FANUC Robot series

R-30*i*B/R-30*i*B Mate CONTROLLER

*i*RVision 2D Vision Application

OPERATOR'S MANUAL

B-83304EN-1/02

• Original Instructions

Before using the Robot, be sure to read the "FANUC Robot Safety Manual (B-80687EN)" and understand the content.

The products in this manual are controlled based on Japan’s “Foreign Exchange and Foreign Trade Law”. The export from Japan may be subject to an export license by the government of Japan.
Further, re-export to another country may be subject to the license of the government of the country from where the product is re-exported. Furthermore, the product may also be controlled by re-export regulations of the United States government.
Should you wish to export or re-export these products, please contact FANUC for advice.

In this manual we have tried as much as possible to describe all the various matters.
However, we cannot describe all the matters which must not be done, or which cannot be done, because there are so many possibilities.
Therefore, matters which are not especially described as possible in this manual should be regarded as “impossible”.

SAFETY PRECAUTIONS

Thank you for purchasing FANUC Robot.
This chapter describes the precautions which must be observed to ensure the safe use of the robot.
Before attempting to use the robot, be sure to read this chapter thoroughly.

Before using the functions related to robot operation, read the relevant operator's manual to become familiar with those functions.

If any description in this chapter differs from that in the other part of this manual, the description given in this chapter shall take precedence.

For the safety of the operator and the system, follow all safety precautions when operating a robot and its peripheral devices installed in a work cell.
In addition, refer to the "FANUC Robot SAFETY HANDBOOK (B-80687EN)".

1 WORKING PERSON

The personnel can be classified as follows.

Operator:
- Turns robot controller power ON/OFF
- Starts robot program from operator's panel

Programmer or teaching operator:
- Operates the robot
- Teaches robot inside the safety fence

Maintenance engineer:
- Operates the robot
- Teaches robot inside the safety fence
- Maintenance (adjustment, replacement)

- An operator cannot work inside the safety fence.
- A programmer, teaching operator, and maintenance engineer can work inside the safety fence. The working activities inside the safety fence include lifting, setting, teaching, adjusting, maintenance, etc.
- To work inside the fence, the person must be trained on proper robot operation.

During the operation, programming, and maintenance of your robotic system, the programmer, teaching operator, and maintenance engineer should take additional care of their safety by using the following safety precautions.

- Use adequate clothing or uniforms during system operation
- Wear safety shoes
- Use helmet

2 DEFINITION OF WARNING, CAUTION AND NOTE

To ensure the safety of users and prevent damage to the machine, this manual indicates each precaution on safety with "Warning" or "Caution" according to its severity. Supplementary information is indicated by "Note". Read the contents of each "Warning", "Caution" and "Note" before attempting to use the robots.

> ⚠**WARNING**
> Applied when there is a danger of the user being injured or when there is a danger of both the user being injured and the equipment being damaged if the approved procedure is not observed.

> ⚠**CAUTION**
> Applied when there is a danger of the equipment being damaged, if the approved procedure is not observed.

> **NOTE**
> Notes are used to indicate supplementary information other than Warnings and Cautions.

- Read this manual carefully, and store it in a sales place.

3 WORKING PERSON SAFETY

Working person safety is the primary safety consideration. Because it is very dangerous to enter the operating space of the robot during automatic operation, adequate safety precautions must be observed.
The following lists the general safety precautions. Careful consideration must be made to ensure working person safety.

(1) Have the robot system working persons attend the training courses held by FANUC.

> FANUC provides various training courses. Contact our sales office for details.

(2) Even when the robot is stationary, it is possible that the robot is still in a ready to move state, and is waiting for a signal. In this state, the robot is regarded as still in motion. To ensure working person safety, provide the system with an alarm to indicate visually or aurally that the robot is in motion.
(3) Install a safety fence with a gate so that no working person can enter the work area without passing through the gate. Install an interlocking device, a safety plug, and so forth in the safety gate so that the robot is stopped as the safety gate is opened.

> The controller is designed to receive this interlocking signal of the door switch. When the gate is opened and this signal received, the controller stops the robot (Please refer to "STOP TYPE OF ROBOT" in SAFETY PRECAUTIONS for detail of stop type). For connection, see Fig.3 (a) and Fig.3 (b).

(4) Provide the peripheral devices with appropriate grounding (Class A, Class B, Class C, and Class D).

(5) Try to install the peripheral devices outside the work area.
(6) Draw an outline on the floor, clearly indicating the range of the robot motion, including the tools such as a hand.
(7) Install a mat switch or photoelectric switch on the floor with an interlock to a visual or aural alarm that stops the robot when a working person enters the work area.
(8) If necessary, install a safety lock so that no one except the working person in charge can turn on the power of the robot.

The circuit breaker installed in the controller is designed to disable anyone from turning it on when it is locked with a padlock.

(9) When adjusting each peripheral device independently, be sure to turn off the power of the robot
(10) Operators should be ungloved while manipulating the operator’s panel or teach pendant. Operation with gloved fingers could cause an operation error.
(11) Programs, system variables, and other information can be saved on memory card or USB memories. Be sure to save the data periodically in case the data is lost in an accident.
(12) The robot should be transported and installed by accurately following the procedures recommended by FANUC. Wrong transportation or installation may cause the robot to fall, resulting in severe injury to workers.
(13) In the first operation of the robot after installation, the operation should be restricted to low speeds. Then, the speed should be gradually increased to check the operation of the robot.
(14) Before the robot is started, it should be checked that no one is in the area of the safety fence. At the same time, a check must be made to ensure that there is no risk of hazardous situations. If detected, such a situation should be eliminated before the operation.
(15) When the robot is used, the following precautions should be taken. Otherwise, the robot and peripheral equipment can be adversely affected, or workers can be severely injured.
- Avoid using the robot in a flammable environment.
- Avoid using the robot in an explosive environment.
- Avoid using the robot in an environment full of radiation.
- Avoid using the robot under water or at high humidity.
- Avoid using the robot to carry a person or animal.
- Avoid using the robot as a stepladder. (Never climb up on or hang from the robot.)
(16) When connecting the peripheral devices related to stop(safety fence etc.) and each signal (external emergency , fence etc.) of robot. be sure to confirm the stop movement and do not take the wrong connection.
(17) When preparing trestle, please consider security for installation and maintenance work in high place according to Fig.3 (c). Please consider footstep and safety bolt mounting position.

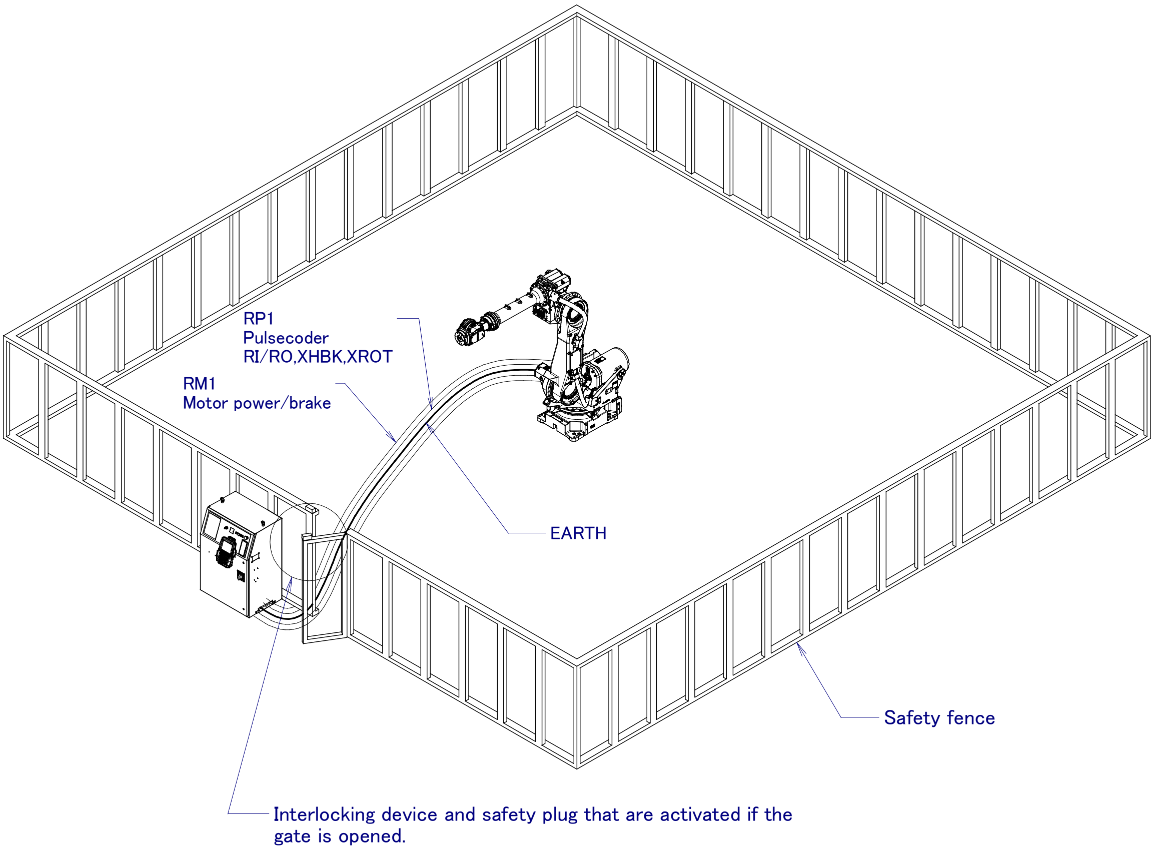
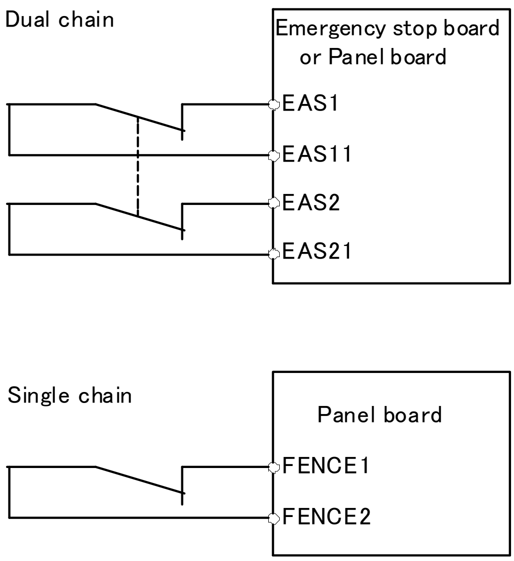


Fig. 3 (a) Safety fence and safety gate



(Note)

In case of R-30*i*B, R-30*i*B Mate
Terminals EAS1,EAS11,EAS2,EAS21 are provided on the emergency stop board.

In case R-30*i*A
Terminals EAS1,EAS11,EAS2,EAS21 are provided on the emergency stop board or connector panel

In case R-30*i*A Mate
Terminals EAS1,EAS11,EAS2,EAS21 or FENCE1,FENCE2 are provided on the emergency stop board or in the connector panel of CRM65 (Open air type).

Refer to the ELECTRICAL CONNCETIONS Chapter of CONNECTION of controller maintenance manual for details.

Fig. 3 (b) Limit switch circuit diagram of the safety fence

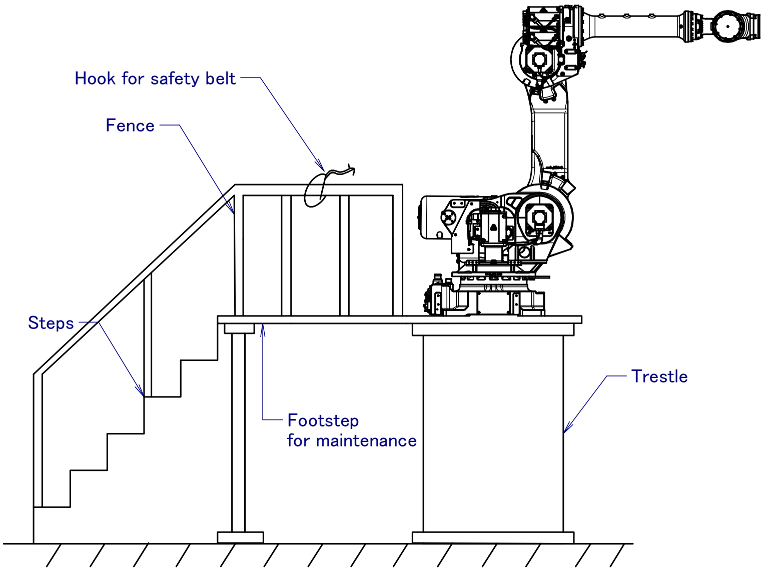


Fig.3 (c) Footstep for maintenance

3.1 OPERATOR SAFETY

The operator is a person who operates the robot system. In this sense, a worker who operates the teach pendant is also an operator. However, this section does not apply to teach pendant operators.

(1) If you do not have to operate the robot, turn off the power of the robot controller or press the EMERGENCY STOP button, and then proceed with necessary work.
(2) Operate the robot system at a location outside of the safety fence
(3) Install a safety fence with a safety gate to prevent any worker other than the operator from entering the work area unexpectedly and to prevent the worker from entering a dangerous area.
(4) Install an EMERGENCY STOP button within the operator's reach.

The robot controller is designed to be connected to an external EMERGENCY STOP button. With this connection, the controller stops the robot operation (Please refer to "STOP TYPE OF ROBOT" in SAFETY PRECAUTIONS for detail of stop type), when the external EMERGENCY STOP button is pressed. See the diagram below for connection.

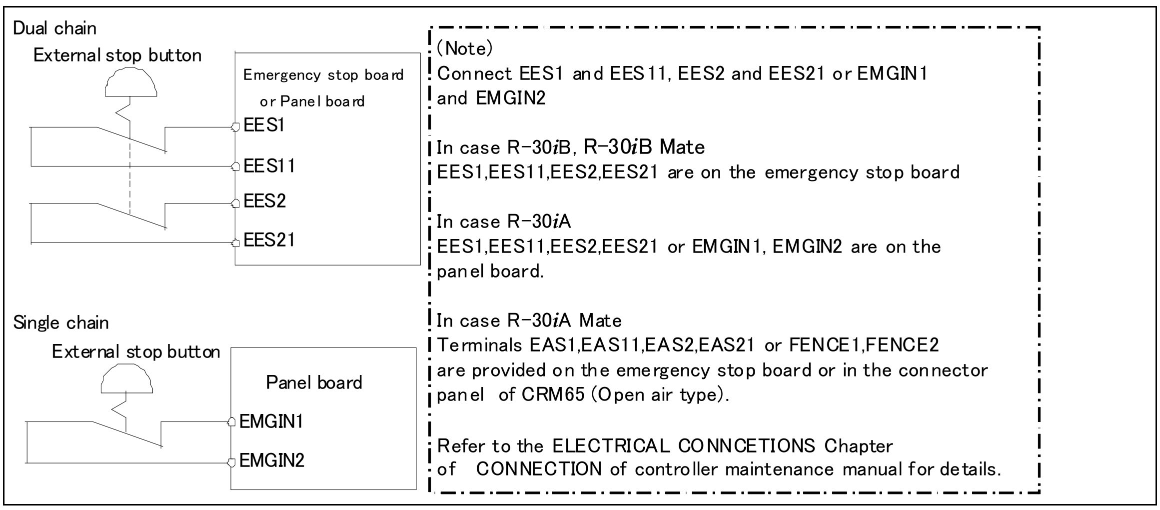


Fig.3.1 Connection diagram for external emergency stop button

3.2 SAFETY OF THE PROGRAMMER

While teaching the robot, the operator must enter the work area of the robot. The operator must ensure the safety of the teach pendant operator especially.

(1) Unless it is specifically necessary to enter the robot work area, carry out all tasks outside the area.
(2) Before teaching the robot, check that the robot and its peripheral devices are all in the normal operating condition.
(3) If it is inevitable to enter the robot work area to teach the robot, check the locations, settings, and other conditions of the safety devices (such as the EMERGENCY STOP button, the DEADMAN switch on the teach pendant) before entering the area.
(4) The programmer must be extremely careful not to let anyone else enter the robot work area.
(5) Programming should be done outside the area of the safety fence as far as possible. If programming needs to be done in the area of the safety fence, the programmer should take the following precautions:
    - Before entering the area of the safety fence, ensure that there is no risk of dangerous situations in the area.
    - Be prepared to press the emergency stop button whenever necessary.
    - Robot motions should be made at low speeds.
    - Before starting programming, check the entire system status to ensure that no remote instruction to the peripheral equipment or motion would be dangerous to the user.

Our operator panel is provided with an emergency stop button and a key switch (mode switch) for selecting the automatic operation mode (AUTO) and the teach modes (T1 and T2). Before entering the inside of the safety fence for the purpose of teaching, set the switch to a teach mode, remove the key from the mode switch to prevent other people from changing the operation mode carelessly, then open the safety gate. If the safety gate is opened with the automatic operation mode set, the robot stops (Please refer to "STOP TYPE OF ROBOT" in SAFETY PRECAUTIONS for detail of stop type). After the switch is set to a teach mode, the safety gate is disabled. The programmer should understand that the safety gate is disabled and is responsible for keeping other people from entering the inside of the safety fence. (In case of R-30*i*A Mate Controller standard specification, there is no mode switch. The automatic operation mode and the teach mode is selected by teach pendant enable switch.)

Our teach pendant is provided with a DEADMAN switch as well as an emergency stop button. These button and switch function as follows:
(1) Emergency stop button: Causes an emergency stop (Please refer to "STOP TYPE OF ROBOT" in SAFETY PRECAUTIONS for detail of stop type) when pressed.
(2) DEADMAN switch: Functions differently depending on the teach pendant enable/disable switch setting status.
    (a) Disable: The DEADMAN switch is disabled.
    (b) Enable: Servo power is turned off when the operator releases the DEADMAN switch or when the operator presses the switch strongly.
    Note) The DEADMAN switch is provided to stop the robot when the operator releases the teach pendant or presses the pendant strongly in case of emergency. The R-30*i*B/R-30*i*B Mate/R-30*i*A/ R-30*i*A Mate employs a 3-position DEADMAN switch, which allows the robot to operate when the 3-position DEADMAN switch is pressed to its intermediate point. When the operator releases the DEADMAN switch or presses the switch strongly, the robot stops immediately.

The operator's intention of starting teaching is determined by the controller through the dual operation of setting the teach pendant enable/disable switch to the enable position and pressing the DEADMAN switch. The operator should make sure that the robot could operate in such conditions and be responsible in carrying out tasks safely.

Based on the risk assessment by FANUC, number of operation of DEADMAN SW should not exceed about 10000 times per year.

The teach pendant, operator panel, and peripheral device interface send each robot start signal. However the validity of each signal changes as follows depending on the mode switch and the DEADMAN switch of the operator panel, the teach pendant enable switch and the remote condition on the software.

In case of R-30*i*B/R-30*i*B Mate/R-30*i*A Controller or CE or RIA specification of R-30*i*A Mate Controller

Mode	Teach pendant enable switch	Software remote condition	Teach pendant	Operator panel	Peripheral device
AUTO mode	On	Local	Not allowed	Not allowed	Not allowed
		Remote	Not allowed	Not allowed	Not allowed
	Off	Local	Not allowed	Allowed to start	Not allowed
		Remote	Not allowed	Not allowed	Allowed to start
T1, T2 mode	On	Local	Allowed to start	Not allowed	Not allowed
		Remote	Allowed to start	Not allowed	Not allowed
	Off	Local	Not allowed	Not allowed	Not allowed
		Remote	Not allowed	Not allowed	Not allowed

T1,T2 mode: DEADMAN switch is effective.

In case of standard specification of R-30*i*A Mate Controller

Teach pendant enable switch	Software remote condition	Teach pendant	Peripheral device
On	Ignored	Allowed to start	Not allowed
Off	Local	Not allowed	Not allowed
	Remote	Not allowed	Allowed to start

(6) (Only when R-30*i*B/R-30*i*B Mate /R-30*i*A Controller or CE or RIA specification of R-30*i*A Mate controller is selected.) To start the system using the operator’s panel, make certain that nobody is the robot work area and that there are no abnormal conditions in the robot work area.
(7) When a program is completed, be sure to carry out a test operation according to the procedure below.
  (a) Run the program for at least one operation cycle in the single step mode at low speed.
  (b) Run the program for at least one operation cycle in the continuous operation mode at low speed.
  (c) Run the program for one operation cycle in the continuous operation mode at the intermediate speed and check that no abnormalities occur due to a delay in timing.
  (d) Run the program for one operation cycle in the continuous operation mode at the normal operating speed and check that the system operates automatically without trouble.
  (e) After checking the completeness of the program through the test operation above, execute it in the automatic operation mode.
(8) While operating the system in the automatic operation mode, the teach pendant operator should leave the robot work area.

3.3 SAFETY OF THE MAINTENANCE ENGINEER

For the safety of maintenance engineer personnel, pay utmost attention to the following.

(1) During operation, never enter the robot work area.
(2) A hazardous situation may arise when the robot or the system, are kept with their power-on during maintenance operations. Therefore, for any maintenance operation, the robot and the system should be put into the power-off state. If necessary, a lock should be in place in order to prevent any other person from turning on the robot and/or the system. In case maintenance needs to be executed in the power-on state, the emergency stop button must be pressed.
(3) If it becomes necessary to enter the robot operation range while the power is on, press the emergency stop button on the operator panel, or the teach pendant before entering the range. The

maintenance personnel must indicate that maintenance work is in progress and be careful not to allow other people to operate the robot carelessly.

(4) When entering the area enclosed by the safety fence, the maintenance worker must check the entire system in order to make sure no dangerous situations exist. In case the worker needs to enter the safety area whilst a dangerous situation exists, extreme care must be taken, and entire system status must be carefully monitored.

(5) Before the maintenance of the pneumatic system is started, the supply pressure should be shut off and the pressure in the piping should be reduced to zero.

(6) Before the start of teaching, check that the robot and its peripheral devices are all in the normal operating condition.

(7) Do not operate the robot in the automatic mode while anybody is in the robot work area.

(8) When you maintain the robot alongside a wall or instrument, or when multiple workers are working nearby, make certain that their escape path is not obstructed.

(9) When a tool is mounted on the robot, or when any moving device other than the robot is installed, such as belt conveyor, pay careful attention to its motion.

(10) If necessary, have a worker who is familiar with the robot system stand beside the operator panel and observe the work being performed. If any danger arises, the worker should be ready to press the EMERGENCY STOP button at any time.

(11) When replacing a part, please contact FANUC service center. If a wrong procedure is followed, an accident may occur, causing damage to the robot and injury to the worker.

(12) When replacing or reinstalling components, take care to prevent foreign material from entering the system.

(13) When handling each unit or printed circuit board in the controller during inspection, turn off the circuit breaker to protect against electric shock.
If there are two cabinets, turn off the both circuit breaker.

(14) A part should be replaced with a part recommended by FANUC. If other parts are used, malfunction or damage would occur. Especially, a fuse that is not recommended by FANUC should not be used. Such a fuse may cause a fire.

(15) When restarting the robot system after completing maintenance work, make sure in advance that there is no person in the work area and that the robot and the peripheral devices are not abnormal.

(16) When a motor or brake is removed, the robot arm should be supported with a crane or other equipment beforehand so that the arm would not fall during the removal.

(17) Whenever grease is spilled on the floor, it should be removed as quickly as possible to prevent dangerous falls.

(18) The following parts are heated. If a maintenance worker needs to touch such a part in the heated state, the worker should wear heat-resistant gloves or use other protective tools.

- Servo motor
- Inside the controller
- Reducer
- Gearbox
- Wrist unit

(19) Maintenance should be done under suitable light. Care must be taken that the light would not cause any danger.

(20) When a motor, reducer, or other heavy load is handled, a crane or other equipment should be used to protect maintenance workers from excessive load. Otherwise, the maintenance workers would be severely injured.

(21) The robot should not be stepped on or climbed up during maintenance. If it is attempted, the robot would be adversely affected. In addition, a misstep can cause injury to the worker.

(22)When performing maintenance work in high place, secure a footstep and wear safety belt.

(23) After the maintenance is completed, spilled oil or water and metal chips should be removed from the floor around the robot and within the safety fence.

(24) When a part is replaced, all bolts and other related components should put back into their original places. A careful check must be given to ensure that no components are missing or left not mounted.

(25) In case robot motion is required during maintenance, the following precautions should be taken :

- Foresee an escape route. And during the maintenance motion itself, monitor continuously the whole system so that your escape route will not become blocked by the robot, or by peripheral equipment.
- Always pay attention to potentially dangerous situations, and be prepared to press the emergency stop button whenever necessary.

(26) The robot should be periodically inspected. (Refer to the robot mechanical manual and controller maintenance manual.) A failure to do the periodical inspection can adversely affect the performance or service life of the robot and may cause an accident

(27) After a part is replaced, a test operation should be given for the robot according to a predetermined method. (See TESTING section of “Controller operator’s manual”.) During the test operation, the maintenance staff should work outside the safety fence.

4 SAFETY OF THE TOOLS AND PERIPHERAL DEVICES

4.1 PRECAUTIONS IN PROGRAMMING

(1) Use a limit switch or other sensor to detect a dangerous condition and, if necessary, design the program to stop the robot when the sensor signal is received.

(2) Design the program to stop the robot when an abnormal condition occurs in any other robots or peripheral devices, even though the robot itself is normal.

(3) For a system in which the robot and its peripheral devices are in synchronous motion, particular care must be taken in programming so that they do not interfere with each other.

(4) Provide a suitable interface between the robot and its peripheral devices so that the robot can detect the states of all devices in the system and can be stopped according to the states.

4.2 PRECAUTIONS FOR MECHANISM

(1) Keep the component cells of the robot system clean, and operate the robot in an environment free of grease, water, and dust.

(2) Don’t use unconfirmed liquid for cutting fluid and cleaning fluid.

(3) Employ a limit switch or mechanical stopper to limit the robot motion so that the robot or cable does not strike against its peripheral devices or tools.

(4) Observe the following precautions about the mechanical unit cables. Failure to follow precautions may cause mechanical troubles.

- Use mechanical unit cable that have required user interface.
- Don’t add user cable or hose to inside of mechanical unit.
- Please do not obstruct the movement of the mechanical unit cable when cables are added to outside of mechanical unit.
- In the case of the model that a cable is exposed, Please do not perform remodeling (Adding a protective cover and fix an outside cable more) obstructing the behavior of the outcrop of the cable.
- When installing user peripheral equipment on the robot mechanical unit, please pay attention that equipment does not interfere with the robot itself.

(5) The frequent power-off stop for the robot during operation causes the trouble of the robot. Please avoid the system construction that power-off stop would be operated routinely. (Refer to bad case example.) Please execute power-off stop after reducing the speed of the robot and stopping it by hold stop or cycle stop when it is not urgent. (Please refer to "STOP TYPE OF ROBOT" in SAFETY PRECAUTIONS for detail of stop type.)
(Bad case example)

- Whenever poor product is generated, a line stops by emergency stop.
- When alteration was necessary, safety switch is operated by opening safety fence and power-off stop is executed for the robot during operation.
- An operator pushes the emergency stop button frequently, and a line stops.
- An area sensor or a mat switch connected to safety signal operate routinely and power-off stop is executed for the robot.

(6) Robot stops urgently when collision detection alarm (SRVO-050) etc. occurs. Please try to avoid unnecessary power-off stops. It may cause the trouble of the robot, too. So remove the causes of the alarm.

5 SAFETY OF THE ROBOT MECHANISM

5.1 PRECAUTIONS IN OPERATION

(1) When operating the robot in the jog mode, set it at an appropriate speed so that the operator can manage the robot in any eventuality.
(2) Before pressing the jog key, be sure you know in advance what motion the robot will perform in the jog mode.

5.2 PRECAUTIONS IN PROGRAMMING

(1) When the work areas of robots overlap, make certain that the motions of the robots do not interfere with each other.
(2) Be sure to specify the predetermined work origin in a motion program for the robot and program the motion so that it starts from the origin and terminates at the origin.
Make it possible for the operator to easily distinguish at a glance that the robot motion has terminated.

5.3 PRECAUTIONS FOR MECHANISMS

(1) Keep the work areas of the robot clean, and operate the robot in an environment free of grease, water, and dust.

5.4 PROCEDURE TO MOVE ARM WITHOUT DRIVE POWER IN EMERGENCY OR ABNORMAL SITUATIONS

For emergency or abnormal situations (e.g. persons trapped in or by the robot), brake release unit can be used to move the robot axes without drive power.

Please refer to controller maintenance manual and mechanical unit operator’s manual for using method of brake release unit and method of supporting robot.

6 SAFETY OF THE END EFFECTOR

6.1 PRECAUTIONS IN PROGRAMMING

(1) To control the pneumatic, hydraulic and electric actuators, carefully consider the necessary time delay after issuing each control command up to actual motion and ensure safe control.
(2) Provide the end effector with a limit switch, and control the robot system by monitoring the state of the end effector.

7 STOP TYPE OF ROBOT

The following three robot stop types exist:

Power-Off Stop (Category 0 following IEC 60204-1)

Servo power is turned off and the robot stops immediately. Servo power is turned off when the robot is moving, and the motion path of the deceleration is uncontrolled.
The following processing is performed at Power-Off stop.

- An alarm is generated and servo power is turned off.
- The robot operation is stopped immediately. Execution of the program is paused.

Controlled stop (Category 1 following IEC 60204-1)

The robot is decelerated until it stops, and servo power is turned off.
The following processing is performed at Controlled stop.

- The alarm "SRVO-199 Controlled stop" occurs along with a decelerated stop. Execution of the program is paused.
- An alarm is generated and servo power is turned off.

Hold (Category 2 following IEC 60204-1)

The robot is decelerated until it stops, and servo power remains on.
The following processing is performed at Hold.

- The robot operation is decelerated until it stops. Execution of the program is paused.

> ⚠ **WARNING**
> The stopping distance and stopping time of Controlled stop are longer than the stopping distance and stopping time of Power-Off stop. A risk assessment for the whole robot system, which takes into consideration the increased stopping distance and stopping time, is necessary when Controlled stop is used.

When the emergency stop button is pressed or the FENCE is open, the stop type of robot is Power-Off stop or Controlled stop. The configuration of stop type for each situation is called *stop pattern*. The stop pattern is different according to the controller type or option configuration.

There are the following 3 Stop patterns.

Stop pattern	Mode	Emergency stop button	External Emergency stop	FENCE open	SVOFF input	Servo disconnect
A	AUTO	P-Stop	P-Stop	C-Stop	C-Stop	P-Stop
	T1	P-Stop	P-Stop	-	C-Stop	P-Stop
	T2	P-Stop	P-Stop	-	C-Stop	P-Stop
B	AUTO	P-Stop	P-Stop	P-Stop	P-Stop	P-Stop
	T1	P-Stop	P-Stop	-	P-Stop	P-Stop
	T2	P-Stop	P-Stop	-	P-Stop	P-Stop
C	AUTO	C-Stop	C-Stop	C-Stop	C-Stop	C-Stop
	T1	P-Stop	P-Stop	-	C-Stop	P-Stop
	T2	P-Stop	P-Stop	-	C-Stop	P-Stop

P-Stop: Power-Off stop
C-Stop: Controlled stop
-: Disable

The following table indicates the Stop pattern according to the controller type or option configuration.

Option	R-30*i*B/R-30*i*B Mate
Standard	A (*)
Controlled stop by E-Stop (A05B-2600-J570)	C (*)

(*) R-30*i*B/R-30*i*B Mate does not have servo disconnect. R-30*i*B Mate does not have SVOFF input.

Option	R-30*i*A				R-30*i*A Mate		
	Standard (Single)	Standard (Dual)	RIA type	CE type	Standard	RIA type	CE type
Standard	B (*)	A	A	A	A (**)	A	A
Stop type set (Stop pattern C) (A05B-2500-J570)	N/A	N/A	C	C	N/A	C	C

(*) R-30*i*A standard (single) does not have servo disconnect.
(**) R-30*i*A Mate Standard does not have servo disconnect, and the stop type of SVOFF input is Power-Off stop.

The stop pattern of the controller is displayed in "Stop pattern" line in software version screen. Please refer to "Software version" in operator's manual of controller for the detail of software version screen.

"Controlled stop by E-Stop" option

When "Controlled stop by E-Stop" (A05B-2600-J570) option (In case of R-30*i*A/R-30*i*A Mate, it is Stop type set (Stop pattern C) (A05B-2500-J570)) is specified, the stop type of the following alarms becomes Controlled stop but only in AUTO mode. In T1 or T2 mode, the stop type is Power-Off stop which is the normal operation of the system.

Alarm	Condition
SRVO-001 Operator panel E-stop	Operator panel emergency stop is pressed.
SRVO-002 Teach pendant E-stop	Teach pendant emergency stop is pressed.
SRVO-007 External emergency stops	External emergency stop input (EES1-EES11, EES2-EES21) is open. (R-30*i*A/R-30*i*B/R-30*i*B Mate controller)
SRVO-194 Servo disconnect	Servo disconnect input (SD4-SD41, SD5-SD51) is open. (R-30*i*A controller)
SRVO-218 Ext.E-stop/Servo Disconnect	External emergency stop input (EES1-EES11, EES2-EES21) is open. (R-30*i*A Mate controller)
SRVO-408 DCS SSO Ext Emergency Stop	In DCS Safe I/O connect function, SSO[3] is OFF.
SRVO-409 DCS SSO Servo Disconnect	In DCS Safe I/O connect function, SSO[4] is OFF.

Controlled stop is different from Power-Off stop as follows:

- In Controlled stop, the robot is stopped on the program path. This function is effective for a system where the robot can interfere with other devices if it deviates from the program path.
- In Controlled stop, physical impact is less than Power-Off stop. This function is effective for systems where the physical impact to the mechanical unit or EOAT (End Of Arm Tool) should be minimized.
- The stopping distance and stopping time of Controlled stop is longer than the stopping distance and stopping time of Power-Off stop, depending on the robot model and axis. Please refer to the operator's manual of a particular robot model for the data of stopping distance and stopping time.

In case of R-30*i*A or R-30*i*A Mate, this function is available only in CE or RIA type hardware.

When this option is loaded, this function cannot be disabled.

The stop type of DCS Position and Speed Check functions is not affected by the loading of this option.

⚠ **WARNING**

The stopping distance and stopping time of Controlled stop are longer than the stopping distance and stopping time of Power-Off stop. A risk assessment for the whole robot system, which takes into consideration the increased stopping distance and stopping time, is necessary when this option is loaded.

TABLE OF CONTENTS

APPENDIX

1 PREFACE

This chapter describes an overview of this manual which should be noted before operating the *i*RVision function.

1.1 OVERVIEW OF THE MANUAL

Overview

This manual describes how to operate *i*RVision controlled by the R-30*i*B/ R-30*i*B Mate controller. This manual is directed to users who are reasonably familiar with the FANUC two-dimensional vision.
In this manual, only the operation and the technique of programming for the dedicated sensor functions are explained, assuming that the installation and the setup of the robot are completed. Refer to the "R-30*i*B/ R-30*i*B Mate CONTROLLER OPERATOR'S MANUAL (Basic Operation) (B–83284EN)" about other operations of FANUC Robots.

> ⚠**CAUTION**
> This manual is based on R-30*i*B system software of V8.20P/01 version. Note that the functions and settings not described in this manual may be available, and some notation differences are present, depending on the software version.

Contents of this manual

Chapter 1	How to use this manual.
Chapter 2	About vision system
Chapter 3	Overview of each application
Chapter 4	Setup of 2D Single-view Vision Process
Chapter 5	Setup of 2D Multi-view Vision Process
Chapter 6	Setup of Depalletizing Vision Process
Chapter 7	Setup of 3D Tri-View Vision Process
Chapter 8	Camera calibration
Chapter 9	Frame setting
Chapter 10	Setup of snap in motion
Chapter 11	Trouble shooting
Appendix	

1.2 RELATED MANUALS

This section introduces related manual.

R-30*i*B/R-30*i*B Mate CONTROLLER OPERATOR'S MANUAL (Basic Operation) B-83284EN

This is the main manual of R-30*i*B/R-30*i*B Mate Controller. This manual describes the following items for manipulating workpieces with the robot:

- Setting the system for manipulating workpieces
- Operating the robot
- Creating and changing a teach pendant program
- Executing a teach pendant program
- Status indications
- Backup and restore robot programs.

This manual is used on an applicable design, robot installation, robot teaching.

R-30*i*B CONTROLLER MAINTENANCE MANUAL B-83195EN

This manual describes the maintenance and connection of R-30*i*B Controller.

R-30*i*B Mate CONTROLLER MAINTENANCE MANUAL B-83525EN

This manual describes the maintenance and connection of R-30*i*B Mate Controller.

R-30*i*B/R-30*i*B Mate CONTROLLER OPERATOR'S MANUAL (Alarm Code List) B-83284EN-1

This manual describes the error code listings, causes, and remedies of R-30*i*B/R-30*i*B Mate Controller.

R-30*i*B/R-30*i*B Mate CONTROLLER Optional Function OPERATOR'S MANUAL B83284EN-2

This manual describes the software optional functions of R-30*i*B/R-30*i*B Mate Controller.

R-30*i*B/R-30*i*B Mate CONTROLLER Sensor Mechanical Unit / Control Unit OPERATOR'S MANUAL B-83434EN

This manual describes the connection between sensors which is a camera or 3D Laser Sensor and R-30*i*B/R-30*i*B Mate Controller, and maintenance of sensors.

R-30*i*B/R-30*i*B Mate CONTROLLER *i*RVision OPERATOR'S MANUAL (Reference) B-83304EN

This manual is the reference manual for *i*RVision on the R-30*i*B/R-30*i*B Mate controller. This manual describes each functions which are provided by *i*RVision. This manual describes the meanings (e.g. the items on *i*RVision setup screen, the arguments of the instruction, and so on.

R-30*i*B/R-30*i*B Mate CONTROLLER *i*RVision 3D Laser Vision Sensor Application OPERATOR'S MANUAL B-83304EN-2

This manual is desired to first refer to when you start up systems of *i*RVision 3D Laser Sensor Compensation. This manual describes startup procedures of *i*RVision 3D Laser Sensor Compensation, creating programs, caution, technical know-how, response to several cases, and so on.

R-30*i*B/R-30*i*B Mate CONTROLLER *i*RVision Inspection Application OPERATOR'S MANUAL B-83304EN-3

This manual is desired to first refer to when you start up systems of inspection which uses *i*RVision. This manual describes startup procedures of inspection system which uses *i*RVision, creating programs, caution, technical know-how, response to several cases, and so on.

R-30*i*B CONTROLLER *i*RVision Visual Tracking OPERATOR'S MANUAL B-83304EN-4

This manual is desired to first refer to when you start up systems of *i*RVision Visual Tracking. This manual describes startup procedures of *i*RVision Visual Tracking system, creating programs, caution, technical know-how, response to several cases, and so on.

R-30*i*B/R-30*i*B Mate CONTROLLER *i*RVision Bin Picking Application OPERATOR'S MANUAL B-83304EN-5

This manual is desired to first refer to when you start up systems of *i*RVision Bin Picking. This manual describes startup procedures of *i*RVision Bin Picking system, creating programs, caution, technical know-how, response to several cases, and so on.

R-30*i*A/R-30*i*A Mate/R-30*i*B/R-30*i*B Mate CONTROLLER Ethernet Function OPERATOR’S MANUAL B-82974EN

This manual describes the robot networking options such as FTP, RIPE, PC Share, and so on.

2 ABOUT VISION SYSTEM

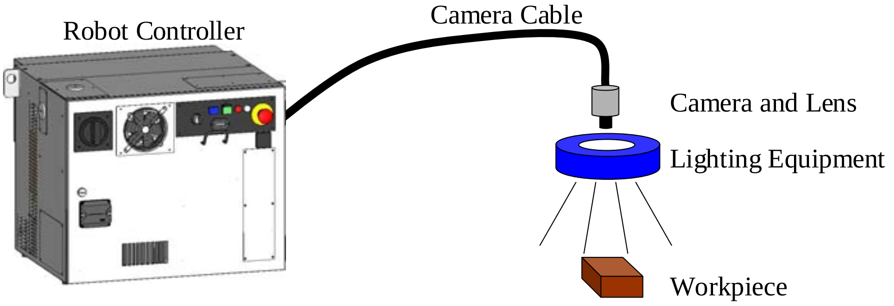
This chapter explains the fundamental items of the vision system.
The following eight items are explained.

1 Basic configuration
2 Fixed camera and robot-mounted camera
3 Size of a camera's field of view
4 Fixed frame offset and tool offset
5 Calculation of the offset data
6 Part Z height
7 Camera calibration
8 Memory card preparation

2.1 BASIC CONFIGURATION

*i*RVision consists of the following components:

- Camera and lens
- Camera cable
- Lighting Equipment
- Camera multiplexer (used if needed)



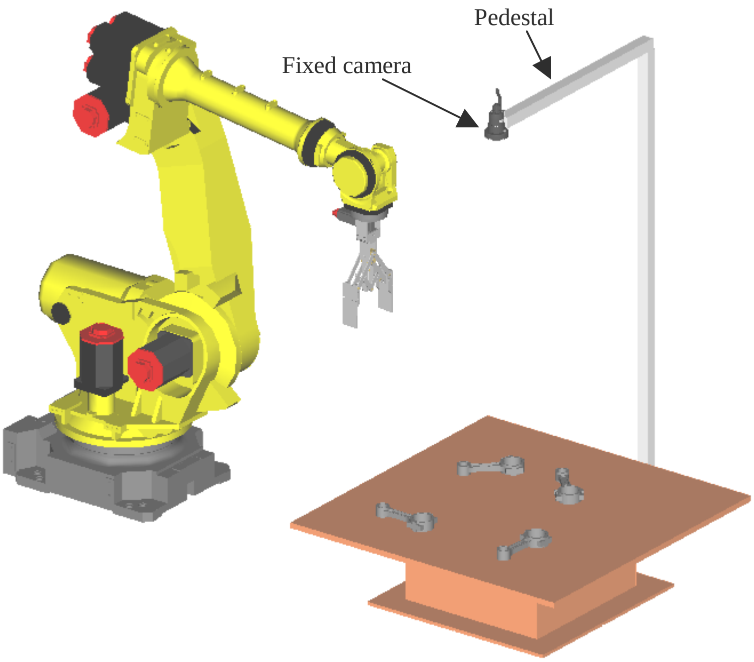
For detailed information about the connection method between the Robot Controller and a camera, please refer to "R-30*i*B/ R-30*i*B Mate CONTROLLER Sensor Mechanical / Control unit OPERATOR'S MANUAL (B-83434EN)".
The camera in the 3D Laser Vision Sensor can also be used as the two-dimensional compensation, because the CCD camera and lens are common.

2.2 FIXED CAMERA AND ROBOT-MOUNTED CAMERA

According to the size and position of a workpiece, it is decided where a camera is installed.

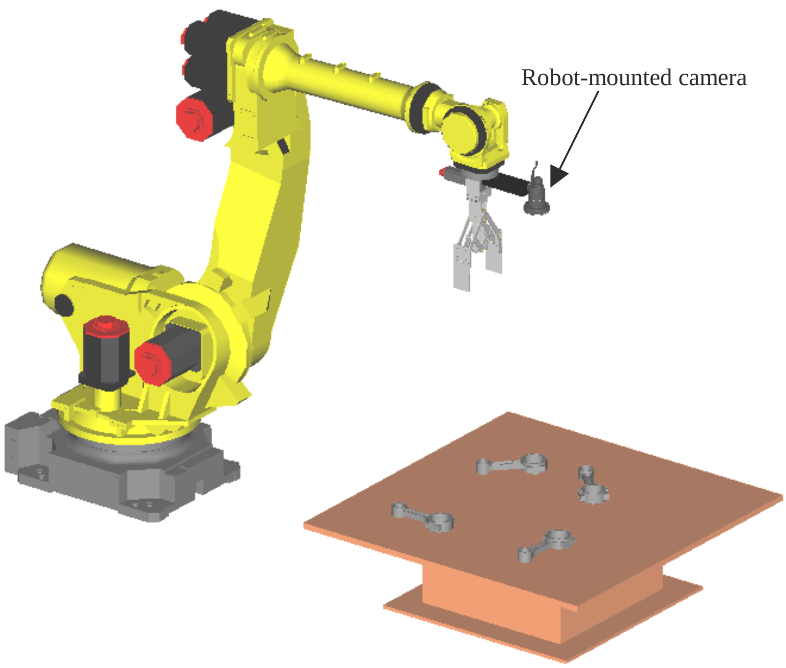
Fixed camera

- A fixed camera is attached to the top of the pedestal or another fixed structure and a workpiece is detected.
- In this method, the camera always sees the same view from the same distance.
- An advantage of a fixed camera is that the robot cycle time can be reduced because *i*RVision can take and process a picture while the robot performs another task.
- The pedestal to which the camera is attached should be rigid and not shake or vibrate.



Robot-mounted camera

- The robot-mounted camera is mounted on the wrist unit of the robot.
- By moving the robot, measurement can be done at different locations between the workpiece and the camera.
- When a robot-mounted camera is used, *i*RVision calculates the position of the workpiece while taking into account the camera movement resulting from the robot being moved.
- The camera must be mounted off the final axis of the robot. For example, the camera must be mounted off the sixth axis of a six axes robot.



2.3 SIZE OF A CAMERA'S FIELD OF VIEW

The size of the camera's field of view is decided by the size and position of the workpiece.
Some cameras offered from FANUC are shown in the following table.

Camera	Image size	Cell size
Kowa digital camera (SC130E B/W)	1/8 ″ QVGA (320 pixel × 240 pixel)	5.3 μm
	1/4 ″ QVGA (320 pixel × 240 pixel)	10.6 μm
	1/4 ″ VGA (640 pixel × 480 pixel)	5.3 μm
	1/2 ″ VGA (640 pixel × 480 pixel)	10.6 μm
	1/3 ″ XGA (1024 pixel × 768 pixel)	5.3 μm
	1/2 ″ SXGA (1280 pixel × 1024 pixel)	5.3 μm
	VGA_WIDE (1280 pixel × 480 pixel)	5.3 μm
	VGA_TALL (640 pixel × 960 pixel)	5.3 μm
Kowa digital camera (SC130E COLOR)	1/4 ″ QVGA (320 pixel × 240 pixel)	10.6 μm
	1/2 ″ VGA (640 pixel × 480 pixel)	10.6 μm
Kowa digital camera (SC130C) Old model	1/6 ″ QVGA (320 pixel × 240 pixel)	6.7 μm
	1/3 ″ QVGA (320 pixel × 240 pixel)	13.4 μm
	1/3 ″ VGA (640 pixel × 480 pixel)	6.7 μm
	2/3 ″ VGA (640 pixel × 480 pixel)	13.4 μm
	1/2 ″ XGA (1024 pixel × 768 pixel)	6.7 μm
	2/3 ″ SXGA (1280 pixel × 1024 pixel)	6.7 μm
	VGA_WIDE (1280 pixel × 480 pixel)	6.7 μm
	VGA_TALL (640 pixel × 960 pixel)	6.7 μm
Kowa digital camera (SC310CM) Old model	1/6 ″ QVGA (320 pixel × 240 pixel)	6.4 μm
	1/3 ″ VGA (640 pixel × 480 pixel)	6.4 μm
	1/2 ″ XGA (1024 pixel × 768 pixel)	6.4 μm
Analog camera (XC-56)	Image size cannot be changed (640 pixel × 480 pixel)	7.4 μm
Analog camera (XC-HR50)	Image size cannot be changed (640 pixel × 480 pixel)	7.4 μm

A size of a camera's field of view is decided by three factors, the size of an image sensor, the focal distance of a lens, and the distance from a camera to a workpiece.

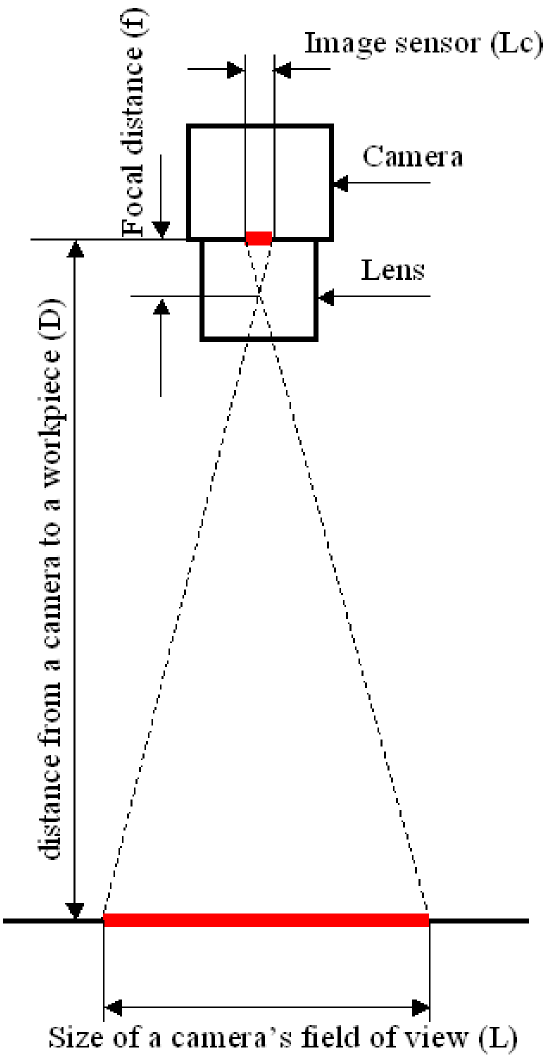
The size of an image sensor (Lc) is calculated by the following formula.
Lc = Cell size × Image size (pixels)

The rough value of the camera's field of view (L) is calculated by the following formula.
L = (D − f) ÷ f × Lc

When the distance from a camera to a workpiece is 700mm, image size is selected 1/2 ″ SXGA with the Kowa Digital Camera (SC130E B/W), the example of view size is shown in the following table.

Focal distance of a lens	Size of a camera's field of view
8mm	587mm × 469mm
12mm	389mm × 311mm
16mm	290mm × 232mm
25mm	183mm × 147mm

A calculation result is a rough value. Depending on the kind of lens, an error may occur in the value of a calculation result. When exact view size is required, actually measure.



There is the following method to enlarge view size.

- Increase the distance from the camera to the workpiece.
- Exchange a lens that is the shorter focal distance.
- When use the Kowa Digital Camera, enlarge the image size.

If the distance from a camera to a workpiece is too near, a lens is not in focus.
The minimum object distance of each lens offered from FANUC is shown in the following table.

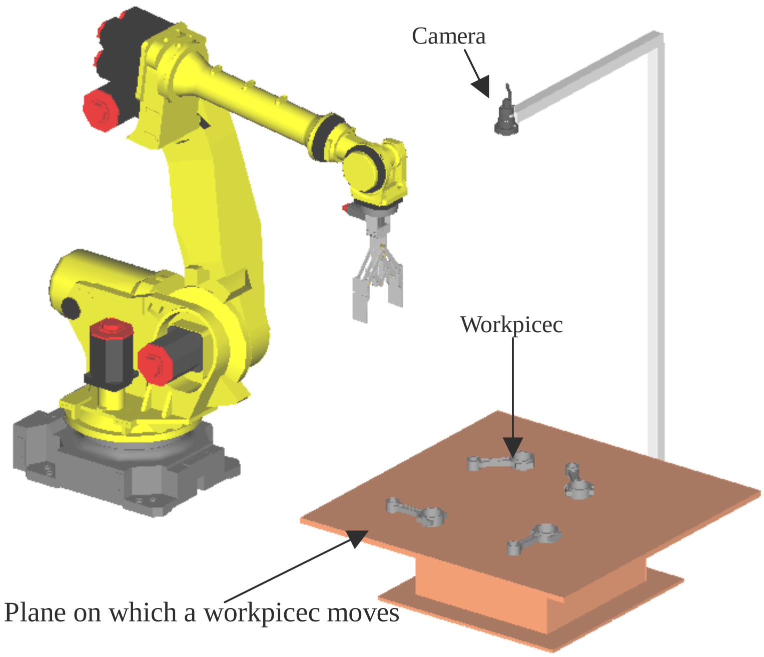
Focal distance of a lens	Minimum object distance
8mm	260mm
12mm	260mm
16mm	290mm
25mm	210mm

2.4 FIXED FRAME OFFSET AND TOOL OFFSET

There are two kinds of robot position offset, *fixed frame offset* and *tool offset*. *i*RVision supports both kinds of robot position offsets.

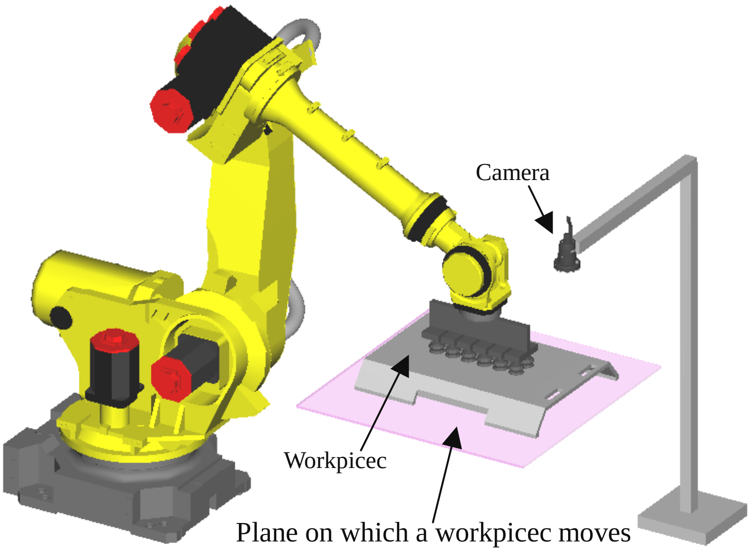
Fixed frame offset

With fixed frame offset, the workpiece offset is measured in a coordinate frame fixed with respect to the robot base. A workpiece placed on a fixed surface or a container is viewed by a camera, and the vision system measures its position. The robot then adjusts its taught positions so that it can manipulate (pick up, for example) the workpiece properly.



Tool offset

With tool offset, the workpiece offset is measured in a coordinate frame that moves with the robot tool. This method is useful for grippers where the part position in the gripper can vary, such as vacuum grippers. A workpiece held by the robot is viewed by a camera, and the vision system measures its position relative to the gripper. The robot then offsets its taught positions so that it can manipulate (place, for example) the workpiece properly.



2.5 CALCULATION OF THE OFFSET DATA

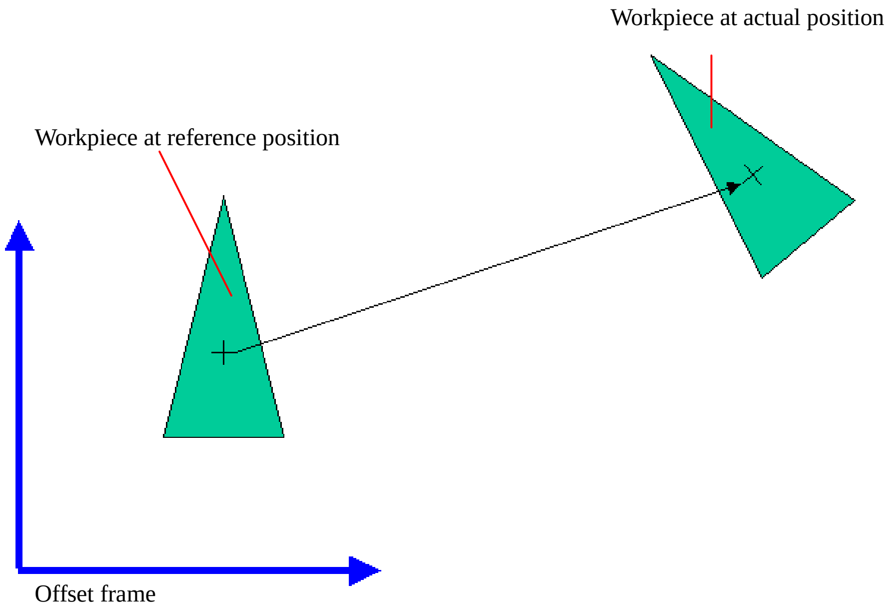
In this subsection, the calculation method of the offset data is explained.

Reference position and actual position

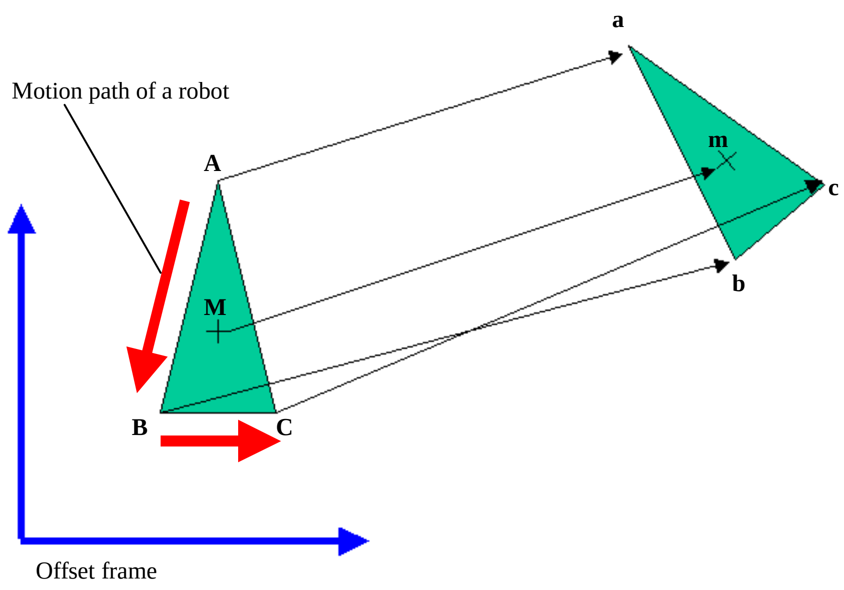
The offset data is calculated from the position of the original workpiece, set when the reference position was taught and the current workpiece position. The position of the workpiece set when the robot program was taught is called as the *reference position*, and the current workpiece position is called the *actual position*. *i*RVision measures the reference position when the robot program is taught, and stores it internally. The operation of teaching the reference position to *i*RVision is called *reference position setting*.

Offset data

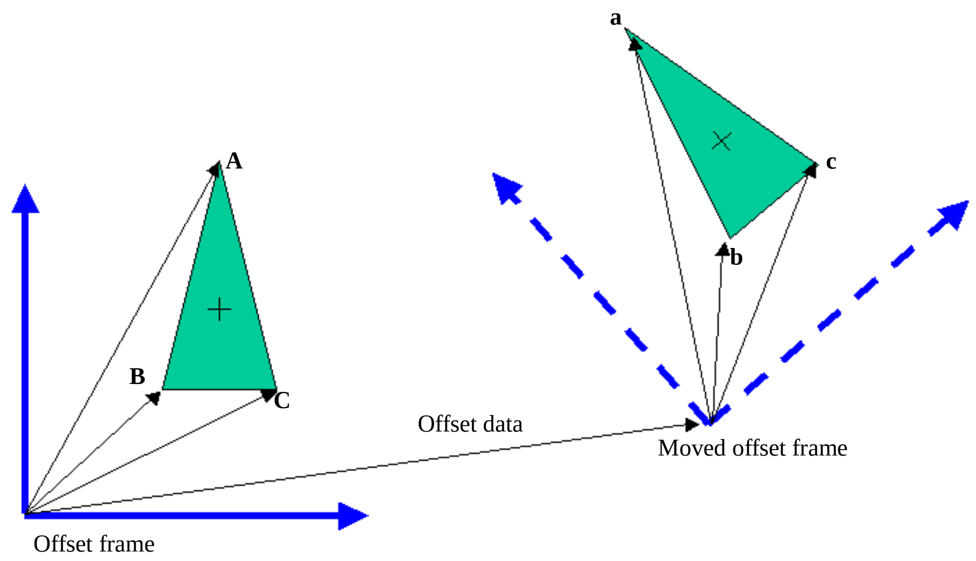
In the case of the following figure, the position of "+" mark is a found position of a workpiece. If a robot approaches only to the position of "+" mark, the offset data can be calculated by subtracting the value of actual position and reference position. Although it is easy to understand how to calculate the offset data by subtraction, there are also limitations. The found position approach to guiding the robot is only useful when guiding the TCP of the robot to the origin of the part. For the preceding reason this method of using the found position for robot guidance is not common practice.



One limitation to the found position method is realized when there is the requirement for multiple offsets. When a robot traces from the position of A on a workpiece to B and C as shown in the following figure, -- a, b and c -- each position information is required. However, the movement of (a – A), (b – B) and (c – C) differ from the movement of the found position (m – M). So, it is necessary to calculate the offset data of a, b and c individually, which is not a trivial task using the found position.



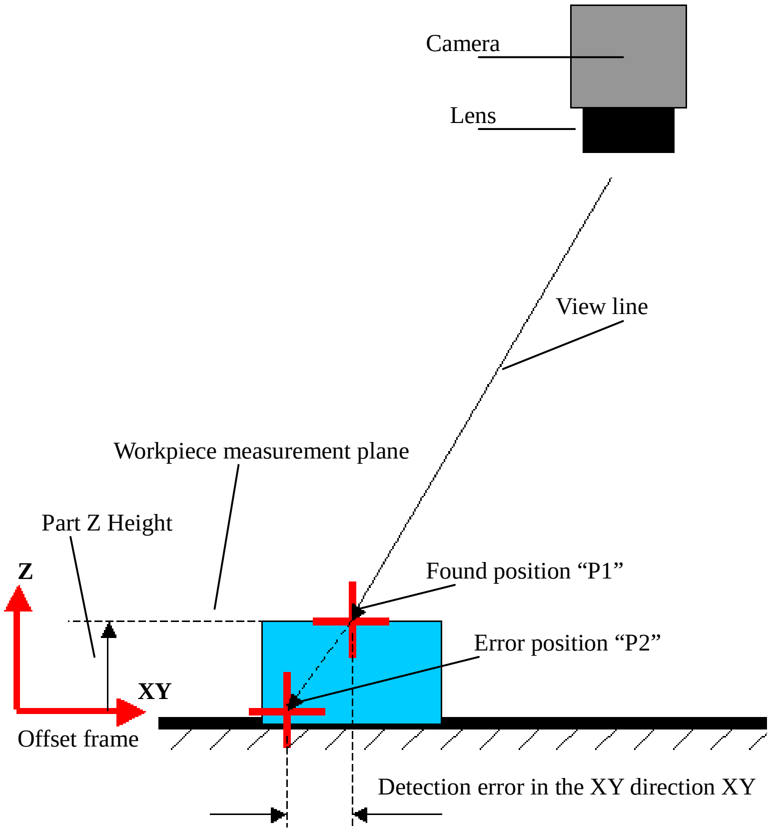
When *i*RVision uses an offset frame, it becomes unnecessary to calculate the position of each point individually. In the following figure, *i*RVision moves the offset frame to a new position. The position of the workpiece relative to the offset frame is the same as the position of the workpiece at the reference position by moving the offset frame, it becomes unnecessary to calculate the offset data for each point individually, and teaching becomes easy. *i*RVision outputs the movement of offset frame as the offset data. Since the offset data is the movement of the coordinate system, it differs from the actual movement of the workpiece. Moreover, the offset data does not become an intuitive value in many cases. As the workpiece rotates and there is a large distance between the origin of the workpiece and the origin of the offset frame the difference between the offset data and the actual movement of a workpiece become large. In this case, it is not useful for the user to study the X and Y components of an offset individually. The frame offset approach is the common solution for robot guidance with *i*RVision.



2.6 PART Z HEIGHT

Part Z Height is the height in millimeters of the found edges of the part with respect to the offset frame. In the case of the following figure, when a two-dimensional camera detects a workpiece, the origin position of a workpiece will be in somewhere on the view line which connects a workpiece to a camera. Therefore, in order to determine the point on the view line, it is necessary to set up the height of a workpiece (Part Z Height) beforehand. In two-dimensional compensation with *i*RVision, the height of the workpiece measurement plane in the offset frame is set up as part z height. By setting up the part z height, the XY position of a workpiece is correctly calculated from the intersection point of the view line and the measurement plane. (“P1” in the following figure)

The part Z height is an important setting which influences compensation accuracy of a robot. So, set up the part Z height correctly. When the part is placed the center of field of view, the accuracy is good. However, the part moves to the edges of the field of view and the scale of the offset is too small, it is possible that part Z height is not set properly. In the following figure, when 0 mm is incorrectly set up in the part z height, the found position of the workpiece is calculated as it is “P2”, and a detection error occurs in the XY direction.

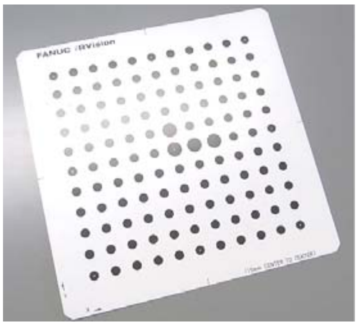


2.7 CAMERA CALIBRATION

There are two kinds of methods for a camera calibration, those are Grid Pattern Calibration and Robot-generated Grid Calibration.

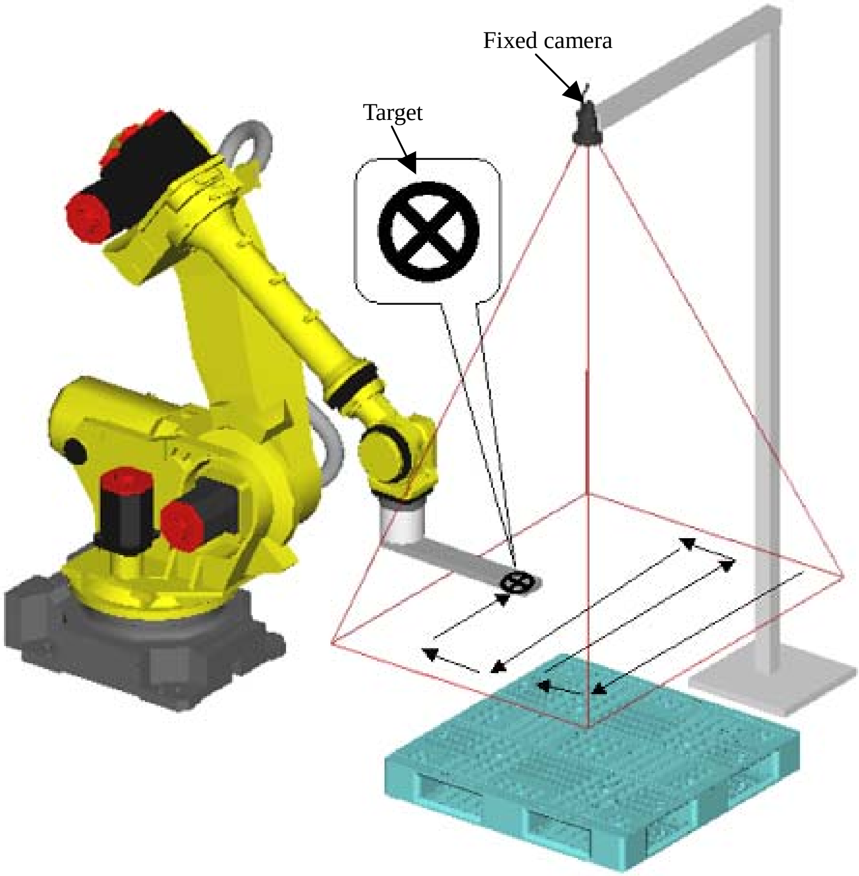
Grid Pattern Calibration

The Grid Pattern Calibration is the standard method to calibrate the camera. A fixture called the calibration grid is used to calibrate the camera. Prepare a calibration grid beforehand. A calibration grid which is bigger than a field of view is recommended. A standard calibration grid is available from FANUC in several sizes. It is strongly recommended that you order a calibration grid as well as a camera and lens.



Robot-generated Grid Calibration

The function moves a target, mounted on the robot end of arm tooling, in the camera's field of view to generate a virtual grid pattern for camera calibration. Unlike Grid Pattern Calibration, this calibration method does not require a calibration grid as large as the camera’s field of view and is therefore suitable for calibrating a large field of view. When the Robot-generated Grid Calibration is used, a calibration grid is unnecessary. Prepare the target that can be attached to a robot. When performing the calibration of the fixed camera, the Robot-generated Grid Calibration can be used. When using a robot-mounted camera, the Robot-generated Grid Calibration cannot be used. When using a robot-mounted camera, perform the Grid Pattern Calibration for a camera calibration.



2.8 MEMORY CARD PREPARATION

*i*RVision can save failed images to a memory card or a USB memory inserted into the robot controller. It is recommended that at the time of system start-up and integration, a memory card or a USB memory be inserted to save failed images to the memory card or a USB memory. By doing so, the locator tool parameter can be adjusted using the failed images. Moreover, when the system is reinstalled after being moved, for example, camera images before reinstallation, if saved, can be checked against camera images after reinstallation to see if there is any major difference.
To enable vision log, check “Enable logging” on the *i*RVision configuration screen. For details, see Section 3.4, ”VISION CONFIG” in the *i*RVision operator's manual (Reference) (B-83304EN).
Note that even if "Log Failed Images" is set in the vision program, no failed images can be saved when no memory card or no USB memory is inserted.

When the free space of the memory device is less than the specified value (2 Mbytes by default), old vision logs are deleted to make enough free space for writing a new vision log. *i*RVision can delete only vision logs when the free space of the memory device is less than the specified value. If there are no vision logs which can be deleted, CVIS-130 “No free disk space to log” alarm is posted and the vision log will not be recorded.

⚠ **CAUTION**

1 Deleting old vision logs takes time. To avoid the need to do so, it is recommended to delete or to export vision logs to an external device on a regular basis to ensure that the memory device has enough free space. For information about how to export vision logs to an external device or how to delete them, see Section 10.3, "VISION LOG MENU" in the *i*RVision operator's manual (Reference) (B-83304EN).
2 If the free space of a memory device falls below the specified value as a result of other files being written to the memory device, the vision log function will try to delete vision logs until the free space is larger than the required value in the next vision execution. In this case, it may take time before the next vision execution can start, if there is a lot of data to be deleted. For example, storing everything to the memory card could cause such a case. However, it will not cause any problems if there is a backup already written to the memory card and its size is as large as that of new backup.
3 If you have vision logs recorded in a memory card with one controller and then execute a vision process with that memory card inserted into another controller, the vision logs recorded with the original controller may get overwritten.
4 Be sure to format Memory Card or USB memory with FAT16.
5 When save the log in a memory card or a USB memory, detection may take longer time. After the adjustment of Vision Process is completed, disable the Vision Log. For details, see Section 3.3, "VISION LOG" in the *i*RVision operator's manual (Reference) (B-83304EN).

A memory card or a USB memory, when inserted, can be used to back up all data in the robot controller. If all data in the robot controller is backed up, the vision data can be backed up at the same time. Be sure to back up all data in the robot controller upon completion of startup or integration.
Moreover, use a memory card or a USB memory recommended by FANUC. If a memory card or a USB memory other than those recommended is used, a normal operation is not guaranteed, and a bad influence may occur on the controller.

3 OVERVIEW OF EACH APPLICATION

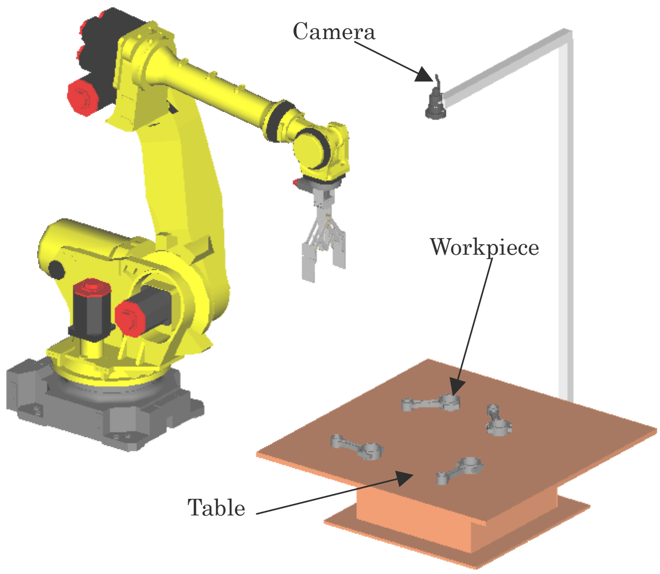
The two-dimensional compensation function can be used in several applications. At present, it can be used for the following four applications.

<1> 2D Single-view Vision Process
<2> 2D Multi-view Vision Process
<3> Depalletizing Vision Process
<4> 3D Tri-View Vision Process

The 2D Single-view Vision Process and 2D Multi-view Vision Process enable workpieces to be compensated in the parallel movement (X, Y) direction or the rotational movement (R) direction. In the Depalletizing Vision Process, compensation can be done not only in the (X, Y, R) directions but also in the height (Z) direction of the workpieces. In the 3D Tri-View Vision Process compensation can be done in the (X, Y, Z, W, P, R) directions.
This chapter outlines the above four applications, and Chapters 4 to 7 explain the setup procedures in detail. The 2D Single-view Vision Process is the most typical vision application. The setup procedure of the 2D Single-view Vision Process can apply to other vision application settings. Chapter 8 explains the setup procedures of camera calibration. Chapter 9 explains the setup procedures of the frames. Chapter 10 explains the setup procedures in snap-in-motion. Chapter 11 gives details of troubleshooting. The appendix explains a concrete setting procedure of applications.
For details of each setup item, refer to the *i*RVision Operator's Manual (Reference) (B-83304EN).

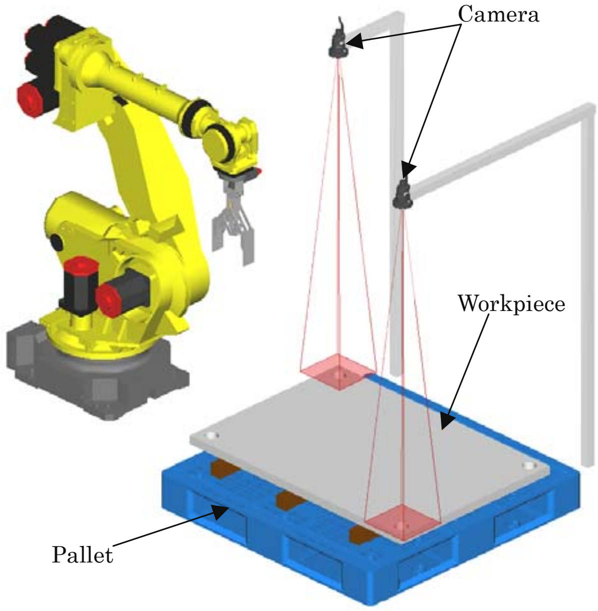
3.1 OVERVIEW OF 2D SINGLE VIEW VISION PROCESS

The 2D Single-view Vision Process is a function which detects the position of a workpiece using a camera. Then, the 2D Single-view Vision Process compensates a position of the workpiece which moves to the parallel movement (X, Y) direction or the rotational movement (R) direction.
The example of a layout is shown in the following figure. A workpiece that moves on a table is detected and a robot picks up it.



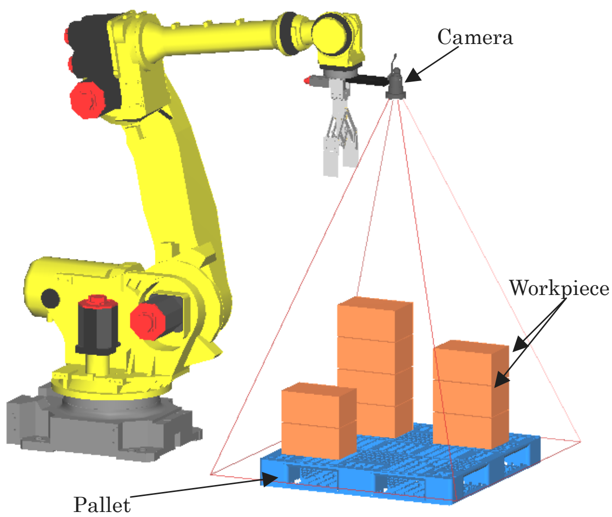
3.2 OVERVIEW OF 2D MULTI VIEW VISION PROCESS

The 2D Multi-view Vision Process measures multiple points of a workpiece to perform two-dimensional compensation. This function is used to measure multiple points of a large workpiece that cannot be contained in the field of view of a single camera.
The layout of a system with the 2D Multi-view Vision Process is the same as for 2D Single-view Vision Process. The example of a layout is shown in the following figure. The two corners of the large workpiece are detected by using the two cameras. The robot picks up the workpiece with the single offset from the 2D Multi-view vision process.



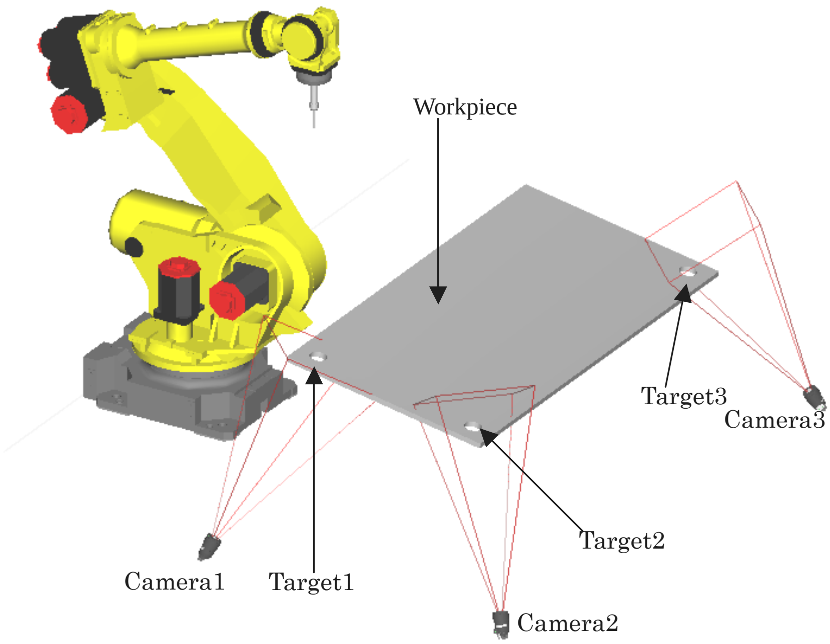
3.3 OVERVIEW OF DEPALLETIZING VISION PROCESS

Depalletizing Vision Process is a vision program that performs compensation in the vertical direction in addition to standard two-dimensional compensation. This function measures the height of the workpieces based on the size of the workpiece image viewed by the camera or based on a known height input via a robot register. In the following figure, the stacked workpieces on the pallet are detected using a camera, and a robot picks up in order from the highest workpiece.



3.4 OVERVIEW OF 3D TRI-VIEW VISION PROCESS

The 3D Tri-View Vision Process is the function for making three-dimensional compensation by measuring three detection targets of a large workpiece such as a car body. Compensation is applied to all of six degrees of freedom for parallel displacement (X, Y, Z) and rotation (W, P, R) of the workpiece. In the following figure, three detection targets of a large workpiece are detected and the three-dimensional position of the workpiece is measured.



4 2D SINGLE VIEW VISION PROCESS

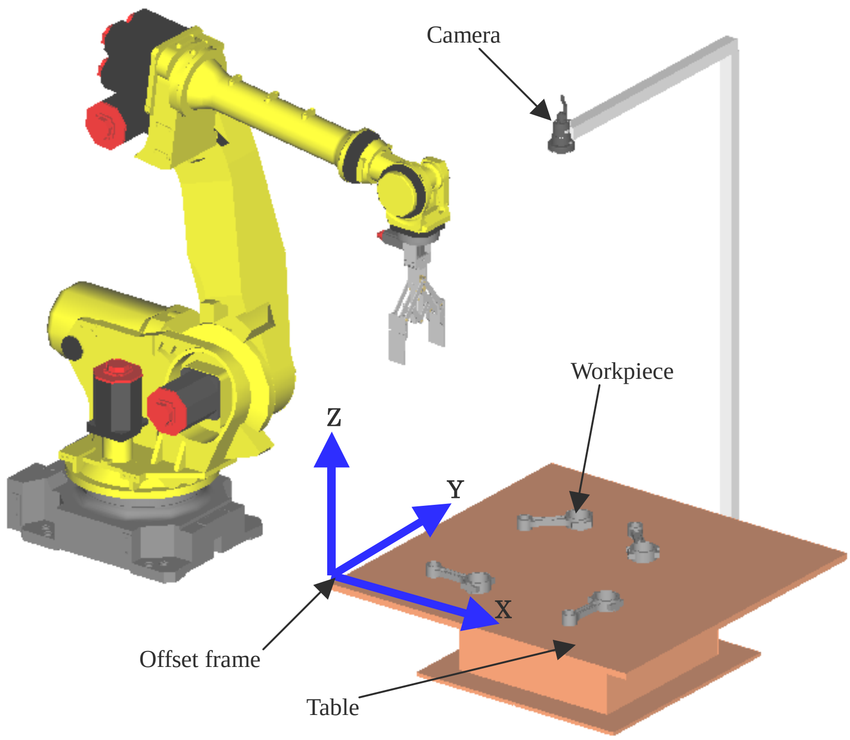
The 2D Single-view Vision Process is a function which detects the position of a workpiece using a camera. Then, the 2D Single-view Vision Process compensates the position of the workpiece which moves to the parallel movement (X, Y) direction or the rotational movement (R) direction. With a 2D Single-view Vision Process, the following four configurations can be used:

<1> Fixed frame offset with a fixed camera
<2> Fixed frame offset with a robot-mounted camera
<3> Tool offset with a fixed camera
<4> Tool offset with a robot-mounted camera

This chapter describes the setup procedure for a 2D Single-view Vision Process by using the following four application examples: <1> Fixed frame offset with a fixed camera, <2> Fixed frame offset with a robot-mounted camera and <3> Tool offset with a fixed camera.
In the configuration of "<4> Tool offset with a robot-mounted camera” a robot holds the camera and robot B holds the workpiece, and the grip error of the workpiece held by robot B is measured. One robot acquires the current position of the other robot, and vice versa, so that the inter-robot communication function is used. If the camera held by robot A is handled as a fixed camera, the same setup as "<3> Tool offset with a fixed camera" results.

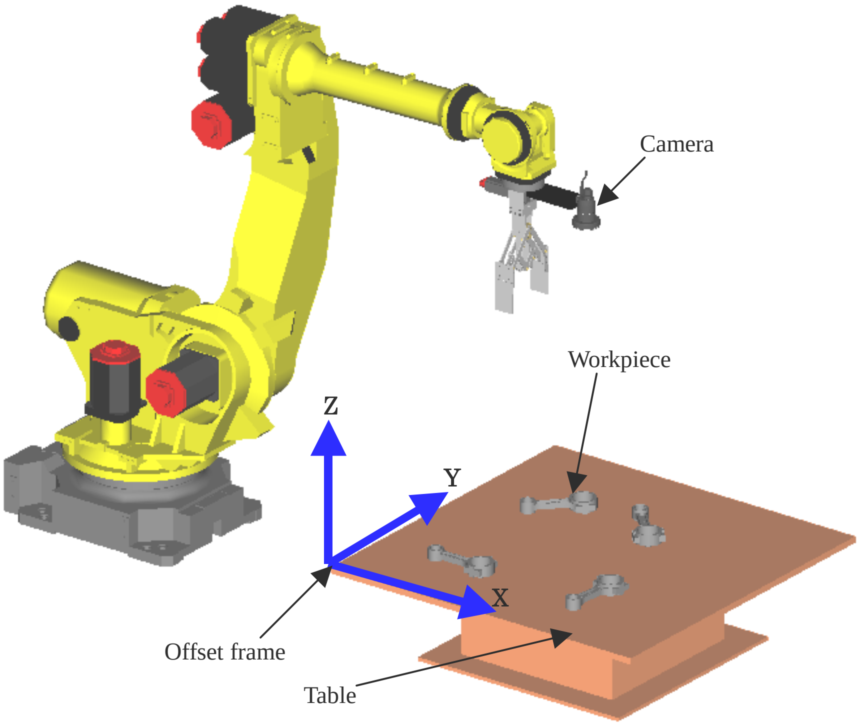
Fixed frame offset with a fixed camera

An example of a layout for a "fixed frame offset with a fixed camera" is given below.



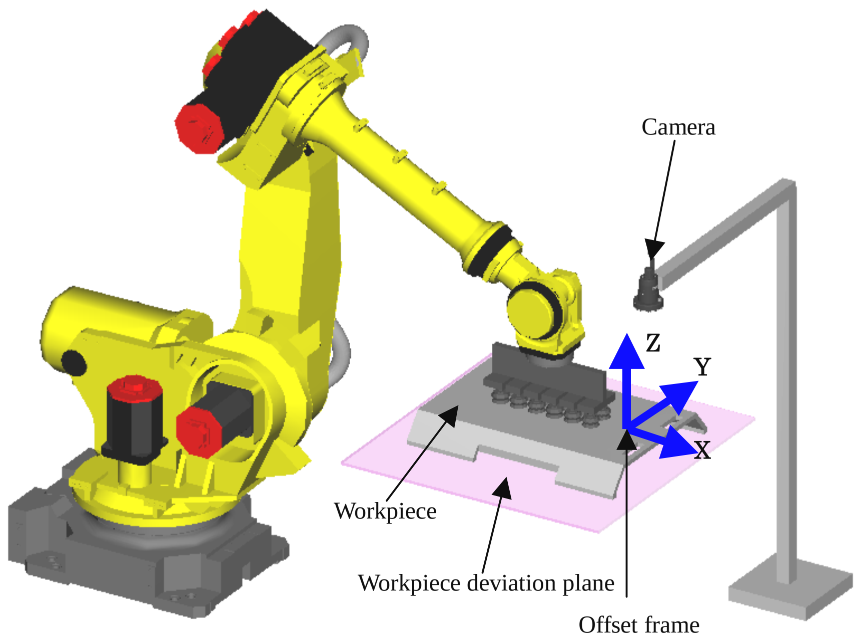
Fixed frame offset with a robot-mounted camera

An example of a layout for a "fixed frame offset with a robot-mounted camera" is given below.



Tool offset with a fixed camera

An example of a layout for a "tool offset with a fixed camera" is given below.



4.1 FEATURES AND NOTES

Features

- Most universal vision applications using two-dimensional compensation can be implemented.
- Fixed frame offset and tool offset can be performed.
- Both a fixed camera and a robot-mounted camera can be used.
- When a robot-mounted camera is used, the position of a workpiece can be measured even when the robot moves in the X and Y directions of the offset. This capability is provided because the current position of a robot is considered in *i*RVision calculation processing when a workpiece position calculation is made.

Notes

- Because this function provides two-dimensional compensation, it is assumed that the height of the workpiece remains unchanged and that the workpiece is not tilted.
- When either a fixed camera or a robot-mounted camera is used, it is best if the optical axis of the camera is normal to the XY plane of the offset frame. When the camera is mounted tilted in the XY plane of the offset frame, the shape of the workpieces can be distorted depending on their position in the field of view. In this case, it is possible that detection of the workpiece become difficult.

4.2 SETUP FOR "FIXED FRAME OFFSET WITH FIXED CAMERA "

Use the following setup procedure for "fixed frame offset with fixed camera":

1. Camera calibration setting

⇩

2. Offset user frame setting

⇩

3. Vision process creation and teaching

⇩

4. Robot program creation and teaching

When initially setting up the vision system, perform all the above procedures. When the position of the camera is shifted or the camera is replaced, redo "1 Camera calibration setting." If the camera is already calibrated a new workpiece is added or changed perform "3 Vision process creation and teaching." and "4 Robot program creation and teaching."

4.2.1 Camera Calibration Setting

There are two methods for a camera calibration, Grid Pattern Calibration and Robot-generated Grid Calibration.

Grid Pattern Calibration

The Grid Pattern Calibration is the standard method to calibrate the camera. A fixture called the calibration grid is used to calibrate the camera. Prepare a calibration grid beforehand. A calibration grid which is bigger than a field of view is recommended. For details of the grid frame calibration, see Section 8.1, “GRID PATTERN CALIBRATION WITH A FIXED CAMERA”. In addition, a large calibration grid is needed when performing the calibration of the large view. Use the Robot-generated Grid Calibration, if it is difficult to prepare a large calibration grid.

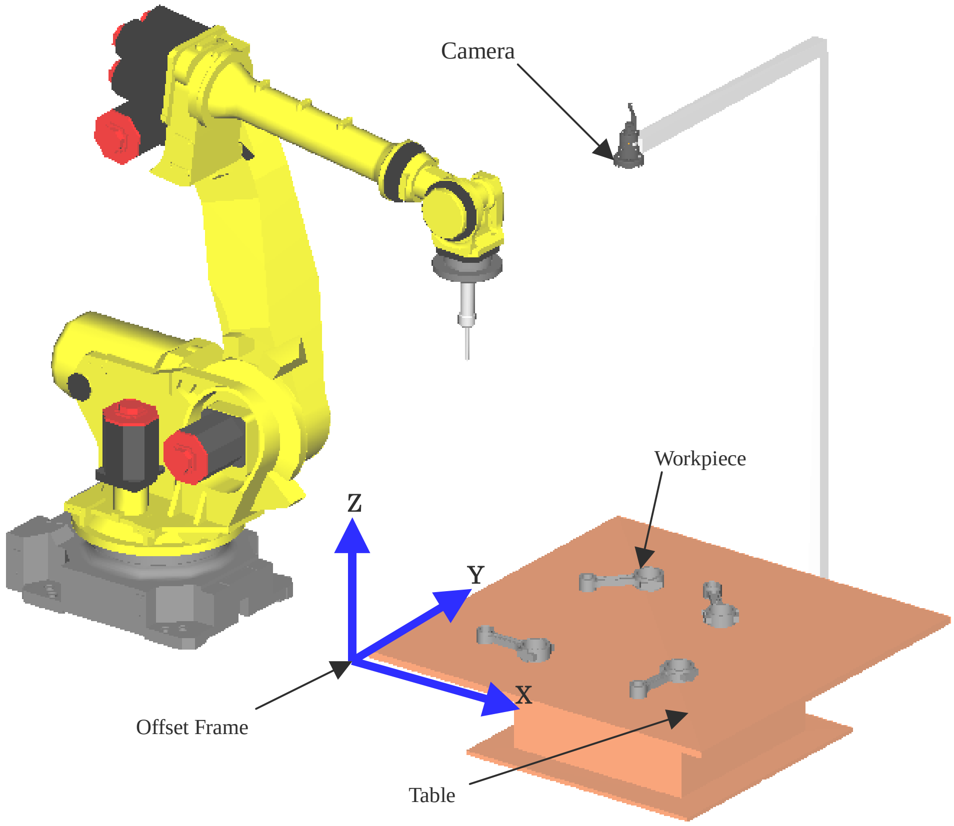
Robot-generated Grid Calibration

The function moves a target, mounted on the robot end of arm tooling, in the camera's field of view to generate a virtual grid pattern for camera calibration. Unlike Grid Pattern Calibration, this calibration method does not require a calibration grid as large as the camera’s field of view and is therefore suitable for calibrating a large field of view. When the Robot-generated Grid Calibration is used, a calibration grid is unnecessary. Prepare the target that can be attached to a robot. When performing the calibration of the fixed camera, the Robot-generated Grid Calibration can be used. When using a robot-mounted camera, the Robot-generated Grid Calibration cannot be used. When using a robot-mounted camera, perform the Grid Pattern Calibration for a camera calibration. For details of the Robot-generated Grid Calibration, see Section 8.3, “ROBOT-GENERATED GRID CALIBRATION”.

