

---

# Multi-Robot

DUCO Robots CO., LTD.

Feb 05, 2024



# CONTENTS

<b>1</b>	<b>Introduction to Multi-machine Collaboration</b>	<b>1</b>
1.1	Usage restrictions . . . . .	1
1.2	functional terms . . . . .	2
1.3	Usage restrictions . . . . .	2
<b>2</b>	<b>Multi-machine Collaboration Configuration</b>	<b>5</b>
2.1	Plug-in installation . . . . .	5
2.2	Master and slave robot communication connection . . . . .	7
2.3	Master robot communication configuration . . . . .	9
2.4	Communication configuration from the robot . . . . .	10
2.5	Master and slave calibration . . . . .	12
<b>3</b>	<b>Multi-machine Co-programming</b>	<b>19</b>
3.1	Function description . . . . .	19
3.2	Function restriction . . . . .	19
3.3	multi-machine coroutine . . . . .	20
3.4	Sync program . . . . .	20
3.5	Joint position follow mode . . . . .	23
3.6	Joint velocity following mode . . . . .	24
3.7	Cartesian position following mode . . . . .	25
3.8	Cartesian speed following mode . . . . .	26
3.9	Feature tool follow mode . . . . .	28
<b>4</b>	<b>Application Cases</b>	<b>31</b>
4.1	Synchronous follow application cases . . . . .	31
4.2	Features follow application cases . . . . .	34

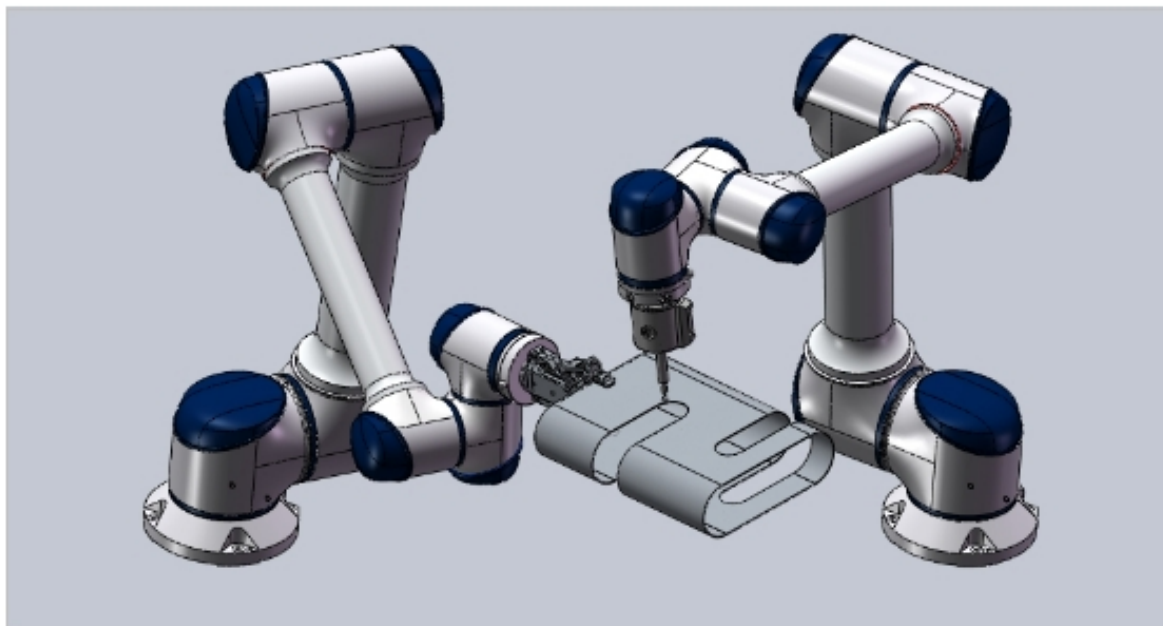


## INTRODUCTION TO MULTI-MACHINE COLLABORATION

### 1.1 Usage restrictions

The multi-machine collaboration function enables two robots to move synchronically with reference to specific modes, such as joint space synchronization, Cartesian space synchronization, master-slave feature following, etc. Using the multi-machine collaboration function, two robots can simultaneously operate the same workpiece in different forms, as shown in the following figure:





### 1.2 functional terms

- Master robot: In multi-machine collaboration, the master robot (also known as the Server side robot) acts as the functional control side and controls the behavior of another or more robots. One master robot can be used to connect to and control another or more robots.
- Slave robot: In the multi-machine collaboration function, the slave robot (also known as the Client robot) acts as the function controlled end and generates relative motion under the control of the master robot during the multi-machine collaborative operation. A slave robot can only be used to connect with and be controlled by another master robot, and cannot be controlled by multiple master robots at the same time.

### 1.3 Usage restrictions

When users choose to use the multi-machine collaboration function, they need to pay attention to the following restrictions:

Robot using multi-machine collaboration need to have MultiMachine plugin packages properly installed and enabled at the same time, with a software version of V2.7.0 and above.

- Before using the master-slave feature following mode of the multi-machine collaboration function, the user needs to confirm that the end tools of the master-slave robot used for the multi-machine collaboration function intersect in the workspace to meet the calibration requirements of the installation posture relationship of the master-slave robot.
- Before using the multi-machine collaboration function, the user needs to confirm that the master-slave robot used for the multi-machine collaboration function can directly pass the network cable connector control cabinet, and try to avoid communication connection through intermediate routes and other links, so as to avoid the final performance decline caused by real-time communication delay;

- Before executing the multi-machine cooperative motion script, the user must correctly calibrate the relationship between the master and slave robots' configuration and relative installation pose, and confirm the communication connection and configuration parameters are effective; otherwise, the script operation effect will be affected, resulting in job risks.
- After the user writes the multi-machine cooperative motion script, since the movement of the slave robot will be directly controlled by the master robot, it is necessary to evaluate whether there is interference in the working space of the slave robot before running the script, so as to avoid the possibility of collision between the robot and external people and objects or the master robot during the movement process.

