Software Manual
TM 3DVision

Original Instructions

Software version: 2.14

Document version: 1.00

Release date:2023-07-05

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Revision History....4
1. TM 3DVision Overview....5
1.1 Notice....5
1.1.1 Scope and Restrictions....5
1.2 Warning and Caution Symbols....5
1.3 Safety Precautions....5
1.4 Validation and Liability....6
1.5 Limitation of Liability....7
1.6 Function Note Symbols....7
2. Hardware Requirement....8
2.1 TM Dongle (included in the package)....8
2.2 3D Camera (designated)....8
2.2.1 The Ensenso N35/N36/N46 Blue Wavelength series....8
2.2.2 Benano 3D Camera....9
2.3 Calibration Plate and Tool (tethered)....10
2.4 Graphic Card (designated)....10
2.5 Memory Module (designated)....11
3. Start Using 3DVision....11
3.1 Configuration....11
3.2 Calibration and Modeling....11
3.2.1 Calibration....12
3.2.1.1 3D Camera Eye to Hand....12
3.2.1.2 3D Camera Eye in Hand....15
3.2.2 3D Modelling....18
3.3 3DVision Process Compilation....34
3.3.1 Initiate....36
3.3.2 Region of Interest....40
3.3.3 Clustering – Find....42
3.3.4 Picking Constrains....58

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Revision History

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1.00	2023-07-05	Original release

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1. TM 3DVision Overview

1.1 Notice

When using TM 3DVision, please insert the TM dongle in the product package into any USB port of the control box. Please note that under the circumstances such as editing/trial running/running, if users want to use the 3DVision features, be sure to have the TM dongle insert on the control box; otherwise, it will lead to the circumstance of not editable or shutdown.

1.1.1 Scope and Restrictions

- The collision check only supports only the end tools (suction nozzles, grippers, etc.) installed on the flange.
- The Ensenso N35/N36/N46 series supports hardware version 3.2 or above and the Benano C2100-400 3D Camera supports hardware version 3.2 or above and Windows 10.
- Supports one single 3D camera at a time only.
- Does not transparent and reflective objects.

This manual applies to the combination of hardware version 5.01 or above and TMflow version 2.14 or above. There will be differences between the functions and interfaces of different software versions. Confirm the software version before using and reading this manual. To confirm the software version, click  at the top right of the screen for the information.

1.2 Warning and Caution Symbols

The table below shows the definitions of the warning and caution levels used in our manuals. Pay close attention to them when reading each paragraph, and observe them to avoid personal injuries or equipment damage.

	**DANGER:** Identifies an imminently hazardous situation which, if not avoided, is likely to result in serious injury, and might result in death or severe property damage.
	**WARNING:** Identifies a potentially hazardous situation which, if not avoided, will result in minor or moderate injury, and might result in serious injury, death, or significant property damage.
	**CAUTION:** Identifies a potentially hazardous situation which, if not avoided, might result in minor injury, moderate injury, or property damage.

Danger, Warning, and Caution Symbols

1.3 Safety Precautions

DANGER:
This product can cause serious injury or death, or damage to itself and other equipment, if the following safety precautions are not observed:

- All personnel who install, operate, teach, program, or maintain the system must read the *Hardware installation Manual*, *Software Manual*, and *Safety Manual* according to the software and hardware version of this product, and complete a training course for their responsibilities in regard to the robot.

Read Manual Label; Impact Warning

- All personnel who design the robot system must read the *Hardware installation Manual*, *Software Manual*, and *Safety Manual* according to the software and hardware version of this product, and must comply with all local and national safety regulations for the location in which the robot is installed.
- The TM AI Cobot must be used for its intended use.
- Results of the risk assessment may require the use of additional risk reduction measures.
- Power to the robot and its power supply must be locked out and tagged out or have means to control hazardous energy or implement energy isolation before any maintenance is performed.
- Dispose of the product in accordance with the relevant rules and regulations of the country or area where the product is used.

1.4 Validation and Liability

The information contained herein neither includes how to design, install, and operate a complete robotic arm system, nor involves the peripherals which may affect the safety of the complete system. The integrators of the robot should understand the safety laws and regulations in their countries and prevent hazards from occurring in the complete system.

This includes but is not limited to:

- Risk assessment of the whole system
- Adding other machines and additional risk reduction measures based on the results of the risk assessment
- Using appropriate software safety features
- Ensuring the user will not modify any safety measures

- Ensuring all systems are correctly designed and installed
- Clearly labeling user instructions
- Clearly marked symbols for installation of the robot arm and the integrator contact details
- Making accessible relevant documents, including the risk assessment and this Manual

CAUTION:
This product is a partly complete machine. The design and installation of the complete system must comply with the safety standards and regulations in the country of use. The user and integrators of the robot should understand the safety laws and regulations in their countries and prevent major hazards from occurring in the complete system.

1.5 Limitation of Liability

No safety-related information shall be considered a guarantee by the Corporation that a TM AI Cobot will not cause personnel injury or property damage.

1.6 Function Note Symbols

The following table defines the functional note symbols used in this manual. Read the paragraphs carefully.

IMPORTANT:
This symbol indicates the relevant functional details to assist programming and use.

NOTE:
This symbol indicates the relevant functional use tips to assist programming efficiency.

Function Note Symbols

2. Hardware Requirement

The hardware requirement of 3DVision is stated below.

- Marked as **tethered** meaning that 3DVision can match with this model only.
- Marked as **designated** meaning that 3DVision can match up with similar models.

TM AI Cobot is not responsible for its applicability if users do not use the device accordingly.

2.1 TM Dongle (included in the package)

Used for starting up 3DVision. Please make sure that TM Dongle is plugged into any of USB ports on the control box when the robot is turned on to use the function.

TM Dongle

2.2 3D Camera (designated)

2.2.1 The Ensenso N35/N36/N46 Blue Wavelength series

The Ensenso N35/N36/N46 Blue Wavelength series cameras come with a variety of lens and angle combinations. Users can choose the camera models based on the working distance and working range. Select the product through the product's official website > Solution & Services > TM Plug&Play > IDS Ensenso N35/N36/N46 3D camera.

Ensenso N3x

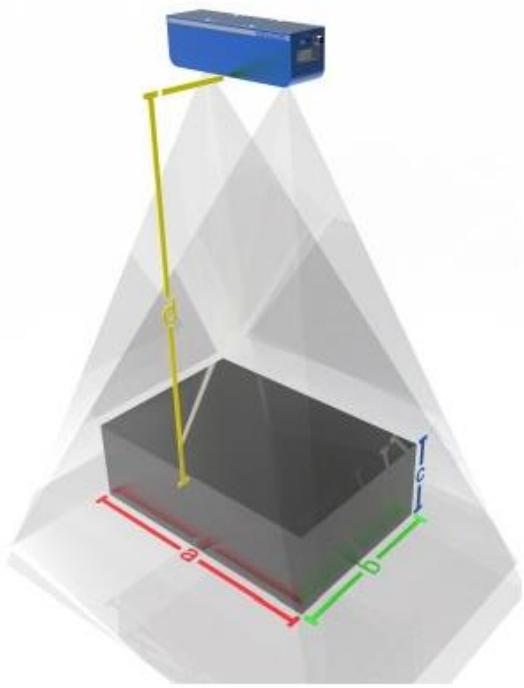
Ensenso N4x

Note

NOTE:
The Ensenso cameras have to go with CAT-6 4 pairs network cables exclusively.

Item	Specification
Device name	Ensenso 3D Camera
Tethered/Designated	Tethered
Model	Ensenso N35/N36/N46 Blue Wavelength series
Connection	GigE
Rated voltage	12 V - 24 V DC / PoE

For product details, please refer to the official website of the product.



Ensenso 3D Camera Schema

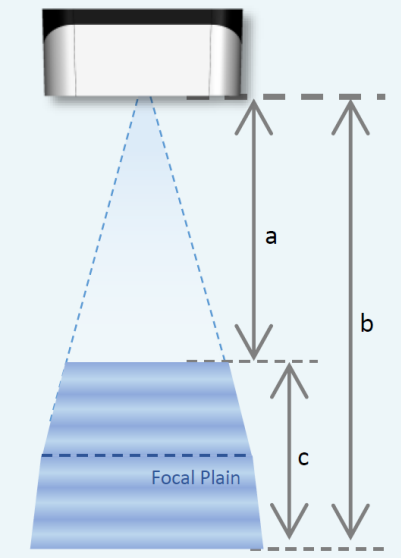
2.2.2 Benano 3D Camera

Benano C2100-400 3D Camera is structured light 3D scanner. Which can scan high quality point cloud but using little more time. Select the product through the product's official website > Solutions & Services > TM Plug&Play > Benano C2100-400 kit for TM.

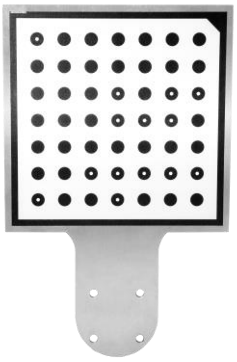
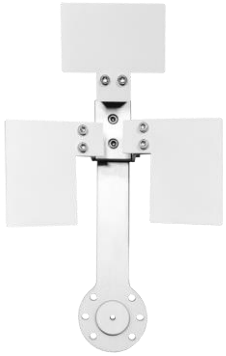
Benano C2100-400

Item	Specification
Point Distance	0.4mm at focal plane
FOV	480x300 mm at focal plane
Accuracy	0.2mm
Working Distance	a:327mm; b:967mm
Depth of Field	c:640 mm
Max speed	One scan per second
Connection Interface	USB3.0, Micro B
Power	12V 2A

For product details, please refer to the official website of the product.



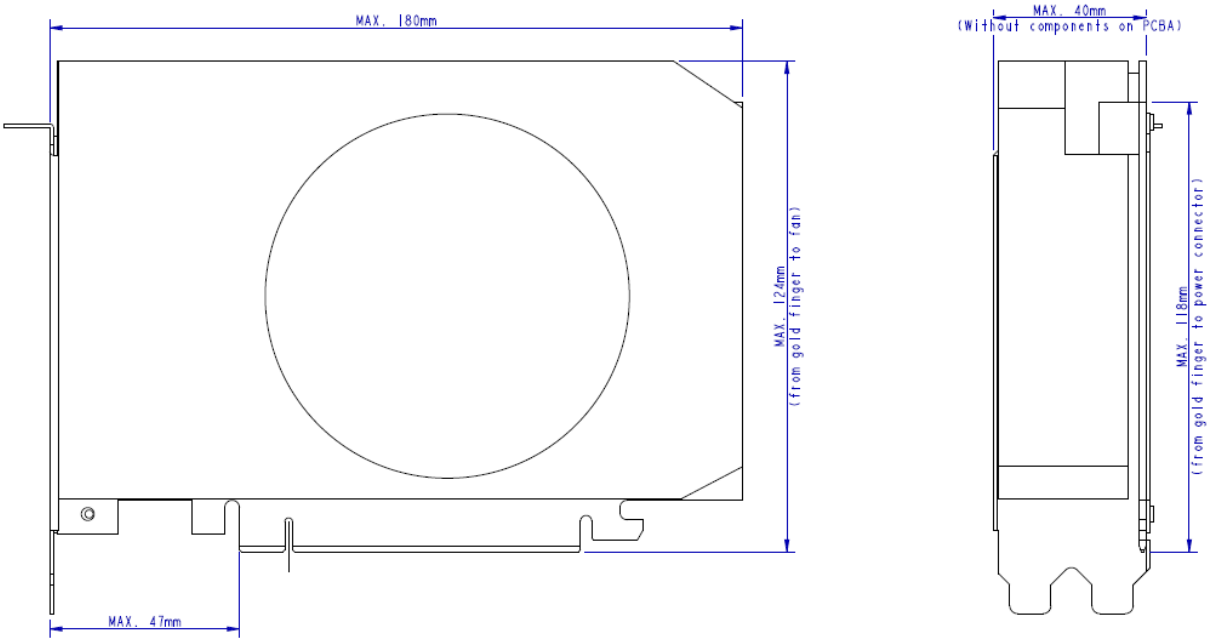
2.3 Calibration Plate and Tool (tethered)

TM 3D Calibration Plate	TM 3D Calibration Tool
For use with the Ensenso N35/N36/N46 series camera during eye-to-hand (ETH) or eye-in-hand (EIH) calibration.	For use with the Benano C2100 series camera during eye-to-hand (ETH) or eye-in-hand (EIH) calibration.
	

2.4 Graphic Card (designated)

The Ensenso N35/N36/N46 series and Benano C2100 series must be equipped with a graphics card compatiable with the hardware version. For hardware version 3.2 or above, the cameras must be equipped with NVIDIA T1000 graphics card, while for hardware version 5.0 or above, it must be equipped with NVIDIA A2000 graphics card. The control box provides a single 8-pin with 180W-limited power for the graphic cards.

The size limit of the graphic card to fit in the control box is as follows.



2.5 Memory Module (designated)

The Ensenso N35/N36/N46 series and Benano C2100 series requires the extra memory module to operate, and users can purchase the official memory expansion kit.

3. Start Using 3DVision

3.1 Configuration

- Hardware

  For users of the Ensenso N35/N36/N46 series and the Benano C2100-400 series 3D camera, please make sure the graphics card and the memory module is installed in the control box and connected to the 3D camera. The 3DVision authorized lock (TM Dongle) in the product package is inserted into the control box.

- Software

  For users of the Ensenso N35/N36/N46 series and the Benano C2100-400 series 3D camera, please install a driver compatible with the camera used. Contact an authorized distributor or a field application engineer of the Corporation.

3.2 Calibration and Modeling

1. In TMflow, navigate to ≡, click **Project**, and click the create new project icon.
2. Add a vision node and click the pencil icon of the vision node. Click the **Select** button next to **Vision Job** to proceed with related settings.
3. In the **Vision Job** tab, click the add icon, input the name of the vision job, and click **OK** to create a new vision job.

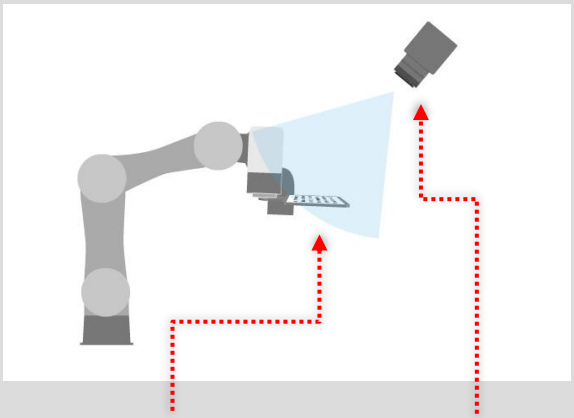
3.2.1 Calibration

3.2.1.1 3D Camera Eye to Hand

The purpose of 3D camera eye to hand calibration is to obtain the relationship between the robot and itself, so that the 3D camera's calculated position can be converted into the position of the robot. The following steps explain the calibration method.

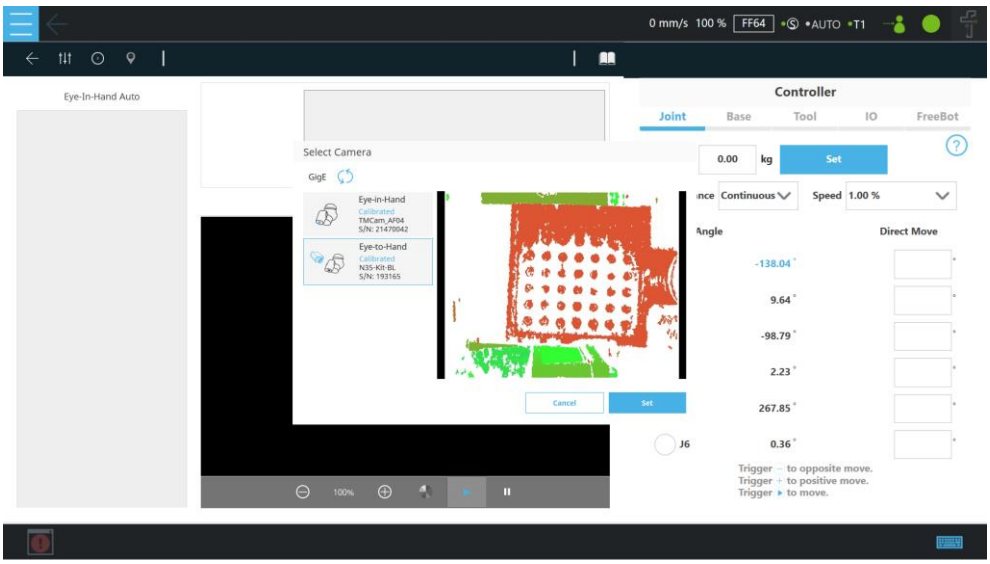
Note

NOTE:
Before 3D camera eye to hand calibration or modeling, the 3D camera must be fixed in ETH mode, and the calibration board or modeling workpiece of the 3D camera must be fixed to the robot flange.



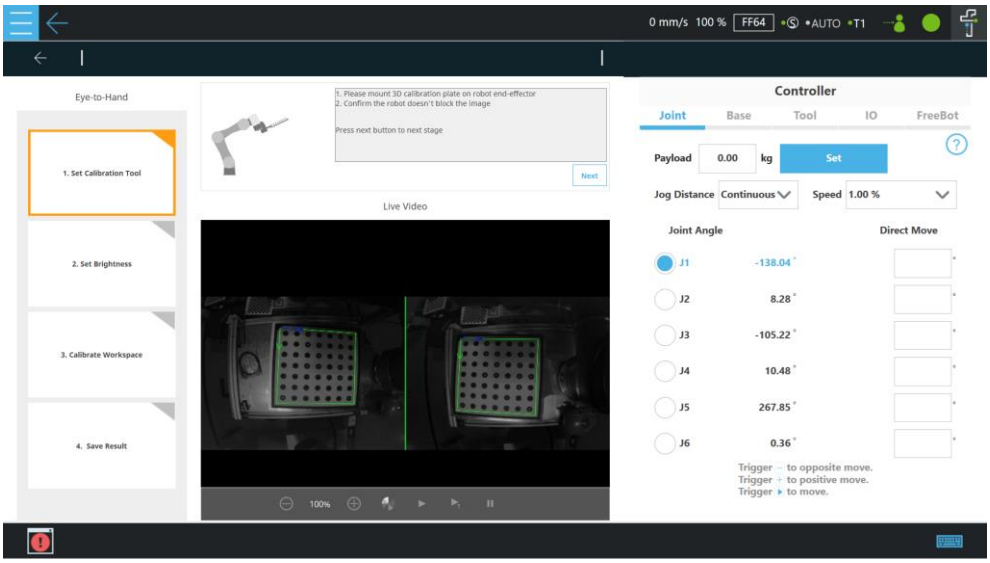
Calibration Board or Model Workpiece 3D Camera

1. Click ≡ in TMflow and go to **Configuration** > **Vision Setting** > **Calibration**.

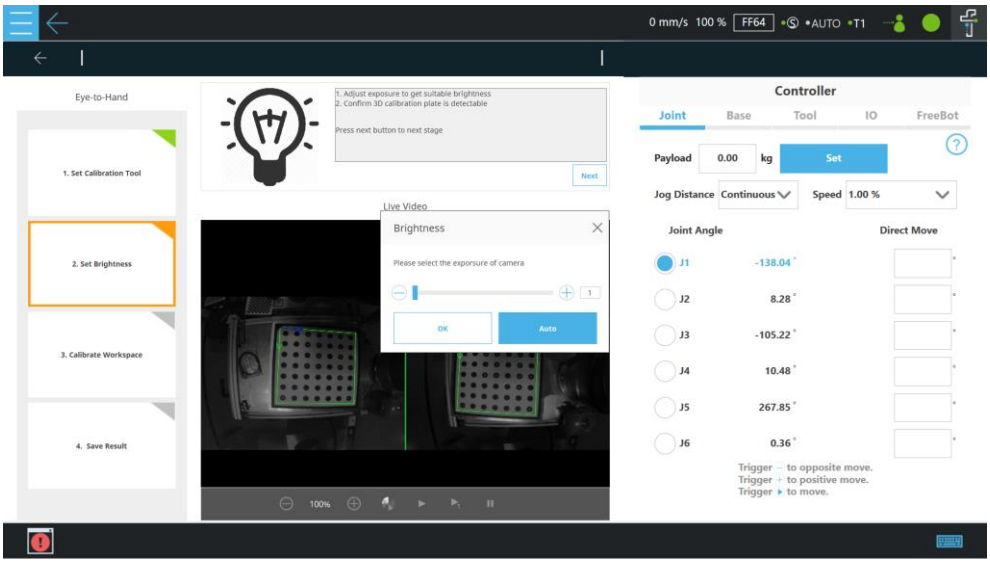


2. When the screen prompts for camera selection, select a camera for **Eye-to-Hand** calibration and click **Set**. Then select **Eye-to-hand** and click **Next**. Select **Manual** and click **Next**. This demnostration of ETH calibration uses the Ensenso camera as an example.

