Mech-Mind Application

Mech-Mind

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This chapter introduces how to build a Mech-Mind Vision System, and provides some suggestions for implementation.

Mech-Mind Vision System is the full vision-based solution provided by Mech-Mind, including Mech-Eye Industrial 3D Cameras, Mech-Mind Software Suite, the robot, peripheral devices, etc.

Hint: For instructions on integrating robots and PLCs with Mech-Mind Vision System, please refer to robot_integrations.

CONSTRUCTION OF A MECH-MIND VISION SYSTEM

This chapter mainly explains how to construct and deploy a Mech-Mind Vision System.

1.1 Software and Hardware

1.1.1 Hardware Structure

In the actual application of Mech-Mind products, it is necessary to implement functions based on a complete system. Generally, a system will include three main modules: **Robot module**, **Camera module** and **Computer module**. Ethernet connection is recommended for the communication within three modules.
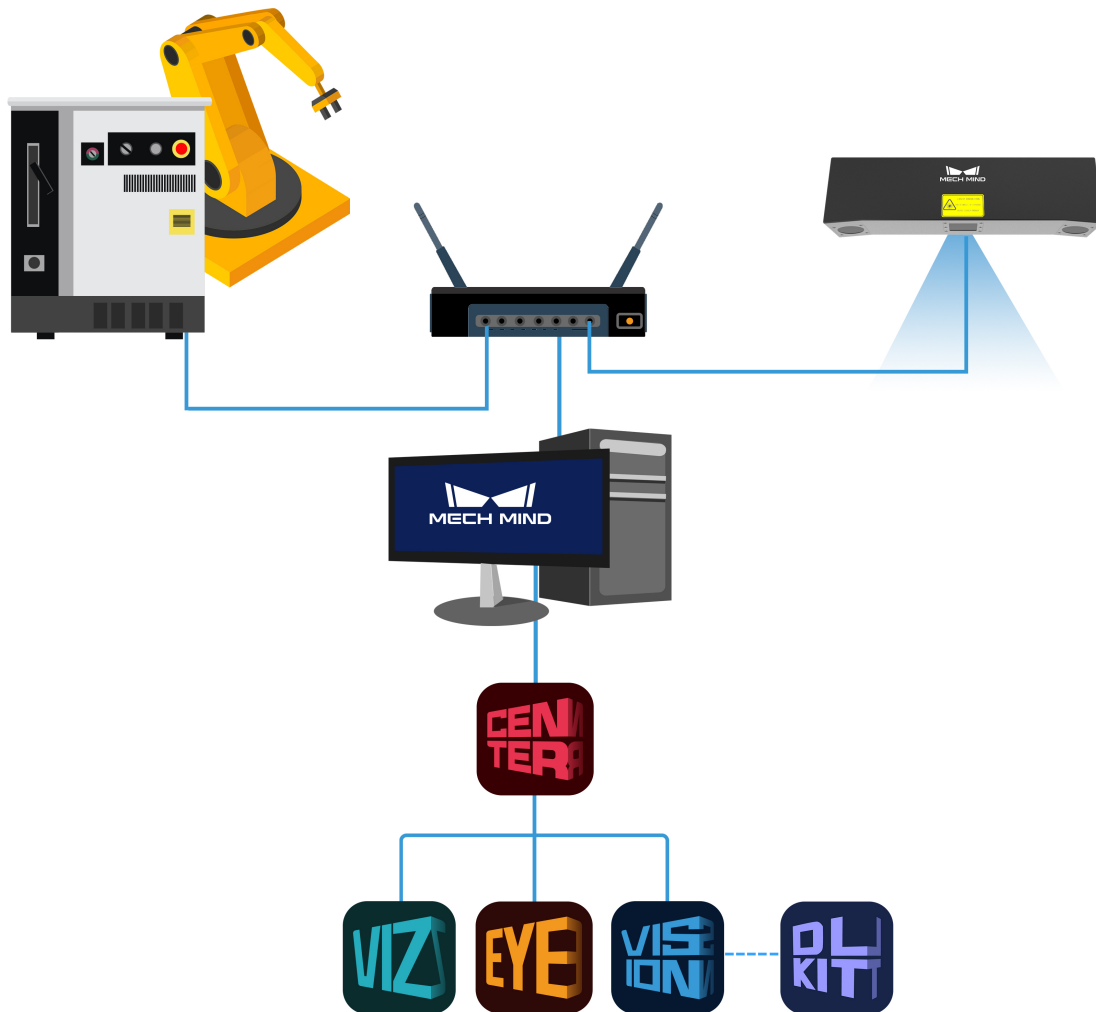
Figure 1 Structure for hardware system

1.1.2 Software Structure

The Mech-Mind Software Suite includes the following two control mechanisms.

1. **Master control**

Many robots can be completely controlled by Mech-Mind Software Suite, in this case the Software Suite is the master station and the robot is the slave station. Mech-Viz can achieve full control and dynamic simulation on the robot, and has a variety of practical functions such as motion planning, collision inspection, singularity avoidance, etc.

This system construction form is widely used in scenarios where the robot process is relatively simple and the process is short.

1. **Robot or host computer master control**

For the complex systems which the robot's process is more complicated, considering the convenience of later maintenance, a robot or host computer can also be used as the master, and Mech-Mind Software Suite can be used as a slave station, which only sends vision pose or simple route. The host system triggers the camera to shoot at the right time. Mech-Mind Software Suite processes the image and sends the result back to the host computer for temporary storage. The host computer can directly call it when the vision result is required.

In this system construction form, it is usually necessary to use a separately written adapter to convert and relay signals. For robots that have not been adapted, that is, Mech-Mind Software Suite has not yet achieved full control on the robot, it can send vision pose.

In Mech-Mind system, Mech-Mind independently developed **Mech-Center**, **Mech-Eye Viewer**, **Mech-Vision** and **Mech-Viz**. For detailed introduction, please refer to system_introduction_all .

1.2 Process for Project Deployment

The process mainly includes **early phase**, **middle phase** and **late phase**.

- The purpose of the early phase is to test whether the target object meets the requirements of Mech-Mind Vision System, and whether it can be detected, collect relevant data;
- The main purpose of debugging in the middle phase is to enable the robot to complete the established process and meet the required takt time of the project;
- The late phase is the project implementation phase, mainly for joint debug, to cooperate with factory production, to meet the production requirements of the factory, and to find and solve small problems during the long-term trial production process.

The project deployment process is shown in the following figure.
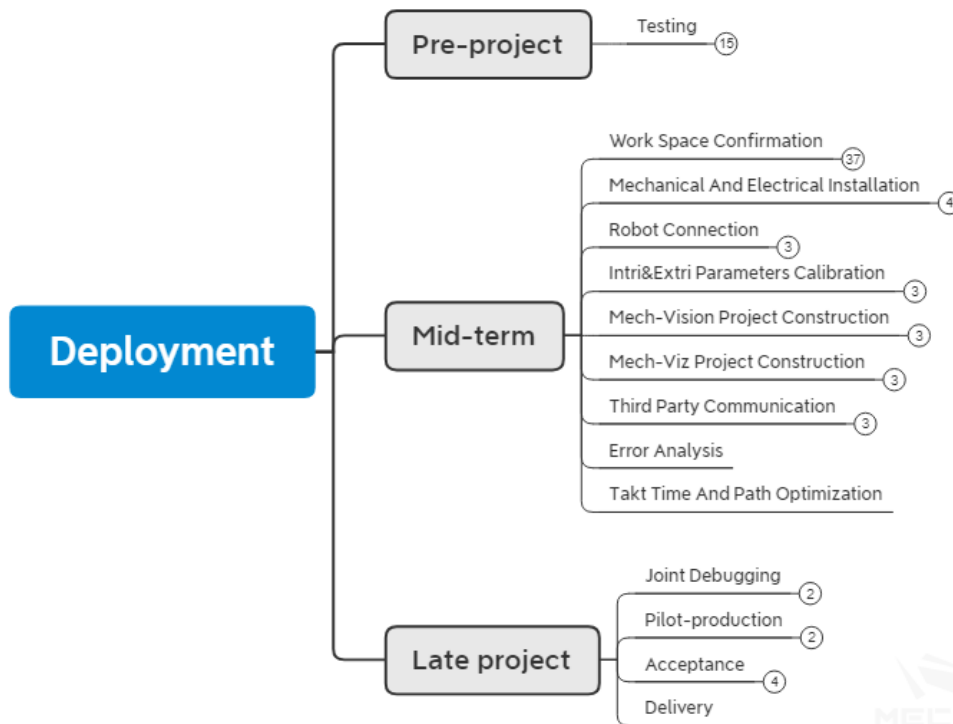
Process for project deployment

1.2.1 Early phase

Test

Point cloud test

1. **Key point** The key point is the features such as round holes, special surfaces, object edges, etc. which is easy to be identified on a workpiece.

2. **Parameter adjustment** After the key point is clarified, when performing a point cloud test, the camera parameters can be adjusted according to the key point so that the details of the point cloud at the key location become obvious. For details about the adjustment on the point cloud of Mech-Eye Viewer, please see the section Parameters adjusting of Parameter Adjustment.

3. **Simple matching** Some simple projects can be judged directly by experience. For some complex workpieces (no obvious features or complex features), a simple Mech-Vision project can be set up in the laboratory to check whether the matching can be performed and whether the expected effect can be achieved when the matching time is ignored. It is also possible to test the accuracy of the match. For different types of identification projects, please refer to Vision Typical typical_applications.

4. **Build a Demo** You can use the existing robots, cameras and end effector (pointers) in the laboratory to build a simple Demo (see *How to build a Demo*) so that show customers more practical results. The main purpose is to directly show the recognition effect and robot reachability.

Data collection

1. **Collection requirement** For projects that require the function of deep learning, data collection may be required. For each project, it has different collection requirements, such as item placement, quantity of collection, light quality, etc.

   Hint: During data collection, the project engineer need to follow the Collection standard from the R&D department, and supplements the amount of data if necessary.

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2. **Environment control** Before the data collection, controlling on the collection environment is required, if the environment is changing or the data collected in poor environment, it will affect the training effect of deep learning model. In the data collection, camera parameters, lighting environment and field of view are mainly adjusted. For details, please refer to Lighting control of *Illumination control*

3. **Upload data** When the data is collected in accordance with the Collection standard , the content can be packaged and uploaded, and the data collected by different batches of different cameras is required to be indicated.

   Hint: The data contains:

   - *Raw data*
   - *Intrinsic parameter of camera*

Hardware inspection

The hardware inspection mainly includes the checking of IPC and cameras used in Mech-Mind Vision System.

Hint:

- IPC will be installed after initial purchase, refers to *Software installation and configuration* . before the shipment, the software of IPC will be checked, the checking mainly includes whether the system environment is up-to-date, whether it is installed successfully, etc.

- After shipment from our plant, the camera intrinsic parameter check will be performed. The intrinsic parameters may be changed during the long-term storage and transportation. Therefore, it is necessary to check the camera intrinsic parameters before the project is implemented.

1.2.2 Middle phase

On-site situation confirmation

Project goal confirmation

1. **Process flow** For the deployment of a project, the most important goals are **takt time** and **project goal**. The takt time is efficiency and is the time it takes for a robot to complete a set of process flow, it may have different strategies and designs for different project requirements. The project goal is the content that needs to be completed for the project deployment, such as loading, depalletizing, etc., and more detailed content is required, such as grasping or placing method, pose, overall accuracy, etc.

   Hint: Familiar with the project process is helpful to have a deep understanding of the overall situation, and you can adopt different scheme strategies for different project processes.

2. **Time nodes** Project time nodes is the time corresponding to the start, deployment, joint debug, trial production, and delivery of the project.

   Hint: Different projects have different time nodes, so a good understanding of the time node will make arrangements for the work reasonable. For demonstration projects, there is no process of joint debug, trial production, and delivery, therefore there will be a big difference in the arrangement of the time nodes.

3. **Control method** There are two main control methods currently used in Mech-Mind Vision System. One is **Mech-Viz main control**, the other is **Robot main control**.

   Hint:

   - The project controlled by Mech-Viz is a regular project, it is required to be processed step by step according to the deployment process;
   - For the project controlled by robot, vision points are sent to robot mainly via Mech_Adpater. When receiving the vision pose, the robot analyzes and performs the operation. It is not necessary to build a Mech-Viz project for such project after completing extrinsic parameter calibration and setting up a Vision project.

Robot confirmation

1. **Whether it works** Check whether the robot can work properly. The main contents that can be followings:
   - Check if the relevant power cable of the robot is connected properly and is not damaged
   - Check if the robot control cabinet is working properly
   - Check if the teach pendant is working properly
   - Check if the I/O board of robot's control cabinet is in good condition
   - Check the dryness inside the robot control cabinet

2. **Hardware and software configuration** The checklist of software and hardware configuration mainly includes **Package permissions and version** and **I/O board**. Wherein, the software package permissions and versions are required to be confirmed. The main reason is that Mech-Mind's robot adaptation system is adapted to a specific software version (mainstream). The later or earlier version may cause communication errors and make the robot unable to control. Therefore it is necessary to confirm the software version of the robot to ensure that the version is appropriate, and upgrade or downgrade it if necessary. The I/O board also is required to be confirmed. Some robots support multiple I/O boards and is required to be reasonably configured to be able to be controlled in Mech-Viz.

Hint: For example, YASKAWA robots may transmit different signals when connecting different I/O boards.

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3. **I/O signal confirmation** I/O signal confirmation indicates confirming the I/O signal that communicates with Mech-Mind Vision System. Such as the workpiece in-position signal, the signals for the end effector opening and closing, etc.

Tip:

- In the case of fewer I/O signals, it can be directly recorded via Mech-Viz;

- If more I/O signals are required in the project, list the I/O table.

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4. **Method for anchoring** The anchoring method refers to the fixing method of the robot base. At present, the main fixing methods include fixing by the chemical bolting and fixing on a movable platform. For the fixing method of the robot and the possible problems, please refer to the Method for *Fixing* .

5. **Null point** After the robot has not been used for a long time or after a collision, it is necessary to confirm the null point of the robot to prevent the losing of robot's null point or the battery for data storage being out of power. For the method of checking the null point, please refer to Null point *Null point* .

6. **Manually controlled Robot** The purpose of the controlling robot manually is to determine whether the robot can reach the working position.

Tip:

- In Eye to Hand mode, control the robot to the farthest distance from the robot to confirm whether the robot is reachable and not at the limit on the soft limit of the robot;

- In Eye in Hand mode, a manually controlled robot and a mobile robot are required to respectively confirm whether the camera's shooting position has visual field interference, whether the camera will interfere with the robot, and whether the robot can reach the farthest workpiece position.

Layout confirmation

The main content of the layout confirmation is to determine whether the position of robot, camera layout, picking box (material rack), etc. are consistent with the drawing, whether the robot's motion will be affected by camera bracket, protective fence, separation wall, etc. and cause possible robot trajectory error or unnecessary collision.

End effector confirmation

Initially confirm whether the end effector of the robot is suitable, and check whether during the movement the end effector will break the signal cable or interference with the robot will occur during the move of the end effector. Meanwhile, it is necessary to confirm whether the calibration will be affected after the end effector is mounted.

Hint: If the end effector is too long, during the calibration process, the robot cannot be calibrated at a deeper position, which may affect the extrinsic parameter results, and may also affect the camera field of view (cannot see the full calibration board).

Confirmation of electrical connection

1. **Power supply** For power supply it needs to confirm whether the power supply is stable. In some factories due to design defects, the provided 380V and 220V power is not stable, especially 220V. Therefore, the voltage is required to be determined before connecting the camera. If it is unstable, an additional voltage regulator must be connected to the camera to ensure that the camera's power supply is stable. At the same time, in a typical Mech-Mind vision system, the equipment using a 3-pin plug include IPC, monitor, router, camera, sometimes two cameras or robots may be used at the same time by a voltage of 220V for power.

   Tip: When using a power strip, prepare one with at least **6** outlets. Finally, check whether the overall layout of the workstation is safe and the cables are not directly exposed. Use **wire arranging groove** and **wire trough** if necessary. For more information about the power supply, please refer to *Power control* .

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2. **Air supply** The inspection of air is mainly focused on **pressure stability** and **pressure level**. Wherein, the stable air pressure mainly determines whether the project can be carried out stably. In some projects, an air pump may be used. When an air pump is used by several places, the air pressure may be unstable, which may cause the situation that the end effector is closed or the suction power of the suction nozzle may be small or large. In addition, for larger suction cups and pneumatic end effector items, additional confirmation of air pressure is required. The air pressure determines the suction power of the suction cup, which is a guarantee of stability when sucking some heavy objects.

Related devices confirmation

When using the robot, other devices or sensors may be used together. Such as proximity sensor, height sensor, air pressure detection device, air pump, safety sensor (grating, safety door), etc.

> **Danger:** Before the formal debug of the robot, it is necessary to confirm each station-related equipment, especially the safety sensors, to ensure that the equipment is stable and operation is safe.

Mechanical and electrical mounting

1. **Mounting camera and camera supporting bracket** When mounting the camera and camera supporting bracket, it is necessary to determine the mounting position and direction for the camera according to the drawings. During mounting, the camera and camera support is required to be fixed. For details, please see Mounting the Camera.

2. **Mounting flange and end effector** Mount the flange and end effector correctly according to the drawings. Before mounting, it is necessary to determine the mounting direction for some axisymmetric end effectors to prevent the repeated work.

3. **Electrical connection** Connect and properly configure the sensors needed in the deployment project. When power on, test the hardware devices of the project such as cameras, IPC, monitors, routers and other devices.

   > **Hint:** Connect the air pipe required on the end effector of the robot. Ensure that the end effector works properly and the air pipe is in the proper length, and will not be unsightly because it is too short or torn by the robot.

4. **Marking and tidying cables** For the projects that use a lot of wires, it is necessary to use labels to mark the wires. It is mainly marked on commonly used cables (Ethernet cables, power cables, etc.) and I/O signal lines (positive and negative anodes, sensors, etc.).

   > **Tip:**
   > - If the camera cables and lighting cables used in the project are too long, arrange these wires after the layout is basically completed, use cable ties to bundle these wires and put them into the cable organizer;
   > - The signal cables on the robot are required to be fixed closely with the robot body or the end effector to prevent it from being torn or hung.

Robot connection

1. **Burn the Robot program** Mech-Mind has different adaptation programs for different robots. In order for the robot to be controlled by Mech-Viz, the adaptation program is required to be burned into the robot. Different robots operate differently, please refer to robot_integrations for details.

2. **Connect Robot via Mech-Center** Before using the Mech-Center to connect the robot, it is necessary to perform different operations on the robot so that the robot is in the signal receiving mode. Refer to robot_integrations. When connecting to the robot via Mech-Center for the first time, user needs to click **Deployment Settings** and enter **Robot Server** page to set **Robot Server Path** and **Host Address**. It is also necessary to check **Autoload Current Project** in Mech-Viz. Then user can create connection to robot by clicking **Connect Robot** in Mech-Center.

3. **Check kinematic parameters** After connecting and synchronizing the robot with the Mech-Center, open Mech-Viz to check the kinematic parameters of the robot. The purpose of checking kinematic parameters is mainly to **obtain correct joint angle** and to **keep the robot pose consistent**.

Calibration for intrinsic and extrinsic parameters

1. **Camera parameter adjustment** In the on-site working environment, it is necessary to adjust the camera parameters, so that the plane of the calibration board can be clearly observed in Mech-Eye Viewer. During the adjustment process, if no best result can be obtained, please refer to Parameter Adjustment.

Hint: The camera parameters which is used for extrinsic parameters calibration are often different from the parameters used for identification. When the extrinsic parameter calibration is completed, it is required to adjust the camera parameters again to obtain a clear point cloud of the workpiece.

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2. **Check intrinsic parameters** Please refer to Check_Camera_Intrinsic_Parameters.

3. **Calibration for extrinsic parameters** Please refer to calibration_guide for the calibration of the camera extrinsic parameter.

Build a Mech-Vision project

The building of a Mech-Vision project is determined by the features of the object (round holes, planes, protrusions, etc.) and point cloud effects. For the building of Mech-Vision project, please refer to typical_applications. When the basic project is set up, modify the parameters to achieve different recognition effects according to the different requirements of the project. For details, please refer to Step User ../../../MechVision/GuideToSteps/GuideToSteps . If any errors occur in the process of project building, refer to ../../../MechVision/FAQ/FAQ .