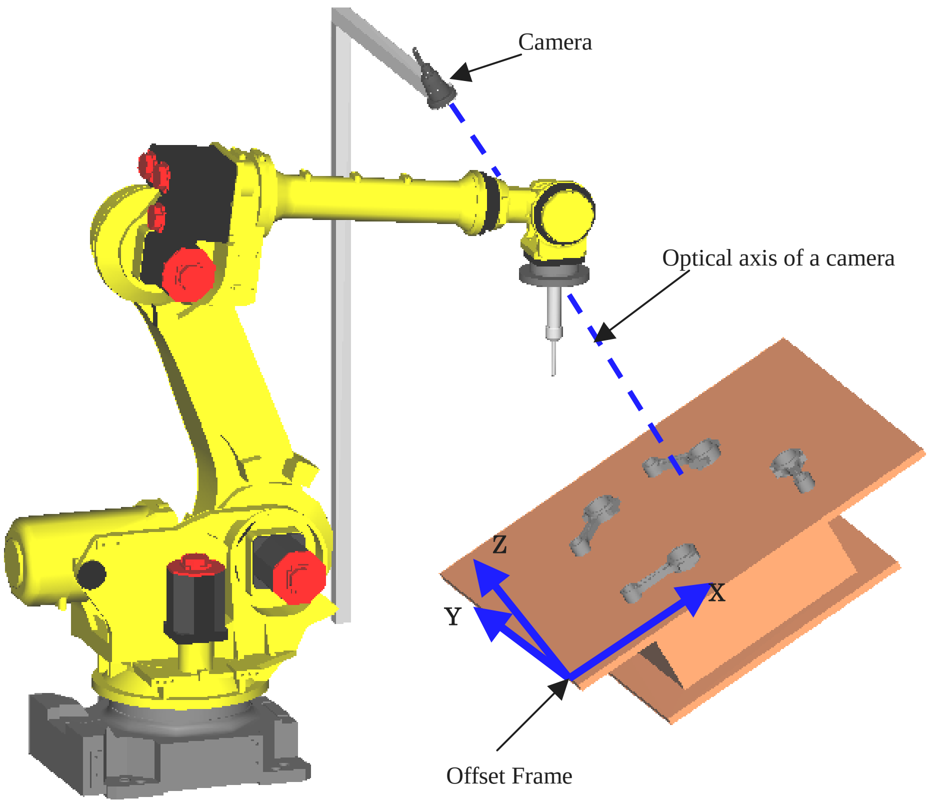
4.2.2 Offset Frame Setting

An offset frame is the coordinate system used for calculation of the vision offset data in the 2D Single-view Vision Process. A found position is outputted as a position in the offset frame. In the fixed frame offset, the offset frame is a user frame.

Set an offset frame so that the XY plane of the offset frame is parallel with the table plane on which the workpiece is placed. Otherwise, the required compensation precision may not be obtained.



The figure below shows a case where a workpiece is placed on a non-horizontal plane.
Ensure that the optical axis of the camera is normal to the plane where the workpiece moves.



There are two methods to teach the offset frame, one is manually touch-up the frame with a pointer tool, and another is the Automatic Grid Frame Set Function.

Touch-up

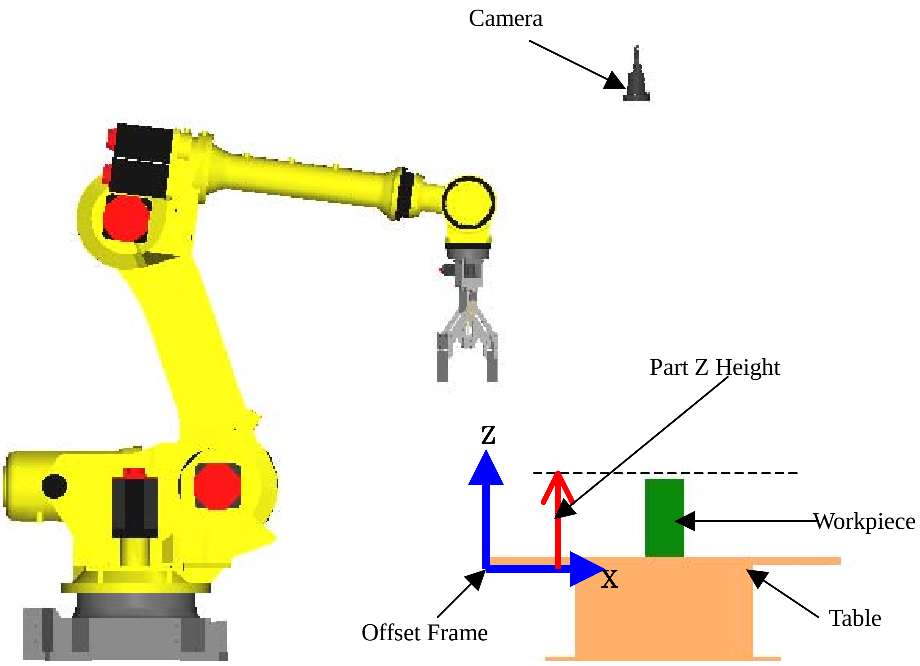
To manually teach a user frame, a pointer tool with a taught TCP is required. In general, set the TCP accurately on the pointer installed on the robot gripper. Set the robot TCP in an available UTool. To reuse the pointer TCP, the reproducibility of the pointer installation is required. If the reproducibility of the pointer installation is not assured, the TCP needs to be re- taught each time a pointer is installed. For details, see Section 9.1.1, “User frame setting with a pointer tool”.

Automatic Grid Frame Set Function

The Automatic Grid Frame Set Function sets the calibration grid frame using a camera. Install a calibration grid so that the XY plane of the calibration grid is parallel with the plane on which the workpiece is placed, and perform the Automatic Grid Frame Set Function. For details, see Section 9.2, “Frame setting with the Automatic Grid Frame Set Function”. A calibration grid is used for setup. Moreover, in the case of a fixed camera, prepare a camera for the Automatic Grid Frame Set Function separately. And perform the Automatic Grid Frame Set Function using the camera attached to a temporary position of a robot's hand. In addition, the Automatic Grid Frame Set Function is usable with 6-axis robots only. The function cannot be used with 4-axis robots and 5-axis robots. When using 4-axis robots or 5-axis robots, teach the user frame manually.

4.2.3 Vision Process Creation and Teaching

Create a "2D Single-view Vision Process".
If the measurement plane of a workpiece is apart in the Z direction from the XY plane of the offset frame set in Subsection 4.2.2, "Offset Frame Setting", set the Z coordinate of the measurement plane viewed from the XY plane of offset frame in "Part Z Height" of the vision process.

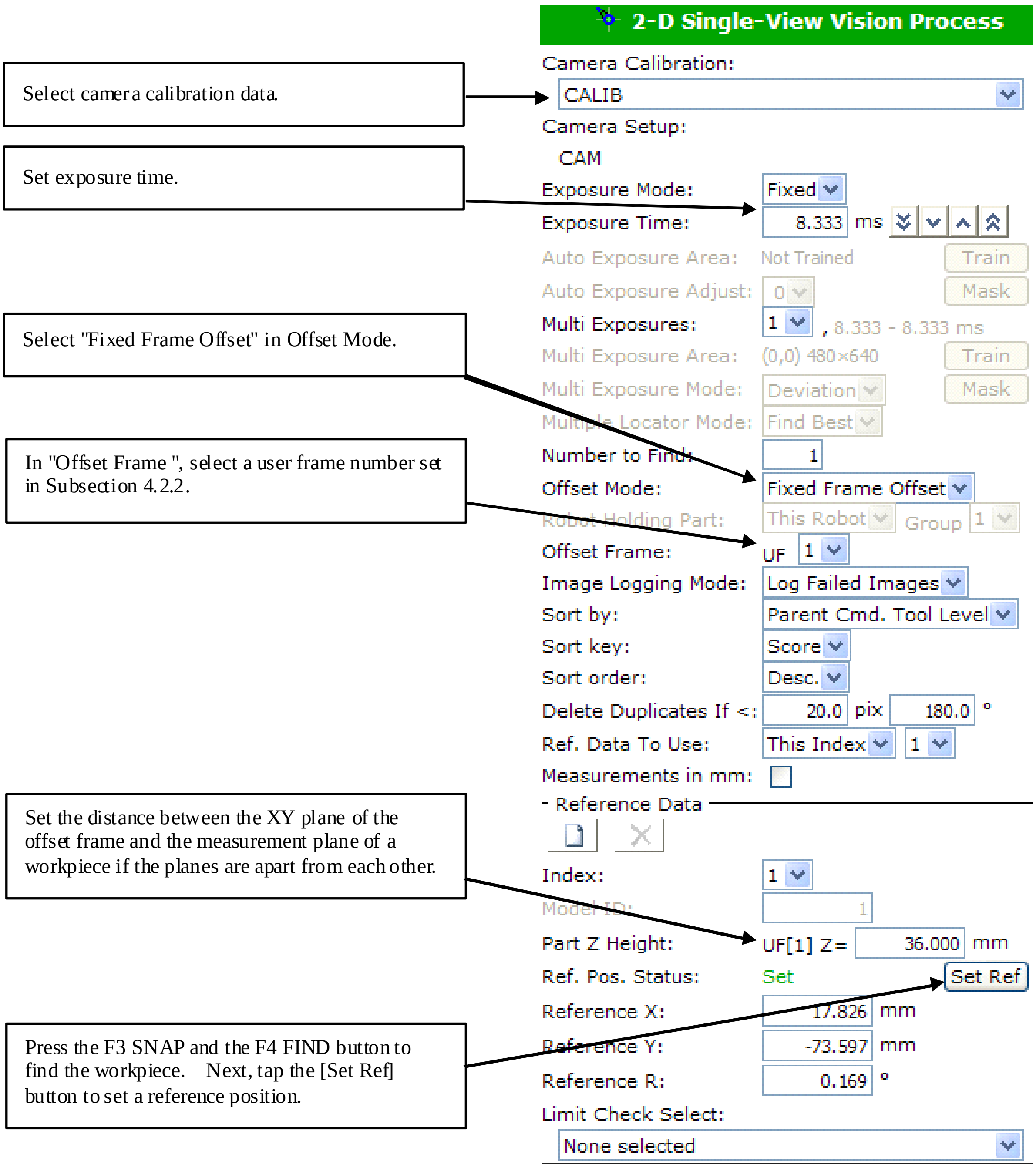


A description of the locator tool is omitted here. For setting of the locator tool, refer to Chapter 7, “COMMAND TOOL” in the *i*RVision Operator’s Manual (Reference) (B-83304EN).

Reference position setting

In this Subsection, the setting method of a reference position is explained. First, open a vision process page as shown below. Next, place a workpiece in the field of view. In addition, do not move the workpiece until the reference position setup is completed. Press the F3 SNAP and F4 FIND buttons to detect a workpiece. Next, tap [Set Ref] in the Reference Data. [Ref. Pos. Status] becomes [Set]. In addition, the value of [Reference X], [Reference Y] and [Reference Z] are inputted. The value is the position of the origin of the workpiece in the offset frame.

Jog the robot to the working position (for example, the pick up position of the workpiece). For an example, refer to sample program of Subsection 4.2.4 "Robot Program Creation and Teaching". LP[2] on the line11 of sample program is a working position for a workpiece. If the robot's current position is set to LP[2], the reference position setting is complete.



4.2.4 Robot Program Creation and Teaching

In the sample program below, a vision process named "A" is used. For fixed frame offset, add the "VOFFSET, VR" instruction as an operation statement.

```
  1:   UFRAME_NUM=1 ;
  2:   UTOOL_NUM=1 ;
  3:   R[1:Notfound]=0      ;
  4:L P[1] 2000mm/sec FINE      ;
  5:    ;
  6:   VISION RUN_FIND 'A'      ;
  7:   VISION GET_OFFSET 'A' VR[1] JMP LBL[100] ;
  8:    ;
  9:   !Handling ;
 10:L P[2] 2000mm/sec CNT100 VOFFSET,VR[1] Tool_Offset,PR[1]      ;
 11:L P[2] 500mm/sec FINE VOFFSET,VR[1]      ;
 12:   CALL HAND_CLOSE      ;
 13:L P[2] 2000mm/sec CNT100 VOFFSET,VR[1] Tool_Offset,PR[3]      ;
 14:   !Handling ;
 15:   JMP_LBL[900] ;
 16:    ;
 17:   LBL[100] ;
 18:   R[1:Notfound]=1      ;
 19:    ;
 20:   LBL[900] ;
```

Execute program ”A” with the vision detection instruction on line 6. Obtain the vision offset of the detected workpiece on line 7. Move to the approach position above the workpiece on line 10. Move to the grasp position on line 11. Move to escape position after grasping the workpiece on line 13.

4.2.5 Robot Compensation Operation Check

Check that a workpiece placed on the table can be detected and handled precisely.

- Place the workpiece in the reference position, find it and check the handling accuracy. If the accuracy of compensation is low, retry the reference position setting.
- Move the workpiece without rotation, find it and check the handling accuracy. If the accuracy is good for reference position, but low for non-rotated workpiece on the edge of the field of view, it is possible that Part Z Height is not set properly. Check the Part Z Height, refer to Subsection 4.2.7, “Vision process Creation and Teaching”
- Rotate the workpiece, find it and check the handling accuracy. If the accuracy is good for moved workpiece without rotation, but low for rotated workpiece and lower for more rotated workpiece, it is possible that offset frame or the calibration grid frame location is not set properly. If the calibration grid frame was manually taught with a pointer, verify the accuracy of the pointer TCP (UTool) used to teach the frame. Moreover, check the offset frame and the calibration grid frame are set precisely, then retry the camera calibration. If it is difficult to re-do the camera calibration, the “ADJ_OFS” may improve the situation without the re-set up the offset frame and the calibration grid location. ADJ_OFS is included in VISION SUPPORT TOOLS. Refer to Subsection 12.1.6, “ADJ_OFS” in the *i*RVision Operator’s Manual (Reference) (B-83304EN) for details.
- Start with lower override of the robot to check that the logic of the program is correct. Next, increase the override to check that the robot can operate continuously.

4.3 SETUP FOR "FIXED FRAME OFFSET WITH ROBOT MOUNTED CAMERA"

Use the following setup procedure for "Fixed frame offset with robot mounted camera ":

1. Camera calibration setting

⇩

2. Offset user frame setting

⇩

3. Vision process creation and teaching

⇩

4. Robot program creation and teaching

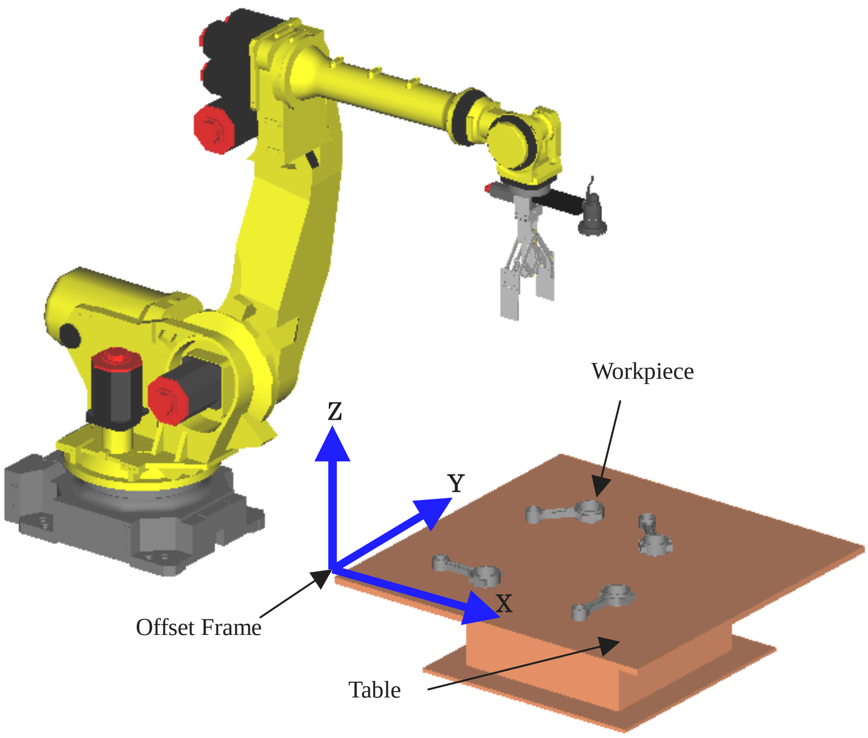
When initially setting up the vision system, perform all the above procedures. When the position of the camera is shifted or the camera is replaced, redo "1 Camera calibration setting." If the camera is already calibrated a new workpiece is added or changed perform "3 Vision process creation and teaching." and "4 Robot program creation and teaching."

4.3.1 Camera Calibration Setting

When using a robot-mounted camera, perform the Grid Pattern Calibration. In the case of a robot-mounted camera, the Robot-generated Grid Calibration cannot be used. For details of the grid frame calibration, see Section 8.2, “GRID PATTERN CALIBRATION WITH A ROBOT-MOUNTED CAMERA”.

4.3.2 Offset Frame Setting

An offset frame is the coordinate system used for calculation of the offset data in the 2D Single-view Vision Process. A found position is outputted as a position in the offset frame. In the fixed frame offset, the offset frame is set as a user frame.
Set an offset frame so that the XY plane of the user frame is parallel with the table plane on which a workpiece is placed.　Otherwise, the required compensation precision may not be obtained.



There are two methods to teach the offset frame, one is manually touch-up the frame with a pointer tool, and another is the Automatic Grid Frame Set Function.

Touch-up

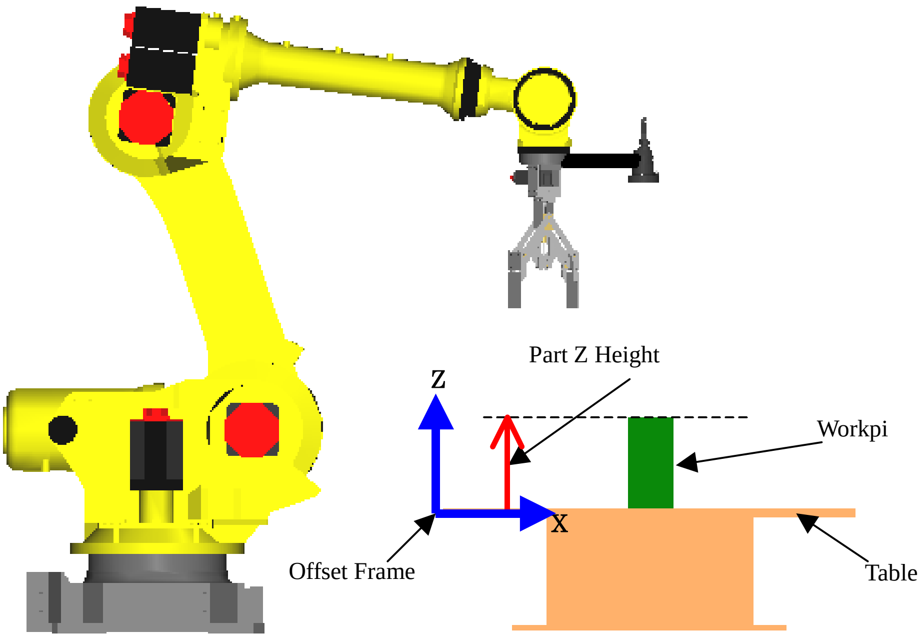
To manually teach a user frame, a pointer tool with a taught TCP is required. In general, set the TCP accurately on the pointer installed on the robot gripper. Set the robot TCP in an available UTool. To reuse the pointer TCP, the reproducibility of the pointer installation is required. If the reproducibility of the pointer installation is not assured, the TCP needs to be re- taught each time a pointer is installed. For details, see Section 9.1.1, “User frame setting with a pointer tool”.

Automatic Grid Frame Set Function

The Automatic Grid Frame Set Function sets the calibration grid frame using a camera. Install a calibration grid so that the XY plane of the calibration grid is parallel with the plane on which the workpiece is placed, and perform the Automatic Grid Frame Set Function. For details, see Section 9.2, “Frame setting with the Automatic Grid Frame Set Function”. A calibration grid is used for setup. Moreover, in the case of a fixed camera, prepare a camera for the Automatic Grid Frame Set Function separately. And perform the Automatic Grid Frame Set Function using the camera attached to a temporary position of a robot's hand. In addition, the Automatic Grid Frame Set Function is usable with 6-axis robots only. The function cannot be used with 4-axis robots and 5-axis robots. When using 4-axis robots or 5-axis robots, teach the frame manually.

4.3.3 Vision Process Creation and Teaching

Create a "2D Single-view Vision Process".
If the measurement plane of a workpiece is apart in the Z direction from the XY plane of the offset frame set in Subsection 4.3.6, "Offset Frame Setting", set the Z coordinate of the measurement plane viewed from the XY plane of offset frame in "Part Z Height" of the vision process.

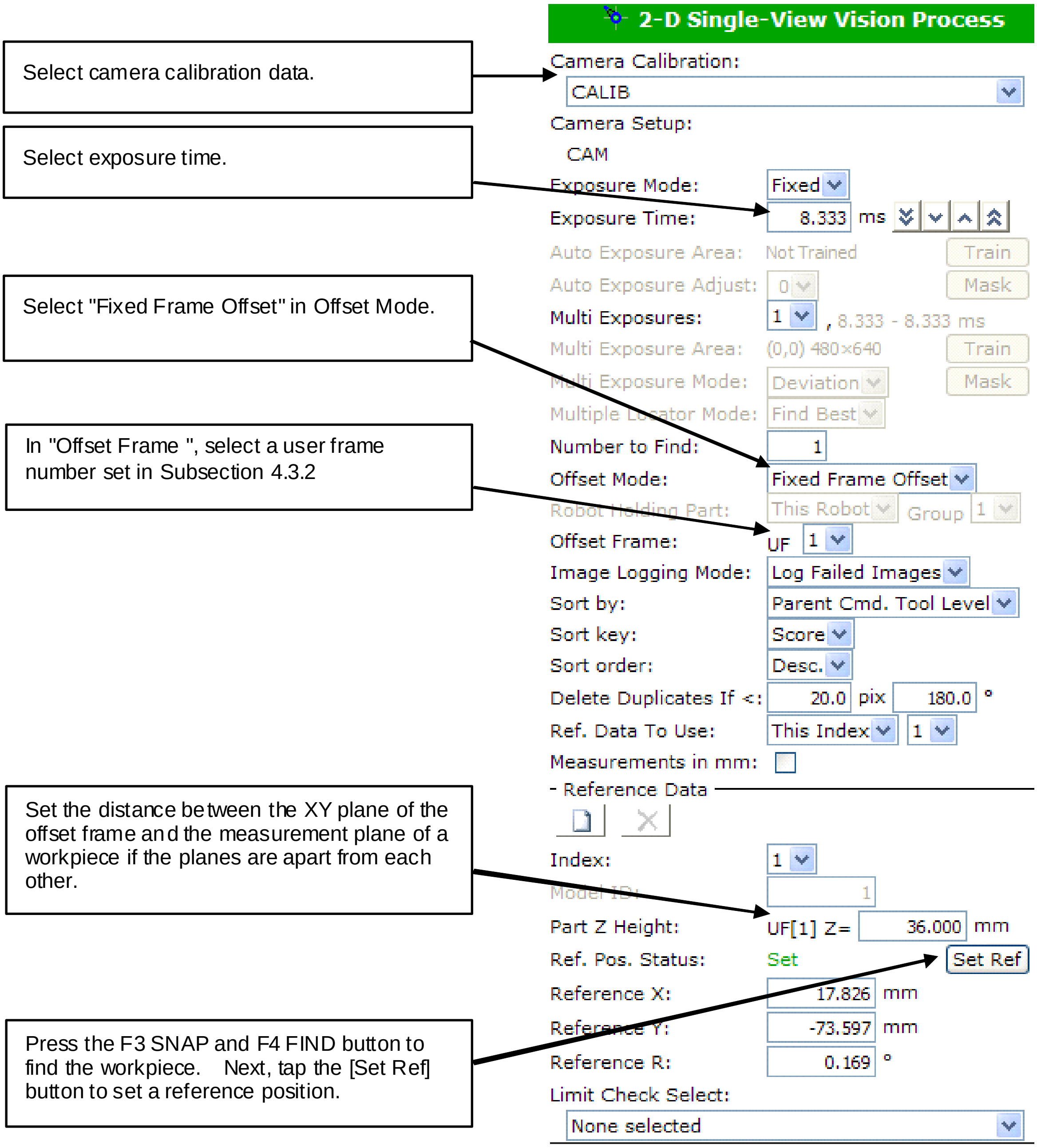


A description of the locator tool is omitted here. For setting of the locator tool, refer to Chapter 7, “COMMAND TOOL” in the *i*RVision Operator’s Manual (Reference) (B-83304EN).

Reference position setting

In this Subsection, the setting method of a reference position is explained. First, open the vision process page as shown below. Next, move the camera to a position that is able to snap a workpicec. In addition, place a workpiece in the field of view. Do not move the workpiece until the reference position setup is completed. Press the F3 SNAP and F4 FIND buttons to detect the workpiece. Next, Tap [Set Ref] in the Reference Data. [Ref. Pos. Status] becomes [Set]. The value of [Reference X], [Reference Y] and [Reference Z] are inputted. The value is the position of the origin of the workpiece in the offset frame.

Jog the robot and move to working position (for example, pick up a workpiece). For an example, refer to sample program of Subsection 4.3.4 "Robot Program Creation and Teaching". LP[2] on the line11 of sample program is a working position for a workpiece. If the robot's current position is set to LP[2], the reference position setting is complete.



4.3.4 Robot Program Creation and Teaching

In the sample program below, a vision process named "A" is used. For fixed frame offset, add the "VOFFSET, VR" instruction as an operation statement.

```
  1:   UFRAME_NUM=1 ;
  2:   UTOOL_NUM=1 ;
  3:   R[1:Notfound]=0      ;
  4:L P[1] 2000mm/sec FINE      ;
  5:   WAIT R[1] ;
  6:   VISION RUN_FIND 'A'      ;
  7:   VISION GET_OFFSET 'A' VR[1] JMP LBL[100] ;
  8:    ;
  9:   !Handling ;
 10:L P[2] 2000mm/sec CNT100 VOFFSET,VR[1] Tool_Offset,PR[1]      ;
 11:L P[2] 500mm/sec FINE VOFFSET,VR[1]      ;
 12:   CALL HAND_CLOSE      ;
 13:L P[2] 2000mm/sec CNT100 VOFFSET,VR[1] Tool_Offset,PR[3]      ;
 14:   !Handling ;
 15:   JMP_LBL[900] ;
 16:    ;
 17:   LBL[100] ;
 18:   R[1:Notfound]=1      ;
 20:    ;
 21:   LBL[900] ;
```

Move to camera position to snap on line 4. Execute a "WAIT" instruction to remove the possible vibration of a camera on line 5. Execute program "A" with the vision run_find instruction on line6. Obtain the measurement result of the detected workpiece with the vision get_offset instruction on line 7. Move to approach position above the workpiece on line 10. Move to grasp position on line 11. Move to the escape position after grasping the workpiece on line 13.

4.3.5 Robot Compensation Operation Check

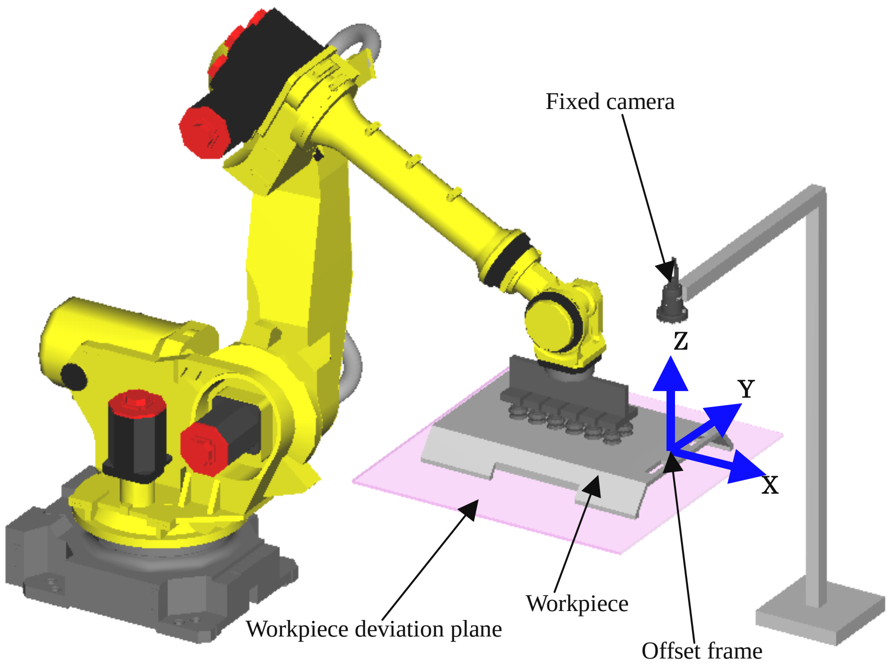
Check that a workpiece placed on the table can be detected and handled precisely.

- Place the workpiece on the reference position, find it and check the handling accuracy. If the accuracy of compensation is low, retry the reference position setting.
- Move the workpiece without rotation, find it and check the handling accuracy. If the accuracy is good for reference position, but low for non-rotated workpiece on the edge of the field of view, it is possible that Part Z Height is not set properly. Check the Part Z Height, refer to Subsection 4.3.3, "Vision process Creation and Teaching"
- Rotate the workpiece, find it and check the handling accuracy. If the accuracy is good for moved workpiece without rotation, but low for rotated workpiece and lower for more rotated workpiece, it is possible that offset frame or the calibration grid frame location is not set properly. If the calibration grid frame was manually taught with a pointer, verify the accuracy of the pointer TCP (UTool) used to teach the frame. Moreover, check the offset frame and the calibration grid frame are set precisely, then retry the camera calibration. If it is difficult to re-do the camera calibration, the "ADJ_OFS" may improve the situation without the re-set up the offset frame and the calibration grid location. ADJ_OFS is included in VISION SUPPORT TOOLS. Refer to Subsection 12.1.6, "ADJ_OFS" in the *i*RVision Operator's Manual (Reference) (B-83304EN) for details.
- Depending on robot motion, a camera may vibrate at snap position. Execute "WAIT" instruction to remove the possible vibration of a workpiece before the "VISION RUN_FIND".
- Start with lower override of the robot to check that the logic of the program is correct. Next, increase the override to check that the robot can operate continuously.

4.4 SETUP FOR "TOOL OFFSET WITH FIXED CAMERA "

Tool offset measures, with a camera, how much a workpiece gripped by a robot is deviated from the correct grip position. This feature performs compensation so that the robot places the gripped workpiece at the predetermined position correctly.

An example layout for "tool offset with fixed camera" is given below.



Use the following setup procedure for "tool offset with fixed camera":

1. Camera calibration setting

⇩

2. Offset user frame setting

⇩

3. Vision process creation and teaching

⇩

4. Robot program creation and teaching

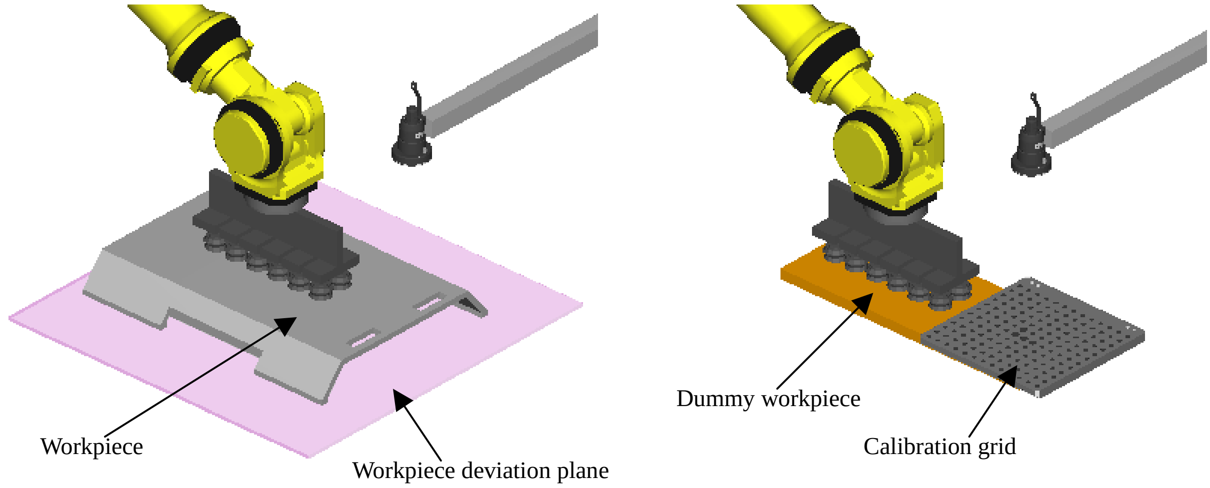
When initially setting up the vision system, perform all the above procedures. When the position of the camera is shifted or the camera is replaced, redo "1 Camera calibration setting." If the camera is already calibrated a new workpiece is added or changed perform "3 Vision process creation and teaching." and "4 Robot program creation and teaching."

4.4.1 Camera Calibration Setting

There are two methods for a camera calibration, those are Grid Pattern Calibration and Robot-generated Grid Calibration.

Grid Pattern Calibration

When the Grid Pattern Calibration is used for calibration, it is recommended to set the calibration grid on a dummy workpiece.
The figure below shows an example of setting the calibration grid at a workpiece measurement position. Prepare a dummy workpiece that resembles an actual workpiece and can be gripped. Setup work can be simplified by setting a calibration grid on a dummy workpiece. Set the dummy workpiece for calibration so that the XY plane of the calibration grid is parallel with the plane on which a workpiece moves.



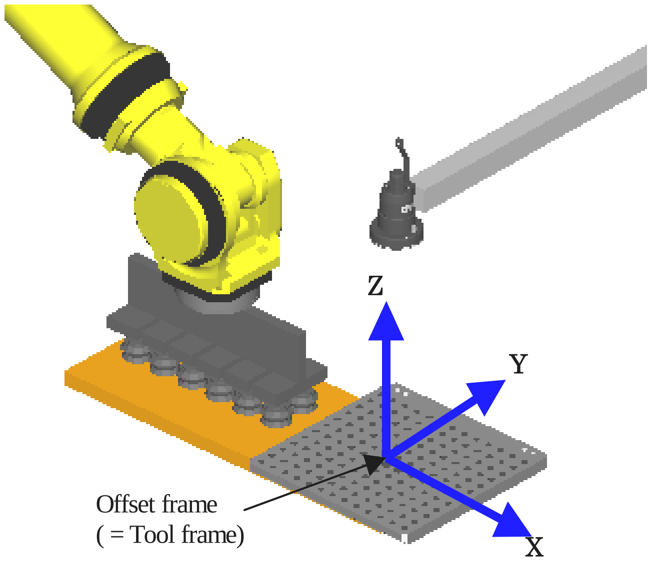
When the calibration grid is placed so that the XY plane of the calibration grid is parallel with the plane on which a workpiece moves, the setup of the offset frame becomes easier. For details of the grid frame calibration, see Section 8.1, “GRID PATTERN CALIBRATION WITH A FIXED CAMERA”.

Robot-generated Grid Calibration

When the Robot-generated Grid Calibration is used for calibration, it is recommended to set the target on a dummy workpiece. Prepare a dummy workpiece that resembles an actual workpiece and can be gripped. Setup work can be simplified by setting a target on a dummy workpiece. Set a target for calibration so that the XY plane of the target is parallel with the plane on which a workpiece moves. When the target is placed so that the XY plane of the target is parallel with the plane on which a workpiece moves, the setup of the offset frame becomes easier. For details of the Robot-generated Grid Calibration, see Section 8.3, “ROBOT-GENERATED GRID CALIBRATION”.

4.4.2 Offset Frame Setting

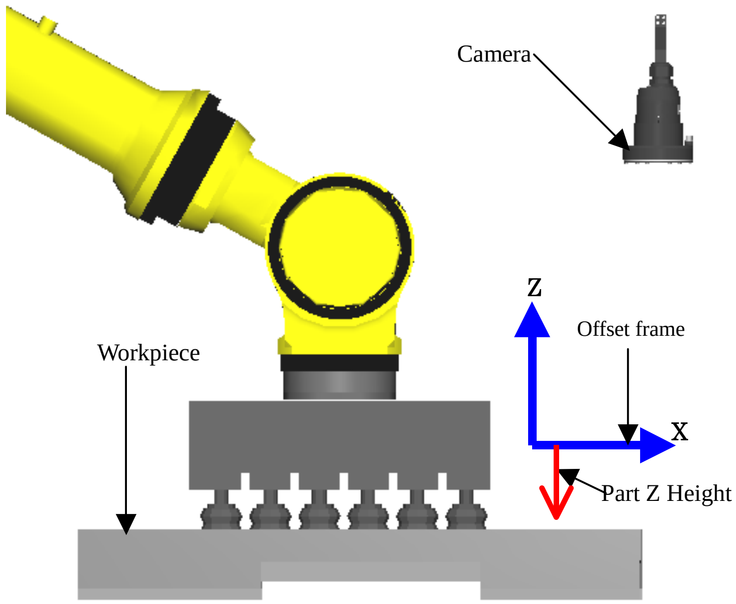
An offset frame is the coordinate system used for calculation of the offset data in the 2D Single-view Vision Process. A found position is outputted as a position in the offset frame. In the fixed frame offset, the offset frame is set as a user frame, but in the tool offset, it is set as a tool frame.
In a tool offset, set a tool frame so that the XY plane of the tool frame is parallel with the workpiece deviation plane.
When performing the Grid Pattern Calibration, if the XY plane of the tool frame that is set in Subsection 8.1.3, "Calibration Grid Frame Setting" is parallel with the workpiece deviation plane, the tool frame can be used as the offset frame.



When performing the Robot-generated Grid Calibration, if the XY plane of the tool frame (UTool for work space) that is set in Subsection 8.3.5, "Measuring target position" is parallel with the workpiece deviation plane, the tool frame can be used as the offset frame. In this case, it is recommended using another tool frame number that is copied value of the UTool for work space. For example, when the UTool for work space number is nine, copy the value of the UTool for work space to the contents of anther tool frame (for example, UTool 1), and select the tool frame number as the offset frame number.

4.4.3 Vision Process Creation and Teaching

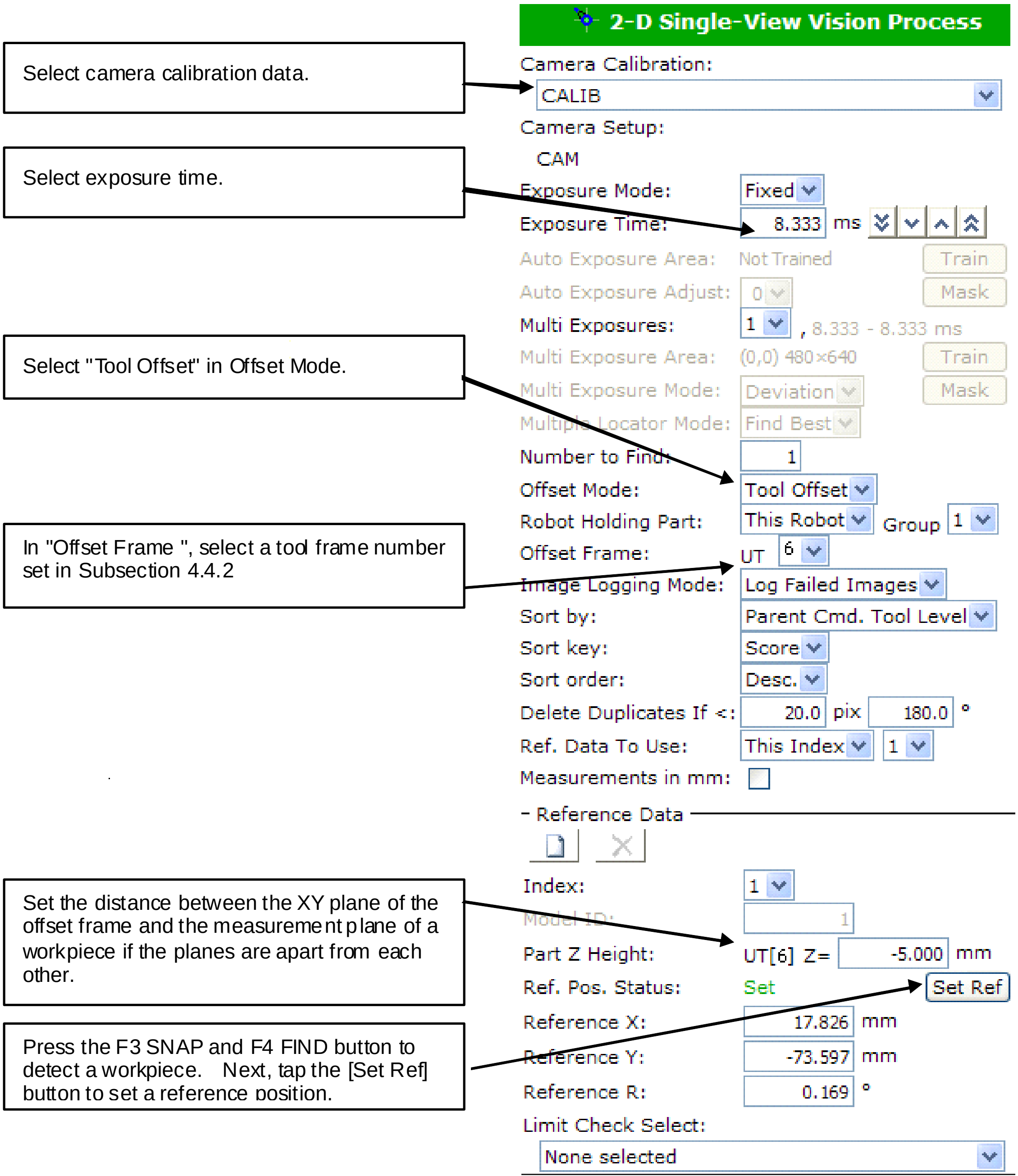
Create a "2D Single-view Vision Process".
Only for tool offset, select the tool frame number set up in Subsection 4.4.2 "Offset Frame Setting".
Select the tool frame number in the vision process screen.
If the measurement plane of a workpiece is apart in the Z direction from the XY plane of the offset frame set in Subsection4.4.2, "Offset Frame Setting", set the Z coordinate of the measurement plane viewed from the XY plane of the offset frame in "Part Z Height" of the vision process.



A description of the locator tool is omitted here. For setting of the locator tool, refer to Chapter 7, “COMMAND TOOL” in the *i*RVision Operator’s Manual (Reference) (B-83304EN).

Reference position setting

In this Subsection, the setting method of a reference position is explained. First, open a vision process page as shown below. Next, grasp a workpiece with a robot and move it into a filed of view. In addition, do not move a workpiece in a robot gripper until a reference position setup is completed. Press the F3 SNAP and F4 FIND buttons to detect a workpiece. Next, tap [Set Ref] in the Reference Data. [Ref. Pos. Status] becomes [Set]. In addition, the value of [Reference X], [Reference Y] and [Reference Z] are inputted. The value is the position of the origin of the workpiece in the offset frame.
Jog the robot and move to working position (for example, place a workpiece). For an example, refer to sample program of Subsection 4.4.4 "Robot Program Creation and Teaching". LP[2] on the line11 of sample program is a working position for a workpiece. If the robot's current position is set to LP[2], the reference position setting is complete.



4.4.4 Robot Program Creation and Teaching

In the sample program below, a vision process named "A" is used. For tool offset, add the "VOFFSET, VR" instruction as an operation statement.

```
   1:  UFRAME_NUM=1 ;
   2:  UTOOL_NUM=6 ;
   3:  R[1:Notfound]=0     ;
   4:L P[1] 2000mm/sec FINE     ;
   5:  WAIT R[1] ;
   6:  VISION RUN_FIND 'A'     ;
   7:  VISION GET_OFFSET 'A' VR[1] JMP LBL[100] ;
   8:   ;
   9:  !Handling ;
  10:L P[2] 2000mm/sec CNT100 VOFFSET,VR[1] Offset,PR[1]     ;
  11:L P[2] 500mm/sec FINE VOFFSET,VR[1]     ;
  12:  CALL HAND_OPEN     ;
  13:L P[2] 2000mm/sec CNT100 VOFFSET,VR[1] Offset,PR[3]     ;
  14:  !Handling ;
  15:  JMP_LBL[900] ;
  16:   ;
  17:  LBL[100] ;
  18:  R[1:Notfound]=1     ;
  19:   ;
  20:  LBL[900] ;
```

Move workpiece to position to snap on line 4. Execute a “WAIT” instruction to remove the possible vibration of the workpiece on line 5. Execute vision process ”A” with the vision run_find instruction on line 6. Obtain the offset result of the detected workpiece with the vision get_offset instruction on line 7. Move to the approach position to place the workpiece on line 10. Move to the position to place the workpiece on line 11. Move to the escape position after the workpiece is placed on line 13.

4.4.5 Robot Compensation Operation Check

Check that a workpiece gripped by the robot can be detected and positioned precisely at a desired location.

- Place the workpiece on the reference position, find it and check the handling accuracy. If the accuracy of compensation is low, retry the reference position setting.
- Move the workpiece without rotation, find it and check the handling accuracy. If the accuracy is good for reference position, but low for non-rotated workpiece on the edge of the field of view, it is possible that Part Z Height is not set properly. Check the Part Z Height, refer to Subsection 4.4.3, “Vision process Creation and Teaching”
- Rotate the workpiece, find it and check the handling accuracy. If the accuracy is good for moved workpiece without rotation, but low for rotated workpiece and lower for more rotated workpiece, it is possible that the offset frame or the calibration grid frame is not set properly. If the calibration grid frame was manually taught with a pointer, verify the accuracy of the pointer TCP (UTool) used to teach the frame. Moreover, check the offset frame and the calibration grid frame are set precisely, then, retry the camera calibration.
- Depending on robot motion, a workpiece may vibrate at snap position. Execute “WAIT” instruction to remove the possible vibration of a workpiece before the “VISION RUN_FIND”.
- Start with lower override of the robot to check that the logic of the program is correct. Next, increase the override to check that the robot can operate continuously.

5 2D MULTI VIEW VISION PROCESS

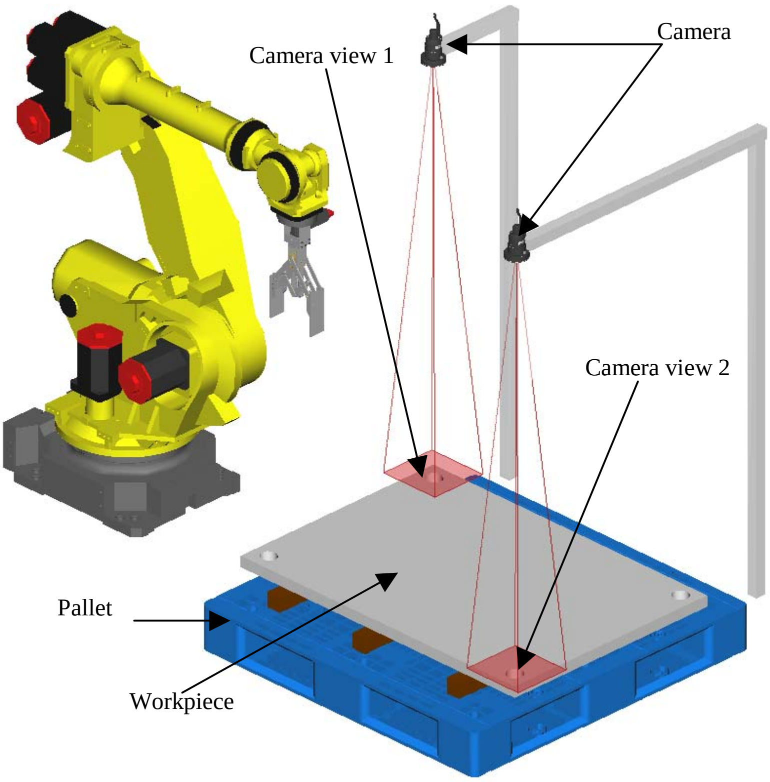
The 2D Multi-view Vision Process measures multiple points of a workpiece to perform two-dimensional compensation. This function is used to measure multiple points of a large workpiece that cannot be contained in the field of view of a single camera. This chapter describes the setup procedure for 2D Multi-view Vision Process by using the following three application examples:

<1> Fixed frame offset with fixed camera
<2> Fixed frame offset with robot-mounted camera
<3> Tool offset with fixed camera

The basic setting method is the same as for 2D Single-view Vision Process. Unlike 2D Single-view Vision Process, 2D Multi-view Vision Process adds "camera views".

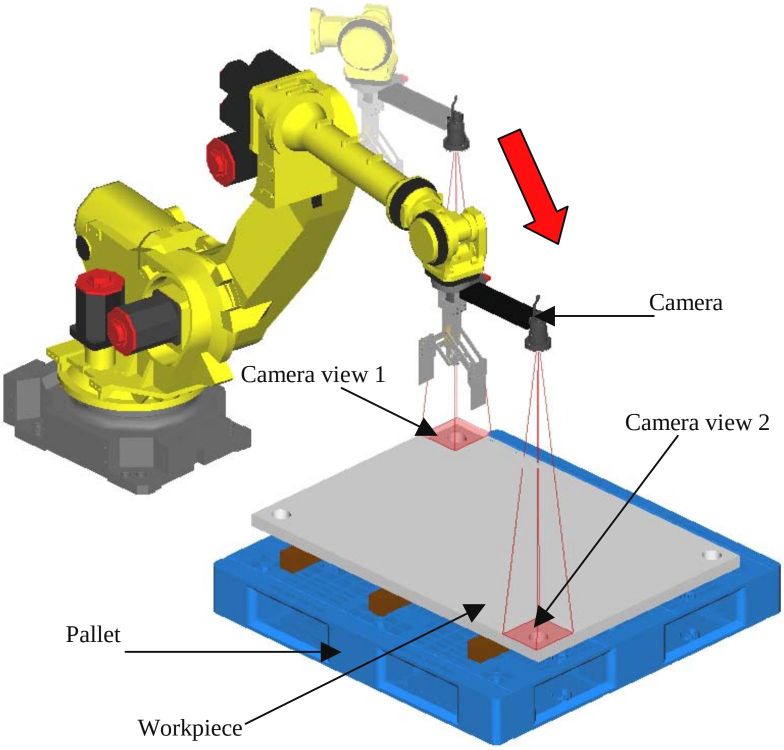
Fixed frame offset with fixed camera

An example of layout for "fixed frame offset with fixed camera" is shown below. A robot detects two points of a workpiece with two cameras and performs fixed frame offset.



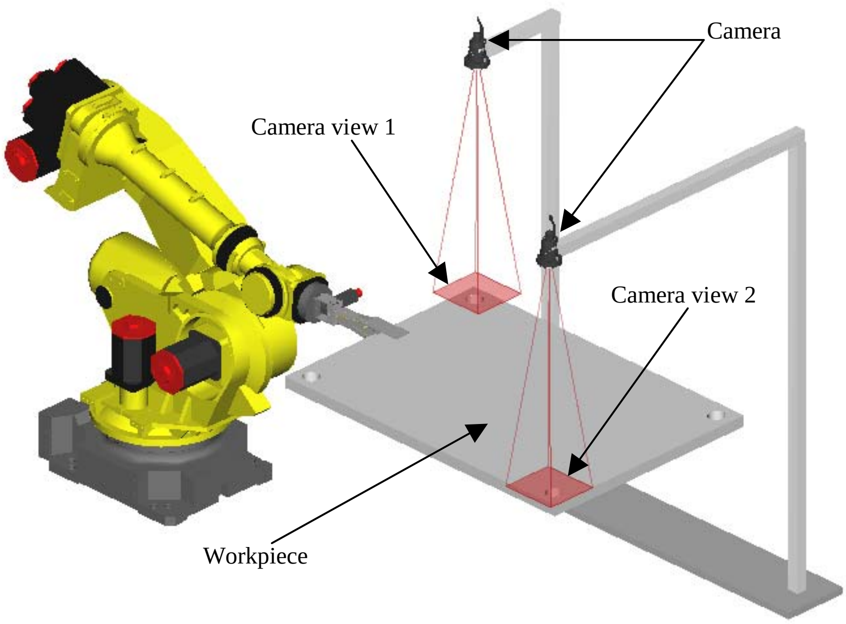
Fixed frame offset with robot-mounted camera

An example of layout for "fixed frame offset with robot-mounted camera" is shown below. A robot detects two points of a workpiece with a robot mounted camera and performs fixed frame offset.

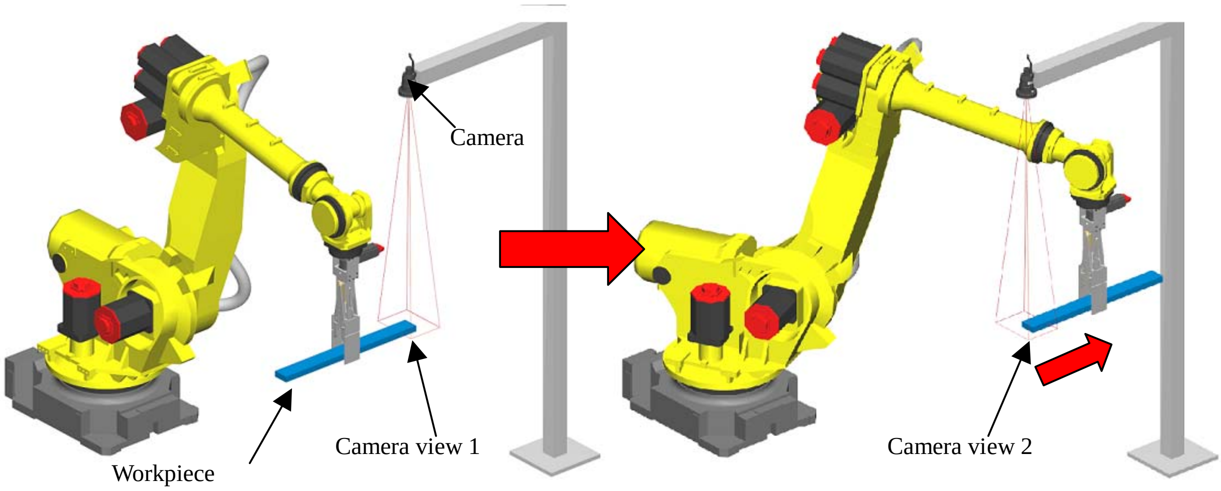


Tool offset with fixed camera

An example of layout for "tool offset with fixed camera" is shown below. A robot detects two points of a workpiece with two cameras and performs tool offset.



The following figure is another example of a layout. A robot detects two points of a workpiece with a camera and performs tool offset.



5.1 FEATURES AND NOTES

Features

- This function performs two-dimensional compensation by measuring multiple points of a large workpiece that cannot be contained in the field of view if only one point is measured.
- Fixed frame offset and tool offset can be performed.
- Both a fixed camera and robot-mounted camera can be used.
- When a robot-mounted camera is used, the position of a workpiece can be measured even when the robot moves in the X and Y directions of the offset frame. This capability is provided because the current position of a robot is considered in *i*RVision calculation processing when a workpiece position calculation is made.

Notes

- Fixed frame offset is applied in the X, Y, and R directions. Accordingly, it is assumed that the measurement planes are in parallel with the X and Y plane of the offset frame and are not tilted
- Up to four measurement points (camera views) can be set.
- When either a fixed camera or a robot-mounted camera is used, it is best if the optical axis of the camera is normal to the XY plane of the offset frame. When the camera is mounted tilted in the XY plane of the offset frame, the shape of the workpieces can be distorted depending on their position in the field of view. In this case, it is possible that detection of the workpiece become difficult.

5.2 SETUP FOR "FIXED FRAME OFFSET WITH FIXED CAMERA"

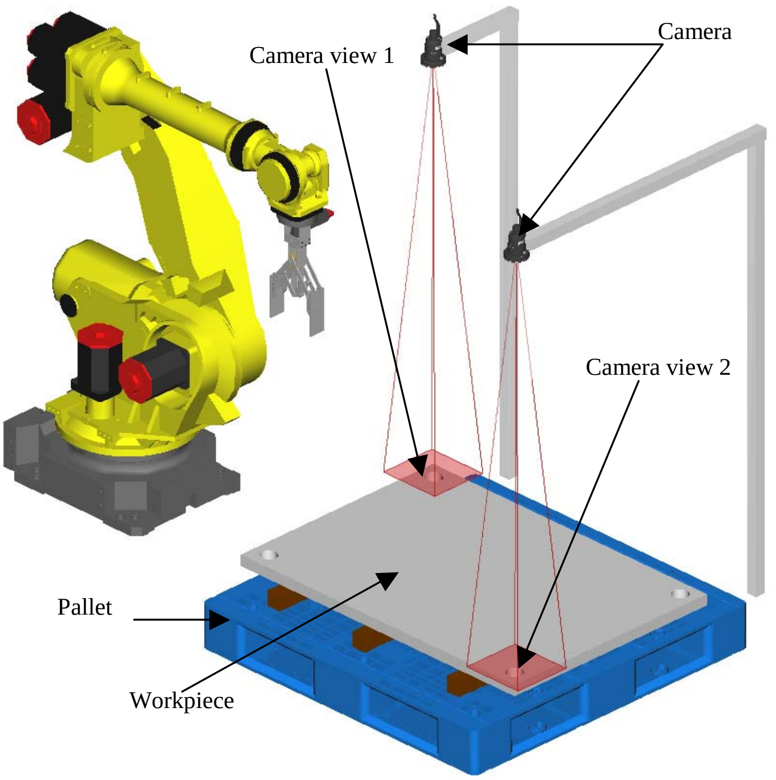
Use the following setup procedure for "fixed frame offset with fixed camera":

1. Camera calibration setting
2. Offset user frame setting
3. Vision process creation and teaching
4. Robot program creation and teaching

When initially setting up the vision system, perform all the above procedures. When the position of the camera is shifted or the camera is replaced, redo "1 Camera calibration setting." If the camera is already calibrated a new workpiece is added or changed perform "3 Vision process creation and teaching." and "4 Robot program creation and teaching."

5.2.1 Camera Calibration Setting

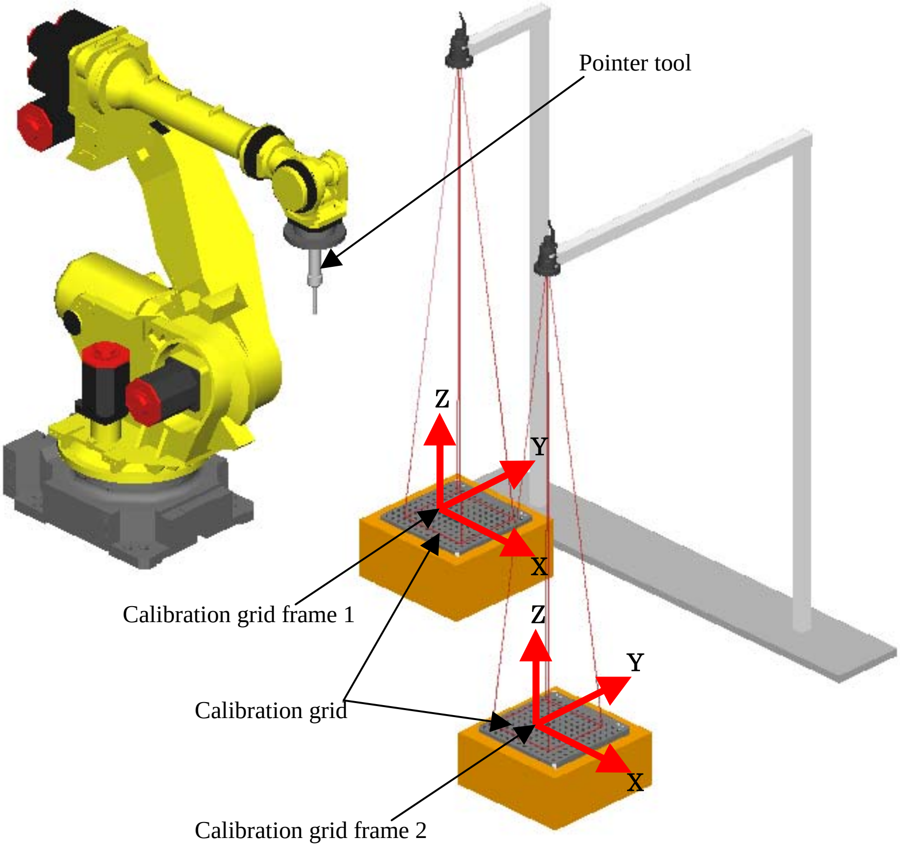
In the 2D Multi-view Vision Process, it is necessary to create calibration data for each camera. Create the camera calibration data as many as number of cameras. For example, when the layout is following figure, teach the two camera setting data and the two camera calibration data.



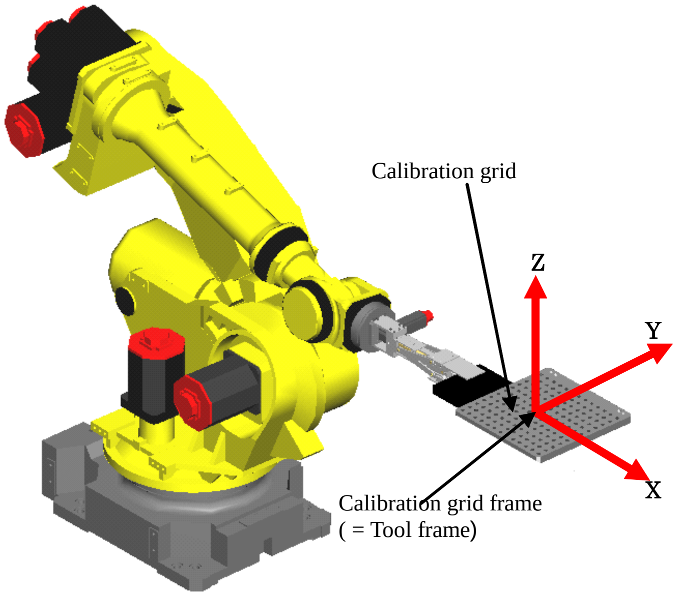
There are two methods for a camera calibration, those are Grid Pattern Calibration and Robot-generated Grid Calibration.

Grid Pattern Calibration

When the calibration grids are fixed, create the calibration grid frames of each camera as the following figure.



As the following figure, a calibration may be performed with a calibration grid mounted on the robot. In this case, the calibration can be performed with only the one calibration grid frame. The Automatic Grid Frame Set Function for the calibration grid frame setting is recommended.



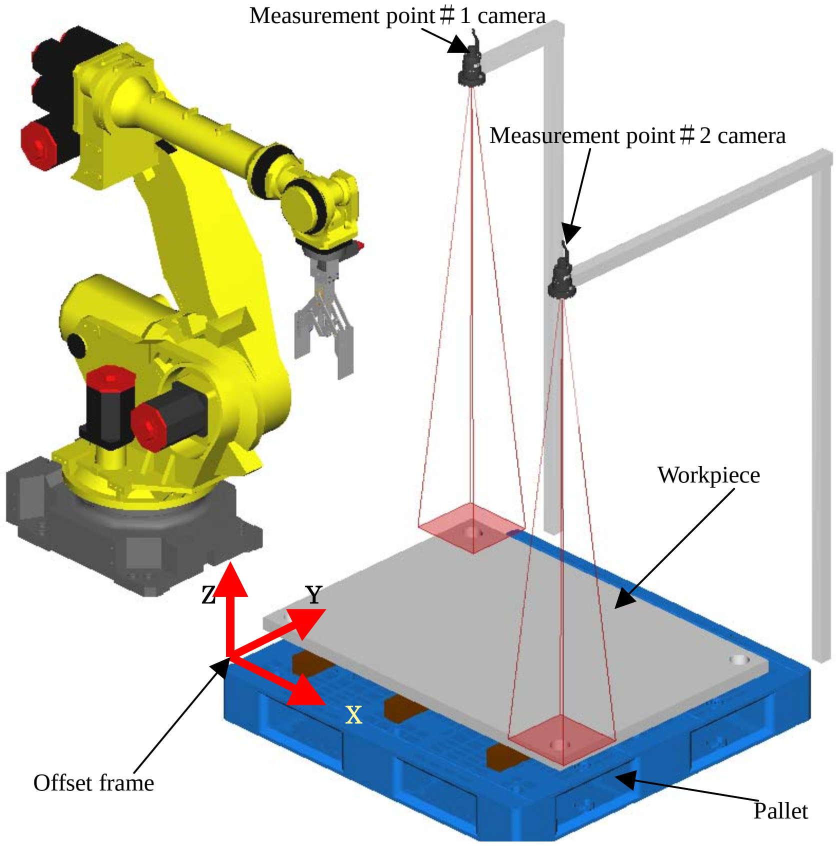
For details of the grid frame calibration, see Section 8.1, “GRID PATTERN CALIBRATION WITH A FIXED CAMERA”.

Robot-generated Grid Calibration

When the Robot-generated Grid Calibration utility is used, the camera calibration for each camera can be performed with a target. For details of the Robot-generated Grid Calibration, see Section 8.3, “ROBOT-GENERATED GRID CALIBRATION”.

5.2.2 Offset Frame Setting

An offset frame is the coordinate system used for calculation of the vision offset. A found position is outputted as a position in the offset frame. In the fixed frame offset, the offset frame is set as a user frame. Set an offset frame so that the XY plane of the offset frame is parallel with the table plane on which the workpiece is placed. Otherwise, the required compensation precision may not be obtained.
Even though there are multiple cameras or camera views in the 2D Multiview Vision Process, there is only one offset and only one offset frame.



There are two methods to teach the offset frame, one is manually touch-up the frame with a pointer tool, and another is the Automatic Grid Frame Set Function.

Touch-up

To manually teach a user frame, a pointer tool with a taught TCP is required. In general, set the TCP accurately on the pointer installed on the robot gripper. Set the robot TCP in an available UTool. To reuse the pointer TCP, the reproducibility of the pointer installation is required. If the reproducibility of the pointer installation is not assured, the TCP needs to be re- taught each time a pointer is installed. For details, see Section 9.1.1, “User frame setting with a pointer tool”.

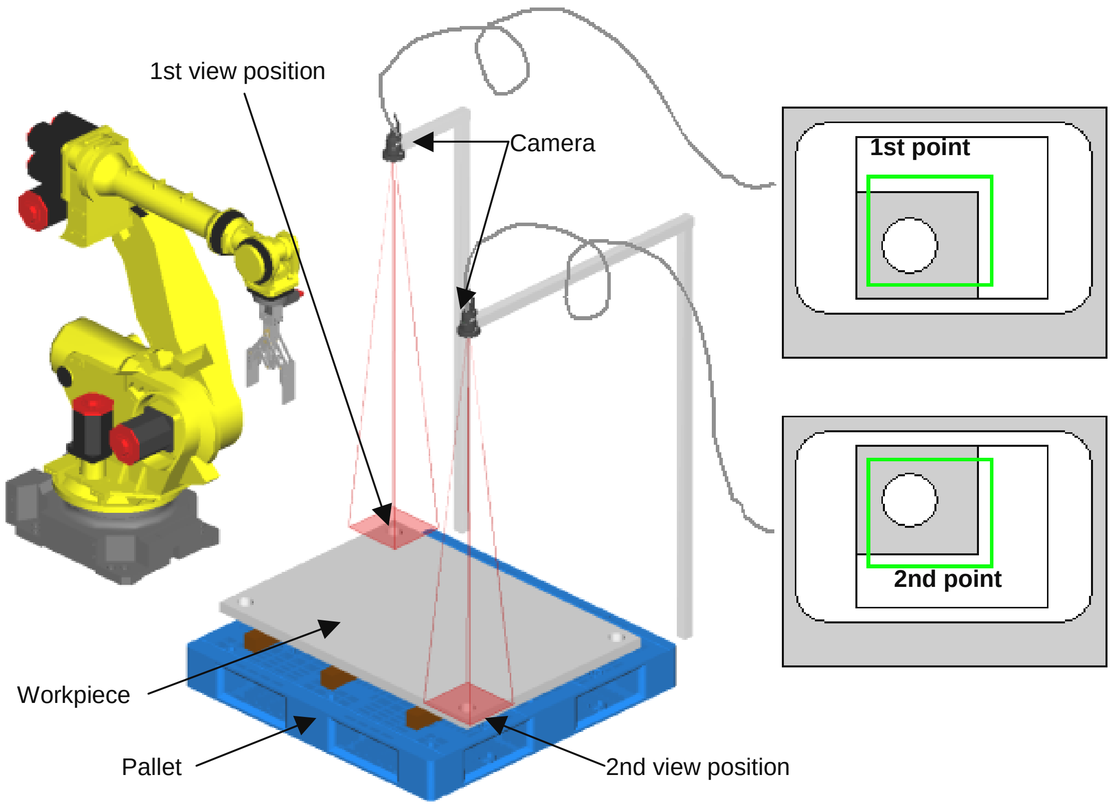
Automatic Grid Frame Set Function

The Automatic Grid Frame Set Function sets the calibration grid frame using a camera. Install a calibration grid so that the XY plane of the calibration grid is parallel with the plane on which the workpiece is placed, and perform the Automatic Grid Frame Set Function. For details, see Section 9.2, “Frame setting with the Automatic Grid Frame Set Function”. A calibration grid is used for a setup. Moreover, in the case of a fixed camera, prepare a camera for the Automatic Grid Frame Set Function separately. And perform the Automatic Grid Frame Set Function using the camera attached to a temporary position of a robot's hand. In addition, the Automatic Grid Frame Set Function is usable with 6-axis robots only. The function cannot be used with 4-axis robots and 5-axis robots. When using 4-axis robots or 5-axis robots, teach the user frame manually.

5.2.3 Vision Process Creation and Teaching

Create a program for "2D Multi-view Vision Process". The basic program setting method is the same as for two-dimensional compensation based on a single camera. Unlike 2D Single-view Vision Process,

2D Multi-view Vision Process adds "camera views". There can be as many camera views as the number of measurement points.
For each measurement point, a camera view is named camera view 1 or camera view 2. "COMMAND TOOL" comes under each camera view.



Use the following procedure to teach a 2D Multi-view Vision Process:

1. Teach locator tool for camera view 1.

⇩

2. Teach locator tool for camera view 2.

⇩

3 Select camera view 1 then press the F3 SNAP and the F4 FIND button to detect a taught model.

⇩

4. Select camera view 2 then press the F3 SNAP and the F4 FIND button to detect a taught model.

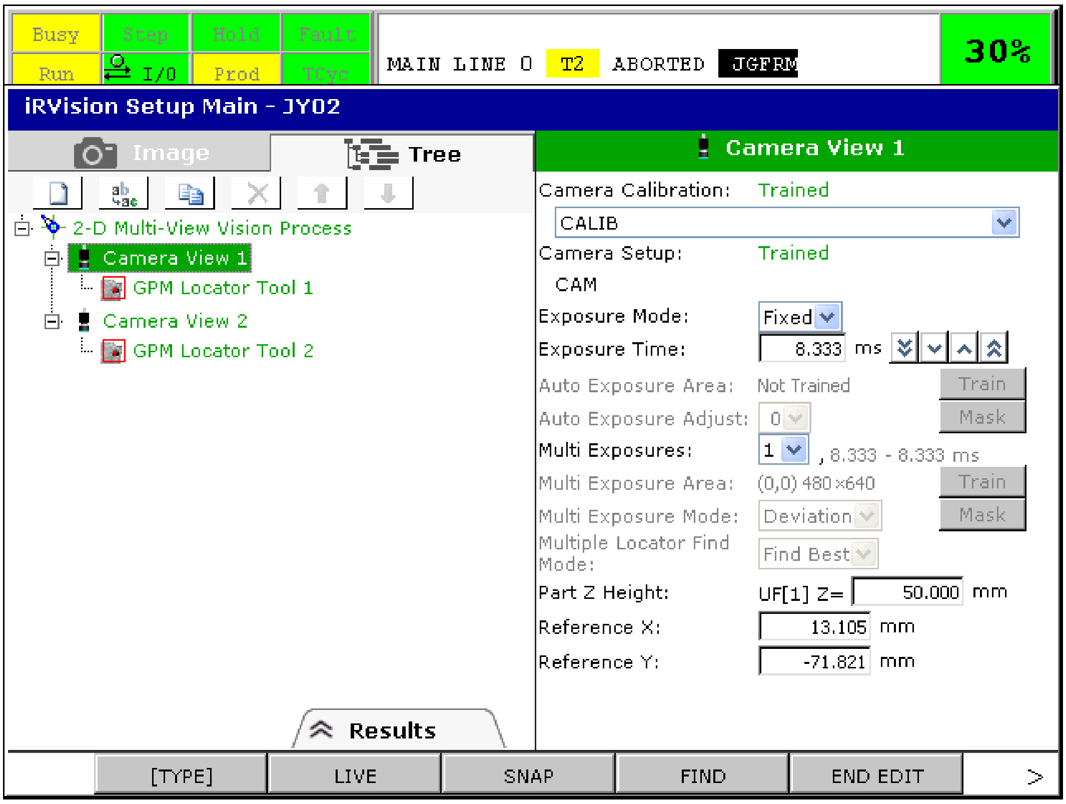
⇩

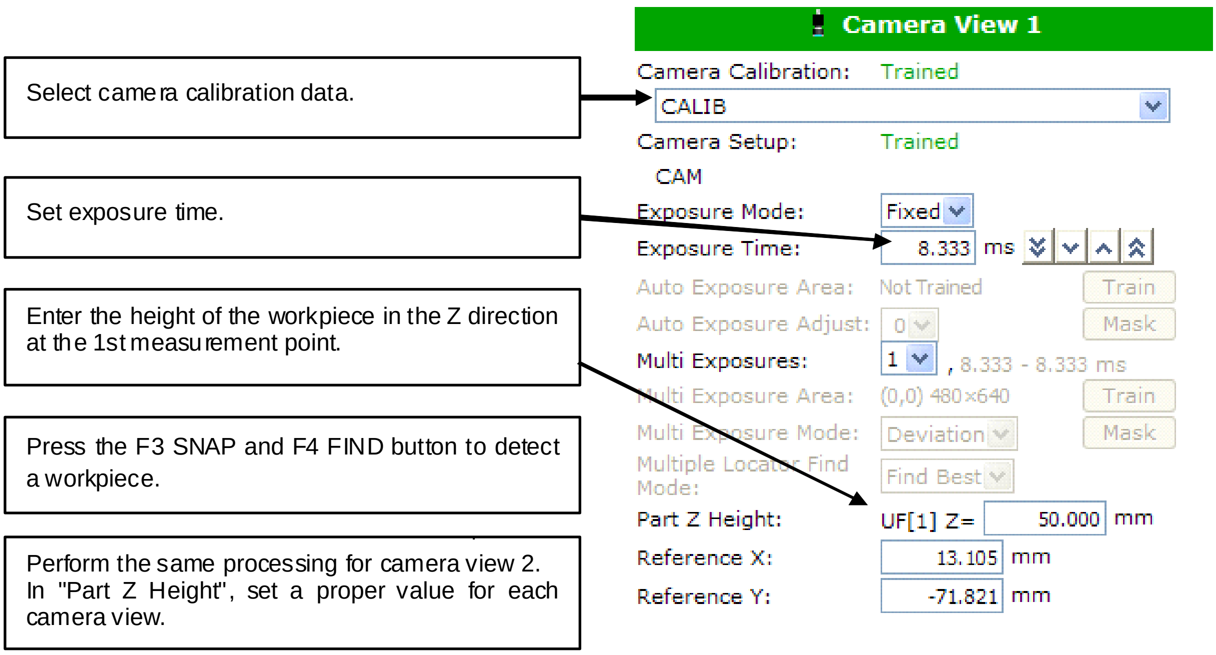
5. Select "2D Multi-View Vision Process" then set a reference position.

Set the reference position immediately after detecting the model with the two camera views. If the teach screen is closed, the procedure needs to be performed all over again starting with model detection using each of the two camera views.

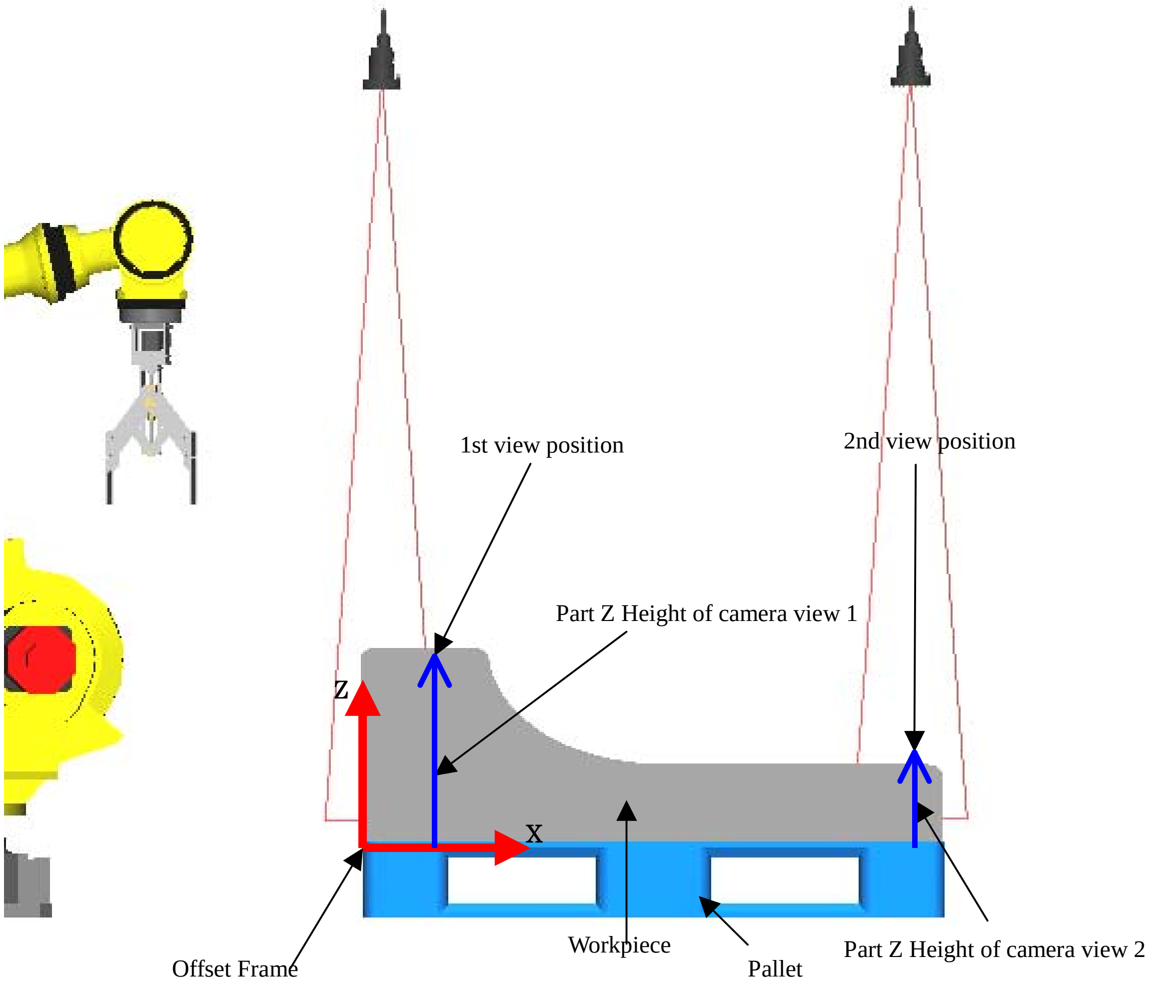
Camera view teaching

With each camera view, teach the locator tool. A detailed description of the locator tool is omitted here. For setting of the locator tool, refer to Chapter 7, "COMMAND TOOL" in the *i*RVision Operator's Manual (Reference) (B-83304EN).



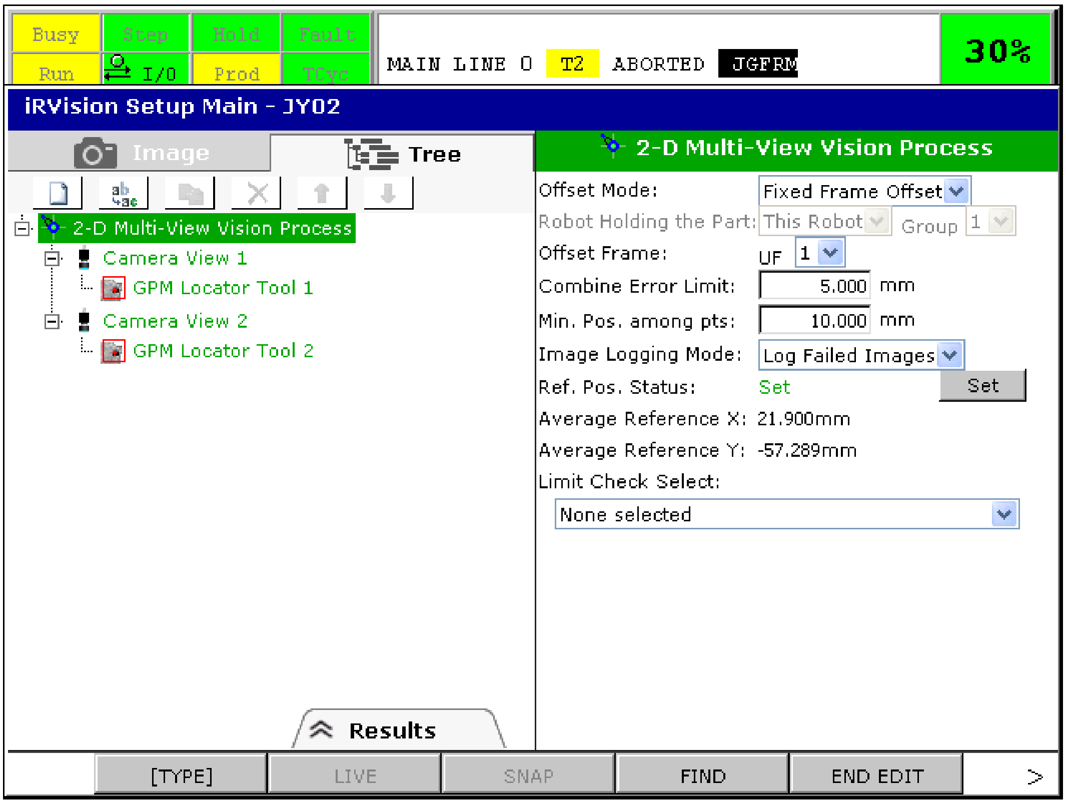


If the measurement plane of a workpiece is apart from the XY plane of the offset frame, set the Z coordinate of the measurement plane viewed from the XY plane of offset frame in "Part Z Height" of the vision process.
In "Part Z Height", set a proper value for each camera view as shown below.



Reference position setting

Upon normal completion of detection with each camera views, set a reference position. First, open a vision process page as shown below. Next, place a workpiece in the field of view. In addition, do not move a workpiece until a reference position setup is completed. Select the Camera View 1 page in the vision process, press the F3 SNAP and the F4 FIND buttons to detect the target of Camera View 1. Next, select the Camera View 2 page in the vision process, press the F3SNAP and F4 FIND buttons to detect the target of Camera View 2. Select the 2-D Multi-view Vision Process page in the vision process, and press the F4 FIND button to detect the workpiece. Then, tap [Set Ref] button in the Reference Data. [Ref. Pos. Status] becomes [Set]. In addition, the value of [Average Reference X] and [Average Reference Y] are inputted. The value is the average reference position of each camera views. The position is relative to the offset frame.
Jog the robot to working position (for example, pick up a workpiece). For an example, refer to sample program of Subsection 5.2.4 "Robot Program Creation and Teaching". LP[2] on the line11 of sample program is a working position for a workpiece. If a robot's current position is set to LP[2], the reference position setting is complete.



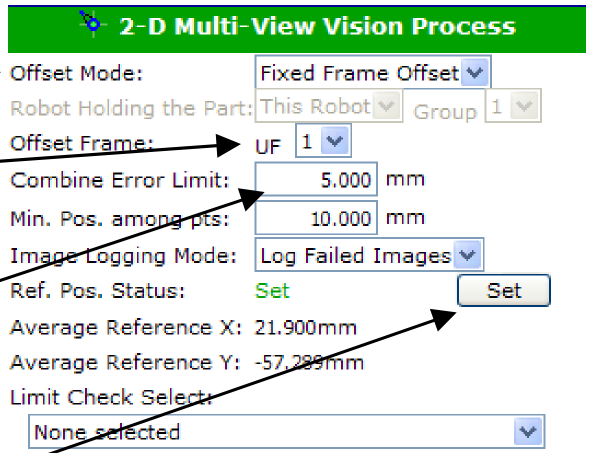
Select "Fixed Frame Offset" in Offset Mode.

Select the offset frame number.

In “Combine Error Limit”, set a proper value as needed.

Immediately after detecting a workpiece by pressing the F3 SNAP and F4 FIND button with each camera view, tap the [Set] button. This sets a reference position for all camera views.

Only when a fixed camera is used, a reference position can be set by pressing the F3 SNAP and F4 FIND button once on the vision process screen.



5.2.4 Robot Program Creation and Teaching

In the sample program below, a vision process named "A" is used. Two characteristic positions of a large workpiece are detected. If multiple fixed cameras are used, no camera view number needs to be specified in the "VISION RUN_FIND" instruction. . For fixed frame offset, add the "VOFFSET, VR" instruction as an operation statement.

```
   1:  UFRAME_NUM=1 ;
   2:  UTOOL_NUM=1 ;
   3:  R[1:Notfound]=0      ;
   4:L P[1] 2000mm/sec FINE      ;
   5:    ;
   6:  VISION RUN_FIND 'A'      ;
   7:  VISION GET_OFFSET 'A' VR[1] JMP LBL[100] ;
   8:    ;
   9:  !Handling ;
  10:L P[2] 2000mm/sec CNT100 VOFFSET,VR[1] Tool_Offset,PR[1]      ;
  11:L P[2] 500mm/sec FINE VOFFSET,VR[1]      ;
  12:  CALL HAND_CLOSE      ;
  13:L P[2] 2000mm/sec CNT100 VOFFSET,VR[1] Tool_Offset,PR[3]      ;
  14:  !Handling ;
  15:  JMP_LBL[900] ;
  16:  ;
  17:  LBL[100] ;
  18:  R[1:Notfound]=1      ;
  19:    ;
  20:  LBL[900] ;
```

Obtains the measurement result of the detected workpiece on line7. Move to the approach position above the workpiece on line10. Move to the grasp position on line11. Move to escape position after grasping the workpiece on line13.
When a fixed camera is used, one "VISION RUN_FIND" instruction measures all camera views prepared beforehand. When the images of all camera views have been snapped, the line after the "VISION RUN_FIND” instruction is executed.

5.2.5 Robot Compensation Operation Check

Check that multiple points of a workpiece can be detected and that the workpiece can be handled correctly.

- Place the workpiece on the reference position, find it and check the handling accuracy. If the accuracy of compensation is low, retry the reference position setting.
- Move the workpiece without rotation, find it and check the handling accuracy. If the accuracy is good for reference position, but low for non-rotated workpiece on the edge of the field of view, it is possible that Part Z Height is not set properly. Check the Part Z Height, refer to Subsection 5.2.3, “Vision process Creation and Teaching”
- Rotate the workpiece, find it and check the handling accuracy. If the accuracy is good for a moved workpiece without rotation, but low for rotated workpiece and lower for more rotated workpiece, it is possible that the offset frame or the calibration grid frame is not set properly. If the calibration grid frame was manually taught with a pointer, verify the accuracy of the pointer TCP (UTool) used to teach the frame. Moreover, check the offset frame and the calibration grid frame are set precisely, then retry the camera calibration.
- Start with lower override of the robot to check that the logic of the program is correct. Next, increase the override to check that the robot can operate continuously.

5.3 SETUP FOR "FIXED FRAME OFFSET WITH ROBOT-MOUNTED CAMERA "

Use the following setup procedure for "fixed frame offset with robot-mounted camera":

1. Camera calibration setting

⇩

2. Offset user frame setting

⇩

3. Vision process creation and teaching

⇩

4. Robot program creation and teaching

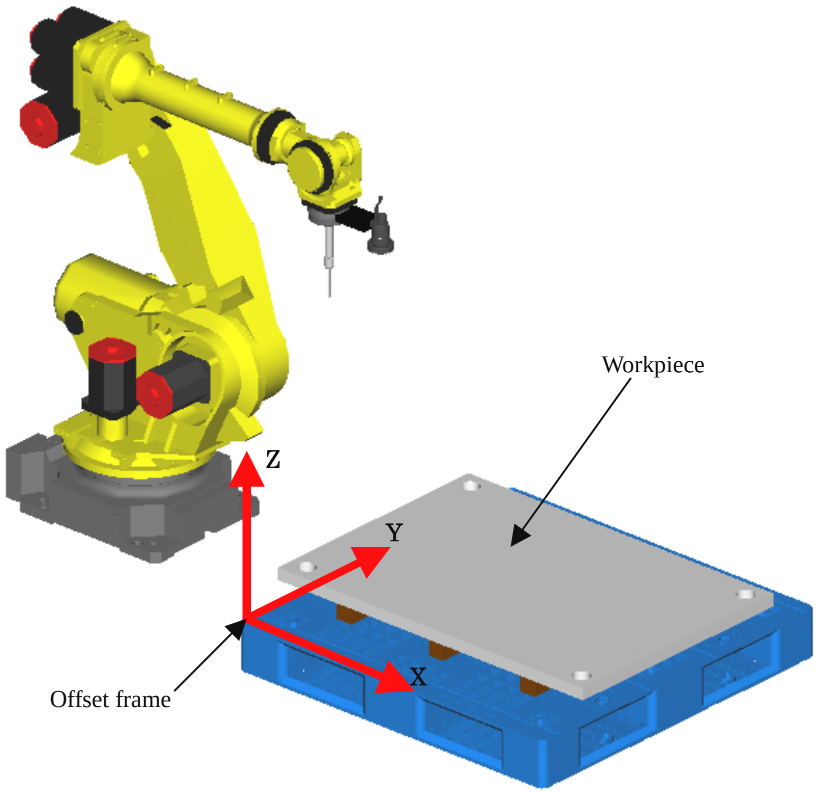
When initially setting up the vision system, perform all the above procedures. When the position of the camera is shifted or the camera is replaced, redo "1 Camera calibration setting." If the camera is already calibrated a new workpiece is added or changed perform "3 Vision process creation and teaching." and "4 Robot program creation and teaching."