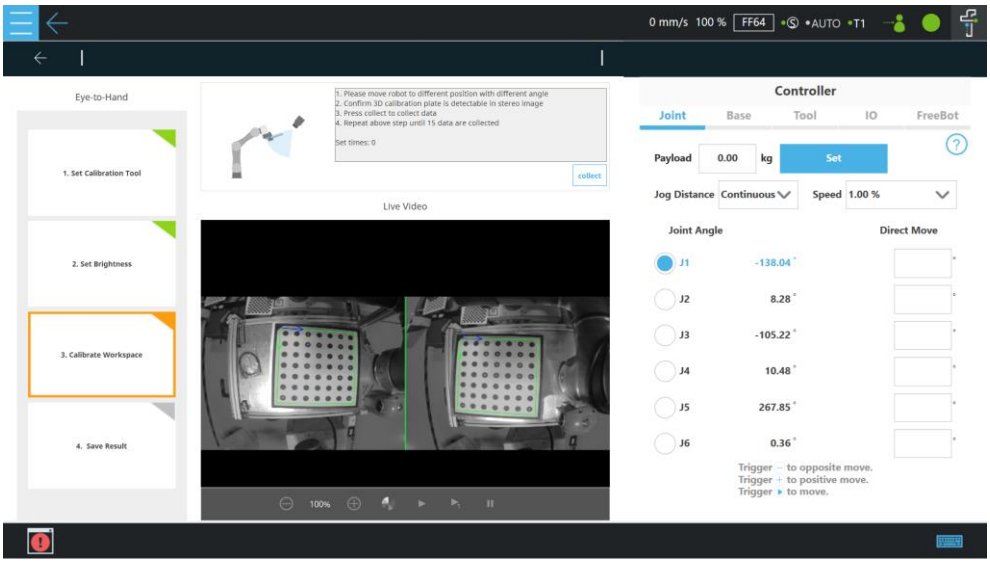
3. After confirming that the calibration board is detected (as indicated by the green-circled area), click **Next**.



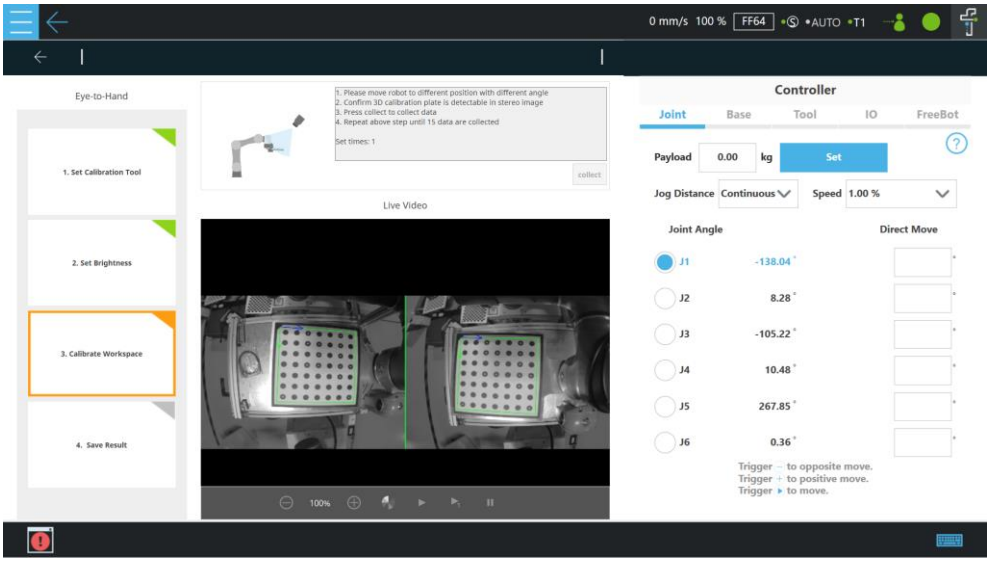
4. Adjust the exporsure manually or automatically to make the screen look moderate. Click **OK**, then **Next**.



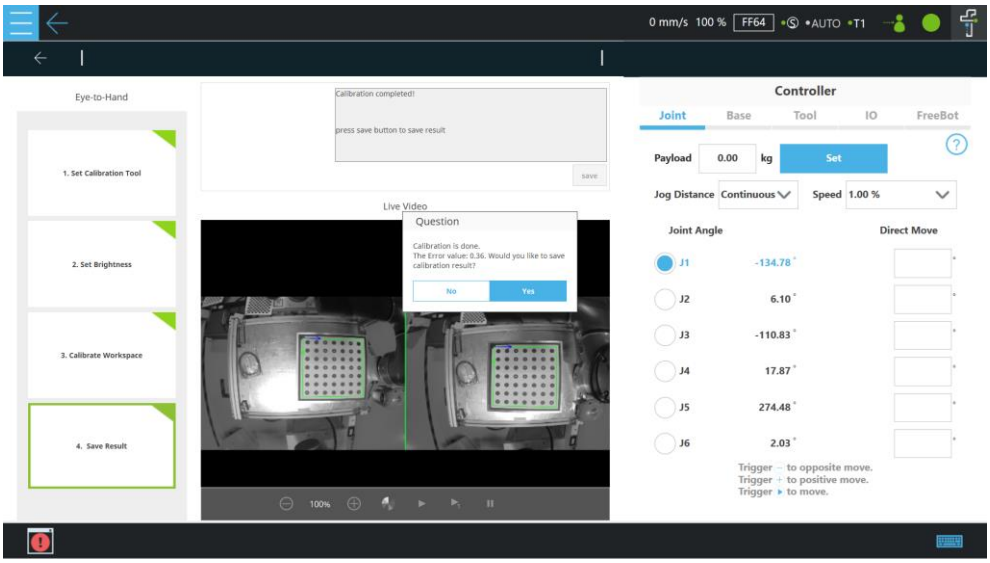
5. Once confirming that the camera recognizes the calibration board, click **collect**.



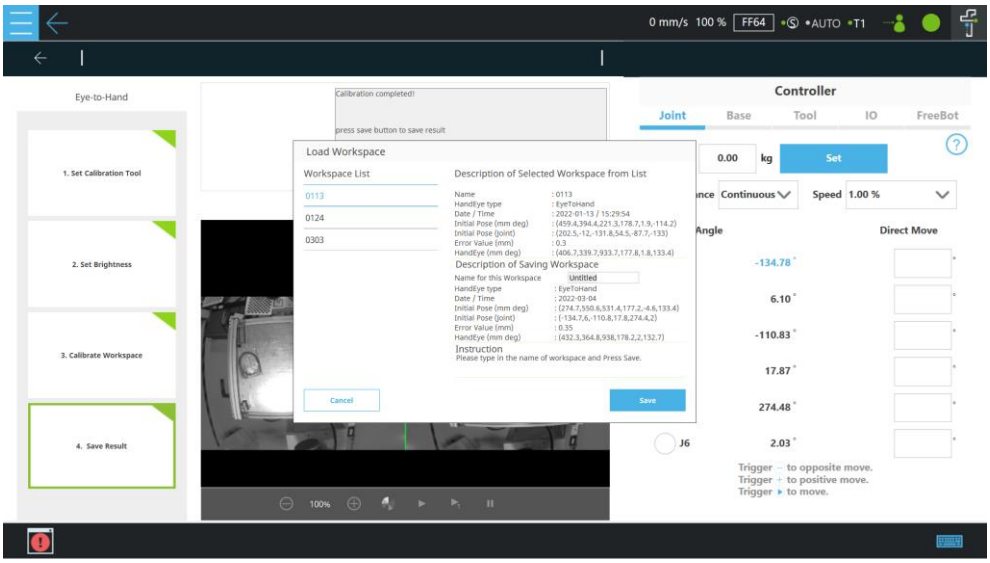
6. Once clicked **collect**, the collect button will be grayed out before moving the robot. After properly moving the robot, users can collect the next one.



7. Repeat moving the robot and click **collect** to make the robot have a variety of posture changes for a total of 15 takes for the calibration reference with a variety of point information. Afterwards the system automatically calculates the hand-eye parameters and returns a calculation result in a pop-up window.



8. Now, users can click **Save** to save the calibration result or modify the workspace name.

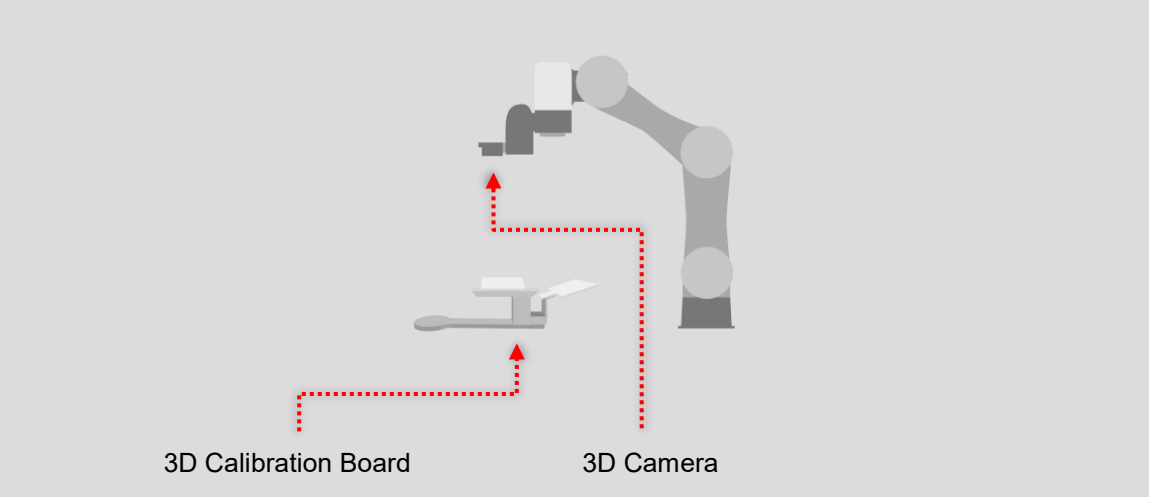


3.2.1.2 3D Camera Eye in Hand

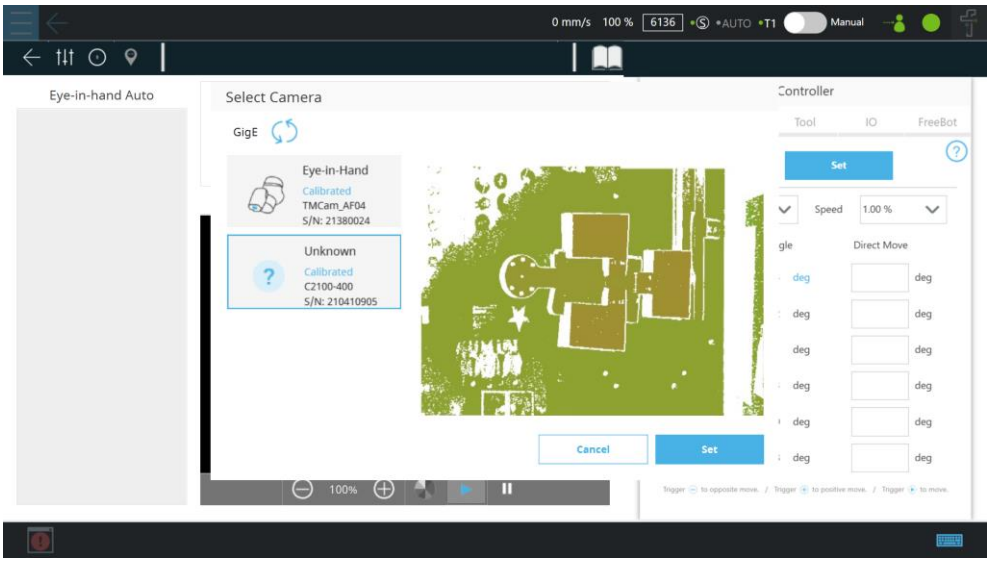
With the EIH 3D Camera, 3D Bin Picking can be applicable to the mobile robot with more flexibility. In comparison to ETH, there is no need to calibrate every time the robot-environment changes.

Note

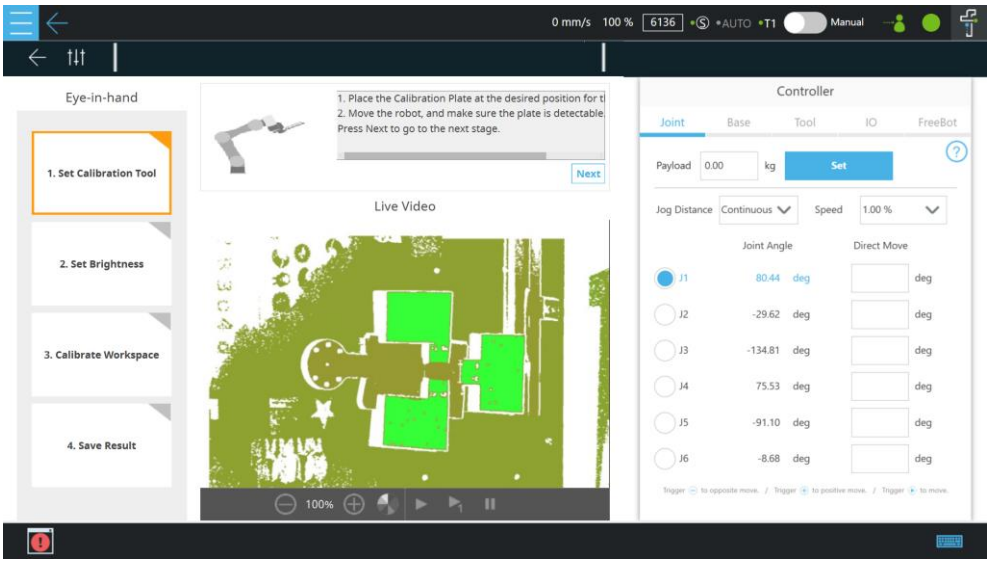
NOTE:
Before 3D camera eye in hand calibration or modeling, the 3D camera must be fixed on the tool end of the robot in EIH mode and connected to the control box. The 3D calibration board of the 3D camera must be placed in an appropriate location, and use the cable to connect the 3D camera and the control box.



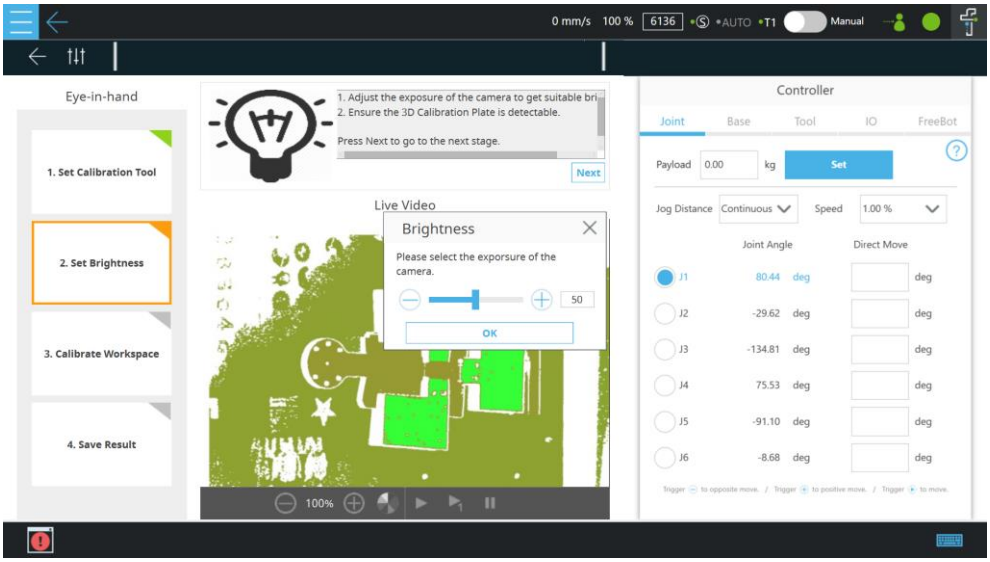
1. Go to ≡, click **Configuration** > **Vision Setting** > **Calibration**.



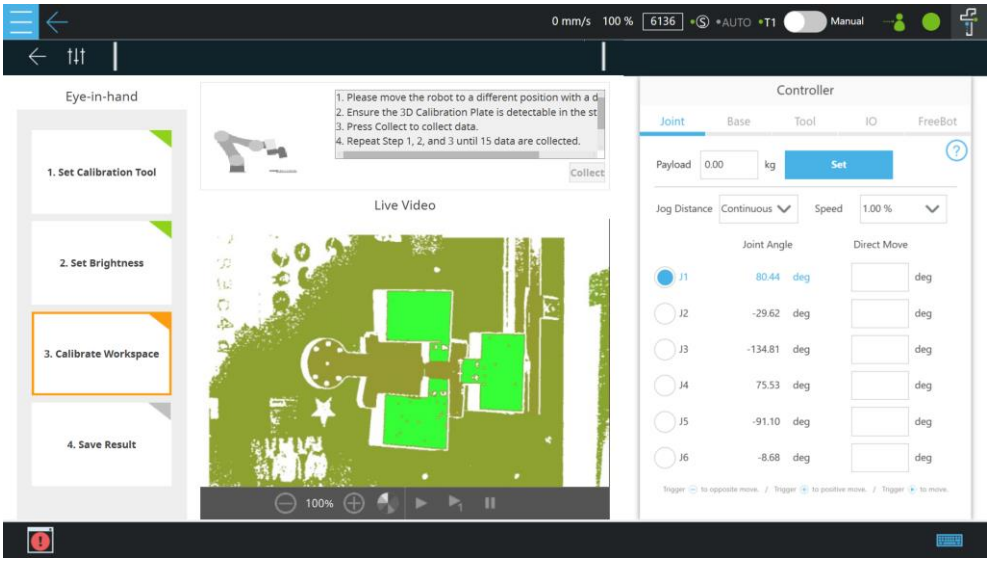
2. When the screen prompts for calibration selection, select a camera for **Eye-in-Hand** calibration and click **Set**. Then select **Eye-in-hand** and click **Next**. Select **Manual** and click **Next**. This demnostration of EIH calibration uses the Benano 3D camera as an example.
3. Move the robot to make the 3D calibration board in the sight as shown in the Live Video. Once detected by the camera, the 3D calibration board will be shown in green. After confirming that the 3D calibration board is shown in green, click **Next**.