Build a Mech-Viz project

Build a Mech-Viz project according to the customer requirements, the robot motion and I/O signals. For details, please see viz_userguide and skills_guide.

Third party communications

If the third party communication is required, it is necessary to determine **communication method** and communicate the preliminary ** communication protocol** as soon as possible. Prepare and test the Adapter in advance to ensure that the two parties can communicate normally and not affect the project progress because of the communication connection.

Error control

For error analysis, please refer to Error *Error control* .

Route optimization

For route optimization, please refer to route *Takt Time and Path Optimization* .

1.2.3 Late phase

Joint debug

In the joint debug phase, it is necessary to cooperate with the entire production line for testing. For example: Using a conveyor belt to move the material instead of manual handling, the robot can complete the grasping of one or more objects in the box under the supervision.

During the coordination phase, errors may occur during the troubleshooting process, such as failure to keep up with the takt time and the signal of in place is not detected, etc.

Tip: In order to reduce the tedious operation procedures, integrate multiple programs and start them with **one click** in HMI, which reduces the complexity of the software and the learning cost, and improves ease of use.

Trial production (Accompany production)

The main principles in the trial production phase are No major issues, Solve minor issues . In the trial production phase, all the requirements determined in the early stage of the project should have been met, and no major problems should occur during the production process (robot stop, recognition errors, etc.). Solve all minor problems, such as the unsatisfactory wire layout on the site, no labels, tiny adjustments on the point position, etc.

Handover acceptance

1. **Customer training, operation manual, etc.** Train the customers who use the project, including basic software operation, camera calibration, problem checking and other functions. Meantime, train the customers with TeamViewer and Simple troubleshooting to facilitate later maintenance.

Create project operation manuals, and help customers to follow the operation manuals to perform the camera shooting and robot operation.

2. **Handover checklist** Create Handover checklist , determine the delivery content, confirm and take away Extra purchased items .

3. **Software and project backup** Perform Software and project backup, determine the Version of currently used Mech-Viz and Mech-Vision and backup project and original image used on-site , to facilitate later debug, maintenance and learning share.

4. **Project summary** Make a reasonable and appropriate Project summary , record the problems encountered during the project and related solutions and less commonly used techniques to help other engineers to learn and improve overall debug and deployment level.

1.3 Camera Mounting

1.3.1 Robot-Camera Architecture Setup

A camera can be mounted based on two types of architecture:

- **Eye-in-hand (EIH)**: The camera is rigidly mounted on the robot end flange plate and moves with the robot.

- **Eye-to-hand (EIH)**: The camera observes the robot from a fixed external point, typically above the object from a certain height.

Figure 3. Eye in Hand
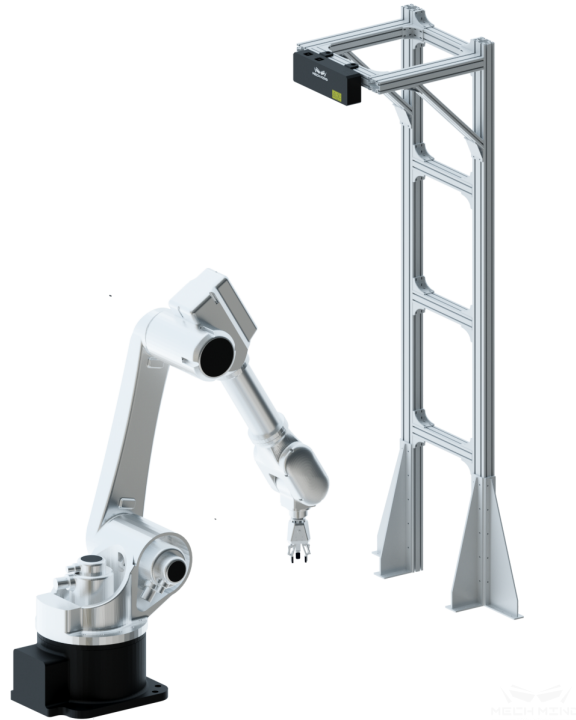
Figure 4. Eye to Hand

The camera must be connected with cables and signal wires from Mech-Mind to ensure the quality of signal transmission and reduce noise. For EIH, please ensure that the supplied camera cables attached to the robot are put inside the dress pack to avoid any damage.

Hint: Please add extension cords when necessary.

1.3.2 Camera Stands

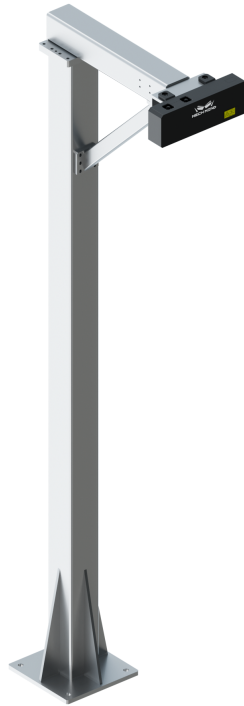The camera can be fixed on the stand or can slide horizontally on the stand, as shown below.

Figure 5. Camera stand with fixed mounting point

Figure 6. Camera stand with slide rail

Based on the experience of earlier projects, if the camera supporting stand have issues with stability, reliability, and fixation firmness, intrinsic and extrinsic parameter errors will occur, and the camera lens will go loose, which affects the debugging progress and reliability of subsequent operations. Therefore, the following requirements are specifically proposed for the design and mounting of the camera supporting stand:
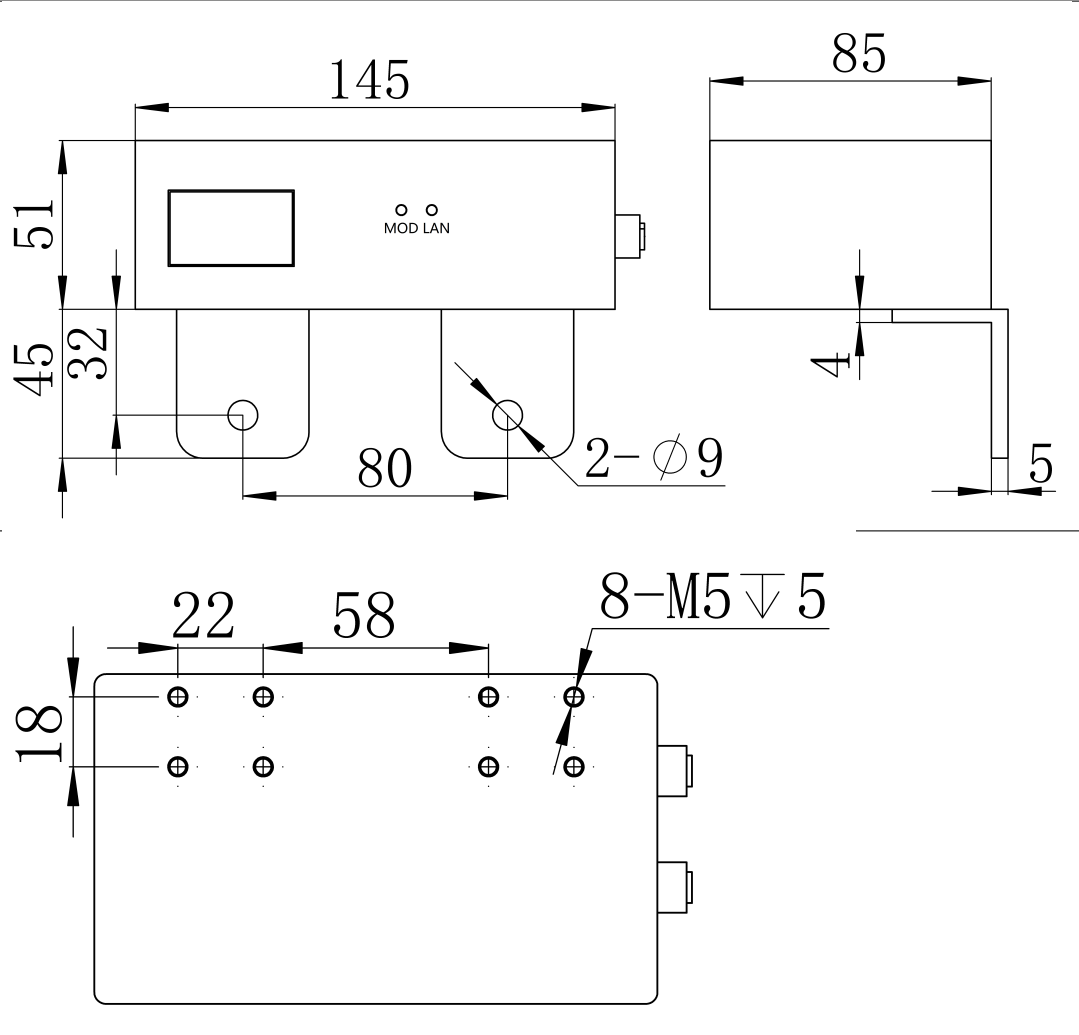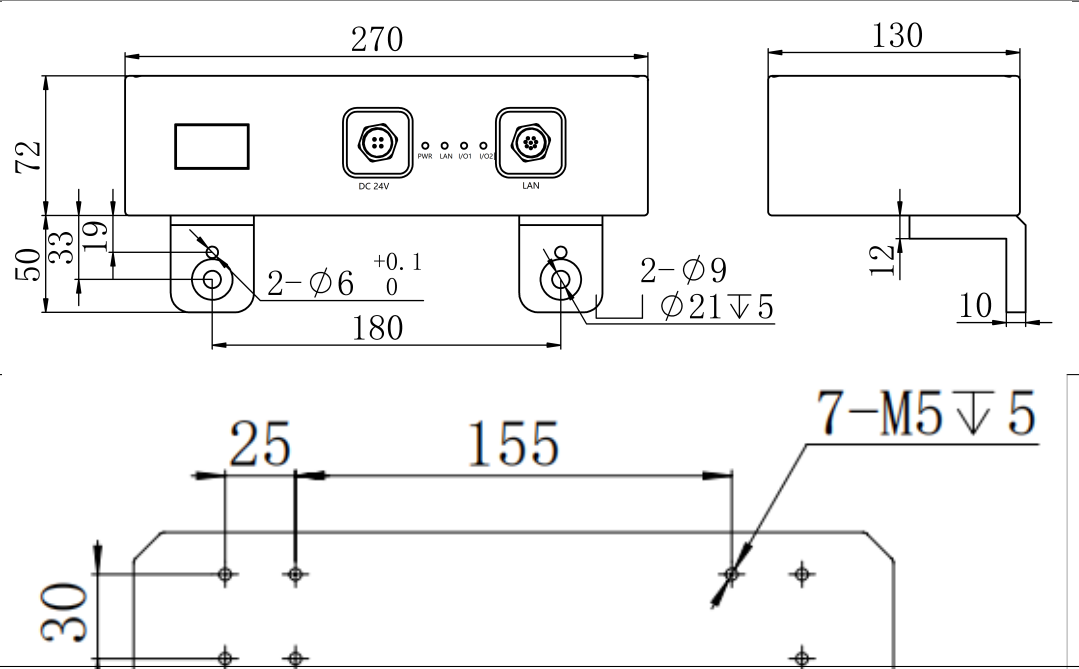
- For demonstrational projects, a temporary camera stand of the European Standard 8080 profile will suffice; for practical projects, a steel structure camera stand is recommended.

- All the main parts of the temporary camera supporting stand should be of European Standard 8080 profile. Only the triangular supports can be of the European Standard 4080 profile. At least two posts are needed to erect the stand.

- For steel structure camera stand, the main parts should be of steel square bars, with a size of at least $100{\times}100{\times}6mm$, a recommended size of $100{\times}100{\times}8mm$ and above; the thickness of the bottom plate should be more than 10mm with a size of $300{\times}350mm$ and above.

- The camera supporting stand should be anchored to the floor with chemical bolts. Expansion bolts should not be used.

- For Eye in Hand, please make sure the camera is mounted on a sufficient height with no obstruction in the field of view.

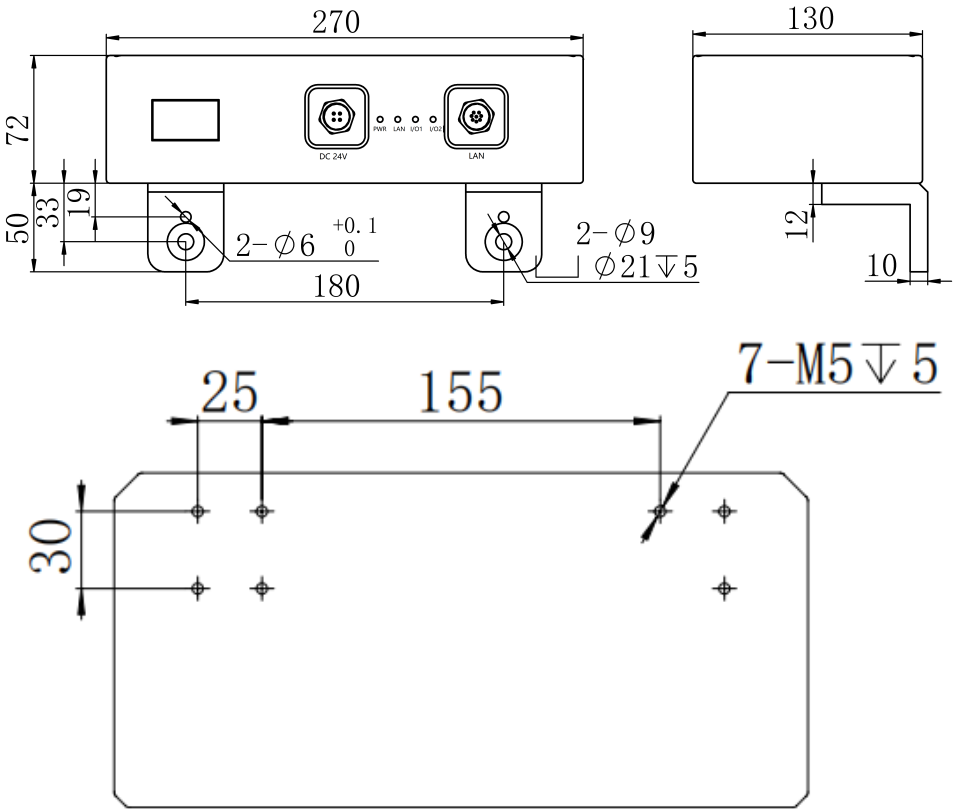- All parts of the braskt should be far away from any lines, cables, cords, wires. Otherwise, the reachable space of the end effector and calibration accuracy and efficiency will be severely affected.
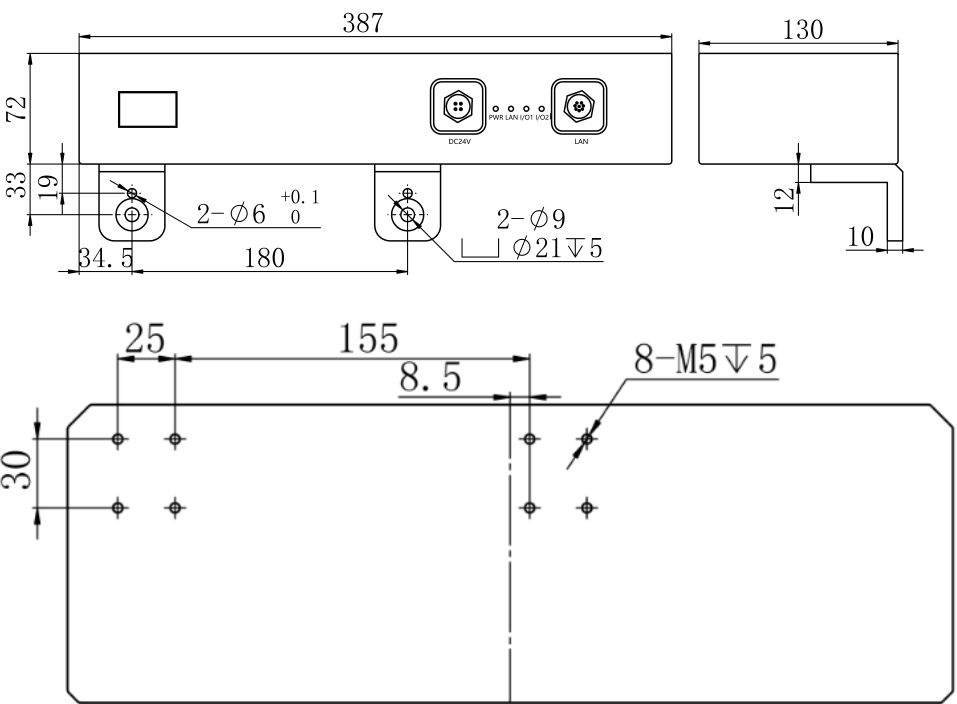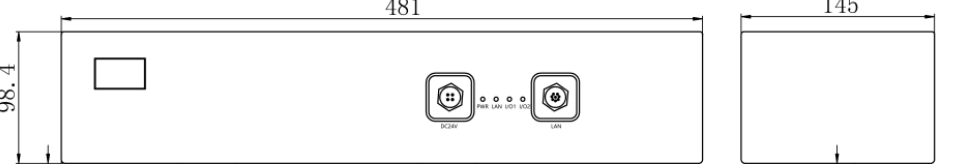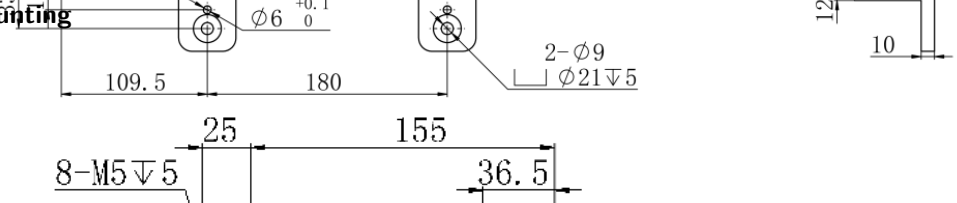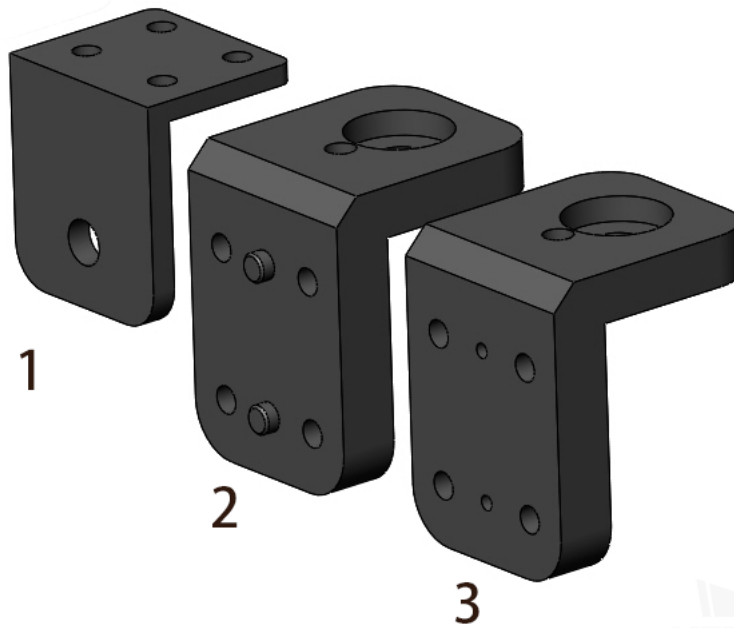
Recommended camera stand designs:

Figure 7. Several camera stand designs:
Left: temporary camera stand
Middle: steel structure stand
Right: Gantry stand

1.3.3 Fixation Dimensions of All Camera Models

Model	Fixation Dimensions for Type A (the upper) and Type B (the lower)
Nano	
Log S	

Model	Fixation Dimensions for Type A (the upper) and Type B (the lower)
Pro S Enhanced	
Pro M Enhanced	
Deep	

1.3.4 Right-Angle Brackets

No.	Name	Applicable Camera Models
1	label_R001593-B	Nano V3
2	label_C000316-B	Laser L V3S Series
3	label_C000316-A	Deep, Log S, Log M Series

Please click on the names for detailed dimensions.

1.4 Communication system

1.4.1 Supported communication protocols

At present, TCP/IP protocol is mainly used in the communication between Mech-Mind vision system and the external devices, and other Ethernet-based communication protocols, such as Modbus, Ethernet/IP, Profibus, Profinet, etc. are also supported.