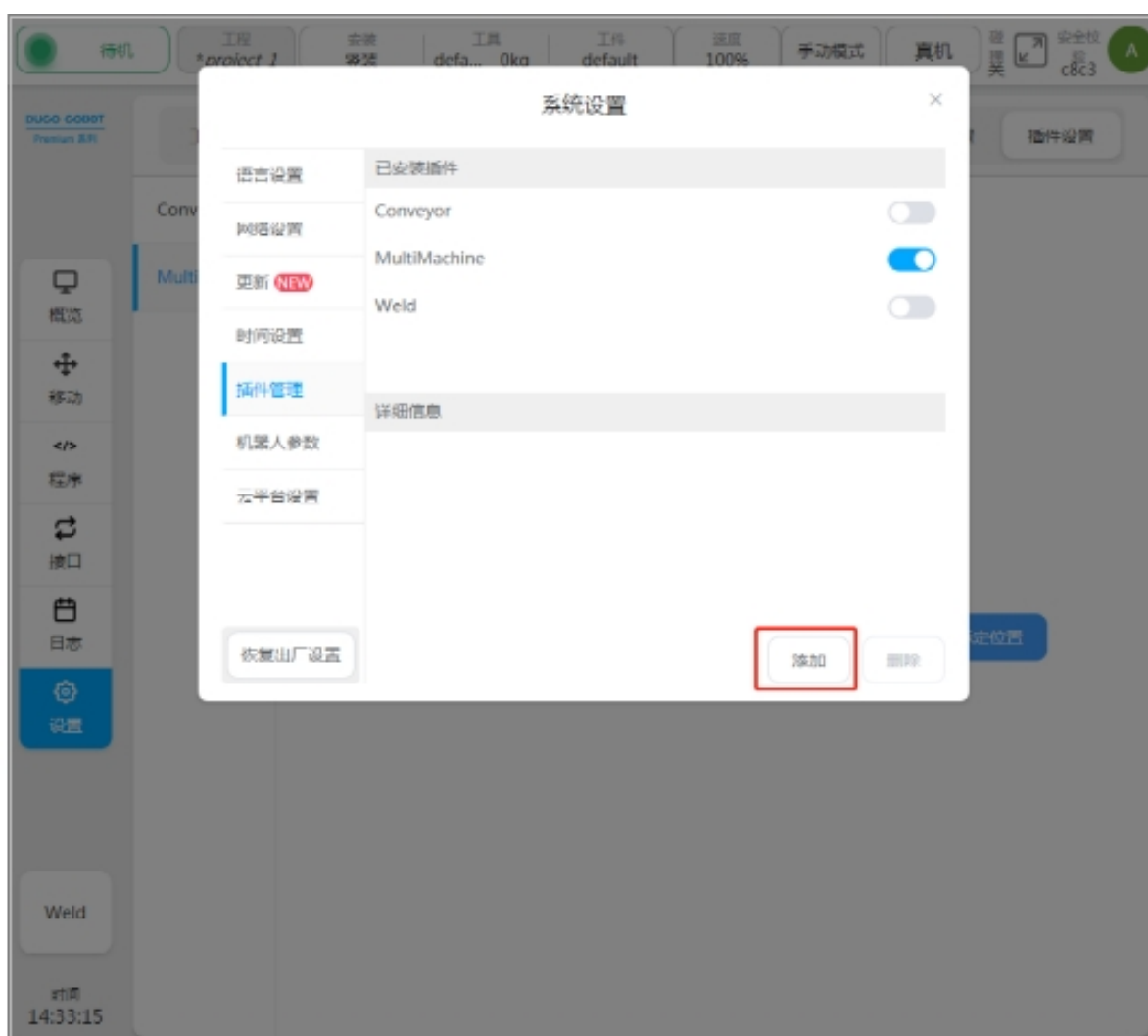


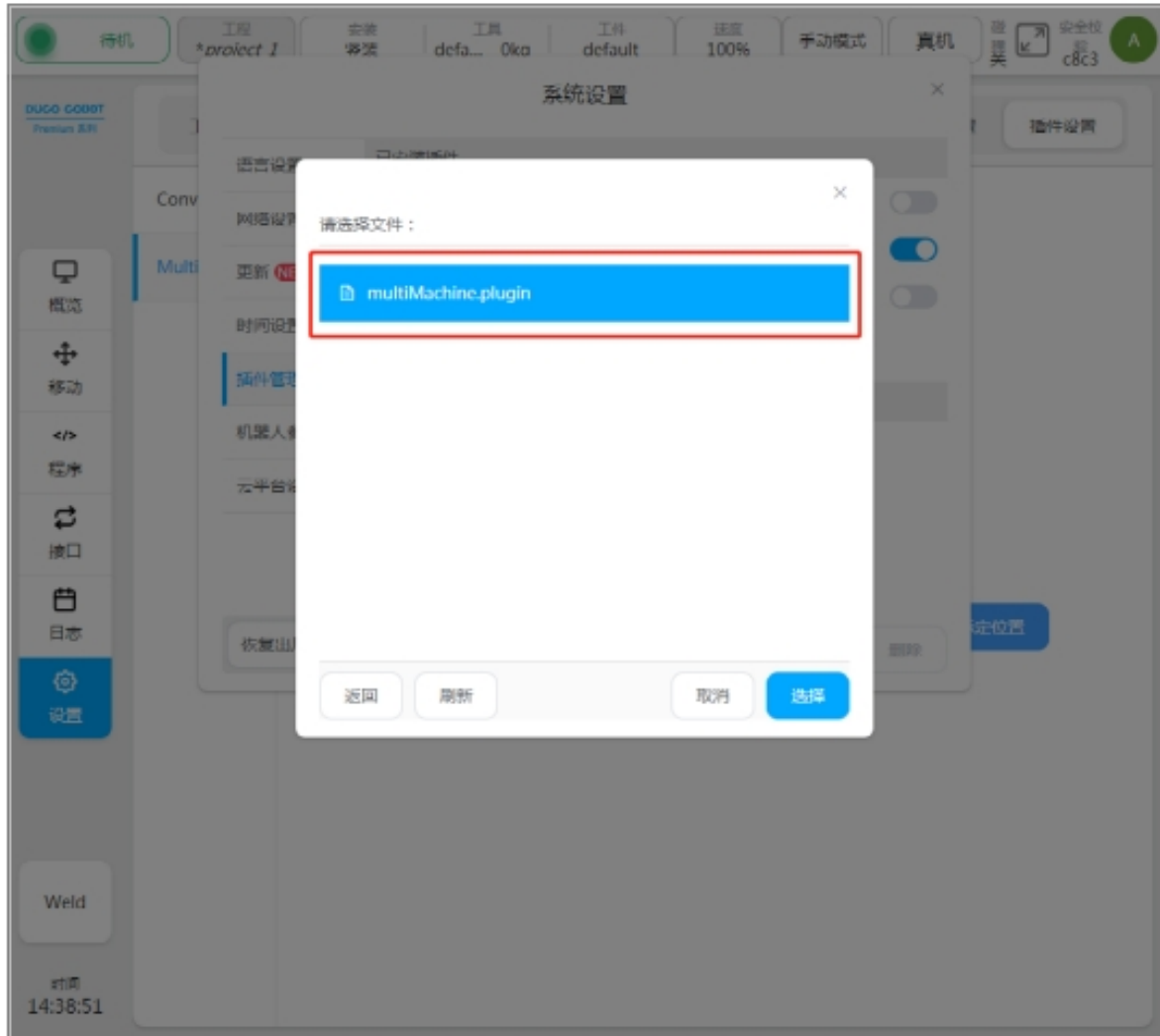


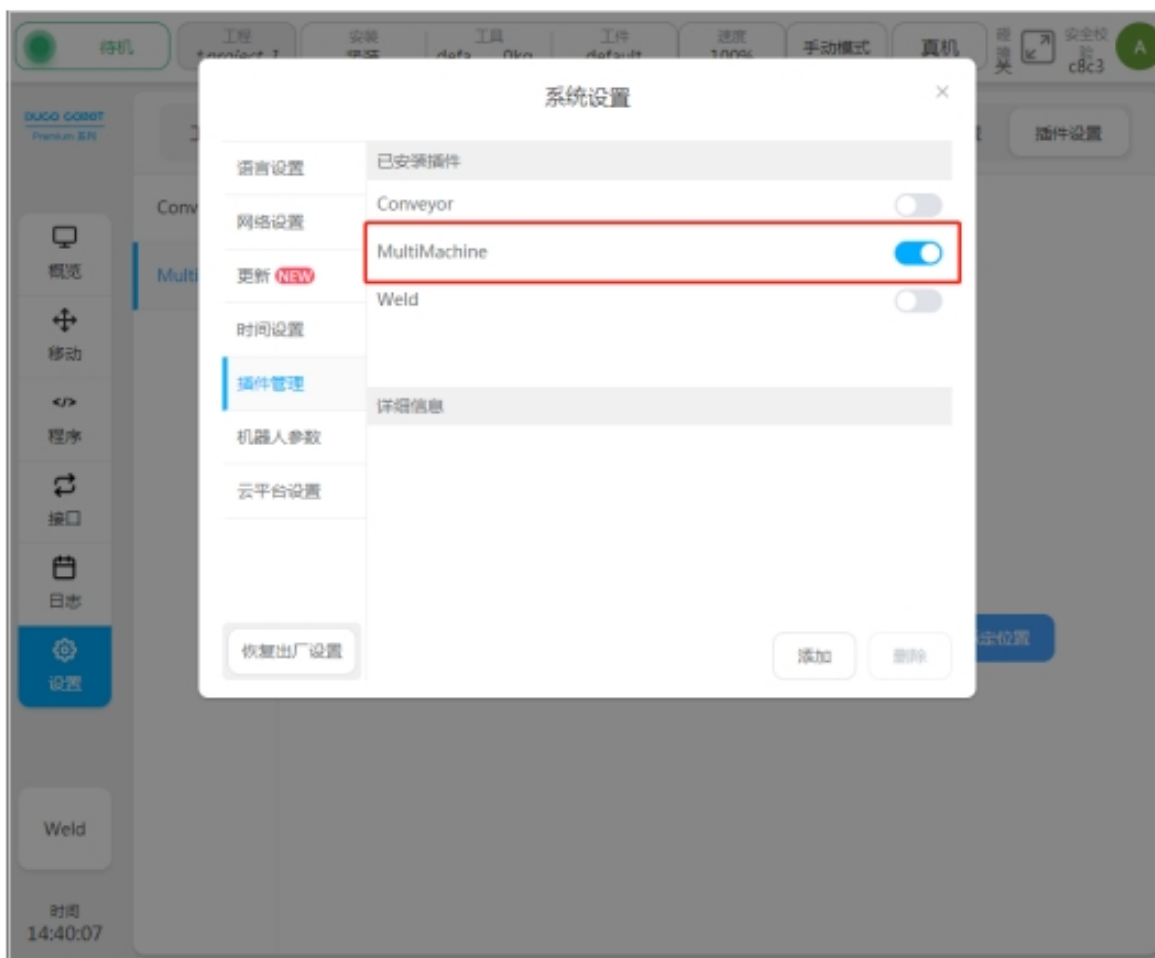
## MULTI-MACHINE COLLABORATION CONFIGURATION

### 2.1 Plug-in installation

Users need to properly install MultiMachine plug-ins before using multi-machine collaboration. As shown in the picture below:







## 2.2 Master and slave robot communication connection

The user must correctly connect the LAN ports on the master and slave robot control cabinets through network cables, and change the IP addresses of the corresponding LAN ports on the controller to the same network segment to ensure that the conditions for establishing TCP/IP communication between the master and slave controllers are met, as shown in the following figure: Master robot LAN port IP configuration:



IP configuration from the robot LAN port:



Note that the LAN interface corresponding to the connection between the master and slave robot cannot be configured with the same IP address; otherwise, IP address conflicts may occur and the communication cannot be normal. In addition, the LAN interface between the master and slave robot control cabinets should be directly connected by network cables as much as possible, and the connection by routing and other methods may lead to the reduction of communication quality and affect the use of the final multi-machine collaboration function.

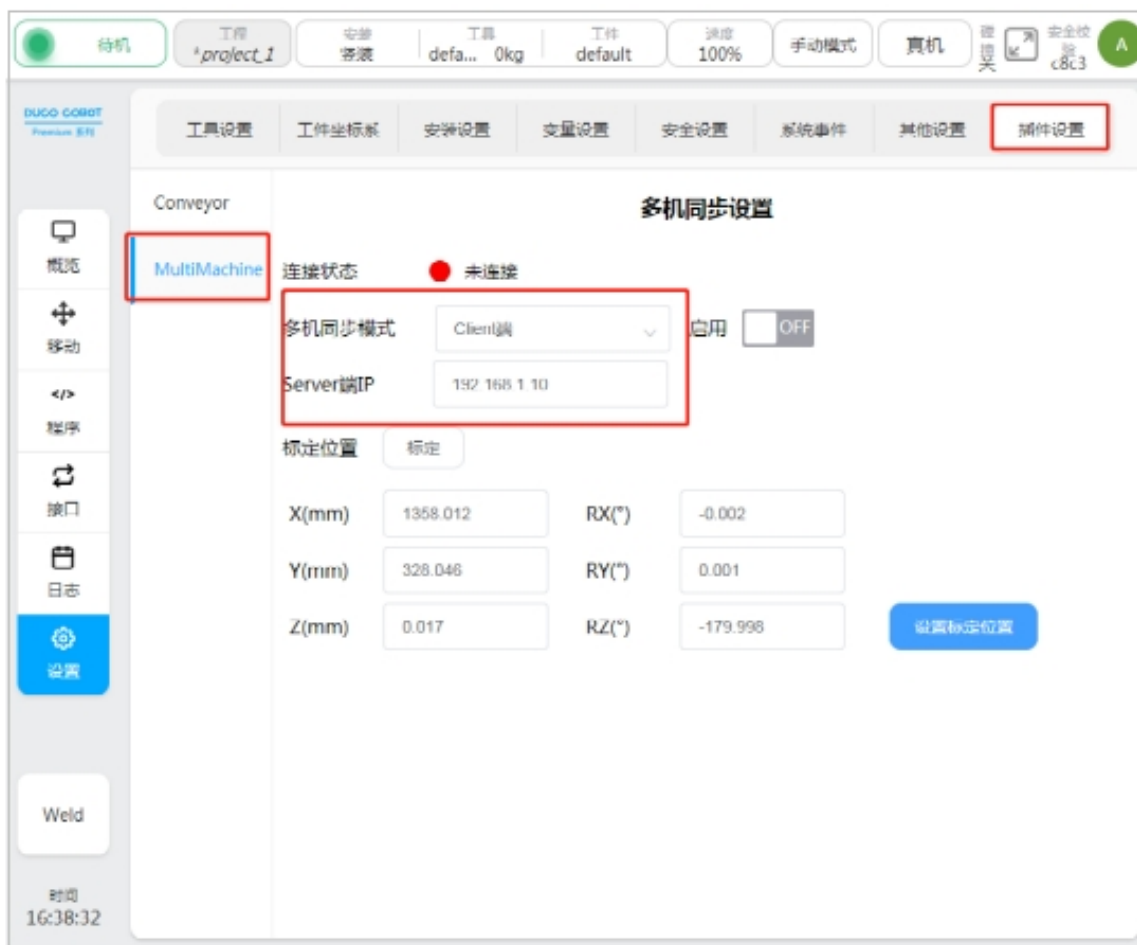
## 2.3 Master robot communication configuration

The user needs to determine and configure the robot as the main control end during the use of the multi-machine collaboration function, as shown in the following figure:

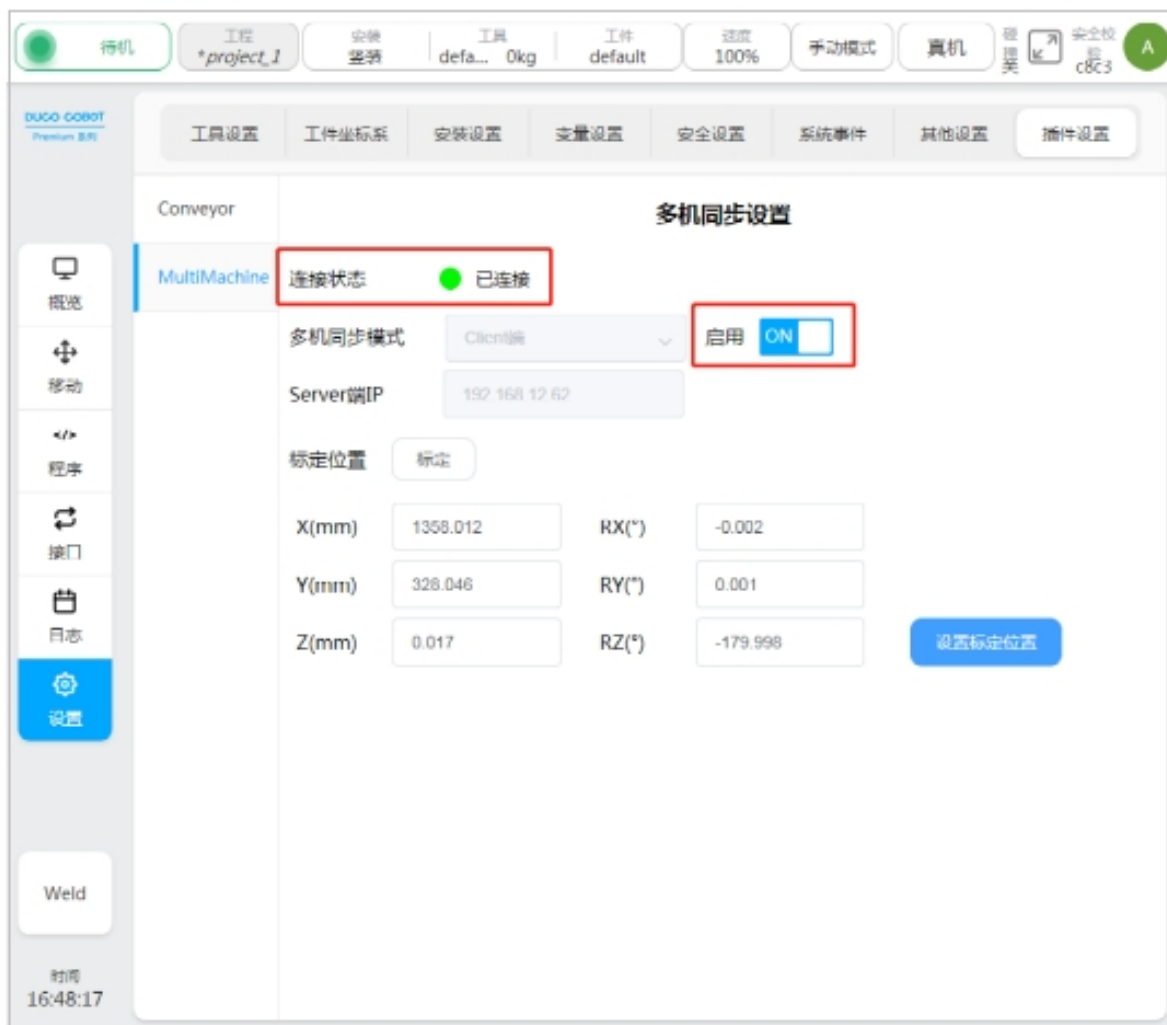


### 2.4 Communication configuration from the robot

The user needs to determine the robot as the slave controlled end during the use of the multi-machine collaboration function and configure it, as shown in the following figure:



It should be noted that the slave robot needs to correctly configure the IP address of the LAN port of the master robot corresponding to the connected control end, so as to realize the communication between the master and slave. After the slave robot is correctly configured, the multi-machine collaboration function of the slave robot can be enabled to confirm whether the communication is correctly connected, as shown in the following figure:

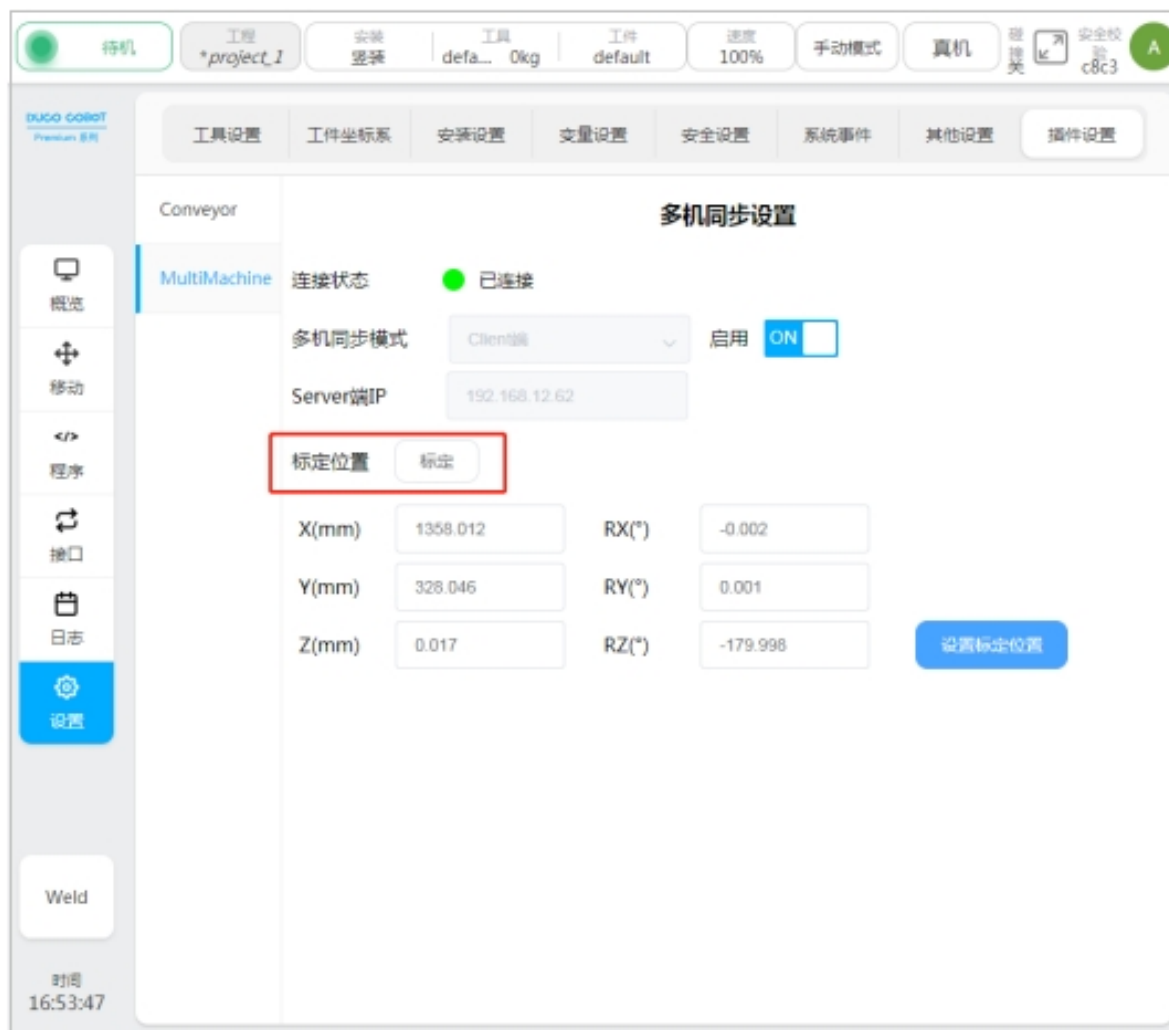


For slave robot, if communication is normal, the connection status indicator will light up.

## 2.5 Master and slave calibration

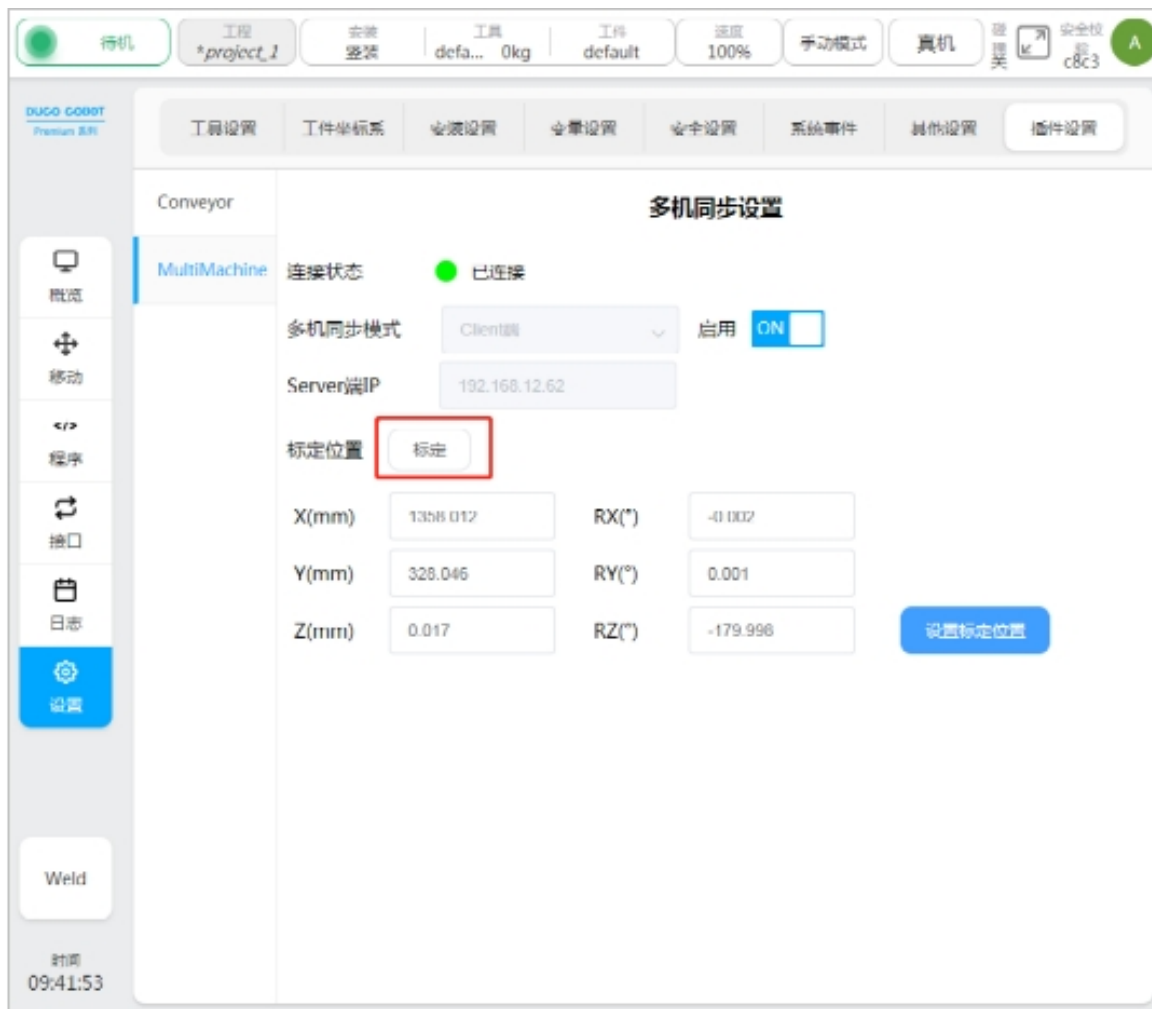
After completing the communication configuration of the master-slave robot and confirming that the connection has been established normally, the multi-machine collaboration function can be used only after the master-slave installation position and pose relationship of the slave robot are calibrated. As shown in the picture below:

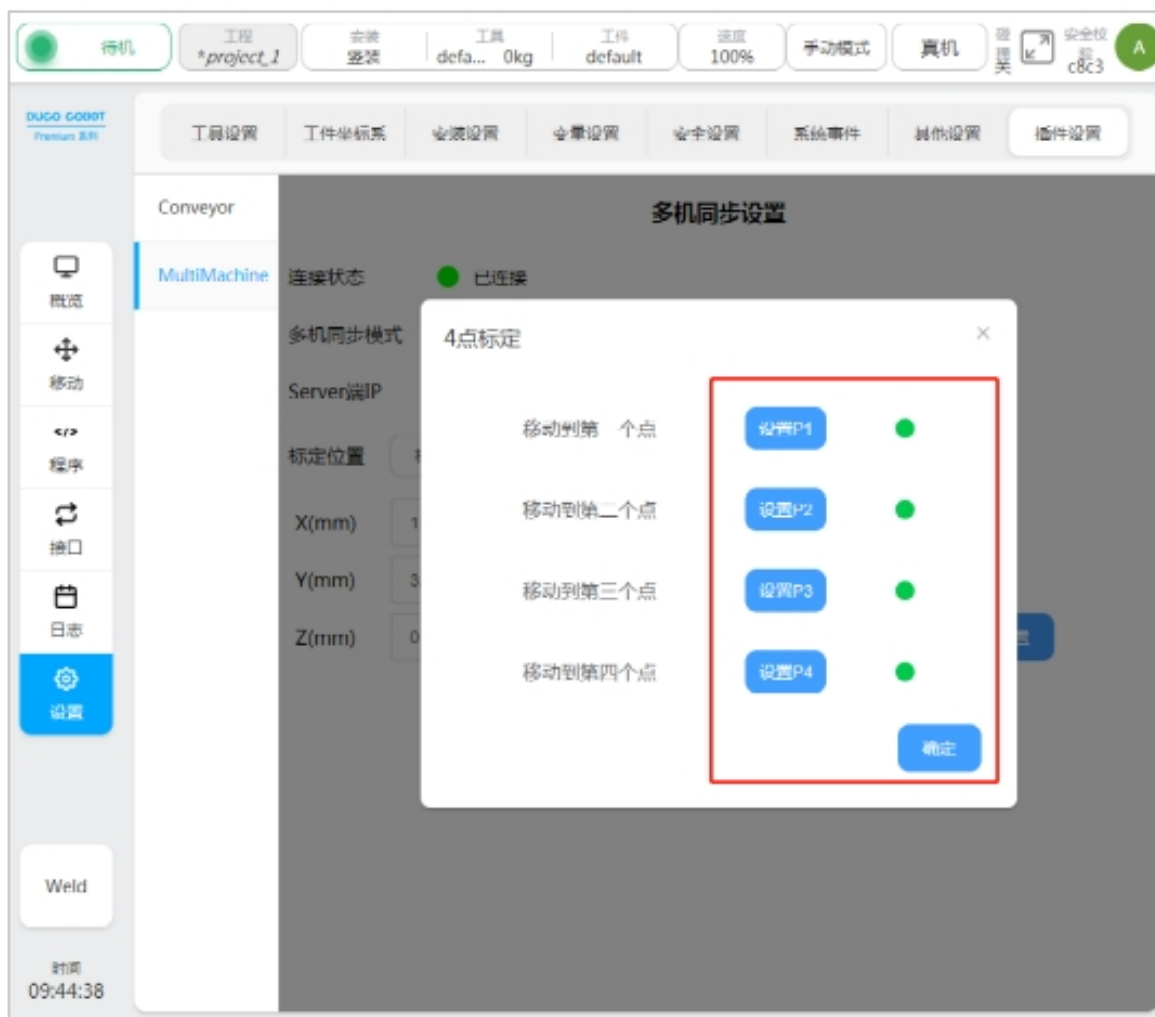




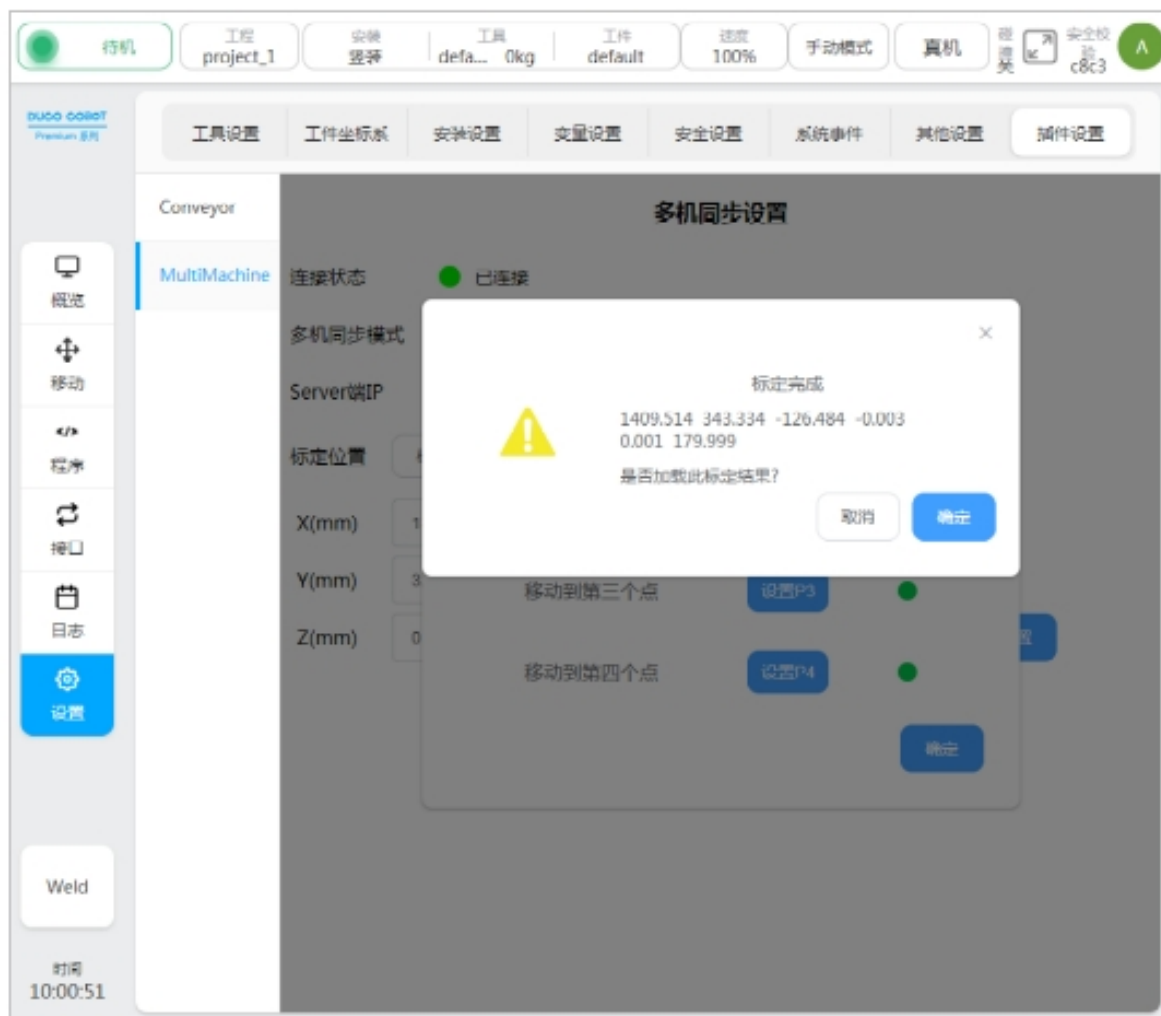
In the calibration process, the robot tool needs to be switched to the current tool, and the tool center of the master and slave robot needs to be moved to the same point in space respectively, and recorded. After repeating the above process 4 times, the calibration of the relative installation pose relationship between the current master and slave robot can be completed. As shown in the picture below:

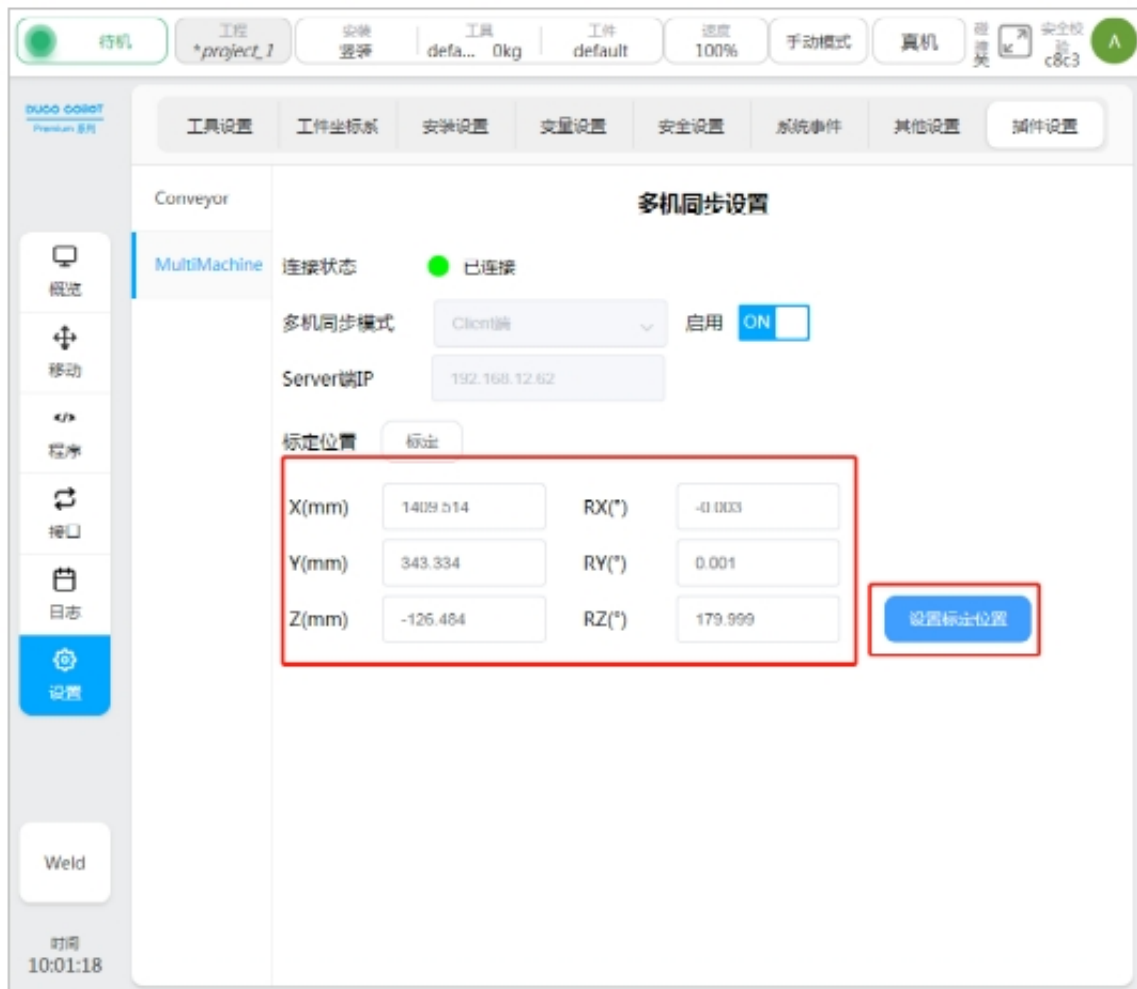
Illustration: (master and slave robot tools move to the same point in space)





After confirming the successful configuration of the calibration point of the master-slave relationship for four times, click OK to obtain the description relationship between the base coordinate system of the slave robot and the base coordinate system of the master robot, and fill the results into the configuration parameters to take effect. As shown in the picture below:







## MULTI-MACHINE CO-PROGRAMMING

### 3.1 Function description

The user chooses to use the multi-machine cooperative programming function, which can realize the master robot to control the slave robot, so that the slave robot can reference the multi-machine cooperative mode set by the user to reference the master robot's motion state to synchronize the movement, so as to realize the scene requirements of the master and slave robot to work on the same workpiece.

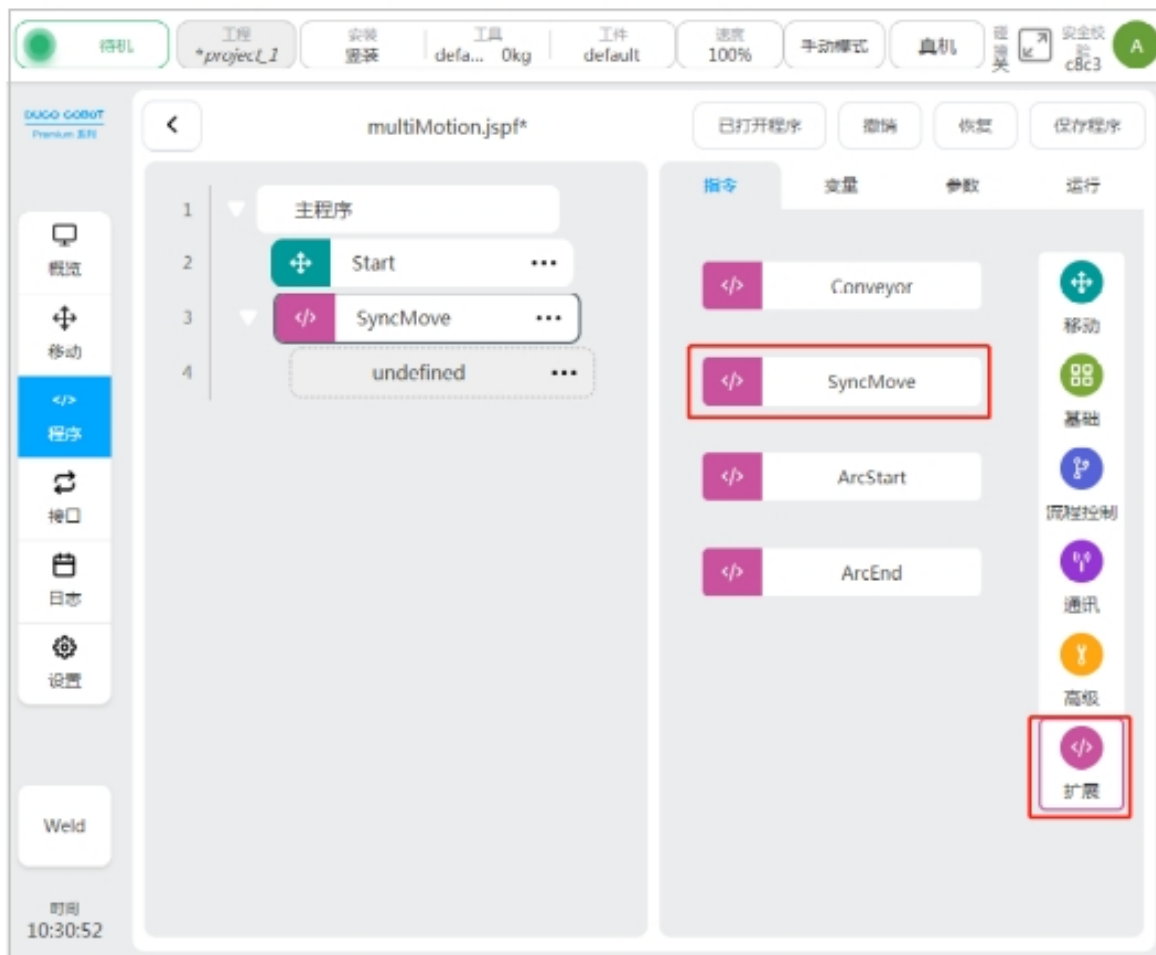
### 3.2 Function restriction

When using the multi-machine co-programming function, users need to pay attention to the following limitations:

- To use this function, it is necessary to ensure that the master and slave robots have established a stable communication connection.
- To use this function, ensure that the master and slave robots have correctly configured their own multi-machine collaboration configuration parameters.

### 3.3 multi-machine coroutine

When the user chooses to use the multi-machine co-programming function, the multi-machine co-program can be added in the robot programming interface - extension, as shown in the following figure:



Multimachine coroutines include:

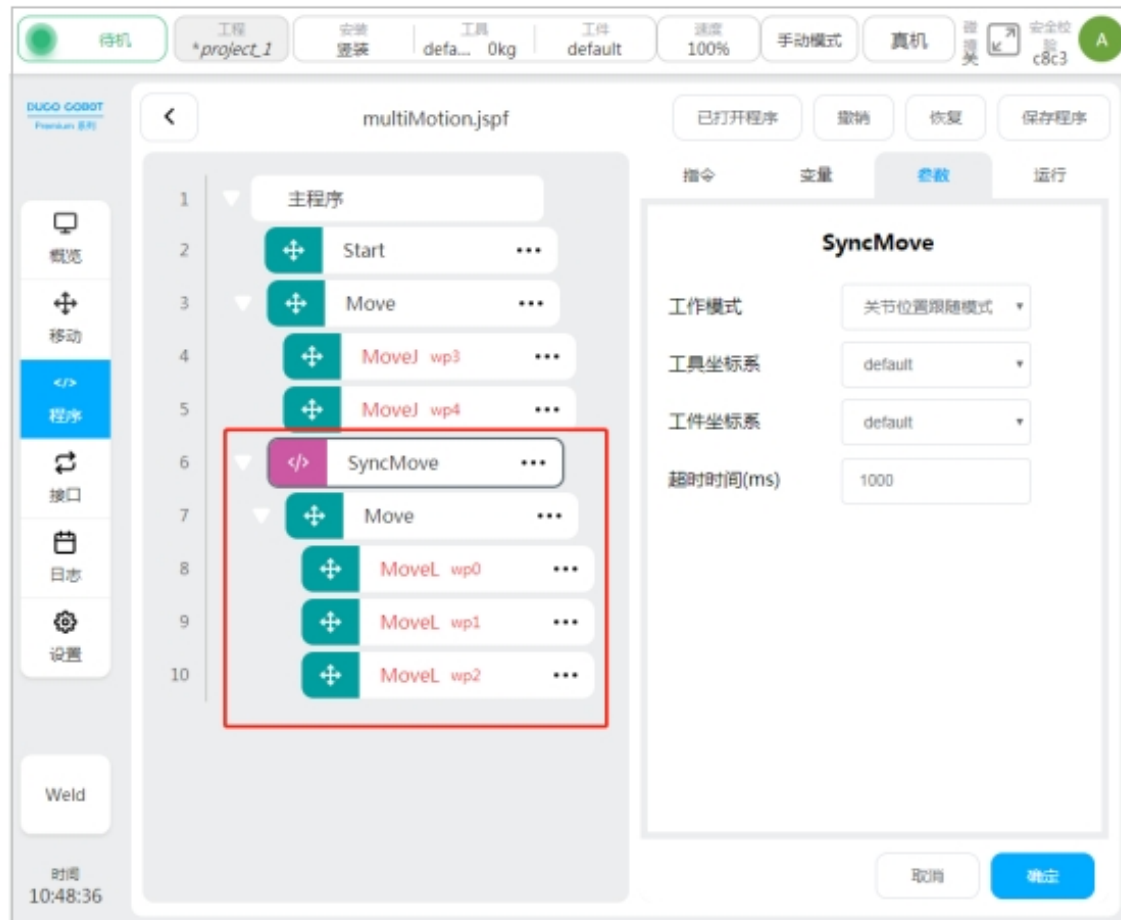
- SyncMove program

### 3.4 Sync program

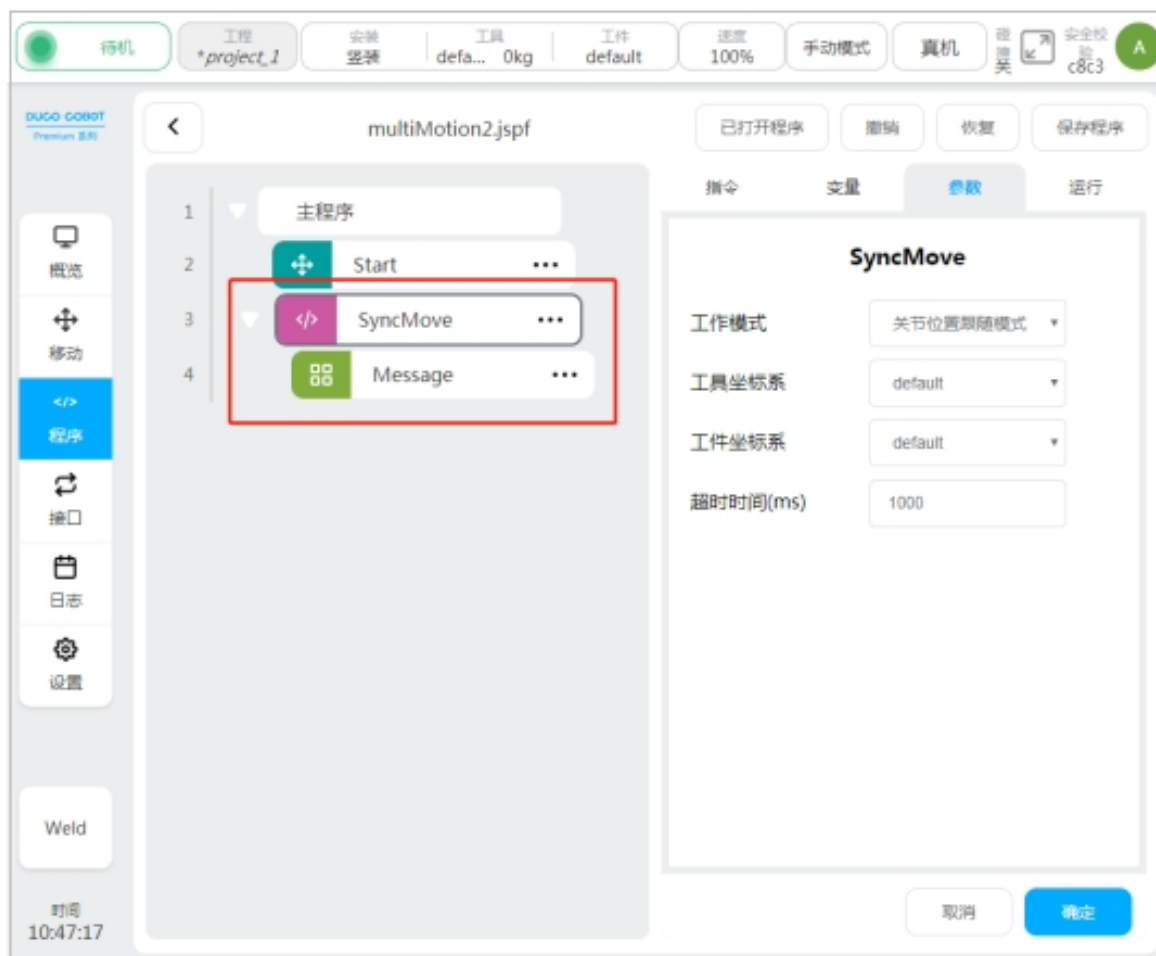
Users can choose to use Sync program to make the master and slave robot work in multi-machine cooperative mode respectively.

The master robot is shown in the picture below:



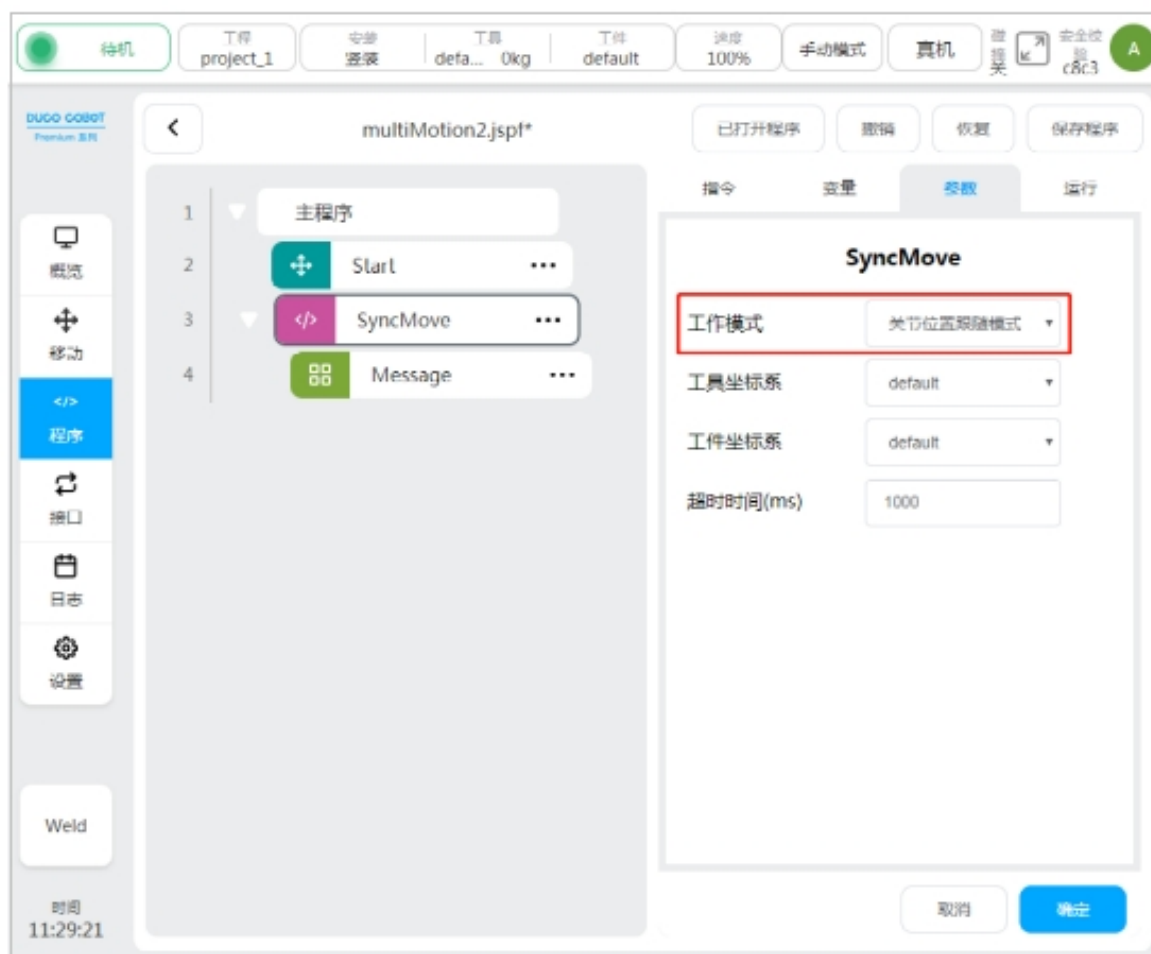


The slave robot is shown below:



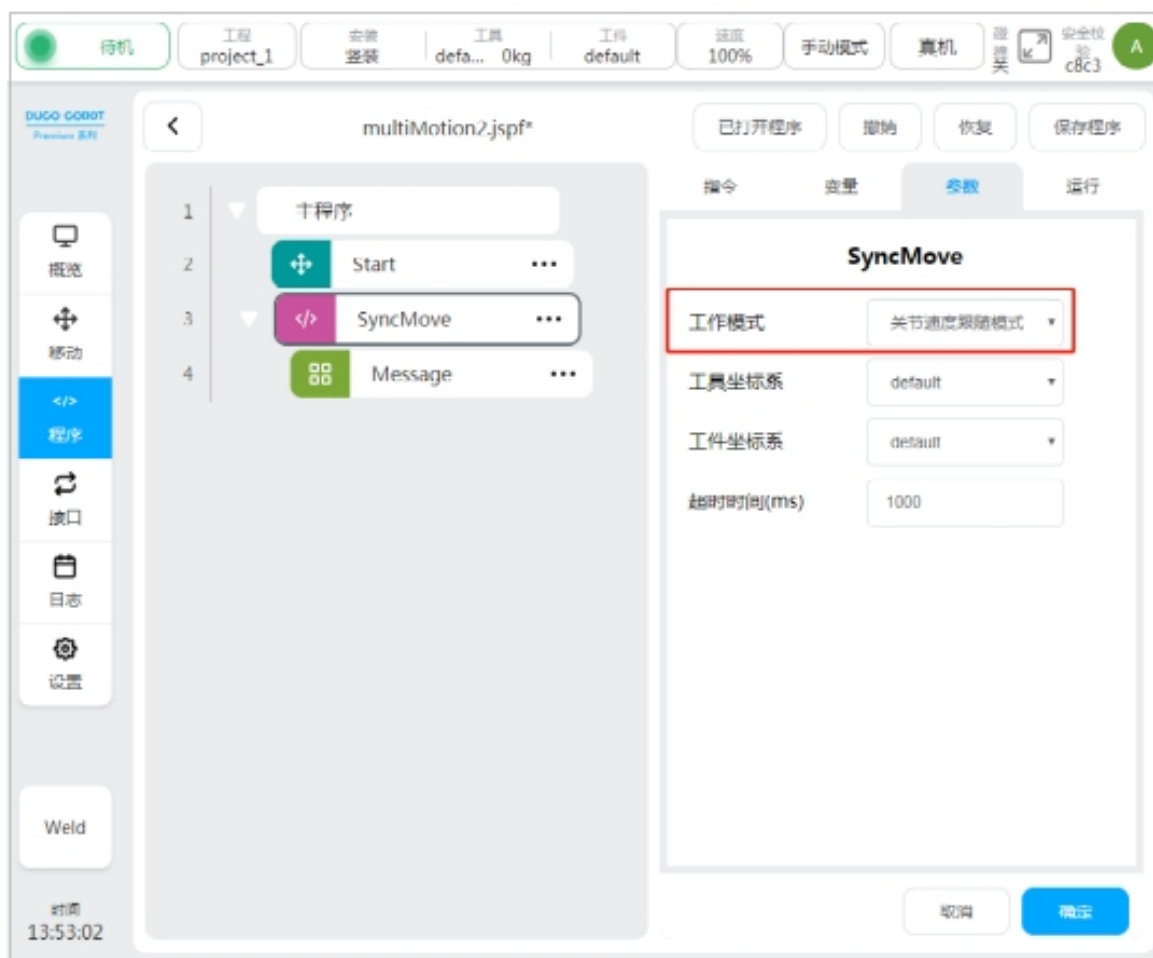
When the user chooses to use the SyncMove program, if and only if the master-slave robot program runs to the SyncMove program at the same time, the master-slave robot sends a synchronization signal to the other party and starts executing the subnode program under the root node of the SyncMove program. If either of the master and slave robot does not detect the synchronization signal of the other robot within the timeout period, it is considered that the synchronization of the multi-machine collaboration function fails and an error is reported.

### 3.5 Joint position follow mode



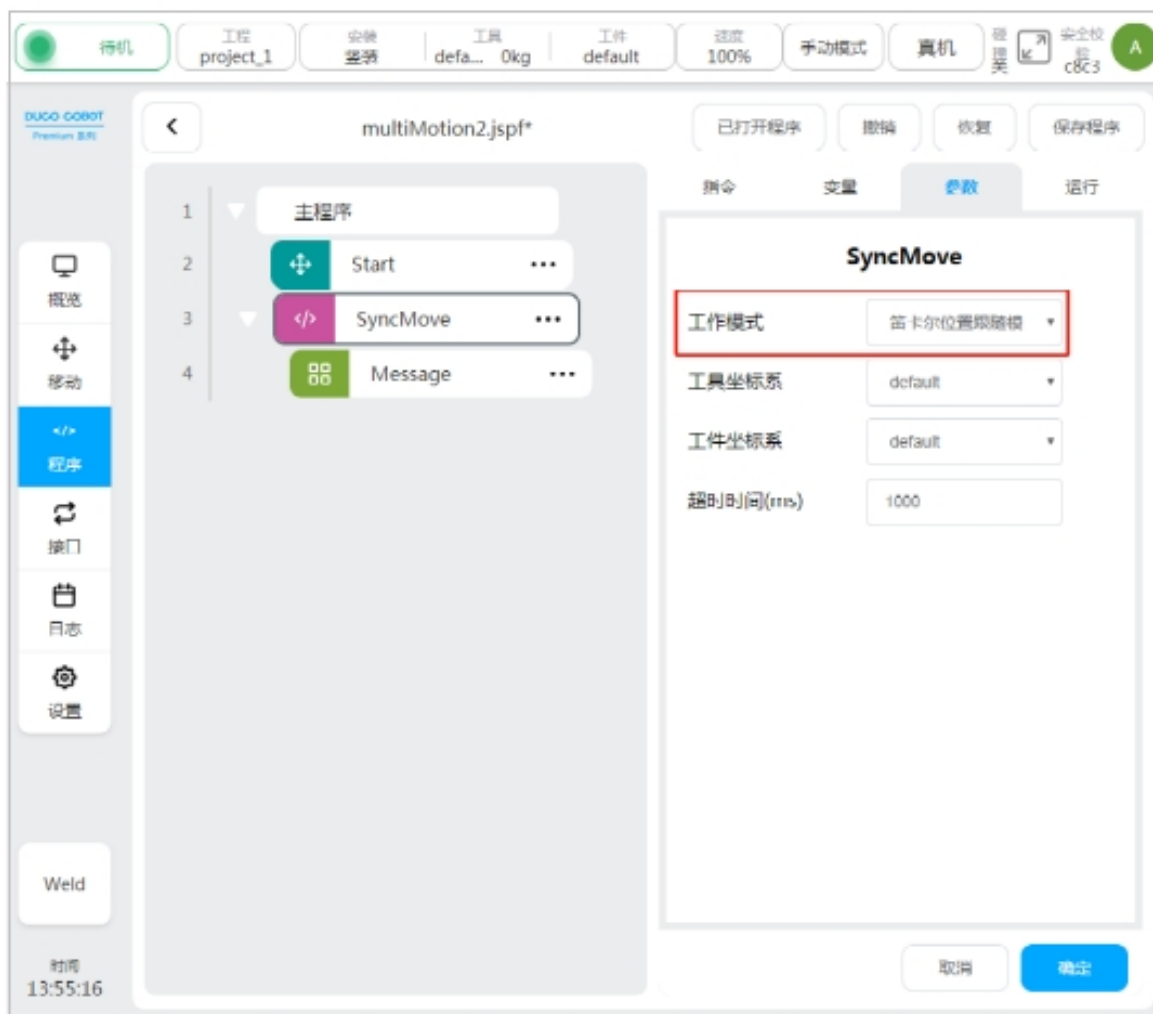
When the user uses the SyncMove program and configures the working mode as the joint position following mode, the slave robot will carry out synchronous joint space position movements according to the movements under the root node of the master robot SyncMove program, and strictly ensure the same joint space position instructions. It should be noted that when the master and slave robots execute the SyncMove program at the same time, if the current joint position is different, the slave robot will automatically move the robot joint to the same position as the master robot joint in the form of Movej, and then synchronize the joint position with the master robot from this position. In the process of synchronous movement, the master robot will execute all the scripts under the root node of the SyncMove program, and the slave robot will keep running the SyncMove program until all the programs under the root node of the master robot SyncMove program are finished, and the master and slave robots will send the end synchronization signal to each other. The two parties confirm that the follow-up procedure will be carried out after the synchronous movement is completed.