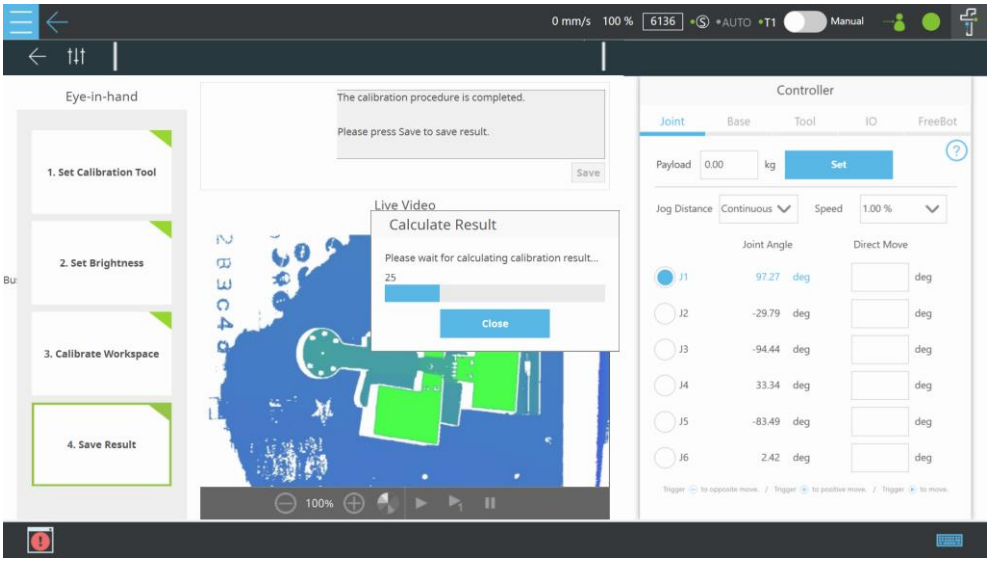
4. Adjust the brightness manually to make the screen look moderate. Click **OK**, and then click **Next**.



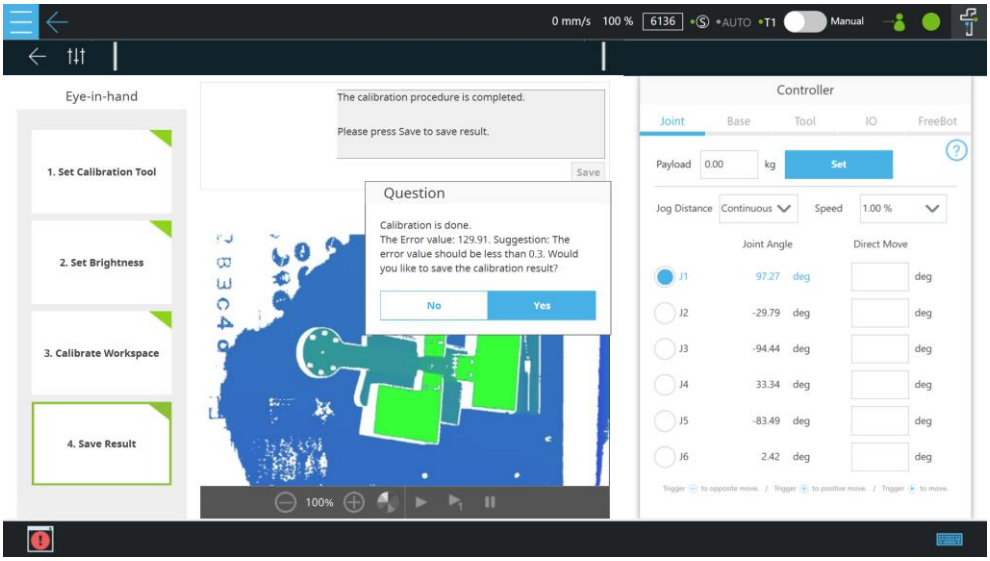
5. Move the robot to capture the 3D calibration board with 15 different posture changes.



6. After 15 takes, the system will calculate the calibration result automatically.

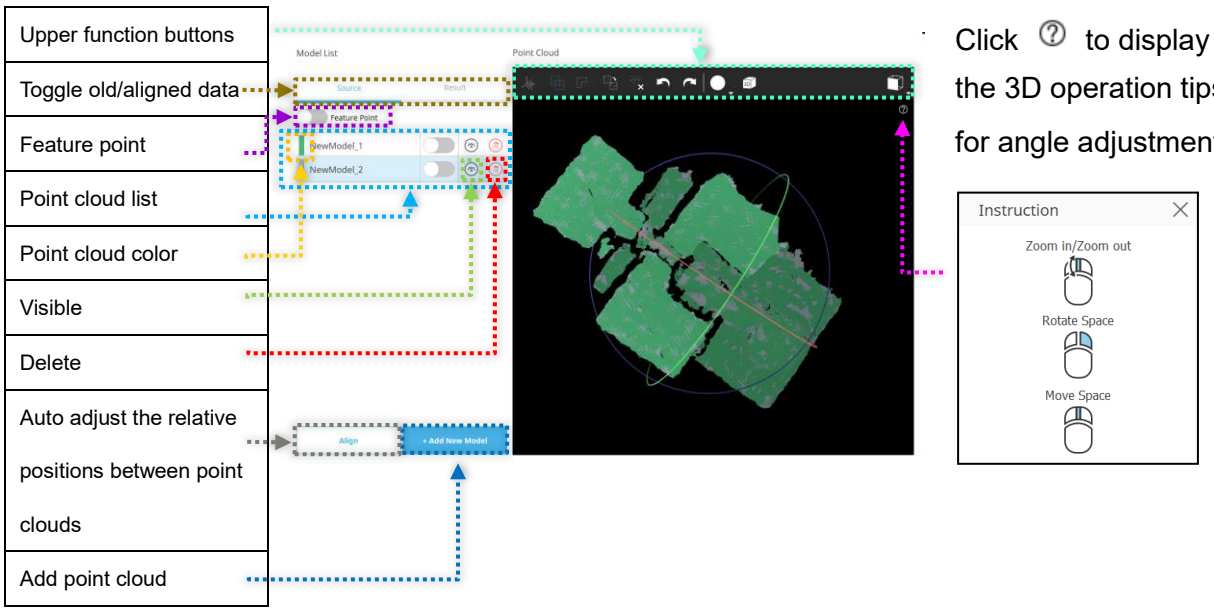


7. The system will generate the stadard deviation after the calibration. Now, users can click **Yes** to save the calibration result and apply the result to the 3D vison task editing.



3.2.2 3D Modelling

3D modeling aims to create a 3D model by having the target photographed through a 3D camera. In the ETH modeling process, users can choose the pick workpiece method of having the target fixed to the robot flange and use the 3D camera to take on various angles. Users can also choose the place workpiece method of having the target fix to the plane and use the 3D camera to take at one angle. In the EIH modeling process, the user fixed the target in the same position on the plane and adapt the 3D camera to take with one single angle or various angles.



3D Modelling

NOTE:

1. Click the **Feature Point** button to extract features from the point clouds, removing the flat parts.
2. Click the **Align** button to make point clouds more compact and decrease the 3D camera calibration errors of breaking point clouds into layers and pieces.

In the 3D adjustment tab:

- Press and hold the right mouse button to rotate the viewing angle
  Press and hold the right mouse button outside the circle to move the point cloud around the axis that points to the screen.
  Press and hold the right mouse button to move within the circle, and the point cloud will follow the direction of the mouse movement.
- Press and hold the middle mouse button to pan the point cloud
  Press and hold the middle mouse button on the screen and move, the point cloud will follow the direction of the mouse movement.
- Roll the mouse wheel to zoom the viewing angle
  Roll the mouse wheel on the screen, and the angle of view will zoom in or out.

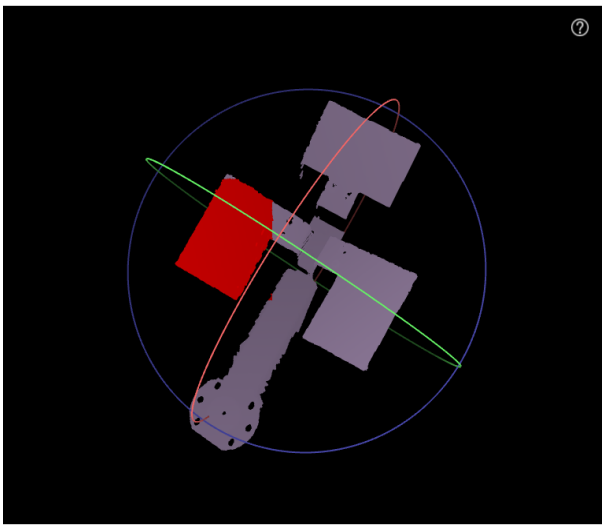
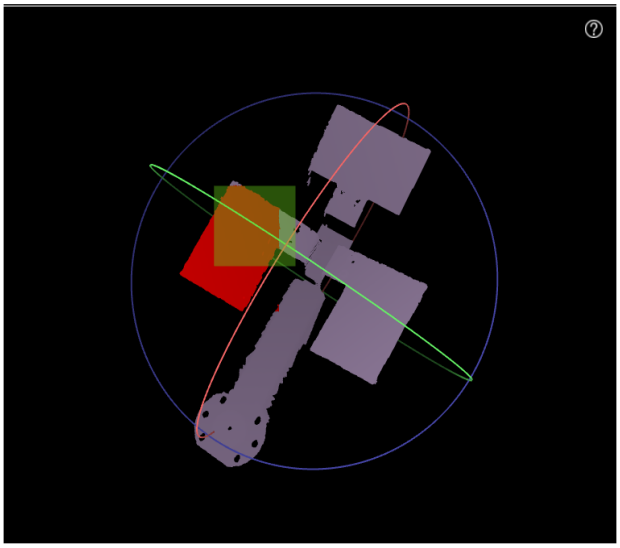
The 3D adjustment tabs include: 3D Editor, Box range, Point cloud viewer, and Modeling.

- Upper function buttons

  There is a row of function buttons above the point cloud. When the leftmost mode switching icon appears white, it denotes it is now in the delete point mode.

Point Cloud Select Icons

Button icon descriptions:

	Click to change the toolbar item. Switch between the delete point mode and edit base mode.
	One of the select modes. In this select mode, users can frame the interested point cloud. The selected point cloud will be in red as shown below.  Point Cloud Select
	One of the select modes. When the button is in green, it means it is in the mode. If it is in white, click it to switch to this mode. In this select mode, users can frame the point cloud marked as not interested, and the framed point cloud will be deselected from the region of the previsouly selected point cloud as shown below.  Point Cloud Select to Delete

	One of the select modes. Click the button to reverse the selected area from the current selected area, and the unselected area will be selected instead.
	Delete points marked as to be deleted as in red.
	Recover the last deletion.
	Redo the next deletion.
	Switch the frame selection tool.
	Crop the point cloud
	Click to change the viewpoint.

When the leftmost button above the point cloud is in green, it means it is in the edit base mode. After clicking, it will switch the button list as shown below.

Point Cloud Edit Coordinates Icons

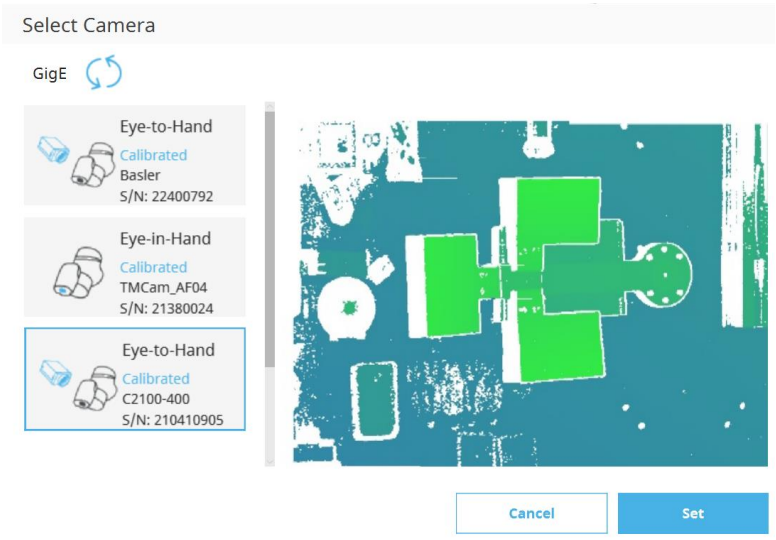
Button icon descriptions:

	Click once to switch to delete point mode (white) or edit base mode (gray).
	One of the edit modes. When it is in green, it means that it is in the mode. If it is in white, click it to switch to this mode. In this mode, the point cloud base can be panned. The method is to hold the left mouse button and then move the mouse and the point cloud base will follow the direction of the mouse movement.
	One of the edit modes. When it is in green, it means that it is in the mode. If it is in white, click it to switch to this mode. In this mode, the point cloud base can be rotated by holding the left mouse button. If the mouse moves outside of the three circles, it can be rotated along the axis perpendicular to the screen. Move inside of the three circle, the point cloud base will rotate with the direction of mouse movement.

	Move the base origin to the point cloud center automatically.
	Click to align the point cloud with the base. Press and hold on the circumferences to rotate the axis of the base. Press and hold on the base to move the base.
	Click to change the viewpoint.

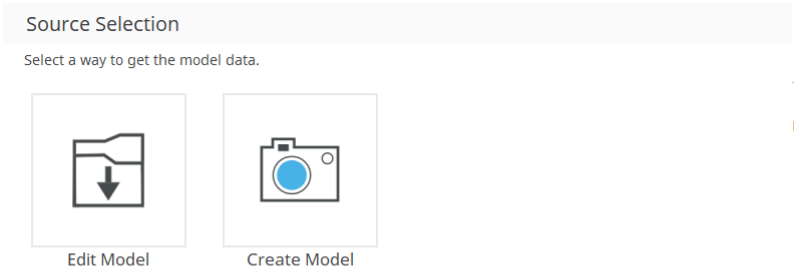
3D modeling is explained below.

1. Go to **Configuration** > **Vision Setting** > **Modeling**. Select a 3D camera from the Select Camera page on the left and click **Set**.

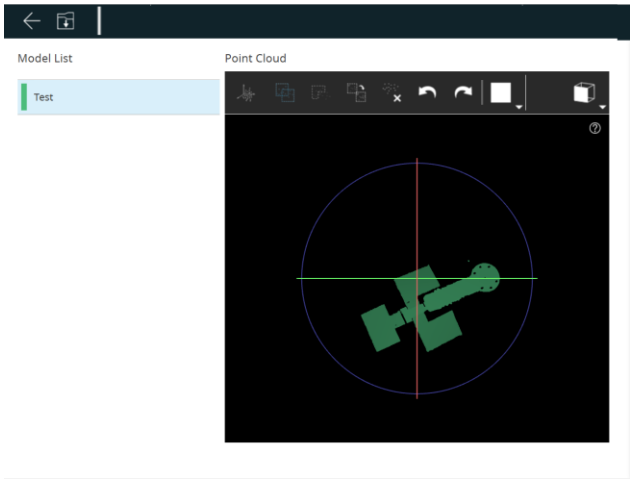


2. In the **Select a way to get model data** prompt, select **Create Model** to model the point cloud with the current 3D camera. Then click **Next**.

   Once **Create Model** is selected, users will be directed to the modeling tab if they have chosen an EIH 3D camera in the previous step or to the **Select the mode** prompt if they have chosen an ETH 3D camera. For instructions on modeling with an EIH 3D camera, go to Step 3. For instructions on modeling with an ETH 3D camera, go to **Modeling with an eye-to-hand 3D camera**.



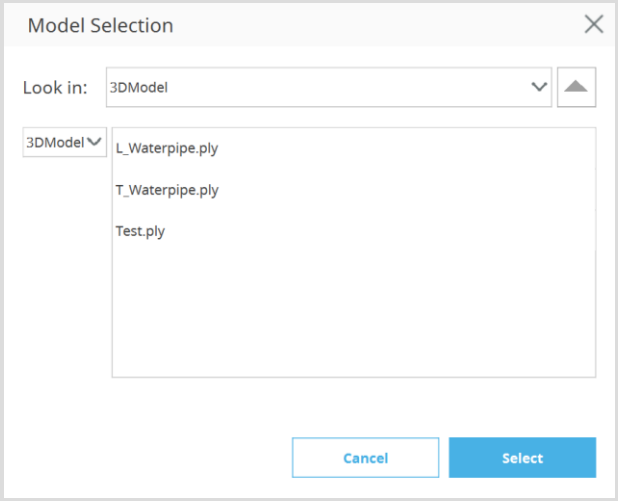
If **Edit Model** is selected, users can select the created model file from the **Model List** for editing. Please refer below for instructions.



Note

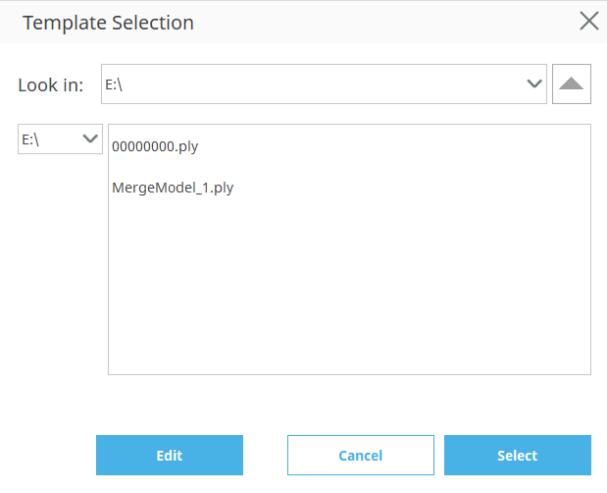
NOTE:

- If **Edit Model** is clicked, the window for selecting a model file (in the CAD format) will prompt.

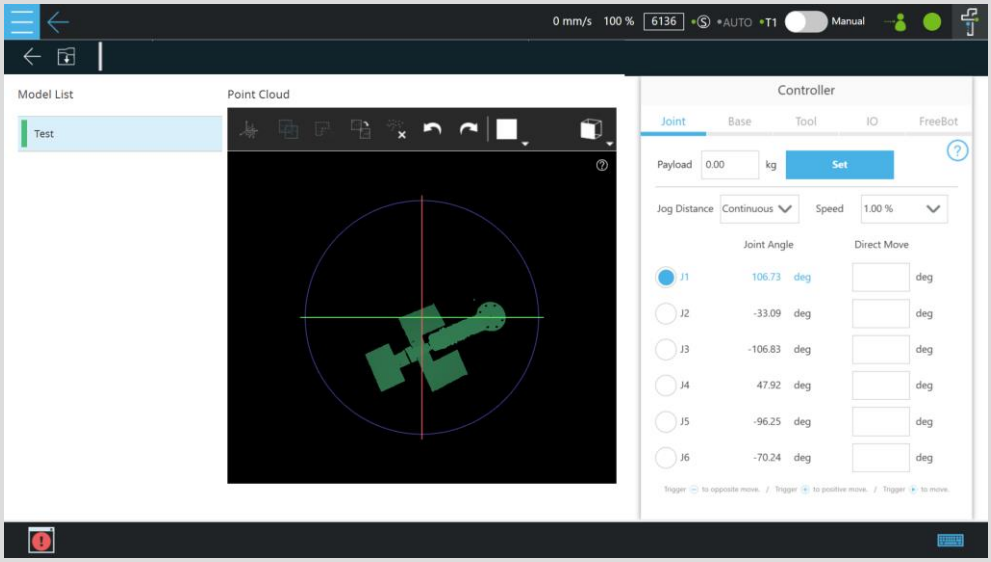


- Users can select the model file that has been edited from the folder **3D Model** in TMflow

or read the model file from the flash drive labeled **TMROBOT**. The three file extension currently supports are .ply, .stl, and .obj. The following shows an example for reading from the flash drive. If it is a folder, it will be marked as one.



- After selecting the CAD file, users will enter the **Modeling** tab to edit the saved point cloud file or the 3D drawing file obtained from another device.



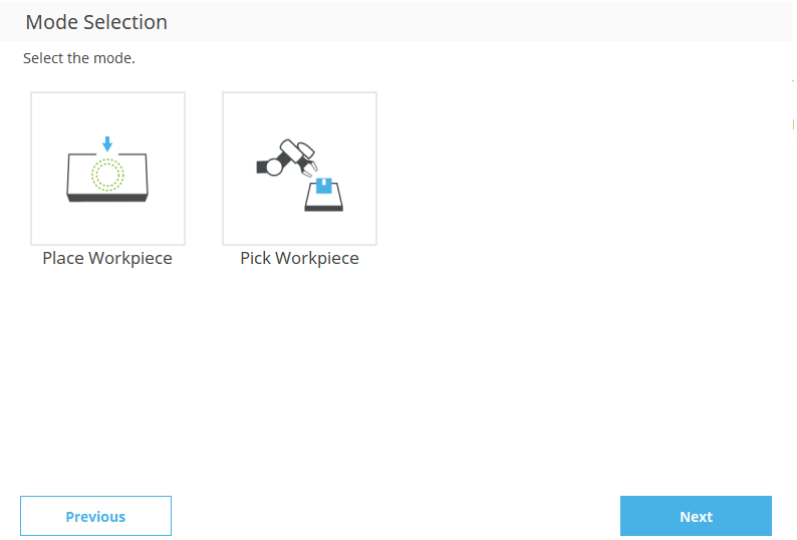
The currently opened file's name displays under the **Model List**. If it is retrieved from the camera, it will use NewModel as the default name. The current 3D point cloud status displays at the right, and the R, G, and B of the three circle colors correspond to the X, Y, and Z axes, respectively.

