle	License for the Software Suite
8		Calibration board	Calibrates the camera
9		Flange adapter	Connects the calibration board to the robot flange
10		Camera DC power cable (standard: 20 meters)	Connects the camera and the DIN rail power supply; Longer power cables are an option
11		Camera Ethernet cable (standard: 20 meters)	Connects the camera and the IPC; longer camera Ethernet cables are an option
12		DIN rail power supply (standard)	Supplies power to Mech-Eye Industrial 3D Camera; The camera power adaptor is an option
13	Packing list		List of all the devices and accessories in the package

Contact Mech-Mind if any items are missing or damaged.

Prepare Other Materials

In this tutorial, besides the items in the package, you still need to prepare the materials shown in the following table by yourself.

Item	Function
Monitor	Provides display for the IPC
HDMI cable	Connects the monitor and the IPC
RJ45-to-RJ45 Ethernet cable	Connects the IPC and the robot controller

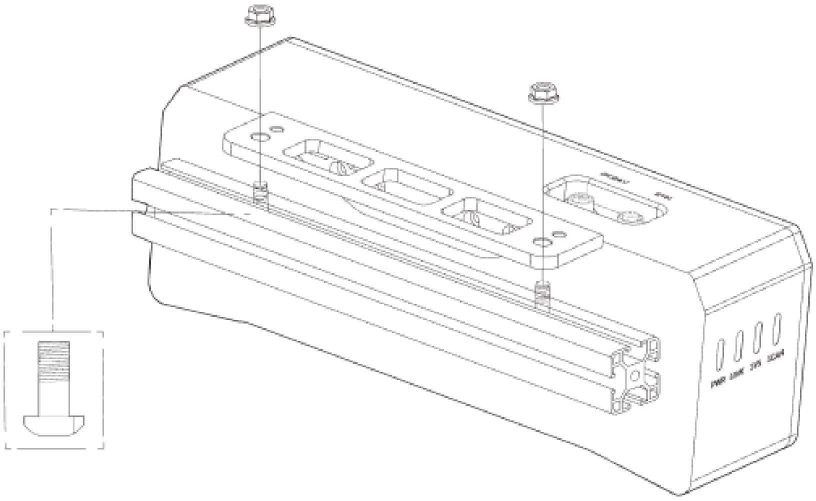
In this tutorial, the IPC and robot controller are directly connected through an RJ45-to-RJ45 Ethernet cable, and the IPC and the camera are directly connected through the camera Ethernet cable. Alternatively, you can use a router to connect the IPC and the robot controller, and the IPC and the camera, which is not covered in this topic.

Install Hardware

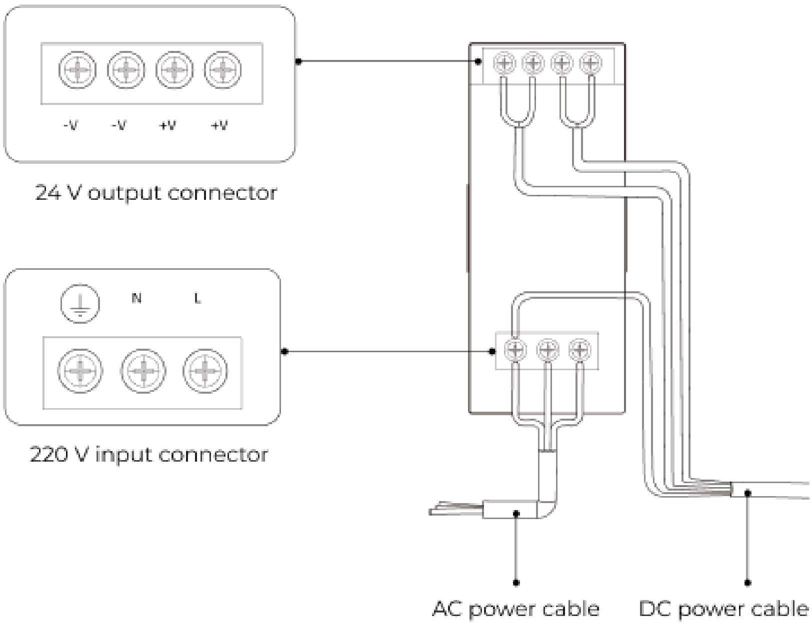
Mount the Camera

In this tutorial, the camera is mounted on the camera mounting frame (that is the Eye to Hand mounting mode). In addition, the camera can also be mounted onto the end terminal of the robot (that is the Eye in Hand mounting mode).

1. Get the camera mounting bolts and wrench from the camera accessory box.
2. Tighten the two bolts with the wrench as shown below.

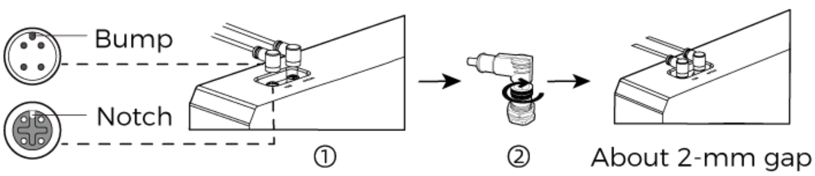


3. Please remove the lens protection film after mounting the camera.
4. Power the camera with the DIN rail power supply.
    - Connect the DC power cable:
        - Connect the +V wire to the +V connectors of the 24 V output connectors;
        - Connect the -V wire to the -V connectors of the 24 V output connectors;
        - Connect the PE wire to the 220 V input connector ⏚.



5. Install the Ethernet cable of the camera.

    Make sure the bump of the M12 connector and the notch of the ETH port, and tighten the nut after plugging in the cable.

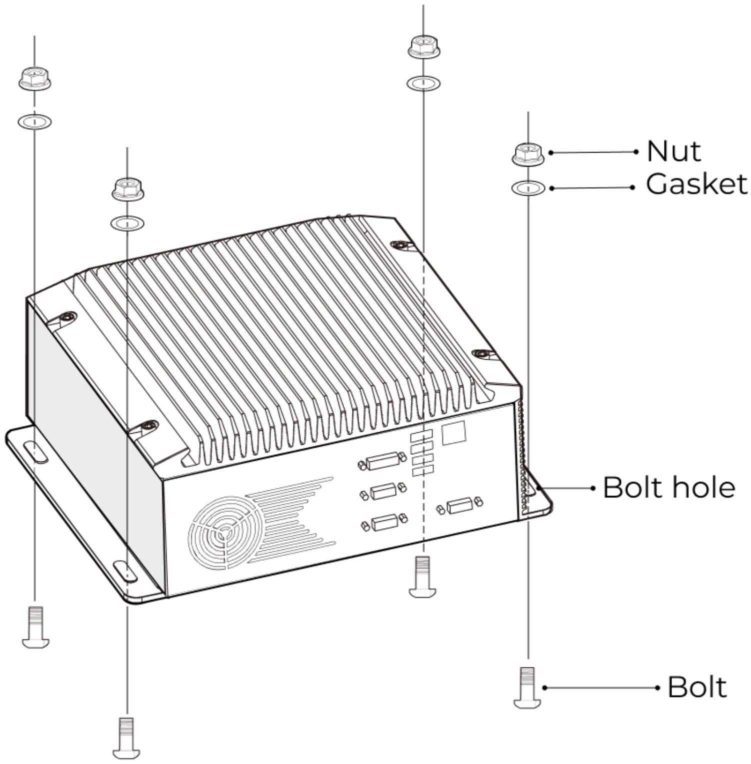


Mount the IPC

> The IPC is normally mounted in the control cabinet of the robot. The environment in which the IPC is mounted requires good heat dissipation, ventilation, and dust protection. It should be mounted at a location where Ethernet cables, HDMI cable, and USB ports can be easily mounted and serviced.

To mount the IPC, follow these steps:

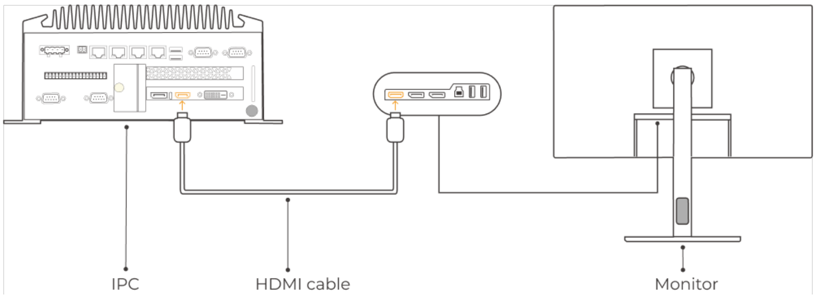
1. Prepare the wrench, bolts, nuts, and gaskets that are not included in the package beforehand.
2. If the robot controller is designed with mounting holes for the IPC in it, secure the IPC in the controller: place the bolt, gasket, and nut one by one, and tighten the two bolts with a wrench, as shown below.



> If the location of the robot controller is already fixed, skip this step and just place the IPC inside the controller.

3. Connect the IPC and the monitor with the HDMI cable.

   Plug one end of the HDMI cable into the HDMI port of the monitor, and the other end into the HDMI port of the IPC, as shown below.



4. Connect the IPC to the power supply unit with the power adaptor.

   Plug the power cable of the power adaptor into the power connector of the IPC. Connect the adaptor to the power supply on the other end.

5. Insert the license dongle.

   Plug the license dongle into a USB port of the IPC.

6. After the IPC is connected to the power supply, switch on the IPC.
   - If the IPC is started normally, the power indicator should be solid on.
   - If the IPC cannot be started, contact Mech-Mind Technical Support.

Connect the Network

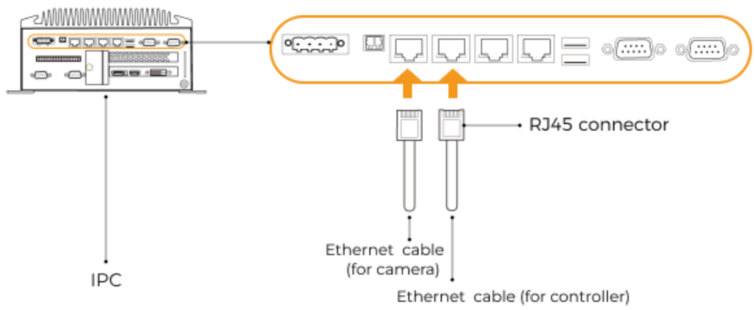
In this section, you will learn how to connect the network between the IPC and the camera, and between the IPC and the robot.

In the following sections, the following IP addresses will be used for network settings. Please adjust the network settings according to your actual network environment.

<table>
<tr><th colspan="2">Device</th><th>IP address</th></tr>
<tr><td rowspan="2">IPC</td><td>Ethernet port connecting to the camera</td><td>192.168.100.10</td></tr>
<tr><td>Ethernet port connecting to the robot controller</td><td>192.168.200.10</td></tr>
<tr><td colspan="2">Camera</td><td>192.168.100.20</td></tr>
<tr><td colspan="2">Robot</td><td>192.168.200.20 (already set on the robot)</td></tr>
</table>

Connect the IPC and the Camera, and the IPC and the Robot Controller

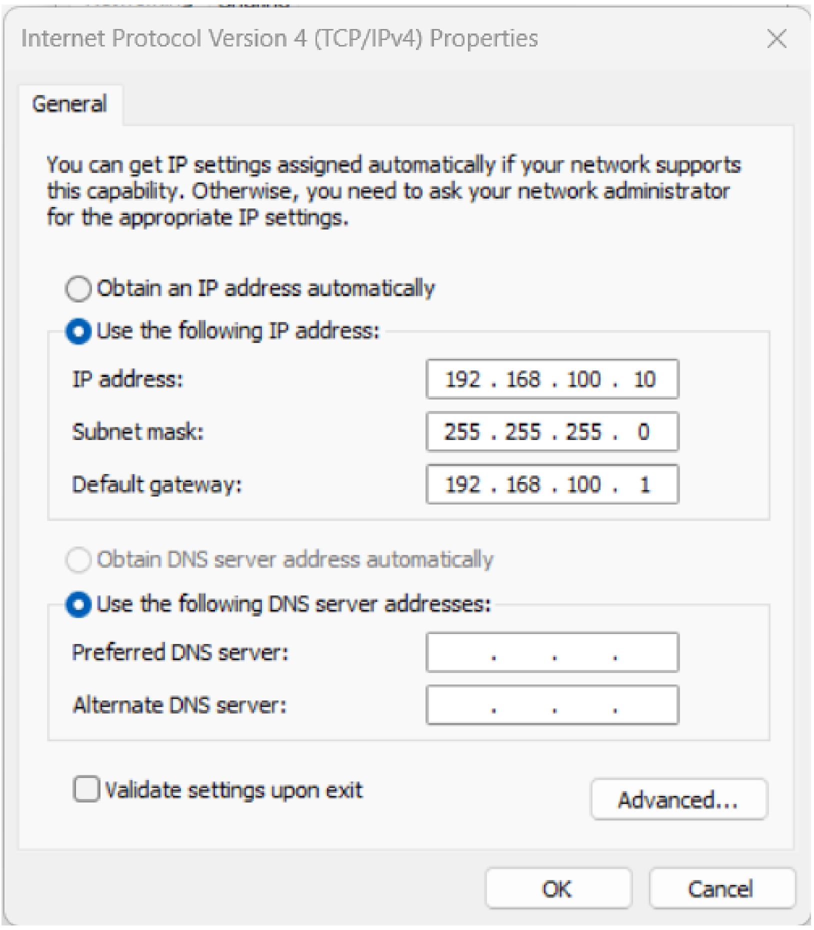
1. Plug the other end of the Ethernet cable connected to the camera into an Ethernet port of the IPC.



2. Use an RJ45-to-RJ45 Ethernet cable to plug one end into the Ethernet port of the robot controller and the other end into an Ethernet port of the IPC.

Set the IP Addresses on the IPC

1. Select Control Panel › Network and Internet › Network and Sharing Center › Change adapter settings on the IPC. The **Network Connections** page will be displayed.
2. Right-click the Ethernet port connected to the camera, and select **Rename** to rename the Ethernet port, such as "To_camera".
3. Right-click the Ethernet port connected to the camera, and select **Properties** to enter the **Ethernet Properties** page.
4. Select the **Internet Protocol Version 4 (TCP/IPv4)** checkbox, and then click the [**Property**] button to enter the **Internet Protocol Version 4 (TCP/IPv4) Properties** page.
5. Select the **Use the following IP address** radio button, set the **IP address** parameter to "192.168.100.10", **Subnet mask** to "255.255.255.0", and **Default gateway** to "192.168.100.1", and then click the [**OK**] button.

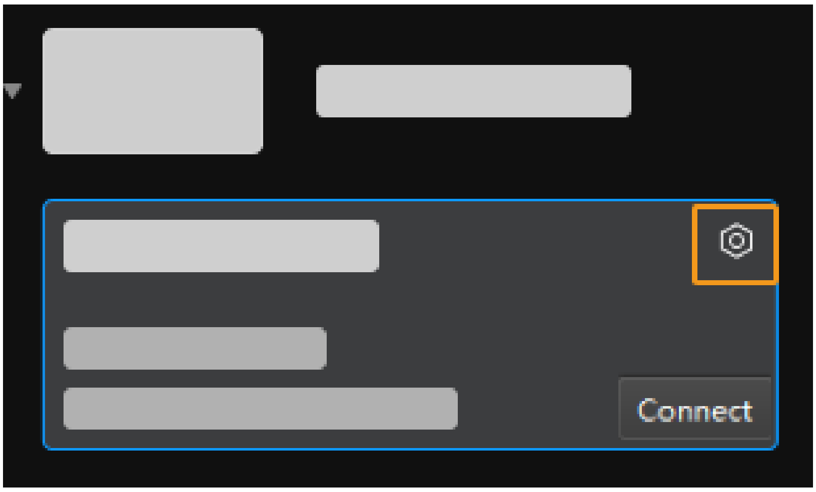


6. Repeat steps 2 to 5 to rename the Ethernet port connected to the robot controller (for example, “To_robot”), and set the IP address for this Ethernet port. For example, set the IP address of this Ethernet port to “192.168.200.10”.

> The IP address of the robot and that of the IPC Ethernet port connected to the robot controller must be on the same subnet.

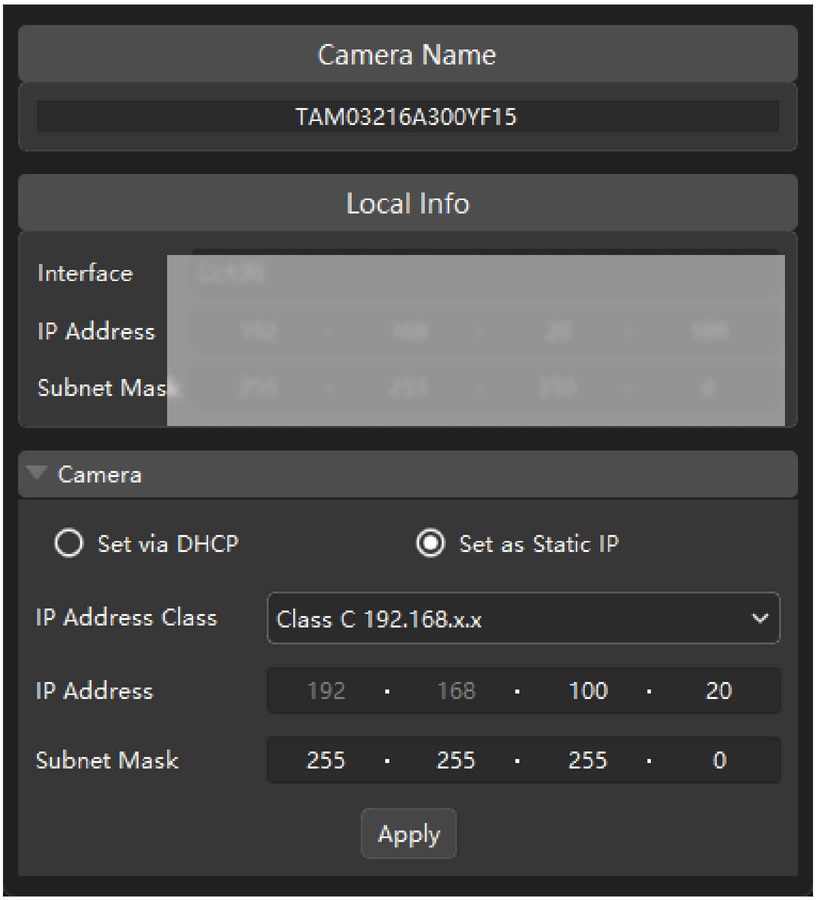
Set the Camera IP Address

1. Double-click on the desktop of the IPC to open and run Mech-Eye Viewer.
2. Select the camera in the camera list, and hover the cursor on the camera. Click to open the **Config Camera Network** dialog box.



If the camera cannot be found or connected, please refer to Camera Troubleshooting.

3. In the **Camera** area, select the **Set as Static IP** radio button, set **IP Address Class** to “Class C 192.168.x.x”, **IP Address** to **192.168.100.20**, and **Subnet Mask** to “255.255.255.0” and then click **[Apply]**.



The IP address of the camera and that of the IPC Ethernet port connected to the camera must be on the same subnet.

Test the Network Connectivity

1. Press `Win` + `R` to open the **Run** dialog box.

2. Type cmd in the **Run** dialog box, and then click **[OK]**.
3. Type **ping XXX.XXX.XX.XX** in the command prompt window and press **[Enter]** to execute the command.

   Replace XXX.XXX.XX.XX with the actual IP address of the camera/robot.

If the network connectivity is normal, you should receive the following response:

```
Pinging XXX.XXX.XX.XX with 32 bytes of data:
Reply from XXX.XXX.XX.XX: bytes=32 time<1ms TTL=128
Reply from XXX.XXX.XX.XX: bytes=32 time<1ms TTL=128
Reply from XXX.XXX.XX.XX: bytes=32 time<1ms TTL=128
Reply from XXX.XXX.XX.XX: bytes=32 time<1ms TTL=128
```

Upgrade the Software (Optional)

The IPC purchased from Mech-Mind already has the latest version of Mech-Mind Software Suite installed.

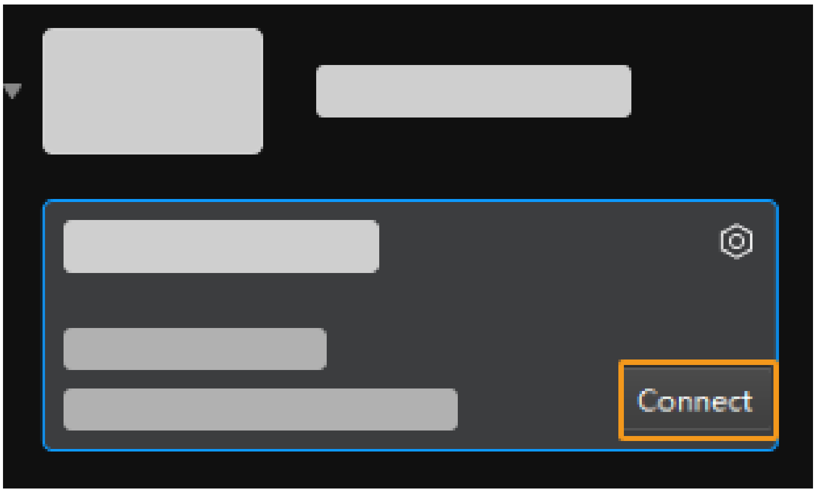
Please check if all software on the IPC is running with the latest version. If so, skip this section; if not, follow the sections below to update the software to the latest versions.