5.3.1 Camera Calibration Setting

When the 2D Multi-view Vision Process is performed with a robot-mounted camera, the targets on the workpiece are found with one camera in different robot position. So, one camera setting data and one calibration data are required. When using a robot-mounted camera, perform the Grid Pattern Calibration. In the case of a robot-mounted camera, the Robot-generated Grid Calibration cannot be used. For details of the grid frame calibration, see Section 8.2, “GRID PATTERN CALIBRATION WITH A ROBOT-MOUNTED CAMERA”.

5.3.2 Offset Frame Setting

An offset frame is the coordinate system used for calculation of the offset data. A found position is outputted as a position in the offset frame. In the fixed frame offset, the offset frame is set as a user frame. Set an offset frame so that the XY plane of the user frame is parallel with the table plane on which a workpiece is placed. Otherwise, the required compensation precision may not be obtained.



There are two methods to teach the offset frame, one is touch-up with the pointer tool, and another is the Automatic Grid Frame Set Function.

Touch-up

To manually teach a user frame, a pointer tool with a taught TCP is required. In general, set the TCP accurately on the pointer installed on the robot gripper. Set the robot TCP in an available UTool. To reuse the pointer TCP, the reproducibility of the pointer installation is required. If the reproducibility of the pointer installation is not assured, the TCP needs to be re- taught each time a pointer is installed. For details, see Section 9.1.1, “User frame setting with a pointer tool”.

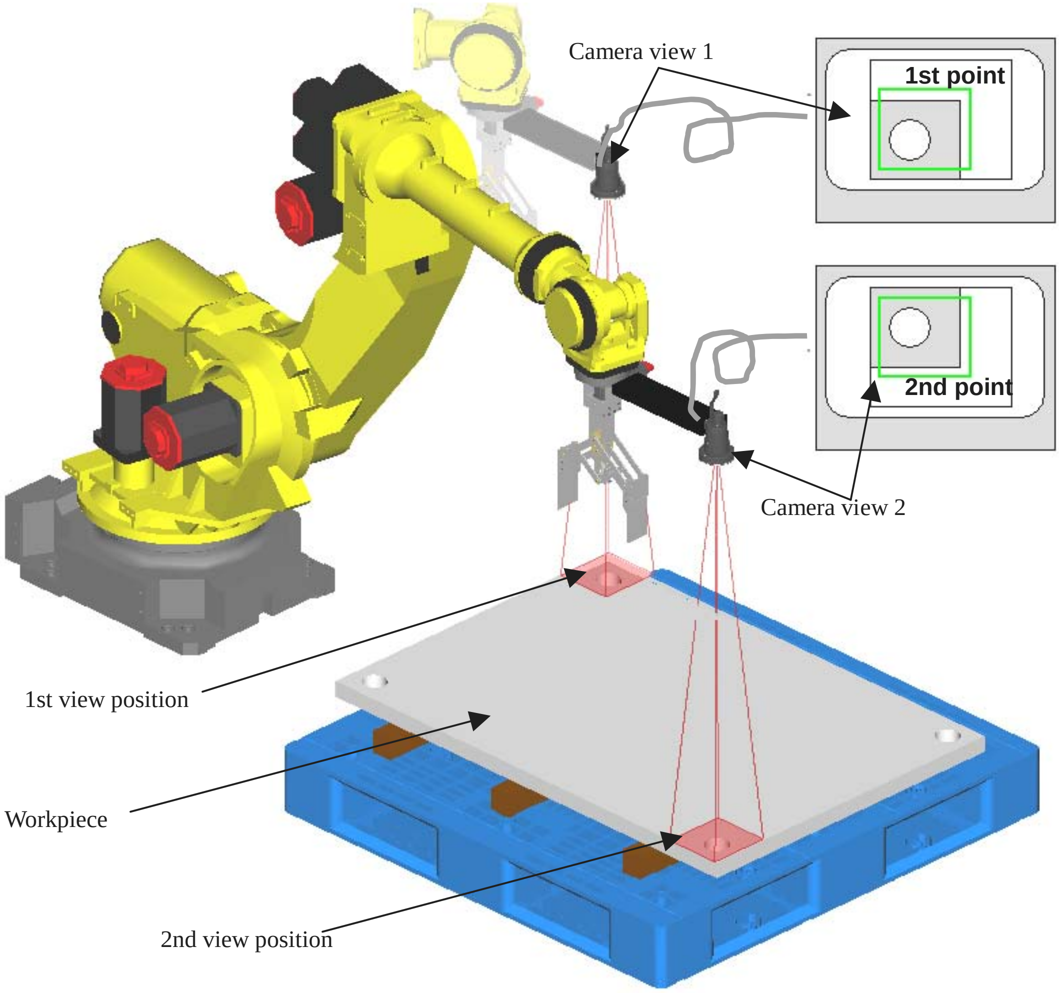
Automatic Grid Frame Set Function

The Automatic Grid Frame Set Function sets the calibration grid frame using a camera. Install a calibration grid so that the XY plane of the calibration grid is parallel with the plane on which the workpiece is placed, and perform the Automatic Grid Frame Set Function. For details, see Section 9.2, “Frame setting with the Automatic Grid Frame Set Function”. A calibration grid is used for setup. Moreover, in the case of a fixed camera, prepare a camera for the Automatic Grid Frame Set Function separately. And perform the Automatic Grid Frame Set Function using the camera attached to a temporary position of a robot's hand. In addition, the Automatic Grid Frame Set Function is usable with 6-axis robots only. The function cannot be used with 4-axis robots and 5-axis robots. When using 4-axis robots or 5-axis robots, teach the frame manually.

5.3.3 Vision Process Creation and Teaching

Create a program for "2D Multi-view Vision Process". The basic program setting method is the same as for 2-D Single-View Vision Process. Unlike 2D Single-view Vision Process, 2D Multi-view Vision Process adds "camera views". There can be as many camera views as the number of measurement points.

For each measurement point, a camera view is named camera view 1 or camera view 2. "COMMAND TOOL" comes under each camera view.



Use the following procedure to teach a 2D Multi-view Vision Process:

1. Move the robot to the first measurement position then teach the locator tool for camera view 1.

2. Select camera view 1 then press the F3 SNAP and the F4 FIND button to detect a taught model.

3. Move the robot to the second measurement position then teach the locator tool for camera view 2.

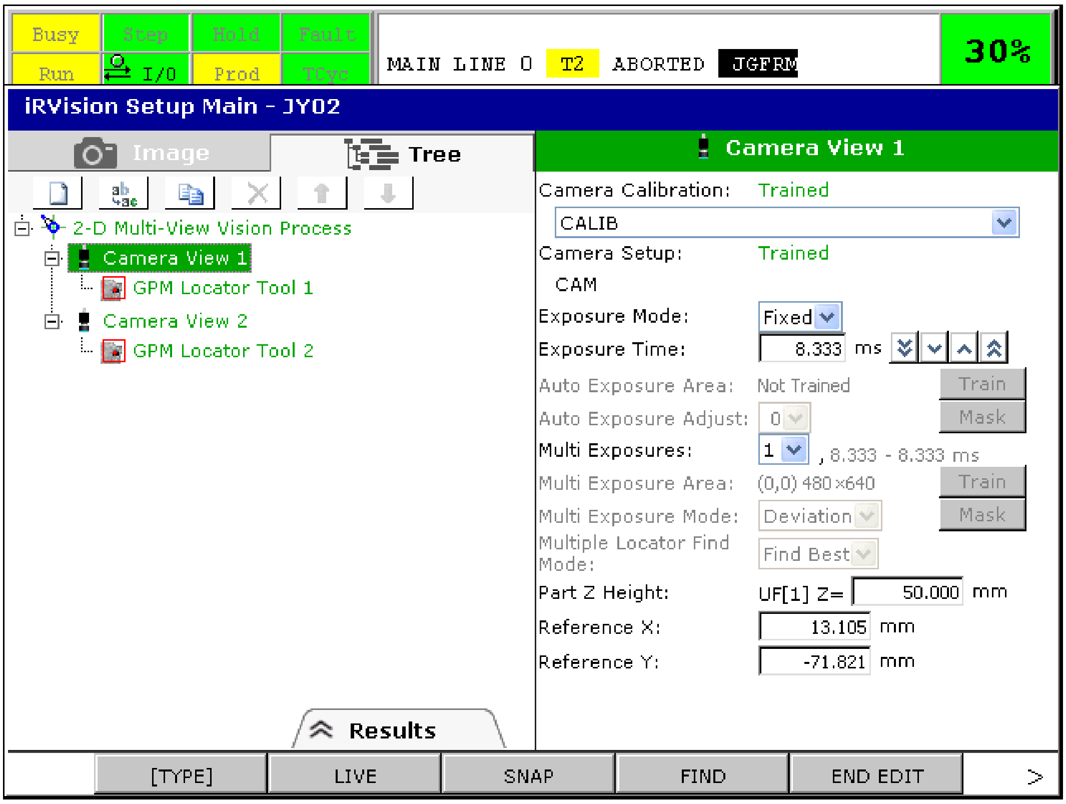
4. Select camera view 2 then press the F3 SNAP and the F4 FIND button to detect a taught model.

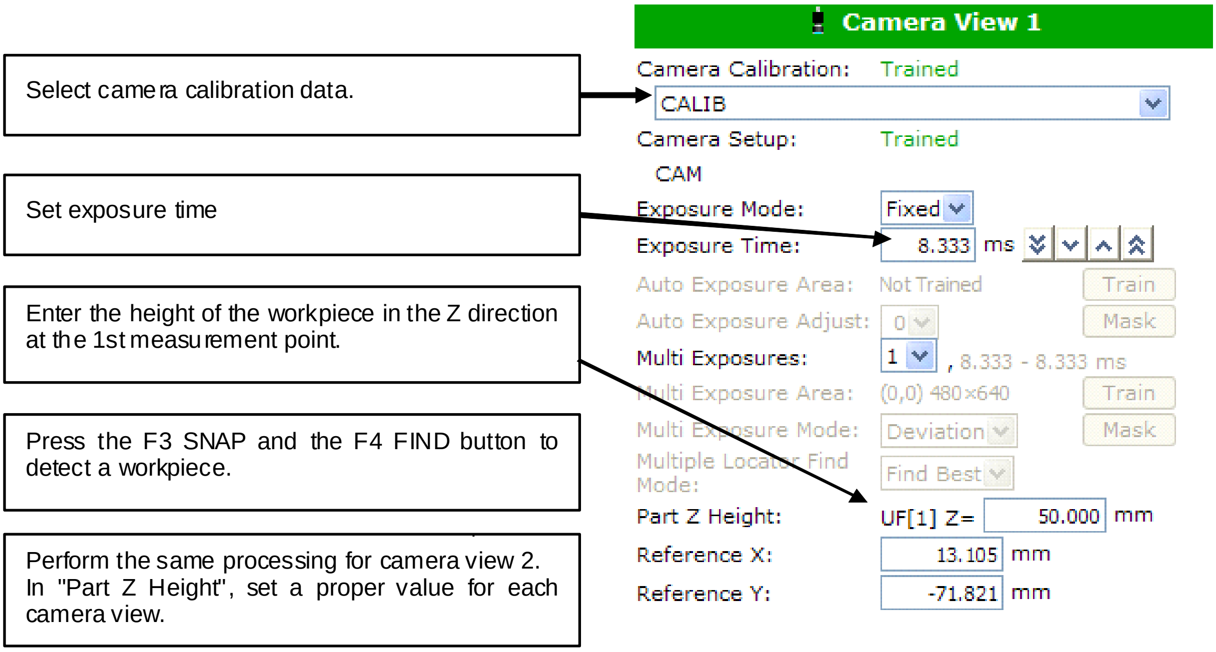
5. Select "2D Multi-view Vision Process" then set a reference position.

Set a reference position immediately after detecting a model with two camera views. If the teach screen is closed, the procedure needs to be performed all over again starting with model detection using each of the two camera views.

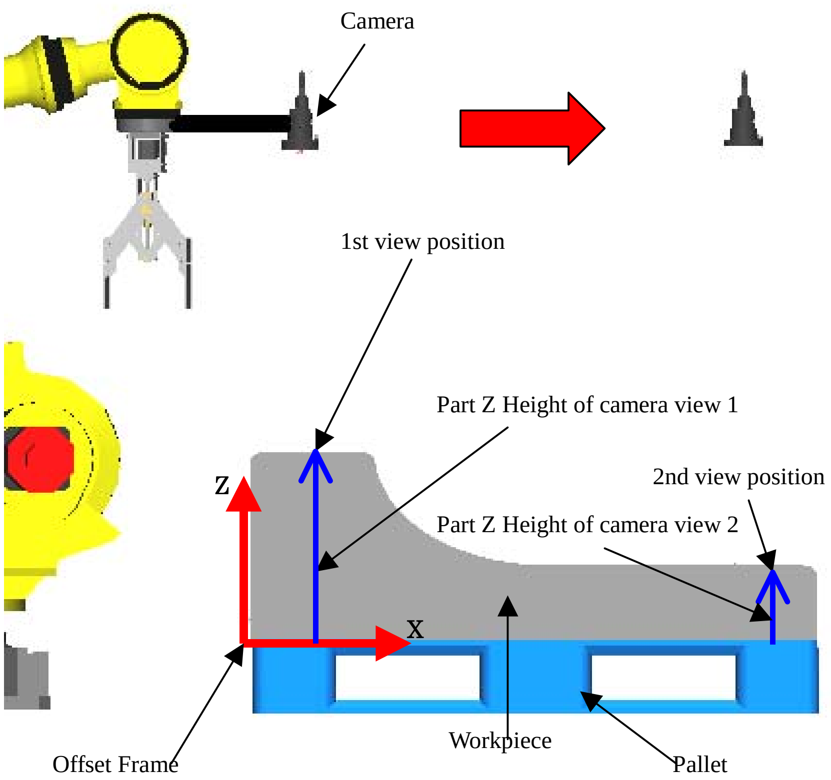
Camera view teaching

With each camera view, teach the locator tool. A detailed description of the locator tool is omitted here. For setting of the locator tool, refer to Chapter 7, “COMMAND TOOL” in the *i*RVision Operator’s Manual (Reference) (B-83304EN).





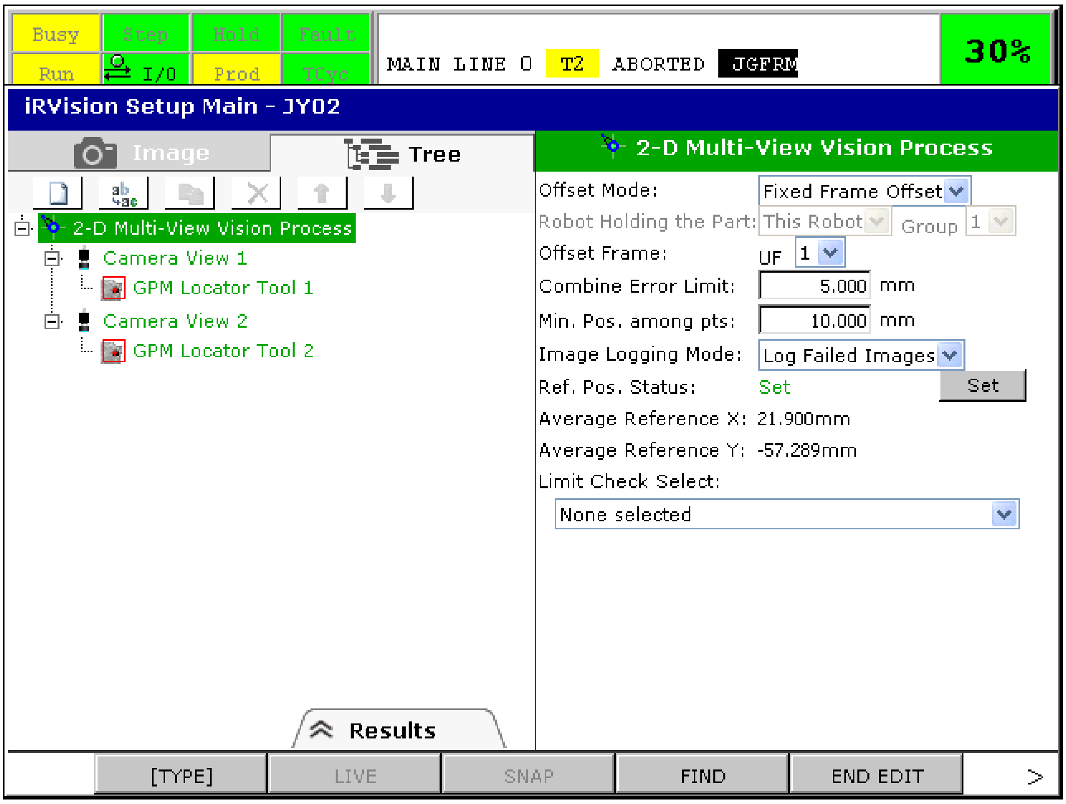
If the measurement plane of a workpiece is apart from the XY plane of the offset frame, set the Z coordinate of the measurement plane viewed from the XY plane of offset frame in "Part Z Height" of the vision process.
In "Part Z Height", set a proper value for each camera view as shown below.

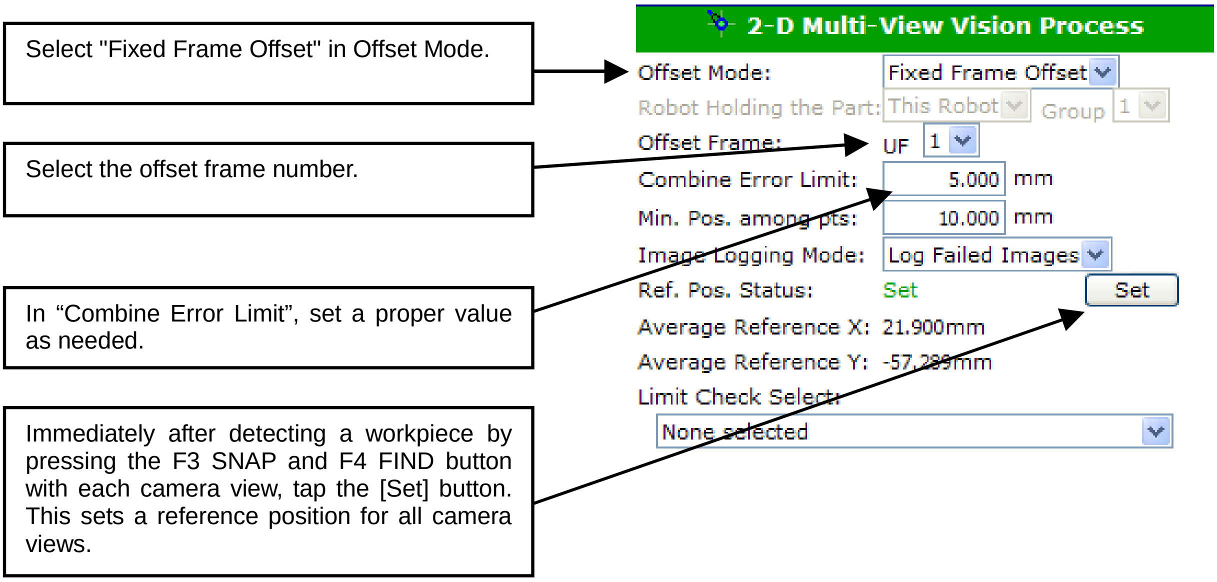


Reference position setting

Upon normal completion of detection with each camera views, set a reference position. First, open the vision process page as shown below. Next, move the camera to a position that is able to snap the target in the Camera View 1. In addition, do not move the workpiece until a reference position setup is completed. Select the Camera View 1 page in the vision process, press the F3 SNAP and the F4 FIND buttons to detect the target of Camera View 1. In addition, teach the robot’s current position as the snapping position for Camera View 1. For an example, refer to sample program of Subsection 5.3.4 "Robot Program Creation and Teaching". LP[1] on the line4 of sample program is a snapping position for a Camera View 1. Set the robot's current position to LP[1] as the snapping position for a Camera View 1. Next, move the camera to a position that is able to snap the target in the Camera View 2. Select the Camera View 2 page in the vision process, press the F3 SNAP and the F4 FIND buttons to detect the target of Camera View 2. In addition, teach the robot’s current position as the snapping position for Camera View 2. Select the 2-D Multi-view Vision Process page in the vision process, and press the F4 FIND button to detect the workpiece. Then, tap [Set Ref] button in the Reference Data. [Ref. Pos. Status] becomes [Set]. In addition, the value of [Average Reference X] and [Average Reference Y] are inputted. The value is the average reference position of each camera views. The position is relative to the offset frame.

Jog the robot and move to working position (for example, pick up a workpiece). For an example, refer to sample program of Subsection 5.3.4 "Robot Program Creation and Teaching". LP[3] on the line14 of sample program is a working position for a workpiece. If a robot's current position is set to LP[3], the reference position setting is complete.





5.3.4 Robot Program Creation and Teaching

In the sample program below, a vision process named "A" is used. Two characteristic positions of a large workpiece are found by moving the robot-mounted camera. Program A has two camera views, so that each camera view number is added to the "VISION RUN_FIND" instruction. For fixed frame offset, add the "VOFFSET, VR" instruction as an operation statement.

```
 1:  UFRAME_NUM=1 ;
 2:  UTOOL_NUM=1 ;
 3:  R[1:Notfound]=0     ;
 4:L P[1] 2000mm/sec FINE     ;
 5:  WAIT R[1] ;
 6:  VISION RUN_FIND 'A' CAMERA_VIEW[1]     ;
 7:L P[2] 2000mm/sec FINE     ;
 8:  WAIT R[1] ;
 9:  VISION RUN_FIND 'A' CAMERA_VIEW[2]     ;
10:  VISION GET_OFFSET 'A' VR[1] JMP LBL[100] ;
11:   ;
12:  !Handling ;
13:L P[3] 2000mm/sec CNT100 VOFFSET,VR[1] Tool_Offset,PR[1]     ;
14:L P[3] 500mm/sec FINE VOFFSET,VR[1]     ;
15:  CALL HAND_CLOSE     ;
16:L P[3] 2000mm/sec CNT100 VOFFSET,VR[1] Tool_Offset,PR[3]     ;
17:  !Handling ;
18:  JMP_LBL[900] ;
19:   ;
20:  LBL[100] ;
21:  R[1:Notfound]=1     ;
22:   ;
23:  LBL[900] ;
```

When a camera image has been snapped, the line after the "VISION RUN_FIND" instruction is executed. Move to position of camera view 1 to snap on line 4. Execute "WAIT" instruction to remove the possible vibration of a camera on line5. Execute a camera view 1 of program "A" with the vision detection instruction with on line 6. Move to the position of camera view 2 to snap on line 7. Obtain the offset result of the detected workpiece on line 10. Move to approach position above the workpiece on line 13. Move to grasp position on line14. Move to escape position after grasping the workpiece on line 16.

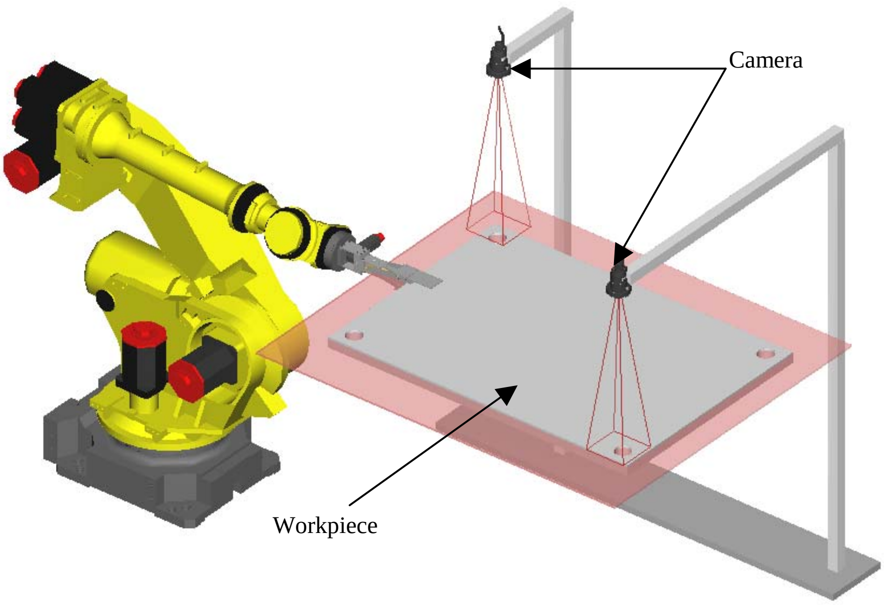
5.3.5 Robot Compensation Operation Check

Check that multiple points of a workpiece can be detected and that the workpiece can be handled correctly.

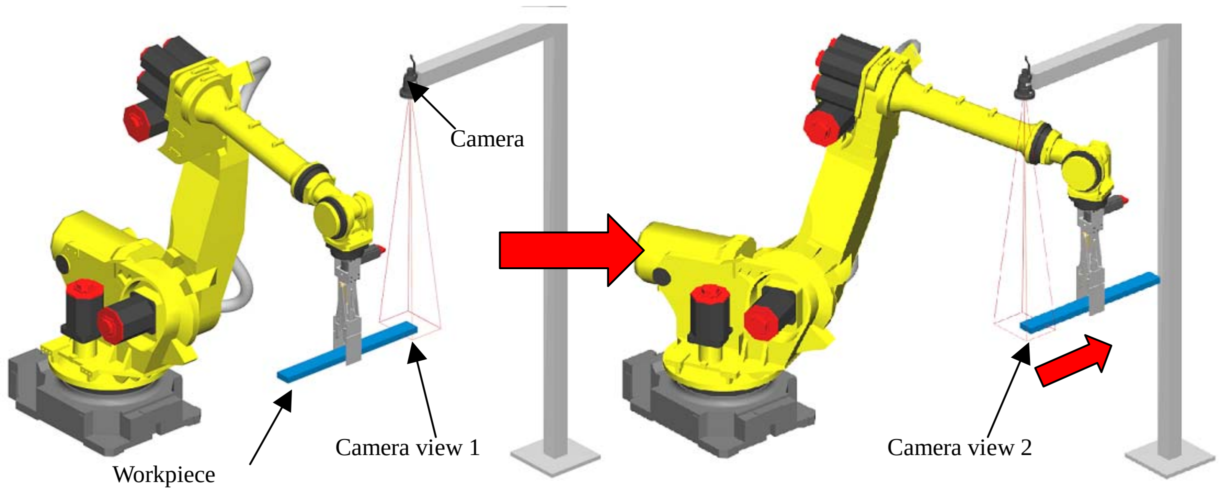
- Place the workpiece on the reference position, find it and check the handling accuracy. If the accuracy of compensation is low, retry the reference position setting.
- Move the workpiece without rotation, find it and check the handling accuracy. If the accuracy is good for reference position, but low for non-rotated workpiece on the edge of the field of view, it is possible that Part Z Height is not set properly. Check the Part Z Height, refer to Subsection 5.3.1, “Vision process Creation and Teaching”
- Rotate the workpiece, find it and check the handling accuracy. If the accuracy is good for a moved workpiece without rotation, but low for rotated workpiece and lower for more rotated workpiece, it is possible that the offset frame or the calibration grid frame is not set properly. If the calibration grid frame was manually taught with a pointer, verify the accuracy of the pointer TCP (UTool) used to teach the frame. Moreover, check the offset frame and the calibration grid frame are set precisely, then retry the camera calibration.
- Depending on robot motion, a camera may vibrate at snap position. Execute “WAIT” instruction to remove the possible vibration of a workpiece before the “VISION RUN_FIND”.
- Start with lower override of the robot to check that the logic of the program is correct. Next, increase the override to check that the robot can operate continuously.

5.4 SETUP FOR "TOOL OFFSET WITH FIXED CAMERA"

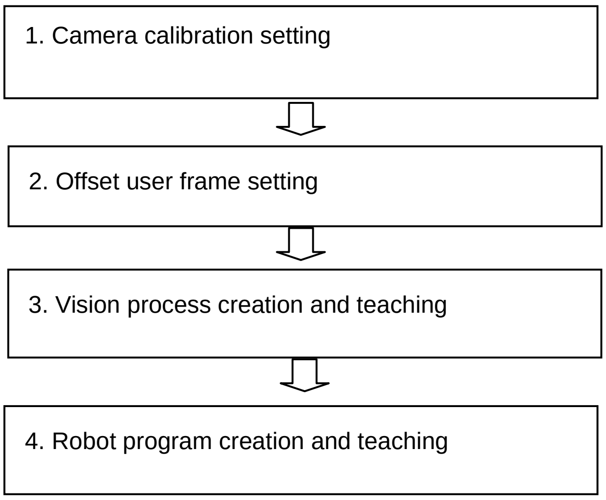
An example of layout for "tool offset with fixed camera" is shown below. A robot detects two points of a workpiece with two cameras and performs tool offset.



The following figure is another example of a layout. A robot detects two points of a workpiece with a camera and performs tool offset. A robot grips a workpiece and detects a point of workpiece as the camera view 1. Next, the robot moves and detects another point of workpiece as the camera view 2. When the layout is following figure, teach a camera setting data and a camera calibration data. Moreover, use same camera calibration data for each camera view in the camera view setting.



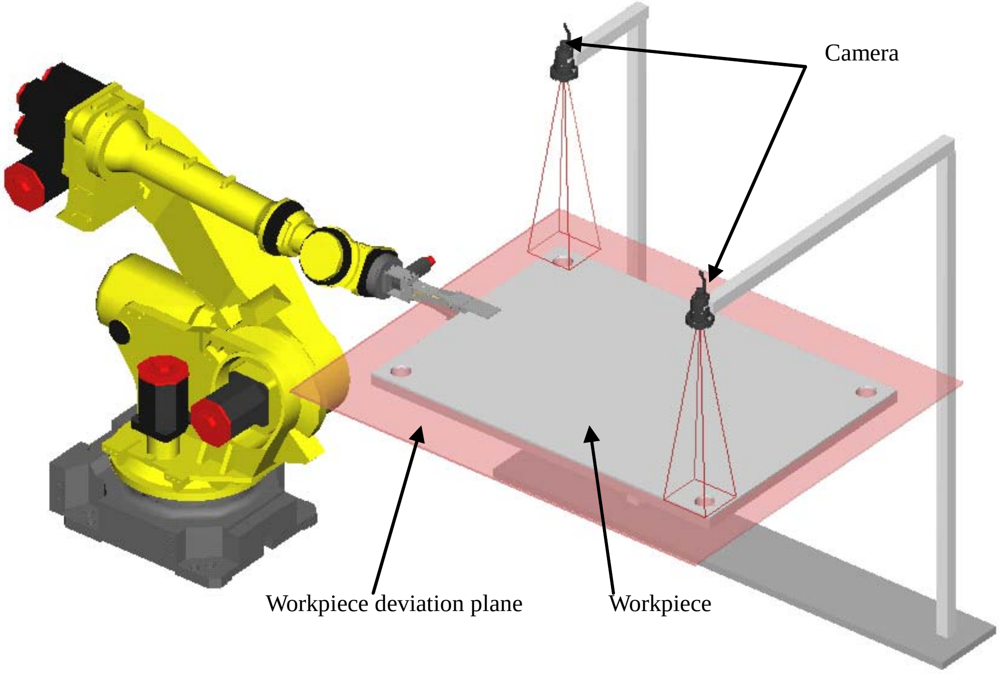
Use the following setup procedure for "tool offset with fixed camera":



When initially setting up the vision system, perform all the above procedures. When the position of the camera is shifted or the camera is replaced, redo "1 Camera calibration setting." If the camera is already calibrated a new workpiece is added or changed perform "3 Vision process creation and teaching." and "4 Robot program creation and teaching."

5.4.1 Camera Calibration Setting

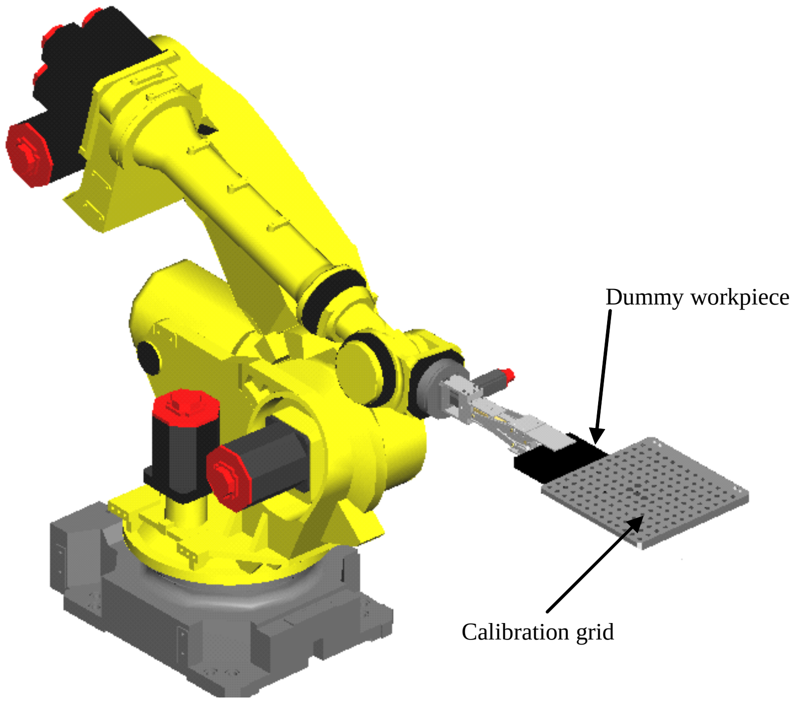
In the 2D Multi-view Vision Process, it is necessary to create calibration data for each camera. Create the camera calibration data as many as number of cameras. For example, when the layout is following figure, teach the two camera setting data and the two camera calibration data.



There are two kinds of methods for a camera calibration, those are Grid Pattern Calibration and Robot-generated Grid Calibration.

Grid Pattern Calibration

When the Grid Pattern Calibration is used for calibration, it is recommended to set the calibration grid on a dummy workpiece. In this case, calibration for each camera can be performed with only one calibration grid frame. When set a calibration grid frame, it is recommended to use the Automatic Grid Frame Set Function The figure below shows an example of setting the calibration grid at a workpiece measurement position. Prepare a dummy workpiece that resembles an actual workpiece and can be gripped. Setup work can be simplified by setting a calibration grid on a dummy workpiece. Set the dummy workpiece for calibration so that the XY plane of the calibration grid is parallel with the plane on which a workpiece moves.



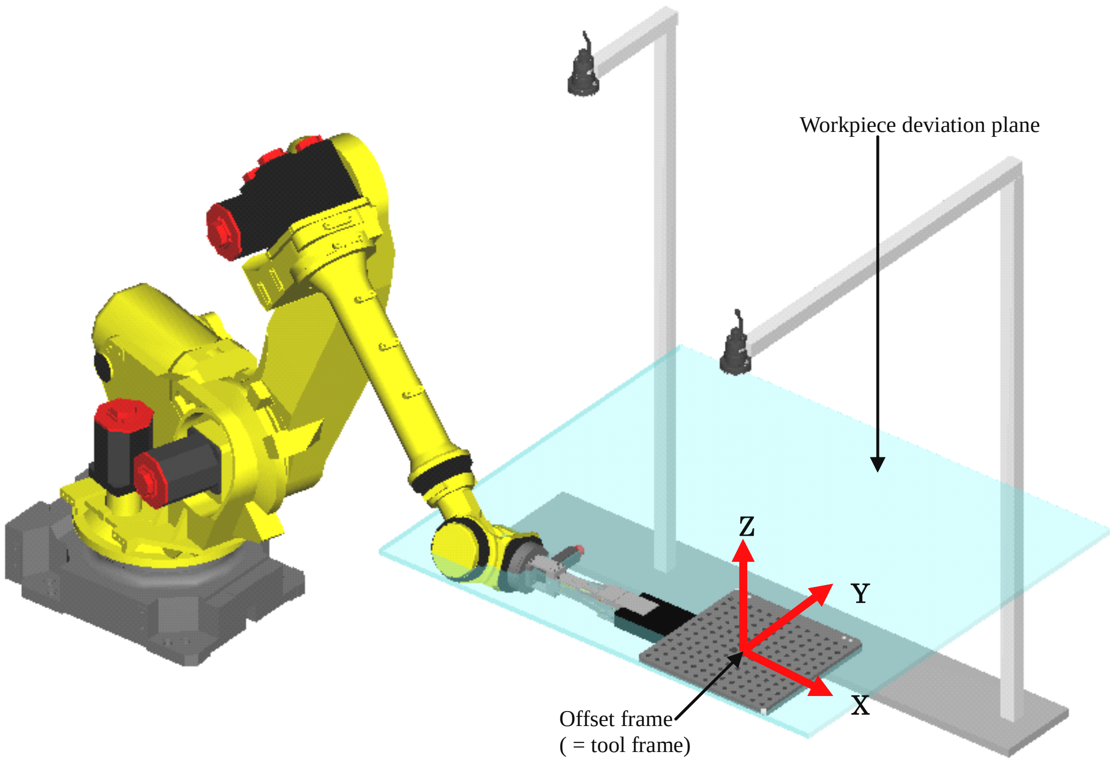
When the calibration grid is placed so that the XY plane of the calibration grid is parallel with the plane on which a workpiece moves, a setup of the offset frame becomes easy. For details of the grid frame calibration, see Section 8.1, “GRID PATTERN CALIBRATION WITH A FIXED CAMERA”.

Robot-generated Grid Calibration

When the Robot-generated Grid Calibration is used for calibration, it is recommended to set the target on a dummy workpiece. Prepare a dummy workpiece that resembles an actual workpiece and can be gripped. Setup work can be simplified by setting a target on a dummy workpiece. Set a target for calibration so that the XY plane of the target is parallel with the plane on which a workpiece moves. When the target is placed so that the XY plane of the target is parallel with the plane on which a workpiece moves, a setup of the offset frame becomes easier. For details of the Robot-generated Grid Calibration, see Section 8.3, “ROBOT-GENERATED GRID CALIBRATION”.

5.4.2 Offset frame Setting

An offset frame is the coordinate system used for calculation of the offset data. A found position is outputted as a position in the offset frame. In the fixed frame offset, the offset frame is set as a user frame, but in the tool offset, it is set as a tool frame. Although the number of camera setting data and camera calibration data are created the same as the number of cameras, the number of offset frame is one. In a tool offset, set a tool frame so that the XY plane of the tool frame is parallel with the workpiece deviation plane.
When performing the Grid Pattern Calibration, if the XY plane of the tool frame that is set in Subsection 8.1.3, "Calibration Grid Frame Setting" is parallel with the workpiece deviation plane, the tool frame can be used as the offset frame.

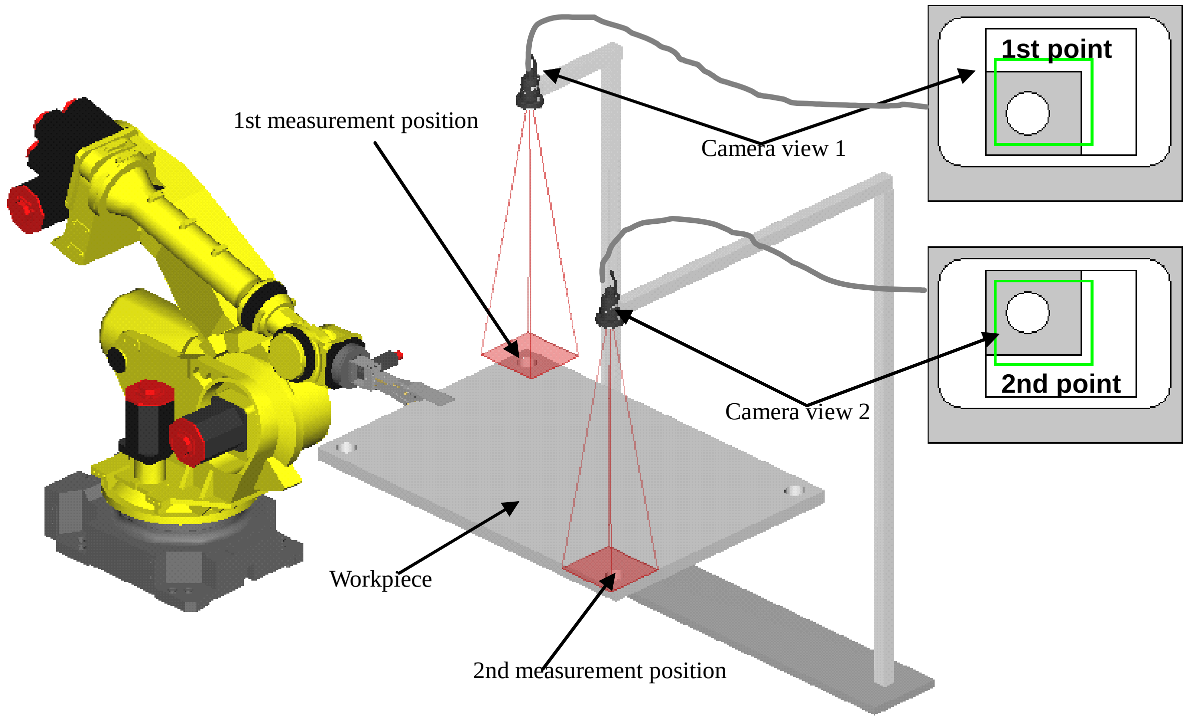


When performing the Robot-generated Grid Calibration, if the XY plane of the tool frame (UTool for work space) that is set in Subsection 8.3.5, "Measuring target position" is parallel with the workpiece deviation plane, the tool frame number can be selected as the offset frame. In this case, it is recommended using another tool frame number that is copied value of the UTool for work space. For example, when the

UTool for work space number is nine, copy the value of the UTool for work space to the contents of anther tool frame (for example, UTool 1), and select the tool frame number as the offset frame number.

5.4.3 Vision Process Creation and Teaching

Create a program for "2D Multi-view Vision Process ". The basic program setting method is the same as for two-dimensional compensation based on one camera. Unlike two-dimensional compensation based on one camera, two-dimensional compensation based on multiple cameras adds "camera views" as many as the number of measurement points.
For each view, a camera view is named camera view 1 or camera view 2. “COMMAND TOOL” comes under each camera view.



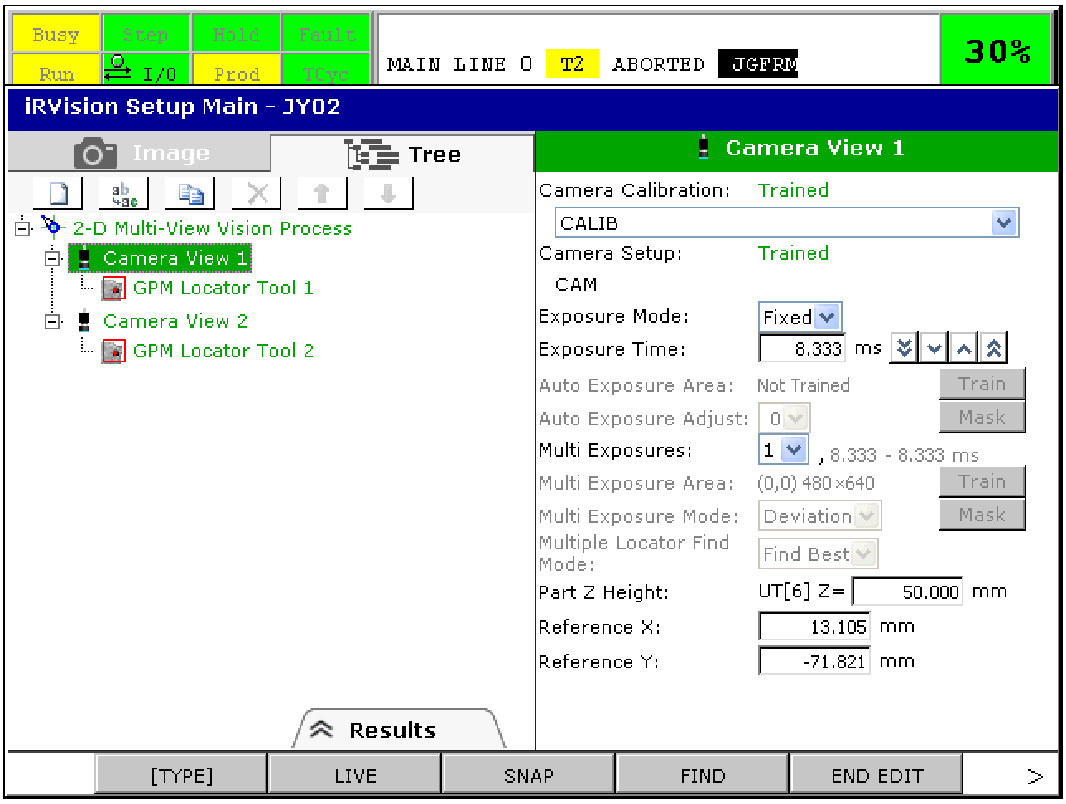
Use the following procedure to teach the 2D Multi-view Vision Process:

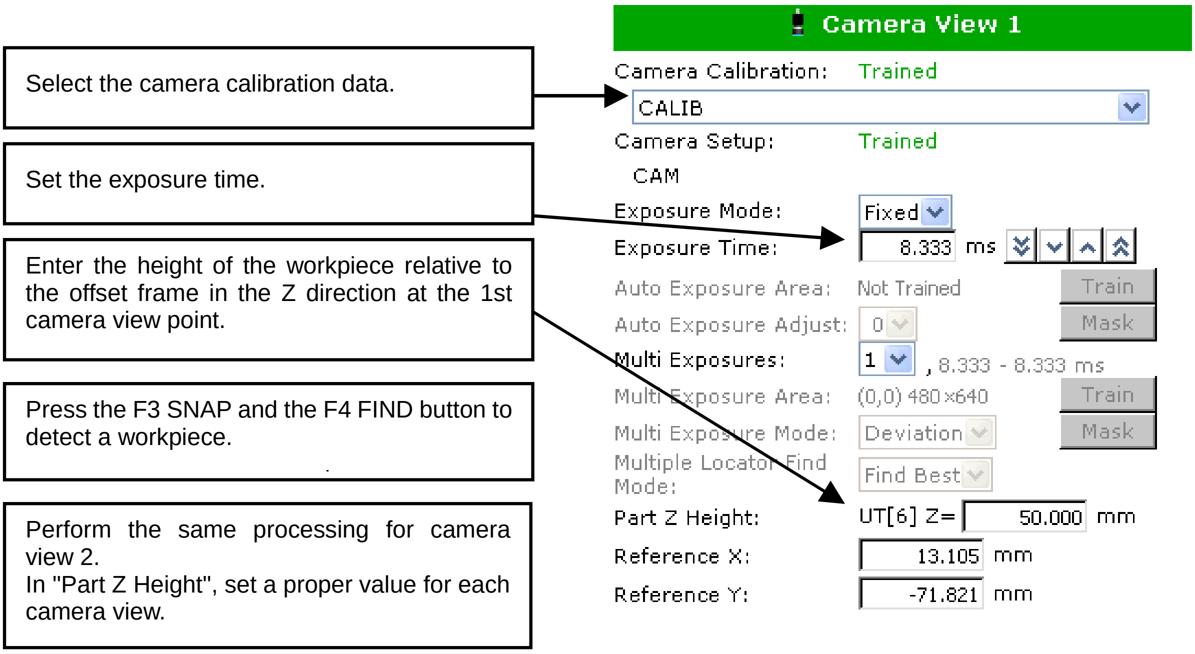
1. Teach the locator tool for camera view 1.
2. Select camera view 1 then press the F3 SNAP and the F4 FIND button to find
3. Teach the locator tool for camera view 2.
4. Select camera view 2 then press the F3 SNAP and the F4 FIND button to find
5. Select "2D Multi-View Vision Process" then set a reference position.

Set the reference position immediately after finding the model with two camera views. If the teach screen is closed, the procedure needs to be performed all over again starting with model detection using each of the two camera views.

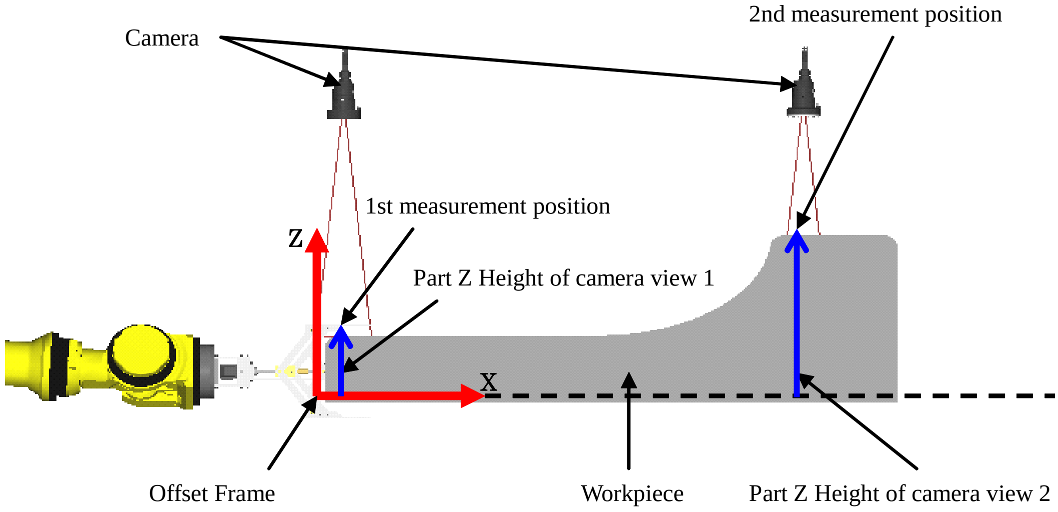
Camera view teaching

With each camera view, teach the locator tool. A detailed description of the locator tool is omitted here. For setting of the locator tool, refer to Chapter 7, “COMMAND TOOL” in the *i*RVision Operator’s Manual (Reference) (B-83304EN).



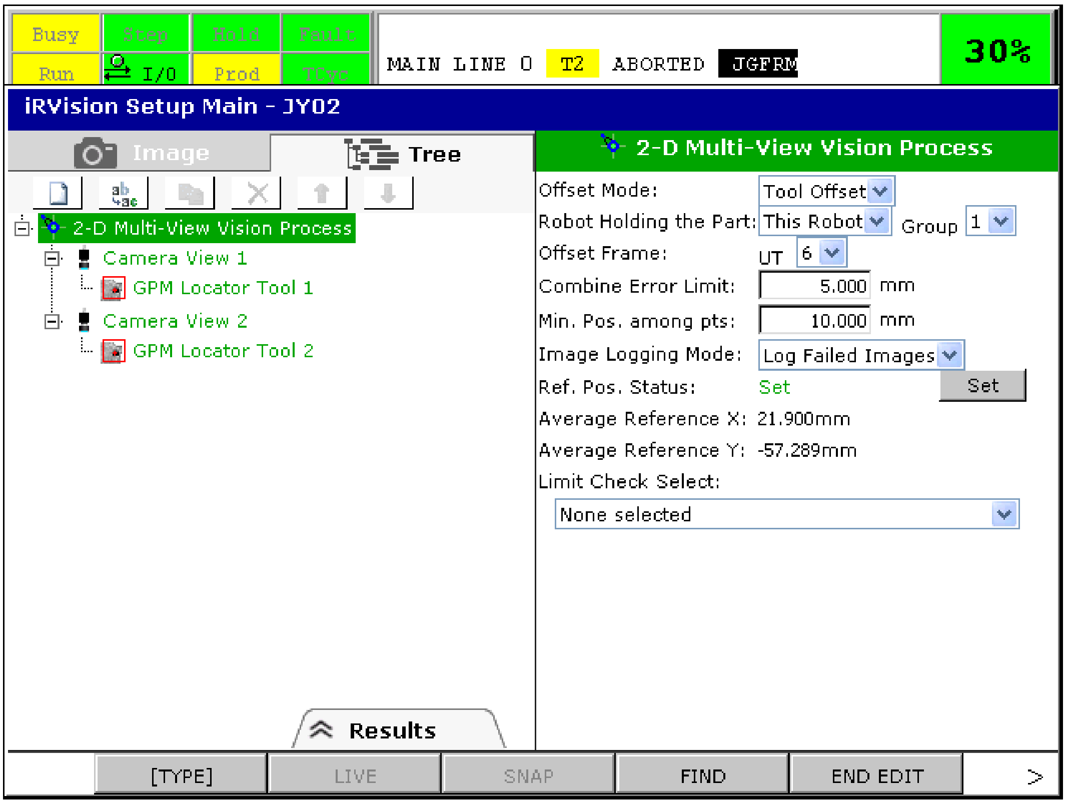


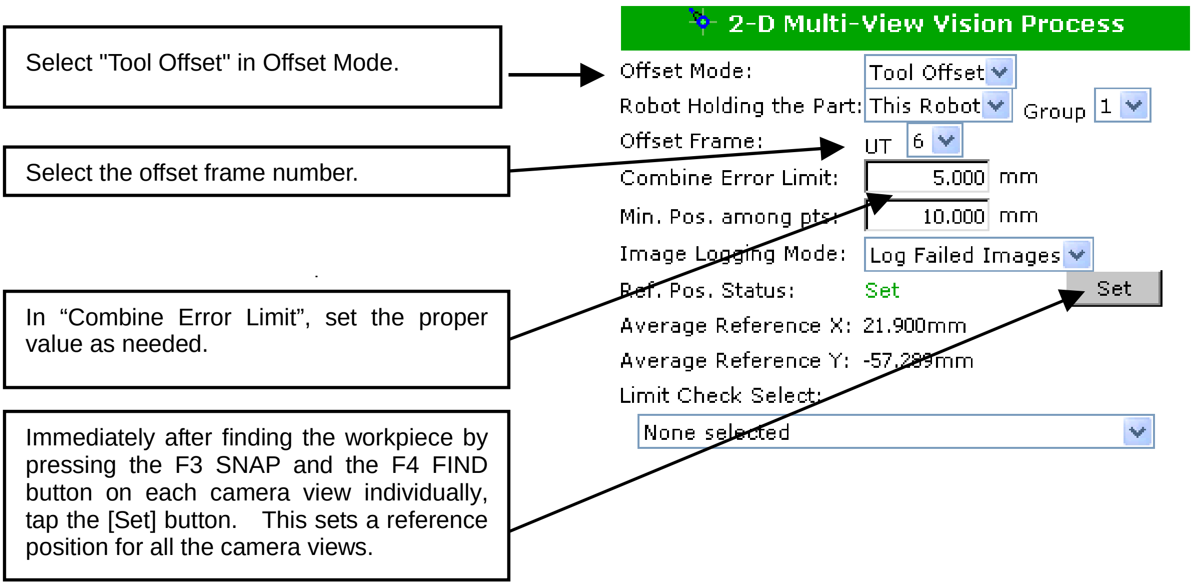
If the measurement plane of a workpiece is apart from the XY plane of the offset frame, set the Z coordinate of the measurement plane viewed from the XY plane of offset frame in "Part Z Height" of the vision process.
In "Part Z Height", set a proper value for each camera view as shown below.



Reference position setting

Upon normal completion of detection with each camera views, set a reference position. First, open a vision process page as shown below. Next, move a workpieced to a position that is able to snap the target in the Camera View 1. Select the Camera View 1 page in the vision process, press the F3 SNAP and the F4 FIND buttons to detect the target of Camera View 1. In addition, teach the robot’s current position as the snapping position for Camera View 1. For an example, refer to sample program of Subsection 5.4.4 "Robot Program Creation and Teaching". LP[1] on the line4 of sample program is a snapping position for a Camera View 1. Set the robot's current position to LP[1] as the snapping position for a Camera View 1. Next, move the workpiece to a position that is able to snap the target in the Camera View 2. Select the Camera View 2 page in the vision process, press the F3 SNAP and the F4 FIND buttons to detect the target of Camera View 2. In addition, teach the robot’s current position as the snapping position for Camera View 2. Select the 2-D Multi-view Vision Process page in the vision process, and press the F4 FIND button to detect the workpiece. Then, tap [Set Ref] button in the Reference Data. [Ref. Pos. Status] becomes [Set]. In addition, the value of [Average Reference X] and [Average Reference Y] are inputted. The value is the average reference position of each camera views. In addition, the position is described on the offset frame.
Jog the robot and move to working position (for example, place the workpiece). For an example, refer to sample program of Subsection 5.4.4 "Robot Program Creation and Teaching". LP[3] on the line14 of sample program is a working position for the workpiece. If a robot's current position is set to LP[3], the reference position setting will complete.





5.4.4 Robot Program Creation and Teaching

In the sample program below, a vision process named "A" is used. For tool offset, add the "VOFFSET, VR" instruction as an operation statement.

```
  1:   UFRAME_NUM=1 ;
  2:   UTOOL_NUM=6 ;
  3:   R[1:Notfound]=0      ;
  4:L P[1] 2000mm/sec FINE      ;
  5:   WAIT R[1] ;
  6:   VISION RUN_FIND 'A' CAMERA_VIEW[1]      ;
  7:L P[2] 2000mm/sec FINE      ;
  8:   WAIT R[1] ;
  9:   VISION RUN_FIND 'A' CAMERA_VIEW[2]      ;
 10:   VISION GET_OFFSET 'A' VR[1] JMP LBL[100] ;
 11:     ;
 12:   !Handling ;
 13:L P[2] 2000mm/sec CNT100 VOFFSET,VR[1] Tool_Offset,PR[1]      ;
 14:L P[2] 500mm/sec FINE VOFFSET,VR[1]      ;
 15:   CALL HAND_OPEN      ;
 16:L P[2] 2000mm/sec CNT100 VOFFSET,VR[1] Tool_Offset,PR[3]      ;
 17:   !Handling ;
 18:   JMP_LBL[900] ;
 19:     ;
 20:   LBL[100] ;
 21:   R[1:Notfound]=1      ;
 22:     ;
 23:   LBL[900] ;
```

Move the workpiece to the position to snap on line 4. Execute a “WAIT” instruction to remove the possible vibration of the workpiece on line 5. Execute a camera view 1 of program ”A” with the vision detection instruction with the line 6. Move the workpiece to the position to snap at camera view 2 on line 7. Obtain the offset result of the detected workpiece on line 10. Move to the approach position to place the workpiece on line13. Move to the position to place the workpiece on line14. Move to escape position after the workpiece is placed on line 16.

5.4.5 Robot Compensation Operation Check

Check that a workpiece gripped by the robot can be detected and positioned precisely at a desired location.

- Place the workpiece on the reference position, find it and check the handling accuracy. If the accuracy of compensation is low, retry the reference position setting.
- Move the workpiece without rotation, find it and check the handling accuracy. If the accuracy is good for reference position, but low for non-rotated workpiece on the edge of the field of view, it is possible that Part Z Height is not set properly. Check the Part Z Height, refer to Subsection 5.4.3, “Vision process Creation and Teaching”
- Rotate the workpiece, find it and check the handling accuracy. If the accuracy is good for a moved workpiece without rotation, but low for rotated workpiece and lower for more rotated workpiece, it is possible the offset frame or the calibration grid frame is not set properly. If the calibration grid frame was manually taught with a pointer, verify the accuracy of the pointer TCP (UTool) used to teach the frame. Moreover, check the offset frame and the calibration grid frame are set precisely, then retry the camera calibration.
- Depending on robot motion, a workpiece may vibrate at snap position. Execute “WAIT” instruction to remove the possible vibration of a workpiece before the “VISION RUN_FIND”.
- Start with lower override of the robot to check that the logic of the program is correct. Next, increase the override to check that the robot can operate continuously.

6 SETUP OF DEPALLETIZING VISION PROCESS

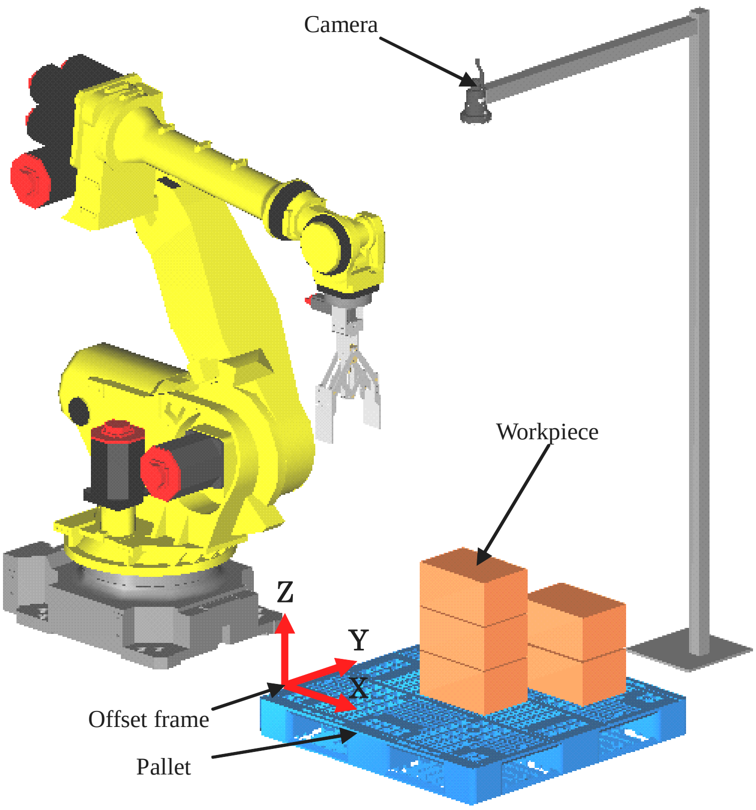
The Depalletizing Vision Process is a vision process that performs compensation in the vertical direction in addition to standard two-dimensional compensation. This function measures the height of the workpieces based on the size of the workpiece image viewed by the camera.
This chapter describes the setup procedure for Depalletizing Vision Process in the following two application examples:

<1> "Fixed frame offset with fixed camera"
<2> "Fixed frame offset with robot-mounted camera"

For the each application, the basic program setting method is the same as for 2D Single-view Vision Process. However, the Depalletizing Vision Process differs from the 2D Single-view Vision Process about the method of reference position setting. Specifically, sets the relationship between the height of workpieces and the size of the workpiece viewed by the camera. In this point, the Depalletizing Vision Process differs from the 2D Single-view Vision Process.

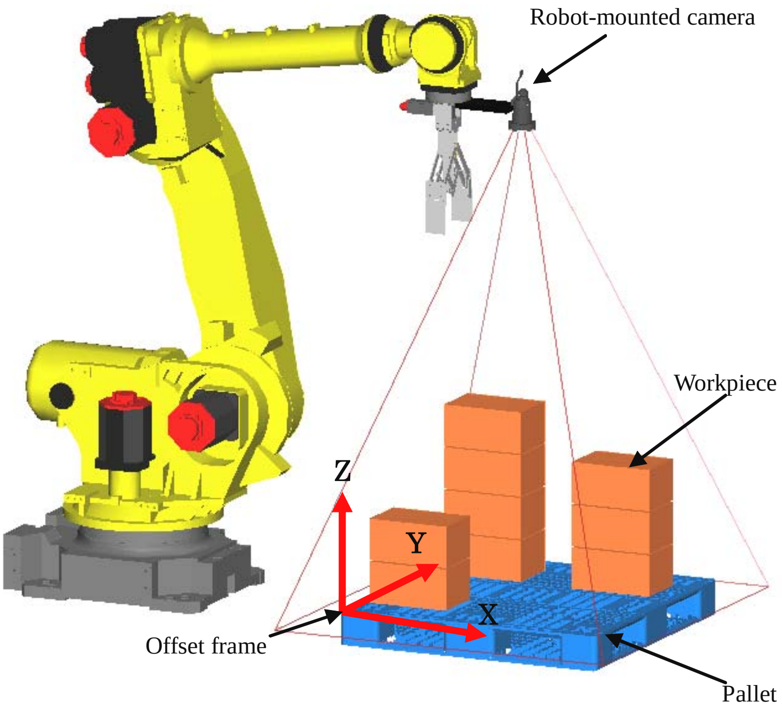
Fixed frame offset with fixed camera

An example of layout for "fixed frame offset with fixed camera" is given below.



Fixed frame offset with robot-mounted camera

An example of layout for "fixed frame offset with robot-mounted camera" is given below.



6.1 FEATURES AND NOTES

Features

- The Depalletizing Vision Process has two methods called “App. Z Modes” for determining the height of the workpieces.
  1. Calculate From Found Scale
     - This function performs compensation in the vertical (Z) direction in addition to ordinary two-dimensional compensation.
     - The height (standard Z coordinate) of the workpieces are measured based on the size of the workpiece image viewed by the camera.
     - When a robot-mounted camera is used, the position of a workpiece can be measured even when the robot moves in the X, Y, and Z directions of the offset frame. This capability is provided because the current position of a robot is considered in *i*RVision calculation processing when a workpiece position calculation is made.
     - After an operation for picking up a workpiece from one location of the pallet is taught, a workpiece can be picked up from any location on the pallet.

  2. Use Register Value
     - A user defined robot register is used to define the current Z height of the workpiece.
     - This mode can be used for any application where the height of the part varies. The height of the current workpiece must be inputted into the robot register prior to finding.
     - The height of the current workpiece must come from another source outside of iRVision.

Notes

- As with ordinary two-dimensional compensation, it is assumed that the workpiece is not tilted.
- The camera position for measurement is determined from the thickness of a workpiece and the number of layers.

- When either a fixed camera or a robot-mounted camera is used, it is best if the optical axis of the camera is normal to the XY plane of the offset frame. When the camera mounted tilted in the XY plane of the offset frame, it seems that the shape of the workpiece is distorted depending on the place of a field of view. In this case, it is possible that detection of the workpiece become difficult.
- As mentioned above, a height change due to a change in the number of layers is calculated from the detected workpiece size information. A viewed image of the workpieces can slightly vary, resulting the height measurement differing from the actual height of the current layer. To protect against a system failure, it is recommended to have error compensation in the gripper and a sensor for detecting a contact with a workpiece on the gripper. For example, when the gripper contacts the workpiece, an input can be used along with a high-speed skip function.
- The height of the workpieces are measured based on the size of the workpiece image viewed by the camera. As a guideline, two workpieces found one layer apart should have a difference in size by at least 5%.
- As the distance between the camera and workpiece increases, the precision in height measurement is degraded. So, minimize this distance whenever possible.
- As the distance between the camera and workpieces increases, the precision in height measurement is degraded. If a workpiece to be measured is located far away, the workpiece can be measured again by approaching the workpiece if the camera is robot-mounted. In this case, the same vision program can be used. This is because the current position of the robot is considered when a workpiece position calculation is made.
- Ensure that the camera focuses on both the workpiece at the top and the workpiece at the bottom.
- Ensure that lighting is provided evenly to the workpiece at the top and the workpiece at the bottom whenever possible. This is a key to stable workpiece detection and precise size measurement. When a robot-mounted camera is used, it is recommended to install a ring light around the camera.

6.2 SETUP FOR "FIXED FRAME OFFSET WITH FIXED CAMERA"

Use the following setup procedure for "fixed frame offset with fixed camera":

1. Camera calibration setting

⇩

2. Offset user frame setting

⇩

3. Vision process creation and teaching

⇩

4. Robot program creation and teaching

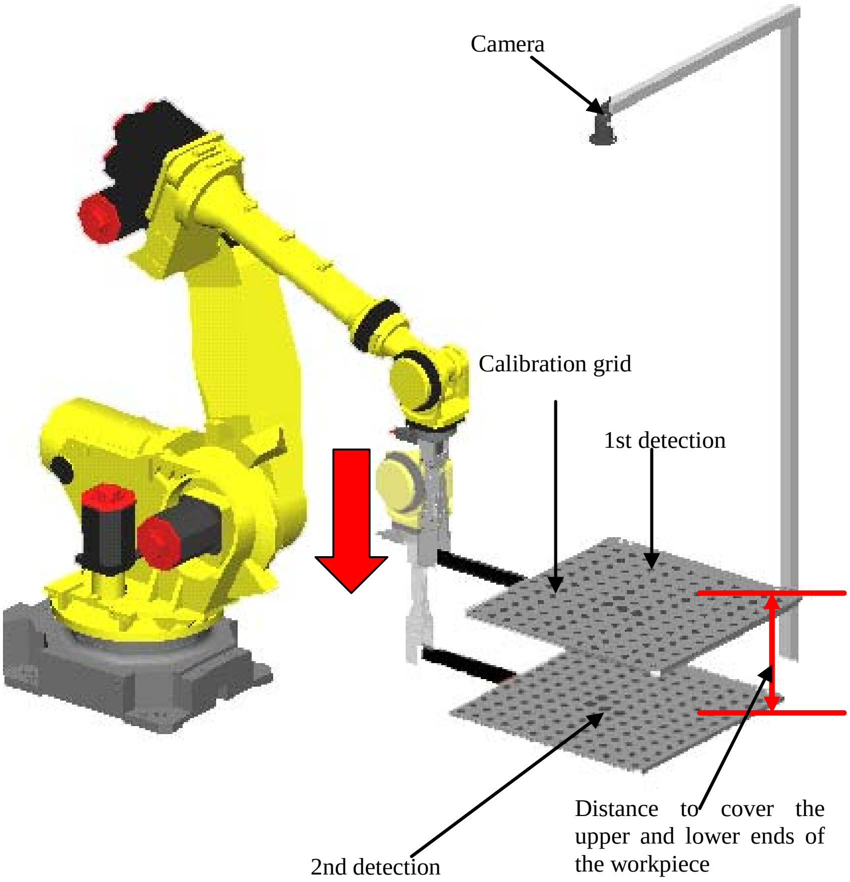
When initially setting up the vision system, perform all the above procedures. When the position of the camera is shifted or the camera is replaced, redo "1 Camera calibration setting." If the camera is already calibrated a new workpiece is added or changed perform "3 Vision process creation and teaching." and "4 Robot program creation and teaching."

6.2.1 Camera Calibration Setting

There are two methods for a camera calibration, those are Grid Pattern Calibration and Robot-generated Grid Calibration.

Grid Pattern Calibration

For details of the grid frame calibration, see Section 8.1, “GRID PATTERN CALIBRATION WITH A FIXED CAMERA”. In the Section 8.1.3, “Calibration Grid Frame Setting”, when the calibration grid is robot-mounted, it is recommended that the up/down distance for two-plane calibration be set to a value that covers the upper and lower ends of the workpiece on the pallet.

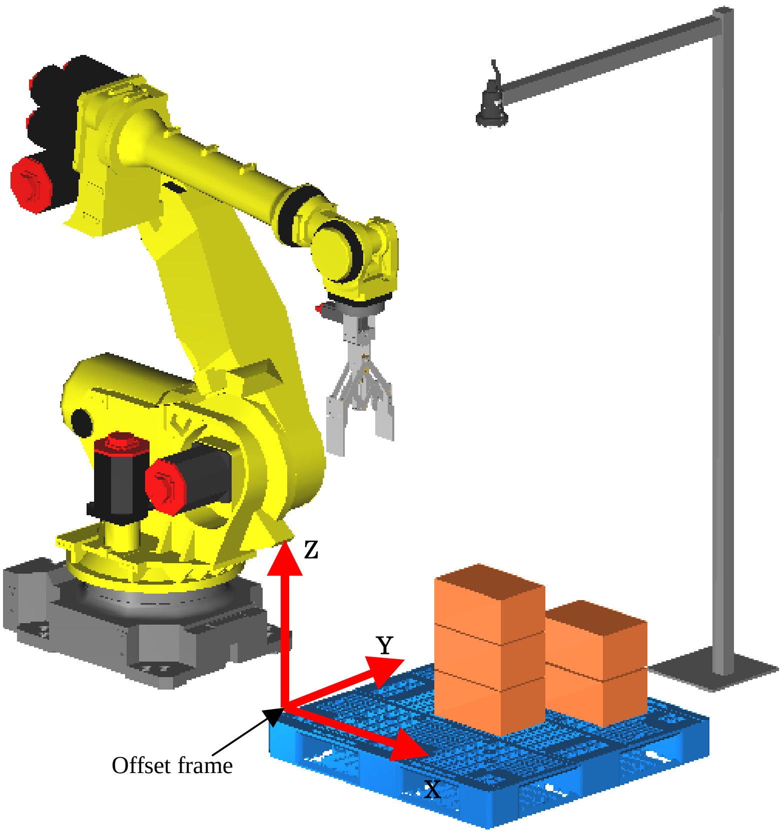


Robot-generated Grid Calibration

For details of the Robot-generated Grid Calibration, see Section 8.3, “ROBOT-GENERATED GRID CALIBRATION”. When perform the Depalletizing Vision Process with fixed camera, the size of field of view becomes large in many cases. So, it is recommended that the Robot-generated Grid Calibration is used for a camera calibration.

6.2.2 Offset Frame Setting

An offset frame is the coordinate system used for calculation of the offset data. A found position is outputted as a position in the offset frame. In the fixed frame offset, the offset frame is set as a user frame. Set an offset frame so that the XY plane of the offset frame is parallel with the table plane on which the workpiece is placed. Otherwise, the required compensation precision may not be obtained.



There are two methods to teach the offset frame, one is manually touch-up the frame with the pointer tool, and another is the Automatic Grid Frame Set Function.

Touch-up

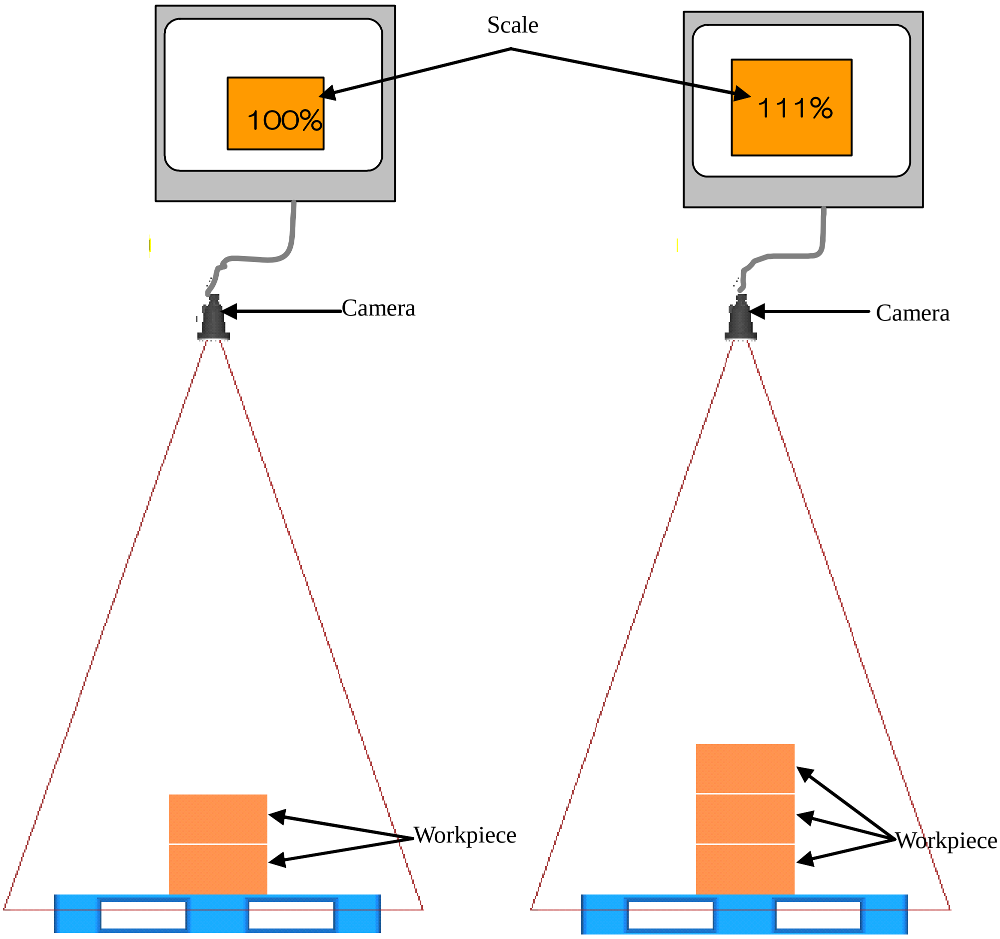
To manually teach a user frame, a pointer tool with a taught TCP is required. In general, set the TCP accurately on the pointer installed on the robot gripper. Set the robot TCP in an available UTool. To reuse the pointer TCP, the reproducibility of the pointer installation is required. If the reproducibility of the pointer installation is not assured, the TCP needs to be re- taught each time a pointer is installed. For details, see Section 9.1.1, “User frame setting with a pointer tool”.

Automatic Grid Frame Set Function

T The Automatic Grid Frame Set Function sets the calibration grid frame using a camera. Install a calibration grid so that the XY plane of the calibration grid is parallel with the plane on which the workpiece is placed, and perform the Automatic Grid Frame Set Function. For details, see Section 9.2, “Frame setting with the Automatic Grid Frame Set Function”. A calibration grid is used for setup. Moreover, in the case of a fixed camera, prepare a camera for the Automatic Grid Frame Set Function separately. And perform the Automatic Grid Frame Set Function using the camera attached to a temporary position of a robot's hand. In addition, the Automatic Grid Frame Set Function is usable with 6-axis robots only. The function cannot be used with 4-axis robots and 5-axis robots. When using 4-axis robots or 5-axis robots, teach the frame manually.

6.2.3 Vision Program Creation and Teaching

Create a program for Depalletizing Vision Process. The basic program setting method is the same as for 2D Single-view Vision Process. Unlike 2D Single-view Vision Process, Depalletizing Vision Process sets the relationship between the height of workpieces and the size of the workpiece viewed by the camera.

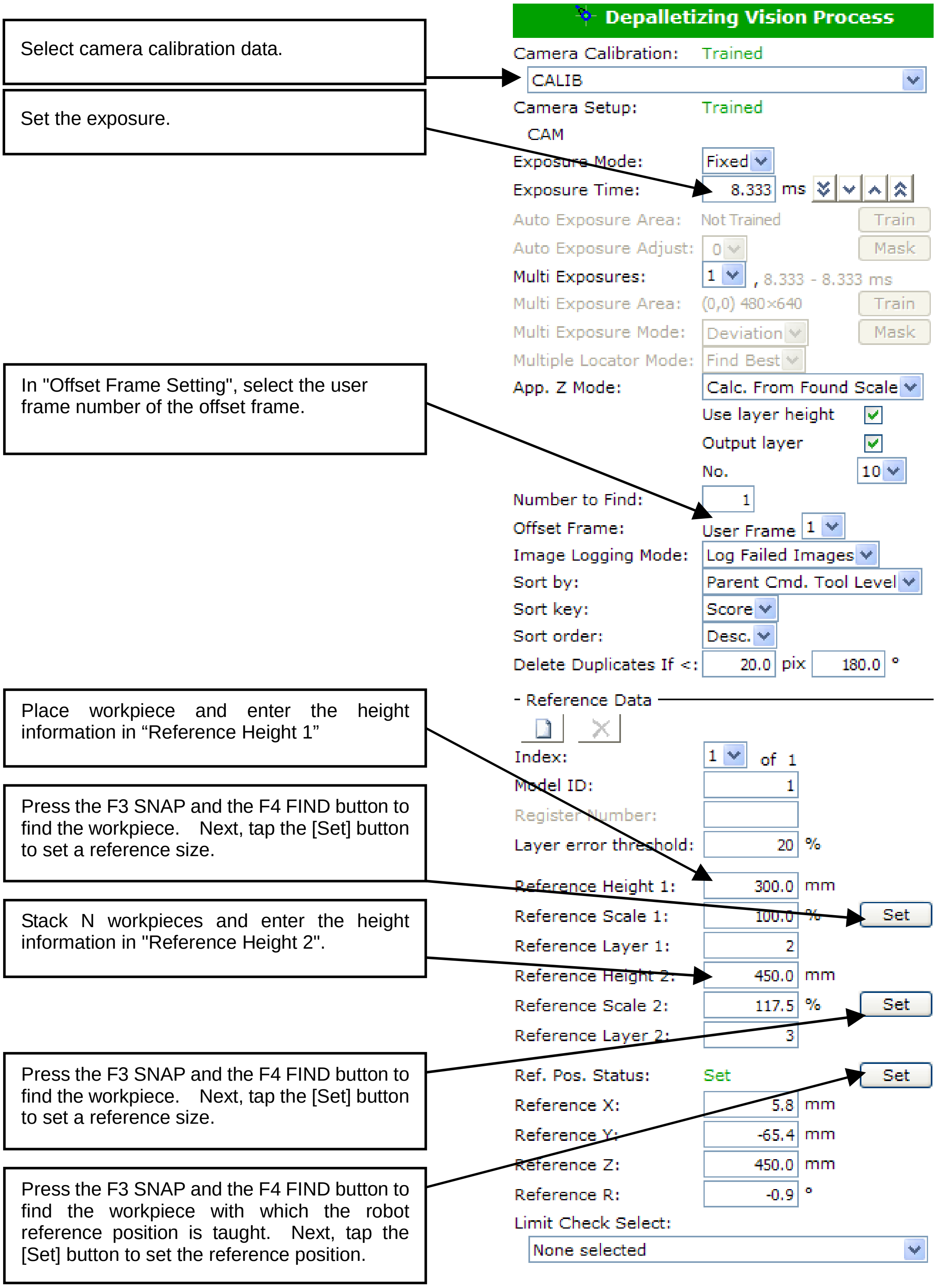


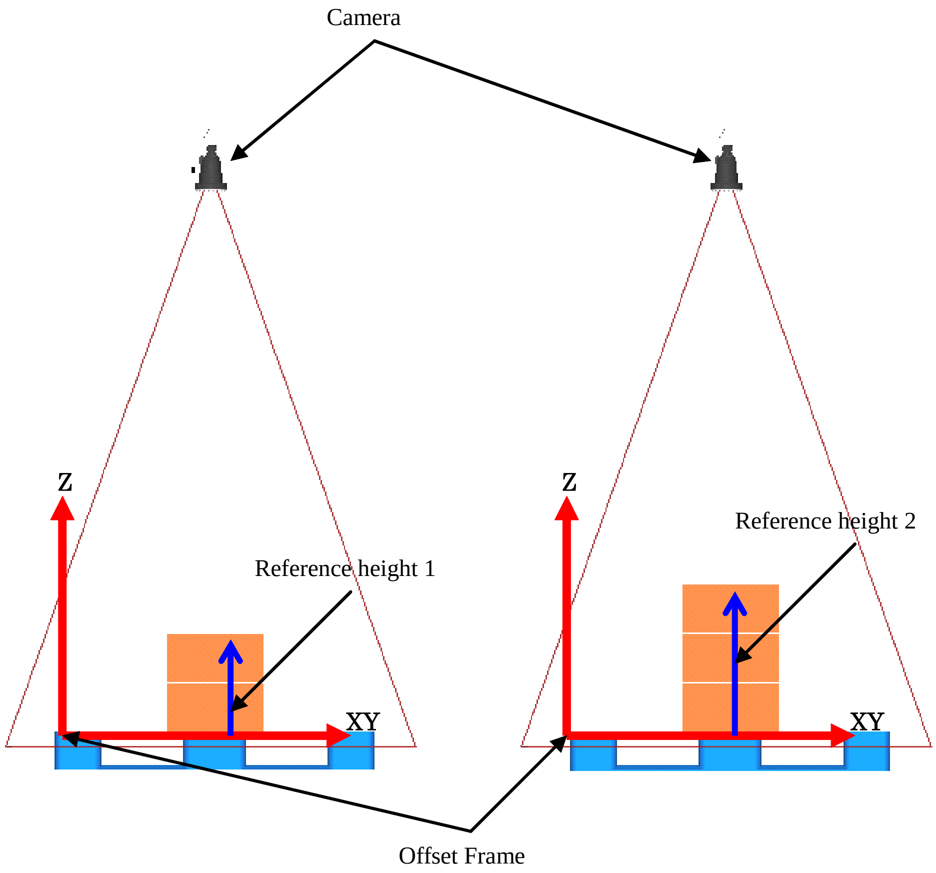
A description of the locator tool is omitted here. For setting of the locator tool, refer to Chapter 7, “COMMAND TOOL” in the *i*RVision Operator’s Manual (Reference) (B-83304EN).

Reference position setting

Teach a reference position. At first, open a vision process page as shown below. Next, place a workpiece on the pallet and set the layer number in Reference Layer 1. In addition, set the height of the Reference Layer 1 viewed from the XY plane of offset frame in the Reference Height 1. Press the F3 SNAP and the F4 FIND buttons to detect the workpiece of the Reference Height 1. Next, tap the [Set] button in the [Reference Scale 1]. The value of Reference Scale 1 is inputted. Next, stack N workpieces and set the number of layers in the Reference Layer 2. Then, set the height of the Reference Layer 2 viewed from the XY plane of offset frame in the Reference Height 2.. Press the F3 SNAP and the F4 FIND buttons to detect the workpiece of the Reference Height 2. Next, tap the [Set] button in the [Reference Scale 2]. The value of Reference Scale 2 is inputted. Press the F4 FIND button to detect the workpiece. Then, tap the [Set Ref] button in the Reference Data. [Ref. Pos. Status] becomes [Set]. In addition, the values of [Reference X], [Reference Y], [Reference Z] and [Reference R] are inputted. The values are relative to the offset frame.

Jog the robot and move to working position (for example, pick up a workpiece). For an example, refer to sample program of Subsection 6.2.4 "Robot Program Creation and Teaching". LP[2] on the line11 of sample program is a working position for a workpiece. If a robot's current position is set to LP[2], the reference position setting is complete.


Select camera calibration data.
Set the exposure.
In "Offset Frame Setting", select the user frame number of the offset frame.
Place workpiece and enter the height information in “Reference Height 1”
Press the F3 SNAP and the F4 FIND button to find the workpiece. Next, tap the [Set] button to set a reference size.
Stack N workpieces and enter the height information in "Reference Height 2".
Press the F3 SNAP and the F4 FIND button to find the workpiece. Next, tap the [Set] button to set a reference size.
Press the F3 SNAP and the F4 FIND button to find the workpiece with which the robot reference position is taught. Next, tap the [Set] button to set the reference position.
Depalletizing Vision Process
Camera Calibration: Trained
CALIB
Camera Setup: Trained
CAM
Exposure Mode: Fixed
Exposure Time: 8.333 ms
Auto Exposure Area: Not Trained Train
Auto Exposure Adjust: 0 Mask
Multi Exposures: 1 , 8.333 - 8.333 ms
Multi Exposure Area: (0,0) 480x640 Train
Multi Exposure Mode: Deviation Mask
Multiple Locator Mode: Find Best
App. Z Mode: Calc. From Found Scale
Use layer height
Output layer
No. 10
Number to Find: 1
Offset Frame: User Frame 1
Image Logging Mode: Log Failed Images
Sort by: Parent Cmd. Tool Level
Sort key: Score
Sort order: Desc.
Delete Duplicates If <: 20.0 pix 180.0 °
Reference Data
Index: 1 of 1
Model ID: 1
Register Number:
Layer error threshold: 20 %
Reference Height 1: 300.0 mm
Reference Scale 1: 100.0 % Set
Reference Layer 1: 2
Reference Height 2: 450.0 mm
Reference Scale 2: 117.5 % Set
Reference Layer 2: 3
Ref. Pos. Status: Set Set
Reference X: 5.8 mm
Reference Y: -65.4 mm
Reference Z: 450.0 mm
Reference R: -0.9 °
Limit Check Select:
None selected



6.2.4 Robot Program Creation and Teaching

In the sample program below, a vision process named "A" is used. For fixed frame offset, add the "VOFFSET, VR" instruction as an operation statement.

```
   1:   UFRAME_NUM=1 ;
   2:   UTOOL_NUM=1 ;
   3:   R[1:Notfound]=0      ;
   4:L P[1] 2000mm/sec FINE     ;
   5;
   6:   VISION RUN_FIND 'A'      ;
   7:   VISION GET_OFFSET 'A' VR[1] JMP LBL[100] ;
   8:    ;
   9:   !Handling ;
  10:L P[2] 2000mm/sec CNT100 VOFFSET,VR[1] Tool_Offset,PR[2]      ;
  11:L P[2] 500mm/sec FINE VOFFSET,VR[1]      ;
  12:   CALL HAND_CLOSE      ;
  13:L P[2] 2000mm/sec CNT100 VOFFSET,VR[1] Tool_Offset,PR[3]      ;
  14:   !Handling ;
  15:   JMP_LBL[900] ;
  16:    ;
  17:   LBL[100] ;
  18:   R[1:Notfound]=1      ;
  20:    ;
  21:   LBL[900] ;
```

Obtain the offset result of the detected workpiece on line 7. Move to the position above the workpiece on line 10. Move to the grasp position on line 11. Move to the escape position after grasping the workpiece on line 13.

6.2.5 Robot Compensation Operation Check

Check that a workpiece placed on the pallet can be detected and handled precisely.

- Place the workpiece on the reference position, find it and check the handling accuracy. If the accuracy of compensation is low, retry the reference position setting.
- Move the workpiece without rotation, find it and check the handling accuracy. If the accuracy is good for the reference position, but low for non-rotated workpiece on the edge of the field of view, it is possible that Part Z Height is not set properly. Check the Part Z Height, refer to Subsection 6.2.3, "Vision Process Creation and Teaching"
- Rotate the workpiece, find it and check the handling accuracy. If the accuracy is good for a moved workpiece without rotation, but low for rotated workpiece and lower for more rotated workpiece, it is possible that the offset frame or the calibration grid frame is not set properly. If the calibration grid frame was manually taught with a pointer, verify the accuracy of the pointer TCP (UTool) used to teach the frame. Moreover, check the offset frame and the calibration grid frame are set precisely, then retry the camera calibration.
- Stack several workpieces then move the robot to the top workpieces. Check that the robot moves to the workpieces correctly. Remove the workpiece and repeat with the next workpiece. Start with lower override of the robot to check that the logic of the program is correct. Next, increase the override to check that the robot can operate continuously.