- Modbus can support 240 devices to communicate on the same network, and uses the master/slave architecture, which is a common connection mode between the industrial electronic devices.

- Ethernet/IP is an application-layer communication protocol used in the industry to enable communication between the control system and its components, such as PLCs, I/O modules, and etc.

- Profibus is a site-level and unit-level network, suitable for medium and small data transmission.

- Profinet is an advanced communication system supporting distributed automation. It has a modular structure, and users can choose different functions according to the requirements.

1.4.2 Network construction

Note: This section uses the most basic Mech-Viz main control robot, without external sensors and host computer, and uses TCP/IP protocol as an example to explain network construction.

According to the structure diagram of *Software and Hardware* , the router is required to connect the robot, Mech-Eye camera to the IPC (Industrial Personal Computer) respectively. It is assumed that the IPC uses a wireless adapter to connect to the Internet, and is separated from the wired LAN. In the internal wired LAN, the robot's IP is static, and the Mech-Eye camera uses DHCP mode by default.

1.4.3 FAQ

Can not find the camera

If the on-site camera can not be found, perform level-by-level troubleshooting according to the methods as shown in the figure below. If the camera is still not found by this method, please contact us.
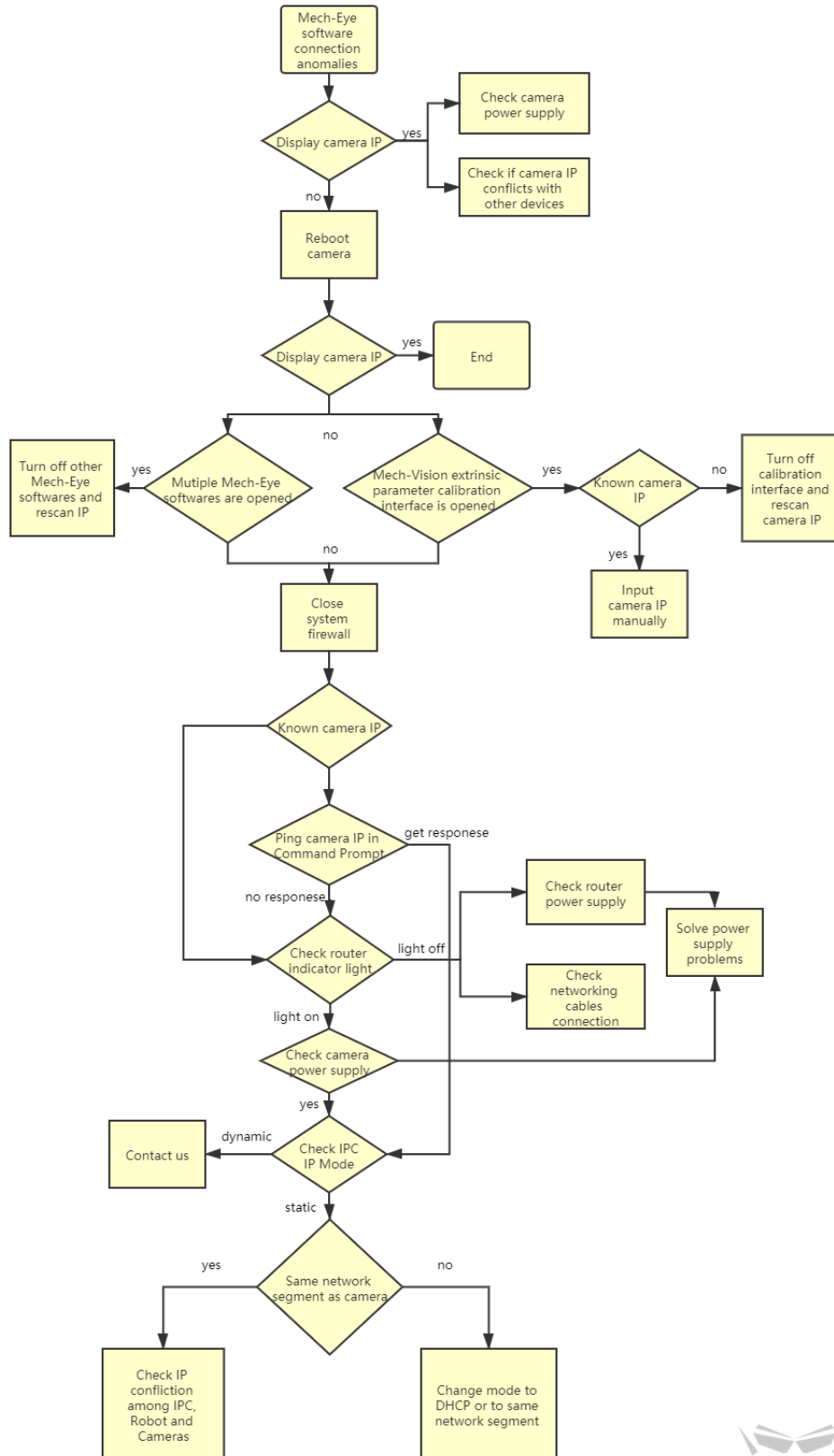
Figure 1 How to solve the problem if camera IP can not be found

Set camera IP to static

According to the requirements of different sites, the camera IP address may be required to be static to prevent being occupied by other devices. Here two ways to set the camera IP to static.

1. **Static IP address of router** Since the router uses the DHCP service, a new IP addresses will be reassigned to the accessed devices. TP-LINK can be used to set the IP addresses to static for the accessed devices.

2. **Mech-Eye set static IP** Please see Mech-Eye Industrial 3D Camera User Manual.

1.5 Computer configuration

1.5.1 Performance configuration

IPC (Industrial Personal Computer)

Minimum configuration requirements

> **CPU**: i7-6700/7700
> **RAM**: 8G
> **GPU**: GTX 1050TI | **Hard disk**: 128G SSD | **Remark**: General project requirements

Recommended configuration

> **CPU**: i5-8400/8500 or i7-8700
> **Memory**: 16G
> **GPU**: GTX 1070
> **Hard disk**: 256G SSD
> **Remark**: Projects with sufficient cost/performance requirements

External device

Configuration for external device

> **Configuration**: Basic configuration
> **USB 3.0**: 2
> **Gigabit Ethernet**: 2
> **Support auto-start**: Yes

1.5.2 Software installation and configuration

version 2.1

Activate Windows

For brand computers, the system is usually activated automatically when startup for the first time. If the system is not activated, click the troubleshooting button in the figure below after connected to the network, and the system will automatically be activated.
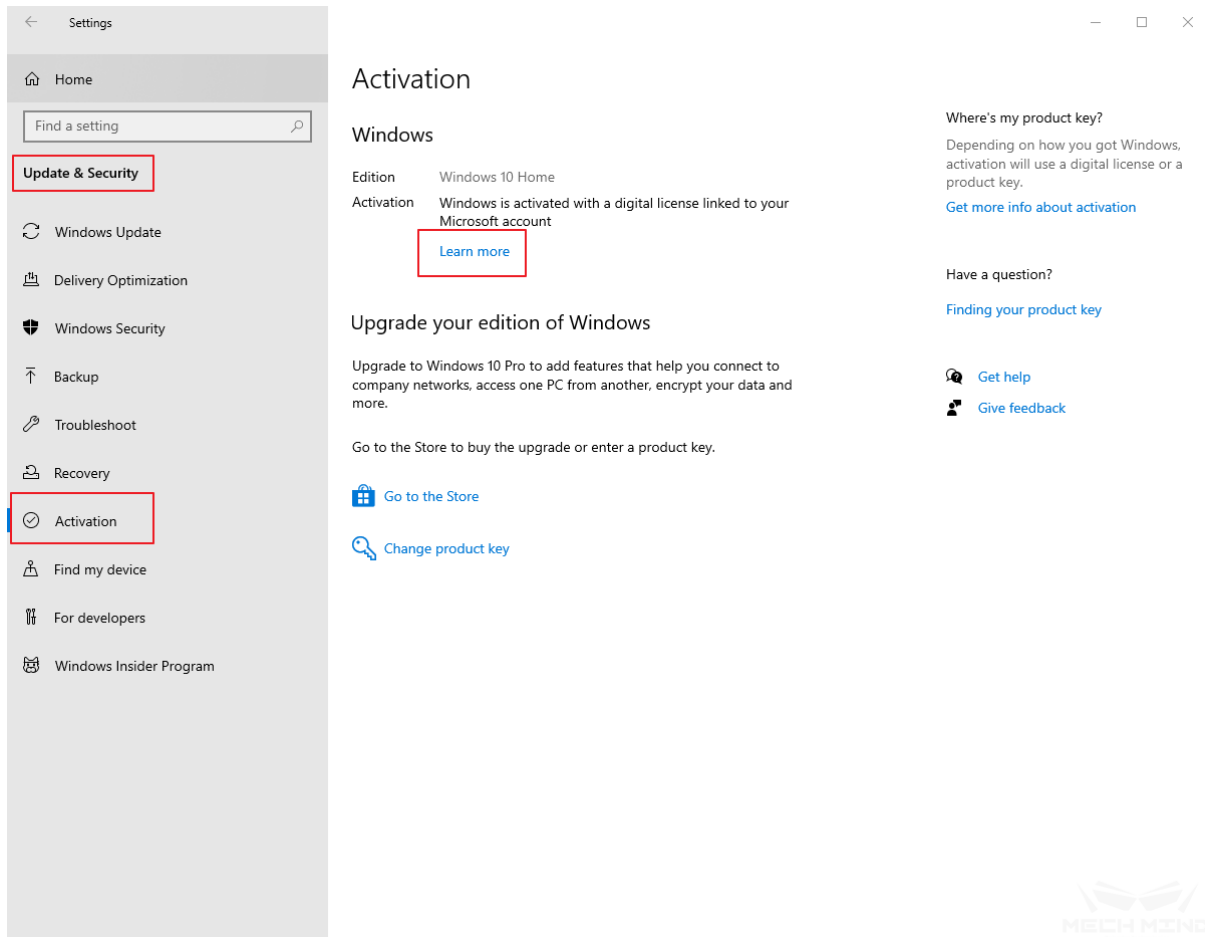
Activate Windows

Uninstall the pre-installed software

For branded computers, when the system is activated, uninstall all unnecessary software pre-installed in the system first, especially the pre-installed anti-virus software which may affect the communication between the camera and the robot.

Hard disk partition

Before installing the program, ensure that there are at least two partitions on the hard disk of the IPC. Programs such as Mech-Viz and Mech-Vision should be installed on a disk other than C drive.

If there is only C drive on IPC, it is required to partition the hard disk. If the icon "Computer" does now show on the new Win10 desktop, perform the following steps: right-click on the desktop → Personalize → Themes → Change desktop icons and check "Computer".
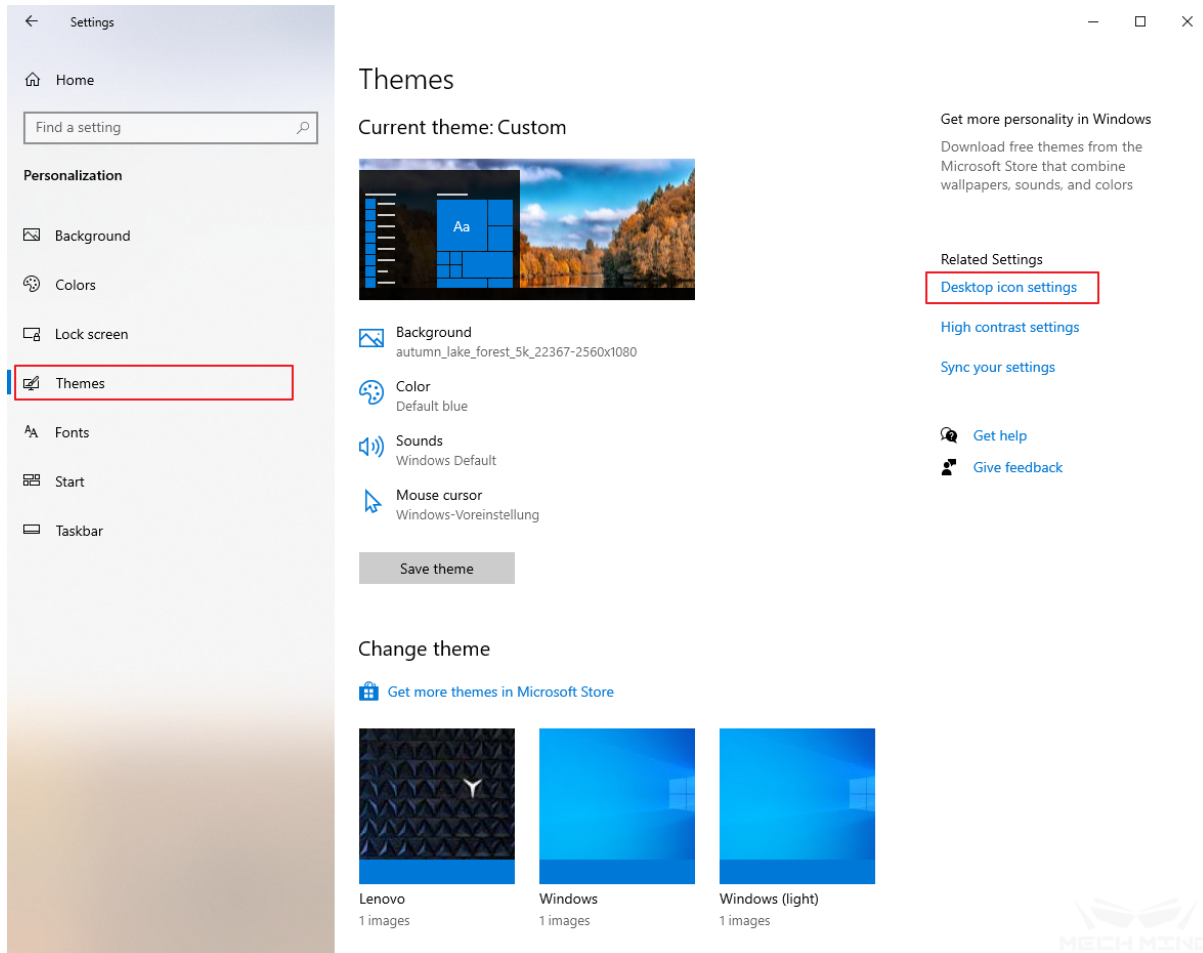
Add desktop icon
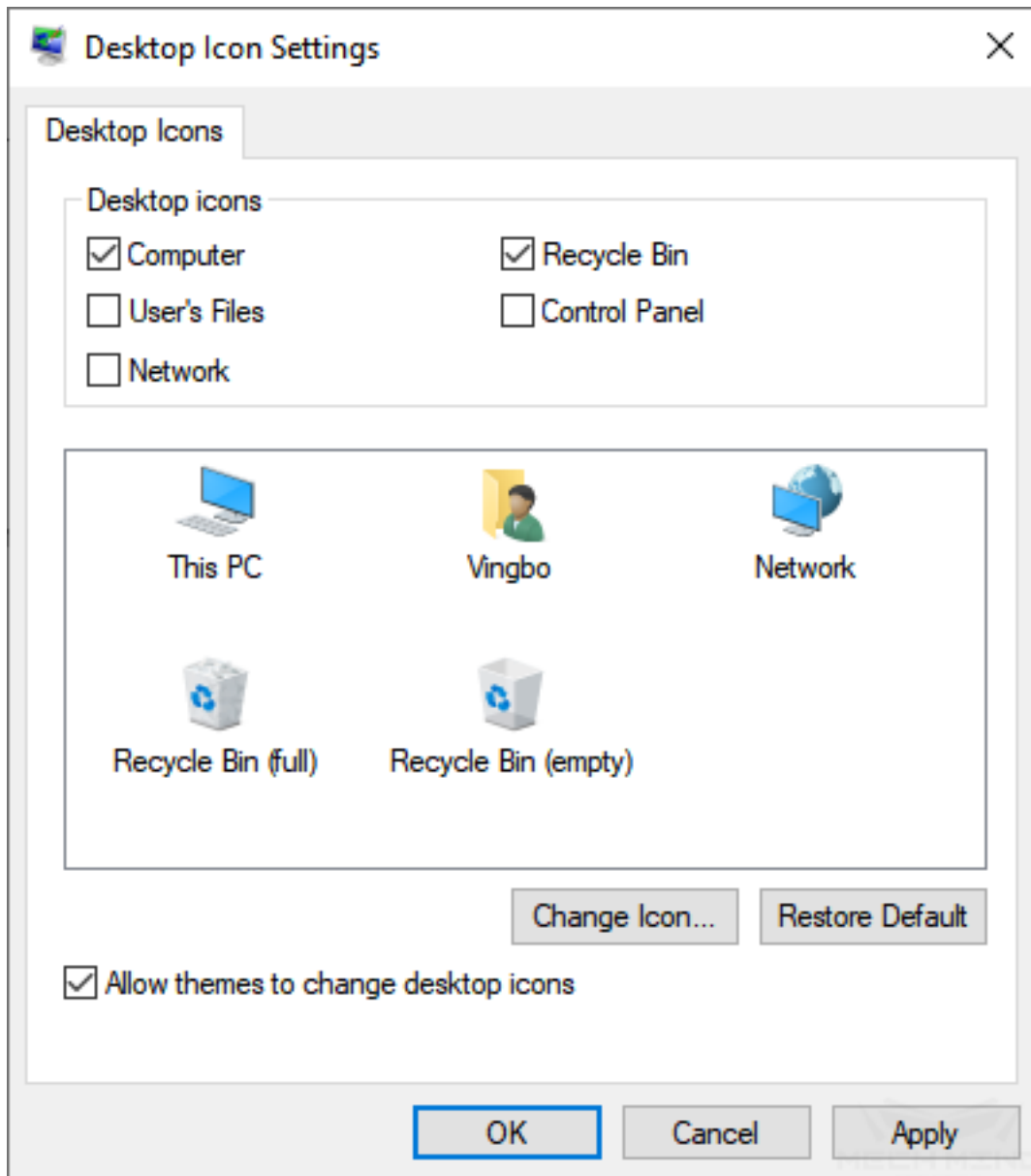
Add desktop icon

Then perform the partition on the hard disk. Right-click the Computer icon → Manage → Disk Management. Go to the next interface and select a disk.
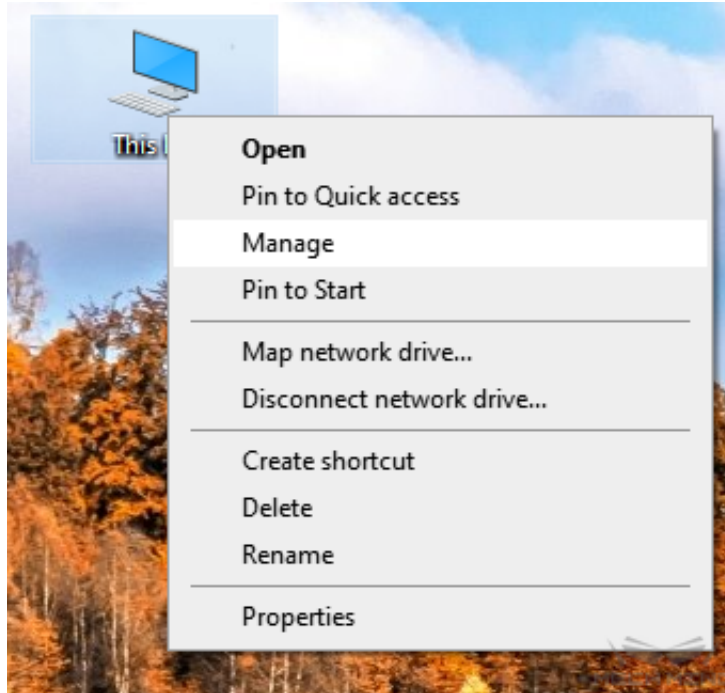
Disk Management
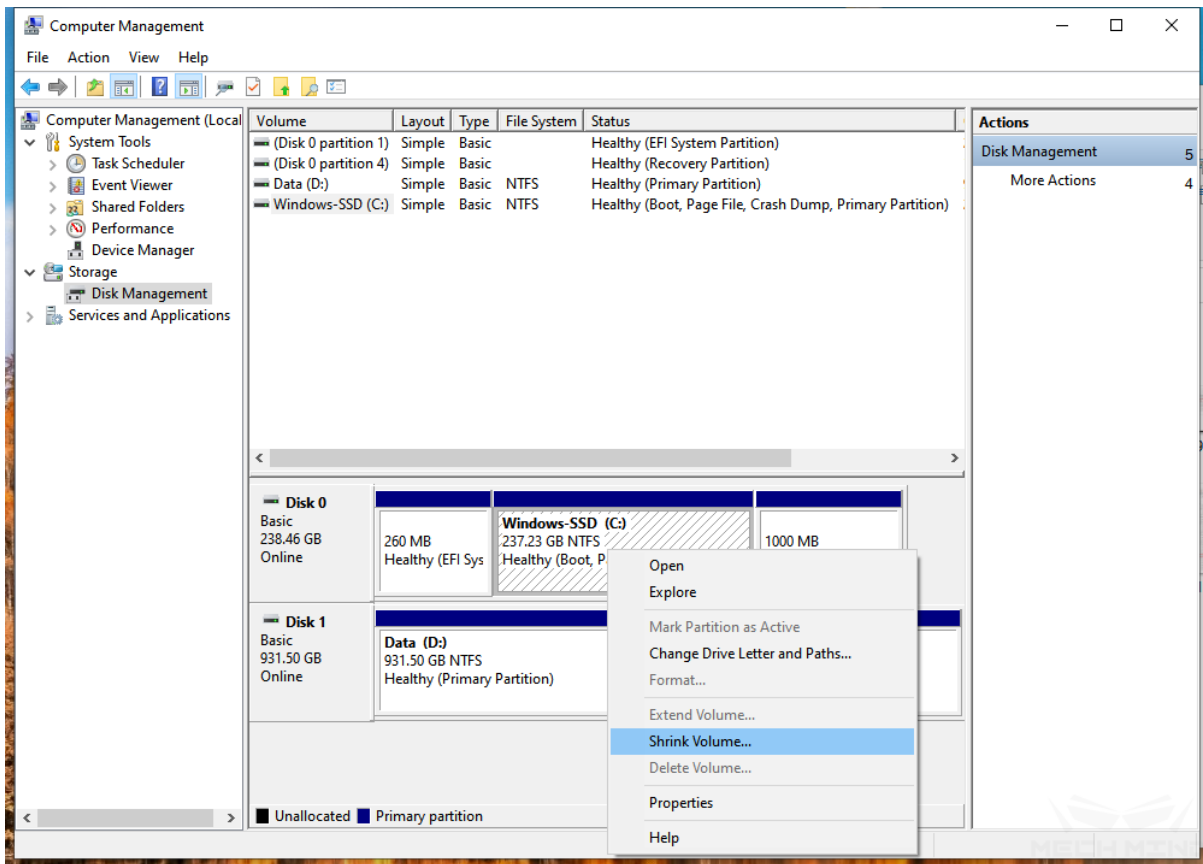
Disk Management

Disk partition first, right-click → Shrink Volume, and follow the step to complete the disk partition. Then right-click the shrunk disk and follow the prompts to create a new volume step by step to partition the hard disk. It is not necessary to partition large D disk space, 30G is enough, ensure that C disk space is sufficient.