There is no **Align** button, **Add New Model** button, and tab function under the Model List on this page.

Modeling with an eye-to-hand 3D camera

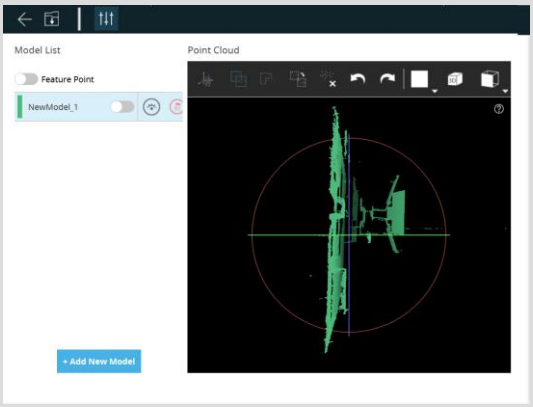
In the **Select the mode** prompt, click **Place Workpiece** to go to the **Modeling** tab; or click **Pick Workpiece** to load the work plane and convert the point cloud base to

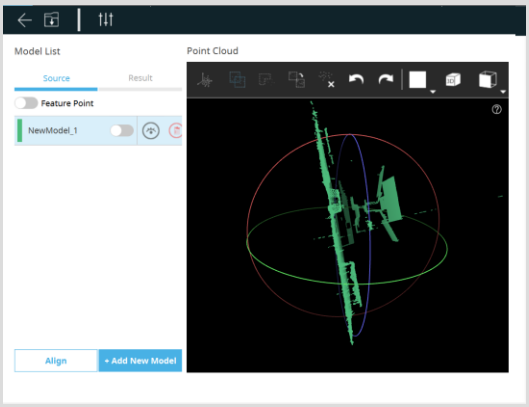
the robot flange.



Note

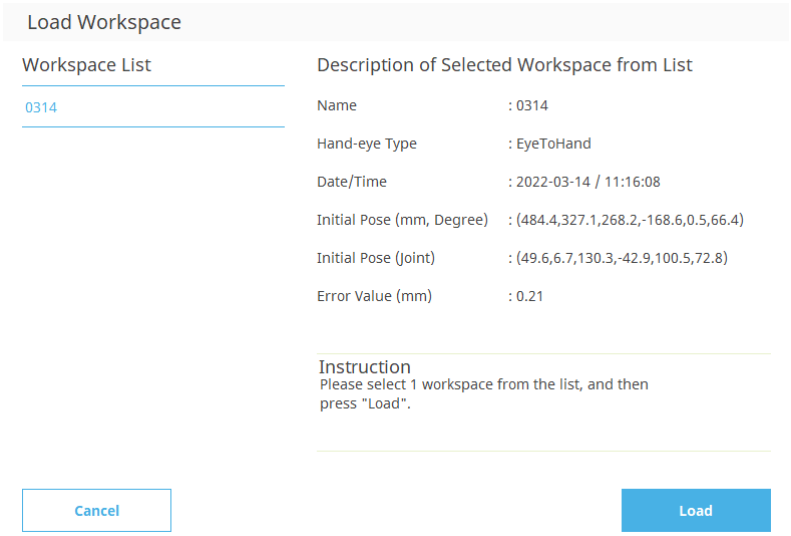
NOTE:
After clicking **Place Workpiece**, there is no **Align** button and tabs under the Model List as shown as below left. Click **Pick Workpiece** and the screen will be shown as below right.



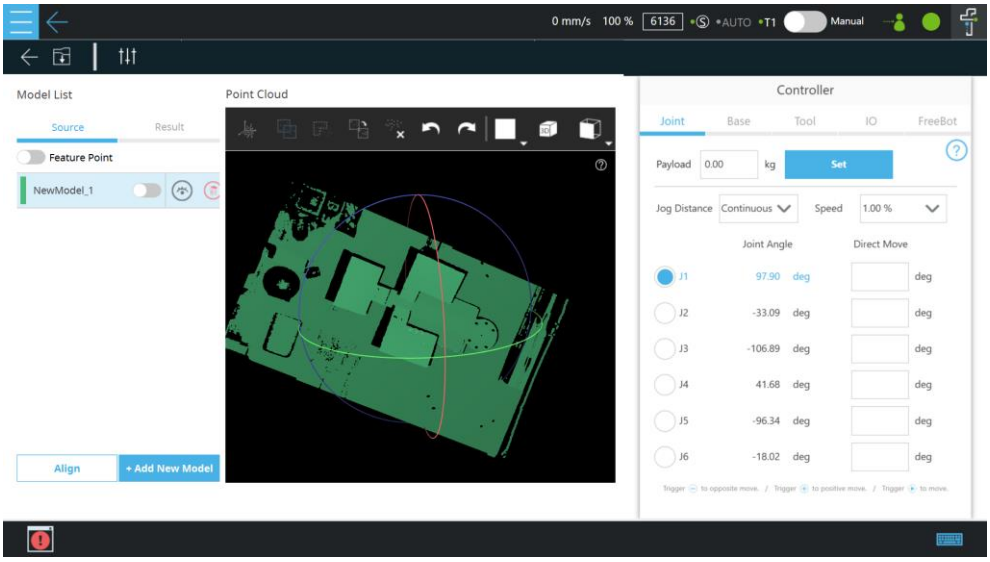


※The following instructions use **Pick Workpiece** as an example

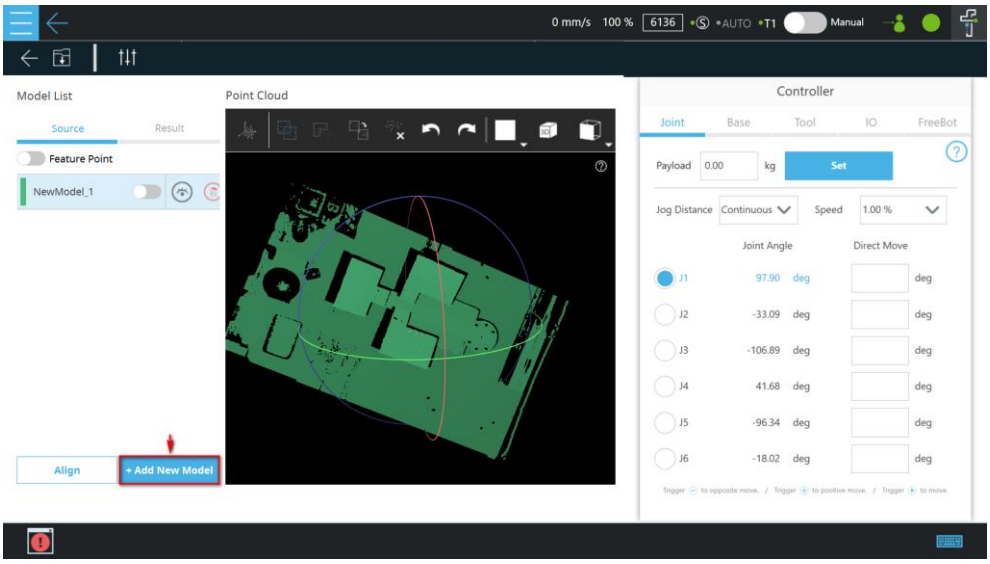
In the **Load Workspace** prompt, click the desired hand-eye parameter to use. Generally speaking, the latest calibrated parameters are suggested to use. If the modeling effect is not good, please perform 3D Camera Eye to Hand Calibration again.



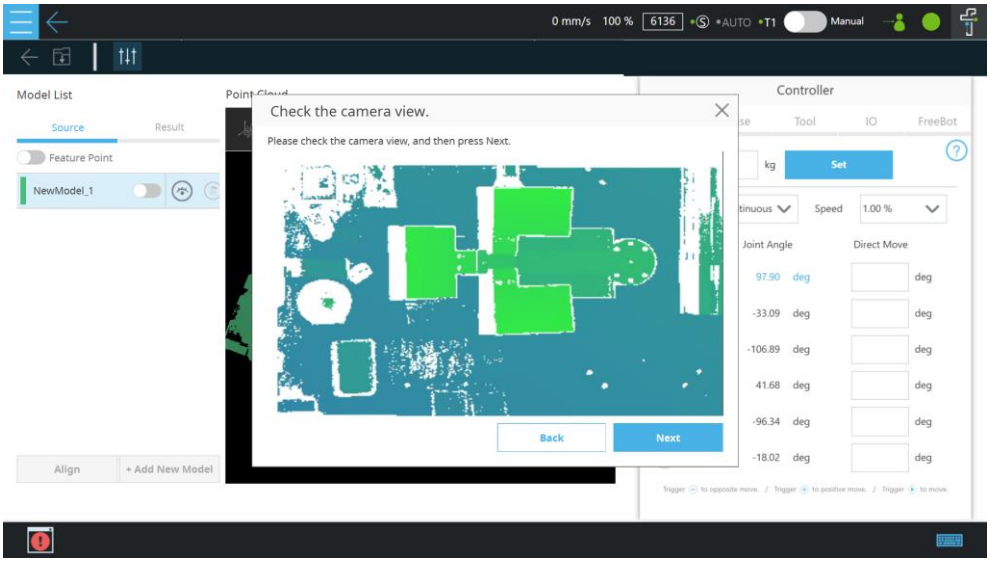
3. In the **Modeling** tab, the first point clouds are automatically taken and shown on the middle screen. Users can click the right mouse button to rotate and the middle button to pan for the appropriate viewing angle adjustment.



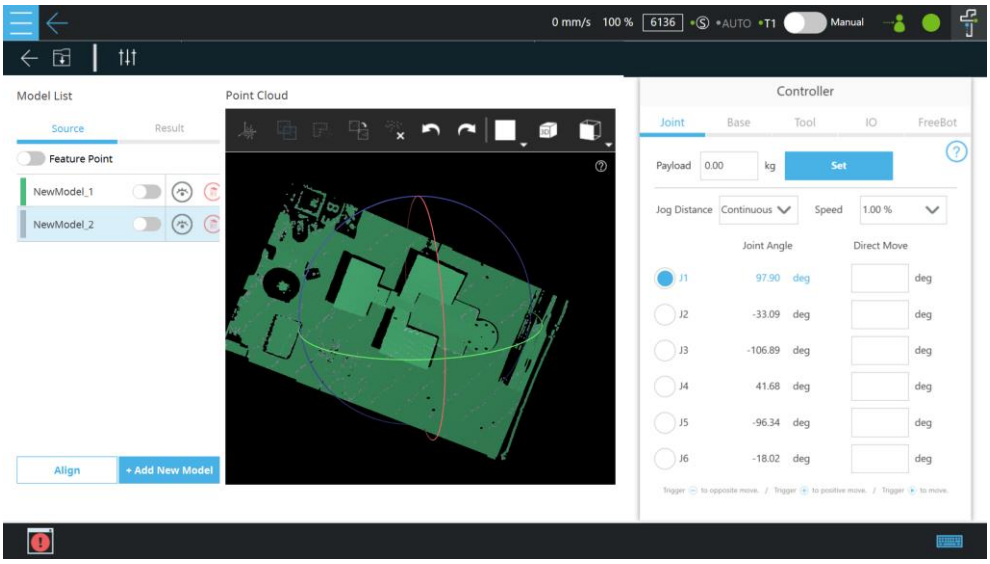
4. Click **Add New Model** to take a new point cloud.



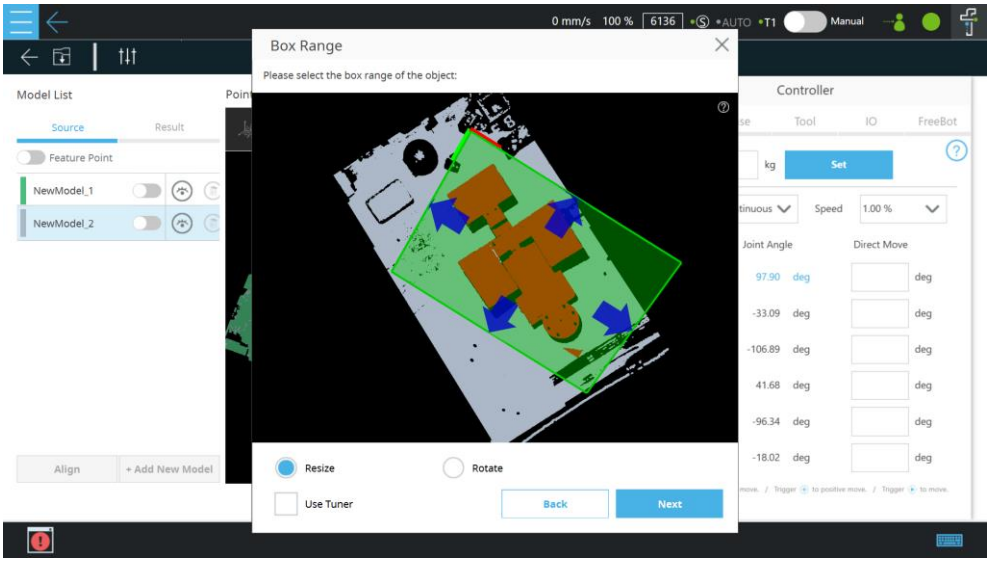
5. Rotate and move the robot flange for the 3D camera to view different parts of the workpiece. Click **Next** to take this point cloud.



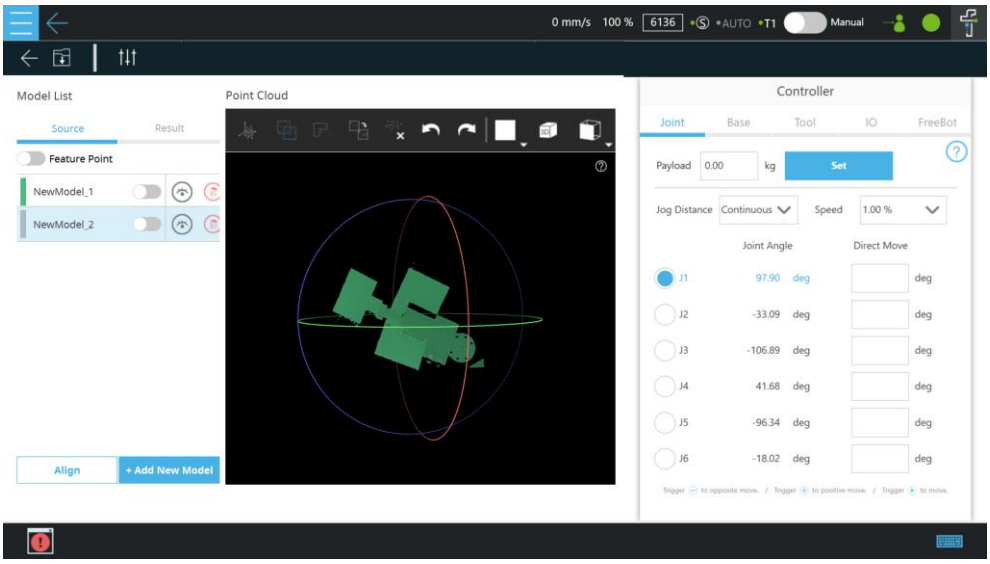
6. Both old and new point clouds will be on the flange of the robot base. It is, therefore, required to remove the environmental point cloud. Click the point cloud cut icon to crop.



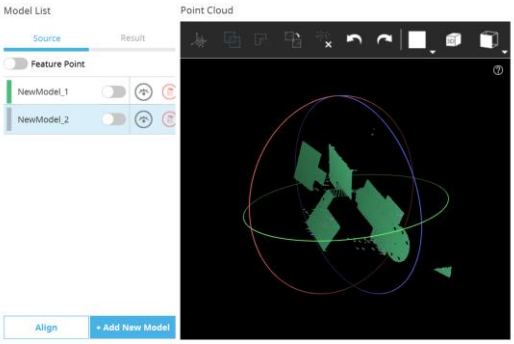
7. Use the mouse to adjust the position of the 3D Crop Box to make it contain the point cloud near the workpiece only. After adjusting, click **Next** to crop.

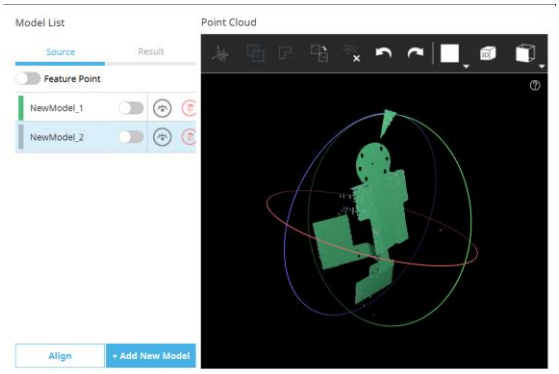


8. 3D Crop Box will take effect on all point clouds. Please repeat the steps of turning and moving the workpiece as well as taking a new point cloud.