6.3 SETUP FOR "FIXED FRAME OFFSET WITH ROBOT-MOUNTED CAMERA "

Use the following setup procedure:

1. Camera calibration setting

⇩

2. Offset user frame setting

⇩

3. Vision process creation and teaching

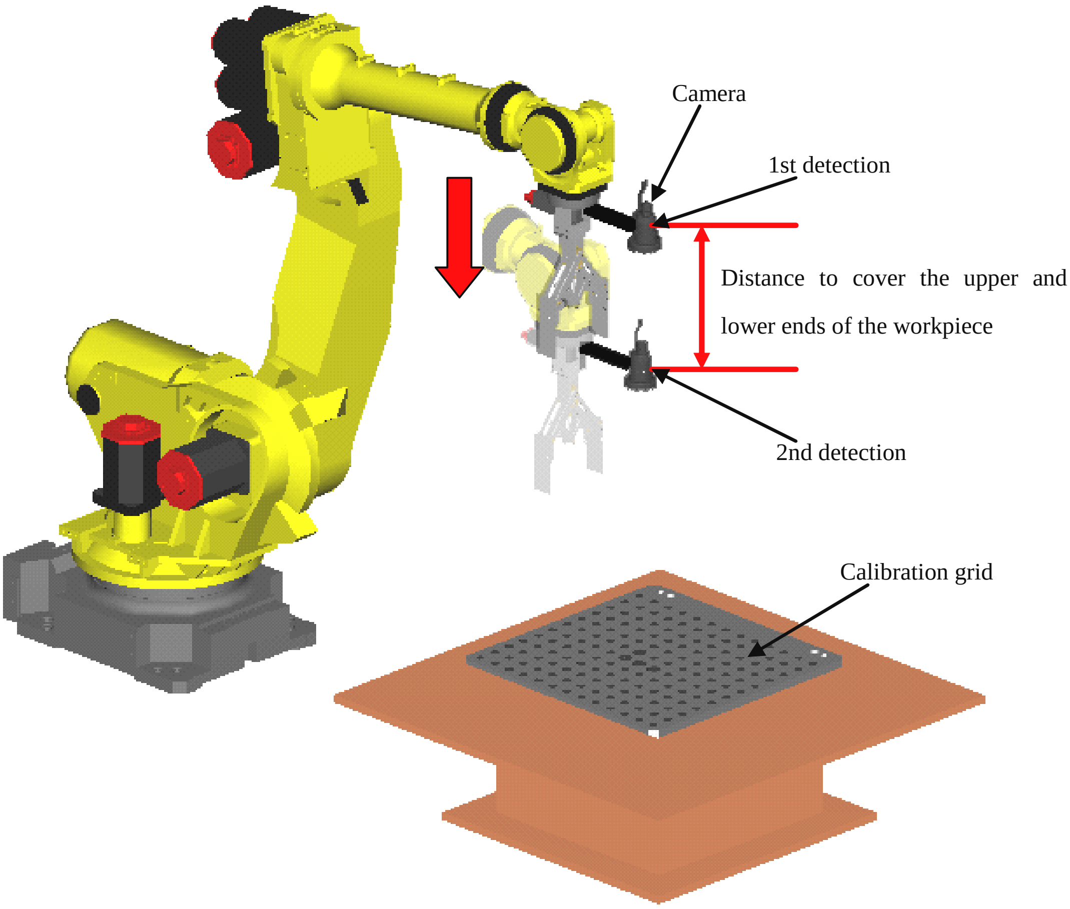
⇩

4. Robot program creation and teaching

When initially setting up the vision system, perform all the above procedures. When the position of the camera is shifted or the camera is replaced, redo "1 Camera calibration setting." If the camera is already calibrated a new workpiece is added or changed perform "3 Vision process creation and teaching." and "4 Robot program creation and teaching."

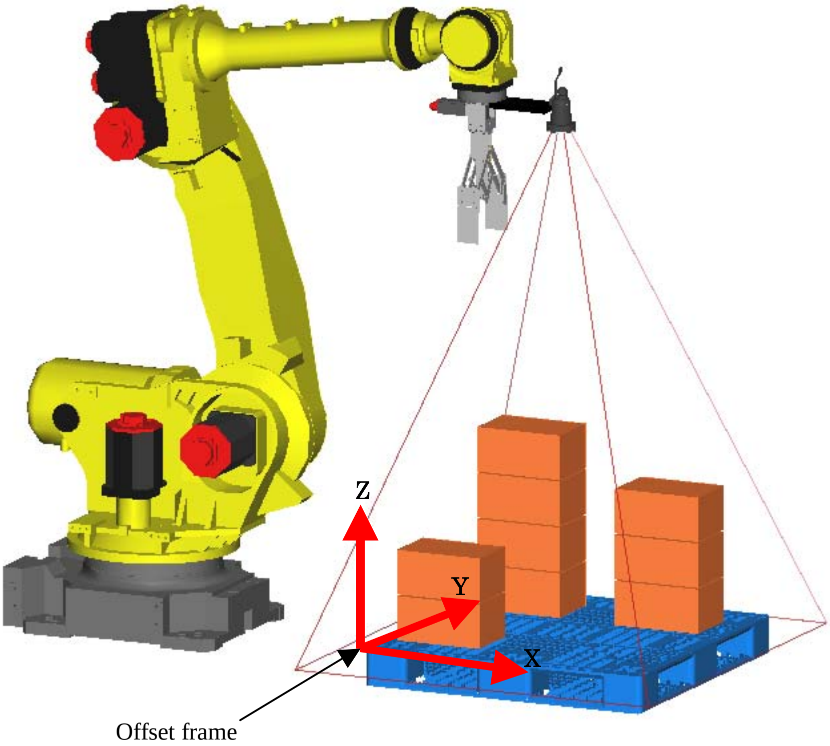
6.3.1 Camera Calibration Setting

When using a robot-mounted camera, perform the Grid Pattern Calibration. In the case of a robot-mounted camera, the Robot-generated Grid Calibration cannot be used. For details of the grid frame calibration, see Section 8.2, “GRID PATTERN CALIBRATION WITH A ROBOT-MOUNTED CAMERA”. In the Section 8.2.4, “Camera Calibration Data Creation and Setting”, when perform the two-plane calibration, it is recommended that the up/down distance for two-plane calibration be set to a value that covers the upper and lower ends of the workpiece in the pallet.



6.3.2 Offset Frame Setting

An offset frame is the coordinate system used for calculation of the offset data. A found position is outputted as a position in the offset frame. In the fixed frame offset, the offset frame is set as a user frame. Set an offset frame so that the XY plane of the user frame is parallel with the table plane on which a workpiece is placed. Otherwise, the required compensation precision may not be obtained.



There are two methods to teach the offset frame, one is touch-up with the pointer tool, and another is the Automatic Grid Frame Set Function.

Touch-up

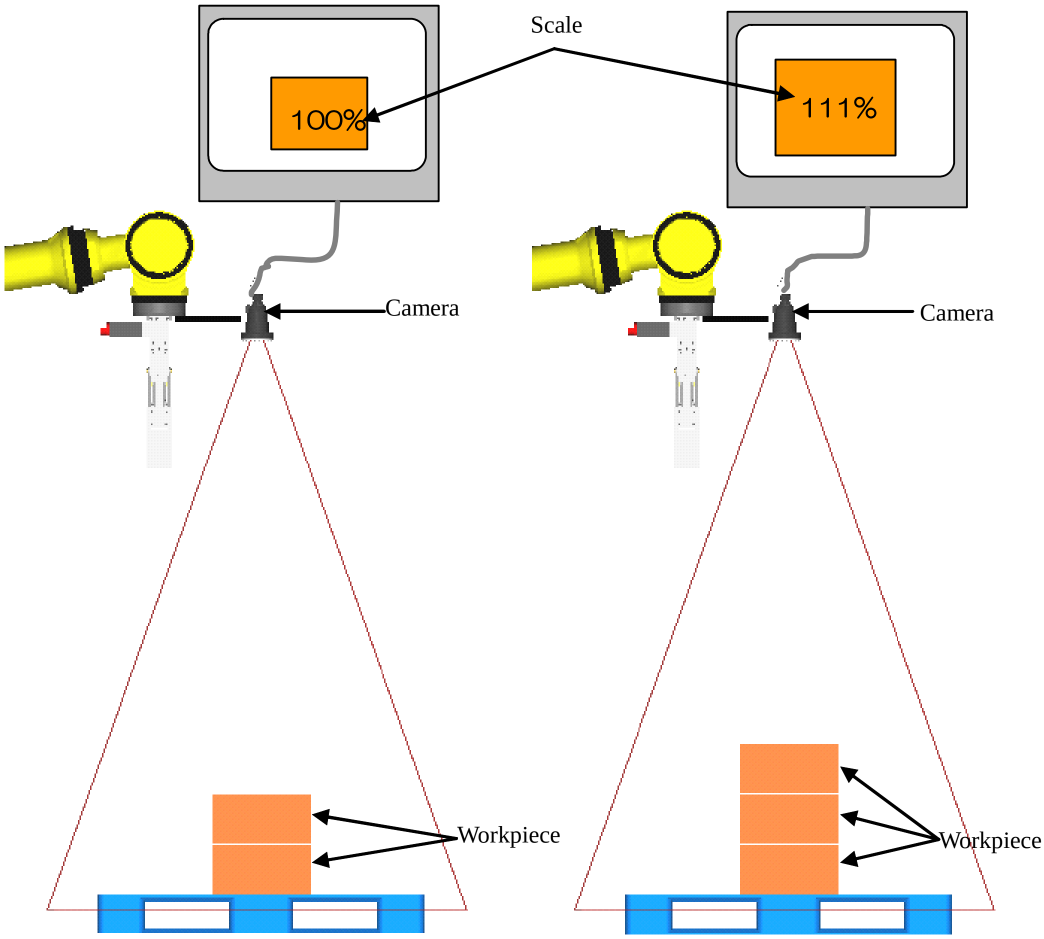
To manually teach a user frame, a pointer tool with a taught TCP is required. In general, set the TCP accurately on the pointer installed on the robot gripper. Set the robot TCP in an available UTool. To reuse the pointer TCP, the reproducibility of the pointer installation is required. If the reproducibility of the pointer installation is not assured, the TCP needs to be re- taught each time a pointer is installed. For details, see Section 9.1.1, “User frame setting with a pointer tool”.

Automatic Grid Frame Set Function

The Automatic Grid Frame Set Function sets the calibration grid frame using a camera. Install a calibration grid so that the XY plane of the calibration grid is parallel with the plane on which the workpiece is placed, and perform the Automatic Grid Frame Set Function. For details, see Section 9.2, “Frame setting with the Automatic Grid Frame Set Function”. A calibration grid is used for setup. Moreover, in the case of a fixed camera, prepare a camera for the Automatic Grid Frame Set Function separately. And perform the Automatic Grid Frame Set Function using the camera attached to a temporary position of a robot's hand. In addition, the Automatic Grid Frame Set Function is usable with 6-axis robots only. The function cannot be used with 4-axis robots and 5-axis robots. When using 4-axis robots or 5-axis robots, teach the frame manually.

6.3.3 Vision Process Creation and Teaching

Create a process for Depalletizing Vision Process. The basic process setting method is the same as for 2D Single-view Vision Process. Unlike 2D Single-view Vision Process, Depalletizing Vision Process sets the relationship between the height of workpieces and the size of the workpiece viewed by the camera.



A description of the locator tool is omitted here. For setting of the locator tool, refer to Chapter 7, “COMMAND TOOL” in the *i*RVision Operator’s Manual (Reference) (B-83304EN).

Reference position setting

Teach a reference position. At first, open a vision process page as shown below. Next, place a workpiece on a height of the Reference Layer 1. Set the height of the Reference Layer 1 viewed from the XY plane of offset frame in the Reference Height 1. Move the camera to the position to detect the workpiece. Press the F3 SNAP and the F4 FIND buttons to detect the workpiece of the Reference Height 1. Next, tap the [Set] button in the [Reference Scale 1]. The value of Reference Scale 1 is inputted. Next, stack N workpieces and set the number of stages in the Reference Layer 2. Set the height of the Reference Layer 2 viewed from the XY plane of offset frame in the Reference Height 2. Move the camera to the position to detect the workpiece. Press the F3 SNAP and the F4 FIND buttons to detect the workpiece of the Reference Height 2. Next, tap the [Set] button in the [Reference Scale 2]. The value of Reference Scale 2 is inputted. Press the F4 FIND button to detect the workpiece. Then, tap [Set Ref] button in the Reference Data. [Ref. Pos. Status] becomes [Set]. In addition, the values of [Reference X], [Reference Y], [Reference Z] and [Reference R] are inputted. The values are relative to the offset frame.
Jog the robot and move to working position (for example, pick up a workpiece). For example, refer to sample program of Subsection 6.3.4 "Robot Program Creation and Teaching". LP[2] on the line11 of sample program is a working position for a workpiece. If a robot's current position is set to LP[2], the reference position setting is complete.

Select camera calibration data.

Set the exposure time.

In "Offset Frame Setting", select the user frame number of the offset frame.

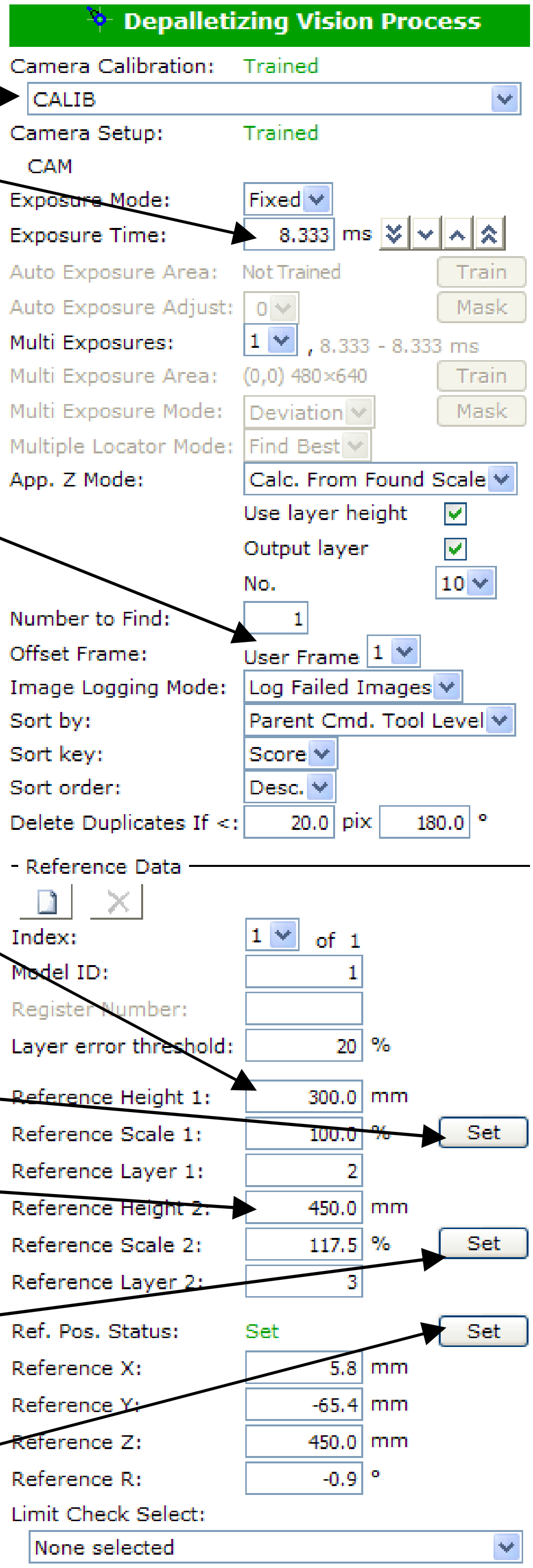
Place workpiece and enter the height information in “Reference Height 1”

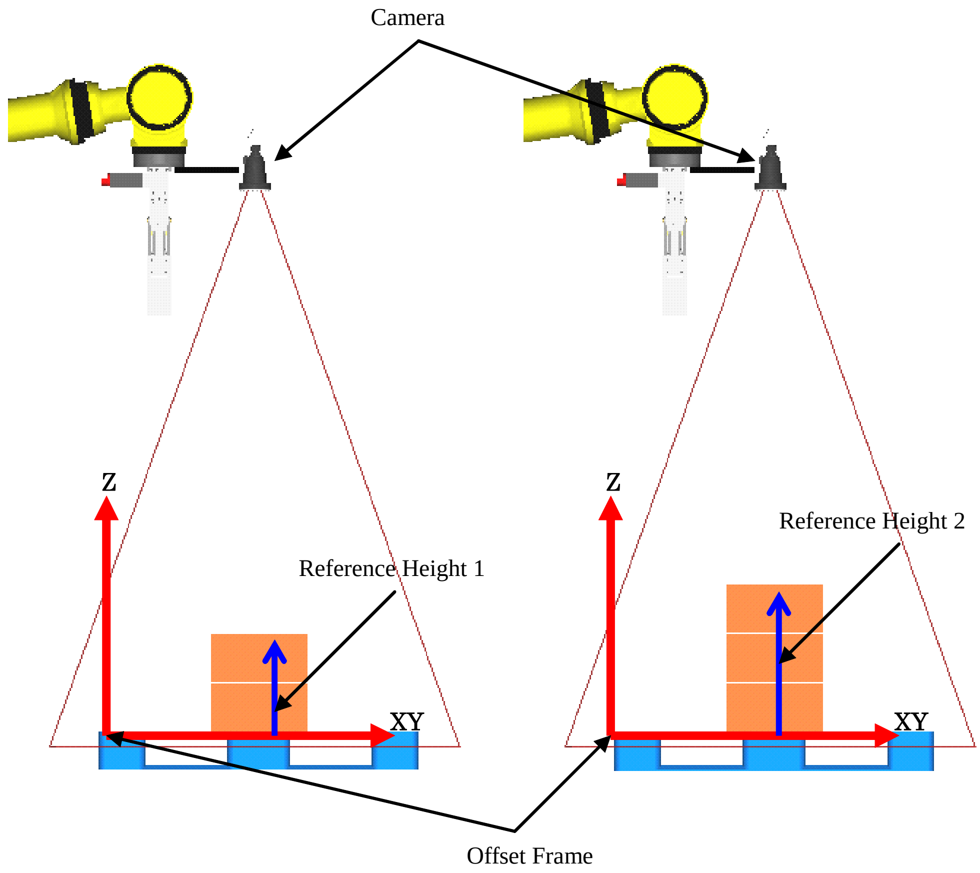
Press the F3 SNAP and the F4 FIND button to find the workpiece. Next, tap the [Set] button to set a reference size.

Stack *n* workpieces and enter the height information in "Reference Height 2".

Press the F3 SNAP and the F4 FIND button to find the workpiece. Next, tap the [Set] button to set a reference size.

Press the F3 SNAP and the F4 FIND button to find the workpiece with which the robot reference position is taught. Next, tap the [Set] button to set the reference position.





6.3.4 Robot Program Creation and Teaching

In the sample program below, a vision process named "A" is used. A robot-mounted camera is used, and the "OFFSET" instruction is used on line 4 to shift the camera image snap position on the pallet. Shifting the image snap robot position by adding a constant value to the value of PR[1] simplifies programming. For fixed frame offset, add the "VOFFSET,VR" instruction as an operation statement.

```
  1:  UFRAME_NUM=1 ;
  2:  UTOOL_NUM=1 ;
  3:  R[1:Notfound]=0      ;
  4:L P[1] 2000mm/sec FINE Offset,PR[1]    ;
  5:  WAIT R[1] ;
  6:  VISION RUN_FIND 'A'     ;
  7:  VISION GET_OFFSET 'A' VR[1] JMP LBL[100] ;
  8:    ;
  9:  !Handling ;
 10:L P[2] 2000mm/sec CNT100 VOFFSET,VR[1] Tool_Offset,PR[2]     ;
 11:L P[2] 500mm/sec FINE VOFFSET,VR[1]     ;
 12:  CALL HAND_CLOSE     ;
 13:L P[2] 2000mm/sec CNT100 VOFFSET,VR[1] Tool_Offset,PR[3]     ;
 14:  !Handling ;
 15:  JMP_LBL[900] ;
 16:    ;
 17:  LBL[100] ;
 18:  R[1:Notfound]=1      ;
 20:    ;
 21:  LBL[900] ;
```

Move to camera position to snap on line 4. Execute “WAIT” instruction to remove the possible vibration of a camera on line5. Execute process ”A” with the vision detection instruction on line 6. Obtain the measurement result of the detected workpiece on line7. Move to the approach position above the workpiece on line10. Move to the grasp position on line11. Move to the escape position after grasping the workpiece on line13.

6.3.5 Robot Compensation Operation Check

Check that a workpiece placed on the pallet can be detected and handled precisely.

- Place the workpiece on the reference position, find it and check the handling accuracy. If the accuracy of compensation is low, retry the reference position setting.
- Move the workpiece without rotation, find it and check the handling accuracy. If the accuracy is good for reference position, but low for non-rotated workpiece on the edge of the field of view, it is possible that Part Z Height is not set properly. Check the Part Z Height, refer to Subsection 6.3.3, “Vision Process Creation and Teaching”
- Rotate the workpiece, find it and check the handling accuracy. If the accuracy is good for a moved workpiece without rotation, but low for rotated workpiece and lower for more rotated workpiece, it is possible that the offset frame or the calibration grid frame is not set properly. . If the calibration grid frame was manually taught with a pointer, verify the accuracy of the pointer TCP (UTool) used to teach the frame. Moreover, check the offset frame and the calibration grid frame are set precisely, then, retry the camera calibration.
- Depending on robot motion, a camera may vibrate at snap position. Execute “WAIT” instruction to remove the possible vibration of a workpiece before the “VISION RUN_FIND”.
- Stack several workpieces then move the robot to the top workpieces. When performing the touch-up with pointer tool to set up the frame, check that the robot moves to the workpieces correctly. Remove the workpiece and repeat with the next workpiece. Start with lower override of the robot to check that the logic of the program is correct. Next, increase the override to check that the robot can operate continuously.

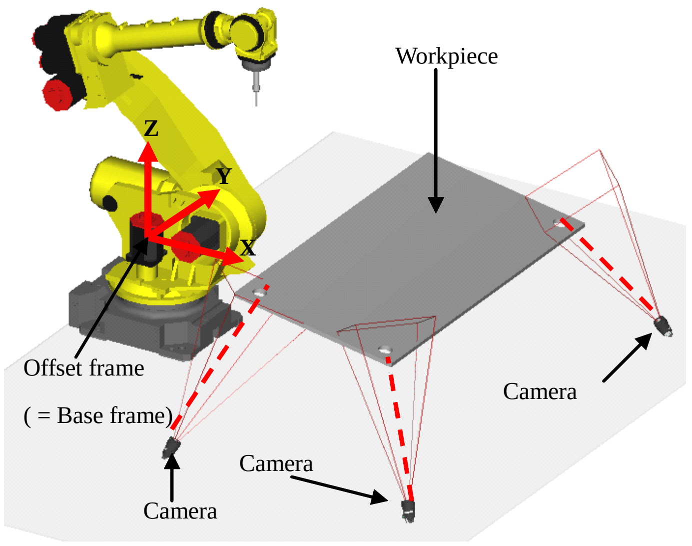
7 SETUP OF 3D TRI-VIEW VISION PROCESS

The 3D Tri-View Vision Process is the function for making three-dimensional compensation by measuring three detection targets of a large workpiece such as a car body.
This chapter describes the setup procedure for 3D Tri-View Vision Process by using the following two application examples:

<1> Fixed frame offset with fixed camera
<2> Fixed frame offset with robot mounted camera

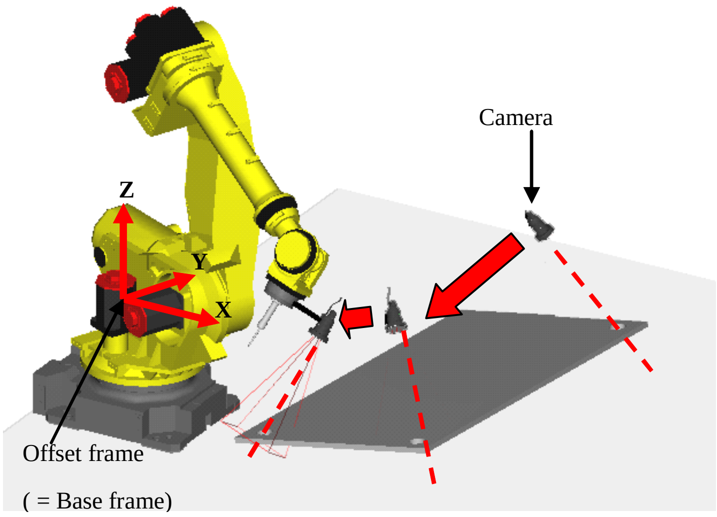
Fixed frame offset with fixed camera

An example of layout for "fixed frame offset with fixed camera" is given below. Three points of a workpiece are measured by three fixed cameras.



Fixed frame offset with robot mounted camera

An example of layout for "fixed frame offset with robot mounted camera" is given below. Three points of a workpiece are measured by moving one camera.



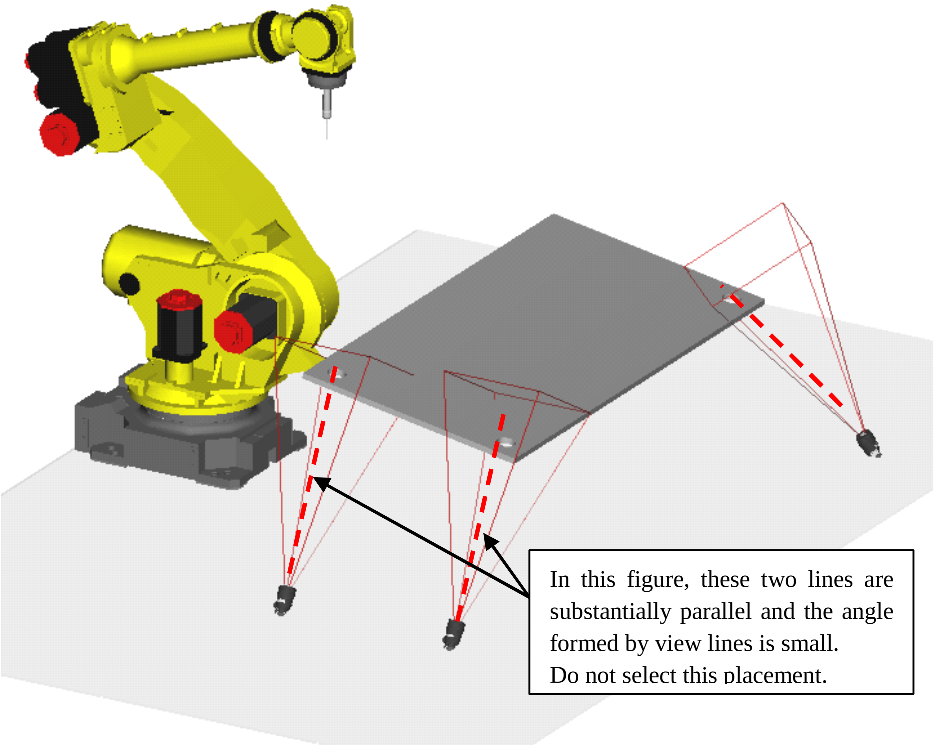
7.1 FEATURES AND NOTES

Features

- Three-dimensional compensation is made by measuring three points on a large workpiece that has the potential to move in 3 dimensions.
- Compensation is applied to all of six degrees of freedom for parallel displacement (X, Y, Z) and rotation (W, P, R) of the workpiece.
- The number of measurement points (number of camera views) is three and cannot be changed.
- The 3D Tri-View Vision Process has camera views in a program as two-dimensional compensation based on multiple cameras. There are three camera views for measuring a total of three detection targets.
- During detection, a total of three view lines (one for each camera view) are measured. A triangle that takes the three detection targets as vertices and has known shape is applied to the three view lines to identify the position of each detection target on the corresponding view line and obtain the three-dimensional position and posture of the workpiece.
- Only “fixed frame offset” can be performed.
- Both a fixed camera and a robot mounted camera can be used.
- A robot mounted camera can measure a detection target while moving the position of the robot to the three locations. This capability is provided because the current position of a robot is considered in *i*RVision calculation processing when a target position calculation is made.

Notes

- The following conditions must be met when determining detection targets. (For a car body, the reference holes are suitable).
  - The exact relative position or distance between the three detection targets must be known. The should be obtained from a drawing.
  - The relative relation between the positions of the three detection targets and the work positions does not change individually.
  - Three detection targets can be set so that the whole workpiece can be covered.
  - The triangle having the three detection targets as its vertices is not too shallow.
  - The shapes of the detection targets are constant.
  - There is no portion having a similar shape near the detection targets.
- Determine the camera view so that the detection targets do not fall outside the camera view even when they deviate at the maximum. However, if the camera field of view is too wide, the required compensation accuracy may not be obtained.
- When the detection targets are detected, three view lines are measured. The cameras need to be placed so that any pair of view lines is not parallel and any angle formed by two view lines is large to some extent (if possible, 60 degrees or more). If the angle formed by view lines is tool small, the required precision may not be obtained.



Preparation for drawings etc. about a workpiece

The 3D Tri-View Vision Process uses the distance between detection targets for calculation, so it is necessary to input the coordinates of detection targets of the workpiece in an arbitrary coordinate system. The coordinate system is not important because the relative distance between the targets is what is important. Typically the coordinates of the targets in the workpiece come from a drawing.

7.2 SETUP FOR "FIXED FRAME OFFSET WITH FIXED CAMERA"

Three fixed cameras measure 3 points of the workpiece.
Use the following setup procedure for "Fixed frame offset with fixed camera ":

1. Camera calibration setting

⇩

2. Vision process creation and teaching

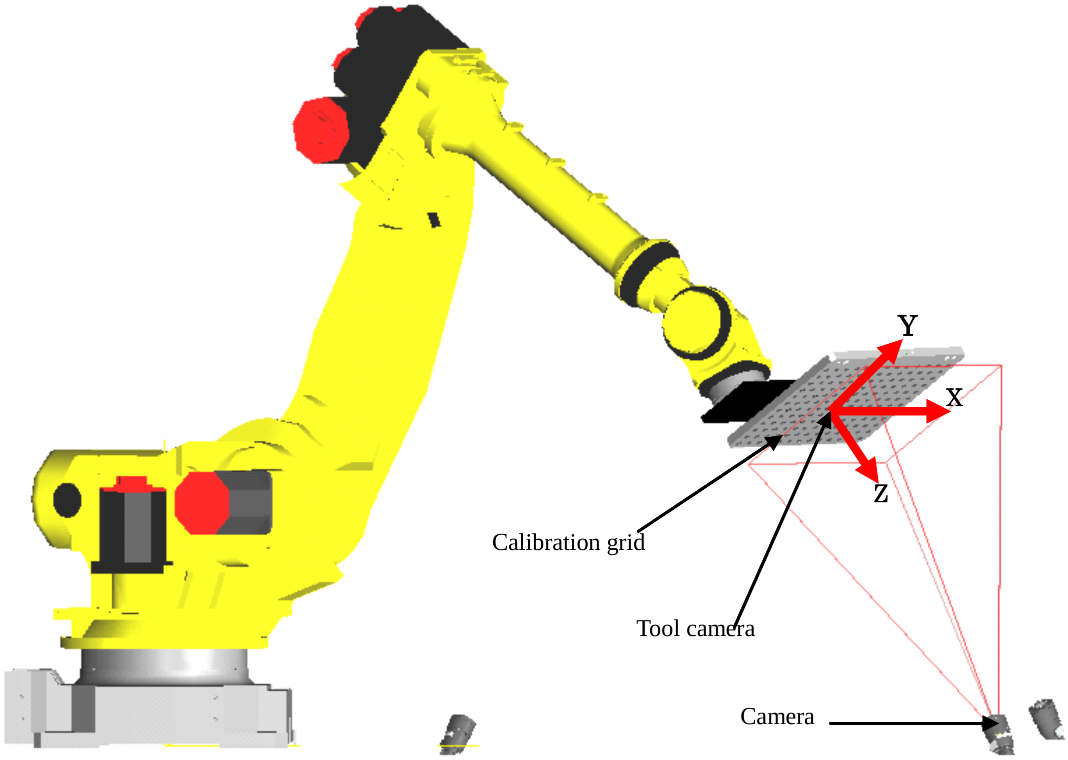
⇩

3. Robot program creation and teaching

When initially setting up the vision system, perform all the above procedures. When the position of the camera is shifted or the camera is replaced, redo "1 Camera calibration setting." If the camera is already calibrated a new workpiece is added or changed perform "2 Vision process creation and teaching." and "3 Robot program creation and teaching."

7.2.1 Camera Calibration Setting

In the 3D Tri-View Vision Process, perform the two-plane by using calibration grid that is mounted on the robot. For details of the grid frame calibration, see Section 8.1, “GRID PATTERN CALIBRATION WITH A FIXED CAMERA”. In addition, when perform camera calibration for the 3D Tri-View Vision Process, be careful of the following points.



Application frame

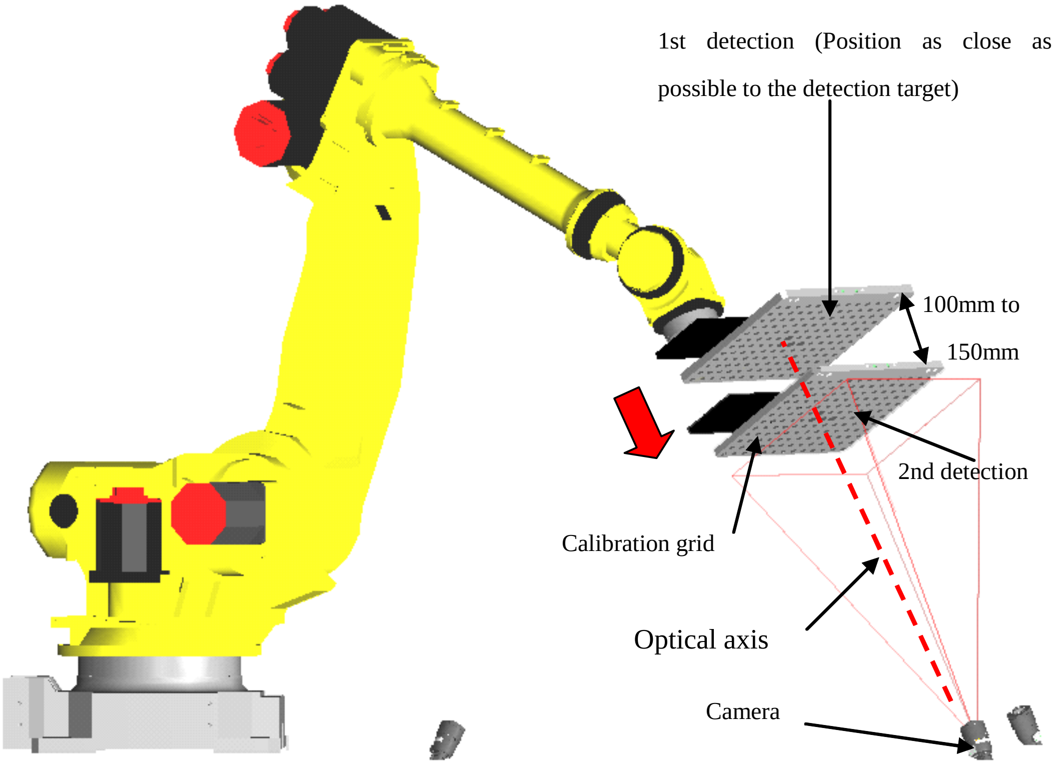
In the 3D Tri-View Vision Process, the application frame is the user frame used in the camera calibration, and for vision offset data. The reference position and the found position are outputted as a position on the application frame in the 3D Tri-View Vision Process. Moreover, in the 3D Tri-View Vision Process, a workpiece is large in many cases. So, Two or more robots may use one compensation data. In this case, set up the application frame on a plane which is a common for all robots, and use this user frame as a application frame. (Set the same application frame number for all robot).

Calibration grid frame setting

Install the calibration grid on the mounted robot. When set a calibration grid frame, it is recommended to use the Automatic Grid Frame Set Function. Set a tool frame as the calibration grid frame.

Camera calibration data creating and setting

Perform the calibration for all cameras. Create three camera setup data files and three camera calibration data files. Note "Application frame" number must be the same in all calibration data used.
Perform two-plane calibration by moving the robot up and down as shown in the figure below. Perform detection by bringing calibration surface 1 as close as possible to the detection target. The up/down distance for two-plane calibration should be 100 to 150 mm.
Detect the calibration grid at two different heights. Move the calibration grid along the optical axis of the camera. Perform robot jog without changing the calibration grid posture.



7.2.2 Vision Process Creation and Teaching

Create a vision process for the 3D Tri-View Vision Process. For each measurement point, a camera view is named Camera View 1 or Camera View 2. "GPM Locator Tool" comes under each camera view.
Use the following procedure to teach “3D Tri-View Vision Process”.

1. Select calibration data for camera view, and teach fundamental data.

⇩

2. Teach the locator tool of camera view.

⇩

3. Select camera view then press the F3 SNAP and the F4 FIND button to detect a taught model.

⇩

4. Perform steps 1, 2, and 3 above for all camera views, select "3D Tri-View Vision Process" in the tree view and press F3 SNAP button to perform detection.

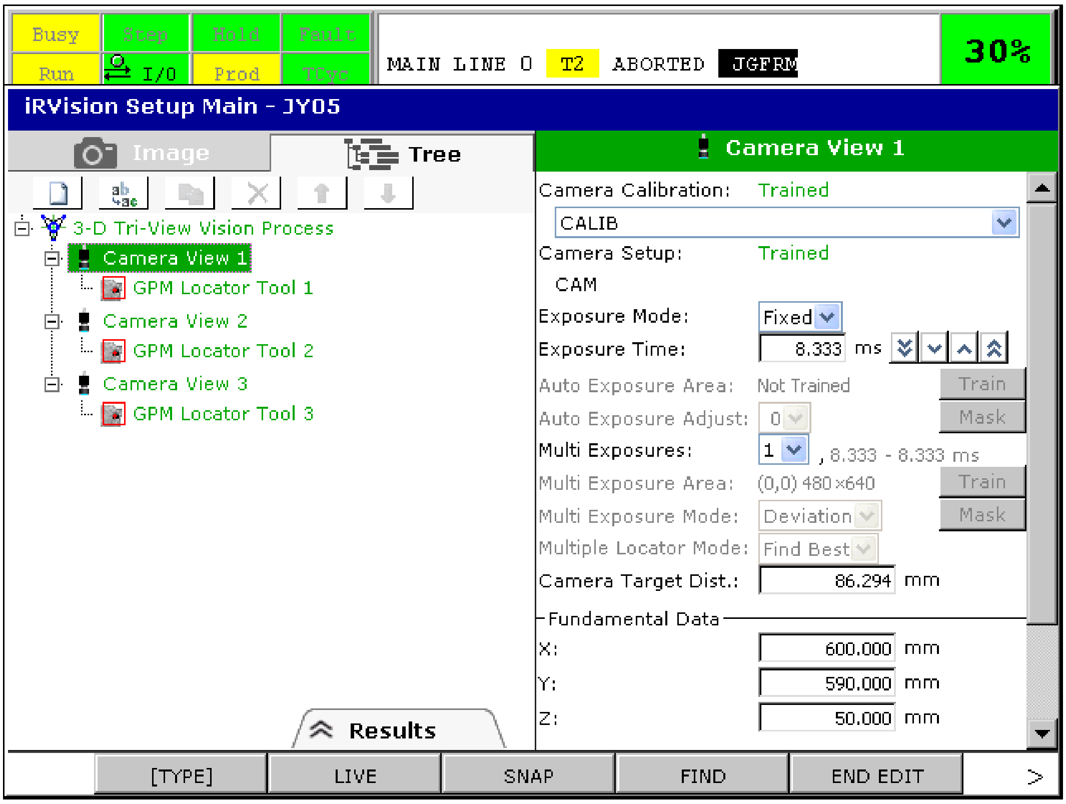
⇩

5. Tap [Set Ref. Pos.] button to set a reference position.

Camera View Teaching

With each camera view, teach the locator tool. A detailed description of the locator tool is omitted here. For setting of the locator tool, refer to Chapter 7, “COMMAND TOOL” in the *i*RVision Operator’s Manual (Reference) (B-83304EN).

Select each camera view and set each fundamental data as shown below.



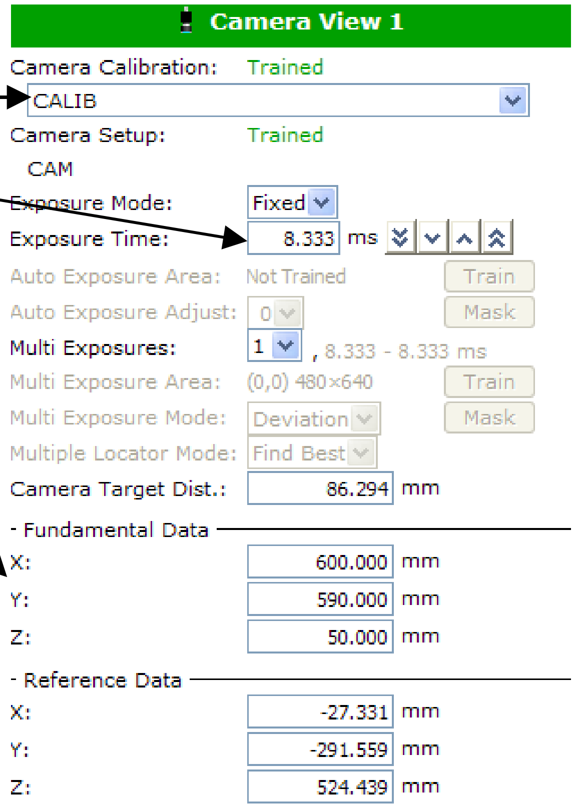
Select the camera calibration data

Set the exposure time.

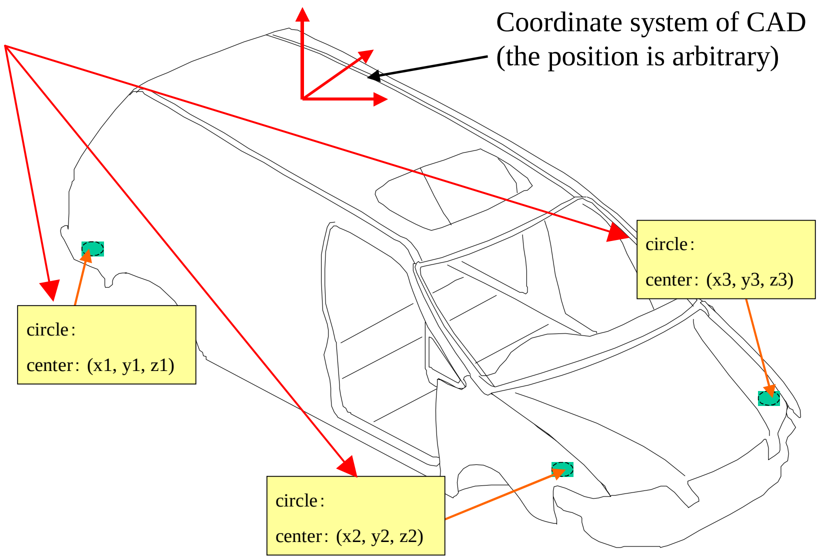
Set the fundamental data. Enter the coordinates of the detection target in any coordinate system. (For example, the coordinate in a drawing)

Press the F3 SNAP and the F4 FIND button to detect the workpiece.

Perform the same processing for camera view 2 and camera view 3.



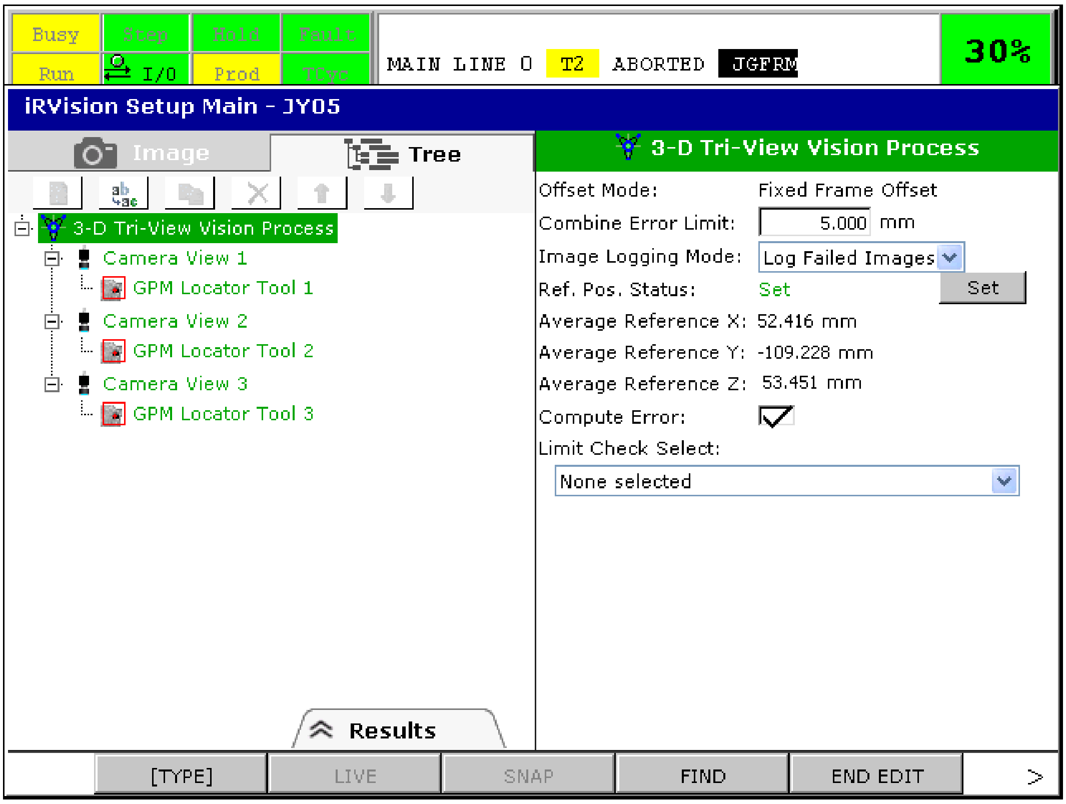
- Example of entering fundamental data: This is an example of entering CAD data of the workpiece. Enter the coordinates of the detection target displayed in CAD as fundamental data.

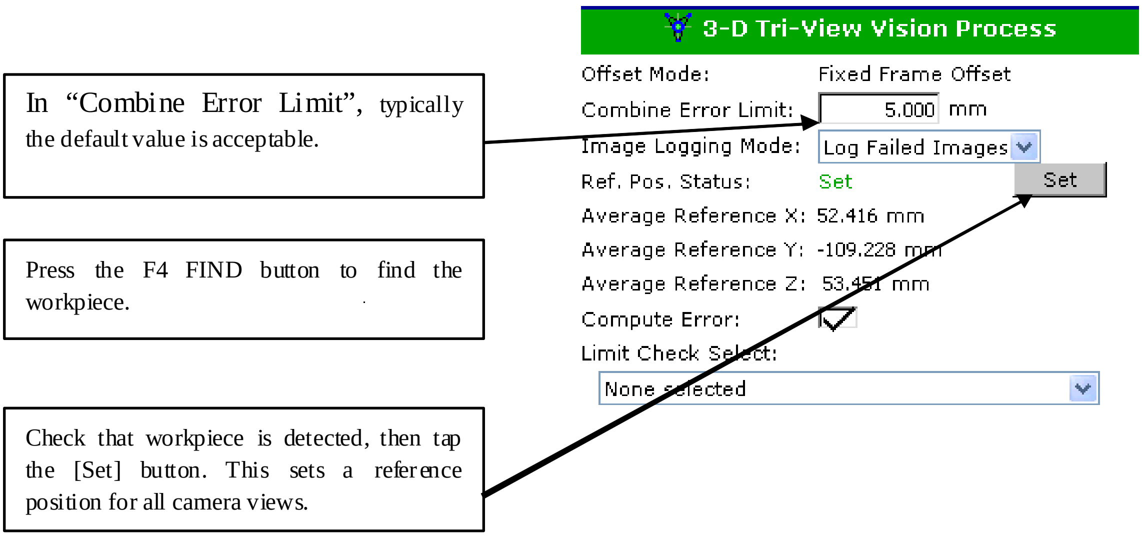


Reference position setting

If the fundamental data of the each camera view is set and the locator tool of the each camera view is taught, select the Camera View 1 and press the F3 SNAP and the F4 FIND buttons to detect a target of Camera View 1. Then, do not move the workpiece until the reference position setup is completed. If

the detection of Camera View 1 is success, detect the targets of Camera View 2 and Camera View 3 same as the Camera View 1. Next, select the 3D Tri-View Vision Process page in the vision process, and press the F4 FIND button to detect the workpiece. Then, tap the [Set] button. [Ref. Pos. Status] becomes [Set]. In addition, the value of [Average Reference X], [Average Reference Y] and [Average Reference Z] are displayed. The value is the average reference position of each camera views. In addition, the position is described on the application frame.
Jog the robot and move to working position (for example, pick up the workpiece). For an example, refer to sample program of Subsection 7.2.3 "Robot Program Creation and Teaching". LP[2] on the line11 of sample program is a working position for a workpiece. If a robot's current position is set to LP[2], a reference position setting will complete.





7.2.3 Robot Program Creation and Teaching

In the sample program below, a vision process named "A" is used. Three targets of a workpiece are found. If multiple fixed cameras are used, no camera view number needs to be specified in the "VISION RUN_FIND" instruction. For fixed frame offset, add the "VOFFSET, VR" instruction as an operation statement.

```
   1:   UFRAME_NUM=1 ;
   2:   UTOOL_NUM=1 ;
   3:   R[1:Notfound]=0      ;
   4:L P[1] 2000mm/sec FINE      ;
   5:    ;
   6:   VISION RUN_FIND 'A'      ;
   7:   VISION GET_OFFSET 'A' VR[1] JMP LBL[100] ;
   8:    ;
   9:   !Handling ;
  10:L P[2] 2000mm/sec CNT100 VOFFSET,VR[1] Tool_Offset,PR[1]      ;
  11:L P[2] 500mm/sec FINE VOFFSET,VR[1]      ;
  12:   CALL HAND_CLOSE      ;
  13:L P[2] 2000mm/sec CNT100 VOFFSET,VR[1] Tool_Offset,PR[1]      ;
  14:   !Handling ;
  15:   JMP_LBL[900] ;
  16:    ;
  17:   LBL[100] ;
  18:   R[1:Notfound]=1      ;
  19:    ;
  20:   LBL[900] ;
```

Obtain the offset result of the detected workpiece on line 7. Move to approach above the workpiece on line 10. Move to the grasp position on line11. Move to escape position after grasping the workpiece on line 13.
When a fixed camera is used, one "VISION RUN_FIND" instruction measures all camera views prepared beforehand. When the images of all camera views have been snapped, the line after the "VISION RUN_FIND” instruction is executed.

7.2.4 Robot Compensation Operation Check

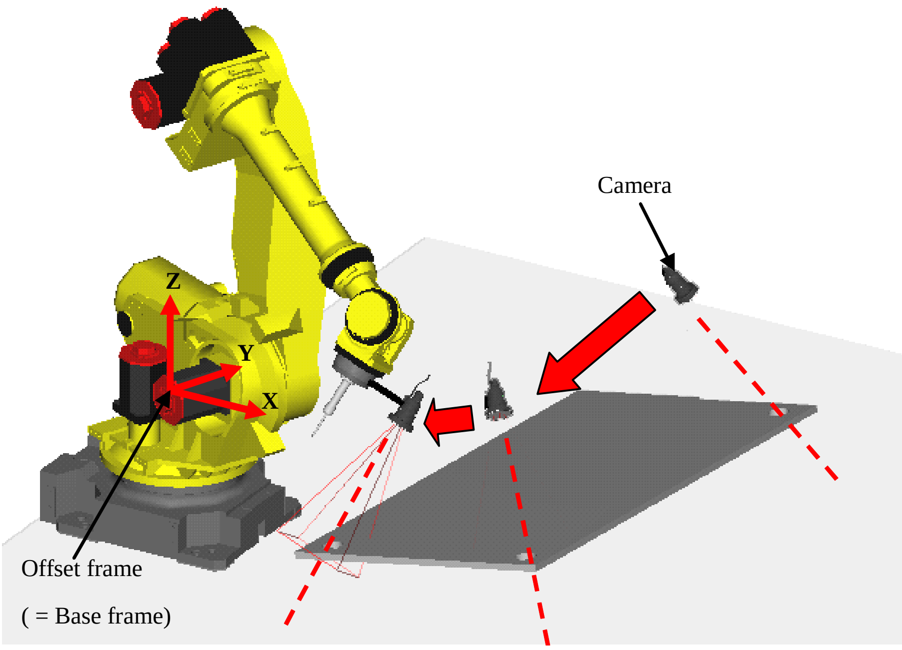
Check that three points of a workpiece can be detected and that the compensation can be performed correctly.
At first, place the workpiece in the reference position, find it and check the handling accuracy. If the accuracy of compensation is low, retry the reference position setting. Moreover, check the following things.

- Check the relative relation location among three detection targets and workpiece itself dose not have individual difference.
- Check whether the each view positions with fundamental data are set correctly.
- Check the calibration position. The 1st detection needs to be performed at position as close as possible to the detection target.

Start with lower override of the robot to check that the logic of the program is correct. Next, increase the override to check that the robot can operate continuously.

7.3 SETUP FOR "FIXED FRAME OFFSET WITH ROBOT-MOUNTED CAMERA"

An example of layout for "fixed frame offset with robot-mounted camera" is shown below. Three targets of a workpiece are measured by moving one camera.



Use the following setup procedure:

1. Camera calibration setting

⇩

2. Vision process creation and teaching

⇩

3. Robot program creation and teaching

When initially setting up the vision system, perform all the above procedures. When the position of the camera is shifted or the camera is replaced, redo "1 Camera calibration setting." If the camera is already calibrated a new workpiece is added or changed, perform "2 Vision process creation and teaching." and "3 Robot program creation and teaching."

7.3.1 Camera Calibration Setting

When perform the 3D Tri-View Vision Process with a robot-mounted camera, the three targets on the workpiece are found with one camera in different robot positions. Only one camera setup and one camera calibration is required. When using a robot-mounted camera, perform the Grid Pattern Calibration. In the case of a robot-mounted camera, the Robot-generated Grid Calibration cannot be used. For details of the grid frame calibration, see Section 8.2, “GRID PATTERN CALIBRATION WITH A ROBOT-MOUNTED CAMERA”.

Application frame

In the 3D Tri-View Vision Process, the application frame is the user frame used in the camera calibration, and for vision offset data. The reference position and the found position are outputted as a position on the application frame in the 3D Tri-View Vision Process. Moreover, in the 3D Tri-View Vision Process, a workpiece is large in many cases. So, Two or more robots may use one compensation data. In this case, set up the application frame on a plane which is a common for all robots, and use this user frame as a application frame. (Set the same application frame number for all robot).

Calibration grid frame setting

When set a calibration grid frame, it is recommended that use the Automatic Grid Frame Set Function. Set a user frame as the calibration grid frame.

7.3.2 Vision Process Creation and Teaching

Create a vision process for 3D Tri-View Vision Process. For each measurement point, a camera view is named camera view 1 or camera view 2. "GPM Locator Tool" comes under each camera view.
Use the following procedure to teach the process for "3D Tri-View Vision Process".

1. Select calibration data for camera view, and set the fundamental data.

⇩

2. Move the camera to a proper position and teach the locator tool of a camera view. Record the current camera position in the robot program (see Subsection 7.3.3).

⇩

3. Select camera view then press the F3 SNAP and the F4 FIND button to detect a taught model.

⇩

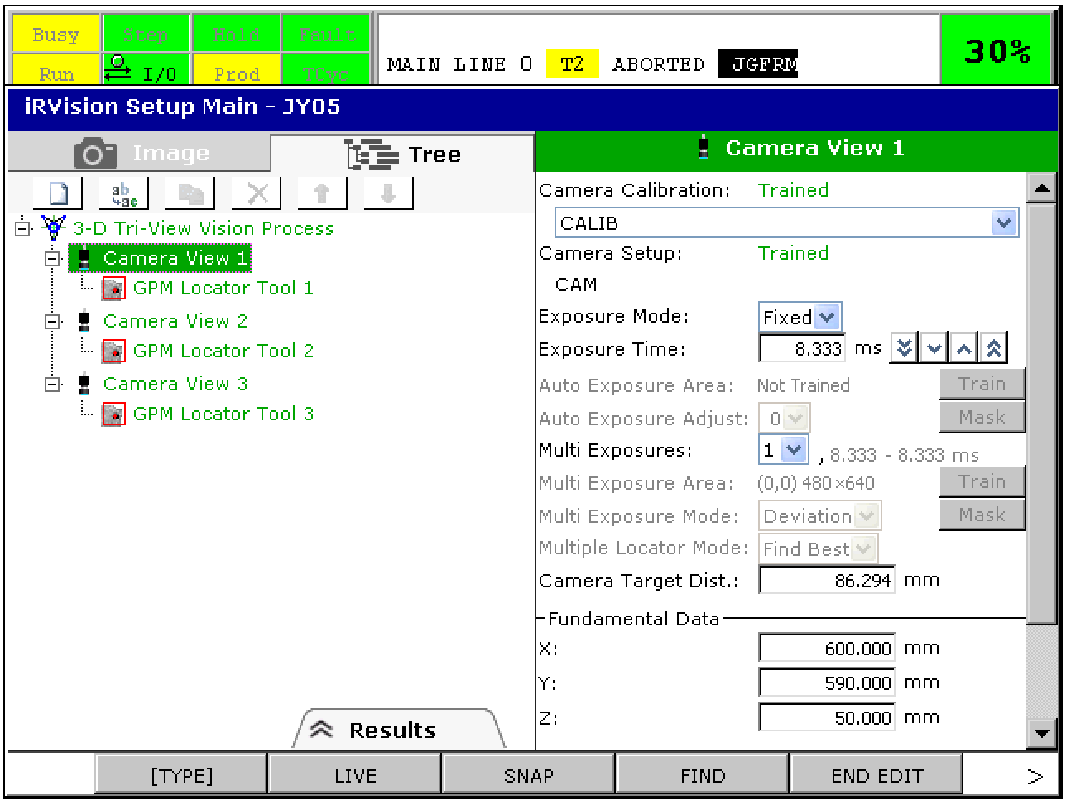
4. Perform steps 1, 2, and 3 above for all camera views, select "3D Tri-View Vision Process" in the tree view and press F4 FIND button to perform detection.

⇩

5. Tap [Set Ref. Pos] button to set a reference position.

Camera View Teaching

With each camera view, teach the locator tool. A description of the locator tool is omitted here. For setting of the locator tool, refer to Chapter 7, “COMMAND TOOL” in the *i*RVision Operator’s Manual (Reference) (B-83304EN). Select each camera view and set each fundamental data as shown below.



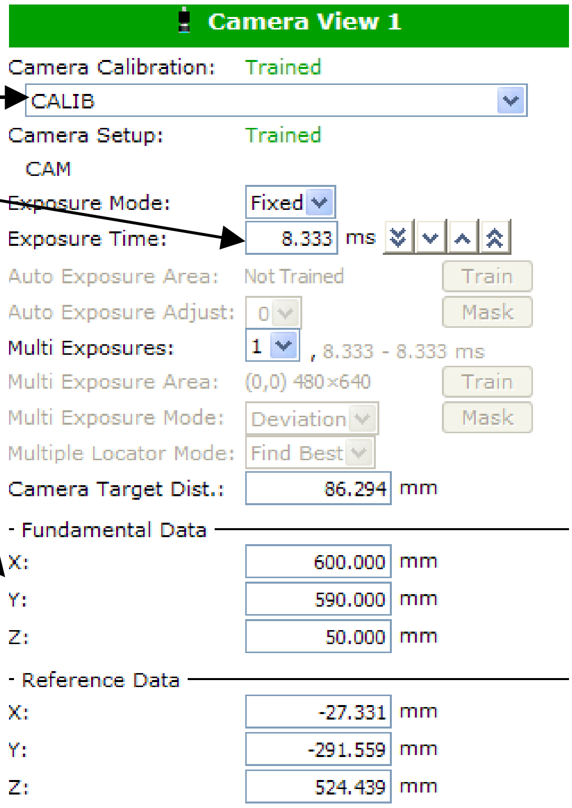
Select the camera calibration data

Set the exposure time.

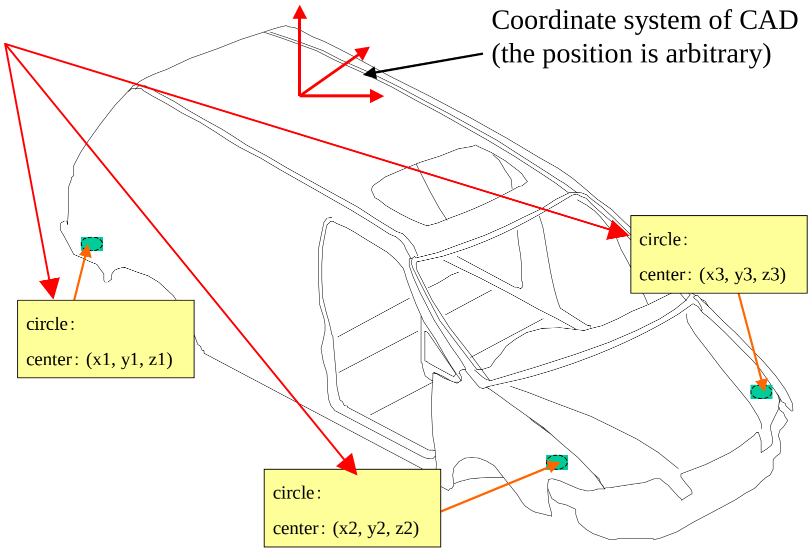
Set the fundamental data. Enter the coordinates of the detection target in any coordinate system. (For example, the coordinate in a drawing)

Press the F3 SNAP and the F4 FIND button to detect the workpiece.

Perform the same processing for camera view 2 and camera view 3.



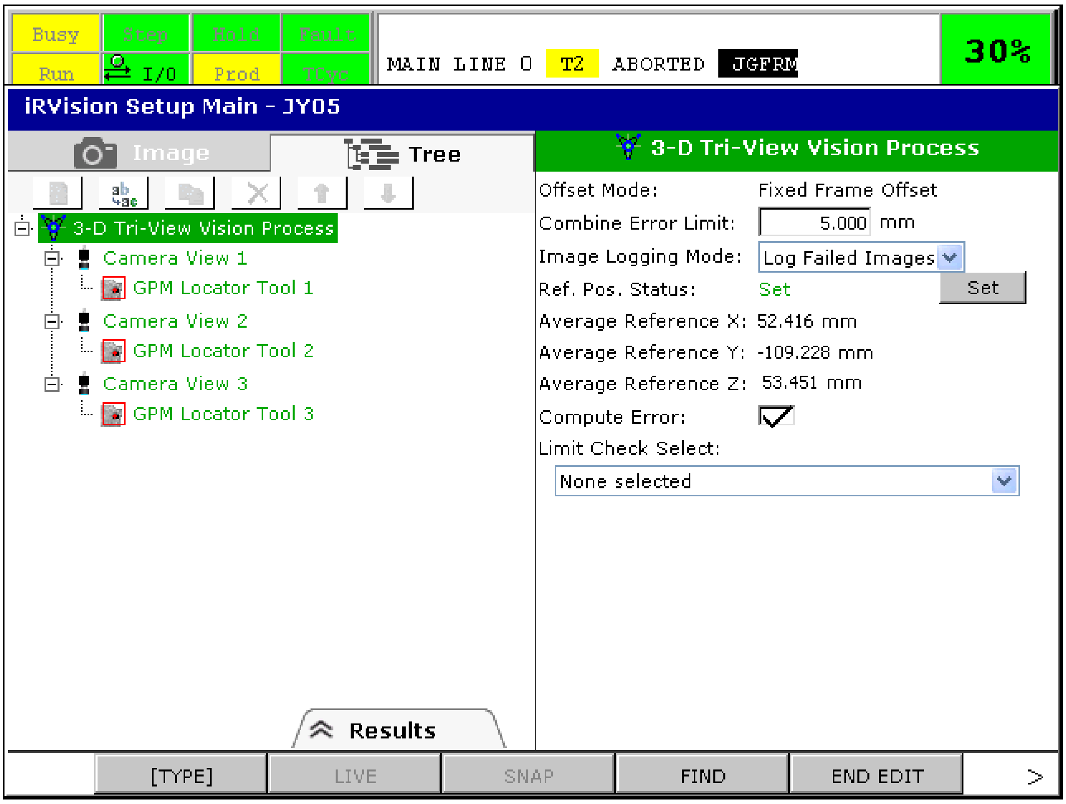
- Example of entering fundamental data: This is an example of entering CAD data of the workpiece. Enter the coordinates of the detection target displayed in CAD as fundamental data.

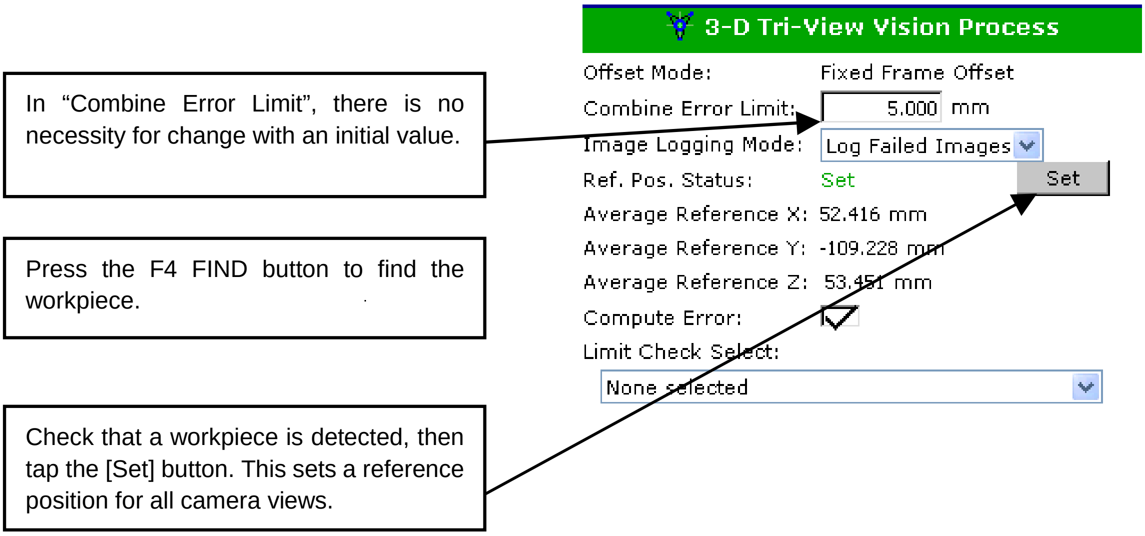


Reference position setting

Move the camera to the first position that is detected the target of Camera View 1, and teach the locator tool (for example GPM Locator Tool as shown below) for Camera View 1. In addition, set the fundamental data for the first position. Then, teach the robot's current position as the snapping position for Camera View 1. For an example, refer to sample program of Subsection 7.3.3 "Robot Program Creation and Teaching". LP[1] on the line 4 of sample program is the first snapping position. Select the Camera View 1 and press the F3 SNAP and the F4 FIND buttons to detect a target of Camera View 1. Then, do not move the workpiece until the reference position setup is completed. If the detection of Camera View 1 is successful, move the camera to the second position. In addition, teach the Camera View 2 same as the Camera View 1. Setup Camera View 3 in the same way. If detections of all camera views from the Camera View 1 to the Camera View 3 are success, select the 3D Tri-View Vision Process page in the vision program as shown below. Press the F4 FIND button to detect the workpiece. Then, tap the [Set] button. [Ref. Pos. Status] becomes [Set]. In addition, the value of [Average Reference X], [Average Reference Y] and [Average Reference Z] are displayed. The value is the average reference position of each camera views. In addition, the position is offset in the application frame.

Jog the robot and move to working position (for example, pick up the workpiece). For an example, refer to sample program of Subsection 7.3.3 "Robot Program Creation and Teaching". LP[4] on the line 17 of sample program is a working position for a workpiece. If the robot's current position is set to LP[4], the reference position setting is complete.





7.3.3 Robot Program Creation and Teaching

In the sample program below, a vision process named "A" is used. Three targets of a workpiece are found by moving the robot-mounted camera. Vision process A has three camera views which have different view positions of robot mounted cameras, so that each camera view number is added to the "VISION RUN_FIND" instruction. For fixed frame offset, add the "VOFFSET, VR" instruction as an operation statement.

```
  1:   UFRAME_NUM=1 ;
  2:   UTOOL_NUM=1 ;
  3:   R[1:Notfound]=0      ;
  4:L P[1] 2000mm/sec FINE      ;
  5:   WAIT R[1] ;
  6:   VISION RUN_FIND 'A' CAMERA_VIEW[1]      ;
  7:L P[2] 2000mm/sec FINE      ;
  8:   WAIT R[1] ;
  9:   VISION RUN_FIND 'A' CAMERA_VIEW[2]      ;
 10:L P[3] 2000mm/sec FINE      ;
 11:   WAIT R[1] ;
 12:   VISION RUN_FIND 'A' CAMERA_VIEW[3]      ;
 13:   VISION GET_OFFSET 'A' VR[1] JMP LBL[100] ;
 14:    ;
 15:   !Handling ;
 16:L P[4] 2000mm/sec CNT100 VOFFSET,VR[1] Tool_Offset,PR[1]      ;
 17:L P[4] 500mm/sec FINE VOFFSET,VR[1]      ;
 18:   CALL HAND_CLOSE      ;
 19:L P[4] 2000mm/sec CNT100 VOFFSET,VR[1] Tool_Offset,PR[1]      ;
 20:   !Handling ;
 21:   JMP_LBL[900] ;
 22:    ;
 23:   LBL[100] ;
 24:   R[1:Notfound]=1      ;
 25:    ;
 26:   LBL[900] ;
```

Move to the position of camera view 1 to snap on line 4. Execute “WAIT” instruction to remove the possible vibration of a camera on line 5. Execute camera view 1 of vision process ”A” with the vision run_find instruction on line 6. When the camera image has been snapped, the line after the "VISION RUN_FIND" instruction is executed. Move to the position of camera view 2 to snap on line7. Move to the position of camera view 3 to snap on line 10. Obtain the offset of the detected workpiece on line 13. Move to the approach position above the workpiece on line 16. Move to the grasp position on line 17. Move to the escape position after grasping the workpiece on line19.

7.3.4 Robot Compensation Operation Check

Check that three points of a workpiece can be detected and that the compensation can be performed correctly.
At first, place the workpiece on the reference position, find it and check the handling accuracy. If the accuracy of compensation is low, retry the reference position setting. Moreover, check the following things.

- Check the relative relation location among the three detection targets and the workpiece itself does not have individual difference.
- Check whether the each view positions with fundamental data are set correctly.

Start with lower override of the robot to check that the logic of the program is correct. Next, increase the override to check that the robot can operate continuously.

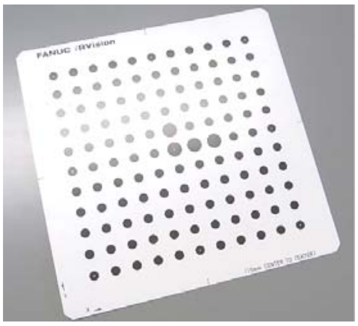
8 CAMERA CALIBRATION SETTING

This chapter explains the setting procedure of camera calibration. The following items are explained in this chapter.

<1> Grid pattern calibration with a fixed camera (Section 8.1)
<2> Grid pattern calibration with a robot-mounted camera (Section 8.2)
<3> Robot-generated Grid Calibration (Section 8.3)

8.1 GRID PATTERN CALIBRATION WITH A FIXED CAMERA

The Grid Pattern Calibration is the standard method to calibrate the camera. A fixture called the calibration grid is used to calibrate the camera. Prepare a calibration grid beforehand. Usually, prepare a calibration grid which is the bigger than the field of view. A standard calibration grid is available from FANUC in several sizes. It is strongly recommended that you order a calibration grid as well as a camera and lens.



It is not necessary to detect all the dots on the calibration grid. There are 11 × 11 dots in the standard calibration grid of FANUC. If 7 × 7 dots are detected, the camera calibration is performed with sufficient accuracy. (The four big dots need to be detected.) In order to show all the dots in field of view, it is not necessary to prepare a small calibration grid. In order to perform a calibration with accuracy sufficient to the edge of the field of view, even if the number of detectable dots became fewer, prepare the bigger calibration grid than a field of view.
Use the following setup procedure for "GRID PATTERN CALIBRATION WITH A FIXED CAMERA":

1. Application frame setting

⇩

2. Camera setting data creation and teaching

⇩

3. Calibration grid frame setting

⇩

4. Camera calibration data creation and teaching

⇩

5. Camera calibration data checking

In the 2D Multi-view Vision Process, when the calibration grid is fixed, it is necessary to perform "2 Camera setting data creation and setting." for each camera.
In the 2D Multi-view Vision Process, when the calibration grid is mounted on a robot, it is necessary to perform "2 Camera setting data creation and setting.", "4 Camera calibration data creation and teaching." and "5 Camera calibration data checking." for each camera.
Moreover, In the 3D Tri-View Vision Process, when a calibration grid is mounted on a robot, it is necessary to perform "2 Camera setting data creation and setting.", "4 Camera calibration data creating and teaching." and "5 Camera calibration data checking." for each camera.

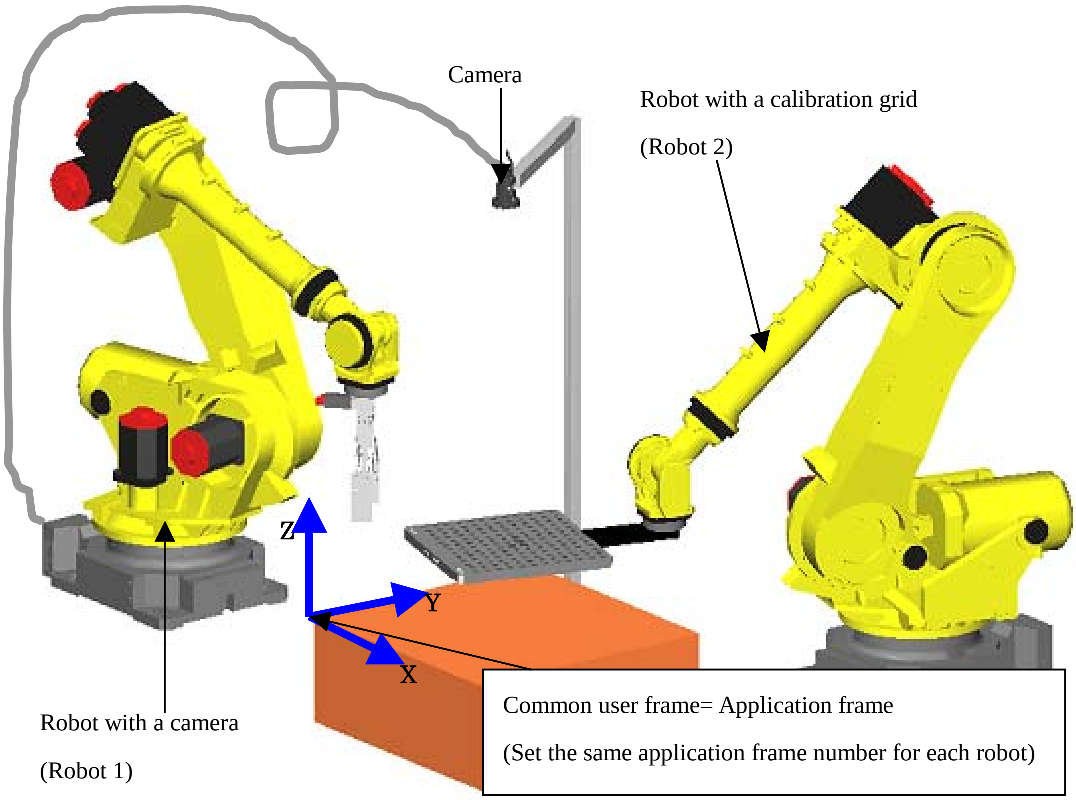
8.1.1 Application Frame Setting

An application frame is the robot's user frame to be used for camera calibration. The application frame number is set in subsection 8.1.4, “Camera calibration data creation and setting.” The default value for the application frame is zero (world). In almost all cases, the default is appropriate. However, in the following cases, set a user frame and select the user frame number as the application frame.

- The camera is mounted on different robot which is not the robot for compensation.
- The calibration grid is mounted on different robot which is not the robot for compensation.
- The multiple robots uses the same vision offset .

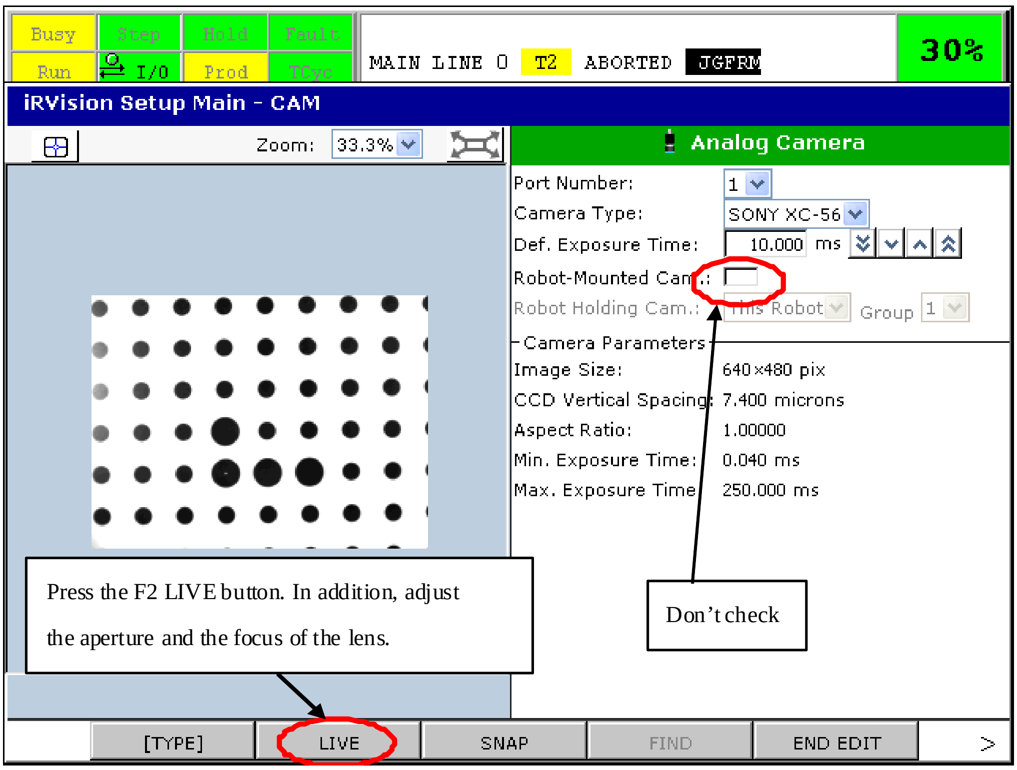
In these cases, set the inter-controller communication between robots. For these inter-controller communications, ROS Interface Packet over Ethernet (RIPE) function is used. For details about the RIPE function, please refer to “R-30iA/R-30iA Mate/R-30iB/R-30iB Mate CONTROLLER Ethernet Function OPERATOR’S MANUAL” (B-82974EN).

The following figure is an example where the calibration grid is mounted on a different robot which is not the robot for compensation. In the following figure, when robot 1 to which the camera is connected, and robot 2 by which the calibration grid is attached are separate robots, set up the application frame on a plane which is a common for each robot, and use this user frame as the application frame. (Set the same application frame number for each robot) For details, see Chapter 9, “FRAME SETTING”.



8.1.2 Camera Setting Data Creation and Teaching

With *i*RVision, items such as the camera type and camera installation method are set in camera setup tool. Whether to install a camera on the robot or on a fixed stand is set in the camera setup tool. When using a fixed camera, do not check "Robot-Mounted Camera".



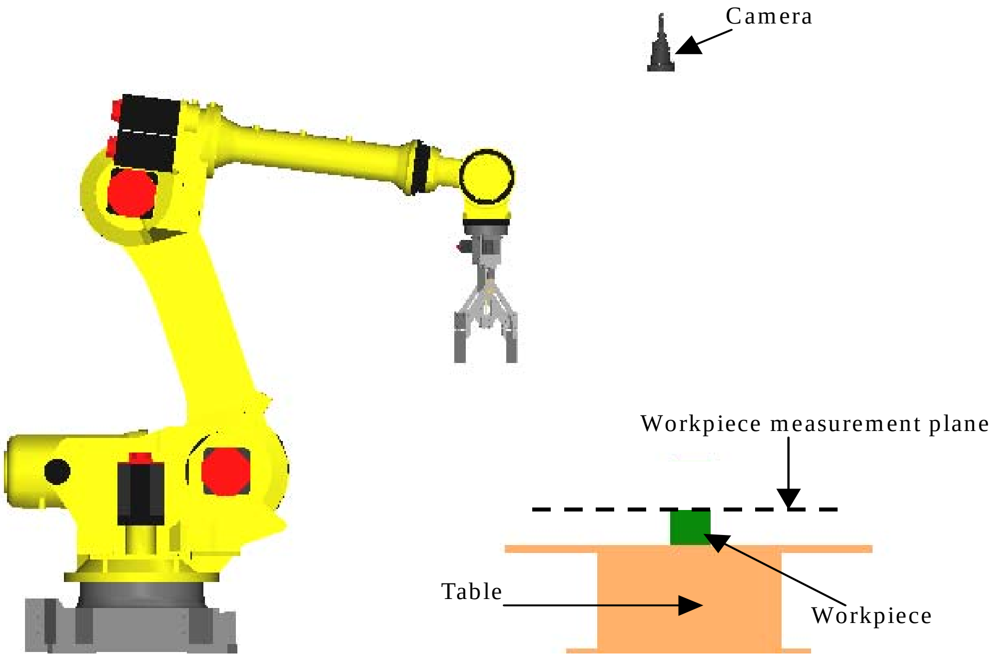
Press the F2 LIVE button, and adjust the aperture and the focus of the lens. Adjust the aperture and the focus of a lens before calibrating the camera. If the aperture and the focus of the lens are re-adjusted, it is necessary to re-do the camera calibration.

8.1.3 Calibration Grid Frame Setting

Teach the calibration grid location in a user frame or a tool frame.
To calibrate using calibration grid that is fixed, teach a user frame to the grid. To calibrate by mounting the grid on the robot, teach a tool frame to the grid.
Properly secure the calibration grid and teach the location.. The teaching precision here affects compensation precision. So, perform this teaching process precisely. Note that the frame used for the calibration grid setup might differ from the application frame and the offset frame.

8.1.3.1 When a grid is fixed

It is recommended to install the calibration grid near the workpiece measurement plane. As shown below, it is recommended to install the calibration grid so that the distance from the camera to the workpiece measurement plane is the same as the distance from a camera to the calibration grid.



When the calibration grid is fixed, teach it in a user specified user frame number.
After the calibration grid frame is set, do not move a calibration grid until calibration is completed. There are two methods to teach the user frame, one is to manually touch-up with the pointer tool, and another is the Automatic Grid Frame Set Function.

Touch-up

To manually teach a user frame, a pointer tool with a taught TCP is required. In general, set the TCP accurately on the pointer installed on the robot gripper. If the accuracy of this TCP setting is low, the precision in handling of a workpiece by the robot is also degraded, especially when the workpiece is rotated. Set the robot TCP an available UTool. To reuse the pointer TCP, the reproducibility of pointer installation is required. If the reproducibility of the pointer installation is not assured, a TCP needs to be re-taught each time a pointer is installed. For details, see Section 9.1.1, “User frame setting with a pointer tool”.

Automatic Grid Frame Set Function

The Automatic Grid Frame Set Function sets the calibration grid frame using a camera. Install a calibration grid so that the XY plane of the calibration grid is parallel with the plane on which the workpiece is placed, and perform the Automatic Grid Frame Set Function. For details, see Section 9.2, “Frame setting with the Automatic Grid Frame Set Function”. A calibration grid is used for setup. Moreover, in the case of a fixed camera, prepare a camera for the Automatic Grid Frame Set Function separately. And perform the Automatic Grid Frame Set Function using the camera attached to a temporary position of a robot's hand. In addition, the Automatic Grid Frame Set Function is usable with 6-axis robots only. The function cannot be used with 4-axis robots and 5-axis robots. When using 4-axis robots or 5-axis robots, teach the user frame manually.

8.1.3.2 When the calibration grid is mounted on the robot

When a calibration grid is mounted on the robot, teach the calibration grid in a user specified tool frame.
There are two methods to teach the calibration grid frame, one is touch-up with the pointer tool to the calibration grid, and another is the Automatic Grid Frame Set . The Automatic Grid Frame Set method is recommended when possible.

Touch-up

When manually teaching the calibration grid tool frame, prepare a fixed pointer on a table. Use the 6 point method to teach the tool frame. Use either [Tool Frame Setup / Six Point(XY)] or [Tool Frame Setup / Six Point(XZ)]. The calibration grid frame is taught as a tool frame. Make sure that the calibration grid is fixed securely to the robot end of arm tooling so that it remains in place while the robot moves. It is recommended that positioning pins or other appropriate means may be used so that the calibration grid can be re-mounted to the same position. If the accuracy of this calibration grid setting is low, the precision in handling of a workpiece by the robot is also degraded. Set a calibration grid frame in an arbitrary tool frame. For details, see Section 9.1.2, “Tool frame setting with a pointer tool”.

Automatic Grid Frame Set Function

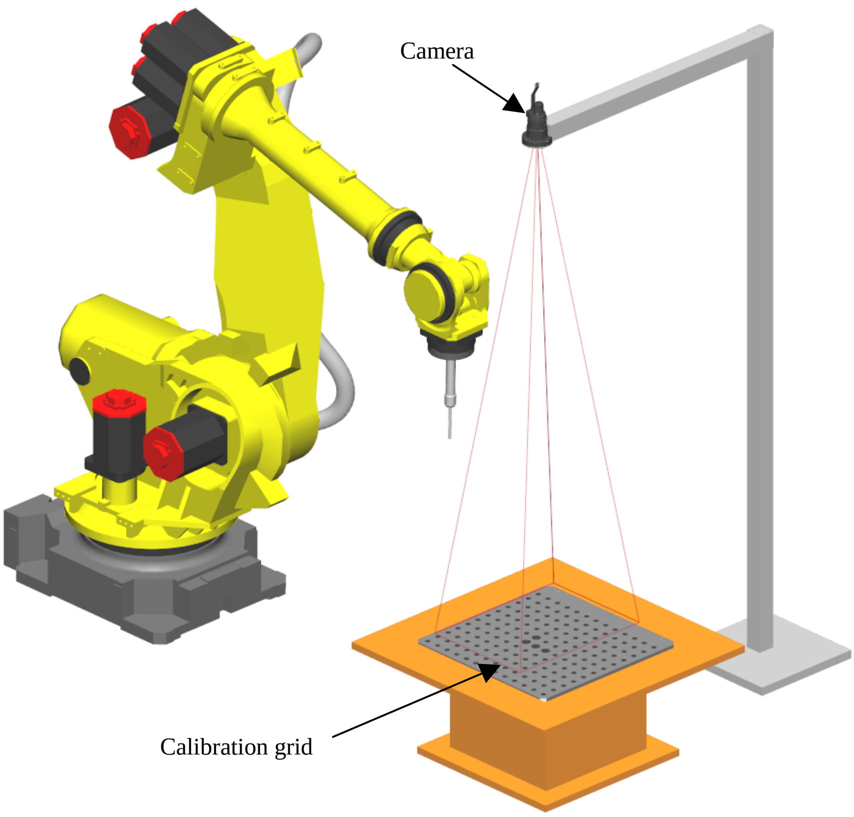
The Automatic Grid Frame Set Function sets the calibration grid frame using a camera. Install a calibration grid so that the XY plane of the calibration grid is parallel with the plane on which the workpiece is placed, and perform the Automatic Grid Frame Set Function. For details, see Section 9.2, “Frame setting with the Automatic Grid Frame Set Function”. A calibration grid is used for setup. Moreover, in the case of a fixed camera, prepare a camera for the Automatic Grid Frame Set Function separately. And perform the Automatic Grid Frame Set Function using the camera attached to a temporary position of a robot's hand. In addition, the Automatic Grid Frame Set Function is usable with 6-axis robots only. The function cannot be used with 4-axis robots and 5-axis robots. When using 4-axis robots or 5-axis robots, teach the user frame manually.

8.1.4 Camera Calibration Data Creation and Teaching

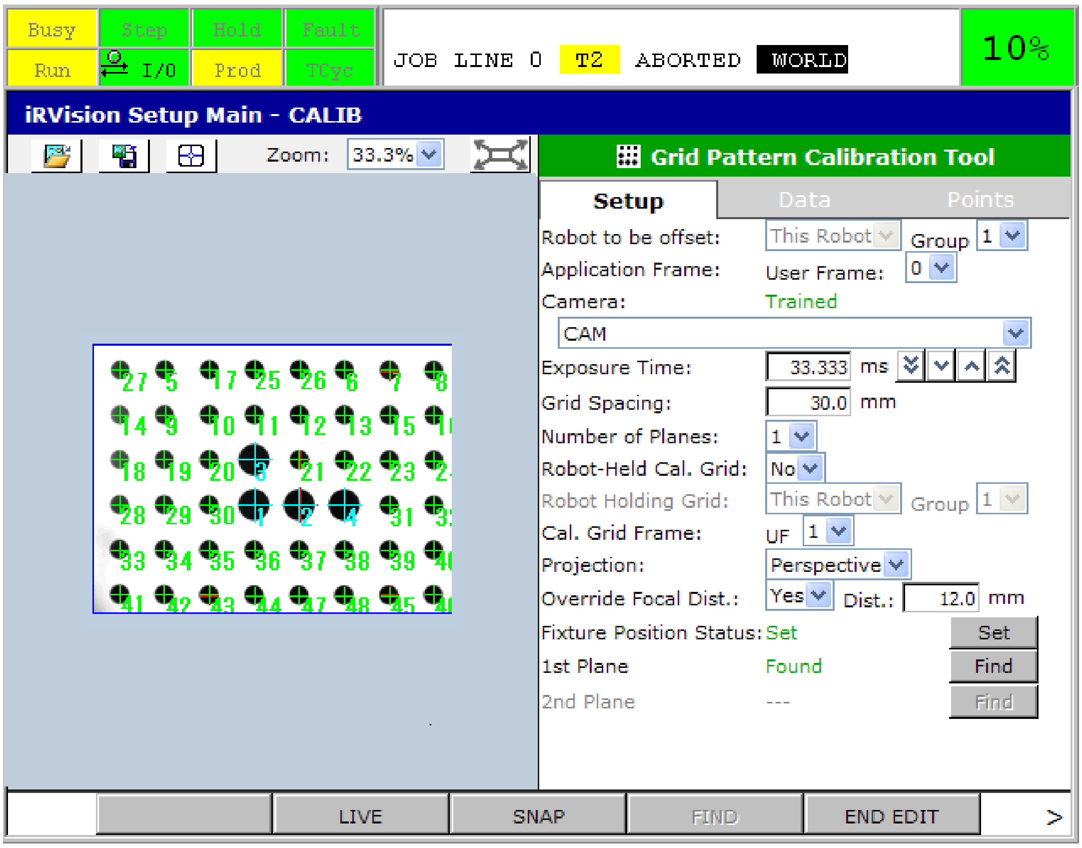
On the calibration data setting screen, select the application frame number set in Subsection 8.1.1, " Application Frame Setting", and a frame number set in Subsection 8.1.3, "Calibration Grid Frame Setting" correctly.