- Downloading and installing Mech-Eye SDK
- Downloading and installing Mech-Vision, Mech-Viz and Mech-Center

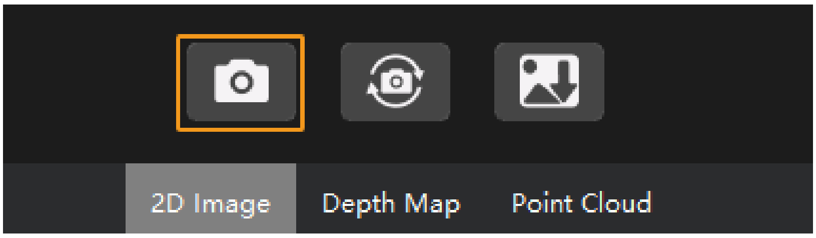
Confirm That the Vision System Can Capture Images Normally

After testing the network connectivity between the IPC and the camera/robot, please confirm that the vision system can capture images normally:

1. Place workpieces at the center of the camera's field of view (FOV), and make sure that the workpieces on the edge and top are all within the FOV.
2. Open and start Mech-Eye Viewer by double-clicking on the desktop of the IPC.
3. Select the camera in the camera list and click **[Connect]**.



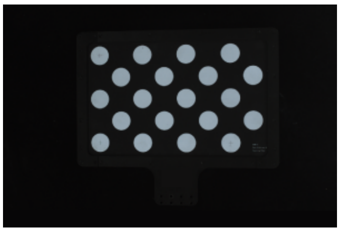
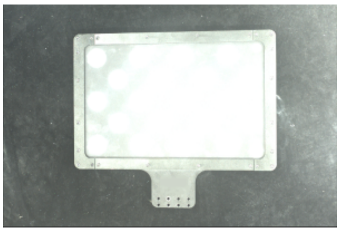
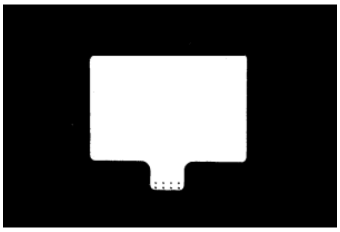
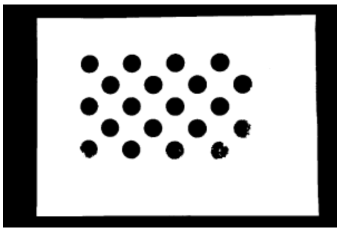
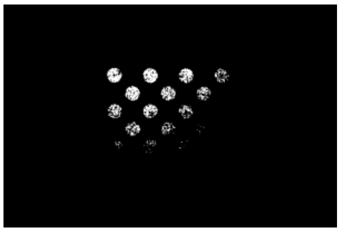
4. After the camera is connected, click **[Capture once]**.



5. Make sure that the captured images meet the following standard.

   ◦ 2D image: the captured 2D image is not significantly overexposed (too white to recognize objects) or underexposed (too dark to recognize object details).

   ◦ Depth map and point cloud: All relevant parts of the object can be recognized.

	Normal	Overexposed	Underexposed
2D image			
Point cloud			

If the captured images do not meet the required standard, please use Mech-Eye Viewer to adjust camera parameters.

Up to now, you have learned how to build the vision system.

3.2. Robot Interface Configuration

In this tutorial, you will learn how to load the Master-Control program files to the ABB robot and configure the Master-Control communication.

- In this section, you will load the robot Master-Control program and the configuration files to the robot system to establish the communication between the vision side and the robot, thus helping the Mech-Mind Software Suite obtain control over the robot.
- If you are using the robots of other brands, you can find instructions on setting up the Master-Control communication configuration with the desired robot from the section Master-Control Communication.

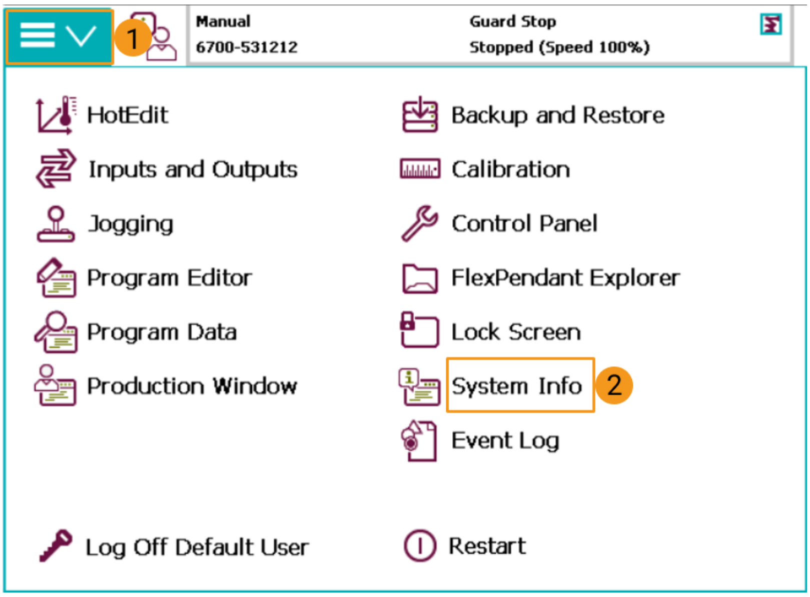
▶ https://www.youtube.com/watch?v=kPFvHWFKlYA/PLVcMd7cW2rXWbHhTQX8m2R1r6PhX6vrCI *(YouTube video)*

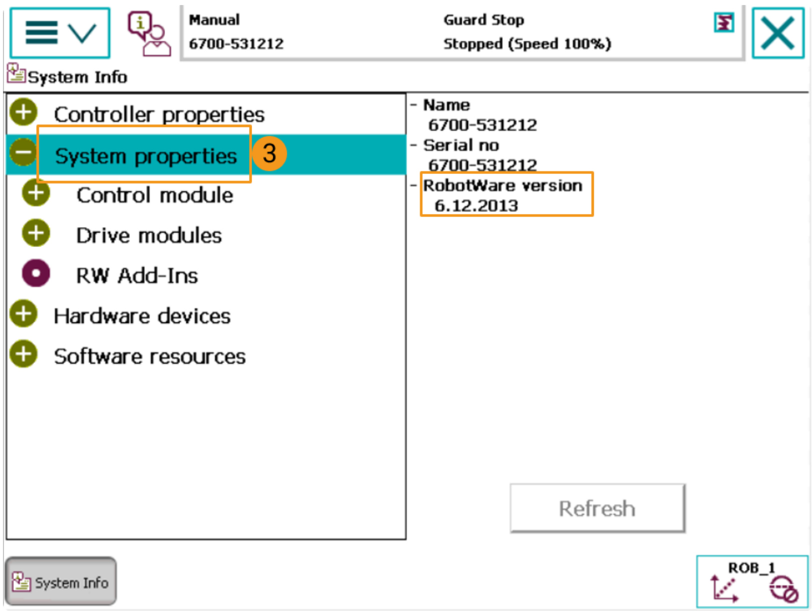
Video Tutorial: Robot Interface Configuration

Preparation

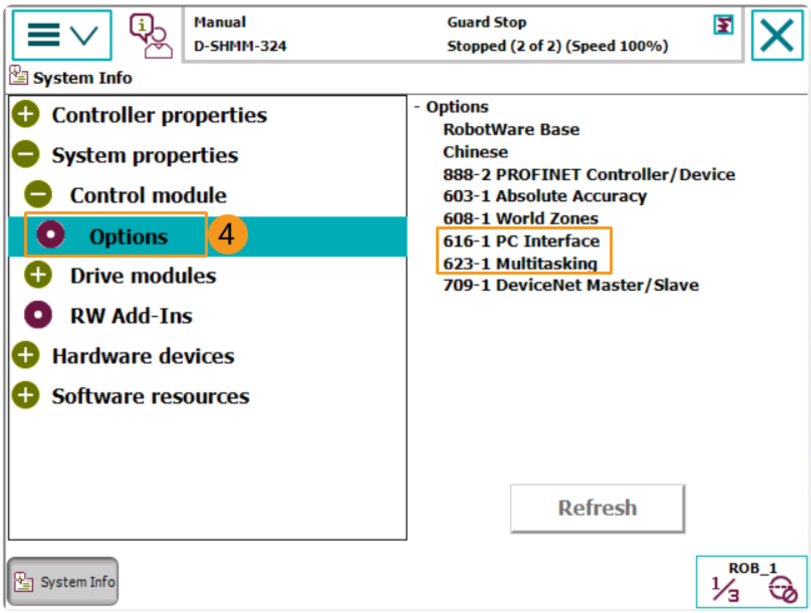
Check the Controller and RobotWare Version

1. Make sure that D652 or DSQC1030 IO board has been installed on the robot controller.
2. Confirm that the RobotWare version is 6.0 or above on the teach pendant.





3. Confirm that the following control modules have been installed on the teach pendant.
   - 623-1 Multitasking
   - 616-1 PCInterface



> If the preceding conditions cannot be met, the vision side cannot communicate with the robot through the master-control mode. Please contact the vendor of your robot.

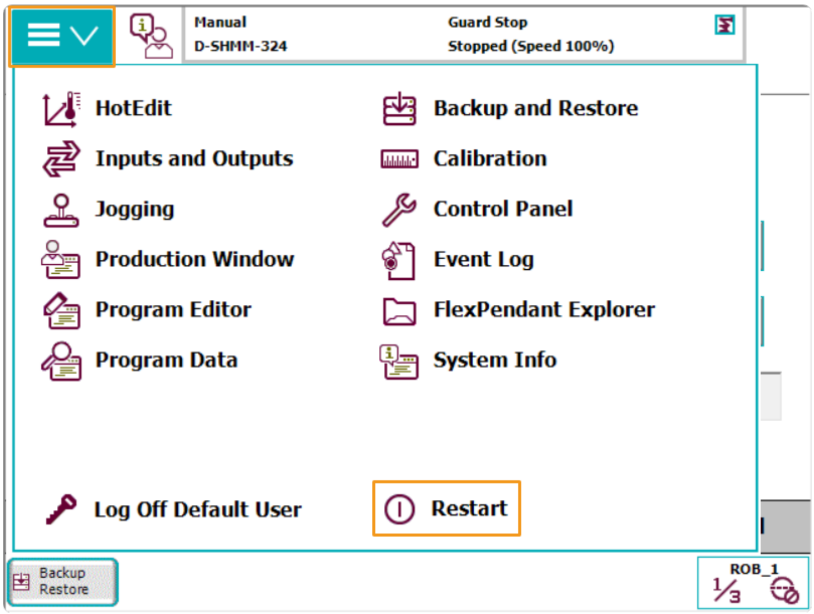
Reset the Robot System

After checking the software and hardware status of the controller, reset the robot system. If you are using a new robot, skip this section.

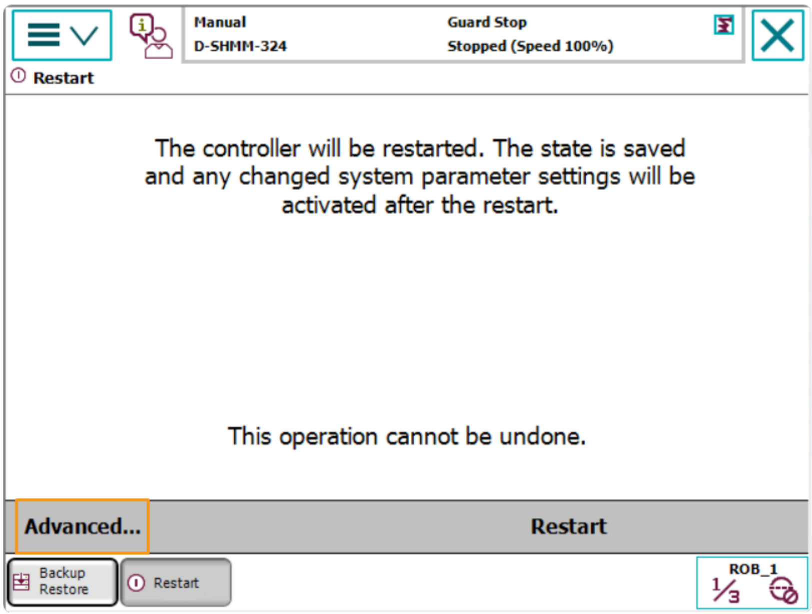
> Resetting the system will restore the factory settings. Please make sure that you have completed the backup operation.

To reset the robot system, follow these steps:

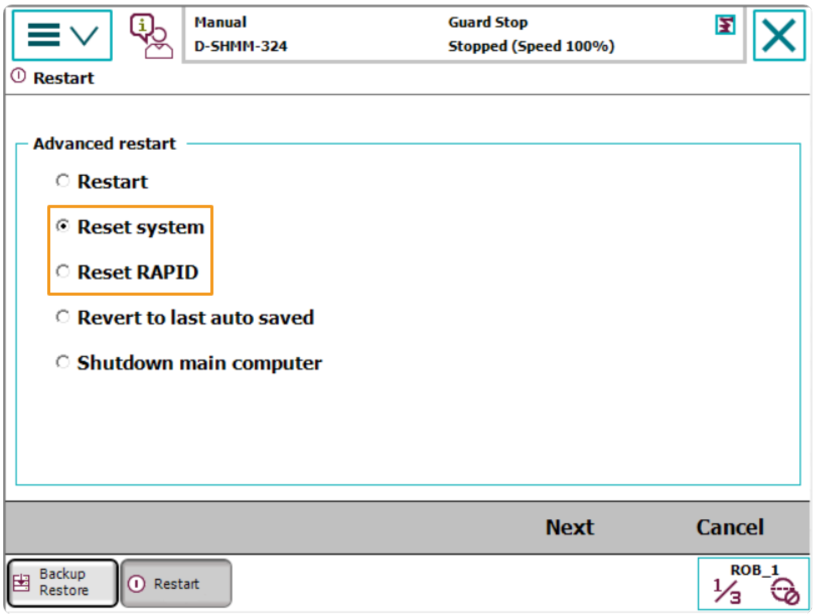
1. On the teach pendant, go to the home page using the menu in the upper-left corner, and then press [Restart].



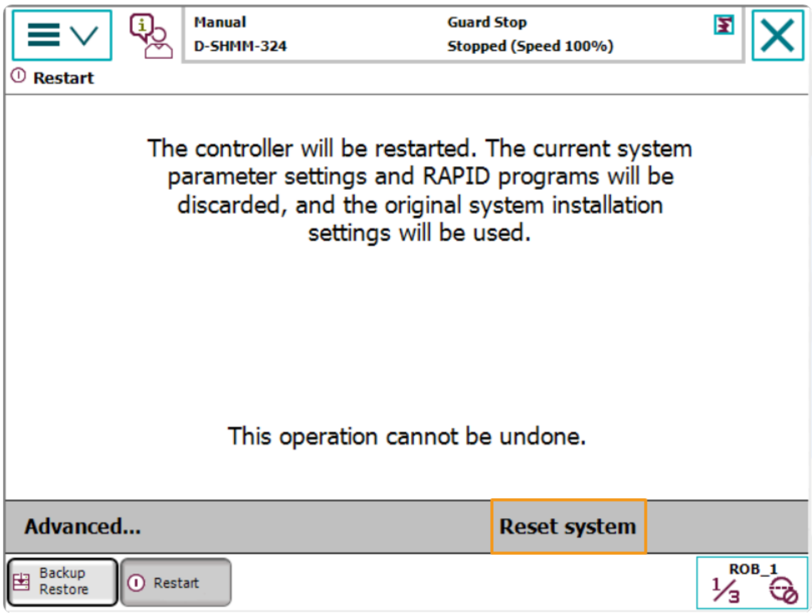
2. Press [Advanced...].



3. Select **Reset system** and then press [**Next**].



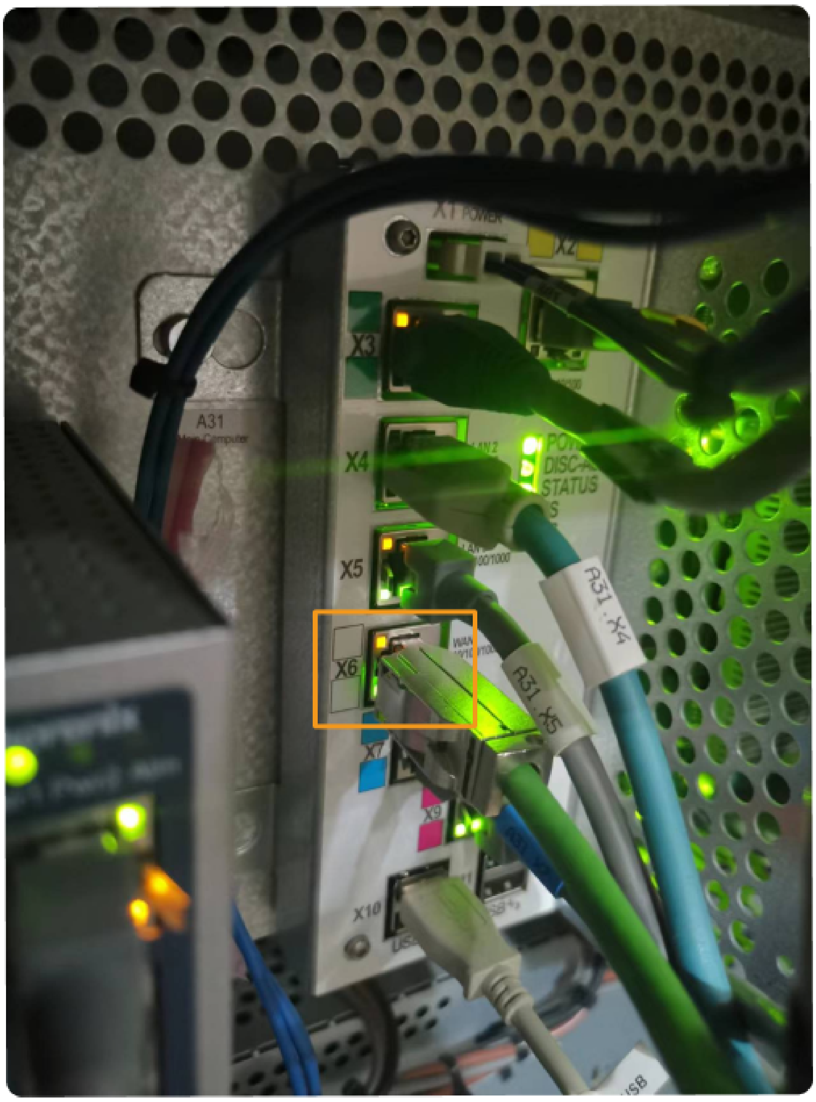
4. Press [**Reset system**].



Resetting the system takes 1 to 2 minutes. Resetting is completed when the home page is displayed again on the teach pendant.

Connect the Network

1. Connect the IPC Ethernet Cable to the **X6 (WAN)** port on the robot controller, as shown below.



2. Make sure that the IP address of the ABB robot and that of the IPC are in the same subnet.

Prepare the Program Files

1. On the IPC, open the `Mech-Center/Robot_Server/Robot_FullControl/abb/server on ABB` folder of the Mech-Mind Software Suite's installation directory.
2. Copy this folder to the USB flash drive, and insert it into the computer installing the RobotStudio software.

> RobotStudio is the simulation and offline programming software for ABB robots. This software can be installed on the IPC or another computer. In this example, RobotStudio is installed on another computer.

File description:

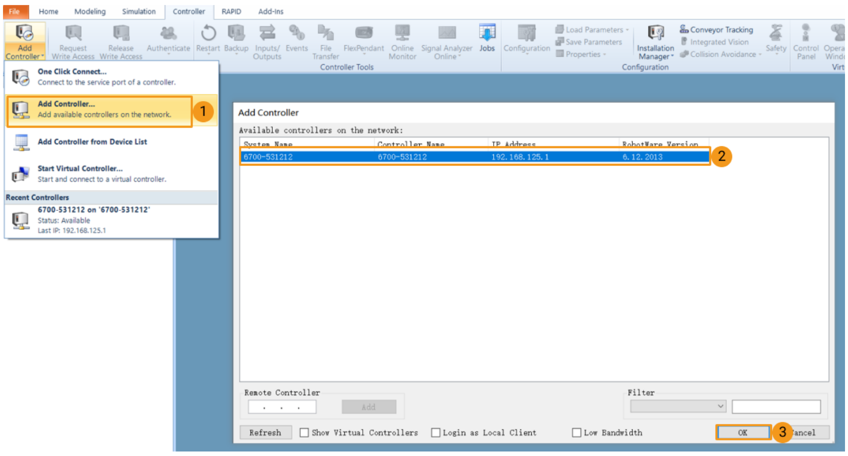
- "MM" folder: includes the robot program modules.
- "config": robot configuration files.
  - If the D652 IO board is used on site, you should use the D652.cfg and SYS.cfg files.
  - If the DSQC1030 IO board is used on site, you should use the DSQC1030.cfg and SYS.cfg files.

