Education Kit User Manual

JAKA Lens X

JAKA MiniCobo

Document version: V1.0.0

Notes:

The content in this user manual is the exclusive property of the Shanghai JAKA Robotics Ltd. ("JAKA"). Without the written consent of JAKA, the content may not be used in any form.

We will regularly revise and improve the user manual, and the content may be changed without notice. Please check the factual product information carefully before using this manual.

The information in the user manual is not the commitment of JAKA. JAKA is not liable for any error that may appear in this manual, or any accident or indirect injury arising from the use of this manual and the products described therein. Before installing and using the product, read this manual carefully.

The pictures in this manual are for reference only.

If the hardware is modified or disassembled, JAKA is not responsible for the after-sales.

Users are reminded to use safety equipment and comply with safety regulations when using and repairing cameras.

Programmers, visual system designers, and debuggers of the JAKA Education Kit must be familiar with the programming methods and system application installation of JAKA robots and JAKA Lens X.

About the Manual

This manual mainly contains basic methods for using the education kit.

This manual mainly provides guidelines for the overall project and function construction of the JAKA education kit. For more detailed instructions on JAKA MiniCobo and JAKALensX, please consult the product user manual.

This manual is intended for users who have received basic mechanical and electrical training. This is helpful in installing and using the camera.

More Information

For more product information, please scan the QR code on the right to visit our official website www.jaka.com.

Contents

Product catalog (Education Kit)

Name	Quantity
Lens 2D camera	1
Composite wire	1
Visual calibration board	2
2.5D positioning plate	2
Gigabit switch	1
European standard converter	1
camera mounting flange	1
Quick Start Manual	1
Accessories bag	1

Product Catalog(Lens 2D Camera)

Name	Quantity
Lens 2D camera	1
Composite wire	1
Visual calibration board	2
2.5D positioning plate	2
Gigabit switch	1
European standard converter	1
camera mounting flange	1
Quick Start Manual	1
Accessories bag	1

1. Foreword

JAKA collaborative robot will serve you wholeheartedly. Wherever the eyes go, there goes the body.

Figure 1.1-1

1.1 Introduction

JAKA Lens X is a visual system using JAKA robot camera, with the control system inserted in the robot control cabinet. The camera is equipped with JAKA's self-developed visual operation software: the algorithm layer runs under the JAKA robot's 64-bit system control cabinet; the interface uses a Web page to support cross-platform access. Enter the IP address of the control cabinet in the browser to run the camera's operation interface. The new generation of machine vision software uses a fully graphical interface. Users can complete vision applications including disordered grabbing, loading and unloading, depalletizing, visual guidance positioning/assembly, defect detection, measurement, AGV-equipped visual high-precision positioning and other advanced machines without writing code.

The software has three major features: simplicity, powerful functions, and multilingual support. Simplicity: graphical, code-free interface, simple UI design, and clear functional partitions; users do not need any professional programming skills, just "add algorithm module - configure module parameters - connect module connections" to complete Construction of visual engineering. Powerful function: it contains a wealth of visual algorithm modules (2D general processing algorithms, 2D feature processing, 2D matching, measurement and other special algorithms, etc.), which can be applied to multiple typical actual scenarios and supports parallel processing to maximize the use of computer hardware resources to improve software operation efficiency. Multilingual support: Chinese and English language packs are available in the software, and software language can be switched by one clicking.

2. Software and hardware installation configuration

2.1 Device preparation

1) A laptop. It is recommended to use Win7 or plus system and install Google Chrome;

2) A set of JAKA education kit.

2.2 Hardware installation

2.2.1 Installation position for each component

The relative installation positions of components such as the Minicab, switches, power strips, light source controllers, power adapters, and robot mounting bases in the kit and the base plate, as well as the installation positions of the cover plate and operating panel are as shown below.

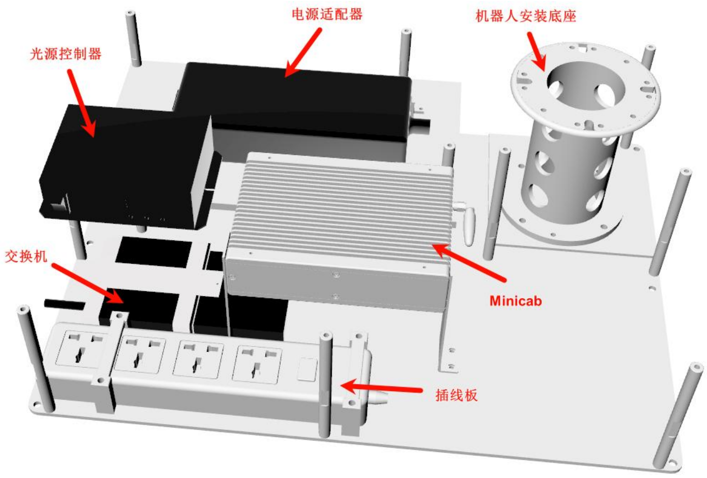


Figure 2.2-1

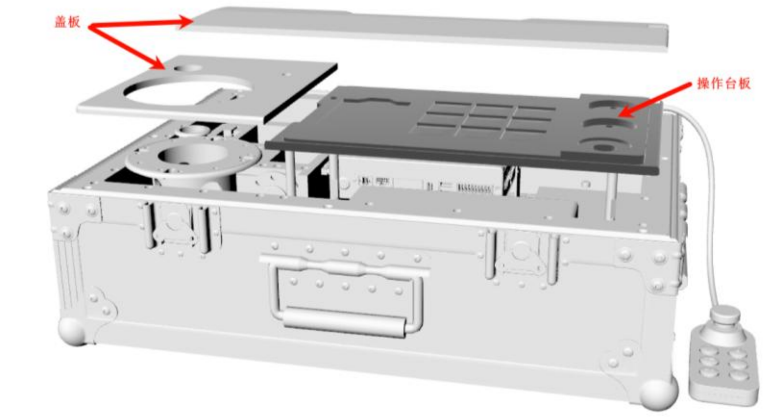


Figure 2.2-2

2.2.2 Robot installation

Installation direction: The power cable at the base of the main body should face the direction of the right table, as shown in the figure below.

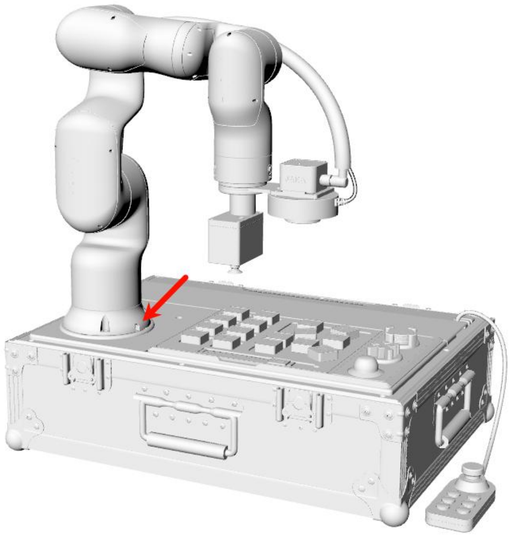


Figure 2.2-3

2.2.3 End tool installation

1. Install the 2D camera and the camera adapter board together. When installing, pay attention to the installation direction of the 2D camera. The relative position of the camera's wiring harness interface and the adapter board is as shown below.

Figure 2.2-4

2. Install the ring light source on the camera adapter board. During installation, it is recommended that the wiring harness interface of the ring light source be in the same direction as the camera wiring harness interface as shown below to facilitate wiring harness bundling.

Figure 2.2-5

3. Install the camera bracket and VAC electric chuck at the end of the robot flange. The offset direction of the camera bracket and the offset direction of the VAC electric chuck form an angle of 90°. First adjust the angles of each joint of the robot to: J1: 0°, J2: 0°, J3: -90°, J4: 0°, J5: -90°, J6: 0°. In this robot posture, the offset direction of the VAC electric suction cup is outward and the offset direction of the camera bracket is to the right.

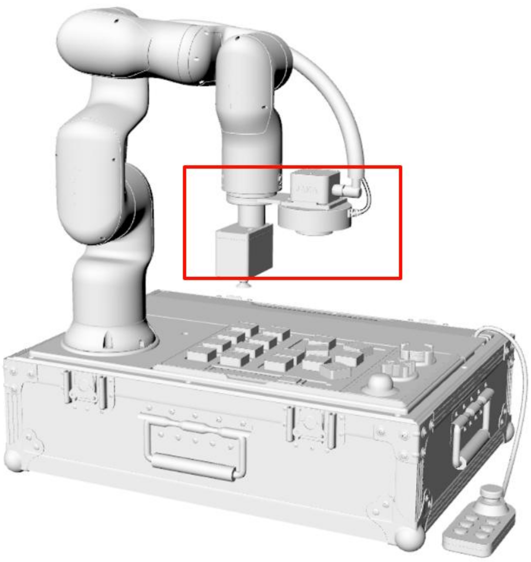


Figure 2.2-6

2.2.4 Hardware wiring

After the camera is assembled, fix the camera on the end flange of the robot.

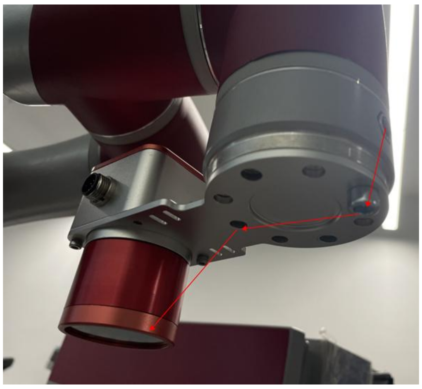


Figure 2.2-7

The camera cable is a composite cable (including network cable and power cable). Connect the network cable at one end of the composite cable to a gigabit router/switch on the same network as the robot. The other two power cables are connected to 24V in white and 0V in black, such asFigure 2.2-8is shown.

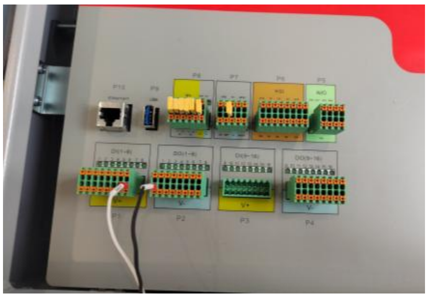


Figure 2.2-8

As shown in Figure2.2-9, when the camera power supply is normal and the network is connected normally, the indicator light lights up blue. If the camera's power supply is normal but the communication is abnormal, the indicator light will light up blue; when the camera is taking pictures, the indicator light will light up blue and flash. The indicator light on older versions of the camera lights up green when powered normally.

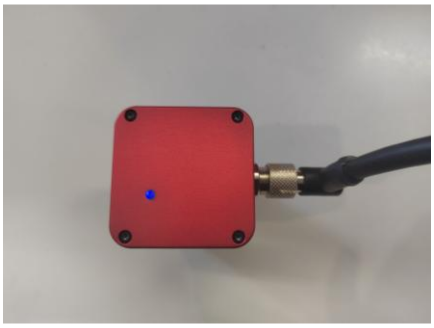


Figure2.2-9

The camera control system consists of multiple parts. Figure 2.2-10 is an example of the JAKA Lens X system.

1. Windows devices

2. Gigabit switch

3. JAKA control cabinet

4. JAKA Lens 2D camera

5. Gigabit network cable 1

6. Gigabit network cable 2: Please connect the MiniCab control cabinet to LAN2.

7. JAKA Lens 2D cable: Connect the crystal head to the Gigabit switch, and connect the 24V power cord to the control cabinet.

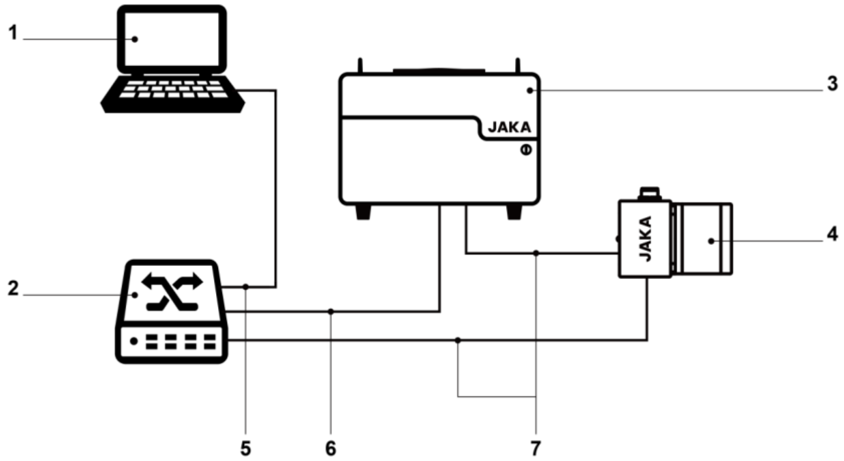


Figure 2.2-10

Note: The camera network cable, debugging PC network cable, and robot controller are all connected to the same Gigabit switch.

2.3 Software Basic Configuration

2.3.1 Robot Zu APP Configuration

1. Configure the LAN2 network port IP of the robot control cabinet to 192.168.1.10, as shown below. It is not recommended to set other IPs, as other IPs will complicate the configuration of subsequent robot programs.

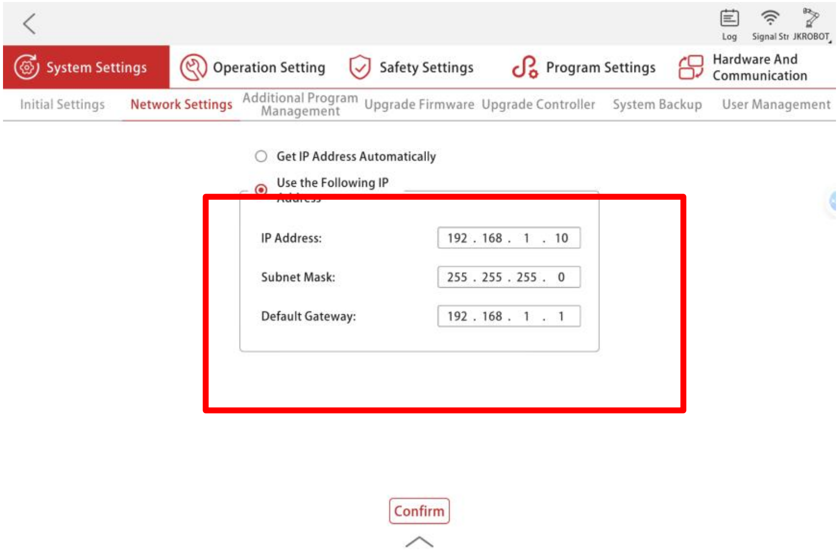


Figure 2.3-1

2. Set the TCP coordinates of the VAC electric suction cup. Since the size, the relative position of the electric suction cup and the TCP data are. The data can be set by manual input without a need for four-point calibration. The specific data can be set to X: -9.5, Y: -42, Z: 100, as shown below.

