FANUC Robot series

R-30*i*B CONTROLLER

*i*RVision 3D Laser Vision Sensor Application

OPERATOR'S MANUAL

B-83304EN-2/01

• 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 user 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 oscillator.

> ⚠**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.

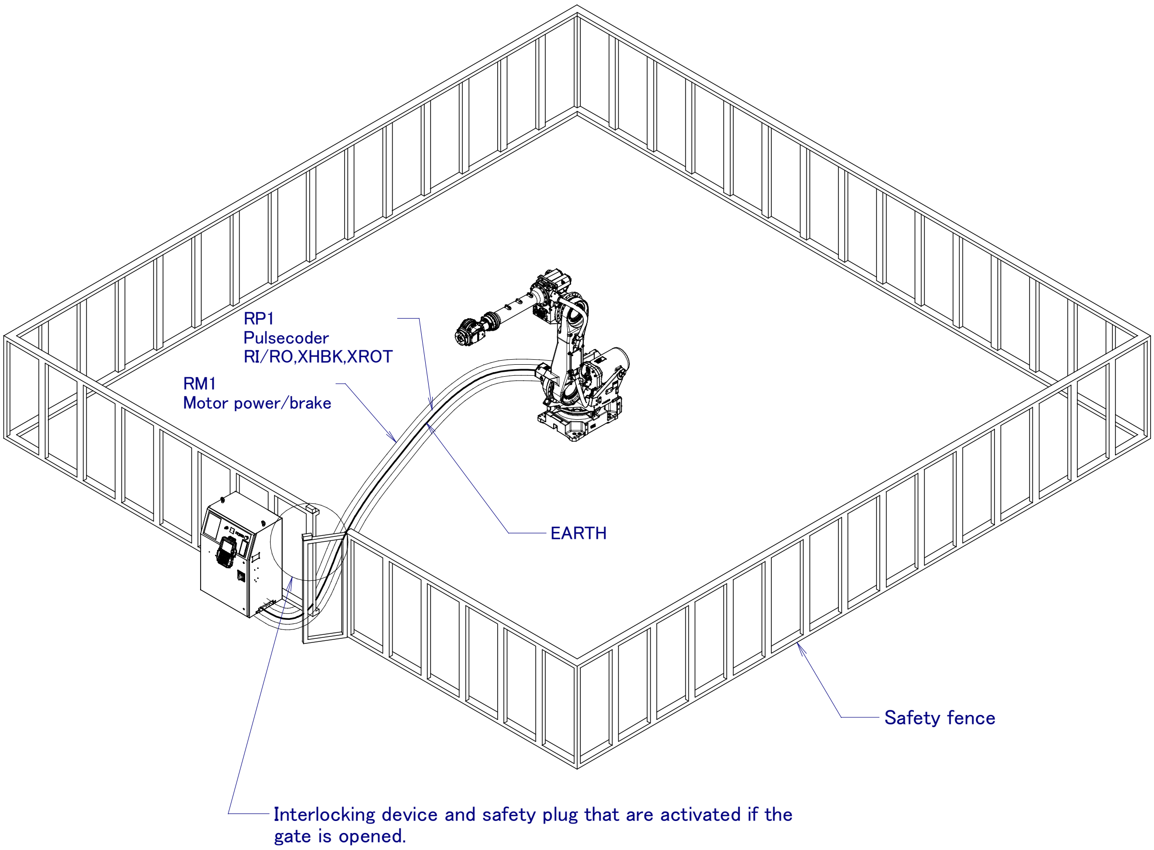

Fig. 3 (a) Safety fence and safety gate

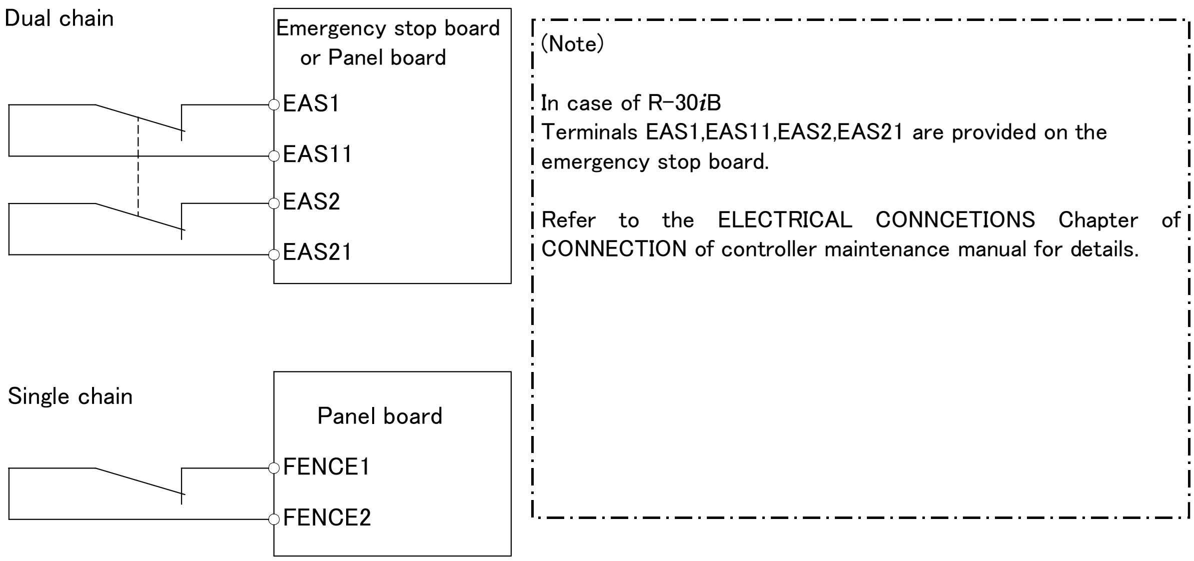

Fig. 3 (b) Limit switch circuit diagram of the safety fence

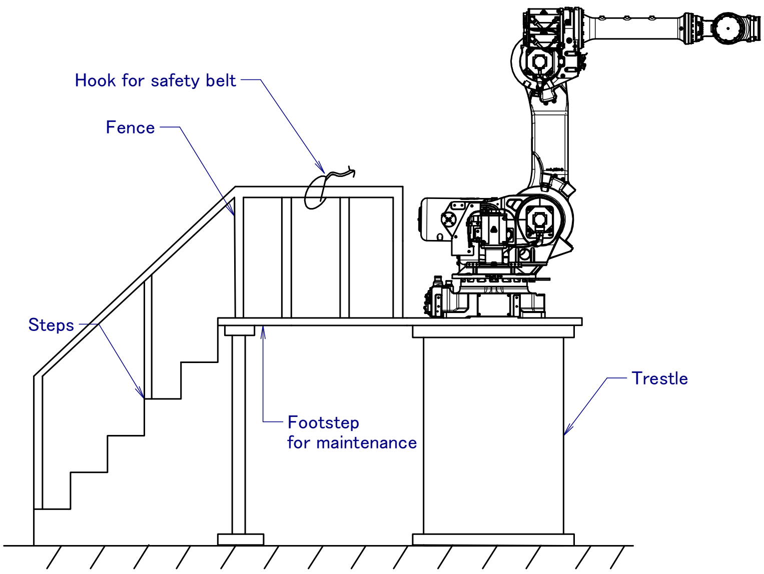

Fig.3 (c) Footstep for maintenance

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.

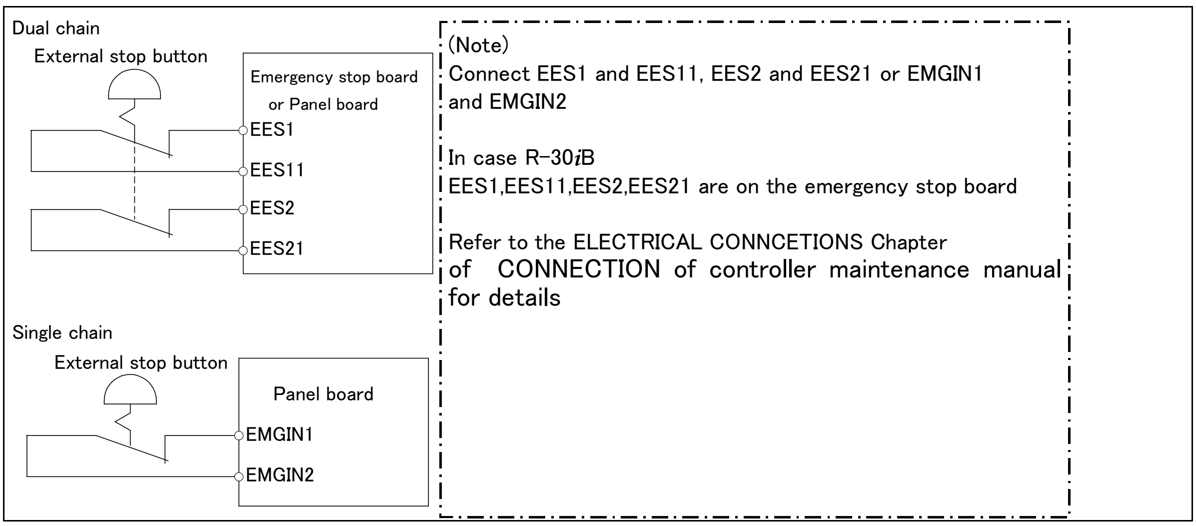

Fig.3.1 Connection Diagram for External Emergency Stop Button

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.

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 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 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.

(6) 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. When theses attentions are not kept, unexpected troubles might occur.
   - 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.
   - Please do not interfere with the other parts of mechanical unit when install equipments in the robot.
(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. The frequent urgent stop by alarm causes 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
Standard	A (*)
Controlled stop by E-Stop (A05B-2600-J570)	C (*)

(*) R-30*i*B does not have servo disconnect.

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 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*B controller)
SRVO-218 Ext.E-stop/Servo Disconnect	External emergency stop input (EES1-EES11, EES2-EES21) is open. (R-30*i*B 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.

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.

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1 PREFACE

This chapter describes an overview of this manual and safety precautions regarding the FANUC 3D Laser Vision Sensor, which should be noted before operating the *i*RVision function.

1.1 ABOUT THIS MANUAL

1.1.1 About This Manual

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.
This manual is directed to users who have taken the *i*RVision 3D Laser Vision Sensor course at FANUC Training Center.

When you would like to know the meanings (e.g. the items on *i*RVision setup screen, the arguments of the instruction, and so on), please refer to the “R-30*i*B CONTROLLER *i*RVision OPERATOR'S MANUAL (Reference)”.
About other operations of FANUC Robots, please refer to the “R-30*i*B CONTROLLER OPERATOR’S MANUAL (Basic Operation)”.
About other operations, please refer to manuals which are introduced in "1.1.2 Related manuals".

> ⚠ **CAUTION**
> This manual is based on R-30*i*B system software, version V8.10P/04. 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.

1.1.2 Organization of This Manual

Chapter	Description
Chapter 1, "PREFACE"	Describes an overview of this manual and precautions for the 3D Laser Vision Sensor. Especially about precautions, be sure to read thoroughly.
Chapter 2, "ABOUT VISION SYSTEM"	Describes the fundamental items of vision system such as the measurement principle of the 3D Laser Vision Sensor, the kind of method of positioning camera, the kind of robot position offset, and so on.
Chapter 3, "TEACHING EXAMPLE "	Describes a flow of setup procedures and a detail of teaching procedures as an example of the case of robot-mounted camera + fixed frame offset in 3DL Single-View Vision Process.
Chapter 4, "3DL SINGLE-VIEW VISION PROCESS"	Describes an overview of the setup procedures and teaching procedures. Please refer to chapter 3 for the details.
Chapter 5, "3DL MULTI-VIEW VISION PROCESS"	Describes an overview of the setup procedures and teaching procedures. Please refer to chapter 3 for the details.
Chapter 6, "3DL CURVED SURFACE SINGLE VISION PROCESS"	Describes an overview of the setup procedures and teaching procedures. Please refer to chapter 3 for the details.
Chapter 7, "3DL CROSS-SECTION VISION PROCESS "	Describes an overview of the setup procedures and teaching procedures. Please refer to chapter 3 for the details.
Chapter 8, "VISION APPLICATION "	Describes a detail of method of using 3D Laser Vision Sensor with 2D vision, and the system in which multiple robots participate.
Chapter 9, " TROUBLESHOOTING "	

1.1.3 Related Manuals

This section introduces related manual for *i*RVision.

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

This is the main manual of R-30*i*B 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 program
- Executing a 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 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 Controller.

R-30*i*B CONTROLLER Sensor Mechanical / 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 Controller, and maintenance of sensors.

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

This manual is the reference manual for *i*RVision on the R-30*i*B controller. This manual describes each function which is provided by *i*RVision. When you would like to know the meanings (e.g. the items about the *i*RVision setup screen, the arguments of the instruction, and so on), please refer to this manual.

R-30*i*B CONTROLLER *i*RVision 2D Vision Application OPERATOR’S MANUAL B-83304EN-1

This manual is desired to first refer to when you start up systems of *i*RVision 2D Compensation and 2.5D Compensation. This manual describes startup procedures of *i*RVision 2D Compensation and 2.5D Compensation system, creating programs, caution, technical know-how, response to several cases, and so on.

R-30*i*B 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 Application 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 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.

1.2 PRECAUTIONS FOR 3D LASER VISION SENSOR

This section describes precautions to be taken for the 3D Laser Vision Sensor before using it.

1.2.1 Safety of Laser Sensor

The 3D Laser Vision Sensor is a visual sensor, which detects the position and posture of an object using semiconductor lasers.

> ⚠ **CAUTION**
> Observe user's safety and fire precautions in accordance with the safety standards and the regulations, which the country and the region provide when you use this sensor. Moreover, when the safety standards and regulations are changed or newly enacted, please follow them.

The laser classification used in the sensor
Semiconductor lasers → Class IIIa Laser (cf. FDA 1040.10)
Class 3R Laser (cf. IEC Pub.60825 / JIS C6802)

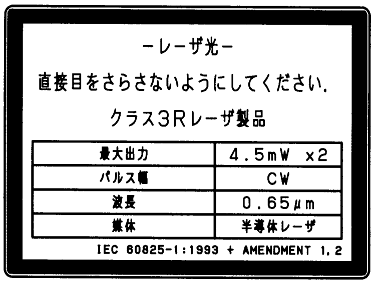
1.2.2 Laser Beam

The semiconductor laser beam is a visible optical laser with a wave length of 650nm. It is necessary to pay attention to its operation though the maximum output power is at most 4.5mW x 2. Do not irradiate the output beam from the sensor directly to your eyes. Moreover, do not look straight at the scattered light for a long time.

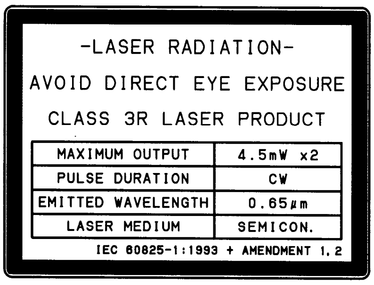
1.2.3 Warning Label

The warning labels which inform the danger of the laser beam irradiation are affixed on this laser sensor. Moreover, the warning labels in accordance with United States FDA standard are prepared as an option. Fig. 1.2.3 (a) and Fig. 1.2.3 (b) show the warning labels used.

① Explanatory label (for IEC/JIS)



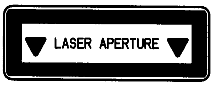
JIS (general type)



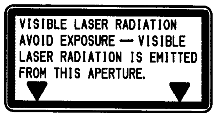
IEC (general type)

② Aperture label

JIS (general type)

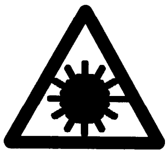


IEC (general type)

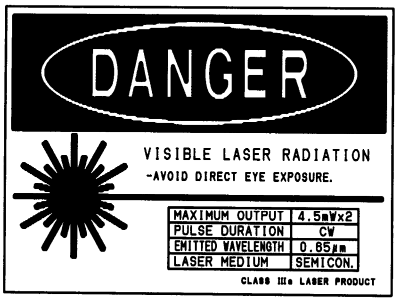


FDA (general type)

③ Warning label



IEC/JIS

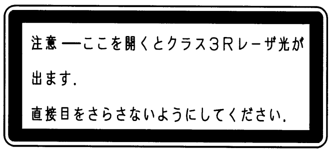


FDA

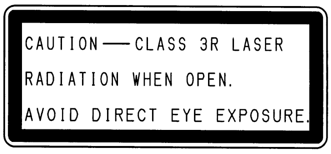
Fig. 1.2.3 (a) Warning labels (1)

④ Address label (for FDA)

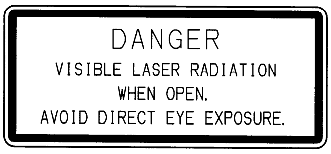
⑤ Access panel label



JIS



IEC



FDA

⑥ Certification label (for FDA)

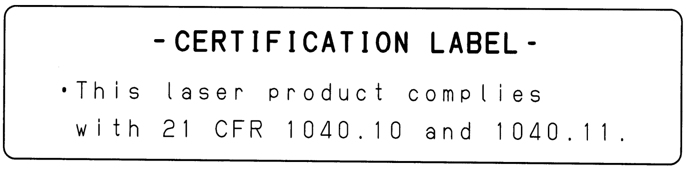


Fig. 1.2.3 (b) Warning labels (2)

2 ABOUT VISION SYSTEM

This chapter explains the fundamental items about vision system. Before starting a system, be sure to read this chapter thoroughly.

2.1 *i*RVision

FANUC robots are teaching-playback robots. In a teaching-playback system, specific tasks are taught to robots in advance, which then in turn work exactly as they are taught. Teaching-playback robots play back the motion just as it was taught.

Conversely speaking, what this type of robot can do is limited to what it is taught in advance. This means that, if you want the robot to manipulate every workpiece in the same way, you need to place every workpiece at exactly the same position.

Therefore, in the usual system, the exclusive jig for fixing the position and posture of a workpiece is necessary. Moreover, when the kind of a workpiece changes, the man-hours to change and adjust the jig is necessary too.

Such restrictions are eliminated by using *i*RVision. *i*RVision measures the position of each workpiece by using cameras, and it adjusts the robot motion so that the robot can manipulate the workpiece in the same way as programmed even if the position of the workpiece is different from the workpiece position set when the robot program was taught.

Thereby, the cost of peripheral equipments such as the exclusive jig and man-hours days can be greatly reduced. So, the compact system with the high flexibility can be built.

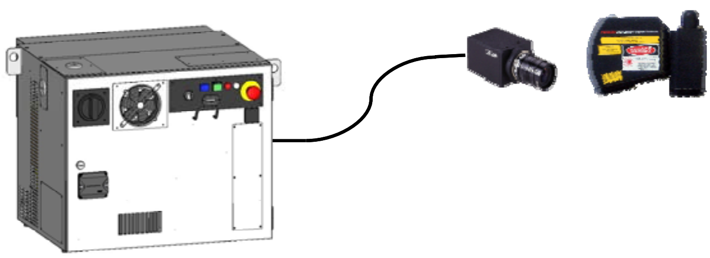
*i*RVision is the vision function integrated into the FANUC robot controller. There are 2D Vision Sensor and 3D Laser Vision Sensor in *i*RVision.

2.2 BASIC CONFIGURATION

*i*RVision consists of the following components:

2D Vision Sensor system
- Robot controller
- Camera & lens
- Camera cable
- Camera multiplexer (used if needed)
- Lighting Equipment

3D Laser Vision Sensor system
- Robot controller
- 3D Laser Vision Sensor
- Camera cable
- Camera multiplexer (used if needed)
- Lighting Equipment



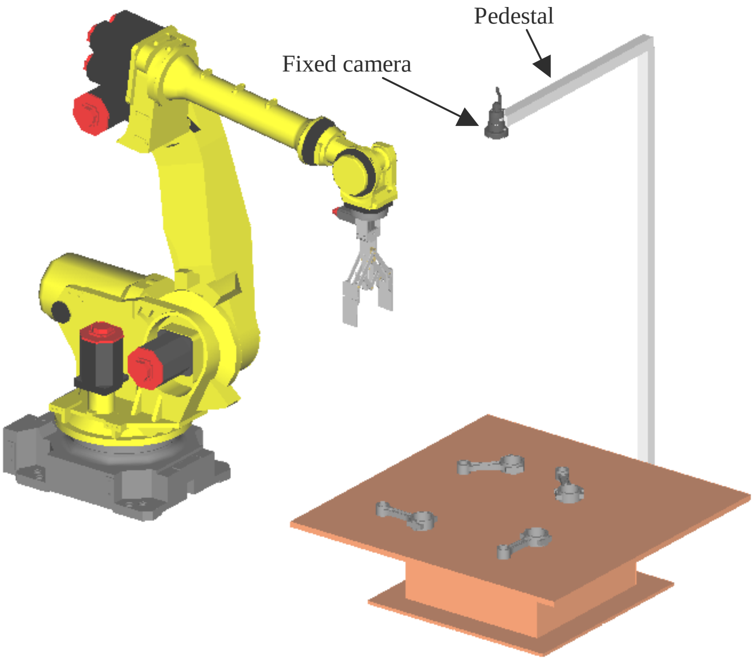
For detail about the connection between the robot controller, a camera, and the 3D Laser Vision Sensor, please refer to “R-30*i*B CONTROLLER Sensor Mechanical / Control unit OPERATOR’S MANUAL”.
A camera and lens of 3D Laser Vision Sensor can also be used as the 2D compensation, because the camera and lens are common.

2.3 FIXED CAMERA AND ROBOT-MOUNTED CAMERA

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

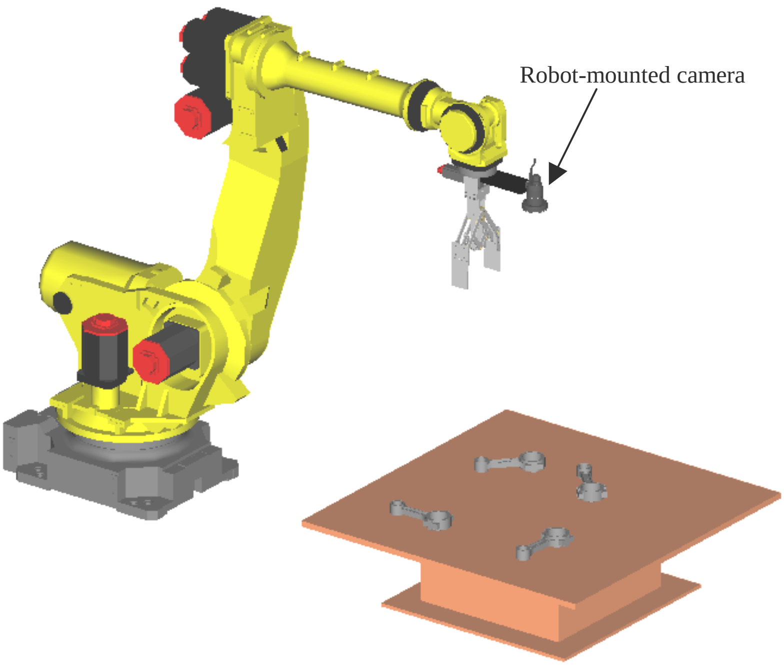
Fixed camera

- 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 prepare the thing with sufficient strength not shaking in vibration.



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.

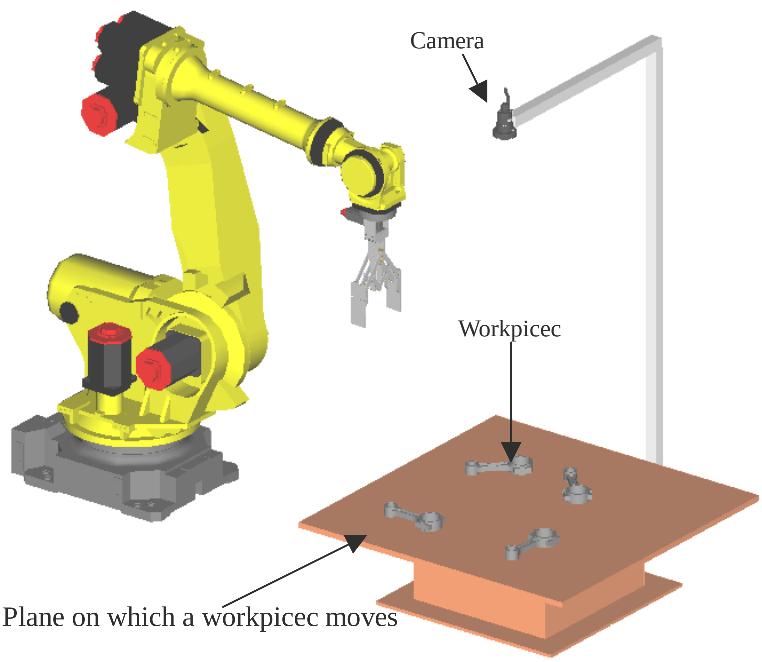


2.4 FIXED FRAME OFFSET AND TOOL OFFSET

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

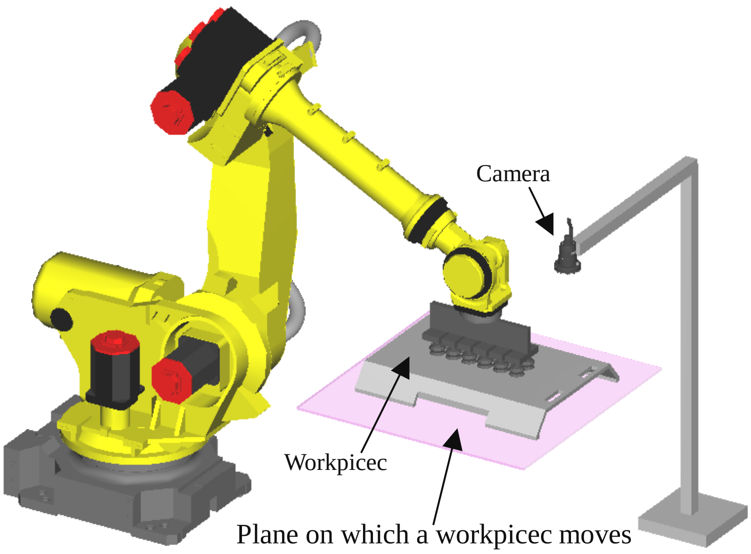
Fixed frame offset

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.



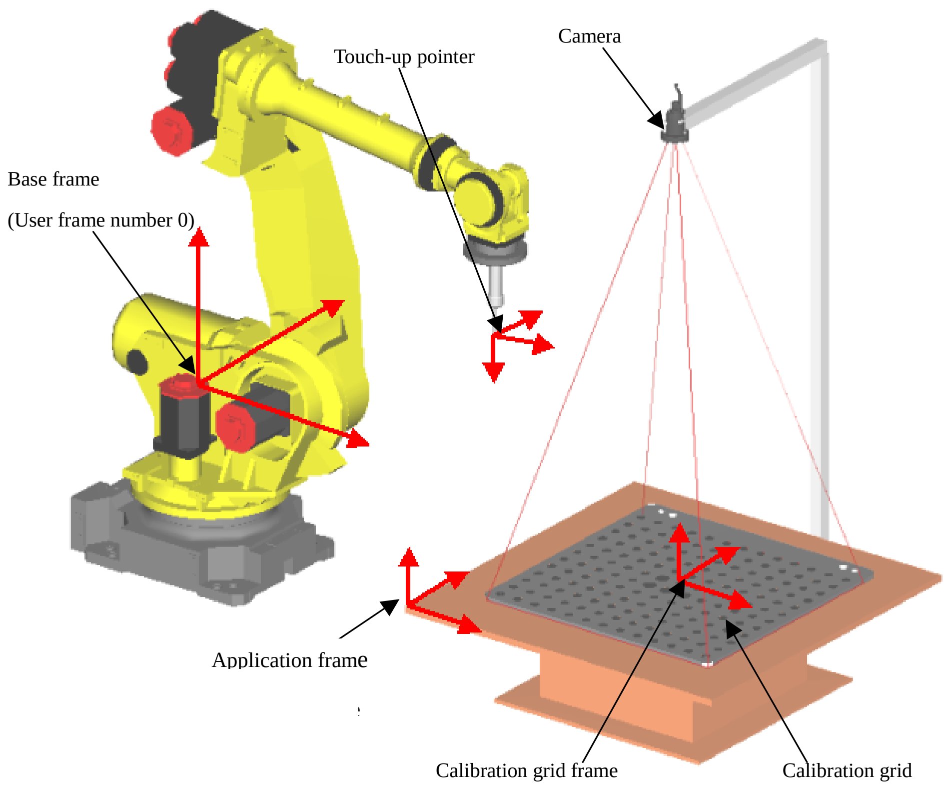
Tool offset

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 COORDINATE SYSTEMS USED FOR A VISION SYSTEM

It is necessary to set up some coordinate systems for a vision system.



Touch-up pointer

Set the TCP accurately on the touch-up pointer installed on the robot gripper. The touch-up pointer is required to teach the application frame, the calibration grid frame and the offset frame.

Application frame and offset frame

The application frame is a coordinate system specified on the calibration teach screen, and the offset frame is a coordinate system specified on the vision process teach screen.

In the fixed frame offset, the only application frame is used.

In the fixed frame offset, the application frame is a user frame used for calculation of an offset data. The offset data in the fixed frame offset is outputted as the value on the user frame.
Set the application frame so that the XY plane of the user frame is parallel with the table plane on which a workpiece moves. As shown in the above figure, when a workpiece moves on a table, set the application frame so that the XY plane of the user frame is parallel with the table plane on which a workpiece moves. Set up correctly the application frame. When the plane on which a workpiece moves is not parallel to the XY plane of the application frame, compensation accuracy worsen.
When two or more robots work together, it is necessary to set the sharing user frame and to specify it as the application frame.

In the tool offset, both of the application frame and the offset frame are used.

In the tool offset, the application frame is a user frame to be used for camera calibration. If there is no user frame to be specifically specified, select a base frame of a robot. (The user frame number of the base frame is 0.)
When two or more robots work together, it is necessary to set the sharing user frame and to specify it as the application frame.

In the tool offset, the offset frame is a tool frame used for calculation of an offset data. The offset data in the tool offset is outputted as the value on the tool frame.
Set the offset frame so that the XY plane of the tool frame is parallel with the plane on which a workpiece moves. When the plane on which a workpiece moves is not parallel to the XY plane of the offset frame, compensation accuracy worsen.

Calibration grid frame

Set the calibration grid location in a user frame or tool frame. As shown in the above figure, when the calibration grid is fixed on a table, teach a user frame to the grid. When the calibration grid is installed on the robot gripper, teach a tool frame to the grid.

The calibration grid is set with the touch-up pointer taught TCP. The case of a robot-mounted camera, and when a calibration grid is installed on a robot, the calibration grid frame can also be set up using the grid frame setting function. Moreover, it is also possible to set up the calibration grid frame using a grid frame setting function with robot-mounted camera that is installed temporarily for setting.

NOTE

The grid frame setting function sets the calibration grid frame using a camera. Compared with the manual touch-up setting 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. In grid frame setting, the calibration grid is measured from multiple directions by using a camera and the measured calibration grid frame is set in the user frame area or tool frame area of the robot controller. For details, please refer to “10.2 GRID FRAME SETTING” in “*i*RVision OPERATOR’S MANUAL (Reference)”.

2.6 CALCULATION OF THE OFFSET DATA

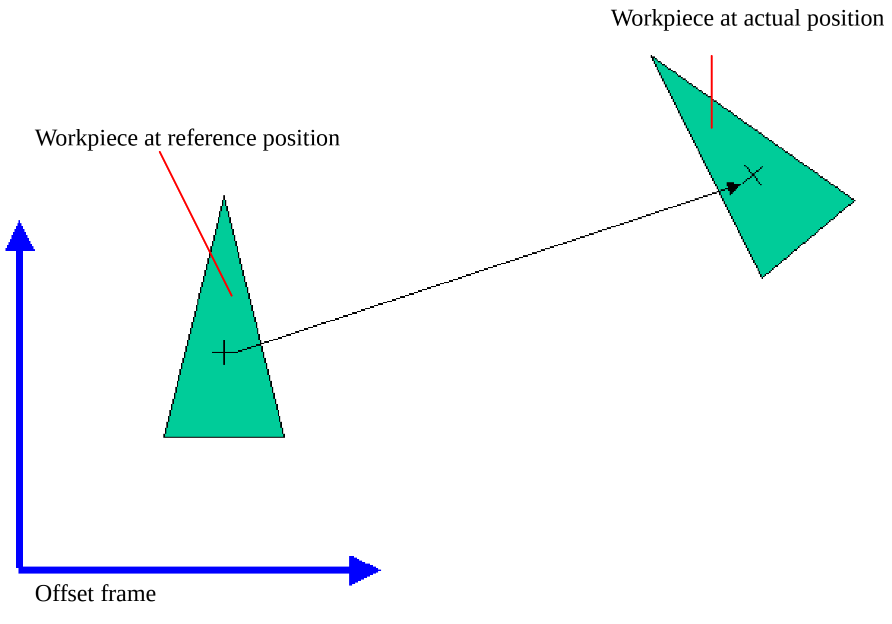
In this section, the calculation method of the offset data is explained.

Reference position and actual position

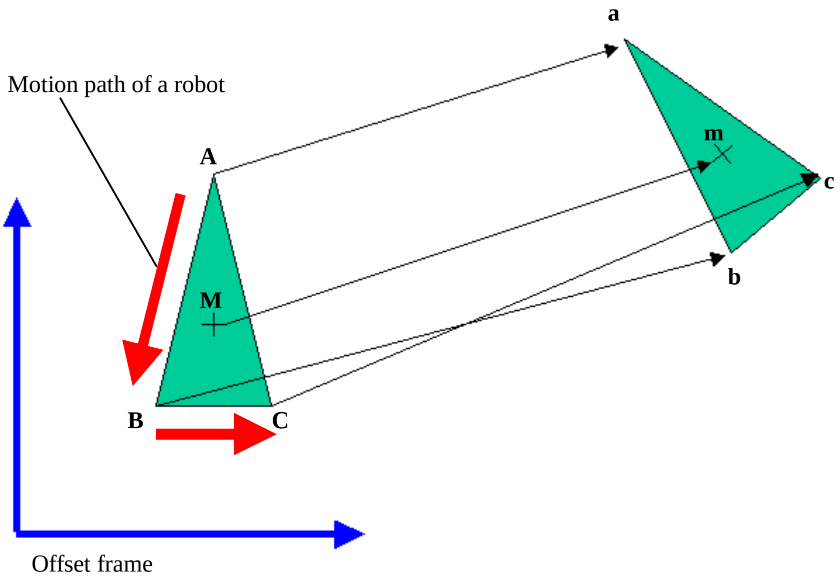
The Offset data is calculated from the position of the original workpiece set when the reference position was taught and the current workpiece position. The position of the workpiece set when the robot program was taught is called as the reference position, and the current workpiece position is called 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

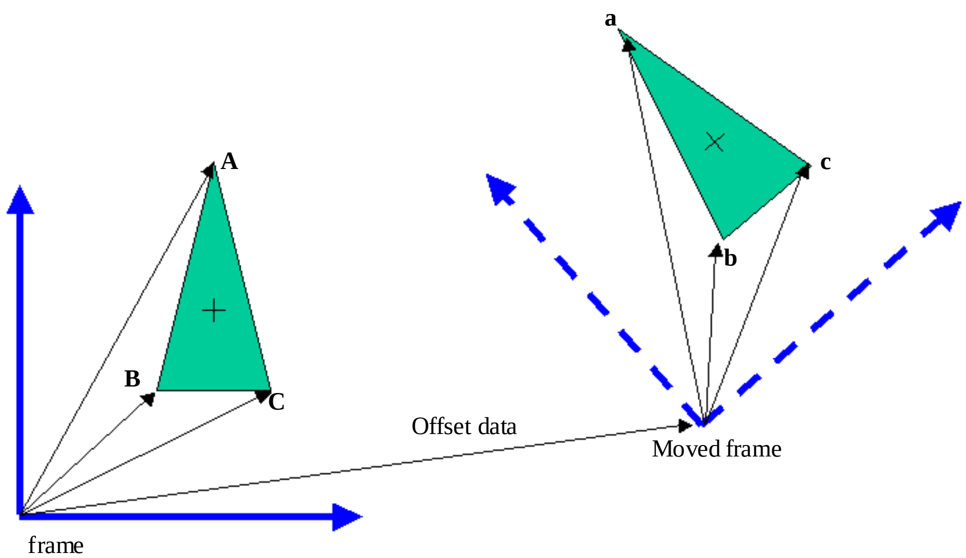
In the case of the following figure, the position of "+" mark is a found position of a workpiece. If a robot approaches only to the position of "+" mark, the offset data can be calculated by subtracting the value of actual position and reference position. Although it is easy to understand how to calculate the offset data by subtraction, there are also limitations. This type of offset is calcuated using simple addition. 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 postion 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.



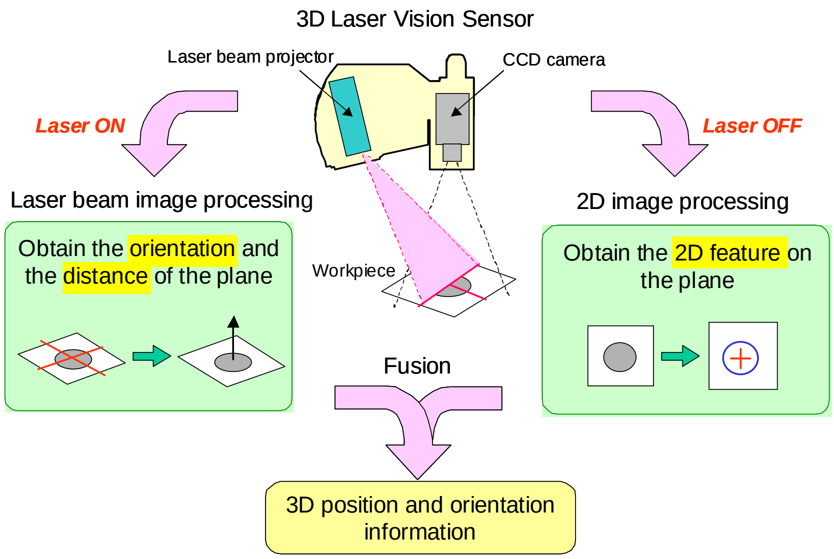
2.7 3D LASER VISION SENSOR

The 3D Laser Vision Sensor has the 3D measurement by a structured light method. The 3D Laser Vision Sensor measures the 3D position and posture of a workpiece by using a hybrid system of the 2D image processing and the 3D measurement.

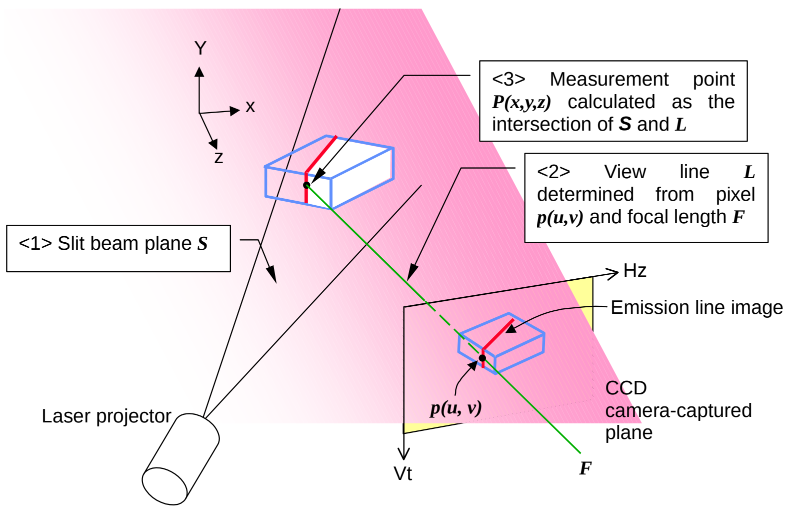
2.7.1 Measurement Principle

This sub section explains the measurement principle of the 3D Laser Vision Sensor.

The 3D Laser Vision Sensor has a function, which captures the laser beam directed to a workpiece from the laser projector into an image, and analyzes the image to measure the 3D position of the part to which the laser beam is directed. Combining this function with the 2D image processing function can measure the 3D position and posture of a workpiece.



The following figure shows the principle of how the 3D position of the part to which the laser beam is directed is obtained. The calibrated 3D Laser Vision Sensor has known the expression for obtaining view line *L* using slit beam plane *S* <1> and pixel *p(u,v)* <2>. Specifying all pixels on the laser emission line on the CCD camera-captured plane (laser slit image) sequentially can obtain the 3D position of each point on the emission line on the actual workpiece.



A 3D straight line can be calculated using a straight line obtained with one laser slit in the laser slit image and the 3D position of each point on the emission line on the straight line. With the 3D Laser Vision Sensor, two 3D straight lines can be obtained because the sensor outputs two laser slits. A 3D plane can be calculated using two 3D straight lines.

1. Extract a 2D straight line from one laser slit image.

2. Calculate the 3D position on each point on 2D straight line.

3. Calculate one 3D straight line using 3D position of each point calculated in 2.

4. Similarly, calculate a 3D straight line using the other laser slit image.

5. Calculate a 3D plane using two 3D straight lines.

2.7.2 Plane for Measurement

For 3D position and posture measurement made by the 3D Laser Vision Sensor, workpieces should have a single plane with a size of about at least a 20mm diameter area in the camera view field to allow laser slit beams to be detected.
It is not necessary that a intersection of laser slit beams exists on this plane. But two laser slit beams should exist on this plane.
And workpieces should have features detectable by the 2D detection function in the camera view field when measurement this plane.

2.7.3 Standoff

When the 3D Laser Vision Sensor measures a workpiece, a standard distance between a workpiece and the 3D Laser Vision Sensor is called “Standoff”.

There are two kinds of standoff of the 3D Laser Vision Sensor, 400mm and 600mm.

The 400mm standoff 3D Laser Vision Sensor is designed so that the distance to a workpiece during measurement ranges from 350mm to 450mm. The 600mm standoff sensor is designed so the distance ranges from 550mm to 650mm.

Use a 600 mm standoff to increase the FOV (field of view) by 50 percent. The 600 mm standoff can also be used to keep the senor from entering a shadow bin during the find and pick operations.

The 3D Laser Vision Sensor is usually adjusted at the FANUC factory to be focused for a 400mm standoff.

If the 600mm standoff sensor is necessary, please specify to FANUC SALES at the time of order.

2.8 CALIBRATION GRID

In both cases of a robot-mounted camera and a fixed camera, it is necessary to teach a robot where a camera of the 3D Laser Vision Sensor is installed. By performing the camera calibration, the position and posture of the camera can be taught.

In the camera calibration of the 3D Laser Vision Sensor, a jig for the camera calibration called a calibration grid is used. Please prepare a calibration grid in advance.

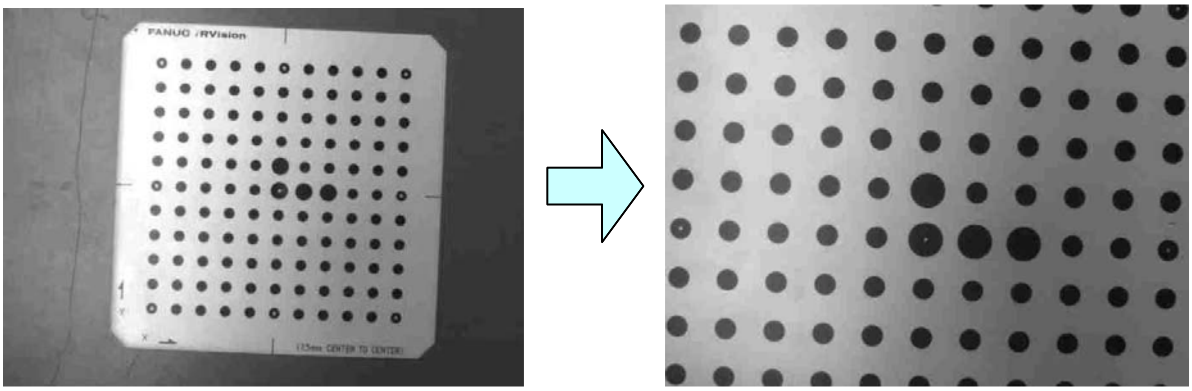
For details of a calibration grid, please refer to “11.1 CALIBRATION GRID“ in “*i*RVision OPERATOR’S MANUAL (Reference)”

Like a camera and a lens, FANUC provides several kinds of calibration grid with which sizes differ. Please use the calibration grid according to the size of camera view field.

Usually, a calibration grid larger than the size of camera view field should be prepared.

It is not necessary to detect all the black dots on a calibration grid. There are 11 × 11 dots in the standard calibration grid of FANUC. If 7 × 7 or more dots are detected in the camera view field, a camera calibration is performed with sufficient accuracy. (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.



2.9 MEMORY CARD PREPARATION

*i*RVision can save undetected images to a memory card inserted into the main board of the robot controller. It is recommended that at the time of system start-up and integration, a memory card be inserted to save undetected images to the memory card. By doing so, the locator tool parameter can be adjusted using undetected 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, please refer to ”3.4 VISION CONFIG” in “*i*RVision OPERATOR’S MANUAL (Reference)”.

Note that even if "Log Failed Images" is set in the vision program, no undetected images can be saved when no memory card is inserted.

Moreover, if the log in a memory card increases, detection may take longer time. To avoid this, it is recommended to export vision logs to a PC or other device periodically. For details, please refer to ”3.3 VISION LOG” in “*i*RVision OPERATOR’S MANUAL (Reference)”.

A memory card, 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 recommended by FANUC. If a memory card other than those recommended is used, a normal operation is not guaranteed, and a bad influence may occur on the controller.

3 TEACHING EXAMPLE

There are the following vision processes for the 3D Laser Vision Sensor compensation.

(1) 3DL Single-View Vision Process
(2) 3DL Multi-View Vision Process
(3) 3DL Curved Surface Single Vision Process
(4) 3DL Cross Section Vision Process

And there are the following robot position offset in each vision process.

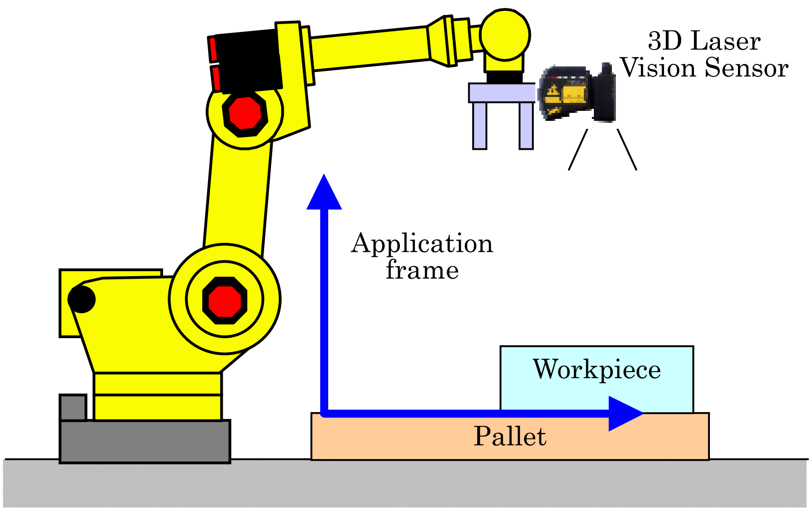
(1) Robot-mounted camera + fixed frame offset
(2) Fixed sensor + tool offset

This chapter describes the setup procedures and teaching details of the “robot-mounted camera + fixed frame offset” in 3DL Single-View Vision Process which is the most fundamental application of 3D Laser Vision Sensor.
Also in the case of other application, you can perform the setup and teaching by applying the explanation in this chapter.
For details of each teaching item, please refer to “10.2 GRID FRAME SETTING“ in “*i*RVision OPERATOR’S MANUAL (Reference)”

The 3DL Single-View Vision Process measures one point of a workpiece for its 3D position and posture using the 3D Laser Vision Sensor, and provides compensation for robotic handling of the workpiece.

3.1 LAYOUT

This section describes a typical system layout of the 3D Laser Vision sensor system and provides notes on setup. Use a robot-mounted camera or a fixed sensor.



- With the automatic exposure or multi-exposure function, *i*RVision can handle changes in brightness to some extent. In a place where there is a large difference in illumination between the daytime and nighttime, however, some measures must be taken to keep a certain level of illumination at any time. Major methods include shutting out the sunlight and installation of a fluorescent lamp.
- When lighting such as a fluorescent lamp is installed, the inverter type is suitable. This type has less variation in brightness when an image is snapped. When lighting is provided for a wider area

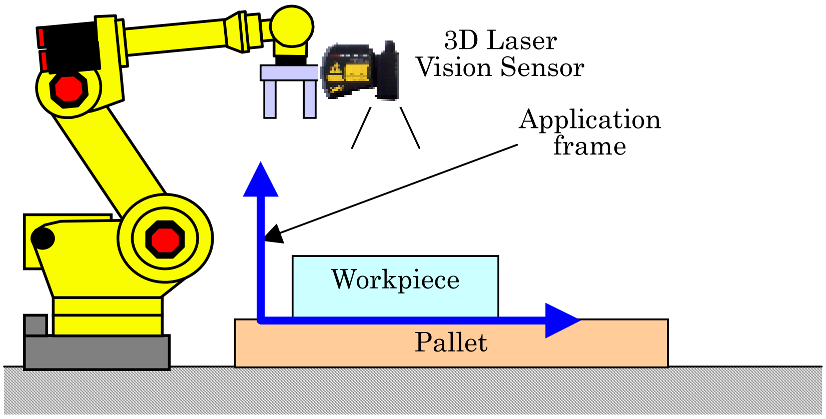
than the workpiece installation area, there is less variation in brightness in the image of a workpiece even if the workpiece is tilted.

- When measurements are made with the 3D Laser Vision Sensor, the robot is positioned just above the workpiece, so the measurement area tends to become dark because of the shadow of the robot. For this reason, it is recommended that a LED ring light be installed in front of the camera of the 3D Laser Vision Sensor.
- To perform fixed frame offset, set a user frame as required. It is recommended that the end of arm tooling be designed in advance so that a touch-up pin can be mounted.
- To perform tool offset, a calibration grid must be mounted on the robot or teaching workpiece. It is recommended that the end of arm tooling be designed in advance so that a calibration grid can be mounted.
- When compensation is provided for operation, the wrist axis may turn largely. Prepare a cable long enough for such robot behavior.
- If the installation position of the 3D Laser Vision Sensor is displaced from the right position, correct compensation cannot be performed. The risk of displacement due to interference and so on can be reduced by installing a guard for the sensor.