Environment configuration for deep learning

Please refer to Mech-DLK Environment Configuration

Test Mech-Viz and Mech-Vision

Before testing Mech-Viz and Mech-Vision, install the encryption lock driver first. After *CodeMeterRuntime.exe* installation is complete, test whether Mech-Viz and Mech-Vision can run properly. It should be fine under normal circumstances.

Test Mech-Center

Test whether Mech-Center can be started up properly. Run **Mech-Center Installer Tool** after Mech-Center installation to check if all required Python packages are installed. Install the missing Python packages if needed. Then Mech-Center can be started properly.

Modify power options

It must ensure that IPC can always work even not in operation. Open "Settings" from the "Start" menu. Then click System → Power & sleep → change the setting both the display and sleep wait time to Never.
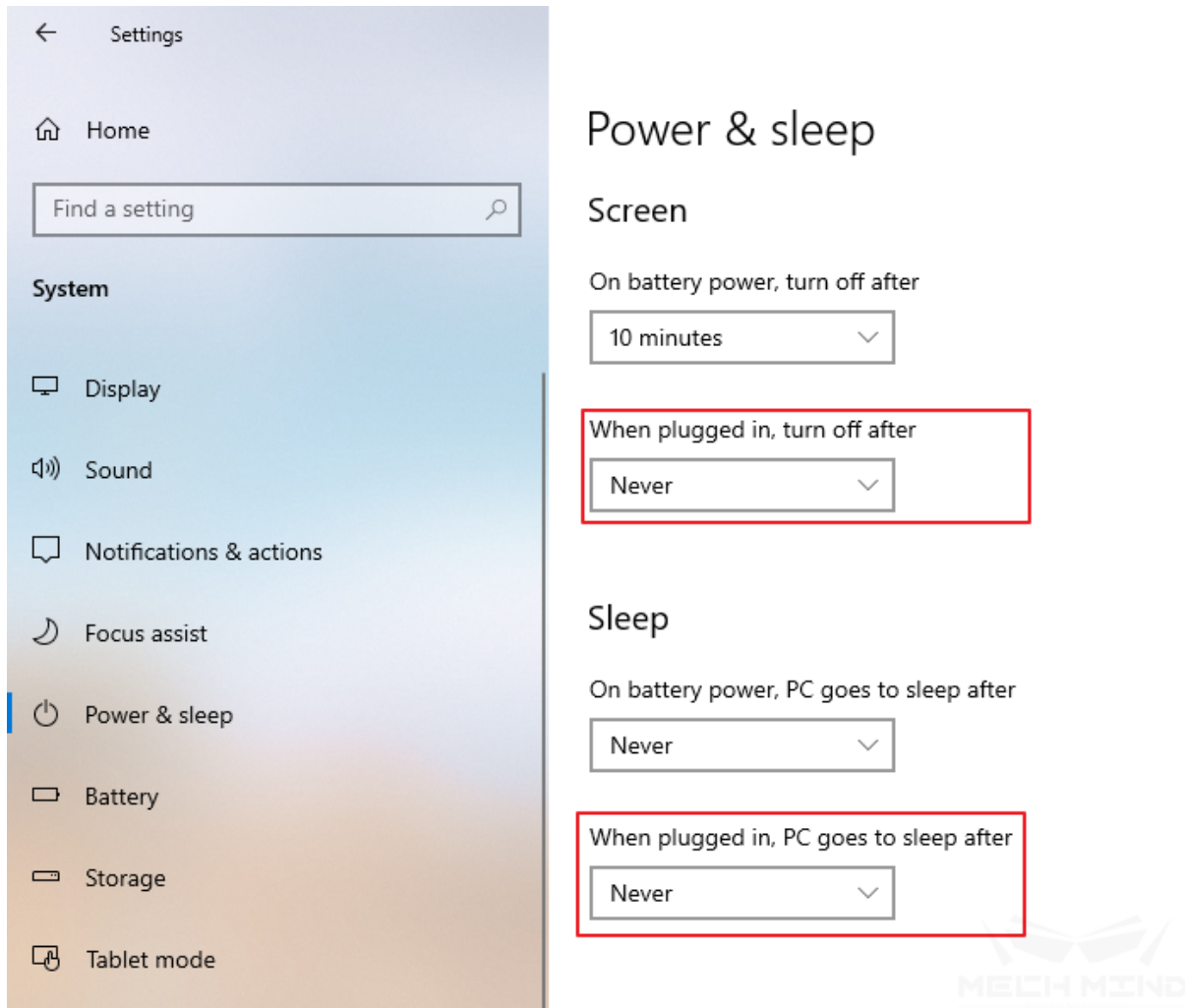
Windows settings

Turn off the firewall and automatic updates

The new Python file package can automatically turn off Windows automatic updates and firewalls during the installation process.

Install necessary software

Copy the necessary software in the shared folder to the IPC, the engineer can install and use it if necessary. There are many softwares currently included. The required softwares include:

- NetAssist (Network assistant)
- Notepad++ (Code review)
- TeamViewer (Remote assistance)
- Winrar (Decompression)
- CodeMeter (Encryption lock driver)

Solution for CUDA installation failure

Uninstall all NVIDIA products.

And delete all NVIDIA folders in the C drive.
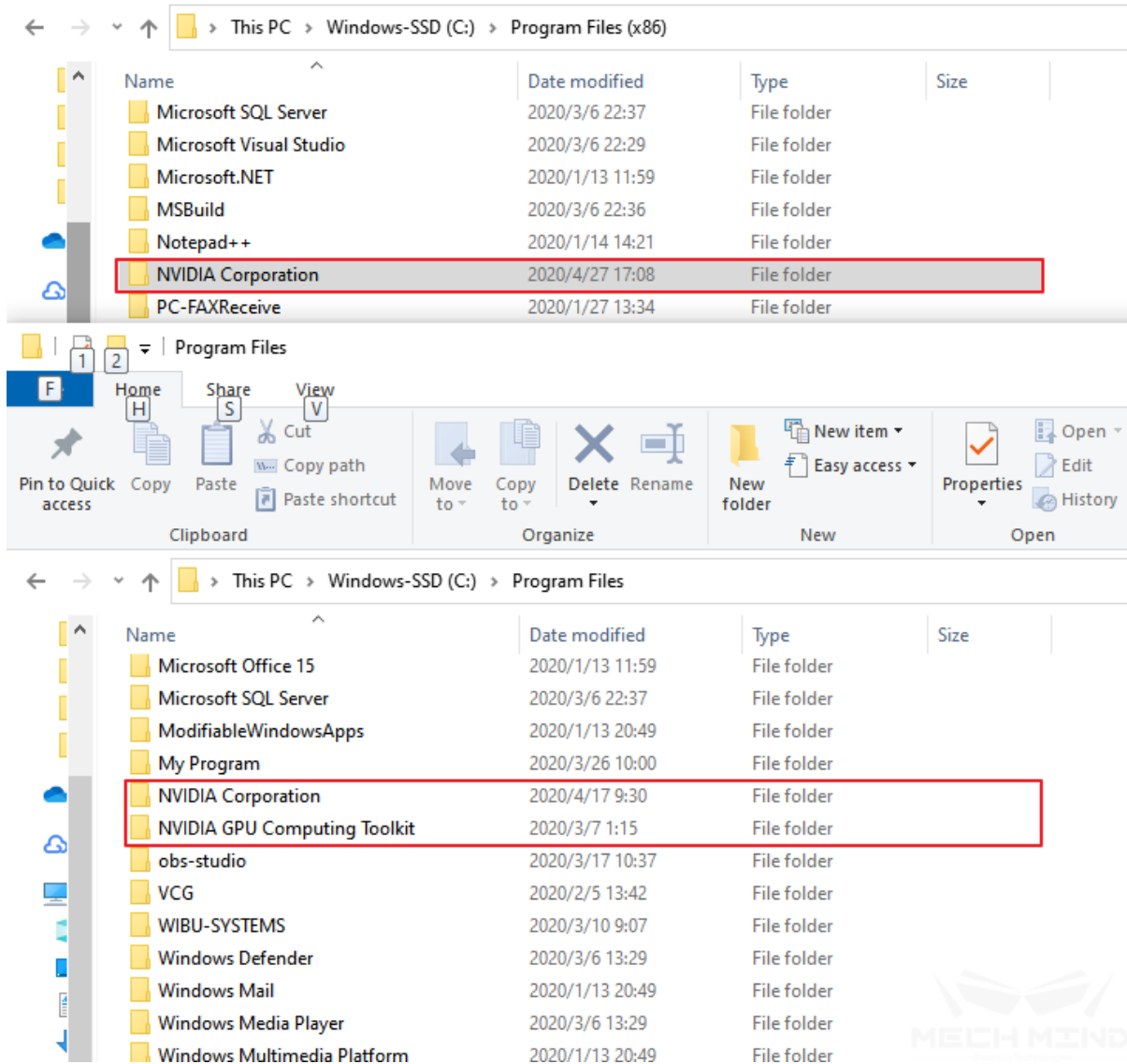
Delete all NVIDIA folders

If the folder cannot be deleted because the file in the folder is in use. Please use "Ctrl+Alt+Del" to start task manager. In the task manager process tab, manually terminate all processes marked with the NVIDIA icon. Then the folder can be deleted successfully.
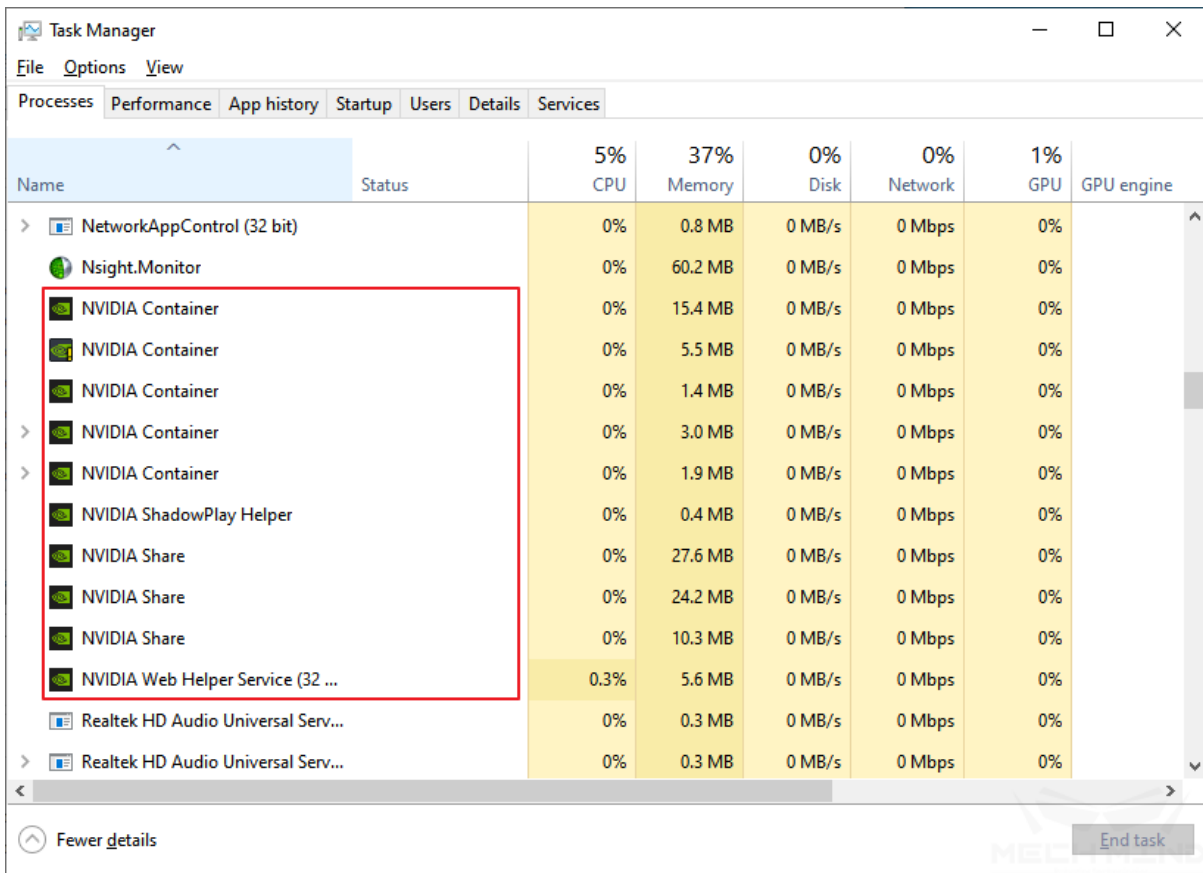
Manually terminate all NVIDIA process

Restart after the removal is complete, try to reinstall CUDA 10.0.

Remove garbled text on console

If there is a lot of garbled texts in the background printout, try to solve it as follows:
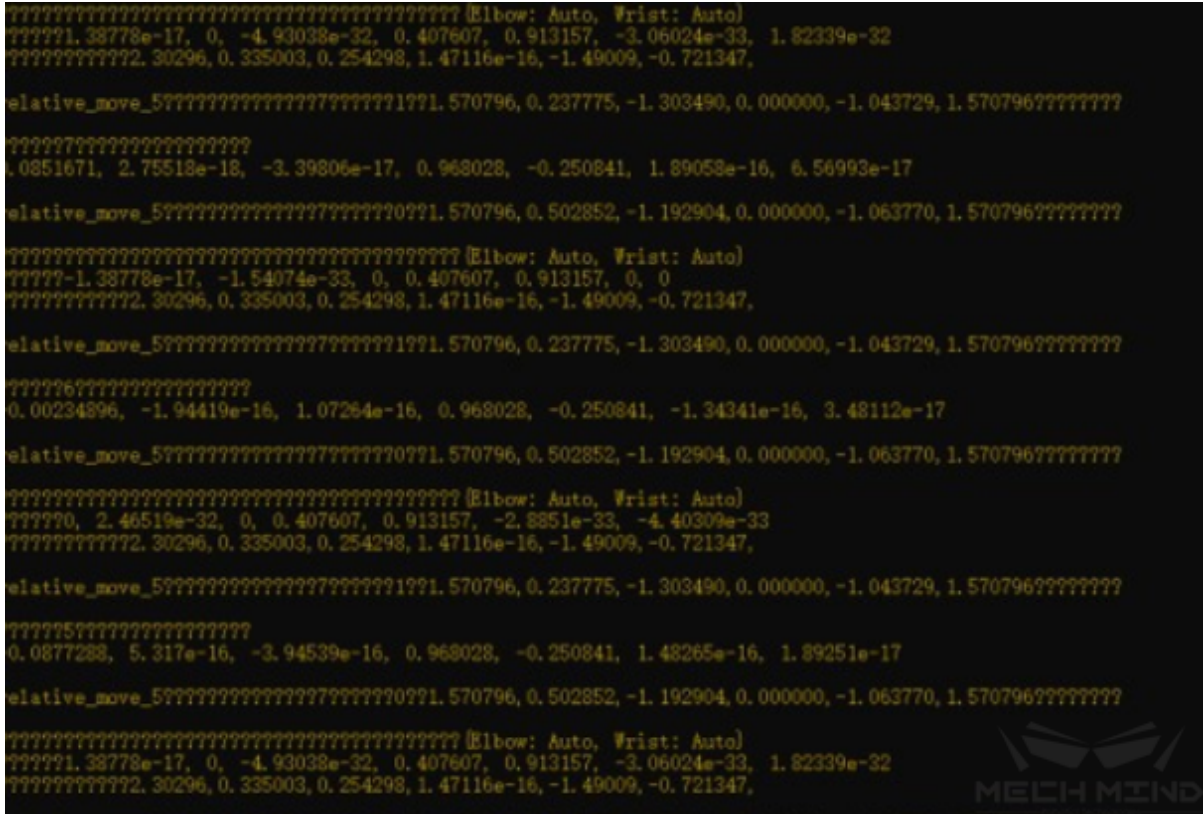
Garbled text on console