### 3.6 Joint velocity following mode




When the user uses the SyncMove program and configures the working mode as joint velocity following mode, the slave robot will carry out joint space velocity synchronous movement according to the movement under the root node of the master robot SyncMove program, and strictly ensure the same joint space velocity instruction. It should be noted that when the master and slave robots execute the SyncMove program at the same time, when the joint position is different, the slave robot will start to move at the current position. In the process of synchronous movement, the master robot will execute all the scripts under the root node of the SyncMove program, and the slave robot will keep running the SyncMove program until all the programs under the root node of the master robot SyncMove program are finished, and the master and slave robots will send the end synchronization signal to each other. The two parties confirm that the follow-up procedure will be carried out after the synchronous movement is completed.

### 3.7 Cartesian position following mode

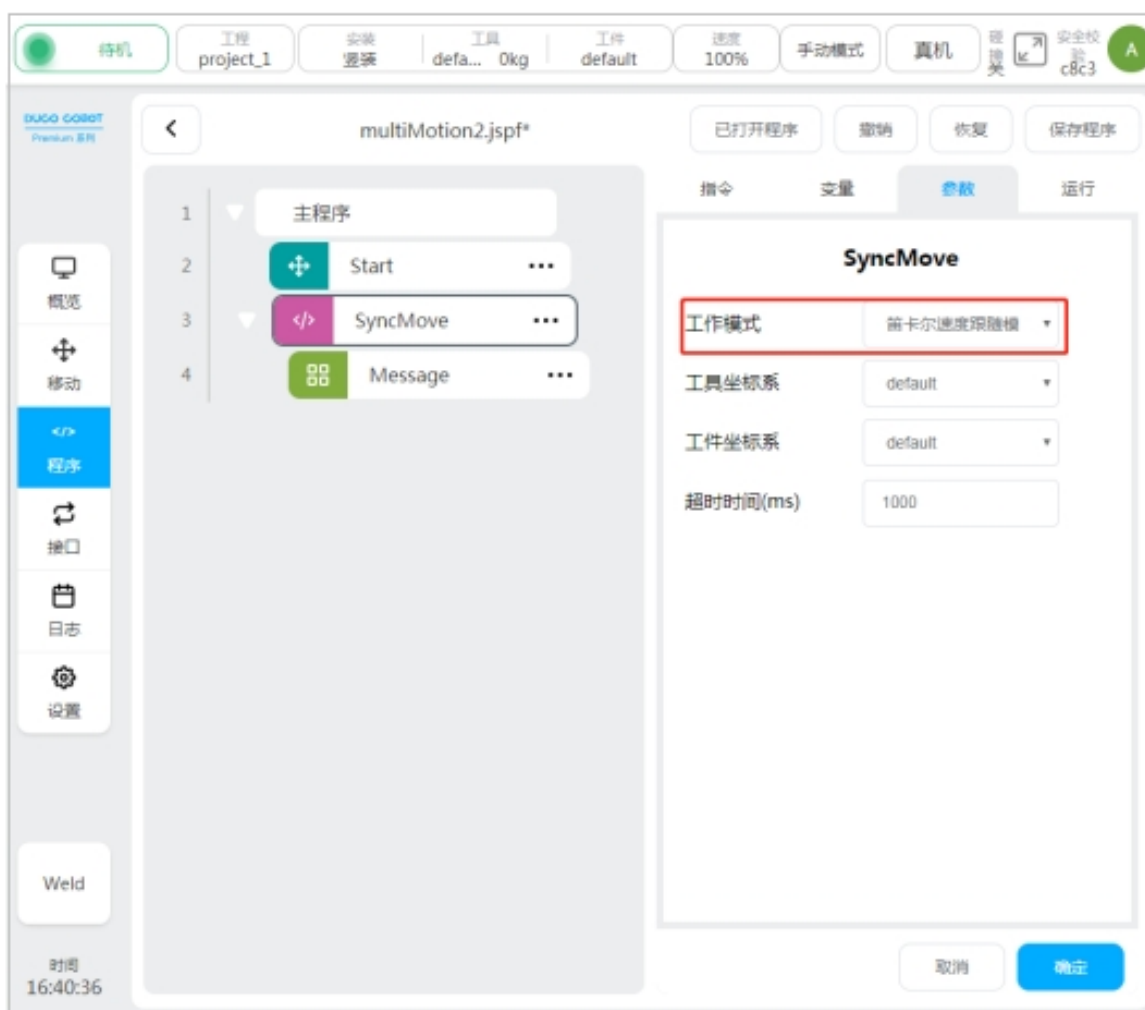


When the user uses the SyncMove program and sets the working mode to Cartesian position following mode, the slave robot will carry out synchronous Cartesian space position movement according to the movement under the node of the master robot SyncMove program, and strictly ensure the same Cartesian space position instruction. It should be noted that the Cartesian position is described in the position and pose of the tool coordinate system configured in the respective SyncMove program of the master and slave robot in the corresponding workpiece coordinate system configured. When the master and slave robots execute SyncMove program at the same time, if the current Cartesian position is different, the slave robot will automatically move the robot tool reference to its workpiece coordinate system in the form of MovejPose to the same position as the master robot tool reference to its workpiece coordinate system. From this position, it synchronizes with the main robot to move in the Cartesian position.

In the process of synchronous movement, the master robot will execute all the scripts under the node of the SyncMove program, and the slave robot will keep running the SyncMove program until all the programs under the node of the master robot SyncMove program are finished, and the master and slave robots will send the end synchronization signal to each other. The two parties confirm that the follow-up procedure will be carried out after the synchronous movement is completed.


 <b>Care</b>	<p>In Cartesian position following mode, if the master robot uses a joint space motion program similar to Movej during synchronous motion, the slave robot will still follow with reference to the pose description of the master robot tool coordinate system in the workpiece coordinate system. If the joint space movement of the main robot passes through the singular configuration of the robot, the joint stall will be generated from the robot.</p>
---	--

### 3.8 Cartesian speed following mode

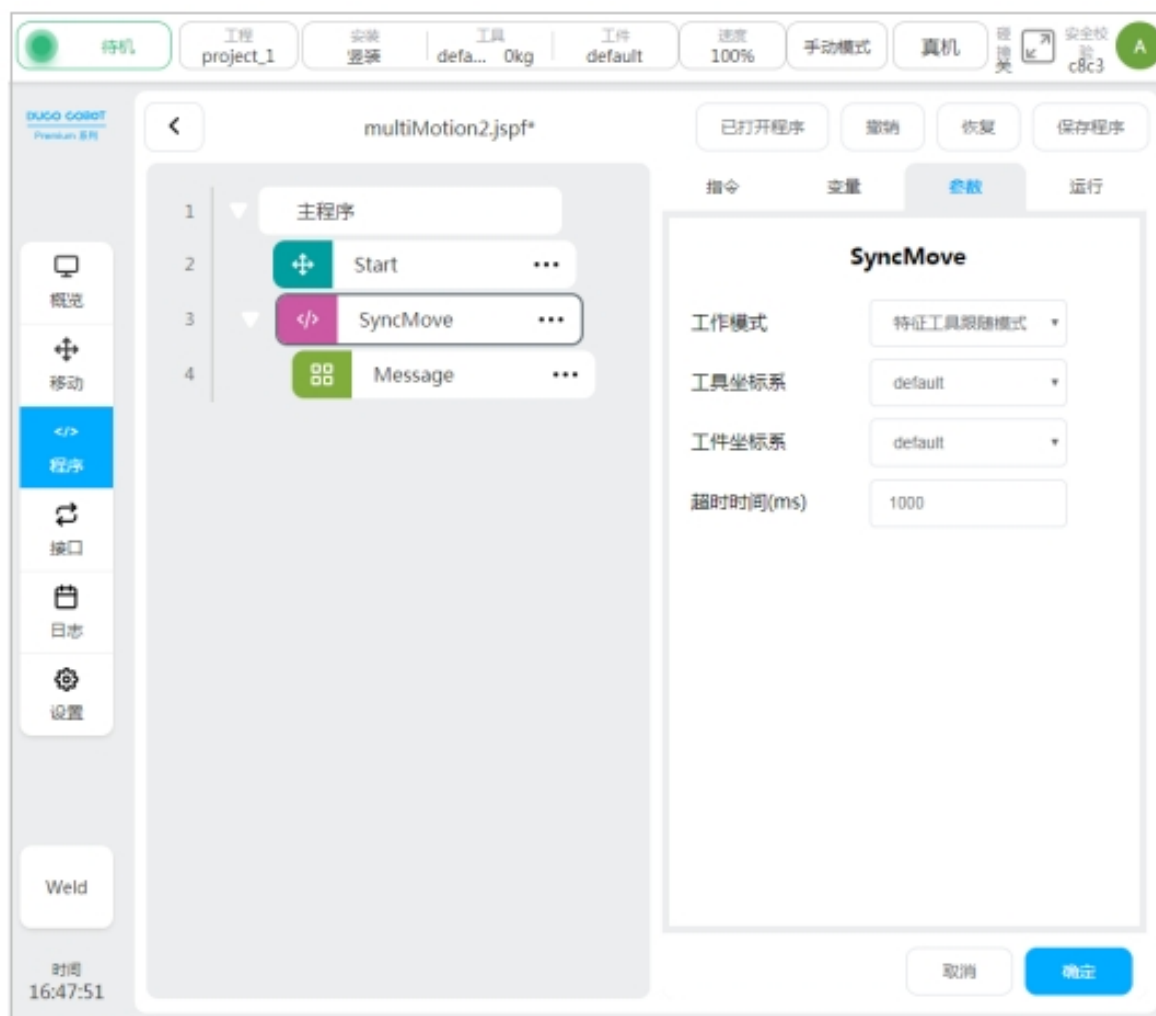


When the user uses the SyncMove program and sets the working mode to Cartesian speed follow mode,

the slave robot will carry out synchronous Cartesian space speed movement according to the movement under the node of the master robot SyncMove program, and strictly ensure the same Cartesian space speed instruction. It should be noted that the Cartesian velocity describes the pose velocity of the tool coordinate system configured in the respective SyncMove program of the master and slave robot in the corresponding workpiece coordinate system configured. In the process of synchronous movement, the master robot will execute all the scripts under the node of the SyncMove program, and the slave robot will keep running the SyncMove program until all the programs under the node of the master robot SyncMove program are finished, and the master and slave robots will send the end synchronization signal to each other. The two parties confirm that the follow-up procedure will be carried out after the synchronous movement is completed.

 <b>Care</b>	<p><b>In the Cartesian speed following mode, if the master robot uses a joint space motion program similar to Movej during synchronous motion, the slave robot will still follow by referring to the pose description in the master robot tool coordinate system in the workpiece coordinate system. If the joint space movement of the main robot passes through the singular configuration of the robot, the joint stall will be generated from the robot.</b></p>
---	--


### 3.9 Feature tool follow mode



When the user uses the SyncMove program and configures the working mode as the feature tool following mode, the slave robot will use the position of the tool configured according to the master robot SyncMove program as the workpiece coordinate system moving from the robot itself. That is, the workpiece coordinate system configured in all motion programs configured under the root node of the robot SyncMove program will no longer be valid, and the motion generated by the master robot tool in space will generate the following motion corresponding to the slave robot. At this time, the slave robot will use the tool sitting position of the master robot as the workpiece coordinate system, and execute the movement instructions below the root node of the SyncMove program (similar to the conveyor belt following).

In the process of synchronous movement, both the master robot and the slave robot will execute all scripts under the root node of the SyncMove program until all programs under the root node of the master robot and the slave robot SyncMove program are finished, and the master and slave robots will send the end synchronization signal to each other. The two parties confirm that the follow-up procedure will be carried out after the synchronous movement is completed.