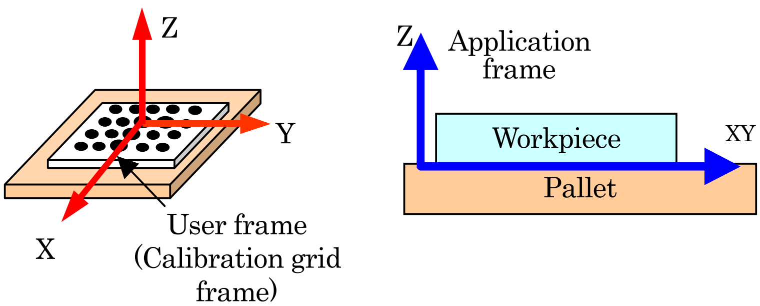
- When the 3D Laser Vision Sensor has to be mounted on a movable part of the end of arm tooling, errors in positioning of the movable part should be suppressed as much as possible to avoid adversely affecting measurement.
- The 3D Laser Vision Sensor is designed so that the distance to the workpiece during measurement ranges either from 350mm to 450mm or from 550mm to 650mm (depending on the setup of the sensor). Check that the robot can reach all Measurement Positions and that the end of arm tooling does not interfere with peripheral equipment during measurement. Ensure an appropriate measurement distance.
- When the 3D Laser Vision Sensor is to be mounted on the robot and used as a robot-mounted camera, mount it on such a place that the sensor does not touch a workpiece, container, or peripheral equipment when the robot picks up the workpiece as well as when the sensor is used for measurement.

3.2 SETUP FOR “ROBOT-MOUNTED CAMERA + FIXED FRAME OFFSET”

An example of layout for “robot-mounted camera + fixed frame offset” is given below.



Setup for “robot-mounted camera + fixed frame offset” includes setting the “calibration grid frame” and the “application frame” in a user frame with an arbitrary number. The “Calibration grid frame” can be set easily and correctly by using the camera of the 3D Laser Vision Sensor (grid frame setting function).



Use the following setup procedure for “robot-mounted camera + fixed frame offset”.

1. Create and teach camera setup tool.

2. Set the calibration grid frame with an arbitrary number.

Use the vision grid pattern setting for this setting.

3. Set the TCP at the tip of touch-up pin mounted on the end of arm tooling.

The TCP set here is used to set the “application frame”.

4. Set the user frame for application frame with arbitrary number.

5. Create and teach camera calibration tool.

6. Create and teach the vision process tool.

7. Create and teach the robot program.

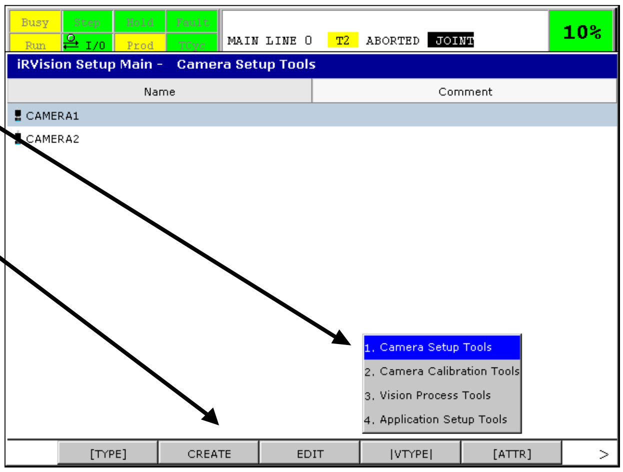
8. Check the robot compensation operation.

3.2.1 Creating and Teaching Camera Setup Tool

First, define the camera setup tool to be used.

1. Press F4[VTYPE], and select [Camera Setup Tools].

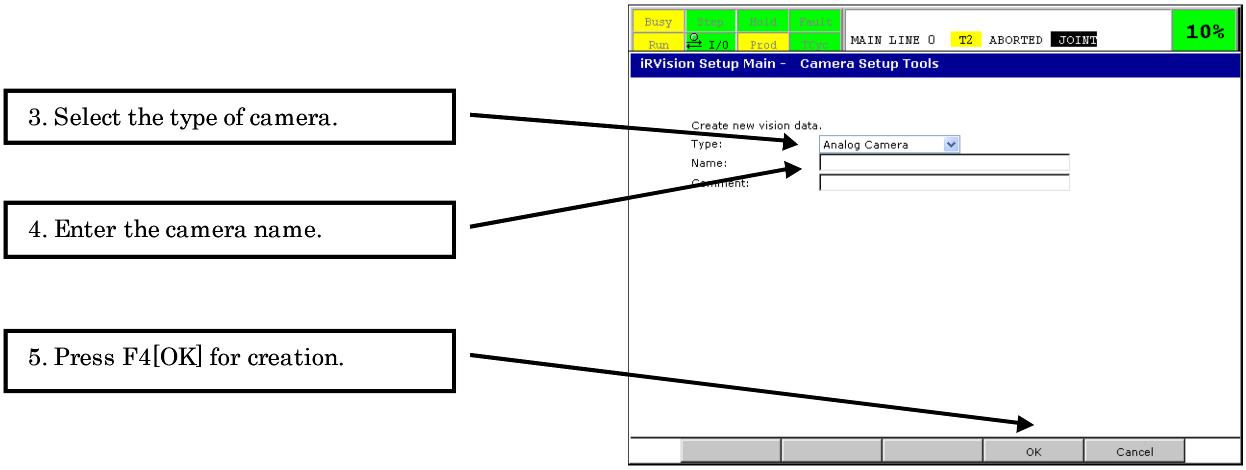
2. Press F2[CREATE].



1. **Press F4[VTYPE], and select [Camera Setup Tools].**
   [Camera Setup Tools] on the main screen defines the built-in camera of the 3D Laser Vision Sensor used or a 2D camera.

2. Press F2[CREATE].

When the F2[CREATE] is pressed, the following screen appears, allowing the settings of a new camera to be added:



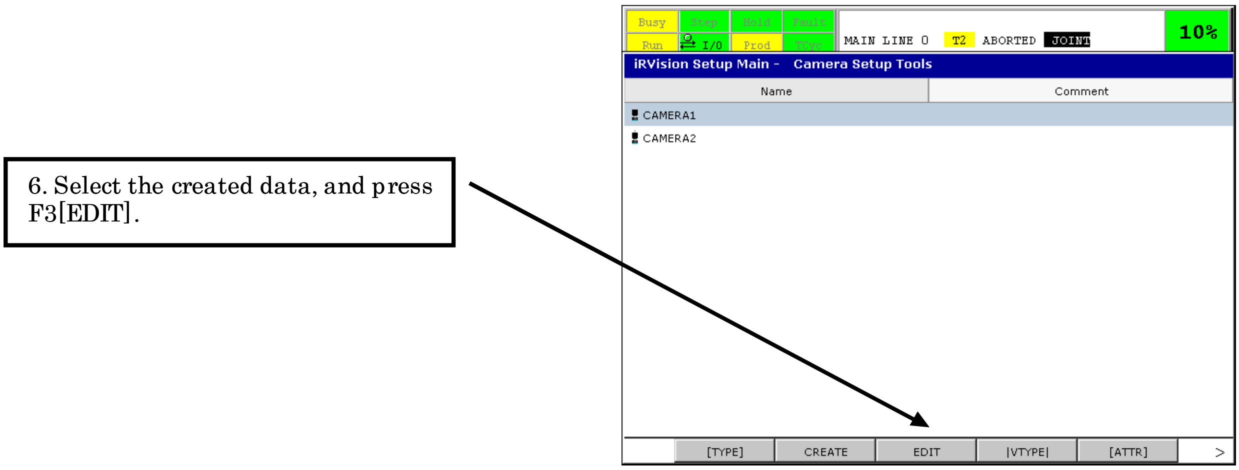
3. Select the type of camera

By default, [KOWA Digital Camera] is selected as the type of the camera. [KOWA Digital Camera] or [Analog Camera] can be selected.

<u>Select [Analog Camera] for 3D Laser Vision Sensor.</u>

4. Enter the camera name

Assign a unique name to the camera setup tool.



6. Select the created data, and press F3[EDIT].

Select the created camera setup tool, and press F3[EDIT]. The camera setup tool setup screen is then displayed.

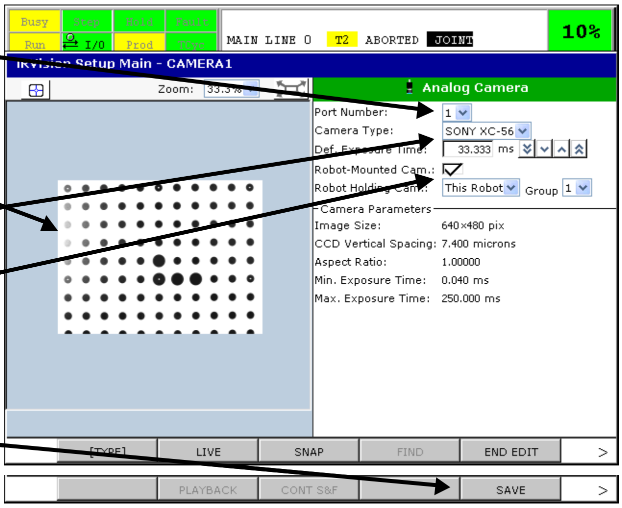
7. Specify the camera port number.

8. Check that the image is shown.

9. Select the type of camera.

10. When the robot holds the camera, check [Robot-Mounted Camera].

11. After modification, press F10[SAVE] then F5[END EDIT].



7. Specify the camera port number

From [Port Number], select the port to which the 3D Laser Vision Sensor is connected.

8. Check that the image is shown

Check that the image display window shows an image with the selected [Port Number]. If no image is displayed, the selected port number and the port number of a port in the multiplexer to which the camera cable is connected do not match. Check the connection. If the image is displayed black when the camera cable was connected correctly, lightning might be insufficient. Try setting the maximum exposure time in [Exposure Time]. If the image is still not displayed, the hardware might be defective.

9. Select the type of camera

Select the type of the camera used from the combo box according to the currently used 3D Laser Vision Sensor.

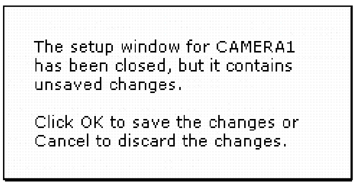
10. When the robot holds camera, check [Robot-Mounted Camera]

When the 3D Laser Vision Sensor is mounted on the robot, click and enable the [Robot-Mounted Camera] checkbox. When selecting the robot-mounted camera, specify [Robot Holding the Camera] and the [Group] number of the robot.

For normal applications in which one 3D Laser Vision Sensor is mounted on the robot, the setting of the camera is completed just by checking the [Robot-Mounted Camera] check box. For applications using the 3D Laser Vision Sensor as a fixed camera, uncheck the check box.
Please be sure to check the [Robot-Mounted Camera] check box.

11. After modification, press F10[SAVE] then F5[END EDIT].

When settings have been modified, press F10[SAVE] to save the modifications. Pressing F5[END EDIT] closes the setup screen regardless of whether the data has been modified or not. If modifications not saved are present, the following screen is displayed:



If F4[OK] is pressed, modifications are saved. If F5[Cancel] is pressed, modifications are not saved, and the original data before modification is restored.

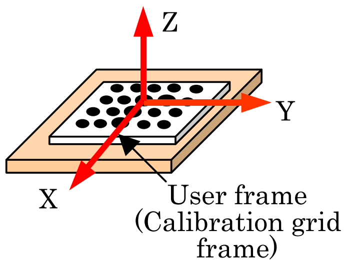
3.2.2 Setting Calibration Grid Frame

When a calibration grid is installed on a fixed place, set the calibration grid frame in a user frame with an arbitrary number. For this setting, use the grid frame setting function. After securing the calibration grid, execute the grid frame setting function. For details of the grid frame setting function, please refer to “10.2 GRID FRAME SETTING“ in “*i*RVision OPERATOR’S MANUAL (Reference)”. Note that the user frame for calibration grid frame differs from the “Application Frame” described in the following subsection.

In addition to the method of using the grid frame setting function, the following method is also available: Touch up the grid with a pointer mounted on the robot end of arm tooling precisely, then set a user frame as shown in the figure below. Please refer to “11.2.1 Setting Based on Touch-up” in “*i*RVision OPERATOR’S MANUAL (Reference)”. In this case, the operation described in the next subsection, “Setting the TCP of the Robot” must be performed in advance. The TCP setting precision and touch-up precision directly affect the compensation precision. Set the TCP and touch up the grid precisely.

The calibration grid can be installed on any surface. At this time, the X-Y plane of the calibration grid should be matched with the X-Y plane of the world frame of the robot unless the robot is installed at a tilt or any other special situations prevent these planes from matching. When these planes match, calibration can be performed more easily than when these planes do not match.

It can be removed after the completion of calibration, but it is strongly recommended that the grid be left installed in the system. This is because if a displacement should occur in calibration for the 3D Laser Vision Sensor due to a factor such as impact, recovery work can be simplified greatly. If the calibration grid must be removed, its installation position should be able to be restored exactly, which can reduce the labor for recovery. For the detailed setup procedure, please refer to “8.1 AUTOMATIC RE-CALIBRATION”.



3.2.3 Setting the TCP of the Robot

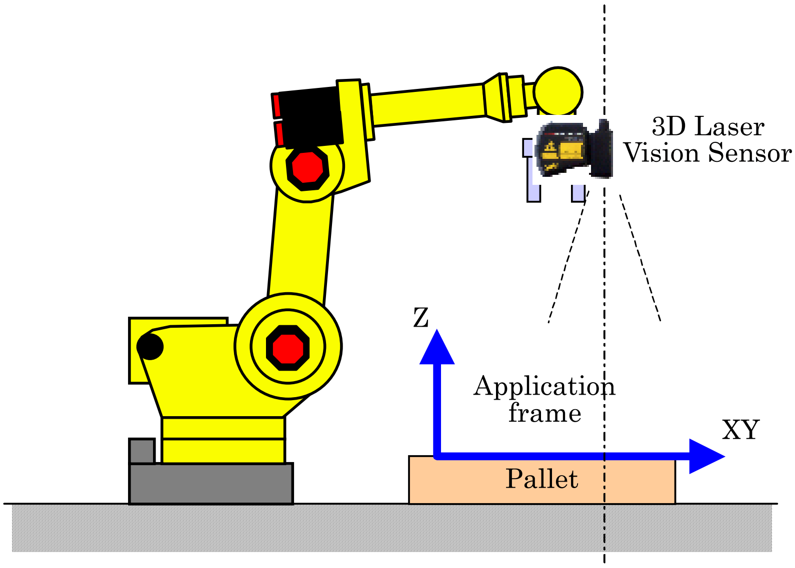
Set the TCP precisely on the tip of the pointer mounted on the end of arm tooling. Set the TCP in a tool frame with an arbitrary number. To set the tool frame, use [Tool Frame Setup / Three Point].

To reuse a TCP set at re-calibration, the reproducibility of the pointer mounting is required. If the reproducibility of the pointer mounting is not assured, a TCP needs to be set each time the pointer is mounted.

3.2.4 Setting an Application Frame

Set a user frame to be used as the reference for the robot compensation operation. The measurement result is output as values in the user frame that has been set.

Set a user frame for a plane such as a pallet using the set robot TCP. For this setting, use [User Frame Setup / Three Point] unless there is specific reason.



Sharing User Frame

When two or more robots work together, it is necessary to configure the system so that these robots share physically the same user frame. This is called the sharing of the user frame. Specifically, the sharing of the user frame is needed in the following cases:

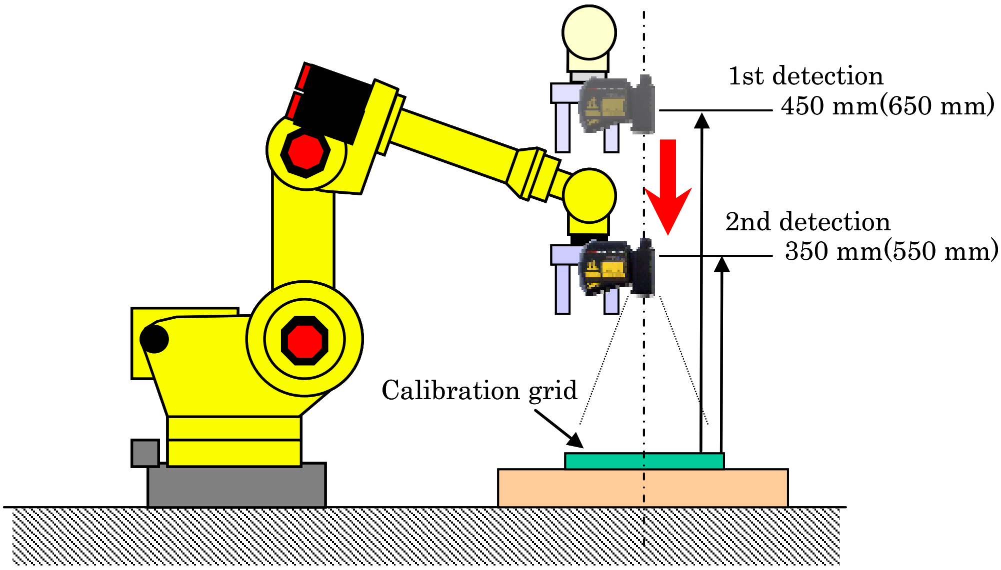
- Multiple robots are offset with a single set of offset data.
- The robot to be offset is different from the robot that has the camera.

User frame sharing requires that all robots use the same user frame number. For example, user frame 5 of robot 1 needs to be physically the same as user frame 5 of robot 2.

> ⚠ **CAUTION**
> If robots share user frames of different numbers, *i*RVision cannot offset the robots correctly. Make sure that the robots share the same user frame number.

3.2.5 Creating and Teaching Camera Calibration Tool

To use the 3D Laser Vision Sensor, 3DL calibration using a calibration grid is required. For a robot-mounted camera, perform 2-plane calibration by moving the robot end of arm tooling up and down as shown in the figure below. For calibration, the appropriate distances between the 3D Laser Vision Sensor and calibration grid are near 350mm and 450mm (near 550mm and 650mm if the standoff of the 3D laser sensor is 600mm). When the calibration grid is detected with the robot and is made to have the same posture as it does when the workpiece is detected, the precision is increased.



After one set of calibration tool is created with 3DL vision calibration, another set of calibration tool does not need to be created even after the camera Measurement Position is changed. This is because *i*RVision uses the current robot position when calculating the position of the workpiece.

Placing the 3D Laser Vision Sensor so that it faces the calibration grid

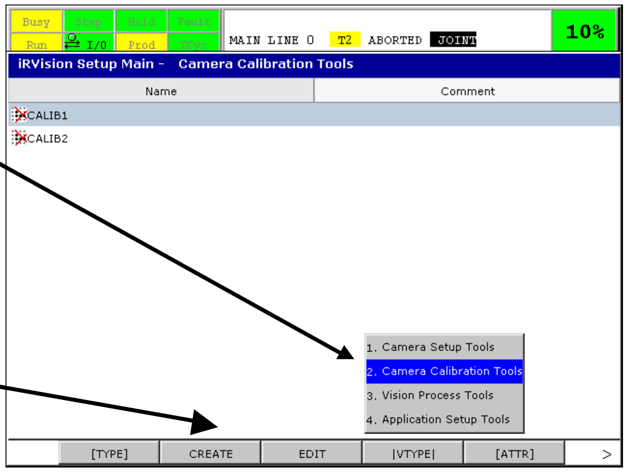
1. Place the 3D Laser Vision Sensor so that it faces the calibration plate.

After setting the user frame for the calibration grid, place the 3D Laser Vision Sensor at a distance of about 400mm from the grid, and set the orientation of the sensor visually so that the sensor and grid face each other.

Setting calibration parameters

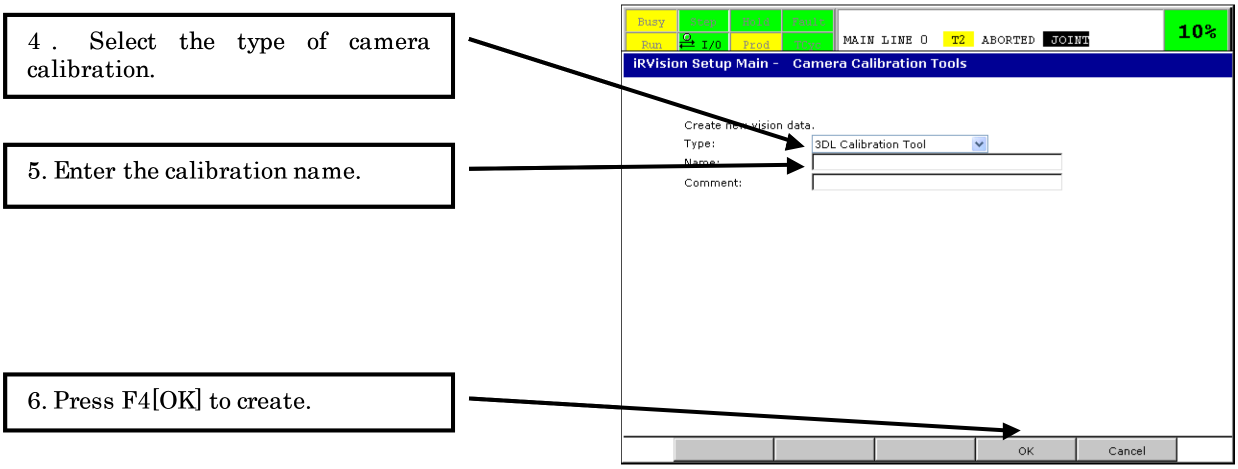
2 . Press F4:[VTYPE] and select [Camera Calibration Tools].

3. Press F2[CREATE].



2. **Press F4[VTYPE] and select [Camera Calibration Tools]**
   After setting up the necessary frames and placing the 3D Laser Vision Sensor so that it faces the calibration grid, select [Camera Calibration Tools] from the setup main screen.

3. **Press F2[CREATE].**
   Press F2[CREATE]. The following screen is then displayed:



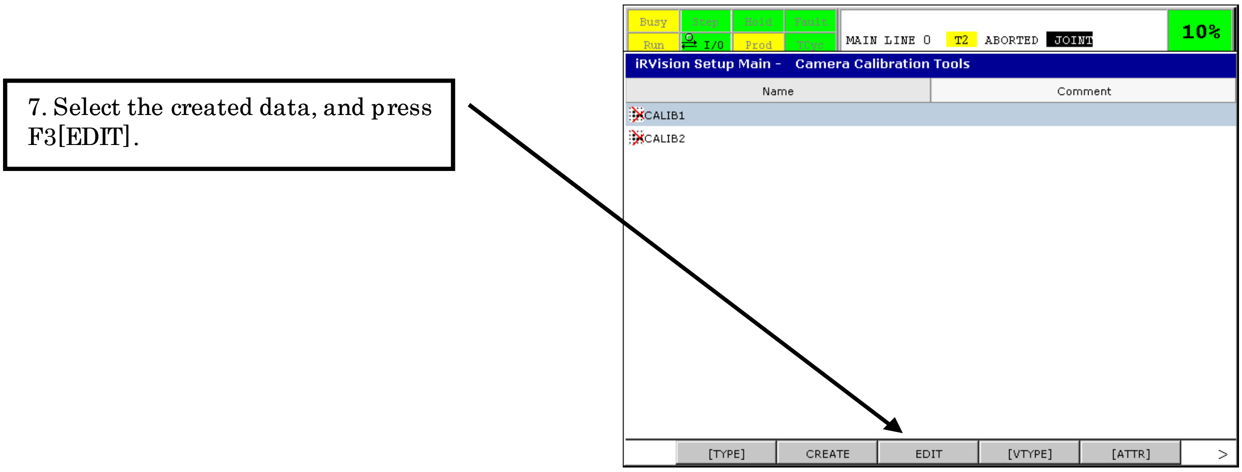
4. Select the type of camera calibration

Select the calibration type. When calibration for the 3D Laser Vision Sensor, select [3DL Calibration Tool]. When calibration for a 2D fixed camera, select [Grid Pattern Calibration Tool] or [Simple 2-D Calibration Tool].

<u>Select [3DL Calibration tool].</u>

5. Enter name of calibration

Assign a unique name to the camera calibration tool.



7. Select the created data, and press F3[EDIT].

Select the created camera calibration tool, and press F3[EDIT]. The setup screen is then displayed.

8. Specify User Frame for the Application Frame.

9. Select [Camera].

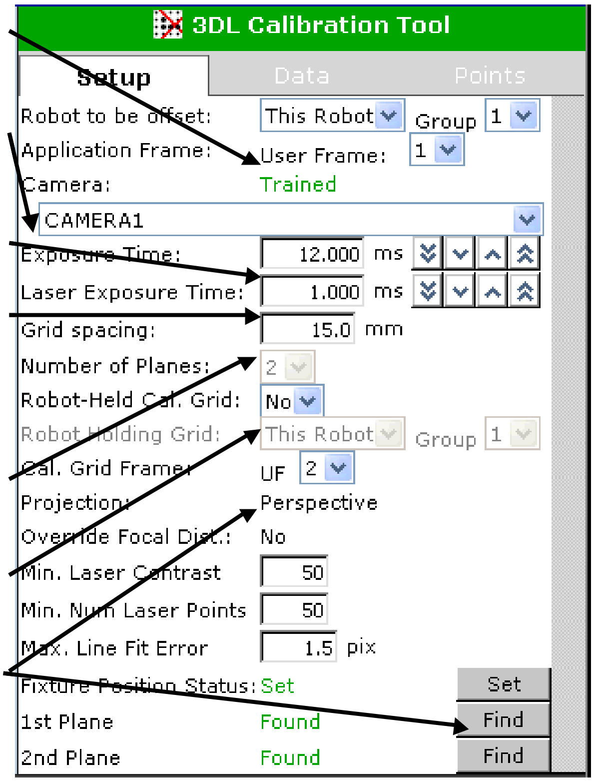
10. Set [Exposure Time].

11. Set [Laser Exposure Time] to be applied for laser measurement.

12. Set [Grid Spacing] between grid points on the calibration grid.

13. Select [No] so that the calibration grid is not moved.

14. Select the "user frame" number for the calibration grid and click the [Set] button.



8. Specify User Frame for the Application Frame.

Select a user frame number to use as the application user frame in [Application Frame]. An application frame is a user frame used when compensating the robot motion based on *i*RVision measurement results. *i*RVision results are output after converting the measurements based on this user frame.

When no particular user frame is specified in the work space for robot compensation, select 0. When compensation values are to be calculated using a user frame set for a pallet, for example, specify the set user frame number.

> ⚠ **CAUTION**
>
> 1 If the user frame specified here and the user frame used for teaching robot motions that are to be compensated do not match, correct compensation cannot be performed.
>
> 2 After calibration, do not change the number or the content of the application frame. If you change them, recalibrate the sensor. Then teach the reference positions of the vision processes which use the camera calibration tool.

9. Select [Camera]

From the [Camera] combo box, select the 3D Laser Vision Sensor camera setup tool name created. When a camera has been selected, the camera automatically snaps an image, and the image is displayed in the image display window.

10. Set [Exposure Time]

Adjust [Exposure Time] so that the grid pattern on the calibration grid is viewed clearly. If the image is too dark, set a longer exposure time (increase the value). If the image is too bright, set a shorter exposure time (decrease the value). Each time the exposure time is changed, a new image is captured.

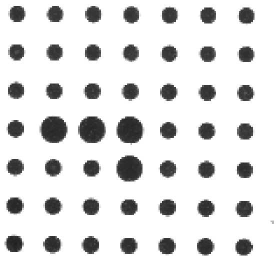
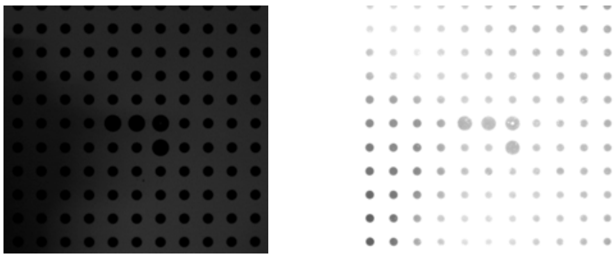


Fig. 3.2.5(a) Example of an image with appropriate exposure time



Too short exposure time   Too long exposure time

Fig. 3.2.5(b) Examples of images with inappropriate exposure time

11. Set [Laser Exposure Time] to be applied for laser measurement

Similarly, adjust [Laser Exposure Time] so that the laser slits can be seen clearly. When [Laser Exposure Time] has been changed, an image is snapped with a new exposure time, and a slit image is displayed in the image display window. Fig. 3.2.5(d) shows that the laser slits fades with too short of an exposure time or runs with too long of an exposure time.

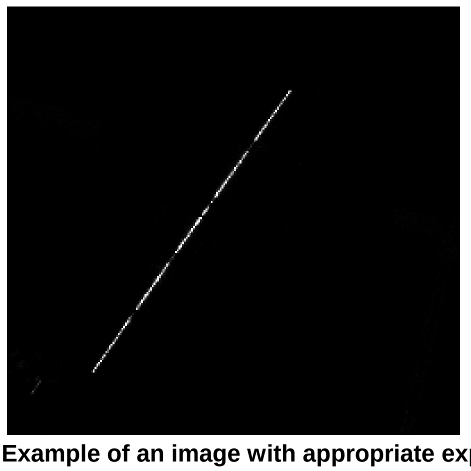
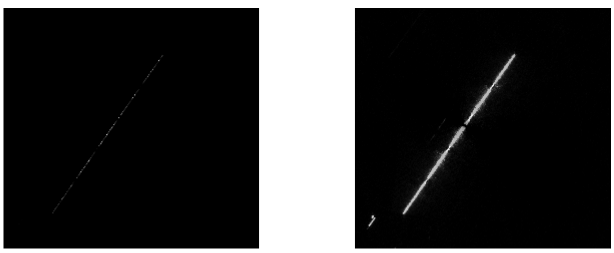


Fig. 3.2.5(c) Example of an image with appropriate exposure time



Too short exposure time   Too long exposure time

Fig. 3.2.5(d) Examples of images with inappropriate exposure time

12. Set [Grid Spacing] between grid points on the calibration grid

Make settings related to the calibration grid. In [Grid spacing], enter the shortest interval between grids on the grid. The following item, [Number of Planes] specifies the number of measurement planes for calibration. At present, 2 is always set.

13. Select [No] so that the calibration grid is not moved

In [Fixture on Robot], select [No] when a 3D Laser Vision Sensor is used as a robot-mounted camera for [Fixed Frame Offset] compensation. When a fixed 3D Laser Vision Sensor is used for [Tool Offset] compensation, select [Yes] since calibration is performed with the calibration grid mounted on the robot.

14. Select the “user frame” number for the calibration grid and click the [Set] button

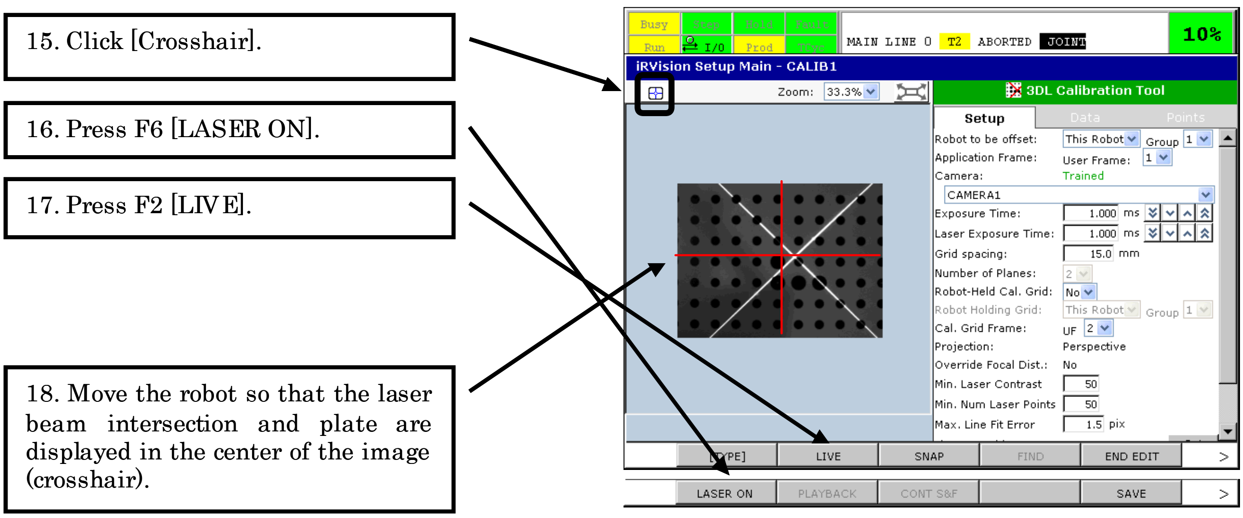
In [Calibration Grid Frame], select the user frame number set for the calibration grid. The frame set here is provided as information used for 3DL calibration and is not used within actual robot programs (except when the frame is the same as [Application Frame]).

When the [Set] button is clicked, the value set for the user frame specified in [Calibration Grid Frame] is recognized as the frame for the calibration grid. Check that [Status of fixture position] indicates that teaching is done. If [Yes] is selected in [Fixture on Robot], [Status of fixture position] is set automatically, and the button becomes invalid, so this operation is unnecessary.

> ⚠ **CAUTION**
> When recalibrating a camera, if you change the position of the calibration grid, set the user frame of the calibration grid frame again. Then click the [Set] button for the calibration grid frame and recalculate it.

Moving the robot to an appropriate position

When the setting of camera calibration described so far is completed, move the robot to an appropriate position by following the steps below to perform calibration.



15. Click [Crosshair].

When the [Crosshair] button is clicked, a vertical line and a horizontal line are displayed, indicating the center of the image. Based on these lines, the calibration grid and the laser beam intersection can be aligned with the center of the image.

16. Press F6[LASER ON].

When F6[LASER ON] is pressed, the laser turns on.

17. Press F2[LIVE].

When F2[LIVE] is pressed, the camera snaps images successively.

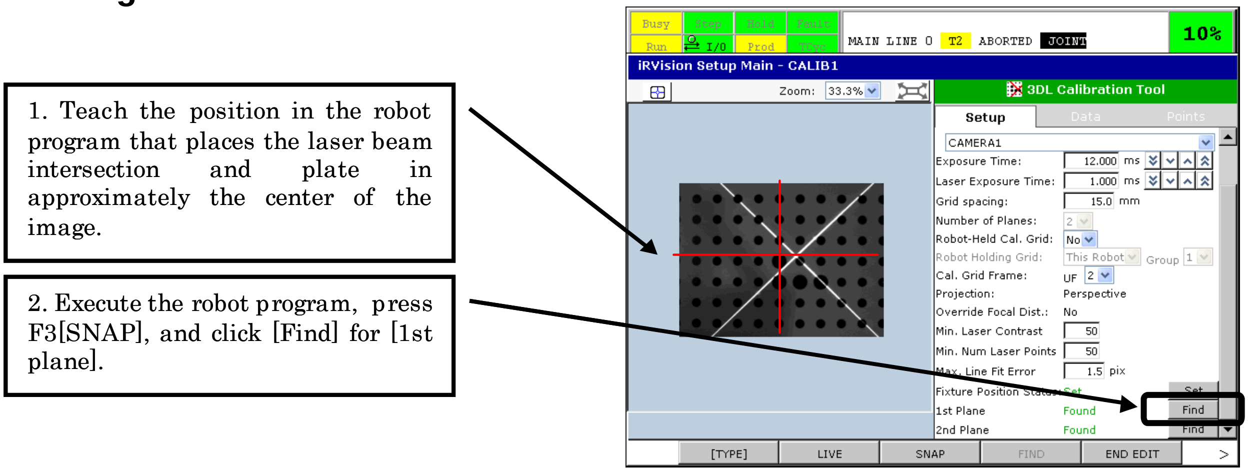
18. Move the robot so that …

Jog the robot so that the grid is placed at the center of the image. The camera of the 3D Laser Vision Sensor and the calibration grid should be about 400mm apart, and the camera's line of sight should be perpendicular to the grid. Then, adjust the distance between the 3D Laser Vision Sensor and the grid so that the laser beam intersection is positioned at the center of the grid.

Parameters for detecting the laser points

Parameters for detecting the laser points should be adjusted for calibration only when a correct detection cannot be made just by adjusting the exposure time. If the laser points are detected forcibly by changing the parameter values carelessly, the detection position may not be calculated correctly.

Performing 3DL calibration



1. Teach the position in the …

Create a program as follows:

```
 1:  UFRAME_NUM=1 ;
 2: J P[1] 100% FINE    ;
 3:  PR[99]=LPOS
 4:  PR[99, 1]=0
 5:  PR[99, 2]=0
 6:  PR[99, 4]=0
 7:  PR[99, 5]=0
 8:  PR[99, 6]=0
 9:
10:  !Remove Backlash ;
11:  PR[99, 3]=60
12: L P[1] 800mm/sec FINE    ;
  :  Offset,PR[99]
13:
14:  !1st Plane ;
15:  PR[99, 3]=50
16: L P[1] 800mm/sec FINE    ;
  :  Offset,PR[99]
17:  PAUSE ;
18:   ;
19:  !2nd Plane ;
20:  PR[99, 3]=(-50)
21: L P[1] 800mm/sec FINE    ;
  :  Offset,PR[99]
22:  PAUSE ;
23:  END
```

Specify the number set for [User Frame] in [Calibration Grid Frame].

Teach the robot position after movement.

Position taught for always snapping an image following movement in the same direction considering backlash.

Click the [Snap and Find] button for [1st Plane].

Click the [Snap and Find] button for [2nd Plane].

For the user frame number, specify the frame set for the calibration grid. After the robot has moved to an appropriate position for camera calibration, teach the position for P[1]. In the above sample robot program, [Set new id ?] appears on the teach pendant. Select F5[NO]. The calibration grid is actually measured at a position obtained by performing [Fixes Frame Offset] compensation for the taught position. Carefully operate the robot hand and camera not to cause them to interfere with the peripheral equipment and workpiece.

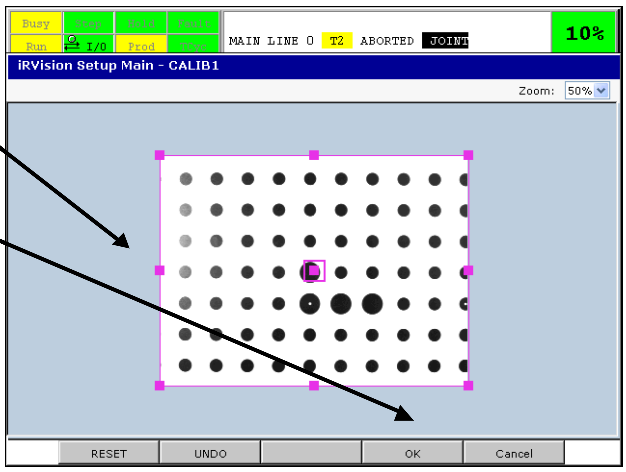
2. Execute the robot program, press F3[SNAP], and click [Find] for [1st plane]

Execute the robot program for calibration. After the robot stops at a Measurement Position, press F3[SNAP], and click the [Find] button for [1st Plane] to make the first calibration plane detection.

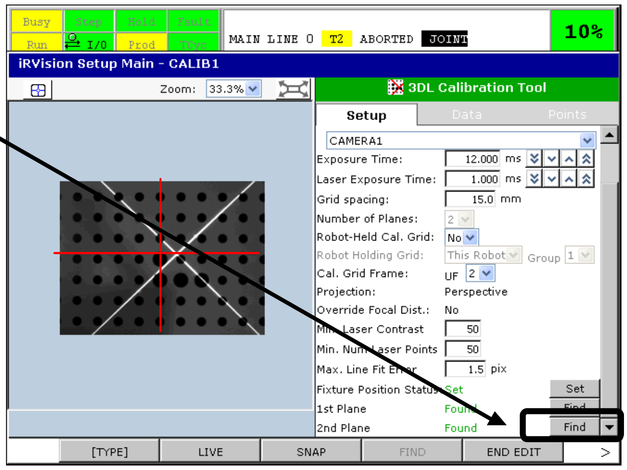
Detecting the calibration plane

3. Teach the search window to enclose only perfect grids in the calibration grid.

4. Press F4 [OK].



5 . Restart the program, press F3[SNAP], and click [Find] for 2nd Plane to teach the search window



3. **Teach the search window to enclose only perfect grids in the calibration grid**
   If the search range includes an area outside the calibration grid, a grid detection error could occur. So, teach the window so that only the grid pattern is enclosed.

4. **Press F4[OK]**
   When modification of the window is completed, press F4[OK]. Check that all grids are detected and that the laser slits are detected clearly. If the detection is successful, [1st Plane] shows [Found].

5. **Restart the program, press F3[SNAP], and click [Find] for 2nd Plane to teach the search window**
   Restart the robot program. After the program stops at the next Measurement Position, press F3[SNAP], and click the [Find] button for [2nd Plane] to make the second calibration plane detection. Check that all grids are detected and that the laser slits are detected clearly. If the detection is successful, [2nd Plane] shows [Found].

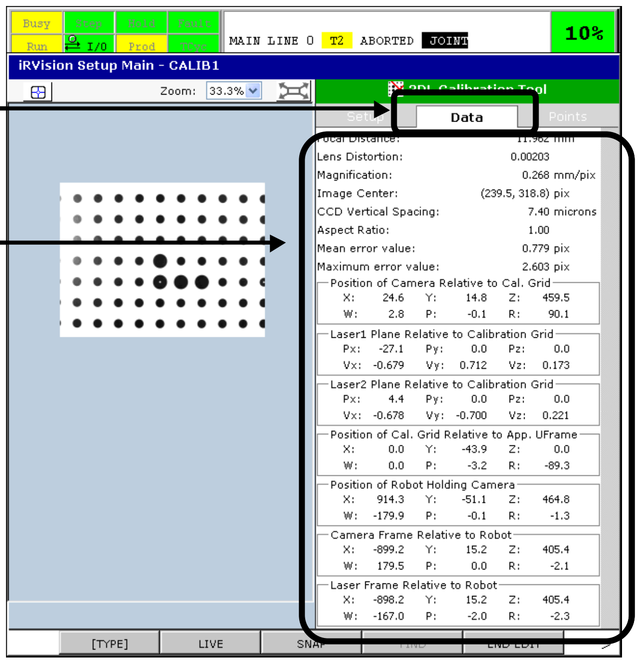
   When [Status of fixture position] indicates that setting is done, and [1st Plane] and [2nd Plane] indicate that the calibration planes have been detected, 3DL calibration is completed. Check that [Status] for camera calibration shows [Trained].

Checking the Precision of 3DL Calibration

Checking [Data]

1. Click [Data].

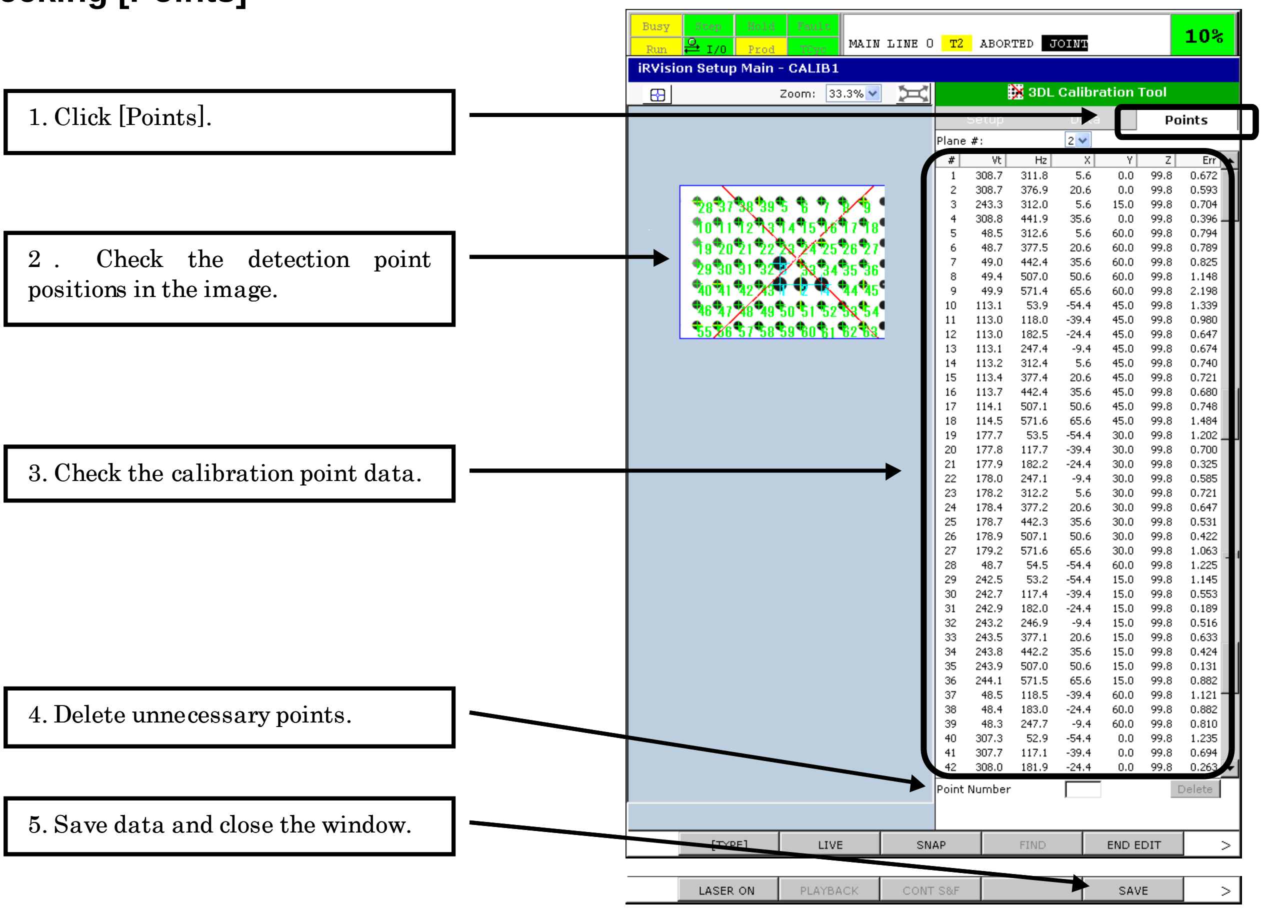
2. Check the calibration data.



1. **Click [Data]**
   When the [Data] tab is clicked, the screen display changes, and details on calibration can be checked.

2. **Check the calibration data**
   If the calculated value in [Focal Distance] is the focal length of the lens used ± 5%, the value is considered to be permissible.
   [Lens Distortion] is usually 0.01 or less for the 8mm lens and 0.005 or less for the 12mm lens.
   [Magnification] depends on the field of view at the time of calibration and the space between grids on the calibration grid. For calibration of a 3D Laser Vision Sensor equipped with an 8mm lens, between 0.35 and 0.45mm/pixel is normally obtained if calibration plane #1 is about 450mm away from the sensor and plane #2 is about 450mm away from the sensor.
   [Image Center] indicates the image center calculated by calibration. The image center is located at around (240, 256). If the calculated center is within the range of this value ±10%, it is permitted. If the indicated value is beyond this permissible range, confirm the calibration procedure, and perform calibration again.

Checking [Points]



1. **Click [Points]**
   When the [Points] tab is clicked, the image display changes, showing details of detected calibration points and a slit detection image.

2. **Check the detection point positions in the image**

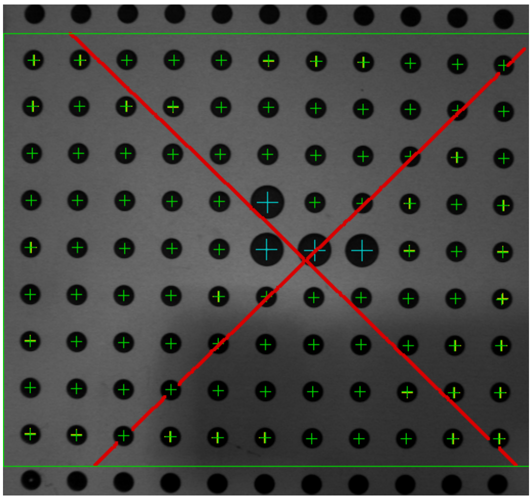


Fig. 3.2.5(e) Example of an image showing appropriate detection points

The image display can be switched between calibration plane #1 and plane #2 by changing the plane number. Check the image to see that there is no detection point at other than the grid positions on the calibration grid and that every grid has a detection point. In addition, check that the detected laser slits are clearly shown within the measurement area.

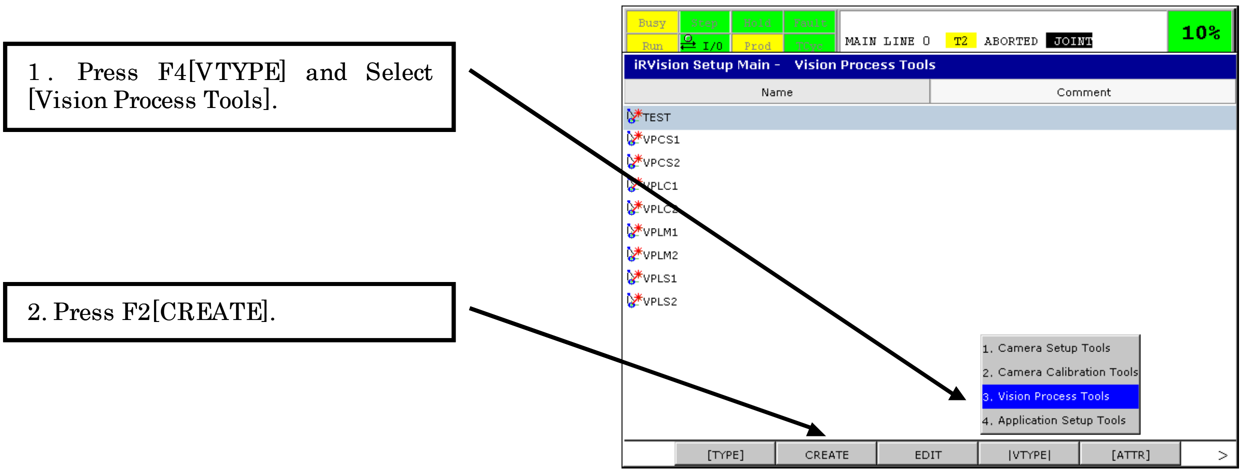
3. **Check the calibration point data**
   When checking calibration points, pay particular attention to the [Err] of each detection point. Normally when a grid on the calibration grid is detected precisely, an error is 1 pixel or smaller.