- If neither the D652 IO board nor the DSQC1030 IO board is used on site, you should use the EIO.cfg and SYS.cfg files.

Load the Program Files to the Robot

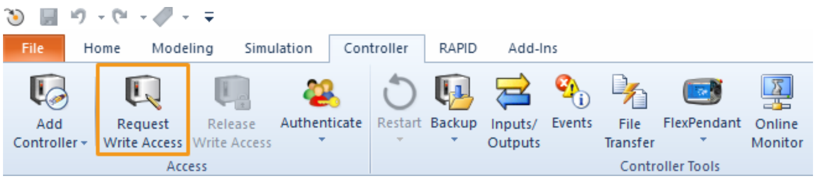
Open RobotStudio and Connect to the Controller

Click the **Controller** menu of RobotStudio, and select Add Controller › Add Controller on the toolbar. In the prompted **Add Controller** dialog box, select the controller, and click the **[OK]** button.



Obtain Write Access to the Robot

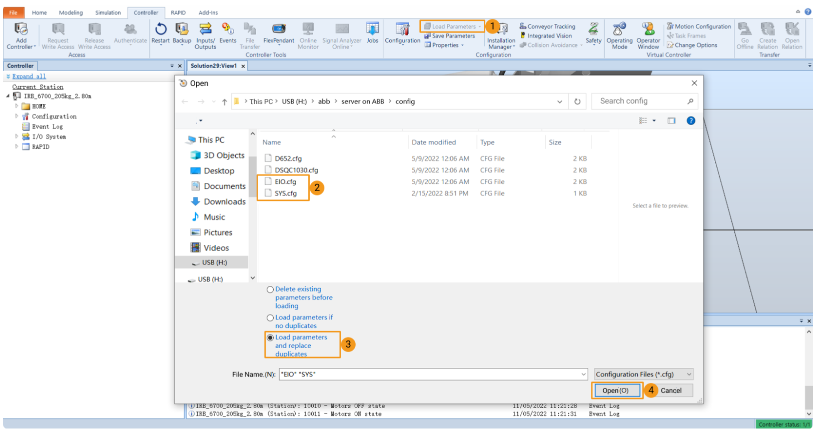
1. On the toolbar, click **Request Write Access** to request the write access to the teach pendant.



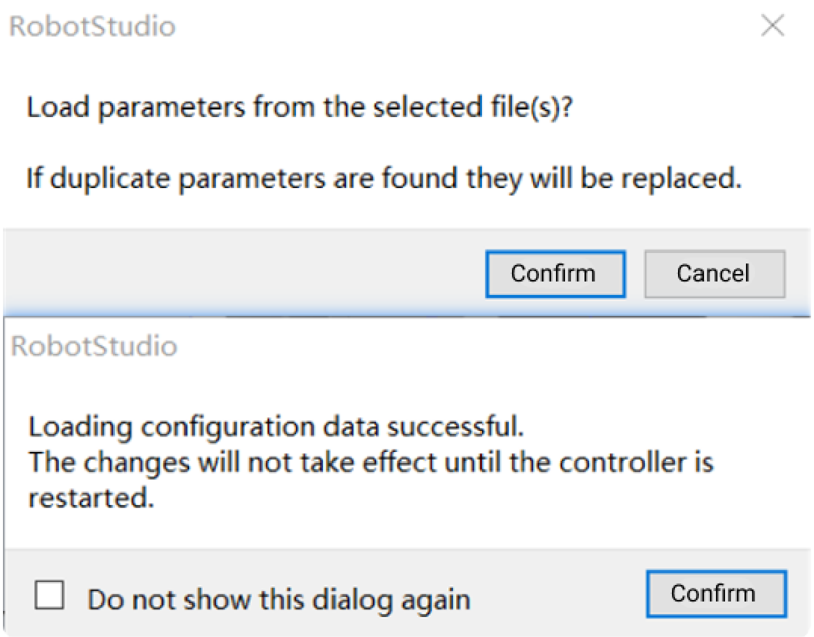
2. In the prompted **Request for Write Access** dialog box on the teach pendant, tap **[Grant]**.

Load the Robot Configuration Files

1. Click the **Controller** menu of RobotStudio, and select Load Parameters on the toolbar. Select the configuration files to import from the USB flash drive, select the **Load parameters and replace duplicates** radio button, and then click the **[Open]** button.

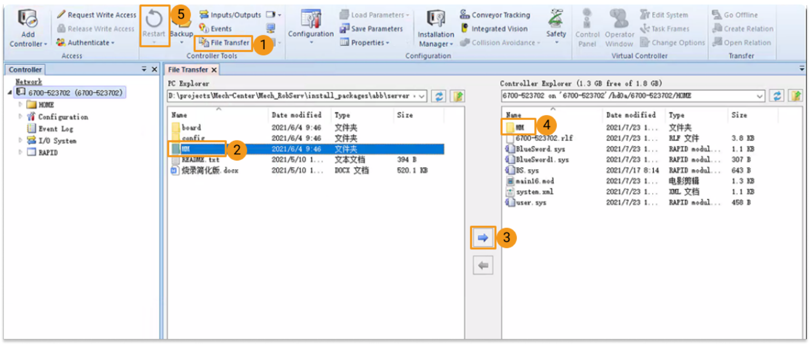


2. In the prompted dialog boxes, click [Confirm].



Load the Robot Program Modules

1. Click the **Controller** menu of RobotStudio, and select **File Transfer** on the toolbar. On the left panel of the **File Transfer** interface, select the “MM” folder, and then click the **Transfer** button to transfer this folder to the HOME directory of the robot system.



2. Click the **Controller** menu of RobotStudio, and select **Restart** on the toolbar to restart the robot system.

Till now, you have loaded the master-control program and the configuration files to the robot.

Test Whether Master-Control Communication Can Be Established

After the robot system has been rebooted, perform the following steps to test whether the master-control communication can be established with the robot:

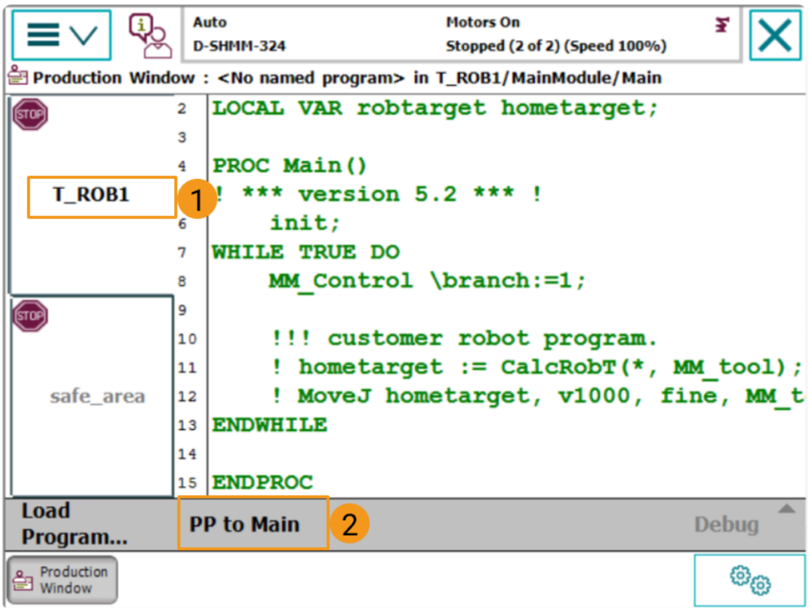
Switch the Robot to Automatic Mode

1. In the robot controller, switch the robot to the automatic mode by using the switch key.
2. In the prompted dialog box on the teach pendant, tap [Confirm].
3. In the robot controller, press the motor power button to power up the robot. When the robot is

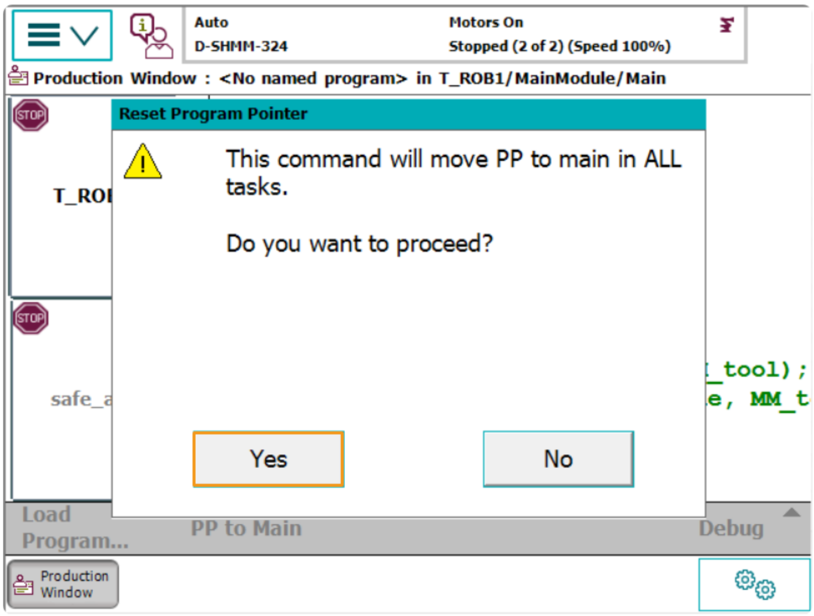
powered on, this button is solid on.

Run the Main Program

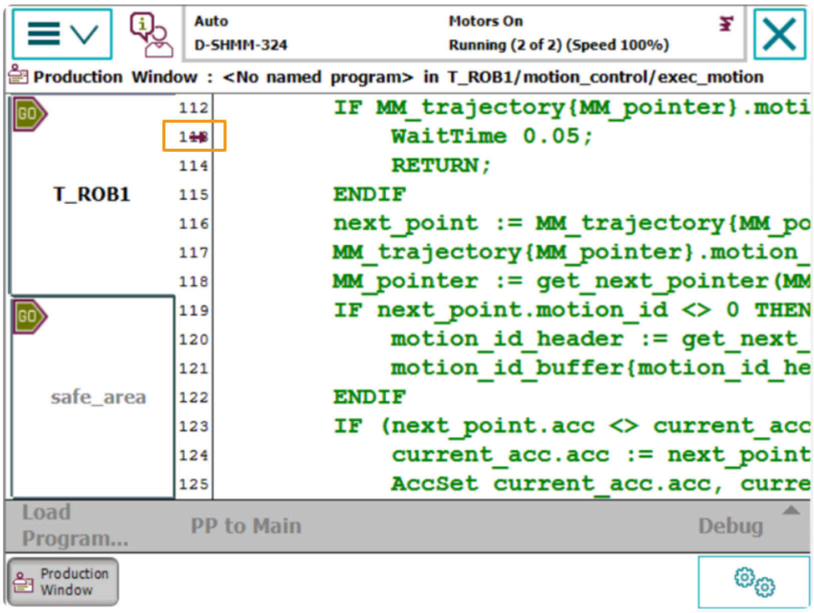
1. On the teach pendant, move the PP of tasks T_ROB1 to main, and tap [PP to Main].



2. In the prompted dialog box, click [Yes].

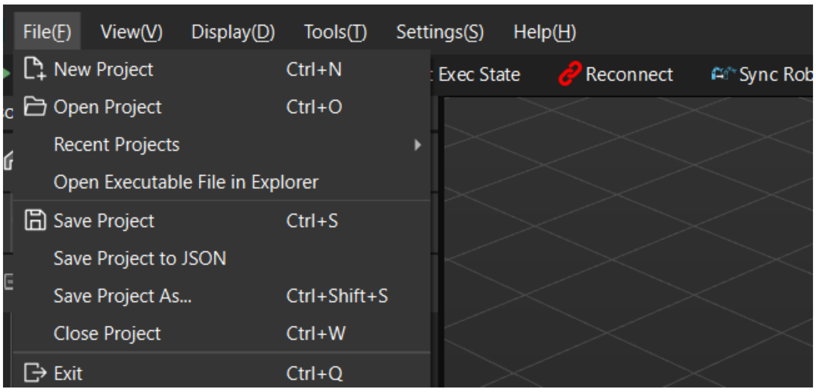


3. Press the run button on the right of the teach pendant.

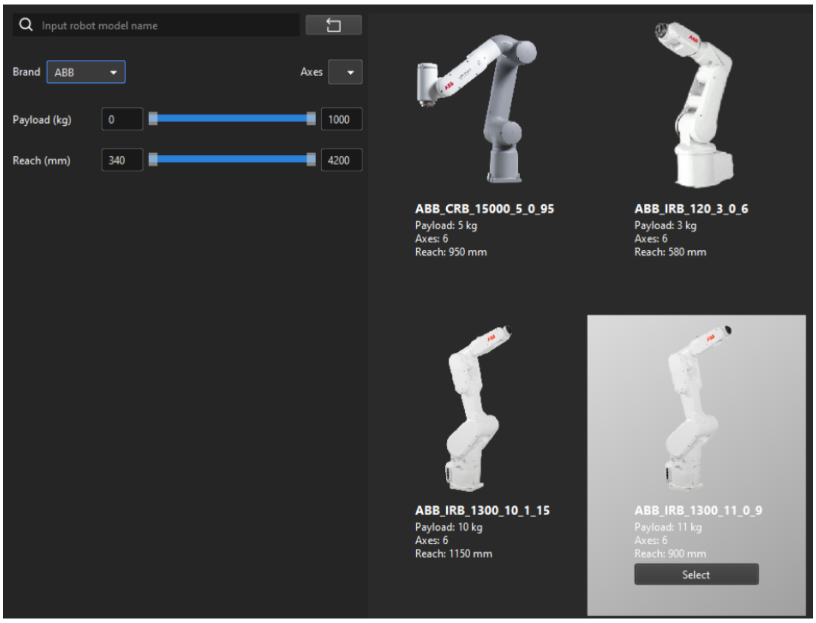


Create a Mech-Viz Project

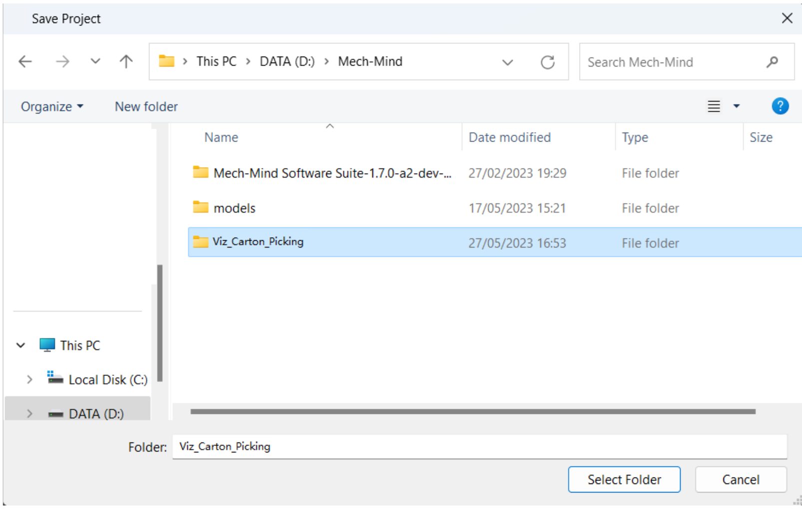
1. Open Mech-Viz, select File › New Project.



2. Set **Brand** to “ABB”, select the robot model “ABB_IRB_1300_11_0_9” on the right panel, and then click [**Select**].

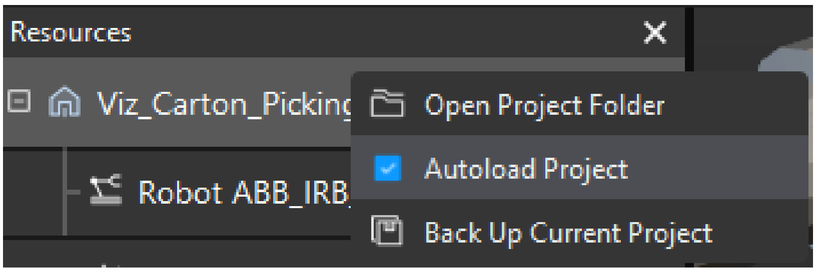


3. Press `Ctrl` + `S`, create a new folder named "Viz_Carton_Picking", select it, and then click [**Select folder**].

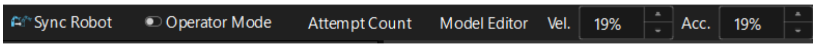


After the Mech-Viz project is saved successfully, in the **Resources** panel, the project name is displayed as "Viz_Carton_Picking".

4. Right-click the project name, and select **Autoload project** checkbox.



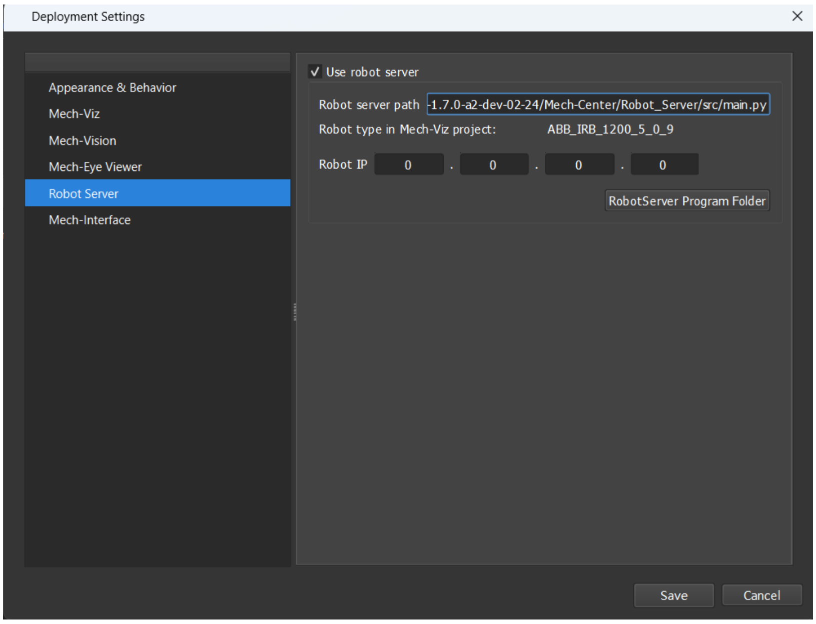
5. For the robot motion safety, on the toolbar, set **Vel.** (velocity) and **Acc.** (acceleration) to a small value, such as 5%.



6. Press `Ctrl` + `S` to save the project.

Configure Master-Control Communication Settings on Mech-Center

1. Open Mech-Center, select Deployment Settings › Robot Server, and then select **Enable Robot Server** checkbox.
2. Make sure that the robot model matches the real robot, set **Robot IP** to the IP address of the real robot, and then click **[Save]**.



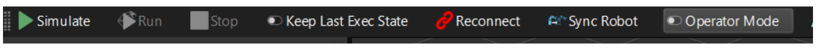
Connect to the Robot

In Mech-Center, click **Connect Robot** on the toolbar.

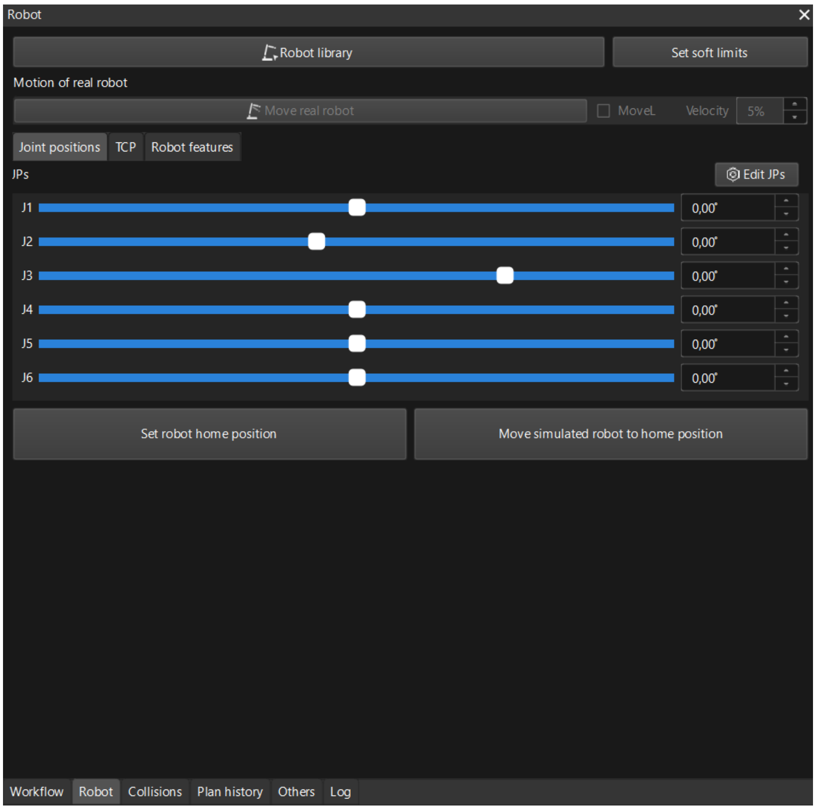
- If the robot is successfully connected, a robot icon with the robot model will be displayed in the Service Status bar, and the corresponding message is printed in the Log panel.
- If the connection fails, please check if any of the operations so far was incorrect.