Right-click the language input to open the language settings → Language management settings → Change system locale → [Beta: Use Unicode UTF-8 for worldwide language support].
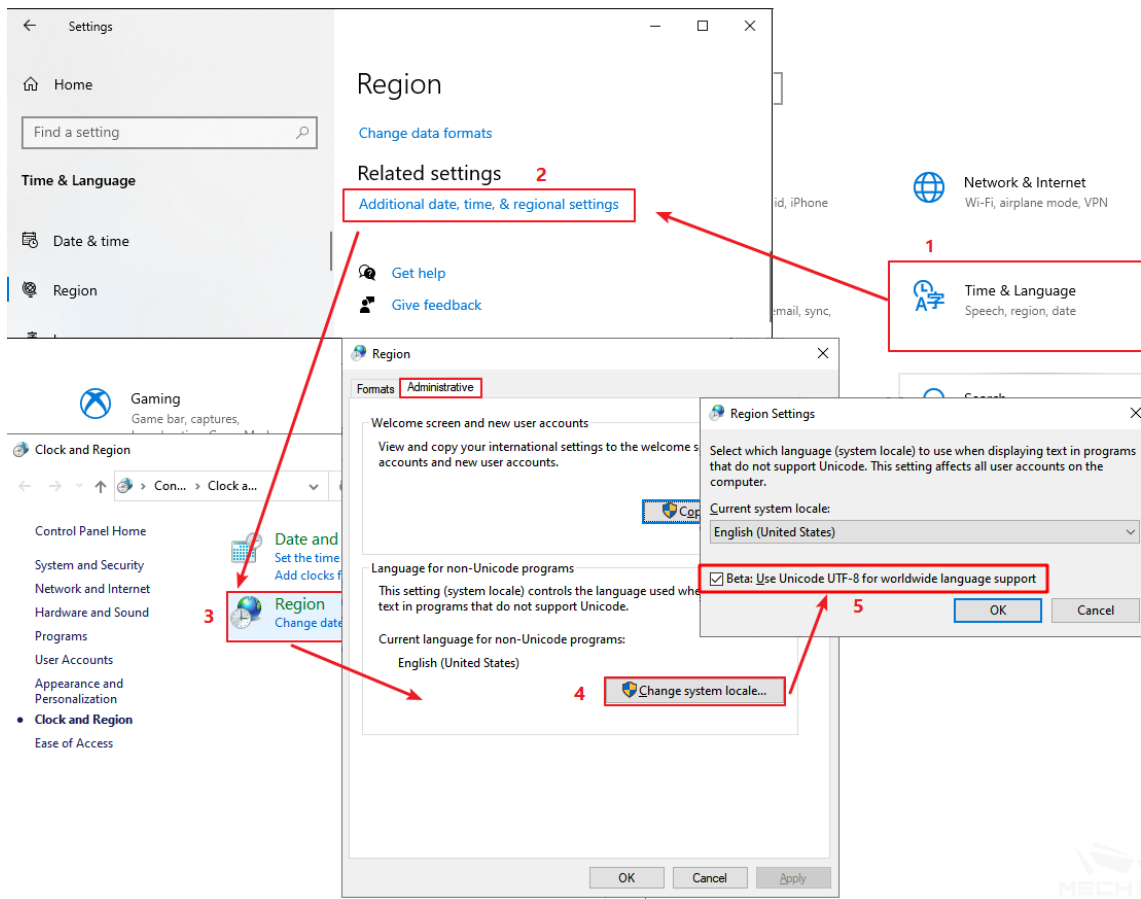
Enable Unicode UTF-8

Common errors and solutions

1. Missing dynamic link library
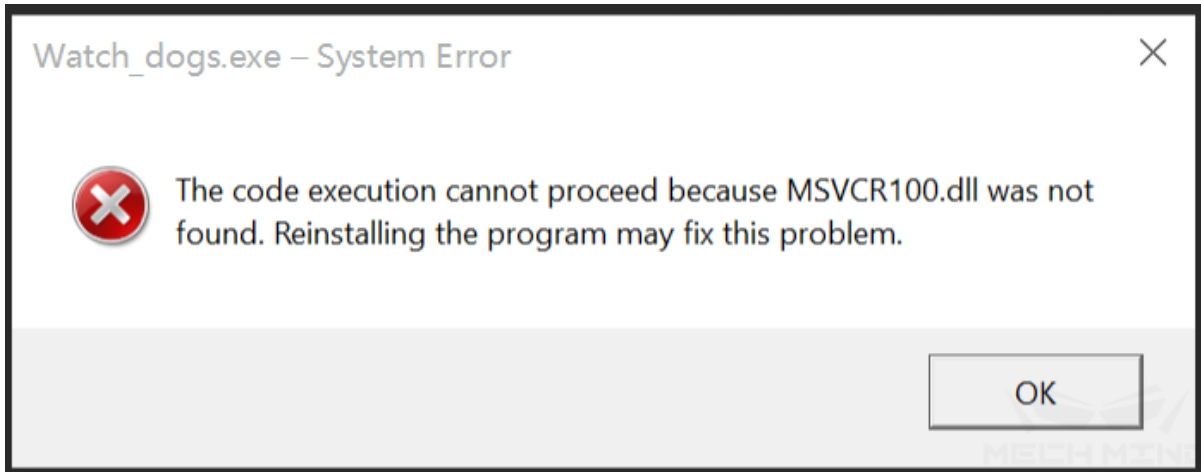
There error is generally due to the incomplete version of the VC++ Redistributable package. You can run the "VC_redist.x64.exe" to repair the VC++ Redistributable package.

1. Mech-Viz/Mech-Vision visualization errors

   Please check the display interface on the back of the host, and make sure that the display cable is plugged into the graphics card rather than the display interface of the motherboard.
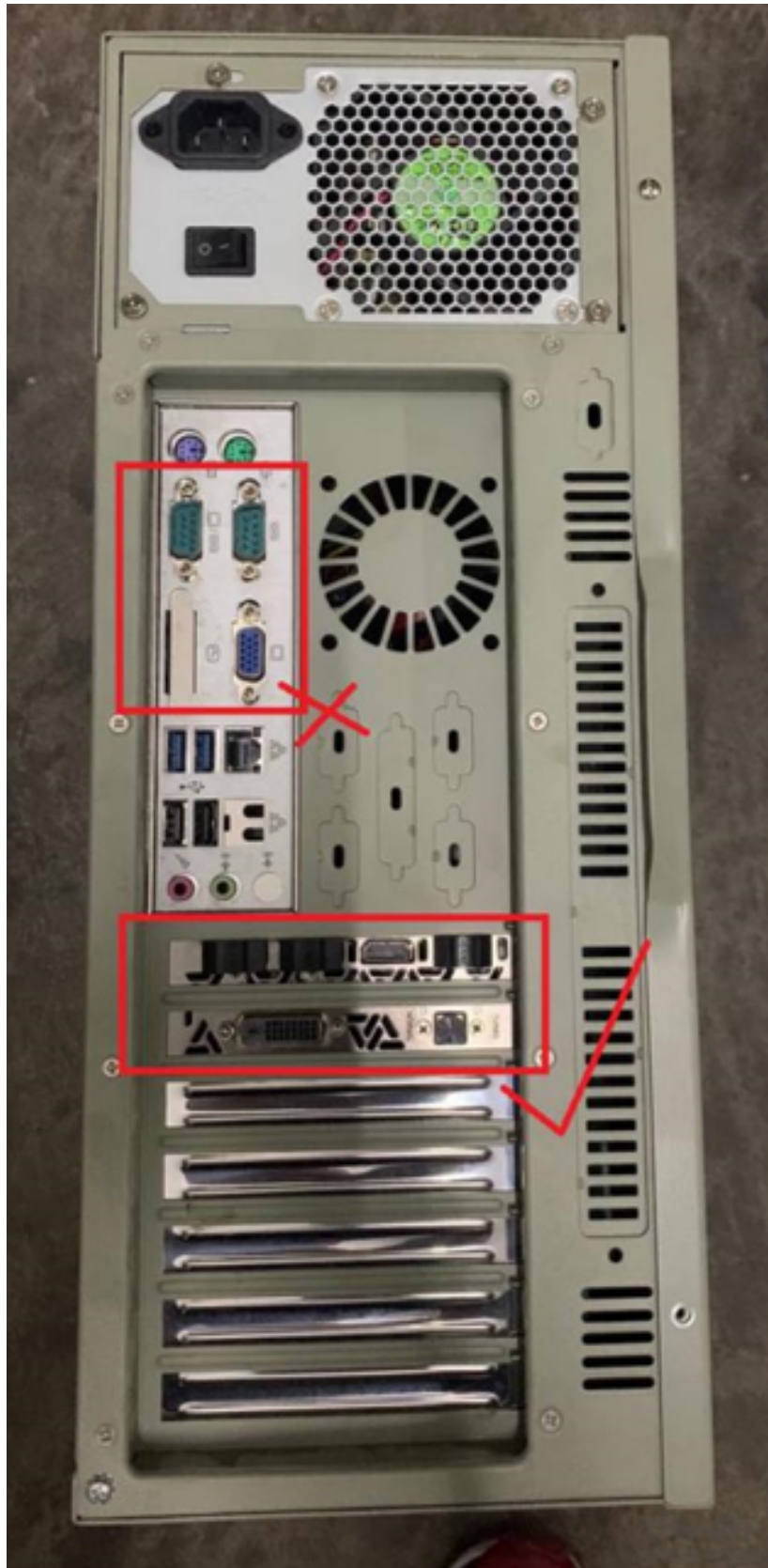
Example for IPC interface

Example for IPC interface

Example for IPC interface
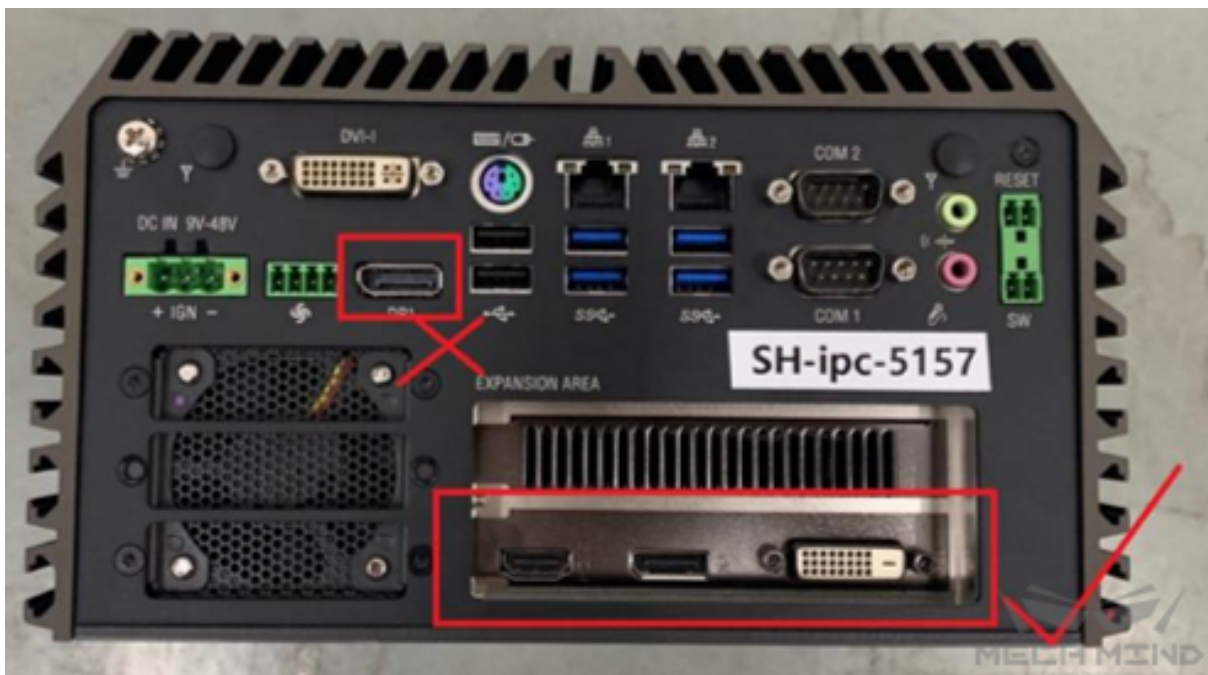
Example for IPC interface

PROJECT DEPLOYMENT ADVICE

This chapter offers the advice for hardware selection, design, and optimization on software and hardware during system building.

2.1 Camera Selection

2.1.1 Camera Selection Principles

1. Clear view: The camera can clearly capture images so that the point cloud of the object is clear with minimum holes or noises, and the features can be fully recognized and displayed.

2. Complete coverage: The field of view is sufficient to cover everything necessary.

3. Accurate results: The point cloud is highly accurate with munimum error.

2.1.2 Camera Selection Standards

Monochrome/Color

If there is a need for color images, such as using deep learning for carton depalletizing projects, select a color camera; otherwise, please select a monochrome camera by default.

Distance

- **Applications of small depth of field**:
    - The distance from the camera to the object is relatively fixed.
    - Examples are flat plate gluing, flat plate gripping, shallow bin picking, etc.
    - Suppose the solution design or measured distance is D. An available model with applicable distance closest to D will be selected.
    - If the available model's applicable distance is significantly different from D, or the project has extremely high focus requirements, the requirements can be discussed separately.

- **Applications of large depth of field**:
    - The distance from the camera to the object is within a large range.
    - Examples are depalletizing, deep bin picking, etc.
    - Suppose the solution design or measured distance range is D1–D2 (D1<D2). An available model with applicable distance closest to D2 will be selected.

– If the available model's applicable distance is significantly different from D2, or the project has extremely high focus requirements, the requirements can be discussed separately.

For detailed camera features and specifications of different models, please see Camera Models.

2.2 Illumination control

For the 3D point cloud by raster cameras and deep learning, the light will affect the effect and stability of visual recognition.

For the 3D point cloud imaging, the point cloud quality can be better when the light is uniform and the surface brightness of the object is low. In the actual environment, the maximum brightness of metal parts is recommended not to exceed 600lux, the brightness of the surface of boxes and gunny bags is recommended not to exceed 800lux, and other scenes should be kept below 500lux to ensure the ideal quality of point cloud. Adding a uniform surface light source in a dark room is the most ideal and stable method to control brightness. In this environment, the brightness of the surface of the workpiece can keep stable and without changes in light and darkness. For the non-darkroom environment, it is recommended to use a shading and supplemental light scheme to improve the quality of 3D point cloud.

For the deep learning, a ideal conditions includes a stable lighting environment, a clearly visible surface of the workpiece is clearly visible, and a stable brightness. In the actual environment, the ambient light changes over time, which may affect the recognition results of the deep learning. Reasonable use of the shading and supplemental light scheme can effectively control the changing of ambient light and stabilize the recognition results of deep learning.

Tip: The white ordinary LED light with a color temperature of 6000k is generally used as light source.

In the actual factory environment, the following points should be checked and guaranteed:

1. **White balance**: The colors in the 2D image should be similar to the images observed via the naked eye, otherwise it is required to adjust the white balance of the camera;

2. **Light intensity**: There should be no direct sunlight and other strong infrared light source on site;

3. **Reflection**: The lighting on site should be even and soft, strong light or complex light directly on the workpiece surface should be avoided;

4. **Stability**: The lighting on site must be stable to avoid great differences in light intensity during the day and night.

5. If the above points cannot be satisfied, it is necessary to consider the using of the shading and supplemental light. The following is the scheme for shading:
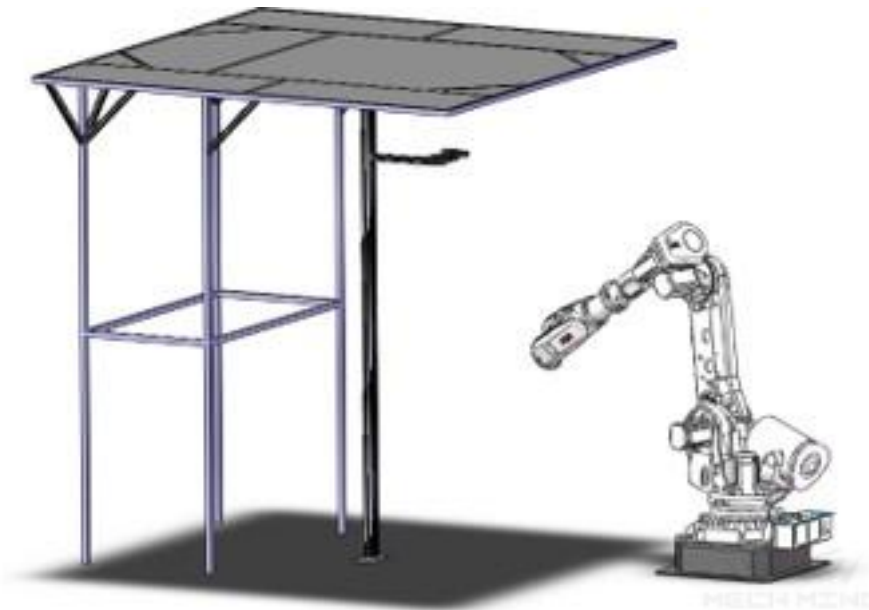
Figure 1 Scheme for shading

2.3 End effector design

During designing the robot's end effectors, try to meet the following requirements should be met as much as possible:

1. Check whether the structure of the end effector can adapt to all products. Especially when it comes to the sorting application with a large number of SKU. It is necessary to consider the symmetry and offset of the end effector.

2. Check whether the end effector suction force, grasping force is sufficient and can grasp all products stably;

3. The end effector of the suction cup can equip vacuum detection sensor according to product features, such as carton products, can determine whether the carton is grasped. It is recommended to add the buffer structure on the end effector, which has a good protective effect on robots and products.

4. avoiding being hanged and ripped off is required for the wiring layout in the robot move.

5. When a singularity occurs in the robot's working position, try to design an end effector containing offset to increase the tolerance of the singularity to the robot. Meanwhile, try to choose 45°, 30° and other common angles.

6. It is necessary to consider the working space of the robot. During meeting the requirements of robot processing, the length of the end effector shouldn't be too long or too short .

7. The 3D model of end effector is required to be kept during designing, which is convenient for subsequent debugging.

Tip: The 3D model of the end effector helps Mech-Viz to accurately detect the collision. Please see collision_detection and end_effector_&_objects/

2.4 Power control

In Mech-Mind Vision System, the main electrical equipment include: robots, Mech-Eye 3D cameras, IPC (Industrial Personal Computer), supplemental light sources, air sources, end effector and various sensors, signal lights, etc. The corresponding power supply requirements are as follows:

- **Robot**: Most robots have strong electrical adaptability and can work in the voltage range of 200 - 600V or even greater. A few robots can only work with voltages around 220V.

- **Camera**: When the Mech-Eye 3D camera is continuously working, the power consumption is about 120W and the voltage is 220V. The camera cable made by Mech-Mind must be used to ensure the stability of power supply and certain anti-interference ability. If the power supply system of the factory is unstable, a voltage regulator is required to ensure the voltage stability.

- **IPC (Industrial Personal Computer)**: The power consumption of the IPC is about 180W, and the voltage 220V.

- **Light source**: The power consumption of the light source driver is about 60W, voltage 220V, it is powered by a 3-core power cord, and is 6000k white light source with adjustable brightness.

- **Air source**: The power consumption of the air compressors is generally large, and the general power consumption is about 1000W, voltage: 220V.

- **Wiring**: All wires are required to be classified and labeled, and the wires must be organized in the line slots to avoid to be exposed and prevent interference with peripheral AGVs and forklifts.

In order to prevent the power supply system from impacting voltage and other problems, a voltage regulator is required to provide power protection for the camera and IPC. If the environment on site has frequent power outages, in order to prevent accidents, it is recommended to add :green: UPS power supply to protect the regular operation of the entire system. If a sensor is required to be connected to the robot, since most robot I/O ports provide 12V power supply with a weak load capacity, it is not suitable for directly driving small electrical equipment such as sensors. It is recommended to configure a special 12V/5V DC power supply for providing the power.

2.5 Robot model selection

When selecting a robot, the following points should be checked whether they can meet the requirements:

1. Check whether it is possible to reach all the required positions for work; whether there are sufficient margins in the X, Y, and Z directions to avoid the problem of singularity;

2. Check whether it can meet the requirements for maximum load of work;

3. The load-bearing capacity of the ground is required to meet the robot's operation limit load;

4. Check whether it interferes with cable, tray, camera support, ceiling, lighting, etc., during the robot operation and the vision calibration;

5. Check the condition that the height of the light source is low, the camera support is too close to the tray, the cable is too close to the robot base, and it is too close between the cable;

6. During end effector offset, it is necessary to consider that the working space of the robot may change;

7. In the case of Eye in Hand, check whether the highest photographing point is reachable when the camera is photographing full stack (Depalletizing&Palletizing);

8. Check whether the base height of the robot matches the actual application;

9. The overall layout is required to be simulated in 3D simulation software to ensure that there is no interference between the robot and other hardware throughout the entire operation.