4. **Delete unnecessary points**
   Check the image, and if there is a detection point at a position other than the grid positions on the calibration grid, enter its detection point number, and click the [Delete] button to delete the detection point.

5. **Save data and close the window**
   Finally, press F10[SAVE] to save the data resulting from the modification. Pressing F5[END EDIT] closes the setup screen.

Checking precision

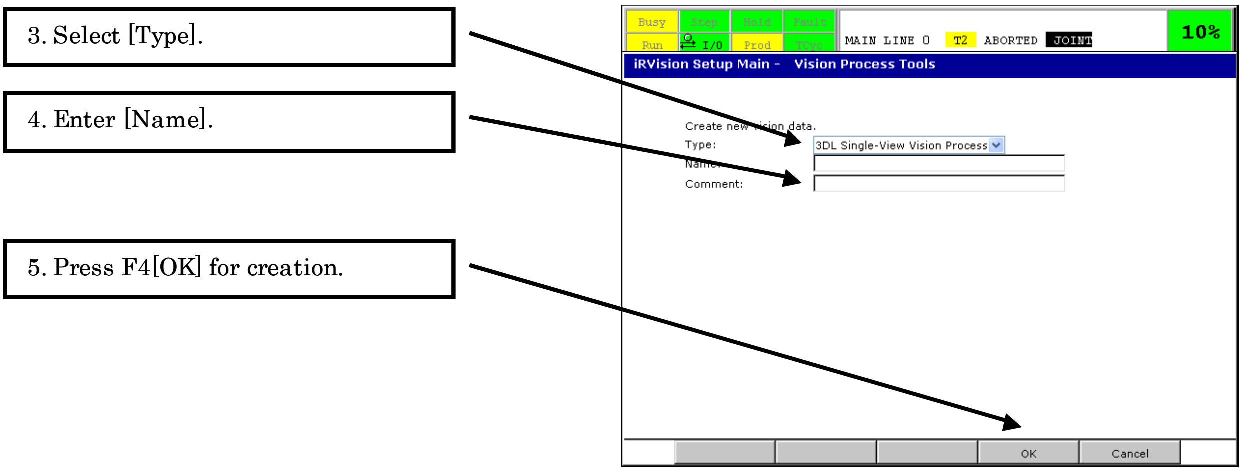
Create a vision process for checking the precision of calibration.



1. **Press F4[VTYPE] and select [Vision Process Tools]**
   Select [Vision Process Tools] from the setup main screen.

2. Press F2[CREATE]

Press F2[CREATE]. The screen shown below is displayed, on which the settings for a new vision process can be added.



3. Select [Type]

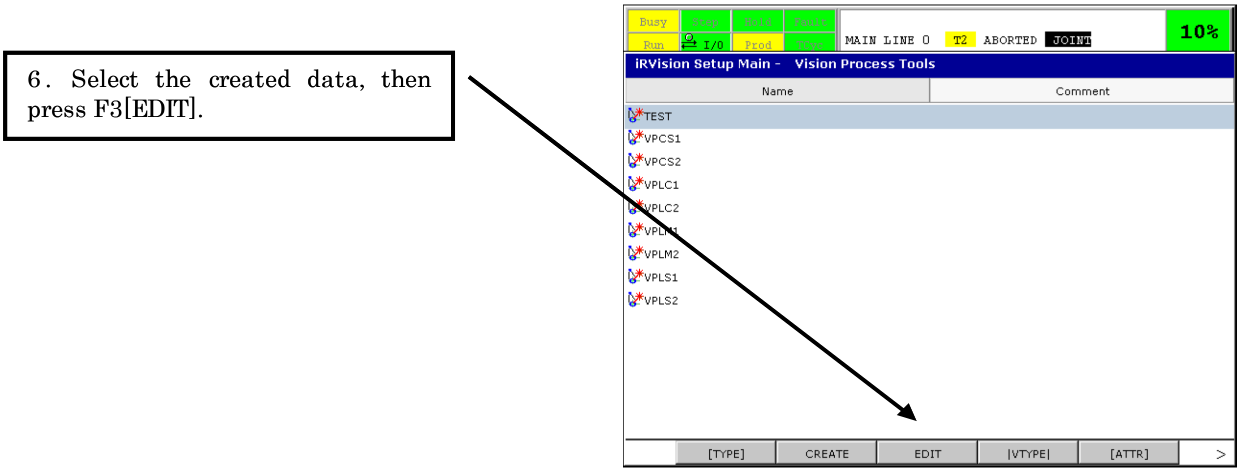
Options vary depending on the installed software option. To create a vision process to check the precision of 3DL calibration, select [3DL Single-View Vision Process].

4. Enter [Name]

Assign a unique name to the vision process.

5. Press F4[OK] for creation

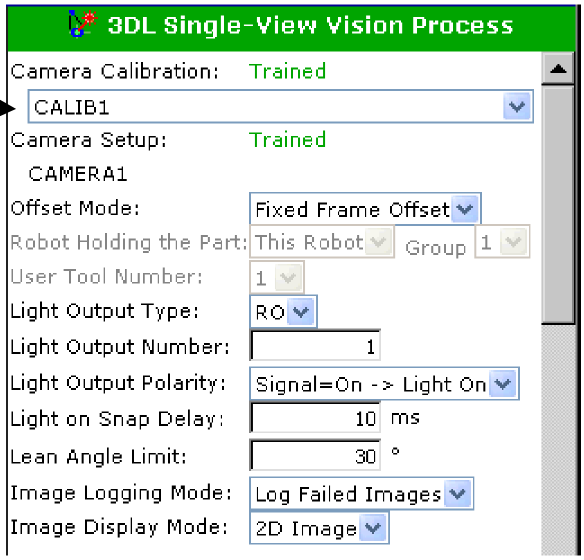
After selecting a type and entering a name, press F4[OK]. A precision check vision process is then created.



6. Select the created data, then press F3[EDIT]

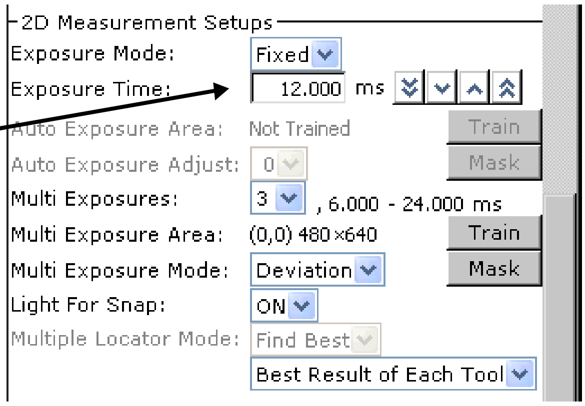
Select Vision Process Tools for the created vision process, then press F3[EDIT]. The setup screen is then displayed.

7. Select [Camera Calibration].

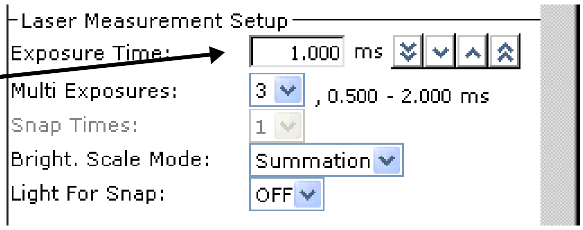


7. Select [Camera Calibration]
Select the name of set 3DL calibration tool.

8. Specify 2D measurement exposure time.

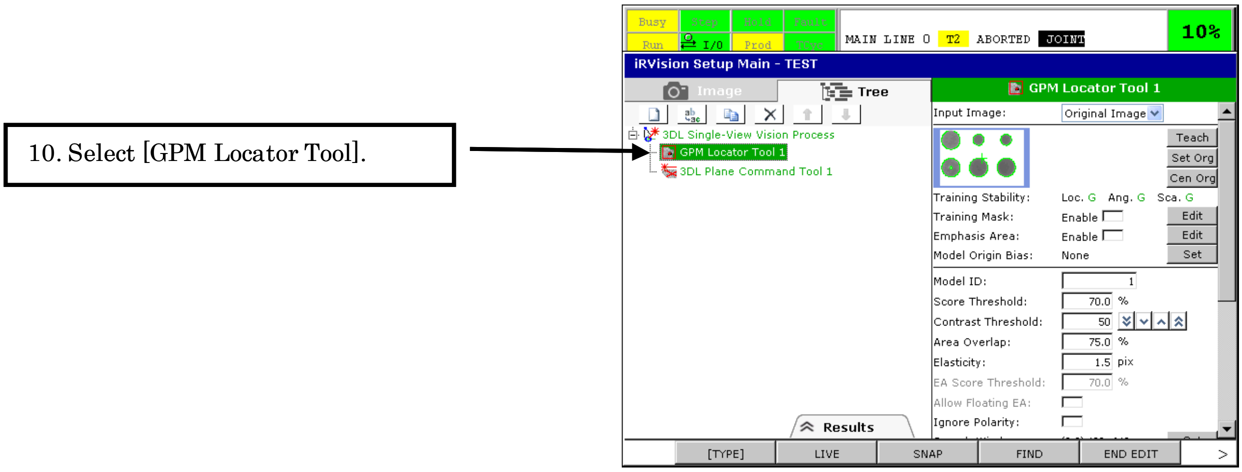


9. Specify laser measurement exposure time.



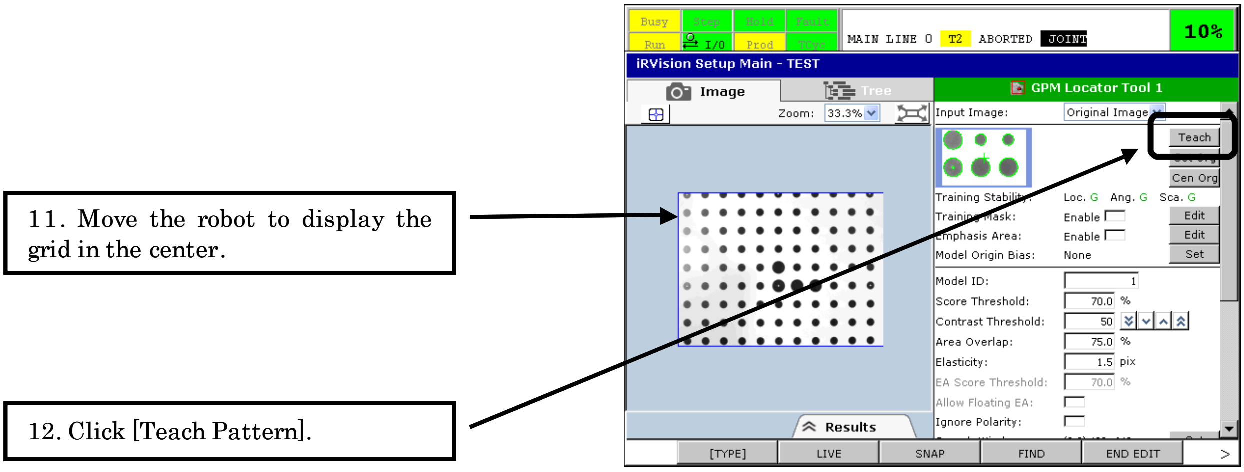
8. Specify 2D measurement exposure time

9. Specify Laser measurement exposure time
Set the same exposure time as set for camera calibration. As in calibration, check that the exposure time of the image shown is appropriate.



10. Select [GPM Locator Tool]

From the tree window, select [GPM Locator Tool1].

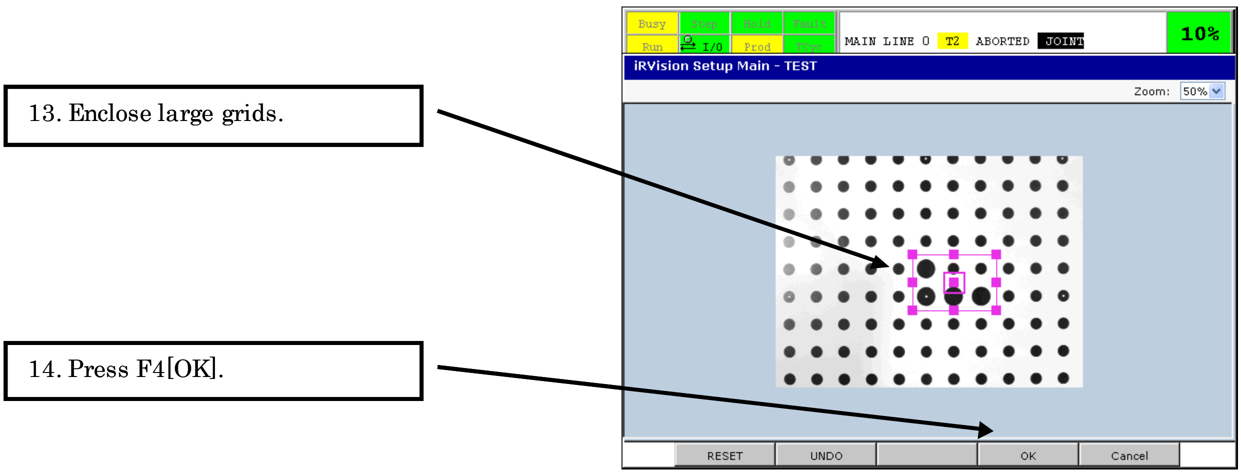


11. Move the robot to display the grid in the center

In the same way as for camera calibration, move the robot so that the laser intersection and the center of the calibration grid are placed in the center of the image. The robot is moved to the position taught in the program created for calibration.

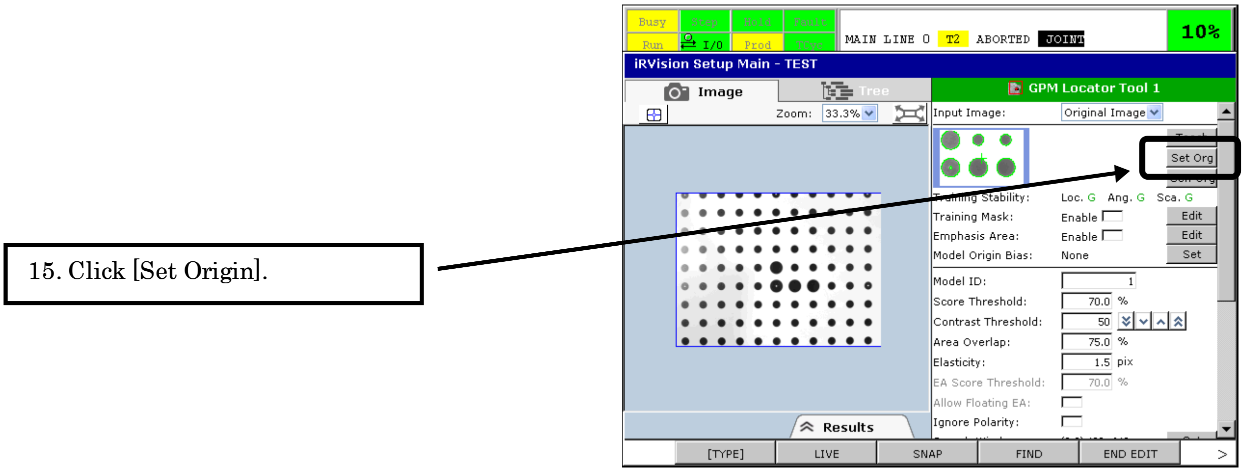
12. Click [Teach Pattern]

When the [Teach Pattern] button is clicked, the GPM Locator Tool model teach screen is displayed.

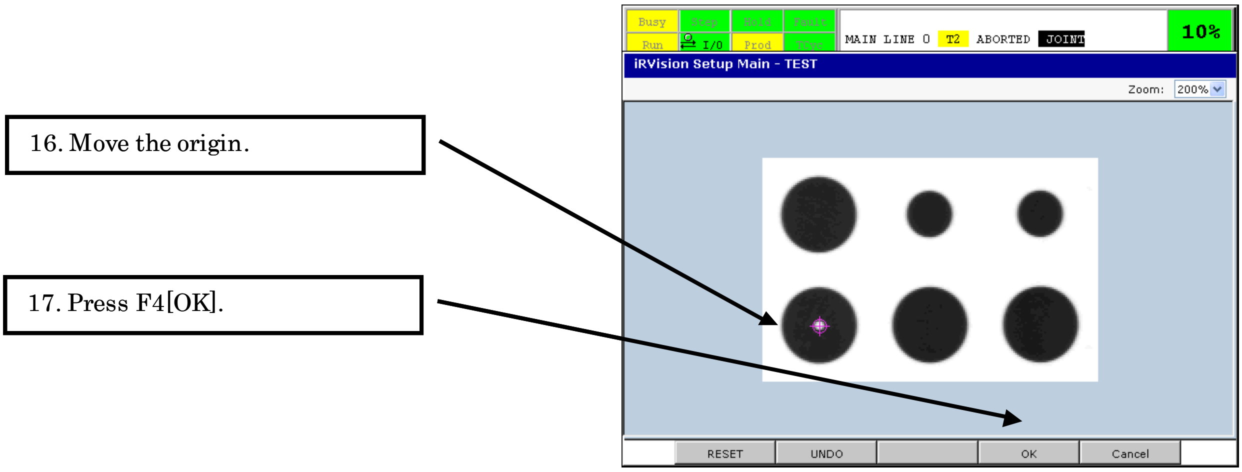


13. Enclose large grids
Change the area to enclose four large grids.

14. Press F4[OK]
When the F4[OK] is pressed, a model is taught, then the taught model is displayed.

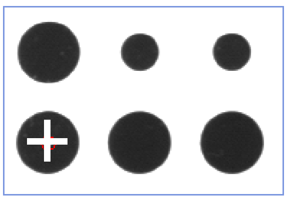


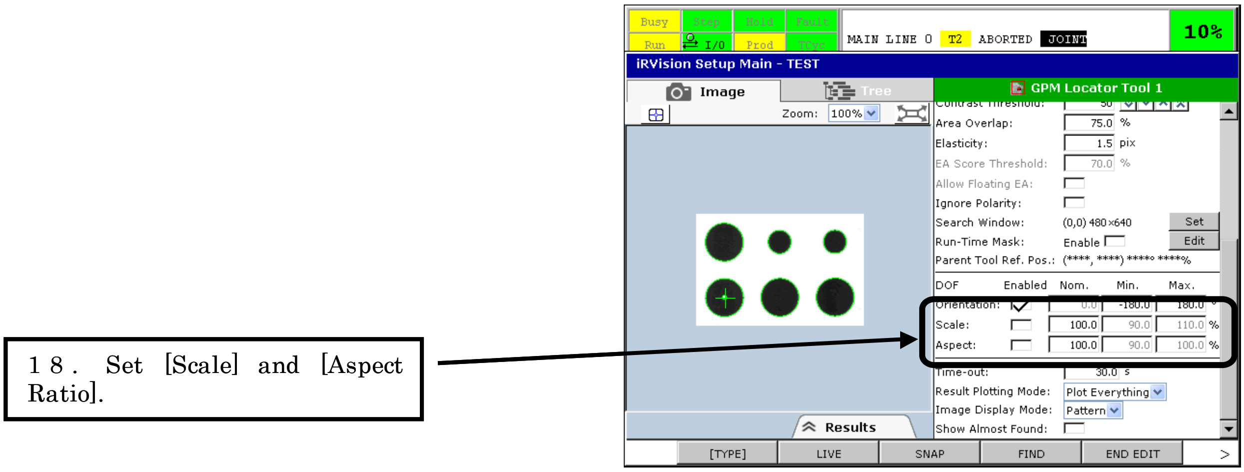
15. Click [Set Origin]
Change the origin of the model to match it with the origin of the frame set for the calibration grid.



16. Move the origin
Move the model origin setting target to the grid at the center of the calibration grid. When the image is zoomed, the origin can be set more precisely.

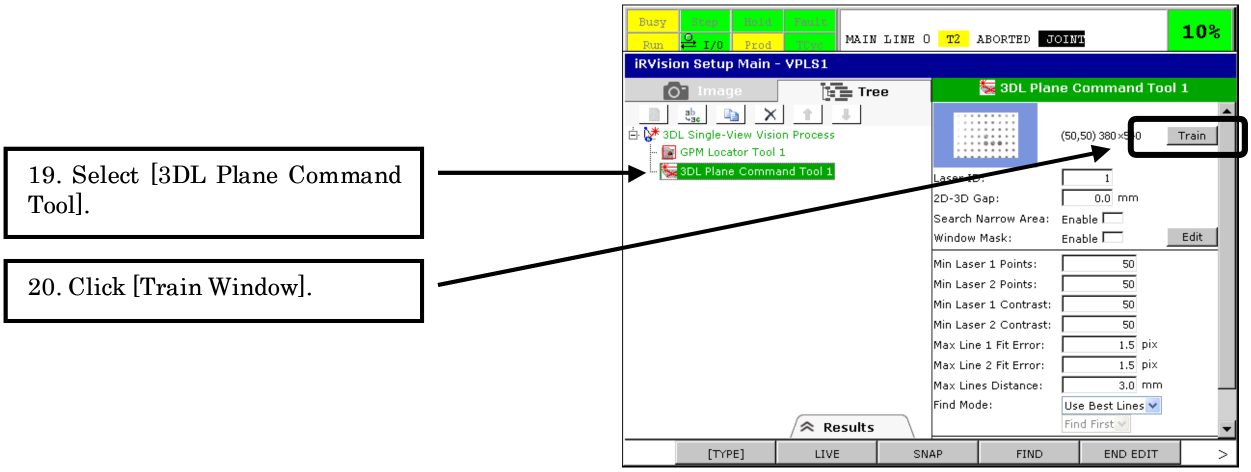
17. Press F4[OK]
Press F4[OK]. A new model origin is then set.





18. Set [Scale] and [Aspect Ratio]

To change the height and angle to be detected, check the check boxes of [Scale] and [Aspect Ratio]. Change the minimum value of [Scale] to 80 and the maximum value to 120. Change the minimum value of [Aspect Ratio] to 80.

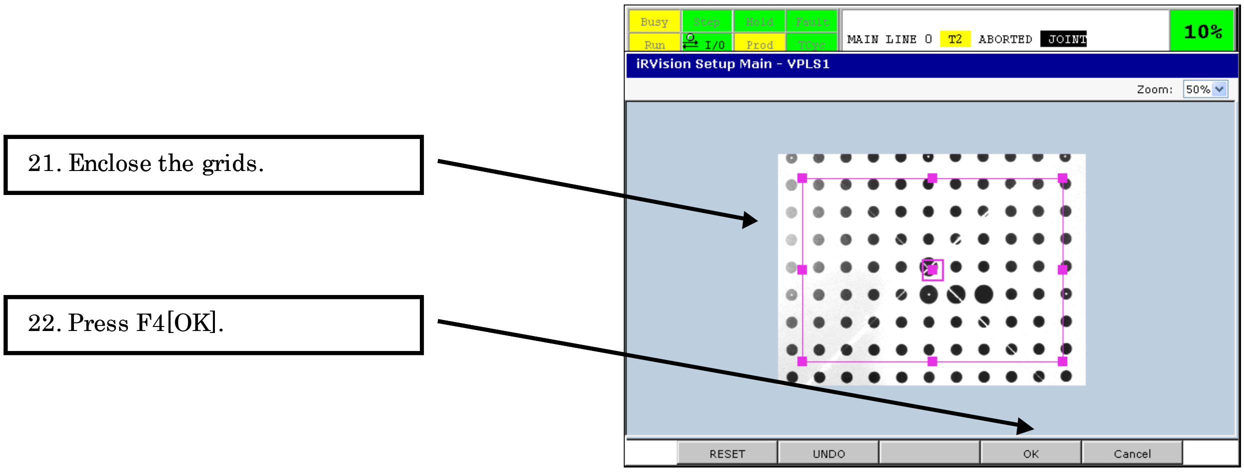


19. Select [3DL Plane Command Tool]

Select [3DL Plane Command Tool1] from the tree window.

20. Click [Train Window]

Click the [Train Window] button. The measurement area teach screen for 3DL Plane Command Tool is then displayed.

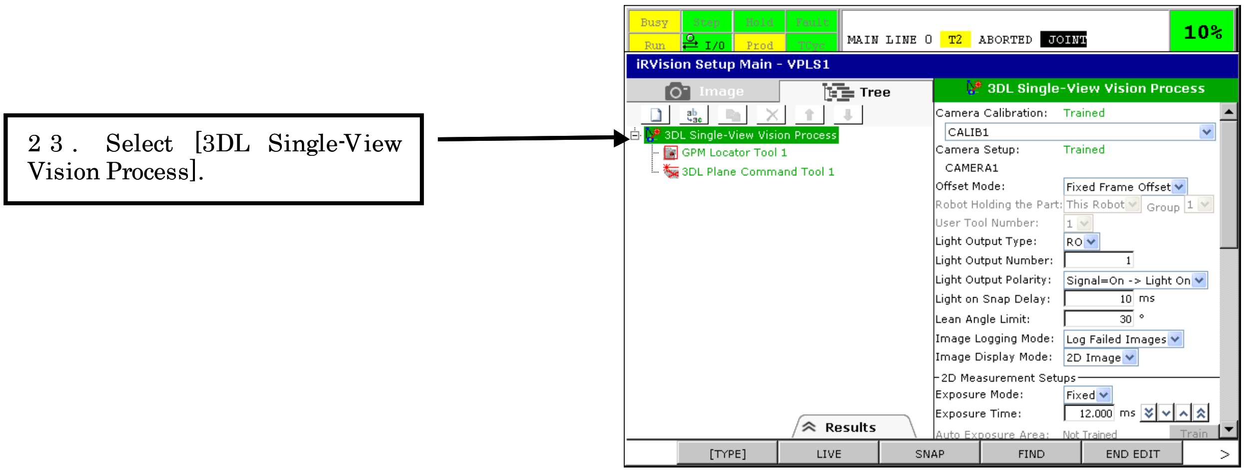


21. Enclose the grids

Enclose the grids on the calibration grid.

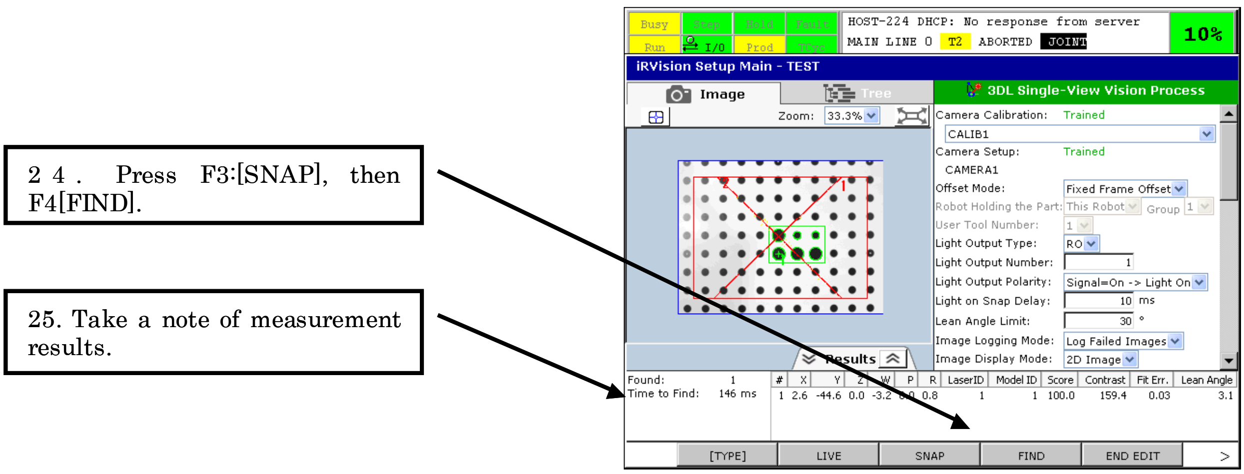
22. Press F4[OK]

When the F4[OK] is pressed, the measurement area is taught.



23. Select [3DL Single-View Vision Process]

Select [3DL Single-View Vision Process] from the tree window.

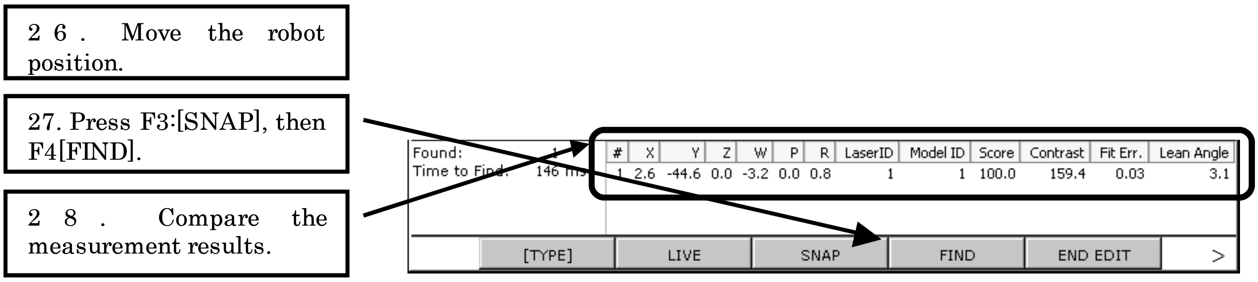


24. Press F3[SNAP], then F4[FIND]

Press F3[SNAP] , then F4[FIND]. An image is then captured, and a detection is made.

25. Take a note of measurement results

Take a note of the X, Y, Z, W, P, and R values in the measurement result obtained when the 3D Laser Vision Sensor and the calibration grid face each other, as reference data.



26. Move the robot position

Change the position and posture of the robot as far as the calibration grid is viewed within the field of view of the camera.

27. Press F3[SNAP], then F4[FIND]

Press F3[SNAP] , then F4[FIND]. An image is then captured, and a detection is made.

28. Compare the measurement results

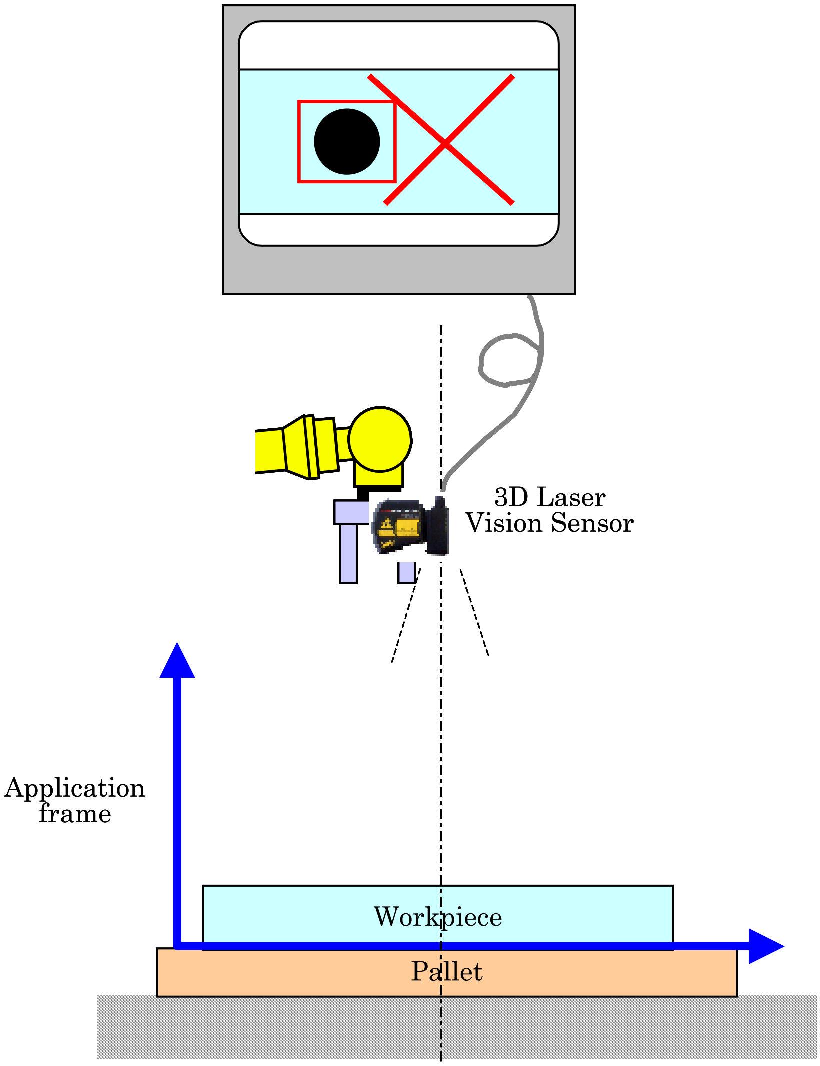
Compare the measurement results with the reference data to confirm that they approximately match. When user frame 0 is specified in [Application Frame] in the set calibration tool, the output results should approximately correspond to the frame set for the calibration grid. When the frame set for the calibration grid is specified in [Application Frame] in the set calibration tool, all elements of the output results should be approximately 0.

29. Repeat the measurement

Repeat a sequence of operations from the movement of the robot to compare measurement results while changing the position and posture of the robot. If variations in results due to errors in the absolute position precision of the robot, precision of the 3D Laser Vision Sensor, and calibration precision are 0.5 mm or less for the X, Y, and Z elements or 1 degree or less for the W and P elements, calibration has been performed normally. If the results contain abnormal values, confirm the calibration procedure, and perform calibration again.

3.2.6 Creating and Teaching a Vision Process

Create a vision process for the “3DL Single-View Vision Process”. For fixed frame offset, first place the workpiece to be picked up at the reference position to teach the reference position. If a reproducible position is set as the reference position, detection models can be added or changed easily.



Use the following procedure to teach a vision process for the 3DL Single-View Vision Process.

1. Specify calibration tool and set parameters.

⇩

2. Move the robot to the measurement position and teach the GPM Locator Tool.

⇩

3. Then, teach the 3DL Plane Command Tool.

⇩

4. Select [3DL Single-View Vision Process], which is the top of the tree view and press F3[SNAP] and F4[FIND] to detect taught model.

⇩

5. Set the reference position.

Placing a reference workpiece

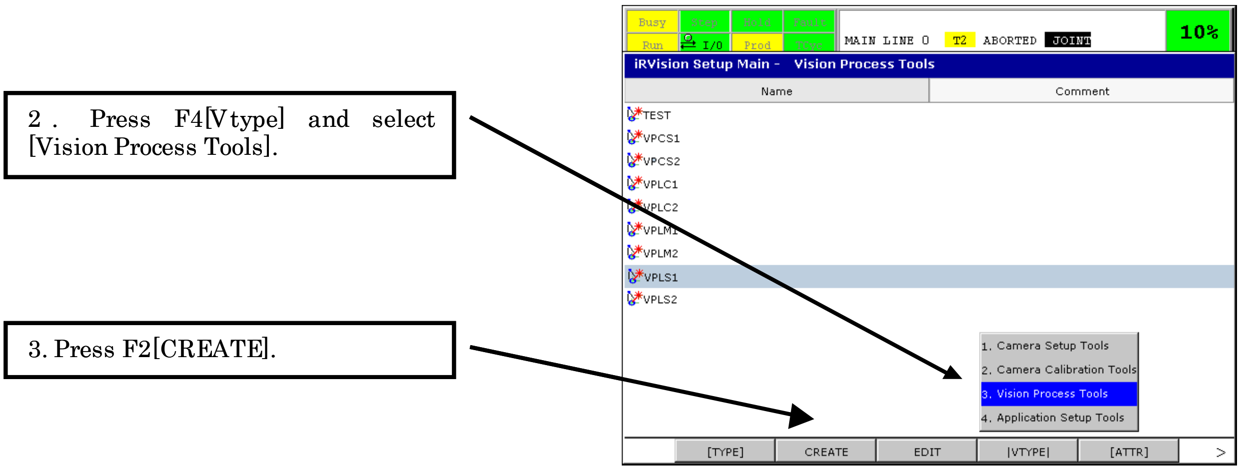
After correct camera calibration is confirmed, teaching of a workpiece to be actually handled is performed. This section mainly explains how to make settings for [Fixes Frame Offset] compensation

1. Place target workpiece at the reference position.

First, place the workpiece to be picked up at the reference position. If a reproducible position is set as the reference position, detection models can be added or changed easily.

Creating a vision process

Next, create a vision process.



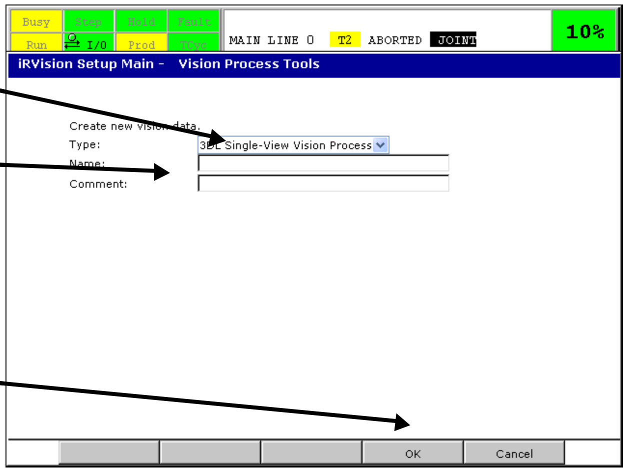
2. **Press F4[VTYPE] and select [Vision Process Tools]**
   Press F4[VTYPE], and select [Vision Process Tools] from the setup main screen.

3. **Press F2[CREATE]**
   When the F2[CREATE] is pressed, the screen shown below is displayed, allowing an additional vision process to be set.

4. Select the vision process type.

5. Enter the vision process name.

6. Press F4[OK] to create the vision process.



4. Select the vision process type

Options vary depending on the installed software option. To create a vision process for 3DL Single-View Vision Process using the 3D Laser Vision Sensor, select [3DL Single-View Vision Process]. To create a vision process for a fixed 2D measurement camera, select [2-D Single-View Vision Process].

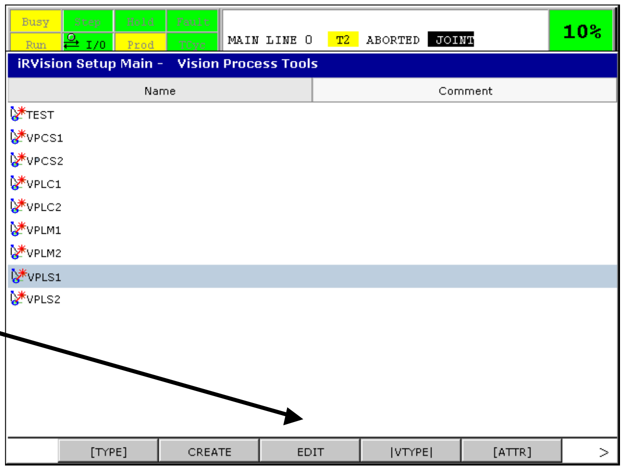
5. Enter the vision process name

Assign a unique name to the vision process.

6. Press F4[OK] to create the vision process

After selecting a type and entering a name, press F4[OK]. A new vision process is then created.

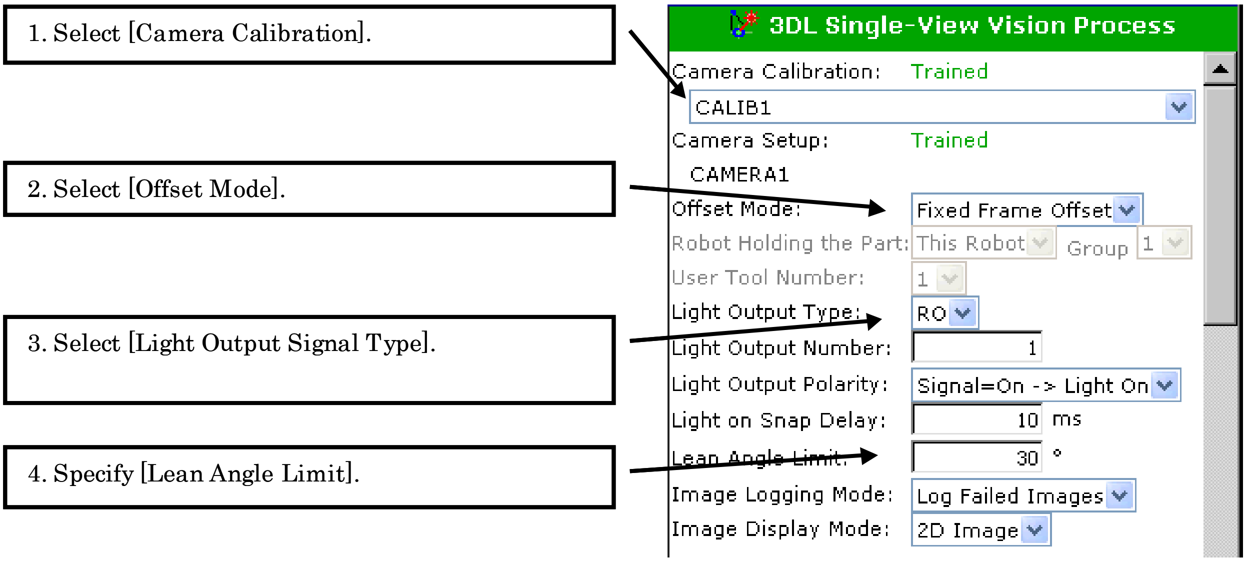
7. Select the created data and press F3[EDIT]



7. Select the created data and press F3[EDIT]

Select Vision Process Tools for the created vision process, then press F3[EDIT]. The setup screen is then displayed.

3.2.6.1 Teaching the vision process



1. **Select [Camera Calibration]**
   From the [Camera Calibration] combo box, select the name of set 3DL calibration tool.

2. **Select [Offset Mode]**
   There are four compensation methods as shown below. Select an appropriate method for an application.
   - Fixed Frame Offset
     [Fixes Frame Offset] compensation is suitable for applications that compensate the robot motion by using *i*RVision measurement results and causes the robot to grip the workpiece as taught when information about the workpiece position and posture is unclear.
   - Tool Offset
     Workpiece position or posture displacement in the robot hand might occur when the robot grips a workpiece whose approximate position is known. This method is suitable for applications that compensate the robot motion by using *i*RVision measurement results to correct such displacement and reproduces the workpiece placement position as taught. When this method is selected, select the target robot for compensation and the group of the robot in [Robot Holding the Part] and [Group], respectively, and select the tool frame for the hand to be compensated in [User Tool Number].
   - Found Position (User)
     As detection positions in the user frame, compensation data is not output, but measurement results of the workpiece position and posture, viewed from the user frame are output. This compensation method cannot compensate the robot motion directly. Compensation values for the robot must be calculated through another program such as a KAREL program.
   - Found Position (Tool)
     As detection positions in the tool frame, compensation data is not output, but measurement results of the workpiece position and posture, viewed from the tool frame are output. This compensation method cannot compensate the robot motion directly. Compensation values for the robot must be calculated through another program such as a KAREL program. When detection position (tool frame) is selected, select the target robot for compensation and the group of the robot in [Robot Holding the Part] and [Group], respectively, and select the tool frame for the hand to be compensated in [User Tool Number].

3. **Select [Light Output Signal Type]**
   To turn on and off the LED installed in front of the camera of the 3D Laser Vision Sensor in conjunction with 3D Laser Vision Sensor vision execution, specify the [Light Output Signal Type].

Depending on the material and status of the plane measured by the 3D Laser Vision Sensor, lighting required for detecting 2D features might adversely affect the detection of the laser slits.
This function can turn on the LED when, for example, 2D features are detected by one 3D measurement and the function can automatically turn off the LED when the laser slits are detected.
When the signal status is changed during vision execution, the original signal status is restored after the vision execution. LED control can therefore be performed during vision execution without adding commands to turn the LED on and off to the robot program.
From the following signal types, select a type suitable for the application:

- Not Used: The LED is not controlled in concert with vision detection.
- DO: DO is used for LED signal control.
- RO: RO is used for LED signal control.

When a Light output signal type is selected to turn the LED on and off during vision execution, set [Light Output Signal Number], [Light Output Signal Polarity], and [Light on Snap Delay]. In [Light Output Signal Number], specify the DO or RO number used for LED switching. [Light Output Signal Polarity] associates a signal state with the LED ON state. If [Signal=ON -> LED=ON] is set, for example, the LED is lit when DO or RO with a specified number is ON. In [Light on Snap Delay], enter a wait time required to change the LED ON state.
Whether the LED is to be on or off during 2D measurement and 3D measurement is set in relevant items separately.

4. **Specify [Lean Angle Limit]**
Lean angle limit is the maximum tilt angle of the workpiece with respect to the reference data, before the found result is considered as not found. For example, if the workpiece cannot be handled by the robot if it is tilted more than 30 degrees, enter 30 as the lean angle limit. Specify a value between 0 and 180.

3.2.6.2 Setting of 2D measurement

5. Select [Exposure Mode].

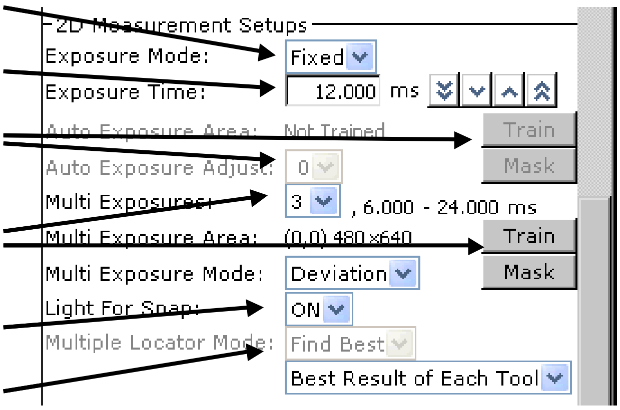
6. Set [Exposure Time].

7. If [Auto Exposure] is used, train [Auto Exposure Area] and select [Auto Exposure Adjust].

8. If [Multi Exposure] is used, select [Multi Exposures] and train [Multi Exposure Area].

9. Select [Light For Snap].

10. If more than one locator tool exists, select [Multiple Locator Find Mode].



5. **Select [Exposure Mode]**
Select the exposure mode for images to be captured when 2D features are detected during 3D Laser Vision Sensor measurement. Select one of the following two modes according to the application and situations:

- Fixed
The fixed exposure mode is useful when there is always a certain level of brightness in the surroundings and images to be captured have fewer variations in brightness. This mode is also useful for applications in which the background brightness changes each time a

measurement is made, such as an application using a 3D Laser Vision Sensor as a robot-mounted camera. Because the shutter speed is fixed, extra processing time is not required, and images can be captured slightly faster than in the automatic exposure mode. The fixed exposure mode, however, is not suitable for changes in brightness, so when the surrounding brightness changes greatly, a non-detection or detection error may result.

- Auto
  If a photometric area and a desired level of brightness of the area are specified in advance, the automatic exposure mode automatically adjusts the exposure time to obtain the specified brightness for the photometric area when an image is captured during vision process execution. This mode is useful when a place that always stays in similar conditions is present as the photometric area in the field of view of the camera and the surrounding brightness changes greatly. Because images are captured to find an appropriate shutter speed, this mode requires a little more time for image capture than the fixed exposure mode. When luminance of the photometric area is extremely low or high, an accurate shutter speed might not be calculated correctly.

6. Set [Exposure Time]

If [Fixed] is specified in [Exposure Mode], set [Exposure Time]. This exposure time is used to snap an image when 2D features are detected and so it does not affect laser slit detection. Adjust the exposure time so that the features of the workpiece are shown with high contrast. The value can be changed by entering a new value manually or using the + and - buttons.

7. If [Auto Exposure] is used, train [Auto Exposure Area] and select [Auto Exposure Adjust]

If [Auto] is selected in [Exposure Mode], teach automatic exposure. Click the [Train] button to display the automatic exposure area setting screen. Set a measurement area in a place in which a certain level of brightness of the image is to be kept within the field of view. The image brightness observed when the area is set is recorded. When an image is captured, the exposure time is automatically adjusted so that the image has the same brightness as the recorded brightness.
After setting the automatic exposure area, to fine-adjust the brightness on the image without teaching the area again, specify a value in the [Auto Exposure Adjust] combo box. If 0 is specified, the exposure time is controlled so that the brightness of the photometric area is the same as the brightness at teaching. Specifying a positive value controls the exposure time to increase brightness, and specifying a negative value controls the exposure time to decrease brightness.

8. If [Multi Exposure] is used, select [Multi Exposures] and train [Multi Exposure Area]

Multi exposure is a function where multiple images are snapped and combined to output one image, in order to produce an image with a wider dynamic range. This function is effective when the brightness of the target changes drastically. However, since multiple images are taken, the processing time will increase. Multi exposure can be selected by selecting a number greater than 1 in [Multi Exposure]. To teach multi exposure area, click the [Train] button to display the multi exposure area setting screen. The measurement area is used for scaling the combined image.

9. Select [Light For Snap]

If DO or RO is selected in [Light Output Signal Type], set [Light For Snap]. Choose from the following three options:

- Not Used: The LED is not controlled at the time of 2D detection.
- ON: The I/O signal specified by [Light Output Signal Number] is turned on at the time of 2D detection.
- OFF: The I/O signal specified by [Light Output Light Output Signal Number] is turned off at the time of 2D detection.

10. If more than one locator tool exists, select [Multiple Locator Find Mode]

When more than one GPM Locator Tool is added to the vision process, specify the GPM Locator Tool execution method in [Multiple Locator Find Mode].

Select one of the following according to the application and situations:

- Find Best
  All GPM Locator Tools added to the vision process are performed, and a detection result having the highest score is output.
- Find First
  GPM Locator Tools added to the vision process are performed sequentially starting with the top of the tree window, and if detection is successful in a GPM Locator Tool, the GPM Locator Tools added below that GPM Locator Tool are not performed.