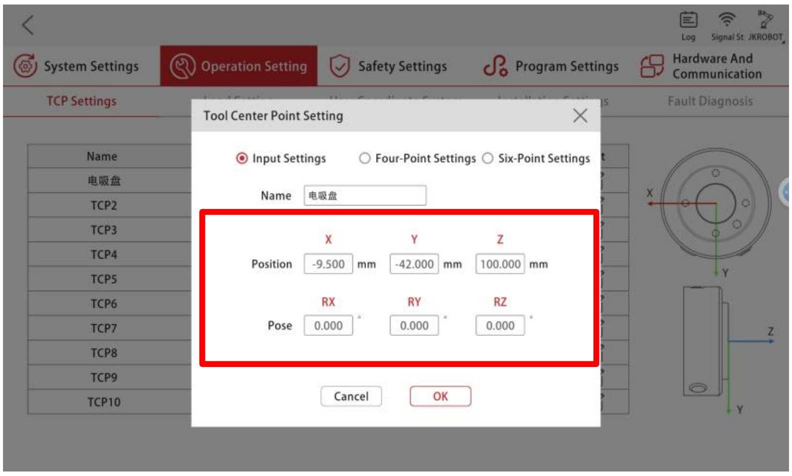


Figure 2.3-2

3. Set the output voltage of the end IO to 24v and set it to enable state, as shown below.

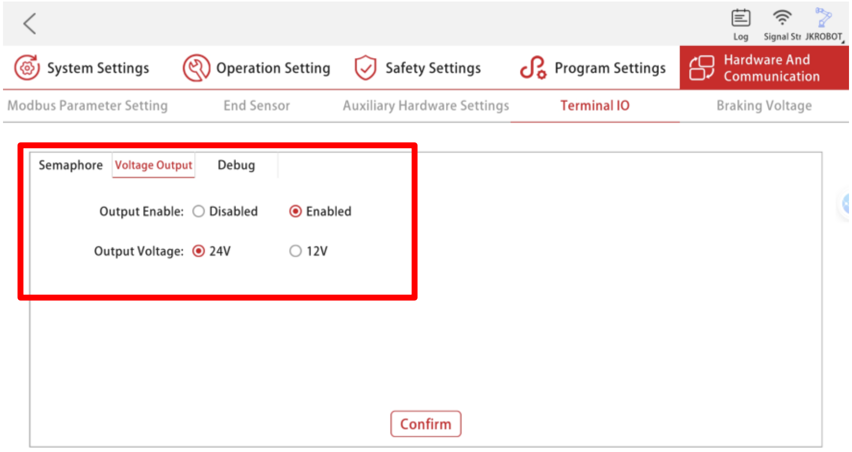


Figure 2.3-3

4. Set the output mode of the two outputs DO1 and DO2 on the tool end to PNP type.

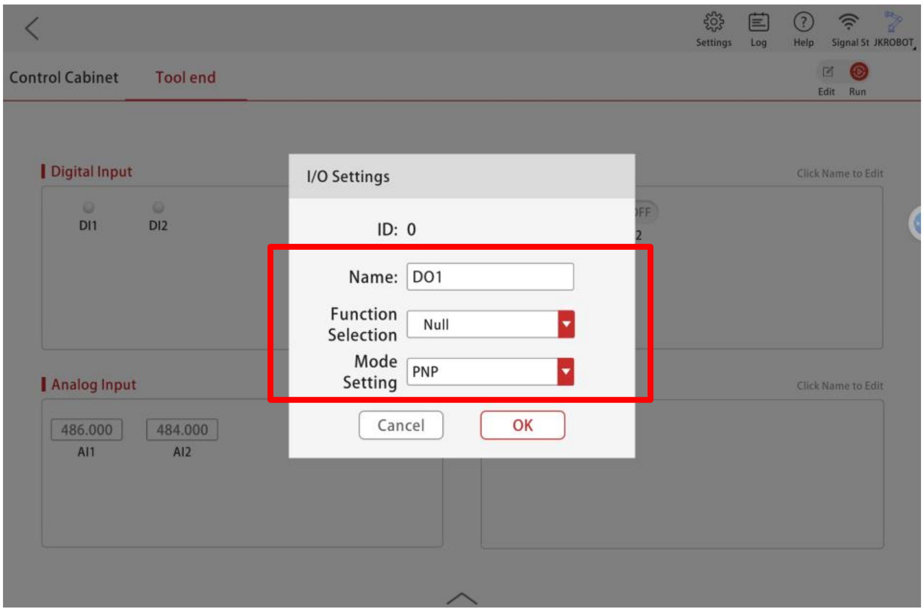


Figure 2.3-4

5. Set UDIO1 as the output type, and set UDIO2 and UDO3 as the output type, as shown below.

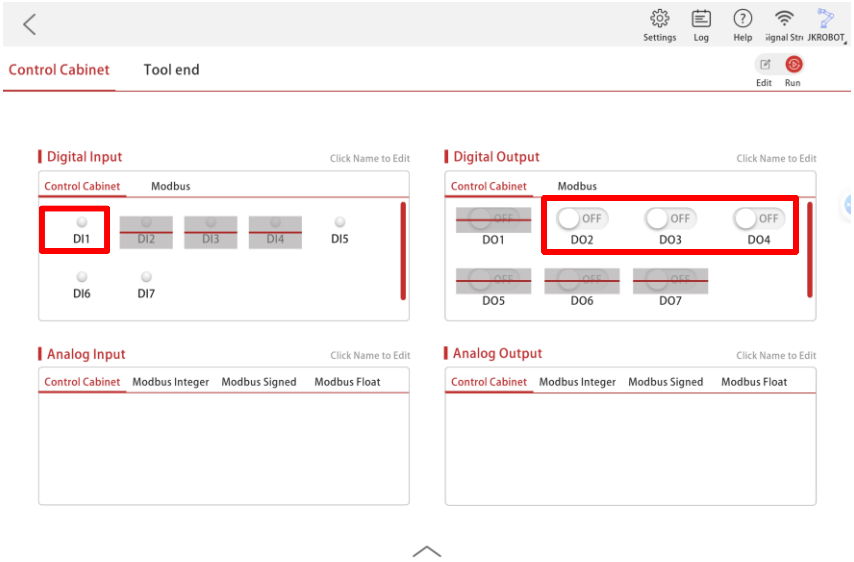


Figure 2.3-5

6. Connect the five wire harnesses of the touch button to the user terminals of the Minicab respectively. The connection sequence is as shown in the table below.

Color	Description
Brown	Connected to user terminal No. 3 terminal channel , 24V
Blue	Connect to user terminal No. 4 terminal channel, GND
Yellow	Connect to user terminal No. 7 terminal channel, DO4
Red	Connect to user terminal No. 9 terminal channel, DO3
Green	Connect to user terminal No. 11 terminal channel, DO2
White	Connect to user terminal No. 13 terminal channel, DI1

2.3.2 LensX authorization

When you use JAKA Lens X for the first time, you need to contact the JAKA technician to get authorization. The steps are as follows:

1) Query the robot IP address on JAKA ZU APP, open the browser, log in to "control cabinet ip:1880" to access

the Lens X software interface, for example: 172.30.0.143:1880.

2) Drag out a Lens X node on the left, click Deploy, and double-click to enter the node

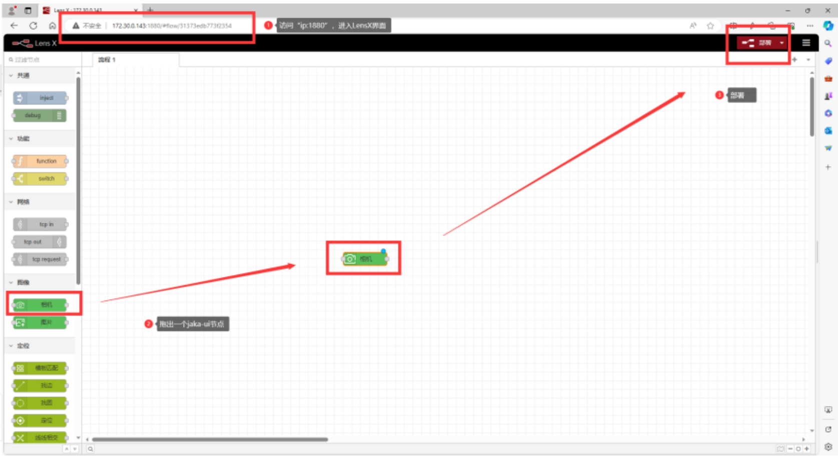


Figure 2.3-6

3) After entering the node, the following interface will pop up, copy this authorization information. If there is no pop-up window, please try to re-enter the node. Send the authorization information to the JAKA technician, get the lic file and upload it. If successful, the upload completion popup will appear.

4) After the upload is completed, click Start Authorization, and finally **reopen the browser. Note: The refresh operation has no effect.**

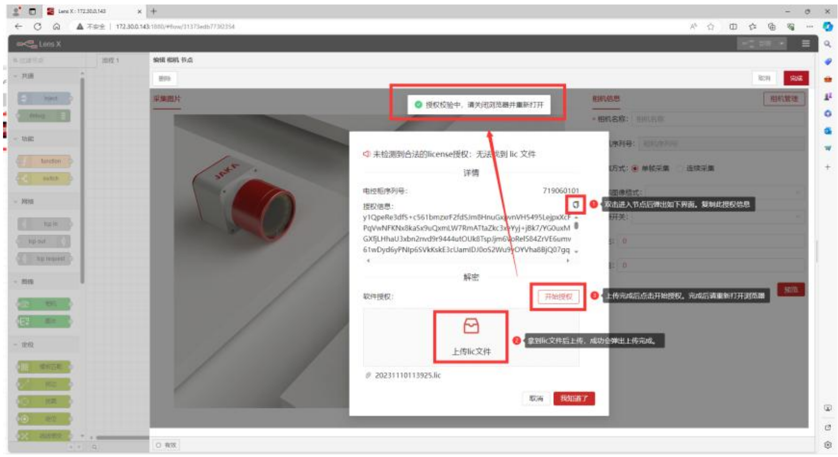


Figure 2.3-7

3. General function description

The project import and camera configuration involved in this chapter are necessary processes for all projects and will be explained here.

3.1 Camera configuration

3.1.1 Configure camera IP

Camera IP can be configured in the "Camera Management" node. The steps are as follows:

1) Drag a camera management node into the process, click Deploy, and then double-click to enter the camera management node, such asFigure 3.1-1.

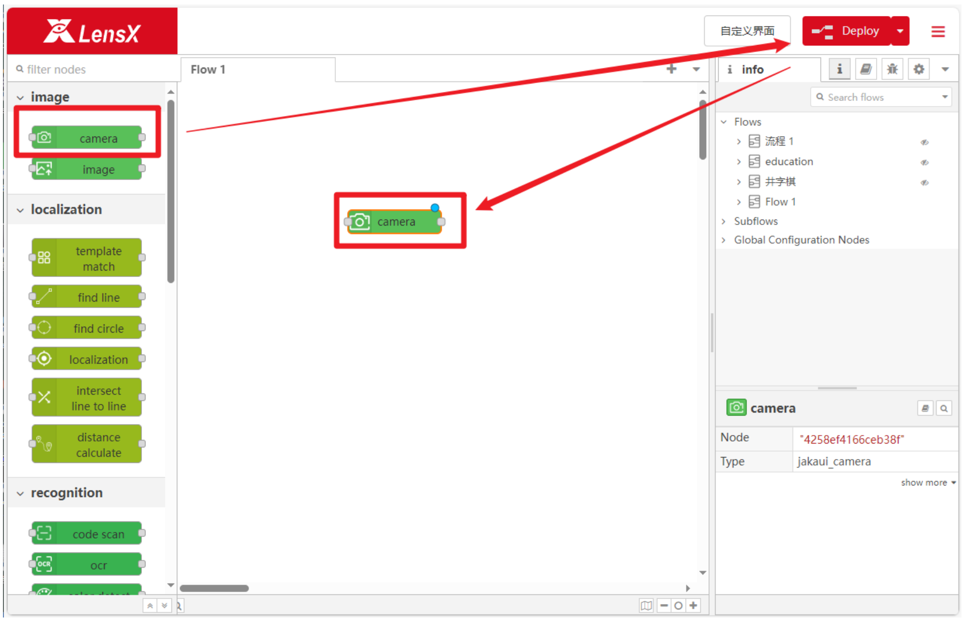


Figure 3.1-1

2) Double-click to enter the camera management node, and click camera management, as shown in Figure 3.1-2.

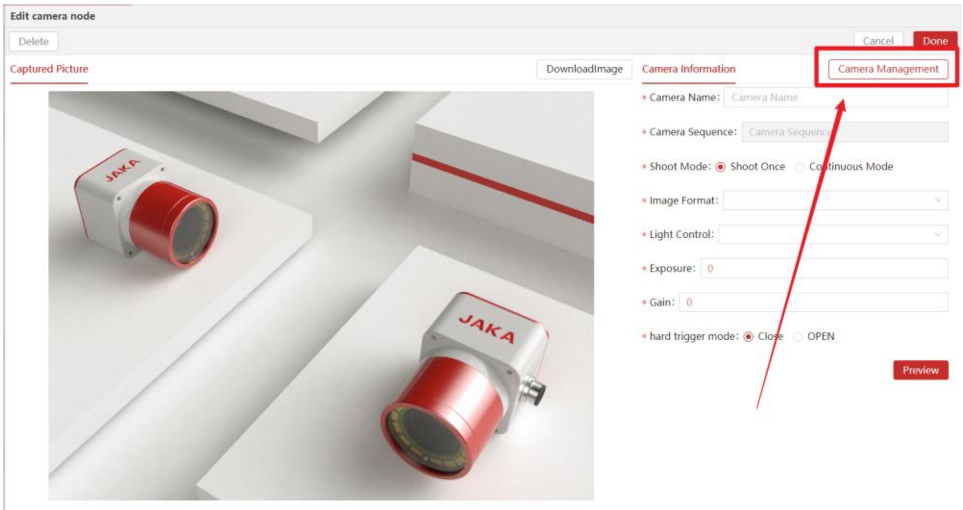


Figure 3.1-2

3) If the camera IP, the debugging PC and the robot are not in the same network segment, there will be a corresponding display in the "Camera Status". Click the edit button to edit the camera IP.