Move the Robot

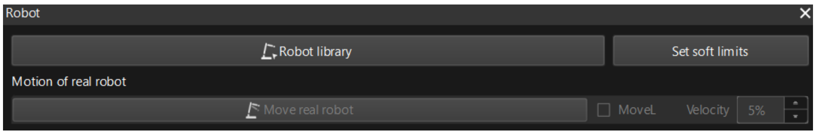
1. In Mech-Viz, click **Sync Robot** in the toolbar to synchronize the pose of the simulated robot to that of the real robot. Then, click **Sync Robot** again to disable the synchronization.



2. On the **Robot** tab, change the joint position of J1 slightly (for example, from 0° to 3°). The simulated robot will move accordingly.



3. Click [**Move real robot**].



When moving the robot, please ensure the safety of personnel. In the case of an emergency, press the emergency stop button on the teach pendant!

If you observe that the real robot moves to the pose of the simulated robot, the master-control communication has been established successfully.

3.3. Hand-Eye Calibration (Master-Control)

In this tutorial, you will perform the automatic hand-eye calibration in the Eye-To-Hand setup.

The hand-eye calibration establishes **the transformation relationship between the camera and robot reference frames (that is camera extrinsic parameters)**. With this relationship, the object pose determined by the vision system can be transformed into that in the robot reference frame, which guides the robot in performing its tasks.

▶ https://www.youtube.com/watch?v=u4m1Jsklfk8/PLVcMd7cW2rXWbHhTQX8m2R1r6PhX6vrCI *(YouTube video)*

Video Tutorial: Hand-Eye Calibration (Master-Control)

Preparation before Calibration

In this section, you will mount the calibration board, adjust the camera parameters, and complete the pre-calibration configuration.

Mount the Calibration Board

> In the Eye to Hand scenario, the calibration board needs to be mounted to the robot flange adapter.

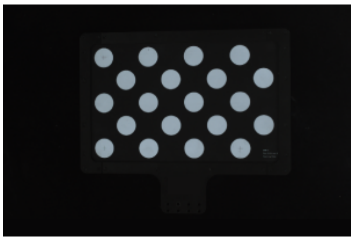
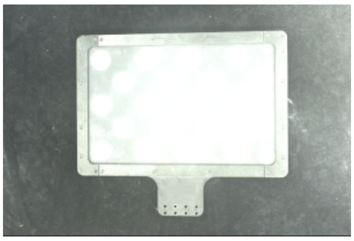
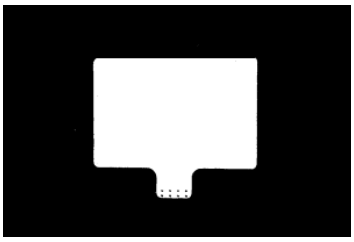
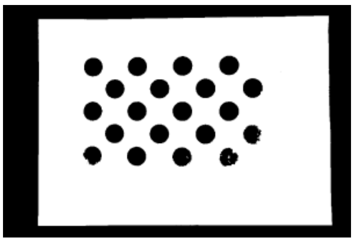
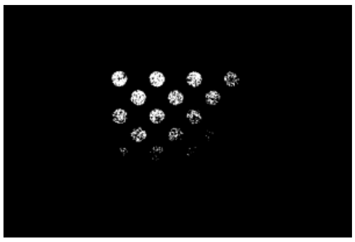
Follow these steps:

1. Take the calibration board and flange adapter out of the system delivery package.
2. Use screws, gaskets, and nuts to fasten the flange adapter to the flange adapter.
3. Use screws, gaskets, and nuts to secure the calibration board to the flange adapter.
4. After mounting the calibration board, move the robot to the top of the lowest workpiece in the work area and into the camera FOV.

Adjust Camera Parameters

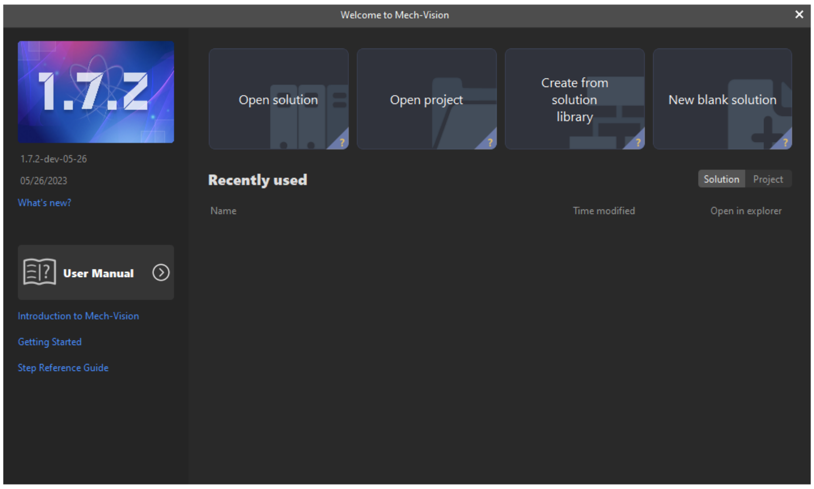
1. In Mech-Eye Viewer, connect to the camera, and then set **Parameter Group** to “calib”.

2. Adjust the 2D parameters to make sure that the 2D image of the calibration board is clear and neither overexposed nor underexposed.
3. Adjust 3D parameters to make sure that the obtained point clouds of the circles on the calibration board are complete and have clear contours. It is recommended to set the **Surface Smoothing** and **Outlier Removal** parameters of **Point Cloud Processing** to **Normal** to reduce point cloud fluctuation.

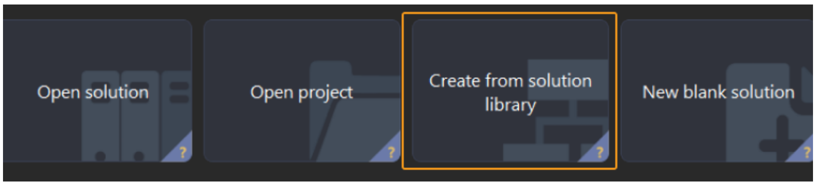
	Normal	Overexposed	Underexposed
2D image			
Point cloud			

Create a Mech-Vision Project and Save It

1. Open Mech-Vision. When the welcome interface as shown below is displayed, it indicates that Mech-Vision is started successfully.

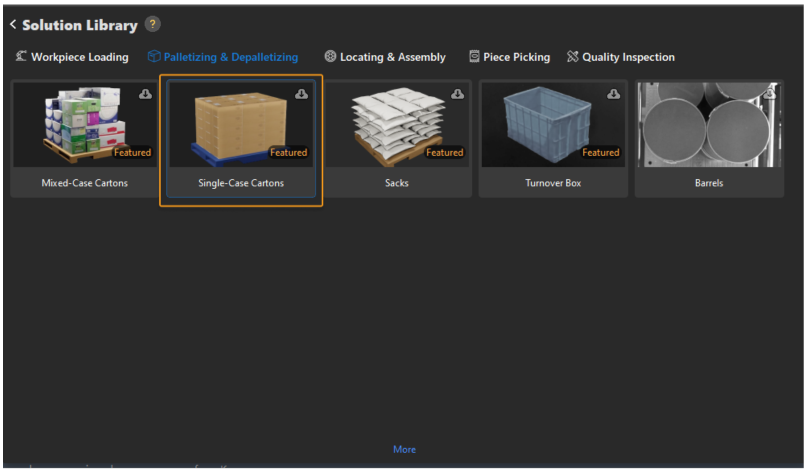


2. In the Welcome interface of Mech-Vision, click [**Create from solution library**] to open the Solution Library.



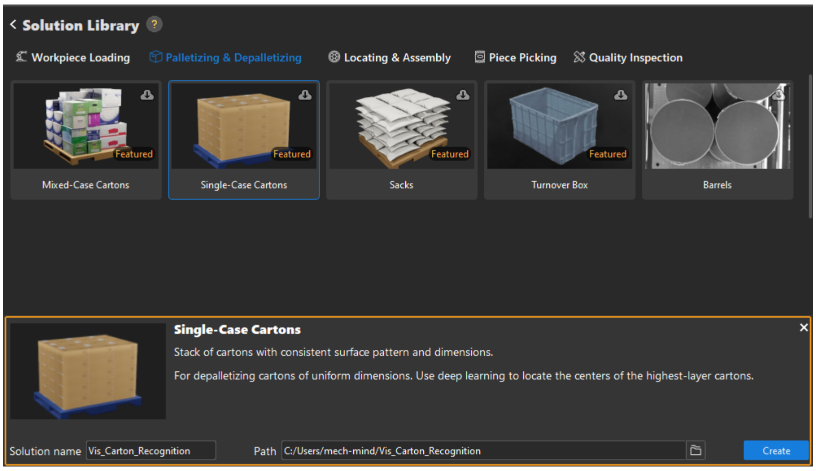
Solution Library is a resource library that provides typical solutions or projects (with example data) coming from different application scenarios.

3. Select the **Single-Case Cartons** project from the Solution Library.



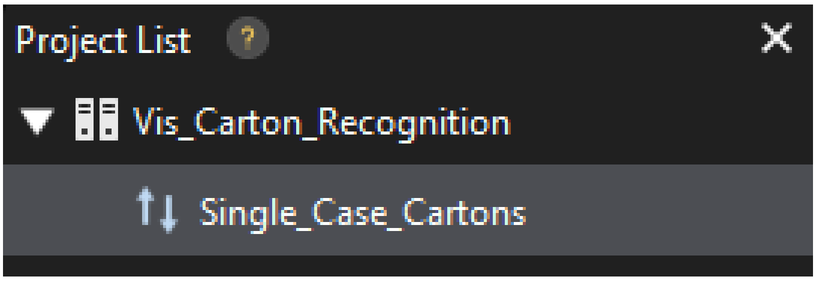
If you cannot find this project in the Solution Library, click [**More**] at the bottom of the Solution Library interface.

4. After this project is selected, the information introducing this project will be displayed on the lower part of the Solution Library interface. Set the solution name and path, and then click [**Create**].

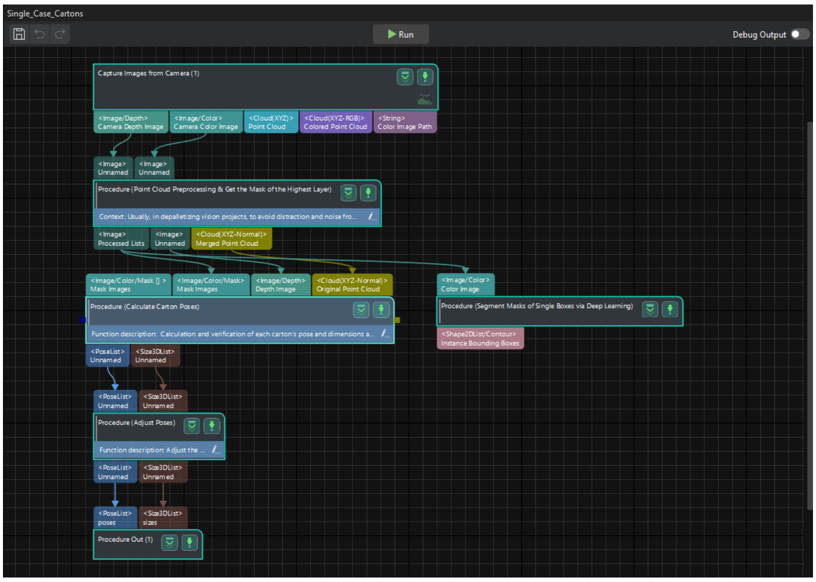


After the project is created, the created solution and project will be displayed in the project list in the upper-left corner of the Mech-Vision main interface.

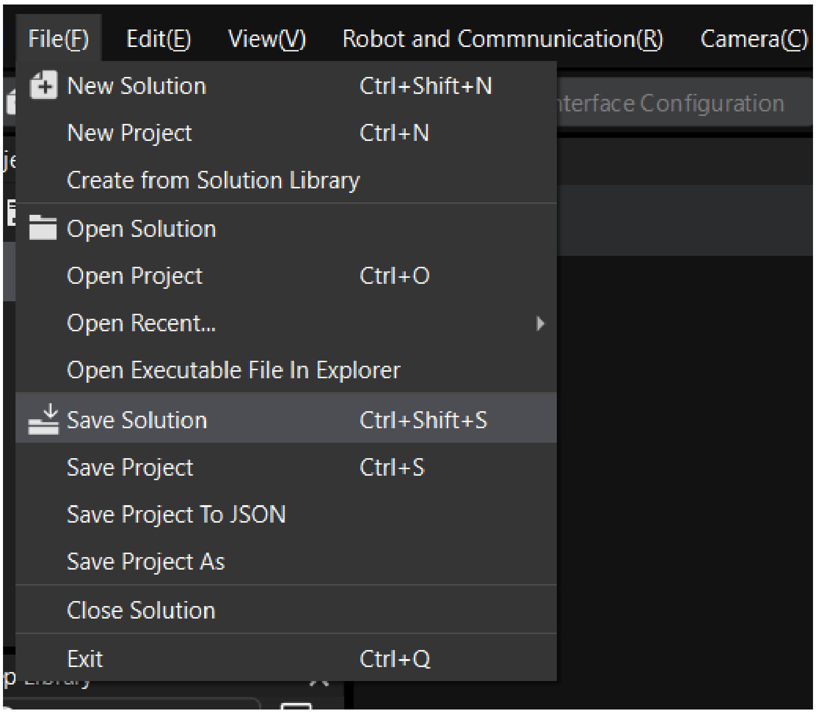
- A **solution** is a set of configurations and data concerning robot and robot communication, vision processing, path planning, etc. that are required for the application of machine vision.
- A **project** is a workflow of vision processing in the solution. Usually, a solution only contains a project, but it may contain more than one project in complex application scenarios. In this tutorial, the solution only needs one project.



In the Graphical Programming Workspace of the main interface, the workflow of the “Single-Case Cartons” project will be displayed.

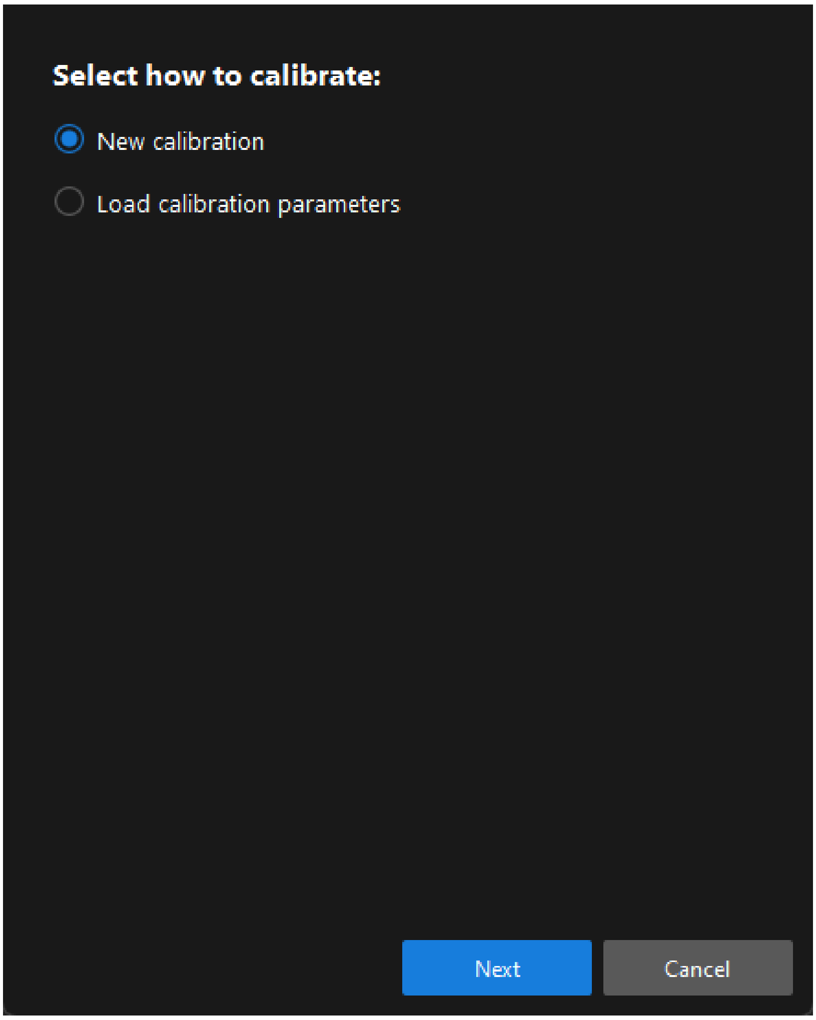


5. On the menu bar, select File › Save Solution.

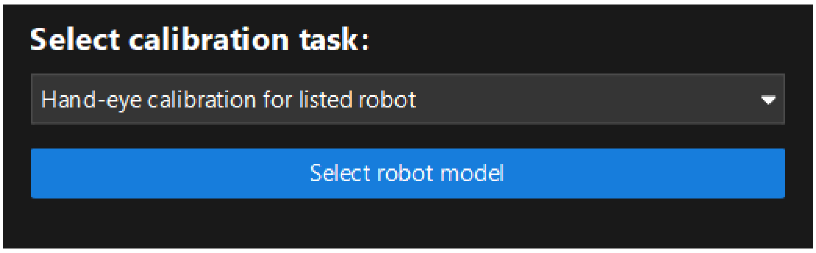


Pre-calibration Configuration

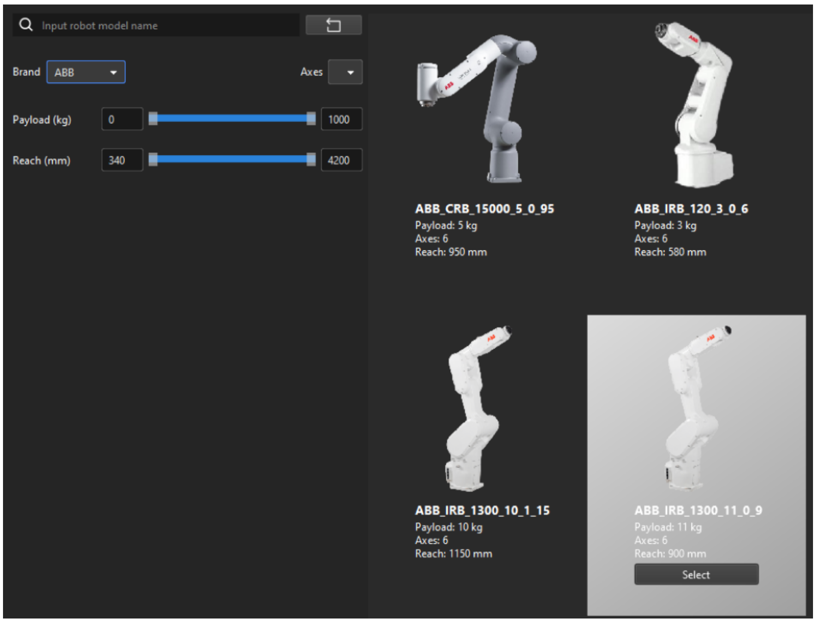
1. In Mech-Vision, click the [**Camera Calibration (Standard)**] on the toolbar. The **Configuration before Calibration** window will be prompted.
2. In the **Select how to calibrate** window, select the **New calibration** radio button, and then click the [**Next**] button.



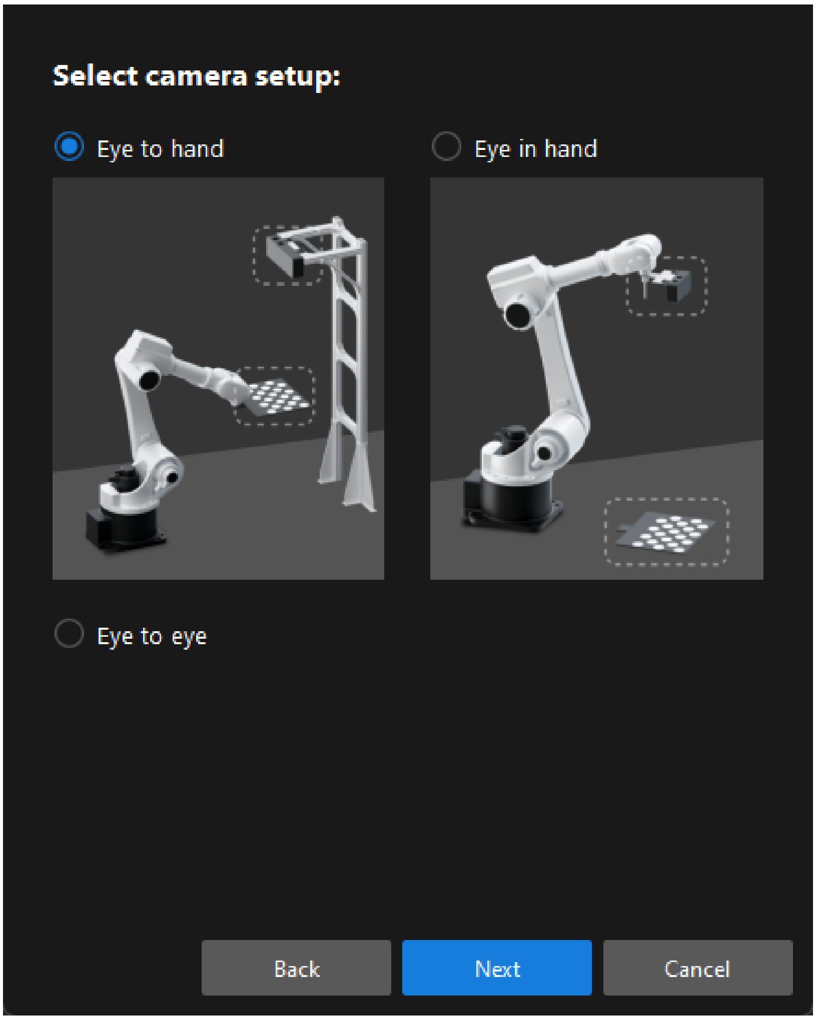
3. In the **Select calibration task** window, select **Hand-eye calibration for listed robot** from the drop-down list box, and click the **[Select robot model]** button.