3.2.6.3 Setting of laser measurement

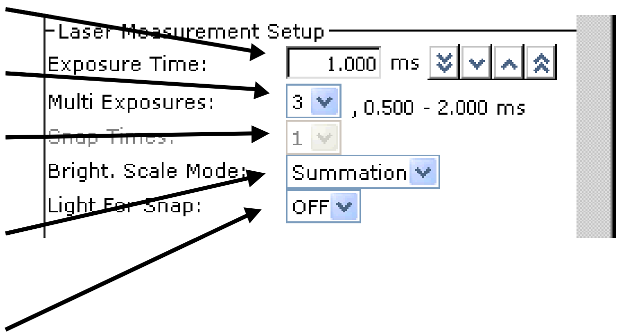
11. Set [Exposure Time].

12. Select [Multi Exposures].

13. If [Multi Exposures] is one, select [Snap Times].

14. If [Multi Exposures] or [Snap Times] is two or more, select [Brightness Scaling Mode].

15. Select [Light For Snap].



11. Set [Exposure Time]

This exposure time is used for capturing an image when the laser points are detected, and so it does not affect detection of 2D features. Adjust the exposure time so that the laser slits are shown with high contrast. The value can be changed by entering a new value manually or using the + and - buttons.

12. Select [Multi Exposures]

Multi exposure is a function where multiple images are snapped and combined to output one image, in order to produce an image with a wider dynamic range. This function is effective when the brightness of the target changes drastically. However, since multiple images are taken, the processing time will increase. Multi exposure can be selected by selecting a number greater than 1 in [Multi Exposure].

13. If [Multi Exposures] is one, select [Snap Times]

If [Multi exposures] is not used, specify [Snap Times]. When this item is specified, image capturing with a certain shutter constant is internally performed as many times as specified, and then image addition is made. Usually, the initial value, 1, is specified without modification. However, when the contrast between the background and the laser beam is low in such a case that a black plane is to be measured, a larger value can be specified to increase the contrast.

14. If [Multi Exposures] or [Snap Times] is two or more, select [Brightness Scaling Mode]

When a value of 2 or greater is set in [Multi Exposures] or [Snap Times], select either of the following as the method for laser slit image synthesis (brightness adjustment mode):

1. Maximum:
   Synthesis is performed with suppressing the maximum brightness 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.
2. Summation:
   All snapped laser slit images are added, and synthesis is performed so that the brightness only of pixels in which halation occurs is suppressed to the maximum displayable brightness.

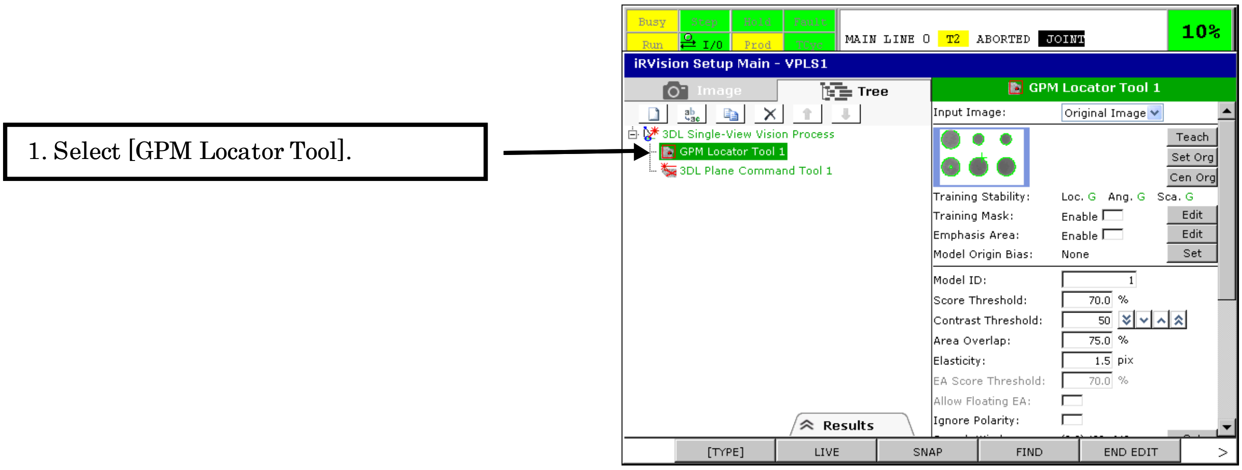
15. Select [Light For Snap]

If DO or RO is selected in [Light Output Signal Type], set [Light For Snap]. Choose from the following three options:

- Not Used: LED control is not performed during 3D detection.
- ON: The I/O signal specified by [Light Output Signal Number] is turned on at the time of 3D detection.
- OFF: The I/O signal specified by [Light Output Signal Number] is turned off at the time of 3D detection.

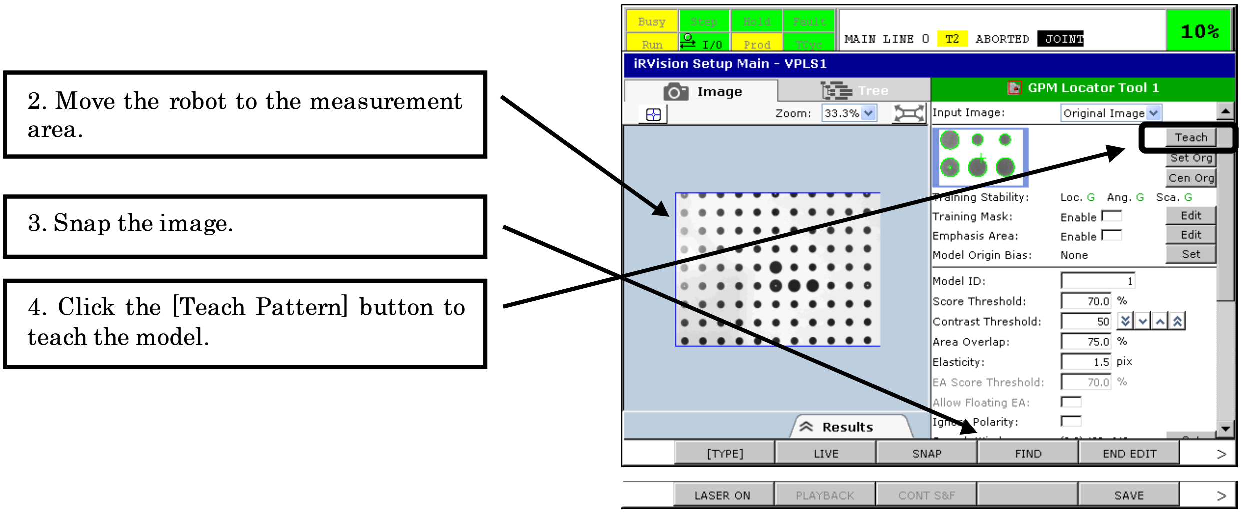
3.2.7 Teaching a GPM Locator Tool

Method of teaching



1. Select [GPM Locator Tool]

When [GPM Locator Tool] is selected in the tree window, the GPM Locator Tool setup screen is displayed.



2. Move the robot to the measurement area

Move the robot position so that the laser beam is directed to the plane to be measured. Follow the steps below to move the robot:

1 Press F2 [LIVE]. The camera then snaps in succession.
2 Press F6[LASER ON]. The button stays pressed, and the laser turns on.
3 Jog the robot so that the workpiece plane to be measured comes in the center of the image. When [Crosshair] button is clicked, center lines appear on the image, which allows easier position alignment.
4 Adjust the distance between the 3D Laser Vision Sensor and the workpiece so that the laser bean intersection comes at the center of the plane. At this time, the distance between the camera of the 3D Laser Vision Sensor and the workpiece plane is about 400mm.

3. Snap the image

After determining the measurement position, press F3[SNAP] to capture an image. Because the measurement area is taught for the image shown on the image display screen, the measurement area cannot be set when no image is captured.

4. Click the [Teach Pattern] button to teach the model

Click the [Teach Pattern] button. The GPM Locator Tool model teach screen is then displayed. Teach 2D features used for position detection. As the features of a model, select features on the same plane to reduce the effects of changes in shape due to parallax. For features that need not be included in the model, [Training Masks] can be set to exclude them from the teach model.

5. Teach the robot position in the robot program

When vision process teaching is performed together with robot program teaching, teach this position as the detection position.

Detection test

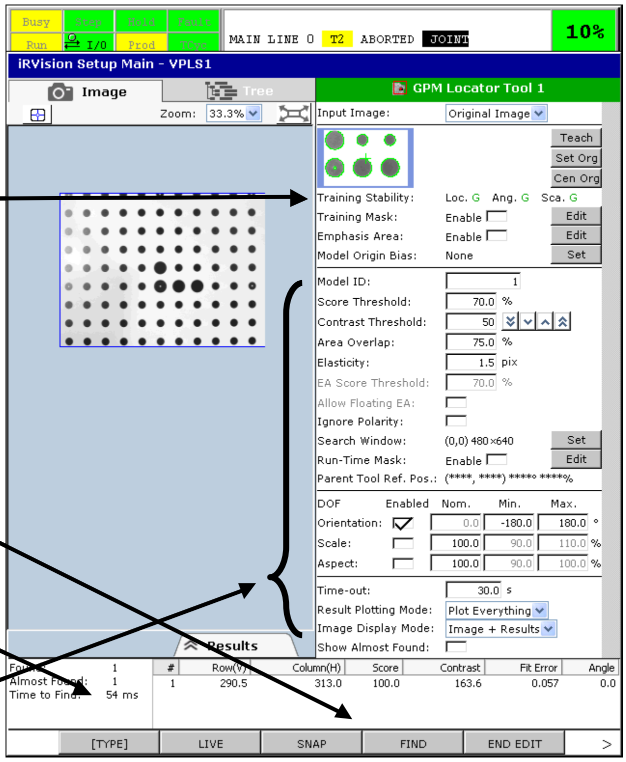
Check whether the taught model is appropriate. If necessary, adjust parameters to enable stable detection.

6. Check [Train Stability].

7. Press F3[SNAP], then F4[FIND]

8. Check measurement results.

9. Adjust parameters.



6. Check [Train Stability]

This item provides a guideline indicating whether the position, angle, and size are detected correctly in the taught model. Evaluations are indicated with [Good], [Poor] and [None]. [None] indicates that stable detection of the model may be impossible. In such a case, change the model, or uncheck [Enabled] of the parameter in question in [Degree of Freedom] to make the parameter invalid.

7. Press F3[SNAP], then F4[FIND]

Press F3[SNAP], then F4[FIND]. An image is then captured, and detection is performed.

8. Check measurement results

First, check that the parts taught with the model are detected correctly on the image display screen. Then, check the score, contrast, and other results of the detected model on the test result display screen. As a guideline to determine whether to ensure stable detection, the score and contrast values in the results should be higher than the set thresholds by at least 10 points.

9. Adjust parameters

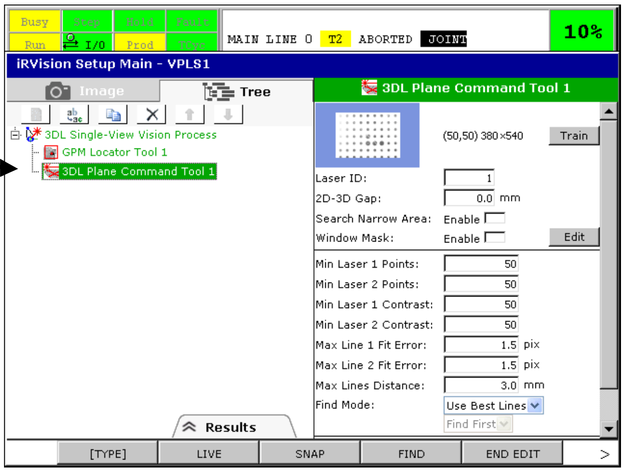
As necessary, 2D detection parameter values can be modified.

3.2.8 Teaching 3DL Plane Command Tool

Method of teaching

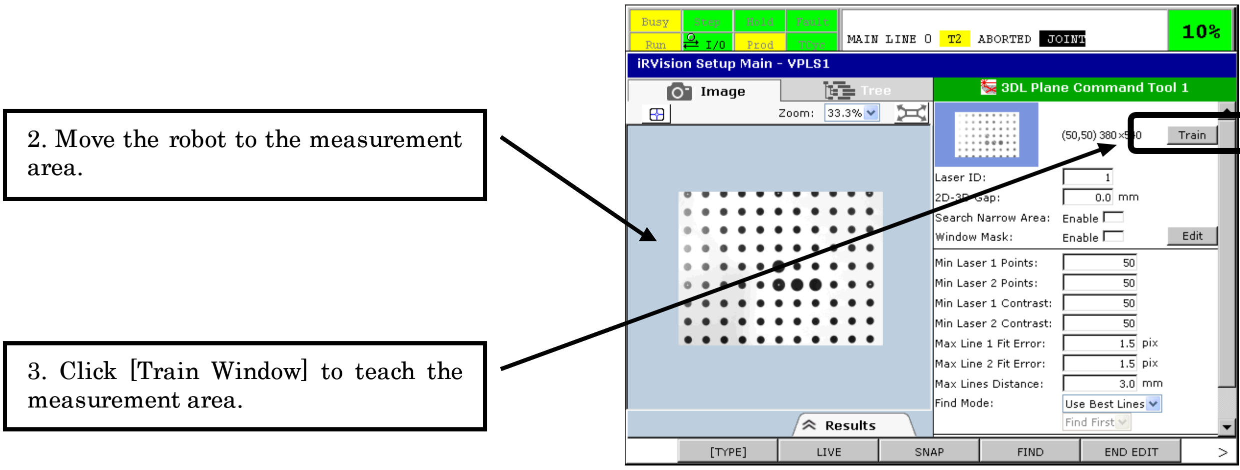
> ⚠ **CAUTION**
> When a GPM Locator Tool has been added to the same vision process, teach the GPM Locator Tool before teaching 3DL Plane Command Tool of the 3D Laser Vision Sensor.

1. Select the [3DL Plane Command Tool].



1. Select [3DL Plane Command Tool]

When [3DL Plane Command Tool] is selected from the tree window, the 3DL Plane Command Tool setup screen is displayed.

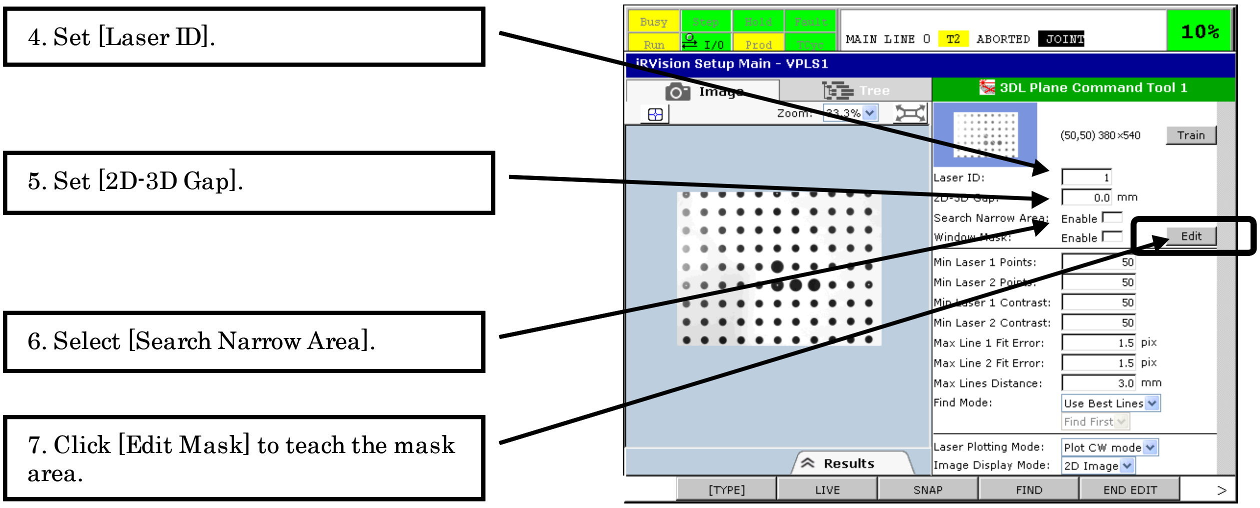


2. **Move the robot to the measurement area**

It is desirable that a measurement be made at the position to which the robot has been moved during teaching of the GPM Locator Tool. If necessary, however, move the robot position so that the laser beam is directed to the plane to be measured. The robot is moved in the same way as for a GPM Locator Tool. If the detection position is moved from the position for the GPM Locator Tool, the position to be taught as the detection position in the robot program must also be taught again.

3. **Click [Train Window] to teach the measurement area**

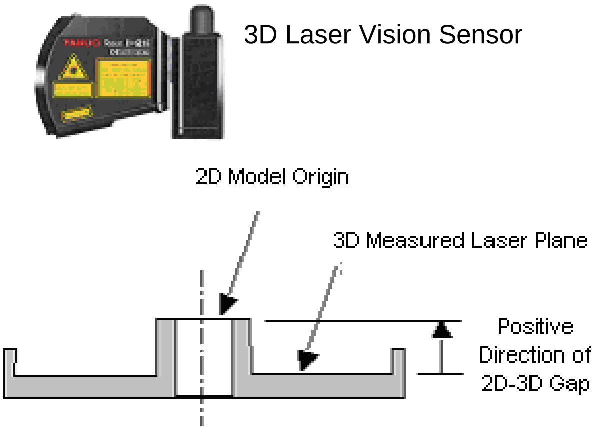
When the [Train Window] button is clicked, teaching of the measurement area can be performed. If a GPM Locator Tool is present in the vision process, the GPM Locator Tool model must be taught in advance. When no detection model has been taught, the measurement area for 3DL Plane Command Tool cannot be set. When the origin of the GPM Locator Tool model is changed or the detection model is taught again after the measurement area is set, the measurement area must be set again.
The displayed red frame indicates the area for laser beam measurement. The area can be modified. A line being modified is displayed in purple. When only the location of the area is being moved without changing the area size, the area frame is displayed in orange.
Upon completion of measurement area setting, a thumbnail of the image used for the measurement area is displayed, and [Trained] is indicated in [Status].



4. **Set [Laser ID]**

When more than one 3DL Plane Command Tool has been added to the vision process, [Laser ID] can be set to determine the 3DL Plane Command Tool of which result is used as the result. Usually, when there is one 3DL Plane Command Tool, the initial value might be left unchanged.

5. **Set [2D-3D Gap]**
When there is a difference in height between the plane on which the GPM Locator Tool detection model was taught and the plane measured by the laser, enter the difference in height from the laser plane. If the detection model plane is nearer than the laser plane to the camera, a positive value must be entered.

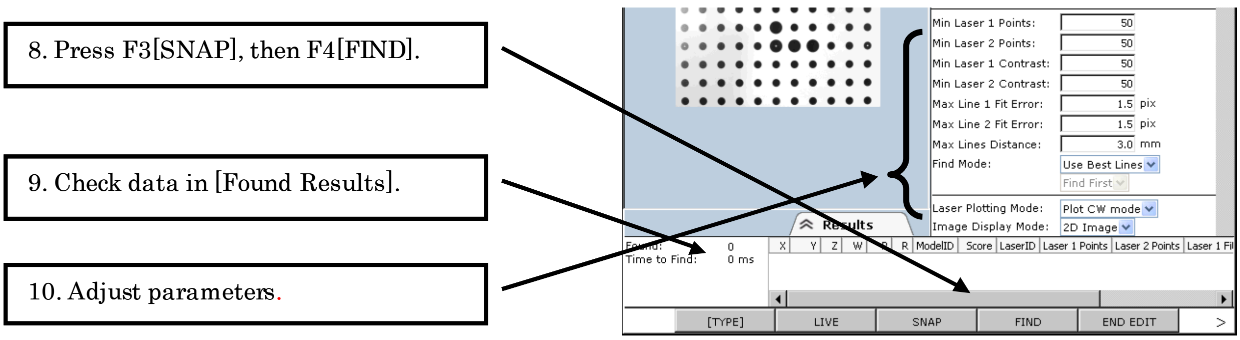


6. **Select [Search Narrow Area]**
When the plane area to be measured is narrow, and few laser points can be used, [Search Narrow Area] can be set to increase the number of points used for measurement. At the same time, processing time also increases. So this item should be set only if necessary.

7. **Click [Edit Mask] to teach the mask area**
When the measurement area includes planes with level difference to which the laser beam is directed, or when there is an area to be excluded from the measurement area, set a mask. To create a mask for the measurement area, click the [Edit Mask] button. Even when a mask has been edited, the mask is ignored if the [Enable] check box is not checked.

Detection test

Check whether the taught area is appropriate. If necessary, adjust parameters to enable stable detection.



8. **Press F3[SNAP], then F4[FIND].**
Press F3[SNAP], then F4[FIND]. An image is captured, and detection is performed.

9. **Check data in [Found Results].**
First, check that laser points are detected correctly on the image display screen. Then, check the results output on the test execution result display screen. By comparing the values of the results with set thresholds, determine whether stable detection can be performed. Before a laser measurement can be made, the taught 2D feature model must be detected.

Laser slit measurement results are displayed. When detection fails, this window can be used to determine the cause of the non-detection.

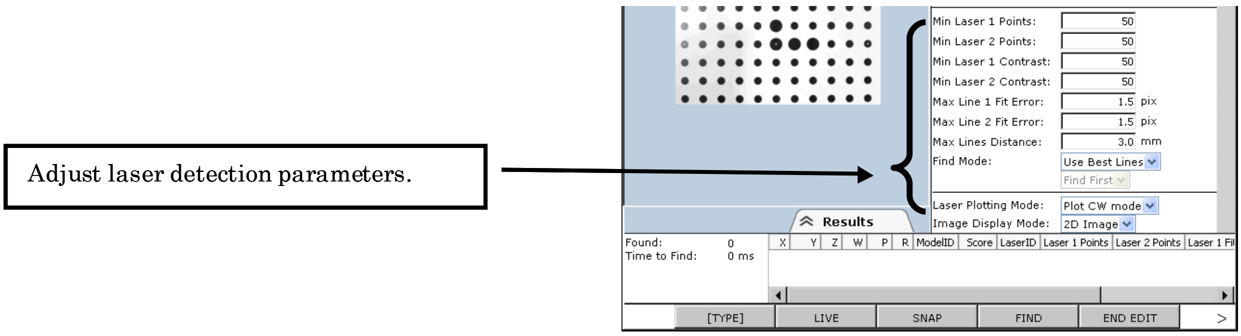
10. Adjust parameters

Parameters can be adjusted so that stable detection of laser points is enabled. Read the description in the following subsection, "3.2.8.1 Parameters for laser points detection", and carefully change parameters.

3.2.8.1 Parameters for laser points detection

Parameters for laser points detection should be adjusted only when correct detection cannot be performed by adjusting the settings for laser measurement in any way. If laser points are detected forcibly, or values are changed carelessly, a correct measurement may not be calculated.

> ⚠ **CAUTION**
> Before changing detection parameter values, check whether the setting of the laser measurement exposure time in the vision process has been adjusted to output an appropriate image.



[Min Num Laser1/2 Points]

If the number of valid points detected within the measurement area except the mask area is smaller than this threshold, the measurement results are ignored. If the measurement area is narrow or detected laser points vary with a change in image brightness, detection might become possible by decreasing the minimum number of laser points. However, as the number of points decreases, the measurement precision might be degraded because the inclination of the workpiece plane is calculated based on the detected points.

The number of valid laser points detected depends on the laser contrast and the laser linear approximate error.

[Min Laser1/2 contrast]

A threshold used for detecting points of a laser beam directed to the measurement area except the mask area.

[Max Line1/2 Fit Error]

When a straight line is generated based on a single laser beam directed to the measurement area except the mask area, an element of the points is regarded as a valid point if an error indicating the distance of the element from the straight line is within a set number of pixels. When the plane to be measured has a rough surface such as a cast surface, setting a larger value may increase valid points. If the set value is too large, precision may lower.

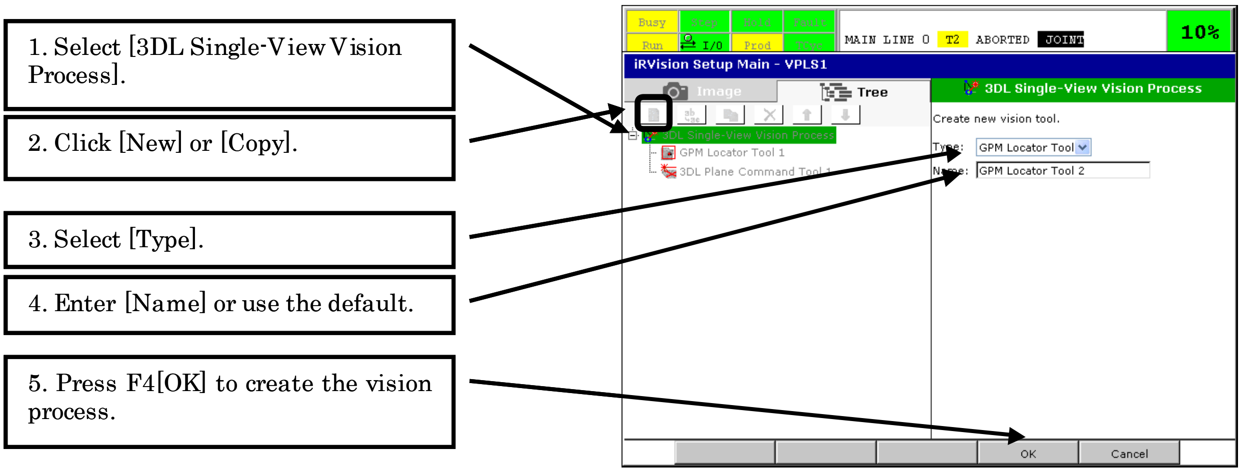
[Max Lines Distance]

The straight lines made up of laser points calculated from the laser slits should theoretically intersect at the intersection point of the laser beams directed to the workpiece plane. Actually, however,

because of errors such as a calibration error and measurement error, a distance of 0 is rarely observed. [Max Lines Distance] is the threshold of the length of the shortest straight line that intersects the two straight lines orthogonally.
The initial value is 3.0mm. If a longer distance than the initial value has to be set, the 3D Laser Vision Sensor might have been calibrated incorrectly. If the robot compensation operation satisfies the required precision, [Max Lines Distance] may be increased as an ad hoc measures, but it is recommended that automatic re-calibration be performed.

3.2.9 Adding Command Tools

Command tools such as a GPM Locator Tool and 3D Laser Vision Sensor 3DL Plane Command Tool can be added as necessary.



1. **Select [3DL Single-View Vision Process]**
When a vision process for 3DL Single-View Vision Process using the 3D Laser Vision Sensor is created, one GPM Locator Tool and one 3DL Plane Command Tool are added to the vision process. To add another command tool to a vision process, select the parent vision process from the tree window.

2. **Click [New] or [Copy]**
When the [New] button is clicked, a new command tool can be added.
To copy an existing command tool, select the command tool, then click the [Copy] button .
The reasons why command tools are added include:
   1. Use of the set detection parameters causes a non-detection to occur.
   2. Models are to be distinguished.

3. **Select [Type]**
From the combo box, select [GPM Locator Tool], [3DL Displacement Command Tool], or [3DL Plane Command Tool].

4. **Enter [Name]**
Assign a unique name to the command tool, if necessary.

3.2.9.1 Addition of a GPM Locator Tool

The laser measurement area window automatically moves depending on the GPM Locator Tool detection results. Therefore, if separate model origins are set for more than one GPM Locator Tool command tool, the laser measurement area may change depending on the detection results. In addition, because a reference position for command tool detection results is set in the vision process, correct robot

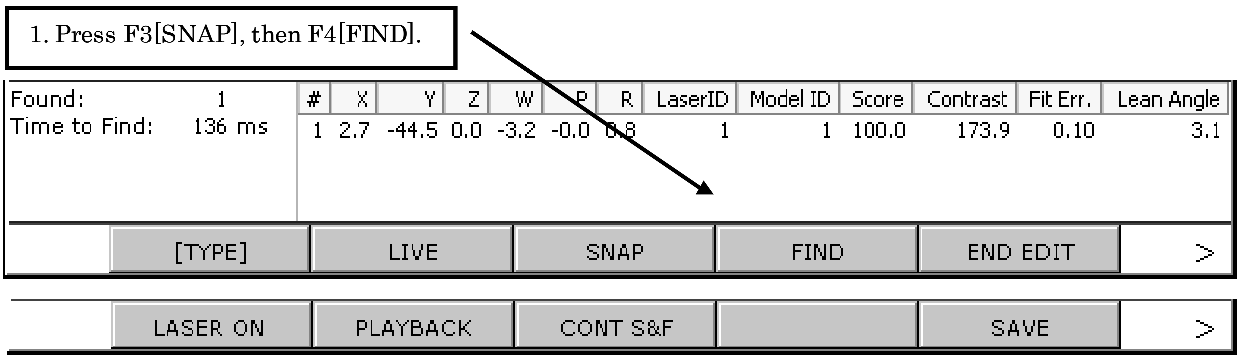
compensation values cannot be calculated with the detection results of command tools having different model origins.
To prevent these problems when multiple GPM Locator Tool command tools are added to a vision process, the model origins taught for all the GPM Locator Tool command tools must match. When the same model origin cannot surely be taught, and a command tool with different detection parameters needs to be added, the best way is to copy an existing command tool.

3.2.9.2 Addition of a 3DL Displacement Command Tool

A 3DL Displacement Command Tool can be added to a vision process if the vision process contains no 3D measurement tools other than 3DL Displacement Command Tools. When a vision process is created, a 3DL Plane Command Tool is initially included in the vision process. So, when a vision process for 3DL Displacement Command Tool is to be created, the 3DL Plane Command Tool must be deleted.

A 3DL Displacement Command Tool is taught in the same manner as a 3DL Plane Command Tool except that there are different parameter setting items.

3.2.10 Test Execution

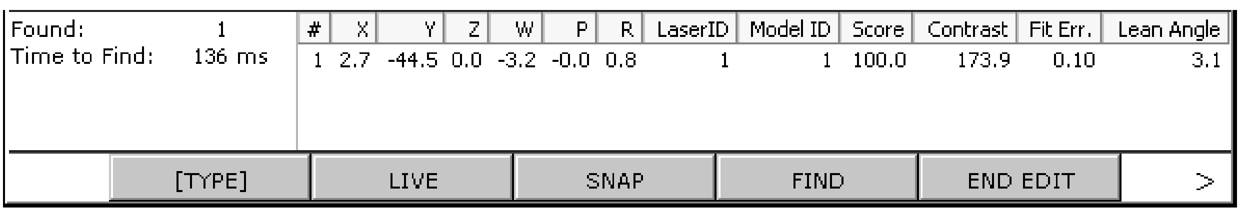


1. **Press F3[SNAP], then F4[FIND].**
   The F3[SNAP] and F4[FIND] executes the vision process once with a newly captured image. The F8[CONT S&F] performs image capture and detection repeatedly. During repeated execution, the F8[CONT S&F] changes to the F8[STOP S&F]. When F8[STOP S&F] is pressed, repeated execution ends. The F4[FIND] executes the vision process once by using the image snapped last without capturing new images. When modifications to parameters have been made for an image that caused a non-detection and then checking is made to see whether the modifications are appropriate or not, capturing of another image should be avoided. In such a case, use the F4[FIND] to perform test execution.

Time to Found

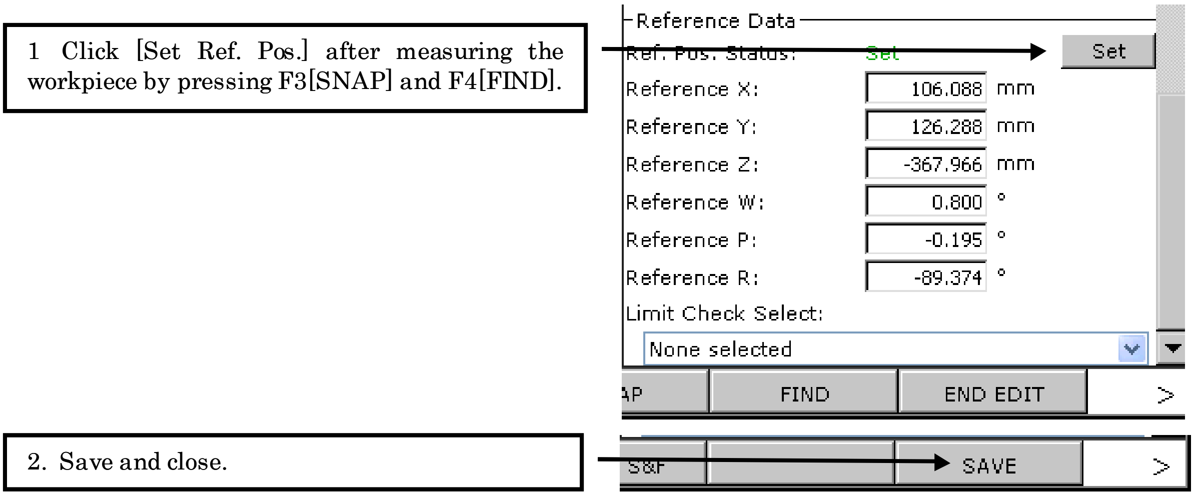
Vision process processing time ([Time to Find]) affects the system cycle time. If processing time is too long, modify the snap conditions, and adjust the taught model of a command tool and detection parameters.

3.2.11 Checking the Found Result Screen



When test execution results in successful detection, the results are displayed. The measured detection position and posture of the workpiece are output using the frame specified as the frame used for compensation during camera calibration. [Laser ID] and [Model ID] indicate which command tool resulted in successful detection.

3.2.12 Setting Reference Position



1. **Click [Set Ref. Pos.] after measuring the workpiece by pressing F3[SNAP] and F4[FIND]**
   When correct detection is confirmed as a result of test execution, set reference data for the vision process. Click the [Set Ref. Pos.] button. Position and posture information in the detection results are then used as reference position data. [Reference Position Status] indicates that setting is done, and [Status] of the vision process indicates that teaching is done. When a compensation method that does not require reference position data is selected, the [Set Ref. Pos.] button becomes invalid, and no setting is required.

2. **Save and close**
   Press F10[SAVE] to save modifications. Press F5[END EDIT] to close the vision process setup screen. This completes the vision process teaching.

3.2.13 Creating and Teaching a Robot Program

In the sample program below, a vision process for the 3DL Single-View Vision Process named “VPLS” is used. The sample program can be used to take out, for example, an unmachined casting. The robot compensates the tool offset according to the measurement result. After supplying the workpiece to the machine, the robot tries to detect another workpiece.

```
 1:  UFRAME_NUM=1
 2:  UTOOL_NUM=1
 3:J P [1:Home] 30% FINE
 4:
 5:  !Measurement
 6:  LBL [10]
 7:J P [2:Measurement Pos] 100% FINE
 8:  WAIT    .30(sec)
 9:  VISION RUN_FIND 'VPLS'
10:  VISION GET_OFFSET 'VPLS' VR[1] JMP LBL[999]
11:
12:  !Grasp
13:L P[3:Approach] 800mm/sec CNT100 VOFFSET,VR[1]
14:L P[4:Grasp] 200mm/sec FINE VOFFSET,VR[1]
15:L P[5:Retract] 800mm/sec CNT100 VOFFSET,VR[1]
16:
17:  !Place
18:L P[6:Approach] 800mm/sec CNT100
19:L P[7:Place] 200mm/sec FINE
20:L P[8:Retruct] 800mm/sec CNT100
21:  JMP LBL[10]
22:
23:  !No workpiece is detected
24:  LBL [999]
25:  ***
```

- Line 1: Set the same value as the number of the application frame.
- Line 8: Wait for robot-vibration to reduce.
- Line 9: Execute measurement.
- Line 10: Get compensation data of the measurement result.
- Line 14: Compensate pickup operation.
- Line 19: Execute placement operation.
- Line 25: Add exception processing when no workpiece is detected.

> **NOTE**
> Measurement is performed after the robot reaches the taught position of the last motion. If the robot is still vibrating, it may affect the accuracy of the measurement. In such cases, please use 'WAIT' or 'acceleration override' to minimize the vibration.

In the sample program above, the vision process 'VPLS' is executed, one vision offset is calculated, and the robot position is compensated by the vision offset.
If no workpiece is detected, it jumps to the label [999].

The command for *i*RVision used in the sample program is explained.

The command of the 9th line executes the specified vision program, snaps an image from a camera, performs image processing and stores the position information on the detected work.

VISION RUN_FIND *(vision-process-name)*

In the execution of a vision location command, when the vision process has snapped an image, the next line of the program is executed, and image processing is performed in the background. This allows vision image processing and another operation such as a robot motion to be performed in parallel.

The command of the 10th line stores a vision offset in a vision register.

```
VISION GET_OFFSET (vision-process-name) VR[a] JMP,LBL[b]
```

This command gets a vision offset from a vision process and stores it in a specified vision register. This command is used after RUN_FIND. If image processing is not yet completed when GET_OFFSET is executed, it waits for the completion of the image processing. However the completion of the RUN_FIND instruction does indicate the image acquisition has completed and the robot can move without blurring the camera image.

GET_OFFSET stores the vision offset for a workpiece in a vision register. When the vision process finds more than one workpiece, GET_OFFSET should be called repeatedly.

If no workpiece is detected or no more offset data is available because of repeated execution of GET_OFFSET, it jumps to the specified label.

At the 13th to 15th line, the robot motion such like as the workpiece handling is compensated with a vision offset.

```
L P[1] 500mm/sec FINE VOFFSET,VR[a]
```

VOFFSET is an optional operation command that is added to a robot motion statement. This command moves the robot to a position compensated with a vision offset data in a specified vision register.

For details of each commands and others, please refer to “10.2 GRID FRAME SETTING“ in “*i*RVision OPERATOR’S MANUAL (Reference)”

3.2.14 Checking Robot Compensation Operation

Check that a workpiece gripped by the robot can be detected and positioned at a desired location exactly. At first, decrease the override of the robot to check that the logic of the program is correct. Next, increase the override and cycle the program again to check its operation.

4 3DL SINGLE-VIEW VISION PROCESS

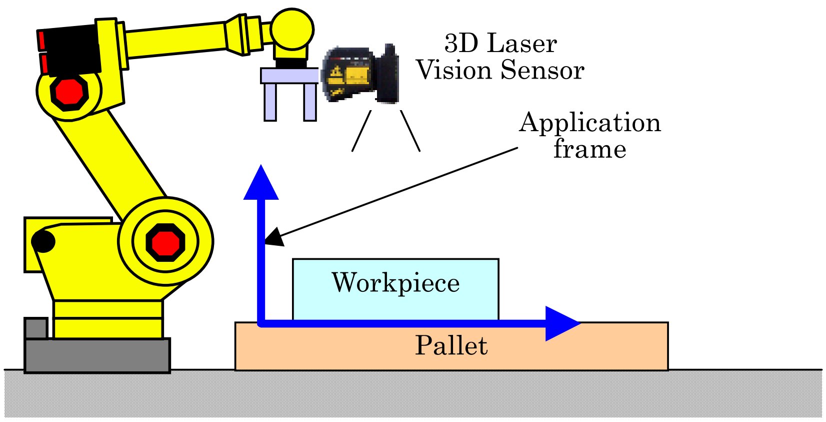
The 3DL Single-View Vision Process measures one point of a workpiece for its 3D position and posture using the 3D Laser Vision Sensor, and provides compensation for robotic handling of the workpiece.

This chapter describes the procedure to set up the 3DL Single-View Vision Process using the following two application examples. For details of the setup procedures and teaching procedures, please refer to Chapter 3 “TEACHING EXAMPLE”.

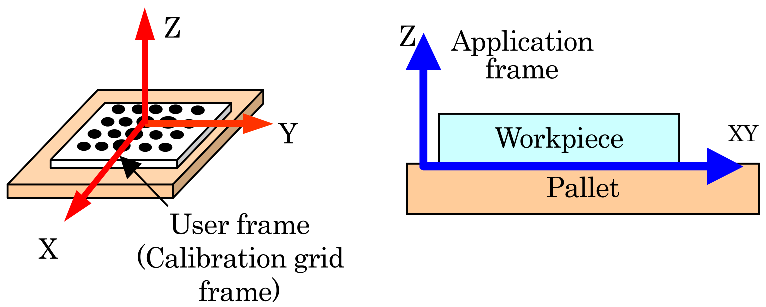
(1) Robot-mounted camera + fixed frame offset
(2) Fixed sensor + tool offset

4.1 SETUP FOR “ROBOT-MOUNTED CAMERA + FIXED FRAME OFFSET”

An example of layout for “robot-mounted camera + fixed frame offset” is given below.



Setup for “robot-mounted camera + fixed frame offset” includes setting the “calibration grid frame” and the “application frame” in a user frame with an arbitrary number. The “Calibration grid frame” can be set easily and correctly by using the camera of the 3D Laser Vision Sensor (grid frame setting function).



Use the following setup procedure for “robot-mounted camera + fixed frame offset”.

1. Create and teach camera setup tool.

2. Set the calibration grid frame with an arbitrary number.
   (Use the vision grid pattern setting for this setting.)

3. Set the TCP at the tip of touch-up pin mounted on the end of arm tooling.
   (The TCP set here is used to set the “application frame”.)

4. Set the user frame for application frame with arbitrary number.

5. Create and teach camera calibration tool.

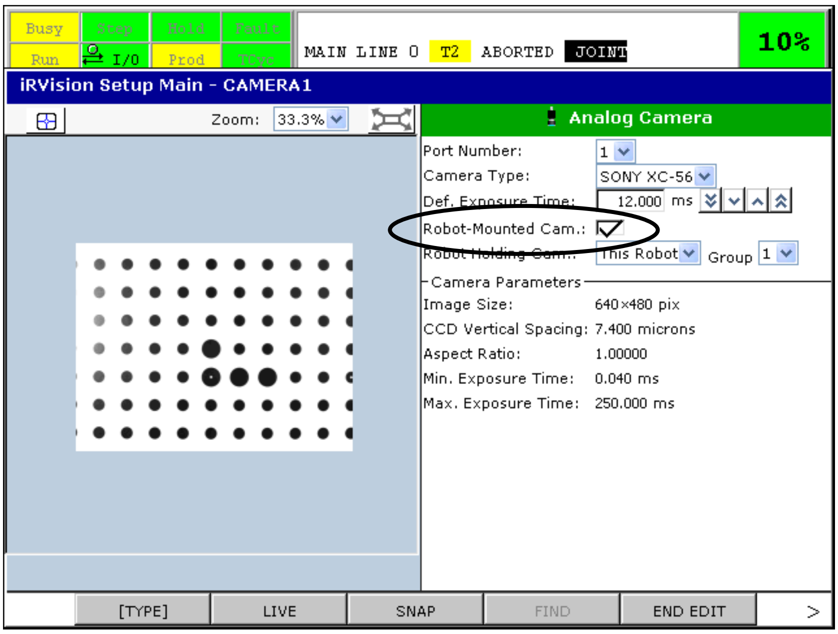
6. Create and teach the vision process tool.

7. Create and teach the robot program.

8. Check the robot compensation operation.

4.1.1 Creating and Teaching Camera Setup Tool

With *i*RVision, items such as camera type are set in camera setup tool. If you want to use the 3D Laser Vision Sensor as a robot-mounted camera, be sure to check the [Robot-Mounted Camera] check box.



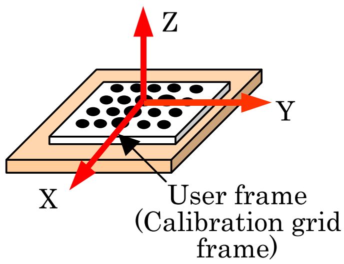
4.1.2 Setting Calibration Grid Frame

When a calibration grid is installed on a fixed place, set the calibration grid frame in a user frame with an arbitrary number. For this setting, use the grid frame setting function. After securing the calibration grid, execute the grid frame setting function. For details of the grid frame setting function, please refer to “10.2 GRID FRAME SETTING“ in “*i*RVision OPERATOR’S MANUAL (Reference)”. Note that the user frame for calibration grid frame differs from the “Application Frame” described in the following subsection.

In addition to the method of using the grid frame setting function, the following method is also available: Touch up the grid with a pointer mounted on the robot end of arm tooling precisely, then set a user frame as shown in the figure below. Please refer to “11.2.1 Setting Based on Touch-up” in “*i*RVision OPERATOR’S MANUAL (Reference)”. In this case, the operation described in the next subsection, “Setting the TCP of the Robot” must be performed in advance. The TCP setting precision and touch-up precision directly affect the compensation precision. Set the TCP and touch up the grid precisely.

The calibration grid can be installed on any surface. At this time, the X-Y plane of the calibration grid should be matched with the X-Y plane of the world frame of the robot unless special situations prevent these planes from matching. When these planes match, calibration can be performed more easily than when these planes do not match.

It can be removed after the completion of calibration, but it is strongly recommended that the grid be left installed in the system. This is because if a displacement should occur in calibration for the 3D Laser Vision Sensor due to a factor such as impact, recovery work can be simplified greatly. If the calibration grid must be removed, its installation position should be able to be restored exactly, which can reduce the labor for recovery. For the detailed setup procedure, please refer to “8.1 AUTOMATIC RE-CALIBRATION”.



4.1.3 Setting the TCP of the Robot

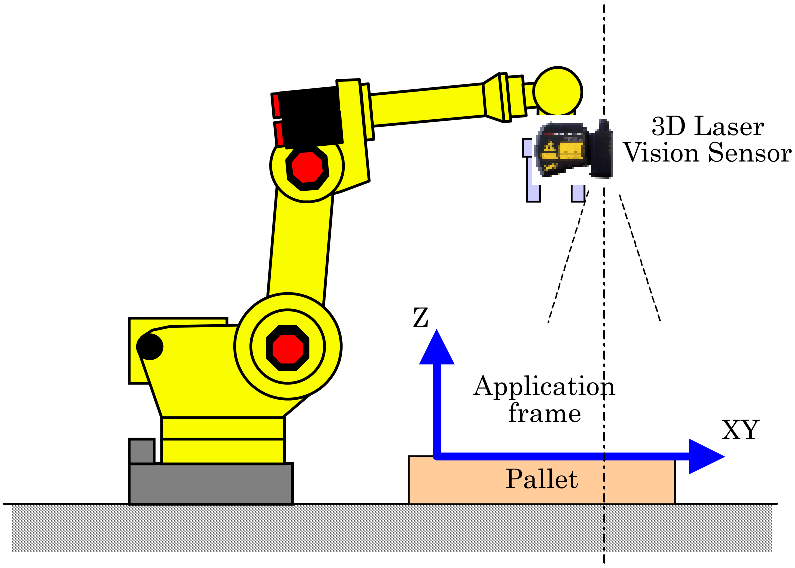
Set the TCP precisely on the tip of the pointer mounted on the end of arm tooling. Set the TCP in a tool frame with an arbitrary number. To set the tool frame, use [Tool Frame Setup / Three Point].

To reuse a TCP set at re-calibration, the reproducibility of the pointer mounting is required. If the reproducibility of the pointer mounting is not assured, a TCP needs to be set each time the pointer is mounted.

4.1.4 Setting an Application Frame

Set a user frame to be used as the reference for the robot compensation operation. The measurement result is output as values in the user frame that has been set.

Set a user frame for a plane such as a pallet using the set robot TCP. For this setting, use [User Frame Setup / Three Point] unless there is specific reason.



Sharing User Frame

When two or more robots work together, it is necessary to configure the system so that these robots share physically the same user frame. This is called the sharing of the user frame. Specifically, the sharing of the user frame is needed in the following cases:

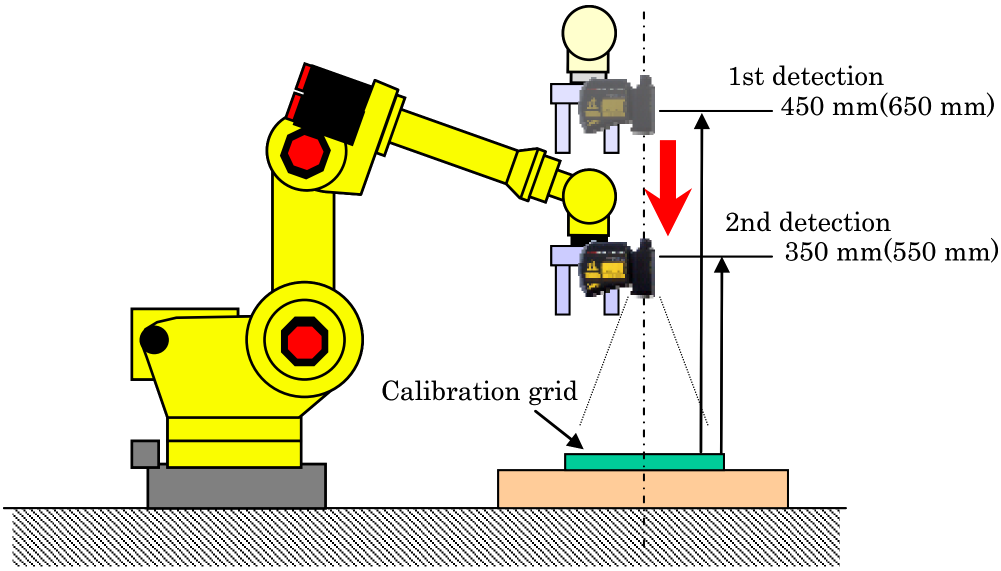
- Multiple robots are offset with a single set of offset data.
- The robot to be offset is different from the robot that has the camera.

User frame sharing requires that all robots use the same user frame number. For example, user frame 5 of robot 1 needs to be physically the same as user frame 5 of robot 2.

⚠ **CAUTION**
If robots share user frames of different numbers, *i*RVision cannot offset the robots correctly. Make sure that the robots share the same user frame number.