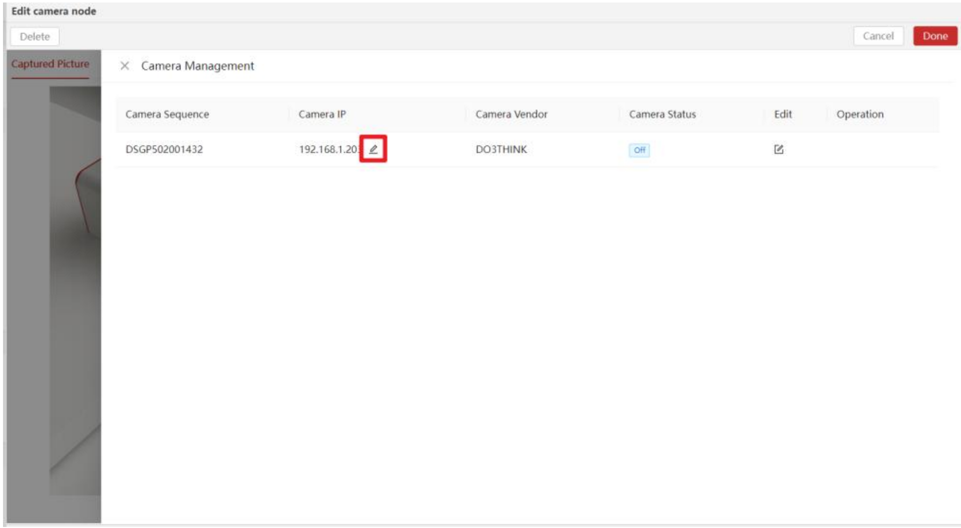


Figure 3.1-3

4) Modify the camera IP to the same network segment as the robot and debugging PC. After saving, you can use the camera normally.

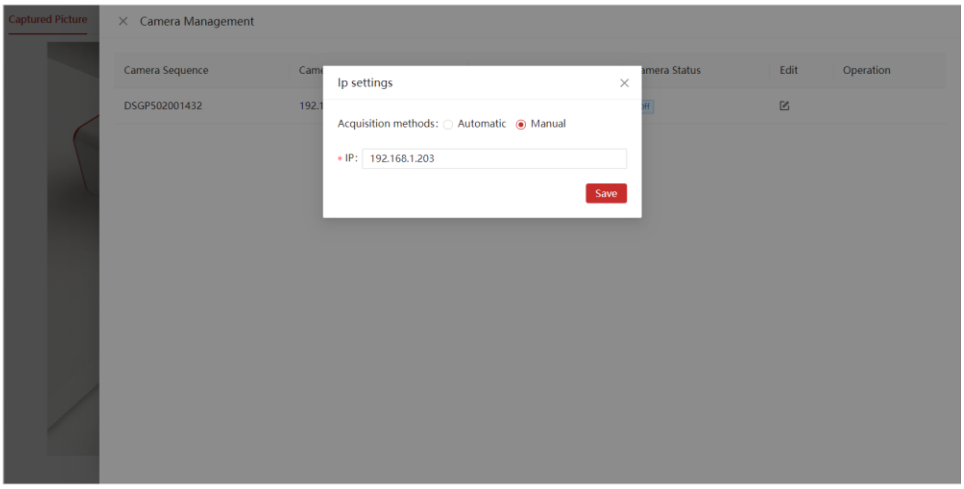


Figure 3.1-4

3.1.2 Camera focus aperture adjustment

Before adjusting the camera focus, you need to determine the robot's camera posture and ensure that the height and field of view meet the camera conditions, and then follow the steps as shown in the figure. **The camera posture has been adjusted in the robot program provided in the resource package. The camera height used in all projects is the same and does not need to be adjusted repeatedly.**

1) After configuring the camera IP in 3.1.1, click the button under the "Operation" column to open the camera.

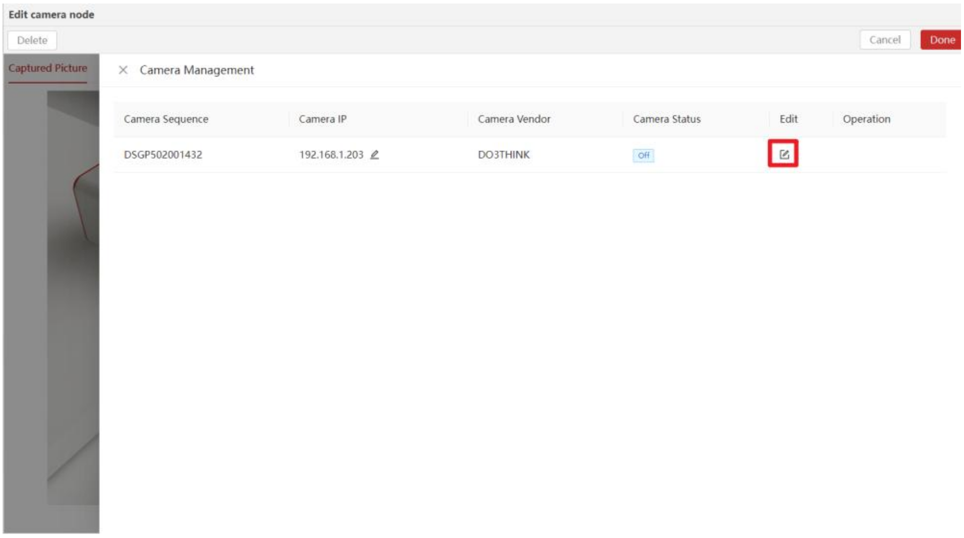


Figure 3.1-5

2) Move the robot to the photographing position.

3) Select continuous acquisition, configure the appropriate exposure and gain, and click Preview to see the

camera's real-time interface on the left. If the image is overly dark, please adjust the camera aperture first. The JAKA Education Kit provides **an additional light source** for the camera; please do not use the camera flash as it can only illuminate a small area directly below the camera.

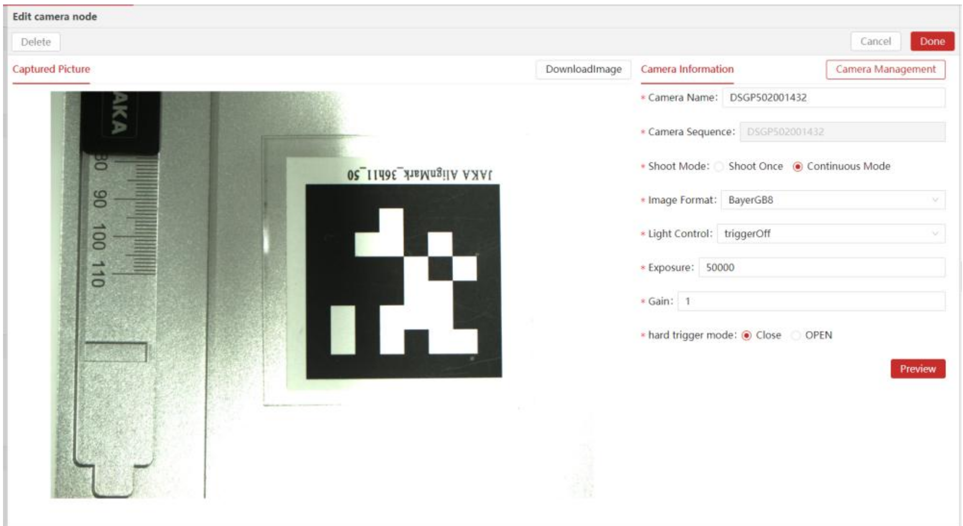


Figure 3.1-6

4) Unscrew the camera back cover and adjust the camera aperture and focus with reference to the live image.

Figure 3.1-7

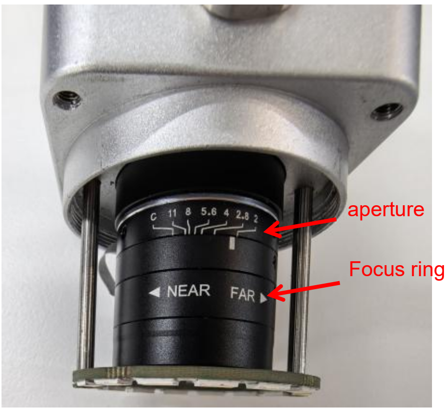


Figure 3.1-8

3.2 Project import

JAKA Lens X software has built-in basic project example processes, which can be used immediately after importing.

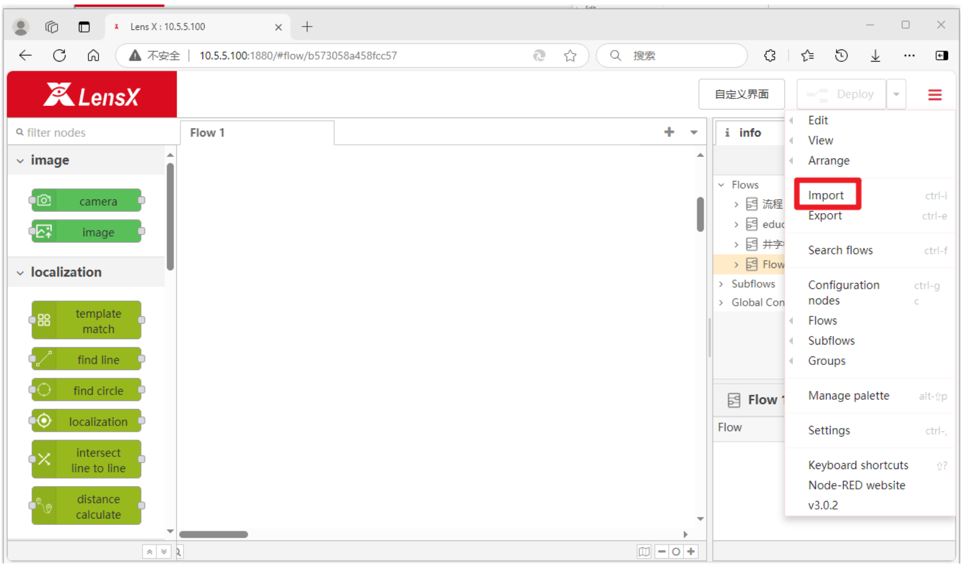


Figure 3.2-1

Select "Education Kit.json" inFigure 3.2-2to import the preconfigured visual program.

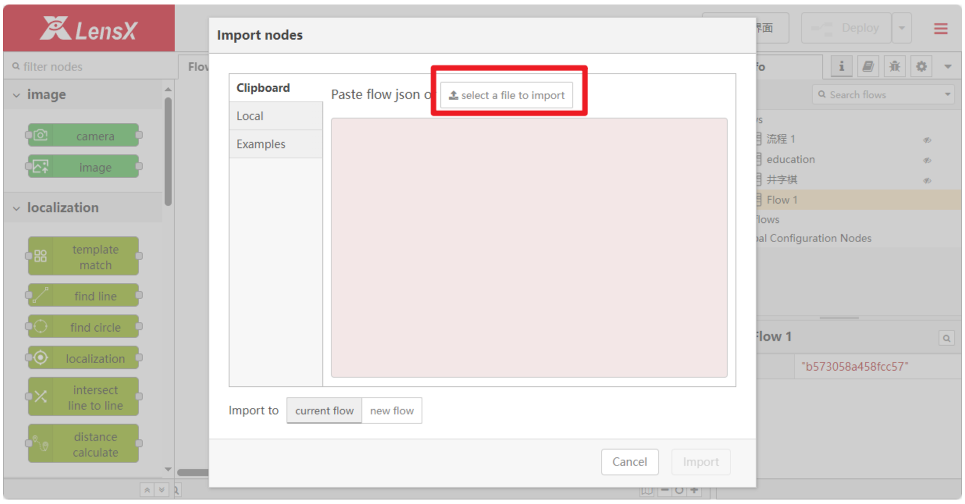


Figure 3.2-2

After importing, it will look like Figure 3.2-3.

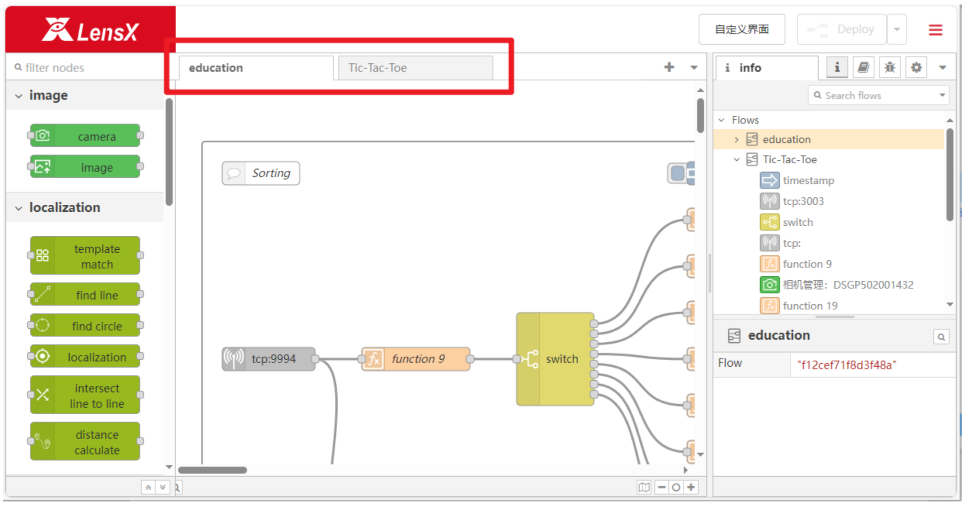


Figure 3.2-3

The robot program can be obtained by downloading the compression package, as shown in Figure 3.2 4.

Figure 3.2-4

Connect the robot and power on, click the programming control button, enter the programming interface, and then click the folder on the right sidebar to open the programming list.

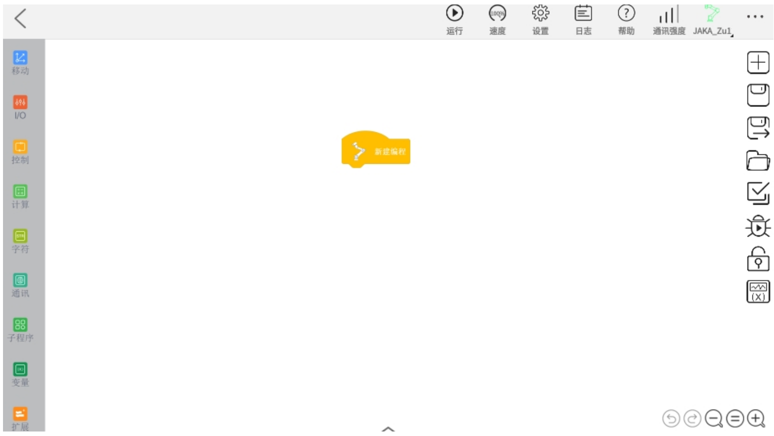


Figure 3.2-5

Click the import program button as shown in the figure, and find the decompression robot program under the computer path (the figure path is the native path, for reference only)

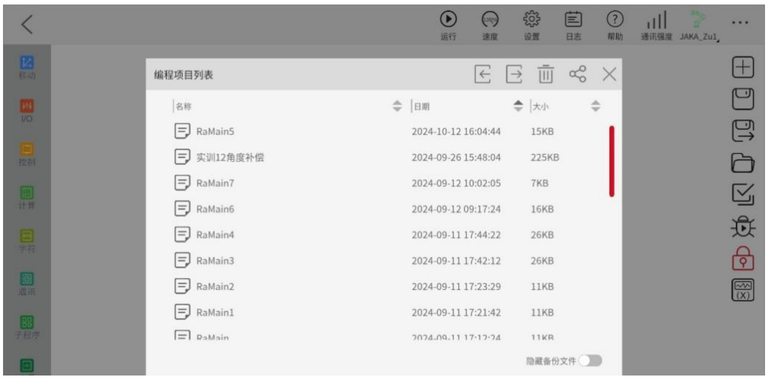


Figure 3.2-6

Figure 3.2-7

Select the robot program, and click the OK button, the program import can only import one program at a time. Program import was successful in Figure 3.2 8As shown

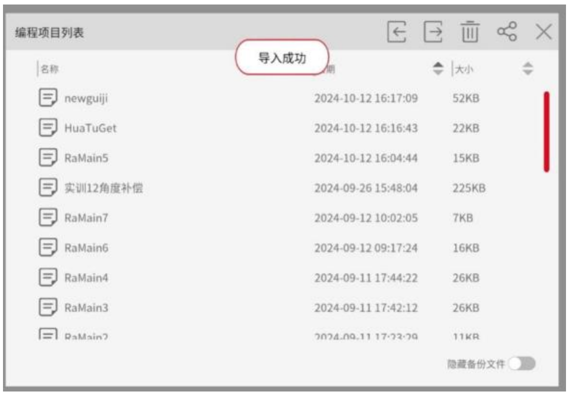


Figure 3.2-8

4. Project Configuration - Digital Block Sorting

This chapter is the construction guide for digital block sorting of JAKA Education kit. Before reading, please ensure that the contents of chapters 2-3 have been completed.