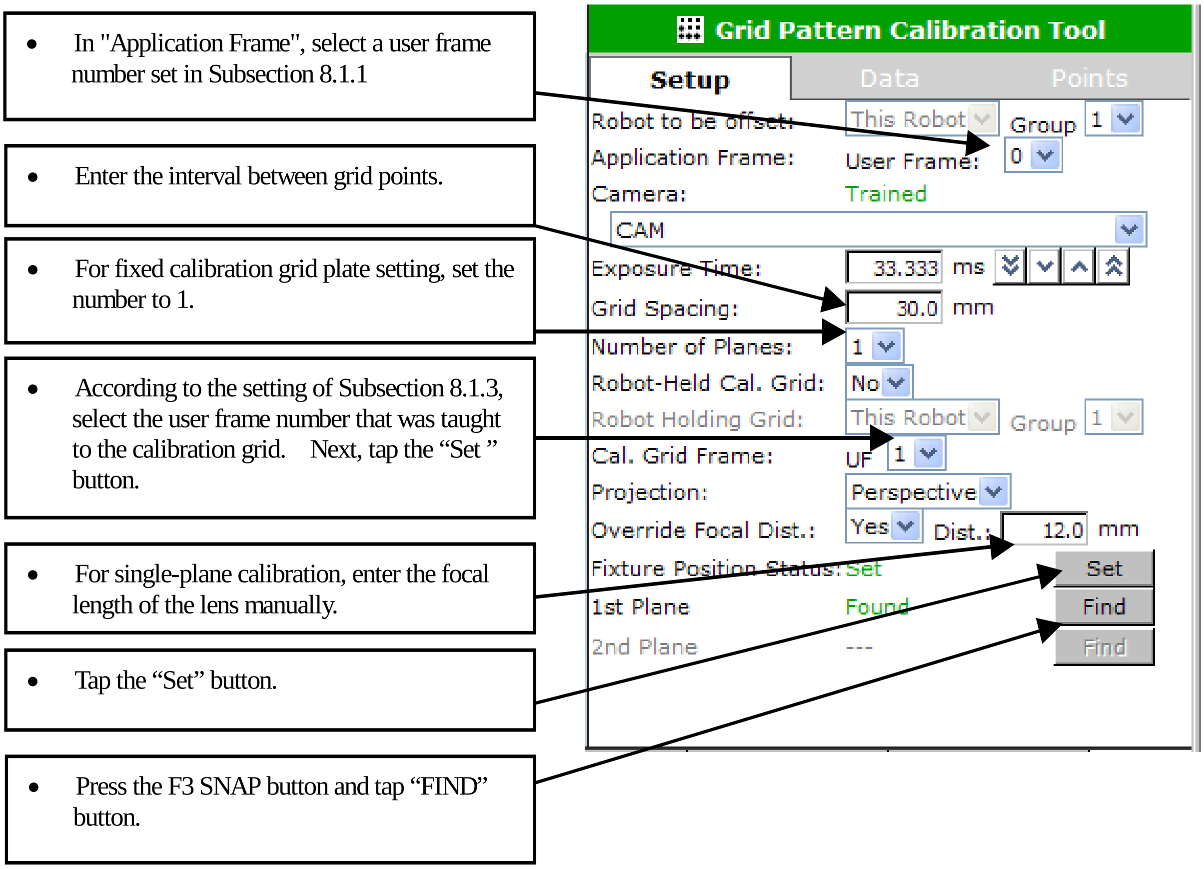
When the calibration grid is fixed

When the calibration grid is fixed as shown in the following figure, perform one-plane calibration. When one-plane calibration is performed, the focal length of the lens cannot be calculated precisely. So, set the focal length of the lens manually after calibration grid detection. If the focal length of the lens used is 12 mm, enter 12.0.



The calibration grid setup page is shown below. The calibration grid image is displayed.



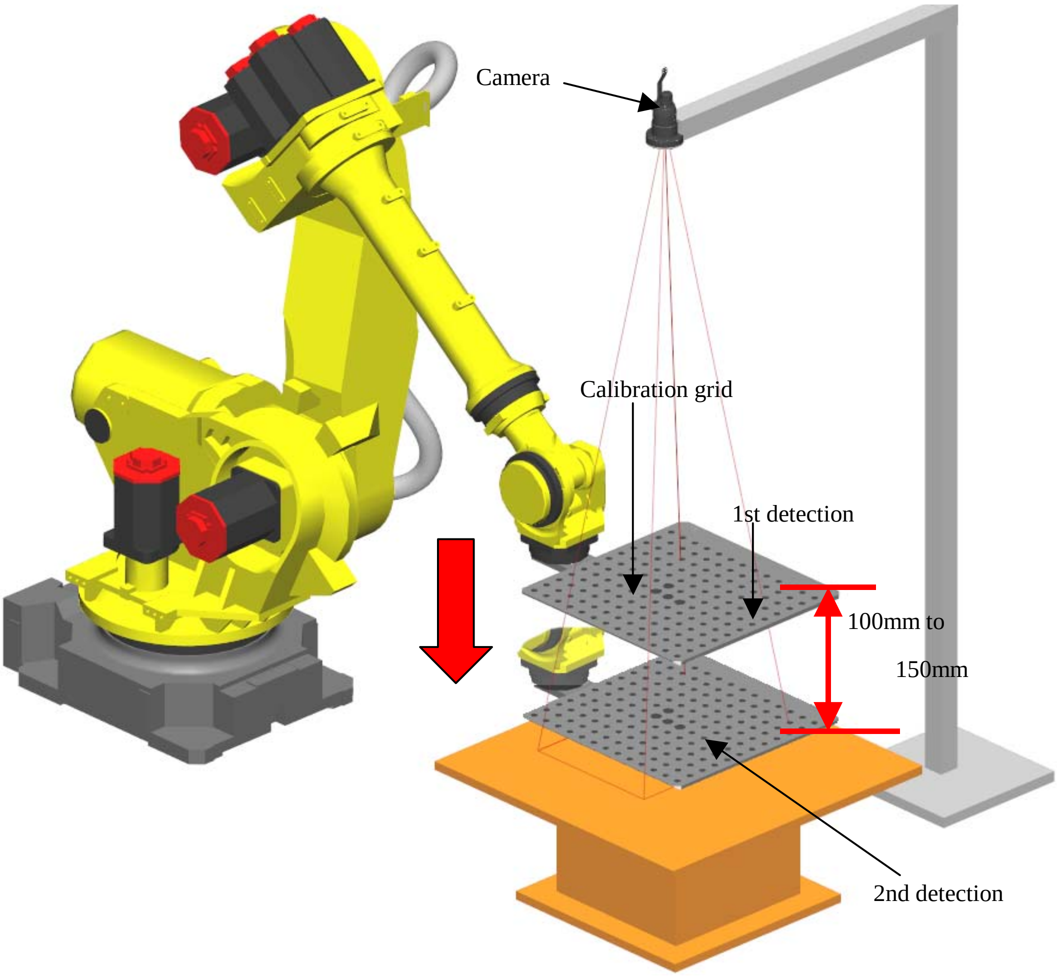


When the calibration grid is robot mounted

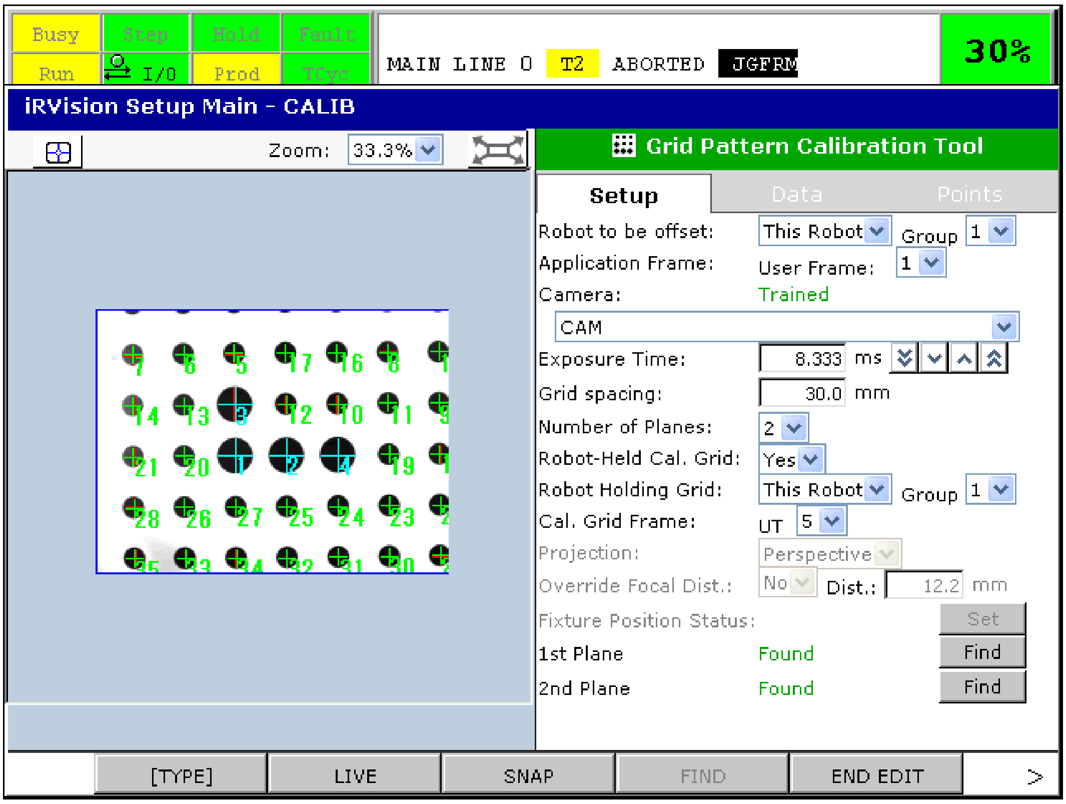
When the calibration grid is robot mounted, perform two-plane calibration by moving the robot up and down as shown in the figure below.

- In the 2D Single-view Vision Process or 2D Multi-view Vision Process, the up/down distance for two-plane calibration should be 100 to 150 mm. It is recommended that the distance between the camera and the calibration grid for one of the planes is the same as the distance between the camera and the workpiece.
- In the Depalletizing Vision Process, it is recommended that the up/down distance for two-plane calibration be set to a value that covers the upper and lower ends of the workpiece in the pallet.
- In the 3D Tri-View Vision Process, perform detection by bringing calibration surface 1 as close as possible to the detection target. In addition, the up/down distance for two-plane calibration should be 100 to 150 mm.

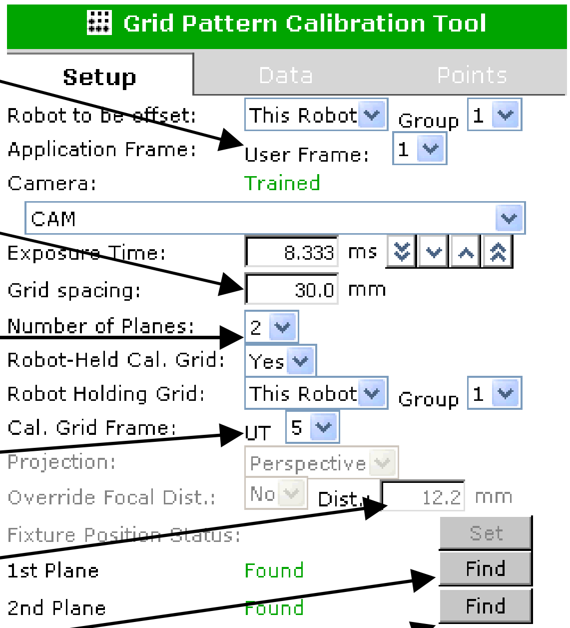
Find the grid pattern at two different heights. When moving the calibration grid up and down, jog the robot without changing the calibration grid posture. Make sure that the calibration grid is fixed securely to the robot end of arm tooling so that it remains in place while the robot moves. It is recommended that positioning pins or other appropriate means may be used so that the calibration grid can be re-mounted in the same position.



The calibration grid setup page is shown below. The calibration grid image is displayed.

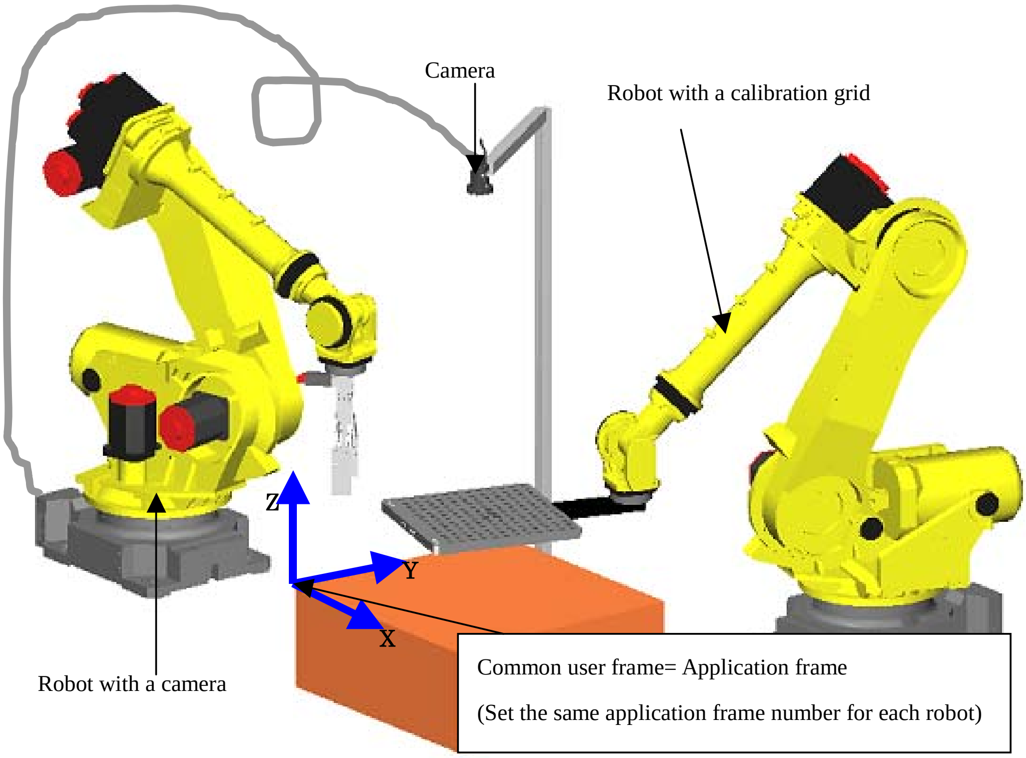


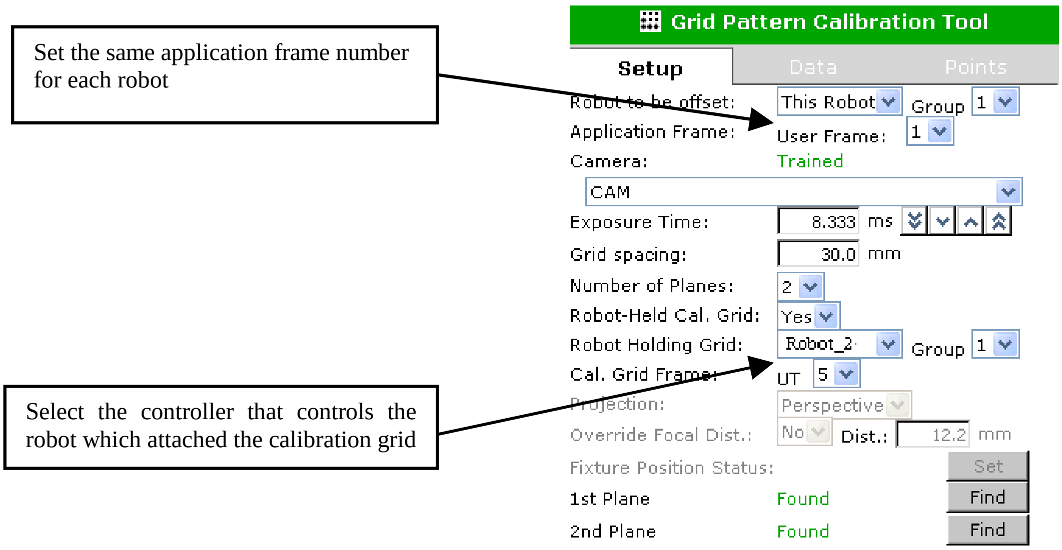
- In "Application Frame", select a user frame number set in Subsection 8.1.1.
- Enter the interval between grid points.
- For installation of a robot mounted calibration grid, set the number of calibration planes to 2.
- According to the setting of Subsection 8.1.3, select the tool frame number that was taught to the calibration grid. Next, tap the “Set ” button.
- For single-plane calibration, enter the focal length of the lens manually.
- Move the calibration grid the proper distance from the camera then press the F3 SNAP button. Next, tap the “Find” button for the first plane.
- Change the distance between the calibration grid and camera then press the F3 SNAP button. Next, tap the “Find” button for the second plane.



When two or more robots are used

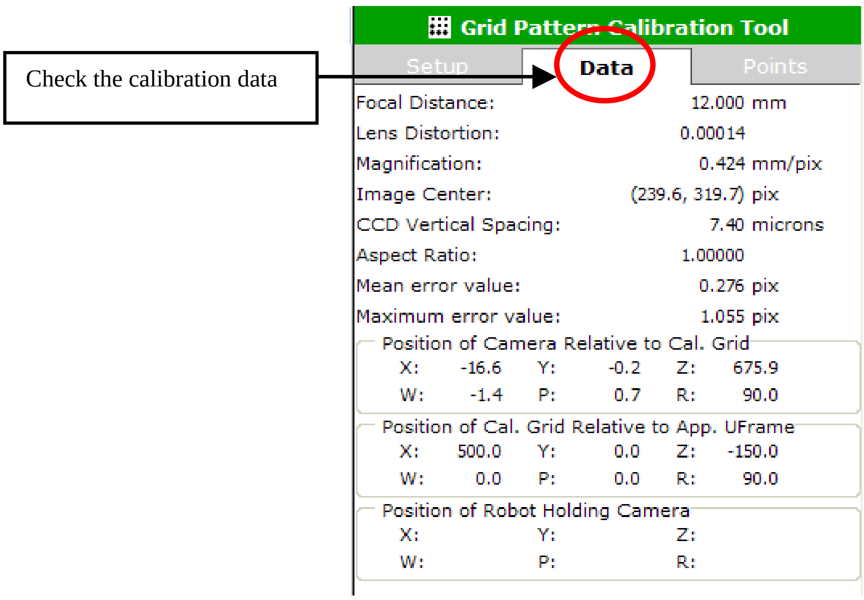
When a robot to which the camera is connected, and the robot by which the calibration grid is attached are separate robots, select the controller that controls the robot which attached the calibration grid for [Robot-Holding Grid] in the calibration setup page as shown below.



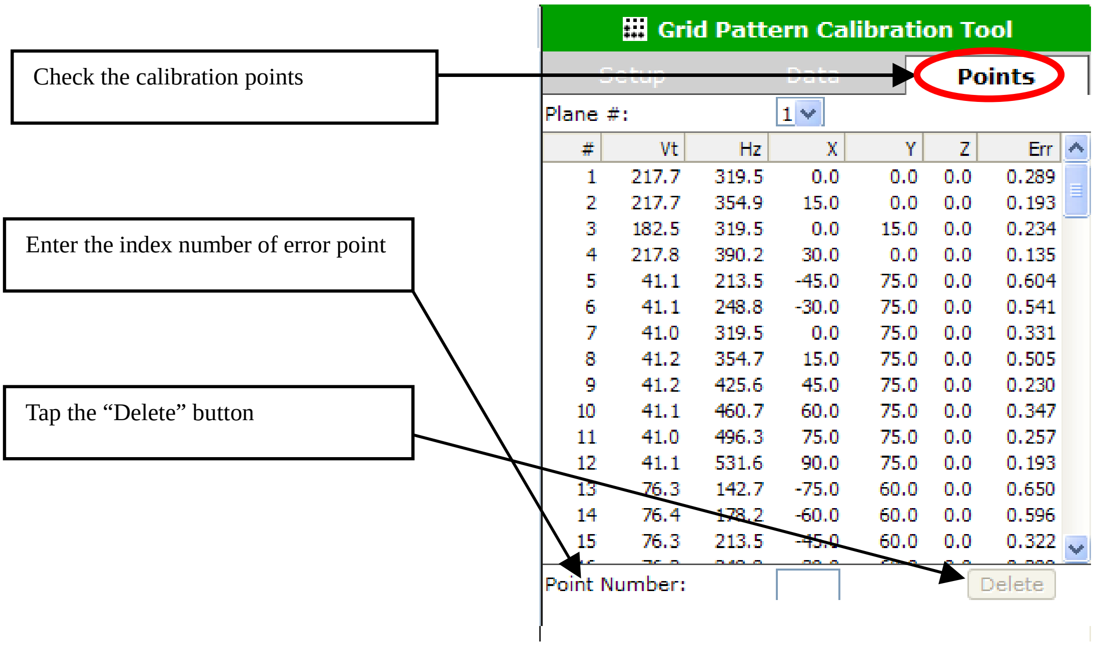


8.1.5 Camera Calibration Data Checking

Check the calculated calibration data. The calibration data page is shown below.
The magnification indicates how many millimeters are equivalent to a pixel. A magnification is calculated by dividing the size of field of view by the image size. For example, when the size of field of view is 262mm × 169mm and the image size is 640pix × 480pix, the calculated magnification is 0.409mm/pix = 262mm × 640pix. When the magnification is incorrect, check the calibration grid frame and grid spacing are set precisely. In addition, since a magnification changes depending distance from a camera, it does not become equally in a field of view. The displayed magnification is the average value near a calibration grid plane.



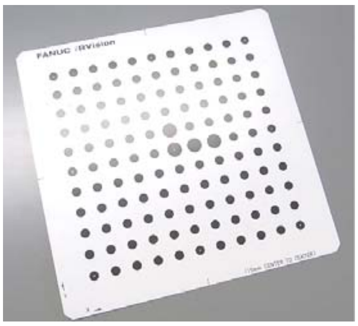
The Points in the calibration page are shown below.
If a crosshair is displayed at a location where no actual grid point is present, enter the index number of that point in the text box to the left of the "Delete" button and then tap the "Delete" button.



If there are no problems in the calibration data and the calibration points, finish the calibration. In addition, the calibration grid can be removed.

8.2 GRID PATTERN CALIBRATION WITH A ROBOT-MOUNTED CAMERA

The Grid Pattern Calibration is the standard method to calibrate the camera. A fixture called the calibration grid is used to calibrate the camera. Prepare a calibration grid beforehand. Usually, prepare a calibration grid which is the bigger than a field of view. A standard calibration grid is available from FANUC in several sizes. It is strongly recommended that you order a calibration grid as well as a camera and lens.



It is not necessary to detect all the dots on the calibration grid. There are 11 × 11 dots in the standard calibration grid of FANUC. If 7 × 7 dots are detected, the camera calibration is performed with sufficient accuracy. (The four big dots need to be detected.) In order to show all the dots in field of view, it is not necessary to prepare a small calibration grid. In order to perform a calibration with accuracy sufficient to the edge of the field of view, even if the number of detectable dots became fewer, prepare the bigger calibration grid than a field of view.

Use the following setup procedure for "GRID PATTERN CALIBRATION WITH A ROBOT-MUONTED CAMERA":

1. Application frame setting

2. Camera setting data creation and teaching

3. Calibration grid frame setting

4. Camera calibration data creation and teaching

5. Camera calibration data checking

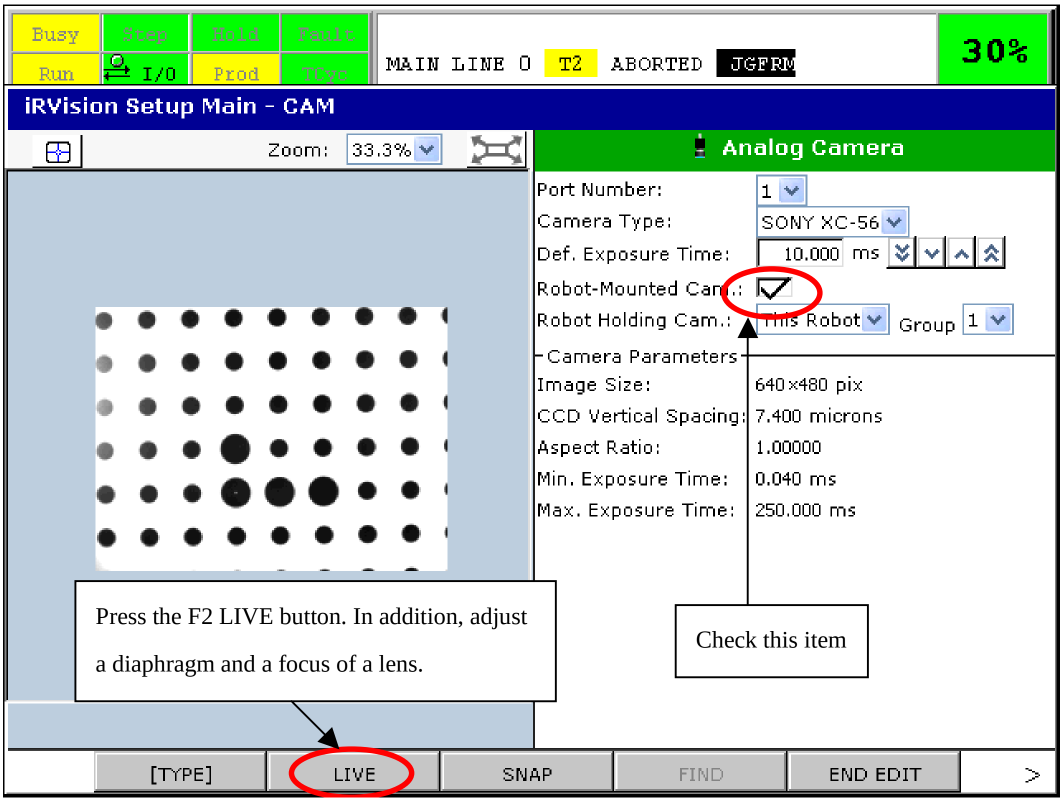
8.2.1 Application Frame Setting

An application frame is the robot's user frame to be used for camera calibration. The application frame number is set in subsection 8.1.4, “Camera calibration data creation and setting.” The default value for the application frame is zero (world). In almost all cases, the default is appropriate. However, in the following cases, set a user frame and select the user frame number as the application frame.

- The camera is mounted on different robot which is not the robot for compensation.
- The calibration grid is mounted on different robot which is not the robot for compensation.
- The multiple robots uses the same vision offset.

8.2.2 Camera Setting Data Creation and Teaching

With *i*RVision, items such as a camera type and camera installation method are set in the camera setup. Whether the camera is installed on the robot or on a fixed stand is set in the camera setup. When using a robot-mounted camera, be sure to check this item.



Press the F2 LIVE button, and adjust the aperture and a focus of a lens. Adjust the aperture and a focus of a lens before performing a camera calibration. If the aperture and a focus of a lens are re-adjusted, it is necessary to re-do a camera calibration.

8.2.3 Calibration Grid Frame Setting

Teach the calibration grid location in a user frame.
To perform calibration by setting the calibration grid that is fixed, teach a user frame to the grid. There are two methods to teach the calibration grid location, one is touch-up with the pointer tool, and another is the Automatic Grid Frame Set Function. It is recommended to use the Automatic Grid Frame Set . Note that the frame used for the calibration grid setup might differ from application frame and offset frame.

Touch-up

To manually teach a user frame, a pointer tool with a taught TCP is required. In general, set the TCP accurately on the pointer installed on the robot gripper. Set the robot TCP in an available UTool. To reuse the pointer TCP, the reproducibility of the pointer installation is required. If the reproducibility of the pointer installation is not assured, the TCP needs to be re- taught each time a pointer is installed. For details, see Section 9.1.1, “User frame setting with a pointer tool”.

Automatic Grid Frame Set Function

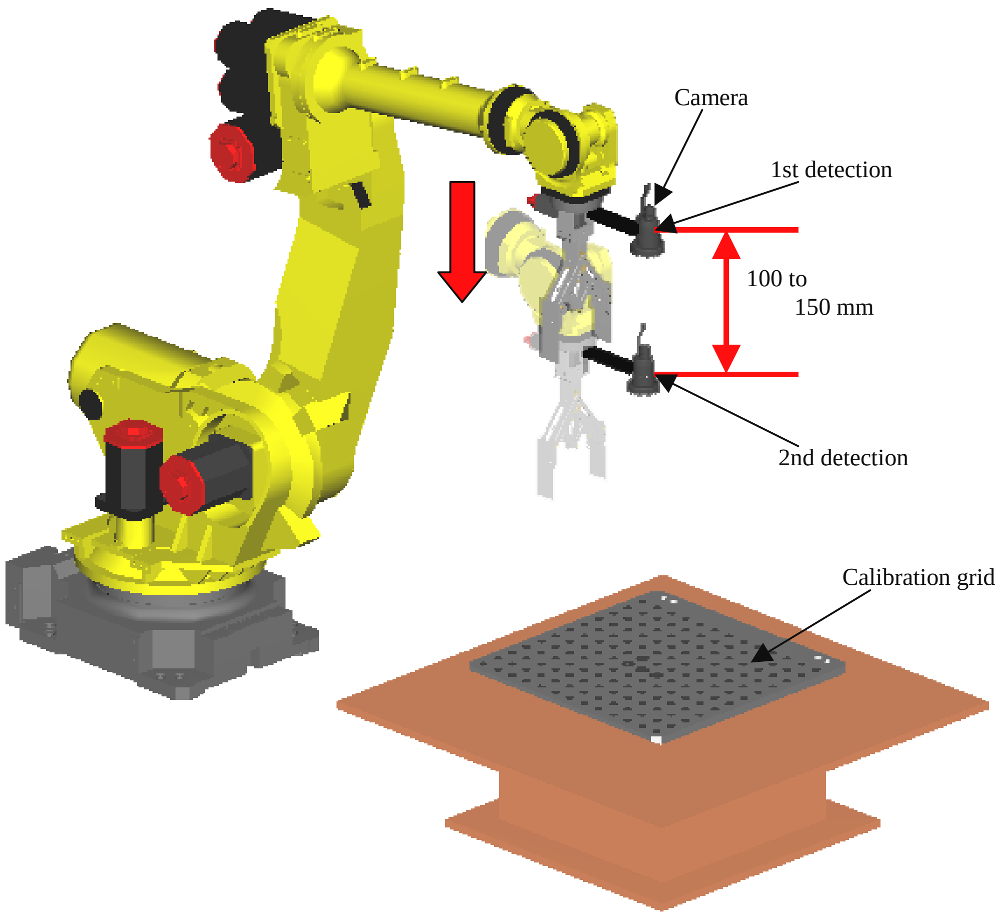
The Automatic Grid Frame Set Function sets the calibration grid frame using a camera. Install a calibration grid so that the XY plane of the calibration grid is parallel with the plane on which the workpiece is placed, and perform the Automatic Grid Frame Set Function. For details, see Section 9.2, “Frame setting with the Automatic Grid Frame Set Function”. A calibration grid is used for setup. Moreover, in the case of a fixed camera, prepare a camera for the Automatic Grid Frame Set Function separately. And perform the Automatic Grid Frame Set Function using the camera attached to a temporary position of a robot's hand. In addition, the Automatic Grid Frame Set Function is usable with 6-axis robots only. The function cannot be used with 4-axis robots and 5-axis robots. When using 4-axis robots or 5-axis robots, teach the user frame manually.

8.2.4 Camera Calibration Data Creation and Setting

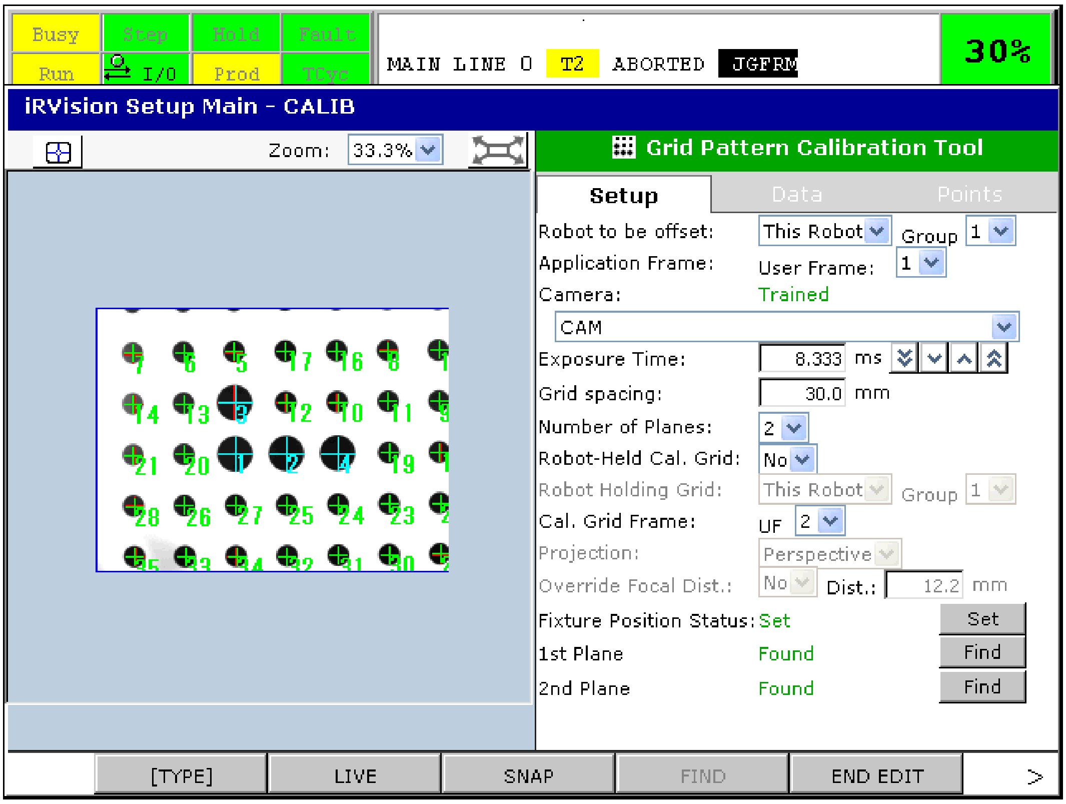
On the camera calibration tools setup screen, select the frame number created in Subsection 8.2.1, "Application Frame Setting", and a frame number created in Subsection 8.2.3, "Calibration Grid Frame Setting" correctly. When a robot-mounted camera is used, perform two-plane calibration by moving the robot up and down as shown in the figure below.

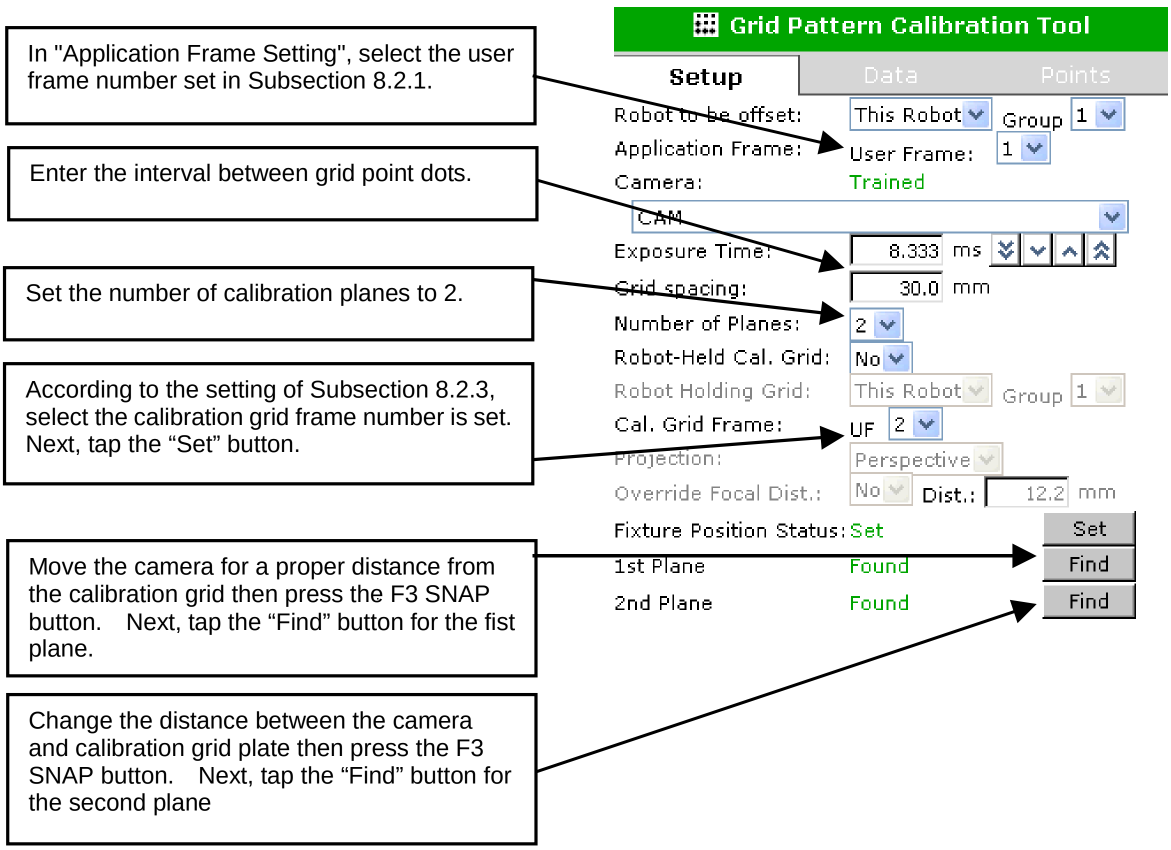
- In the 2D Single-view Vision Process, 2D Multi-view Vision Process or, in the 3D Tri-View Vision Process, the up/down distance for two-plane calibration should be 100 to 150 mm. It is recommended that the distance between the camera and the calibration grid for one of the planes is the same as the distance between the camera and the workpiece.
- In the Depalletizing Vision Process, it is recommended that the up/down distance for two-plane calibration be set to a value that covers the upper and lower ends of the workpiece in the pallet.

Find the calibration grid at two different heights. In this operation, ensure that the posture of the robot for detecting the calibration grid is the same as the posture for detecting a workpiece. When moving the camera up and down, jog the robot without changing the camera posture.



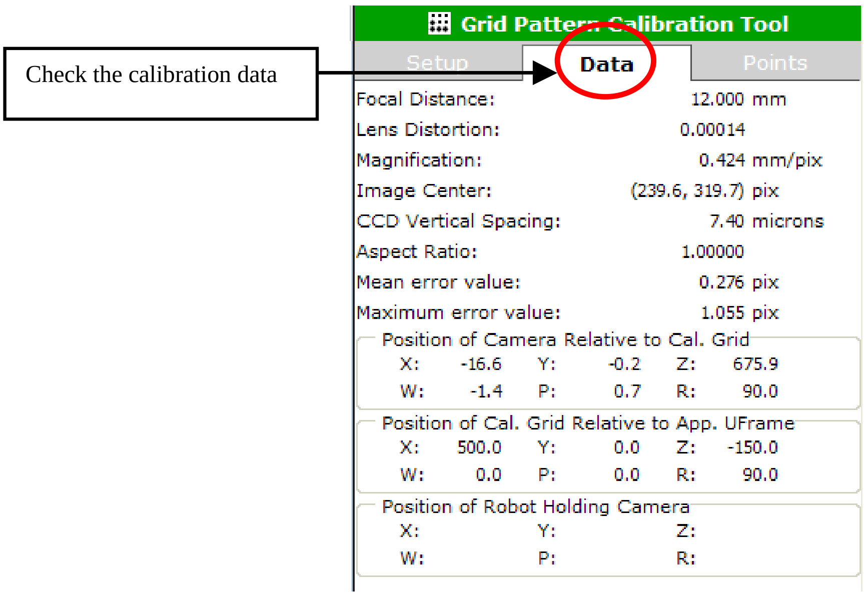
The Grid Pattern Calibration setup screen is shown below.　A calibration grid image is displayed.



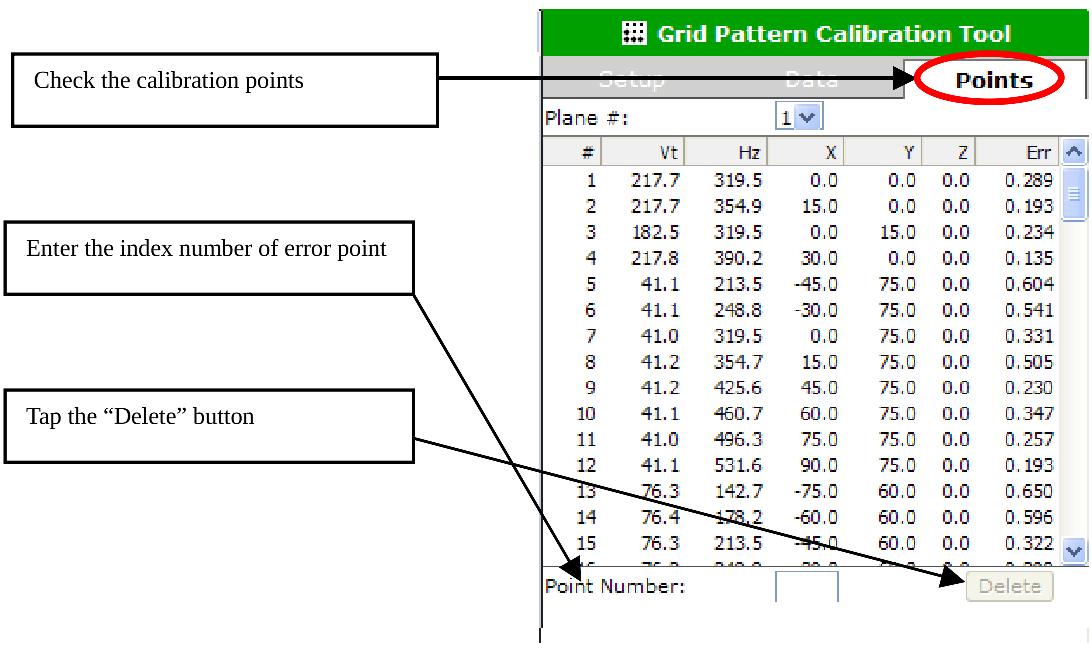


8.2.5 Camera Calibration Data Checking

Check the calculated calibration data. The calibration data page is shown below.
The magnification indicates how many millimeters are equivalent to a pixel. A magnification is calculated by dividing the size of field of view by the image size. For example, when the size of field of view is 262mm × 169mm and the image size is 640pix × 480pix, the calculated magnification is 0.409mm/pix = 262mm × 640pix. When the magnification is incorrect, check the calibration grid frame and grid spacing are set precisely. In addition, since a magnification changes depending distance from a camera, it does not become equally in a field of view. The displayed magnification is the average value near a calibration grid plane.



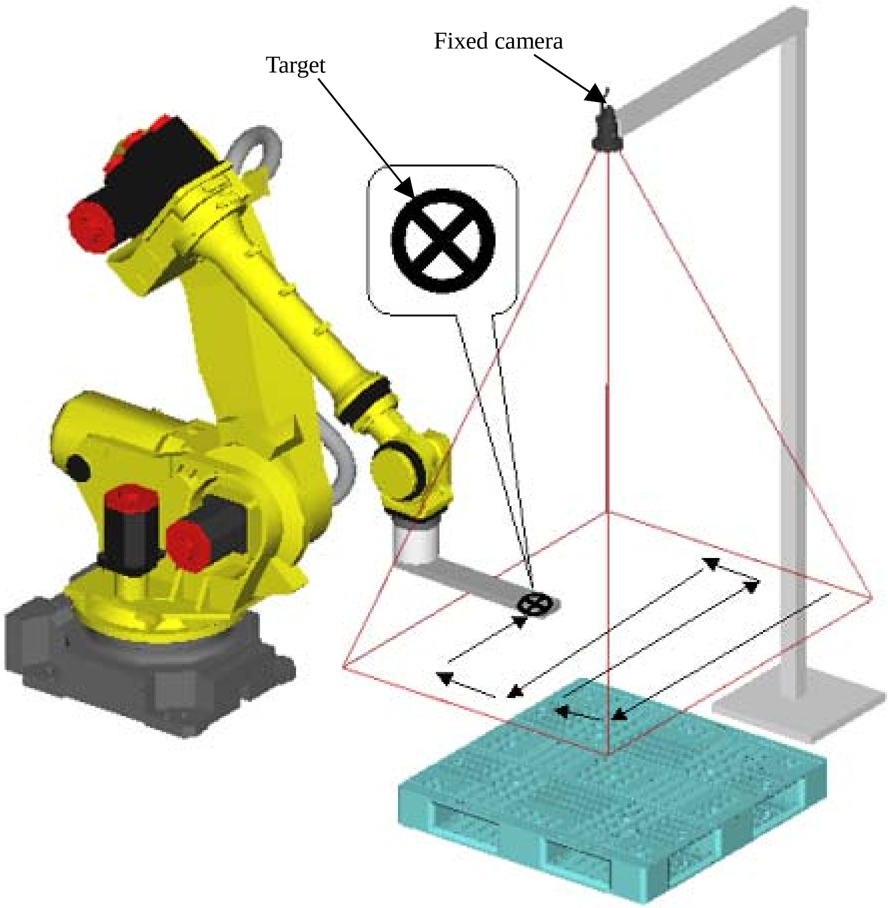
The Points in the calibration page are shown below.
If a crosshair is displayed at a location where no grid point is present, enter the index number of that point in the text box to the left of the "Delete" button and then tap the "Delete" button.



If there are no problems in the calibration data and the calibration points, finish the calibration. In addition, the calibration grid can be removed.

8.3 ROBOT-GENERATED GRID CALIBRATION

Robot-Generated Grid Calibration is a type of general-purpose camera calibration function similar to Grid Pattern Calibration. The function moves the target, mounted on the robot end of arm tooling, in the camera's field of view to generate a virtual grid pattern for camera calibration. Unlike Grid Pattern Calibration, this calibration method does not require a calibration grid as large as the camera's field of view and is therefore suitable for calibrating a large field of view. Also, since it performs 2-plane calibration, the calibration method enables you to accurately calculate the position of the camera and the focal distance of the lens in use. The robot automatically moves and measures the position of the target and the size of the camera's field of view. When performing the calibration of the fixed camera, the Robot-generated Grid Calibration can be used. When using a robot-mounted camera, the Robot-generated Grid Calibration cannot be used. When using a robot-mounted camera, perform the Grid Pattern Calibration for a camera calibration.



Use the following setup procedure for " Robot-generated Grid Calibration ":

1. Application frame setting

↓

2. Selecting and mounting the target

↓

3. Camera setting data creation and teaching

↓

4. Camera calibration data creation and selecting

↓

5. Measuring target position

↓

6. Generating calibration program

↓

7. Executing calibration program

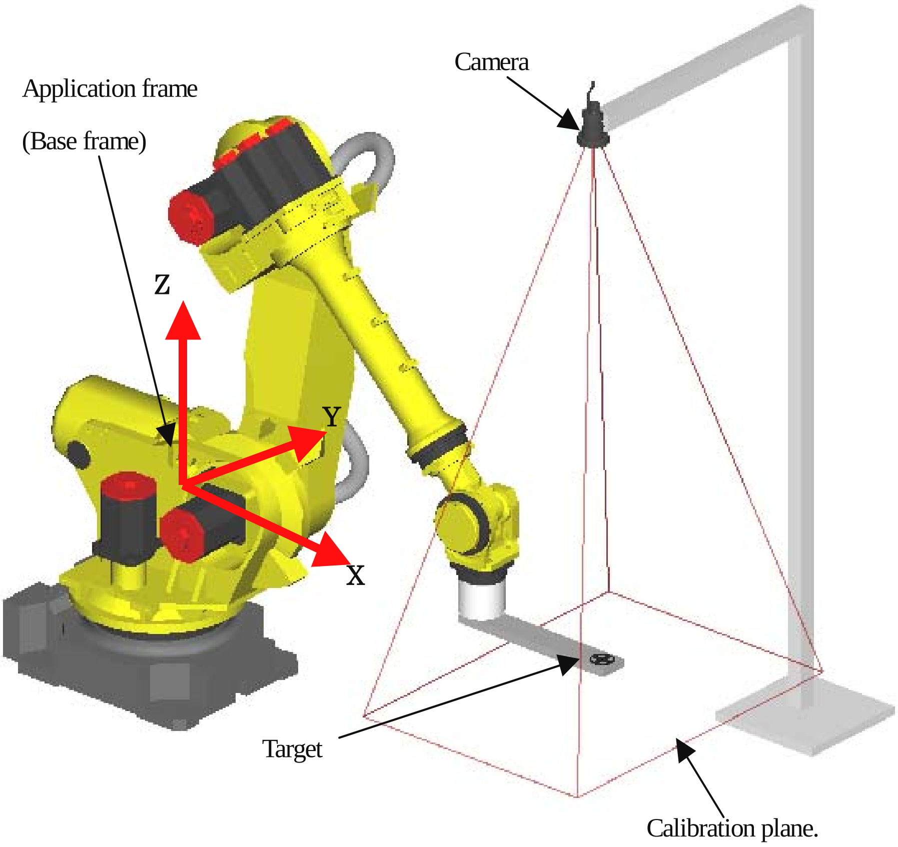
↓

8. Camera calibration data checking

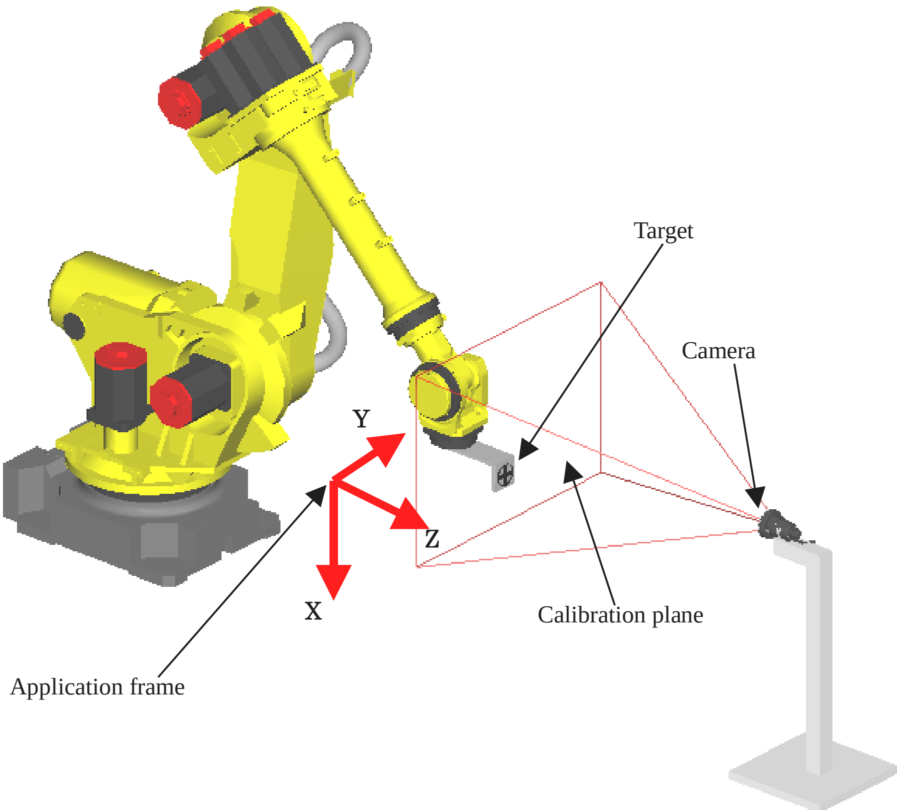
Positioning pins or other appropriate means may be used so that the target can be mounted at the same position for each measurement. This way, a robot program generated for a previous calibration operation can be used for re-calibration. In this case, the re-calibration can execute by performing only the procedure 7 “Executing calibration program”. When the 2D Multi-view Vision Process is used, it is necessary to perform "3 Camera setting data creation and setting", "4 Camera calibration data creation and selecting", "6 Generating calibration program.", "7 Executing calibration program." and "8 Camera calibration data checking." for each camera.

8.3.1 Application Frame Setting

An application frame is the robot's user frame to be used for camera calibration. Set an application frame so that the XY plane of the application frame is almost parallel with the calibration plane. During camera calibration, the robot moves in parallel to the XY plane of the application frame. As shown below, when the XY plane of the calibration plane is parallel with the world frame, user frame number 0 (world frame) can be selected as the application frame.



As shown below, set the user frame so that the XY plane of the user frame is parallel with the calibration plane. A user frame number is arbitrary, and use this user frame number as the application frame number.



8.3.2 Selecting and Mounting the Target

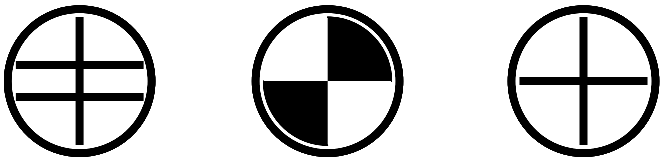
Select the target mark to be used for calibration.

Geometry of the target

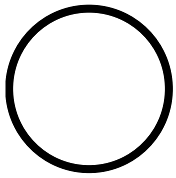
The target must meet the following conditions:

- The features to be taught are on the same one plane.
- The target has a geometry for which any rotation of ±45° or so can be identified.
- The target has a geometry whose size can be identified.

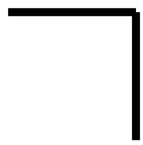
Examples of appropriate target geometries:



Examples of inappropriate target geometries:



The rotation angle cannot be identified.



The size cannot be identified.

Size of the target

Make sure that the size of the target, when captured as an image, is 80 to 100 pixels in both vertical and horizontal directions. For example, when the camera's field of view is about 900 mm (8-mm lens; distance between camera and target is 2000 mm or so), prepare a target that is 120 to 160 mm in diameter.

Mounting the target

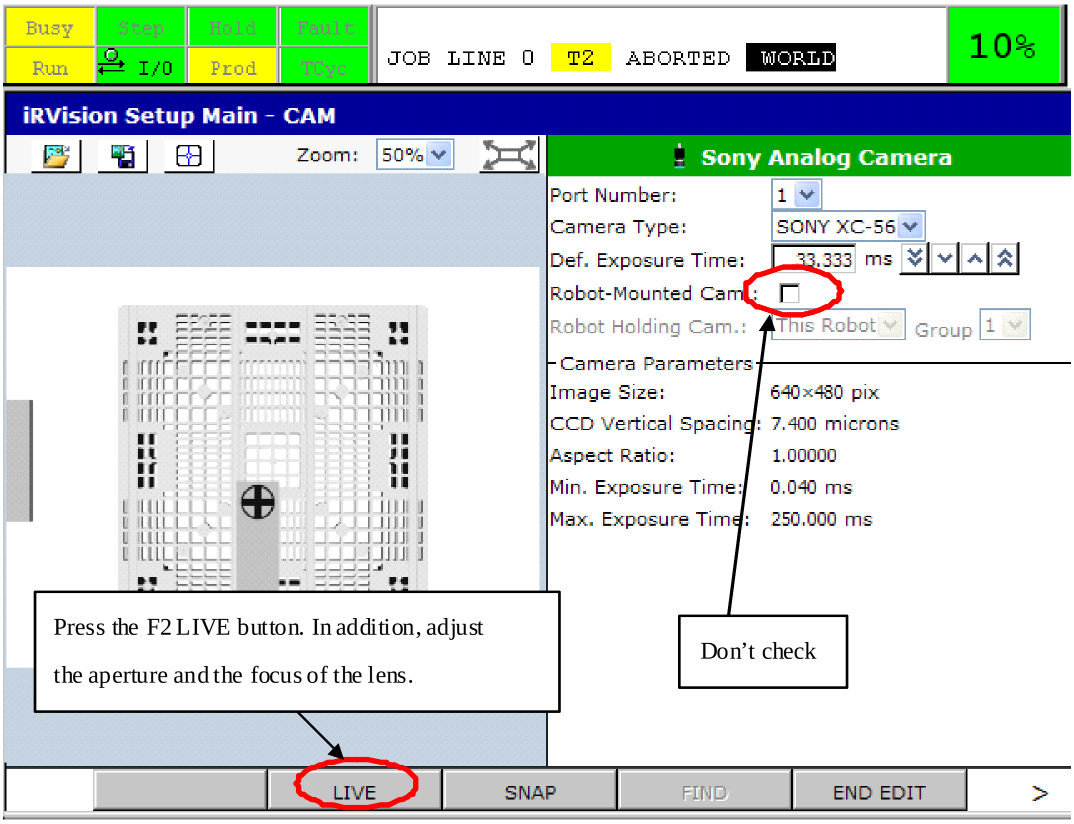
Mount the target to the robot end of arm tooling. Make sure that the target blocked or hidden by the robot arm or tooling when the robot moves through the camera field of view.

> ⚠ **CAUTION**
> Make sure that the target is fixed securely to the robot end of arm tooling so that it remains in place while the robot moves.

> **NOTE**
> 1 Normally, the robot position and posture are set so that the range of robot motion becomes maximal when the robot actually operates. Therefore, mounting the target so that it can be captured by the camera when the robot is in a posture that it takes during operation makes it easier to secure the range of robot motion.
> 2 Positioning pins or other appropriate means may be used so that the target can be mounted at the same position for each measurement. This way, a robot program generated for a previous calibration operation can be used for re-calibration.

8.3.3 Camera Setting Data Creation and Teaching

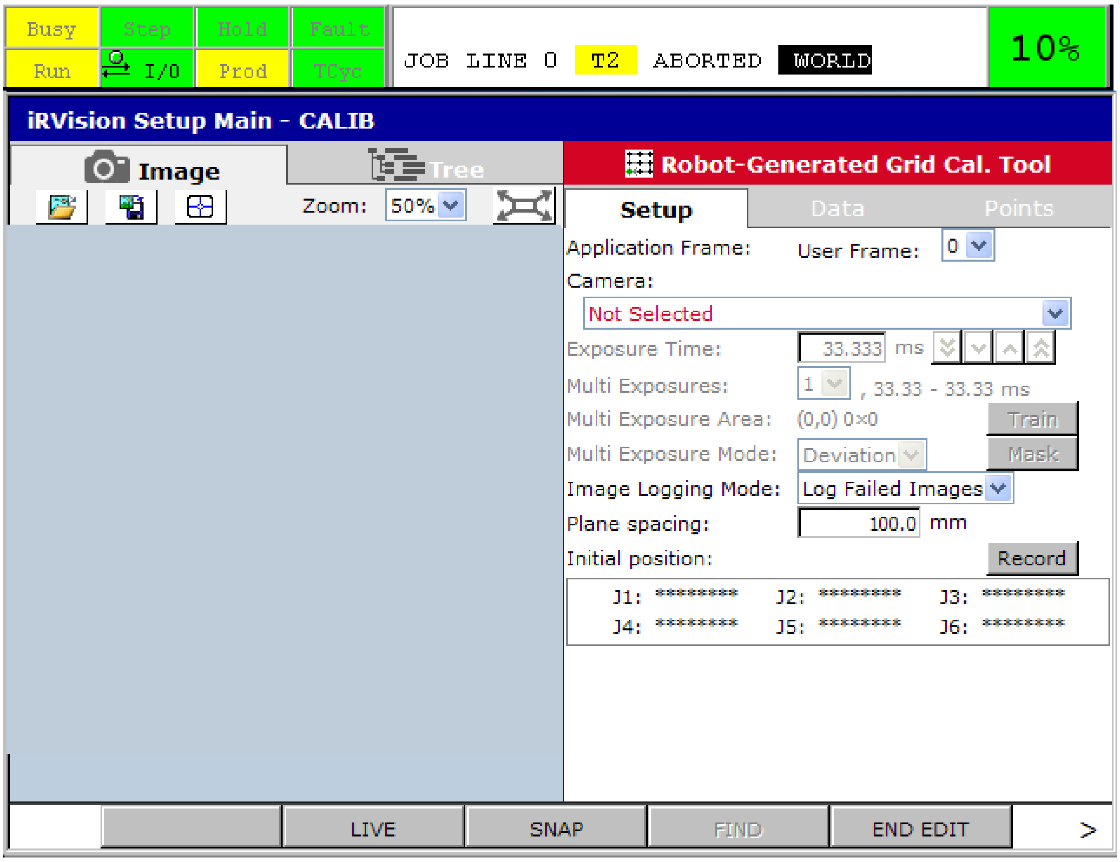
With *i*RVision, items such as a camera type and camera installation method are set in the camera setup. Whether the camera is installed on the robot or on a fixed stand is set in the camera setup When using a fixed camera, do not check "Robot-Mounted Camera".



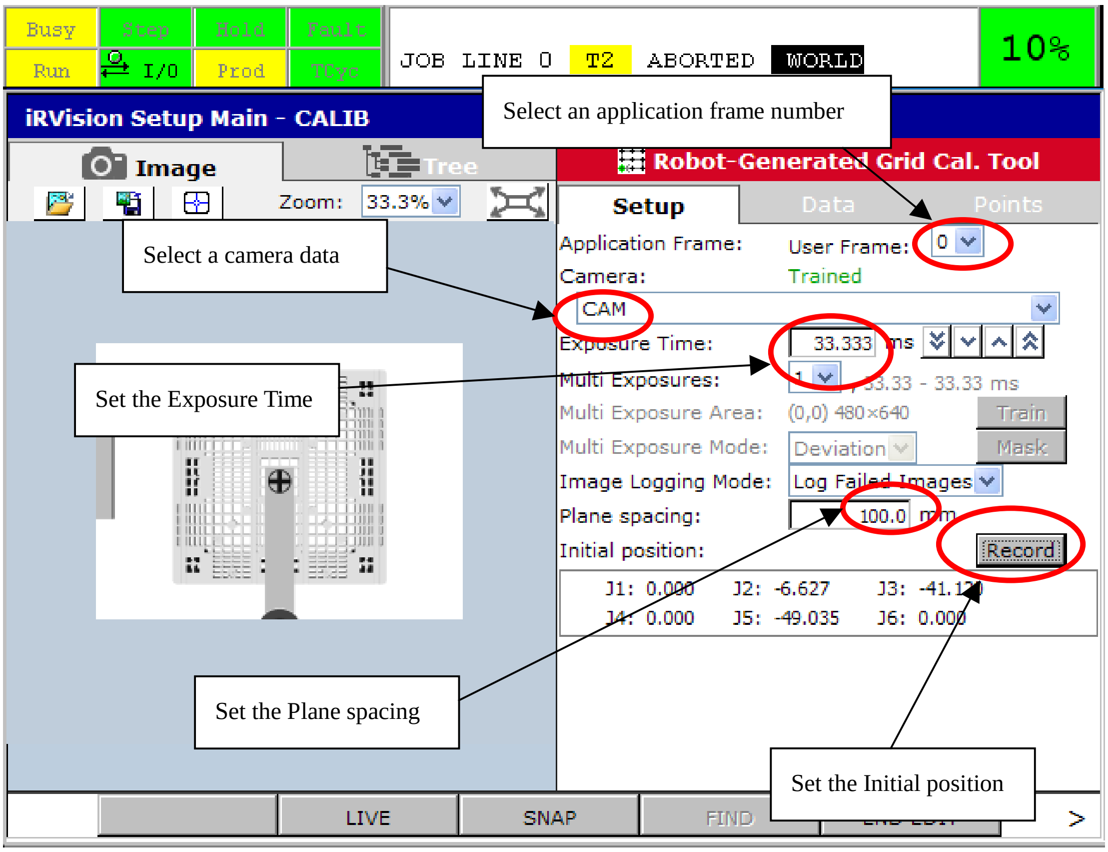
Press the F2 LIVE button, and adjust the aperture and a focus of a lens. Adjust the aperture and a focus of a lens before performing a camera calibration. If the aperture and a focus of a lens are re-adjusted, it is necessary to re-do a camera calibration.

8.3.4 Calibration Data Creation and Selecting

Visit the Vision Setup screen, and create a Robot-Generated Grid Calibration Tool and teach some parameters necessary prior to the execution. If you open the Robot-Generated Grid Calibration setup page, a page like the one shown below appears.



Set the Application Frame number, the Camera Data, the Exposure Time, the Plane spacing and the Initial position.

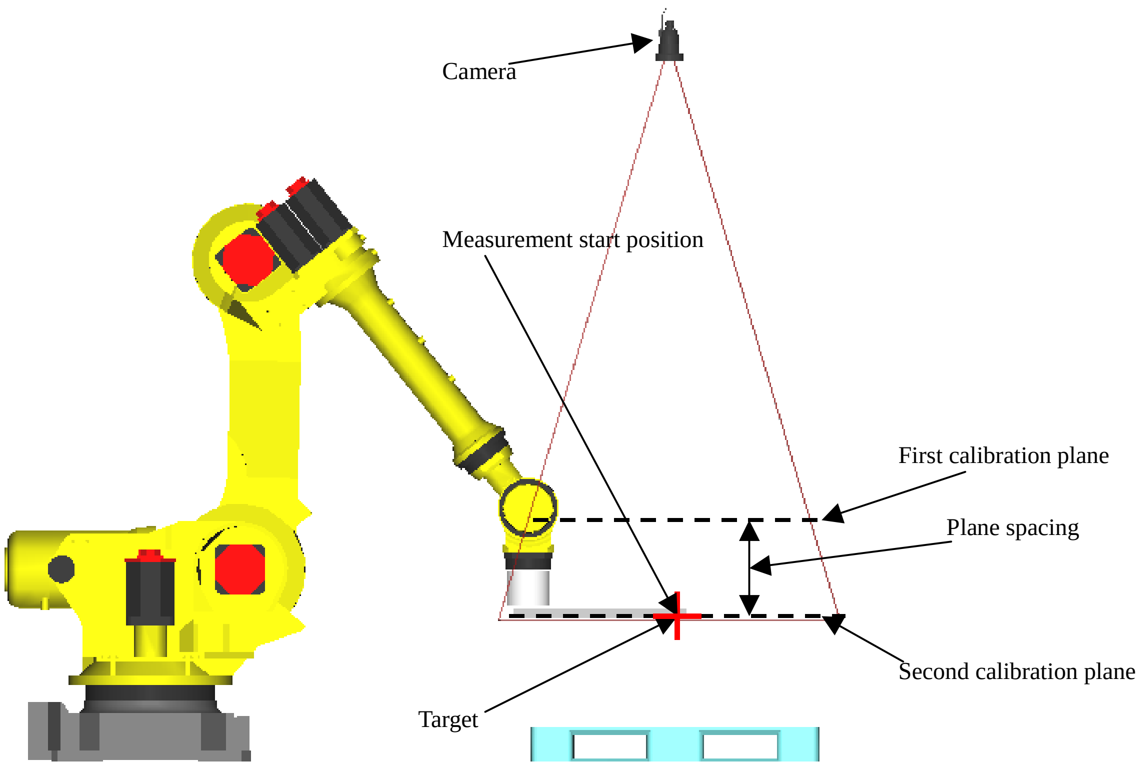


Plane spacing

Specify the spacing between calibration planes 1 and 2. An optimal calibration plane spacing is 10% of the spacing between the camera and calibration plane 1. If you enter a positive value when the Z-axis of the application user frame is directed toward the camera, or if you enter a negative value when the Z-axis is in the opposite direction, calibration plane 2 is located closer to the camera relative to calibration plane 1. This reduces the risk of the robot interfering with peripheral equipment when moving.

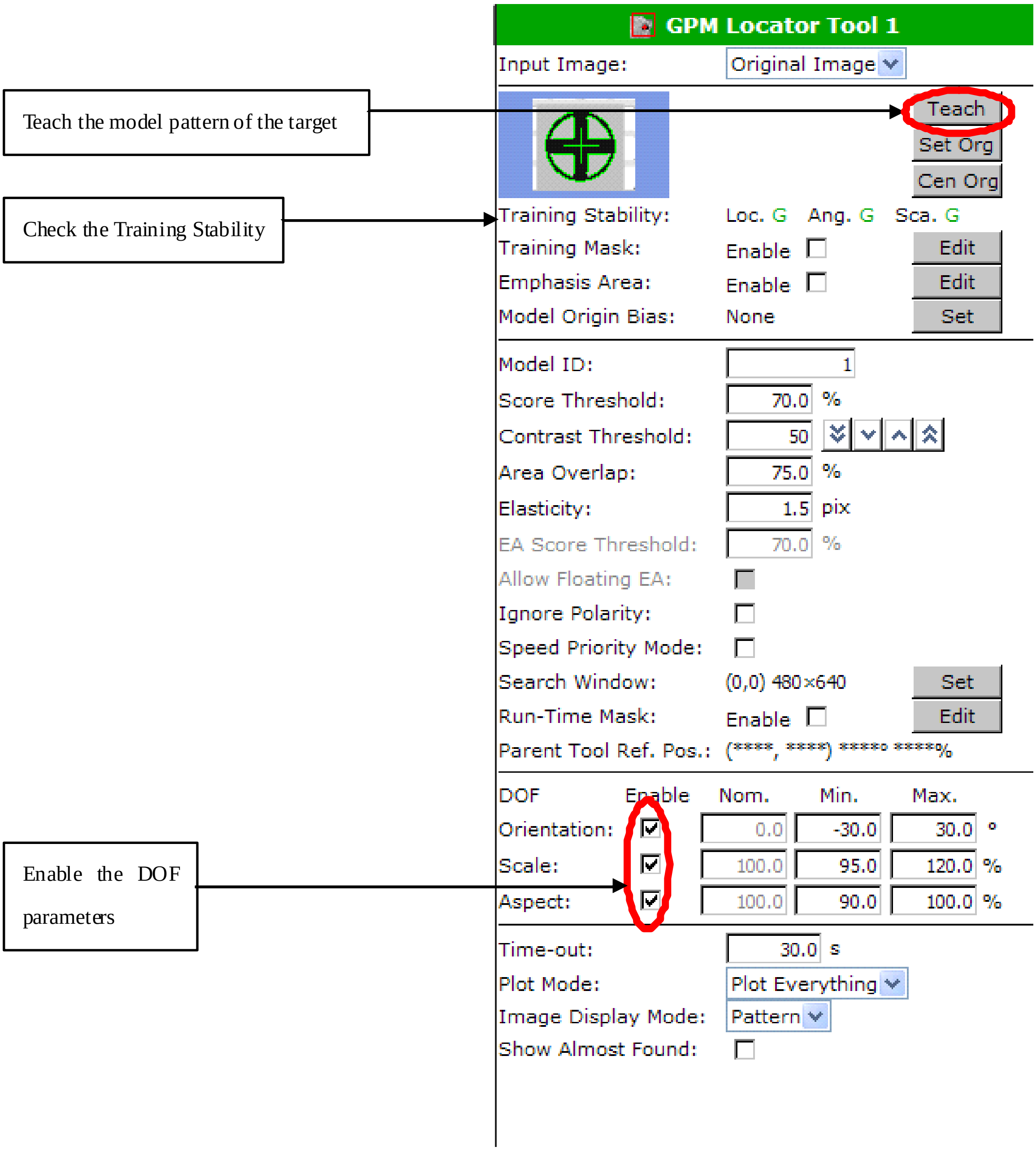
Initial position

Specify the measurement start position. This start position should be set so that the target mounted on the robot end of arm tooling is roughly at the center of the camera's field of view. The height of the start position is equal to that of the calibration plane 1. During camera calibration, the robot moves in parallel to the XY plane of the application frame, while maintaining the posture of the start position. Jog the robot to a place that is appropriate as the start position, and tap the RECORD button.



GPM Locator Tool Setup Page

Select the "GPM Locator Tool" on the tree view, and teach the model pattern. After moving the robot to the recorded start position, teach the model.



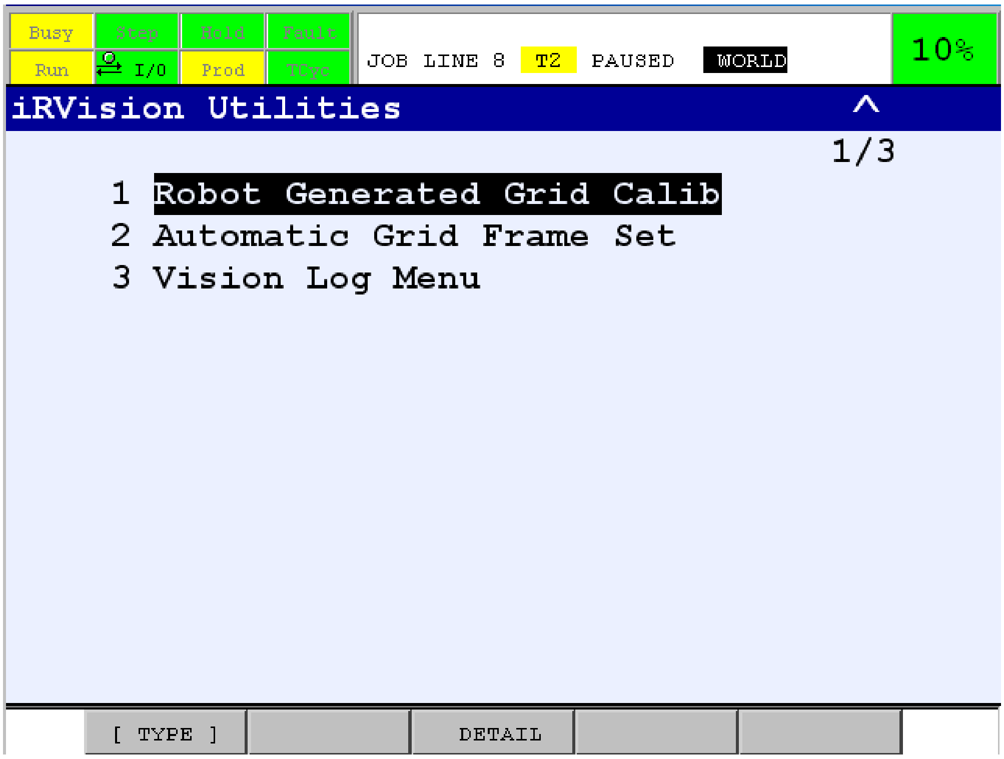
Verify the [Training Stability] of the model pattern to see if [Good] is shown for [Location], [Orientation], and [Scale], respectively. If [None] is shown for any of these items, calibration cannot be performed properly. In that case, use a different shape of target mark.
By default, the range of [Angle] is set to be searched to ±30° and the range of [Scale] is set to be searched to 95% to 120% and the range of [Aspect Ratio] is set to be searched to 90% to 100%. Usually, you don't have to change these parameters. Please adjust these parameters if necessary.

NOTE

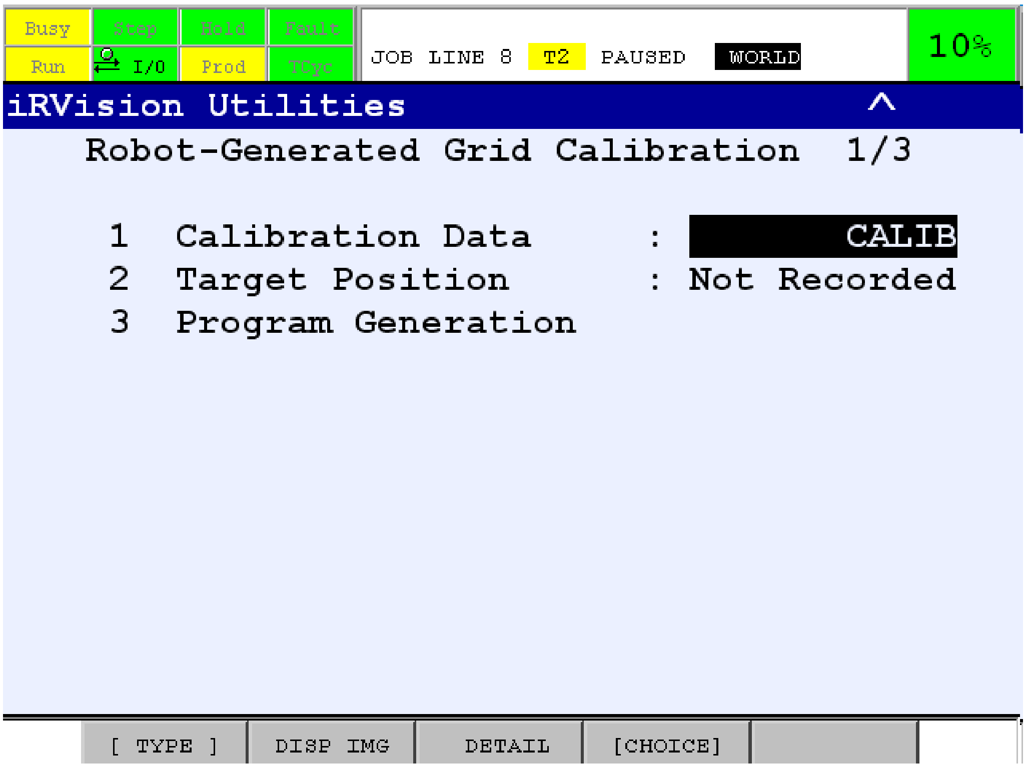
When training the model pattern, the rectangle should not be unnecessarily larger than the area of the target mark. The robot moves the target mark keeping the trained rectangle within the search area. So the larger the trained rectangle is, the smaller the target mark displacement range is, therefore more likely to decrease the accuracy of the camera calibration.

Set up the calibration data. Move to the UTILITY MENU page in the following procedures.

1 Press the MENU key on teach pendant, and select the “5 Vision Utilities” in the “8 *i*RVision”.



Visit the [Robot-Generated Grid Calibration] in the Vision Utility screen, and select the camera calibration data that you just created in [1 Calibration Data].

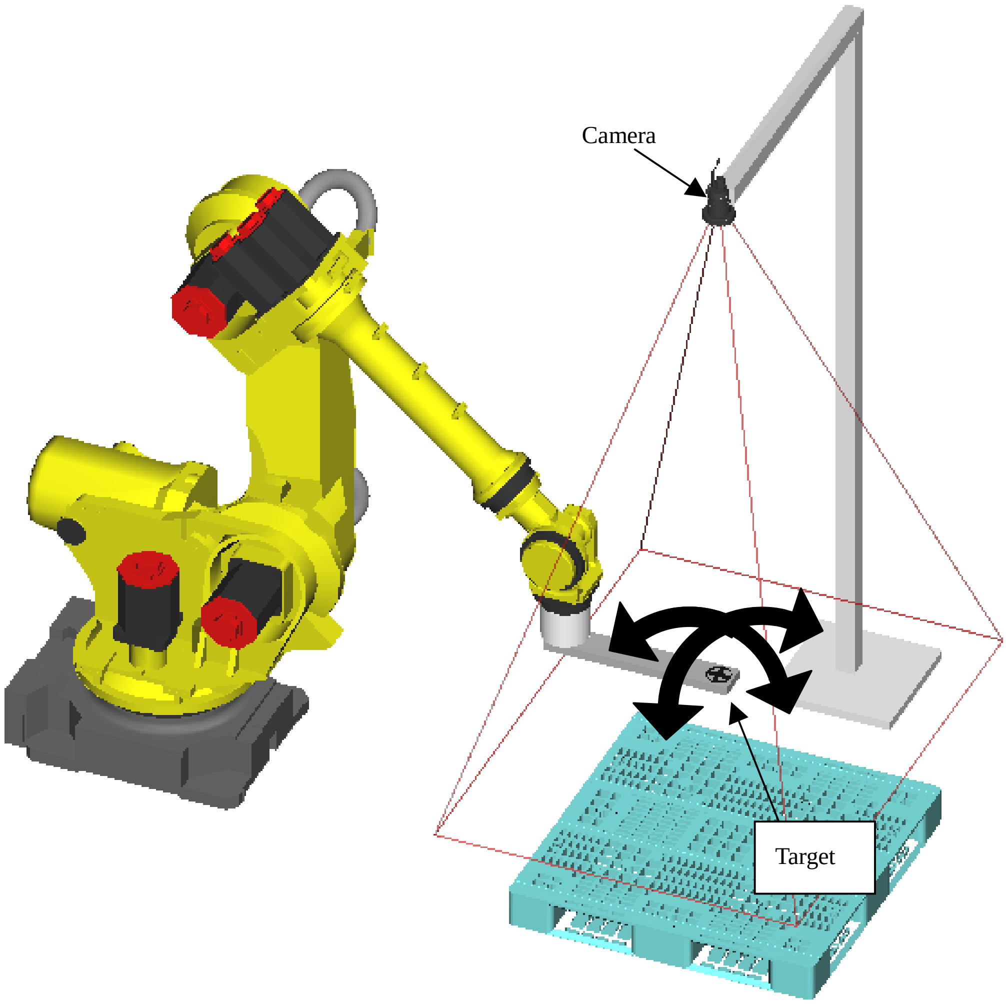


8.3.5 Measuring Target Position

Measures the position of the target mounted on the robot end of arm tooling.

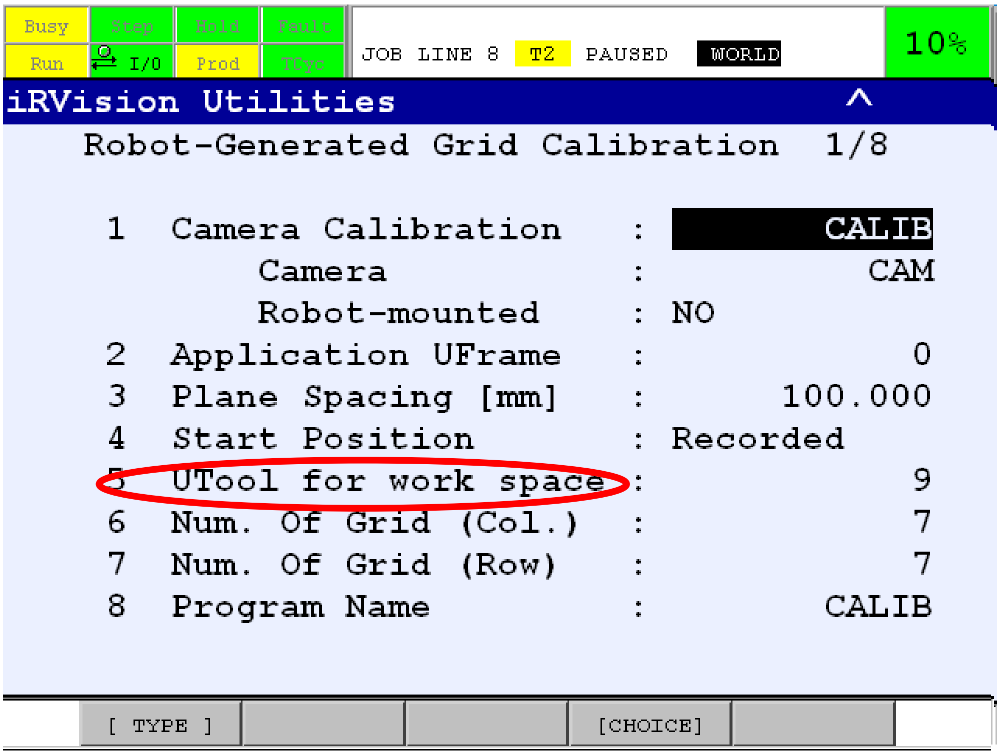
6-axis robot

A 6-axis robot can measure the position of robot-mounted target mark by vision. A robot measures the target by changing the position and posture of the target as shown below.



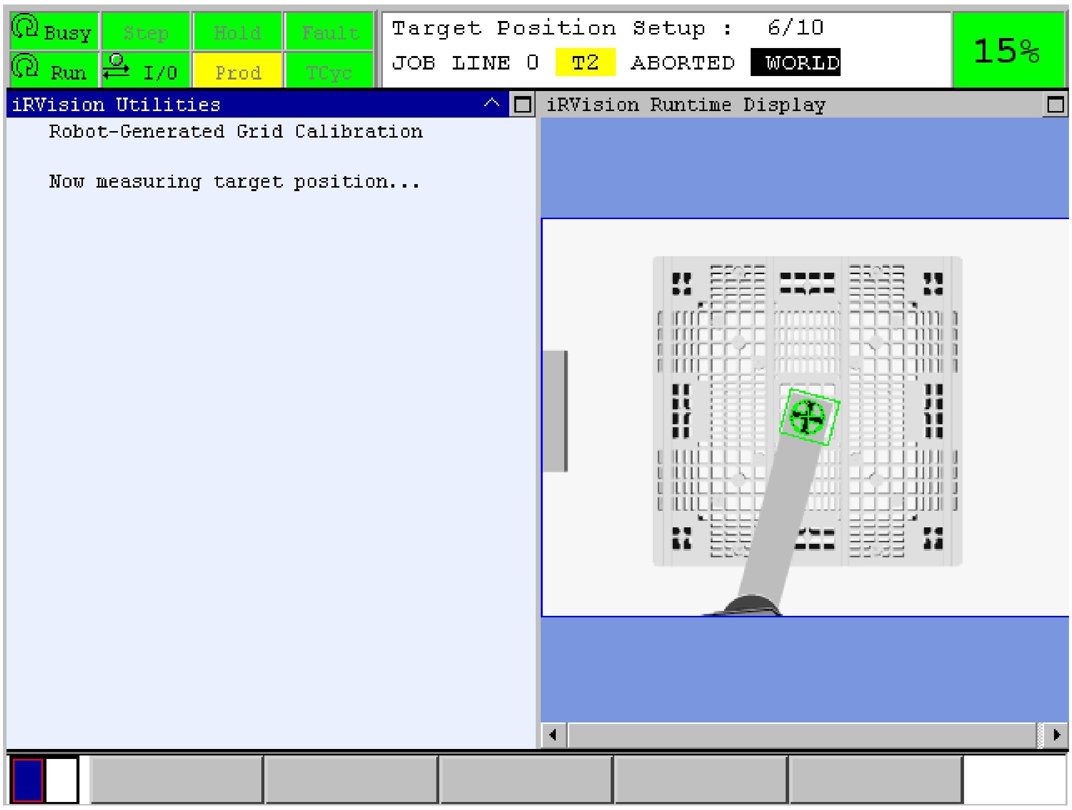
The target location is measured as the following procedures.

1 Verify whether the calibration data which is selected “1 Calibration Data” is proper.
2 If you press F3 DETAIL with the cursor placed on “Calibration Data” in the main menu for Robot-Generated Grid Calibration, a menu like the one shown below appears. Select the “UTool for work space”.

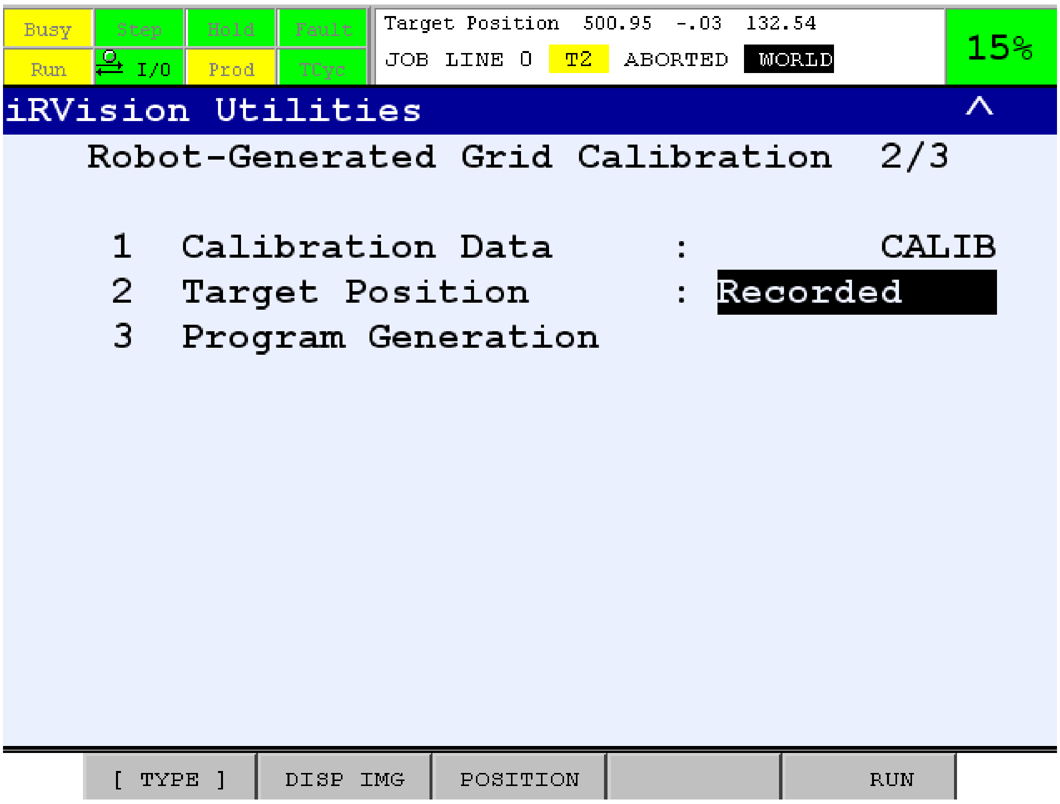


> ⚠ **CAUTION**
>
> Robot-Generated Grid Calibration uses a user tool for the work space when measuring the position of the target or generating a calibration program. Here, specify the number of the user tool for the work space. Since running this function overwrites the values of the specified user tool, specify the number of a user tool whose values can be changed without causing any problem.

3 Place the cursor on “2 Target Position”.
4 Enable the teach pendant, and reset the alarm.
5 Press SHIFT + F5 RUN to start the measurement. Keep holding down SHIFT while the measurement is in progress.



6 When the measurement is complete, the robot stops and the message “Measurement is successfully finished.” appears on the screen.
7 Release the SHIFT button and press F4 OK button.
8 Check that “2 Target Position” becomes “Recorded”.



If the last target position measurement was aborted before completion, the message “Are you sure to resume?” appears when you attempt to perform the target position measurement again on the procedure number 5. To resume the measurement, press SHIFT + F4 RESUME. To restart the measurement from the beginning, press SHIFT + F5 RESTART.