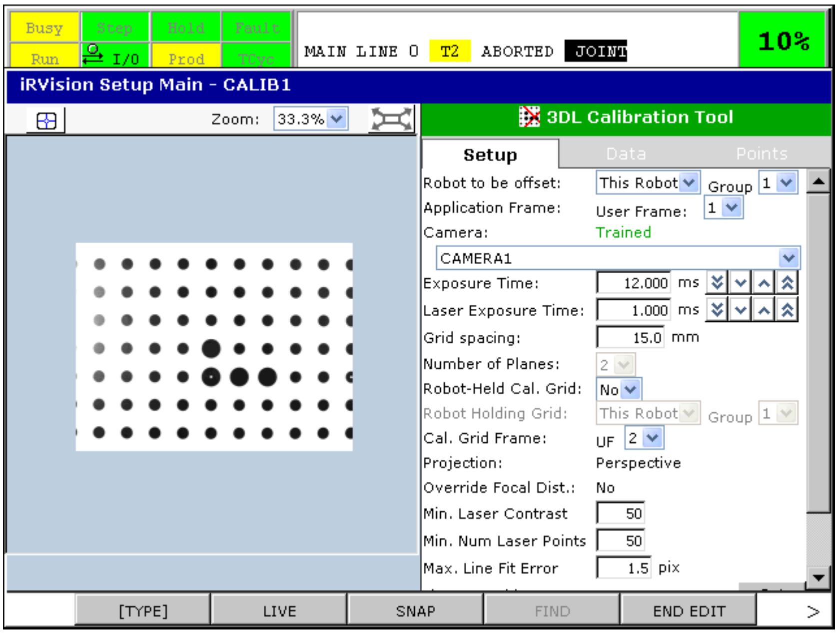
4.1.5 Creating and Teaching Camera Calibration Tool

To use the 3D Laser Vision Sensor, 3DL calibration using a calibration grid is required. For a robot-mounted camera, perform 2-plane calibration by moving the robot end of arm tooling up and down as shown in the figure below. For calibration, the appropriate distances between the 3D Laser Vision Sensor and calibration grid are near 350mm and 450mm (near 550mm and 650mm if the standoff of the 3D laser sensor is 600mm). When the calibration grid is detected with the robot and is made to have the same posture as it does when the workpiece is detected, the precision is increased.



After one set of calibration tool is created with 3DL vision calibration, another set of calibration tool does not need to be created even after the camera Measurement Position is changed. This is because *i*RVision uses the current robot position when calculating the position of the workpiece.

The teach screen for 3DL calibration is shown below. A calibration grid image is displayed.



Select the number of the “user frame” set as the “application frame” in [User Frame].

Enter [Exposure Time] to be applied for grid detection.

Enter [Laser Exposure Time] to be applied for laser measurement.

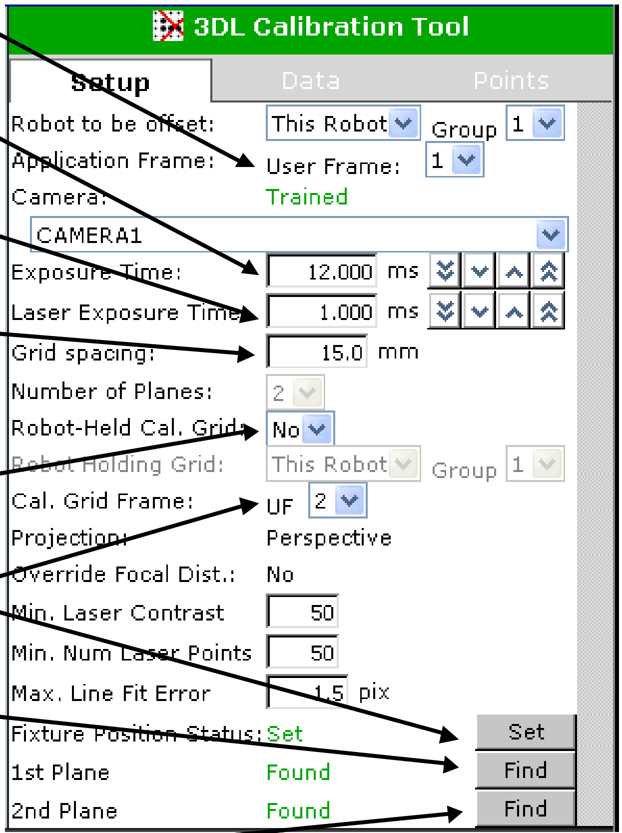
Enter [Grid Spacing] between grid points on the calibration grid.

Select [No] if the calibration grid is a fixed position.

Select the number of the “user frame” in which “calibration grid frame” is set in [User Frame], then click the [Set] button.

Move the camera from the calibration grid by a proper distance, then click the [Find] button for [1st Plane].

Change the distance between the camera and calibration grid, then click the [Find] button for [2nd Plane].

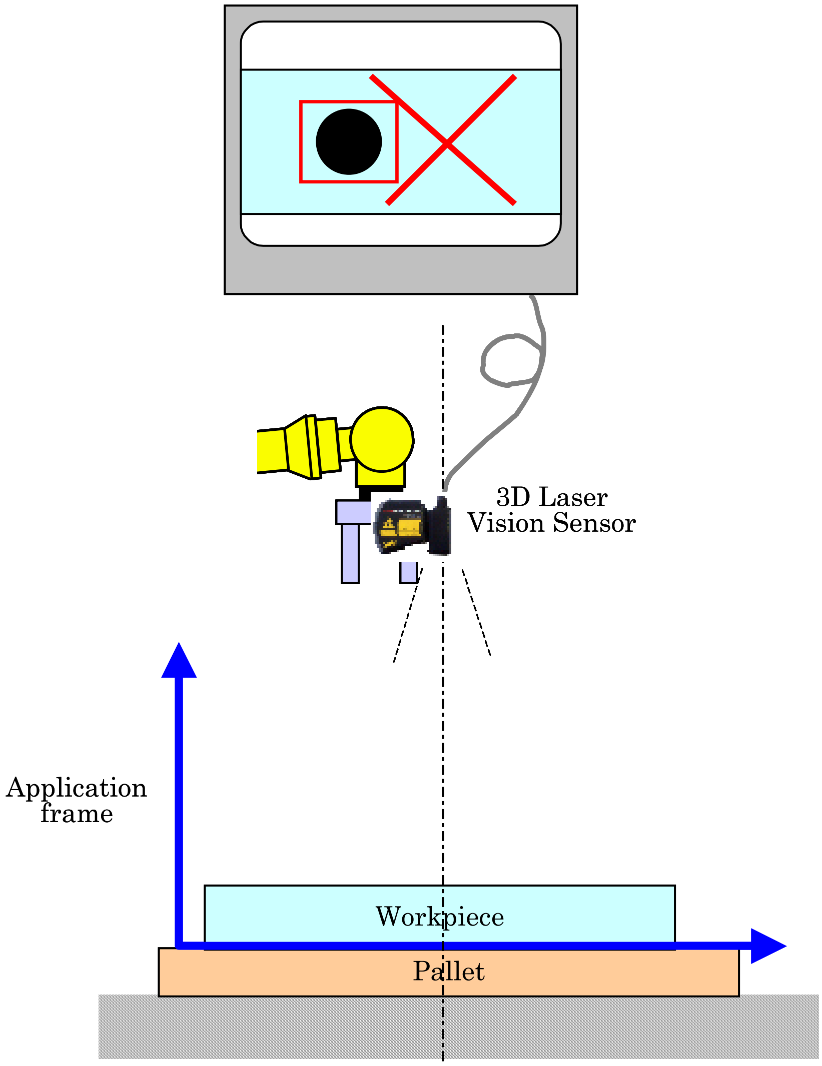


⚠ CAUTION

1. During calibration, the camera position of the 3D Laser Vision Sensor relative to the user frame (whose number is selected in [Application Frame]) is stored. This information is used for actual measurement. After calibration, do not change the number or the content of the application frame. If you change them, recalibrate the sensor. Then teach the reference positions of the vision processes which use the camera calibration tool.
2. When recalibrating a camera, if you change the position of the calibration grid, set the user frame of the calibration grid frame again. Then click the [Set] button for the calibration grid frame and recalculate it.

4.1.6 Creating and Teaching a Vision Process

Create a vision process for the “3DL Single-View Vision Process”. For fixed frame offset, first place the workpiece to be picked up at the reference position to teach the reference position. If a reproducible position is set as the reference position, detection models can be added or changed easily.



Use the following procedure to teach a vision process for the 3DL Single-View Vision Process.

1. Specify calibration tool and set parameters.

⇩

2. Move the robot to the measurement position and teach the GPM Locator Tool.

⇩

3. Then, teach the 3DL Plane Command Tool.

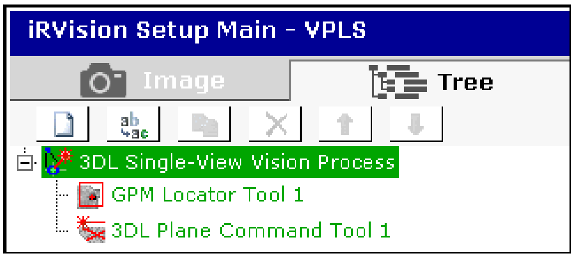
⇩

4. Select [3DL Single-View Vision Process], which is the top of the tree view and press F3[SNAP] and F4[FIND] to detect taught model.

⇩

5. Set the reference position.

Teaching the vision process

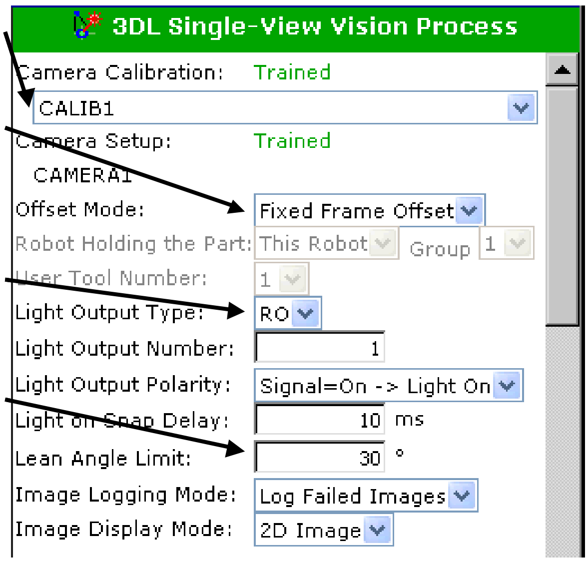


Select “calibration tool" of the camera.

Select [Fixed Frame Offset].

Select [Light Output Signal Type].

Enter the maximum tilt angle of the detection result to the reference position in [Lean Angle Limit].



Select [Exposure Mode] for 2D measurement. (Fixed)

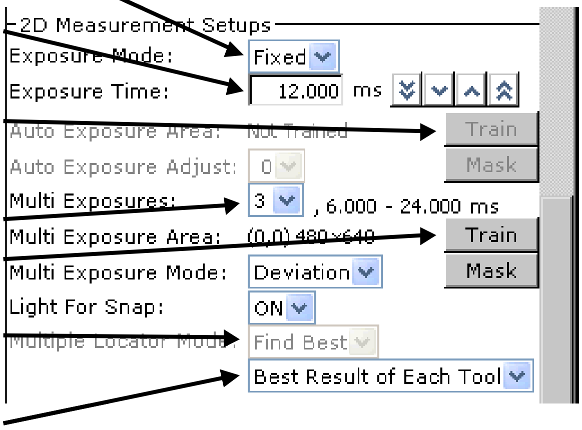
Enter [Exposure Time] to be applied for 2D measurement.

To use "automatic exposure" for 2D measurement, teach the "measurement area" and "mask".

To use "multi exposure" for 2D measurement, select the number of images to be combined and teach the "measurement area" and "mask".

Select which locator tools to execute in the case that multiple locator tools have been made.

Select which results of each locator tool to use in the case that the tool has multiple results.

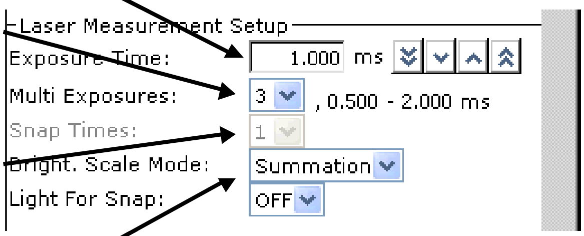


Enter [Exposure Time] to be applied for laser measurement.

Select the number of images to be combined for "multi exposure" for laser measurement in [Multi Exposures].

To snap multiple images during one exposure time for laser measurement, select a number in [Snap Times].

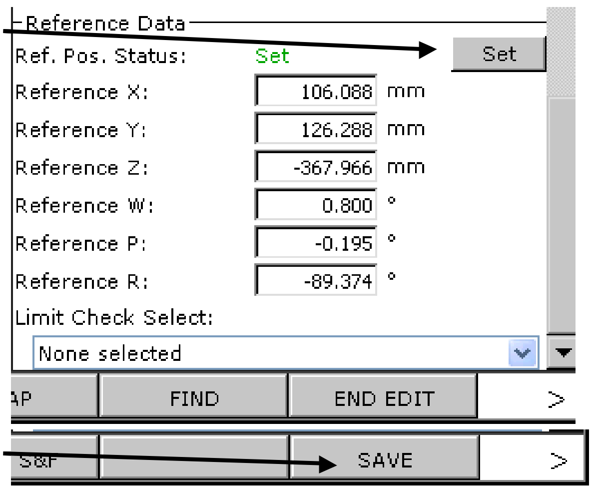
Select [Brightness Scaling Mode] when the value in [Multi Exposures] or [Snap Times] for laser measurement is 2 or greater.



Then, teach the GPM Locator Tool and 3DL Plane Command Tool. For details of the teaching procedure, please refer to Chapter 3 "TEACHING EXAMPLE". After teaching all command tools (GPM Locator Tool and 3DL Plane Command Tool), press F3[SNAP] and F4[FIND] of the vision process to detect the workpiece. When the workpiece is detected correctly, set the reference position.

Immediately after measuring the workpiece by pressing F3[SNAP] and F4[FIND], click the [Set Ref. Pos.] button.

Press F10[SAVE] to save modifications.



4.1.7 Creating and Teaching a Robot Program

In the sample program below, a vision process for the 3DL Single-View Vision Process named “VPLS” is used. The sample program can be used to take out, for example, overlapping metal plates one by one sequentially. The robot compensates the pickup operation according to the measurement result, and picks up a workpiece exactly as taught. After supplying the workpiece to the next process, the robot tries to detect another workpiece.

```
 1:  UFRAME_NUM=1
 2:  UTOOL_NUM=1
 3:J P [1:Home] 30% FINE
 4:
 5:  !Measurement
 6:  LBL [10]
 7:J P [2:Measurement Pos] 100% FINE
 8:  WAIT     .30(sec)
 9:  VISION RUN_FIND 'VPLS'
10:  VISION GET_OFFSET 'VPLS' VR[1] JMP LBL[999]
11:
12:  !Grasp
13:L P[3:Approach] 800mm/sec CNT100 VOFFSET,VR[1]
14:L P[4:Grasp] 200mm/sec FINE VOFFSET,VR[1]
15:L P[5:Retract] 800mm/sec CNT100 VOFFSET,VR[1]
16:
17:  !Place
18:L P[6:Approach] 800mm/sec CNT100
19:L P[7:Place] 200mm/sec FINE
20:L P[8:Retruct] 800mm/sec CNT100
21:  JMP LBL[10]
22:
23:  !No workpiece is detected
24:  LBL [999]
25:  ***
```

- Lines 1–2: Set the same value as the number of the application frame.
- Line 8: Wait for robot-vibration to reduce.
- Line 9: Execute measurement.
- Line 10: Get compensation data of the measurement result.
- Line 14: Compensate pickup operation.
- Line 19: Execute placement operation.
- Line 25: Add exception processing when no workpiece is detected.

> **NOTE**
> Measurement is performed after the robot reaches the taught position on the last motion. If the robot is still vibrating, it may affect the accuracy of the measurement. In such cases, please use 'WAIT' or 'acceleration override' to minimize the vibration.

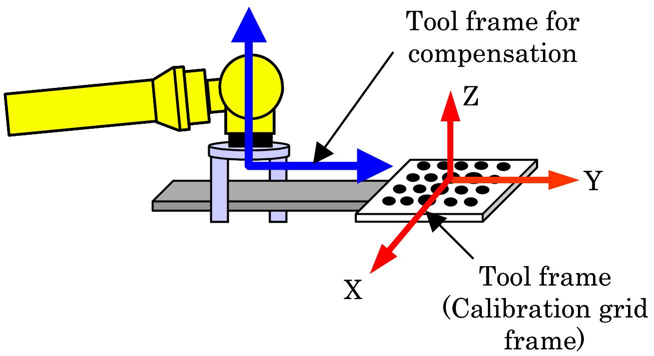
4.1.8 Checking Robot Compensation Operation

Make the robot handle workpieces one by one sequentially and check that it can handle the workpieces exactly. At first, decrease the override of the robot to check that the logic of the program is correct. Next, increase the override and execute the program again to check its operation.

4.2 SETUP FOR “FIXED SENSOR + TOOL OFFSET”

With tool offset, the camera measures how much a workpiece gripped by the robot deviates from the correct grip position. This feature performs compensation so that the robot places the gripped workpiece exactly at the predetermined position.

Setup for “fixed sensor + tool offset” includes setting “calibration grid frame” and “tool frame for compensation” in a tool frame with an arbitrary number. “Calibration grid frame” can be set easily and correctly with the setting using the camera of the 3D Laser Vision Sensor (grid frame setting function).



Use the following setup procedure for “fixed sensor + tool offset”.

1. Create and teach camera setup tool.

⇩

2. Set the calibration grid frame in a tool frame with an arbitrary number.
   - Use the vision grid pattern setting for this setting.

⇩

3. Set an application frame as required.
   - Set the application frame. The world frame may be used. In this case, setting is not required.

⇩

4. Create and teach the camera calibration tool

⇩

5. Set the tool frame for compensation in tool frame with an arbitrary number.

⇩

6. Create and teach the vision process.

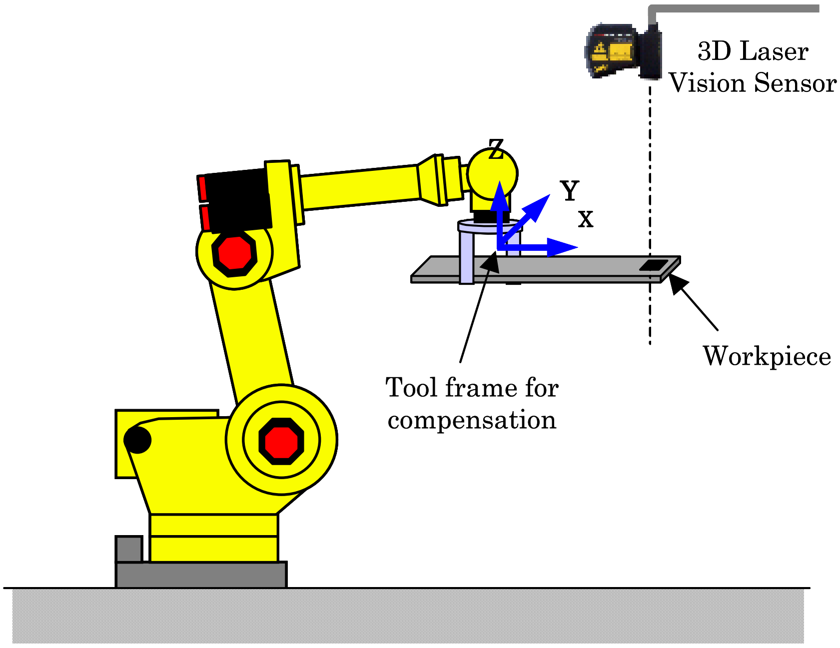
⇩

7. Create and teach the robot program.

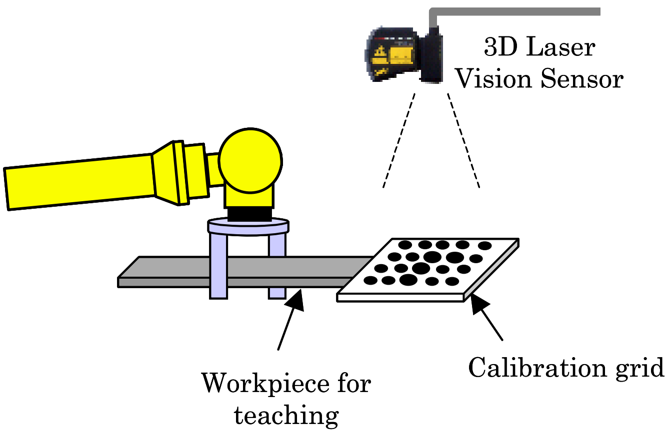
⇩

8. Check the robot compensation operation.

An example of layout for “fixed sensor + tool offset” is given below. A workpiece gripped by the robot is viewed by the fixed sensor to measure the amount of tool offset.

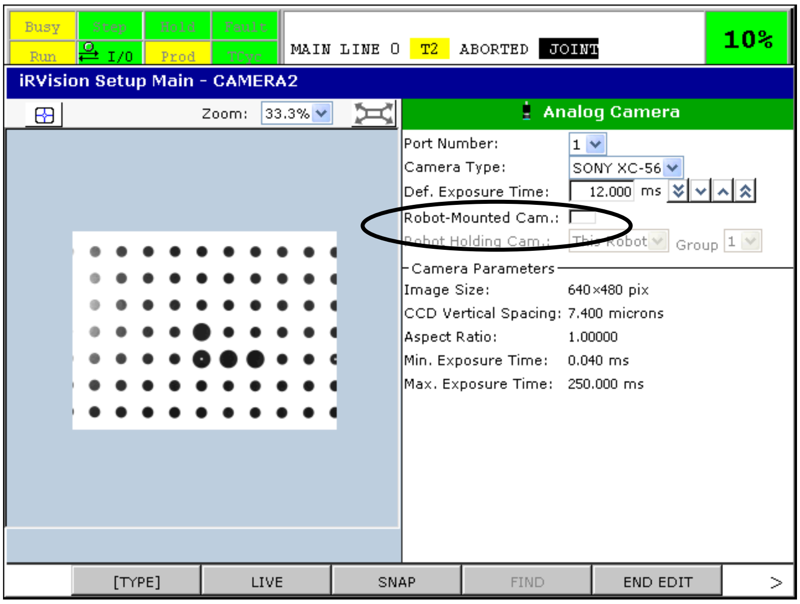


It is recommended that a calibration grid be mounted on the robot end of arm tooling or a teaching workpiece to perform calibration. The figure below shows an example of mounting a calibration grid at a workpiece Measurement Position. Prepare a teaching workpiece that resembles an actual workpiece and that can be gripped. Setup work can be simplified by mounting a calibration grid on the teaching workpiece. In either case, the mounting position should be able to be restored exactly. This is because if a displacement should occur in calibration due to a factor such as impact on the 3D Laser Vision Sensor, recovery work can be simplified greatly.



4.2.1 Creating and Teaching Camera Setup Tool

With *i*RVision, items such as a camera type are set in camera setup tool. If you want to use the 3D Laser Vision Sensor as a fixed sensor, be sure to uncheck the [Robot-Mounted Camera] check box.

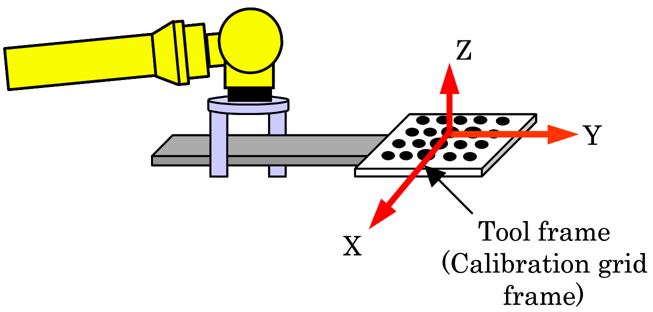


4.2.2 Setting Calibration Grid Frame

When a calibration grid is mounted on the robot end of arm tooling, set the calibration grid frame in a tool frame with an arbitrary number. For this setting, use the grid frame setting function. After securing the calibration grid, execute the grid frame setting function. For details of the grid frame setting function, please refer to "10.2 GRID FRAME SETTING" in "*i*RVision OPERATOR'S MANUAL (Reference)".

In addition to the method of using the grid frame setting function, the following method is also available: Touch up the grid precisely with a pointer secured within the operation range of the robot, then set a tool frame as shown in the figure below. Please refer to "11.2.1 Setting Based on Touch-up" in "*i*RVision OPERATOR'S MANUAL (Reference)". In this case, the touch-up precision affects the compensation precision, and touch up the grid precisely.

It is strongly recommended that the installation position be able to be restored exactly. This is because if a displacement should occur in calibration due to a factor such as impact on the 3D Laser Vision Sensor, recovery work can be simplified greatly. For the detailed setup procedure, please refer to "8.1 AUTOMATIC RE-CALIBRATION".



4.2.3 Setting an Application Frame

With tool offset, the application frame is specified the robot's user frame to be used for camera calibration. Under normal conditions, specify the number “0” as the robot base frame (world). But when two or more robots work together, set the sharing user frame and specify the number of it.

Set a user frame for a plane such as a pallet using the set robot TCP. For this setting, use [User Frame Setup / Three Point] unless there is specific reason.

Sharing User Frame

When two or more robots work together, it is necessary to configure the system so that these robots share physically the same user frame. This is called the sharing of the user frame. Specifically, the sharing of the user frame is needed in the following cases:

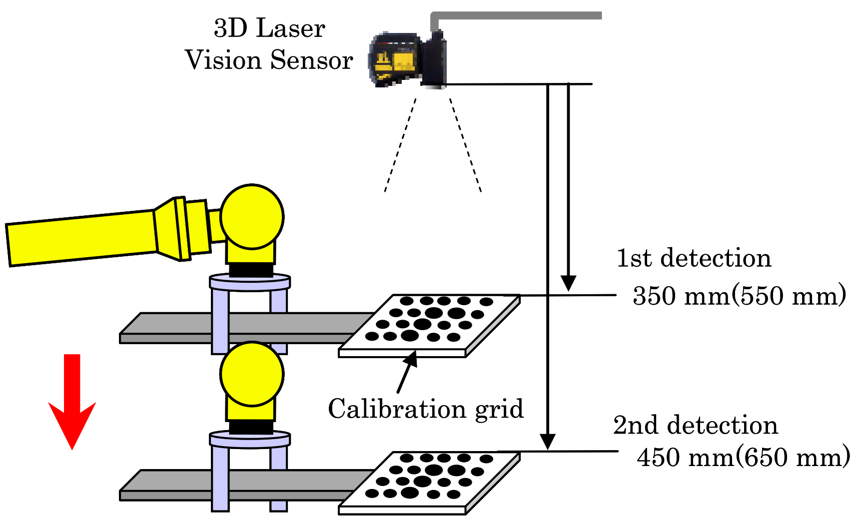
- Multiple robots are offset with a single set of offset data.
- The robot to be offset is different from the robot that has the camera.

User frame sharing requires that all robots use the same user frame number. For example, user frame 5 of robot 1 needs to be physically the same as user frame 5 of robot 2.

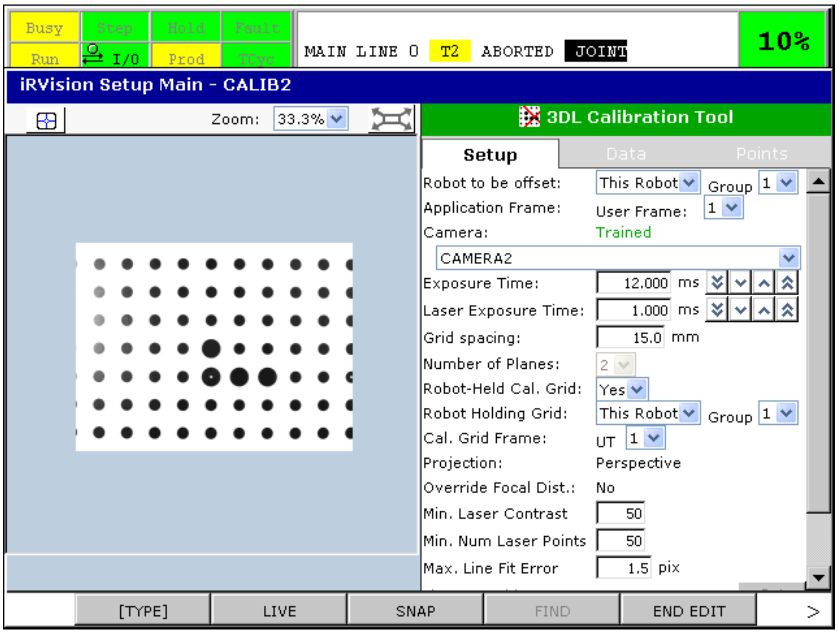
> ⚠ **CAUTION**
> If robots share user frames of different numbers, *i*RVision cannot offset the robots correctly. Make sure that the robots share the same user frame number.

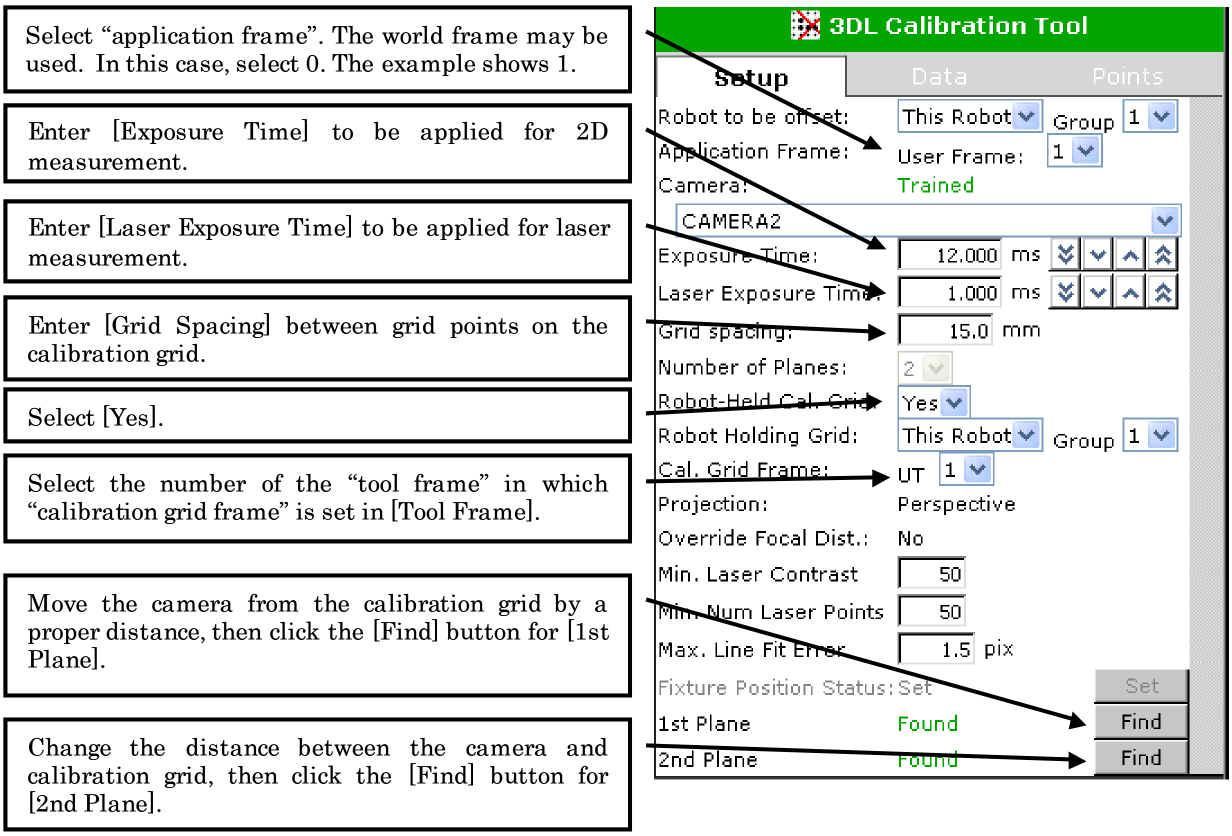
4.2.4 Creating and Teaching Camera Calibration Tool

To use the 3D Laser Vision Sensor, 3DL calibration using a calibration grid is required. For a fixed sensor, perform 2-plane calibration by moving the robot end of arm tooling up and down as shown in the figure below. For calibration, the appropriate distances between the 3D Laser Vision Sensor and calibration grid are near 350mm and 450mm (near 550mm and 650mm if the standoff of the 3D laser sensor is 600mm). When the calibration grid is detected with the robot and is made to have the same posture as it does when the workpiece is detected, the precision is increased.



The teach screen for the 3DL calibration is shown below. A calibration grid image is displayed.

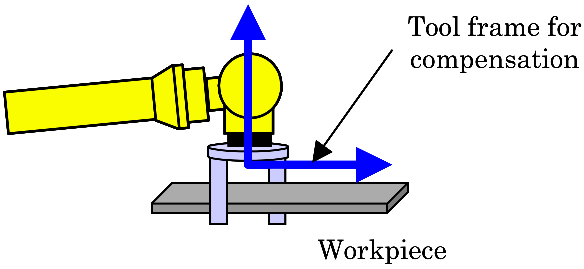




> ⚠ **CAUTION**
> During calibration, how the camera of the 3D Laser Vision Sensor is positioned relative to the user frame (whose number is selected in [Application Frame]) is stored. This information is used for actual measurement. After calibration, do not change the number or the content of the application frame. If you change them, recalibrate the sensor. Then teach the reference positions of the vision processes which use the camera calibration tool.

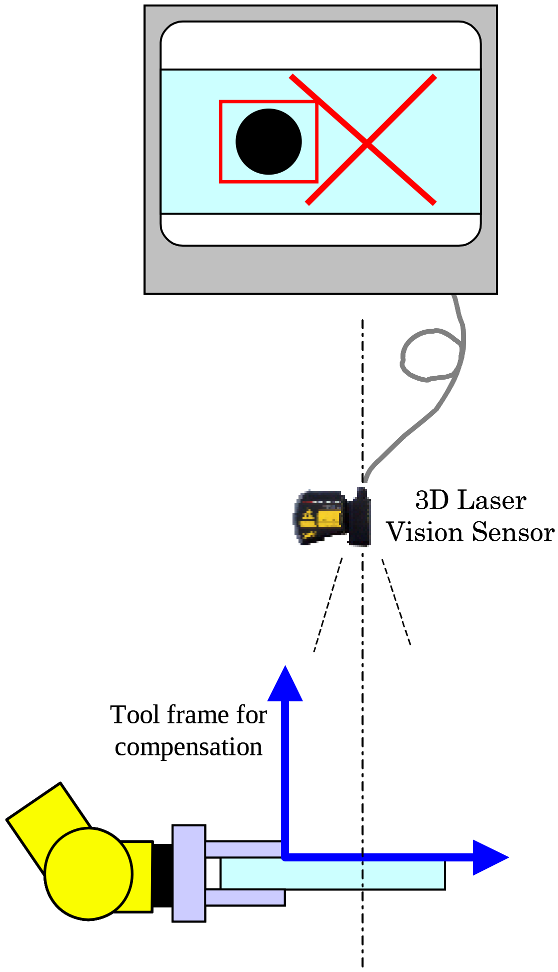
4.2.5 Setting a tool frame for compensation

Set a tool frame to be used as the reference of the tool offset compensation operation by the robot. Tool offset compensation data is output as values in the tool frame set here. To set the tool frame, use [Tool Frame Setup / Six Point].



4.2.6 Creating and Teaching a Vision Process

Create a vision process for the “3DL Single-View Vision Process”. For tool offset, first make the end of arm tooling hold the workpiece to be picked up to teach the reference position. If how the end of arm tooling holds the workpiece can be reproduced with precision, detection models can be added or changed easily.



Use the following procedure to teach a vision process for the 3DL Single-View Vision Process.

1. Set tool frame for compensation in tool frame with an arbitrary number.

2. Specify calibration tool and set parameters.

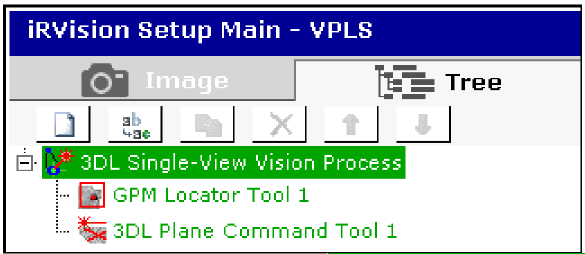
3. Move the robot to the measurement position and teach the GPM Locator Tool.

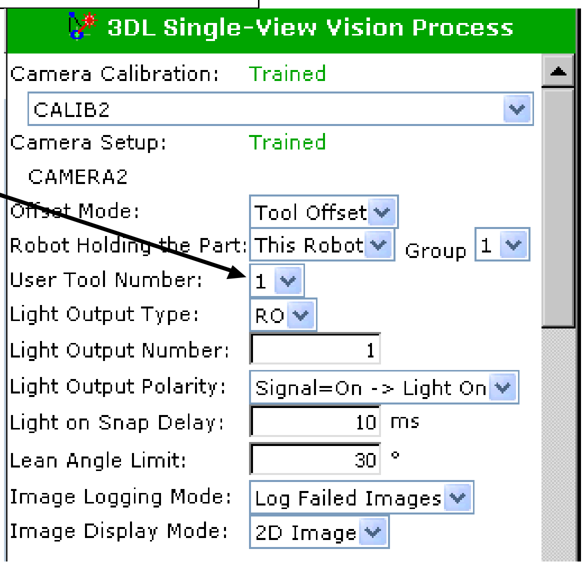
4. Then, teach the 3DL Plane Command Tool.

5. Select [3DL Single-View Vision Process], which is the top of the tree view, and press F3[SNAP] and F4[FIND] to detect the taught model.

6. Set the reference position.

Teaching the vision process





A tool frame different from one set in [Calibration Grid Frame] must be selected here. Select the tool frame for compensation such as the TCP of the end of arm tooling.

Select [Exposure Mode] for 2D measurement. (Fixed)

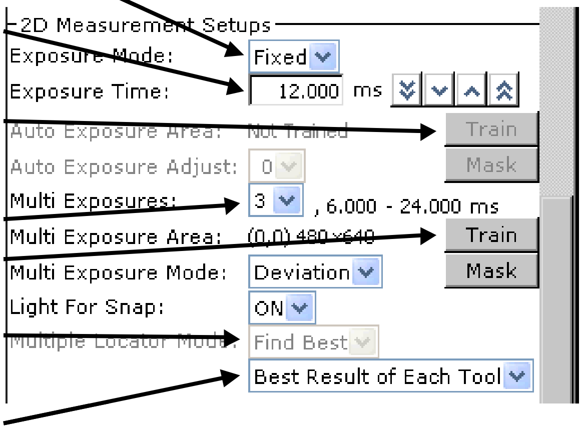
Enter [Exposure Time] to be applied for 2D measurement.

To use "automatic exposure" for 2D measurement, teach the "measurement area" and "mask".

To use "multi exposure" for 2D measurement, select the number of images to be combined and teach the "measurement area" and "mask".

Select which locator tools to execute in the case that multiple locator tools have been made.

Select which results of each locator tool to use in the case that the tool has multiple results.

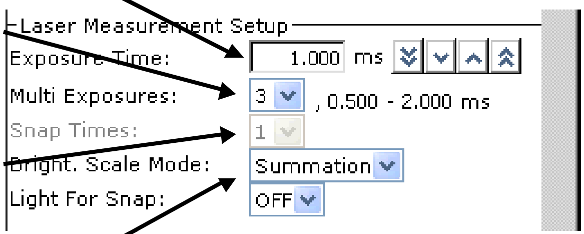


Enter [Exposure Time] to be applied for laser measurement.

Select the number of images to be combined for "multi exposure" for laser measurement in [Multi Exposures].

To snap multiple images during one exposure time for laser measurement, select a number in [Snap Times].

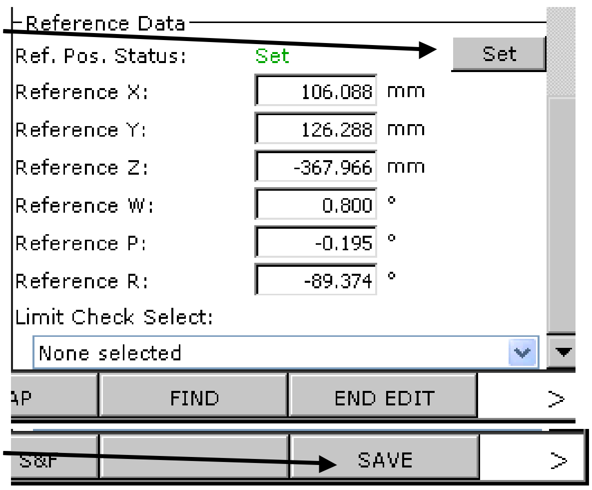
Select [Brightness Scaling Mode] when the value in [Multi Exposures] or [Snap Times] for laser measurement is 2 or greater.



Then, teach the GPM Locator Tool and 3DL Plane Command Tool. For details of the teaching procedure, please refer to Chapter 3 "TEACHING EXAMPLE". After teaching all command tools (GPM Locator Tool and 3DL Plane Command Tool), press F3[SNAP] and F4[FIND] of the vision process to detect the workpiece. When the workpiece is detected correctly, set the reference position.

Immediately after measuring the workpiece by pressing F3[SNAP] and F4[FIND], click the [Set Ref. Pos.] button.

Press F10[SAVE] to save modifications.



4.2.7 Creating and Teaching a Robot Program

In the sample program below, a vision process for the 3DL Single-View Vision Process named “VPLS” is used. The sample program can be used to take out, for example, an unmachined casting. The robot compensates the tool offset according to the measurement result. After supplying the workpiece to the machine, the robot tries to detect another workpiece.

```
 1:  UFRAME_NUM=1
 2:  UTOOL_NUM=1
 3:J P[1:Home] 30% FINE
 4:
 5:  !Grasp
 6:  LBL[10]
 7:L P[2:Approach] 800mm/sec CNT100
 8:L P[3:Grasp] 200mm/sec FINE
 9:L P[4:Retract] 800mm/sec CNT100
10:
11:  !Measurement
12:L P[5:Measurement Pos] 200mm/sec FINE
13:  WAIT    .30(sec)
14:  VISION RUN_FIND 'VPLS'
15:  VISION GET_OFFSET 'VPLS' VR[1] JMP LBL[999]
16:
17:  !Place
18:L P[6:Approach] 800mm/sec CNT100 VOFFSET, VR[1]
19:L P[7:Place] 200mm/sec FINE VOFFSET, VR[1]
20:L P[8:Retract] 800mm/sec CNT100 VOFFSET, VR[1]
21:  JMP LBL[10]
22:
23:  !No workpiece is detected
24:  LBL[999]
25:  ***
```

Specify the application frame number set in calibration data.

Set the same number as for the “tool frame for compensation” set in the vision process.

Wait for robot-vibration to reduce.

Execute measurement.

Get compensation data of the measurement result.

Execute placement operation, compensating the tool offset.

Add exception processing when no workpiece is detected.

> **NOTE**
> Measurement is performed after the robot reaches the taught position on the last motion. If the robot is still vibrating, it may affect the accuracy of the measurement. In such cases, please use 'WAIT' or 'acceleration override' to minimize the vibration.

4.2.8 Checking Robot Compensation Operation

Check that a workpiece gripped by the robot can be detected and positioned at a desired location exactly. At first, decrease the override of the robot to check that the logic of the program is correct. Next, increase the override and cycle the program again to check its operation.

5 3DL MULTI-VIEW VISION PROCESS

The 3DL Multi-View Vision Process measures multiple points of a workpiece for its 3D position and posture using the 3D Laser Vision Sensor, and provides compensation for robotic handling of the workpiece. This function is suitable to measure a large workpiece with precision.

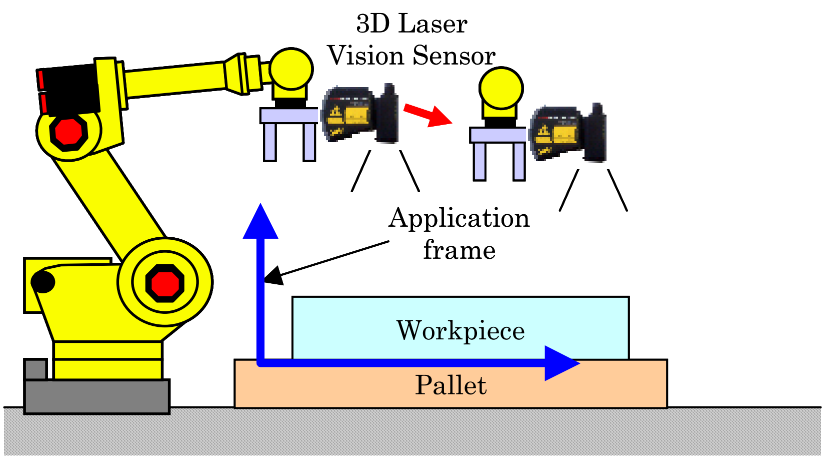
The 3DL Multi-View Vision Process has measurement features almost equivalent to the 3DL Single-View Vision Process when it measures each measurement point. Two to four measurement points can be specified.

This chapter describes the procedure to set up the 3DL Multi-View Vision Process using the following two application examples. For details of the setup procedures and teaching procedures, please refer to Chapter 3 “TEACHING EXAMPLE”.

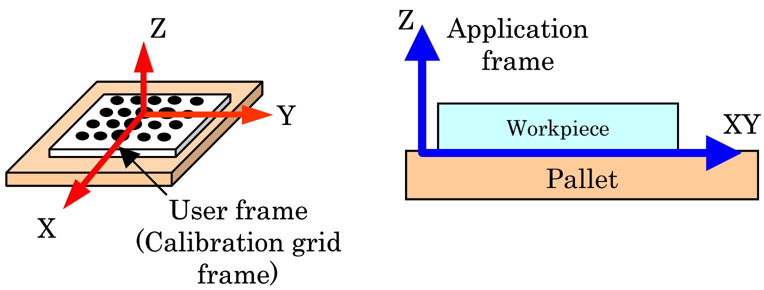
(1) Robot-mounted camera + fixed frame offset
(2) Fixed sensor + tool offset

5.1 SETUP FOR “ROBOT-MOUNTED CAMERA + FIXED FRAME OFFSET”

An example of layout for “robot-mounted camera + fixed frame offset” is given below.



Setup for “robot-mounted camera + fixed frame offset” includes setting “calibration grid frame” and “application frame” in a user frame with an arbitrary number. “Calibration grid frame” can be set easily and correctly with the setting using the camera of the 3D Laser Vision Sensor (grid frame setting function).

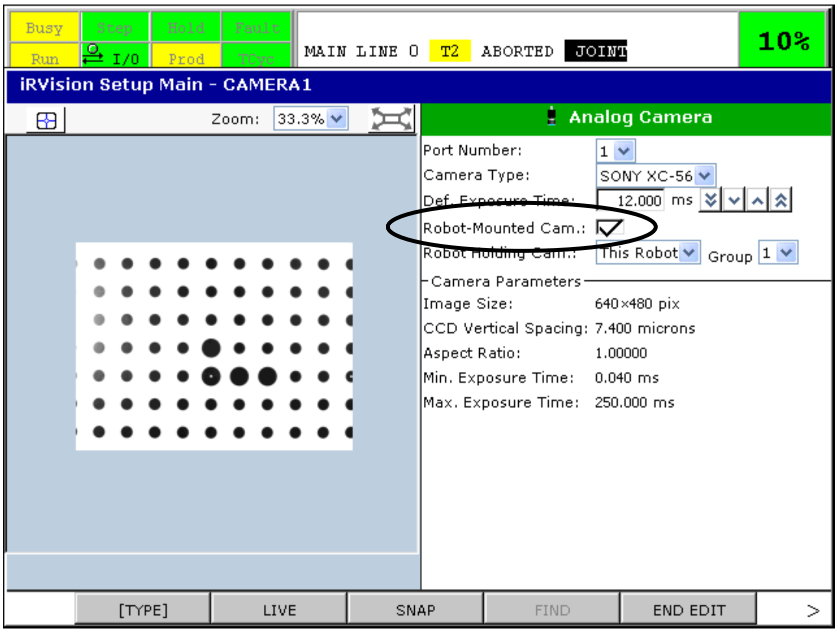


Use the following setup procedure for "robot-mounted camera + fixed frame offset".

1. Create and teach camera setup tool.
2. Set the calibration grid frame in the user frame with an arbitrary number. (Use the vision grid pattern setting for this setting.)
3. Set the TCP at the tip of touch-up pin mounted on the end of arm tooling. (The TCP set here is used to set the "application frame".)
4. Set the application frame in a user frame with an arbitrary number.
5. Create and teach camera calibration tool.
6. Create and teach a vision process.
7. Create and teach a robot program
8. Check the robot compensation operation.

5.1.1 Creating and Teaching Camera Setup Tool

With *i*RVision, items such as camera type are set in camera setup tool. If you want to use the 3D Laser Vision Sensor as a robot-mounted camera, be sure to check the [Robot-Mounted Camera] check box.



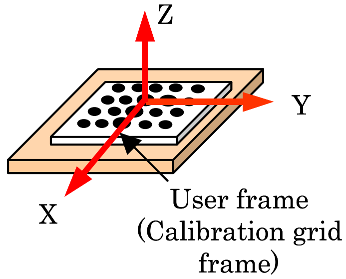
5.1.2 Setting Calibration Grid Frame

When a calibration grid is installed on a fixed place, set the calibration grid frame in a user frame with an arbitrary number. For this setting, use the grid frame setting function. After securing the calibration grid, execute the grid frame setting function. For details of the grid frame setting function, please refer to “10.2 GRID FRAME SETTING“ in “*i*RVision OPERATOR’S MANUAL (Reference)”. Note that the user frame for calibration grid frame differs from the “Application Frame” described in the following subsection.

In addition to the method of using the grid frame setting function, the following method is also available: Touch up the grid with a pointer mounted on the robot end of arm tooling precisely, then set a user frame as shown in the figure below. Please refer to “11.2.1 Setting Based on Touch-up” in “*i*RVision OPERATOR’S MANUAL (Reference)”. In this case, the operation described in the next subsection, “Setting the TCP of the Robot” must be performed in advance. The TCP setting precision and touch-up precision directly affect the compensation precision. Set the TCP and touch up the grid precisely.

The calibration grid can be installed on any surface. At this time, the X-Y plane of the calibration grid should be matched with the X-Y plane of the world frame of the robot unless the robot is installed at a tilt or any other special situations prevent these planes from matching. When these planes match, calibration can be performed more easily than when these planes do not match.

It can be removed after the completion of calibration, but it is strongly recommended that the grid be left installed in the system. This is because if a displacement should occur in calibration for the 3D Laser Vision Sensor due to a factor such as impact, recovery work can be simplified greatly. If the calibration grid must be removed, its installation position should be able to be restored exactly, which can reduce the labor for recovery. For the detailed setup procedure, please refer to “8.1 AUTOMATIC RE-CALIBRTION”.