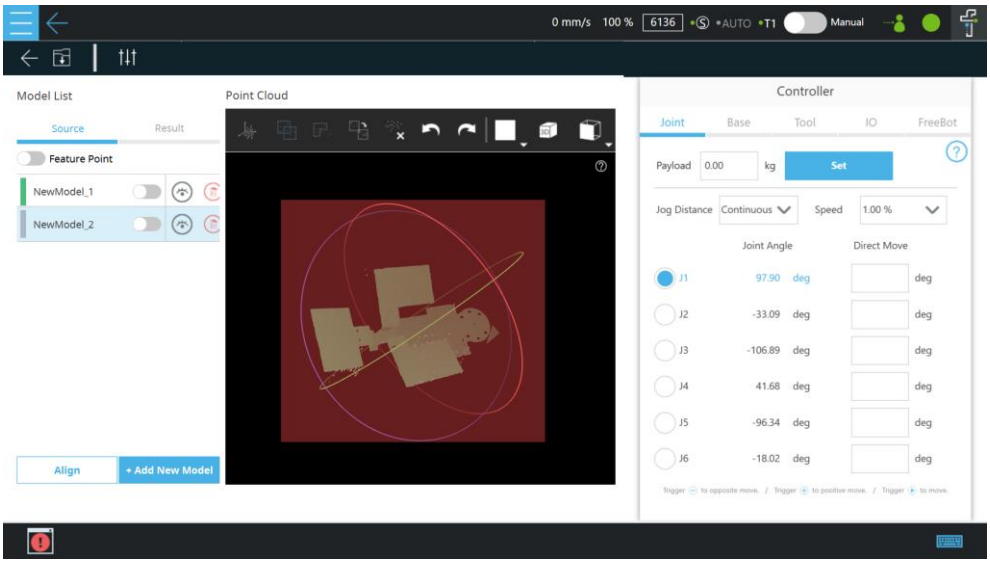


9. Make sure that the point cloud information from various viewing angles of the workpiece is taken.

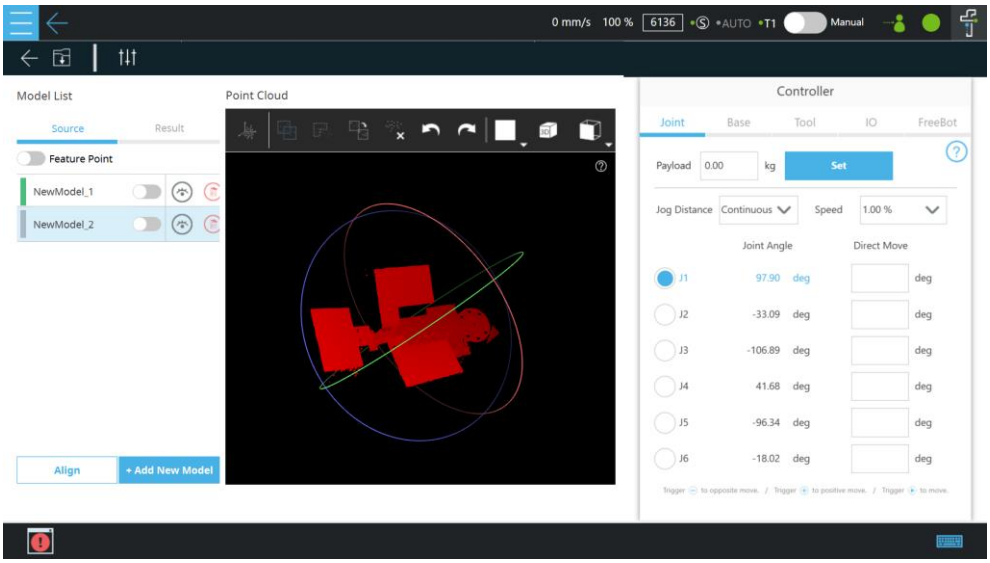




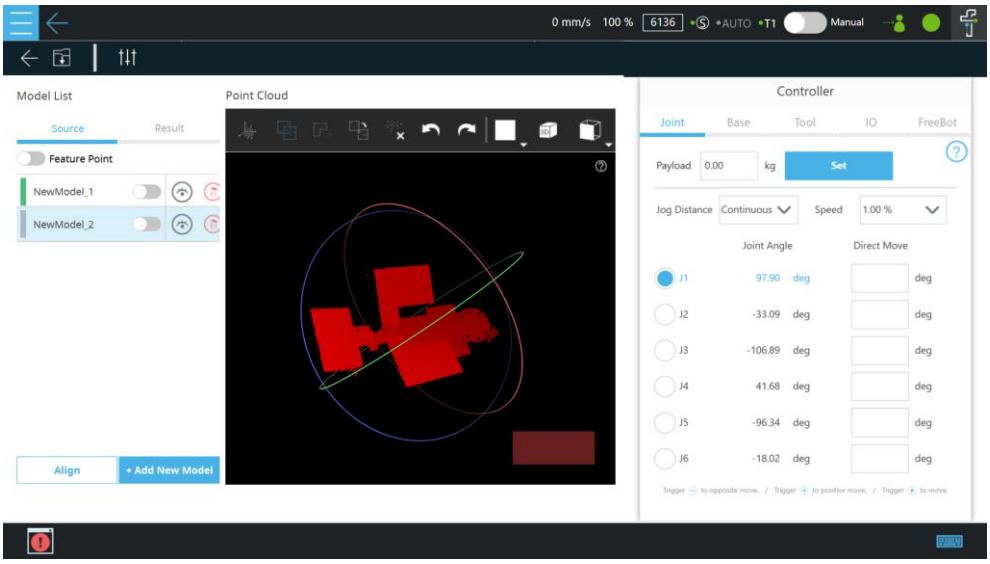
10. Use the select tool and drag with the left mouse button on the screen to select the point cloud.



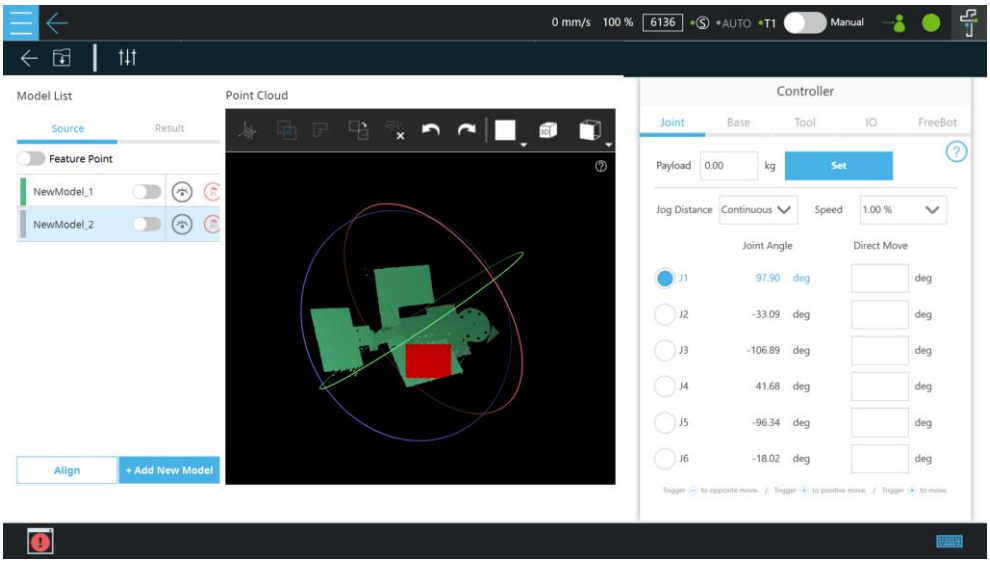
11. The selected point cloud will be in red.



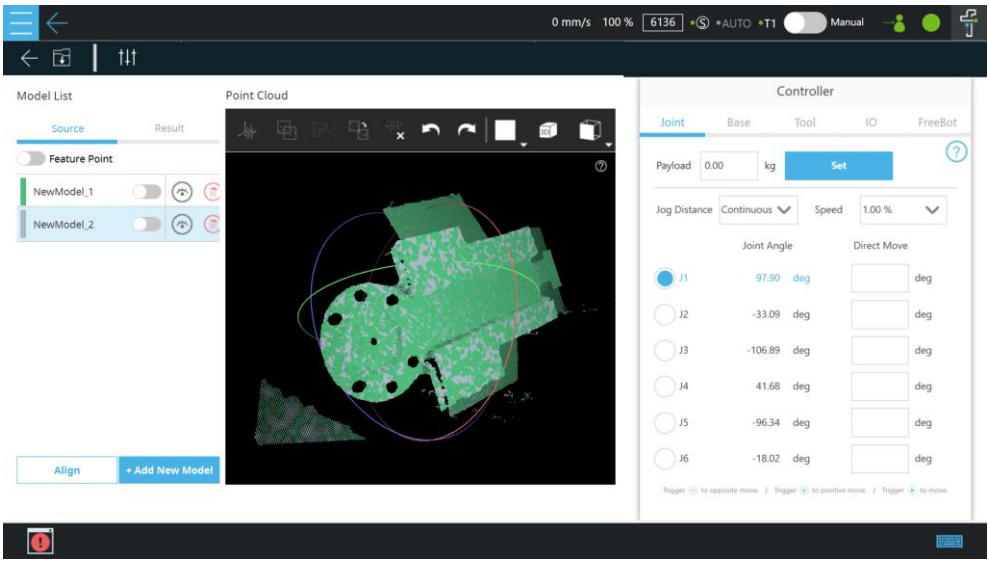
12. The method to frame is the same as dragging the mouse button on the screen with the left button holding. Users can use the right mouse button to rotate and the middle button to pan for a suitable angle of view adjustment to crop the selection.



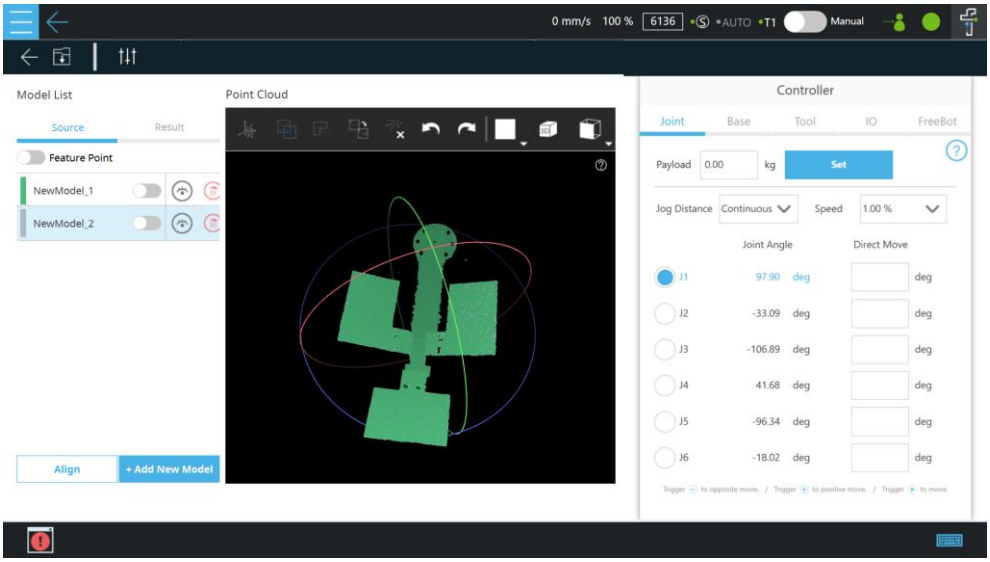
13. The point cloud selected by the cropped selection frame will be in red.



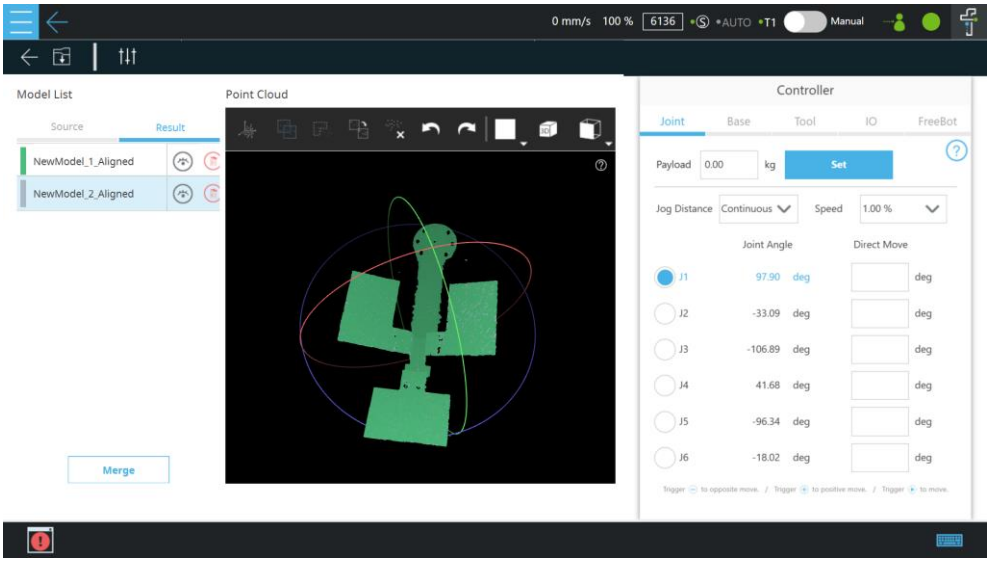
14. There will be noise points on the edge of the point cloud of the workpiece inevitably, which will affect the modeling effect. Please try to remove them as possible.



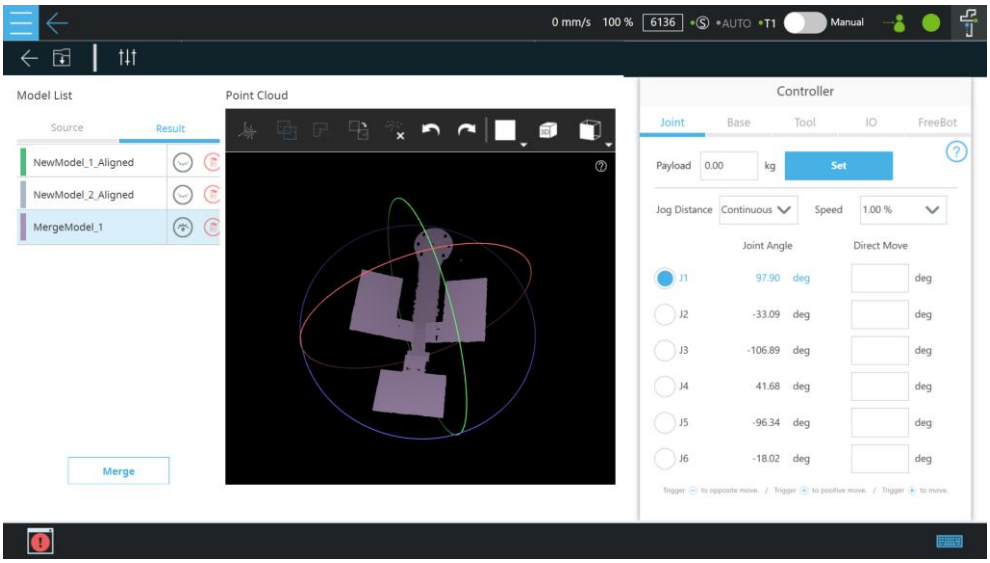
15. Click the crop button to crop the red part. After cropping, click **Align** to make different point clouds fit each other.



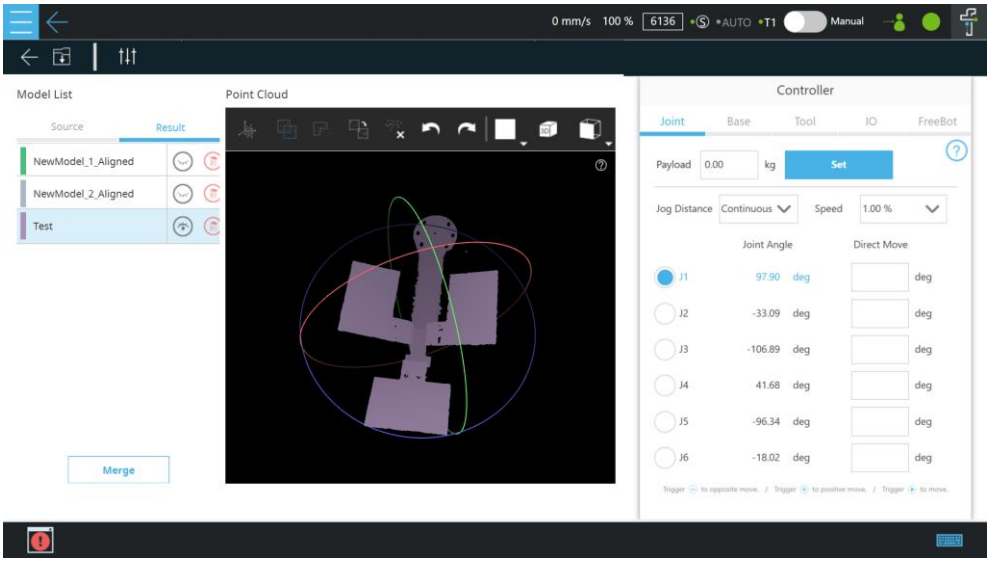
16. After clicking **Align** and checking OK, click **Merge** to combine the point clouds.



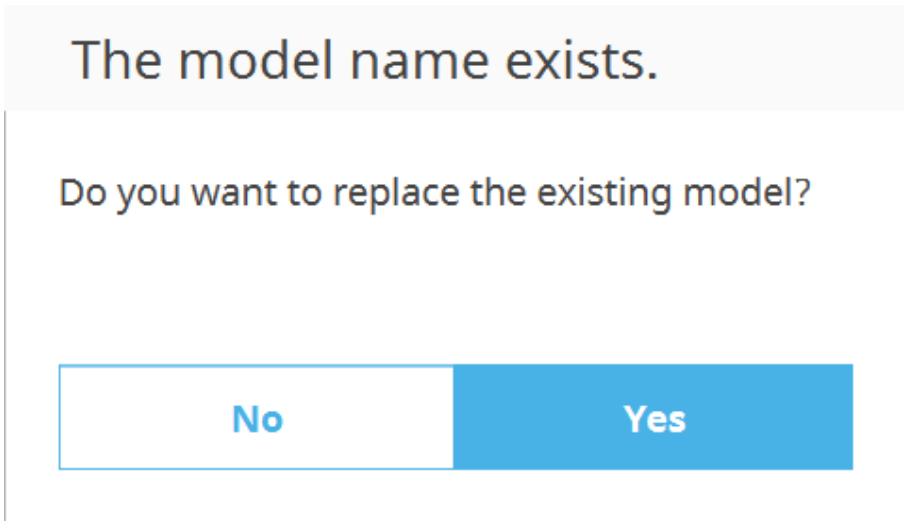
17. After clicking **Merge**, there will be an additional merged point cloud in the point cloud list.



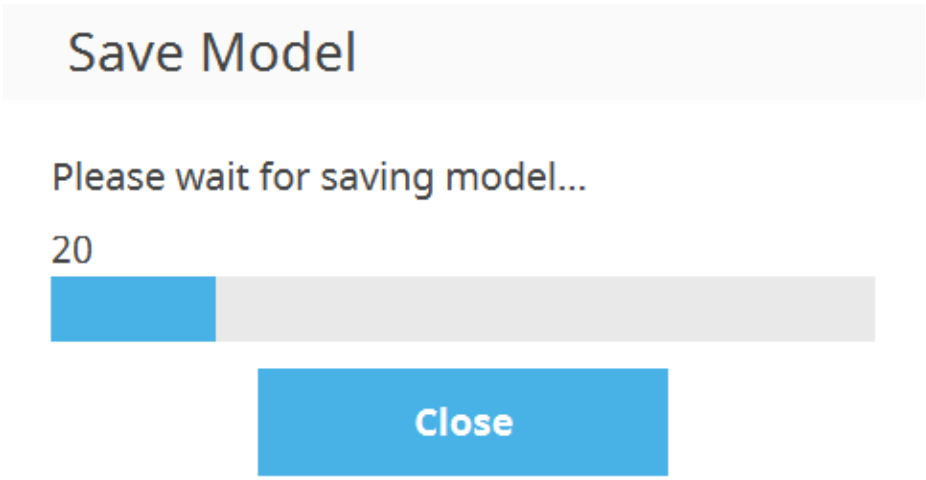
18. Double-click with the left mouse button on the point cloud name to change the name, and then click **Save** to save the point cloud.



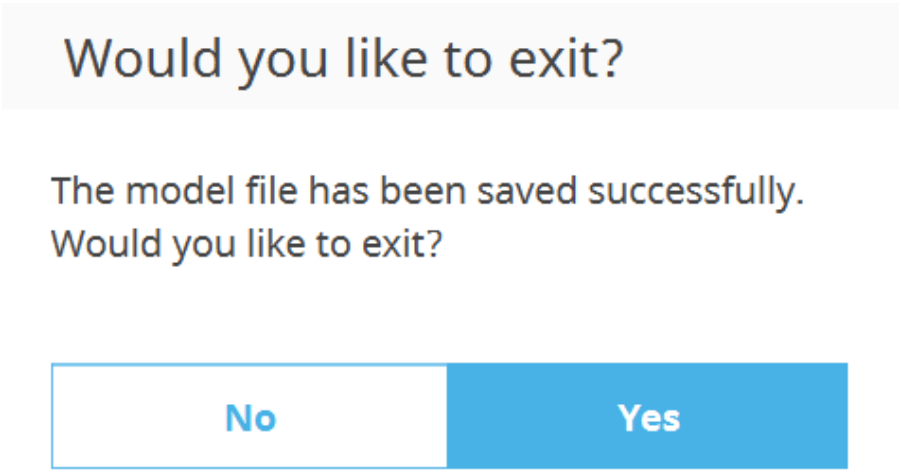
19. If there exists a point cloud file with the same name already, users will be asked whether to overwrite.