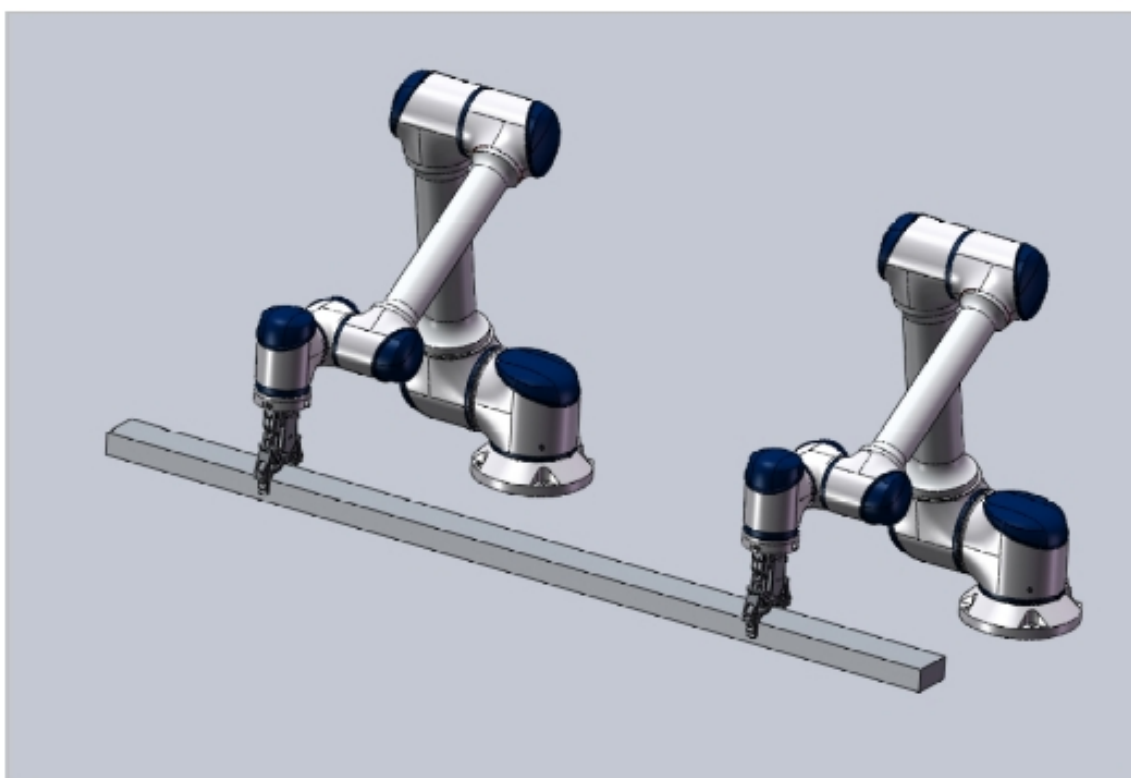


 <b>Care</b>	In the feature tool following mode, it is necessary to consider whether the path of the slave robot will pass through the singular configuration of the robot, if it does, it will cause joint stall of the slave robot.
---	--



## APPLICATION CASES

### 4.1 Synchronous follow application cases



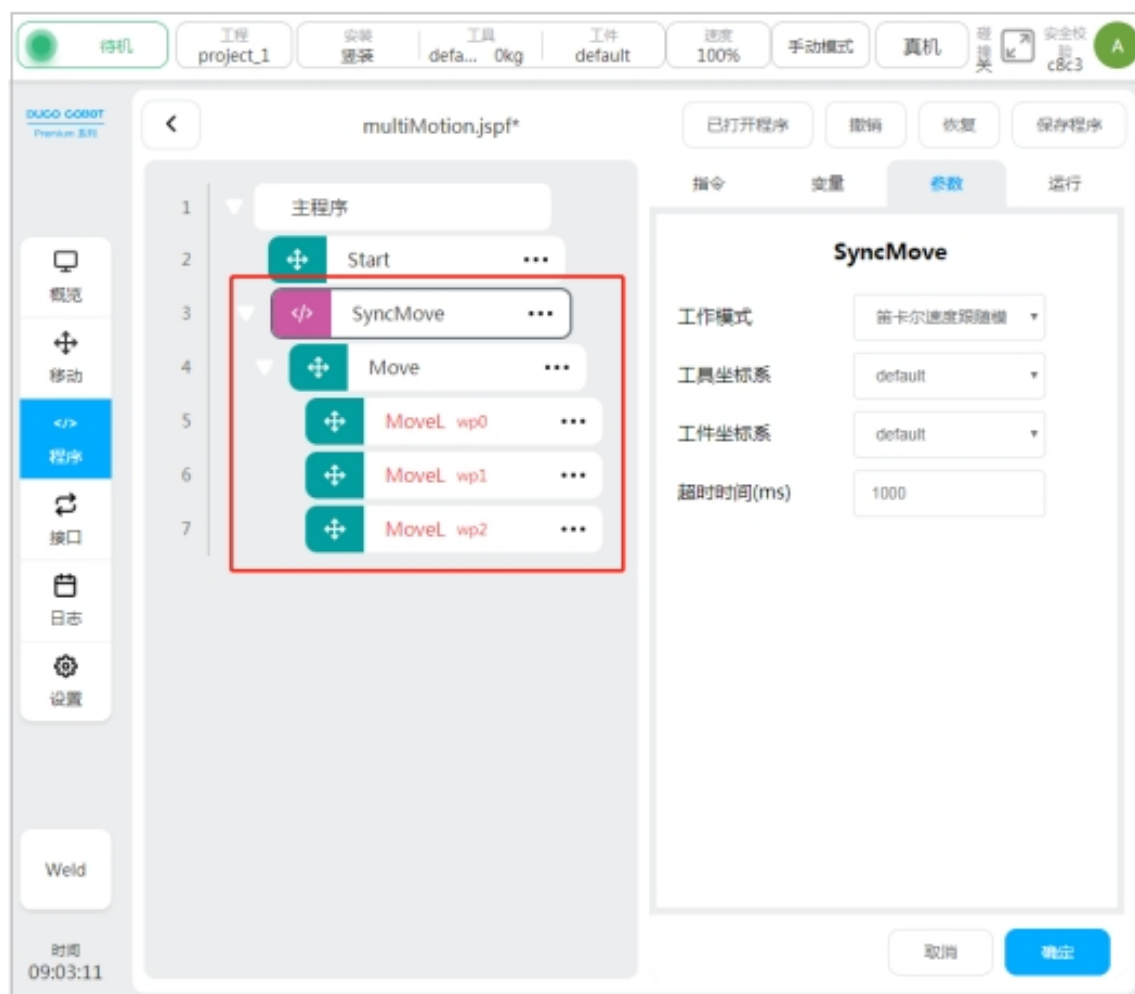
As shown in the figure, two robots are expected to grasp and place the same workpiece at the same time according to the state shown in the figure. Since the workpiece itself is long and the stiffness is large, two robots are required to complete the collaborative work with extremely high precision synchronization, so as to avoid the damage of the workpiece due to the large shear force caused by the non-synchronous movement between the two robots.

For the above conditions, multi-machine co-programming can be achieved in the following ways:

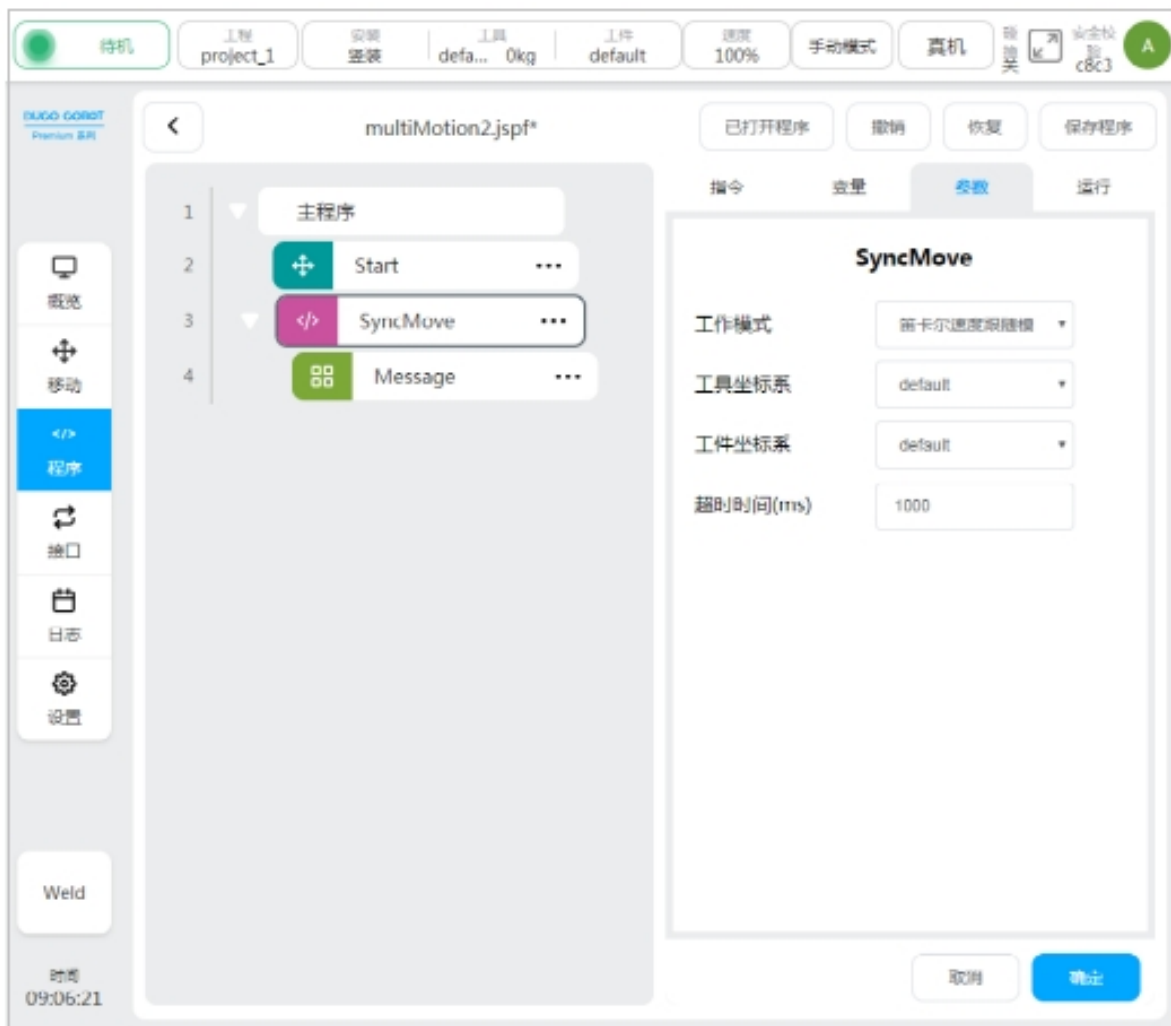
- 1、 Refer to Chapters 3 to 4 to complete the plug-in installation, communication connection debugging, master-slave configuration, master-slave calibration and function activation of the two robots;

- 2、 Write the master robot script program, add the root node of SyncMove script at the starting point of grasping the workpiece, configure the parameters correctly, and add the required motion script for grasping and placing the workpiece under the root node. Because the actual working condition requires the master-slave robots to strictly maintain the synchronization of grasping speed in Cartesian space, so as to avoid

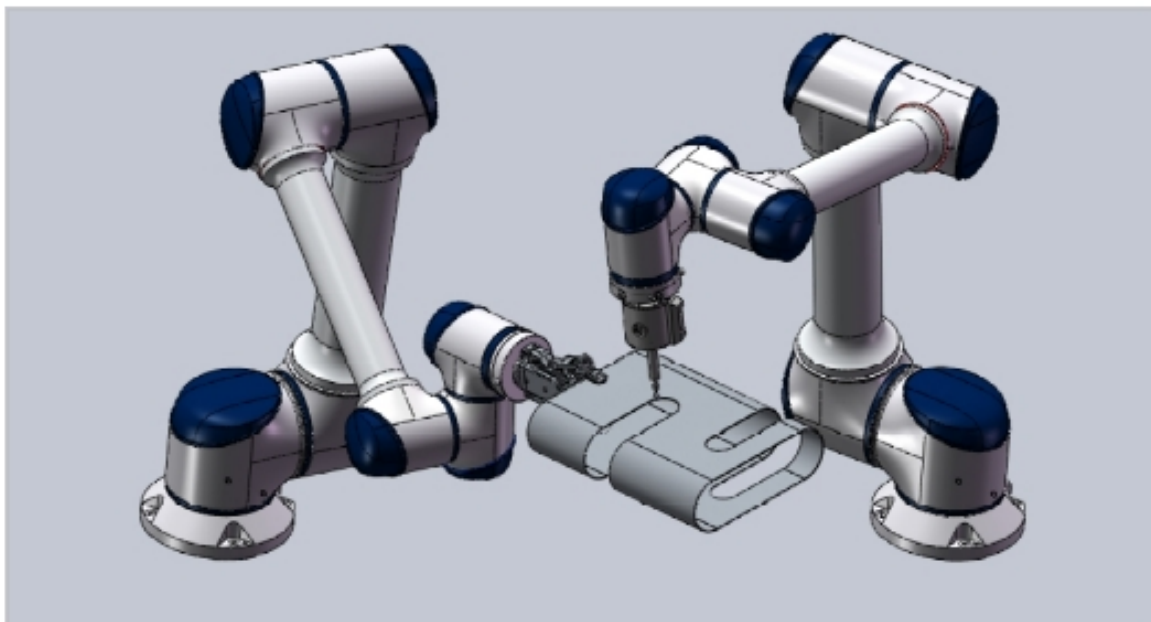
generating shear force on the workpiece, the Cartesian speed following mode can be used. If the two robots are correctly configured with the tool and the workpiece coordinate system, so that the position of their respective tools in the workpiece coordinate system is always the same during the grasping process, the Cartesian position following mode can also be selected. As shown in the picture below:



3. After completing the configuration of the master robot, the slave robot only needs to add the SycMove root node at the starting point of its workpiece grab and configure it, without adding any other instructions below it. As shown in the picture below:



### 4.2 Features follow application cases



As shown in the figure, robot needs to process and polish the workpiece. However, due to the limitation of its space motion range due to its configuration, robot cannot effectively complete the processing of the complete workpiece surface. At this point, another robot is needed to grab the workpiece and move it so that the complete workpiece surface can be processed and polished by robot in its workspace to touch and complete the job.