5.1.3 Setting the TCP of the Robot

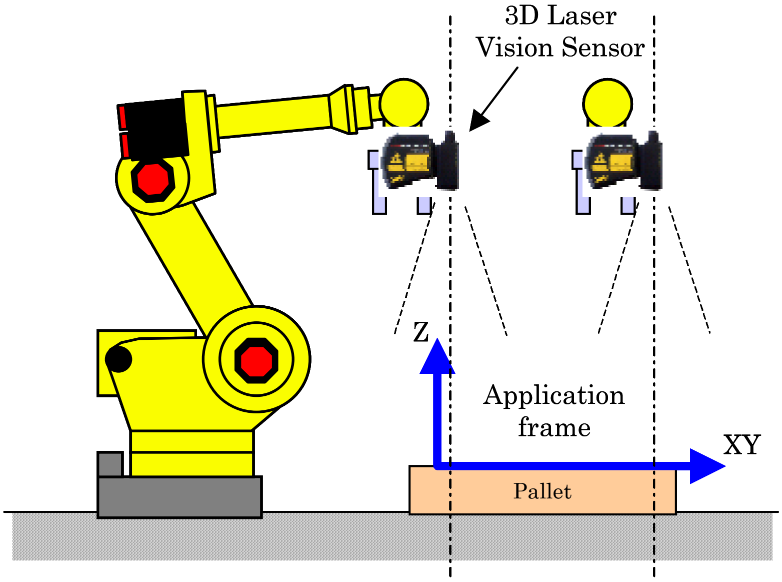
Set the TCP precisely on the tip of the pointer mounted on the end of arm tooling. Set the TCP in a tool frame with an arbitrary number. To set the tool frame, use [Tool Frame Setup / Three Point].

To reuse a TCP set at re-calibration, the reproducibility of the pointer mounting is required. If the reproducibility of the pointer mounting is not assured, a TCP needs to be set each time the pointer is mounted.

5.1.4 Setting an Application Frame

Set a user frame to be used as the reference for the robot compensation operation. The measurement result is output as values in the user frame that has been set.

Set a user frame for a plane such as a pallet using the set robot TCP. For this setting, use [User Frame Setup / Three Point] unless there is specific reason.



Sharing User Frame

When two or more robots work together, it is necessary to configure the system so that these robots share physically the same user frame. This is called the sharing of the user frame. Specifically, the sharing of the user frame is needed in the following cases:

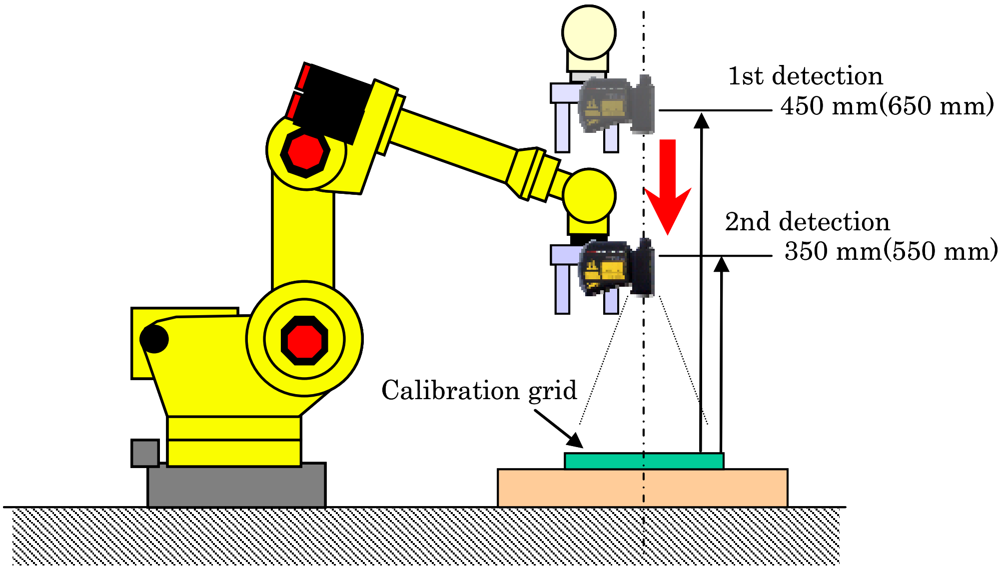
- Multiple robots are offset with a single set of offset data.
- The robot to be offset is different from the robot that has the camera.

User frame sharing requires that all robots use the same user frame number. For example, user frame 5 of robot 1 needs to be physically the same as user frame 5 of robot 2.

> ⚠ **CAUTION**
> If robots share user frames of different numbers, *i*RVision cannot offset the robots correctly. Make sure that the robots share the same user frame number.

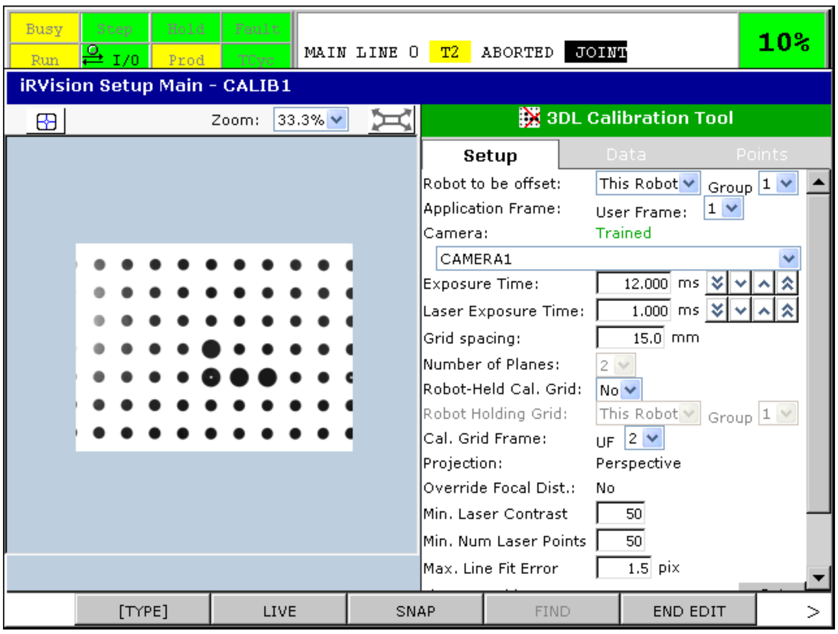
5.1.5 Creating and Teaching Camera Calibration Tool

To use the 3D Laser Vision Sensor, 3DL calibration using a calibration grid is required. For a robot-mounted camera, perform 2-plane calibration by moving the robot end of arm tooling up and down as shown in the figure below. For calibration, the appropriate distances between the 3D Laser Vision Sensor and calibration grid are near 350mm and 450mm (near 550mm and 650mm if the standoff of the 3D laser sensor is 600mm). When the calibration grid is detected with the robot and is made to have the same posture as it does when the workpiece is detected, the precision is increased.



After one set of calibration tool is created with 3DL vision calibration, another set of calibration tool does not need to be created even after the camera Measurement Position is changed. This is because *i*RVision considers the current robot position when calculating the position of the workpiece.

The teach screen for 3DL calibration is shown below. A calibration grid image is displayed.



Select the number of the “user frame” set as the “application frame” in [User Frame].

Enter [Exposure Time] to be applied for grid detection.

Enter [Laser Exposure Time] to be applied for laser measurement.

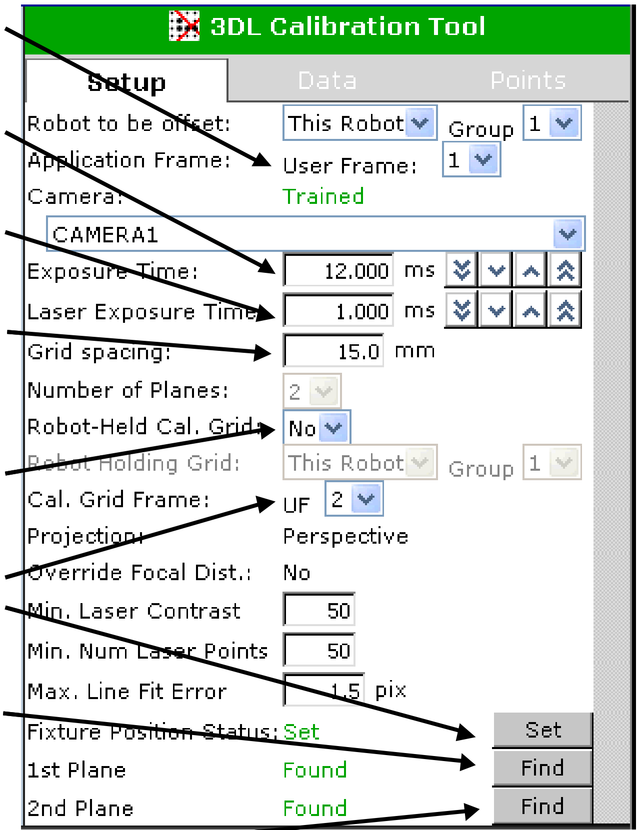
Enter [Grid Spacing] between grid points on the calibration grid.

Select [No] if the calibration grid is a fixed position.

Select the number of the “user frame” in which “calibration grid frame” is set in [User Frame], then click the [Set] button.

Move the camera from the calibration grid by a proper distance, then click the [Find] button for [1st Plane].

Change the distance between the camera and calibration grid, then click the [Find] button for [2nd Plane].



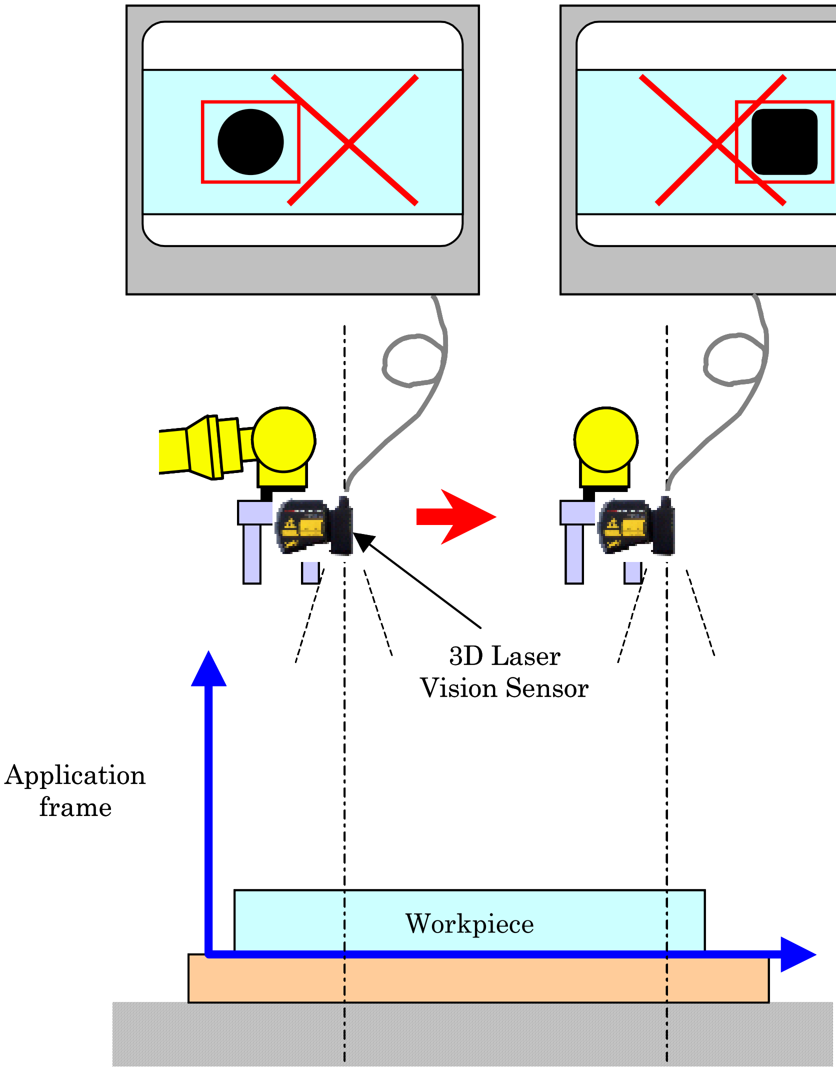
⚠ **CAUTION**

1 During calibration, how the camera of the 3D Laser Vision Sensor is positioned relative to the user frame (whose number is selected in [Application Frame]) is stored. This information is used for actual measurement. After calibration, do not change the number or the content of the application frame. If you change them, recalibrate the sensor. Then teach the reference positions of the vision processes which use the camera calibration tool.

2 When recalibrating a camera, if you change the position of the calibration grid, set the user frame of the calibration grid frame again. Then click the [Set] button for the calibration grid frame and recalculate it.

5.1.6 Creating and Teaching a Vision Process

Create a vision process for the “3DL Multi-View Vision Process”. For fixed frame offset, place the workpiece to be picked up at the reference position in order to teach the reference position. If a reproducible position is set as the reference position, detection models can be added or changed easily.



Use the following procedure to teach a vision process for the 3DL Multi-View Vision Process.

1. Select one camera view, specify calibration tool, and set parameters.

⇩

2. Move the robot to the measurement position and teach the GPM Locator Tool.

⇩

3. Then, teach the 3DL Plane Command Tool.

⇩

4. Return to the camera view, and press F3[SNAP] and F4[FIND] to detect the taught model.

⇩

5. Perform steps 1 to 4 for all camera views

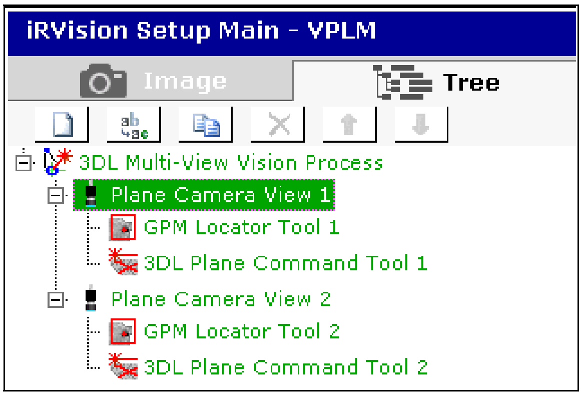
⇩

6. Select the [3DL Multi-View Vision Process] and set parameters.

⇩

7. Set the reference position.

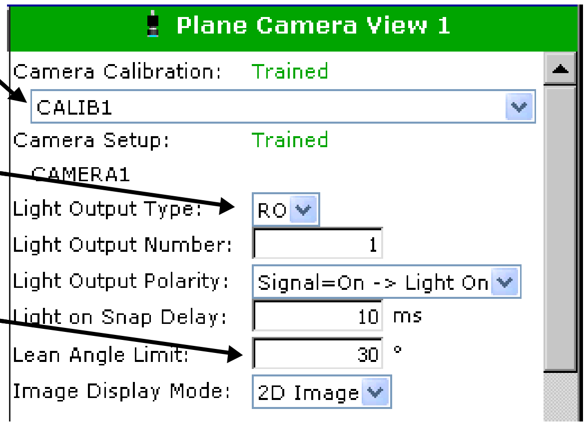
Teaching the camera view



Select “calibration tool" of the camera.

Select [Light Output Signal Type].

Enter the maximum tilt angle of the detection result to the reference position in [Lean Angle Limit].



Select [Exposure Mode] for 2D measurement.

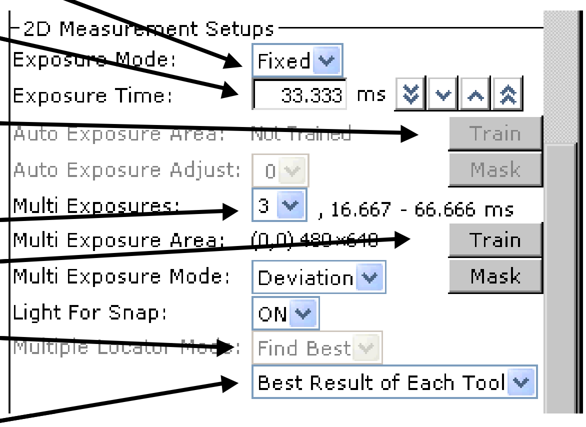
Enter [Exposure Time] to be applied for 2D measurement.

To use "automatic exposure” for 2D measurement, teach the “measurement area” and “mask”.

To use “multi exposure” for 2D measurement, select the number of images to be combined and teach the “measurement area” and "mask”.

Select which locator tools to execute in the case that multiple locator tools have been made.

Select which results of each locator tool to use in the case that the tool has multiple results.

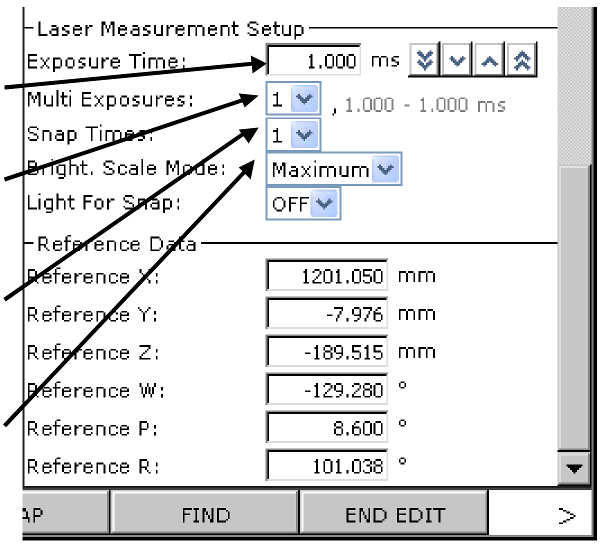


Enter [Exposure Time] to be applied for laser measurement.

Select the number of images to be combined for “multi exposure” for laser measurement in [Multi Exposures].

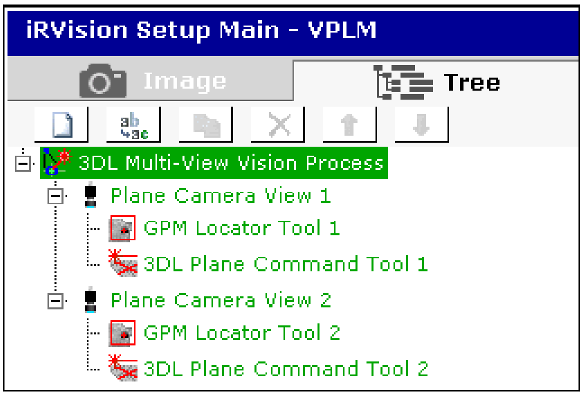
To snap multiple images during one exposure time for laser measurement, select a number in [Snap Times].

Select [Brightness Scaling Mode] when the value in [Multi Exposures] or [Snap Times] for laser measurement is 2 or greater.



Then, teach the GPM Locator Tool and 3DL Plane Command Tool. For details of the teaching procedure, please refer to Chapter 3 “TEACHING EXAMPLE”. After teaching all command tools (GPM Locator Tool and 3DL Plane Command Tool), press F3[SNAP] and F4[FIND] of the vision process to detect the workpiece.

Teaching the vision process

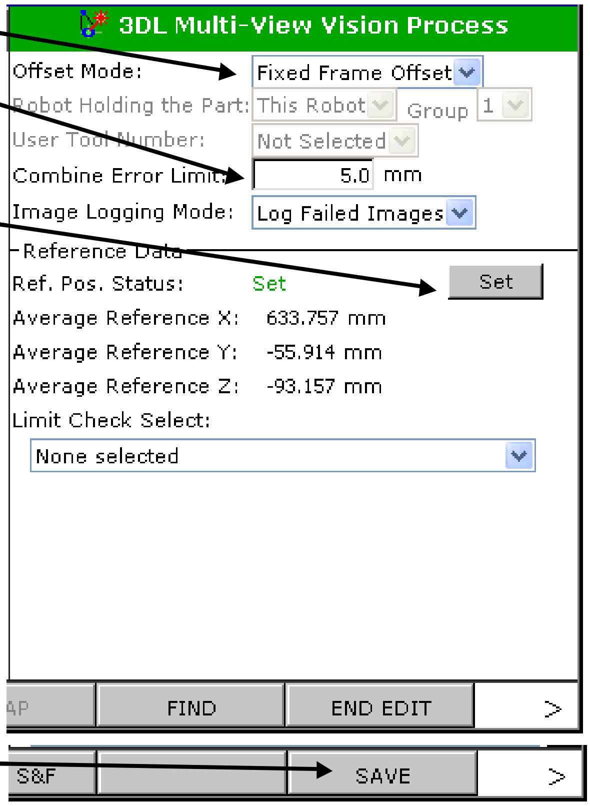


Select [Fixed Frame Offset].

Enter the limit of the combined deviation from the reference position in the measurement result of each camera view in [Combine Error Limit].

After pressing F3[SNAP] and F4[FIND] in each camera view to detect the workpiece, click the [Set Ref. Pos.] button. This operation sets the reference position for all camera views at a time.

Press F10[SAVE] to save modifications.



5.1.7 Creating and Teaching a Robot Program

In the sample program below, a vision process for the 3DL Multi-View Vision Process named “VPLM” is used. The sample program can be used to take out, for example, overlapping metal plates one by one sequentially. The robot compensates the pickup operation according to the measurement result and picks up a workpiece exactly as taught. After supplying the workpiece to the next process, the robot tries to detect another workpiece. In this program, R [11] is used to get the number of workpieces detected in each view (that is, check the detection result).

```
 1:  UFRAME_NUM=1
 2:  UTOOL_NUM=1
 3:J P[1:Home] 30% FINE
 4:
 5:  !Measurement
 6:  LBL[10]
 7:L P[2:Measurement Pos 1] 800mm/sec FINE
 8:  WAIT     .30(sec)
 9:  VISION RUN_FIND 'VPLM' CAMERA_VIEW [1]
10:  VISION GET_NFOUND 'VPLM' R[11] CAMERA_VIEW[1]
11:  IF R[11] < 1, JMP LBL[997]
12:L P[3:Measurement Pos 2] 800mm/sec FINE
13:  WAINT     .30(sec)
14:  VISION RUN_FIND 'VPLM' CAMERA_VIEW [2]
15:  VISION GET_NFOUND 'VPLM' R[11] CAMERA_VIEW[2]
16:  IF R[11] < 1, JMP LBL[998]
17:  VISION GET_OFFSET 'VPLM' VR[1] JMP LBL[999]
18:
19:  !Grasp
20:L P[4:Approach] 800mm/sec CNT100 VOFFSET,VR[1]
21:L P[5:Grasp] 200mm/sec FINE VOFFSET,VR[1]
22:L P[6:Retract] 800mm/sec CNT100 VOFFSET,VR[1]
23:
24:  !Place
25:L P[7:Approach] 800mm/sec CNT100
26:L P[8:Place] 200mm/sec FINE
27:L P[9:Retract] 800mm/sec CNT100
28:  JMP LBL[10]
29:
30:  ! No target is detected in camera view1
31:  LBL[997] ;
32:  *
33:  ! No target is detected in camera view2
34:  LBL[998] ;
35:  *
36:  ! Fail to get offset data
37:  LBL[999]
38:  *
```

- Set the same value as the number of the user frame for compensation.
- Wait for robot-vibration to reduce.
- Execute measurement for camera view 1.
- Check the detection result of camera view 1.
- Wait for robot-vibration to reduce.
- Execute measurement for camera view 2.
- Check the detection result of camera view 2.
- Get compensation data of the measurement result.
- Compensate pickup operation.
- Execute placement operation.
- Add exception processing when no workpiece is detected in camera view 1.
- Add exception processing when no workpiece is detected in camera view 2.
- Add exception processing when compensation data fails to be obtained.

> **NOTE**
> Measurement is performed after the robot reaches the taught position on the last motion. If there is vibration in the robot left, it might cause a negative effect on the accuracy of the measurement. In such cases, please use 'WAIT' or 'acceleration override' to minimize the vibration.

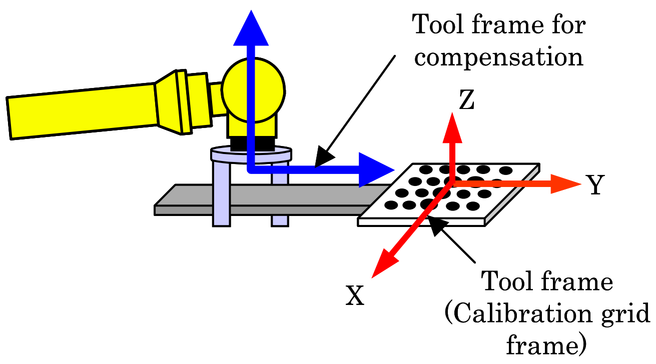
5.1.8 Checking Robot Compensation Operation

Make the robot handle workpieces one by one sequentially and check that it can handle the workpieces exactly. At first, decrease the override of the robot to check that the logic of the program is correct. Next, increase the override and cycle the program again to check its operation.

5.2 SETUP FOR “FIXED SENSOR + TOOL OFFSET”

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

Setup for “fixed sensor + tool offset” includes setting “calibration grid frame” and “tool frame for compensation” in a tool frame with an arbitrary number. “Calibration grid frame” can be set easily and correctly by using the camera of the 3D Laser Vision Sensor (grid frame setting function).



Use the following setup procedure for “fixed sensor + tool offset”.

1. Create and teach camera setup tool.

⇩

2. Set calibration plate installation information in a tool frame with an arbitrary number.

   Use the vision grid pattern setting for this setting.

⇩

3. Set the user frame as required.

   Set the application frame. The world frame may be used. In this case, setting is not required.

⇩

4. Create and teach camera calibration tool.

⇩

5. Set the tool frame for compensation in tool frame with an arbitrary number.

⇩

6. Create a teach vision process.

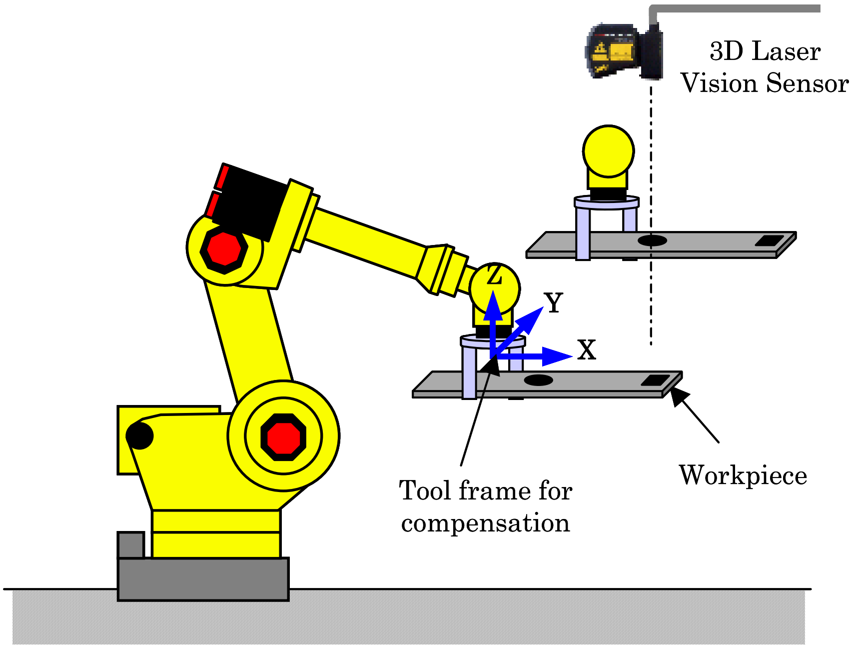
⇩

7. Create and teach a robot program.

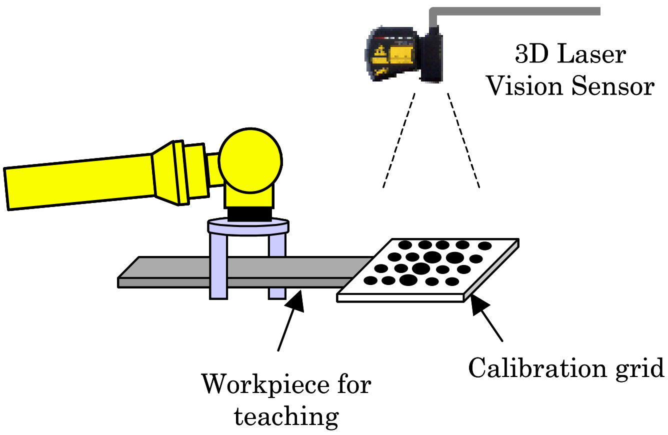
⇩

8. Check the robot compensation operation.

An example layout for “fixed sensor + tool offset” is given below. A workpiece gripped by the robot is viewed by the fixed sensor to measure the amount of tool offset.

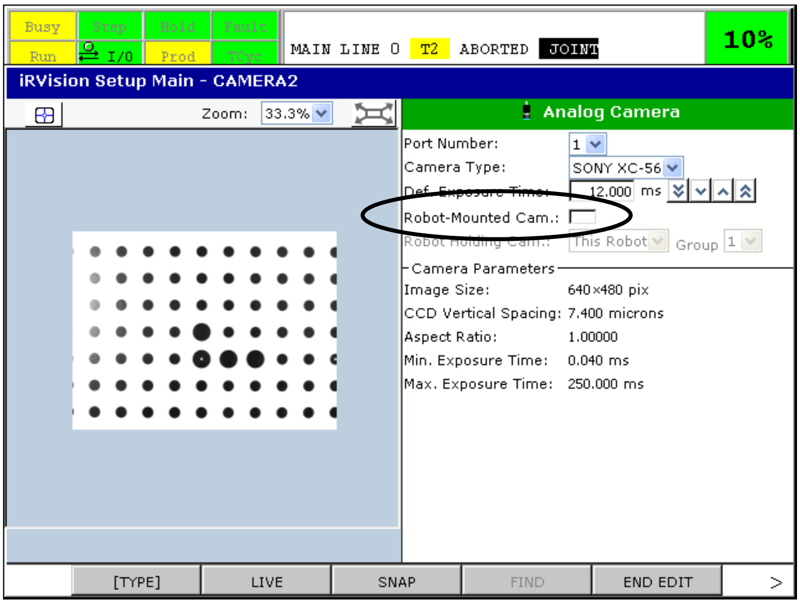


It is recommended that a calibration grid be mounted on the robot end of arm tooling or a teaching workpiece to perform calibration. The figure below shows an example of mounting a calibration grid at a workpiece Measurement Position. Prepare a teaching workpiece that resembles an actual workpiece and that can be gripped. Setup work can be simplified by mounting a calibration grid on the teaching workpiece. In either case, the mounting position should be able to be restored exactly. This is because if a displacement should occur in calibration due to a factor such as impact on the 3D Laser Vision Sensor, recovery work can be simplified greatly.



5.2.1 Creating and Teaching Camera Setup tool

With *i*RVision, items such as camera type are set in camera setup tool. If you want to use the 3D Laser Vision Sensor as a fixed sensor, be sure to uncheck the [Robot-Mounted Camera] check box.

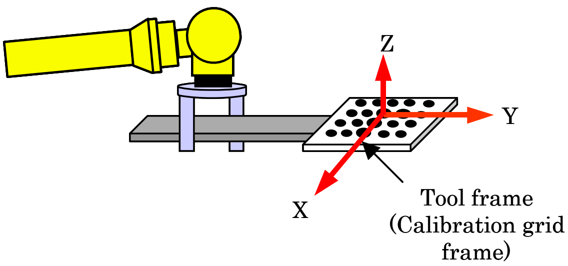


5.2.2 Setting Calibration Grid Frame

When a calibration grid is mounted on the robot end of arm tooling, set the calibration grid frame in a tool frame with an arbitrary number. For this setting, use the grid frame setting function. After securing the calibration grid, execute the grid frame setting function. For details of the grid frame setting function, please refer to "10.2 GRID FRAME SETTING" in "*i*RVision OPERATOR'S MANUAL (Reference)".

In addition to the method of using the grid frame setting function, the following method is also available: Touch up the grid precisely with a pointer secured within the operation range of the robot, then set a tool frame as shown in the figure below. Please refer to "11.2.1 Setting Based on Touch-up" in "*i*RVision OPERATOR'S MANUAL (Reference)". In this case, the touch-up precision affects the compensation precision, and touch up the grid precisely.

It is strongly recommended that the installation position be able to be restored exactly. This is because if a displacement should occur in calibration due to a factor such as impact on the 3D Laser Vision Sensor, recovery work can be simplified greatly. For the detailed setup procedure, please refer to "8.1 AUTOMATIC RE-CALIBRATION".



5.2.3 Setting an Application Frame

With tool offset, the application frame is specified the robot's user frame to be used for camera calibration. Under normal conditions, specify the number “0” as the robot base frame (world). But when two or more robots work together, set the sharing user frame and specify the number of it.

Set a user frame for a plane such as a pallet using the set robot TCP. For this setting, use [User Frame Setup / Three Point] unless there is specific reason.

Sharing User Frame

When two or more robots work together, it is necessary to configure the system so that these robots share physically the same user frame. This is called the sharing of the user frame. Specifically, the sharing of the user frame is needed in the following cases:

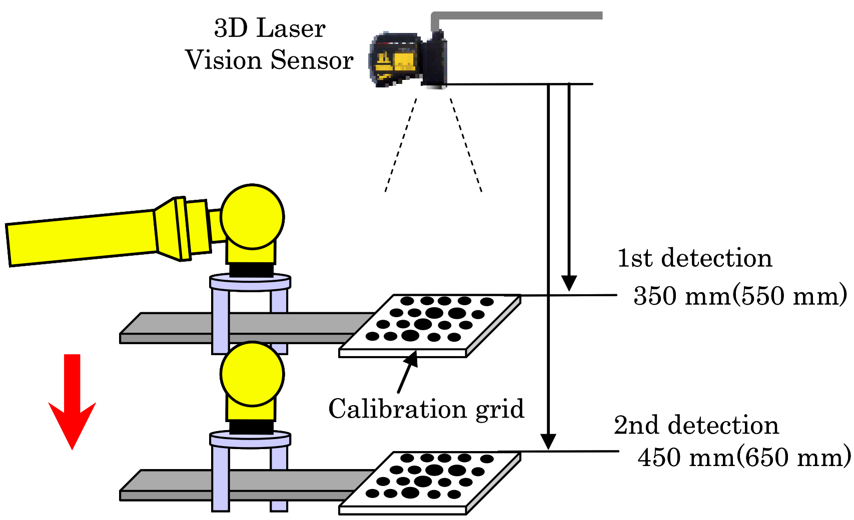
- Multiple robots are offset with a single set of offset data.
- The robot to be offset is different from the robot that has the camera.

User frame sharing requires that all robots use the same user frame number. For example, user frame 5 of robot 1 needs to be physically the same as user frame 5 of robot 2.

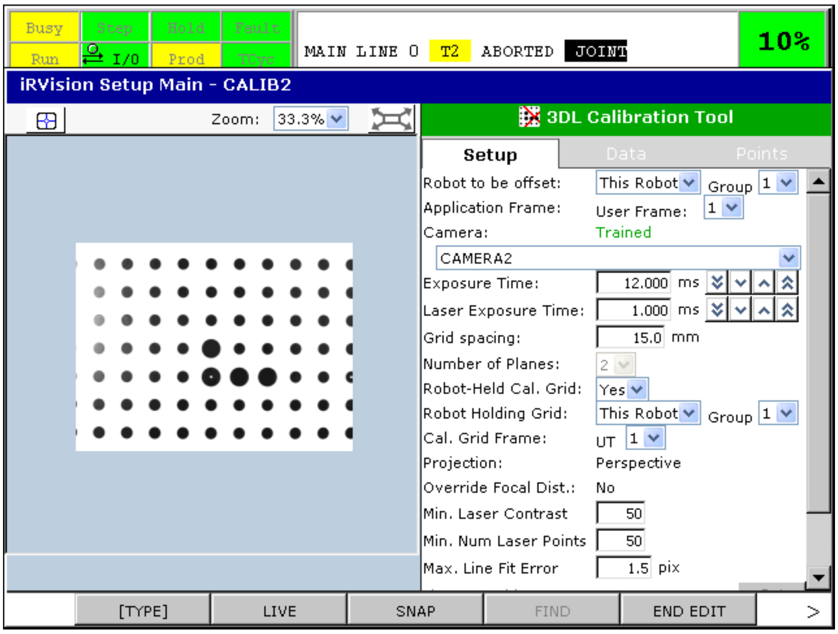
> ⚠ **CAUTION**
> If robots share user frames of different numbers, *i*RVision cannot offset the robots correctly. Make sure that the robots share the same user frame number.

5.2.4 Creating and Teaching Camera Calibration Tool

To use the 3D Laser Vision Sensor, 3DL calibration using a calibration grid is required. For a fixed sensor, perform 2-plane calibration by moving the robot end of arm tooling up and down as shown in the figure below. For calibration, the appropriate distances between the 3D Laser Vision Sensor and calibration grid are near 350mm and 450mm (near 550mm and 650mm if the standoff of the 3D laser sensor is 600mm). When the calibration grid is detected with the robot and is made to have the same posture as it does when the workpiece is detected, the precision is increased.



The teach screen for the 3DL calibration is shown below. A calibration grid image is displayed.



Select "application frame". The world frame may be used. In this case, select 0. The example shows 1.

Enter [Exposure Time] to be applied for 2D measurement.

Enter [Laser Exposure Time] to be applied for laser measurement.

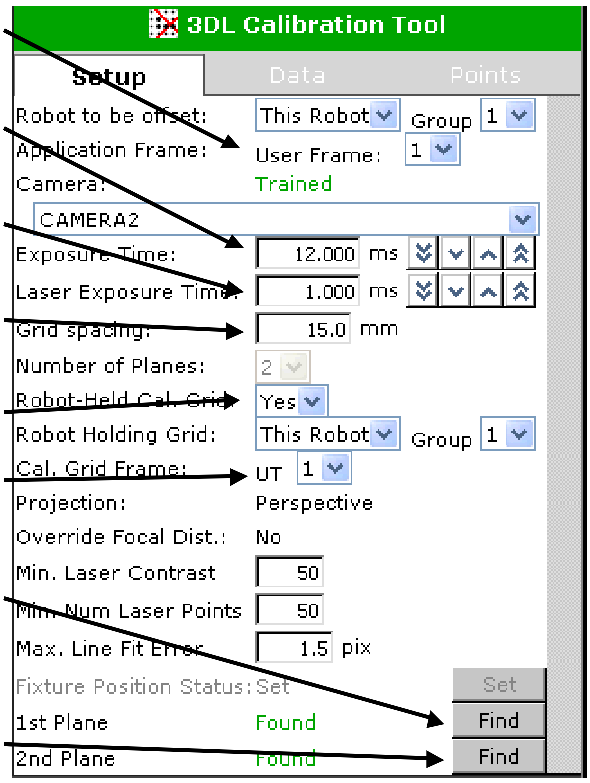
Enter [Grid Spacing] between grid points on the calibration grid.

Select [Yes].

Select the number of the "tool frame" in which "calibration grid frame" is set in [Tool Frame].

Move the camera from the calibration grid by a proper distance, then click the [Find] button for [1st Plane].

Change the distance between the camera and calibration grid, then click the [Find] button for [2nd Plane].

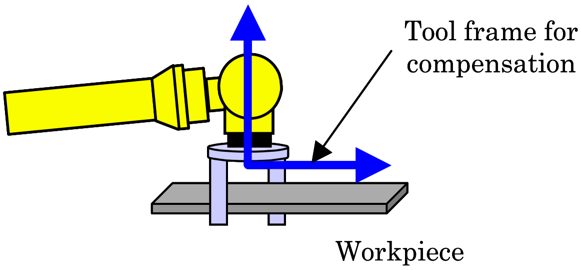


⚠ **CAUTION**

During calibration, how the camera of the 3D Laser Vision Sensor is positioned relative to the user frame (whose number is selected in [Application Frame]) is stored. This information is used for actual measurement. After calibration, do not change the number or the content of the application frame. If you change them, recalibrate the sensor. Then teach the reference positions of the vision processes which use the camera calibration tool.

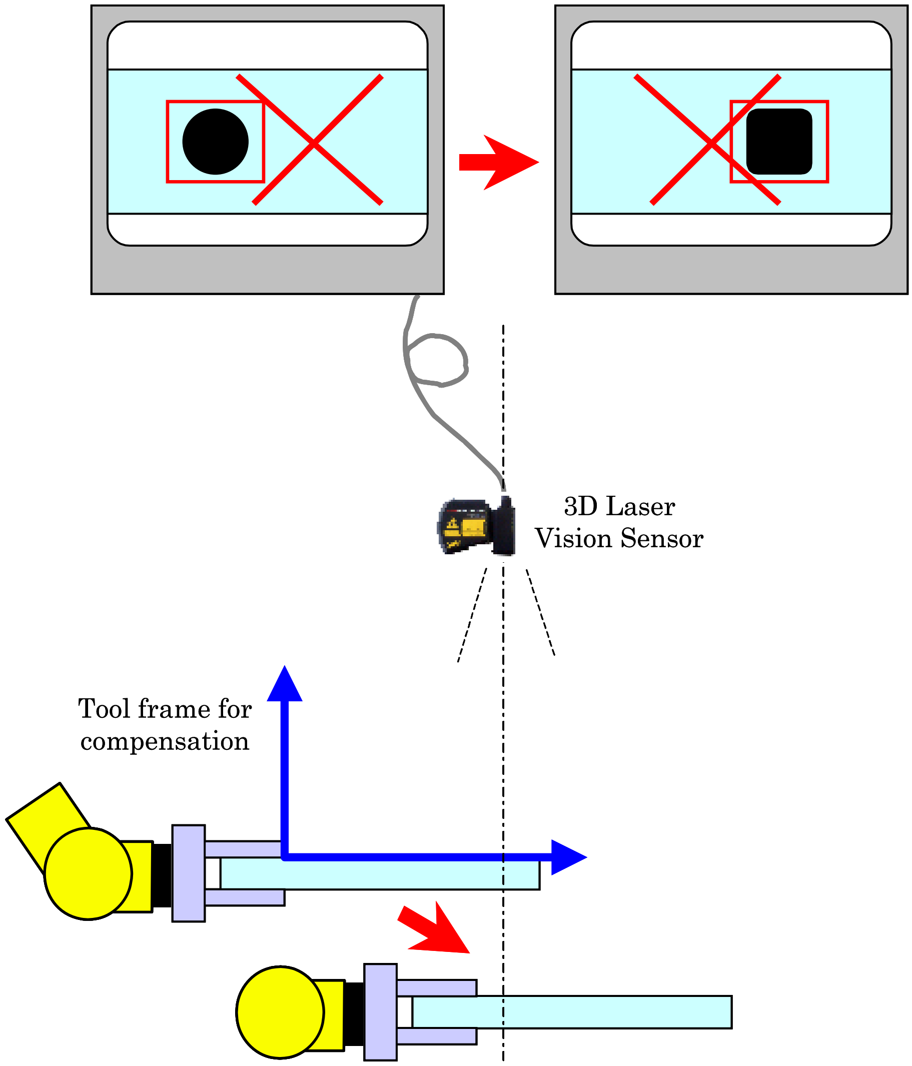
5.2.5 Setting a tool frame for compensation

Set a tool frame to be used as the reference of the tool offset compensation operation by the robot. Tool offset compensation data is output as values in the tool frame set here. To set the tool frame, use [Tool Frame Setup / Six Point].



5.2.6 Creating and Teaching a Vision Process

Create a vision process for the “3DL Multi-View Vision Process”. For tool offset, first make the end of arm tooling hold the workpiece to be picked up to teach the reference position. If how the end of arm tooling holds the workpiece can be reproduced with precision, detection models can be added or changed easily.



Use the following procedure to teach a vision process for the 3DL Multi-View Vision Process.

1. Set the tool frame for compensation in tool frame with an arbitrary number.

⇩

2. Select one camera view, specify calibration data, and set parameters.

⇩

3. Move the robot to the measurement position and teach the GPM Locator Tool.

⇩

4. Then, teach 3DL Plane Command Tool.

⇩

5. Return to camera view, and press F3[SNAP] and F4[FIND] to detect the taught model.

⇩

6. Perform steps 2 to 5 for all camera views.

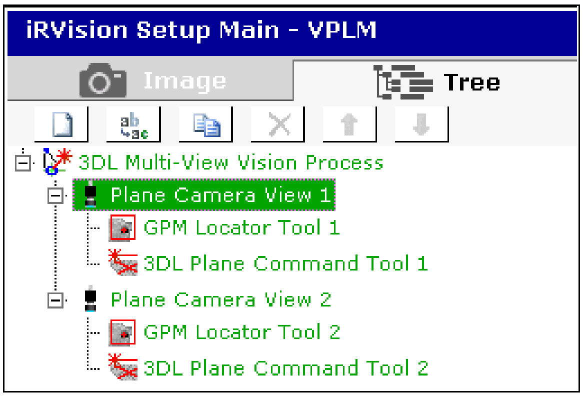
⇩

7. Select [3DL Multi-View Vision Process], which is the top of the tree view, and set the parameters.

⇩

8. Set the reference position.

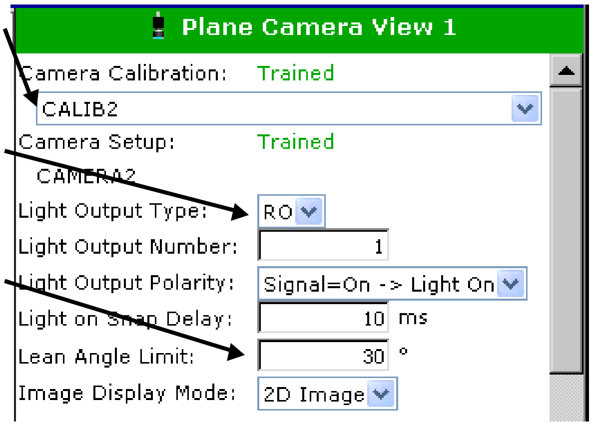
Teaching the camera view



Select “calibration tool” of the camera.

Select [Light Output Signal Type].

Enter the maximum tilt angle of the detection result to the reference position in [Lean Angle Limit].



Select [Exposure Mode] for 2D measurement.

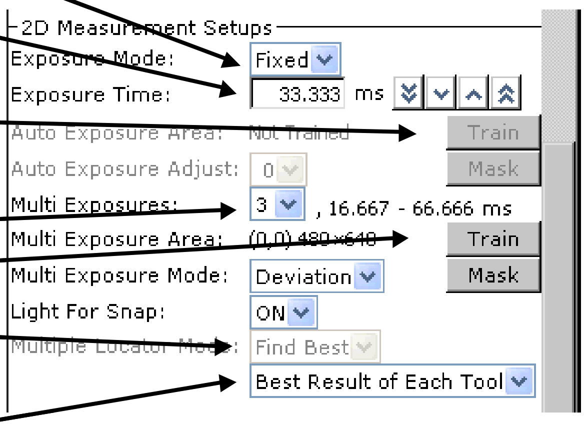
Enter [Exposure Time] to be applied for 2D measurement.

To use "automatic exposure” for 2D measurement, teach the “measurement area” and “mask”.

To use “multi exposure” for 2D measurement, select the number of images to be combined and teach the “measurement area” and "mask”.

Select which locator tools to execute in the case that multiple locator tools have been made.

Select which results of each locator tool to use in the case that the tool has multiple results.

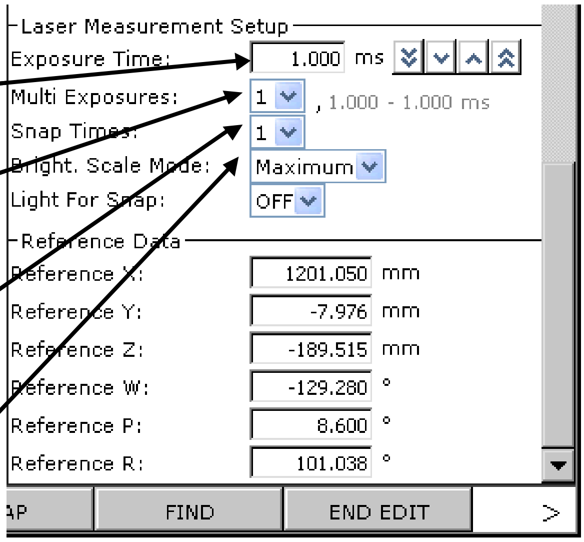


Enter [Exposure Time] to be applied for laser measurement.

Select the number of images to be combined for “multi exposure” for laser measurement in [Multi Exposures].

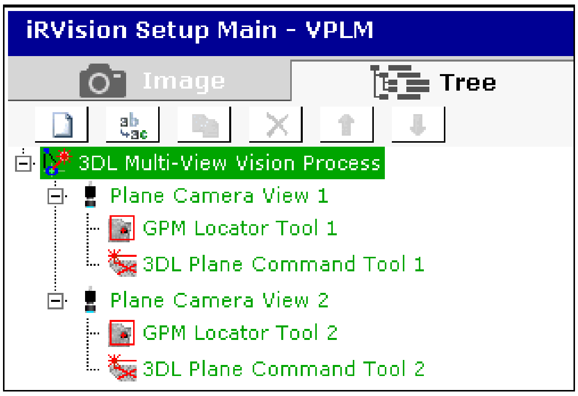
To snap multiple images during one exposure time for laser measurement, select a number in [Snap Times].

Select [Brightness Scaling Mode] when the value in [Multi Exposures] or [Snap Times] for laser measurement is 2 or greater.



Then, teach the GPM Locator Tool and 3DL Plane Command Tool. For details of the teaching procedure, please refer to Chapter 3 “TEACHING EXAMPLE”. After teaching all command tools (GPM Locator Tool and 3DL Plane Command Tool), press F3[SNAP] and F4[FIND] of the camera view to detect the workpiece.

Teaching the vision process



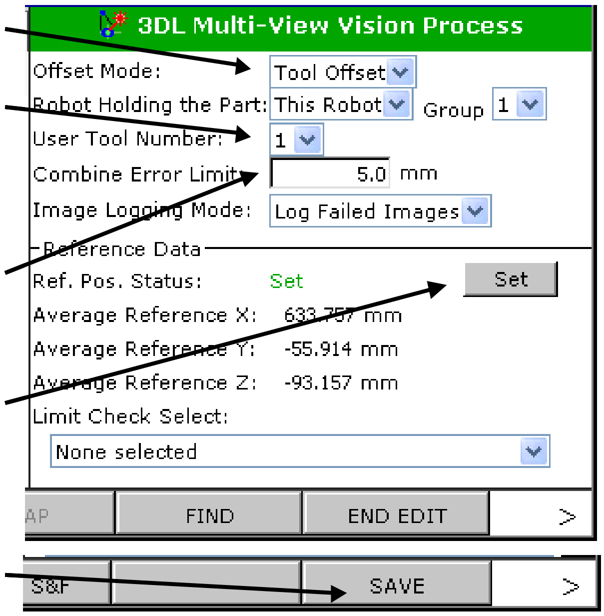
Select [Tool Offset].