2.6 Error control

In the project implementation, one of the most commonly encountered problems is the grasping error. The grasping error is that during the process of grasping the workpiece by the controlled robot, it is found that the robot did not reach the ideal position, instead certain error existing. The causes of errors are various, and they will be analyzed from the three aspects of the extrinsic parameter, vision, and robot. The detailed structure is shown in the figure below.
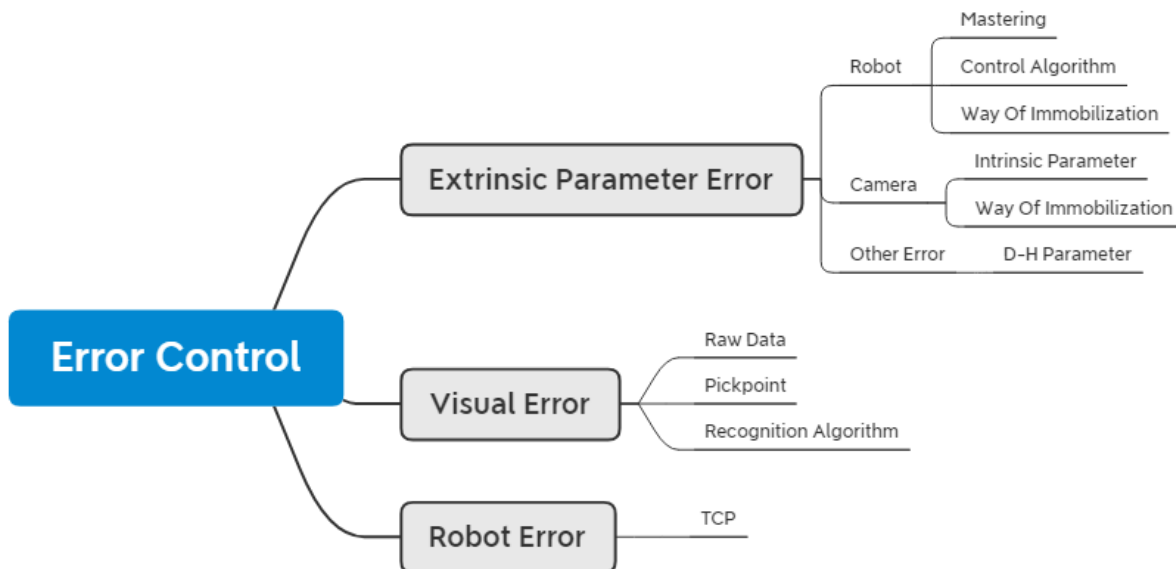

Figure 1 Causes for grasping error

2.6.1 Extrinsic parameter error

Robot

Null point

Null point: The robot controls the movement of each axis for the robot motor via a closed-loop servo system, and controls each motor by the instructions of the controller. The pulse encoder installed on the motor can feedback the signal of the motor to the robot. During the robot's movement, the controller continuously receives and analyzes the signal returned by the encoder, so as to achieve the correct control of the robot during the entire movement. The controller accurately analyzes the information returned by the encoder based on the null point position of each axis, so that the position of the robot can remain unchanged during the operation. During the normal operation of the robot, the null point position and the joint position of the robot will be saved, and the internal battery will be used to maintain power when the controller is normally powered off. This data will be saved every time the robot is shut down normally. Each time the robot is powered on, it will directly read the data in the backup for identification to ensure the same state as when the power was off. The null point of the robot may be shifted or lost under conditions such as impact, battery power loss, or unused for a long time.

If the robot is working under the circumstance that the null point is missing, it will cause:

The robot's joint axes work beyond the soft limits (this is very dangerous);

The robot cannot reach the specified position , different null point position results in different robot end positions under the same joint angle;

The robot cannot move the specified length in the specified direction (such as unable to walk 1 meter correctly).

When using Mech-Vision to calibrate extrinsic parameters, it calculates the points to reach for the multiple robots based on the calibration parameters. When the null point of the robot is lost, it is often impossible to reach the point accurately, and errors occur in the result for the calculation of the extrinsic parameter in the end.

Tip: There are many ways to detect whether the robot null point is missing. Here are two of the most commonly used detection methods:

- Adjust the angle of all axes of the robot to 0° by the teach pendant, and then observe whether the nameplates on the axes of the robot are aligned. If they are not aligned, it is indicated that the robot null point is lost;

- Control the robot to move a certain distance along the specified direction and observe whether the robot's walking distance is consistent with the theoretical distance.

Determine the null point of the robot by the above method, and then the null point calibration of the robot can be performed according to the null calibration method on the different robots.

Control Algorithm

Some newly developed robots have problems with the control algorithm at a low probability, that is, the robot cannot move to a specified position, and there is a deviation. In the case that the robot cannot accurately move to an accurate position, the robot cannot perform the tasks calibrated by the extrinsic parameters in the future.

Fixing

The fixing method of the robot directly determines whether the robot can maintain stability during the long-term operation. Weaker fixing methods, such as the use of expansion bolts or large bases that are not fixed, it cannot guarantee that the robot will remain stable or keep the running at high speed during the long-term operation. If the robot moves, the position relationship between the robot and the camera is destroyed in practice, and the robot will not grasp accurately. This situation is not common and once it happens it is difficult to be detected. Therefore, it is necessary to confirm the fixing method of the robot when fixing the robot.

Tip:

- If the long-term operation is required, it is best to use chemical bolts for fixing, and then perform the robot operation after the chemical bolts are firmly fixed, otherwise it will cause the bolts to loose;

- If the short-term operation is required, such as exhibitions, the robot can be fixed on a relatively stable surface, but the speed of the robot cannot be adjusted to a particularly high level, otherwise it will cause the robot to loose.

Camera

Intrinsic parameter

The extrinsic parameter problems caused by the camera's intrinsic parameters mainly occur at the edge of the camera's field of view or exceed the working distance of the camera. By factory defaults, the reasonable working distance of the camera according to the hardware used was determined. When the camera is working beyond the working distance or edge, because the camera is not accurately calibrated at this position, it will cause deviations in the generated point cloud, and finally it will also cause deviations in the calculated extrinsic parameter.

Tip: It is recommended that when using the camera, it is necessary to determine the working distance of the camera, and check whether the intrinsic parameters of the camera are correct, and finally perform calibration on the working distance of the camera.

Fixing

The reason for the change of the extrinsic parameters on the camera caused by the fixed method is the same as the fixed method of the robot. The stability of the fixed method directly determines whether the station can be used for a long time and keep the extrinsic parameters stable. For details on how to install the camera, please see Mounting the Camera.

Tip: The severe collisions on the camera support or large vibrations may also cause the camera support to become loose. Take special care when fixing and prevent the camera support from being bumped and leaned against.

Other errors

In the process of initial adaptation of the robot, in order to obtain the kinematic relationship of the robot, it is necessary to find the operation parameters of the corresponding robot (hereinafter referred to as D-H parameters) in the major robot websites or instructions. The relationship between the joint axes of the robot can be established by obtaining the operation parameters of the robot. In the actual process, the D-H parameters in the software may be inconsistent with the D-H parameters of the actual robot. There are two possible reasons:

- **This may be due to the difference** error in the number of robot sub-models or the obtained D-H parameters have a certain error with the actual robot;

- **There is a difference between the** manual and the actual robot.

If the D-H parameters are inconsistent, the end position of the robot in the software may be different from that in the teach pendant, which will cause the extrinsic parameter deviation during the calculation.

Tip: To check whether D-H parameters are consistent. After connecting with the robot, observe whether the posture of the 6-axis end of the robot is consistent with the robot end in Mech-Viz under the condition that joint angle is consistent. If they are not consistent, it may be caused by the deviant D-H parameters.

2.6.2 Vision error

Raw data

Raw data: Raw refers to the raw data input to Mech-Vision for processing. The data content mainly includes RGB images and depth images.

When the light (such as day to night) is changed on the work site, the configuration parameters on the camera are not updated in time, which may cause:

- The collected point cloud has too much noise or the details are not obvious, making subsequent matching algorithm unable to continue or identify errors;

- The quality of the collected RGB images changes, and the brightness of the images collected in a dark environment is not enough, resulting in no results in deep learning or poor recognition results.

Tip: If the above situation occurs, the camera parameters in Mech-Eye Viewer is required to be updated, and adjust the 2D and 3D exposures respectively, so that the RGB image and the depth image have better results. Or in project deployment, apply ideal *Illumination control*

Grasping point

Grasping point error is one of the common errors. There are two methods to set the grasping point in Mech-Vision, one is dragging grasping point, and the other is teaching grasping point. The teaching grasping point has a small error under the condition that the robot is accurate, so this situation is not considered here, and the situation of dragging grasping point will be analyzed.

Dragging grasping point is required to be performed in Mech-Vision. Adjust the position of the grasping points based on the template. Dragging grasping point is an inaccurate method, and the position to be reached by the robot cannot be provided accurately, so an ideal position cannot be reached in the actual grasping process. If a more accurate grasping point is required, it is necessary to use the teaching method to obtain the grasping points.

Tip: If there are errors in the grasping points, you can directly find them from the coordinates on the point cloud in the Mech-Viz software whether the grasping points of each workpiece are in the ideal position.

Algorithm

Deviations due to the output by Mech-Vision are collectively referred to as algorithm errors here. The deployment of vision algorithms is often set based on the original images collected on site. If the changes in lighting and working environment occur, the original parameters may not be applicable. It can be found in Mech-Vision and adjusted according to the instructions of the software user manual. Meanwhile, the recognition of some special workpiece may lead to sporadic errors, that is, no problems occur during the long-term operation, and occasional recognition errors occur due to the environmental changes, especially for the axisymmetric objects, the local optimal solution will occur, which leads to recognition error.

> **Attention:** Errors may occur due to template errors on some sites, that is, the template obtained via the STL file is inaccurate with the actual object to be captured, which will cause that the best results cannot be obtained when performing the template matching. The possible reasons for this are
>
> - The STL file is the file for the finished product, but the file to be grasped is the file for the rough material. In the production process, a machining allowance is left to ensure subsequent processes, which results in the workpiece that needs to be identified is larger than the template file.
>
> At this time, you can adjust the scaling of the template appropriately.

2.6.3 Robot error

TCP

The TCP error of the robot manifests itself as an inconsistency between the actual tool center and the theoretical tool center of the robot. Most of the reasons are that the robot TCP calibration is not accurate enough. The situations such as the movement of the cusp, the robot's posture change is not large enough, and it does not coincide with the cusp, etc., all may cause the inaccuracy of the robot TCP. During the use of the software, it is required to create a tool in Mech-Viz and enter the correct TCP value.

Tip: To determinate TCP, a better method is to use a robot to calibrate TCP, and enter the calibrated value into Mech-Viz, and leave a backup on the robot side.

Tip: For a project which does not require the high accuracy, directly adjust the TCP value in the software to improve the accuracy of the grasping.

2.7 Takt Time and Path Optimization

Takt time in Production: Takt time refers to the required time to process one workpiece, that is, the requirement of the user defined annual output on the efficiency of the robot workstation.

At present, most projects have requirements for takt time, and some projects have extremely high requirements for takt time (within 4 or 5 seconds). For projects with high takt time requirements, after the workstation can complete the entire operation process, Mech-Mind Software Suite will optimize the takt time via the vision algorithm optimization and robot route optimization. The takt time includes the camera shooting time, Mech-Vision processing time and the time from Mech-Viz planning to the robot complete the process. Therefore, the entire process for takt time and route optimization can divided into the above three parts, as shown in the following figure.
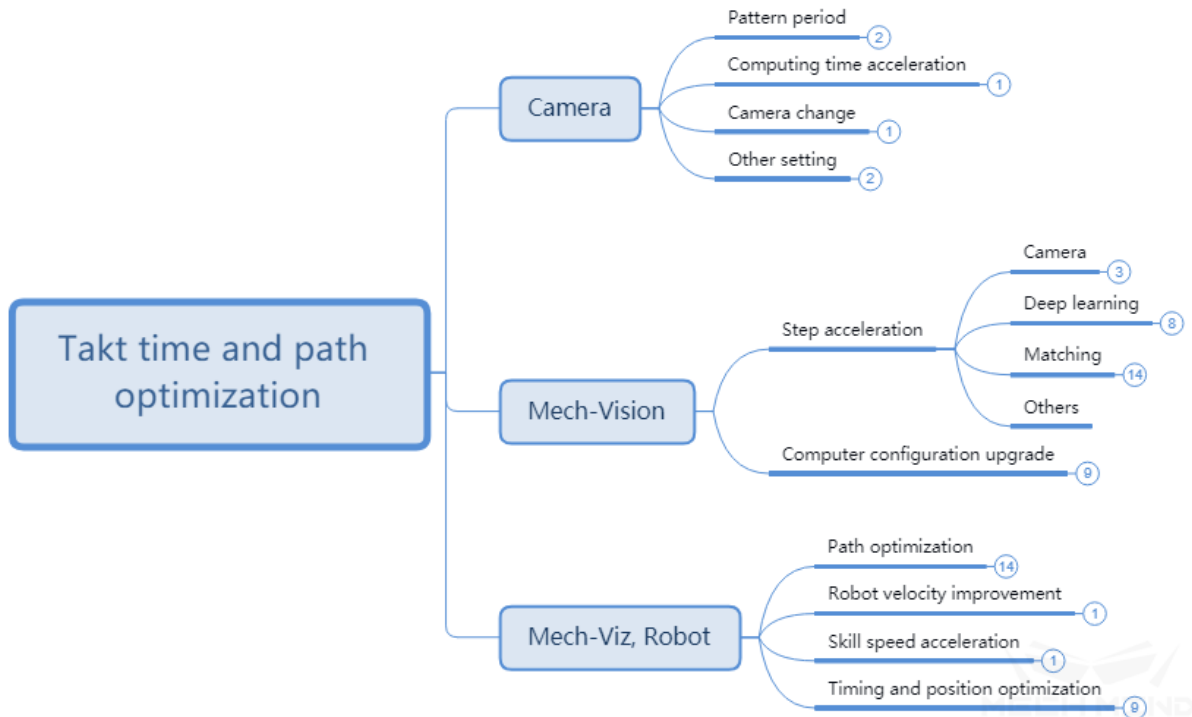
Figure 1 The overall concept for route and takt time optimization

2.7.1 Mech-Eye Viewer

Projection Time

2D/3D Exposure Parameters (HDR)

HDR: The HDR function is a technology that combines photos by shooting objects through different exposure cycles to improve the range of light and dark in photos, and enhance the details of point clouds.

When using Mech-Eye Viewer software, in some usage scenarios: such as recognizing complex structures of metal parts, objects with more details, etc., you can switch the 2D exposure mode and use two to three sets of different 3D exposure times to take pictures. Get more information. At the same time, it should be noted that in more scenes, such as cardboard boxes, flattened workpieces, etc., it will save half of the projection time without HDR. As shown below.

For the adjustment of 2D/3D exposure parameters, please refer to Mech-Eye Viewer - Parameter Adjustment.

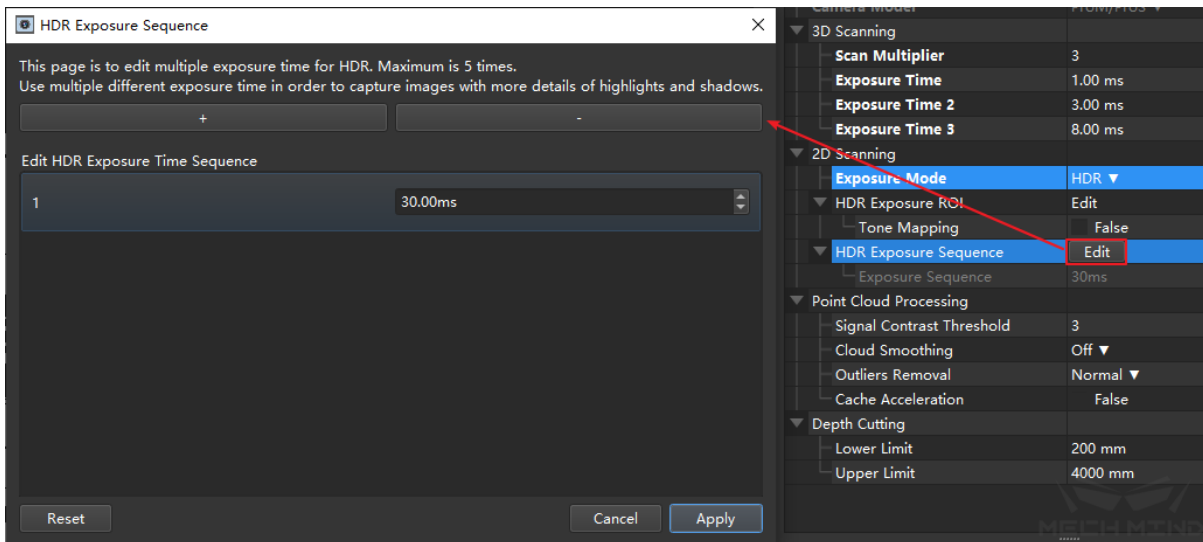Figure 2 Modification on projection time

Update

Using the latest version of Mech-Eye Viewer software and updating the camera firmware version at the same time can increase the speed of generating depth maps and point cloud maps, and improve the speed of photographing.

Camera Replacement

In Mech-Mind's camera appropriate, such as the Deep series of cameras, due to the large field of view, it is necessary to use two optical machines to project separately, and then synthesize the obtained point clouds. Therefore, the projection time will be twice as long as Pro M and Pro S series cameras under normal conditions. After determining the working scope of the scene, using a suitable camera can improve the speed of taking pictures.

Deep ROI

The depth ROI is the divided area in the camera's field of view, it is used to reduce the amount of data to be processed by the camera. The depth ROI can be set in the XY direction and the depth limitation respectively to reduce the number of point clouds as a whole.

The ROI setting in the XY direction is shown in the figure below. The ROI range is determined by drawing a frame after entering.
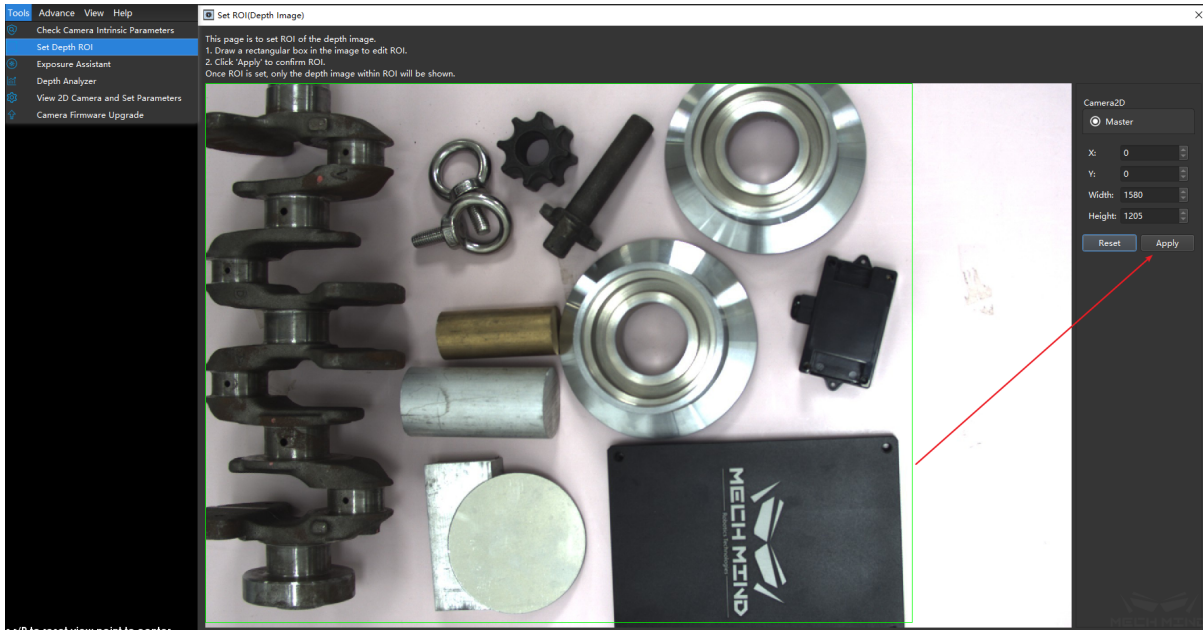
Figure 3 Set the depth ROI (XY)

The limitation in the Z direction are required to be set in the camera parameters. Setting the minimum and maximum depths separately can effectively reduce the number of point clouds. The units in the figure is mm.
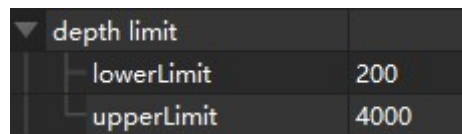
Figure 4 Setting the depth ROI (Z)

2.7.2 Mech-Vision

Step Acceleration

Capture Images from Camera
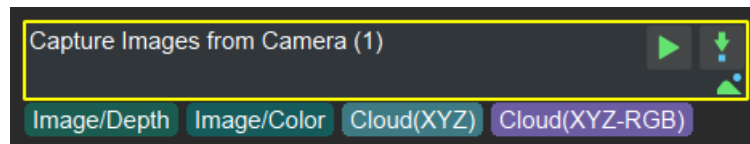
Figure 5 Get images from the camera

capture_images_from_camera is the most important step in Mech-Vision project, and it also takes up about 40% time in most of projects. The time consumed by capture_images_from_camera can be

mainly optimized by the above method. Meanwhile, the function of capture_images_from_camera can also be split, since the camera collects RGB images and depth images and combines them to generate point cloud images. In some projects, point cloud and RGB images may need to be processed respectively at the same time, such as the project with deep learning, they can be processed respectively. As shown in the figure below, since the project is calculated in parallel, more time cab be saved.
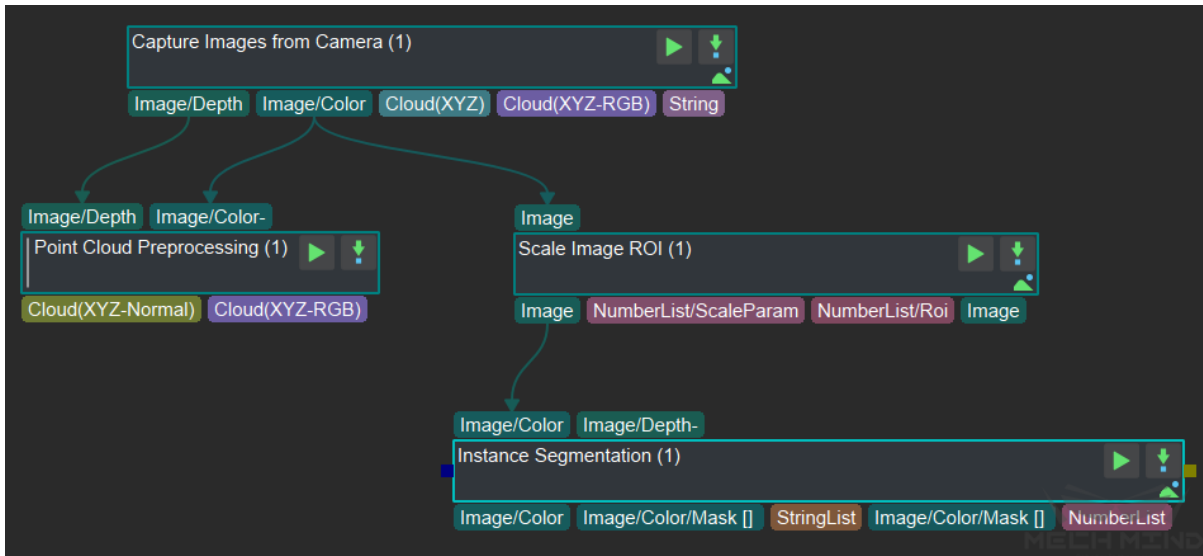

Figure 6 Parallel computing of deep learning and point cloud processing

Point Cloud Processing

In actual projects, the point cloud obtained directly from the camera cannot be used directly, and more specific processing is required, such as point cloud clustering, merging, and so on. The process can also improve the beat by optimizing details. Here are a few related point cloud processing, which will significantly affect the step of the beat and the method of beat optimization.