For the above conditions, multi-machine co-programming can be achieved in the following ways:

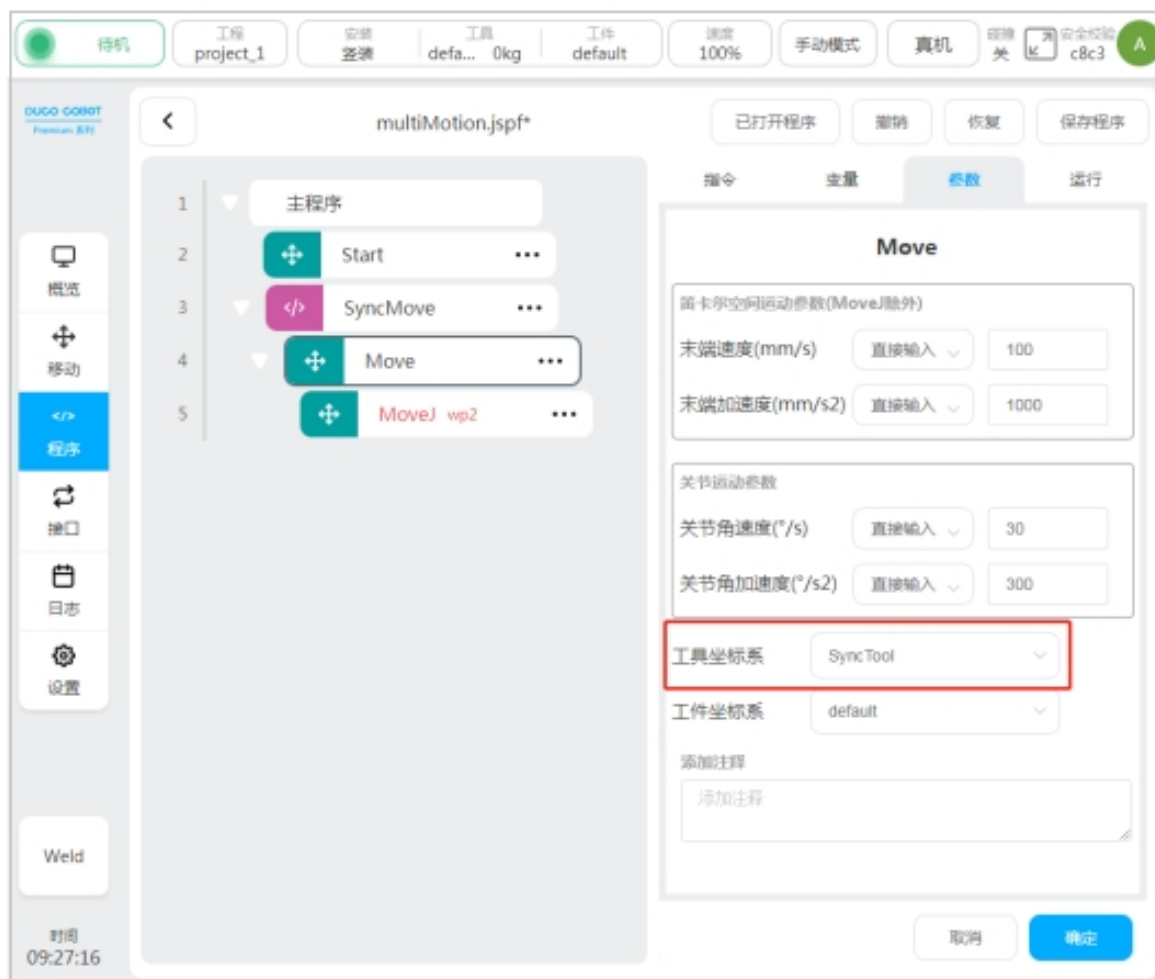
1. Refer to Chapters 3 to 4 to complete the plug-in installation, communication connection debugging, master-slave configuration, master-slave calibration and function activation of the two robots;

2. The master robot acts as the workpiece grasping robot, and selects a feature point on the workpiece after capturing the workpiece as its tool coordinate system to write the motion script during SyncMove synchronous movement, as shown in the following figure:

The screenshot displays the DUCO CORBI software interface for configuring a multiMotion.jspf program. The top status bar shows the robot is in '待机' (Standby) mode, with various system parameters like 'project\_1', '速度 100%', and '手动模式' (Manual Mode). The main workspace shows a sequence of five steps: 1. '主程序' (Main Program), 2. 'Start', 3. 'SyncMove', 4. 'Move', and 5. 'MoveJ wp2'. The 'SyncMove' block is selected, and its configuration panel is open on the right. The configuration panel includes the following settings:

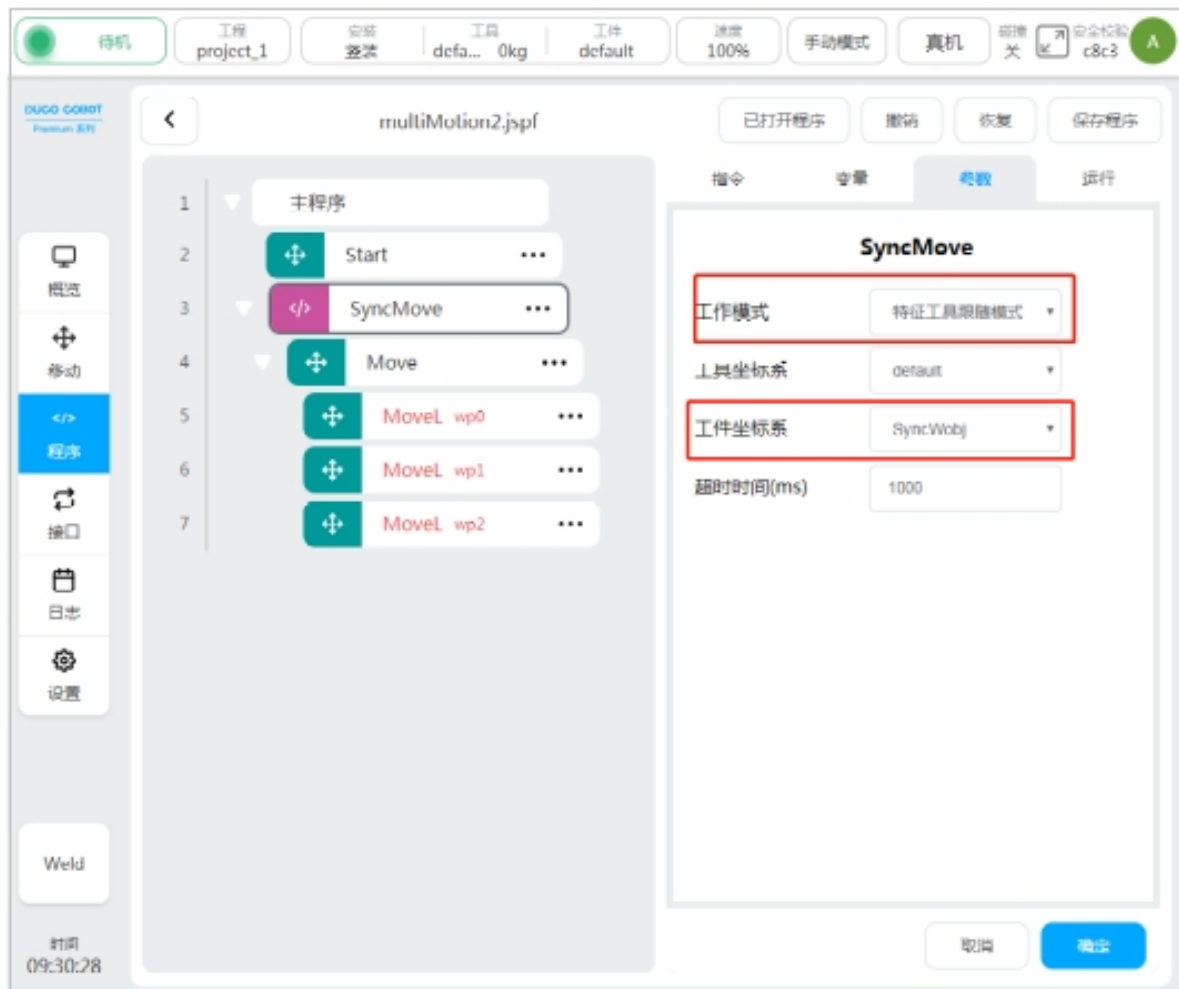
- 工作模式 (Work Mode): 特征工具跟随模式 (Feature Tool Follow Mode)
- 工具坐标系 (Tool Coordinate System): Sync Tool
- 工件坐标系 (Workpiece Coordinate System): default
- 超时时间(ms) (Timeout (ms)): 1000

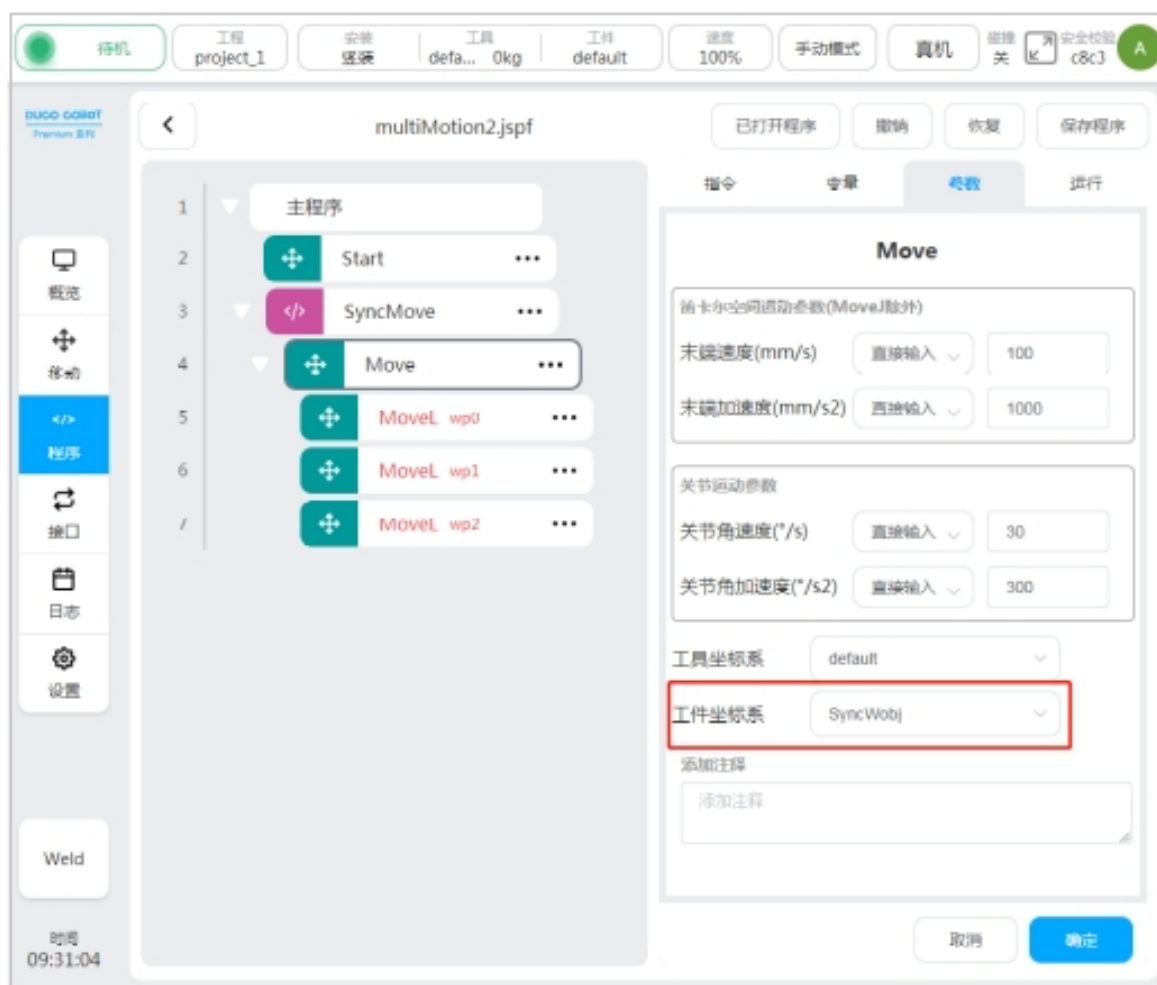
The '工作模式' and '工具坐标系' settings are highlighted with a red box. The interface also includes a left sidebar with navigation options like '概览' (Overview), '移动' (Move), '程序' (Program), '接口' (Interface), '日志' (Log), and '设置' (Settings), along with a 'Weld' button and a timestamp of 09:26:15.



3、From the robot as a working robot, the same feature point on the workpiece should be selected as its workpiece coordinate system, and the workpiece operation track should be taught in the workpiece coordinate system, and it should be added to the root node of SyncMove script. As shown in the picture below:







4. When the master and slave robots enter the synchronization mode, the master and slave robots will start to execute motion commands by referring to the motion script under their respective SyncMove root node. In the synchronization process of the robot, the coordinate system of all the moving reference workpiece will be synchronized with the position of the tool coordinate system of the master robot, and the real-time correction of its own motion instructions, so as to achieve the goal of synchronous job processing.