A tool frame different from one set in [Calibration Grid Frame] must be selected here. Select the tool frame for compensation such as the TCP of the end of arm tooling.

Enter the limit of the combined deviation from the reference position in the measurement result of each camera view in [Combine Error Limit].

After pressing F3[SNAP] and F4[FIND] in each camera view to detect the workpiece, click the [Set Ref. Pos.] button. This operation sets the reference position for all camera views at one time.

Press F10[SAVE] to save modifications.



5.2.7 Creating and Teaching a Robot Program

In the sample program below, a vision process for the 3DL Multi-View Vision Process named “VPLM” is used. The sample program can be used to take out, for example, an unmachined casting. The robot compensates the tool offset according to the measurement result. After supplying the workpiece to the machine, the robot tries to detect another workpiece. In this program, R [11] is used to get the number of workpieces detected in each view (that is, check the detection result).

```
 1:  UFRAME_NUM=1
 2:  UTOOL_NUM=1
 3:J P[1:Home] 30% FINE
 4:   ;
 5:  !Grasp
 6:  LBL[10]
 7:L P[2:Approach] 800mm/sec CNT100
 8:L P[3:Grasp] 200mm/sec FINE
 9:L P[4:Retract] 800mm/sec CNT100
10:
11:  !Measurement
12:L P[5:Measurement Pos1] 800mm/sec FINE
13:  WAIT     .30(sec)
14:  VISION RUN_FIND 'VPLM' CAMERA_VIEW[1]
15:  VISION GET_NFOUND 'VPLM' R[11] CAMERA_VIEW[1]
16:  IF R[11] < 1, JMP LBL[997]
17:L P[6:Measurement Pos2] 800mm/sec FINE
18:  WAIT     .30(sec)
19:  VISION RUN_FIND 'VPLM' CAMERA_VIEW[2]
20:  VISION GET_NFOUND 'VPLM' R[11] CAMERA_VIEW[2]
21:  IF R[11] < 1, JMP LBL[998]
22:  VISION GET_OFFSET 'VPLM' VR[1] JMP LBL[999]
23:
24:  !Place
25:L P[7:Approach] 800mm/sec CNT100 VOFFSET, VR[1]
26:L P[8:Place] 200mm/sec FINE VOFFSET, VR[1]
27:L P[9:Retract] 800mm/sec CNT100 VOFFSET, VR[1]
28:  JMP LBL[10]
29:
30:  !No target is detected in camera view1
31:  LBL[997]
32:  *
33:  !No target is detected in camera view2
34:  LBL[998]
35:  *
36:  !Fail to get offset data
37:  LBL[999]
38:  *
```

- Specify the application frame number set in calibration data.
- Set the same number as for the tool frame for compensation set in the vision process.
- Wait for robot-vibration to reduce.
- Execute measurement for camera view 1.
- Check the detection result of camera view 1.
- Wait for robot-vibration to reduce.
- Execute measurement for camera view 2.
- Check the detection result of camera view 2.
- Get compensation data of the measurement result.
- Execute placement operation, compensating the tool offset.
- Add exception processing when no target is detected in camera view 1.
- Add exception processing when no target is detected in camera view 2.
- Add exception processing when compensation data fails to be obtained.

NOTE

Measurement is performed after the robot reaches the taught position on the last motion. If there is vibration in the robot left, it might cause a negative effect on the accuracy of the measurement. In such cases, please use 'WAIT' or 'acceleration override' to minimize the vibration.

5.2.8 Checking Robot Compensation Operation

Check that a workpiece gripped by the robot can be detected and positioned exactly at a desired location. At first, decrease the override of the robot to check that the logic of the program is correct. Next, increase the override and cycle the program again to check its operation.

6 3DL CURVED SURFACE SINGLE VISION PROCESS

The 3DL Curved Surface Single Vision Process measures one point of a circular cylindrical workpiece for its 3D position and posture using the 3D Laser Vision Sensor, and provides compensation for robotic handling of the workpiece.

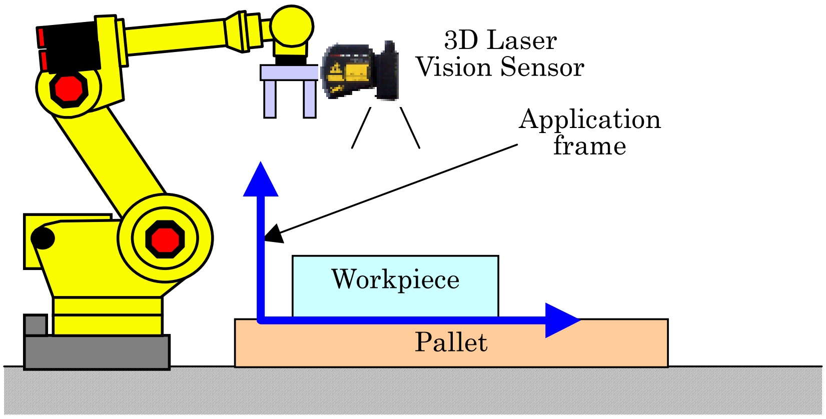
This function cannot measure a plane. For it, use the 3DL Single-View Vision Process. Please refer to Chapter 4 “3DL SINGLE-VIEW VISION PROCESS”.

This chapter describes the procedure to set up the 3DL Curved Surface Single Vision Process using the following two application examples. For details of the setup procedures and teaching procedures, please refer to Chapter 3 “TEACHING EXAMPLE”.

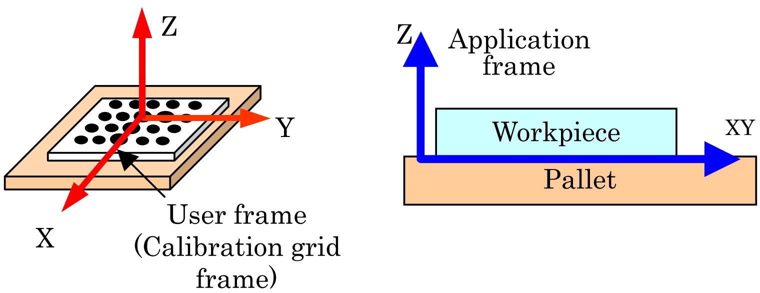
(1) Robot-mounted camera + fixed frame offset
(2) Fixed sensor + tool offset

6.1 SETUP FOR “ROBOT-MOUNTED CAMERA + FIXED FRAME OFFSET”

An example of layout for “robot-mounted camera + fixed frame offset” is given below.



Setup for “robot-mounted camera + fixed frame offset” includes setting the “calibration grid frame” and the “application frame” in a user frame with an arbitrary number. The “Calibration grid frame” can be set easily and correctly by using the camera of the 3D Laser Vision Sensor (grid frame setting function).

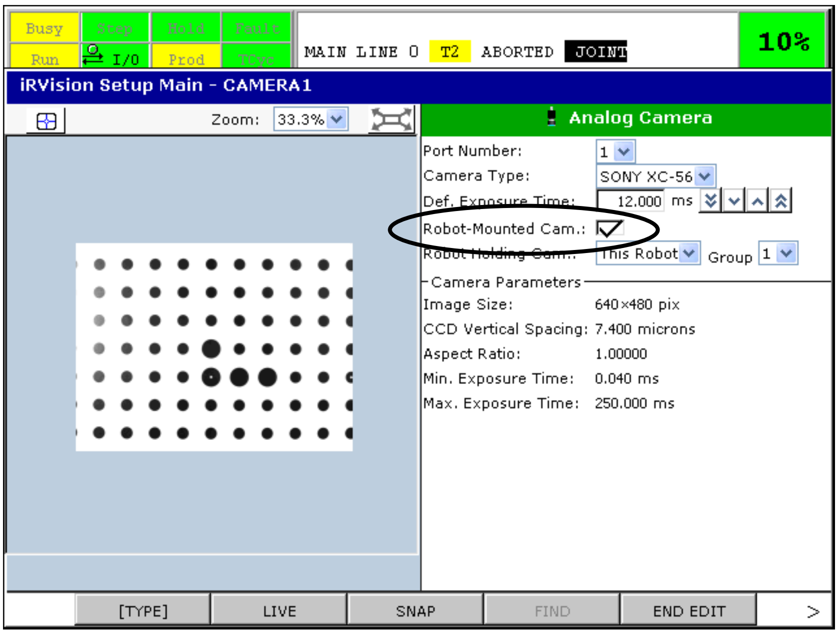


Use the following setup procedure for “robot-mounted camera + fixed frame offset”.

1. Create and teach camera setup tool.
2. Set the calibration grid frame with an arbitrary number.
   - Use the vision grid pattern setting for this setting.
3. Set the TCP at the tip of touch-up pin mounted on the end of arm tooling.
   - The TCP set here is used to set the “application frame”.
4. Set the user frame for application frame with arbitrary number.
5. Create and teach camera calibration tool.
6. Create and teach the vision process.
7. Create and teach the robot program.
8. Check the robot compensation operation.

6.1.1 Creating and Teaching Camera Setup Tool

With *i*RVision, items such as camera type are set in camera setup tool. If you want to use the 3D Laser Vision Sensor as a robot-mounted camera, be sure to check the [Robot-Mounted Camera] check box.



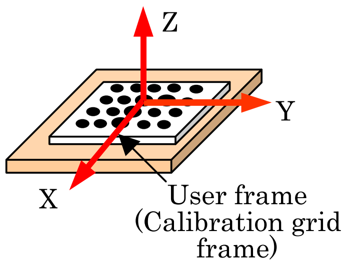
6.1.2 Setting Calibration Grid Frame

When a calibration grid is installed on a fixed place, set the calibration grid frame in a user frame with an arbitrary number. For this setting, use the grid frame setting function. After securing the calibration grid, execute the grid frame setting function. For details of the grid frame setting function, please refer to “10.2 GRID FRAME SETTING“ in “*i*RVision OPERATOR’S MANUAL (Reference)”. Note that the user frame for calibration grid frame differs from the “Application Frame” described in the following subsection.

In addition to the method of using the grid frame setting function, the following method is also available: Touch up the grid with a pointer mounted on the robot end of arm tooling precisely, then set a user frame as shown in the figure below. Please refer to “11.2.1 Setting Based on Touch-up” in “*i*RVision OPERATOR’S MANUAL (Reference)”. In this case, the operation described in the next subsection, “Setting the TCP of the Robot” must be performed in advance. The TCP setting precision and touch-up precision directly affect the compensation precision. Set the TCP and touch up the grid precisely.

The calibration grid can be installed on any surface. At this time, the X-Y plane of the calibration grid should be matched with the X-Y plane of the world frame of the robot unless the robot is installed at a tilt or any other special situations prevent these planes from matching. When these planes match, calibration can be performed more easily than when these planes do not match.

It can be removed after the completion of calibration, but it is strongly recommended that the grid be left installed in the system. This is because if a displacement should occur in calibration for the 3D Laser Vision Sensor due to a factor such as impact, recovery work can be simplified greatly. If the calibration grid must be removed, its installation position should be able to be restored exactly, which can reduce the labor for recovery. For the detailed setup procedure, please refer to “8.1 AUTOMATIC RE-CALIBRATION”.



6.1.3 Setting the TCP of the Robot

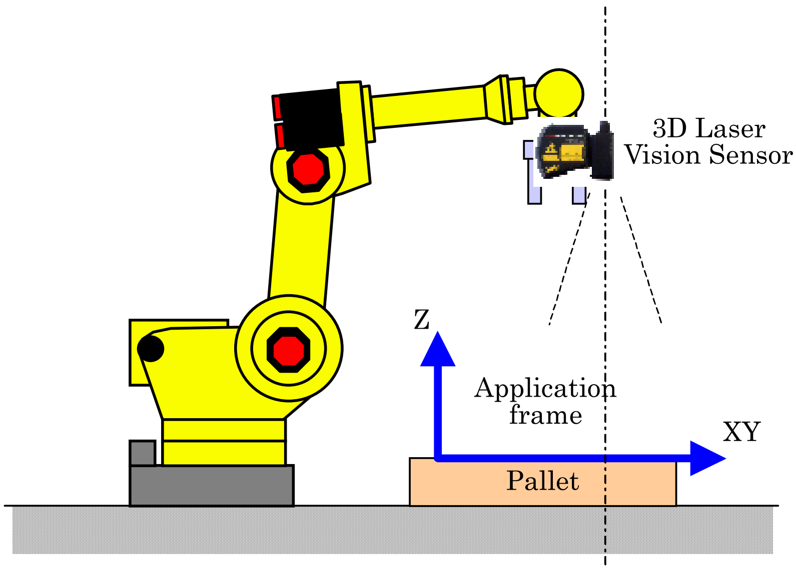
Set the TCP precisely on the tip of the pointer mounted on the end of arm tooling. Set the TCP in a tool frame with an arbitrary number. To set the tool frame, use [Tool Frame Setup / Three Point].

To reuse a TCP set at re-calibration, the reproducibility of the pointer mounting is required. If the reproducibility of the pointer mounting is not assured, a TCP needs to be set each time the pointer is mounted.

6.1.4 Setting an Application Frame

Set a user frame to be used as the reference for the robot compensation operation. The measurement result is output as values in the user frame that has been set.

Set a user frame for a plane such as a pallet using the set robot TCP. For this setting, use [User Frame Setup / Three Point] unless there is specific reason.



Sharing User Frame

When two or more robots work together, it is necessary to configure the system so that these robots share physically the same user frame. This is called the sharing of the user frame. Specifically, the sharing of the user frame is needed in the following cases:

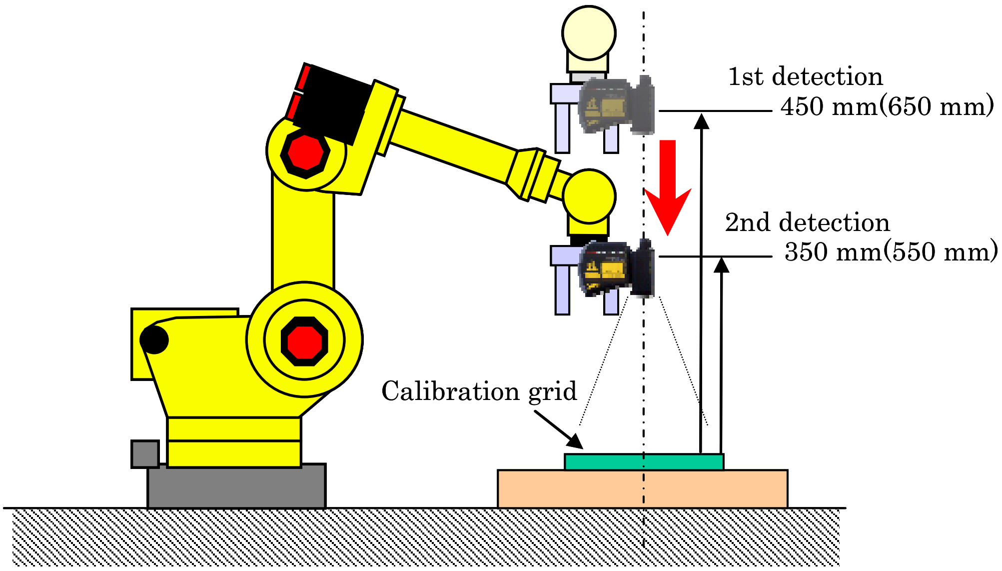
- Multiple robots are offset with a single set of offset data.
- The robot to be offset is different from the robot that has the camera.

User frame sharing requires that all robots use the same user frame number. For example, user frame 5 of robot 1 needs to be physically the same as user frame 5 of robot 2.

> ⚠ **CAUTION**
> If robots share user frames of different numbers, *i*RVision cannot offset the robots correctly. Make sure that the robots share the same user frame number.

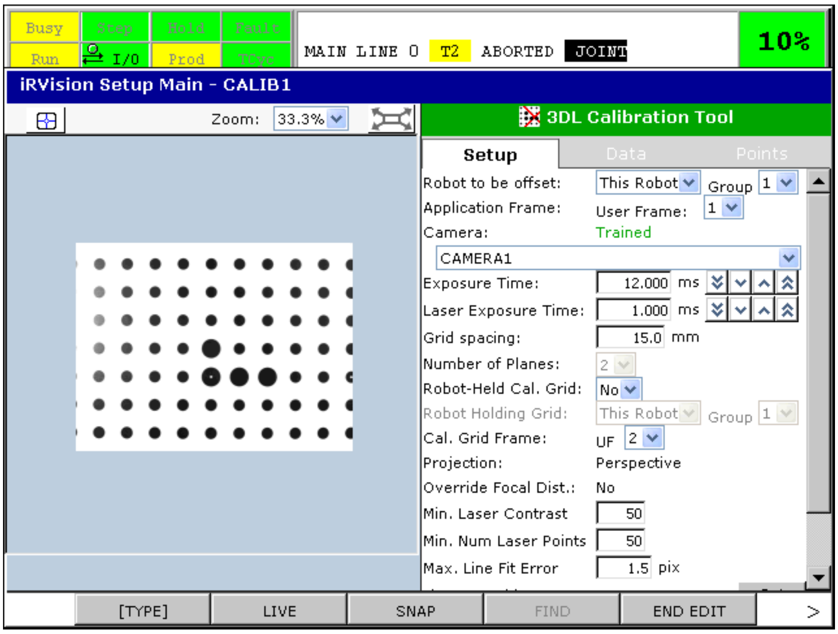
6.1.5 Creating and Teaching Camera Calibration Tool

To use the 3D Laser Vision Sensor, 3DL calibration using a calibration grid is required. For a robot-mounted camera, perform 2-plane calibration by moving the robot end of arm tooling up and down as shown in the figure below. For calibration, the appropriate distances between the 3D Laser Vision Sensor and calibration grid are near 350mm and 450mm (near 550mm and 650mm if the standoff of the 3D laser sensor is 600mm). When the calibration grid is detected with the robot and is made to have the same posture as it does when the workpiece is detected, the precision is increased.



After one set of calibration tool is created with 3DL vision calibration, another set of calibration tool does not need to be created even after the camera Measurement Position is changed. This is because *i*RVision uses the current robot position when calculating the position of the workpiece.

The teach screen for 3DL calibration is shown below. A calibration grid image is displayed.



Select the number of the "user frame" set as the "application frame" in [User Frame].

Enter [Exposure Time] to be applied for grid detection.

Enter [Laser Exposure Time] to be applied for laser measurement.

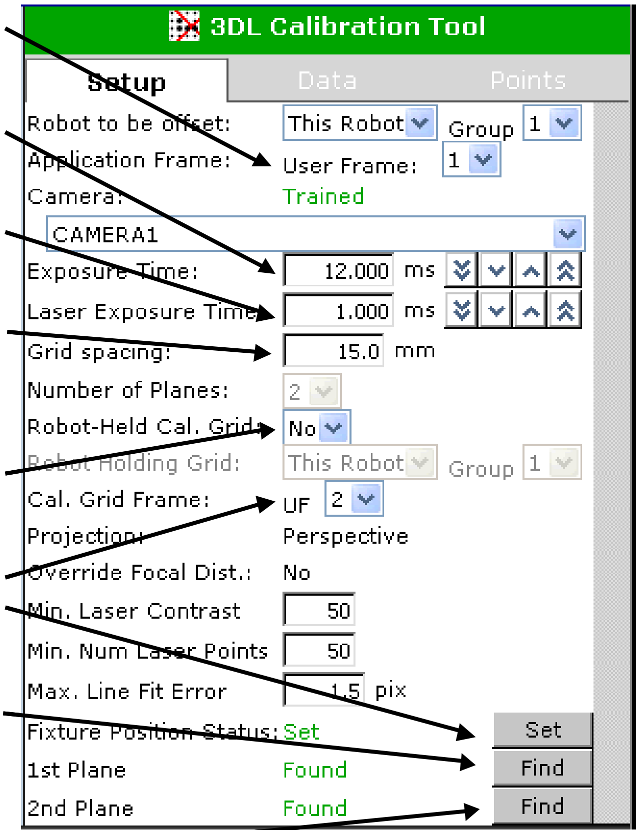
Enter [Grid Spacing] between grid points on the calibration grid.

Select [No] if the calibration grid is a fixed position.

Select the number of the "user frame" in which "calibration grid frame" is set in [User Frame], then click the [Set] button.

Move the camera from the calibration grid by a proper distance, then click the [Find] button for [1st Plane].

Change the distance between the camera and calibration grid, then click the [Find] button for [2nd Plane].



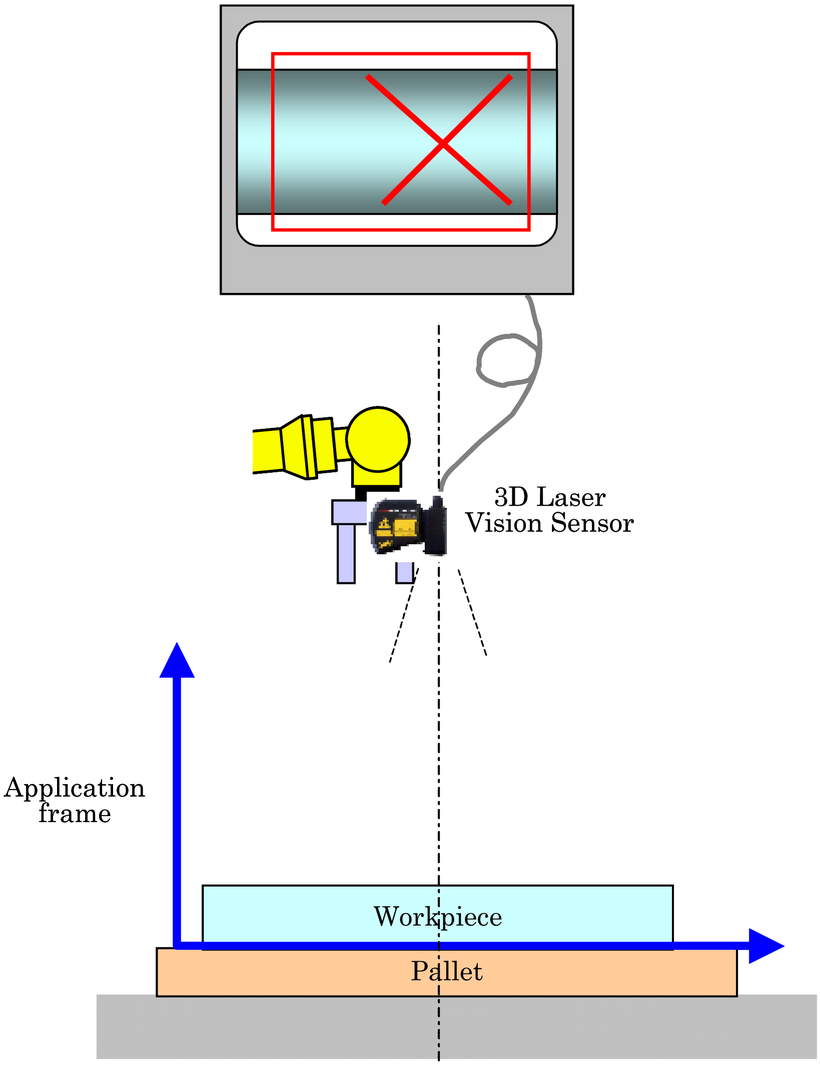
⚠ CAUTION

1 During calibration, how the camera of the 3D Laser Vision Sensor is positioned relative to the user frame (whose number is selected in [Application Frame]) is stored. This information is used for actual measurement. After calibration, do not change the number or the content of the application frame. If you change them, recalibrate the sensor. Then teach the reference positions of the vision processes which use the camera calibration tool.

2 When recalibrating a camera, if you change the position of the calibration grid, set the user frame of the calibration grid frame again. Then click the [Set] button for the calibration grid frame and recalculate it.

6.1.6 Creating and Teaching a Vision Process

Create a vision process for the “3DL Curved Surface Single Vision Process”. For fixed frame offset, first place the workpiece to be picked up at the reference position to teach the reference position. If a reproducible position is set as the reference position, detection models can be added or changed easily.



Use the following procedure to teach a vision process for the 3DL Curved Surface Single Vision Process.

1. Specify calibration tool and set parameters.

⇩

2. Move the robot to the measurement position and teach the Curved Surface Locator Tool.

⇩

3. Then, teach the 3DL Cylinder Command Tool.

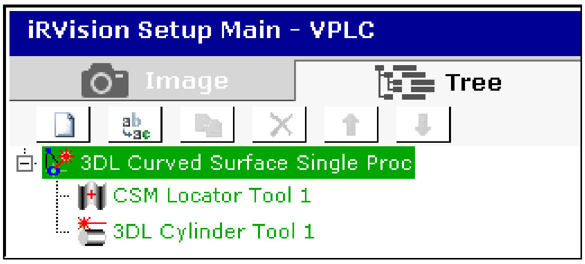
⇩

4. Select [3DL Curved Surface Single Proc], which is the top of the tree view, and press F3[SNAP] and F4[FIND] to detect taught model.

⇩

5. Set the reference position.

Teaching the vision process

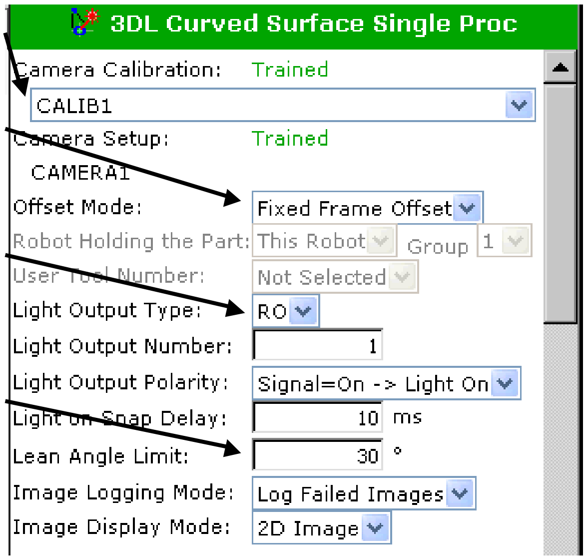


Select “calibration tool" of the camera.

Select [Fixed Frame Offset].

Select [Light Output Signal Type].

Enter the maximum tilt angle of the detection result to the reference position in [Lean Angle Limit].



Select [Exposure Mode] for 2D measurement. (Fixed)

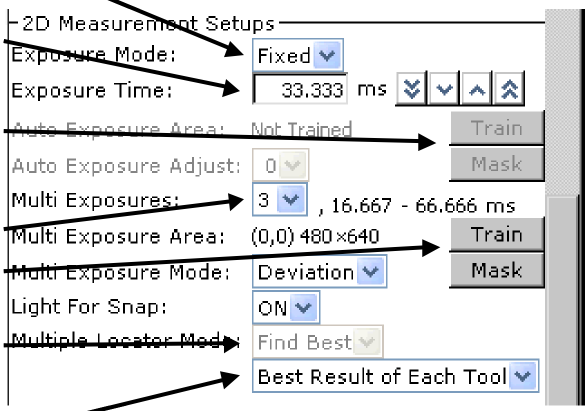
Enter [Exposure Time] to be applied for 2D measurement.

To use "automatic exposure" for 2D measurement, teach the "measurement area" and "mask".

To use "multi exposure" for 2D measurement, select the number of images to be combined and teach the "measurement area" and "mask".

Select which locator tools to execute in the case that multiple locator tools have been made.

Select which results of each locator tool to use in the case that the tool has multiple results.

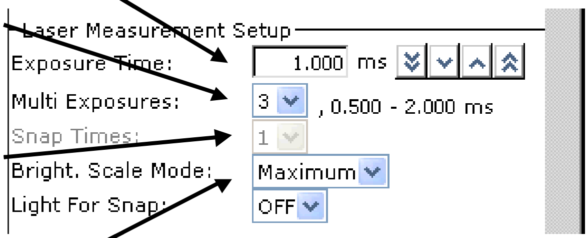


Enter [Exposure Time] to be applied for laser measurement.

Select the number of images to be combined for "multi exposure" for laser measurement in [Multi Exposures].

To snap multiple images during one exposure time for laser measurement, select a number in [Snap Times].

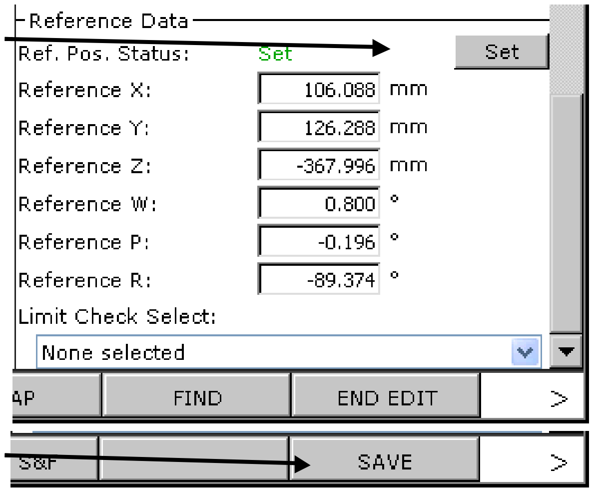
Select [Brightness Scaling Mode] when the value in [Multi Exposures] or [Snap Times] for laser measurement is 2 or greater.



Then, teach the Curved Surface Locator Tool and 3DL Cylinder Command Tool. For details of the teaching procedure, please refer to Chapter 3 "TEACHING EXAMPLE". After teaching all command tools (Curved Surface Locator Tool and 3DL Cylinder Command Tool), press F3[SNAP] and F4[FIND] of the vision process to detect the workpiece. When the workpiece is detected correctly, set the reference position.

Immediately after measuring the workpiece by pressing F3[SNAP] and F4[FIND], click the [Set Ref. Pos.] button.

Press F10[SAVE] to save modifications.



6.1.7 Creating and Teaching a Robot Program

In the sample program below, a vision process for the 3DL Curved Surface Single Vision Process named "VPLC" is used. The sample program can be used to take out, for example, overlapping metal plates one by one sequentially. The robot compensates the pickup operation according to the measurement result, and picks up a workpiece exactly as taught. After supplying the workpiece to the next process, the robot tries to detect another workpiece.

```
 1:  UFRAME_NUM=1
 2:  UTOOL_NUM=1
 3:J P [1:Home] 30% FINE
 4:
 5:  !Measurement
 6:  LBL [10]
 7:L P [2:Measurement Pos] 800mm/sec FINE
 8:  WAIT     .30(sec)
 9:  VISION RUN_FIND 'VPLC'
10:  VISION GET_OFFSET 'VPLC' VR[1] JMP LBL[999]
11:
12:  !Grasp
13:L P[3:Approach] 800mm/sec CNT100 VOFFSET,VR[1]
14:L P[4:Grasp] 200mm/sec FINE VOFFSET,VR[1]
15:L P[5:Retract] 800mm/sec CNT100 VOFFSET,VR[1]
16:
17:  !Place
18:L P[6:Approach] 800mm/sec CNT100
19:L P[7:Place] 200mm/sec FINE
20:L P[8:Retruct] 800mm/sec CNT100
21:  JMP LBL[10]
22:
23:  !No workpiece is detected
24:  LBL [999]
25:  ***
```

Set the same value as the number of the application frame.

Wait for robot-vibration to reduce.

Execute measurement.

Get compensation data of the measurement result.

Compensate pickup operation.

Execute placement operation.

Add exception processing when no workpiece is detected.

NOTE

Measurement is performed after the robot reaches the taught position on the last motion. If the robot is still vibrating, it may affect the accuracy of the measurement. In such cases, please use 'WAIT' or 'acceleration override' to minimize the vibration.

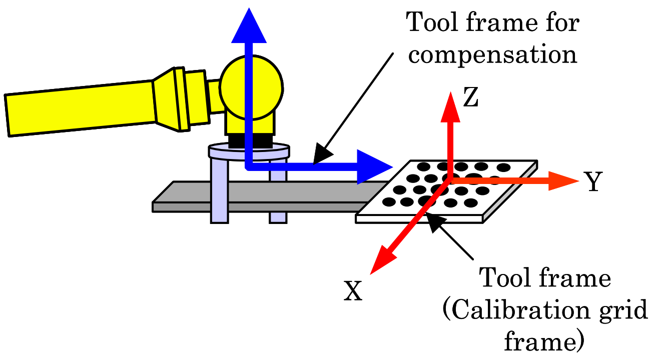
6.1.8 Checking Robot Compensation Operation

Make the robot handle workpieces one by one sequentially and check that it can handle the workpieces properly. At first, decrease the override of the robot to check that the logic of the program is correct. Next, increase the override and execute the program again to check its operation.

6.2 SETUP FOR “FIXED SENSOR + TOOL OFFSET”

With tool offset, the camera measures how much a workpiece gripped by the robot deviates from the correct grip position. This feature performs compensation so that the robot places the gripped workpiece exactly at the predetermined position.

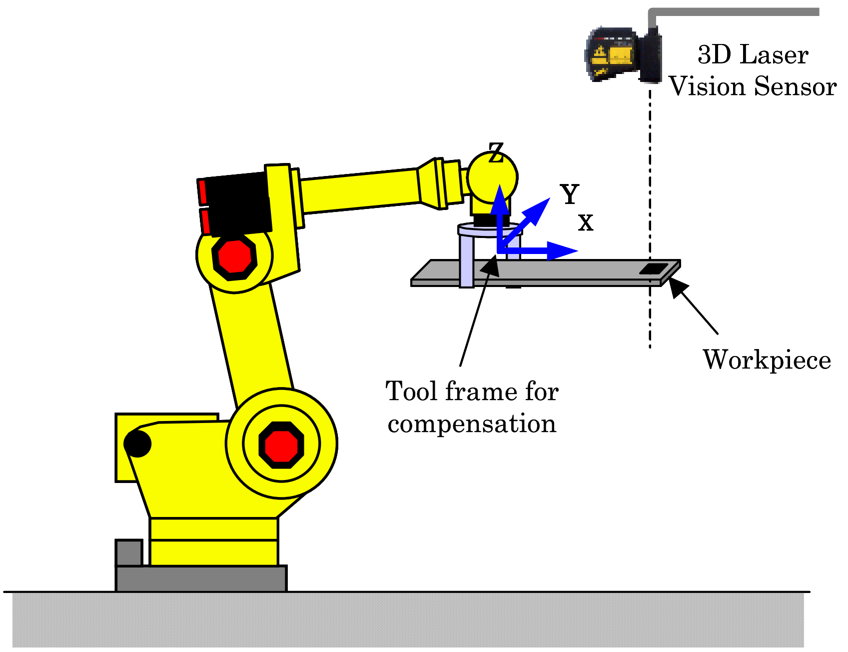
Setup for “fixed sensor + tool offset” includes setting “calibration grid frame” and “tool frame for compensation” in a tool frame with an arbitrary number. “Calibration grid frame” can be set easily and correctly with the setting using the camera of the 3D Laser Vision Sensor (grid frame setting function).



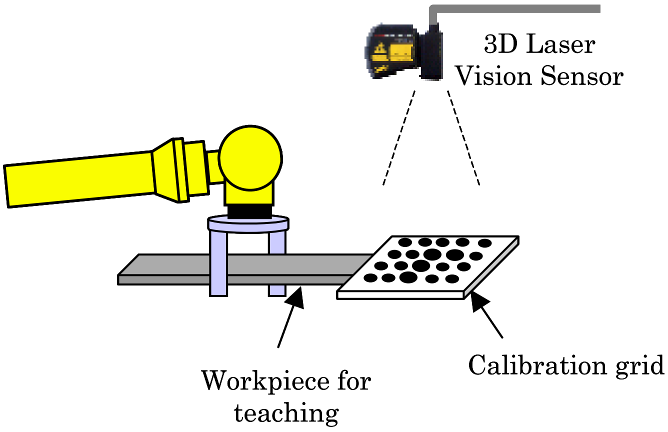
Use the following setup procedure for “fixed sensor + tool offset”.

1. Create and teach camera setup tool.
2. Set the calibration grid frame in a tool frame with an arbitrary number.
   - Use the vision grid pattern setting for this setting.
3. Set an application frame as required.
   - Set the application frame. The world frame may be used. In this case, setting is not required.
4. Create and teach the camera calibration tool.
5. Set the tool frame for compensation in tool frame with an arbitrary number.
6. Create and teach the vision process.
7. Create and teach the robot program.
8. Check the robot compensation operation.

An example of layout for “fixed sensor + tool offset” is given below. A workpiece gripped by the robot is viewed by the fixed sensor to measure the amount of tool offset.

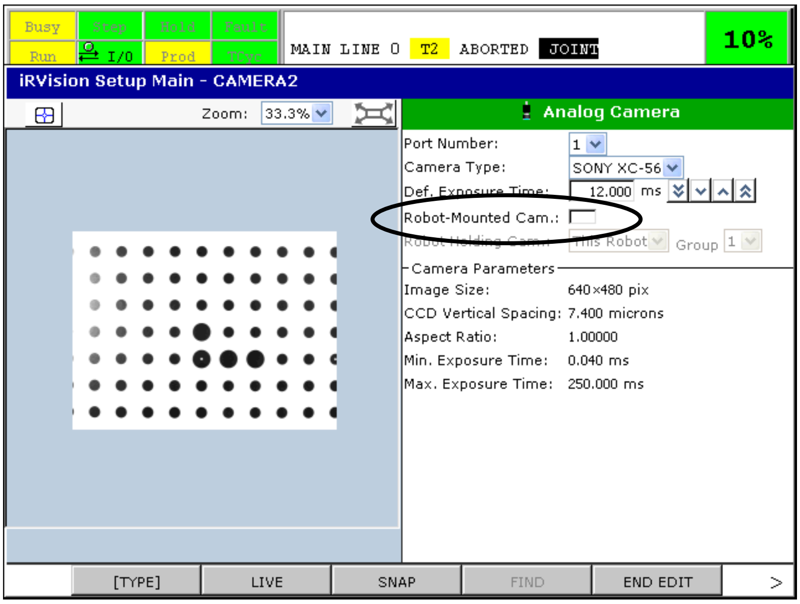


It is recommended that a calibration grid be mounted on the robot end of arm tooling or a teaching workpiece to perform calibration. The figure below shows an example of mounting a calibration grid at a workpiece Measurement Position. Prepare a teaching workpiece that resembles an actual workpiece and that can be gripped. Setup work can be simplified by mounting a calibration grid on the teaching workpiece. In either case, the mounting position should be able to be restored exactly. This is because if a displacement should occur in calibration due to a factor such as impact on the 3D Laser Vision Sensor, recovery work can be simplified greatly.



6.2.1 Creating and Teaching Camera Setup Tool

With *i*RVision, items such as a camera type are set in camera setup tool. If you want to use the 3D Laser Vision Sensor as a fixed sensor, be sure to uncheck the [Robot-Mounted Camera] check box.



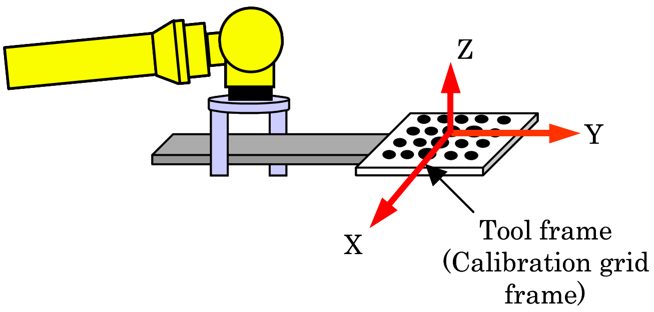
6.2.2 Setting Calibration Grid Frame

When a calibration grid is mounted on the robot end of arm tooling, set the calibration grid frame in a tool frame with an arbitrary number. For this setting, use the grid frame setting function. After securing the calibration grid, execute the grid frame setting function. For details of the grid frame setting function, please refer to “10.2 GRID FRAME SETTING“ in “*i*RVision OPERATOR’S MANUAL (Reference)”.

In addition to the method of using the grid frame setting function, the following method is also available: Touch up the grid precisely with a pointer secured within the operation range of the robot, then set a tool frame as shown in the figure below. Please refer to “11.2.1 Setting Based on Touch-up” in “*i*RVision

OPERATOR'S MANUAL (Reference)". In this case, the touch-up precision affects the compensation precision, and touch up the grid precisely.

It is strongly recommended that the installation position be able to be restored exactly. This is because if a displacement should occur in calibration due to a factor such as impact on the 3D Laser Vision Sensor, recovery work can be simplified greatly. For the detailed setup procedure, please refer to "8.1 AUTOMATIC RE-CALIBRATION".



6.2.3 Setting an Application Frame

With tool offset, the application frame is specified the robot's user frame to be used for camera calibration. Under normal conditions, specify the number "0" as the robot base frame (world). But when two or more robots work together, set the sharing user frame and specify the number of it.

Set a user frame for a plane such as a pallet using the set robot TCP. For this setting, use [User Frame Setup / Three Point] unless there is specific reason.

Sharing User Frame

When two or more robots work together, it is necessary to configure the system so that these robots share physically the same user frame. This is called the sharing of the user frame. Specifically, the sharing of the user frame is needed in the following cases:

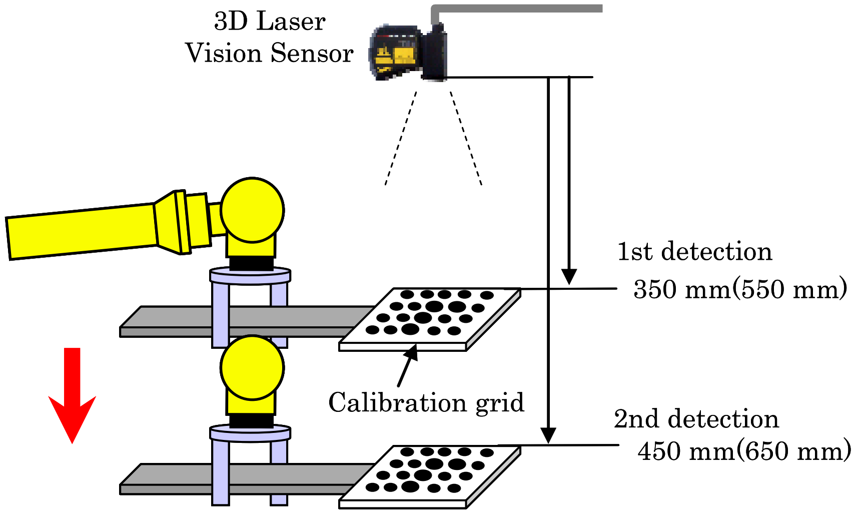
- Multiple robots are offset with a single set of offset data.
- The robot to be offset is different from the robot that has the camera.

User frame sharing requires that all robots use the same user frame number. For example, user frame 5 of robot 1 needs to be physically the same as user frame 5 of robot 2.

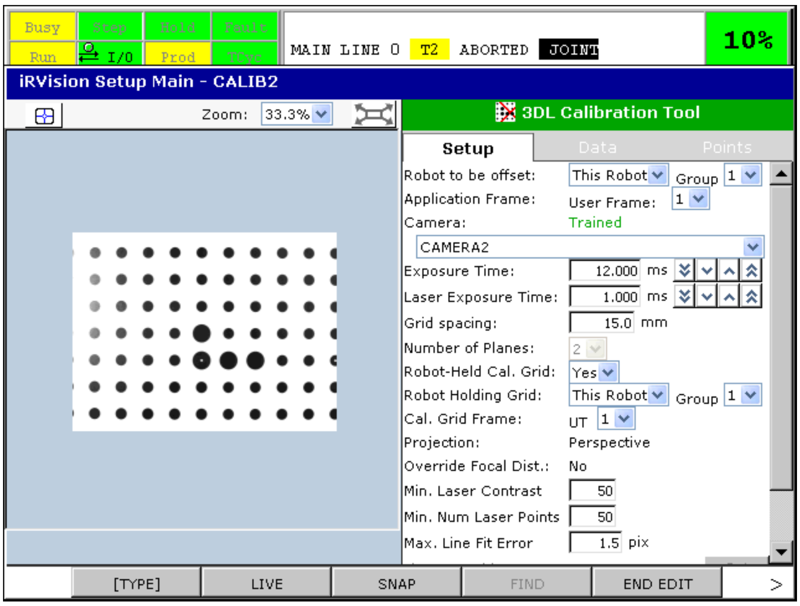
> ⚠ **CAUTION**
> If robots share user frames of different numbers, *i*RVision cannot offset the robots correctly. Make sure that the robots share the same user frame number.

6.2.4 Creating and Teaching Camera Calibration Tool

To use the 3D Laser Vision Sensor, 3DL calibration using a calibration grid is required. For a fixed sensor, perform 2-plane calibration by moving the robot end of arm tooling up and down as shown in the figure below. For calibration, the appropriate distances between the 3D Laser Vision Sensor and calibration grid are near 350mm and 450mm (near 550mm and 650mm if the standoff of the 3D laser sensor is 600mm). When the calibration grid is detected with the robot and is made to have the same posture as it does when the workpiece is detected, the precision is increased.



The teach screen for the 3DL calibration is shown below. A calibration grid image is displayed.



Select “application frame”. The world frame may be used. In this case, select 0. The example shows 1.

Enter [Exposure Time] to be applied for 2D measurement.

Enter [Laser Exposure Time] to be applied for laser measurement.

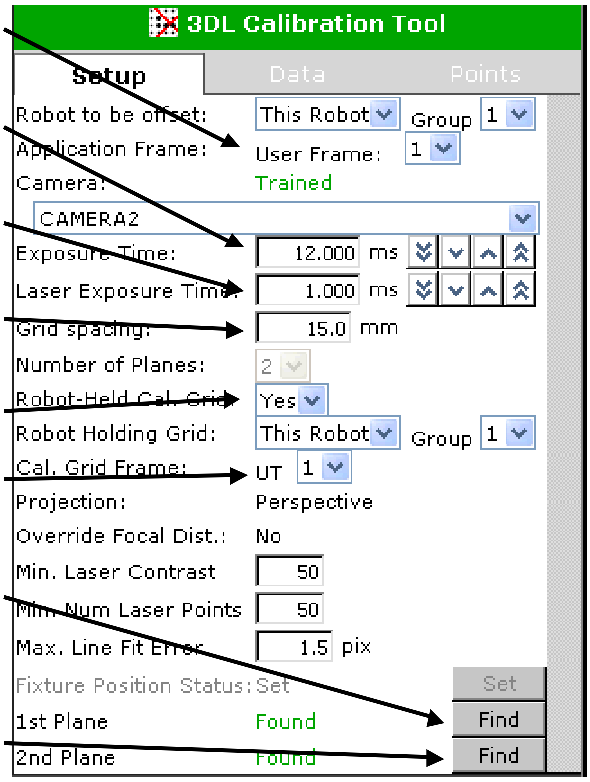
Enter [Grid Spacing] between grid points on the calibration grid.

Select [Yes].

Select the number of the “tool frame” in which “calibration grid frame” is set in [Tool Frame].

Move the camera from the calibration grid by a proper distance, then click the [Find] button for [1st Plane].

Change the distance between the camera and calibration grid, then click the [Find] button for [2nd Plane].

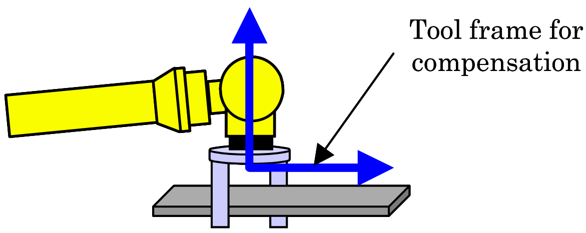


⚠ CAUTION

During calibration, how the camera of the 3D Laser Vision Sensor is positioned relative to the user frame (whose number is selected in [Application Frame]) is stored. This information is used for actual measurement. After calibration, do not change the number or the content of the application frame. If you change them, recalibrate the sensor. Then teach the reference positions of the vision processes which use the camera calibration tool.

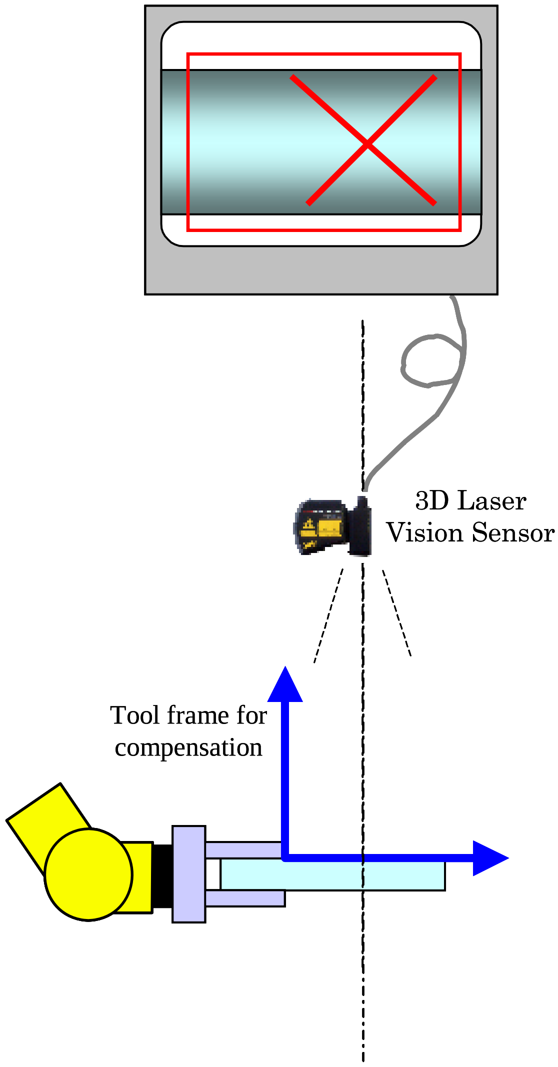
6.2.5 Setting a tool frame for compensation

Set a tool frame to be used as the reference of the tool offset compensation operation by the robot. Tool offset compensation data is output as values in the tool frame set here. To set the tool frame, use [Tool Frame Setup / Six Point].