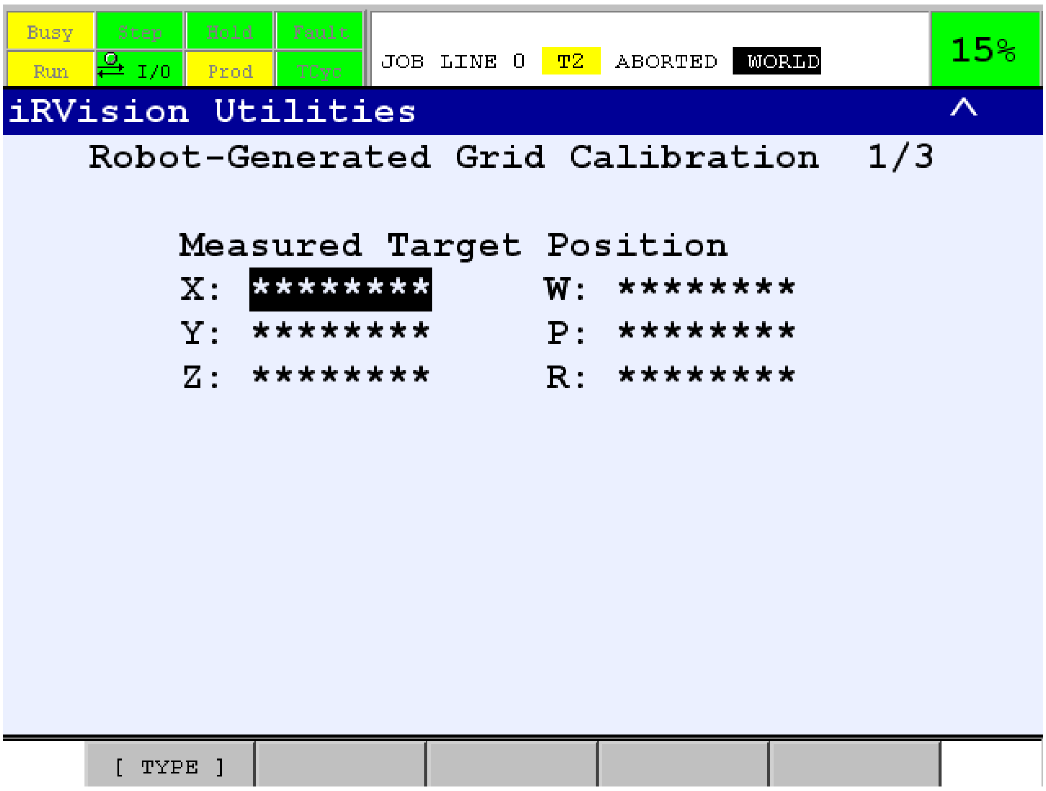
> ⚠ **CAUTION**
> If the camera calibration setup page is opened in the Vision Setup screen, Robot-Generated Grid Calibration cannot perform the measurement. Make sure that the setup page is closed. You can see the status of the measurement on the Vision Runtime screen.

> **NOTE**
> When the field of view contains some area that the robot cannot reach, the robot sometimes cannot measure the target mark position by vision. In this case, you can set the target position by the same steps as a 4- or 5-axis robot.

4- or 5-axis robot

A 4- or 5-axis robot cannot use vision-based measuring. Enter the position of the target mark manually.

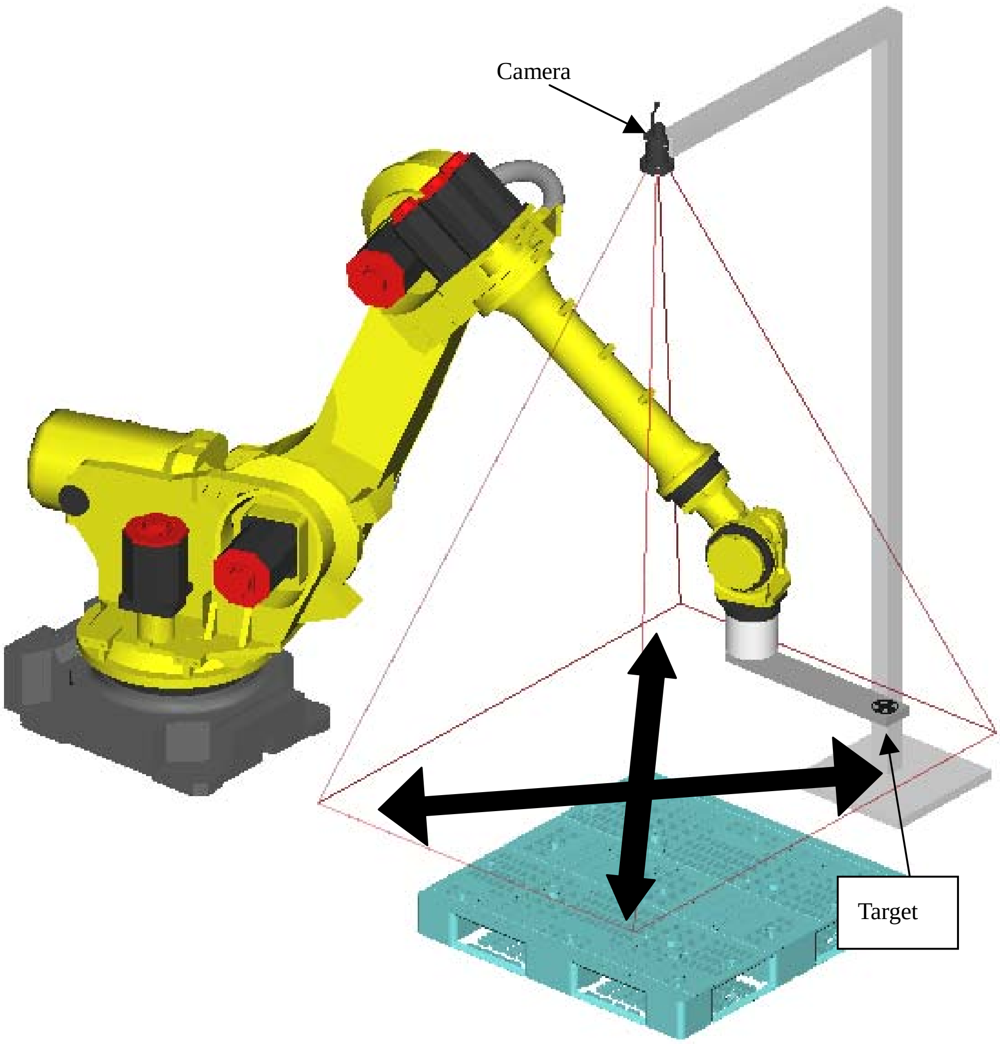
1 Place the cursor on “2 Target Position”, and press F3 POSITION to visit the target position menu.
2 Calculate the model origin position of the target relative to the robot faceplate. Then, input X, Y and Z as the position of the target mark. Input W, P and R to zero.



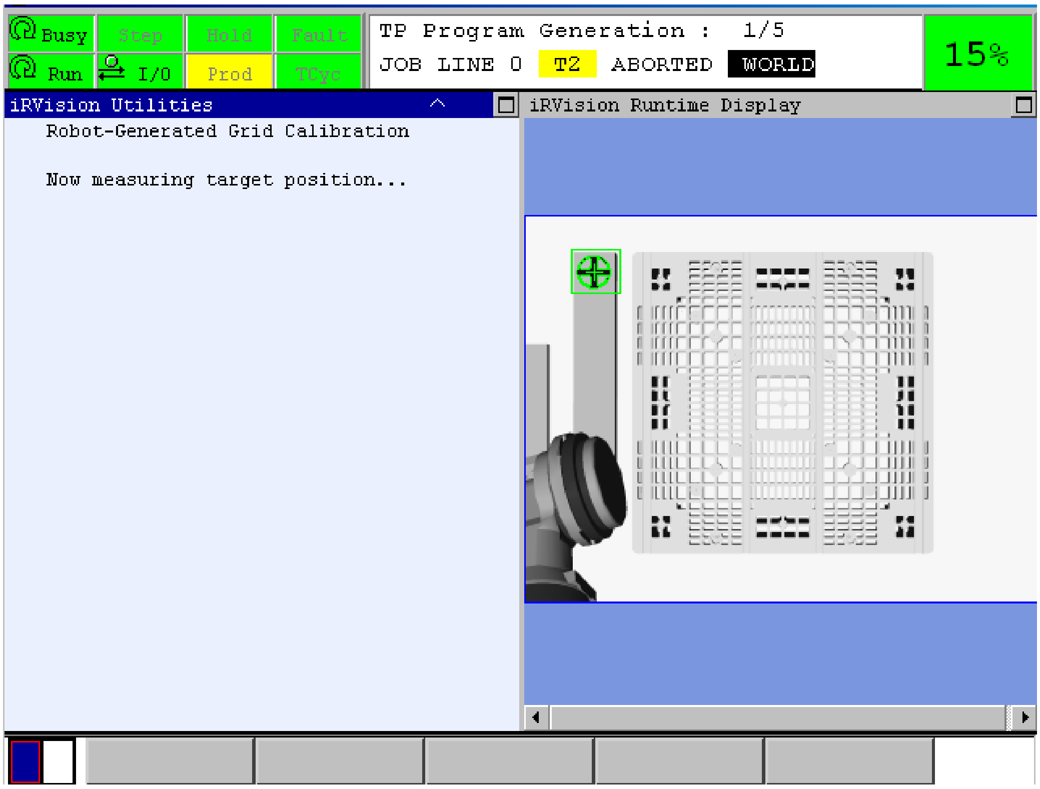
> **NOTE**
> The target position should correspond to the model origin trained in section 8.3.4. If the positions are different, the camera cannot be calibrated properly.

8.3.6 Generating Calibration Program

A robot measures the size of field of view while changes the target position as shown below, and generates a robot program for camera calibration.



1 Verify whether the proper calibration data which is selected “1 Calibration Data”.
2 Verify whether “2 Target Position” is RECORDED.
3 Place the cursor on “3 Program Generation”.
4 Enable the teach pendant, and reset the alarm.



3 Press SHIFT + F5 RUN to start the program generation. Keep holding down SHIFT while the measurement is in progress.
4 When the measurement is complete, the robot stops and the message [Measurement is successfully finished.] appears on the screen.
5 Press F4 OK.

If the last program generation process was aborted before completion, the message "Are you sure to resume?" appears when you attempt to generate a program again on the procedure number 5. To resume the process, press SHIFT + F4 RESUME. To restart the process from the beginning, press SHIFT + F5 RESTART.

> ⚠ **CAUTION**
> If the camera calibration setup page is opened in the Vision Setup screen, Robot-Generated Grid Calibration cannot perform the measurement. Make sure that the setup page is closed. You can see the status of the measurement on the Vision Runtime screen.

The way to limit the target displacement range

In order to avoid the interference with peripheral equipment, you can limit the target displacement range.

1 Open the camera calibration setup page and choose GPM Locator Tool in the tree view.
2 Decrease the size of the search window and omit the area that the interference occurred.
3 Press F10 SAVE to save the camera calibration.
4 Press F5 END EDIT to close the setup page.
5 Visit the Robot-Generated Grid Calibration in Vision Utility, and generate a calibration program again.

Calibration Program

The generated calibration program is like the one shown below. All the robot positions in the calibration program are taught in the joint format.

```
   1:   UFRAME_NUM=2
   2:   UTOOL_NUM=2
   3:L P[1] 1000mm/sec FINE
   4:   VISION CAMREA_CALIB 'CALIB1' REQUEST=1
   5:L P[1001] 1000mm/sec FINE
   6:   CALL IRVBKLSH(1)
   7:   VISION CAMERA_CALIB 'CALIB1' REQUEST=1001
   8:L P[1002] 1000mm/sec FINE
   9:   CALL IRVBKLSH(1)
  10:   VISION CAMERA_CALIB 'CALIB1' REQUEST=1002

        (Repeat as many times as the number of points)

293:L P[2048] 1000mm/sec FINE
294:   CALL IRVBKLSH(1)
295:   VISION CAMERA_CALIB 'CALIB1' REQUEST=2048
296:L P[2049] 1000mm/sec FINE
297:   CALL IRVBKLSH(1)
298:   VISION CAMERA_CALIB 'CALIB1' REQUEST=2049
299:L P[2] 1000mm/sec FINE
300:   VISION CAMERA_CALIB 'CALIB1' REQUEST=2
```

The section of the program that finds an individual calibration program consists of the three lines shown below. This set of three lines is repeated in the middle of the calibration program above.

```
   5:L P[1001] 1000mm/sec FINE
   6:   CALL IRVBKLSH(1)
   7:   VISION CAMERA_CALIB 'CALIB1' REQUEST=1001
```

Each command in the program is briefly explained below.

```
   4:   VISION CAMREA_CALIB 'CALIB1' REQUEST=1
```

If you specify 1 in the request code of the CAMERA_CALIB command, all the calibration points in the specified camera calibration are deleted. This is the first command to be executed in the calibration program.

```
300:   VISION CAMERA_CALIB 'CALIB1' REQUEST=2
```

If you specify 2 in the request code of the CAMERA_CALIB command, camera calibration data is calculated using the found calibration points. This is the last command to be executed in the calibration program.

```
   7:   VISION CAMERA_CALIB 'CALIB1' REQUEST=1001
```

If you specify 1000 or a larger value in the request code of the CAMERA_CALIB command, the program attempts to find a calibration point. The value specified in the request code is recorded as the index of the calibration point, along with the found position.

In an automatically generated calibration program, 1000 to 1999 represent the calibration points on calibration plane 1, and 2000 to 2999 the calibration points on calibration plane 2. Note also that the index of the position data of the preceding motion statement is the same as the request code that is passed to the CAMERA_CALIB command.

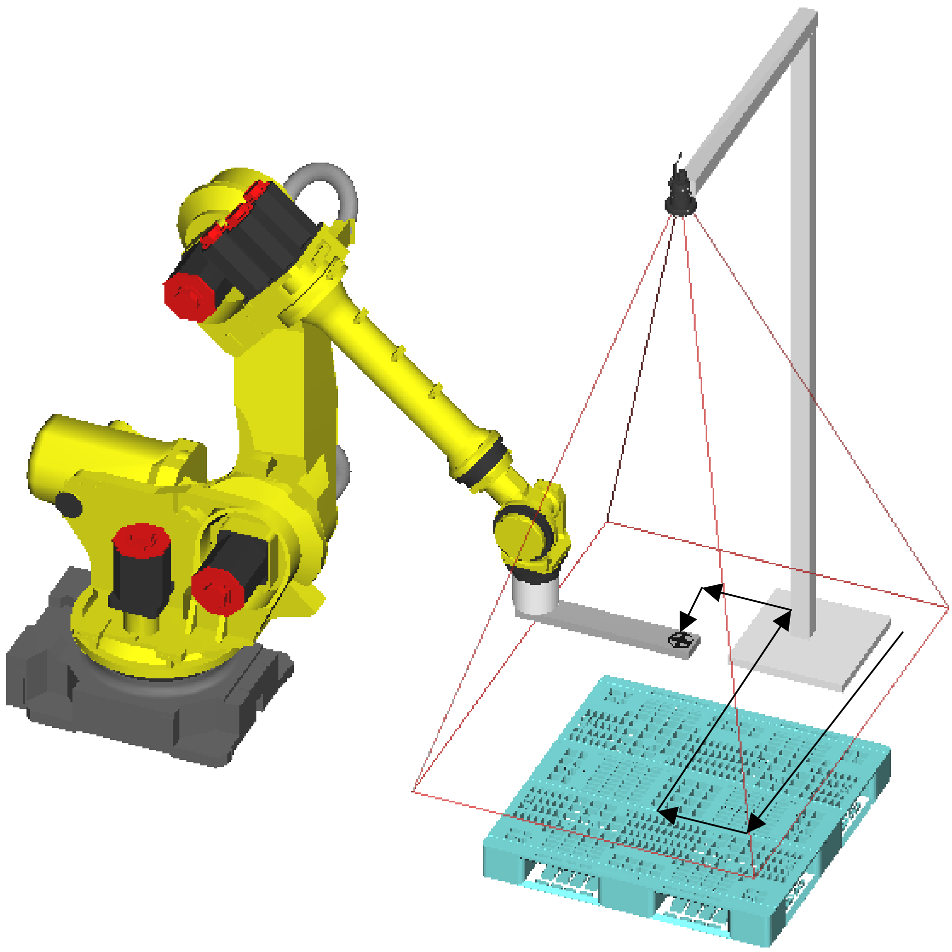
Calibration points do not necessarily need to be found in the order of request codes. If a calibration point is found twice with the same request code, the data of the calibration point that is found first is overwritten by the data of the calibration point found later.

```
6:  CALL IRVBKLSH(1)
```

If the KAREL program IRVBKLSH.PC is called, the robot performs an operation intended to remove the backlash effect at its current position. As the argument, specify the motion group number of the robot that performs the backlash removal operation.

8.3.7 Executing Calibration Program

Select the generated calibration program in the SELECT menu, and run it from the first line to calibrate the camera. A robot moves the target as shown below.



> ⚠ **CAUTION**
> If running the program as is can cause interference, use lower override values. In this case, execute the program while making sure that no interference occurs during operation.

Each calibration point in the generated calibration program can be re-taught or deleted as necessary.

If there is any calibration point that causes the robot to interfere with peripheral equipment, re-teach that point to move it to a position where it does not cause interference, or delete the calibration point. When deleting a calibration point, delete not only the motion statement but also the lines of IRVBKLSH and the CAMERA_CALIB command that are executed after the motion statement.

If there is any calibration point that hinders the robot operation because it is near singularity, re-teach that point to move it to a position where it can avoid singularity, or delete the calibration point. When deleting a calibration point, delete not only the motion statement but also the lines of IRVBKLSH and the CAMERA_CALIB command that are executed after the motion statement.

When re-teaching a calibration point, you may place the target closer to or further away from the camera within a range in which the camera lens remains in focus.

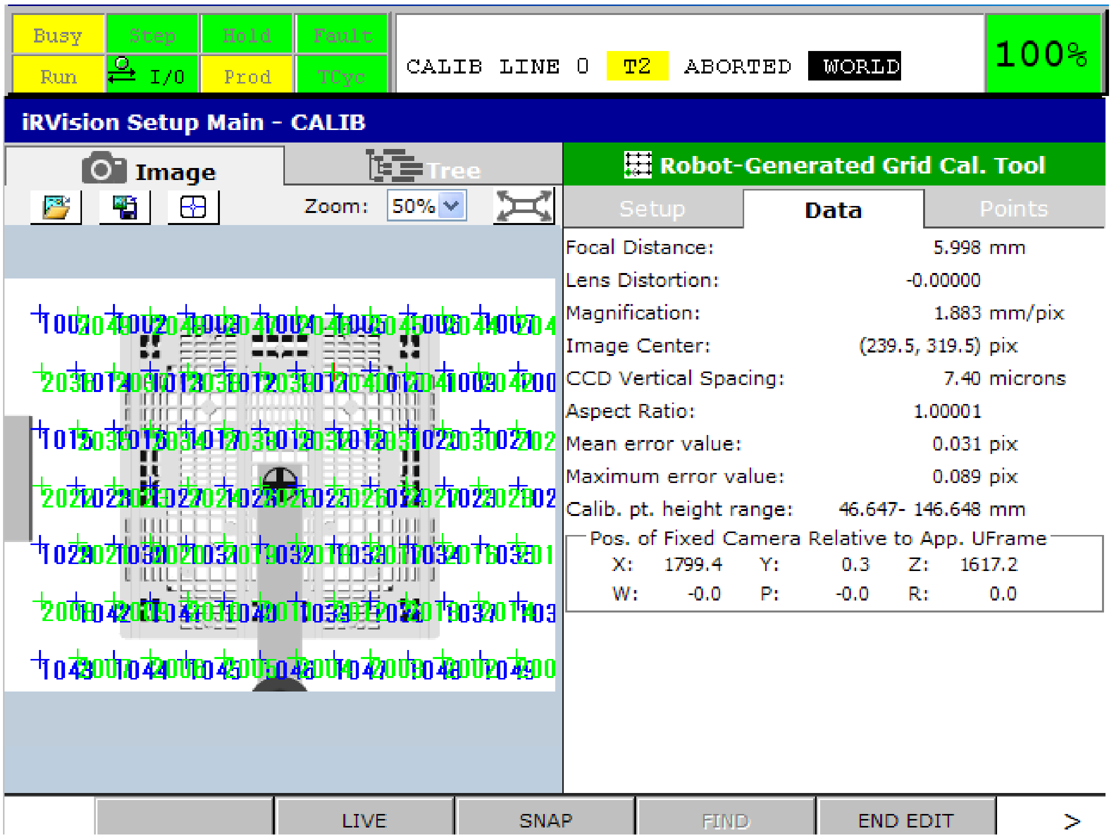
> ⚠ **CAUTION**
> The calibration program does not stop even if the target fails to be found or it is found incorrectly during the program execution. After the program ends, open the Robot-generated Grid Calibration setup page in the Vision Setup screen and check to see if there is any point incorrectly found.

> **NOTE**
> As long as the position where the target is mounted remains unchanged, you can re-calibrate the camera simply by executing the generated calibration program.

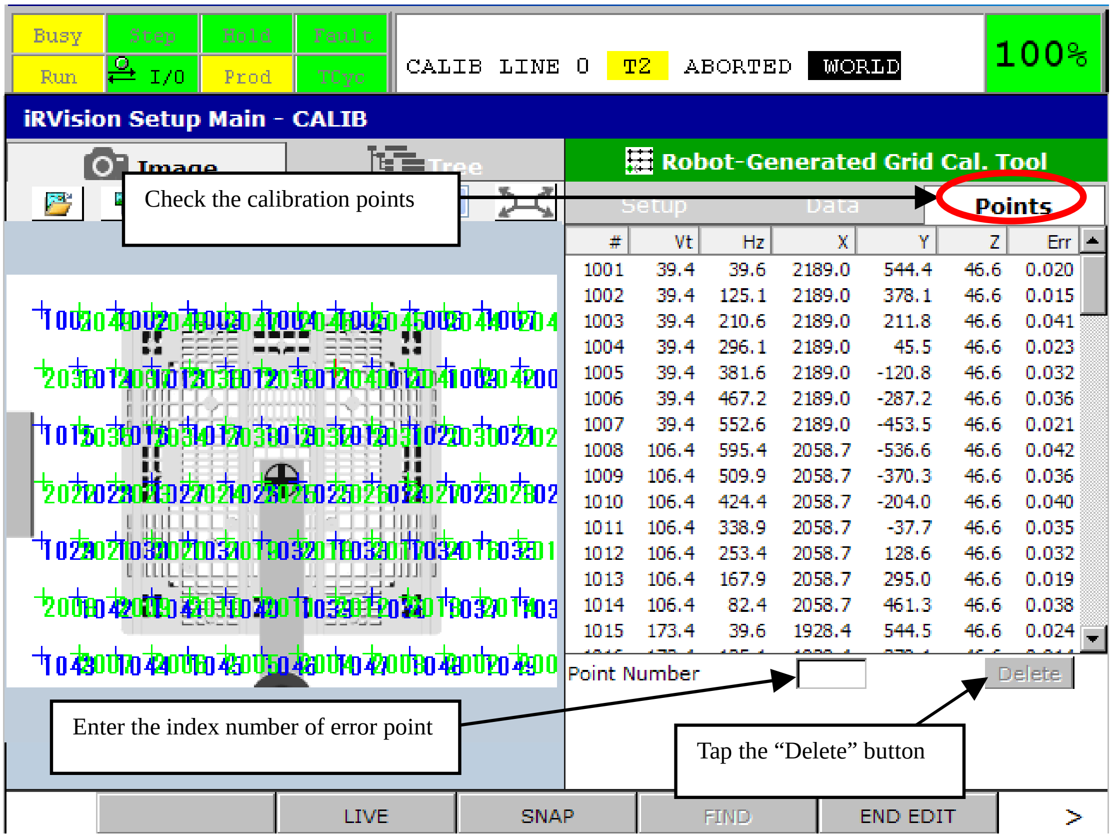
After executing the calibration program to the last, camera calibration is complete. Please verify the calibration points and the calibration results.

8.3.8 Camera Calibration Data Checking

The following figure is camera the calibration screen. Check that the calculated focal distance and the position of fixed camera relative to application frame are correct.



The Points in the calibration page are shown below.
If a crosshair is displayed at a location where no grid point is present, enter the index number of that point in the text box to the left of the "Delete" button and then tap the "Delete" button.



9 FRAME SETTING

This chapter explains the setup procedures of frame. When set an application frame or an offset frame, refers to this chapter. Refer to the "3.9 SETTING COORDINATE SYSTEMS" in the "R-30*i*B/ R-30*i*B Mate CONTROLLER OPERATOR'S MANUAL (Basic Operation) (B-83284EN)" about a general method of frame setting. This chapter explains the following items.

<1> Frame setting with a pointer tool (Section 9.1)
<2> Frame setting with the Automatic Grid Frame Set Function (Section 9.2)

9.1 FRAME SETTING WITH A POINTER TOOL

An user frame or a tool frame is set by physically teaching with a pointer attached on the robot end of the arm tooling. This section explains the following items.

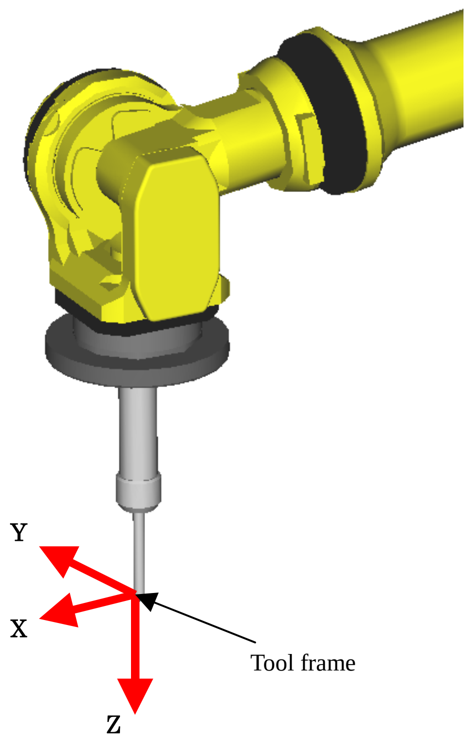
<1> User frame setting with a pointer tool (Subsection 9.1.1)
<2> Tool frame setting with a pointer tool (Subsection 9.1.2)

9.1.1 User Frame Setting with a Pointer Tool

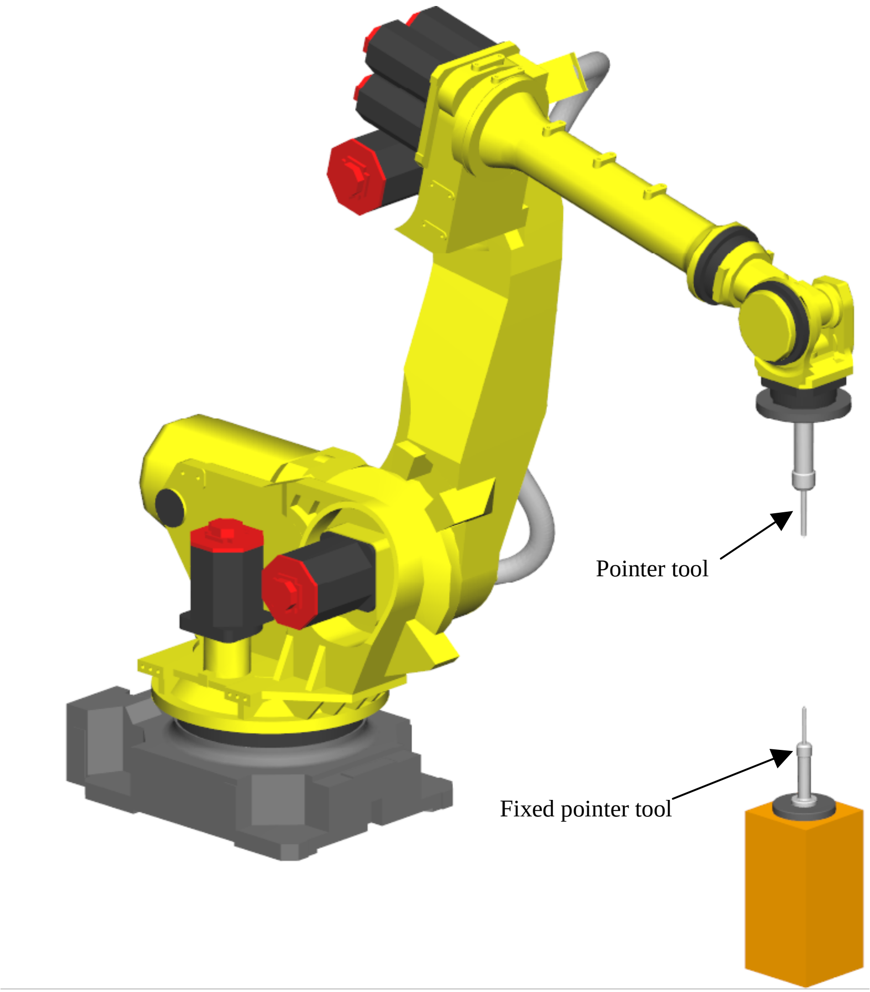
This subsection explains a method for user frame teaching on an arbitrary plane with a pointer attached on the robot end of the arm tooling. It is necessary to perform a TCP setup to a pointer tool as preparation.

9.1.1.1 TCP set up

Attach a pointer tool on the robot end of the arm tooling, and set TCP to an arbitrary tool frame number.



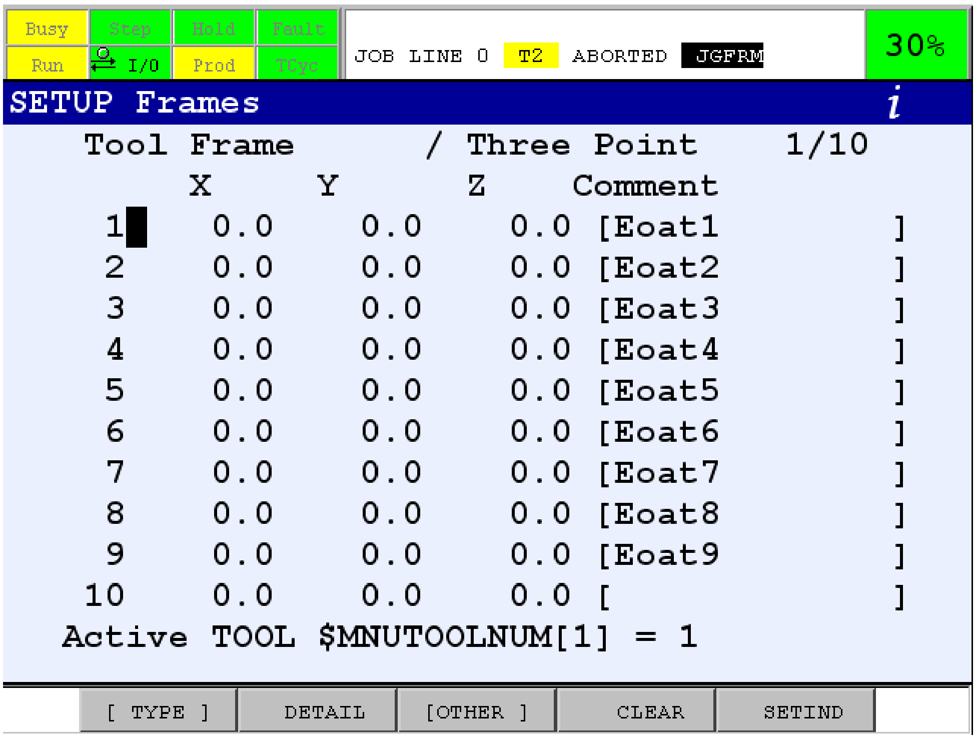
Prepare a pointer tool with a sharp tip. Make sure that the pointer tool is fixed securely to the robot end of arm tooling so that it remains in place while the robot moves. It is recommended that positioning pins or other appropriate means may be used so that the pointer tool can be mounted at the same position. Moreover, prepare another pointer with a sharp tip, and fixed on the table. The position of the fixed pointer on the table is arbitrary. TCP is set up by touch-up the tip of the fixed pointer with the tip of the pointer attached on the robot end of the arm tooling. Use the "Tree point method" for setting a TCP. Set the TCP accurately. If the accuracy of this TCP setting is low, the precision in handling of a workpiece by the robot is also degraded.



Three Point Method

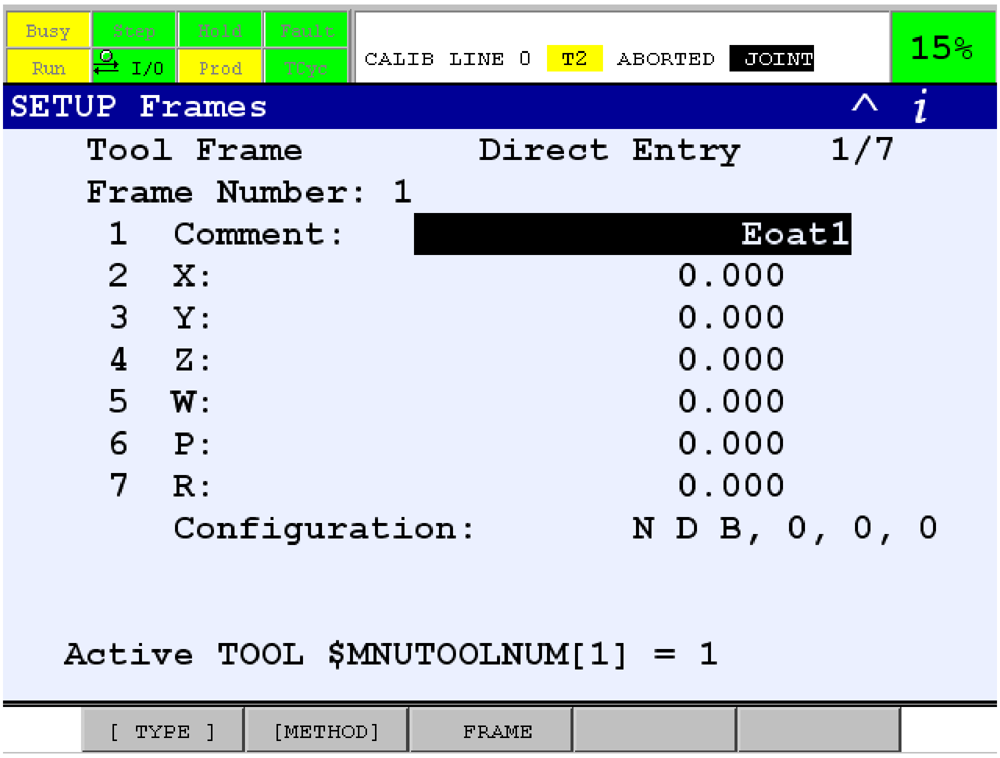
Use the three point method to define the tool center point (TCP). The three approach points must be taught with the tool touching a common point from three different approach statuses.
As a result, the location of TCP is automatically calculated.
To set the TCP accurately, three approach directions had better differ from others as much as possible.
In the three point method, only the tool center point (x, y, z,) can be set. The setting value of tool orientation (w, p, r) is the standard value (0, 0, 0). It is not necessary that change the (w, p, r) value.

1 Press the MENU key. The screen menu is displayed.
2 Select "6 SETUP"
3 Press the F1 [TYPE]. The screen change menu is displayed.
4 Select Frames.
5 Press F3 [OTHER].
6 Select Tool Frame. Tool frame list screen is displayed.



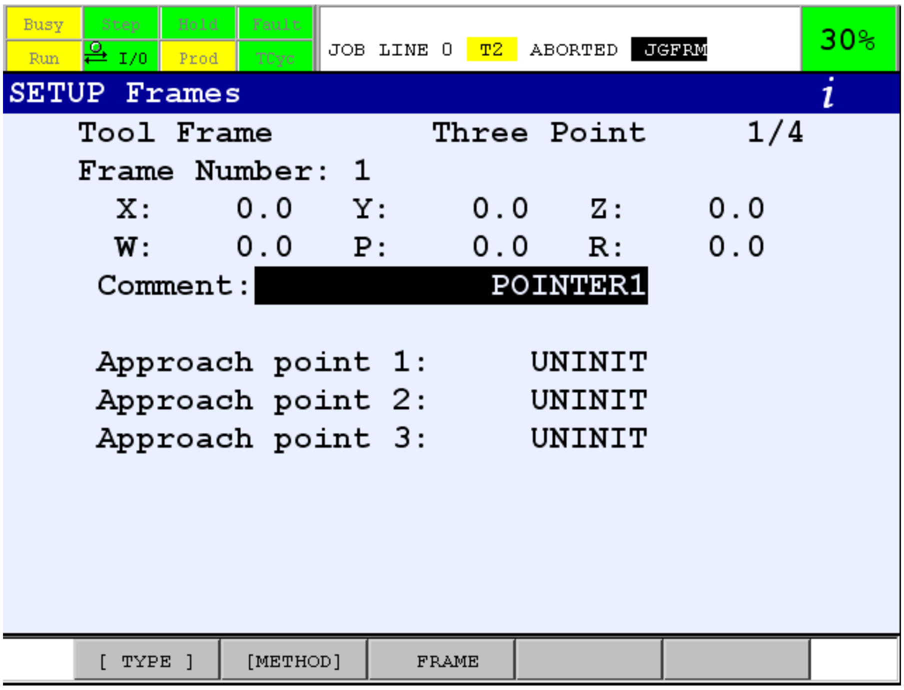
7 Move the cursor to the list of the tool frame number you want to set.

8 Press F2 DETAIL. The tool frame setup screen of the selected frame number is displayed.

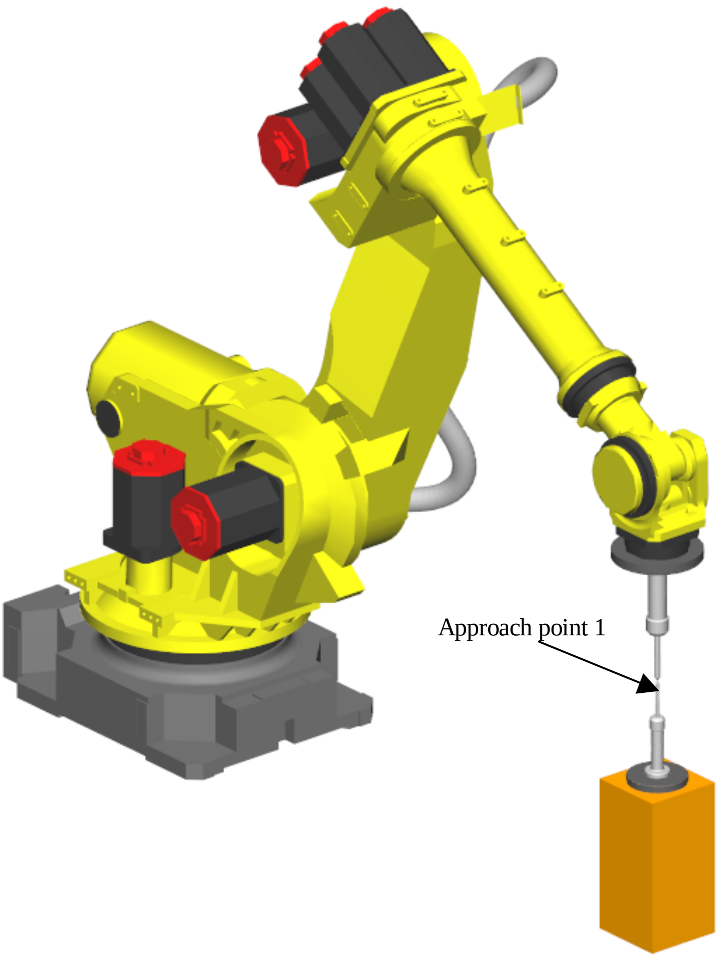


9 Press F2 DETAIL.

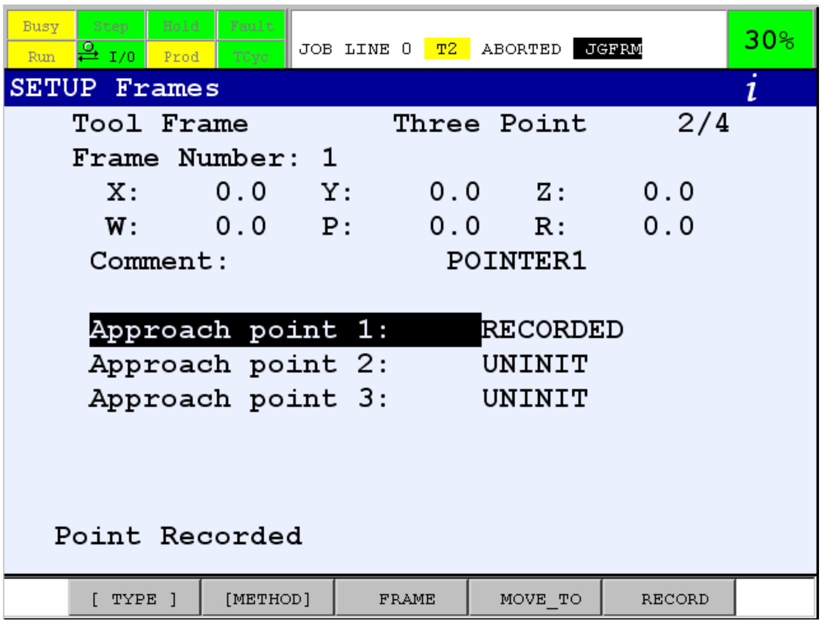
10 Select Tree Point.



11 It recommends inputting a comment, in order to make it easy to distinguish from other tool frame numbers.
12 Move the cursor to the Approach point 1.
13 Jog the robot and record the fixed pointer with the pointer tool.

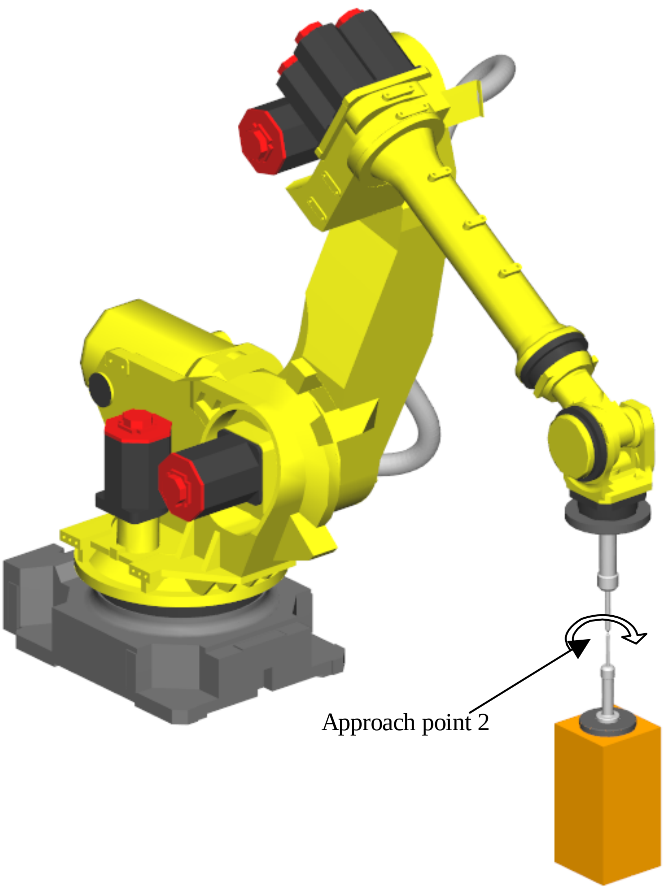


14 Press and hold the SHIFT key and press F5 RECORD to record the data of current position as the reference position. RECORED is displayed once the position is taught.

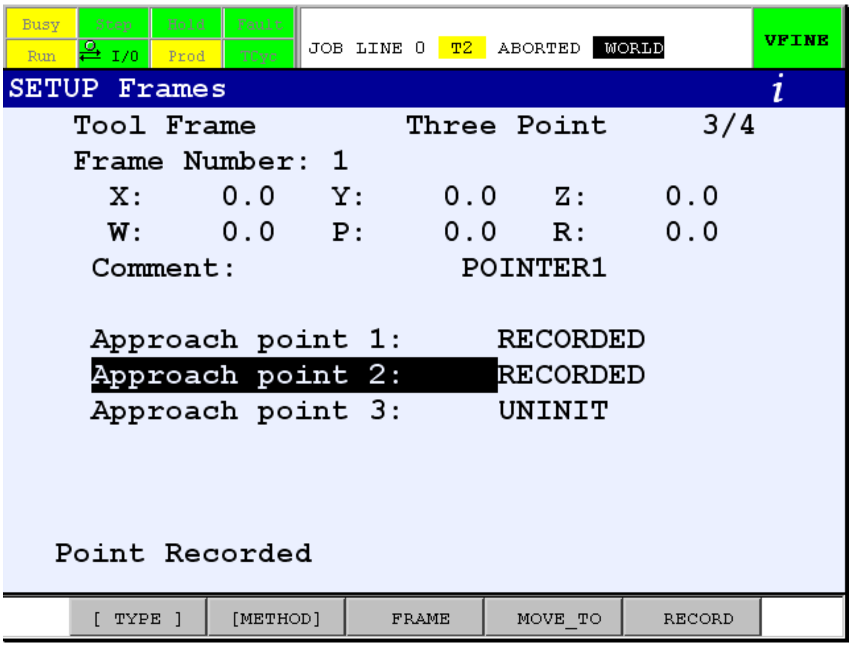


15 Move the cursor to the Approach point 2.

16 Jog the robot and record the fixed pointer with the pointer tool. The position of approach point 2 is same position as the approach point 1. However, the posture of approach point 2 is different from posture of approach point 1. Rotate about the Z direction of the pointer by around 180 degree. In addition, the yaw and pitch is the same as approach point 1.

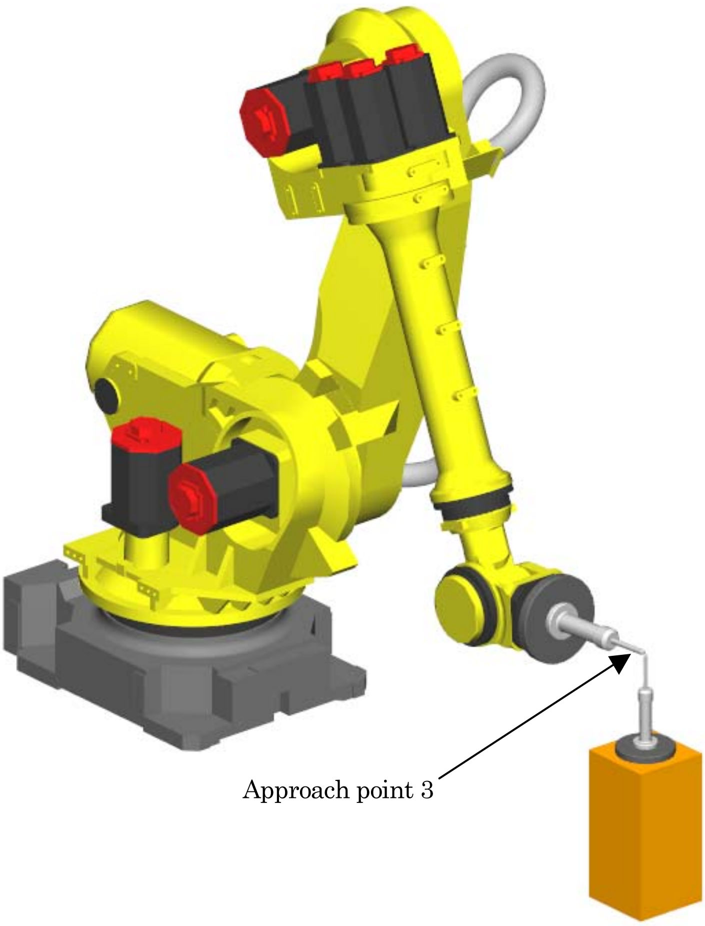


17 Press and hold the SHIFT key and press F5 RECORD to record the data of current position as the reference position. RECORED is displayed once the position is taught.

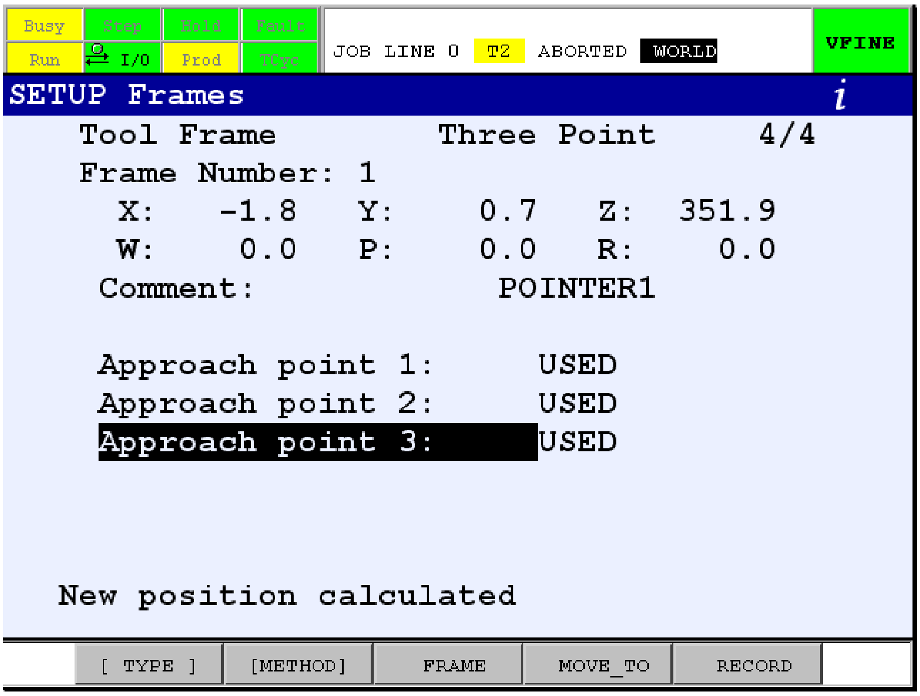


18 Move the cursor to the Approach point 3.

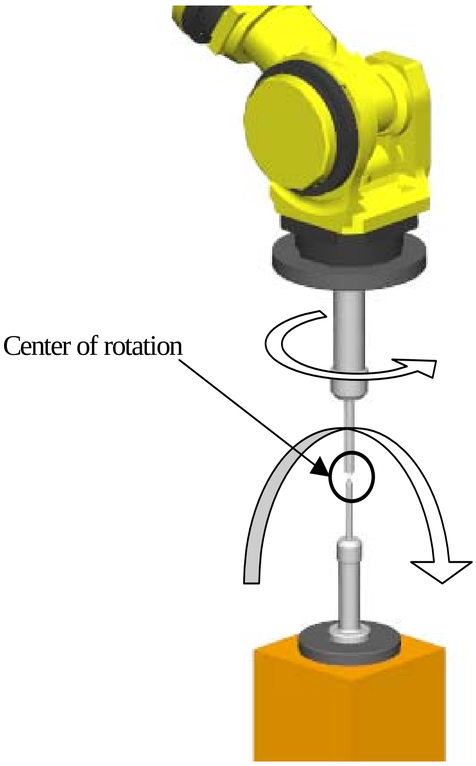
19 Jog the robot and record the fixed pointer with the pointer tool. The position of approach point 3 is same position as the approach point 1 and 2. However, the posture of approach point 3 is different from posture of approach point 1 and 2. Rotate about Yaw and/or Pitch 45 to 90 degrees.



20 Press and hold the SHIFT key and press F5 RECORD to record the data of current position as the reference position.
21 When all the reference points are taught, USED is displayed. The tool frame has been set.



22 To display the tool frame list screen, press the PREV key.
23 Check the TCP is set accuracy. Press F5 SETIND and select the set tool frame number as an effective tool frame now.
24 Jog the robot and record the fixed pointer with the pointer tool.
25 Jog the robot around TCP and change the posture (w, p, r) of pointer tool. If TCP is set accuracy, the tip of pointer tool always points to the tip of the fixed pointer.

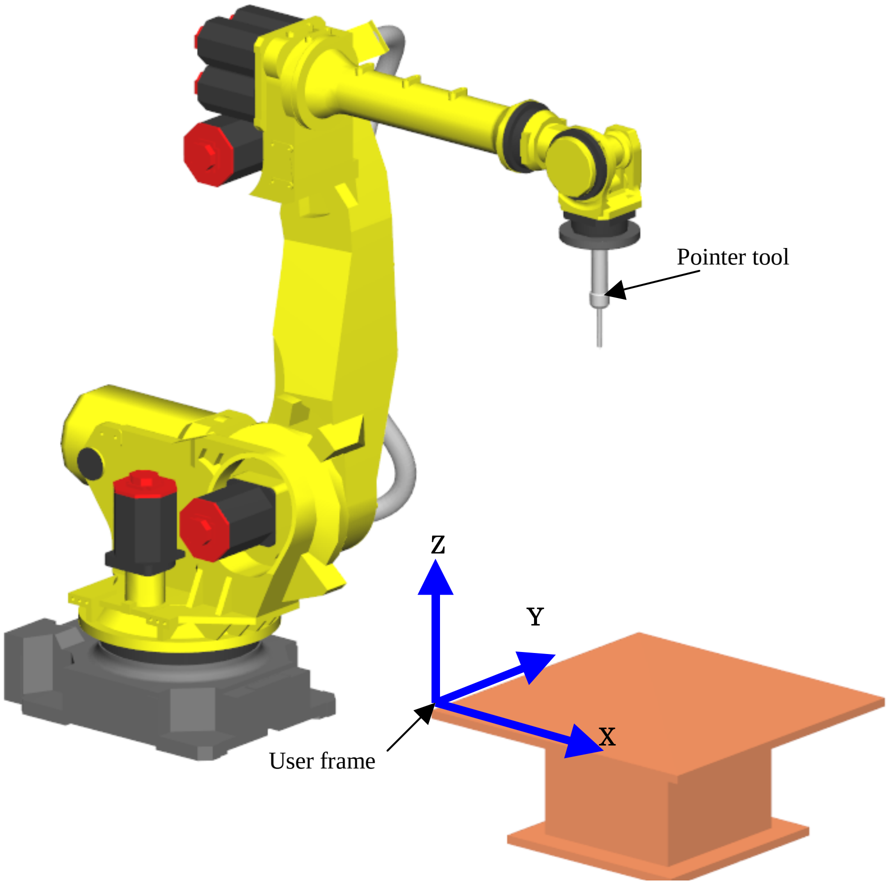


9.1.1.2 User frame setting

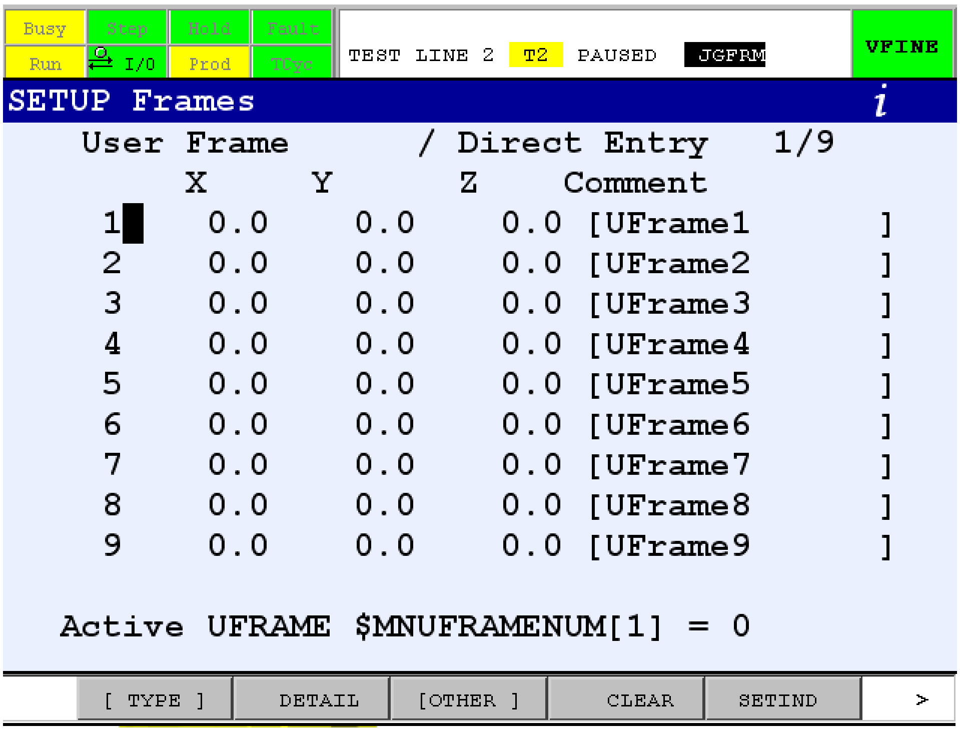
To set a user frame, there are three methods that are “Three point method”, “Four point method” and “Direct entry method”. When the “Three point method” or the “Four point method” are used, use the pointer tool that is set in the Subsection 9.1.1.1 “TCP setting”. The accuracy of the user frame becomes better the further the taught points are apart. When teaching the calibration grid frame, the distance of each taught points by using “Four point method” become longer than using the “Three point method”. When teaching the calibration grid frame, the “Four point method” is recommended. The “Three point method” and the “Four point method” are explained below.

Three point method

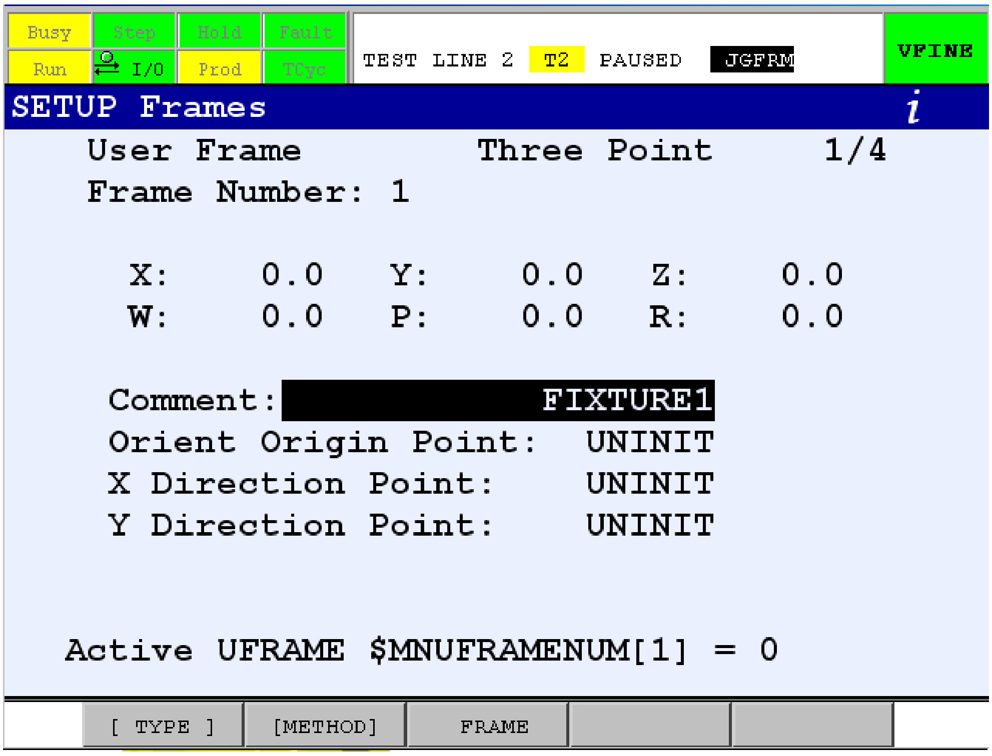
Teach the following three points: the origin of the x–axis, the point which specifies the positive direction of the x–axis, and the point on the x–y plane. In the example in the following figure, the user frame is set on the table so that the XY plane of the user frame is parallel with the table’s plan.



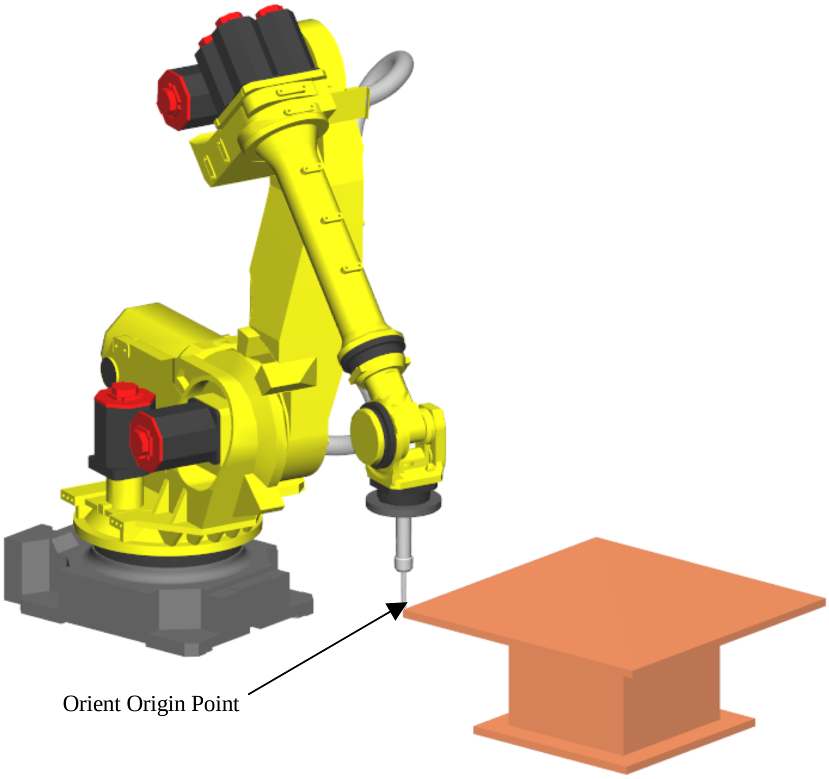
1 Press the MENU key. The screen menu is displayed.
2 Select “6 SETUP”
3 Press the F1 [TYPE]. The screen change menu is displayed.
4 Select Frames.
5 Press F3 [OTHER].
6 Select User Frame. User frame list screen is displayed.



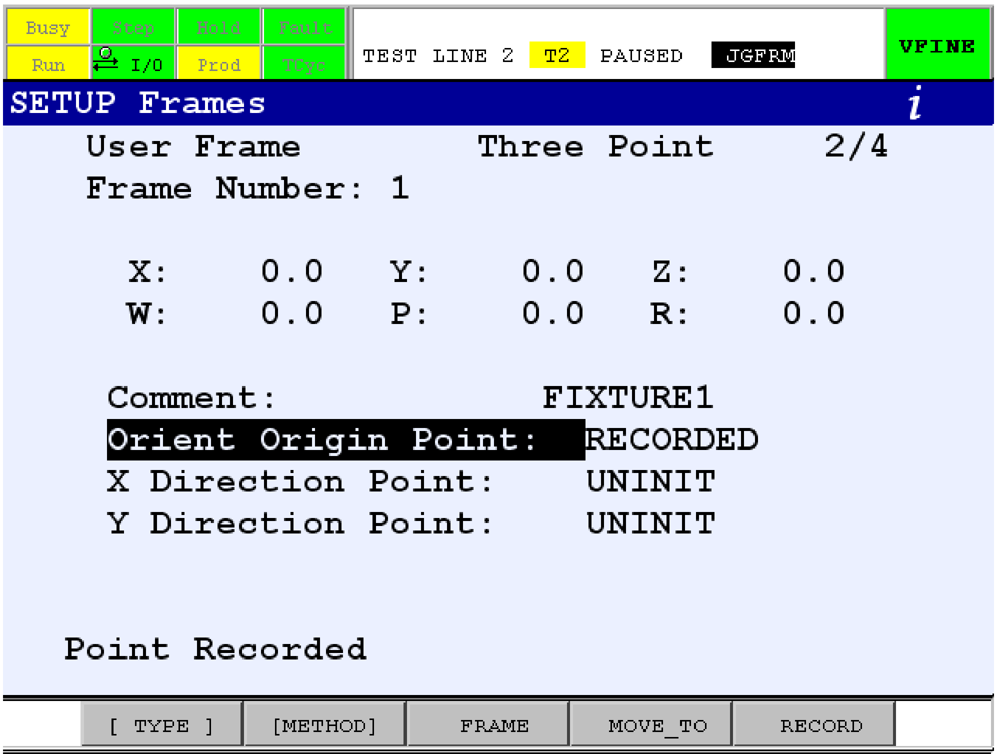
7 Move the cursor to the list of the user frame number you want to set.
8 Press F2 DETAIL. The user frame setup screen of the selected frame number is displayed.
9 Press F2 DETAIL.
10 Select Tree Point.



11 In order to make it easy to distinguish from other user frame numbers, adding a comment is recommended,
12 Move the cursor to the Orient Origin Point.
13 Jog the robot and record the Orient Origin Point with the pointer tool.

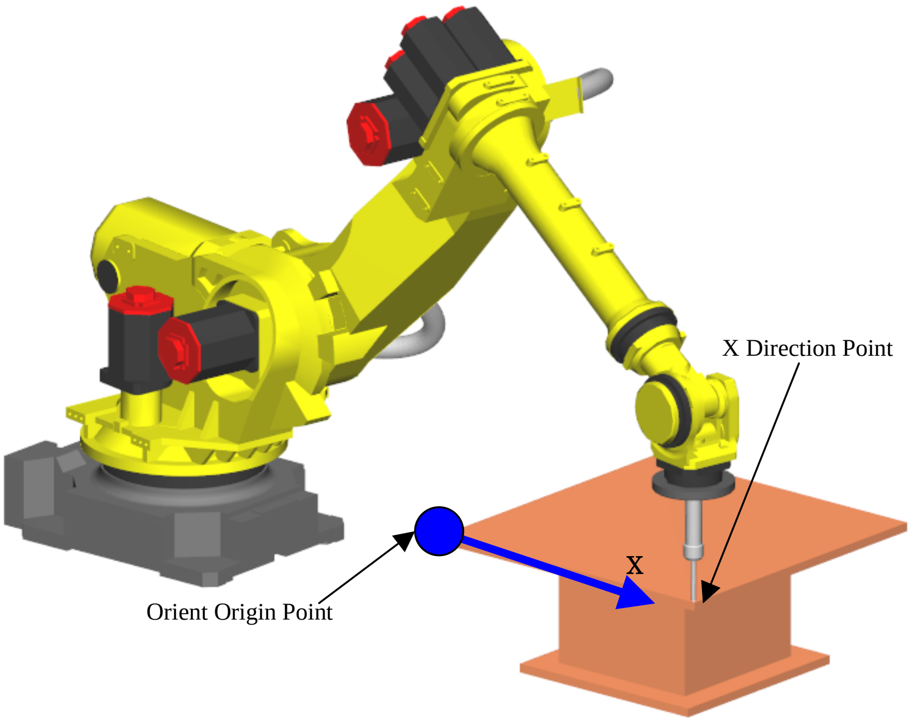


14 Press and hold the SHIFT key and press F5 RECORD to record the data of current position as the Orient Origin Point. RECORED is displayed once the position is taught.

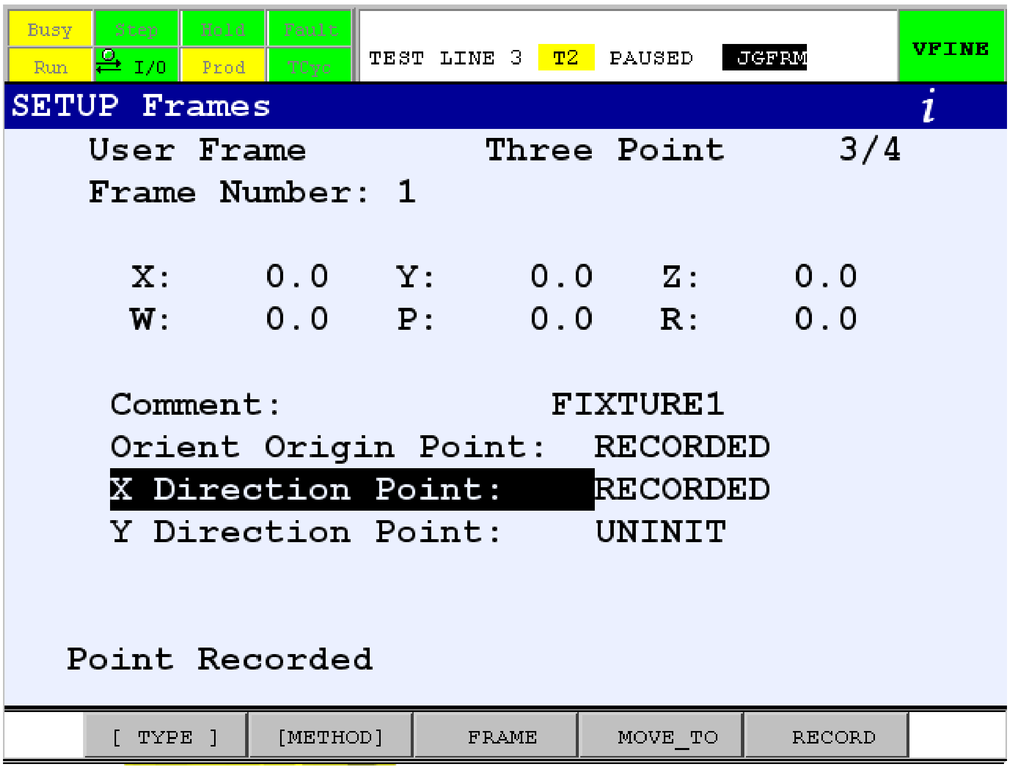


15 Move the cursor to the X Direction Point.

16 Jog the robot and record the X Direction Point with the pointer tool. The direction that connects the Orient Origin Point and the X Direction Point is the x–axis of user frame.

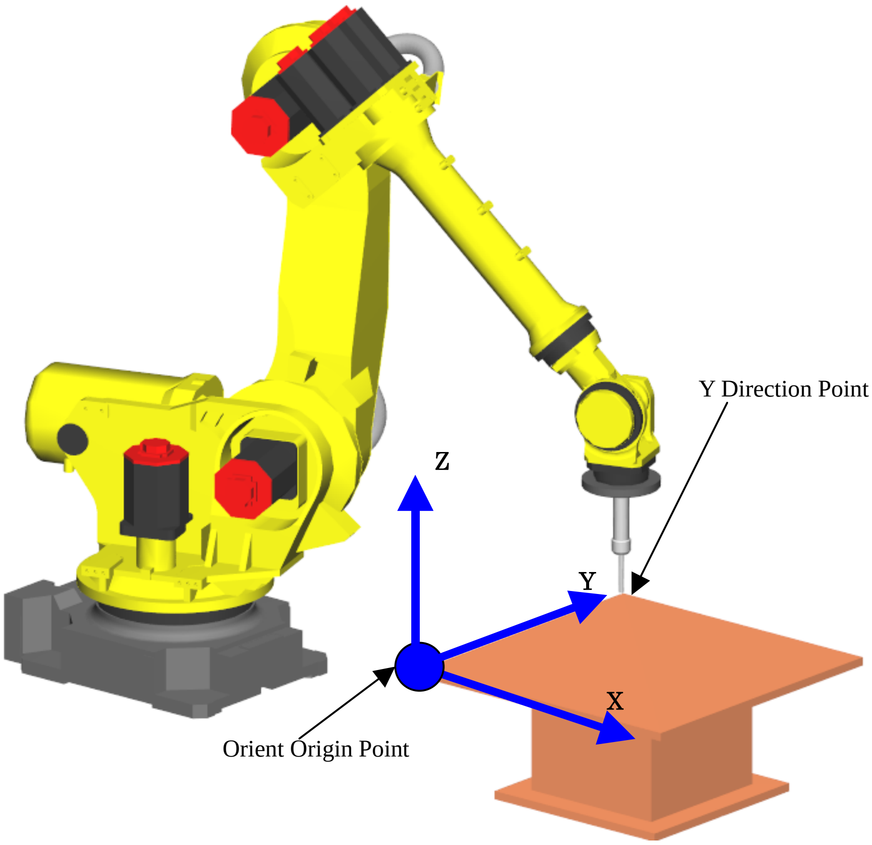


17 Press and hold the SHIFT key and press F5 RECORD to record the data of current position as the X Direction Point. RECORED is displayed once the position is taught.



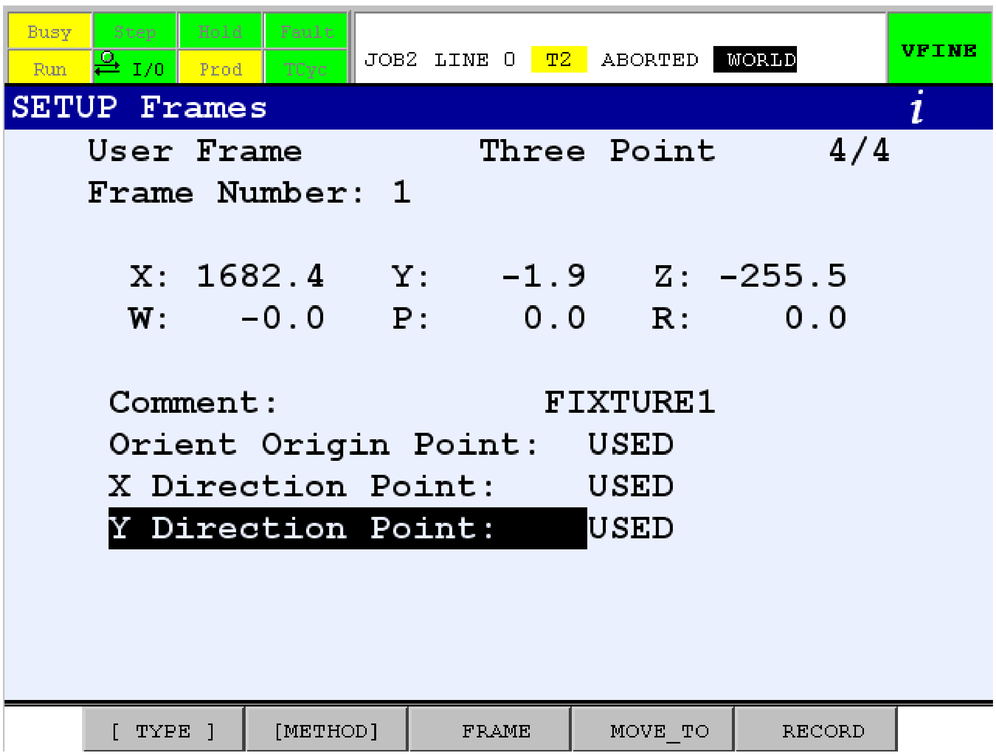
18 Move the cursor to the Y Direction Point.

19 Jog the robot and record the Y Direction Point with the pointer tool. Once the Y Direction Point is recorded, the XY plane of frame will be set.



20 Press and hold the SHIFT key and press F5 RECORD to record the data of current position as the Y Direction Point.

21 When all the reference points are taught, USED is displayed. The user frame has been set.

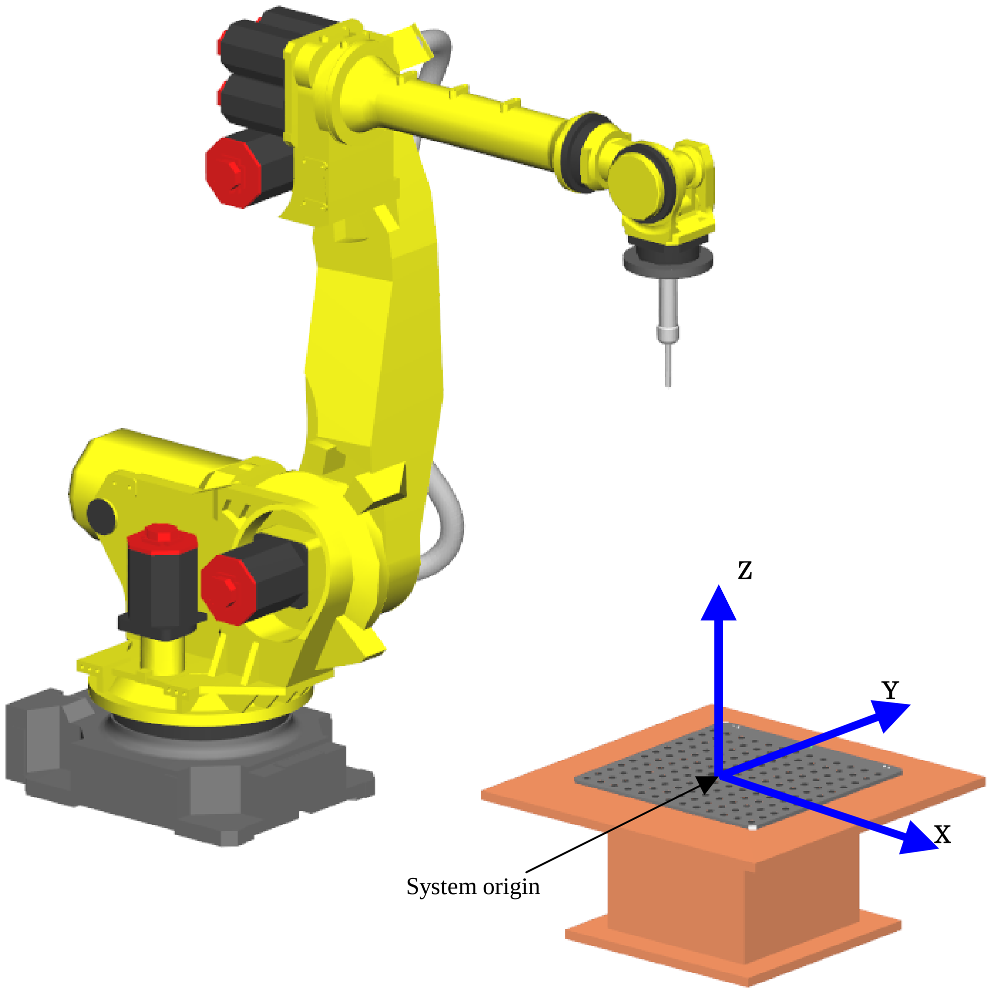


22 To display the user frame list screen, press the PREV key.

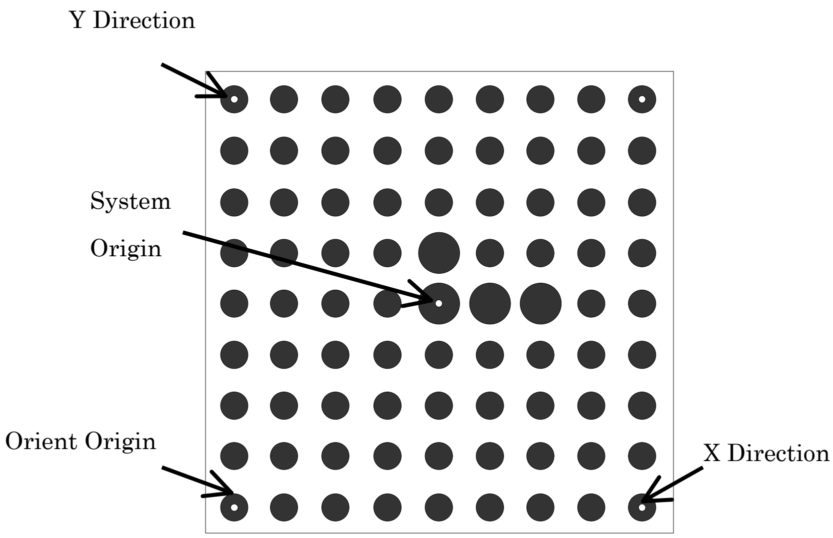
23 Press F5 SETIND and select the set user frame number as an effective user frame now.

Four point method

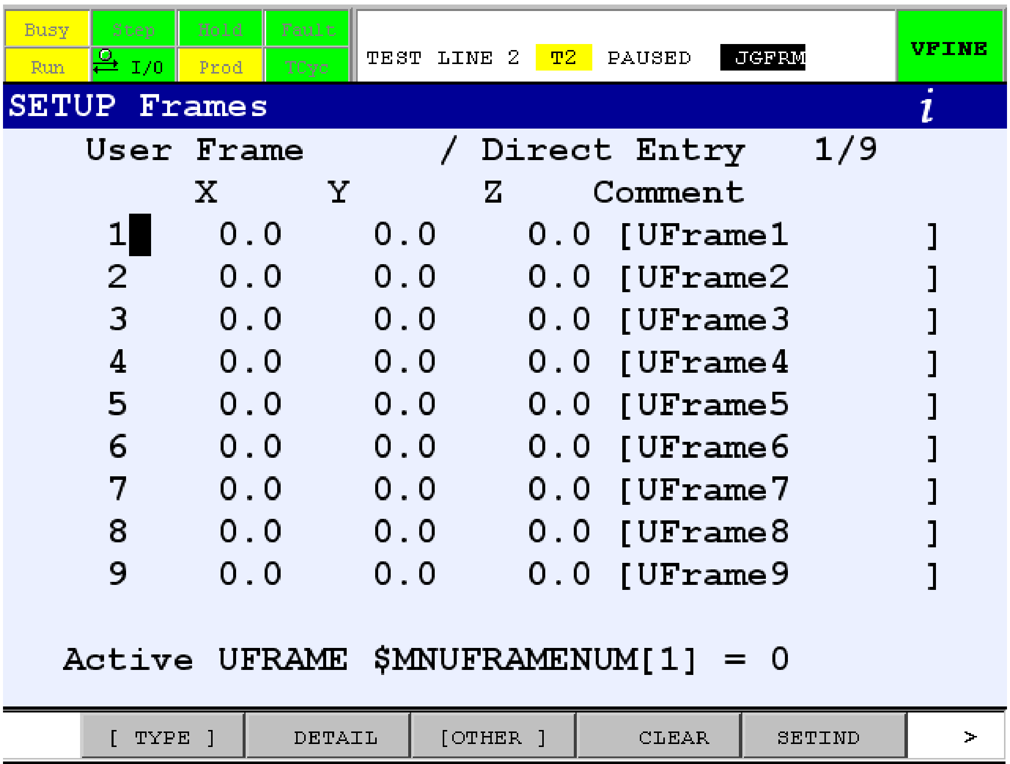
Teach the following four points: the origin of the x–axis parallel to the frame, the point which specifies the positive direction of the x–axis, a point on the x–y plane, and the origin of the frame. In the example of the following figure, the user frame is set on the fixed calibration grid.



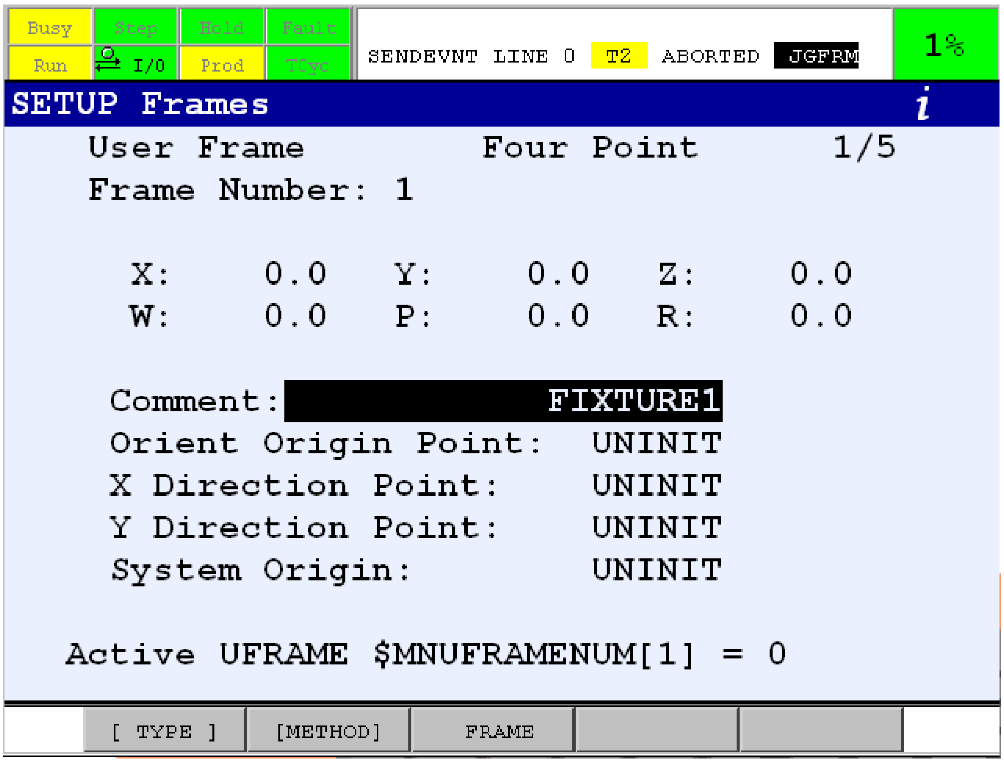
The following figure is a calibration grid. When perform the Grid Pattern Calibration for camera calibration, it is necessary to set up a user frame such as shown in the following figure. Since it is necessary to set a System origin on the center of a calibration grid, when the “Three point method” is used, the distance from the System Origin to the X Direction Point or the Y Direction Point is not maximized. By using “Four point method”, the accuracy of user frame setting becomes better.



1 Press the MENU key. The screen menu is displayed.
2 Select “6 SETUP”
3 Press the F1 [TYPE]. The screen change menu is displayed.
4 Select Frames.
5 Press F3 [OTHER].
6 Select User Frame. User frame list screen is displayed.



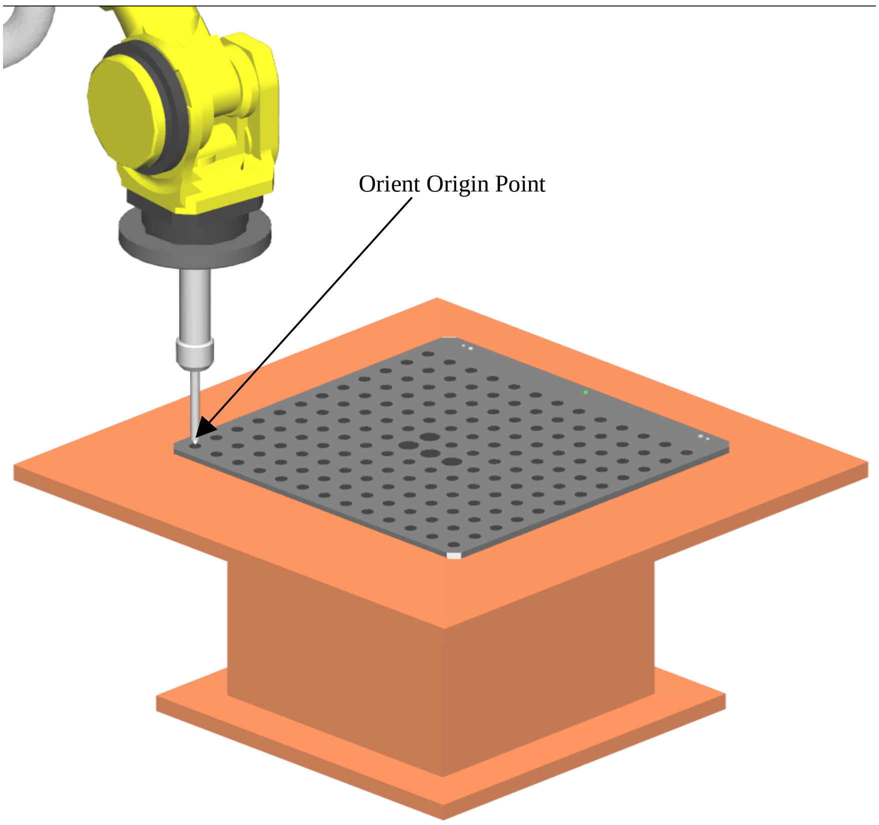
7 Move the cursor to the list of the user frame number you want to set.
8 Press F2 DETAIL. The user frame setup screen of the selected frame number is displayed.
9 Press F2 DETAIL.
10 Select Four Point.



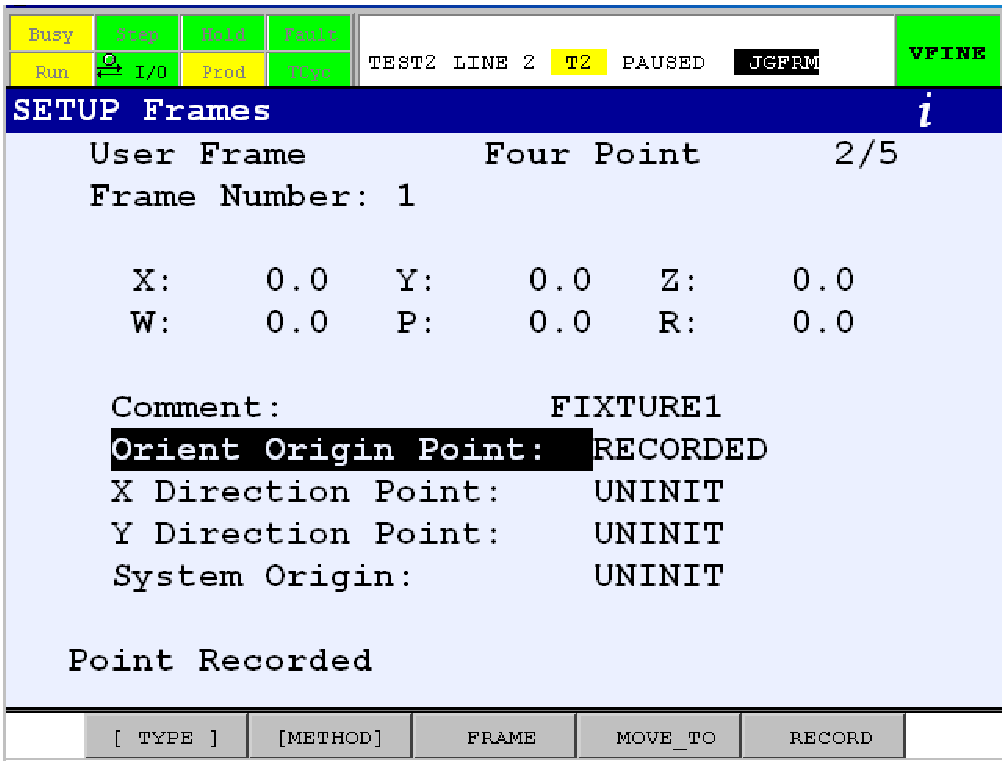
11 In order to make it easy to distinguish from other user frame numbers, adding a comment is recommended,

12 Move the cursor to the Orient Origin Point.

13 Jog the robot and record the Orient Origin Point with the pointer tool.

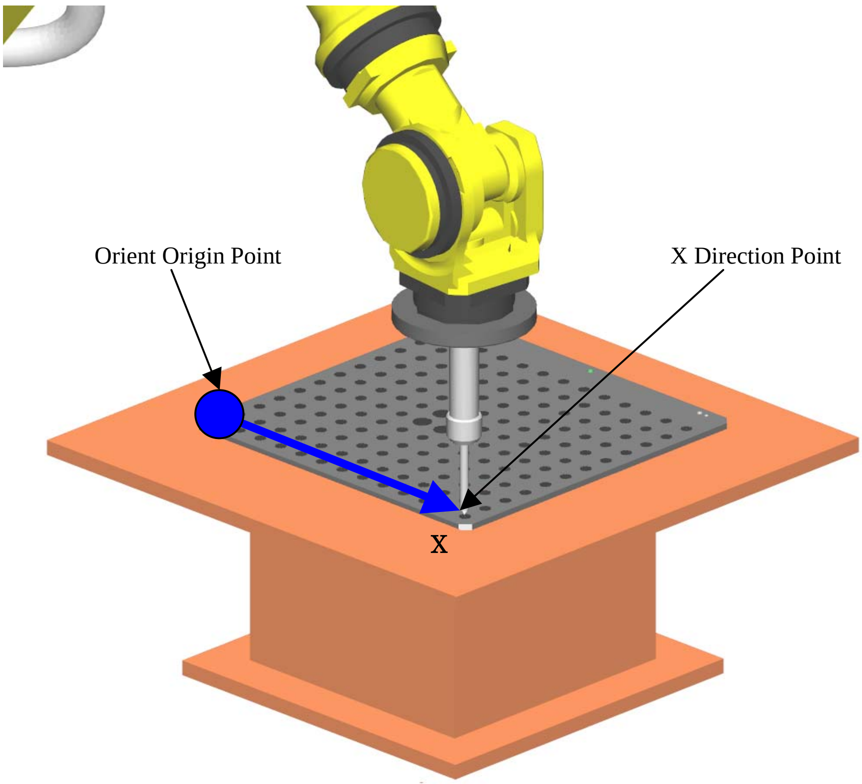


14 Press and hold the SHIFT key and press F5 RECORD to record the data of current position as the Orient Origin Point. RECORED is displayed once the position is taught.