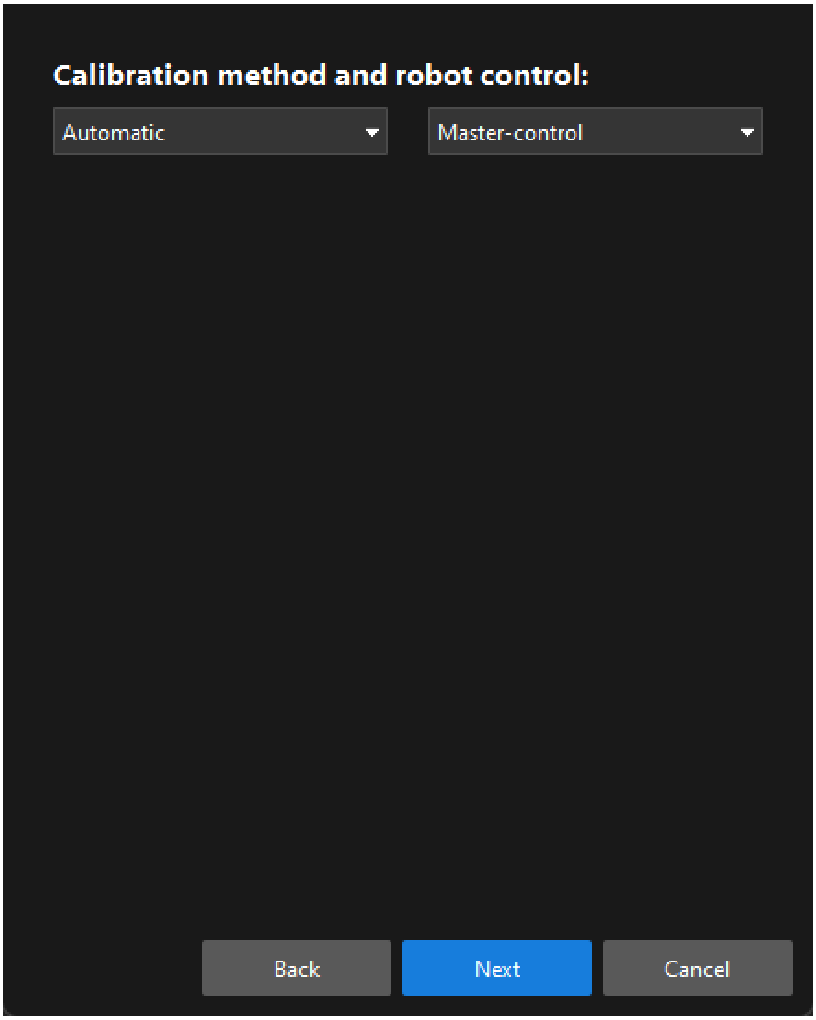
4. Click the **Brand** dropdown box, and select “ABB”. Then, at the right panel, select model “ABB_IRB_1300_11_0_9”, click the **[Select]** button, and then click the **[Next]** button.



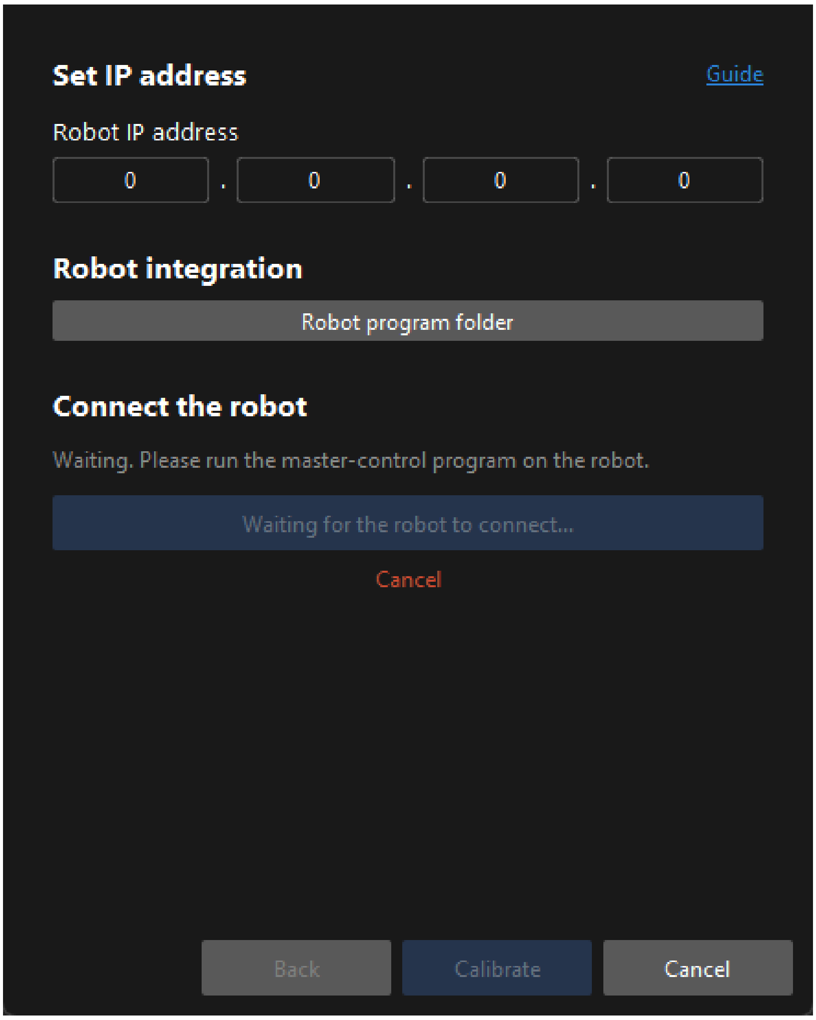
5. In the **Select camera setup** window, select the **Eye to hand** radio button, and then click the [Next] button.



6. In the **Calibration method and robot control** window, select **Automatic** and **Master-control**, and then click the [Next] button.



7. In the **Communication Settings** window, set the **Robot IP address** parameter to the real robot's IP address.

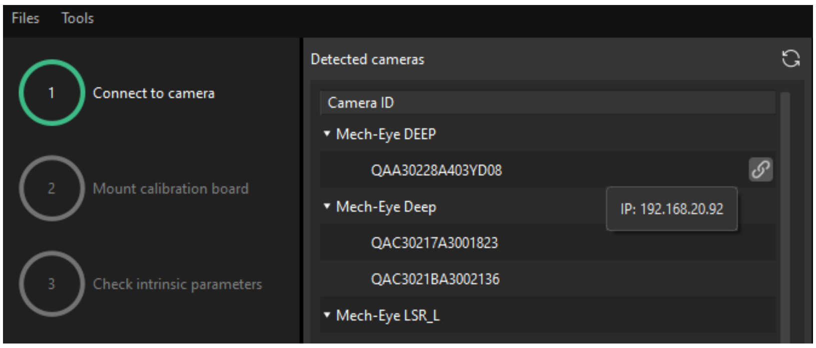


8. On the robot teach pendant, confirm that the MM main program has been started.
9. Return to Mech-Vision, and click the **[Connect the robot]** button in the **Connect the robot** area. The button will turn into **Waiting for the robot to connect...**
10. Wait until the “Connected” status message is displayed in the **Connect the robot** area, and then click the **[Calibrate]** button. The **Calibration (Eye to Hand)** window will be prompted.

Calibration Procedure

Connect to the Camera

1. In the **Connect to Camera** step, find the camera to connect in the **Detected Cameras** list, and click the button.

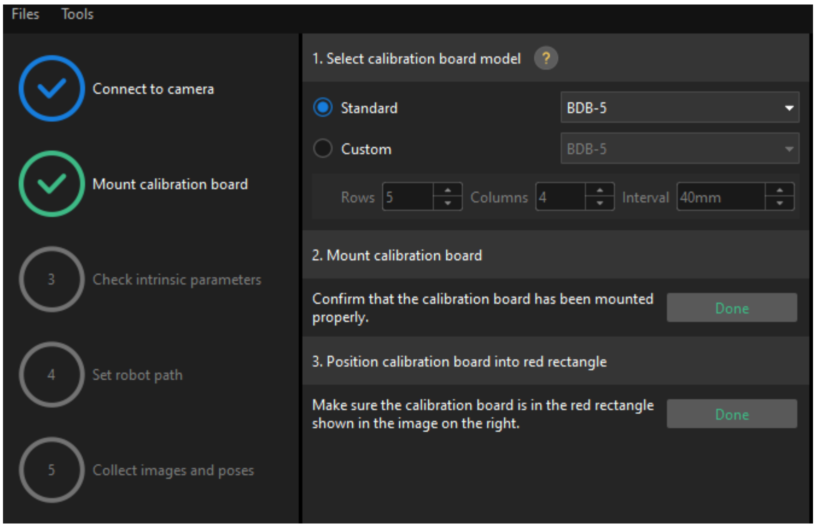


2. After the camera is connected, click the **[Capture once]** or **[Capture live]** button.
3. In the right **Image viewer** panel, ensure that the captured 2D image and depth map meet the calibration requirements and click the **[Next]** button on the bottom bar.

> If the captured image does not meet the calibration requirements, you need to open the Mech-Eye Viewer software to adjust the 2D and 3D exposure parameters and re-capture images.

Mount the Calibration Board

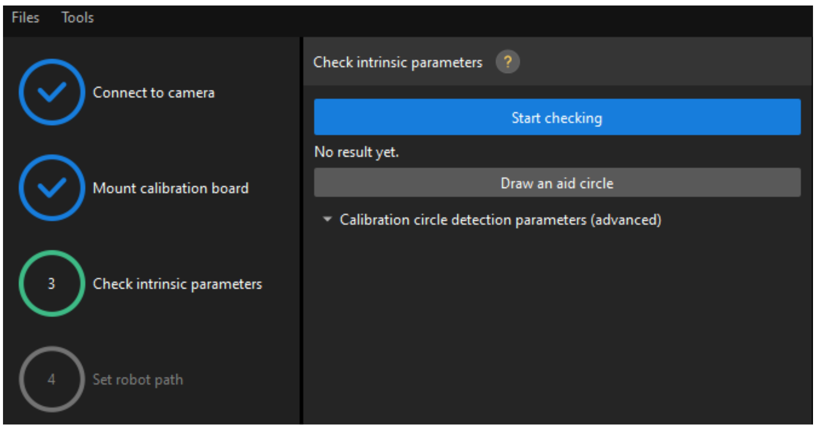
1. In the **Mount calibration board** step, select the **Standard** radio button and select the calibration board model according to its model nameplate in the **1. Select calibration board type** area.
2. Make sure that the calibration board has been attached to the robot flange securely, and then click the **[Confirm]** button in the **2. Mount calibration board** area.
3. Confirm that the calibration board is in the center of the camera's field of view (the red rectangle), and then click the **[Confirm]** button in the **3. Position calibration board into red rectangle** area.



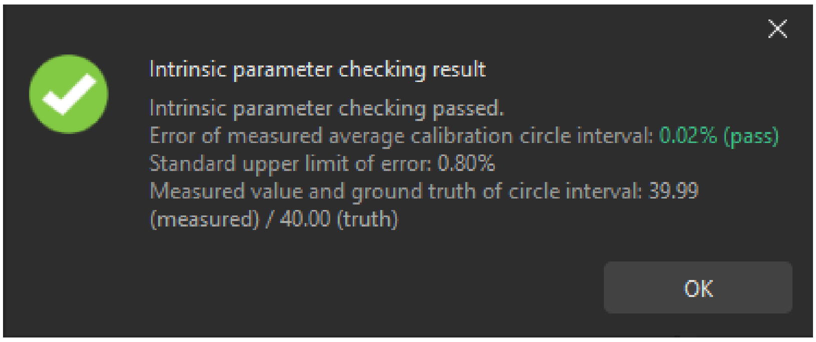
4. After all the operations related to the calibration board are completed, click the **[Next]** button on the bottom bar.

Check Intrinsic Parameters

1. In the **Check intrinsic parameters** step, click the **[Start checking]** button.



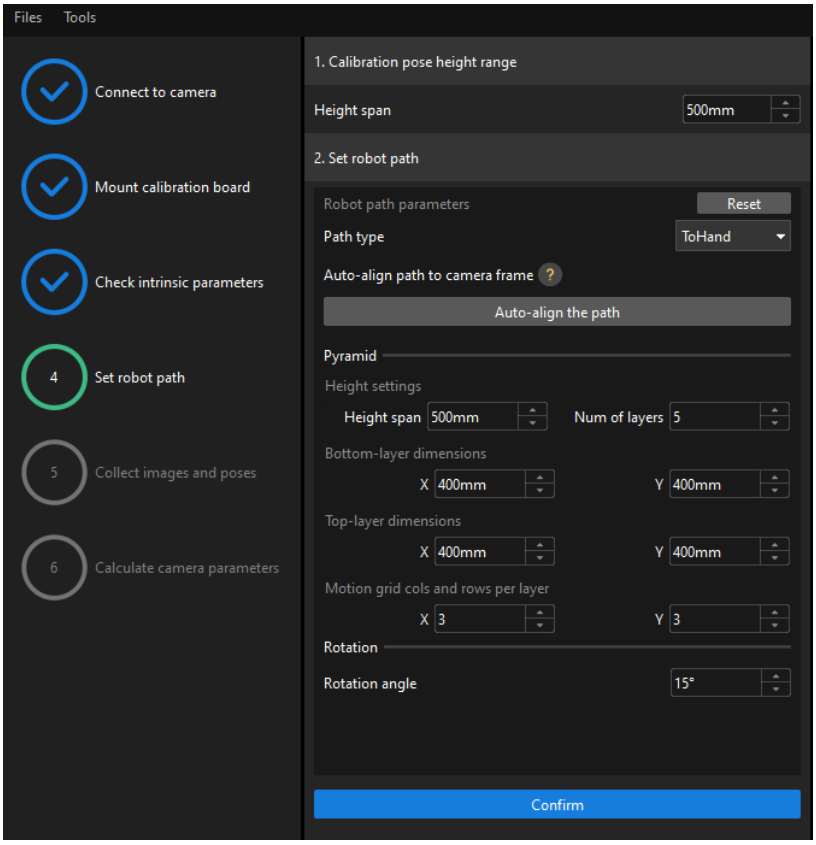
2. Confirm that the camera intrinsic parameters check passes, and then click the [**Next**] button on the bottom bar.



If the camera intrinsic parameter check fails, adjust detection parameters by drawing aid circles or manually adjusting the calibration circle detection parameters.

Set Robot Path

1. In the **Set robot path** step, specify the **Height span** parameter. Please set this parameter according to the working distance range of the calibration board in the camera height direction.



2. Set the **Path type** to **ToHand**, specify the pyramid parameters **Height span**, **Num of layers**, **Bottom-layer dimensions X/Y**, **Top-layer dimensions X/Y**, and **Motion grid cols and rows per layer**, specify the satellite parameter **Rotation angle**, and then click the [**Confirm**] button.

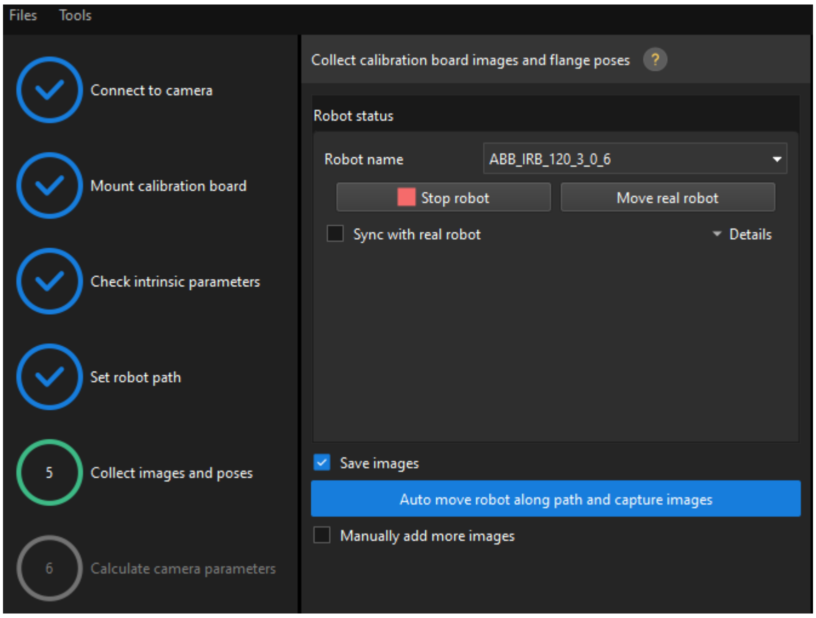
The set robot path should cover the work area.

3. In the right **Scene Viewer** panel, confirm that the waypoints of the automatically generated

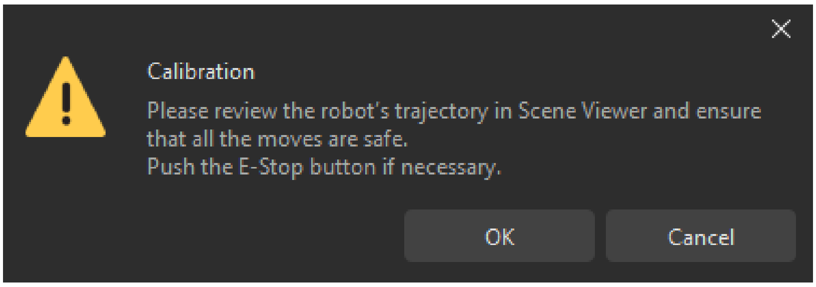
motion path will not collide with obstacles in the environment, and then click the [Next] button.

Collect Images and Poses

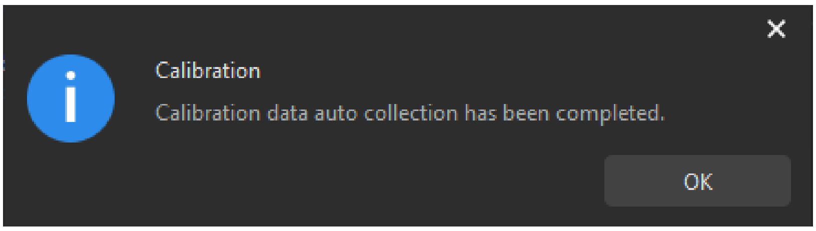
1. In the **Collect images and poses** step, select the **Save images** checkbox.



2. Click the [Control robot to auto move along path and capture images] button.
3. Read the safety window carefully and click the [OK] button.

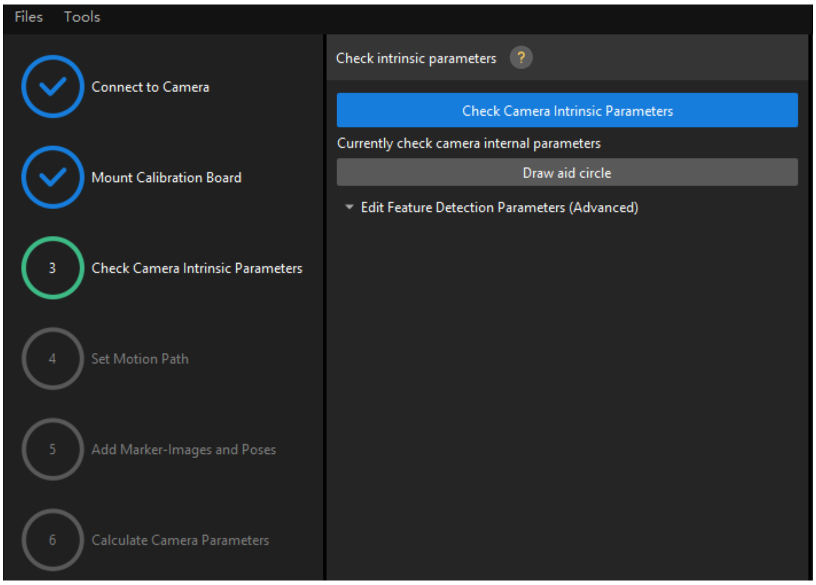


4. Wait until the robot finishes moving along the preset path and the camera finishes capturing images on all waypoints. Captured images can be seen in the right **Marker Image and Pose List** panel during this process.
5. After the automatic image capturing finishes, click the [OK] button, and then click the [Next] button on the bottom bar.