20. It will take a little while to save the file. Please be patient.

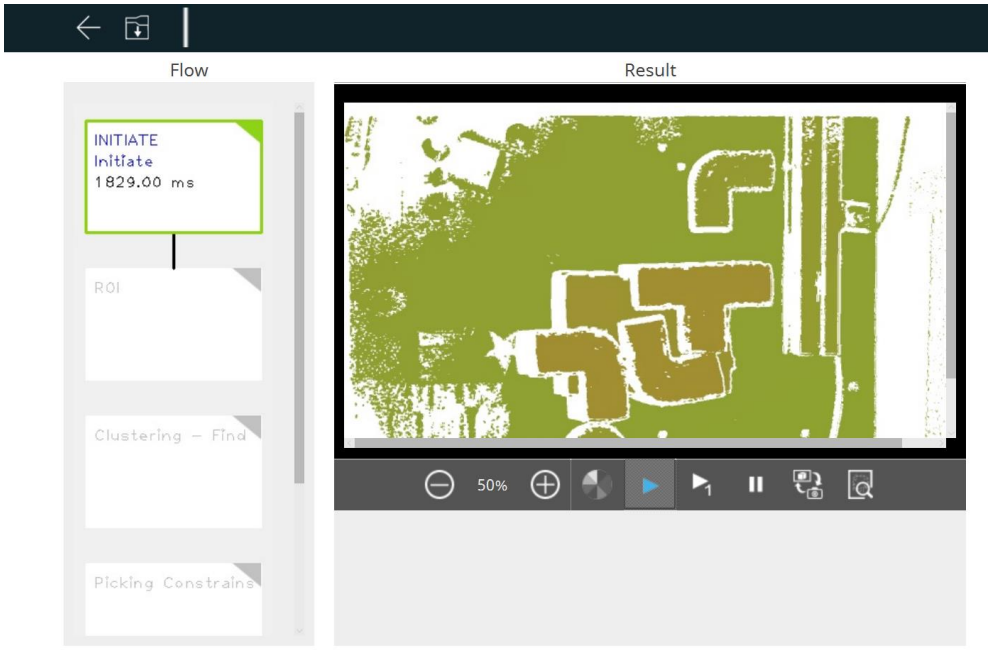


21. After saving, users will be asked whether to leave the Modeling tab.



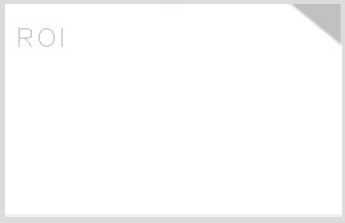
3.3 3DVision Process Compilation

3DVision compilation is a fixed process, and must be edited in order: **Initiate**, **Region of Interesting**, **Clustering** – **Find** (object searching), and **Picking Constrains**. No editing process can be skipped.



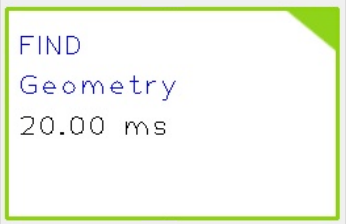
NOTE:

- Process editing status comes with four types:
  a. The upper right corner in gray denotes that the module is editable but not yet edited
  b. The upper right corner in green denotes the module has been edited successfully.
  c. The box framed in green denotes the module is currently running successfully.
  d. The box framed in orange denotes the module is currently running and failed.



(a)

(b)



(c)

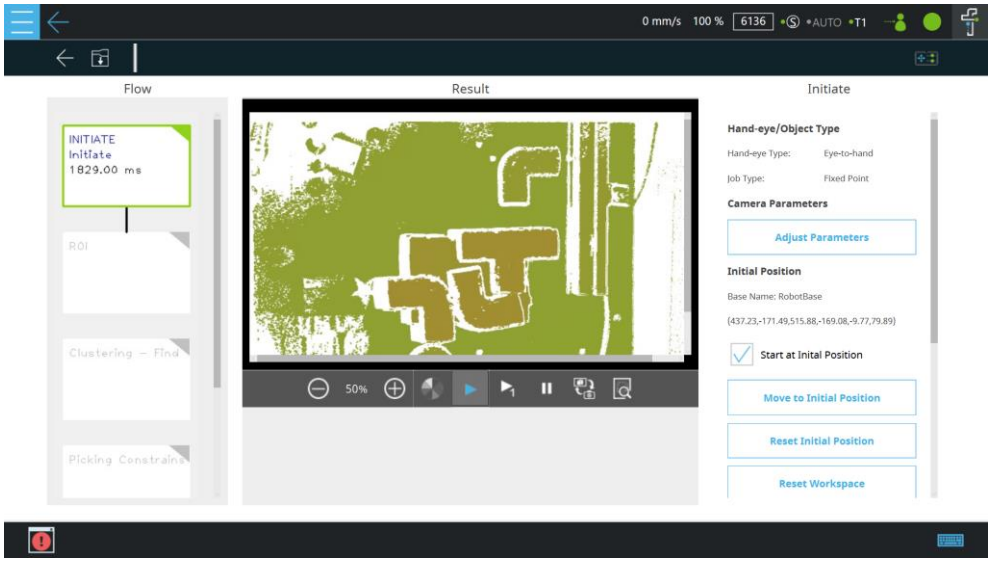
(d)

- If users want to edit a module after editing it, users can left-click or right-click the module. If the module contains multiple methods, right-click and select **change method** to change the method.
- At the bottom right of the live video:

	Toggle between 3D image and 2D image texture. This feature becomes available only when Image Color under Camera Parameter Setting is enabled.
	Display Point Cloud Viewer and different information in the current process. If Image Color is opened, users can switch to the image color display in use. ● Initiate: The point cloud captured from the camera. Users can use it to check if the camera results are good. ● Region of Interest: View the point cloud in the selected range ● Clustering – Find: The point cloud and Find results. The model with the highest matching score will be marked in red when **CAD** is selected. ● Picking Constrains: Point clouds within the ROI and constrained results. Blue denotes OK to pick, and red, not OK to pick.

3.3.1 Initiate

In the process compilation, after clicking **Initiate**, adjust the camera parameters to make the objects in the scene be fully imaged. After confirming that everything is adjusted, click **Save**.



Flow Initiate

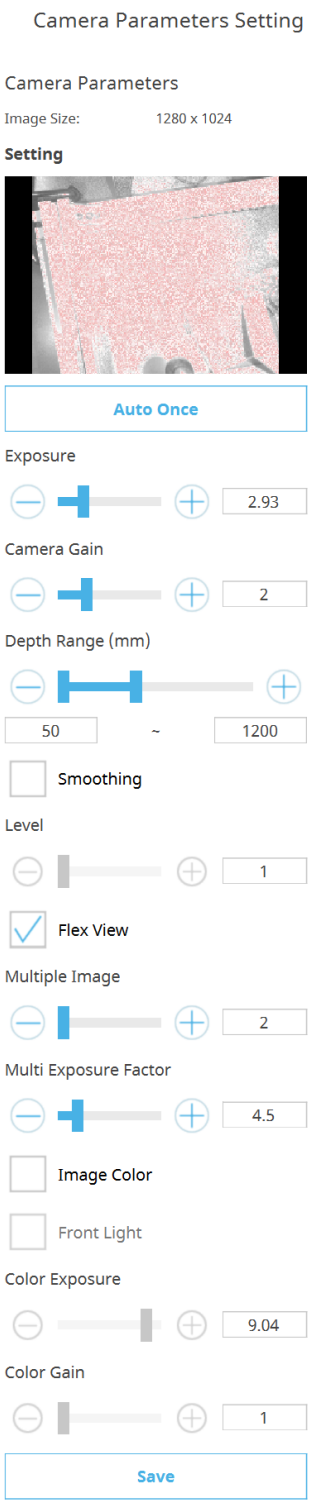
- **Hand-eye Type**:

  The relationship between the 3D camera and the robot. Eye-to-Hand and Eye-in-Hand are both supported. The field below is the relationship between the camera and the object.

- **Camera Parameters**:

  Click to open the 3D camera parameter setting tab. The instructions are as follows:

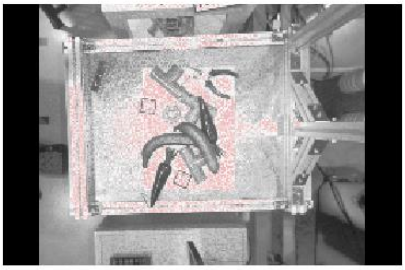
- **Ensenso:**
  - **Auto once**: Automatically adjust the exposure time and gain with the current scene.
  - **Exposure**: Adjust the 3D camera exposure time. This parameter affects the 3D imaging quality.
  - **Camera Gain**: Adjust the 3D camera gain. This parameter affects the 3D imaging quality.
  - **Depth Range**: Set the distance range as a parameter for the 3D camera to calculate. This parameter affects the 3D image acquisition calculation time. The lower the range is, the shorter the depth calculation time it effectively reduces.
  - **Smoothing**: Smooth the distance changes between point clouds. Note that excessive smoothing may damage the original point clouds.
  - **Flex View**: After opening, the 3D camera uses Pattern offset to take multiple images to calculate depth information, which can improve the image quality and some reflection effects. The shooting and calculation time is long, and objects cannot be moved during the process.
    - **Multiple image:** Number of images used in **Flex View**.
    - **Multi Exposure Factor:** After activate **Flex View** and **Multiple image** is greater than 1, **Flex View** function will use two different exposure time values



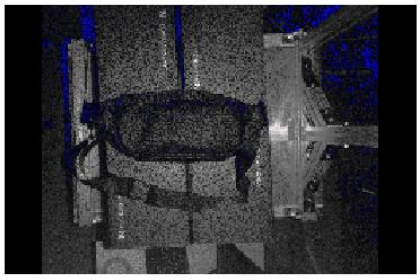
Ensenso 3D Camera Parameter Setting

to get image. Two exposure time values will be **Exposure** and **Exposure** divided by **Multi Exposure Factor**.

- **Image Color:** Enable the camera to take 2D images, thus allowing users to switch image display modes between 2D and 3D. This function requires a specific 3D camera that supports 2D imaging. Make sure this feature is enabled when AI detection or external detection is selected as the clustering method, because both detection processes involve capturing 2D images for analysis.
  - **Front Light:** A fill light that can be enabled when users want to take and correct a color image that is too dark.
  - **Color Exposure:** Adjust the 3D camera's exposure time. This parameter affects the 2D imaging quality.
  - **Color Gain:** Adjust the 3D camera's gain. This parameter affects the 2D imaging quality.
- **Save:** Save the current camera settings. Quit if you don't want to save the settings.

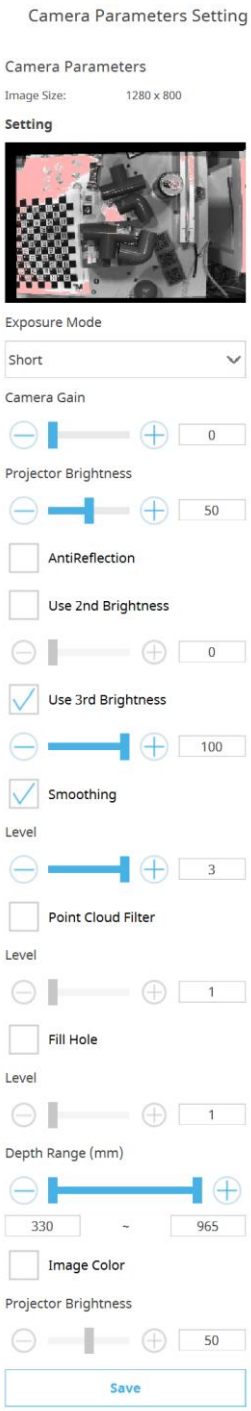


Over-exposed (over-exposed pixels are colored in red)

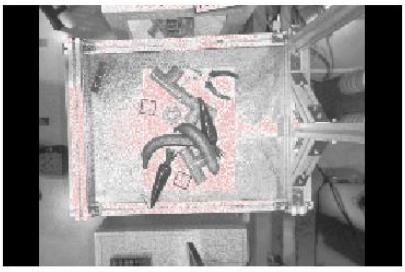


Under-exposed (under-exposed pixels are colored in blue)

- **Benano:**
  - **Exposure Mode**: Switch exposure modes of the camera between Short, Middle and Long.
  - **Camera Gain**: Adjust the gain of the 3D camera. This parameter affects the 3D imaging quality.
  - **Projector Brightness**: Adjust projector brightness. This parameter affects the 3D imaging quality.
  - **Use 2nd Brightness**: Get multiple depth images using adjustable 2nd brightness to calculate depth information after this feature is enabled. This parameter can decrease the impact of light reflections while allowing different objects to be photographed with different levels of exposure.
  - **Use 3rd Brightness**: Get multiple depth images using adjustable 3rd brightness to calculate depth information after this feature is enabled. This parameter can decrease the impact of light reflections while allowing different objects to be photographed with different levels of exposure.
  - **Smoothing**: Smooth the distance changes between point clouds. Note that excessive smoothing may damage the original point clouds.
  - **Point Cloud Filter**: Filter noise of depth image from 3D camera.
  - **Fill Hole**: Automatically fill holes in depth image from 3D camera.
  - **Depth Range**: Set the distance range as a parameter for the 3D camera to calculate. This parameter affects the 3D image acquisition calculation time. The lower the range is, the shorter the depth calculation



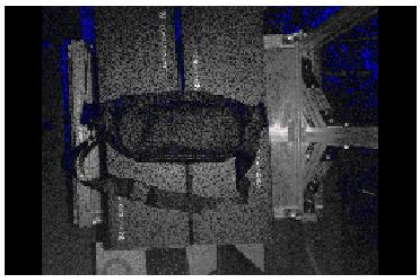
Benano 3D Camera Parameter Setting



time it effectively reduces.

- **Anti-Reflection**: Turn on the anti-reflection mode of the camera in an environment with strong light reflection to obtain better 3D image quality.
- **Image Color**: Enable the camera to take 2D images, thus allowing users to switch image display modes between 2D and 3D. This function requires a specific 3D camera that supports 2D imaging. Make sure this feature is enabled when AI detection or external detection is selected as the clustering method, because both detection processes involve capturing 2D images for analysis.
  - **Project Brightness:** Adjust projector brightness. This parameter affects the 2D imaging quality.
- **Save:** Save the current camera settings. Quit if you don't want to save the settings.

Over-exposed (over-exposed pixels are colored in red)



Under-exposed (under-exposed pixels are colored in blue)

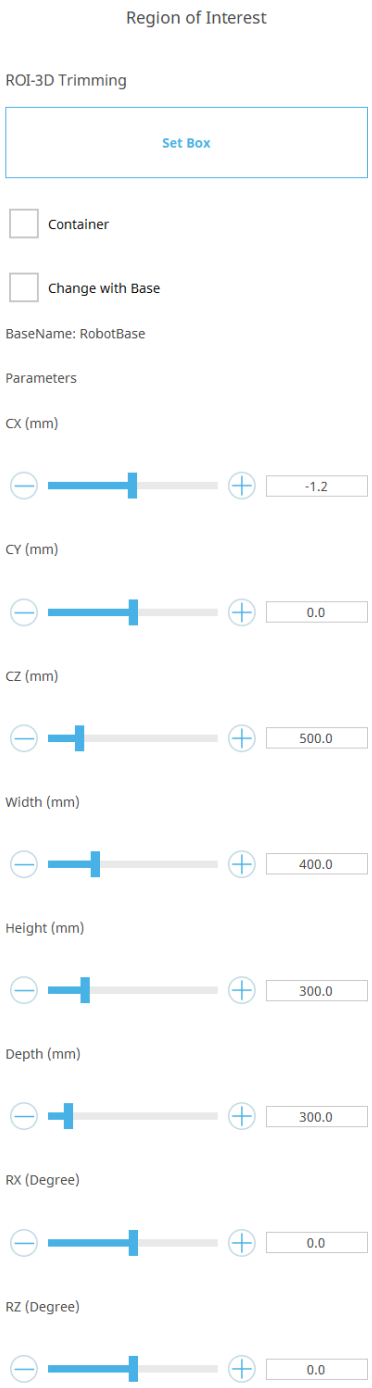
- **Initial Position**:
  - **Base Name**: The name of the base followed by the initial position. The lower field is the position of the robot in the base.
- **Start at Initial Position**: If checked, the robot will return to the initial position during operation; if unchecked, visual recognition will be performed at the current position of the robot.
- **Move to Initial Position**: Move the robot to the initial position
- **Reset Initial Position**: The initial position of the robot can be reset.
- **Reset Workspace**: Choose a different workspace for the robot.
- **Depth Image Visualization**: Choose to display in gray scale or color and set the desired depth to observe. So users can observe the distance by visualizing the different colors. The gray scale displays the depth with black to white, and the color displays the depth with blue, green, and red.
- **Snap-n-go**: If checked, the robot will take snaps while keeping the flow going.

3.3.2 Region of Interest

After completing **Initiate**, click **Region of Interest** in the process compilation. 3D trimming is the

only algorithm applicable for determining a region of interest. It works by creating a 3D cube in the camera space for cropping. The settings are all expressed in a unit that represents the actual distance (mm) of the camera; this can reduce the amount of information and increase the algorithm's calculation speed. While determining a region of interest, users should filter background and noise beyond the region. To modify after an edit, left-click or right-click **Region of Interest** in the process compilation.

The settings and parameters for **Region of Interest** are described as follows:

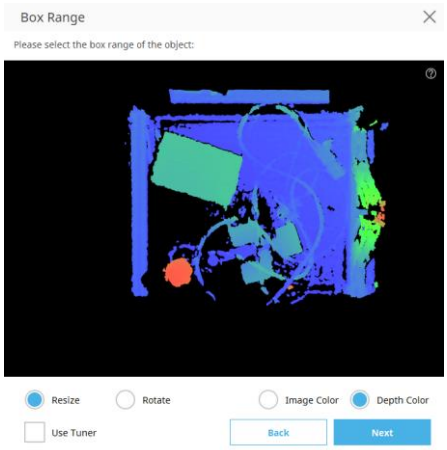


- **Set Box**: The GUI to select the range of the cabinet. Use the mouse to select the target area (green). After selecting, users can adjust to shift, zoom, and rotate the block. During operation, the minimum region limit is slightly larger than the arrow, the rotation angle is limited to ± 45 °, and it is unable to control the surface that is too steep.
  - **Resize**: Use arrows in four directions on each area to adjust the size of the box.
  - **Rotate**: Display arrows on the three axes on the rotating shaft to adjust the box rotation angle.
  - **Use Tuner**: When checked, a small pop-up will prompt for fine tuning after operating the box control.
  - **Image Color**: Selectable only when **Image Color** is enabled in **Initiate**. The absence of color shade denotes depth.
  - **Depth Color**: Depth denotes in shades of color. Selectable only after turning on **Image Color** in **Initiate**
- **Container**: Check to regard the region as a box for the collision check node to perform collision detection.
- **Change with Base:** Check to change the

region with updates on the base.

- **CX** (㎜) : Adjust the X coordinate value of the center of the cropping box.
- **CY** (㎜) : Adjust the Y coordinate value of the center of the cropping box.
- **CZ** (㎜) : Adjust the Z coordinate value of the center of the cropping box.
- **Width** (㎜) : Adjust the width of the cropping box.
- **Height** (㎜) : Adjust the height of the cropping box.
- **Depth** (㎜) : Adjust the depth of the cropping box.
- **RX** (degree) : Rotate the cropping box on the X axis.
- **RY** (degree) : Rotate the cropping box on the Y axis.
- **RZ** (degree) : Rotate the cropping box on the Z axis.

Set Box



Depth Color

Image Color

3.3.3 Clustering – Find

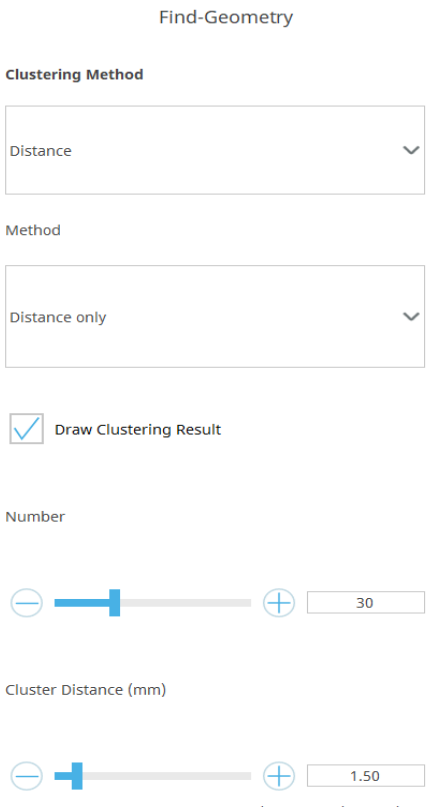
After completing **Region of Interest**, click **Clustering – Find** in the process compilation. Then select **Geometry**, **CAD**, or **Points Pose** as a find algorithm for this process. Different find algorithms support different clustering methods (see the table below for details.)