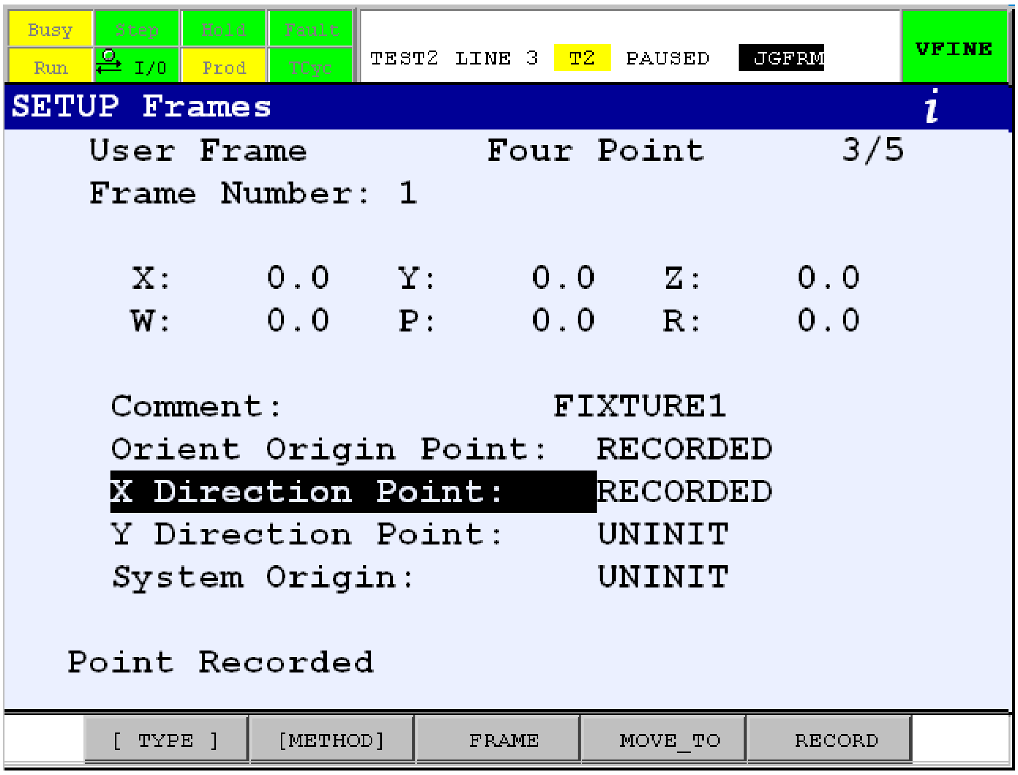


15 Move the cursor to the X Direction Point.

16 Jog the robot and record the X Direction Point with the pointer tool. The direction that connects the Orient Origin Point and the X Direction Point is the x–axis of user frame.

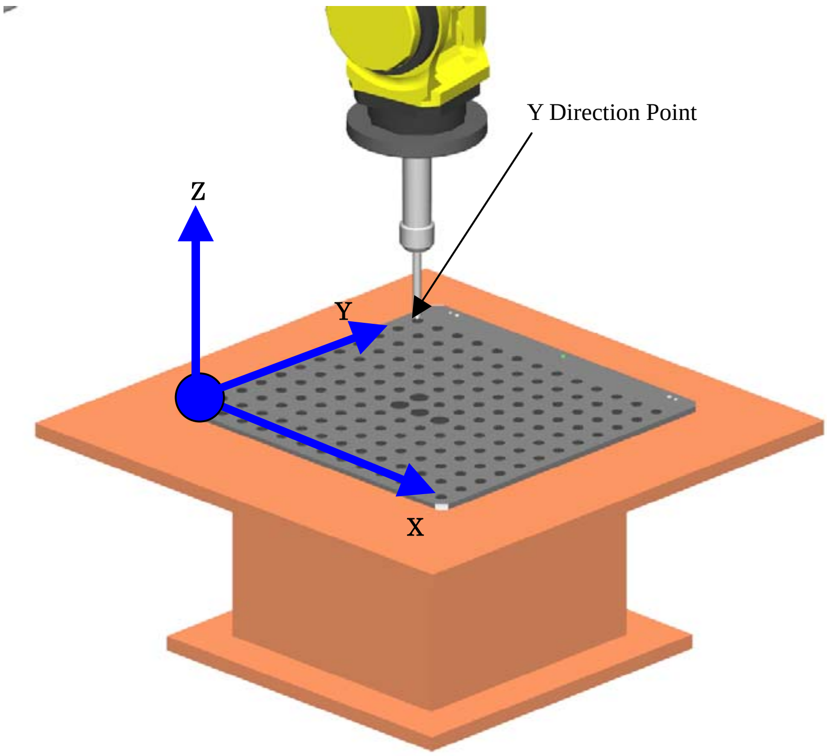


17 Press and hold the SHIFT key and press F5 RECORD to record the data of current position as the X Direction Point. RECORED is displayed once the position is taught.

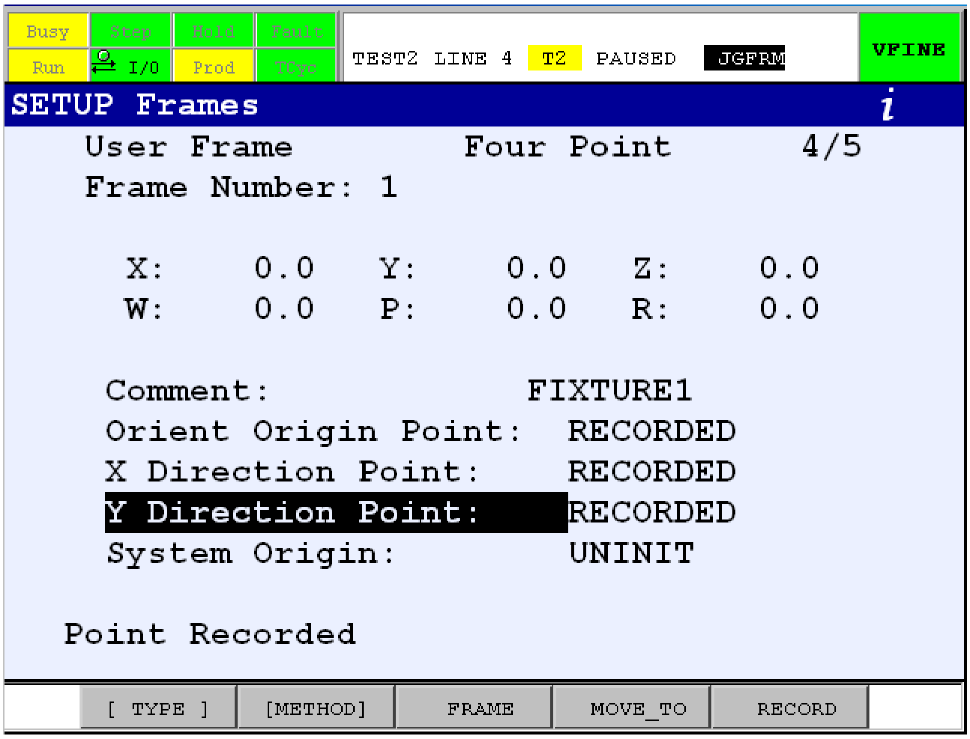


18 Move the cursor to the Y Direction Point.

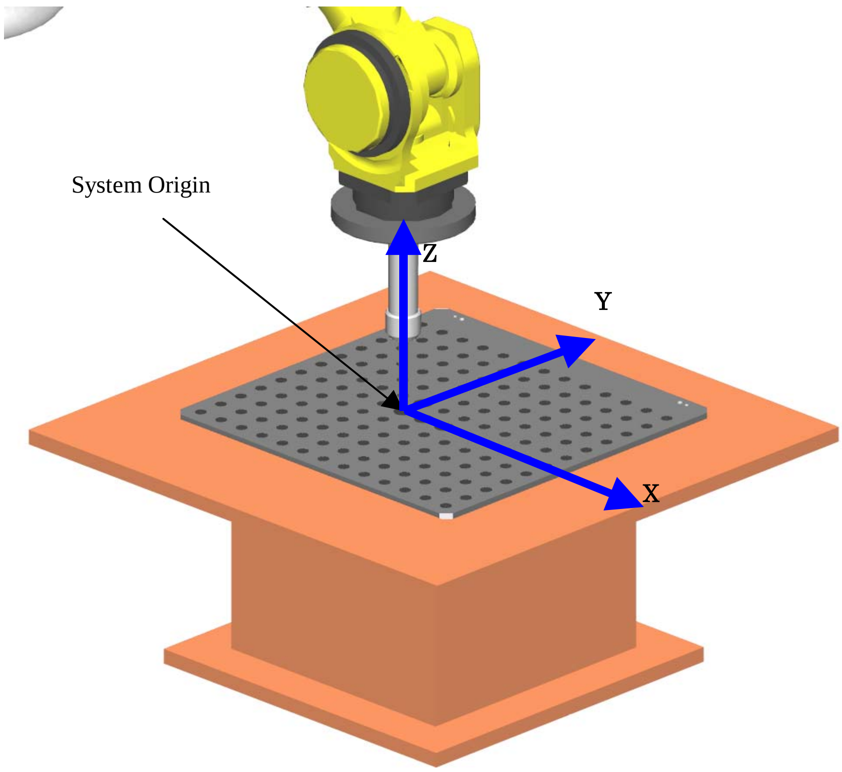
19 Jog the robot and record the Y Direction Point with the pointer tool. Once the Y Direction Point is recorded, the XY plane of frame will be set.



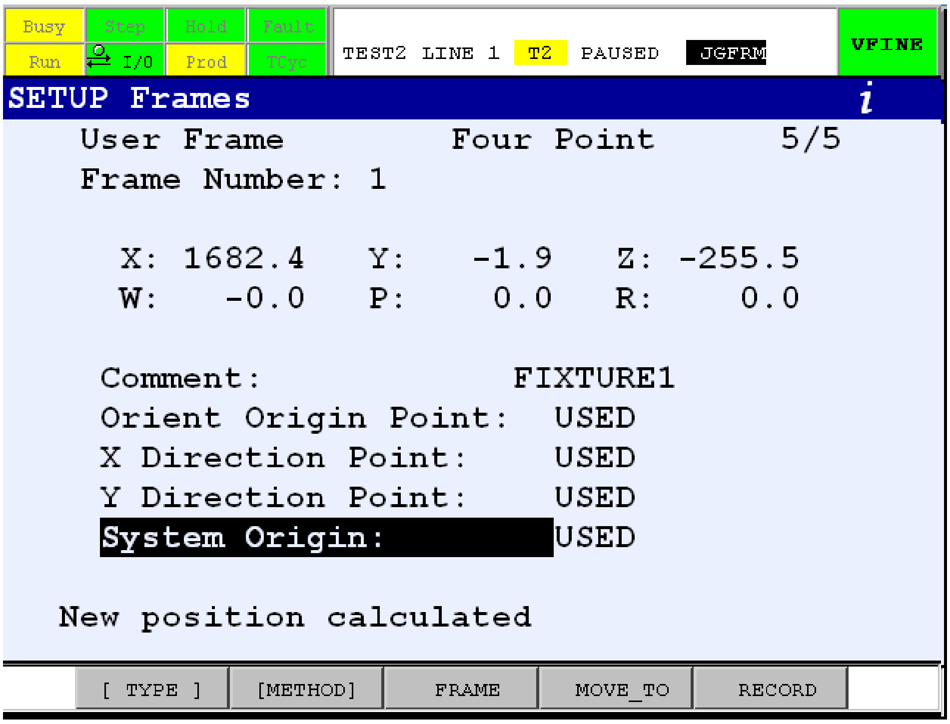
20 Press and hold the SHIFT key and press F5 RECORD to record the data of current position as the Y Direction Point. RECORED is displayed once the position is taught.



21 Jog the robot and record the System Origin with the pointer tool.



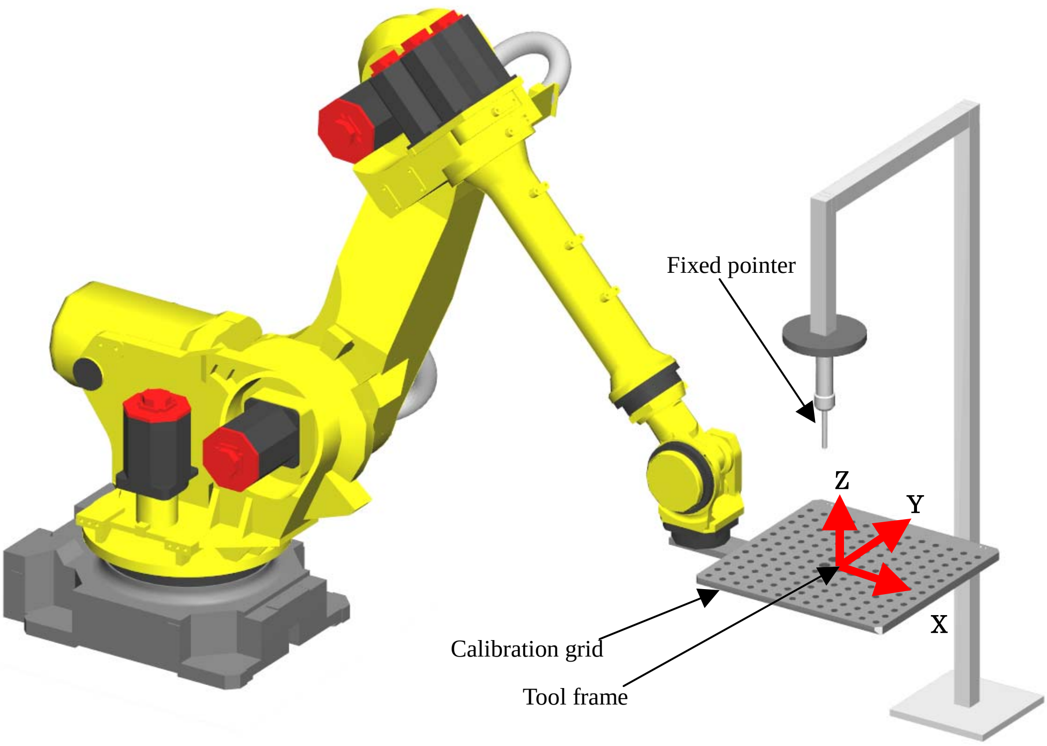
22 Press and hold the SHIFT key and press F5 RECORD to record the data of current position as the System Origin. When all the reference points are taught, USED is displayed. The user frame has been set.



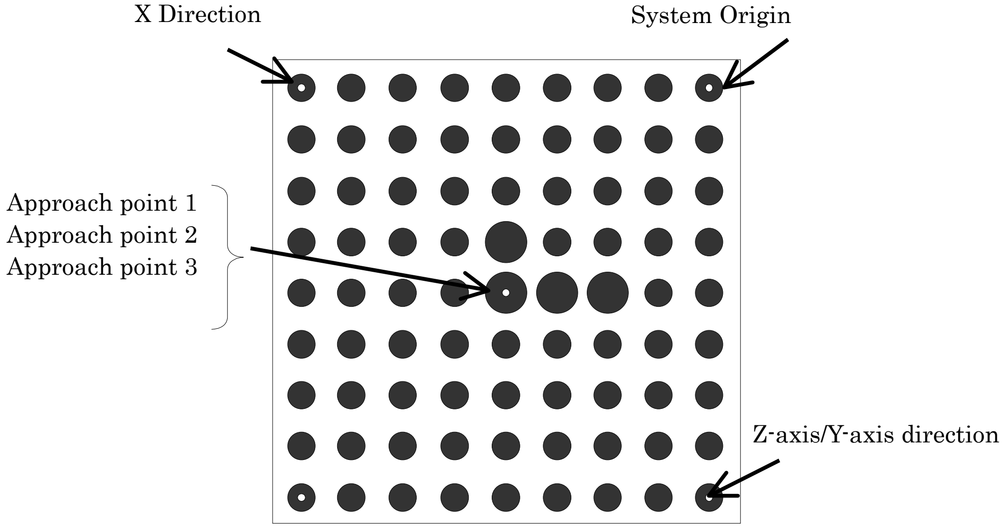
23 To display the user frame list screen, press the PREV key.
24 Press F5 SETIND and select the set user frame number as an effective user frame now.

9.1.2 Tool Frame Setting with a Pointer Tool

This subsection explains teaching a tool frame on the calibration grid that the is mounted on the robot end of arm tooling.



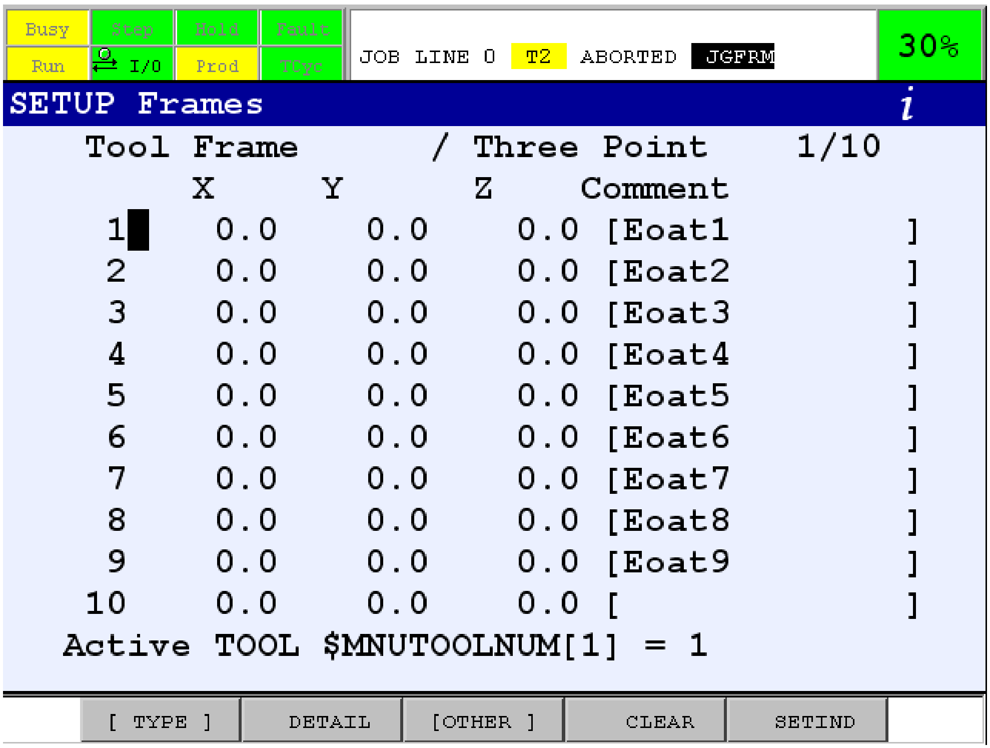
After the pointer for touch-up is secured to a secured stand, select “Tool Frame Setup / Six Point(XY)” or “Tool Frame Setup / Six Point(XZ)”, and teach the six points shown in the figure below by touch-up operation. The position of fixed pointer is arbitrarily.



The user tool set using the “Tool Frame Setup / Six Point(XZ)” method is rotated by 90 degrees about the X-axis with respect to a desired coordinate system. After the frame is taught using the points described above, **manually enter the value of W plus 90**.

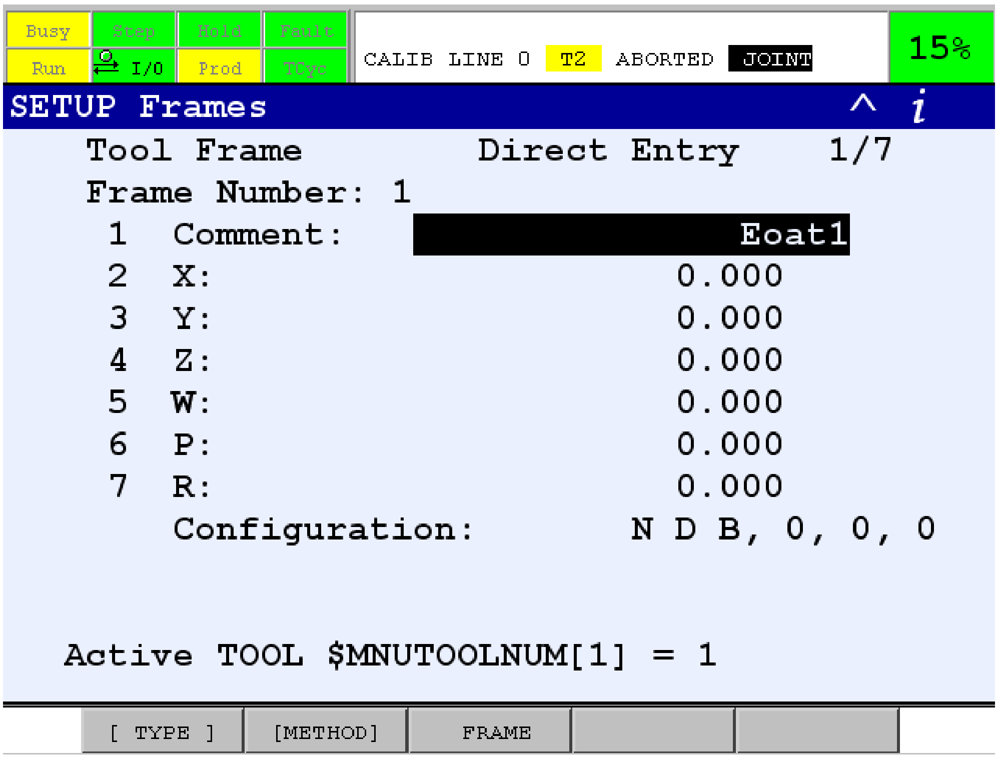
In the example in this subsection, “Tool Frame Setup / Six Point(XY)” is explained. Make sure that the calibration grid is fixed securely to the robot end of arm tooling so that it remains in place while the robot moves. Positioning pins or other appropriate means may be used so that the calibration grid can be mounted at the same position for each measurement. Moreover, set the tool frame accurately on the calibration grid. If the accuracy of this frame setting is low, the precision in handling of a workpiece by the robot is also degraded.

1 Press the MENU key. The screen menu is displayed.
2 Select “6 SETUP”
3 Press the F1 [TYPE]. The screen change menu is displayed.
4 Select Frames.
5 Press F3 [OTHER].
6 Select Tool Frame. Tool frame list screen is displayed.



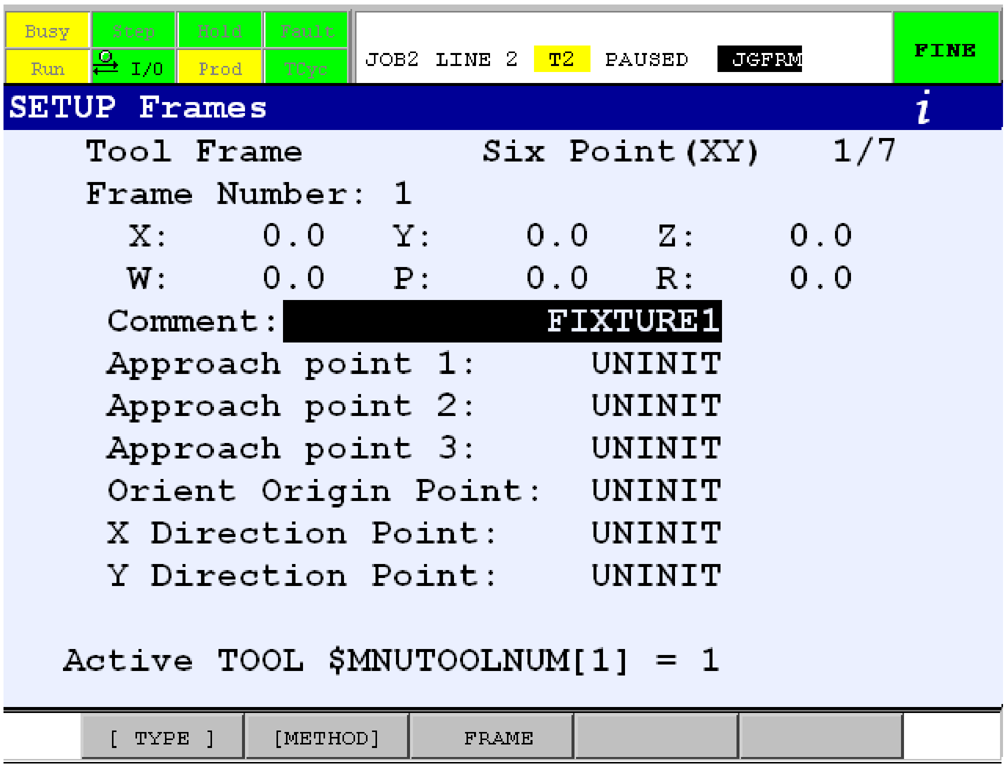
7 Move the cursor to the list of the tool frame number you want to set.

8 Press F2 DETAIL. The tool frame setup screen of the selected frame number is displayed.

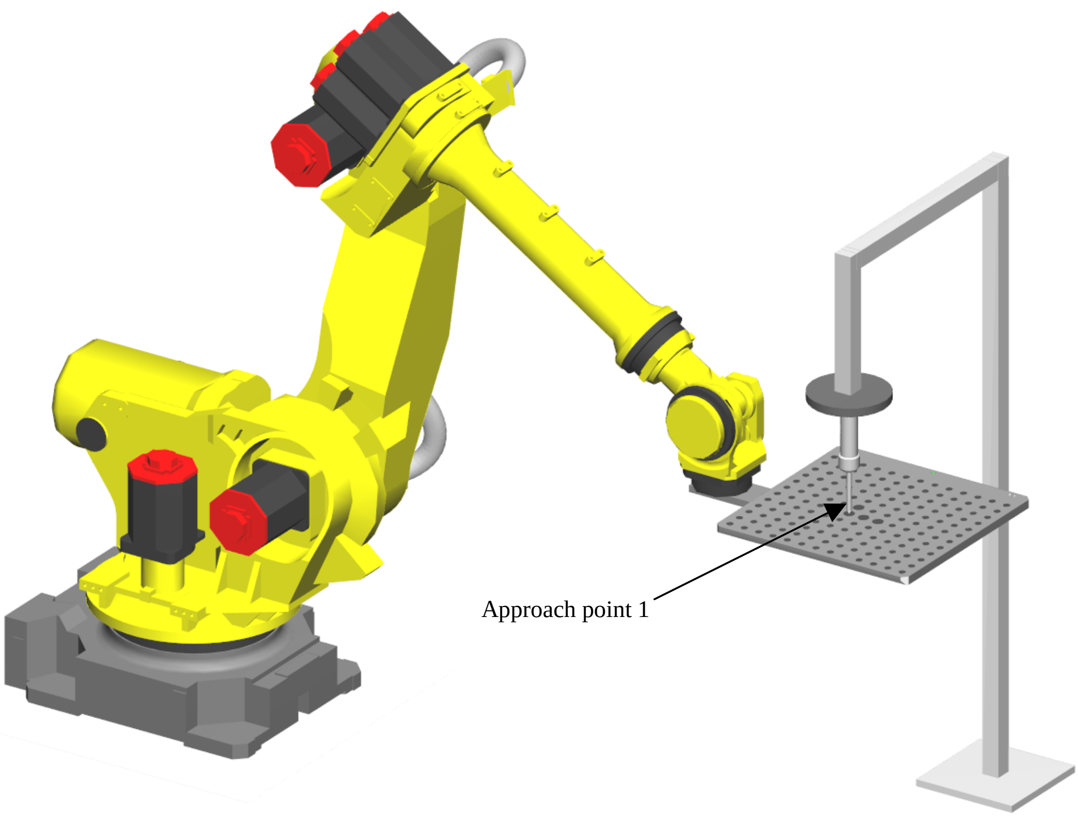


9 Press F2 DETAIL.

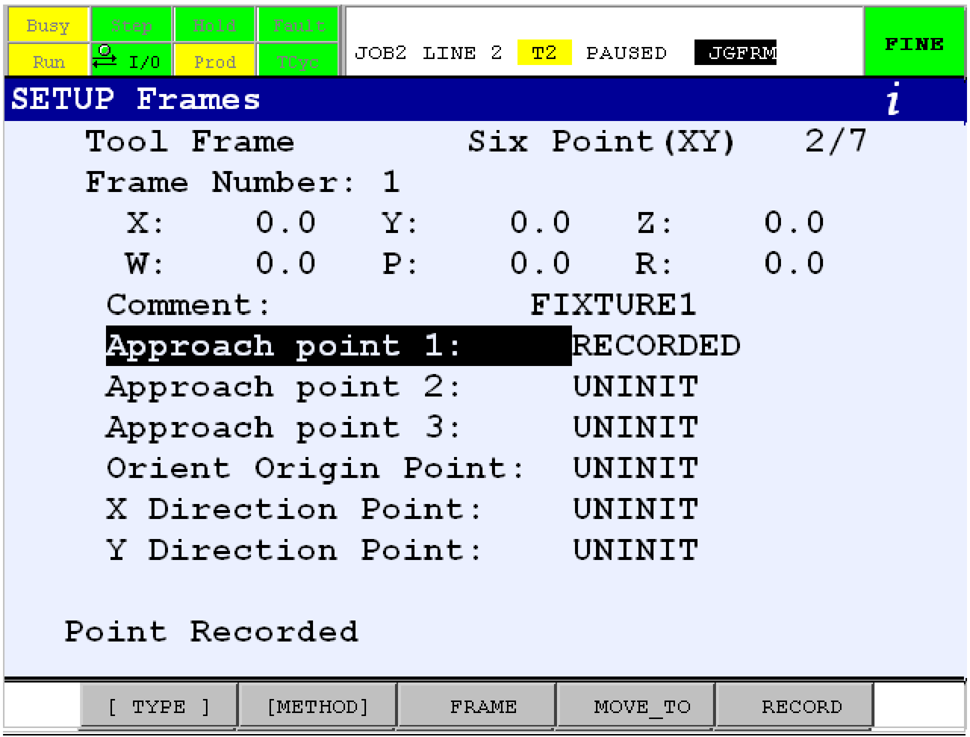
10 Select Six Point (XY).



11 In order to make it easy to distinguish from other user frame numbers, adding a comment is recommended,
12 Move the cursor to the Approach point 1.
13 Jog the robot and record the Approach point 1 with the fixed pointer.

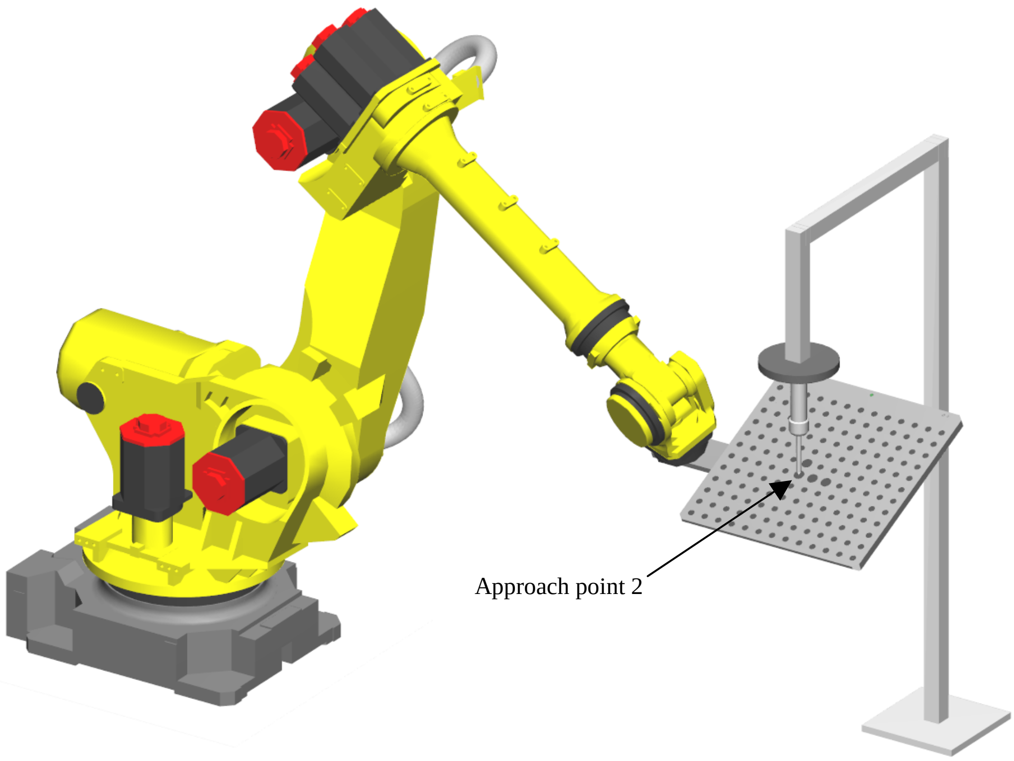


14 Press and hold the SHIFT key and press F5 RECORD to record the data of current position as the reference position. RECORED is displayed once the position is taught.

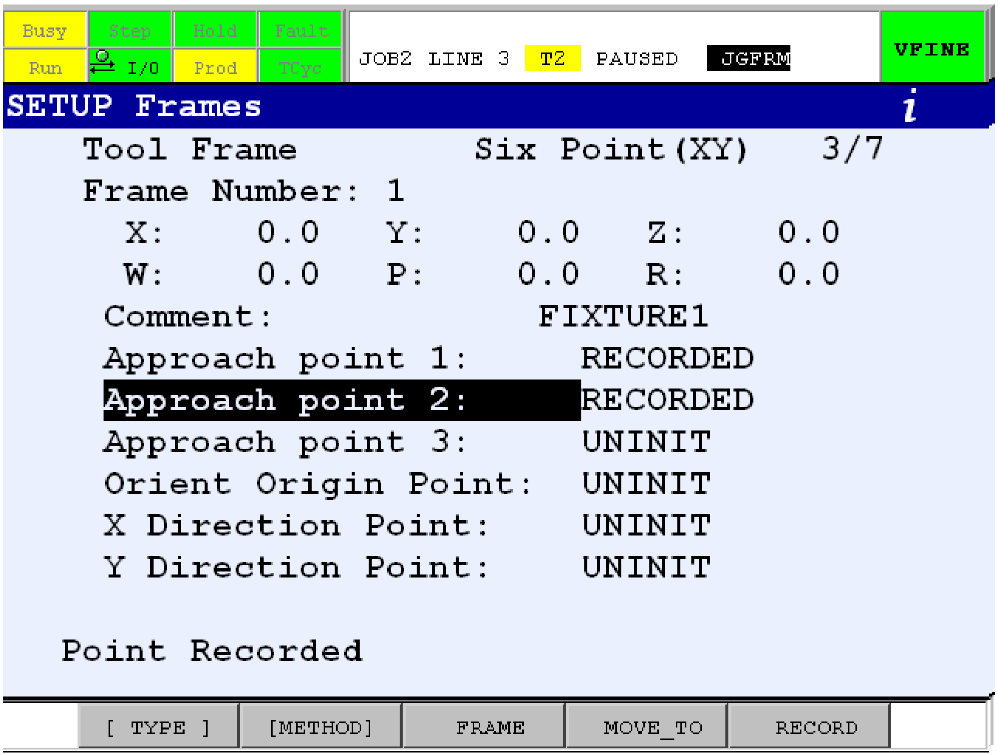


15 Move the cursor to the Approach point 2.

16 Jog the robot and record the Approach point 2 with the fixed pointer. The position of approach point 2 is same position as the approach point 1. However, the posture of approach point 2 is different from the posture of approach point 1.

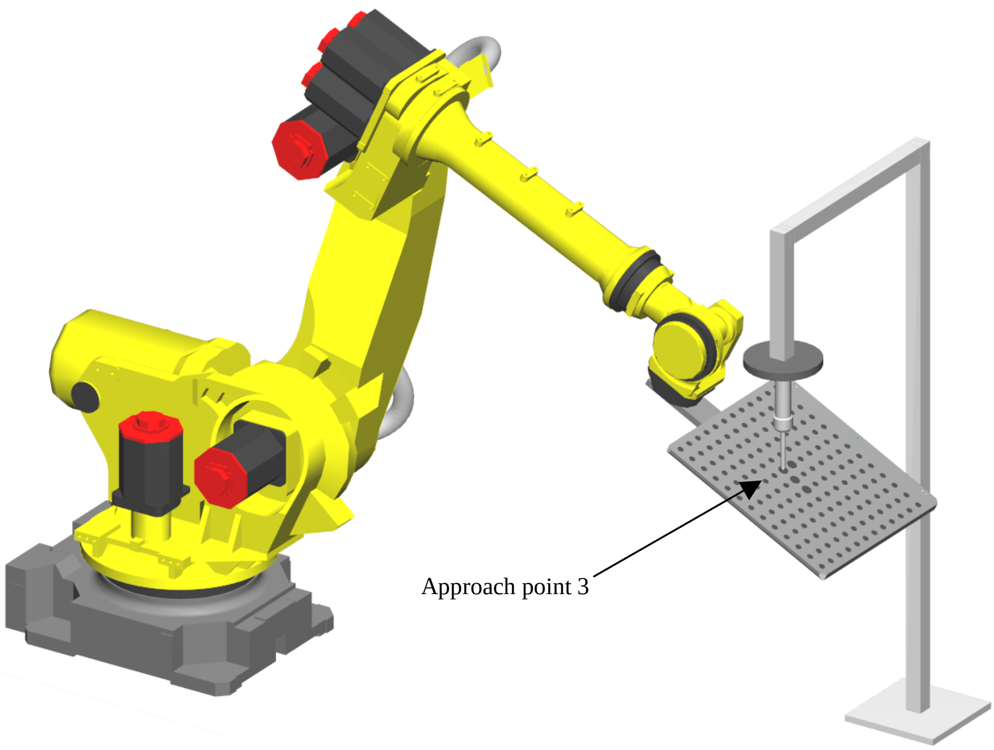


17 Press and hold the SHIFT key and press F5 RECORD to record the data of current position as the reference position. RECORED is displayed once the position is taught.

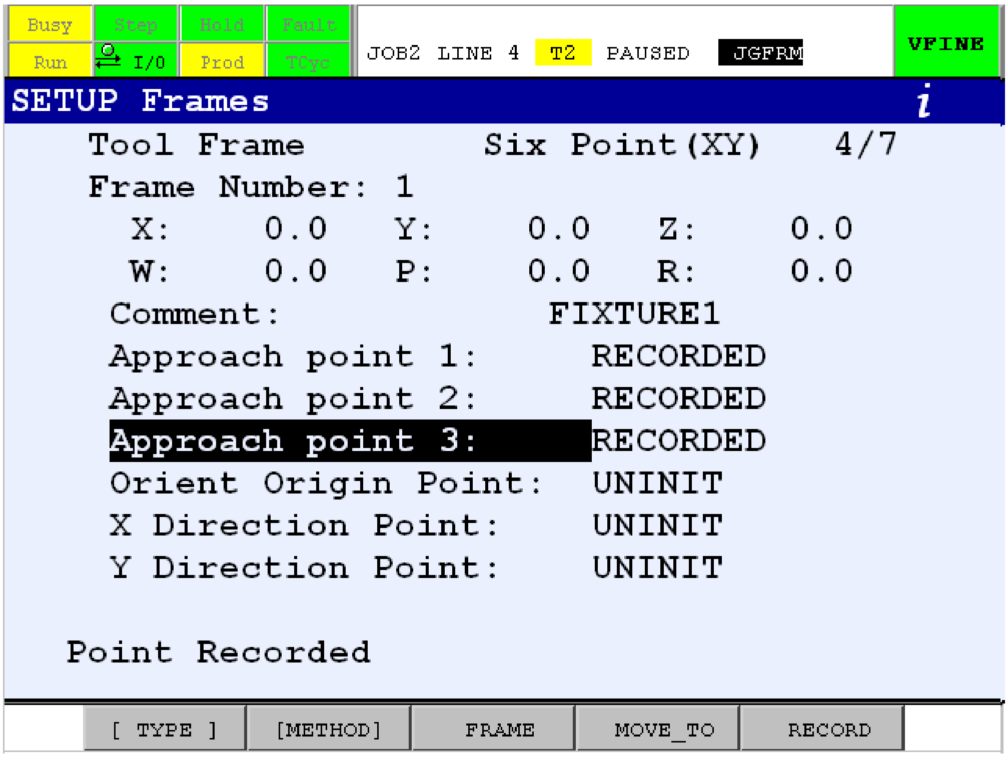


18 Move the cursor to the Approach point 3.

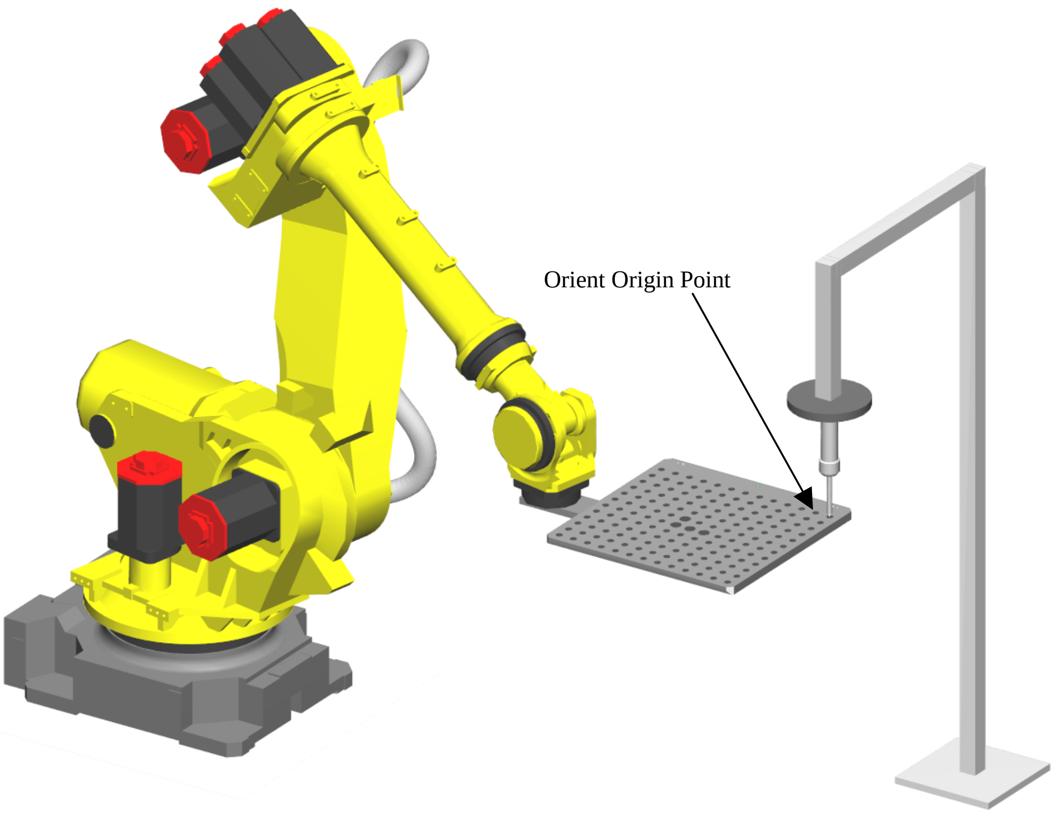
19 Jog the robot and record the Approach point 3 with the fixed pointer. The position of approach point 3 is same position as the approach point 1 and 2. However, the posture of approach point 3 is different from the posture of approach point 1 and 2.



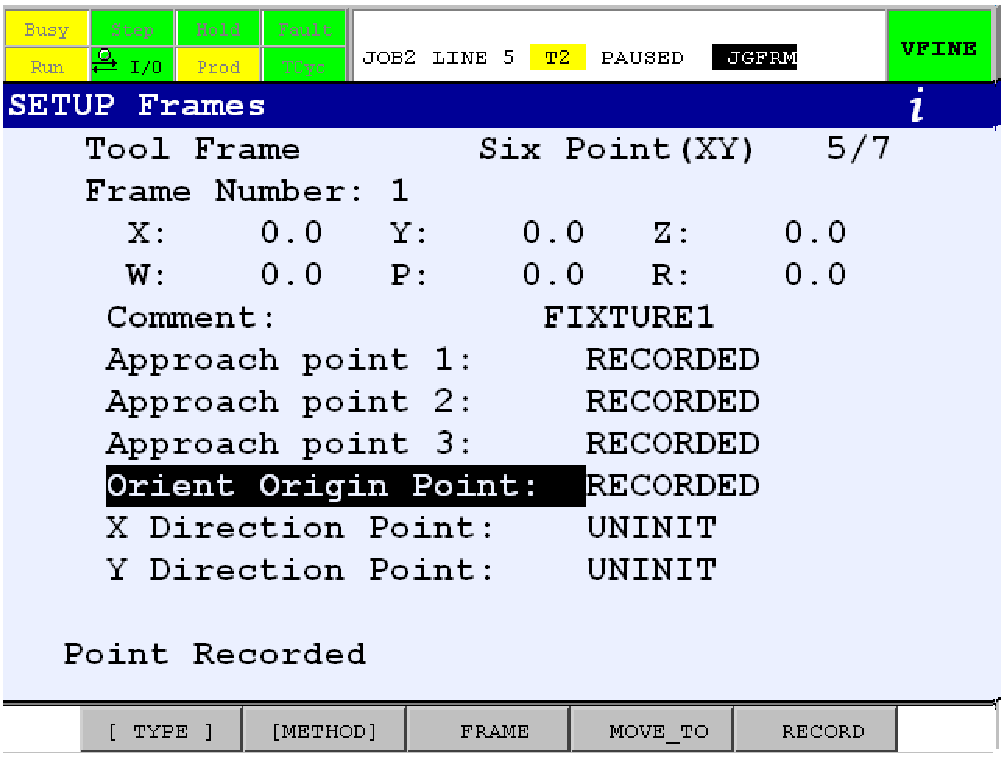
20 Press and hold the SHIFT key and press F5 RECORD to record the data of current position as the reference position. RECORED is displayed once the position is taught.



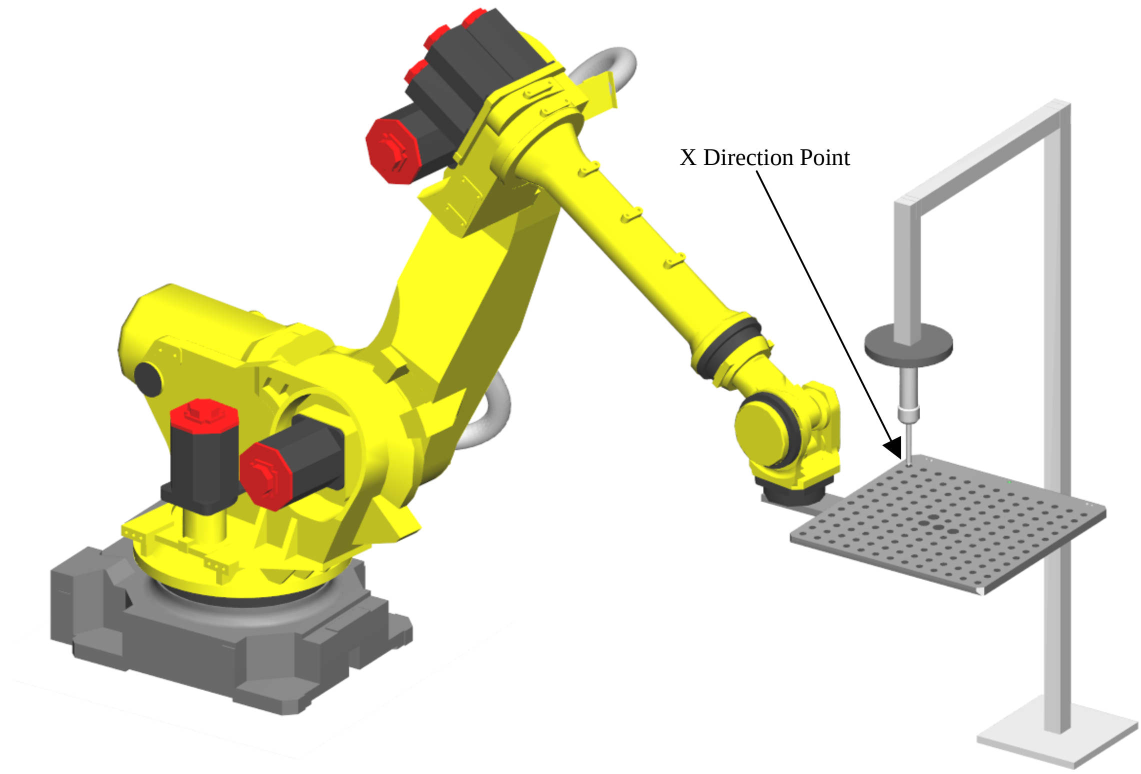
21 Move the cursor to the Orient Origin Point.
22 Jog the robot and record the Orient Origin Point with the fixed pointer.



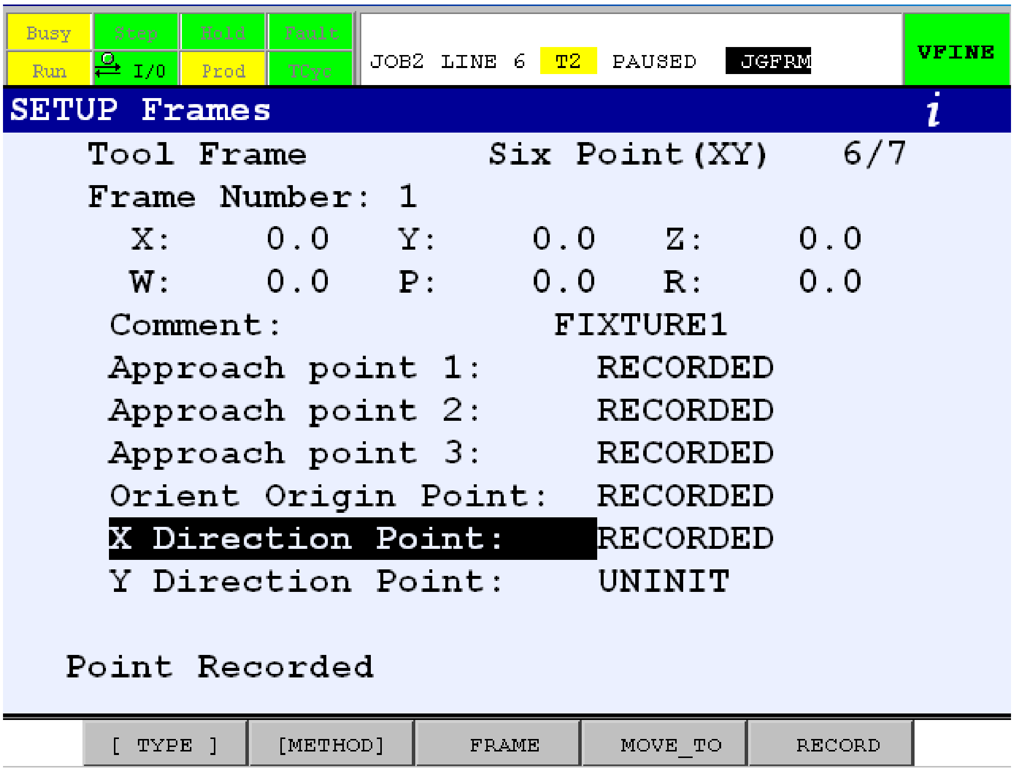
23 Press and hold the SHIFT key and press F5 RECORD to record the data of current position as the reference position. RECORED is displayed once the position is taught.



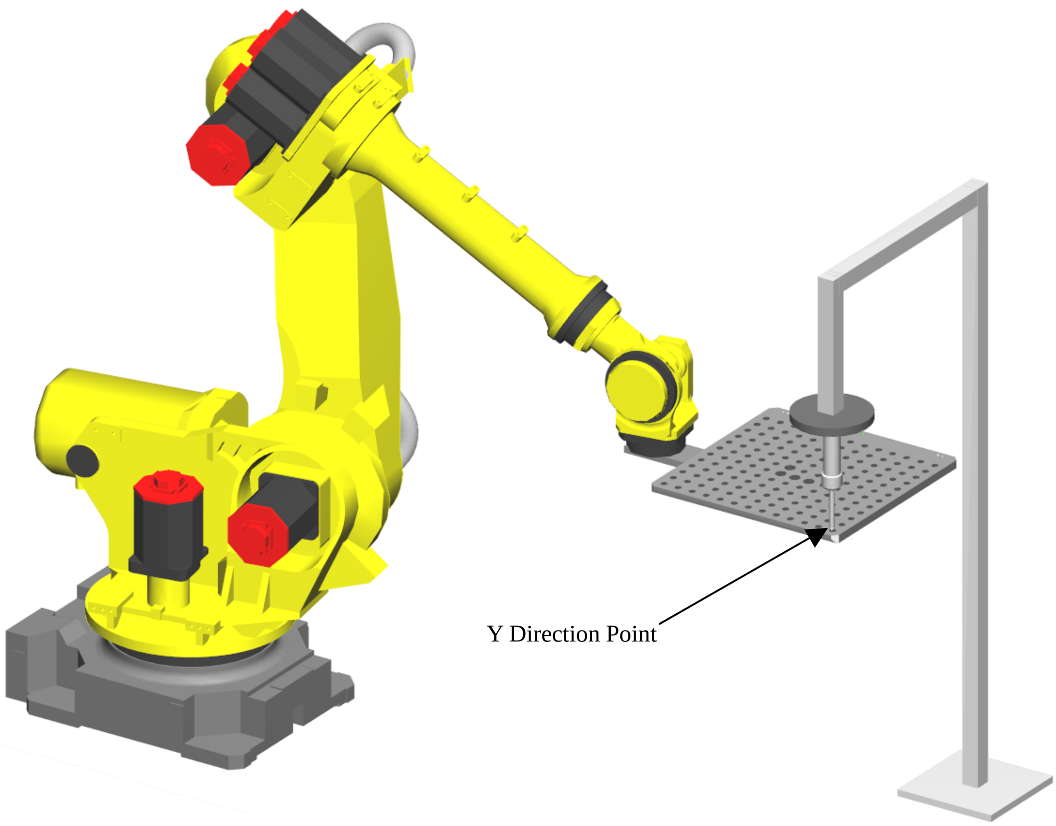
24 Move the cursor to the X Direction Point.
25 Jog the robot and record the X Direction Point with the fixed pointer.



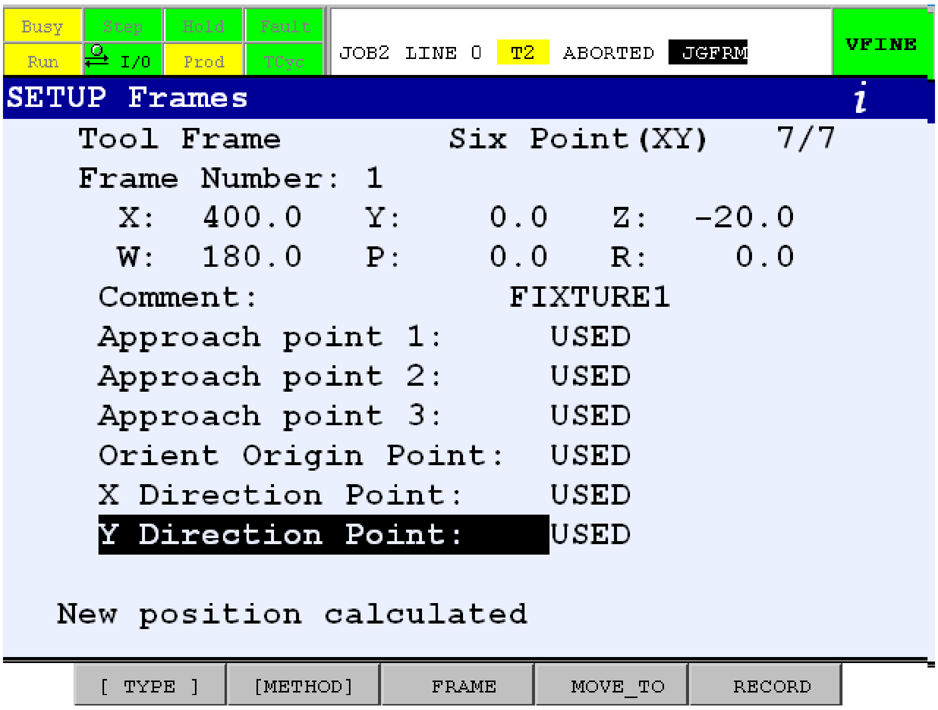
26 Press and hold the SHIFT key and press F5 RECORD to record the data of current position as the reference position. RECORED is displayed once the position is taught.



27 Move the cursor to the Y Direction Point.
28 Jog the robot and record the Y Direction Point with the fixed pointer.



29 Press and hold the SHIFT key and press F5 RECORD to record the data of current position as the reference position. When all the reference points are taught, USED is displayed. The tool frame has been set.

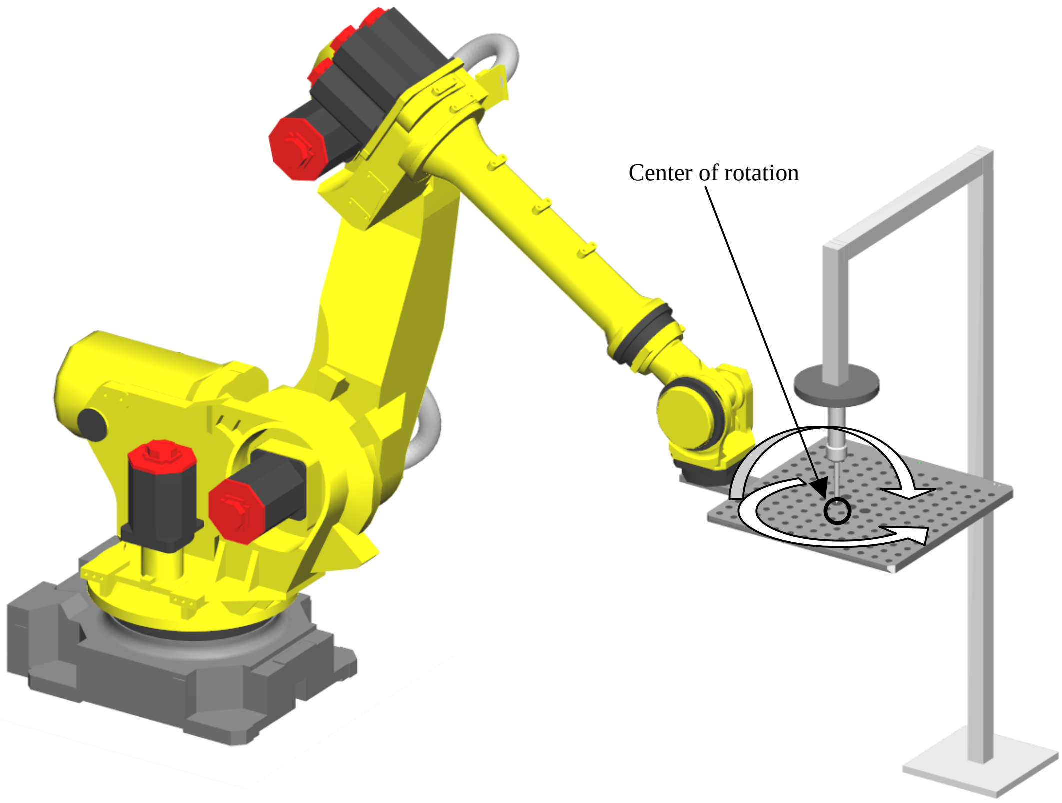


30 To display the tool frame list screen, press the PREV key.

31 Check the TCP is set accuracy. Press F5 SETIND and select the set tool frame number as an effective tool frame now.

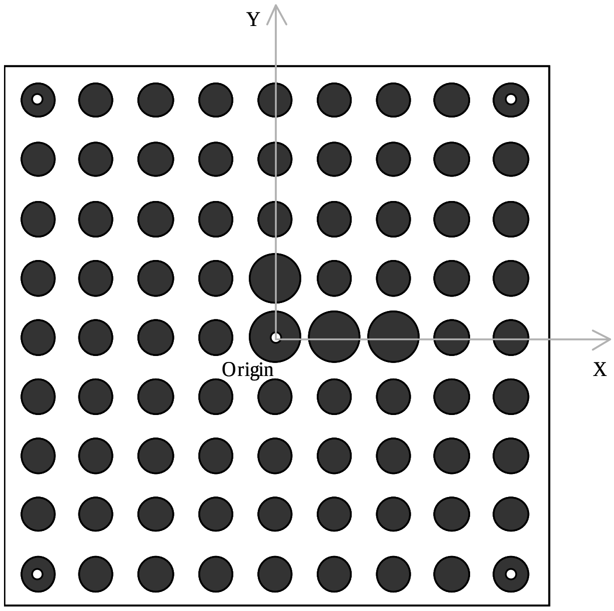
32 Jog the robot and record the center of calibration grid (Approach point 1, 2 or 3) with the fixed pointer.

33 Jog the robot around TCP and change the posture (w, p, r) of calibration grid. If tool frame is set accuracy, the tip of fixed pointer always points to the center of calibration grid.



9.2 FRAME SETTING WITH THE AUTOMATIC GRID FRAME SET FUNCTION

In the Automatic Grid Frame Set Function, the robot holding the camera or the robot holding calibration grid automatically moves to change relative position and orientation between the camera and the calibration grid, and find the grid pattern repeatedly. Finally, the position of the calibration grid frame relative to robot world frame or the robot face plate is identified. When the Automatic Grid Frame Set Function is executed, a frame is set on the calibration grid, as shown in the following figure.



Compared with the manual frame teaching method, the function offers a number of merits, including accurate setting of the frame without requiring user skills, no need for touch-up pointers or to set the TCP for touch-up setting, and semi-automatic easy-to-do operation.

> ⚠ **CAUTION**
> The Automatic Grid Frame Set Function is usable with 6-axis robots only. The function cannot be used with 4-axis robots and 5-axis robots.

9.2.1 Setting Procedure

Use the following setup procedure for the Automatic Grid Frame Set Function:

1. Mounting the calibration grid

⇩

2. Camera data creation and teaching

⇩

3. Setting the parameters

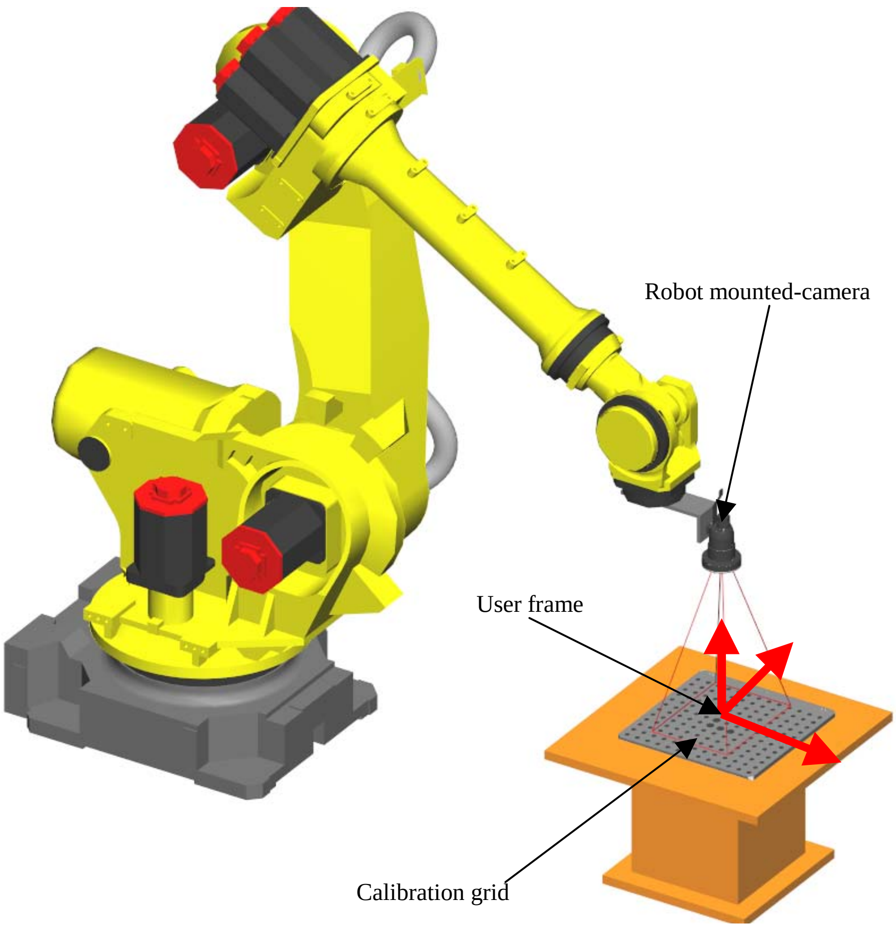
⇩

4. Run Measurement

9.2.1.1 Mounting the calibration grid

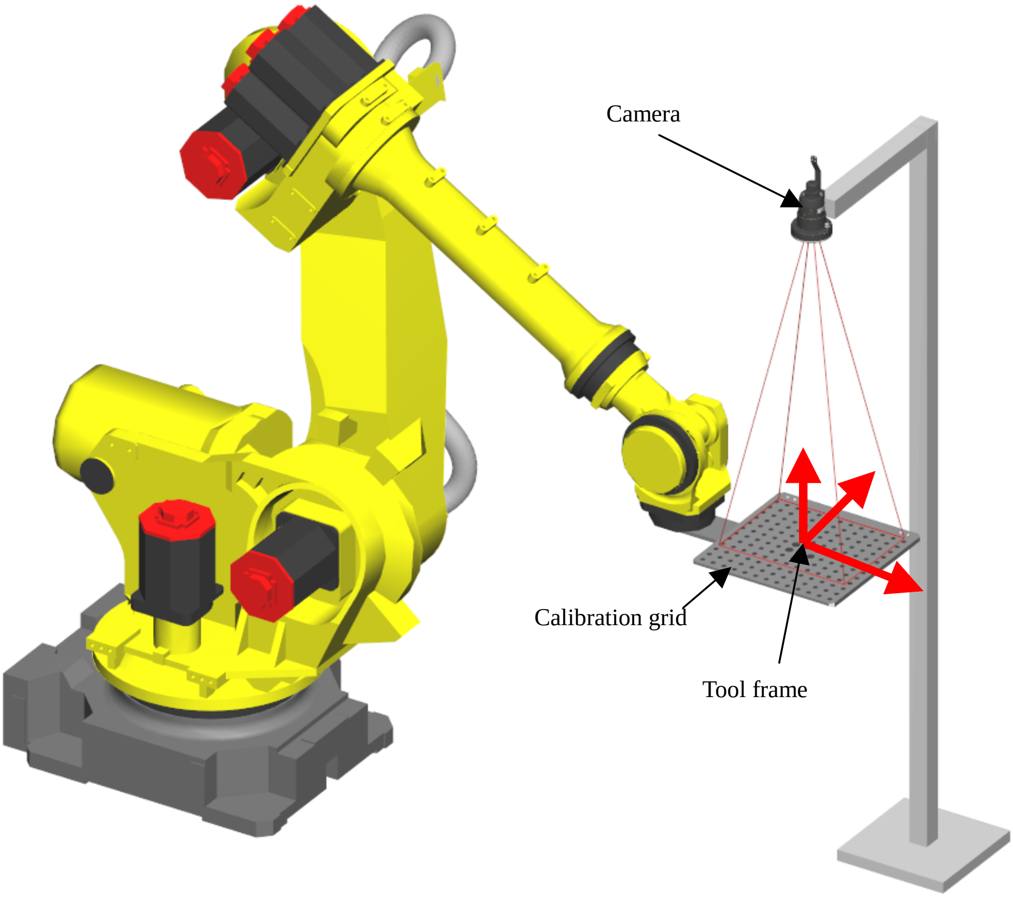
When the calibration grid is secured to a fixed surface

When the calibration grid is secured to fixed surface, a camera mounted on the robot end of arm tooling is used to measure the position of the calibration grid frame. The Automatic Grid Frame Set Function identifies the position of the calibration grid frame relative to the robot world frame , and sets the results in a user specified user frame. When useing a robot-mounted camera, the Automatic Grid Frame Set Function can be performed with the camera currently used. When use a fixed camera, prepare different camera for the Automatic Grid Frame Set Function separately. Then, perform the Automatic Grid Frame Set Function using the camera attached to the temporary position on the robot end of arm tooling.



When the calibration grid is mounted on the robot

When the calibration grid is mounted on the robot, a fixed camera is used to measure the position of the calibration grid frame. The robot moves the calibration grid within the field of view of the fixed camera. The Automatic Grid Frame Set Function identifies the position of the calibration grid frame relative to the robot face plate, and the results are written in a user defined user tool. The Automatic Grid Frame Set Function can be performed with the camera currently used. When there is not sufficient space to perform Automatic Grid Frame Set Function with the camera currently used, prepare different fixed camera and Automatic Grid Frame Set Function can be performed.

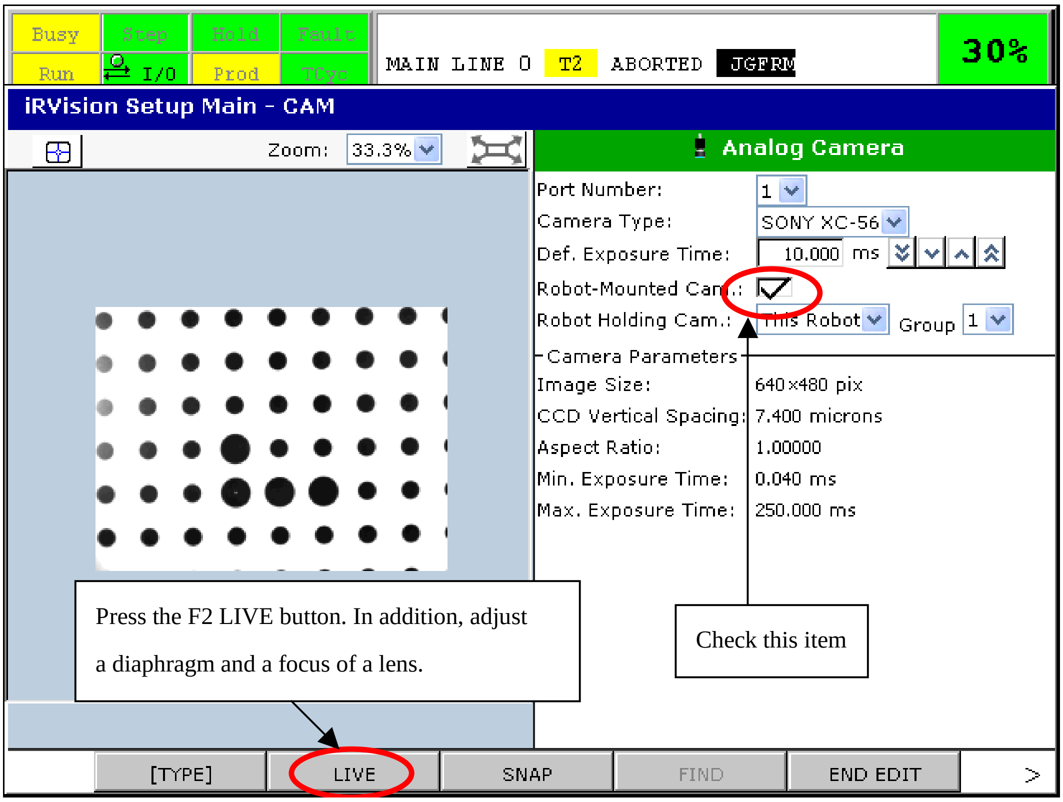


Make sure that the calibration grid is fixed securely so that it does not move during measurement.

> **NOTE**
> To prevent unnecessary circles from being found, check that the calibration grid is free of dirt and flaws. Spreading a plain sheet in the background is effective. Also, make sure to cover the printed text on the calibration grid. Monitor the Runtime Screen while running the utility to verify that unnecessary circles are not found.

9.2.1.2 Camera setting data creation and teaching

With *i*RVision, items such as the camera type and the camera installation method are set in camera setup. Whether to install a camera on the robot or on a fixed stand is set in the camera setup. When using a robot-mounted camera, be sure to check this item. When using a fixed camera, do not check "Robot-Mounted Camera".

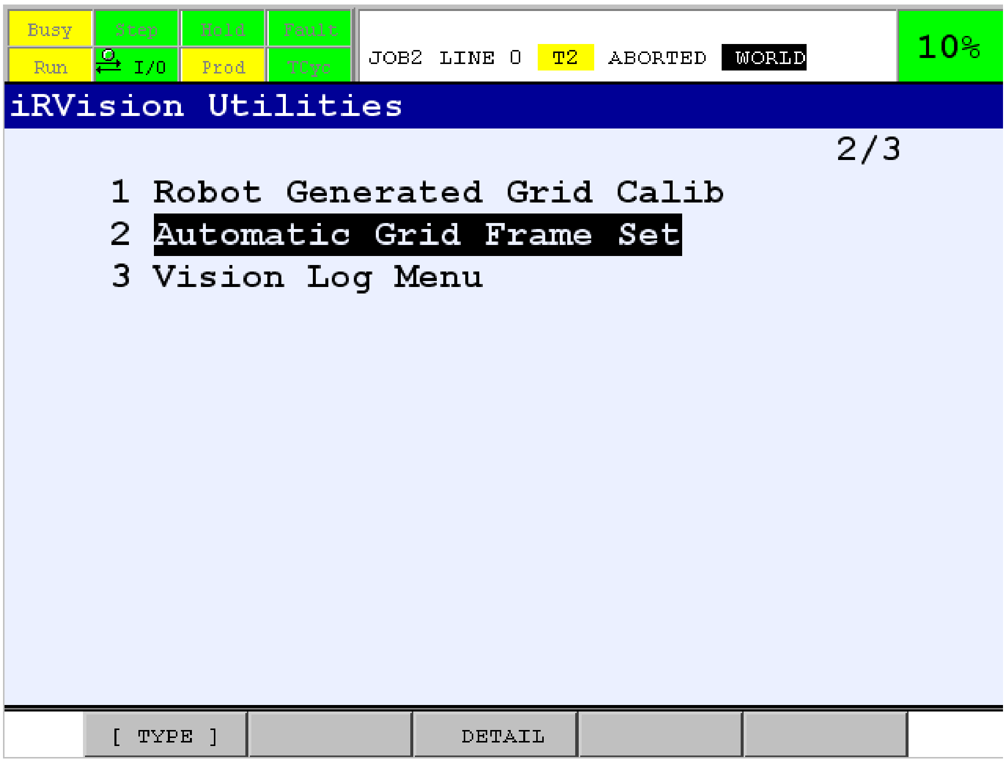


Press the F2 LIVE button, and adjust the aperture and a focus of a lens

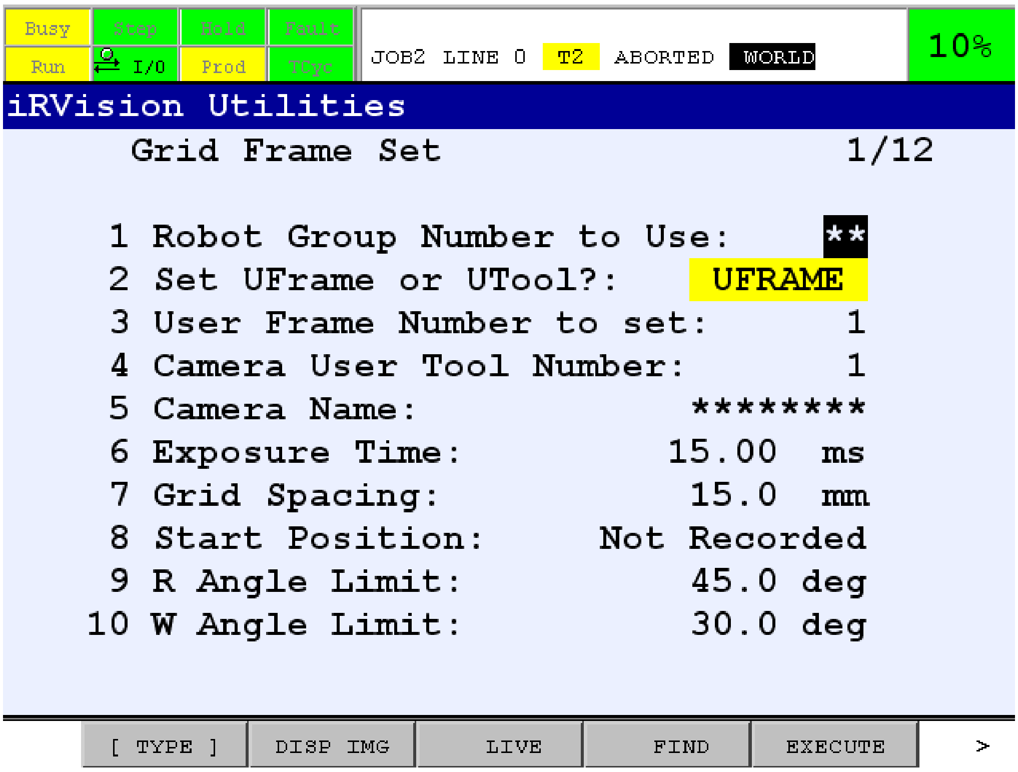
9.2.1.3 Setting the parameters

Set up the calibration data. Move to the UTILITY MENU page in the following procedures.

1 Press the MENU key on teach pendant, and select the “5 Vision Utilities” in the “8 *i*RVision”.



2 If you select “Grid Frame Set” on the *i*RVision utility menu, a menu like the one shown below appears.



> ⚠ **CAUTION**
> The Grid Frame Set menu cannot be opened in more than one window at a time.

Robot Group Number to Use

Specify the group number of the robot to be used for measurement.

Set UFrame or UTool?

Select the frame to be set with the Automatic Grid Frame Set Function - user frame or user tool. To set the user tool with the calibration grid mounted on the robot, select F4 UTOOL. To set the user frame with the calibration grid secured to a table or other fixed surface, select F5 UFRAME.

User Frame Number to set

Specify the number of the user frame to be set. This parameter is used only when “UFRAME” is selected for “Set UFrame or UTool?”. The range of specifiable user frame numbers is 1 to 9.

Tool Frame Number to set

Specify the number of the user tool to be set. This parameter is used only when “UTOOL” is selected for “Set UFrame or UTool?”. The range of specifiable user tool numbers is 1 to 10.

Camera User Tool Number

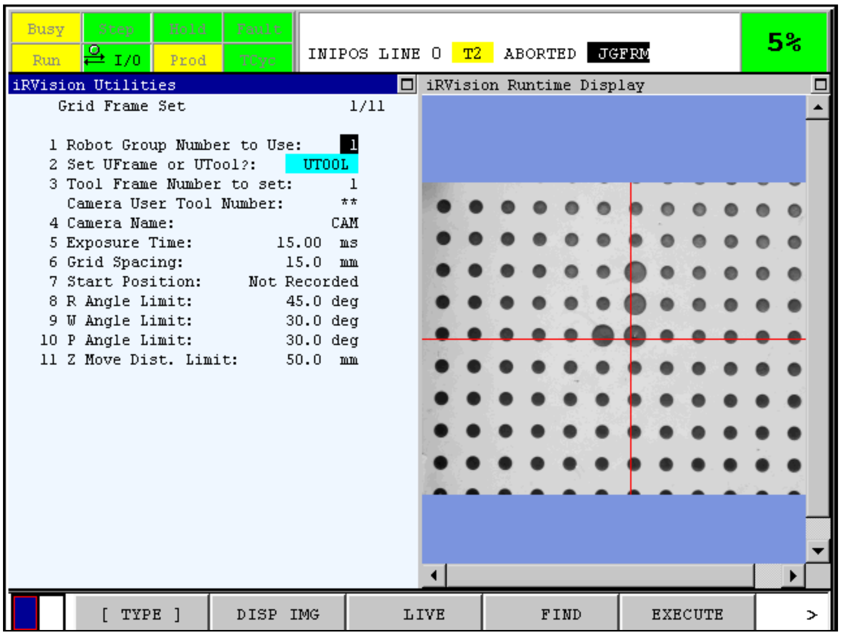
Specify the number of the user tool for the work space to be used during calculation. This parameter is used only when [UFRAME] is selected for “Set UFrame or UTool?”. The user tool you specify here will be overwritten by running this utility. The range of specifiable user tool numbers is 1 to 10.

Camera Name

Specify the name of the camera to be used for measurement. Place the cursor on the line of “Camera Name”, press F4 CHOICE, and select a camera from the pull down menu.

F2 DISP_IMG

Pressing F2 DISP IMG provides a double-window display, with the vision runtime display (camera image) shown on the right side.



F3 LIVE

Pressing F3 LIVE displays the live image of the selected camera on the vision runtime display, as the F3 label changes to “STOPLIVE”. If you press F3 STOPLIVE, the display of the live image is stopped and the F3 label returns to “LIVE”.

F4 FIND

Pressing F4 FIND detect the calibration grid for a trial. The found result is displayed on the vision runtime display.

Exposure Time

Specify the exposure time for the camera to capture an image. Adjust the exposure time so that the black circles of the calibration grid are clearly visible.

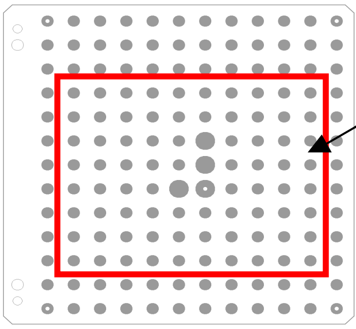
Grid Spacing

Set the grid spacing of the calibration grid in use.

Start Position

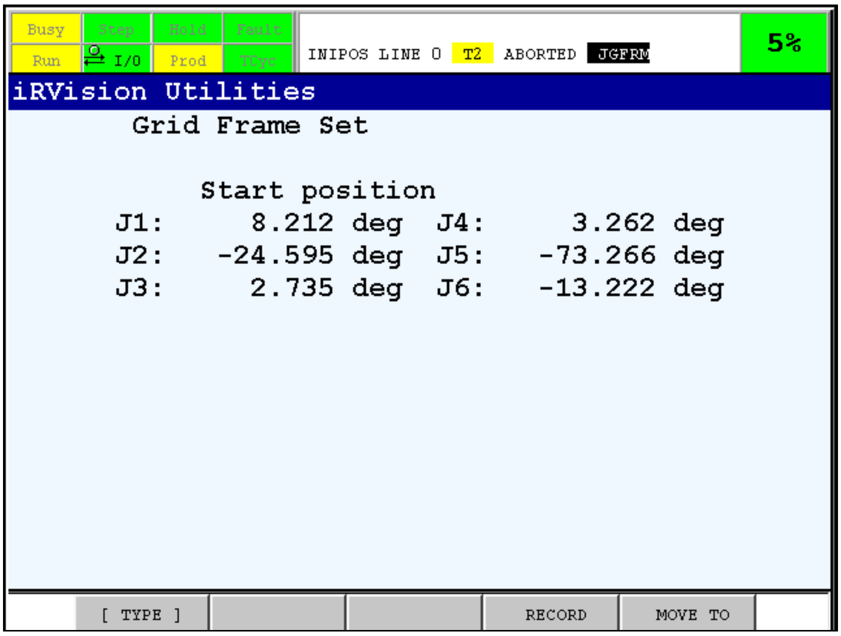
Teach the position where measurement is to be started. To teach the start position, take the following steps:

1. Move the cursor to “7 Start Position”.
2. Jog the robot so that the camera's optical axis is approximately perpendicular to the plate surface of the calibration grid and that all of the four large black circles of the calibration grid are inside the camera's field of view. The distance between the calibration grid and the camera should be appropriate for the grid to come into focus, which is, under normal circumstances, roughly the same as the distance at which camera calibration is performed.



3 Press SHIFT and F4 RECORD at the same time to record the start position. When the start position is recorded, the label changes to “Recorded”.

To check the trained start position, press F3 POSITION. The value of each axis of the start position is displayed, as shown below. To return to the previous menu, press PREV.



To move the robot to the start position, press SHIFT and F5 MOVE TO at the same time.

Operation range

During measurement, the robot automatically moves within the range specified by parameters. To prevent the robot from interfering with peripheral equipment, make sure that there is a sufficient operation space around the measurement area. When the default settings are used, the robot makes the following motions:

- Move 50 mm horizontally in the X, Y, and Z directions
- Rotate by ±45 degrees around the camera's optical axis
- Rotate by ±30-degree about the camera’s X axis (yaw).
- Rotate by ±30-degree about the camera’s Y axis (pitch).

If the operation range defined by the default settings is not possible, you can make the operation range smaller by changing the parameters such as [R Angle Limit], [W Angle Limit], [P Angle Limit], and [Z Move Dist. Limit]. Note, however, that the precision of grid frame setting depends on the amount of motion at the time of measurement. A smaller operation range can lead to lower measurement precision.

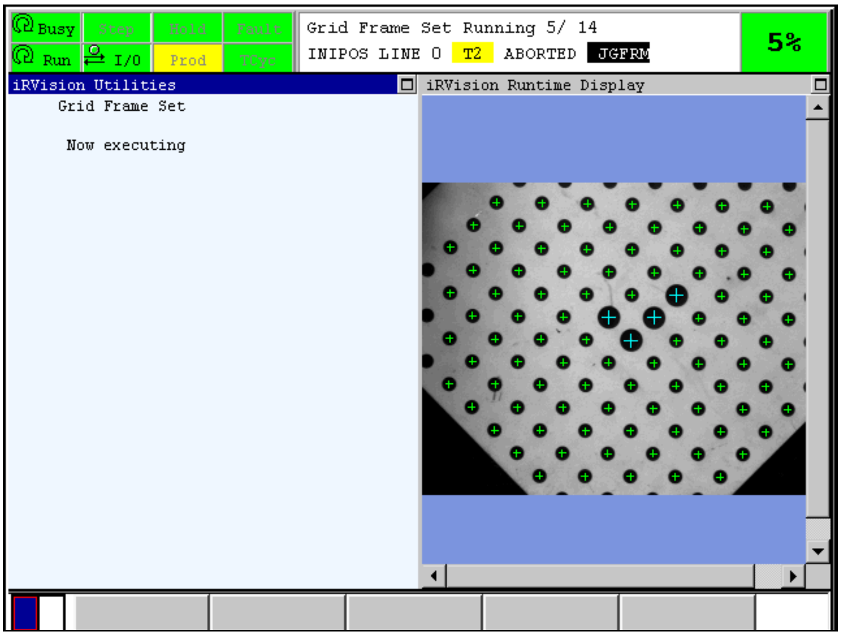
It is therefore recommended that measurements be made using a range as close to the default operation range as possible.

Value initialization

If you press F7 DEFAULT, the set values are initialized. Note that [Camera Name] and [Start Position] are not initialized; set these parameters again individually.

9.2.1.4 Run measurement

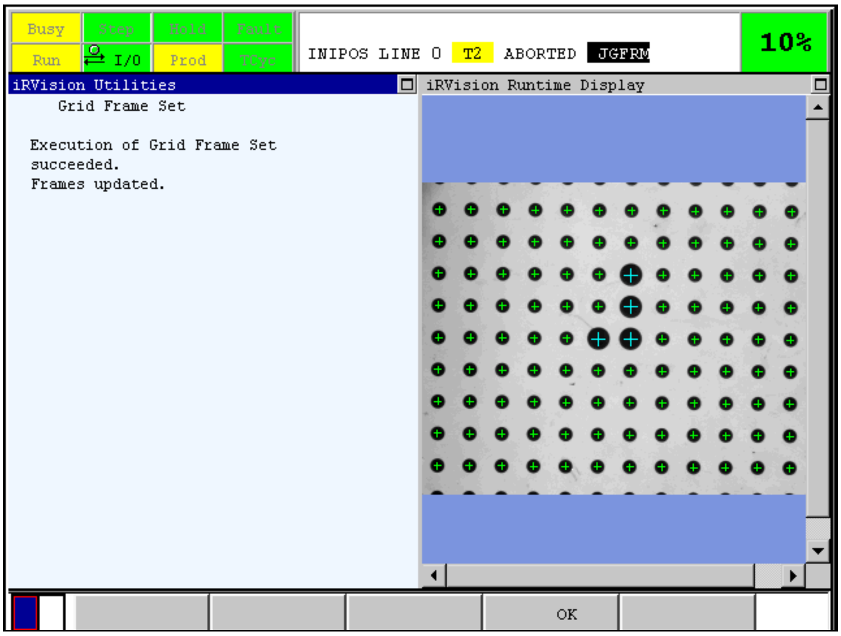
Pressing SHIFT and F5 EXECUTE at the same time starts measurement, causing the robot to start moving. During execution watch image displayed and verify that there are no improperly found calibration grid circles.



⚠ CAUTION

1. Releasing SHIFT while measurement is in progress stops the measurement. In that case, perform the measurement again. You can resume the measurement from where stopped.
2. During measurement, if you perform any operation intended to move to another menu, such as pressing SELECT, the measurement is stopped. In that case, visit the Grid Frame Set menu again and perform the measurement again. You can resume the measurement from where stopped.
3. The robot usually performs operations within an expected range according to the parameter setting. However, the robot can make a motion beyond an expected range, depending on the parameter setting. When running the Grid Frame Set, check that the related parameters are set correctly and decrease the override to 30% or less to ensure that the robot does not interfere with peripheral equipments.
4. If another program is paused, the Grid Frame Set may not be able to move the robot. In that case, abort all the programs using the FUNC menu.

When the measurement is successfully completed, a menu like the one shown below appears. The robot stops after moving to a position where the camera directly faces the calibration grid and the origin of the calibration grid comes to the center of the image.