4.1 Automatic N-point calibration

1) Open the robot program [LensX positioning and grabbing N points], and move the robot to the photo point [Photo].

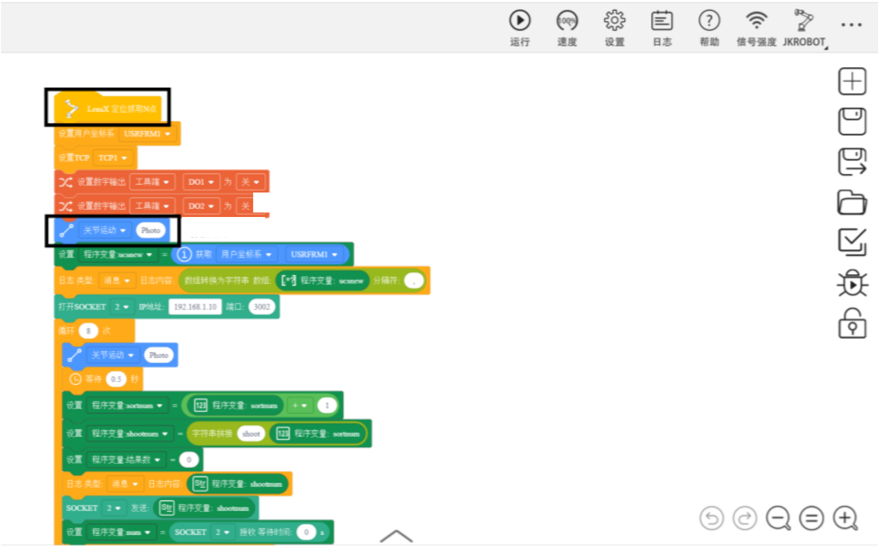


Figure 4.1-1

2) Find the related process of [Calibration] in the vision page and open [Camera Management].

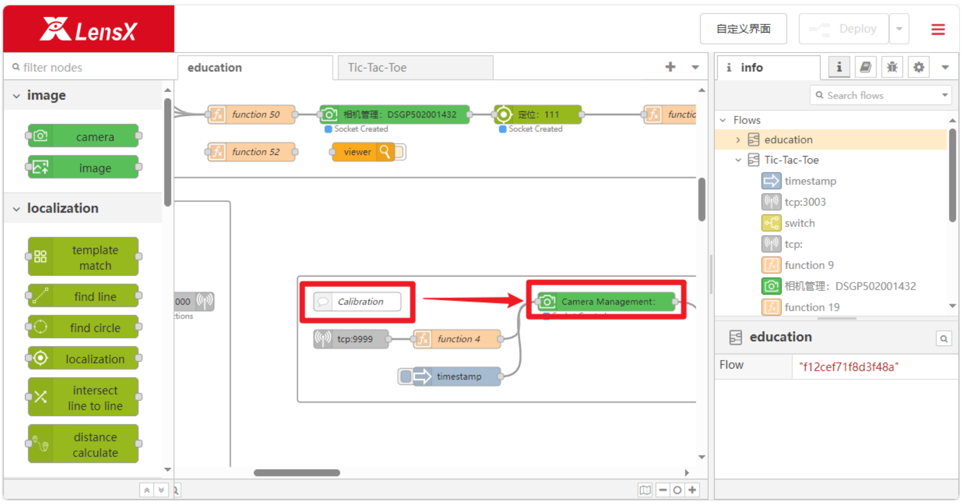


Figure 4.1-2

3) Place the calibration plate in the center of the field of view, adjust the camera exposure and gain, obtain an image with appropriate brightness and click [Finish] to save the settings. As shown inFigure 4.1-3.

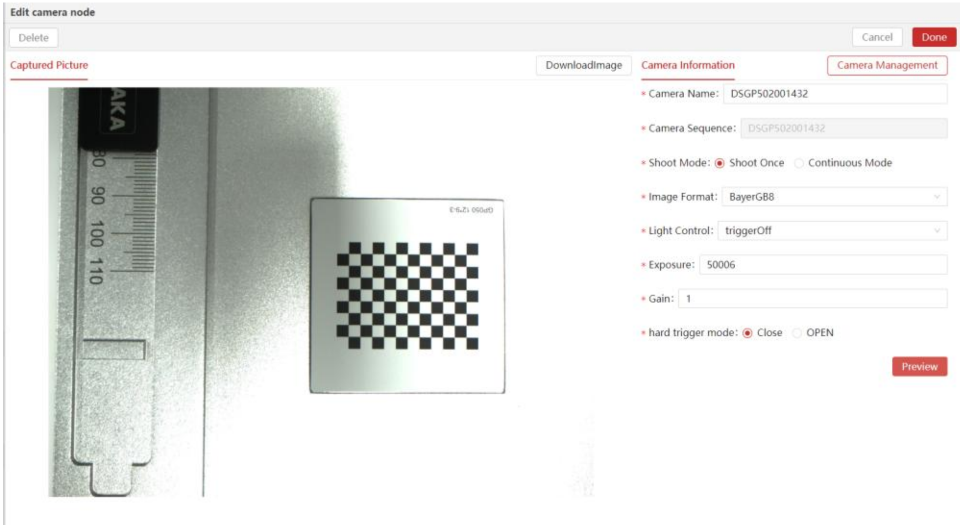


Figure 4.1-3

4) Open the calibration node, such as Figure 4.1-4, configure the calibration parameters, and ensure that [Start Calibration] after the robot is powered on and enabled. If the calibration board exceeds the field of view, please appropriately enlarge and reduce the motion step coefficient. After successful calibration, click [Finish].

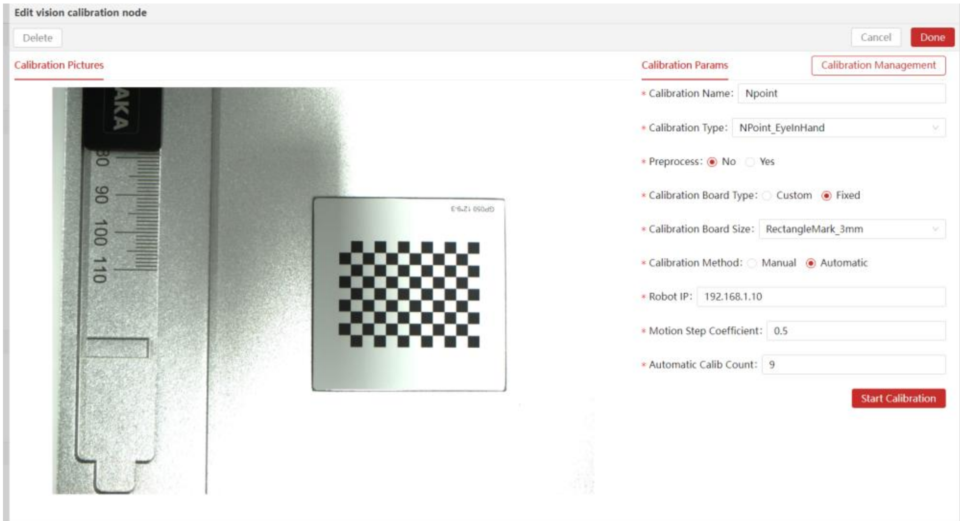


Figure 4.1-4

4.2 Positioning and grabbing visual configuration

1) Find the related process of [Digital Block Capture] on the visual page and open [Camera Management].

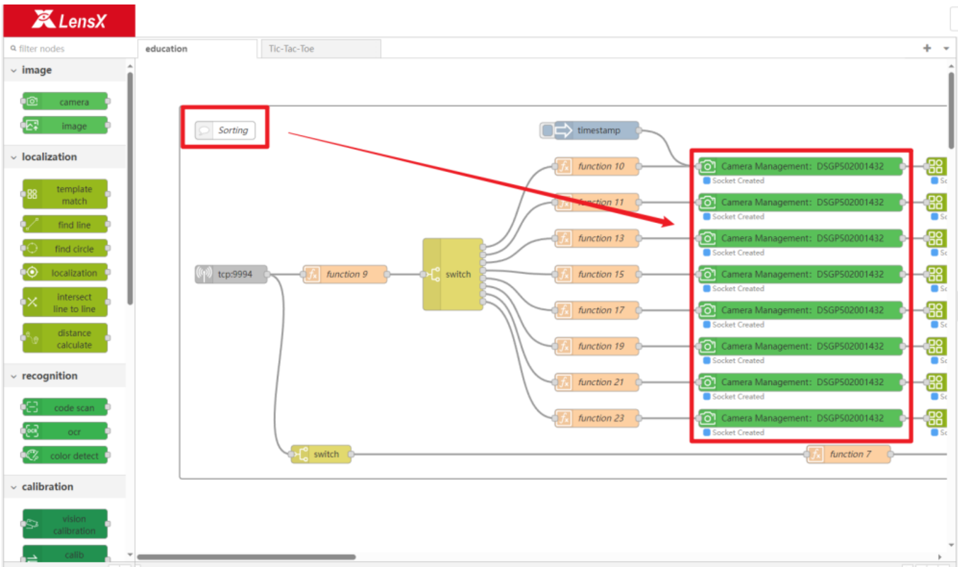


Figure 4.2-1

2) Place all the digital blocks in the center of the field of view, adjust the camera exposure and gain, obtain an image with suitable brightness and click [Finish] to save the settings. As shown in Figure 4.2-2.

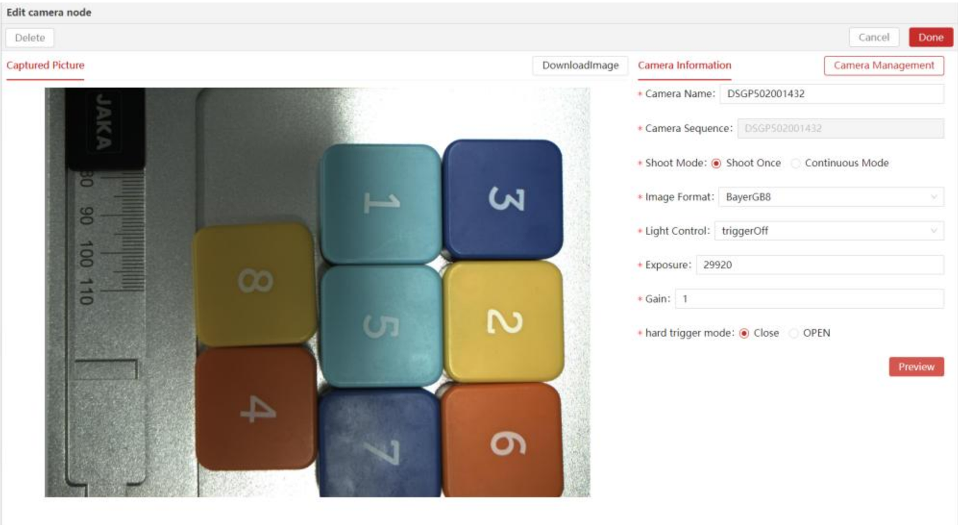


Figure 4.2-2

3) Temporarily connect [Camera] and [Template Matching 1], click the [Timestamp] connected to [Camera] to trigger a photo.

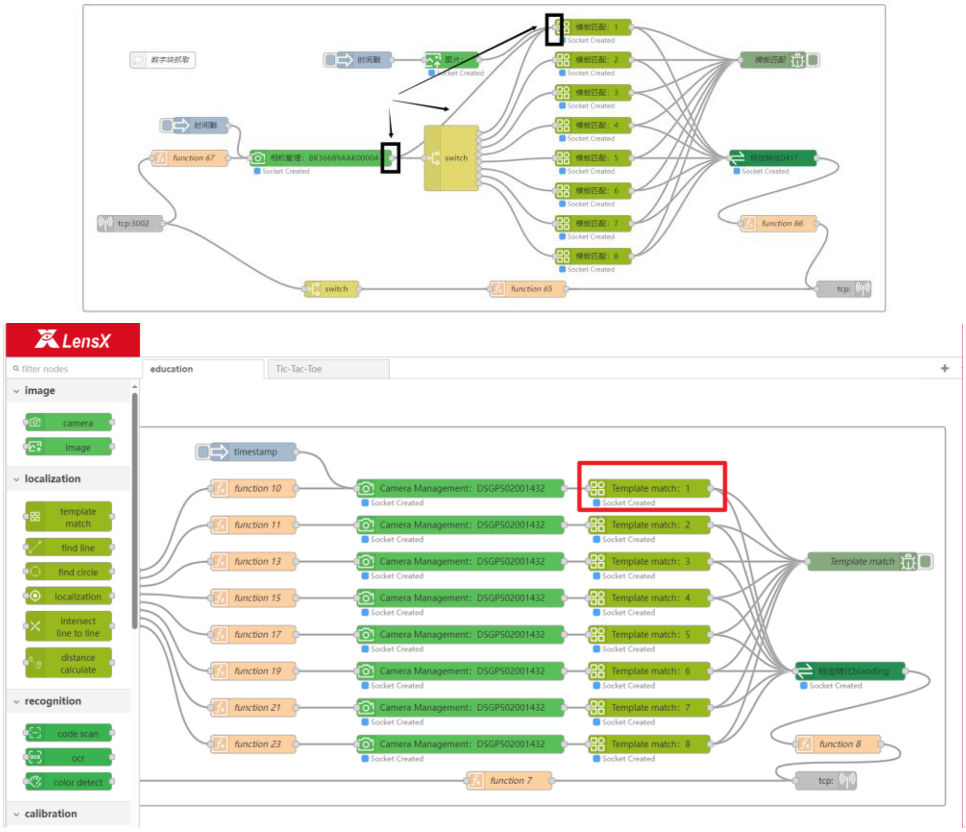


Figure 4.2-3

4) Open the [Template Matching 1] node. For example, Figure 4.2-4 configure template matching parameters. Click Run to create a template for Number Block 1.