Find Algorithm / Clustering Method	Geometry	CAD	Points Pose
Distance	○		○
External Detection	○	○	○
AI+ Detection	○	○	○
No Clustering		○	

*○ means the clustering method is available for the algorithm selected.

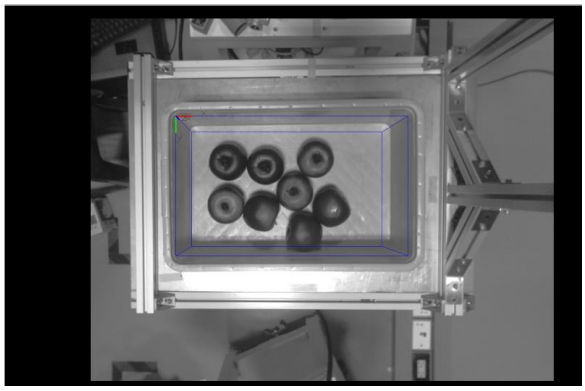
Adjust the down-sampling interval and clustering parameters appropriately to divide the point cloud in the scene into multiple small groups, so that the algorithm only needs to search for targets in each small group subsequently. This reduces the amount of algorithm calculation and the search range. The settings and parameters are described as follows:

- **Clustering Method**: Choose **Distance**, **External Detection**, or **AI+ Detection**.
  - **Distance**
    - **Method**: Select the grouping algorithm.
      Distance only: use the distance between point clouds to distinguish groups.
      Distance and Normal: use the distance between point clouds and the normal vector of the surface formed by the point clouds to distinguish groups.
    - **Draw Clustering Result**: Check to draw the grouping result on the image
    - **Number**: Set the maximum number

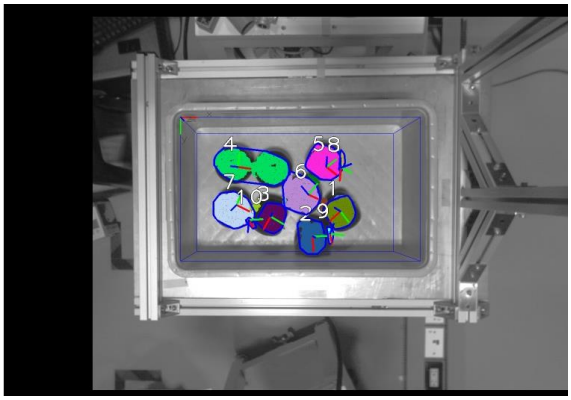


of groups. Select only the top few groups for recognition and analysis

- **Cluster Distance** (㎜) : Set the grouping distance. If the distance between the point clouds is less than this distance, it is regarded as the same group.



Before Clustering

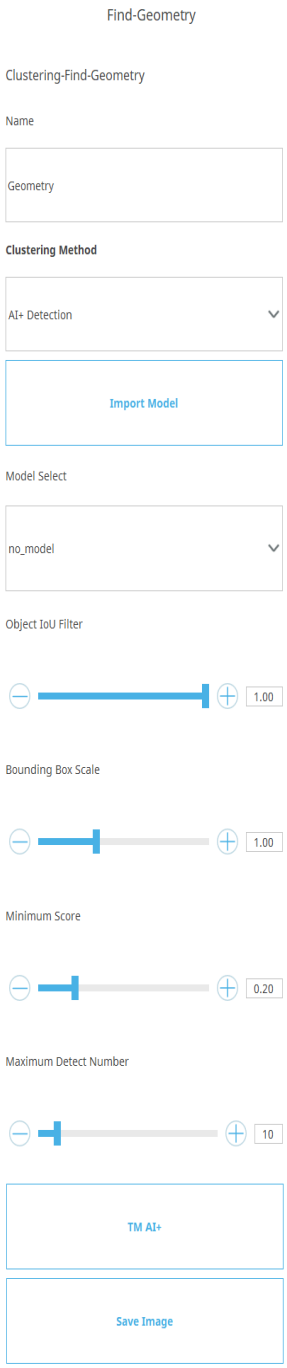


After Clustering

■ **AI+ Detection**

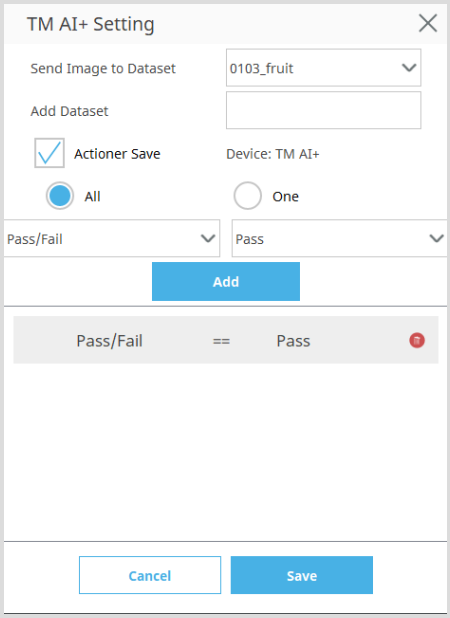
Users can apply 2D images of the camera to AI+ Detection for the point cloud clustering by bounding box detection. The clustered classification can also be used in the subsequent **Find** process. The settings and parameters are described as follows:

- **Model Select**: Select a detection model.
- **Object IoU Filter**: Set the degree of suppressing the bounding box of an overlapping object with the same label. A smaller value means higher suppression.
- **Bounding Box Scale**: Group the point cloud based on the scale of the bounding box.
- **Minimum Score**: Set the minimum score to be taken as an object for the point of the detection result.
- **Maximum Detect Number**: The maximum number of objects that can be displayed on the screen.
- **TM AI+**: Set the gauge to save the image.
- **Save Image**: Click to save the entire source image. The image is saved as yyyy-MM-dd-HH-mm-ss_zzz.png in the path below:
  - On SSD: [drive_letter]:\project_name\job_name\yyyy-MM-dd\Detector\
  - ON TM AI+: data set\



NOTE:

- After clicking **TM AI+**, users can set to save images to the external SSD labeled **TMROBOT** or to TM AI+ Training Server. If saved to TM AI+ Training Server, users can select or add new data set. Use the expression field below to set rules to save images.



- An extra option, **Target Label**, is used to assign the category of the object to find; it appears after users select **AI+ Detection** in **Clustering – Find**. After setting, it detects the category assigned by **Clustering** – **Find**, and the object output to TMflow will go with category information.

The first time users select **AI+ Detection** in **Clustering – Find**, it defaults to **no_model** and generates a virtual bounding box in the center of the image as a standard to accept images for users to save the vision job while deploying untrained models. Users only need to edit distinctively with an object found in the subsequent **Picking Constrains** module. After editing and saving the job, the actioner can accept images with untrained models.

Once there is a trained model, users can import the model and select the model in the dropdown below **Model Select**, and users have to edit the **Picking Constrains** module again for the required detection standard.

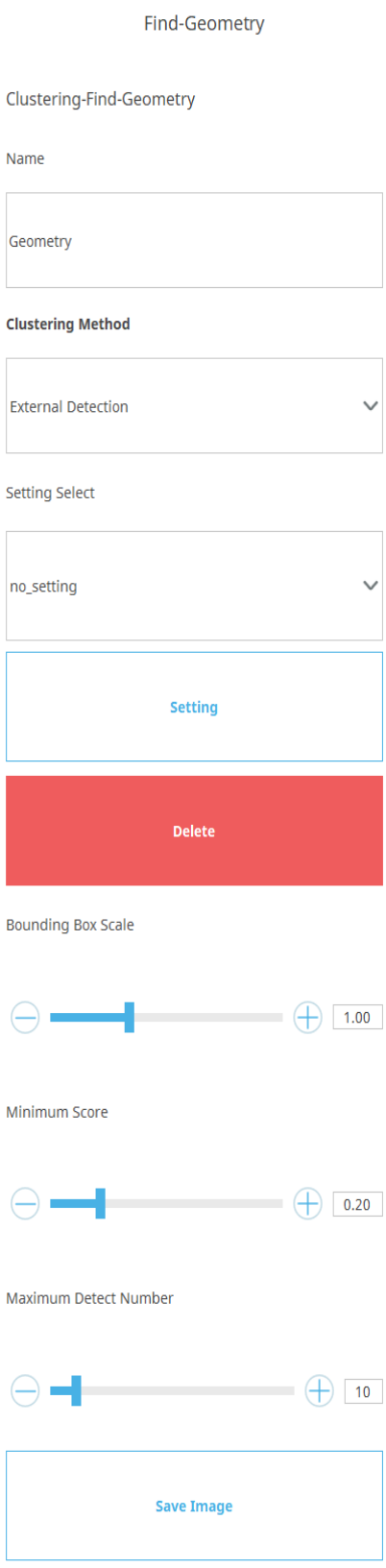
When clicking the **Import Model** button, users can import the model zip file generated by TM AI+. Select the zip file and click **Select** at bottom right will lead to inspect the required file and overwrite or not. A warning message will be prompted for model overwritten. If overwritten, the previous model will be removed and the current model will be copied to TM AI Cobot. This will affect the modules using the previous model.

Users can go to TM AI+ Training Server to download and import models to TM AI Cobot, or set TM AI+ training server in TMflow to connect to TM AI+ Training Server to download models to TM AI Cobot directly.

■ External Detection

External Detection uses a remote computing platform with the HTTP protocol for object detecting and positioning. The settings and parameters are described as follows:

- **Setting Select**: Select a set of configured HTTP parameters. The default goes without any selected detection model.
- **Setting:** Modify the parameters for the selected detection model. The parameters are Get, URL, Post Key, Value, jpg/png, Timeout (ms), and Setting name. A warning message prompts if overwriting HTTP Setting with the same Setting name. No identical individual Setting name of HTTP Setting is allowed in one TM AI Cobot.
- **Bounding Box Scale**: Group the point cloud based on the scale of the bounding box.
- **Minimum Score**: Set the minimum score to be taken as an object for the point of the detection result.
- **Maximum Detect Number**: The maximum number of objects that can be displayed on the screen.
- **Save Image**: Click to save the entire source image. The image is saved as yyyy-MM-dd-HH-mm-ss_zzz.png in the path below:
  - On SSD: [drive_letter]:\project_name\job_name\yyyy-MM-dd\Detector\
  - On TM AI+: data set\



NOTE:

As a network communication protocol, HTTP works only when the connection is established. External Detection use POST cmd on every detection to send pictures to the HTTP server by the configured URL. The HTTP server inspects the pictures by breaking up the relevant key-values and returns the result in the JSON format packets to TM AI Cobot.

Protocol Define of Clusering Find - External_Detection
1. RGB Image size : decided by TM vision image source
2. RGB Image format : jpg or png
3. Depth Image size : decided by TM vision image source
4. Depth Image format : png
5. box_cx: center x, true location on source image, float
6. box_cy: center y, true location on source image, float
7. box_h: height, int
8. box_w: width, int
9. label: object name show on TMvision, string
10. rotation: clockwise, float, in degree
11. score: between 0.00 and 1.00, float
12. message:

if "success", our detection module output annotations
else output error message

Detection Example 1

1. Sample image = "Image.jpg"
2. Depth image = "Depth.png "
3. URL = http://*X.X.X.X*:*port*/api/TEST
4. Request:

$ curl –X POST "http://*X.X.X.X*:*port*/api/TEST" -F file_RGB=@"image.jpg" –F file_Depth=@"depth.png" –F "test_parameter=test"

5. JSON Response

{
"message": "success",
"result": "TEST prediction result",
"annotations": [
{
"box_cx": 1039,
"box_cy": 694,
"box_w": 82,
"box_h": 142,
"rotation": 231.2,
"score": 0.6553,
"label": "Shawn"
},
{
"box_cx": 167,

```
"box_cy": 400,
"box_w": 314,
"box_h": 180,
"rotation": 16.5,
"score": 0.8364,
"label": "Jeffrey"
},
{
"box_cx": 822,
"box_cy": 278,
"box_w": 292,
"box_h": 88,
"rotation": 0.0,
"score": 0.9032
"label": "Thomas"
}
]
}
```


Detection Example 2

1. Sample image = "Image.jpg"
2. Depth image = "Depth.png "
3. URL = http://*X.X.X.X*:*port*/api/other_method
4. Request:

```
$ curl –X POST “http://X.X.X.X:port/api/other_method” -F file_RGB=@"image.jpg" –F
file_Depth=@"depth.png" –F “test_parameter=test”
```

5. JSON Response


```
{
"message": "fail",
"result": "no such method"
}
```


- **No Clustering**

“No Clustering” dispenses with the process of clustering the point clouds. That is, the clouds are processed through the CAD algorithm without being clustered.

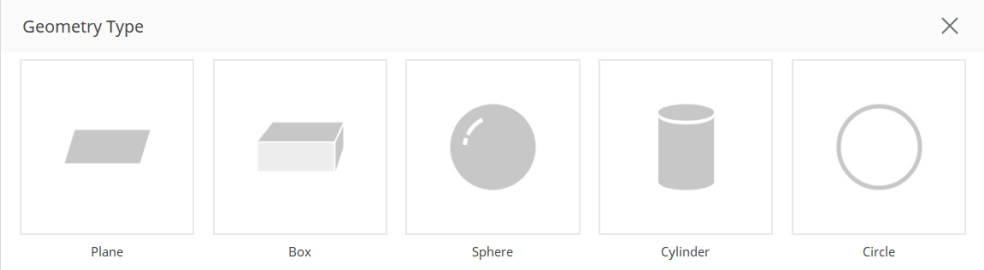
- **3D Find Type**
  - **Geometry**

    The geometric surface features of the object are used to fit the parameters required by the geometric category to find the point cloud cluster that meets the geometric description in the point cloud information, so the point cloud clustering is required. Simultaneous down sampling while the point cloud clustering can achieve a faster calculation speed, but the stability of the recognition result depends on the capturing quality of the object

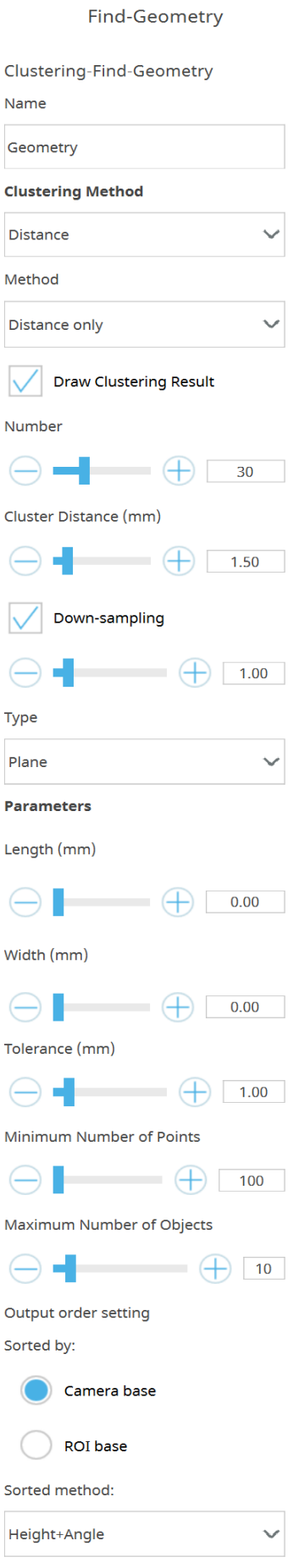
point cloud. Since there is no object characteristics recognition but merely checking whether the point cloud data clusters match simple geometric properties, it takes time to adjust the parameter settings to avoid unexpected results beyond calculation. This is applicable to objects with geometric properties and no CAD.

NOTE:

After selecting **Geometry**, select an appropriate simple geometric form from the **Geometry Type** list. Adjust the parameters of simple geometry to appropriate values to find objects stably: **plane** (length, width), **box** (length, width, and height), **sphere** (radius), **cylinder** (radius and length), **circle** (radius).



- **Name**: The name of the output object
- **Down-Sampling**: Once enabled,. Down-Sampling helps increase the computing speed. Drag the slider below to adjust the point cloud density for down-sampling.
- **Target Label**: Assign the category of the object to find. Available only when **AI+ Detection** is chosen as the Clustering Method.
- **Type**: Five geometric categories provided by the object search module. Set matched parameters based on the geometric category.
  - **Plane**: Find any plane object and frame the bounding box. Set the length and width to determine the size of the object to be searched. When the parameters are both 0, planes in any size will be searched.
  - **Box**: Find any box object and frame the bounding box. Set the length, width, and height to determine the box to be searched. Set both width and height to search for a box plane that matches the combination. When the length, width, and height are all set to 0, box planes in any size will be searched.
  - **Sphere**: Find the object with a sphere surface and frame the outline. Set the minimum radius



(radius) and maximum radius (radius) of the sphere to search.

- **Cylinder**: Find the object with a cylindrical surface and frame the outline. Set the minimum radius (radius) and maximum radius (radius) of the cylinder to search, and set the length to limit the cylindrical size. When the length parameter is 0, cylinders in any length will be searched.
- **Circle**: Find the circle object and frame the outline. Set the minimum radius (radius), maximum radius (radius) and gradient (sensitivity to the edge) of the round object to search.

◆ **Gradient** (**Level**) : Available when circle is selected. Adjust the depth edge gradient threshold. The larger the value, the greater the height variation is required to be taken as an edge.

◆ **Tolerance** (㎜) : Set the tolerance on deviations of searching for geometric objects. The smaller the value, the stricter the parameters that need to fit the settings.

◆ **Minimum Number of Points**: Set the minimum point to be taken as an object for the point of the detection result.

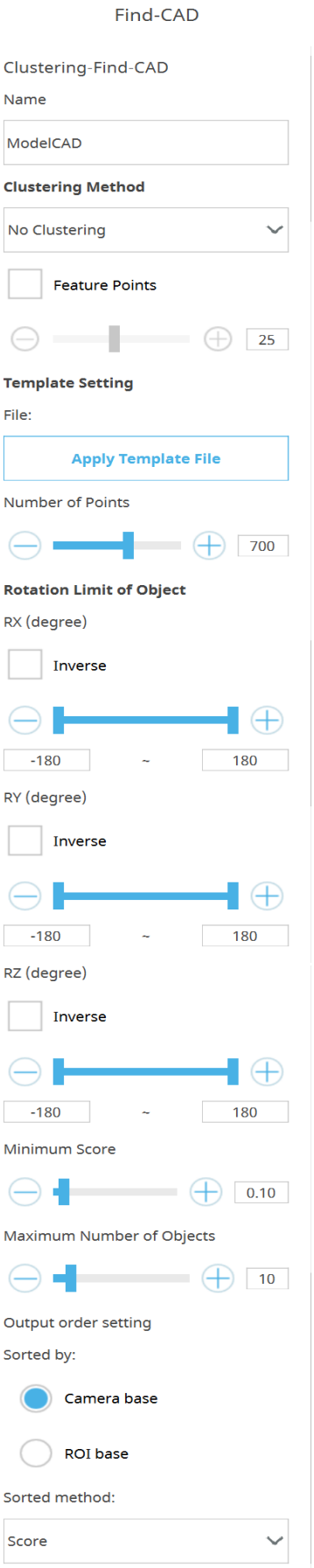
◆ **Maximum Number of Objects** : The maximum number of objects that can be detected on the screen.

- **Output order setting**: Set **Sorted by** to **Camera base** or **ROI base** for output results to be sorted by the base of the camera or ROI. When the maximum number of objects is greater than 1, the output results will be sorted according to the method selected from **Sorted method**.