Extract Point Cloud in ROI

Usually for the scene point cloud, only a part of the area containing the target artifact is of concern to us. At this time, you need to intercept the ROI to focus on a certain area, and filter out most of the non-work area point cloud to greatly improve the beat.
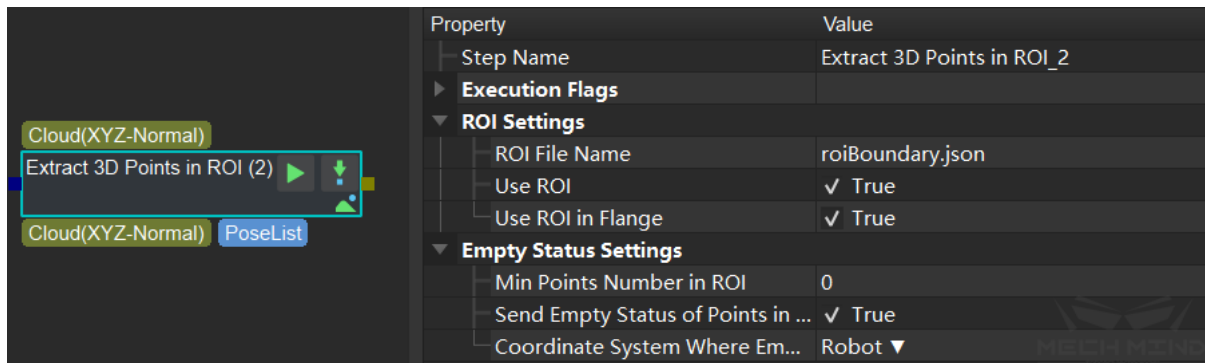
Figure 7 Extracting point cloud in ROI

Down-Sample Point Cloud

This step is used to sample the point cloud to reduce the size of the original point cloud. For most projects that do not have high requirements for point cloud density (such as edge matching, obtaining the highest layer mask, etc.), adding this step can greatly improve the beat. `Sampling interval` The sampling magnification can be controlled and set according to the beat requirement.
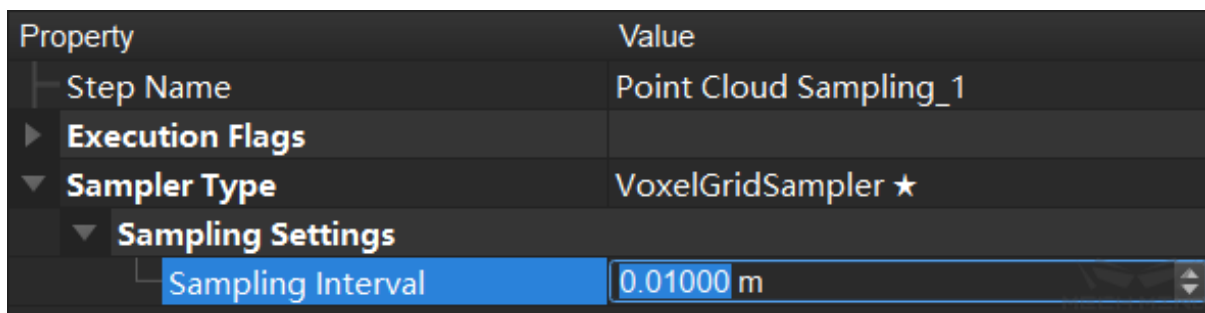
Figure 8 Down-Sample Point Cloud

Calculate the Normal Vector of the Point Cloud and Filter

After the depth map is converted into a point cloud, the normal vector of the point cloud needs to be calculated and filtered. For a host computer with a suitable supporting graphics card (GPU), setting the normal calculation method of GPU acceleration can significantly improve the beat.

Figure 9 Calculate the normal vector of the point cloud and filter

Point Filter

This step filters the points in the point cloud through the set rules to eliminate noise. In order to improve the beat, you can modify the `number of nearest neighbors` used for the average distance estimation, and conduct an experimental test. On the basis of ensuring the accuracy, the parameter can be appropriately reduced.

Figure 10 point filtering

Point Cloud Clustering

This step includes the `GPU acceleration` option. When there are a large number of point clouds, checking this option will increase the beat, otherwise there will be no obvious effect. It is worth noting that when the video memory is insufficient (for example, viz/deep learning takes up too much), it may not decrease but increase, and the parameters should be set according to the actual situation.

Figure 11 Point cloud clustering

3D Matching

3d_matching_steps mainly includes steps 3d_coarse_matching and 3d_fine_matching. Wherein 3d_coarse_matching is mainly used to calculate the approximate position of the template point cloud in the space point cloud, and 3d_fine_matching is mainly used to match the template with the space point cloud. The calculation principles of these two steps are similar, they need to calculate the relative position of each point in the space. Therefore, the more points, the more time will be spent, and the more iterations of the fine matching will also take more time. Therefore, when adjusting these two steps, it is mainly to reduce the number of processing point clouds (data and templates) and reduce the number of iterations (fine matching).

Tip:

- For rough matching, if you select `SurfaceMatching`, adjust `Sampling Settings` to adjust the point cloud density to reduce calculation time. In the case where the density of the down-sampled point cloud cannot be lower, but still needs to increase the beat, consider increasing the `reference/reference point sampling step`.

- Remove a lot of useless point clouds through some early point cloud preprocessing work, such as clustering, ROI, point cloud filtering and other operations.

- When multiple workpieces are matched, the number of matched workpieces can also be appropriately reduced. For example, only 3 workpieces are matched each time to increase the matching speed.

- According to the characteristics of the actual workpiece, the template file is simplified. For example, the edge template is used to match the large workpiece, or the template is down-sampled to reduce the number of point clouds to a smaller range.

- Point direction calculation method: For the template that cannot be directed, use `StandardMode`; for the edge plane object template, use `EdgeTangent`, while ensuring that the recognized object has been well segmented.

Property	Value
Step Name	3D Coarse Matching (Multiple Templa...
▶ **Execution Flags**	
▼ **Model and Pick Point**	
├ Model File (Required)	model.ply
└ Geometric Center File (Require...	
▼ **Cloud Orientation Calculation**	
├ Point Orientation Calc Mode	Origin ▼
└ Number of Searching Points	10
▼ **Processor Type**	**SurfaceMatching ★**
▼ **Sample Settings**	
├ Enable Automatic Downsa...	✓ True
├ Expected Point Number of ...	1000
├ Max Point Number of Sam...	4000
├ Max Point Number of Sam...	30000
├ Sampling Interval	0.010000 m
└ Min Sampling Interval	0.003000 m
▼ **Voting Settings**	
├ Distance Quantification	1.0000
├ Angle Quantification	60
├ Max Vote Ratio	0.8000
├ Reference Point Step	5
└ Referred Point Step	1
▼ **Clustering Settings**	
├ Cluster Ratio	0.1000
├ Threshold of Angle Differe...	15 °
├ Threshold of Distance Diffe...	0.020000 m
└ Output First N Clusters with...	5
▼ **Pose Verification Settings**	
├ Use Pose Verification	✓ True
├ Marked Margin	1
├ Voxel Length	3 mm
└ Maximum Number of Dete...	3
▼ **Results Visualization**	
├ Show Sampled Model Cloud	☐ False
├ Show Sampled Scene Cloud	False
└ Show Matching Results	✓ True

Figure 12 3D coarse matching

Property	Value
Step Name	3D Fine Matching (Multiple Template...
▶ Execution Flags	
Parameters Tuning Level	Advanced ▼
▼ Model and Pick Point	
Model File (Required)	model.ply
Geometric Center File (Require...	
Model Label File (Optional)	
▼ Cloud Orientation Calculation	
Point Orientation Calc Mode	EdgeTangent ▼
▼ Correspondence Settings	GMM ★
Matching Mode	Standard ▼
Standard Deviation	0.005000 m
▼ Sample Settings	
Sampling Interval	0.00500 m
▼ Symmetry Settings	
Symmetry Axis	ROTATE_BY_Z ▼
Angle Step	360.0 °
▼ Model Weight in Validation	
File of Model Fragments with ...	
Weight of Each Point	2.0000
Search Radius When Set Weight	0.0030
▼ Validation Settings	
Confidence Threshold	0.500
Search Radius	0.010000 m
Apply Angle Deviation in Valid...	False
▼ Output Settings	
Maximum Number of Detecte...	1
▼ Results Visualization	
Show Sampled Model Cloud	False
Show Sampled Scene Cloud	False
Show Validation Point Corresp...	False
Show Matching Results	✓ True

Figure 13 3D fine matching

Others

In the project, in addition to capture_images_from_camera and 3d_matching_steps, there are many other Steps. The time consumption for most of the steps can be ignored. If necessary you may make appropriate adjustments according to Mech-Vision /MechVision/GuideToSteps/GuideToSteps .

IPC (Industrial Personal Computer) Performance Improvement

Computer vision and image processing is very computer-intensive. A good-perf rmance IPC (Industrial Personal Computer) can greatly improve the overall speed. Mech-Mind provides IPCs with a minimum configuration of I7 8700 + 1050TI. Configuring a higher CPU and GPU will bring better results.

Tip: 3d_matching_steps mainly consumes CPU resources, while deep learning consumes more GPU resources.

2.7.3 Mech-Viz, Robot

Route Optimization

Robot path optimization mainly refers to the reduction of unnecessary fixed points and unnecessary actions during the movement of the robot. Therefore, the central idea of path optimization is to reduce fixed points and reduce detours.

Tip: The main operations include the following:

- Reduce detours, try to reduce redundant intermediate points in a section of motion without collision, and ensure the smooth operation of the robot.

- Reduce fixed points, in order to ensure robot movement in the early stage.

- Reduce rotation. During the robot's grasping process, the fixture may rotate more than 180°. Through the control of vision engineering and the adjustment of symmetry, this kind of situation can be reduced. Using relative_move at the same time can directly avoid excessive rotation.

- move_parameters, adding no waiting to the steps of most sports can improve the fluency of the robot and reduce pauses.

- To improve the smoothness of the robot's motion trajectory, the turning radius function can also be used appropriately and reasonably to avoid fixed points on the robot's walking line. At the same time, use more joint motions, reduce the use of longer linear motions, and reduce the possibility of the robot moving to singular points. When necessary, use multi-segment joint motions instead of long-distance linear motions to prevent uncontrollable motion states at long distances. For the setting of turning radius and movement type, please refer to BasicMoveInfo

- Avoid singularities. According to the design of Mech-Viz software, when the robot is about to cross the singularity, the robot will slow down appropriately to prevent the robot from reporting errors. Similarly, in the process of workpiece grasping, the robot should try to avoid moving to the vicinity of the singular point to prevent error stop or slow running caused by the singular point. For parameter settings, see RunTime Config

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Speed of Robot

When the robot's workflow is determined, and it can work slowly and stably, the speed of the robot can be gradually increased to the highest speed. The increase on the speed can greatly improve the takt time.

Tip: The speed of each move of robot can be adjusted directly in Mech-Viz.

Speed of movement module in Mech-Viz

When using Mech-Viz for movement tasks, the default BasicMoveInfo is that the acceleration is 50% and the speed is 100%. When the route optimization is completed, the speed and acceleration for each module can be adjusted respectively to achieve control of the speed and acceleration on the robot in different situations.

Tip: When the robot is not grasping the workpiece, the speed and acceleration can be gradually adjusted to the maximum allowable value.
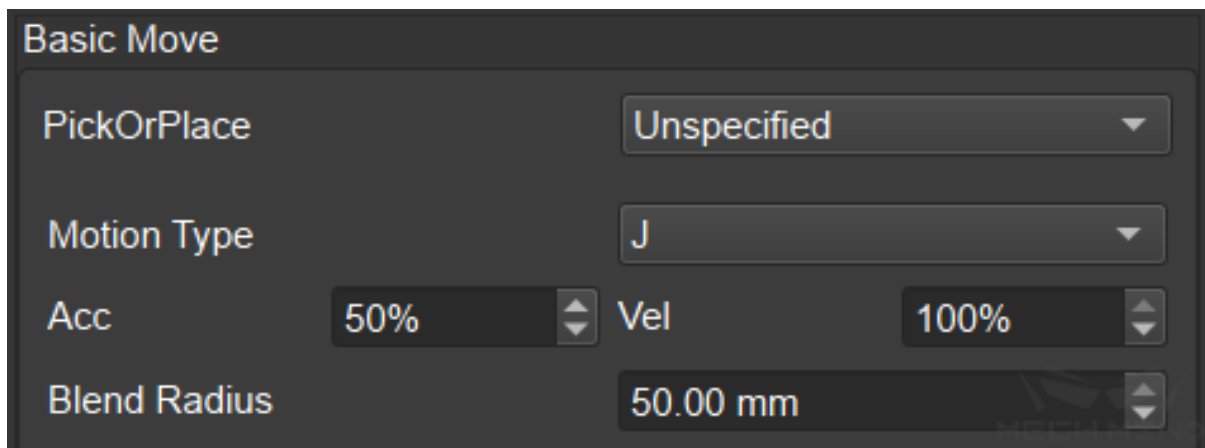

Figure 14 Move speed control in Mech-Viz

Speed of Movement Tasks

When the Mech-Viz software uses movement tasks, BasicMoveInfo defaults to acceleration 50% and speed 100%. After the path optimization is completed, the speed and acceleration of each module can be adjusted separately, and the speed and acceleration of the robot can be controlled under different conditions.
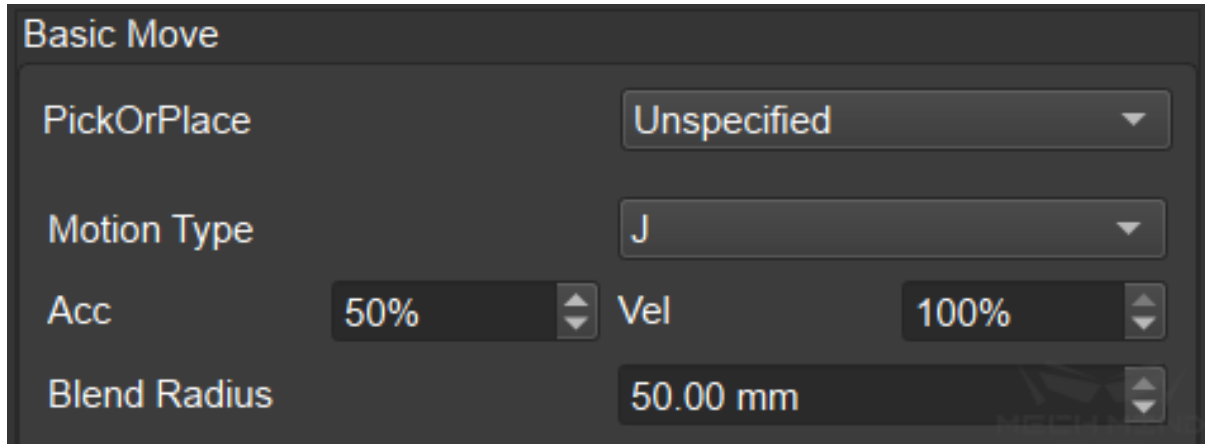

Figure 15 Movement speed control in Mech-Viz

Shooting Process and Timing

In Mech-Viz, visual_look can be used to trigger shooting and the visual data will be processed and outputted via Mech-Vision, the processed results will be used in visual_move to control the robot to move to the specified position. The process for processing the data can run in the background, that is, during the move of the robot, it will process the obtained new data and be ready for the next grasping.

Tip:

- In Mech-Viz, visual_look can be used to trigger shooting and the visual data will be processed and outputted via Mech-Vision, the processed results will be used in visual_move to control the robot to move to the specified position. The process for processing the data can run in the background, that is, during the move of the robot, it will process the obtained new data and be ready for the next grasping.

- In Eye in Hand mode, after the robot grasping the workpiece, the camera can directly take a picture, and perform data processing in the background. When the first workpiece is placed by the robot, it can directly grasp the second workpiece.

Hint:

- In some projects about depalletizing cartons, when ensuring that other boxes will not change after each grasping, the solution of one shot and multiple grasping can be used. Mech-Vision can recognize multiple objects at one time and provide all poses during each recognition process. Therefore, just with one-time recognition, the robot grasps all the recognized cartons and re-shoot after grasping, which can save a lot of camera time.

- Similarly, if the end effector is large enough, you can control the robot to grasp multiple box in different position at one time to improve the takt time of grasping.