Kommentiert [LZ1]: 教育箱内 flow 版本与手册中不同，需要确定

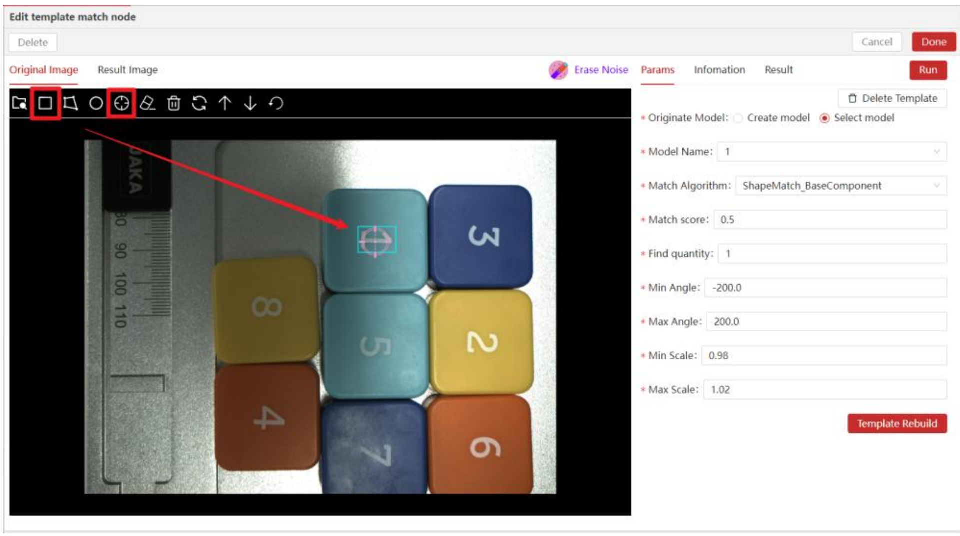


Figure 4.2-4

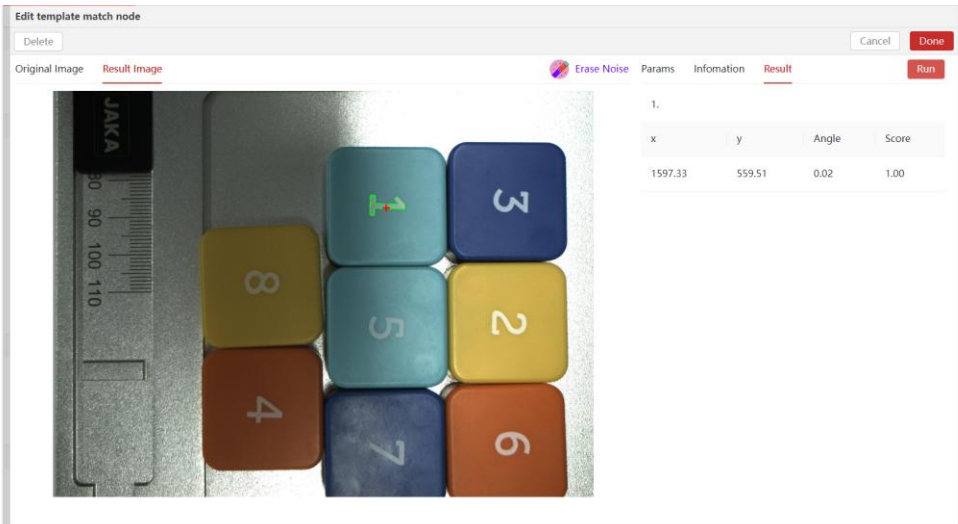


Figure 4.2-5

5) Click Finish to save the template. Delete the connection between [Camera] and [Template Matching 1], temporarily connect [Camera] and [Template Matching 2] together, repeat the third and fourth steps, and create templates for all digital blocks 1-8.

6) Keep the connection between [Camera] and [Template Matching 1] only, open the [Calibration Conversion] node, and select the calibration file created in 4.1. Click Finish.

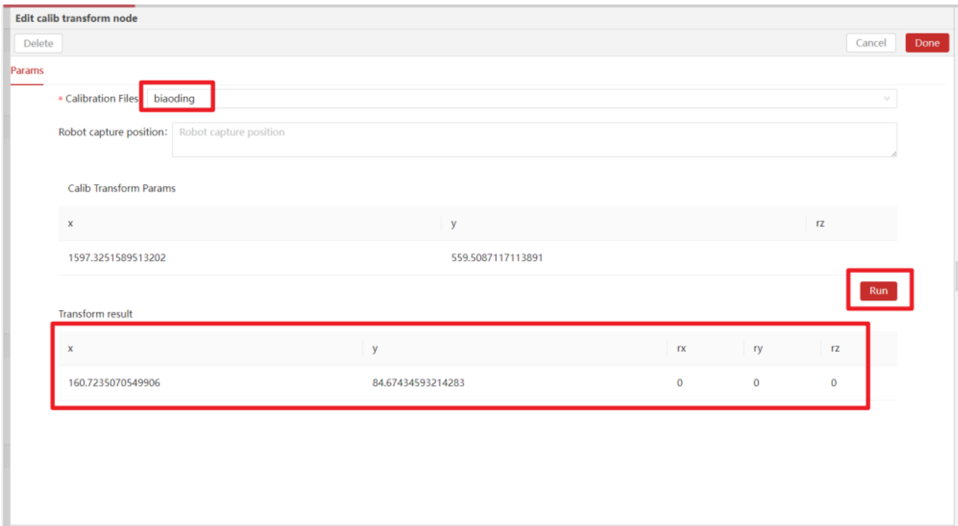


Figure 4.2-6

7) As shown in Figure 4.2-7, click the [Timestamp] connected to [Camera] to trigger a photo and enter the [Calibration Conversion] node. As shown in Figure 4.2-6, click Run, record the calibration conversion results, and click [Finish] to end the visual end configuration.

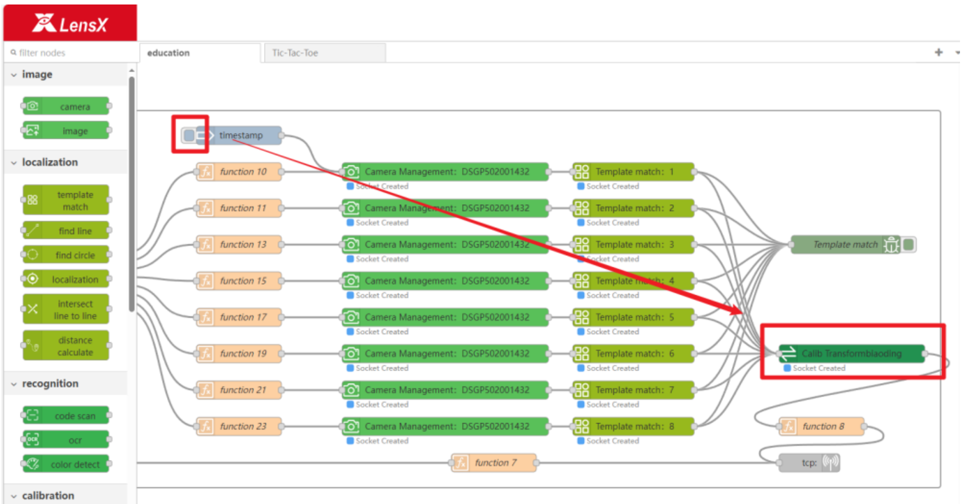


Figure 4.2-7

4.3 Positioning and grabbing robot program configuration

1) Set the calibration conversion result recorded in the previous step to the user coordinate system [Visual Base Point].

Figure4.3-1

2) Set the coordinate system, TCP, and IP.

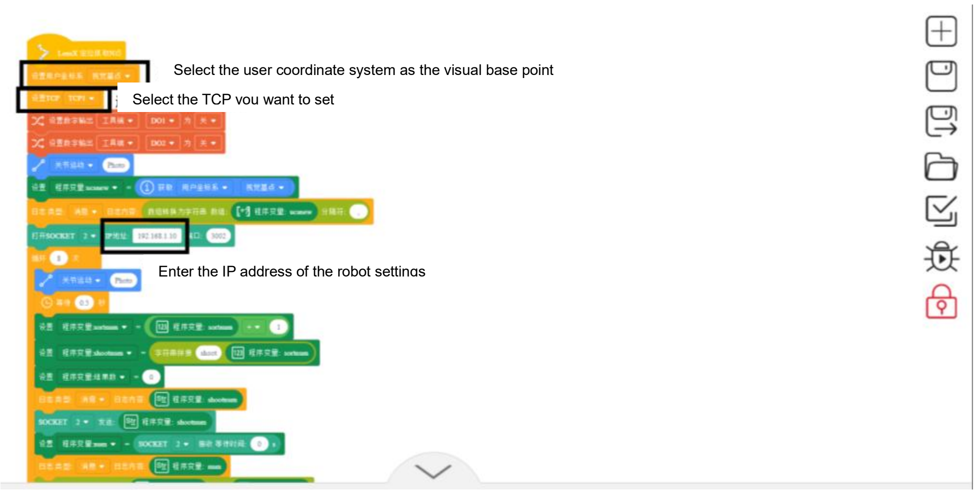


Figure 4.3-2

3) Set the reference point. Set the base point under the [Visual Base Point] coordinate system and [TCP] set in 2.3.1.

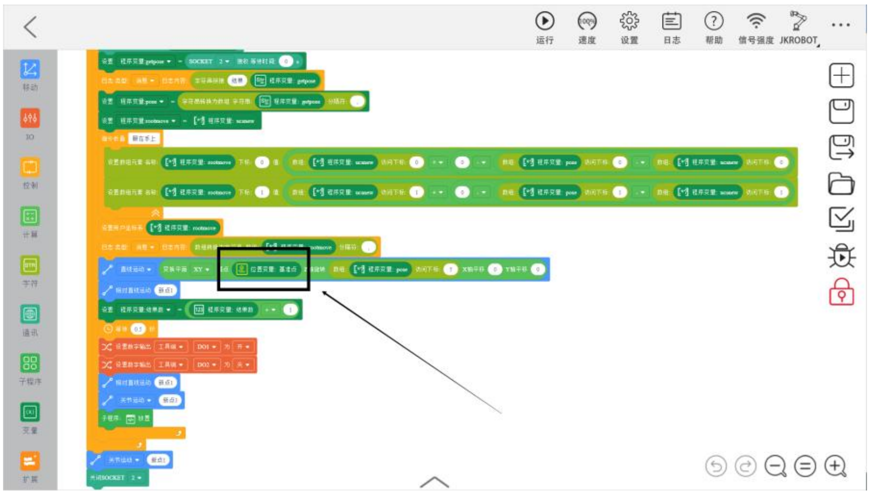


Figure 4.3-3

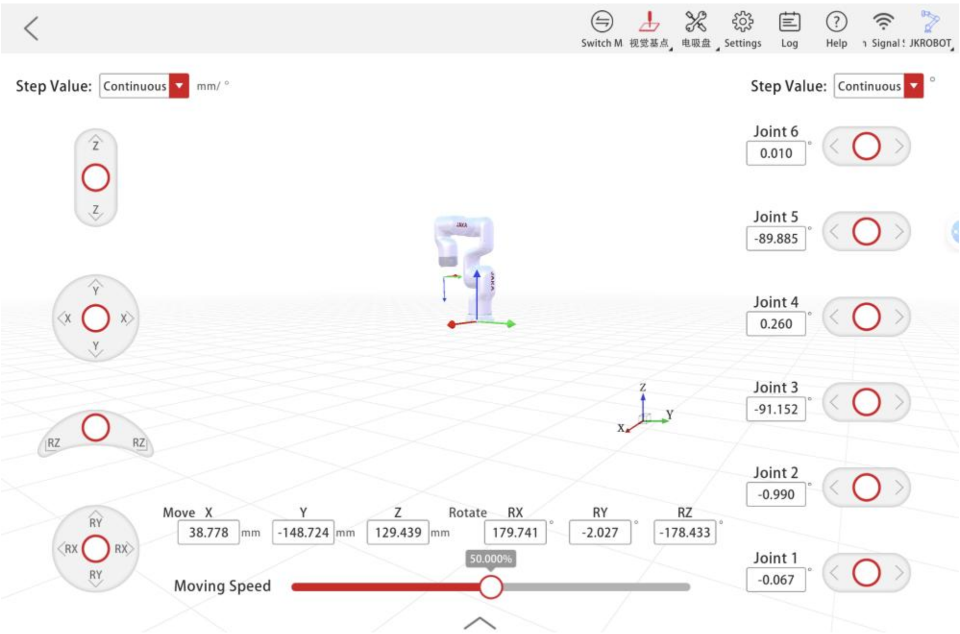
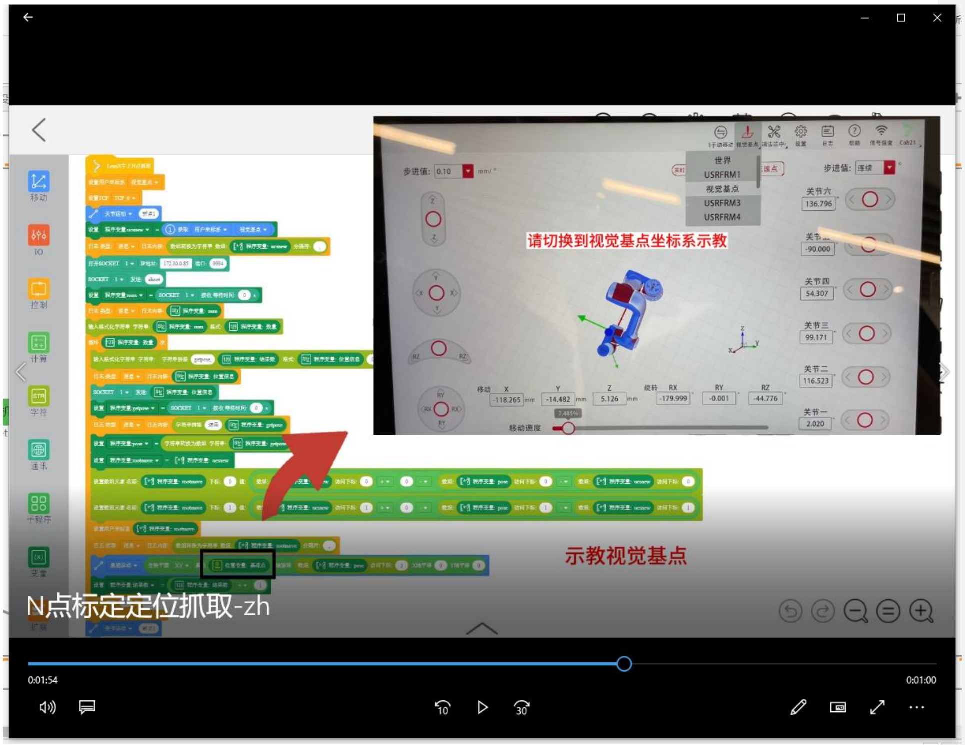


Figure 4.3-4

4) Ensure that the sucking position of the suction cup is the same as the setting position of the [Template Matching] node setting sight.