Calculate Camera Parameters

1. In the **Calculate camera parameters** step, click the **[Calculate camera extrinsic parameters]** button.

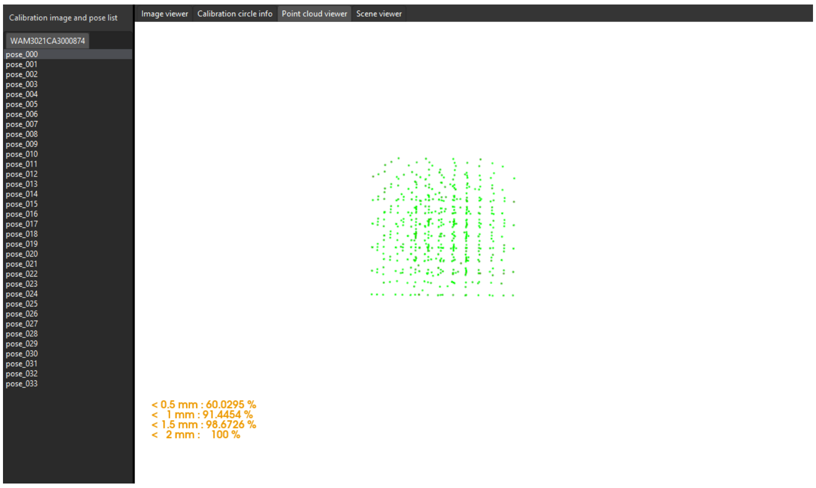


2. In the prompted window indicating calibration success, click the **[OK]** button.
3. View the calibration error of the point cloud in the right **Point cloud viewer** panel.

> The error point cloud shows the deviation between the calculated value and the actual value of the circles on the calibration board.

4. Confirm that the calibration accuracy meets the project requirements.

   Determine the error value with 100% to obtain the rough calibration accuracy. For example, the calibration accuracy in the following figure is within 2 mm.

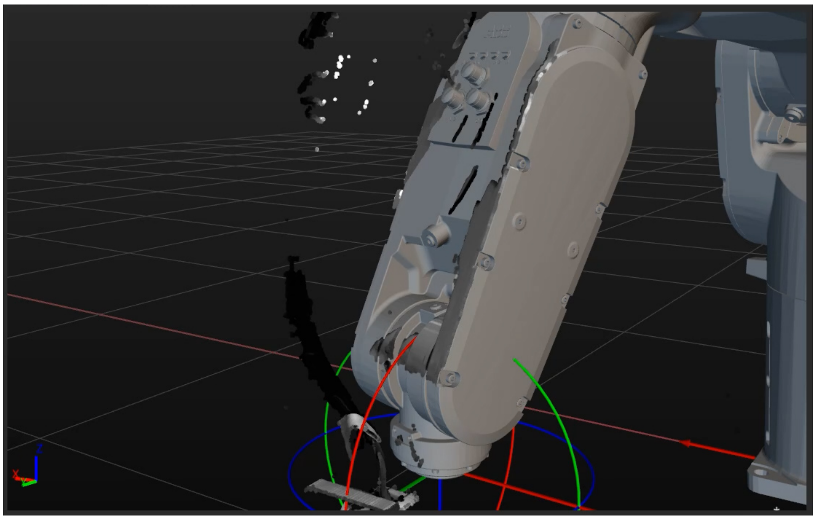


   To improve the calibration accuracy, please refer to the section Calibration Result Check and Analysis.

Validate and Save the Calibration Result

1. After calibration, move the robot arms into the FOV of the camera.
2. In the **Calculate camera parameters** step, click the **[Calculate camera extrinsic parameters]** button. This operation triggers the camera to capture images.
3. Click **Scene viewer** to check the coincidence degree between the point cloud of the robot and the robot model.

   If the point cloud of the robot approximately coincides with the robot model, the calibration is successful.



4. Click the **[Save]** button on the bottom bar. In the prompted **Save Calibration Files** dialog box, click the **[OK]** button. The camera calibration result will be automatically saved in the "calibration" directory of the project.

3.4. Carton Locating

Before using this tutorial, you should have created a Mech-Vision solution using the "Single-Case Cartons" case project in the "Hand-Eye Calibration" section.

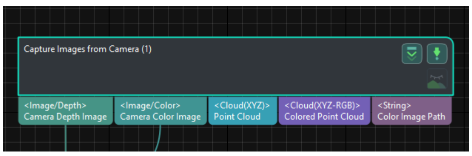
In this tutorial, you will first learn about the project workflow, and then how to deploy the project by adjusting Step parameters, to recognize the cartons' poses and output the vision result.

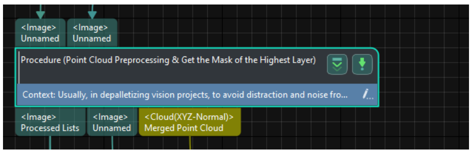
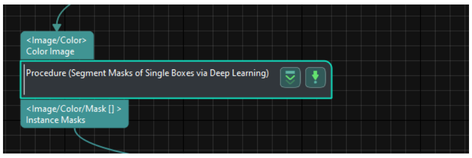
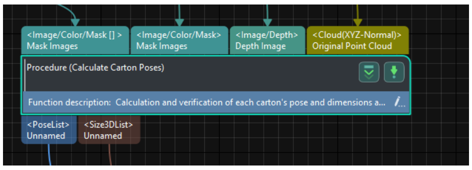
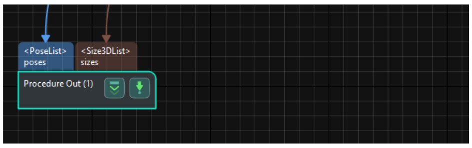
▶ https://www.youtube.com/watch?v=A-3KNbNCkMY/PLVcMd7cW2rXWbHhTQX8m2R1r6PhX6vrCI *(YouTube video)*

Video tutorial: Carton Locating

Introduction to the Project Workflow

The following table describes each Procedure in the project workflow.

No.	Step/Procedure	Image	Description
1	Capture Images from Camera		Connect to the camera and capture images of cartons

No.	Step/Procedure	Image	Description
2	Point Cloud Preprocessing & Get the Mask of the Highest Layer		Perform preprocessing of the cartons' point cloud and get the mask of the highest layer
3	Segment Masks of Individual Cartons Using Deep Learning		Use deep learning inference to segment masks of individual cartons based on the input mask of cartons on the highest layer, which facilitates obtaining the point cloud of an individual carton based on the corresponding mask
4	Calculate Carton Poses		Recognize cartons' poses, and verify or adjust the recognition results based on the input carton dimensions
5	Adjust poses		Transform the reference frame of carton poses and sort the poses of multiple cartons by rows and columns
6	Output		Output the cartons' poses for the robot to pick

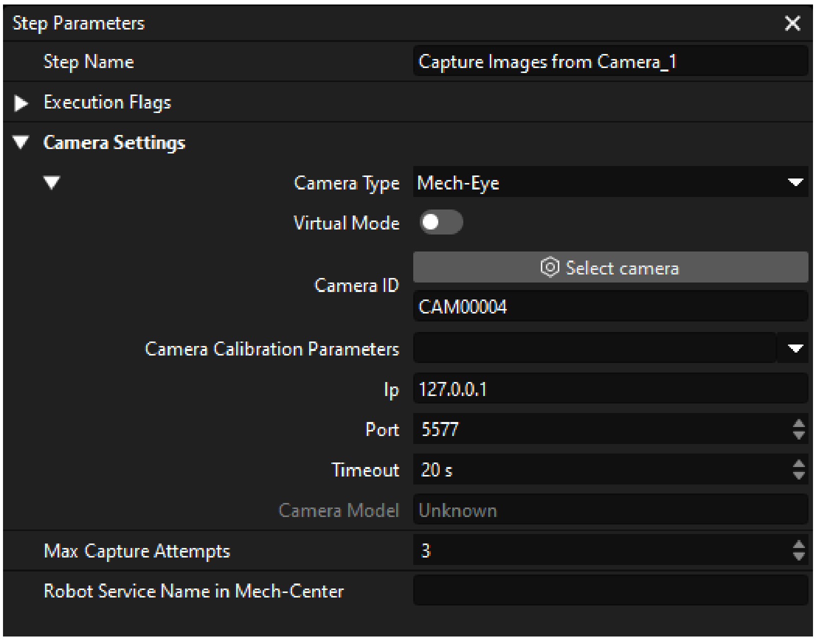
Adjust Step Parameters

In this section, you will deploy the project by adjusting the parameters of each Step or Procedure.

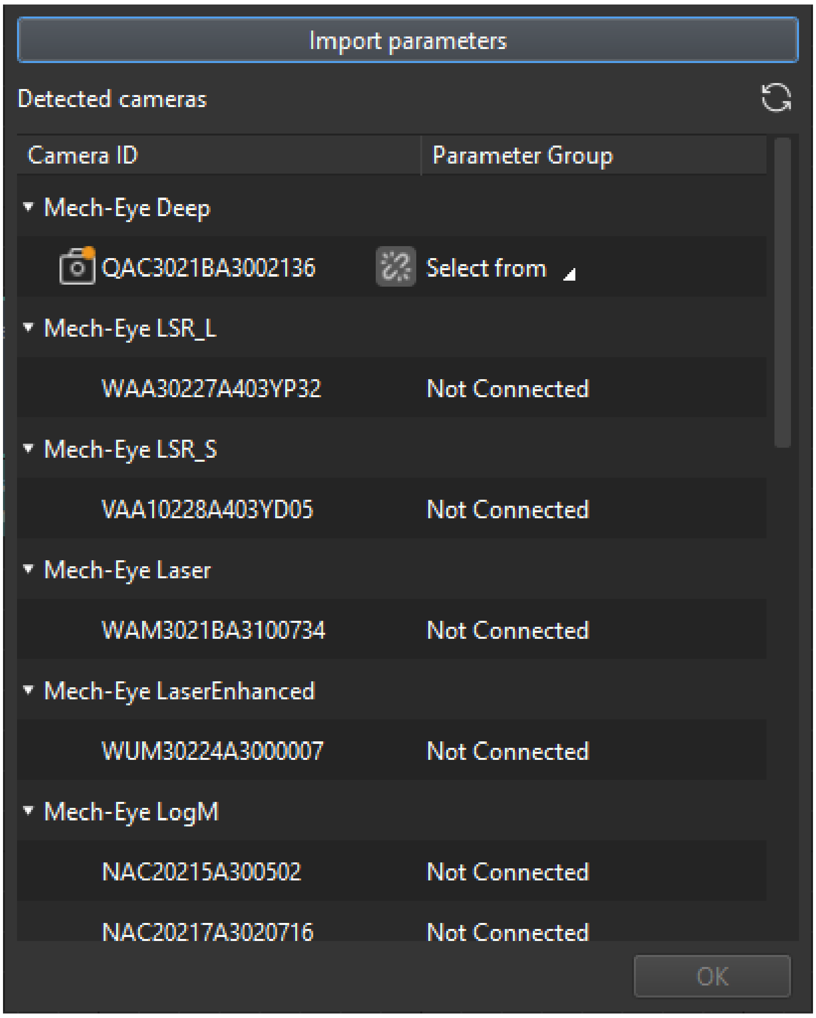
Capture Images from Camera

The "Single-Case Cartons" case project contains virtual data. Therefore, you need to disable the Virtual Mode and connect to the real camera in the "Capture Images from Camera" Step.

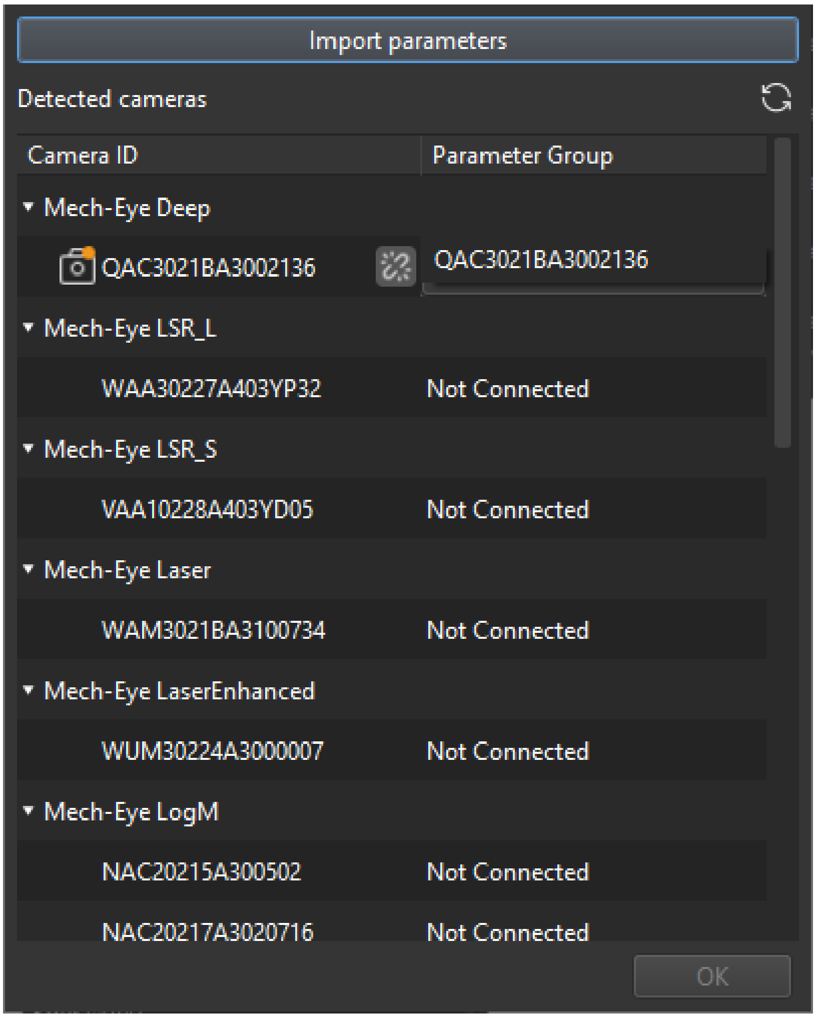
1. Select the "Capture Images from Camera" Step, disable the **Virtual Mode** option, and click **[Select camera]** on the Step parameters tab.



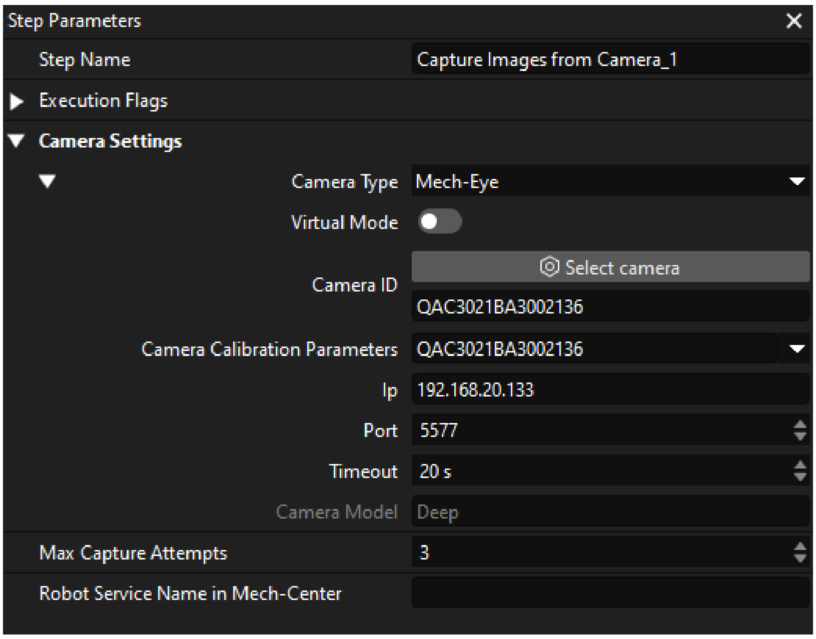
2. In the prompted window, click on the right of the desired camera's serial No. to connect the camera. After the camera is connected, the icon will turn into .



After the camera is connected, click **[Select from]** to select the calibrated parameter group.



3. After the camera is connected and the parameter group is selected, the calibration parameter group, IP address, and ports of the camera will be obtained automatically. Just keep the default settings of the other parameters.



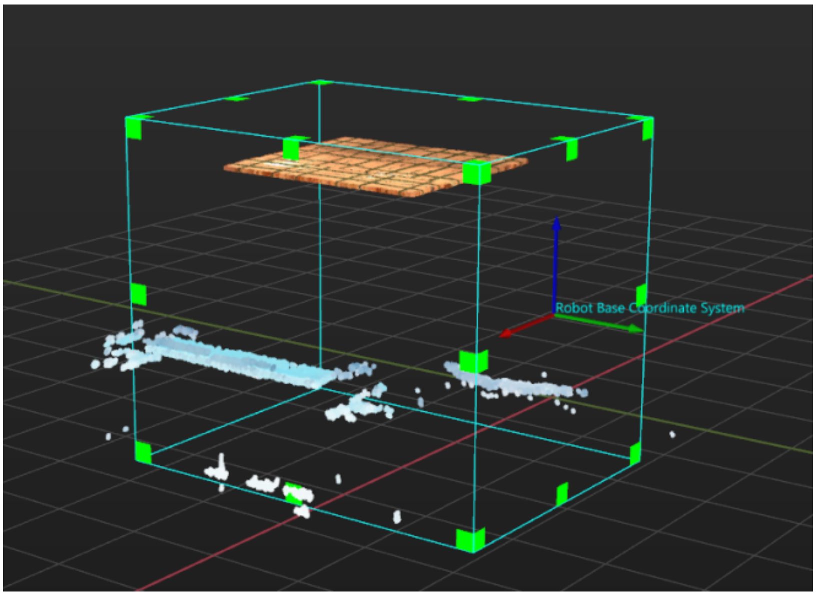
Now, you have connected the software to the camera.

Point Cloud Preprocessing & Get the Mask of the Highest Layer

To prevent the robot from colliding with other cartons while picking items from the non-highest layer, it is necessary to use this Procedure to obtain the mask of the cartons on the highest layer. By giving priority to picking these cartons, you can minimize the risk of collisions during the picking process.

In this Procedure, yo need to adjust the parameter **3D ROI** and **Layer Height**.

1. On the Step parameters tab, click the **[Set 3D ROI]** button to set the 3D ROI.



> The 3D ROI frame should generally include the highest and lowest regions of the carton stack, and contain unwanted points as less as possible.

2. To avoid obtaining the cartons not on the highest layer, set the **Layer Height** parameter. The parameter value should be less than the height of a single carton in the stack, for example, half of the carton height. Usually, you just need to keep the recommended value.

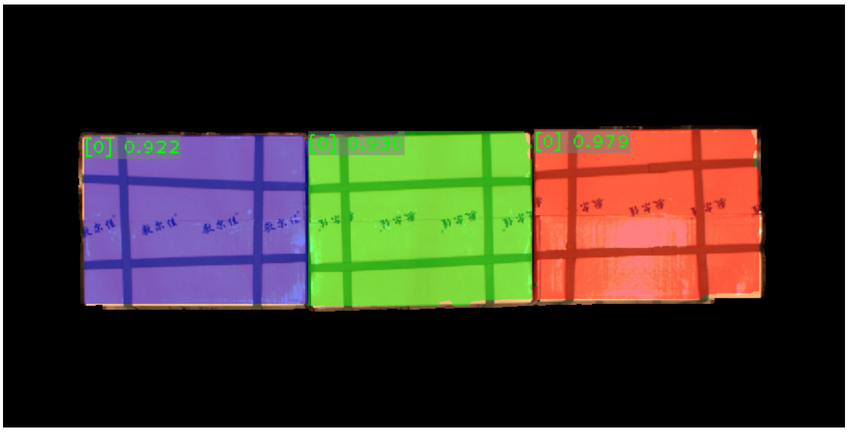
   If the dimensions of single cartons in different stacks are different, you should set the **Layer Height** parameter according to the height of the lowest cartons.

> If the setting of the **Layer Height** parameter is improper, the project will obtain the cartons not on the highest layer, which causes the collision between the robot and other cartons during the picking process.

Segment Masks of Individual Cartons Using Deep Learning

After obtaining the mask of the cartons on the highest layer, you need to use deep learning to segment the masks of individual cartons.

The current case project has a built-in instance segmentation model package suitable for cartons. After running this Procedure, you will get the masks of individual cartons, as shown below.



If the segmentation results are not satisfactory, you can adjust the size of the 3D ROI accordingly.

Calculate Carton Poses

After obtaining the point clouds of individual cartons, you can calculate carton poses. In addition, you can enter the dimensions of the carton to verify the correctness of the recognition results.