2.8 How to build a Demo

2.8.1 The Function of Demo

The following picture shows a common Demo used in the laboratory, which is a combination of a small robot and a camera. Using this Demo can perform simple functions such as **pre-project testing**, **display unit construction**, **training of software**, **data collection**, etc., in the laboratory.
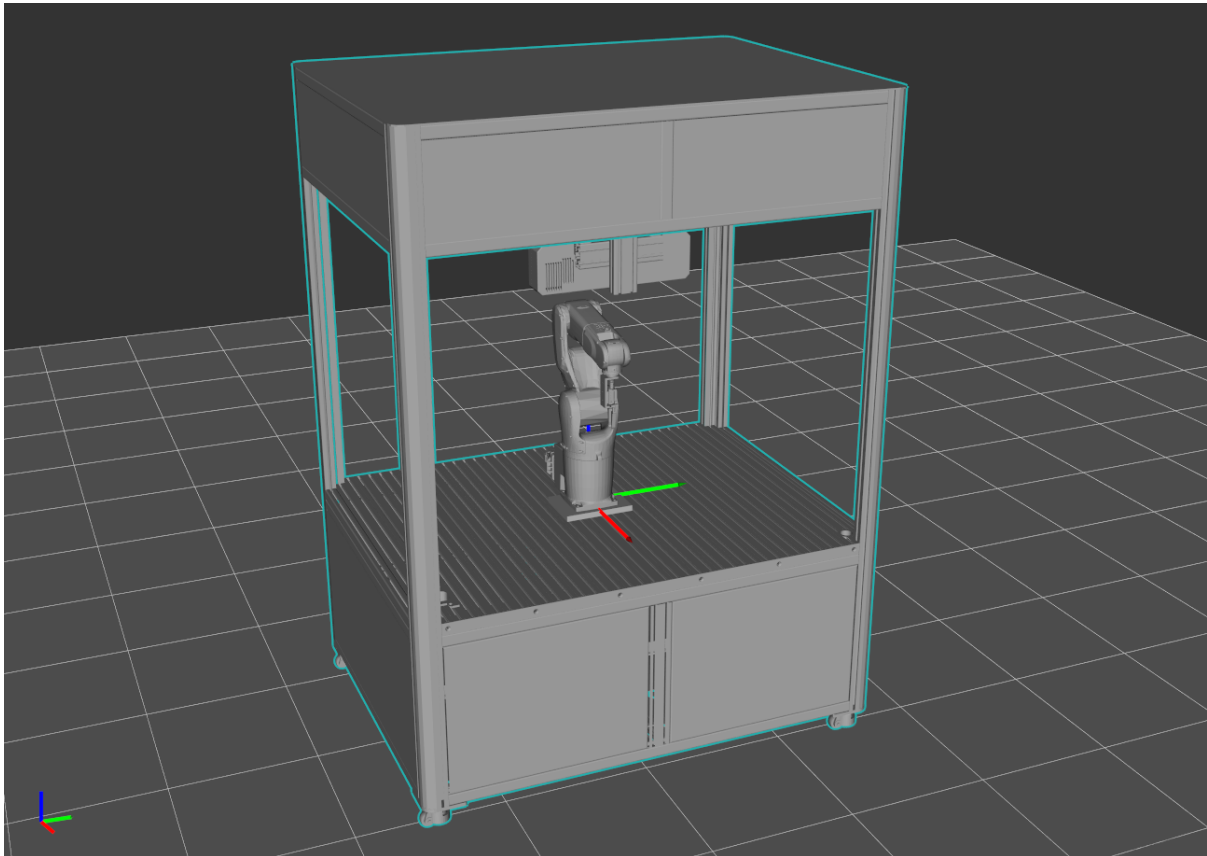

Figure 1 Demo

The Demo supports layouts for a maximum of three boxes (Figure 2), and three cameras are placed at the same time (Figure 3). The surface light source or bar light source can be installed on the top of Demo to meet different project requirements.
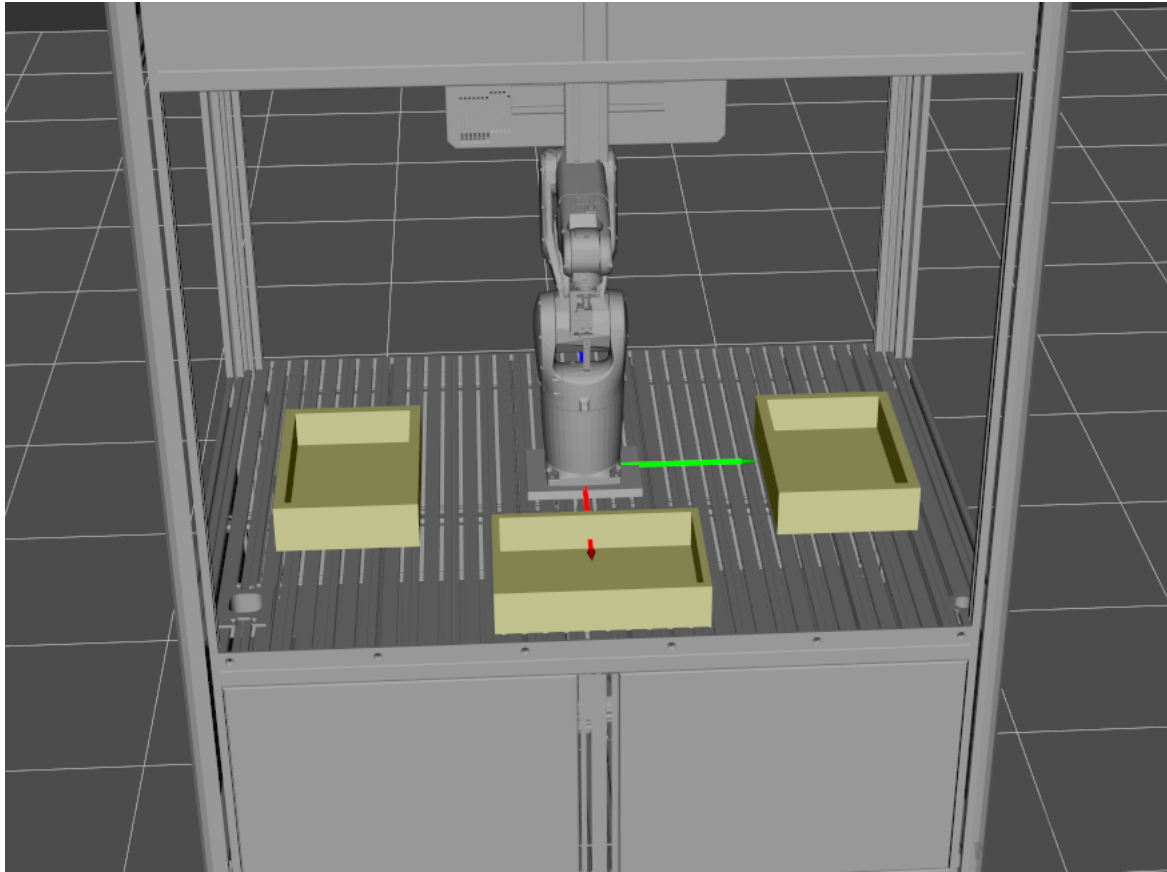
Figure 2 Layout for Demo box
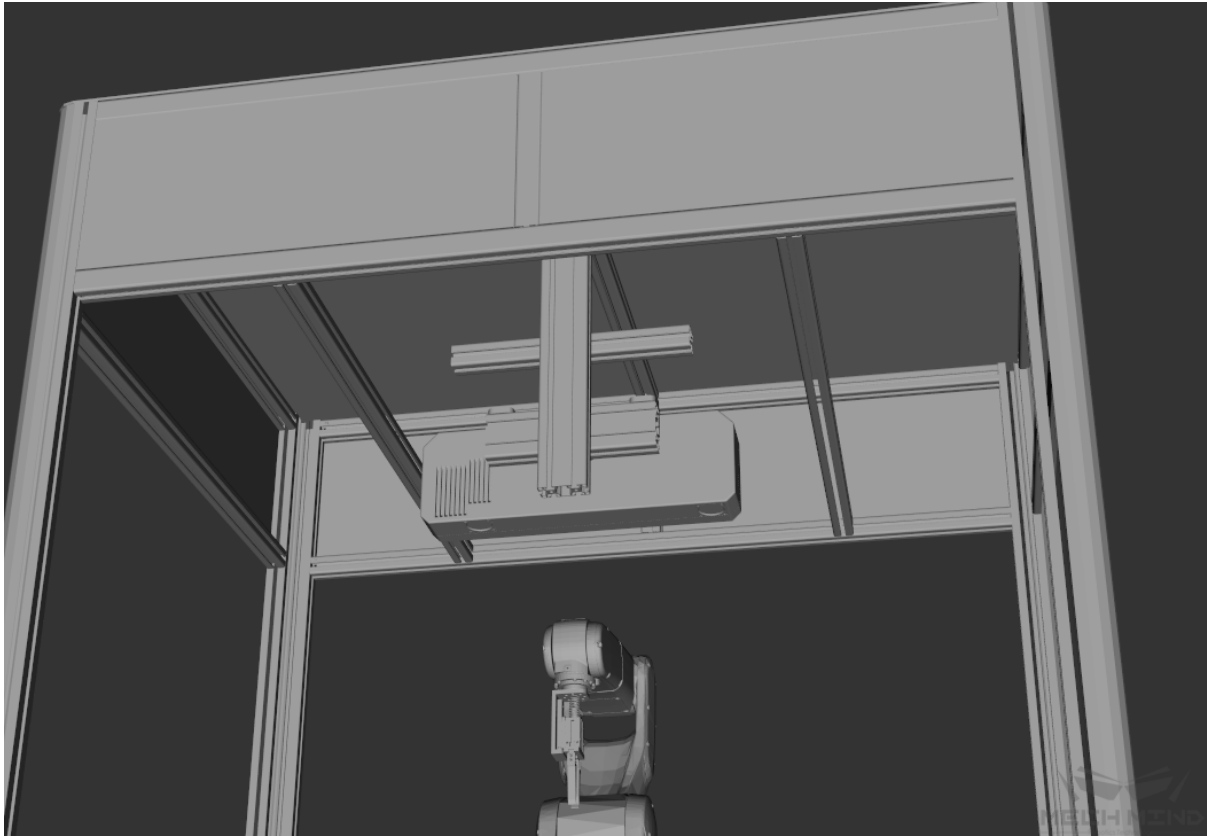
Figure 3 Layout for Demo camera (surface light source or bar light source can be installed on the top)

2.8.2 How to build a Demo

Camera selection

Small Demo usually uses cameras with working distances less than **0.8m**. The available camera models are:

- Mech-Eye Pro M 700C
- Mech-Eye Pro M 700M
- Mech-Eye Pro S 500C
- Mech-Eye Pro S 500M
- Mech-Eye Pro S 700C
- Mech-Eye Pro S 700M

Note: Enhanced series cameras can also be used

Robot selection

Select the commonly used small robots. The adapted robots can be found in Mech-Viz. The available robots are as follows:

- ABB_IRB1200_5_09

- KUKA_KR10_R900_2

- DENSO_VSO_RC8

- UR series

- ...

These robots can be placed in small demos, most of them can take a load of **5-10 Kg** and they can equip small end effector. Similarly, universal end effector, such as pointed needles, single suction cup, can also be designed to grasp simple item and test the accuracy of grasping.

2.9 Summary of Mech-Vision Project Construction of Conventional Matching Scheme

Conventional mactching schems are mainly divided into two categories: Pure matching scheme, deep learning + matching scheme. The difference between the two lies in the way the point cloud area is selected before matching.

- Pure matching scheme' s point cloud area selection depends on point cloud process.

- Deep learning + mactching scheme' s point cloud area selection depends on Mask for deep learning recognition.
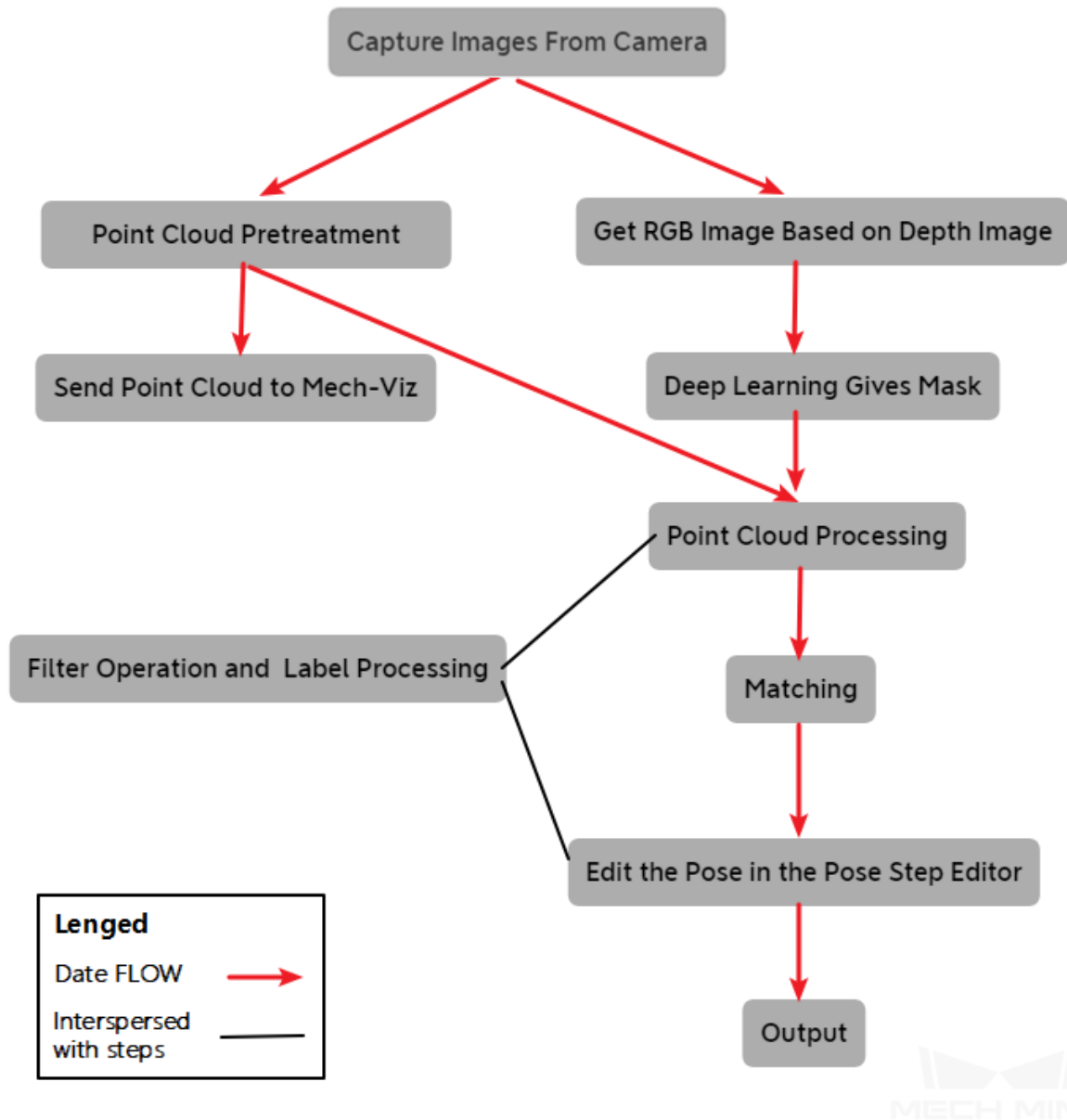
Figure1 Mech-Vision Engineering Structure of Commonly Used Matching Schemes

As shown in *Figure1.* Mech-Vision Engineering Structure of Commonly Used Matching Schemes consists of the following parts.

- capture_images_from_camera : Get camera data. Includes color image and depth image. Choose according to the actual situation or fill in the corresponding camera parameters.

- point_cloud_preprocessing : Make depth images into point cloud and calculate point cloud's normal vector. Extract filtered point cloud in ROI.

- send_point_cloud_to_external_service : The point cloud (XYZ-RGB) converted into the depth image is transferred to the Mech-Viz software for visualization.

- application_get_rgb : Acquire RGB images according to the highest layer in the ROI of the depth image, and remove interference from other regions for subsequent deep learning recognition.

- Deep learning recognition gives Mask: detects and recognizes the target object in the input image, and gives the precise position of the target object in the image (Mask), refer to application_intance_segmentation.

- application_filter, label processing: application_filter performs on-demand filtering of point clouds, poses, labels, etc. Label processing includes design process label usage, mapping, etc.

- Point cloud processing: processing and optimizing the point cloud, so that the point cloud can meet the matching requirements.

- application_match: Contains four methods: single-template edge template matching, single-template full-template matching, multiple-template edge-template matching, and multiple-template full-template matching, which can be used flexibly for different application scenarios.

- Edit pose in pose_editor : The matched output result cannot be directly sent to Mech-Viz for operation, and some processing is required. Such as coordinate system transformation, pose adjustment and pose sorting, etc. Through pose_editor The user can edit the pose quickly.

- procedure_out : Export the results of Mech-Vision to Mech-Viz.

Attention: The application_get_rgb part should be used according to the actual situation. For example, the model data is trained with cutouts. The surrounding environment interferes with the detection target; in other cases, it can be compared with the deep learning recognition effect without adding application_get_rgb.

PRECAUTIONS

Description of precautions

3.1 Project precautions

3.1.1 Application scenarios of carton grabbing

1. Specify pallet size , consider maximum and minimum values of the length, width, and height of the carton , and whether the end effector can picking carton of different sizes ;

2. Carton color affects the recognition, it is required to confirm the color information of the carton;

3. Color and pattern of the carton tape affect the recognition, and such information is required to be clarified;

4. The strap affects the recognition, especially the cable ties seriously affects the result of recognition. It is necessary to confirm color, position, and quantity of the strap;

5. Whether scanning the code is required for the carton. If so, confirm information like whether single-sided or multi-sided bar code is required, the location of the bar code, and the scanning information, etc.;

6. When obtaining requirements in the early stage, confirm whether bar code orientation of the carton need to be considered when palletizing, which will affect symmetry design of the end effector, offset, pipeline layout, and whether the robot operation space is sufficient, etc. ;

7. Check if there is the square carton , it may affect the final recognition results;

8. **It is recommended to pay more attention to the factors affecting recognition, test as much as possible during debug to improve the stability of subsequent production**.

3.1.2 Application scenarios of feeding

1. Confirm the color of the workpiece, whether it is pure black or highly reflective workpiece , whether the point cloud when testing is complete, and whether dual camera is required to solve it;

2. Confirm the type of workpiece, whether there is mixed feeding materials ;

3. Confirm the placing direction of the workpiece, whether it is placed in the same direction or opposite to each other, or placed disorderly;

4. Confirm the upstream and downstream processes, whether the workpiece grasped by the robot is placed on the conveyor belt or on the fixed placement table , and whether the placement accuracy is required;

5. Specify the size of the box, so as to create collision model during debug to avoid the problem of end effector and box collision ;

6. Note whether there is baffle between each layer of the workpiece. If so, it is necessary to confirm whether human intervention or vision guide is applied to make sure the fluent picking process.

3.1.3 Application scenarios of gluing

1. Comfirm the color, specification, type of the workpiece to be glued, whether there is transparent, pure black, highly reflective workpiece;

2. Determine the process for gluing . At present, there are two ways for the glue application. One is extract the gluing trajectory in advance . During the process, the template is called according to current workpiece type. It is suitable for the scenario with complex glue trajectory and high requirements. The other one is that generate trajectory in real-time after detecting , which is suitable for the scenario where the glue trajectory is simple;

3. Comfirm upstream and downstream processes , whether there is other signal input and output;

4. Comfirm whether the customer has special requirements on glue type;

5. Understand the working principle of the gluing machine, and determine how the vision and the gluing machine cooperate;

6. For projects that have a clear requirment: robot controled by Mech-Viz and use templates(3D matching), gluing software can be provided to cooperate with gluing debug;

7. **For gluing scenes, due to the complicated technology, the process is required to be well communicated to determine the visual solution, and the vision work scope should be comfirmed**.

3.1.4 Application scenarios of assembly

1. Comfirm the color, specification, type of the workpiece to be assembled, whether there is transparent, pure black, highly reflective workpiece , whether there is mixed feeding;

2. Confirm whether the robot accuracy and end effector accuracy provided on site can meet the assembly requirements;

3. vision accuracy and assembly accuracy are considered separately to facilitate troubleshooting in subsequent implementation processes;

4. Comfirm the assembly process, whether the camera moves with the workpiece to be assembled (that is shooting during the move) . To confirm whether the stability and takt time for vision are satisfied;

5. **In assembly scenarios, accuracy requirements are the most important consideration. Most assembly procedures require that no collision is allowed during assembly, so the accuracy requirements for translation and rotation are relatively high. More special attention should be paid during the planning.**

Hint: The accuracy includes translation accuracy and rotation accuracy.

3.2 Others

3.2.1 Takt time

Validate the requirements for takt time, including requirements for takt time on vision detection work cycle .

3.2.2 Accuracy

Validate the requirements for the accuracy, including requirements for accuracy on recognition and grasping.

Communication

1. Determine the control method (robot master control/Mech-Viz master control). Determine the communication method based on the technological process.

2. Confirm whether to use touch screen for the operation and whether it is necessary to communicate with PLC, host computer and so on.

3.2.3 Working environment

Temperature: The recommended temperature for using the camera is 0-45°C.

Humidity: Specify the on-site humidity level according to the hardware working environment.

Dust: Specify the on-site dust level according to the hardware working environment.

Illumination: Perform appropriate shading or supplemental light based on the actual lighting condition.