5) After the setting is completed, run the robot program and the 8 digital blocks will be placed on the right side of the tray in order.

Figure

5. Project configuration-2.5D correction

This chapter is a guide for building the 2.5D function of JAKA Education kit. Before reading, please make sure that the contents of chapters 2-3 have been completed.

5.1 Automatic hand and eye calibration

1) Open the robot program [LensX Side Shot 25 Positioning] and move the robot to the photo point [shoot_ref_pose].

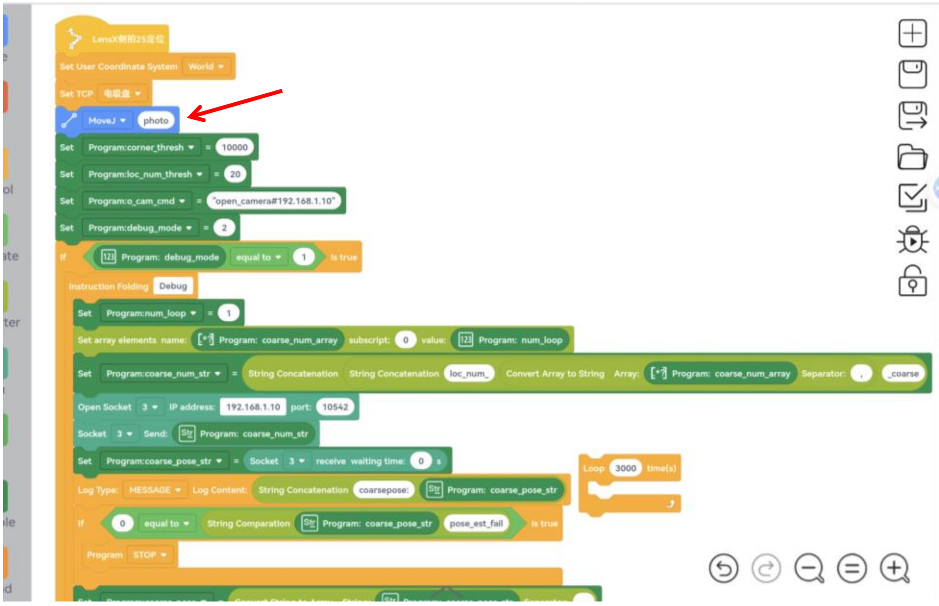


Figure 5.1-1

2) Find the related process of [Calibration] in the vision page and open [Camera Management].

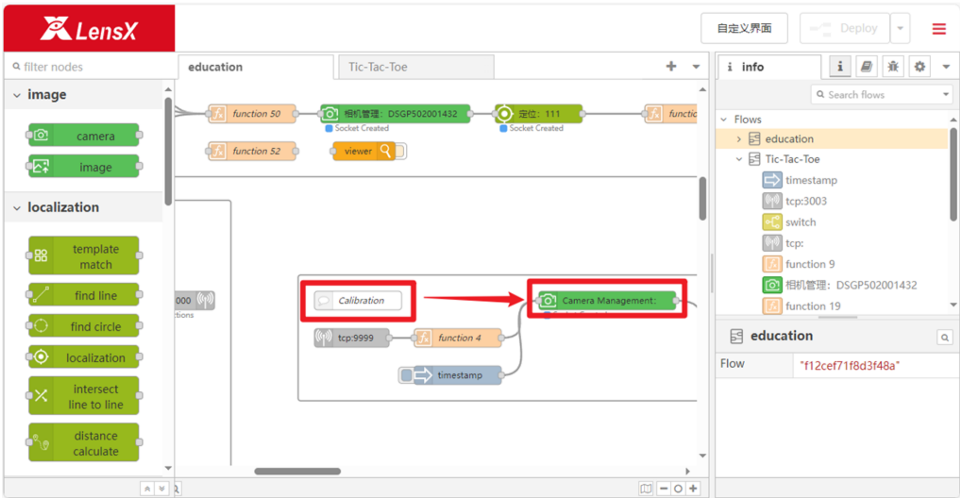


Figure 5.1-2

3) Place the calibration plate in the center of the field of view, adjust the camera exposure and gain, obtain an image with appropriate brightness and click [Finish] to save the settings. As shown in Figure 5.1-3.

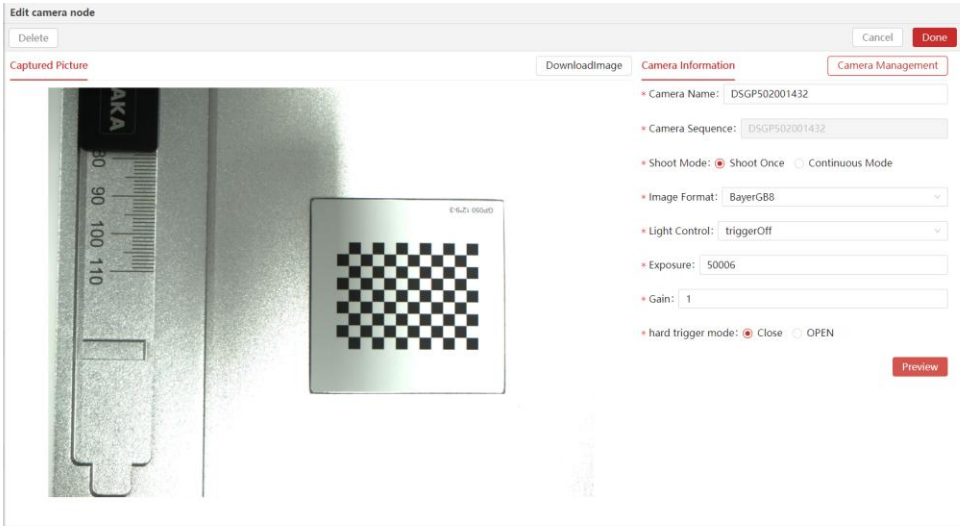
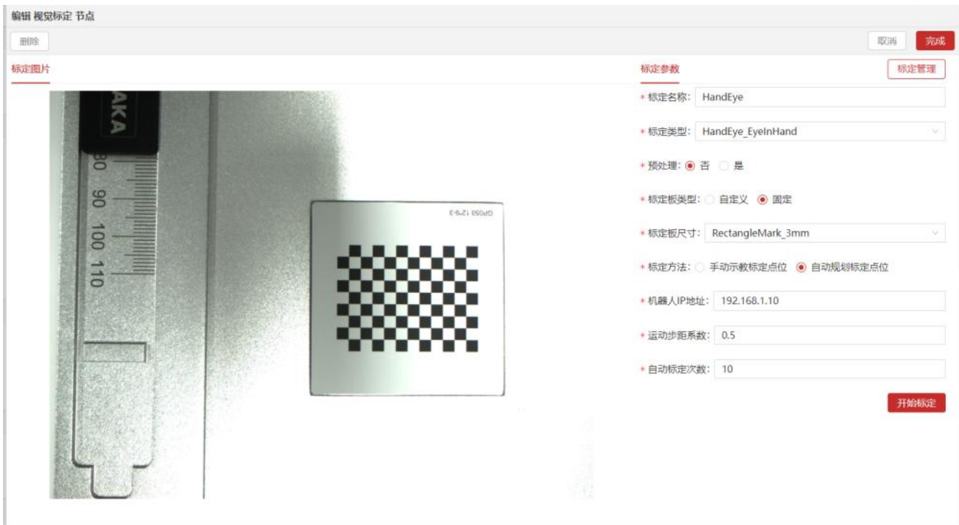


Figure 5.1-3

4) Open the calibration node, such as Figure 5.1-4, configure the calibration parameters, and ensure that [Start Calibration] after the robot is powered on and enabled. If the calibration board exceeds the field of view, please appropriately enlarge and reduce the motion step coefficient. After successful calibration, click [Finish].



Kommentiert [LZ2]: 2.5D 应该使用手眼标定，中文版图片有误，已提供正确版本

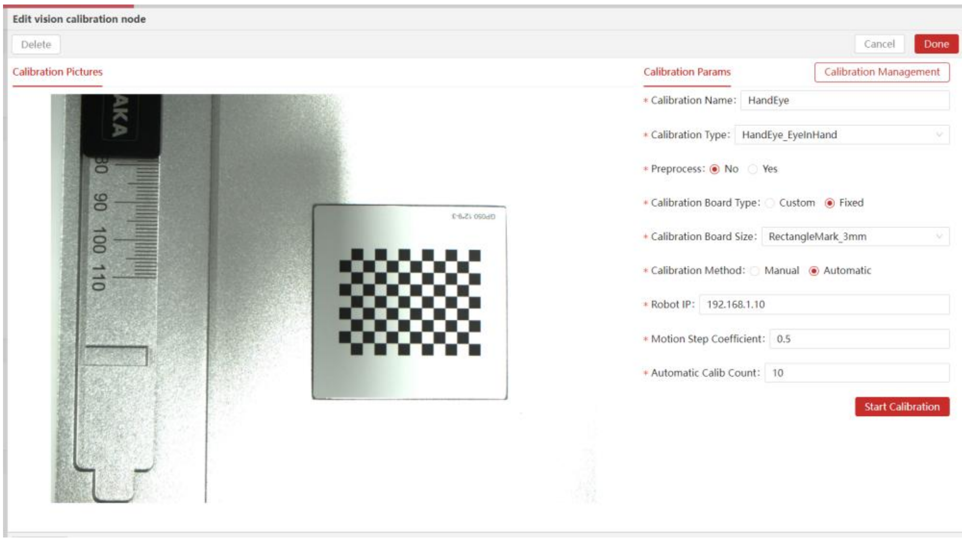

Edit vision calibration node
Delete
Cancel
Done
Calibration Pictures
Calibration Params
Calibration Management
Calibration Name: HandEye
Calibration Type: HandEye_EyeInHand
Preprocess: No Yes
Calibration Board Type: Custom Fixed
Calibration Board Size: RectangleMark_3mm
Calibration Method: Manual Automatic
Robot IP: 192.168.1.10
Motion Step Coefficient: 0.5
Automatic Calib Count: 10
Start Calibration

Figure 5.1-4

5.2 2.5D positioning configuration

The use of the 2.5D side shot function is divided into two stages: Debug and Online. In Debug mode, users manually trigger the run and can observe the corresponding results after each run to determine whether the positioning function is running normally. In Online mode, positioning is triggered through socket network communication, which is suitable for the actual running process of the project.

1) First set the Debug mode. Set the coordinate system to the world coordinate system, TCP to the suction cup TCP set in 2.3.1, and set the value of the program variable debug_mode to the number "1". If a different IP is set in 2.3.1 than in the manual, please modify all IP addresses in the robot program.

Figure 5.2-1

2) Run the robot program and wait for it to block. Don't stop the robot program, perform visual configuration.

3) Find the related process of [2.5D positioning] in the vision page and open [Camera Management].

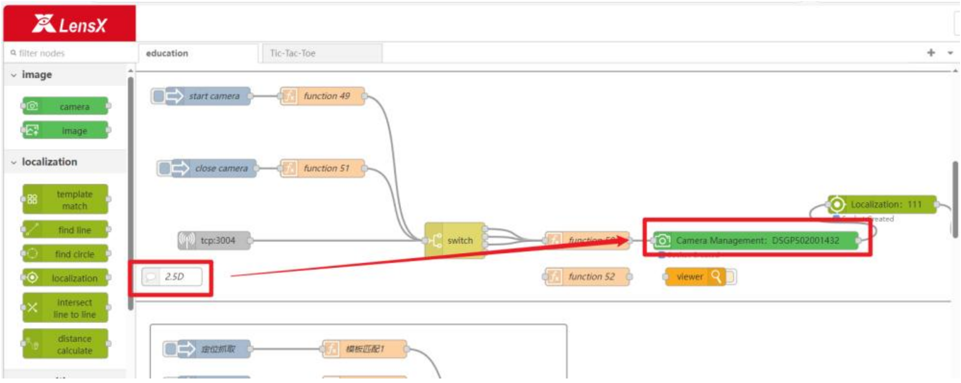


Figure 5.2-2

4) Place the AlignMark in the center of the field of view, adjust the camera exposure gain, obtain images suitable for the two images, and click [Finish] to save the settings. Image quality reference in Figure 5.2-3.

5) Double-click to open the positioning node (as shown in Figure 1-2) and set the positioning node parameters. Among them: 1 is the customized positioning name; 2 the hand-eye calibration file is the calibration file created in Chapter 5.1; 3 the feature code type, it is recommended to use the feature code in the education kit, which is 36h11_50; 4 the tool TCP number is the one created in 2.3.1 The number of TCP; 5 robot IP is the robot IP set in 2.3.1; 6 is the advanced parameter, the default is No, and there will be no further explanation here. After the parameters are configured, click 7 to save the pose, and finally click Run.

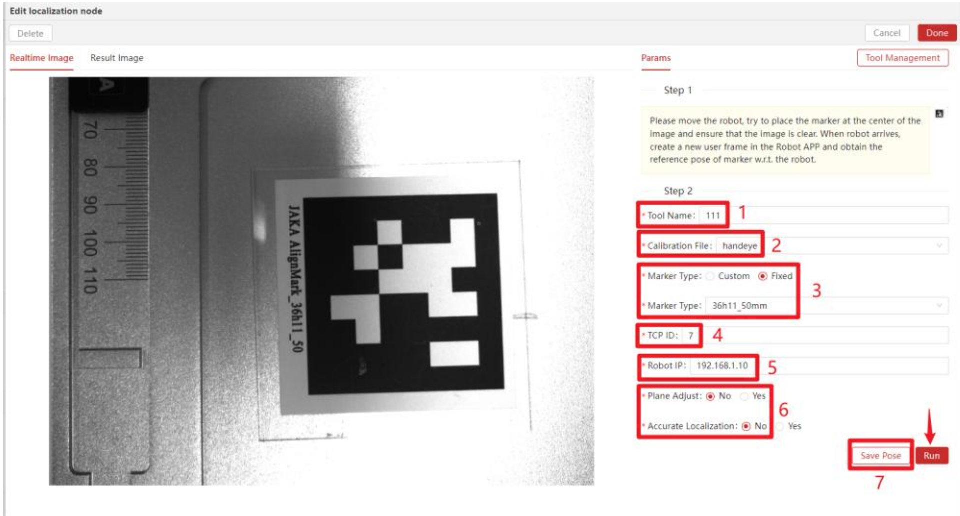


Figure 5.2-3

6) After the robot moves in place, the upper left corner returns to the theoretical positioning error. coarse_trans_error is the translation deviation of the feature board in the camera coordinate system, coarse_rot_error is the rotation deviation of the feature board in the camera coordinate system, coarse_corner_error is the pixel

deviation of the feature board in the camera coordinate system, and loc_coarse_num is the number of robot adjustments in Debug mode. Finally, click on complete at the upper right corner.