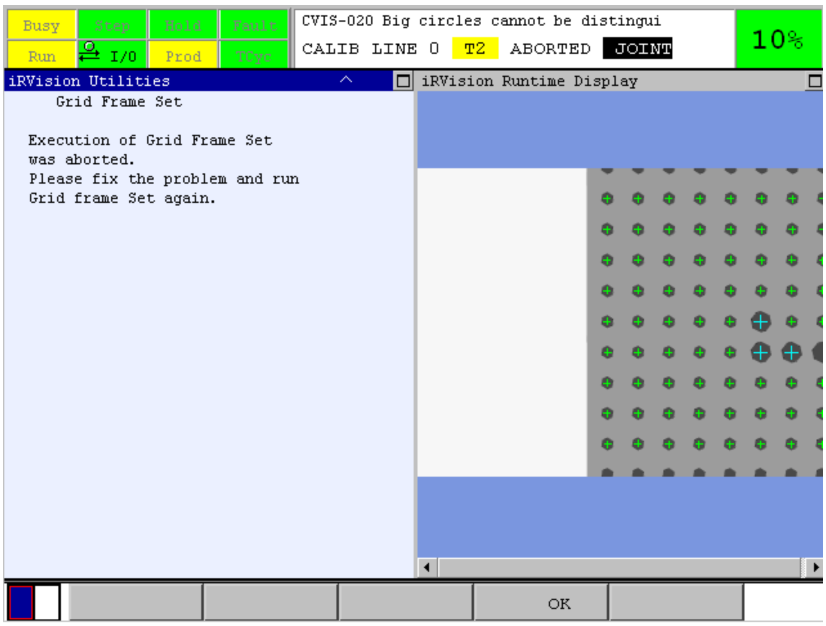


NOTE

You can confirm that the frame is set accurately with the following procedures. First, change the jogging coordinate system to the measured frame. When you set a user tool with Grid Frame Setting, change the jogging coordinate system to the user tool. When you set a user frame, change the jogging coordinate system to the user frame, and then select the user tool selected as "Camera User Tool Number" in the Subsection 9.2.1.3.

Next, start the live image display and jog the robot around the X-, Y- and Z- axes. If the frame is set accurately, the center grid of the gird pattern will keep appearing at the center of the image.

If the utility fails to finish, a menu like the one shown below appears. In that case, press F4 OK to return to the previous menu. Then, change the parameters as appropriate and perform the measurement again. After changing the parameters, pressing SHIFT and F5 RUN at the same time starts the measurement again from the beginning.



9.2.2 Troubleshooting

If the Grid Frame Set does not operate as expected, first check the information provided here.

[CVIS-020 Big circles cannot be distinguished] is issued.

This alarm is posted when the four large black circles of the calibration grid could not be detected. Detection of large black circles failed because of an improper exposure time, or an object other than a grid point was detected. The Vision Runtime screen shows the image when a measurement failed. Check the image and adjust the snapping condition. When some of the large circles are not seen in the camera field of view, try the followings:

- Use a smaller grid pattern
- Use a lens with smaller focal length
- Lengthen the distance between the camera and the grid pattern so that the grid pattern is seen smaller in the image
- Rotate the camera or the grid pattern so that the X axis of the grid pattern does not point below in the image
- Remove noise or clutter from the image that can cause extra grid circles to be improperly found.

[CVIS-015 Too few calibration points] is issued.

This alarm is posted when the number of grid points of the calibration grid detected during measurement is less than 4. Check whether the grid points are contained in the camera's visual field when the robot is placed at the measurement start position, whether the exposure time is proper, and whether the camera port number is correct. This alarm is posted also if a measurement is made when the camera is disabled for hardware trouble.

The program was terminated abnormally with an error.

If an error occurs, the program is terminated forcibly. Modify the setting to enable correct measurement then execute the program from the beginning.

10 SETUP OF SNAP IN MOTION

This function enables *i*RVision to snap an image without stopping robot motion, and is effective when measuring a fixed frame offset with a robot-mounted camera and/or measuring a tool offset of a part held by a robot with a fixed camera or a camera mounted on another robot. Using this function will reduce robot cycle time compared to the legacy way.

10.1 OVERVIEW OF SNAP IN MOTION

This section gives an overview of the function snap-in-motion.

10.1.1 Features

This function enables *i*RVision to snap an image without stopping robot motion, and is effective when measuring a fixed frame offset with a robot-mounted camera and/or measuring a tool offset of a part held by a robot with a fixed camera or a camera mounted on another robot. The following vision processes support this function.

- 2D Single-view Vision Process
- 2D Multi-view Vision Process
- Depalletizing Vision Process
- 3D Tri-View Vision Process

You can calibrate cameras and teach vision processes as you would conventionally.
Calibration of a camera and teaching vision processes are performed in the state where the robot is stopped. Even if it is SNAP IN MOTION, that is the same method with other applications.
Obtaining an accurate robot position at a snapping moment is a key technology to measure a fixed frame offset of part with a robot-mounted camera or a tool offset of a part held by a robot with a fixed camera or a camera mounted on another robot. Conventionally an accurate robot position can be obtained only while a robot remains stationary. The function snap-in-motion enables measuring a fixed frame offset and a tool offset by getting an accurate robot position at a snapping moment.

This function has the following restrictions.
- The robot that holds a camera or a part should be controlled by the controller on which *i*RVision resides.
- Only one robot can move at a snapping moment.

When measuring a tool offset with a robot-mounted camera, two robots are involved. In this case, only one of two robots can move at snapping. The other robot should stop while snapping an image.

*i*RVision assumes a robot that can move at a snapping moment in the following manner:
- If [This Controller] is selected for [Robot Holding the Part], the robot that held a part can move.
- If a robot other than [This Controller] is selected for [Robot Holding the Part] and [This Controller] is selected for [Robot Holding the camera], the robot that holds a camera can move.

Above conditions are used in both cases that two robots are controlled by one controller and two controllers.

10.1.2 Using Snap in Motion

By default, the function snap-in-motion is disabled. To use this function, change the system variable $VSMO_CFG.$ENABLE to TRUE.

$VSMO_CFG.$ENABLE to TRUE.

By setting this system variable to true, the function snap-in-motion itself is enabled. But, to snap an image actually without stopping robot motion, you need to modify your robot program. Refer to the subsection “10.1.4 ROBOT PROGRAM FOR SNAP IN MOTION” about how to modify robot programs. By enabling the function snap-in-motion, the method to obtain a robot position at the snapping moment is changed internally. Basically, you can use camera calibrations, vision processes and robot programs that you taught previously even after this function is enabled. However, potentially a quantity of errors may be observed if you continue to use camera calibrations and vision processes that you have taught before the function is enabled. In such a case, calibrate cameras and teach the reference positions again.

10.1.3 Checking Position and Speed at Snap

When the function snap-in-motion is enabled, the actual position and speed of the robot at the last snapping moment are recorded in the following system variables. Refer to these variables to determine the exposure time and so on in study for application described later.

$VSMO_VAL.$POSITION

It is the actual robot position at the snapping moment. It is in the Cartesian format. X, Y and Z are in millimeters, and W, P and R are in degrees. For a robot-mounted camera, the position of the mechanical interface relative to the application frame is recorded. For tool offset, the position of the user tool that you selected in the camera calibration setup page is recorded.

$VSMO_VAL.$SPEED

It is the actual robot speed at the snapping moment. X, Y and Z are in mm/sec, and W, P and R are in degrees/sec.

10.1.4 Robot Program for Snap in Motion

For snap-in-motion, you need to execute the VISION RUN_FIND instruction in a different manner from usual.

Snap after stopping

This is a sample program to snap an image while stopping the robot as is conventionally done. FINE is specified for P[2] in the second line. While the robot is stopping at P[2], the VISION RUN_FIND instruction snaps an image in the third line. After that, the robot restarts to move to P[3] in the forth line.

```
1: L P[1:start] 500mm/sec FINE
2: L P[2:snap] 500mm/sec FINE
3:   VISION RUN_FIND 'A'
4: L P[3:stop] 500mm/sec FINE
```

Snap in motion

To snap an image without stopping the robot, the VISION RUN_FIND instruction should be executed by using the TIME BEFORE instruction. In the robot program below, CNT100 is specified for P[2] in the second line, and the subprogram FIND.TP is called at the moment that the robot passes through P[2] by using the TIME BEFORE instruction.

```
1: L P[1:start] 500mm/sec FINE
2: L P[2:snap] 500mm/sec CNT100 TB 0.00sec,CALL 'FIND'
3: L P[3:stop] 500mm/sec FINE
```

FIND.TP that is called by the TIME_BEFORE instruction is as below. The VISION RUN_FIND function is executed in this subprogram.

```
1:  VISION RUN_FIND 'A'
```

You can tweak the start time of the TIME BEFORE instruction, or you can use the TIME AFTER instruction or the DISTANCE BEFORE instruction instead of the TIME BEFORE instruction. For these instructions, refer to "R-30*i*B/ R-30*i*B Mate CONTROLLER OPERATOR'S MANUAL (Basic Operation) (B-83284EN)".
If positions P[1] ~ P[3] in the above program are not on a line, the robot moves inside of the original path and does not pass through P[2] because of CNT100. In such a case, modify P[2] so that the robot actually passes through the expected snap position.

10.1.5 Notes

Vibration of robot arm while robot moving is not considered. The bigger the vibration is, the larger the error is.

10.2 STUDY FOR APPLICATION

This section describes issues to consider when the function snap-in-motion is used.

10.2.1 Light and Exposure Time

In the case of snapping an image in motion, the robot is moving even during exposure and it causes image blur. Because this blur can cause detection error, the exposure time should be set a smaller value than usual to mitigate the blur.
Assuming that the robot moves in the direction at a right angle to the optical axis of the camera, the amount of blur is calculated by the expression $V \times T \times N \div S$ in pixels, where V is the velocity at the snapping moment in mm/sec, T is the exposure time in sec, S is the size of the camera field of view in millimeters and N is the number of effective pixels of the camera.

$$\textbf{(Pixels)} = \mathbf{V \times T \times N \div S}$$

Determine the exposure time so that this amount of blur is smaller than 1 pixel and prepare a good light source to get a fully bright image with the selected exposure time.

10.2.2 Image Processing Time and Motion Time

In the case of snapping images in motion, you should consider the relationship between the image processing time and the robot motion time.

GET_OFFSET

The following program calls the subprogram FIND.TP, which include the VISION RUN_FIND instruction, at the moment that the robot passes through P[2] in the second line, and tries to get the resulting vision offset in the fourth line. If P[2] and P[3] were too close and the robot reached P[3] in a short time, the robot would wait for the completion of vision detection in the fourth line, resulting the robot stopping. To avoid such a thing, consider a good layout of the camera so that the image processing finishes while the robot is moving from P[2] to P[3].

```
1: L P[1:start] 500mm/sec CNT100
2: L P[2:snap] 500mm/sec CNT100 TB 0.00sec,CALL FIND
3: L P[3:stop] 500mm/sec CNT100
4:   VISION GET_OFFSET 'A' VR[1] JMP,LBL[1]
5: L P[4:approach] 500mm/sec FINE VOFFSET,VR[1]
```

Continuous RUN_FINDs

In *i*RVision, another vision process cannot be started until the previous vision process completes. So, if the VISION RUN_FIND instruction were called twice at a too short interval, the latter vision process would be kept waiting and its image snapping would not happen at the expected position.
For example, in the following program, if the time to move from P[2] to P[3] is shorter than the time for the image processing for FIND1.TP, snapping an image for FIND2.TP will be delayed.

```
1: L P[1:start] 500mm/sec CNT100
2: L P[2:snap1] 500mm/sec CNT100 TB 0.00sec,CALL FIND1
3: L P[3:snap2] 500mm/sec CNT100 TB 0.00sec,CALL FIND2
4: L P[4:stop] 500mm/sec CNT100
```

Time a vision process takes depends on the shape of the trained model pattern, the detection parameters, the condition of the snapped image and the load of the controller that performs the vision process. Check your vision process time by actually executing the vision process.
In addition, if the vision process executed previously is configured to log images, the next vision process can be kept waiting until the previous vision process completes image logging and snapping an image of the next vision process can be delayed. In such a case, configure the previous vision process not to log images. The delay of snapping an image can be shortened slightly if the 'Enable Logging' is checked off in the *i*RVision configuration setup page.

10.2.3 Shift of Snap Position

Depending on the condition of the controller, timing of snap may be fluctuated slightly. The shift of the snap timing is basically no problem, because *i*RVision can get an accurate robot position at snapping. But if the size of the camera field of view is adjusted so that an image is filled with a part, the shift of the snap timing lead the part being out of the camera field of view and that causes detection failure. Set the size of the camera field of view to have enough margins to accept a quantity of the shift of the snap timing. The size of margin depends on the speed of the robot at snapping. The faster the robot is moving, the bigger the shift of the snapping position is.
Moreover, after turning on the controller, in the first vision find, the find time may be longer. After the first find, the remaining finds take the normal amount of time. It is recommended that the first find after controller power up is not for a snap in motion process.

NOTE

Vision Processes are saved in the FROM or memory card. In addition, If Vision Process is performed, it will remain in the cache in DRAM. Since access to the file in cache is quick, the vision find time of the first operation may be longer then subsequent find times. In addition, there is a limitation in the cache domain of DRAM. So other Vision Processes are run, old Vision Processes in the cache will be deleted from cache. In the system that runs many kinds of Vision Processes in 1 cycle, some of the executed Vision Processes may not remain in cache. The default capacity of the cache is 2 MB.

10.3 SAMPLE APPLICATIONS

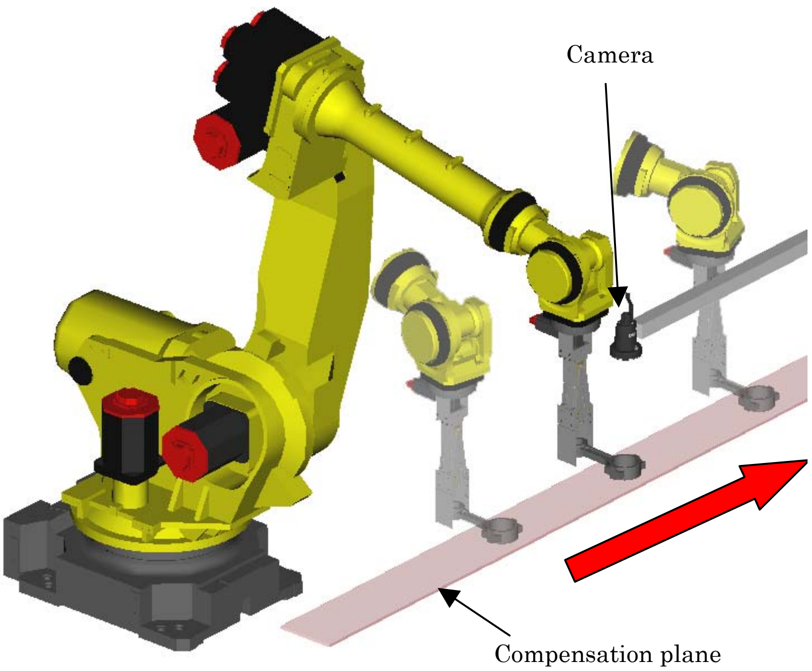
This section demonstrates three sample applications using the function snap-in-motion.

- Tool offset with a fixed-mounted camera (2D Single-view Vision Process)
- Tool offset with a fixed-mounted camera (2D Multi-view Vision Process)
- Fixed frame offset with a robot-mounted camera (3D Tri-view Vision Process)

In either application, generally the setup procedure and items to consider are the same as those of each application without the function snap-in-motion. The descriptions about the area of overlap with those in each vision processes are left out.

10.3.1 Tool Offset with a Fixed Camera (2D single-view vision process)

In a tool offset application with a fixed-mounted camera of 2D Single-view Vision Process, a part held by the robot is shown at the camera and the tool offset is measured. Using the measured tool offset, the robot positions are compensated to put the part in a correct position. The tool offset is usually measured with stopping the robot. Using the function snap-in-motion, the vision detection can be executed while the robot is transporting a part without stopping robot motion.
The subsection “4.4.7 ROBOT PROGRAM CREATION AND TEACHING” in the setup procedure described in the section “4.4 SETUP FOR "TOOL OFFSET WITH FIXED CAMERA"” is different from those using the function snap-in-motion. “ROBOT PROGRAM CREATION AND TEACHING” is explained below.
The figure below is an example of layout in the case of tool offset using 2D Single-view Vision Process with a fixed-mounted camera.



10.3.1.1 Robot program creation and teaching

This subsection demonstrates robot programs for tool offset in motion. Based on sample robot programs below, create appropriate robot programs for your application.

The following two programs are created.

- Main robot program (MAIN.TP)
- Robot program to detect a target (FIND.TP)

MAIN.TP

This is the main program. In this program, the robot moves from the start position P[1] to the stop position P[3] through the snap position P[2], and call the subprogram FIND.TP at the moment that the robot passes through the snap position. After that, the VISION GET_OFFSET instruction is called to get the resulting vision offset. The robot positions P[4] and P[5] are compensated with the vision offset so that the part is put at the correct location.

```
   UFRAME_NUM=1
   UTOOL_NUM=1

 L P[1:start] 500mm/sec CNT100
 L P[2:snap] 500mm/sec CNT100 TB 0.00sec,CALL FIND
 L P[3:stop] 500mm/sec CNT100
   VISION GET_OFFSET 'A'  VR[1] JMP LBL[99]
 L P[4:approach] 500mm/sec FINE VOFFSET,VR[1]
 L P[5:set] 100mm/sec FINE VOFFSET,VR[1]
 L P[4:approach] 100mm/sec FINE VOFFSET,VR[1]
   END
   LBL[99]
   UALM[1]
```

FIND.TP

This is a program called by the TIME BEFORE instruction. This program executes the vision program “A” using the VISION RUN_FIND instruction.

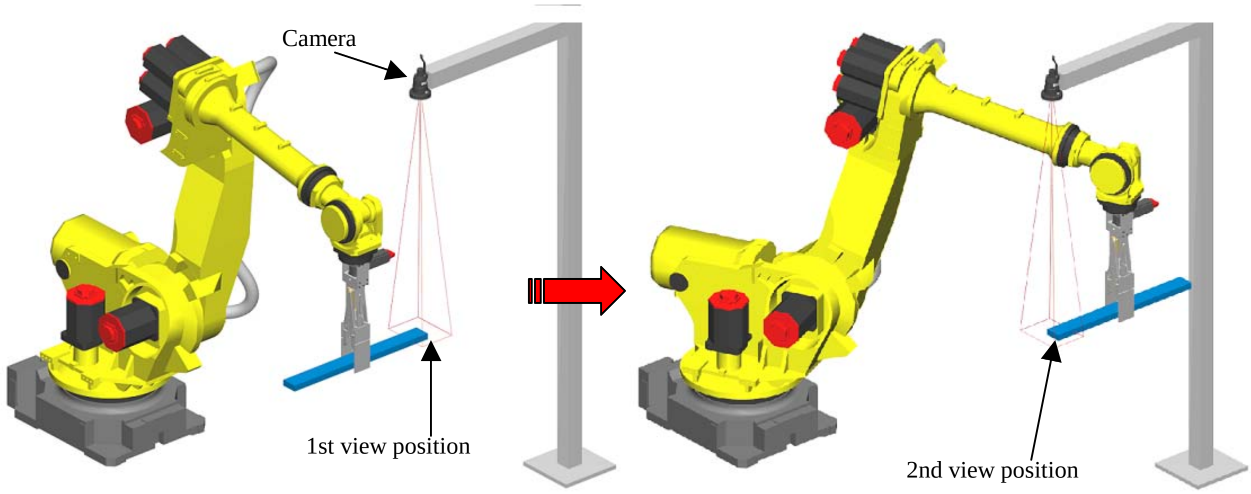
```
   VISION RUN_FIND 'A'
```

10.3.2 Tool Offset with a Fixed Camera (2D multi-view vision process)

In a tool offset application with a fixed-mounted camera of 2D Multi-view Vision Process, features on a part held by the robot are shown at the camera and the tool offset is measured. Using the measured tool offset, robot positions are compensated to put the part at a correct position. The tool offset is usually measured with stopping the robot. Using the function snap-in-motion, the vision detection can be executed while the robot is transporting a part without stopping robot motion.

The subsection “5.4.2 ROBOT PROGRAM CREATION AND TEACHING” in the setup procedure described in the section “5.4 SETUP FOR "TOOL OFFSET WITH FIXED CAMERA"” is different from those using the function snap-in-motion. “ROBOT PROGRAM CREATION AND TEACHING” is explained below.

The figure below is an example of layout in the case of tool offset using 2D Multi-view vision process with a fixed-mounted camera.



10.3.2.1 Robot program creation and teaching

This subsection demonstrates robot programs for tool offset in motion. Based on sample robot programs below, create appropriate robot programs for you application.

Following two programs are created.

- Main robot program (MAIN.TP)
- Robot program to detect a target (FIND.TP)

MAIN.TP

This is the main program. In this program, the robot moves from the start position P[1] to the stop position P[4] through the two snap positions P[2] and P[3], and calls the subprogram FIND.TP with a camera view number as an argument at the moment that the robot passes through the snap positions. In order to confirm that the vision processes are completed in every camera view, it waits until R[1] becomes 2. After that, the VISION GET_OFFSET instruction is called to get the resulting vision offset. The WAIT instruction secures that the VISION GET_OFFSET instruction is executed after the VISION RUN_FIND completion. The robot positions P[5] and P[6] are compensated with the vision offset so that the part is put at the correct location.

```
   UFRAME_NUM=1
   UTOOL_NUM=1

   R[1]=0
L P[1:start] 500mm/sec CNT100
L P[2:snap1] 500mm/sec CNT100 TB 0.00sec,CALL FIND(1)
L P[3:snap2] 500mm/sec CNT100 TB 0.00sec,CALL FIND(2)
L P[4:stop] 500mm/sec CNT100
   WAIT R[1]>=2
   VISION GET_OFFSET 'A' VR[1] JMP LBL[99]
L P[5:approach] 500mm/sec FINE VOFFSET,VR[1]
L P[6:set] 100mm/sec FINE VOFFSET,VR[1]
L P[5:approach] 500mm/sec FINE VOFFSET,VR[1]
   END
   LBL[99]
   UALM[1]
```

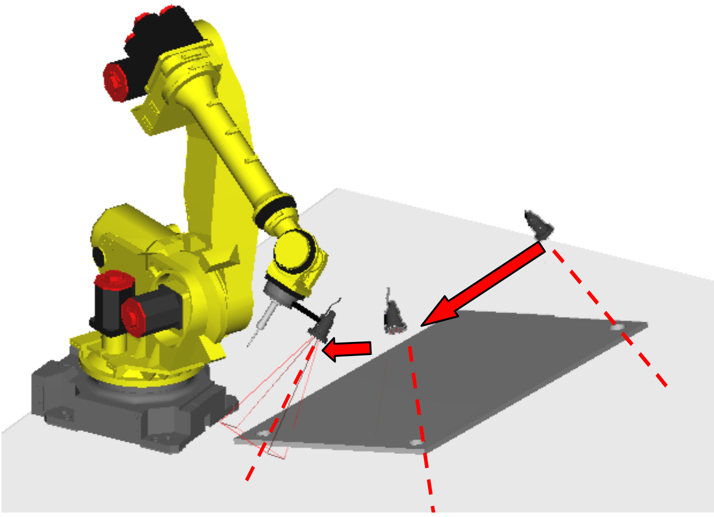
FIND.TP

This is a program called by the TIME BEFORE instruction. This program executes detection of the camera view specified by the argument using the VISION RUN_FIND instruction. And R[1] is incremented after the image acquisition completes.

```
1:   VISION RUN_FIND 'A' CAMERA_VIEW[AR[1]]
2:   R[1]=R[1]+1
```

10.3.3 Fixed Frame Offset with a Robot Mounted Camera (3D Tri-view vision process)

In a fixed frame offset application with a robot-mounted camera of 3D Tri-view Vision Process, three features on a part are detected by the robot mounted-camera and the 3D position of the part is measured. Using the measured position, robot positions are compensated so that the tool of the robot can reach the part. The fixed frame offset is usually measured with stopping the robot. Using the function snap-in-motion, the measurements can be executed continuously without stopping the robot holding the camera at each snap position.
The subsection “7.3.2 ROBOT PROGRAM CREATION AND TEACHING” in the setup procedure described in the section “7.3 SETUP FOR "FIXED FRAME OFFSET WITH FIXED CAMERA"” is different from those using the function snap-in-motion. “ROBOT PROGRAM CREATION AND TEACHING” is explained below.
The figure below is an example of layout in the case of fixed frame offset using 3D Tri-view vision process with a robot-mounted camera



10.3.3.1 Robot program creation and teaching

This subsection demonstrates robot programs for fixed frame offset with a robot-mounted camera in motion. Based on sample robot programs below, create appropriate robot programs for you application.

Following two programs are created.

- Main robot program (MAIN.TP)
- Robot program to detect a target (FIND.TP)

MAIN.TP

This is a main program. In this program, the robot moves from the start position P[1] to the stop position P[5] through the three snap positions P[2] ~ P[4], and calls the subprogram FIND.TP with a camera view number as an argument at the moment that the robot passes through each snap position. To confirm that the vision processes are completed in every camera view, it waits until R[1] become 3. After that, the

VISION GET_OFFSET instruction is called to get the vision offset. The WAIT instruction can prevent that the VISION GET_OFFSET instruction executes previously rather than VISION RUN_FIND is completed. The robot positions P[6] and P[7] are compensated with the vision offset so that the robot holds the part.

```
  1:   UFRAME_NUM=1
  2:   UTOOL_NUM=1
  3:
  4:   R[1]=0
  4: L P[1:start] 500mm/sec CNT100
  5: L P[2:snap1] 500mm/sec CNT100 TB 0.00sec,CALL FIND(1)
  6: L P[3:snap2] 500mm/sec CNT100 TB 0.00sec,CALL FIND(2)
  7: L P[4:snap3] 500mm/sec CNT100 TB 0.00sec,CALL FIND(3)
  8: L P[5:stop] 500mm/sec CNT100
  9:   WAIT R[1]>=3
  9:   VISION GET_OFFSET 'A' VR[1] JMP LBL[99]
 10: L P[6:approach] 500mm/sec FINE VOFFSET,VR[1]
 11: L P[7:hold] 100mm/sec FINE VOFFSET,VR[1]
 12: L P[6:approach] 500mm/sec FINE VOFFSET,VR[1]
 13:   END
 14:   LBL[99]
 15:   UALM[1]
```

FIND.TP

This is a program called by the TIME BEFORE instruction. This program executes detection in the camera view specified by the argument using the VISION RUN_FIND instruction. And R[1] is incremented after the image acquisition completes.

```
  1:   VISION RUN_FIND 'A' CAMERA_VIEW[AR[1]]
  2:   R[1]=R[1]+1
```

11 TROUBLESHOOTING

11.1 ADJUSTMENT METHOD AFTER CAMERA REPLACEMENT

If the camera fails, replace the camera with a new one and adjust the new camera according to the procedure below.
Before removing the faulty camera in use, check that the lens aperture and focus rings are firmly secured. The lens is reusable. By replacing the lens without moving the focus and lens rings, the need for pattern match readjustment can be eliminated for easier adjustment operation.
Use the following replacement and adjustment procedure:

1 Turn off the power to the robot controller.
2 By turning off the power to the controller, the power to the camera is also turned off.
3 Remove the camera.
4 At this time, be careful not to apply force to the lens aperture and focus rings.
5 Remove the lens from the camera.
6 When use the analog camera, change the settings of the DIP switch on the rear panel of the new camera according to the “R-30*i*B/R-30*i*B Mate CONTROLLER Sensor Mechanical Unit / Control Unit OPERATOR’S MANUAL (B-83434EN)”.
7 Attach the lens mentioned above to the new camera.
8 Install and secure the new camera.
9 Perform camera calibration.

This completes the replacement and adjustment operation.

11.2 METHOD OF RESTORING VISION DATA

Prepare the memory card for data back-up described in Section 2.8, "Memory card preparation".
The extension of a vision data file is "VD". Vision data can be completely restored by loading all *.VD files.
If the copy destination robot controller differs from the copy source robot controller, pay attention to the software version. The software version of the copy destination robot controller must be the same as or later than the software version of the copy source robot controller.

11.3 SHORTENING METHODS OF THE DETECTION TIME

Check the following items to shorten the detection time.

- In the vision program page, make the Search Window small to size of the necessary minimum. The narrower the range is, the faster the location process ends.
- When the model size of the locator tool is too large to the field of view, detection time may become long. When the model of the locator tool is taught to full size of the filed of view, detection time may become extremely long.
- In the vision program page, set the smaller range in the DOF-Orientation, DOF-Scale and DOF-Aspect. For example, if a workpiece rotates only ±30 degree, set ±30 degree in the DOF-Orientation. When the DOF-Orientation, DOF-Scale and DOF-Aspect are set to a smaller range, the detection time shortens. Moreover, when the detection that DOF-Orientation enable is performed to the workpiece without a rotational feature on the workpiece, there may be many candidates of matching, so detection time becomes long. When the detection that DOF-Aspect is

enabled to the workpiece, detection time becomes long. In the GPM locator tool, set the Elasticity before enabling a set up of the DOF-Aspect in the vision program screen.

- Disable the Vision Log. If the log increases, detection may take longer time. For details, refer to Section 3.4, ”VISION GONFIG” in the *i*RVision operator's manual (Reference) (B-83304EN).
- If Number of Exposure is set as two or more images, snapping time becomes the longer. Set the necessary minimum number in the Number of Exposure.

11.4 METHODS FOR FINDING FAILED ITEMS IN AN IMAGE

Check the following items to improve the unfound items in the images

- Enable the Vision Log and save images. Adjust the locator tool parameter using the failed images. To enable vision log, check “Enable logging” on the *i*RVision configuration screen. For details, refer to Section 3.4, ”VISION CONFIG” in the *i*RVision operator's manual (Reference) (B-83304EN). After the adjustment is completed, disable the Vision Log. As the size of the log increases, detection may take longer time.
- Refer to failed images and adjust the locator tool parameters. If the workpiece is almost found, enable the show almost found check box in the locator. The results of the almost found workpiece should give a clue why the workpiece was not found.
- When there is a halation (a halo effect from saturation or hot spots) in the image and a workpiece is undetected, it is able to improve the image by using the Number of Exposure. However, if the Number of Exposure is set, the snapping time becomes the longer. When it is required to shorten the detection time, do not increase the Number of Exposure but improve the lighting environment.
- When the contrast between a workpiece the background where the workpiece is placed is low, the shape of a workpiece may not detect clear. If the workpiece is a bright color, select a dark color for a background where the workpiece is placed so that contrast becomes clear.
- In the Depalletizing Vision Process, when a number of layers change and detection becomes impossible, check weather the DOF-Scale is enabled and properly set.

11.5 METHODS FOR LIMITING MISFOUND ITEMS

Check the following items to improve the incorrect detection

- Enable the Vision Log and save images. Adjust the locator tool parameter using the failed images. To enable vision log, check “Enable logging” on the *i*RVision configuration screen. For details, refer to Section 3.4, ”VISION CONFIG” in the *i*RVision operator's manual (Reference) (B-83304EN). After the adjustment is completed, disable the Vision Log. As the size of the log increases, detection may take longer time.
- Refer to the failed images and adjust the locator tool parameters. Make the Search Window as small as possible. Set the DOF-Orientation, DOF-Scale and DOF-Aspect range as small as possible. If it is possible, set the smaller value of the Elasticity and Area Overlap. Enable and train an Emphasis area around the strongest or most unique edges.
- When there are few features of a model pattern of a workpiece, “unintended object” matches at various places within the field of view are possible. By increasing the features or edges of the model, false detection may not be an issue as a result of the noise in the image. When a model with many features is compared with a model with few features, a detection score of model with many features is the lower than a model with few features. However, in this case, set the low value in the Score Threshold in the vision program. If the feature of the model is increased, even if the Score Threshold is set low, it is effective as a measure against incorrect detection.
- If the Allow Floating EA in the vision program is enabled, false finds may occur. Typically, disable the Allow Floating EA.

11.6 THE RETRY OF DETECTION

When the item is not found, it is possible to retry the detection after changing the detection parameters using the Vision Override feature. For details, refer to Section 8.1, ”VISION OVERRIDE” in the *i*RVision operator's manual (Reference) (B-83304EN).
In the 2D Single-view Vision Process, an example to retry with changed the exposure time by using the Vision Override is shown below.
The Vision Override setup page is shown below. For example, a vision process named "A" is used and the Vision Override named "EXPO1" is used.
The sample program is shown below. Execute vision process ”A” with the vision run_find instruction on line 15. In the example, the 20 ms is set in the exposure time. When the detection fails, call the Vision Override on line 20 and the exposure time is changed to a value (for example 25 ms) in the Register[5]. In this state, when vision run_find for vision process ”A” on line 15 is called, the detection is performed with the exposure time of 25 ms.

```
12:  R[20:retry]=0     ;
13:  R[15:notfound]=0     ;
14:  LBL[100] ;
15:  VISION RUN_FIND 'A'     ;
16:  VISION GET_OFFSET 'A' VR[1] JMP LBL[10] ;
17:  JMP LBL[20] ;
18:  LBL[10] ;
19:  IF R[20:retry]=1,JMP LBL[900] ;
20:  VISION OVERRIDE 'EXPO1' R[5] ;
21:  R[20:retry]=1     ;
22:  JMP LBL[100] ;
23:   ;
24:  LBL[20] ;
;
34:  LBL[900] ;
35:  R[15:notfound]=1     ;
;
```

The value you set with the OVERRIDE command is temporary and is not meant to rewrite the contents of a vision process. The value set by this command takes effect only for the RUN_FIND command that is executed immediately after the OVERRIDE command. Once the RUN_FIND command is executed, all the values set by the OVERRIDE command (including those vision overrides associated with vision processes other than the vision process that executes location) are cleared.

11.7 AUTO EXPOSURE AND MULTI EXPOSURE

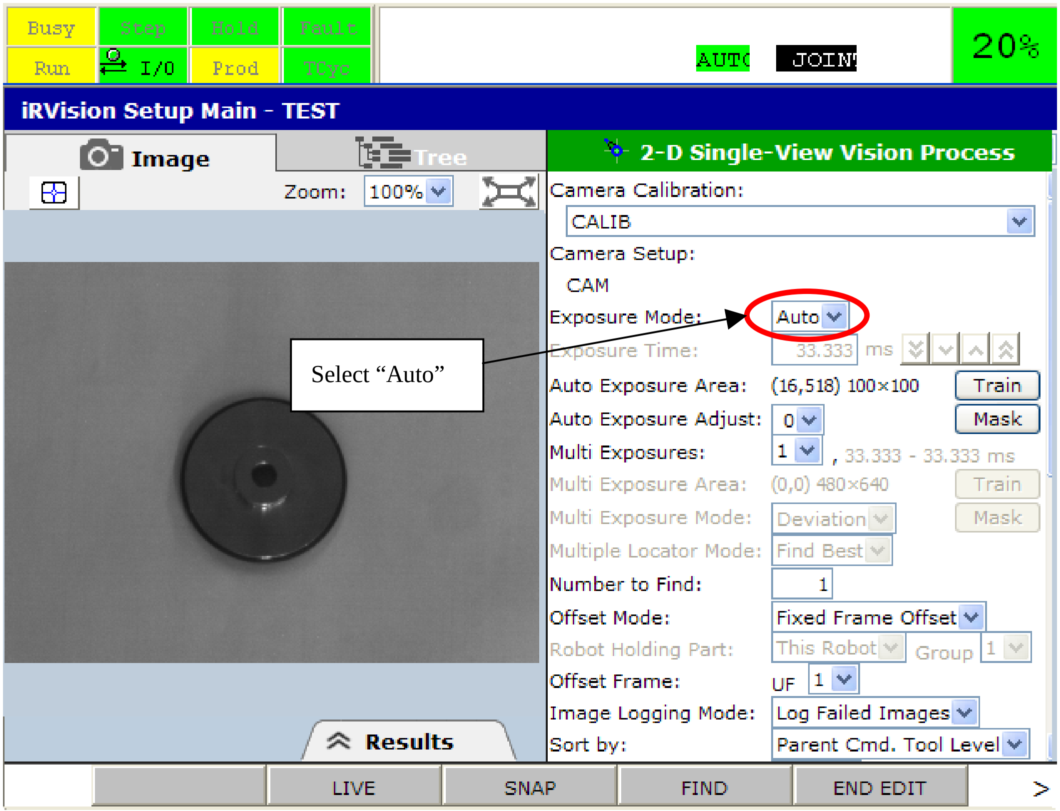
Detection with a camera may be difficult at the place where lighting environment changes. In such a case, the detection may become possible by using Auto Exposure or Multi Exposure even if the lighting changes.

> ⚠ **CAUTION**
> Auto Exposure and Multi Exposure may snap multiple images at once combine them into a single image. So, Auto Exposure and Multi Exposure cannot be used for “Snap in Motion”.

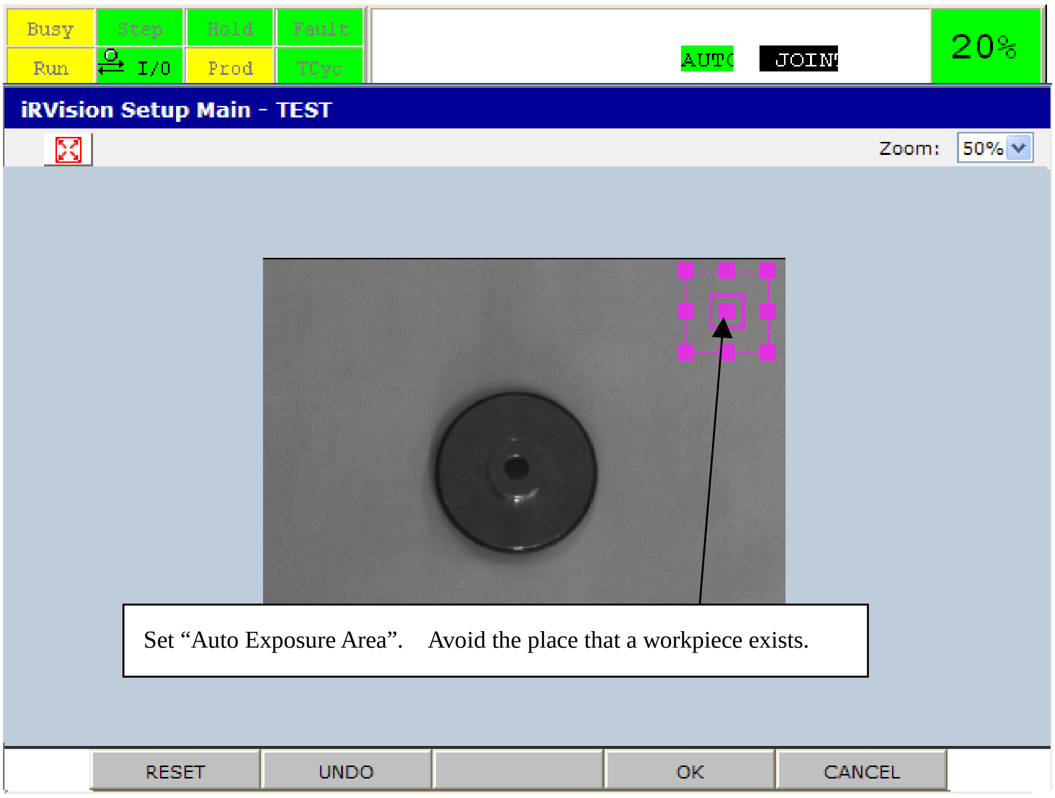
11.7.1 Auto Exposure

When the brightness within a field of view changes based on the time of day, the detection may become difficult. In such a case, the detection may become possible by the using Auto Exposure. Auto Exposure selects an exposure time for image snapping according to the brightness of the surrounding environment that changes from time to time. By saving a reference image in advance, an appropriate exposure time is selected so that the snapped image has the same brightness as that of the reference image.

1 Set [Fixed] in [Exposure Mode].
2 Adjust the exposure time to obtain appropriate brightness for the image.
3 Set [Auto] in [Exposure Mode].



4 If [Auto Exposure Area] is [Not trained], the window opens to set the photometric area. In the case of [Trained], tap the [Train] button to set the photometric area.



5 If there is any area to be ignored in the photometric area, tap the [Mask] button to mask the area to be ignored. For information on how to set a mask, see Subsection 3.7.10, "Editing Masks".

NOTE

1 In [Auto Exposure Mode], a completely white or black area of the image cannot be specified. Set an area in intermediate gray shades as the photometric area.

2 Areas that show large changes in brightness are not appropriate for [Auto Exposure Area]. For example, in an area that might contain a workpiece, it is impossible to make stable measurements because the visible brightness changes largely depending on whether the workpiece is present or not. Choose a background area instead.

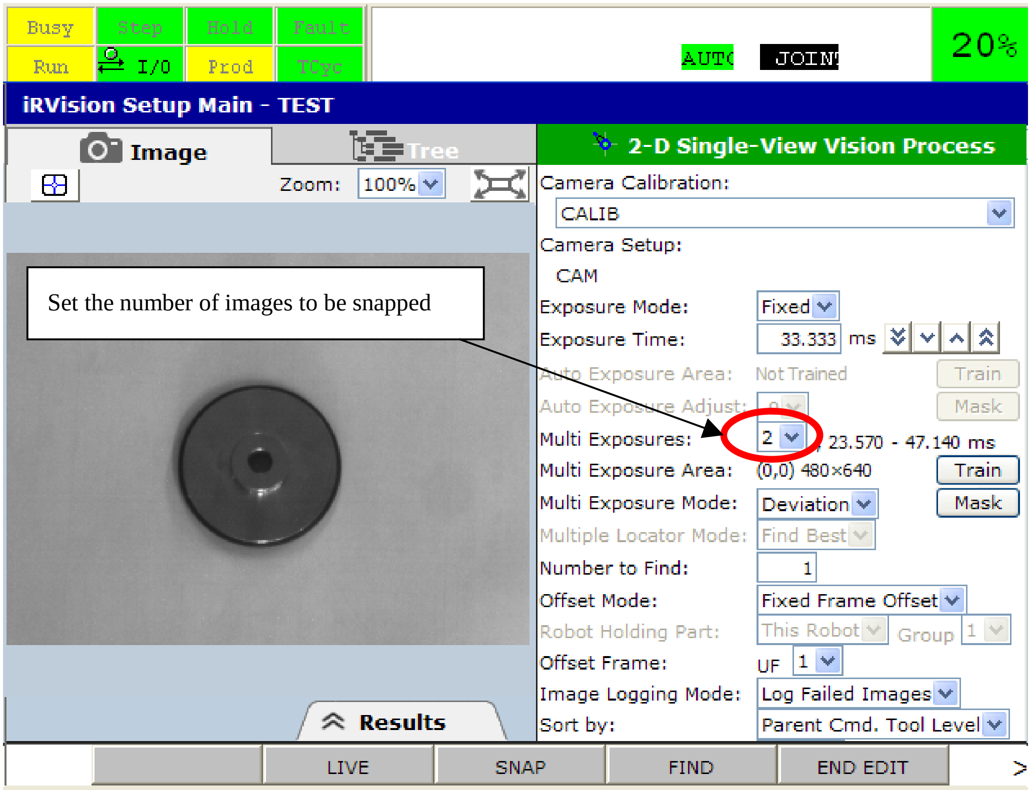
Auto Exposure Adjust

Fine adjustments can be made for automatic exposure to obtain slightly brighter or darker images than the set reference image. A value from -5 to +5 can be selected. As the value increases in the positive direction, snapped images become brighter, and as the value decreases in the negative direction, snapped images become darker.

11.7.2 Multi Exposure

The multi-exposure function snaps multiple images by changing exposure time and combines them to generate an image with a wide dynamic range. It is the same with Auto Exposure, the detection may become possible even if the brightness changes within the field of view. Specify the number of images to be snapped.

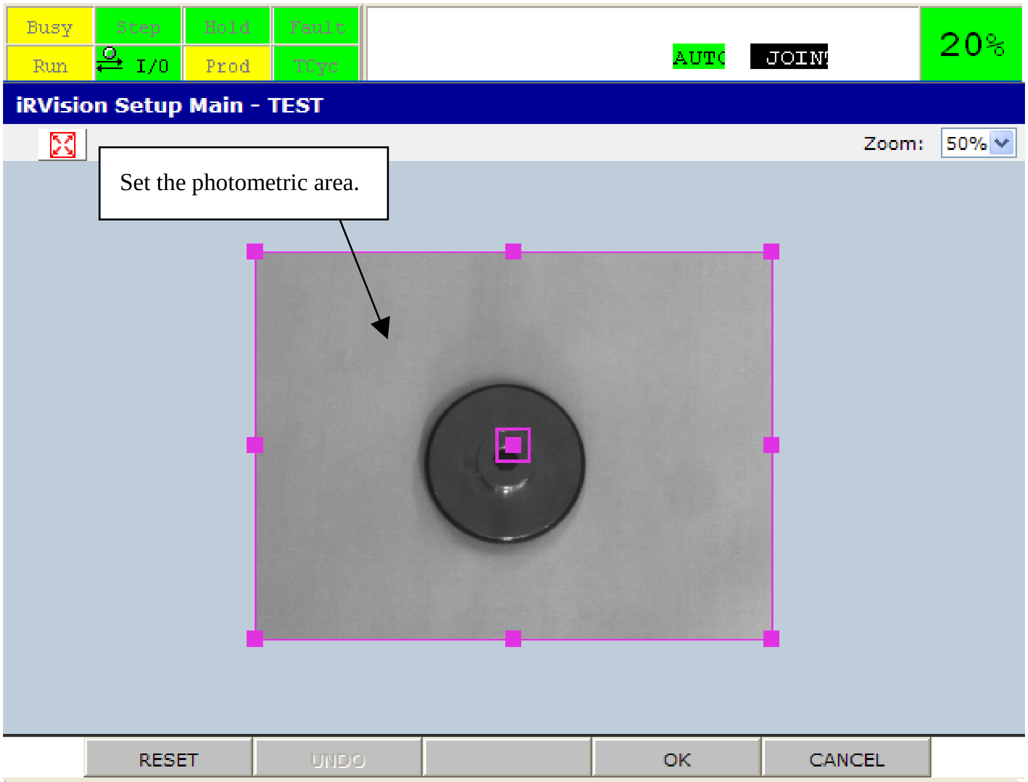
A value from 1 to 6 can be specified. As more images are snapped, a wider dynamic range results, but a longer time is required for image snapping. Moreover, the edge of workpiece on the snapped image may become fuzzy.



Multi Exposure Area

Specify the photometric area used for multi-exposure. Image synthesis is performed based on the brightness in the photometric area. The photometric area is set the full screen, and it is not usually necessary to change. To set the photometric area, tap the [Train] button to set a window.

When the photometric area includes an area of which brightness is to be ignored, tap the [Mask] button to mask the area to be ignored.



Multi Exposure Mode

Select a method for image synthesis in multi-exposure.

Deviation

The standard deviation of the image brightness in the photometric area is calculated, and synthesis is performed so that slight halation occurs in the image. This is the default setting.

Maximum

Synthesis is performed so that no halation occurs in the image in the photometric area. If halation occurs at even one point in the photometric area, the other part becomes relatively dark.

Average

Synthesis is performed simply averaging the gray level of pixels. This method can provide the widest dynamic range but might make the entire image darker.

APPENDIX

A EXAMPLE OF APPLICATION

The example of a vision system is introduced in this chapter.

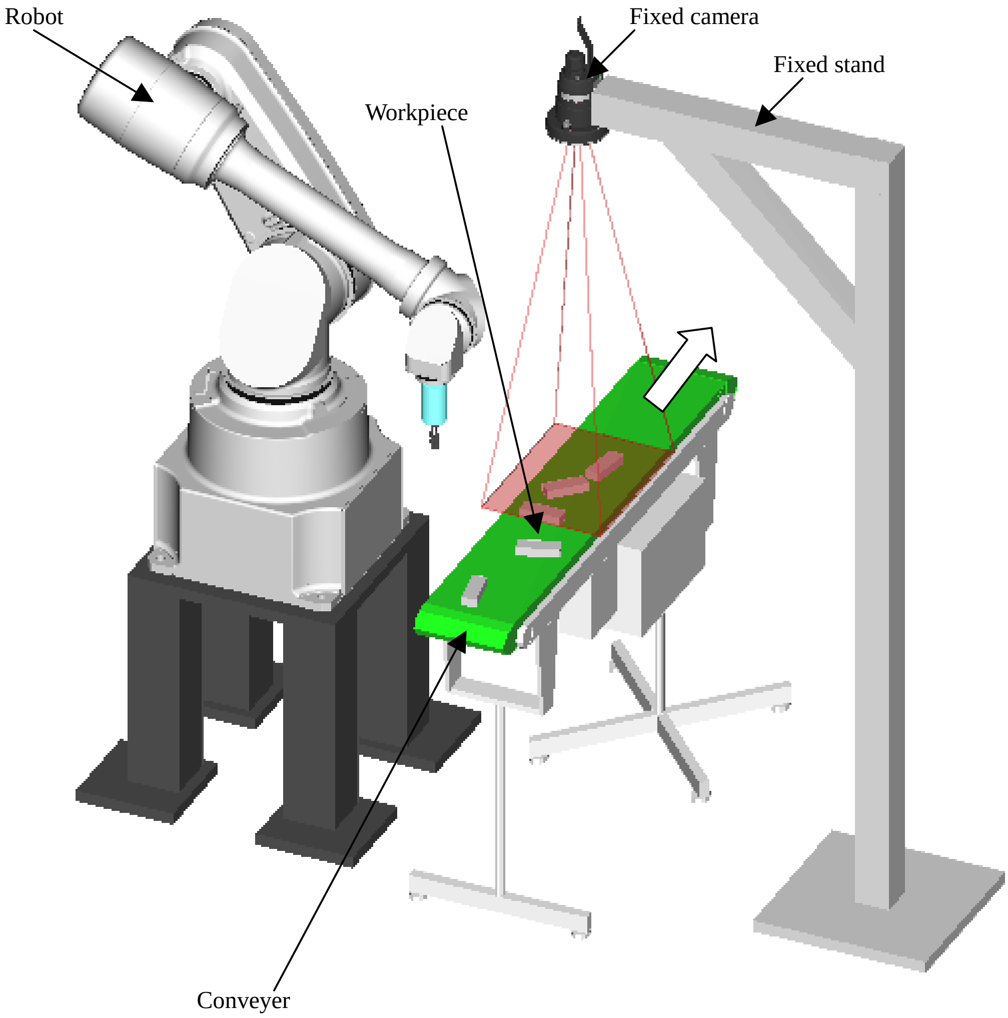
A.1 AN EXAMPLE OF 2D SINGLE VIEW VISION PROCESS

A robot detects workpieces facing up and facing down and picks up only when the workpiece is facing up.

Overview of the system

1 2D single view vision process is used.
2 The workpiece are supplied with the conveyor of pitch sending.
3 Workpieces facing up and facing down are presented to the workcell together.
4 Robot detects and picks only the workpiece facing up. Workpieces facing down are not detected and not picked.

An example of layout is shown below.



A.1.1 Examination of Optical Conditions

Field of view

Determine the required the size of field of view from the information on the width of a conveyer belt and the size of the workpiece. In the example of above layout, the conveyer belt width is 150 mm. The size of field of view shall be 200 mm, slightly larger than the belt width.

Distance from the camera to the workpiece

If the size of field of view is determined, determine the distance from the camera to the workpiece. For the calculation method of the size of field of view, refer to Section 2.3 "SIZE OF A CAMERA'S FIELD OF VIEW".
When the field of view of 200 mm scale is made with the analog camera using a lens with a 12mm focal distance, the distance from the camera to the workpiece is about 680 mm. When a lens with an 8mm is used, the distance from the camera to the workpiece is about 460 mm. In order to avoid interference of the camera and the robot, the lens of focal distance 12 mm shall be used and the distance from the camera to the workpiece shall be 680 mm.

Color of the workpiece and the background

Since the sample workpiece is a bright color, select a dark color for the background so that contrast becomes clear.

Note, in this example, the workpiece has a mark on the top facing surface and no mark on the bottom facing surface.

A.1.2 Vision Setting

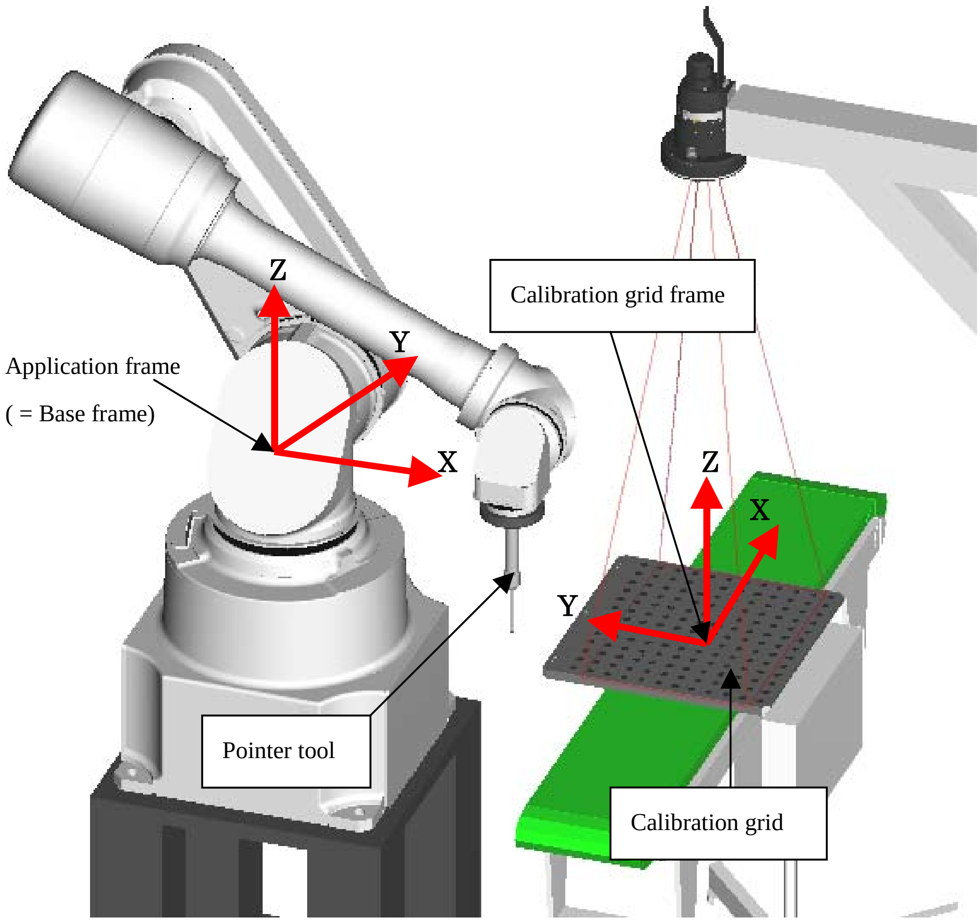
Adjust the aperture and the focus of the lens. For details, refer to Subsection 8.1.2 "Camera Setting Data Creation and Teaching".

Application frame setting

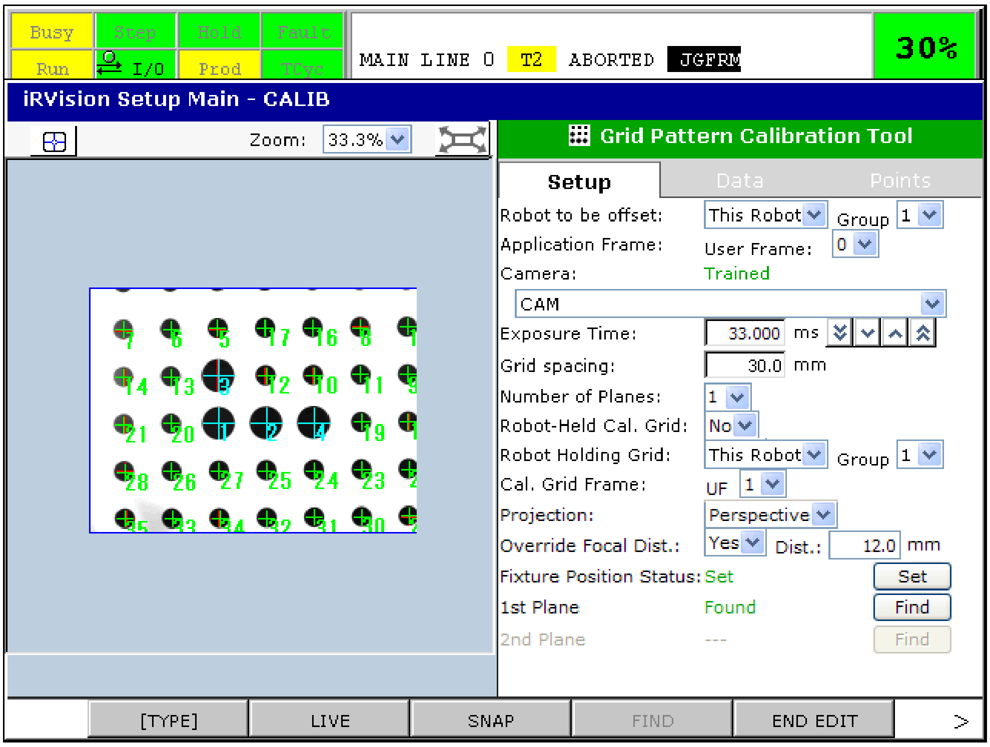
Set user frame number 0 (world frame) for application frame.

Camera calibration

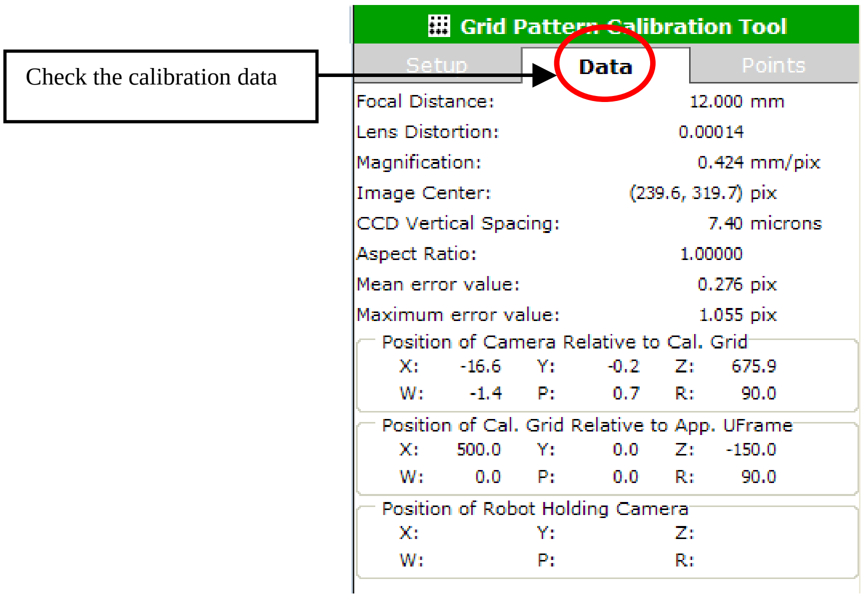
There are two methods for a camera calibration, Grid Pattern Calibration and Robot-generated Grid Calibration. In this example, the Grid Pattern Calibration is used. For details of the grid frame calibration, see Section 8.1, "GRID PATTERN CALIBRATION WITH A FIXED CAMERA". Fix the calibration grid on the conveyer and teach the calibration grid precisely with the pointer tool with the proper TCP set, then set the user frame. In this example, the calibration grid frame is set in the user frame number 1. After the calibration grid frame is set, do not move a calibration grid until the calibration is completed.



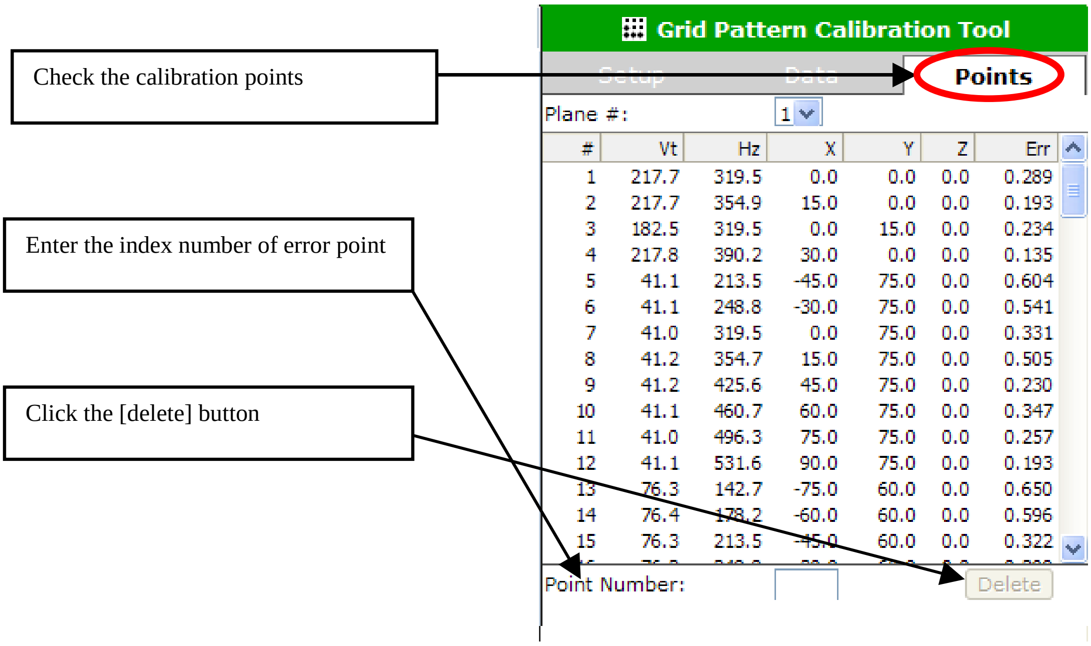
The calibration grid setup page is shown below. The calibration grid image is displayed. Set the [Application Frame], [Camera], [Exposure Time], [Grid spacing], [Number of Planes], [Robot-Held Cal. Grid], [Cal. Grid Frame] and [Override Focal Dist]. Since the Number of Planes is only one, set the focal distance of the lens manually. Next, tap the [Set] button in the [Fixture Position Status]. Press the F3 SNAP button, then press the Find button in the [1st Plane].



Check that the [1st Plane] becomes [Found]. Check the calculated calibration data. The calibration data page is shown below.
The magnification indicates how many millimeters are equivalent to a pixel. The magnification is calculated by dividing the size of field of view by the image size. For example, when the size of field of view is 262mm × 169mm and the image size is 640pix × 480pix, the calculated magnification is 0.409mm/pix = 262mm × 640pix.



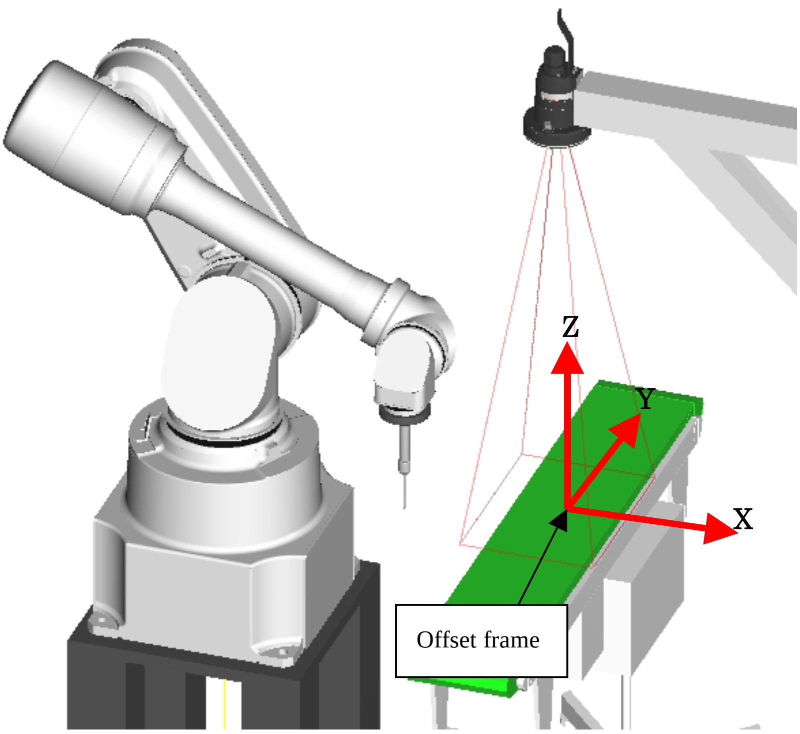
The Points in the calibration page are shown below.
If a crosshair is displayed at a location where no grid point is present, enter the index number of that point in the text box to the left of the [Delete] button and then tap the [Delete] button.



If there is no problem in the calibration data and the calibration points, finish the calibration. In addition, the calibration grid can be removed.

Offset frame setting

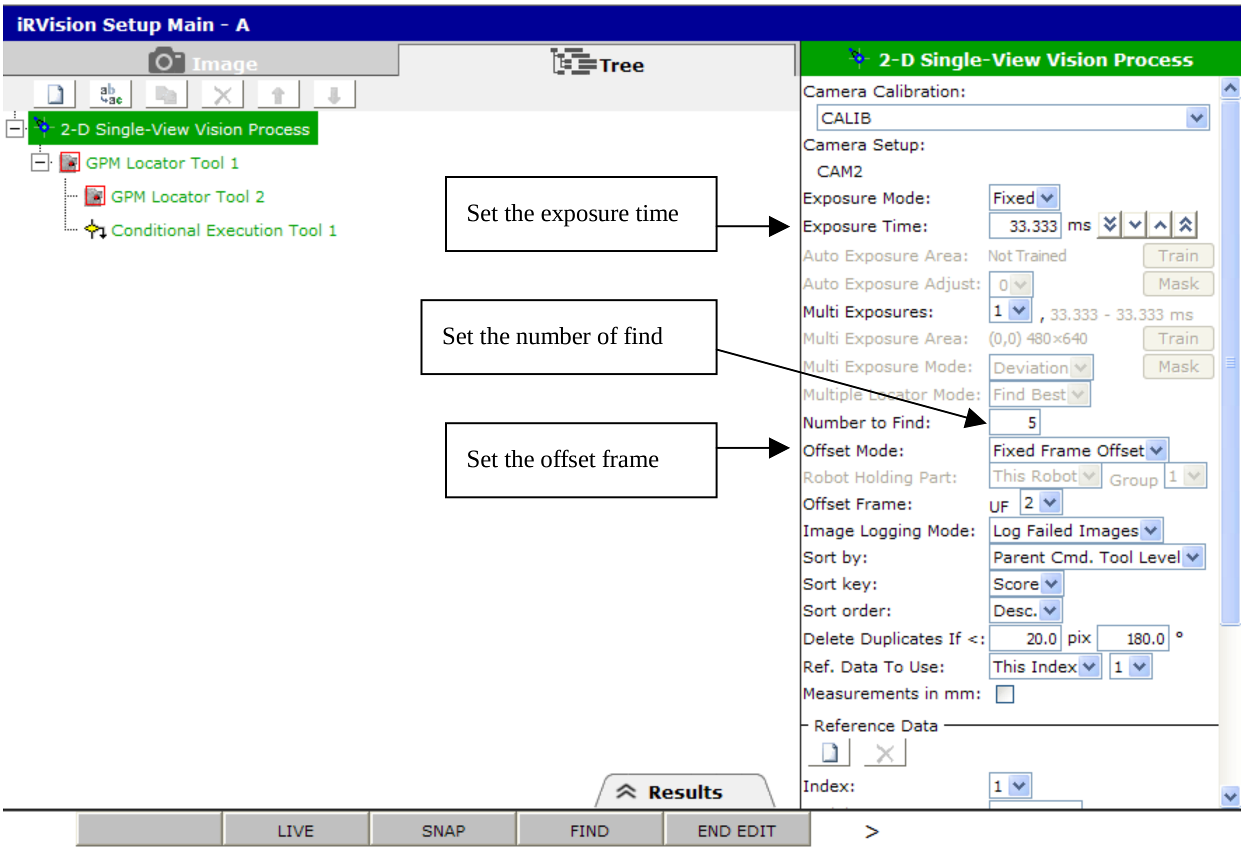
Set the offset frame on the conveyer as shown blow. Set an offset frame so that the XY plane of the offset frame is parallel with the conveyer plane on which the workpieces is placed. In this example, the user frame number for the offset frame is 2. There are two methods to teach the offset frame, one is to manually teach it with the pointer tool, and another is the Automatic Grid Frame Set Function. In this example, the pointer tool is used. For details, see Section 9.1.1, “User frame setting with a pointer tool”.



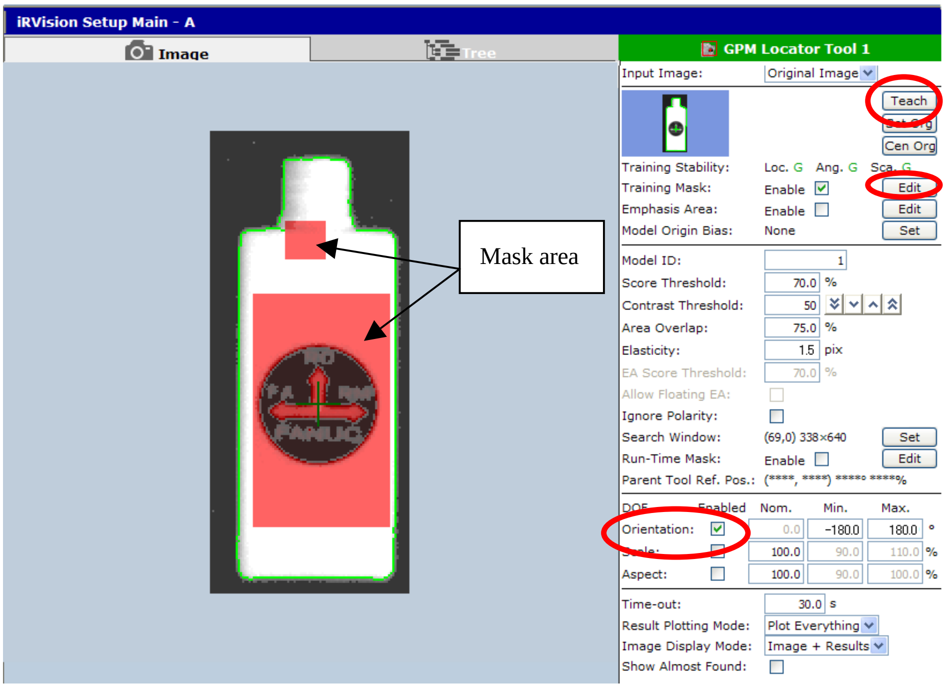
Vision Program Creation and Teaching

Create a "2D Single-view Vision Process". Select the calibration data in the vision process. Adjust the brightness of the image by setting "Exposure Time". In the [Number to Find], enter the maximum number of workpieces to be found per measurement. Following the above example, select the user frame number 2 for the offset frame.

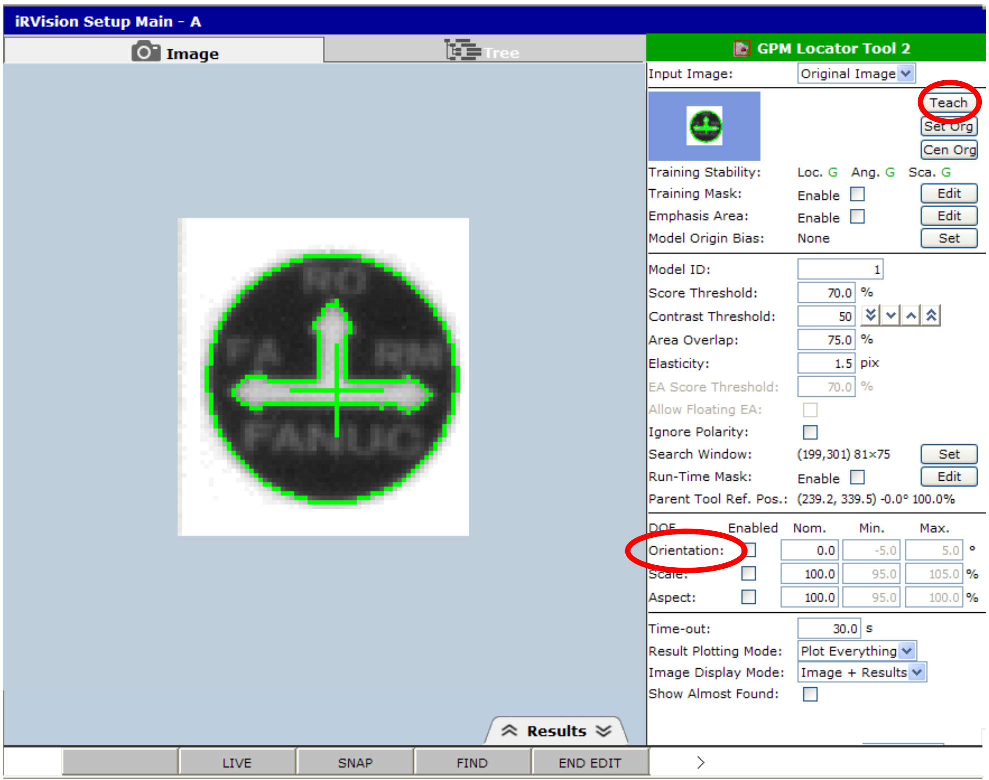
In this example, [GPM Locator Tool 1] detects the shape of a workpiece. Workpieces facing both up and down are detected with [GPM Locator Tool 1]. Next, [GPM Locator Tool 2] is taught under [GPM Locator Tool 1] as a child tool. [GPM Locator Tool 2] detects the mark on a workpiece facing up. If the workpiece is facing up the find is a success. If the workpiece is facing down the find fails. Next, [Conditional Execution Tool 1] is taught under [GPM Locator Tool 1]. Set the [Conditional Execution Tool 1] so that the workpiece without the mark is treated as not found.



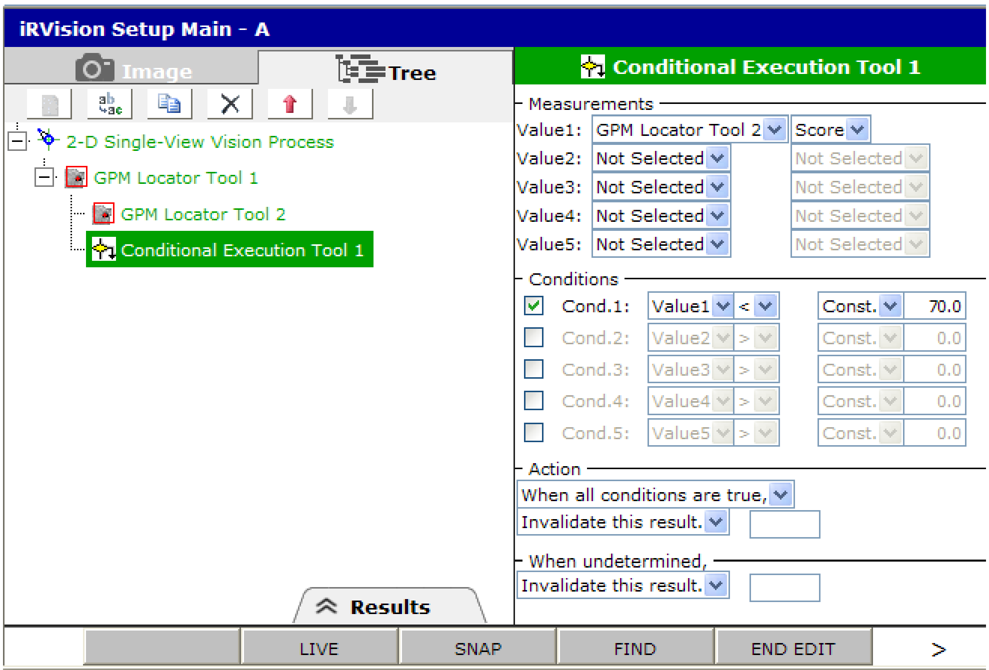
An example of a trained GPM Locator Tool, [GPM Locator Tool 1], is shown below. Place a workpiece in the field of view. Next, press the F3 SNAP button to snap an image. Tap the [Teach] button to teach the shape of the workpiece as detection model. Tap the [Edit] button in the [Training Mask] to remove incorrect features or edges. Since the workpiece rotates with a range of ± 180 degrees, DOF-Orientation is set ± 180 degrees.



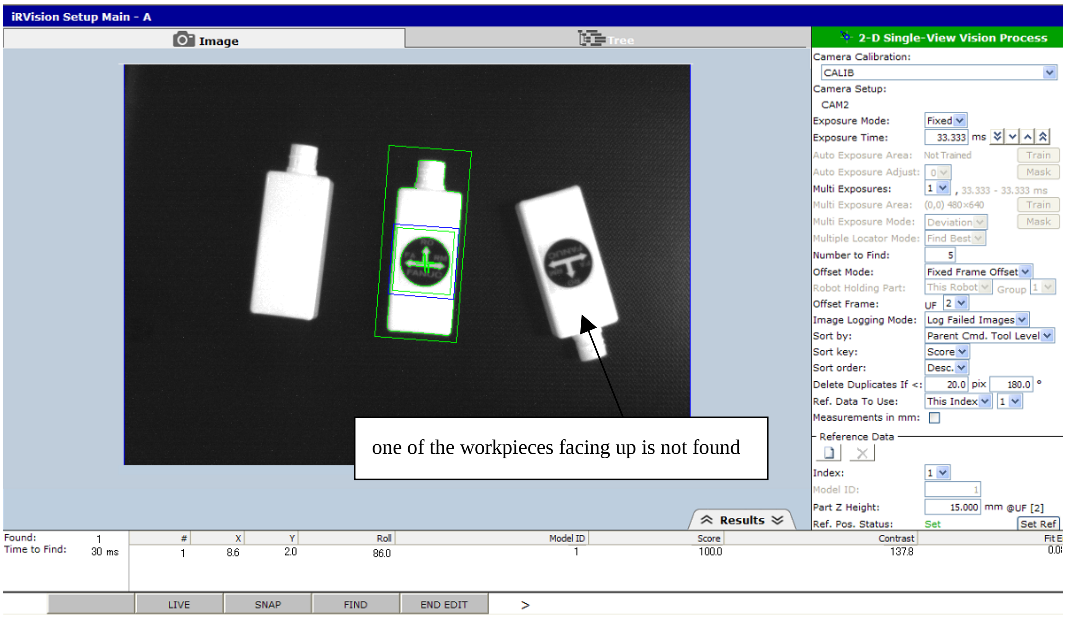
The page of the [GPM Locator Tool 2] is shown below. Place a workpiece in the field of view and Tap [Teach] button. Since the relative position between the shape of workpiece and the mark don’t change, disable the DOF--Orientation.



The page of [Conditional Execution Tool 1] is shown below. If the mark can’t be detected by the [GPM Locator Tool 2], that workpiece is treated as not found by the [Conditional Execution Tool 1]. In the example below the result is invalidated if the score of the [GPM Locator Tool 2] is below 70 or if [GPM Locator Tool 2] fails to find anything. The workpiece is only considered successfully found if both [GPM Locator Tool 1] and [GPM Locator Tool 2] are found.

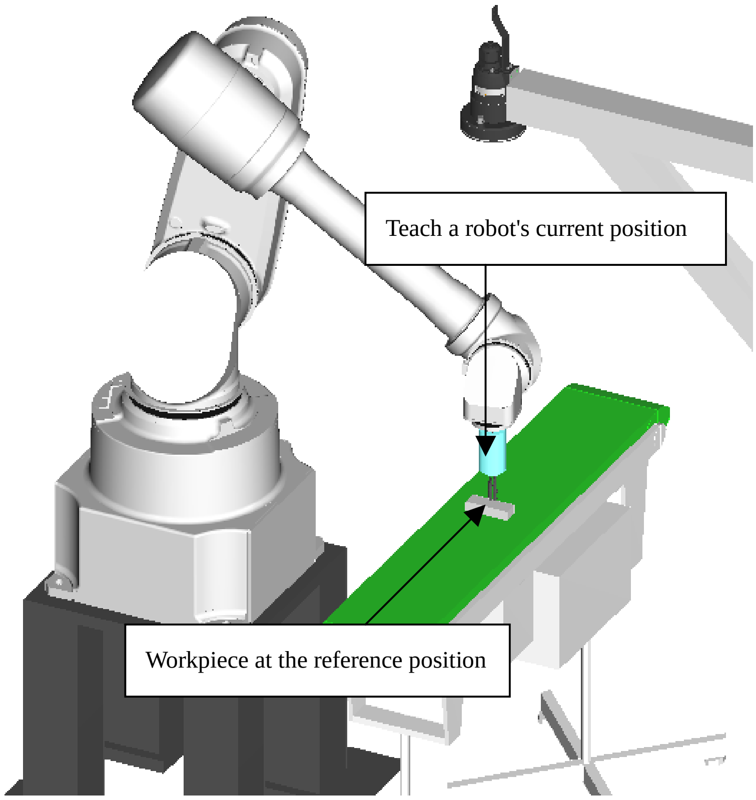


Next, check the detection. Select the [2D Single-view Vision Process] from the tree view, place the workpieces in the field of view. Then, press F3 SNAP] and F4 FIND button. In the following example, one of the workpieces facing up is not found.



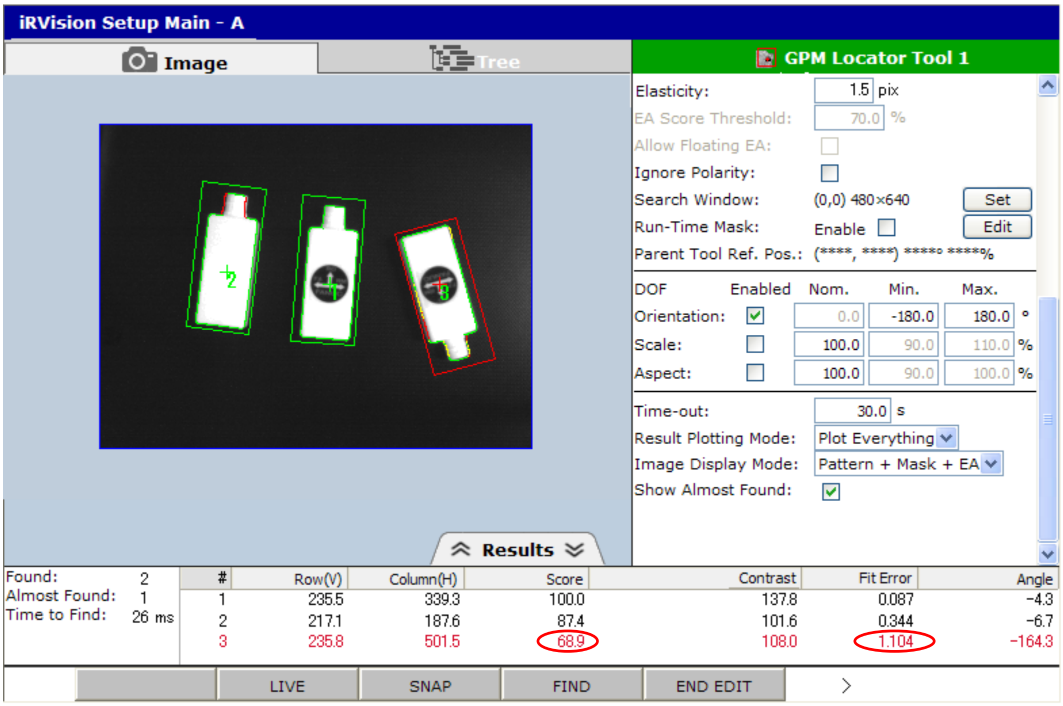
Use the following procedures to determine why the workpiece was not found.
Select the page of [GPM locator Tool 1] from the tree view. Enable [Snow Almost Found]. If there are any workpieces that failed to be found because they fell just short of meeting the score, contrast, orientation, and/or other conditions, its almost found results are displayed. The result appears in a red rectangle on the image. Adjust the detection parameters with showing the [Results] page as shown below.
In the example in the following figure, since the Score in the Results is smaller than a set value (70), the part is considered not found. Moreover, the [Fit Error] is bigger than other workpieces. When a workpiece has individual difference, or when the edge of a model has roundness, the workpiece on an image may distort.

Status] becomes [Set]. In addition, the value of [Reference X], [Reference Y] and [Reference Z] are set. The value is the origin position of the workpiece relative to the offset frame.
Jog the robot and move to the working position (for example, pick up a workpiece). For an example, refer to the sample program in Subsection A.1.3 "Robot Program Creation and Teaching". LP[2] on the line 11 of the sample program is the working position for the workpiece. If the robot's current position is set to LP[2], the reference position setting is complete.

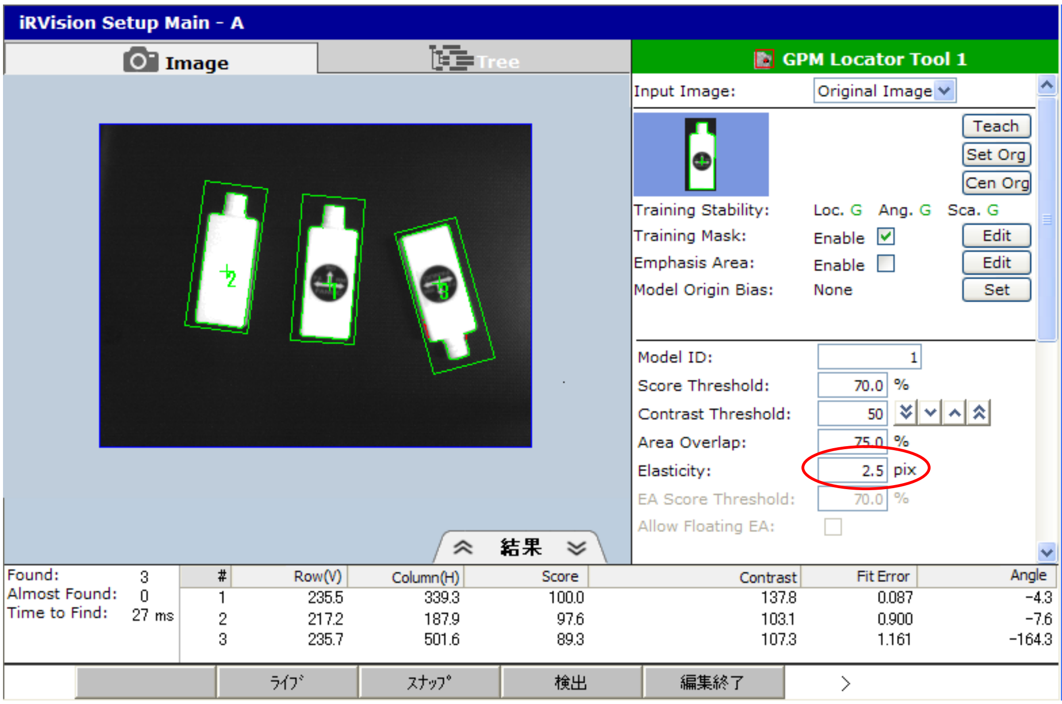


A.1.3 Robot Program Creation and Teaching

In the sample program below, a vision process named "A" is used. For fixed frame offset, add the "VOFFSET, VR" instruction as an operation statement to the motion statements.



Since this workpiece has roundness on the edge, the workpiece on an image it is distorted. Even if the shape changes a little due to the roundness on the edges, it is able to find the workpiece by raising the [Elasticity]. In this example, the [Elasticity] is changed from 1.5 to 2.5. Then, press the F4 FIND button. The workpiece is now found, it is no longer almost found with the new [Elasticity].



Reference position setting

Select [2D Single-view Vision Process] page and place a workpiece in the field of view. Set the Z coordinate of the workpiece measurement plane viewed from the XY plane of offset frame in "Part Z Height" of the Reference Data.

Press the F3 SNAP and F4 FIND buttons to find a workpiece. Then, do not move a workpiece until a reference position setup is completed. Next, tap the [Set Ref] in the Reference Data. The [Ref. Pos.

```
  1:  UFRAME_NUM=1 ;
  2:  UTOOL_NUM=1 ;
  3:  R[1:Notfound]=0     ; ;
  4:L P[1] 2000mm/sec FINE     ;
  5:   ;
  6:  VISION RUN_FIND 'A'     ;
  7:  VISION GET_OFFSET 'A' VR[1] JMP LBL[100] ;
  8:   ;
  9:  !Handling ;
 10:L P[2] 2000mm/sec CNT100 VOFFSET,VR[1] Tool_Offset,PR[1]     ;
 11:L P[2] 500mm/sec FINE VOFFSET,VR[1]     ;
 12:  CALL HAND_CLOSE     ;
 13:L P[2] 2000mm/sec CNT100 VOFFSET,VR[1] Tool_Offset,PR[1]     ;
 14:  !Handling ;
 15:  JMP_LBL[900] ;
 16:   ;
 17:  LBL[100] ;
 18:  R[1:Notfound]=1     ;
 19:   ;
 20:  LBL[900] ;
```

Execute vision process ”A” with the vision run_find instruction on line 6. Obtain the offset result of the found workpiece on line 7. Move to the approach position above the workpiece on line10. Move to the grasp position on line 11. Move to the escape position after grasping the workpiece on line 13.

A.1.4 Robot Compensation Operation Check

Check that a workpiece placed on the conveyer can be detected and handled precisely.

- Place the workpiece near the reference position, find it and check the handling accuracy. If the accuracy of compensation is low, retry the reference position setting.
- Move the workpiece without rotation, find it and check the handling accuracy. If the accuracy is good for reference position, but low for a non-rotated workpiece on the edge of the field of view, it is possible that Part Z Height is not set properly. Check the Part Z Height, refer to Subsection 4.2.3, “Vision Program Creation and Teaching”
- Rotate the workpiece, find it and check the handling accuracy. If the accuracy is good for moved workpiece without rotation, but low for rotated workpiece and lower for more rotated workpiece, it is possible that the offset frame or the calibration grid location is not set properly. If the calibration grid frame was manually taught with a pointer, verify the accuracy of the pointer TCP (UTool) used to teach the frame. , check the offset frame and the calibration grid frame are set precisely, then retry the camera calibration. If it is difficult to retry the camera calibration, the “ADJ_OFS” may improve the situation without the re-set up the offset frame and the calibration grid location. ADJ_OFS is included in VISION SUPPORT TOOLS. Refer to Subsection 12.1.6, “ADJ_OFS” in the *i*RVision Operator’s Manual (Reference) (B-83304EN) for details.
- Start with lower override of the robot to check that the logic of the program is correct. Next, increase the override to check that the robot can operate continuously.

INDEX

<T>

<U>

<V>

<W>

REVISION RECORD

Edition	Date	Contents
02	Sep., 2013	• Applied to R-30*i*B Mate. • Applied to “9 FRAME SETTING” and “10 CAMERA CALIBRATION SETTING”.
01	Oct., 2012	

B-83304EN-1/02

* B - 8 3 3 0 4 E N - 1 / 0 2 *