In the "Calculate Carton Poses" Procedure, set the parameter **Length on X-axis/Y-axis/Z-axis** and **Box Dimension Error Tolerance**:

- **Length on X-axis/Y-axis/Z-axis**: set these parameters according to the actual dimensions of cartons.
- **Box Dimension Error Tolerance**: Keep the default value 30 mm. If the input carton dimensions and the recognized ones are significantly different, you can try to adjust this parameter.

Adjust poses

To facilitate robot picking, you need to adjust the cartons' poses to transform them from the camera reference frame to the robot reference frame after obtaining the cartons' poses.

In this Procedure, you can also sort the cartons' poses by rows and columns to help the robot to pick items in a certain sequence.

- **Ascending (by Carton Pose's X Value in Robot Base Reference Frame)**: Usually, keep the default setting (selected). When this option is selected, cartons in rows will be sorted in the ascending order of carton poses' X-coordinate values in the robot base reference frame; otherwise, cartons in rows will be sorted in the descending order.
- **Ascending (by Carton Pose's Y Value in Robot Base Reference Frame)**: Usually, keep the default setting (selected). When this option is selected, cartons in rows will be sorted in the ascending order of carton poses' X-coordinate values in the robot base reference frame; otherwise, cartons in rows will be sorted in the descending order.

Output

After obtaining the proper carton poses, the "Procedure Out" Step sends the results of the current project to the backend service.

So far, you have deployed the project for carton locating.

3.5. Pick and Place

After having obtained the cartons' poses using a Mech-Vision case project, you can then build a workflow for the Mech-Viz project to guide the robot to pick and place cartons repeatedly.

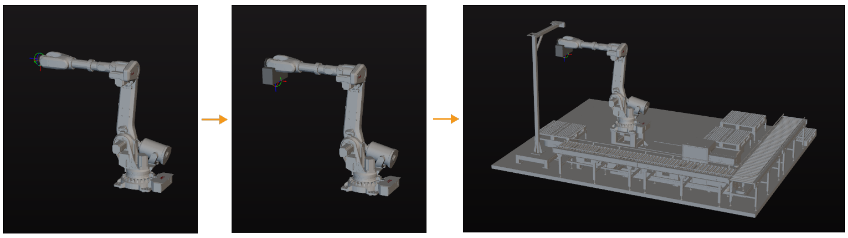
▶ https://www.youtube.com/watch?v=pL4ZbeoDF8A/PLVcMd7cW2rXWbHhTQX8m2R1r6PhX6vrCI *(YouTube video)*

Video Tutorial: Pick and Place

The following figure shows the process of building a project.

Configure the Robot and Scene

To avoid collision with surrounding objects during robot picking and placing, you need to add the tool model, and scene model to the project for collision detection. The process is shown in the figure below.



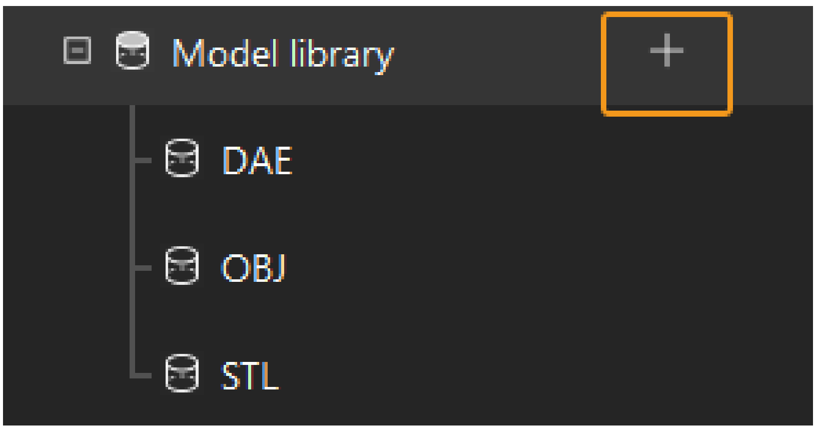
Import and Configure the Tool Model

- Tool refers to the device mounted on the robot end that performs processing/picking jobs.
- In this tutorial, the tool is a gripper containing an array of suction cups.

The end tool should be imported and configured so that its model can be displayed in the 3D simulation space and used for collision detection.

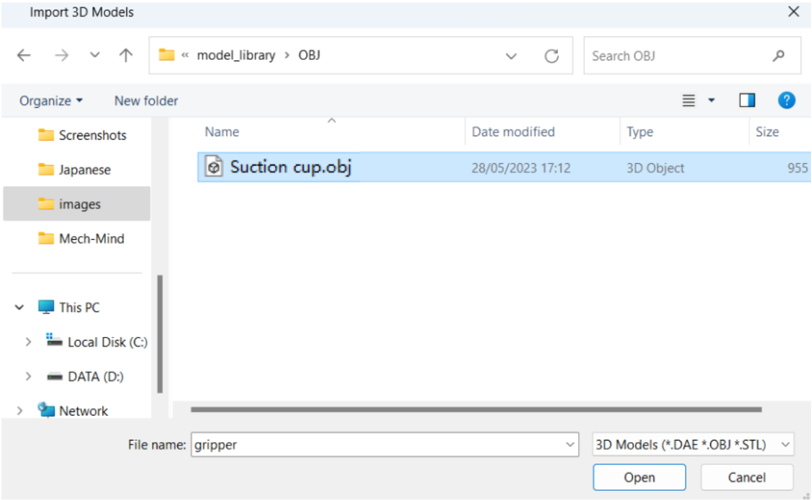
Import the Tool Model

1. Click [+] in Resources › Model Library.

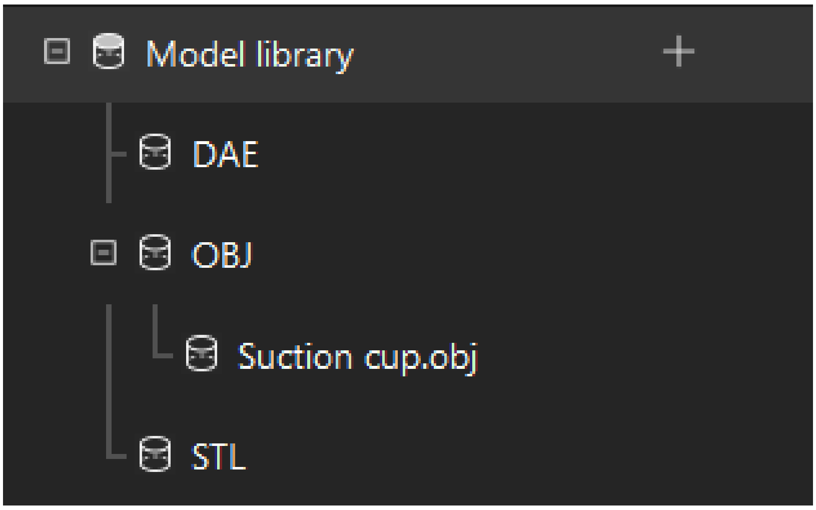


Project resources refer to various fundamental resources used in the project, including the robot, tools, workpieces, and scene objects.

2. In the prompted window, select the collision model file in .obj format, and then click [Open].

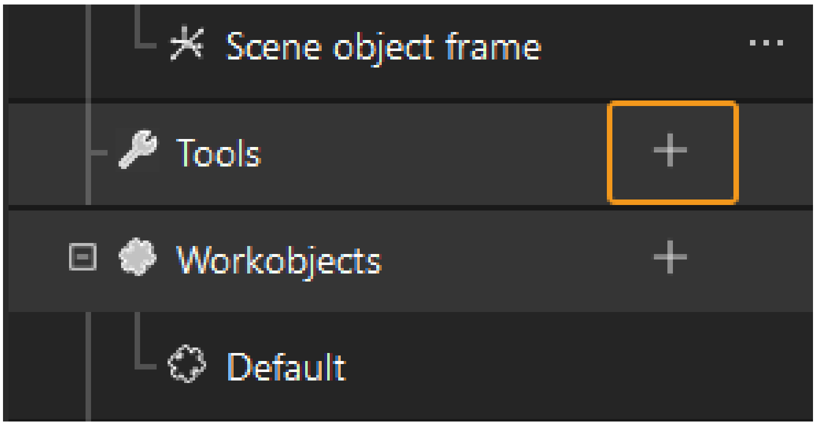


3. After the model is imported, you can see the imported model in the model library.

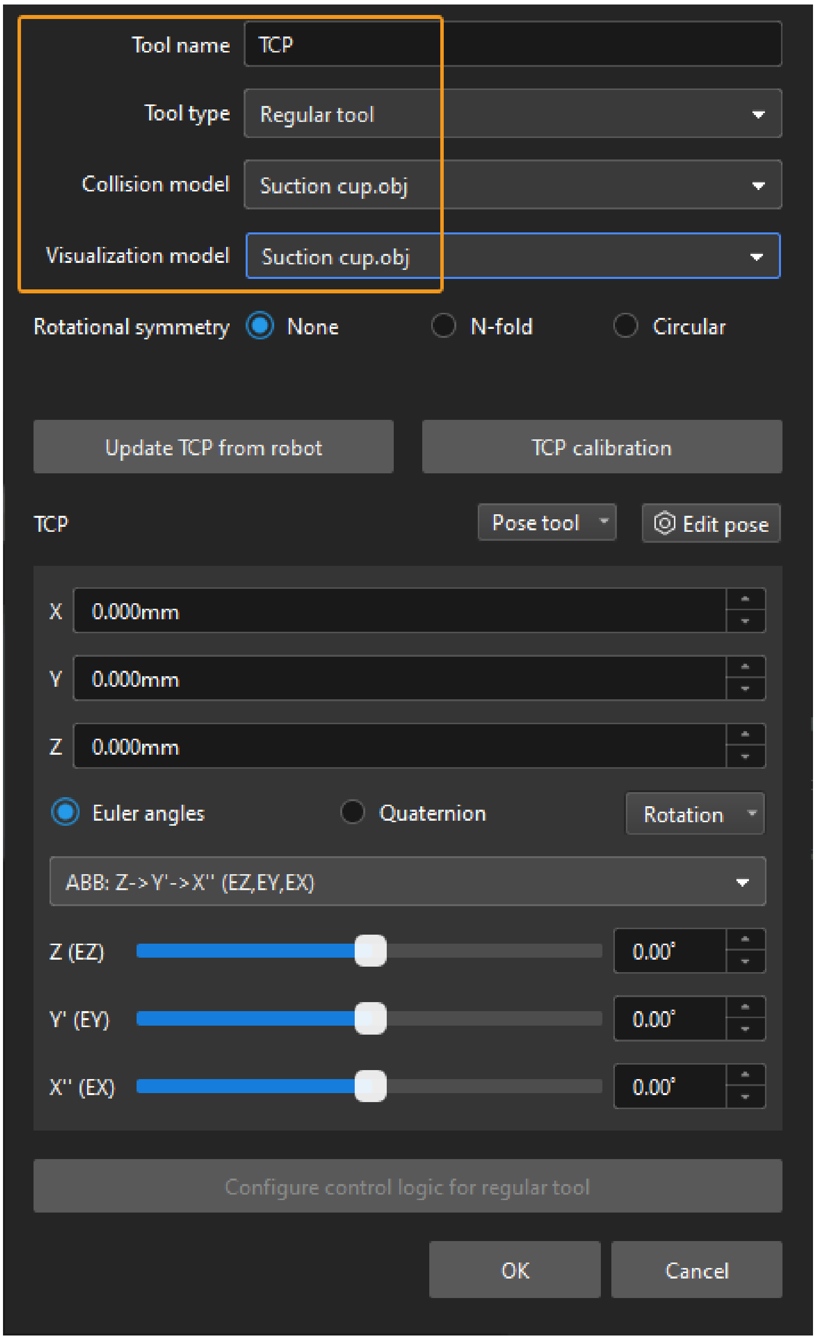


Configure the Tool

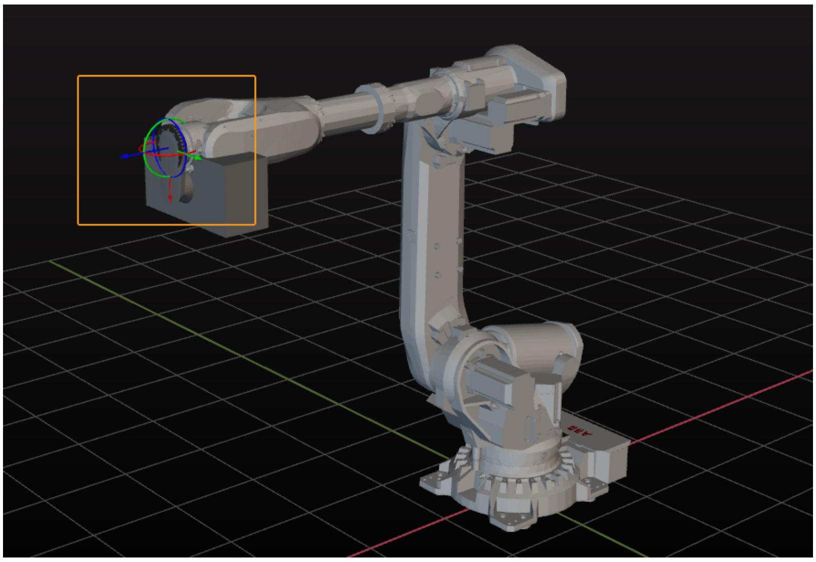
1. Click [+] in Resources › Tools.



2. In the prompted window, enter the tool name, select the imported tool model as the collision model and visualization model, and then click [OK].



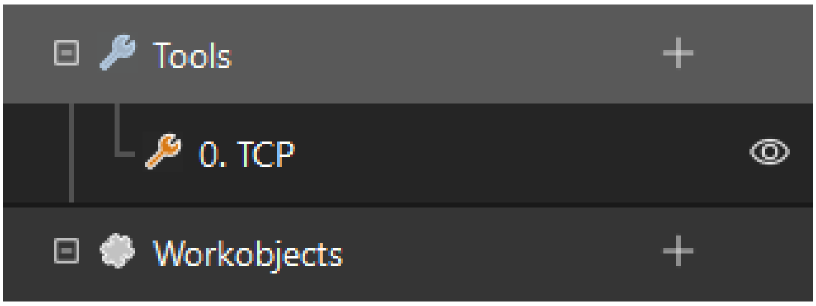
3. After the tool is configured, you can view the configured tool in the 3D simulation space, as shown below.



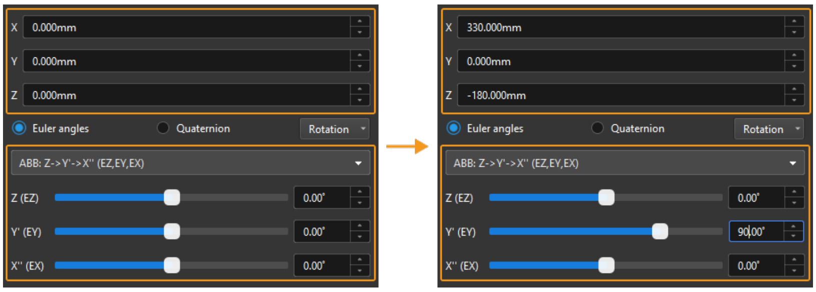
Adjust the Tool

As shown above, the pose of the tool in reference to the robot is obviously wrong. So, you need to adjust the pose of the tool.

1. Double-click the tool model in the model library.

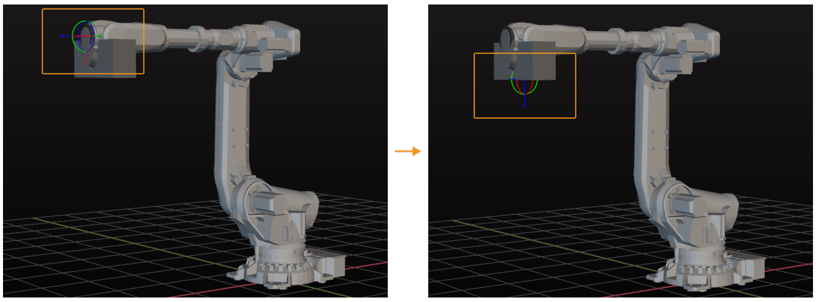


2. In the prompted window, adjust the TCP (Tool Center Point).



The TCP is usually on the tip of the tool. In this tutorial, the TCP in the center points of the suction cups.

3. The tool's poses before and after the adjustment are shown below.

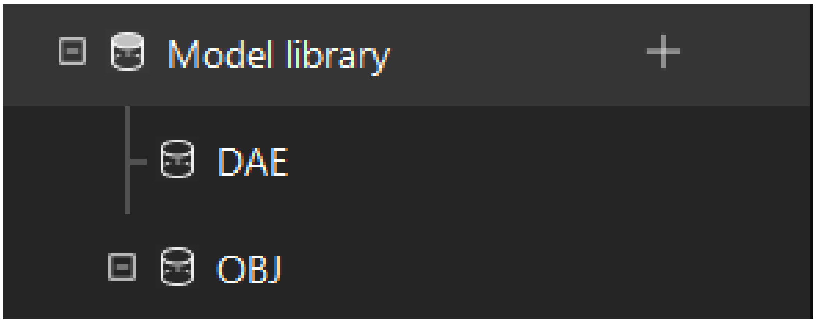


Import and Configure the Scene Model

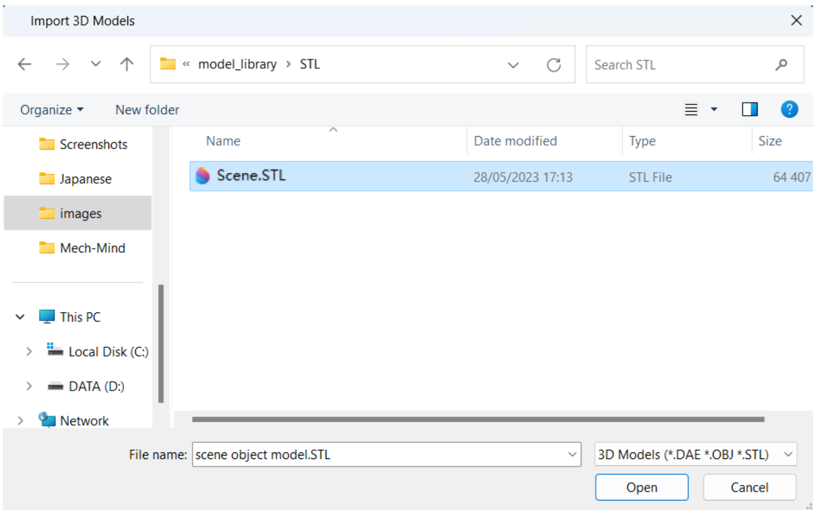
Scene objects are imported and configured to make the scene in the software closer to the real scenario, which facilitates the planning of the robot motion path.

Import the Scene Model

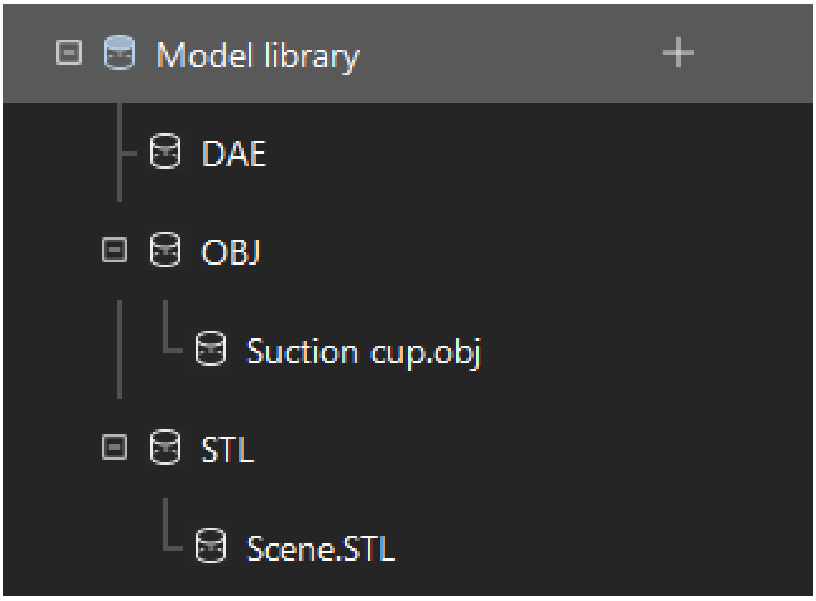
1. Click [+] in Resources › Model Library.