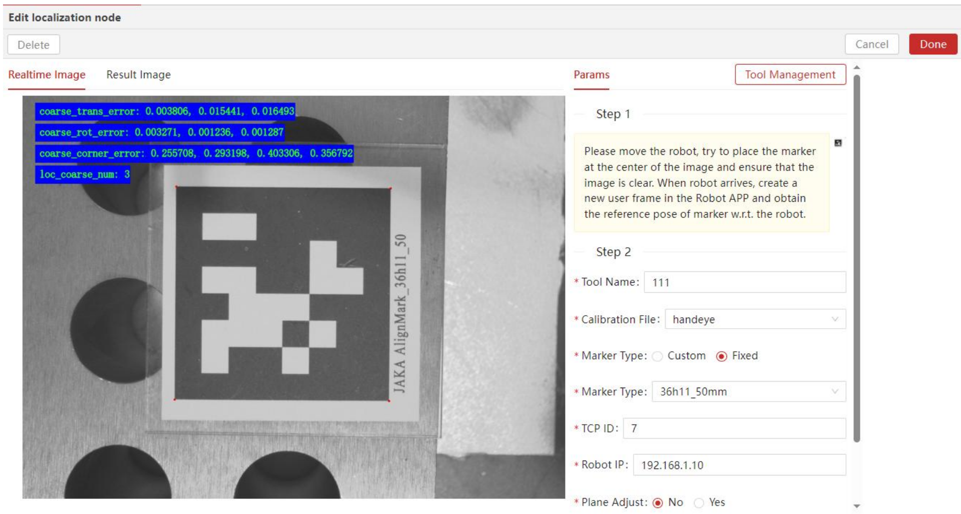


Figure 5.2-4

7) Switch back to the robot program and set the value of the program variable debug_mode to the number "2". After the setting is completed, run the robot program and the robot will adjust its posture to ensure that the relative posture between the camera and AlignMark remains unchanged.

6. Project Configuration-Visual Identity

This chapter is a guidance for setting up visual inspection of JAKA Education Kit. Before reading, please make sure that the contents of chapters 2-3 have been completed.

6.1 Distance Calculation

6.1.1 Length area calibration

1) Open the robot program [Education Kit] and move the robot to the photo point [Distance Measurement].

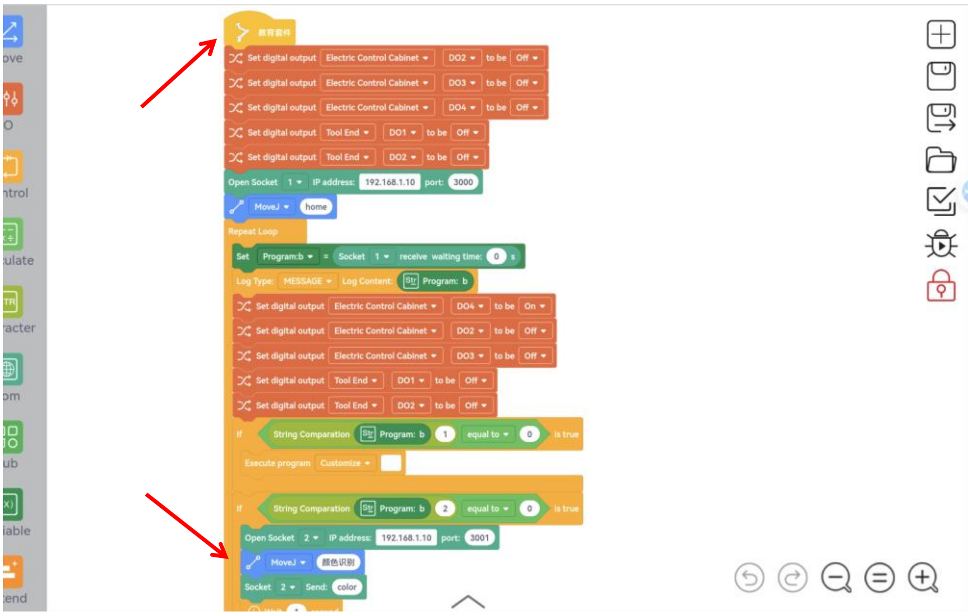


Figure 6.1-1

2) Find the related process of [Calibration] in the vision page and open [Camera Management].

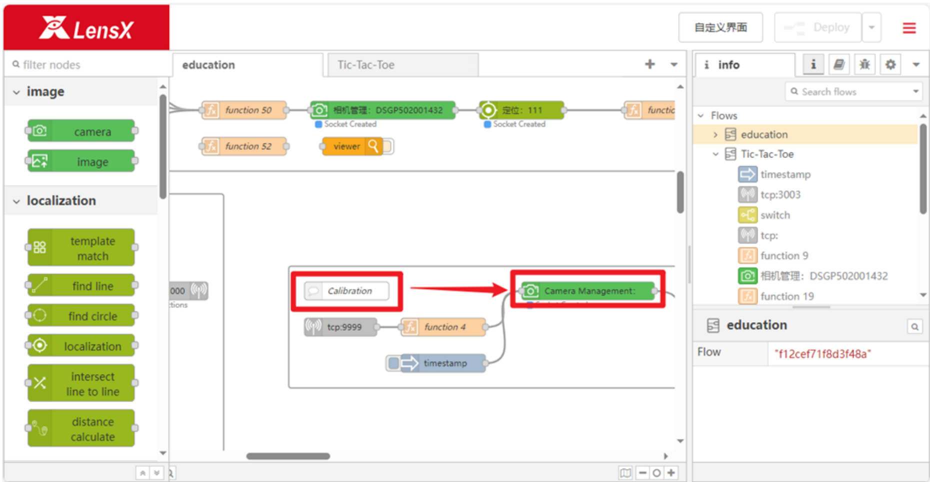


Figure 6.1-2

3) Remove the top board of the education kit, place the calibration board in the center of the field of view, adjust the camera exposure and gain, and click [Finish] to save the settings after obtaining an image with appropriate brightness. As shown in Figure 4.1-3.

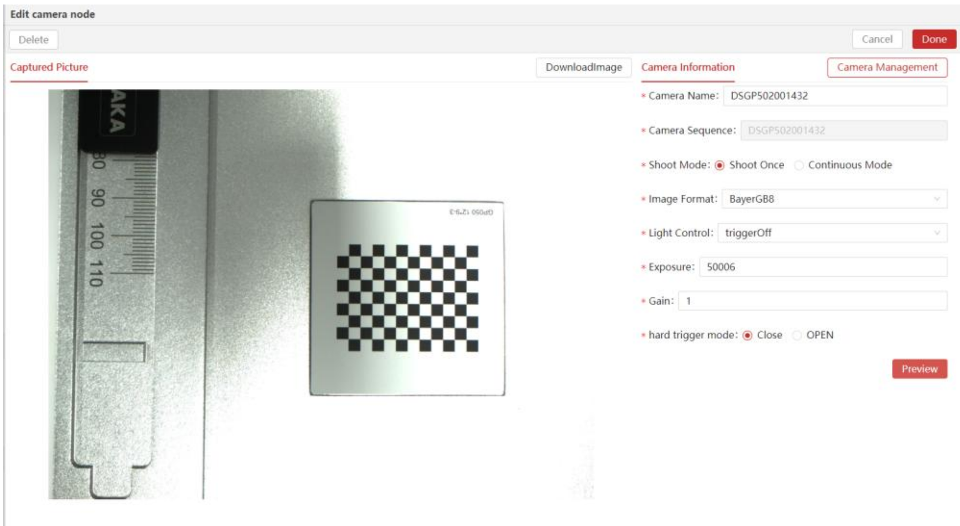


Figure 6.1-3

4) Open the calibration node, such asFigure 4.1-4, configure the calibration parameters, and ensure that [Start Calibration] after the robot is powered on and enabled. If the calibration board exceeds the field of view, please appropriately enlarge and reduce the motion step coefficient. After successful calibration, click [Finish].

Kommentiert [LZ3]: 距离计算应该使用长度面积标定，中文版图片有误，已提供正确版本

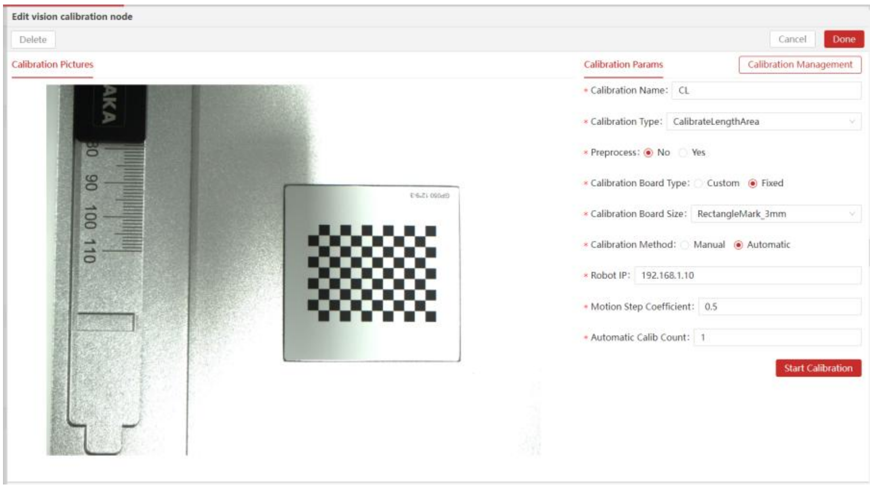

Edit vision calibration node
Delete
Cancel
Done
Calibration Pictures
Calibration Params
Calibration Management
Calibration Name: CL
Calibration Type: CalibrateLengthArea
Preprocess: No Yes
Calibration Board Type: Custom Fixed
Calibration Board Size: RectangleMark_3mm
Calibration Method: Manual Automatic
Robot IP: 192.168.1.10
Motion Step Coefficient: 0.5
Automatic Calib Count: 1
Start Calibration

Figure 6.1-4

6.1.2 Vision program configuration

1) Find the [Distance Calculation] related process in the vision page and open [Camera Management].

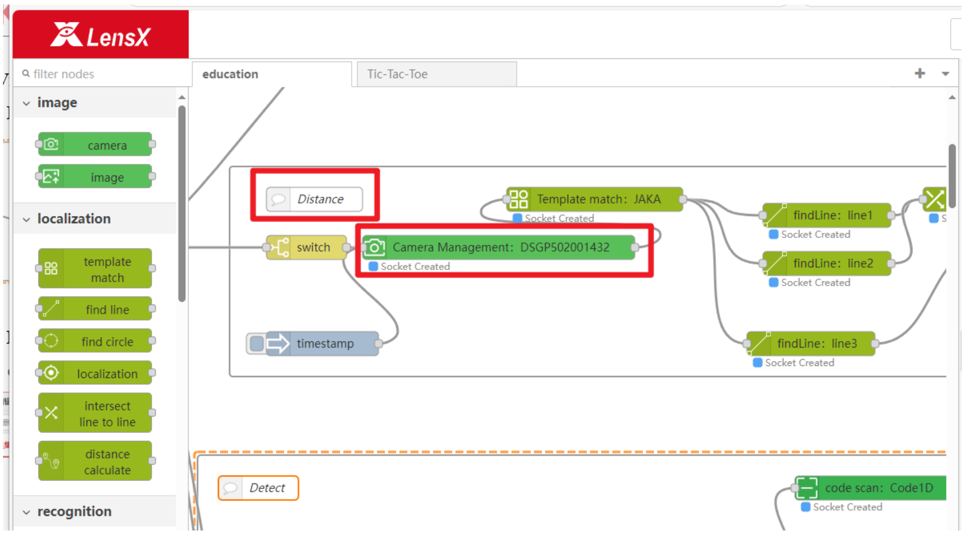


Figure 6.1-5

2) Put the top board of the education kit back, place the JAKA slider in the center of the field of view, adjust the camera exposure and gain, and click [Finish] to save the settings after obtaining an appropriate image.

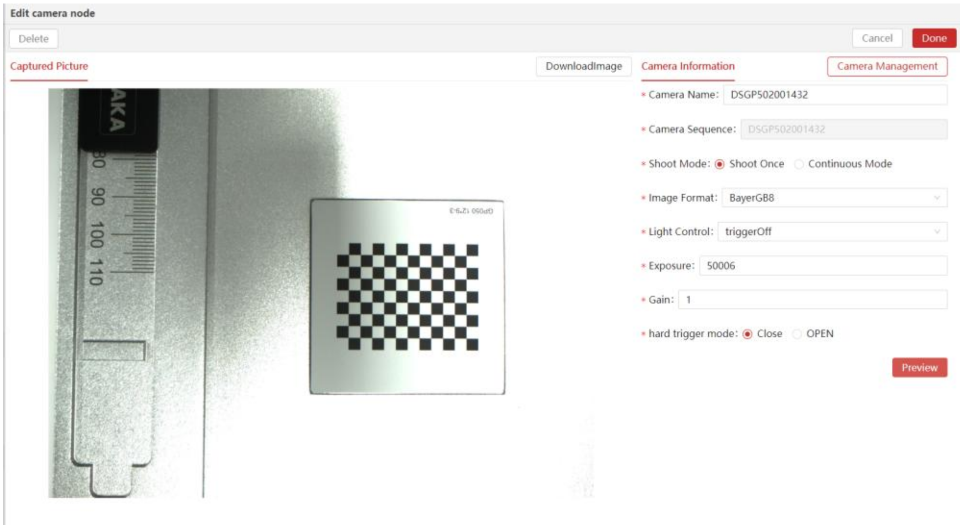


Figure 6.1-6

3) Open the [Template Matching] node and configure the template matching parameters. Click Run to create a template for the JAKA slider.

4) Open the [Edge Finding] node and configure the edge finding parameters.

5) Open the [Line Intersection] node and configure the line intersection parameters.

6) Open the [Distance Calculation] node and configure distance calculation parameters.

7) Open the [Calibration Transformation] node and select the calibration file created in 6.1.1.

6.2 Color recognition

1) Open the robot program [Education Kit] and move the robot to the photo point [Color Recognition].