■ **CAD**

The model created by the 3D modeling function uses the surface characteristics of the object as a template for comparison and finds point cloud that matches the description in the point cloud information. Users can convert from common CAD files to the desired point cloud model through the Modeling function. When different 3D cameras capture different objects, the characteristics of the point cloud information may be varied and different from the ideal CAD file. Therefore, it is recommended to use the Modeling function to build a point cloud model of the object for the stability of better recognition, and generally speaking, it is applicable to objects with obvious surface features. The settings and parameters are described as follows:

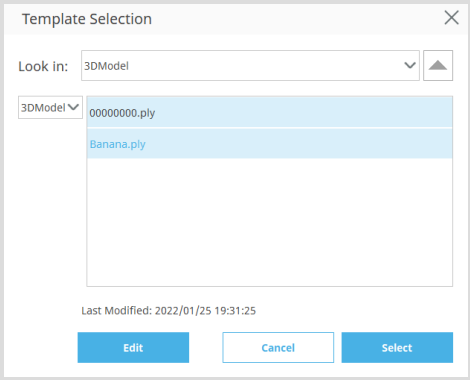
- **Name**: The name of the output object.
- **Target Label**: Assign the category of the object to find. Available only when **AI+ Detection** is chosen as the Clustering Method.
- **Feature Points**: Once enabled, features are extracted from the point clouds, removing flat parts.
- **Apply Template File**: Choose a template model file for searching for the corresponding targets within the current CAD model.
- **Number of Points**: The number of model points used. The more the points are, the longer the relative calculation time it takes.
- **Rotation Limit of Objects**: The posture angle of the object to be detected. Set the range of **RX**, **RY**, **RZ**. RX, RY, and RZ all come with **Inverse**, which leaves their corresponding coordinates from – to + (relative to the robot base) ignored when it is enabled.
- **Minimum Score**: Set the minimum score to be taken as an object for the point of the detection result.
- **Maximum Number of Objects**: The maximum number of objects that can be detected on the screen.
- **Output order setting**: Set **Sorted by** to **Camera base** or **ROI base** for output results to be sorted by the base of the camera or ROI. When the maximum number of objects is greater than 1, the output results will be sorted

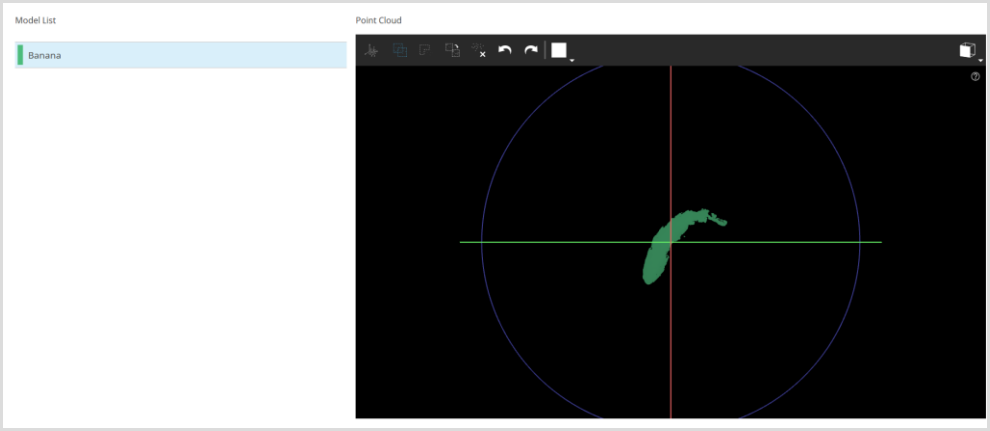


according to the method selected from **Sorted method**.

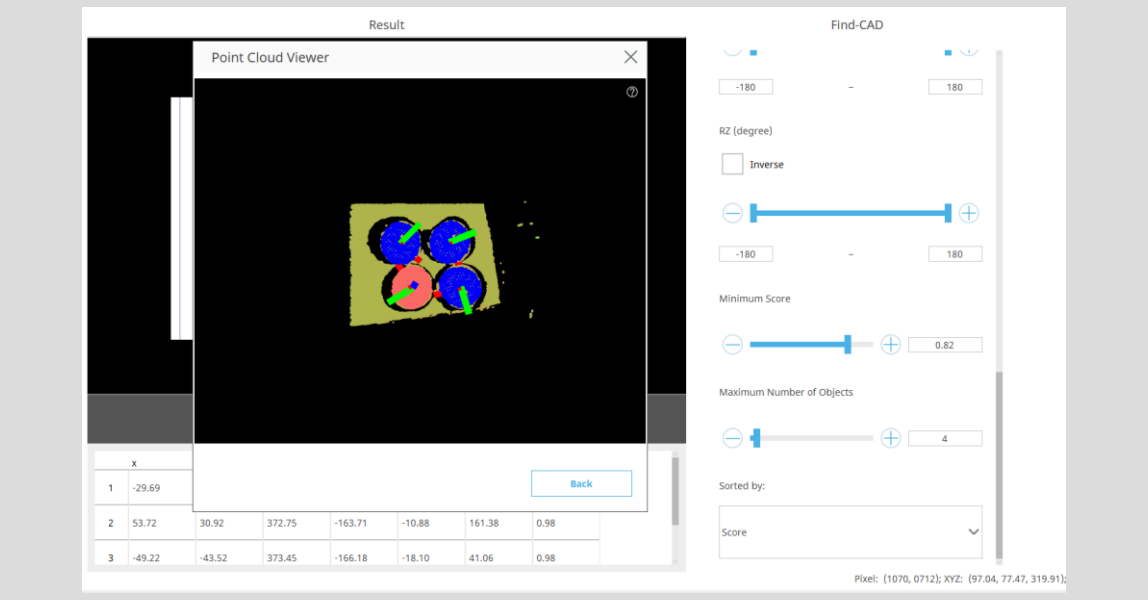
NOTE:
After selecting **CAD**, click **Apply Template File** to select the model file.

- When applying the template file, please select the edited template file to load. Users can also click **Edit** at the bottom left to open the Modeling tab to edit. After editing, click save and the system will automatically update the template file to the module.





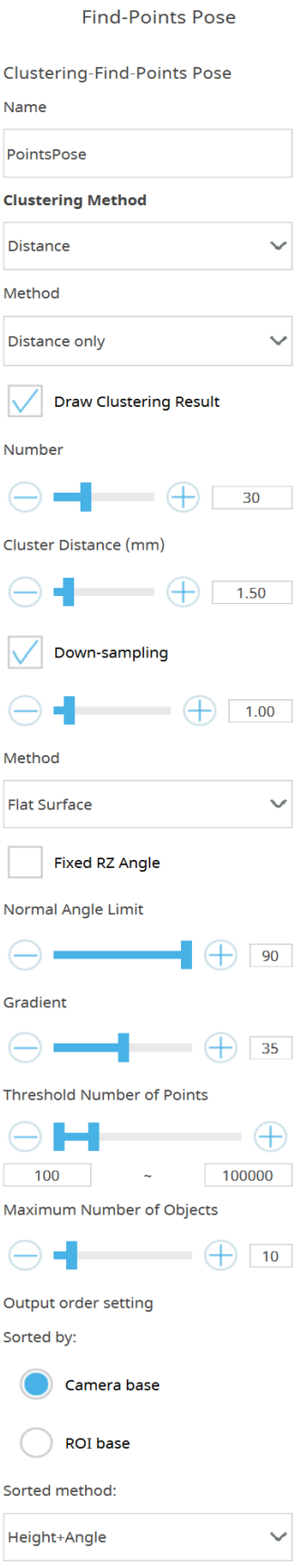
- If an object is found, it will be marked with a red dot in the live video and listed with a matching score. If users want to find multiple objects at the same time, users can drop down the right parameter column to modify the maximum number of objects. If the matching is prone to failure, users can adjust the **Minimum Score** or the number of points in the sampling point cloud. The greater the number of sampling cloud points in the model, the longer the matching calculation it takes, but generally it comes with the more persisted results. The score may be affected by the quality of the point cloud and the angle of the workpiece. Users can sort the found objects with the height or the matching score, which will affect the order of the robot. At this time, users can view the matching between the point cloud model and the current capturing point cloud in the point cloud viewer. The object with the highest score are marked in red and the rest in blue.



■ **Points Pose**

Users can use Points Pose looking for objects without specific shapes by finding objects with the point cloud feature in each cluster for flat surface, principal component, Detection center as a reference location for suction. There is no guarantee to the pose of the object for the point cloud is directly estimated.

- **Name**: The name of the output object.
- **Down-Sampling**: Once enabled,. Down-Sampling helps increase the computing speed. Drag the slider below to adjust the point cloud density for down-sampling.
- **Target Label**: Assign the category of the object to find. Available only when **AI+ Detection** is chosen as the Clustering Method.
- **Method**: The methods for estimating the point cloud are **Detection Center**, **Flat Surface** and **Principal Component**. Detection Center is available only when AI+ Detection is chosen as the Clustering Method.
- **Fixed RZ Angle**: Check to fix the RZ coordinate of the object without changing along with the point cloud.
- **Normal Angle Limit**: Set the maximum output angle of the Z-axis of the object as gauged by the included angle between the object and the camera Z-axis.
- **Gradient**: When selecting **Flat Surface**, users can set the gradient threshold of the flat surface.
- **Threshold Number of Points**: The minimum amount to be taken as an object for the point of the detection result
- **Maximum Number of Objects**: The maximum amount of objects to output
- **Output order setting**: Set **Sorted by** to **Camera base** or **ROI base** for output results to be sorted by the base of the camera or ROI. When the maximum number of objects is greater than 1, the output results will be sorted according to



the method selected from **Sorted method**.

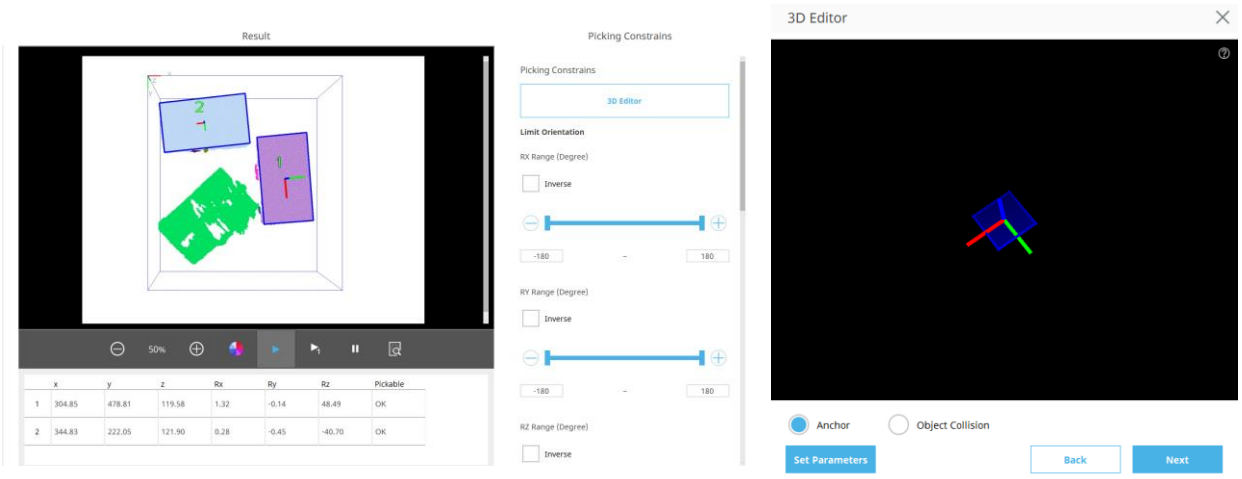
NOTE:
In **Method**:

- **Detection Center** uses the bounding box center by the AI+ Detection clustering as the suction location. An oversized or shifted framing of the AI+ Detection bounding box will make errors in calculating the suction location. Users can adjust the bounding box scale to improve or retrain the model. This method should not be used for objects with the bounding box center at locations not suitable for suction, such as holes or edges.
- **Flat Surface** uses the center of the largest flat surface area in the clusters as the suction location. Finding the center of the largest flat surface in the cluster may fall in different areas of the object. This method is not suitable for object center suction.
- **Principal Component** analyzes the main component in the cluster to calculate the suction center and find the main axis. For the center of the object that comes with the feature not suitable for suction, after stacking, it may make the unsuitable suction center to face the camera, and the probability of the calculation result for the suction point is at the position not suitable for suction. Therefore, the center of the object is not suitable for suction such holes or edges and corners are not suitable to use this method.

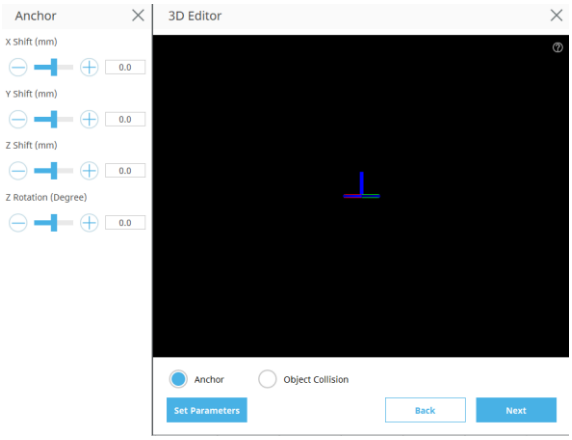
3.3.4 Picking Constrains

After completing **Clustering** – **Find**, click **Picking Constrains** in the process compilation. Appropriately adjust and set the gauge for picking and placing objects including the choice and the judgment for objects after the discovery of objects based on the site conditions such as workpieces, tools, and work platforms. Users can filter unfavorable gauge of the object picking based on the usage conditions to improve the picking efficiency and reduce the danger.

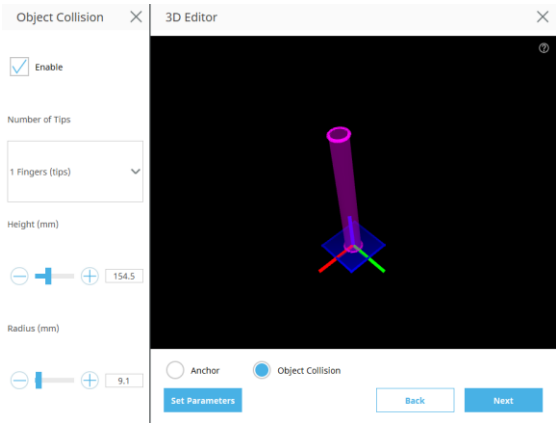
Click **3D Editor**, and click **Set Parameters** at the bottom left of the **3D Editor** tab.



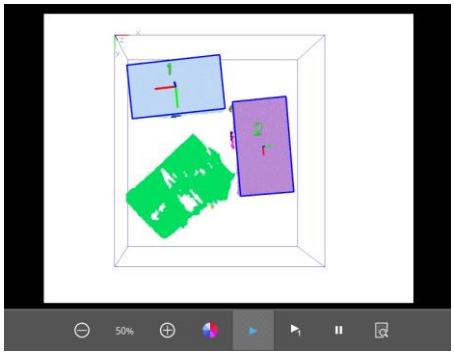
Adjust the tool position when picking up workthe piece and the RZ angle.

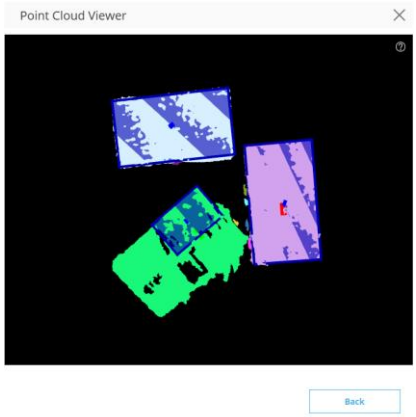


Set the position of the space position for the tool may occupy when picking up the workpiece to decide whether it can be picked up. Users can set the number of claws, the length, and the radius of the tool.

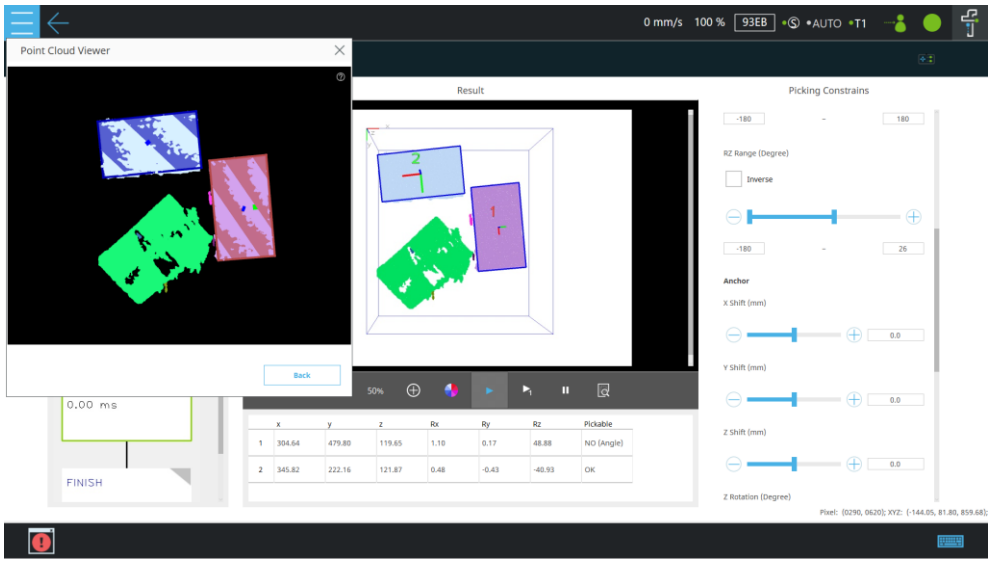


Users can also observe the relationship between the point cloud and the search results to decide whether to adjust the previously set parameters.





If the object is determined to be unable to pick, it will be marked with a red dot.

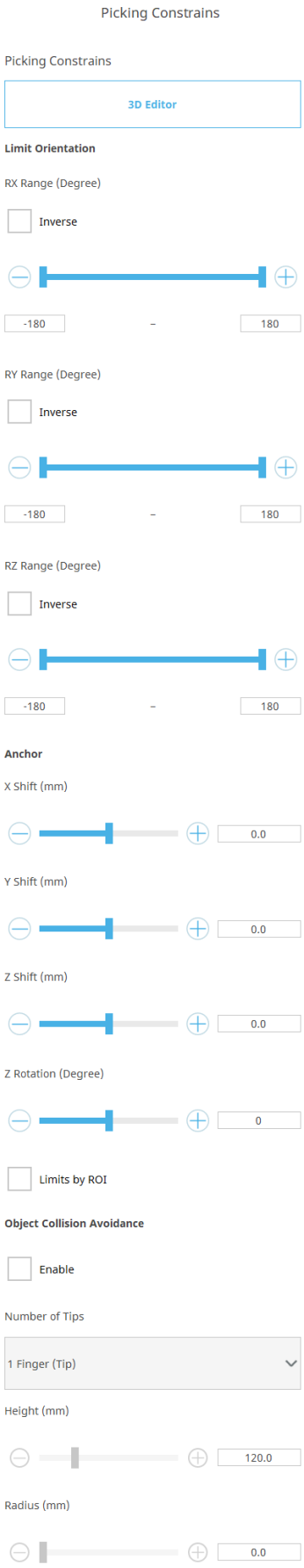


The settings and parameters are described as follows:

- **Limit Orientation**: Convert the recognized object to the robot base, limit the angle of the robot when picking the object, and filter the target that exceeds the set value.
  - **RX Range (degree) ***: Set the recognition object within the range of the robot base RX ± degree.
  - **RY Range (angle) ***: Set the recognition object within the range of the robot base RY ± degree.
  - **RZ Range(degree)***: Set the recognition object within the range of the robot base RZ ± degree.

*RX, RY, and RZ all come with **Inverse**, which leaves their corresponding coordinates from – to + (relative to the robot base) ignored when it is enabled.

- **Anchor**: Allow users to change the object recognition center (base center).
  - **X, Y, Z Shift** (㎜) : The base is shifted on the X, Y, and Z axes.
  - **Z Rotate** (**angle**) : Rotate the base on the Z axis.
- **Limits by ROI**: Ignores an object whose center is beyond the ROI.
- **Object Collision Avoidance**: Identify objects above the Z axis in the center of the recognition target and filter the targets of other objects the tool collides with while picking.
  - **Number of Tips**: Select the tip number of Tool. When the number is set to 1 Finger, Tip Type is fixed as a cylinder.
  - **Tip Type**: Select a cylinder or a cuboid.
  - **Height** (㎜) : Set the gripper height of the cylinder or the cuboid.
  - **Width** (㎜) : Set the gripper width of the cuboid.
  - **Stroke**(㎜): Set the gripper stroke of the cuboid (including the gripper angle).
  - **Spacing** (㎜) : Set the tool tip clearance.
  - **Radius** (㎜) : Set the radius of the cylindrical tip.



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