2. In the prompted window, select the scene object model file, and then click [Open].

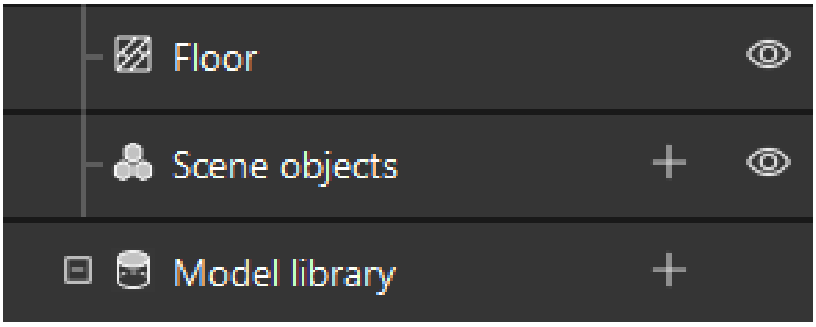


3. After the model is imported, you can see the imported model in the model library.

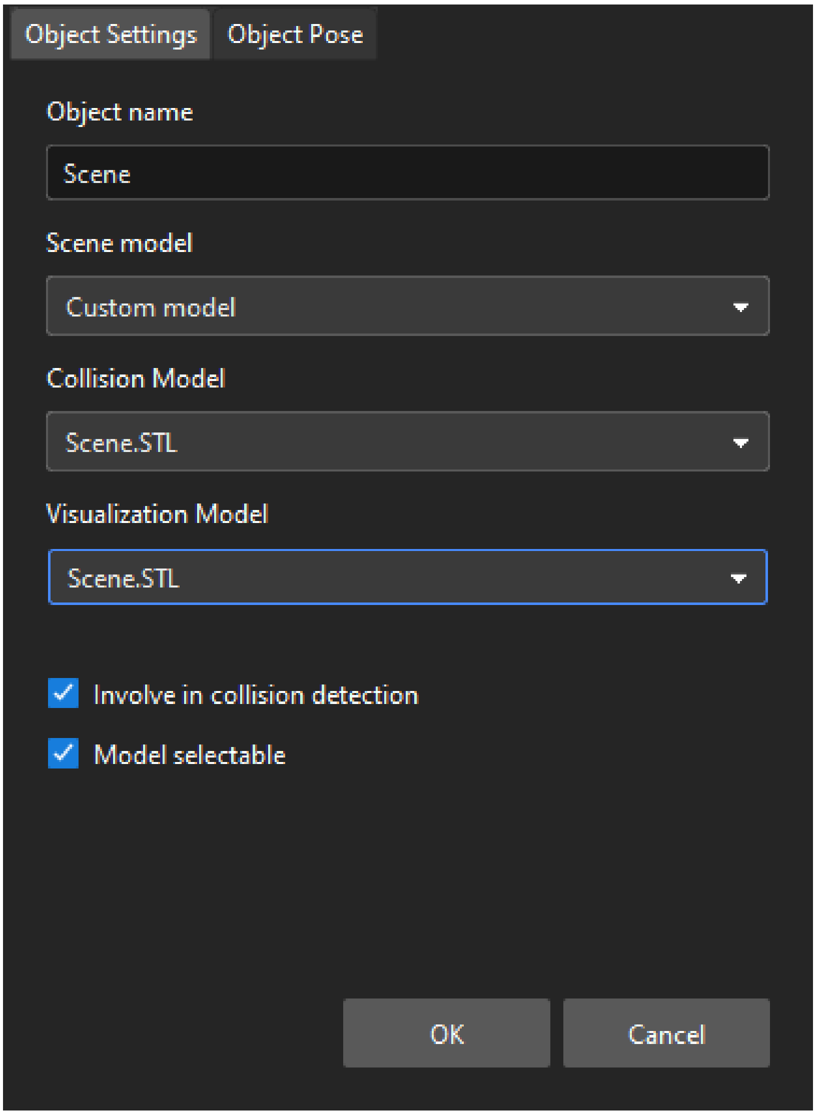


Configure the Scene Model

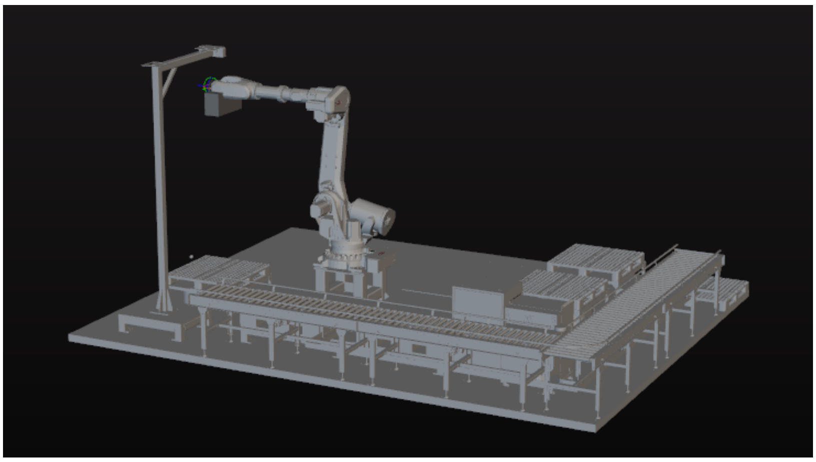
1. Click [+] in Resources › Scene Objects.



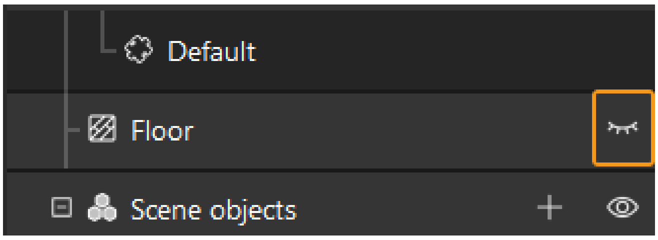
2. In the prompted window, enter the object name, select “Custom model” as the “Scene model”, select the imported scene object model as the collision model and visualization model, and then click [OK].



3. After configuration, the scene object is displayed in the 3D simulation space.



To view the scene model better, you can hide the floor.



After configuring the models, click **[Sync Robot]** on the toolbar to keep the simulated robot's pose consistent with that of the real robot.

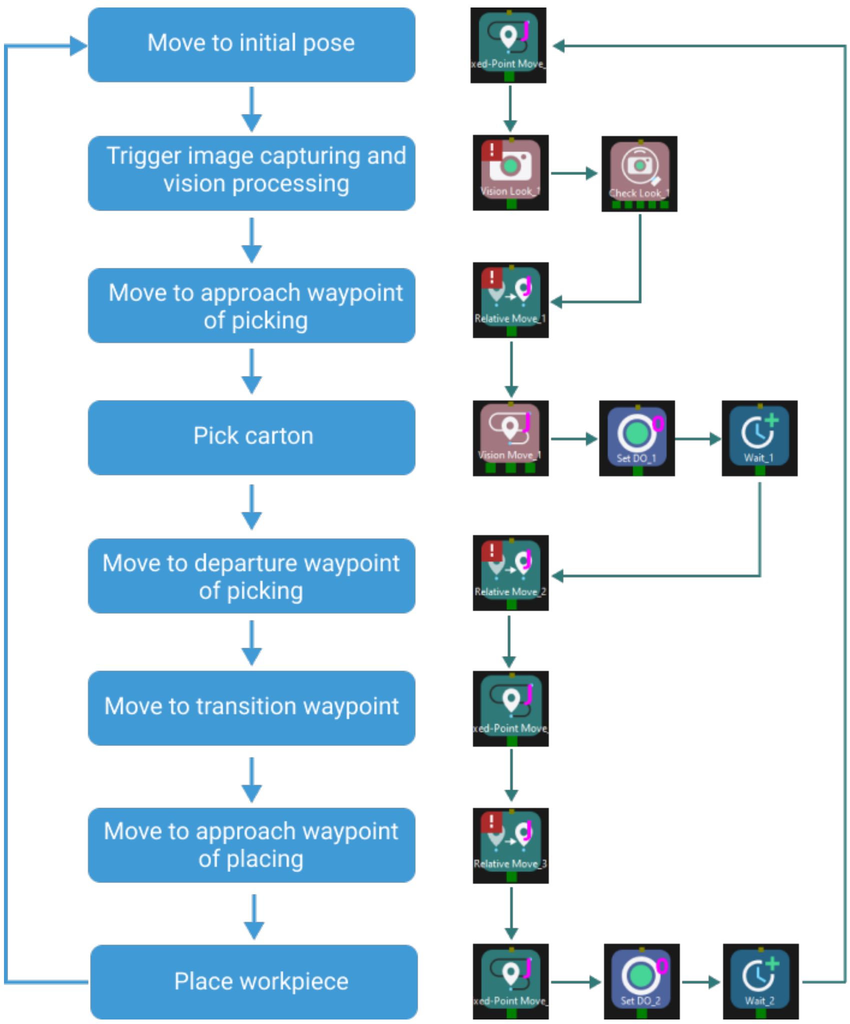
Build a Workflow

After configuring the models, you can now start to build a workflow. Drag a step from the step library to the graphical programming workspace, set the parameters of the Steps, and connect Steps to achieve preset program functions.

- The workflow refers to the robot motion control program built in the flowchart form in Mech-Viz.
- A Step refers to a robot programming function module.

Introduction to the Project Workflow

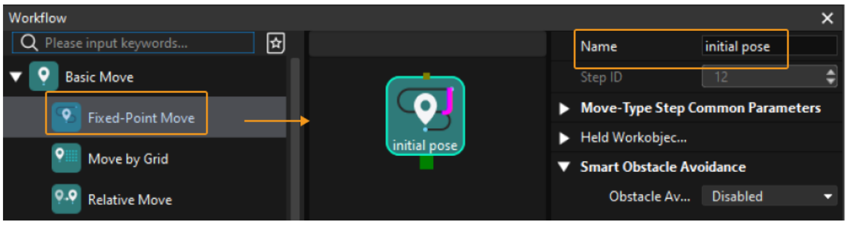
The built workflow is shown below.



Move to “Initial Pose”

The initial pose is the initial point of the robot motion, and it also should be a safe position. At this pose, the robot should be away from the objects to pick and the surrounding devices, and should not block the camera’s FOV.

After the robot arrives at the self-defined initial pose, select **Fixed-Point Move** in the Step Library, and drag it to the graphical programming workspace, rename it as “initial pose”. Then click **[Sync Robot]** on the toolbar to record the current pose of the robot for this Step.



Trigger Image Capturing and Vision Processing

Step	Vision Look
Description	Start the Mech-Vision project to obtain the vision recognition result.
Operation	Find the “Vision Look” Step in the Step Library, and drag it to the graphical programming workspace.
Parameter Settings	Select **Single_Case_Cartons** from the **Vision Name** drop-down list.
Image	

After the “Vision Look” Step, add the **Check Look** Step to check whether there is any vision result.

Step	Check Look
Description	Check whether there is any vision result.
Operation	Find the “Check Look” Step in the Step Library, and drag it to the graphical programming workspace.
Parameter Settings	Keep the default parameter settings.

Move the Robot to the Approach Waypoint of Picking

When picking cartons, if the robot directly moves from the initial pose to the picking waypoint, collision with the cartons may occur. After obtaining the vision recognition result, you can then use the **Relative Move** step to move the robot to the approach waypoint.

Step	Relative Move
Description	Move according to the vision recognition result.
Operation	Find the “Relative Move” Step in the Step Library, drag it to the graphical programming workspace, and rename it as “Approach waypoint 1”.

Parameter Settings	Set **Relative Move Dependency** to **Next waypoint**; set **Waypoint type** to **Tool**, and set the **Z** coordinate to a proper value, such as -300mm.
Image	 

Pick the Carton

After the robot has arrived at the approach waypoint, you can control the robot to pick cartons. The picking process can be divided into two steps.

1. Step 1: Use the **Vision Move** Step to control the robot to arrive at the picking waypoint.
2. Step 2: Use the **Set DO** Step to control the robot to pick the carton using the suction cups.

See the following for details.

Step	Vision Move
Description	Move according to the vision recognition result.
Operation	Find the "Vision Move" Step in the Step Library, and drag it to the graphical programming workspace.
Parameter Settings	Select **Single_Case_Cartons** from the **Vision Service Name** drop-down list.
Image	

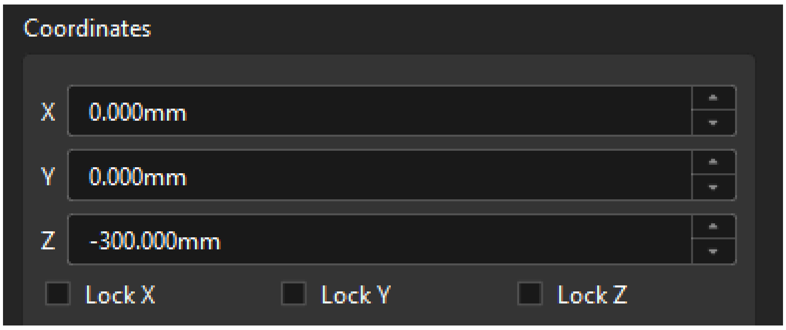
Step	Set DO
Description	Control the suction cups to pick the carton.
Operation	Find the "Set DO" Step in the Step Library, drag it to the graphical programming workspace, and rename it as "Trigger Suction Cup".
Parameter Settings	Set the **Digital Out Value** and **DO Port** parameters to **1**. These parameter values are reference only. Please determine them according to actual on-site requirements.
Image	

To ensure that the robot can pick the carton securely, add the **Wait** Step.

Step	Wait
Description	To avoid the failures to pick cartons.
Operation	Find the “Wait” Step in the Step Library, drag it to the graphical programming workspace, and rename it as “Wait for firm gripping”.
Parameter Settings	Set the **Wait Time** parameter to **1000ms**.
Image	

Move the Robot to the Departure Waypoint of Picking

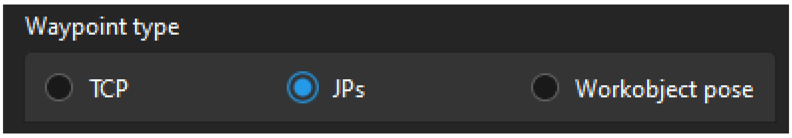
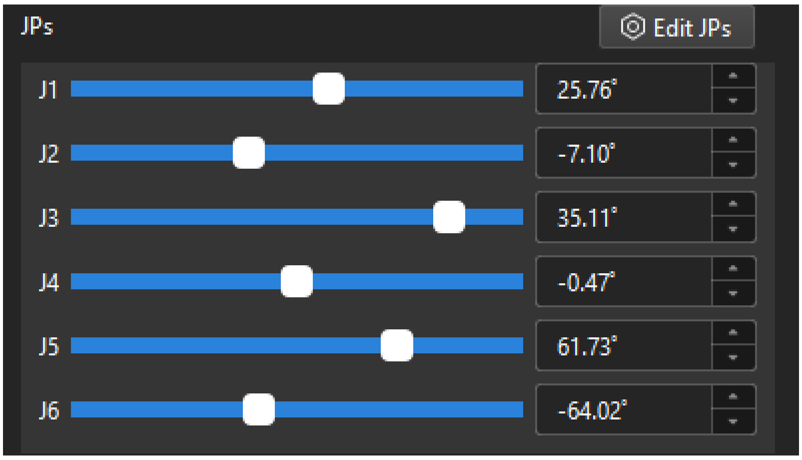
After the robot picks the carton, you need to use the **Relative Move** Step to move the robot to the departure waypoint to avoid the collision between the carton and the scene objects.

Step	Relative Move
Description	Move according to the vision recognition result.
Operation	Find the “Relative Move” Step in the Step Library, drag it to the graphical programming workspace, and rename it as “Departure waypoint”.
Parameter Settings	Set **Relative Move Dependency** to **Next waypoint**; set **Waypoint type** to **Tool**, and set the **Z** coordinate to a value larger than the height of the cartons. For example, if the carton height is 500 mm, set the **Z** coordinate to -600 mm.
Image	 

Move the Robot to a Transition Waypoint

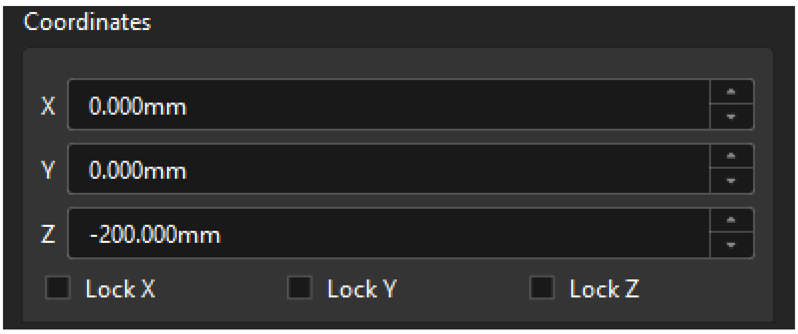
To avoid collision, you can add transition waypoints using the **Fixed-Point Move** Step after the departure waypoint to optimize the picking and placing path.

Step	Fixed-Point Move
Description	Optimize the robot picking and placing path
Operation	Find the “Fixed-Point Move” Step in the Step Library, drag it to the graphical programming workspace, and rename it as “Transition waypoint”.
Parameter Settings	Set **Waypoint type** to **JPs** and set the **JPs** values.

Image	 

Move the Robot to the Approach Waypoint of Placing

Before the robot places the carton, you need to use the **Relative Move** Step to move the robot to the approach waypoint for placing to avoid collision between the carton and the scene object.

Step	Relative Move
Description	Move according to the vision recognition result.
Operation	Find the "Relative Move" Step in the Step Library, drag it to the graphical programming workspace, and rename it as "Approach waypoint 2".
Parameter Settings	Set **Relative Move Dependency** to **Next waypoint**; set **Waypoint type** to **Tool**, and set the **Z** coordinate to a proper value, such as **-200 mm**.
Image	 

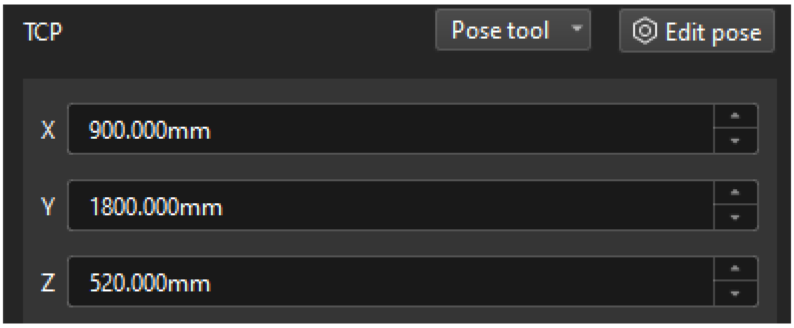
Place the Carton

After the robot arrives at the approach waypoint for placing, you can control the robot to place cartons. The picking process can be divided into two steps.

1. Step 1: Use the **Fixed-Point Move** Step to control the robot to arrive at the placing waypoint.

2. Step 2: Use the **Set DO** Step to control the robot to release the suction cups to place the carton.

See the following for details.

Step	Fixed-Point Move
Description	Control the robot to arrive at the placing waypoint.
Operation	Find the “Fixed-Point Move” Step in the Step Library, drag it to the graphical programming workspace, and rename it as “Placing waypoint”.
Parameter Settings	Set a proper **TCP** as the placing waypoint.
Image	

Step	Set DO
Description	Release the suction cups to place the carton.
Operation	Find the “Set DO” Step in the Step Library, drag it to the graphical programming workspace, and rename it as “Release suction cup”.
Parameter Settings	Set the **Digital Out Value** parameter to **0** and the **DO Port** parameter to **1**. These parameter values are reference only. Please determine them according to actual on-site requirements.
Image	

Since it takes time for the suction cup to release, you need to add the **Wait** Step to avoid the failure of placing the carton by the robot.

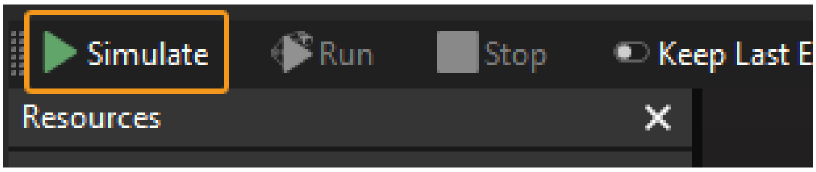
Step	Wait
Description	Avoid the failure of placing the carton by the robot.
Operation	Find the “Wait” Step in the Step Library, drag it to the graphical programming workspace, and rename it as “Wait for release”.
Parameter Settings	Set the **Wait Time** parameter to **1000ms**.
Image	

Connect Steps

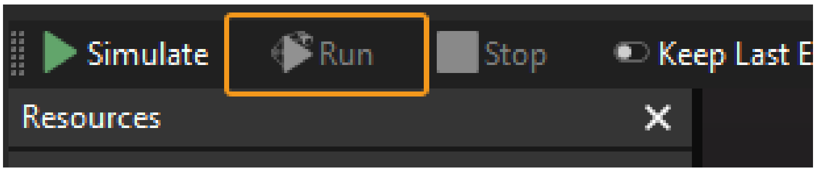
After the preceding Steps are added, connect them one by one. To control the robot to pick and place cartons repeatedly, you need to connect the exit port of "Placing Wait" to the entry port of "Initial Pose".

Simulate and Run the Project

1. After all the Steps are connected properly, click the **[Simulate]** button on the toolbar to simulate the Mech-Viz project.



2. If the project runs as expected in simulation, click the **[Run]** button on the Mech-Viz toolbar to run the project with the real robot.



It is recommended that the robot should move at a low speed and that you pay attention to the robot motion trajectory. In the case of an emergency, press the emergency stop button on the teach pendant.