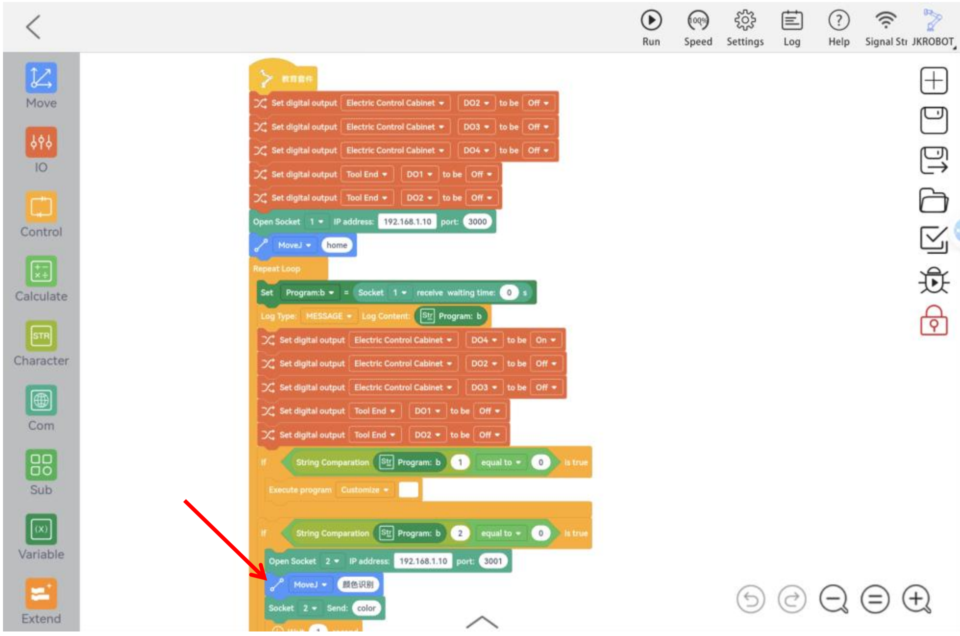


Figure 6.2-1

2) Find the related process of [Color Recognition] in the vision page and open [Camera Management].

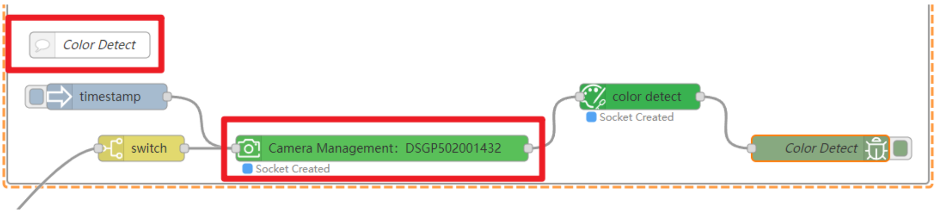


Figure 6.2-2

3) Place the colored block in the center of the field of view, adjust the camera exposure and gain, and click [Finish] to save the settings after obtaining a suitable image.

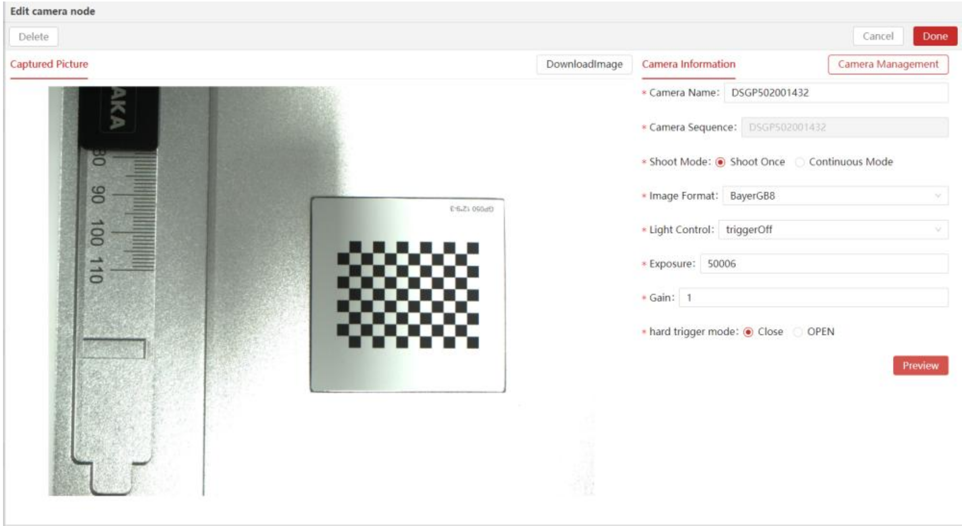


Figure 6.2-3

4) Open the [Color Recognition] node and configure color recognition parameters.

6.3 Scan code text recognition

1) Open the robot program [Education Kit] and move the robot to the photo point [Scan QR Code Character Recognition].

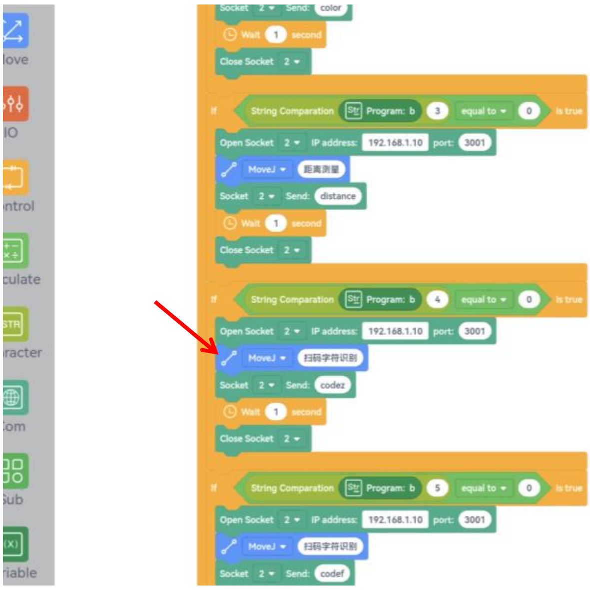


Figure 6.3-1

2) Find the related process of [Code Scanning Text Recognition] on the visual page and open [Camera Management].

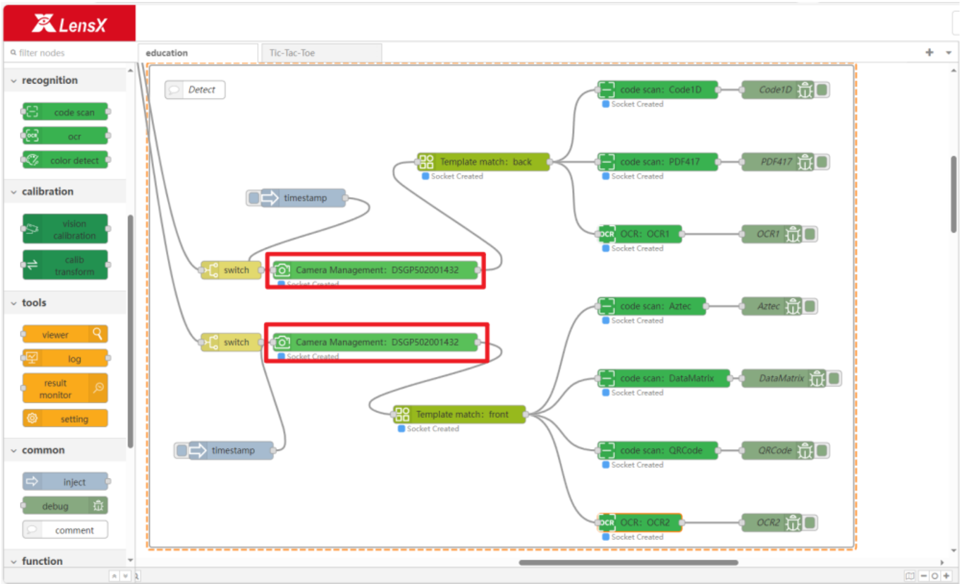


Figure 6.3-2

3) Remove the top board of the education kit, place the scanned text recognition board in the center of the field of view, adjust the camera exposure and gain, obtain an image with appropriate brightness and click [Finish] to save the settings.

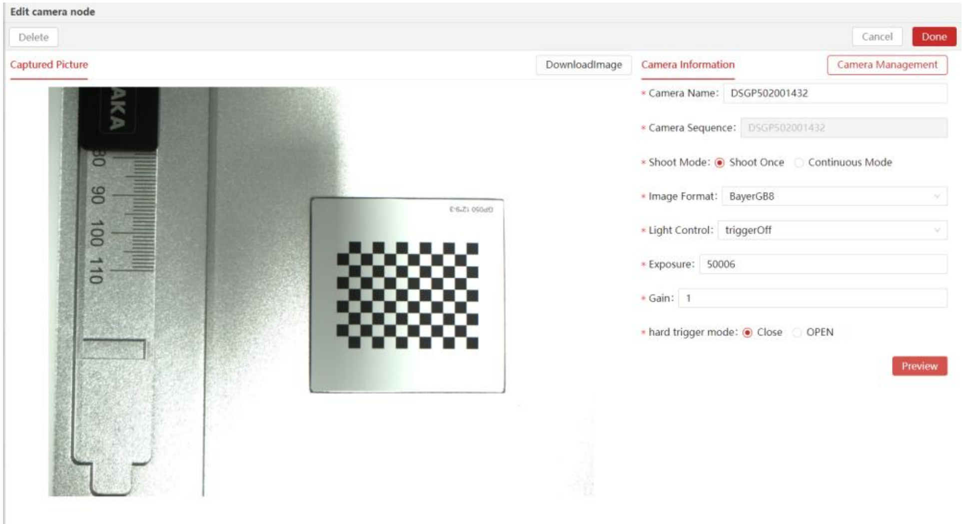


Figure 6.3-3

4) Configure the front, open the [Template Matching: Front] node, and configure the template matching

parameters.

5) Open the [Code Scanning Recognition] node in sequence and configure the QR code recognition parameters.

6) Open the [Text Recognition] node in sequence and configure the text recognition parameters.

7) Configure the back side, open the [Template Matching: Back Side] node, and configure the template matching parameters.

5) Open the [Code Scanning Recognition] node in sequence and configure the QR code recognition parameters.

6) Open the [Text Recognition] node in sequence and configure the text recognition parameters.

7. Project Configuration-Tic Tac Toe Interactive Game

This chapter is a guide for setting up the Tic-Tac-Toe interactive game of the JAKA Education Kit. Before reading, please make sure that the contents of Chapters 2-3 have been completed.

Instructions: In this game, the robot plays circle chess and the player plays cross chess. There will be different robot actions and interactive button lights for draws, robot wins, and player wins. After the player touches the button after completing the chess game, the robot will execute the next move. When the robot action is completed, the button will light up green and the player can perform the next move.

1) Open the robot program [Tic-Tac-Toe] and move the robot to the photo point [Photo]. Set the coordinate system to the world coordinate system, and set the TCP to the sucker TCP established in 2.3.1.

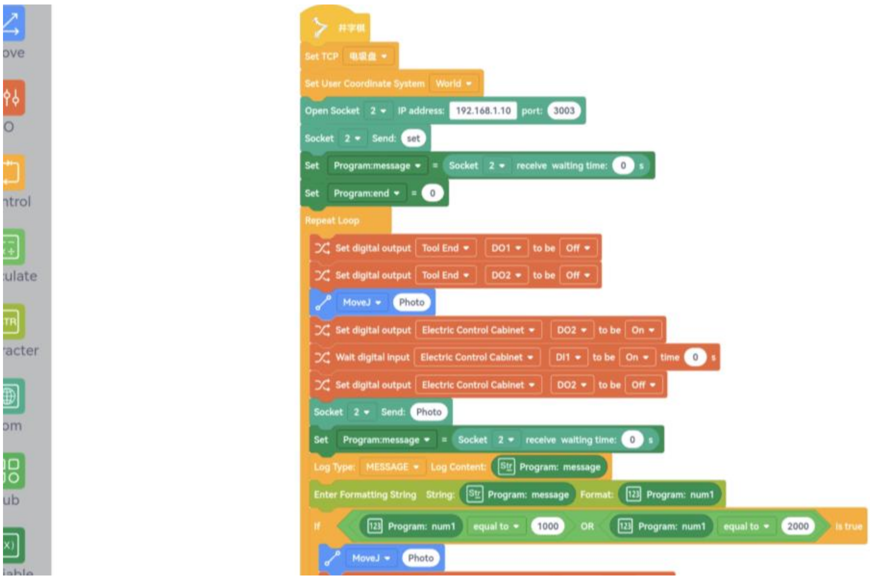


Figure 6.32-1

2) Find the related process of [Tic-Tac-Toe] in the visual page and open [Camera Management].

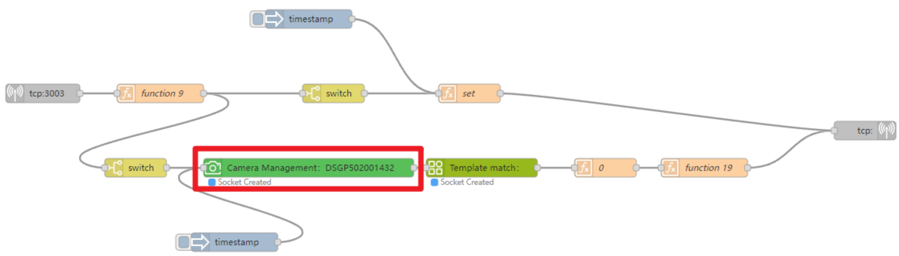


Figure 6.32-2

3) Place the tic-tac-toe board in the center of the field of view and insert a cross. Adjust the camera exposure and gain, and click [Finish] to save the settings after obtaining a suitable image.

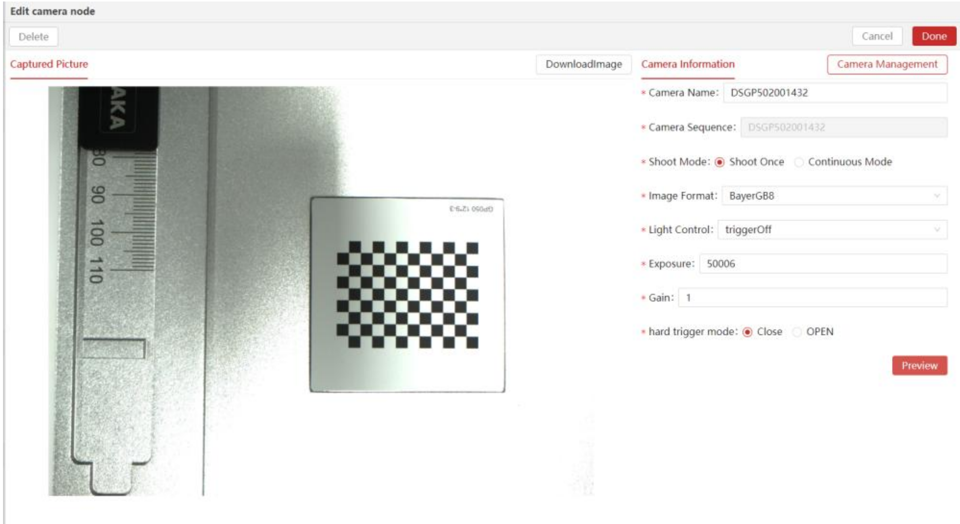


Figure 6.32-5

4) Open the [Template Matching] node, configure the template matching parameters, and create a template for Cross Chess.

8. Customized interactive interface configuration

VISUALIC is a custom interactive interface paired with JAKA Lens X, designed to visualize the execution results of vision software. This chapter is a guide for building custom pages used in the JAKA education kit. It will display some functions that require intuitive visualization on the Web side. Before reading, please ensure that the contents of Chapters 2-7 have been completed.

8.1 Configure the main page

Configure the main page and jump button

8.2 Digital block scraping page

Placeholder

8.3 Distance calculation

Placeholder

8.4 Color recognition

Placeholder

8.5 Identify the front

Placeholder

8.6 Identify the flip side

Placeholder