6.2.6 Creating and Teaching a Vision Process

Create a vision process for the “3DL Curved Surface Single Vision Process”. For tool offset, first pick the workpiece so it is aligned in the gripper as expected. Jog robot so workpiece is in the center of the FOV.(record this as the view position in a TP program). Train the workpiece and set as the reference position (Set Reference). In many cases it is best to place the workpiece at a fixed location and record a pick position. This will ensure that the part will appear in the reference position when the robot moves to the view position. This maintains precision and allows for easy re-training of the vision target.



Use the following procedure to teach a vision process for the 3DL Curved Surface Single Vision Process.

1. Set tool frame for compensation in tool frame with an arbitrary number.

⇩

2. Specify calibration tool and set parameters.

⇩

3. Move the robot to the measurement position and teach the Curved Surface Locator Tool.

⇩

4. Then, teach the 3DL Cylinder Command Tool.

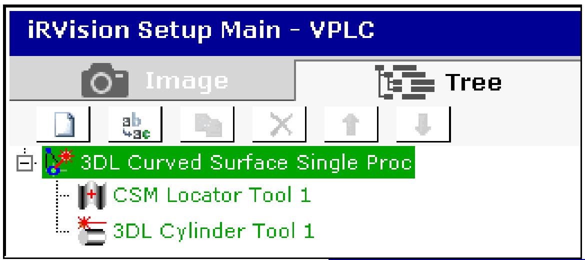
⇩

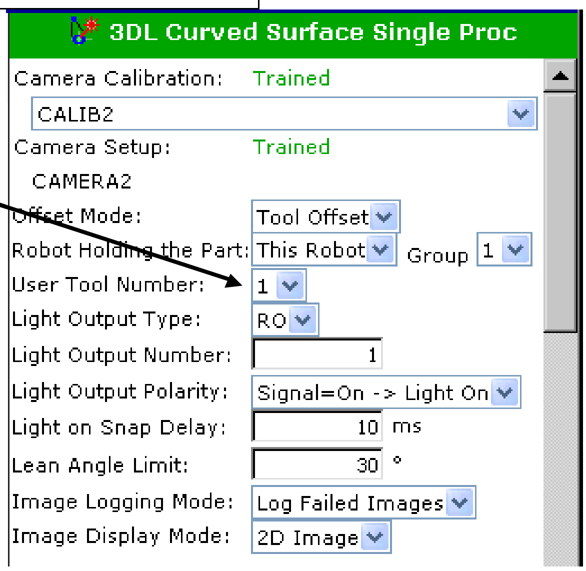
5. Select [3DL Curved Surface Single Proc], which is the top of the tree view, and press F3[SNAP] and F4[FIND] to detect the taught model.

⇩

6. Set the reference position.

Teaching the vision process





A tool frame different from one set in [Calibration Grid Frame] must be selected here. Select the tool frame for compensation such as the TCP of the end of arm tooling.

Select [Exposure Mode] for 2D measurement. (Fixed)

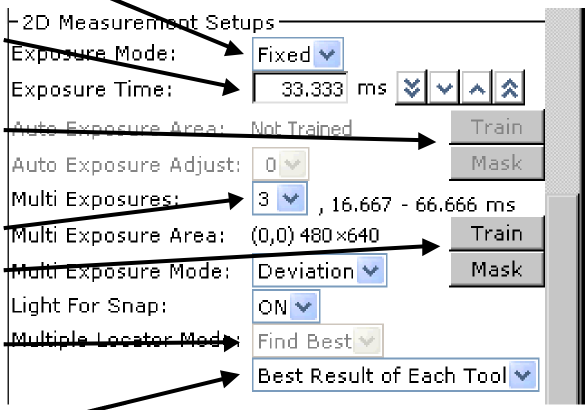
Enter [Exposure Time] to be applied for 2D measurement.

To use "automatic exposure" for 2D measurement, teach the "measurement area" and "mask".

To use "multi exposure" for 2D measurement, select the number of images to be combined and teach the "measurement area" and "mask".

Select which locator tools to execute in the case that multiple locator tools have been made.

Select which results of each locator tool to use in the case that the tool has multiple results.

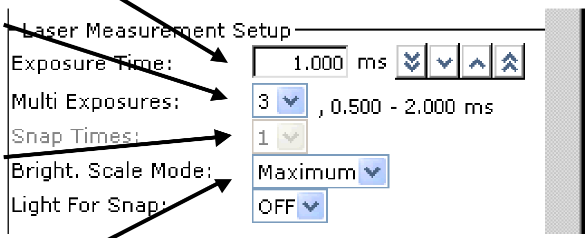


Enter [Exposure Time] to be applied for laser measurement.

Select the number of images to be combined for "multi exposure" for laser measurement in [Multi Exposures].

To snap multiple images during one exposure time for laser measurement, select a number in [Snap Times].

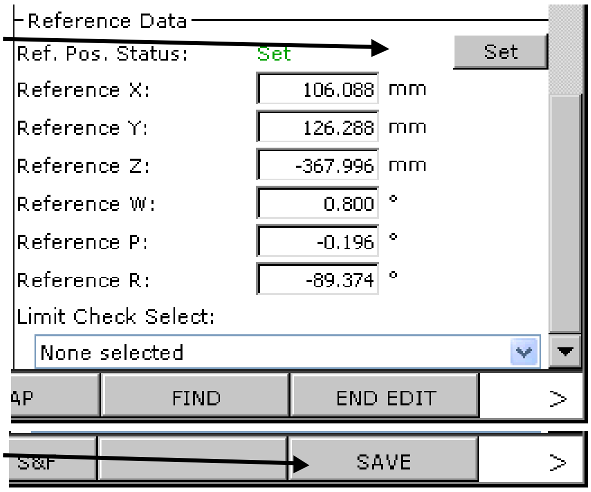
Select [Brightness Scaling Mode] when the value in [Multi Exposures] or [Snap Times] for laser measurement is 2 or greater.



Then, teach the Curved Surface Locator Tool and 3DL Cylinder Command Tool. For details of the teaching procedure, please refer to Chapter 3 "TEACHING EXAMPLE". After teaching all command tools (Curved Surface Locator Tool and 3DL Cylinder Command Tool), press F3[SNAP] and F4[FIND] of the vision process to detect the workpiece. When the workpiece is detected correctly, set the reference position.

Immediately after measuring the workpiece by pressing F3[SNAP] and F4[FIND], click the [Set Ref. Pos.] button.

Press F10[SAVE] to save modifications.



6.2.7 Creating and Teaching a Robot Program

In the sample program below, a vision process for the 3DL Curved Surface Single Vision Process named "VPLC" is used. The sample program can be used to take out, for example, circular cylindrical castings. The robot compensates the tool offset according to the measurement result. After supplying the workpiece to the machine, the robot tries to detect another workpiece.

```
 1:  UFRAME_NUM=1
 2:  UTOOL_NUM=1
 3:J P[1:Home] 30% FINE
 4:
 5:  !Grasp
 6:  LBL[10]
 7:L P[2:Approach] 800mm/sec CNT100
 8:L P[3:Grasp] 200mm/sec FINE
 9:L P[4:Retract] 800mm/sec CNT100
10:
11:  !Measurement
12:L P[5:Measurement Pos] 800mm/sec FINE
13:  WAIT    .30(sec)
14:  VISION RUN_FIND 'VPLC'
15:  VISION GET_OFFSET 'VPLC' VR[1] JMP LBL[999]
16:
17:  !Place
18:L P[6:Approach] 800mm/sec CNT100 VOFFSET, VR[1]
19:L P[7:Place] 200mm/sec FINE VOFFSET, VR[1]
20:L P[8:Retract] 800mm/sec CNT100 VOFFSET, VR[1]
21:  JMP LBL[10]
22:
23:  !No workpiece is detected
24:  LBL[999]
25:  ***
```

Specify the application frame number set in calibration data.

Set the same number as for the "tool frame for compensation" set in the vision process.

Wait for robot-vibration to reduce.

Execute measurement.

Get compensation data of the measurement result.

Execute placement operation, compensating the tool offset.

Add exception processing when no workpiece is detected.

NOTE

Measurement is performed after the robot reaches the taught position on the last motion. If there is vibration in the robot left, it might cause a negative effect on the accuracy of the measurement. In such cases, please use 'WAIT' or 'acceleration override' to minimize the vibration.

6.2.8 Checking Robot Compensation Operation

Check that a workpiece gripped by the robot can be detected and positioned at a desired location properly. At first, decrease the override of the robot to check that the logic of the program is correct. Next, increase the override and cycle the program again to check its operation.

7 3DL CROSS SECTION VISION PROCESS

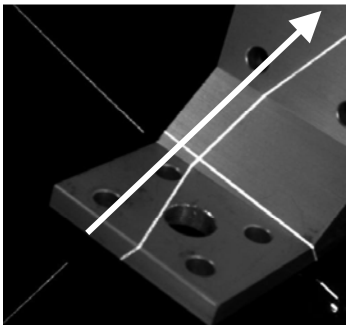
The 3DL Cross-Section Vision Process measures the 3D position of a predetermined section of a workpiece by generating an image of the cross-section illuminated by the laser of the 3D Laser Vision Sensor, and detecting the feature of the cross-section image.
This function can be used particularly when the target workpiece does not meet the following condition required by other 3D Laser Vision Sensor measurement functions: Workpieces should have the same plane with a size of about at least 20-mm diameter area in the field of view of the camera to allow laser slit beams to be detected, and have features detectable by the 2D detection function in the field of view of the camera when a 3DL Plane Command Tool is executed.
This function can output the Measurement Position only, however, while other 3D Laser Vision Sensor measurement functions can output compensation data for compensating robot operation. This is because:

- Since the target compensation using the points on the cross-section differs depending on the application, this function can be used more flexibly as a result by customizing the robot program for each application.

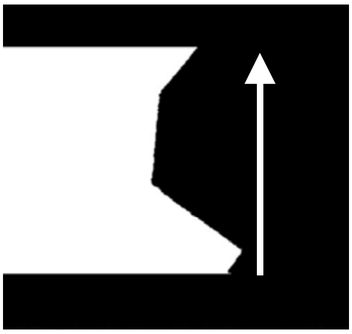
For the above reason, to compensate robotic handling of the workpiece, it is necessary to perform measurement as many times as required, synthesize the measurement results, and calculate compensation data. For whether the 3D Laser Vision Sensor is applicable for a specific application and the required robot compensation method, contact FANUC.

What is a cross-section image?

Information consisting of 3D points obtained by illuminating the laser on a workpiece is projected as an image on the laser plane. The right figure of the following two figures shows a cross-section image. The left figure shows an image when the laser is illuminated on a workpiece. The arrow indicates the correspondence with the cross-sectional image in the right figure.



Laser image on a workpiece



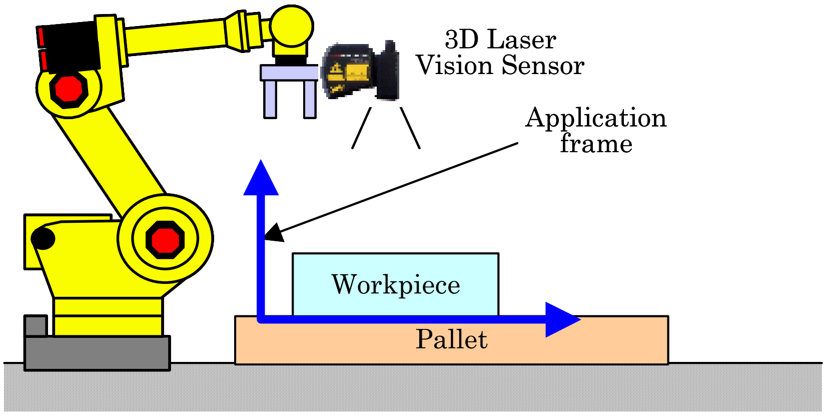
Cross-section image

This chapter describes the procedure to set up the 3DL Cross Section Vision Process using the following two application examples. For details of the setup procedures and teaching procedures, please refer to Chapter 3 “TEACHING EXAMPLE”.

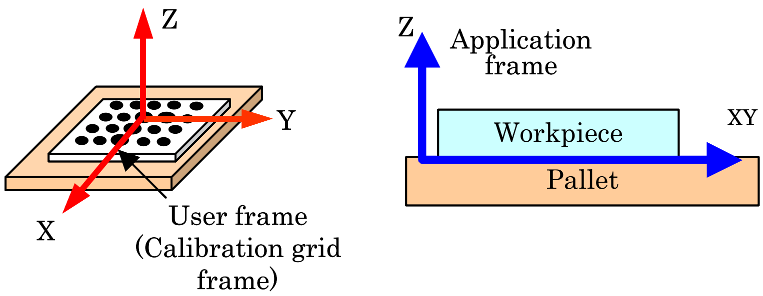
(1) Robot-mounted camera + fixed frame offset
(2) Fixed sensor + tool offset

7.1 SETUP FOR "ROBOT-MOUNTED CAMERA + FIXED FRAME OFFSET"

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



Setup for "robot-mounted camera + fixed frame offset" includes setting the "calibration grid frame" and the "application frame" in a user frame with an arbitrary number. The "Calibration grid frame" can be set easily and correctly using the camera of the 3D Laser Vision Sensor (grid frame setting function).

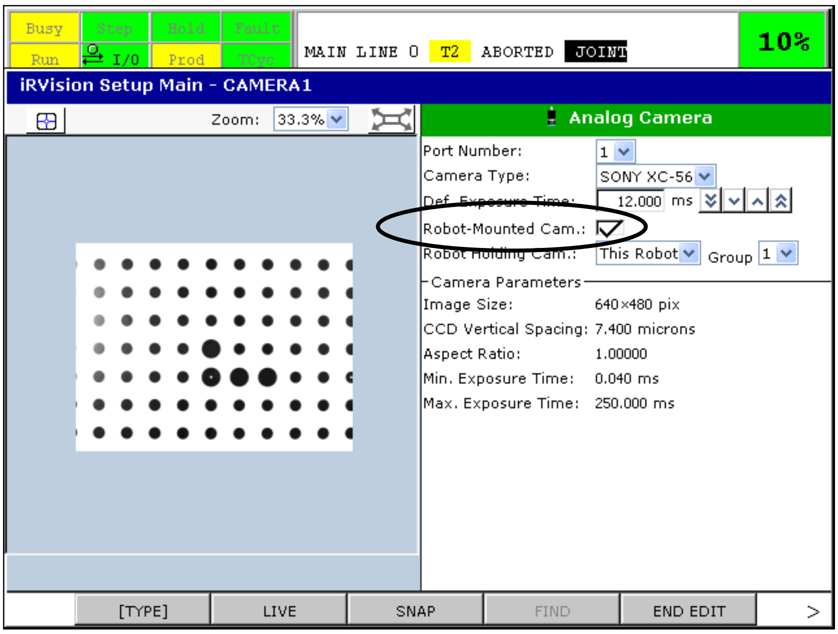


Use the following setup procedure for “robot-mounted camera + fixed frame offset”.

1. Create and teach camera setup tool.
2. Set the calibration grid frame with an arbitrary number.
   - Use the vision grid pattern setting for this setting.
3. Set the TCP at the tip of the touch-up pin mounted on the end of arm tooling.
   - The TCP set here is used to set the “application frame”.
4. Set the user frame for the application frame with an arbitrary number.
5. Create and teach camera calibration tool.
6. Create and a teach vision process.
7. Create and teach the robot program.
8. Check the robot compensation operation.

7.1.1 Creating and Teaching Camera Setup Tool

With *i*RVision, items such as camera type are set in camera setup tool. If you want to use the 3D Laser Vision Sensor as a robot-mounted camera, be sure to check the [Robot-Mounted Camera] check box.



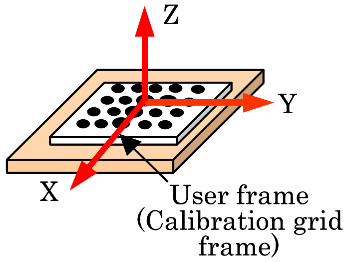
7.1.2 Setting Calibration Grid Frame

When a calibration grid is installed on a fixed place, set the calibration grid frame in a user frame with an arbitrary number. For this setting, use the grid frame setting function. After securing the calibration grid, execute the grid frame setting function. For details of the grid frame setting function, please refer to “10.2 GRID FRAME SETTING“ in “*i*RVision OPERATOR’S MANUAL (Reference)”. Note that the user frame for calibration grid frame differs from the “Application Frame” described in the following subsection.

In addition to the method of using the grid frame setting function, the following method is also available: Touch up the grid with a pointer mounted on the robot end of arm tooling precisely, then set a user frame as shown in the figure below. Please refer to “11.2.1 Setting Based on Touch-up” in “*i*RVision OPERATOR’S MANUAL (Reference)”. In this case, the operation described in the next subsection, “Setting the TCP of the Robot” must be performed in advance. The TCP setting precision and touch-up precision directly affect the compensation precision. Set the TCP and touch up the grid precisely.

The calibration grid can be installed on any surface. At this time, the X-Y plane of the calibration grid should be matched with the X-Y plane of the world frame of the robot unless the robot is installed at a tilt or any other special situations prevent these planes from matching. When these planes match, calibration can be performed more easily than when these planes do not match.

It can be removed after the completion of calibration, but it is strongly recommended that the grid be left installed in the system. This is because if a displacement should occur in calibration for the 3D Laser Vision Sensor due to a factor such as impact, recovery work can be simplified greatly. If the calibration grid must be removed, its installation position should be able to be restored exactly, which can reduce the labor for recovery. For the detailed setup procedure, please refer to “8.1 AUTOMATIC RE-CALIBRATION”.



7.1.3 Setting the TCP of the Robot

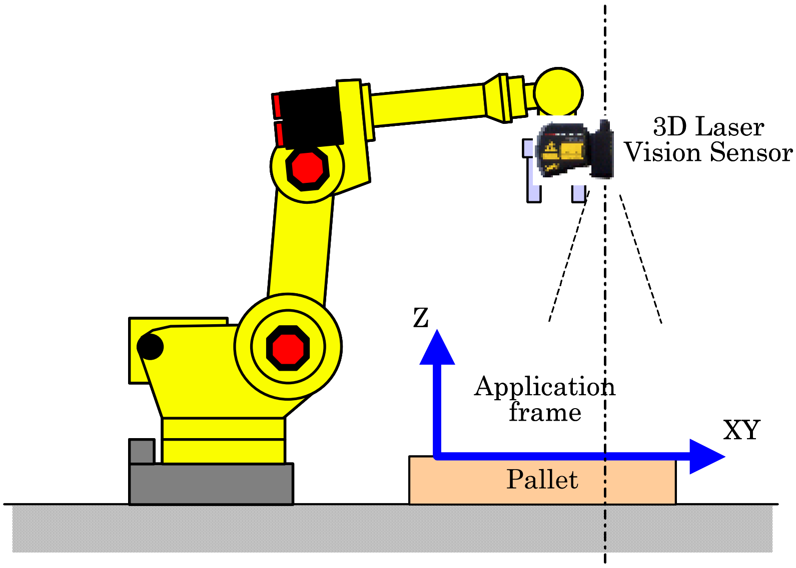
Set the TCP precisely on the tip of the pointer mounted on the end of arm tooling. Set the TCP in a tool frame with an arbitrary number. To set the tool frame, use [Tool Frame Setup / Three Point].

To reuse a TCP set at re-calibration, the reproducibility of the pointer mounting is required. If the reproducibility of the pointer mounting is not assured, a TCP needs to be set each time the pointer is mounted.

7.1.4 Setting an Application Frame

Set a user frame to be used as the reference for the robot compensation operation. The measurement result is output as values in the user frame that has been set.

Set a user frame for a plane such as a pallet using the set robot TCP. For this setting, use [User Frame Setup / Three Point] unless there is specific reason.



Sharing User Frame

When two or more robots work together, it is necessary to configure the system so that these robots share physically the same user frame. This is called the sharing of the user frame. Specifically, the sharing of the user frame is needed in the following cases:

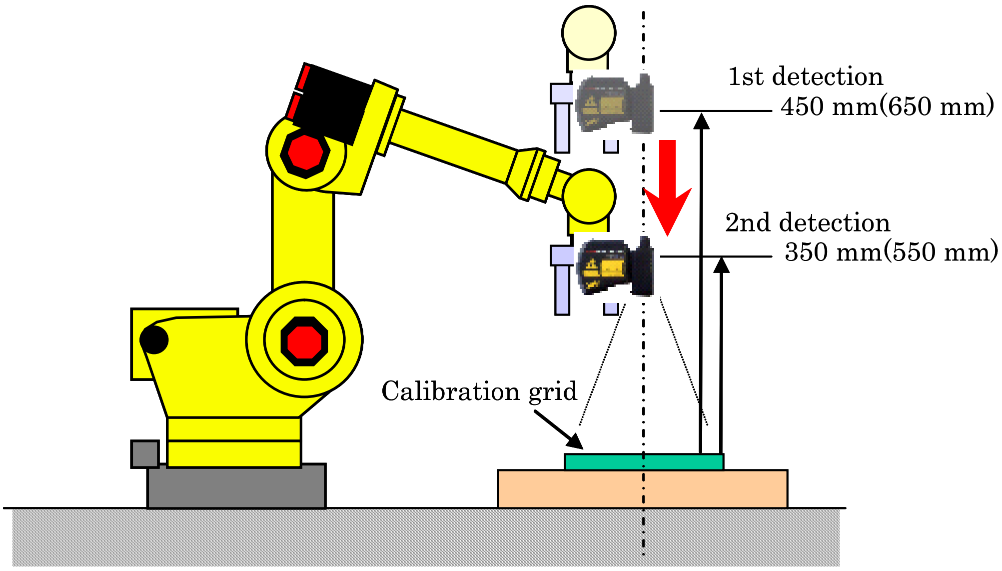
- Multiple robots are offset with a single set of offset data.
- The robot to be offset is different from the robot that has the camera.

User frame sharing requires that all robots use the same user frame number. For example, user frame 5 of robot 1 needs to be physically the same as user frame 5 of robot 2.

> ⚠ **CAUTION**
> If robots share user frames of different numbers, *i*RVision cannot offset the robots correctly. Make sure that the robots share the same user frame number.

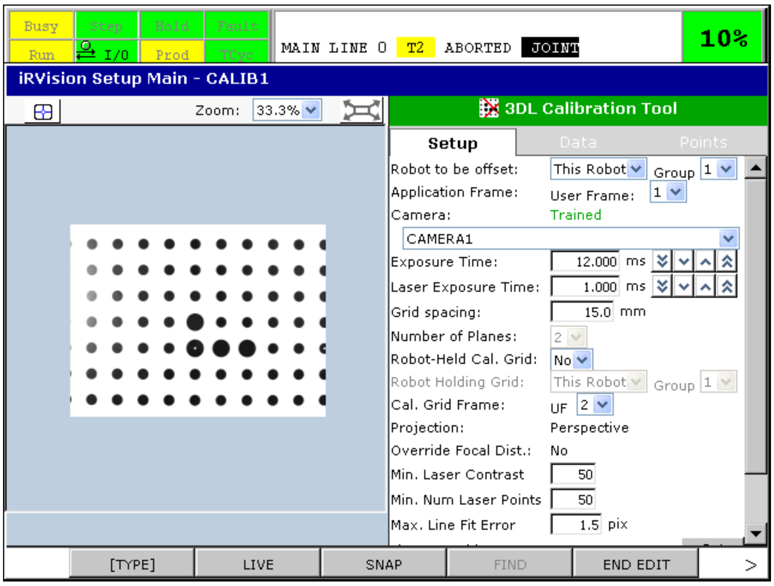
7.1.5 Creating and Teaching Camera Calibration Tool

To use the 3D Laser Vision Sensor, 3DL calibration using a calibration grid is required. For a robot-mounted camera, perform 2-plane calibration by moving the robot end of arm tooling up and down as shown in the figure below. For calibration, the appropriate distances between the 3D Laser Vision Sensor and calibration grid are near 350mm and 450mm (near 550mm and 650mm if the standoff of the 3D laser sensor is 600mm). When the calibration grid is detected with the robot and is made to have the same posture as it does when the workpiece is detected, the precision is increased.



After one set of calibration tool is created with 3DL vision calibration, another set of calibration tool does not need to be created even after the camera Measurement Position is changed. This is because *i*RVision considers the current robot position when calculating the position of the workpiece.

The teach screen for 3DL calibration is shown below. A calibration grid image is displayed.



Select the number of the "user frame" set as the "application frame" in [User Frame].

Enter [Exposure Time] to be applied for grid detection.

Enter [Laser Exposure Time] to be applied for laser measurement.

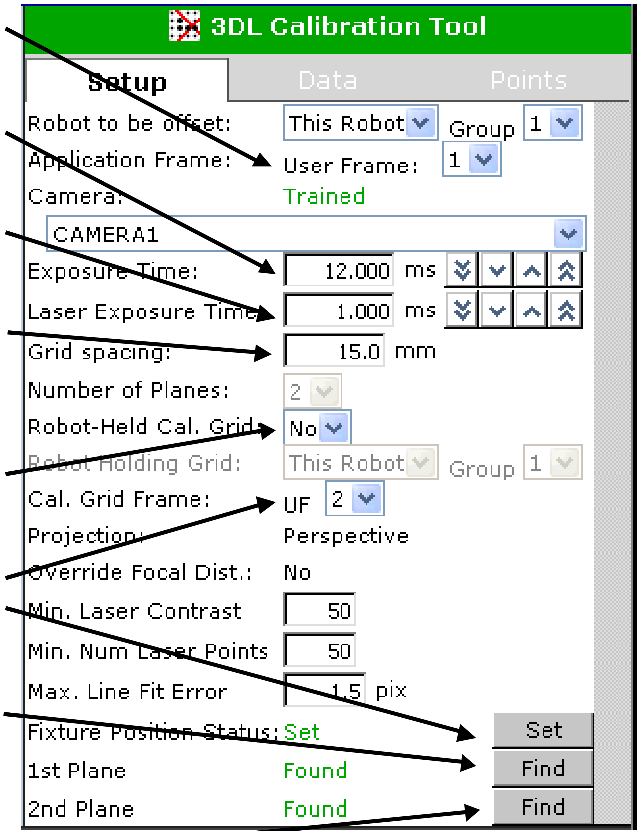
Enter [Grid Spacing] between grid points on the calibration grid.

Select [No] if the calibration grid is a fixed position.

Select the number of the "user frame" in which "calibration grid frame" is set in [User Frame], then click the [Set] button.

Move the camera from the calibration grid by a proper distance, then click the [Find] button for [1st Plane].

Change the distance between the camera and calibration grid, then click the [Find] button for [2nd Plane].

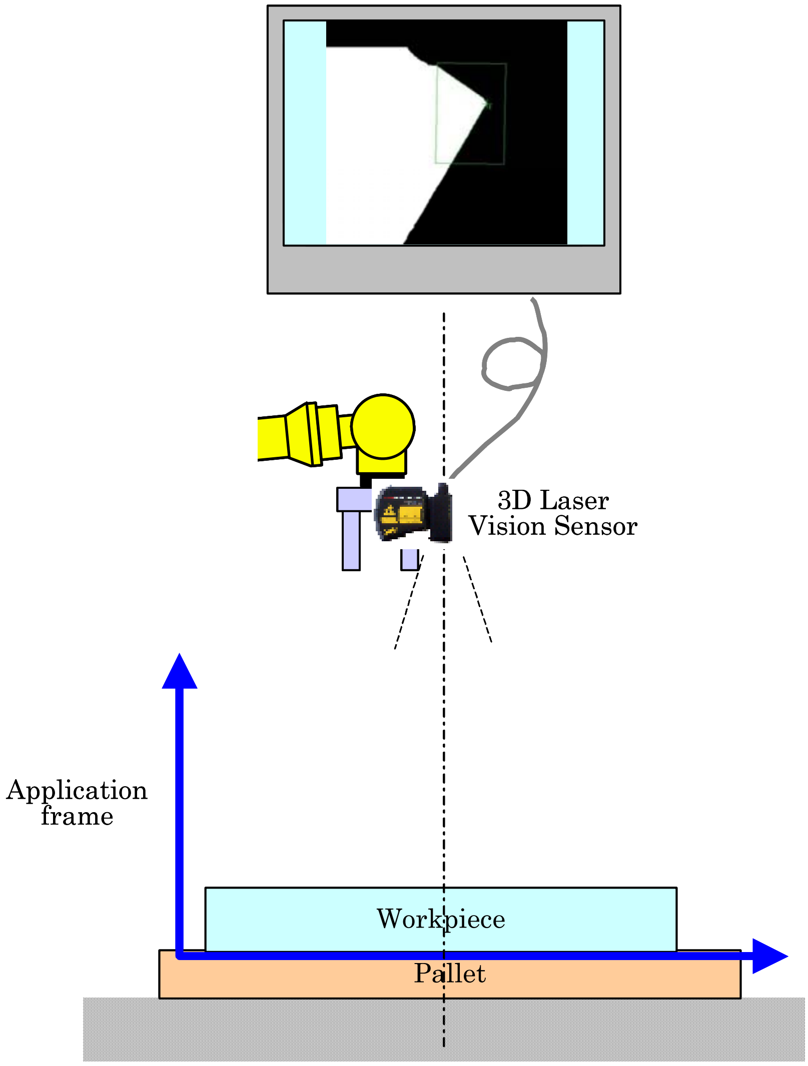


⚠ CAUTION

1. During calibration, how the camera of the 3D Laser Vision Sensor is positioned relative to the user frame (whose number is selected in [Application Frame]) is stored. This information is used for actual measurement. After calibration, do not change the number or the content of the application frame. If you change them, recalibrate the sensor. Then teach the reference positions of the vision processes which use the camera calibration tool.
2. When recalibrating a camera, if you change the position of the calibration grid, set the user frame of the calibration grid frame again. Then click the [Set] button for the calibration grid frame and recalculate it.

7.1.6 Creating and Teaching a Vision Process

Create a vision process for the “3DL Cross-Section Vision Process”.



Use the following procedure to teach a vision process for the “3DL Cross-Section Vision Process”.

1. Specify calibration tool, and set parameters.

⇩

2. Move the robot to the measurement position and teach the 3DL Cross-Section Vision Process

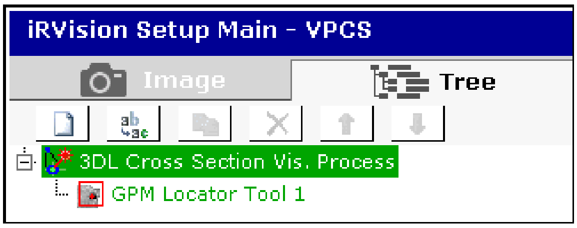
⇩

3. Generate a cross-section image and teach the GPM Locator tool.

⇩

4. Select the [3DL Cross-Section Vision Process], and press F3[SNAP] and F4[FIND] to detect the taught model. When the model can be detected correctly, operation is complete.

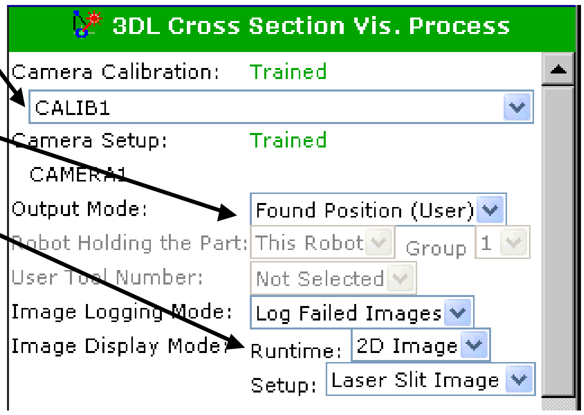
Teaching the vision process



Select “calibration tool" of the camera.

Select [Found Position (User)].

[Image Display Mode]:
[Runtime]: Select an image to be displayed on the runtime monitor.



Teach the measurement area for laser measurement.

If there is an unnecessary region in the measurement area, teach a mask.

Select [Laser Number] for generating a cross-section image. In a laser slit image, 1: From the lower left to the upper right, 2: From the upper left to the lower right

Enter [Effective Z Range] for laser measurement.

Enter [Exposure Time] for laser measurement.

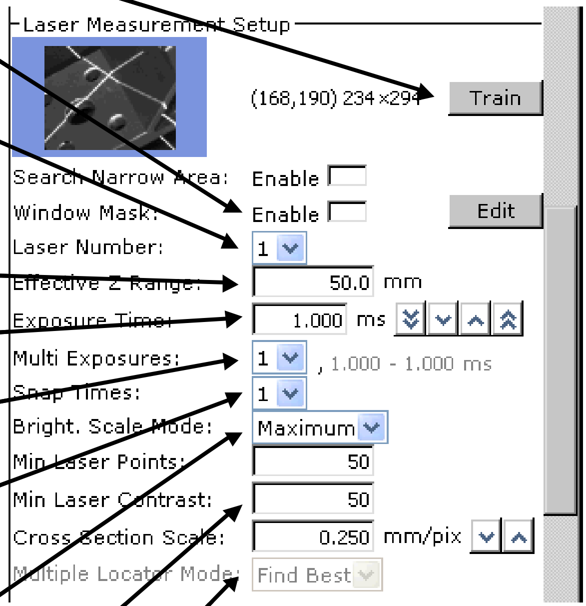
Select the number of images to be combined for "multi exposure" for laser measurement.

To snap multiple images during one exposure time for laser measurement, select a number in [Snap Times].

Select [Brightness Scaling Mode] when the value in [Multi Exposures] or [Snap Times] for laser measurement is 2 or greater.

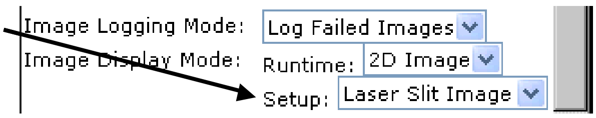
Set [Min Num Laser Points], [Min Laser Contrast], and [Scale of Cross Section] for laser measurement as required.

Select [Multiple Locator Find Mode] if two or more GPM Locator Tools are taught.

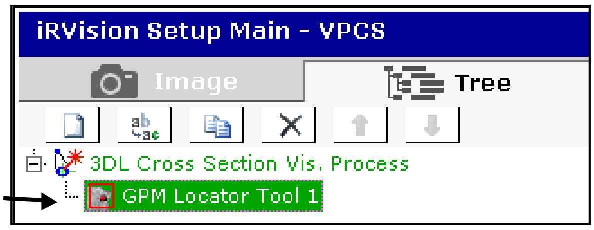


After the completion of the above setting, select [Cross Section Image] for [Setup] in [Image Display Mode]. A cross-section image of the workpiece generated by the laser selected in [Laser Number] is displayed. In this state, teach the GPM Locator Tool.

[Image Display Mode]:
[Setup]: Select [Cross Section Image] to be used for teaching.

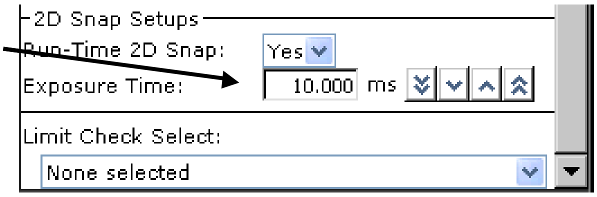


Select [GPM Locator Tool].



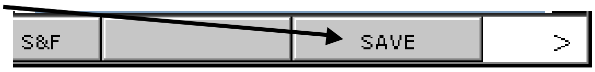
SUPPLEMENT
Set the model origin correctly because the position of the model origin specified by the GPM Locator Tool is used as the final detection position.

When [Fixed] is selected for the 2D image, enter [Exposure Time].



Finally, configure the 2D image settings. These 2D image settings are used only for obtaining an image to be displayed. Changing them does not affect the actual measurement result.

After the setting is complete, be sure to press F10[SAVE] to save the modifications.



7.1.7 Creating and Teaching a Robot Program

This sample is used to measure four points on a window frame; grip a windshield positioned in advance, and put the panel on the auto body. Four vision processes using the 3DL Cross-Section Vision Process are prepared and named “VPCS1” to “VPCS4”, respectively. Calibration tool calculated by the robot program is used not with the vision offset command, but with the position compensation command. How many measurement points are required differs depending on the actual application.

This sample uses the following registers:
R [4]: Reference execution flag
PR [1] to PR [4]: Contains measurement points 1 to 4.
PR [5]: Contains the combined result of measurement points 1 to 4.
PR [6]: Contains the combined result of reference execution.
PR [10]: Contains compensation data.
VR [1]: Temporarily contains the result of each measurement.
In addition, user frame 9 is temporarily used.

In This sample, the program which combines the measurement results of the four points is prepared according to the actual application.
For whether the 3D Laser Vision Sensor is applicable for a specific application and the required robot compensation method, contact FANUC.

```
UFRAME_NUM=1
UTOOL_NUM=1
J P[1:Home] 30% FINE

!Measurement
LBL[10]
L P[5:Measurement Pos1] 800mm/sec FINE
WAIT     .30(sec)
VISION RUN_FIND 'VPCS1'
VISION GET_OFFSET 'VPCS1' VR [1] JMP LBL [999]
PR[1]=VR[1].FOUND_POS[1]

L P[6:Measurement Pos2] 800mm/sec FINE
WAIT     .30(sec)
VISION RUN_FIND 'VPCS2'
VISION GET_OFFSET 'VPCS2' VR [1] JMP LBL [999]
PR[2]=VR[1].FOUND_POS[1]

L P[7:Measurement Pos3] 800mm/sec FINE
WAIT     .30(sec)
VISION RUN_FIND 'VPCS3'
VISION GET_OFFSET 'VPCS3' VR [1] JMP LBL [999]
PR[3]=VR[1].FOUND_POS[1]

L P[8:Measurement Pos4] 800mm/sec FINE
WAIT     .30(sec)
VISION RUN_FIND 'VPCS4'
VISION GET_OFFSET 'VPCS4' VR [1] JMP LBL [999]
PR[4]=VR[1].FOUND_POS[1]

CALL ********(1, 2, 3, 4, 5)
CALL OFS_RJ3 (4, 5, 0, 6, 0, 10, 0)
UFRAME[9] = PR[10]
PR[10] = UFRAME[9]

! Grasp windshield
L P[9:Approach] 800mm/sec CNT100
L P[10:Grasp] 200mm/sec FINE
L P[11:Retract] 800mm/sec CNT100
 ;
! Place windshield
L P[12:Approach] 800mm/sec CNT100 OFFSET, PR[10]
L P[13:Place] 200mm/sec FINE OFFSET, PR[10]
L P[14:Retract] 800mm/sec CNT100 OFFSET, PR[10]
END

!No workpiece is detected
LBL[999]
*
```

Specify the application frame number set in calibration data.

Wait for robot-vibration to reduce.

Measure point 1.

Get the point 1 measurement result.

Wait for robot-vibration to reduce.

Measure point 2.

Get the point 2 measurement result.

Wait for robot-vibration to reduce.

Measure point 3.

Get the point 3 measurement result.

Wait for robot-vibration to reduce.

Measure point 4.

Get the point 4 measurement result.

Prepare the program which combines the measurement results of the four points.

Calculate compensation data.

Placement operation according to the position and posture of the auto body.

Add exception processing when no workpiece is detected.

NOTE

Measurement is performed after the robot reaches the taught position on the last motion. If there is vibration in the robot left, it might cause a negative effect on the accuracy of the measurement. In such cases, please use 'WAIT' or 'acceleration override' to minimize the vibration.

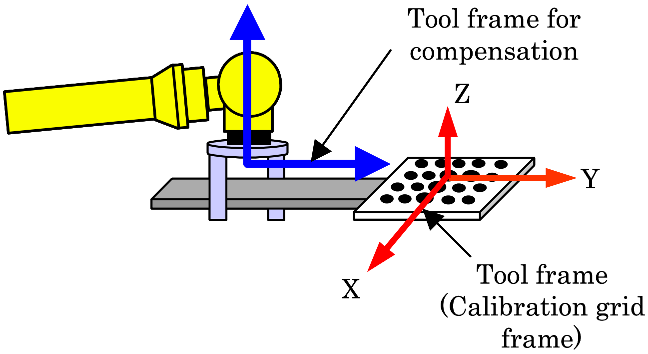
7.1.8 Checking Robot Compensation Operation

Check that as many points as required are measured, compensation data is calculated using the robot program, and the robot can handle the workpiece exactly. At first, decrease the override of the robot to check that the logic of the program is correct. Next, increase the override and cycle the program again to check its operation.

7.2 SETUP FOR “FIXED SENSOR + TOOL OFFSET”

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

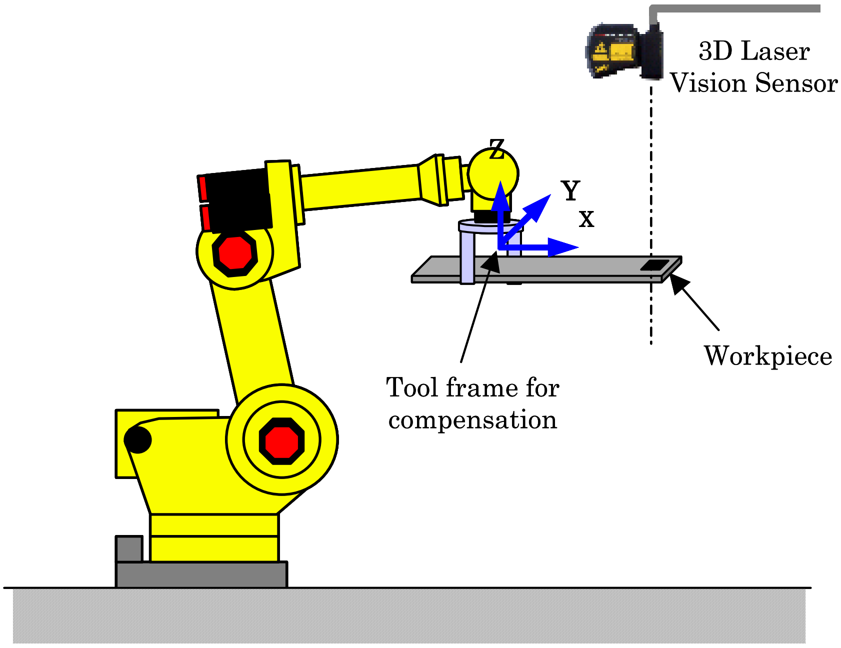
Setup for “fixed sensor + tool offset” includes setting “calibration grid frame” and “tool frame for compensation” in a tool frame with an arbitrary number. “Calibration grid frame” can be set easily and correctly with the setting using the camera of the 3D Laser Vision Sensor (grid frame setting function).



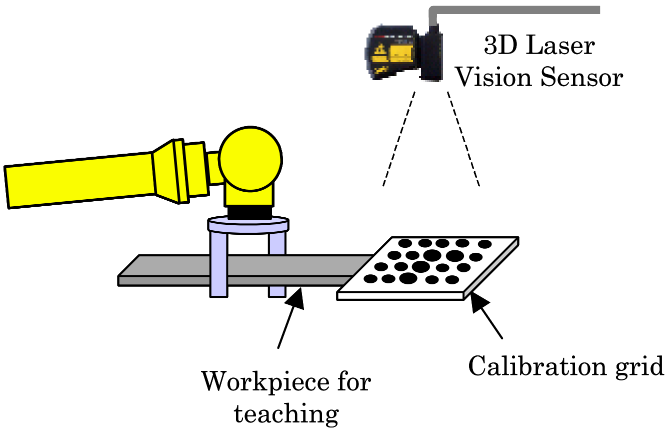
Use the following setup procedure for “fixed sensor + tool offset”.

1. Create and teach camera setup tool.
2. Set the calibration plate installation information in the tool frame with an arbitrary number.
   - Use the vision grid pattern setting for this setting.
3. Set the user frame as required.
   - Set the application frame. The world frame may be used. In this case, setting is not required.
4. Create and teach camera calibration tool.
5. Set tool frame for compensation in tool frame with an arbitrary number.
6. Create and teach the vision process.
7. Create and teach the robot program.
8. Check the robot compensation operation.

An example layout for "fixed sensor + tool offset" is given below. A workpiece gripped by the robot is viewed by the fixed sensor to measure the amount of tool offset.

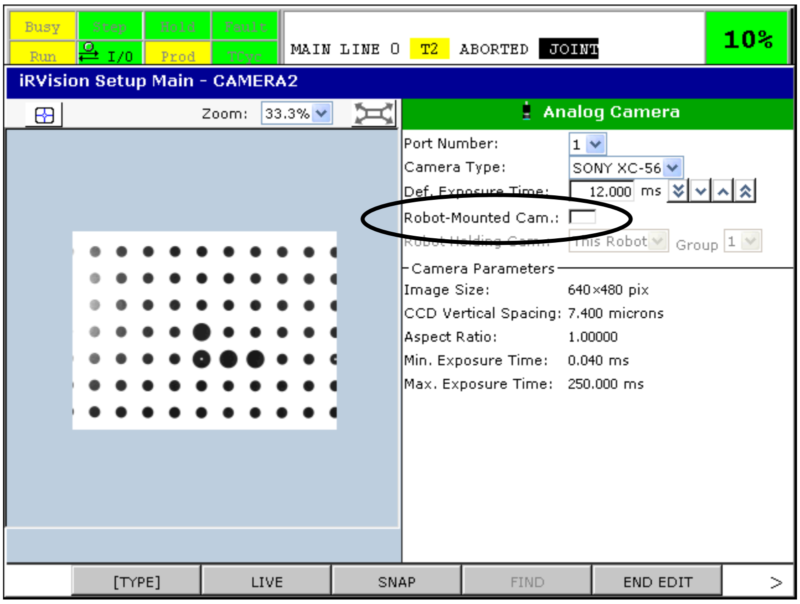


It is recommended that a calibration grid be mounted on the robot end of arm tooling or a teaching workpiece to perform calibration. The figure below shows an example of mounting a calibration grid at a workpiece Measurement Position. Prepare a teaching workpiece that resembles an actual workpiece and can be gripped. Setup work can be simplified by mounting a calibration grid on the teaching workpiece. In either case, the mounting position should be able to be restored exactly. This is because if a displacement should occur in calibration due to a factor such as impact on the 3D Laser Vision Sensor, recovery work can be simplified greatly.



7.2.1 Creating and Teaching Camera Setup Tool

With *i*RVision, items such as camera type are set in camera setup tool. If you want to use the 3D Laser Vision Sensor as a fixed sensor, be sure to uncheck the [Robot-Mounted Camera] check box.

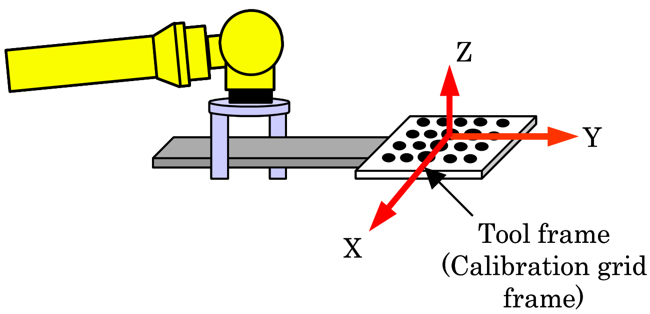


7.2.2 Setting Calibration Grid Frame

When a calibration grid is mounted on the robot end of arm tooling, set the calibration grid frame in a tool frame with an arbitrary number. For this setting, use the grid frame setting function. After securing the calibration grid, execute the grid frame setting function. For details of the grid frame setting function, please refer to “10.2 GRID FRAME SETTING“ in “*i*RVision OPERATOR’S MANUAL (Reference)”.

In addition to the method of using the grid frame setting function, the following method is also available: Touch up the grid precisely with a pointer secured within the operation range of the robot, then set a tool frame as shown in the figure below. Please refer to “11.2.1 Setting Based on Touch-up” in “*i*RVision OPERATOR’S MANUAL (Reference)”. In this case, the touch-up precision affects the compensation precision, and touch up the grid precisely.

It is strongly recommended that the installation position be able to be restored exactly. This is because if a displacement should occur in calibration due to a factor such as impact on the 3D Laser Vision Sensor, recovery work can be simplified greatly. For the detailed setup procedure, please refer to “8.1 AUTOMATIC RE-CALIBRATION”.



7.2.3 Setting an Application Frame

With tool offset, the application frame is specified the robot's user frame to be used for camera calibration. Under normal conditions, specify the number “0” as the robot base frame (world). But when two or more robots work together, set the sharing user frame and specify the number of it.

Set a user frame for a plane such as a pallet using the set robot TCP. For this setting, use [User Frame Setup / Three Point] unless there is specific reason.

Sharing User Frame

When two or more robots work together, it is necessary to configure the system so that these robots share physically the same user frame. This is called the sharing of the user frame. Specifically, the sharing of the user frame is needed in the following cases:

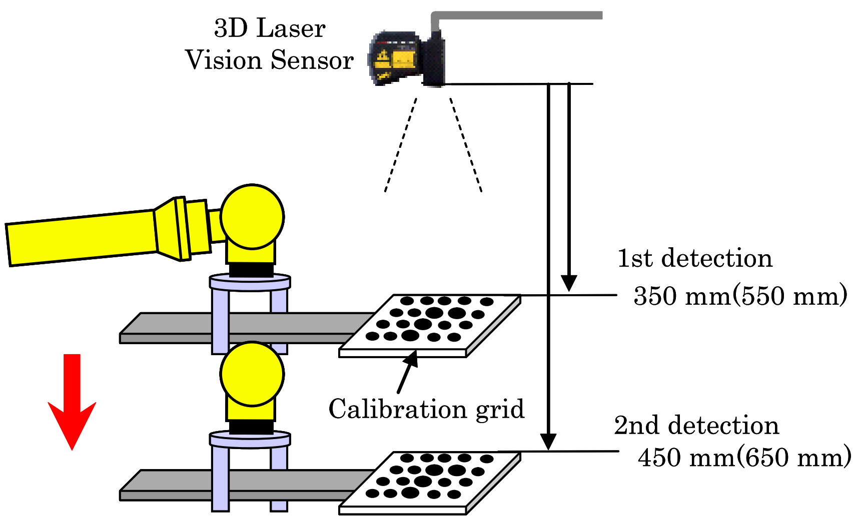
- Multiple robots are offset with a single set of offset data.
- The robot to be offset is different from the robot that has the camera.

User frame sharing requires that all robots use the same user frame number. For example, user frame 5 of robot 1 needs to be physically the same as user frame 5 of robot 2.

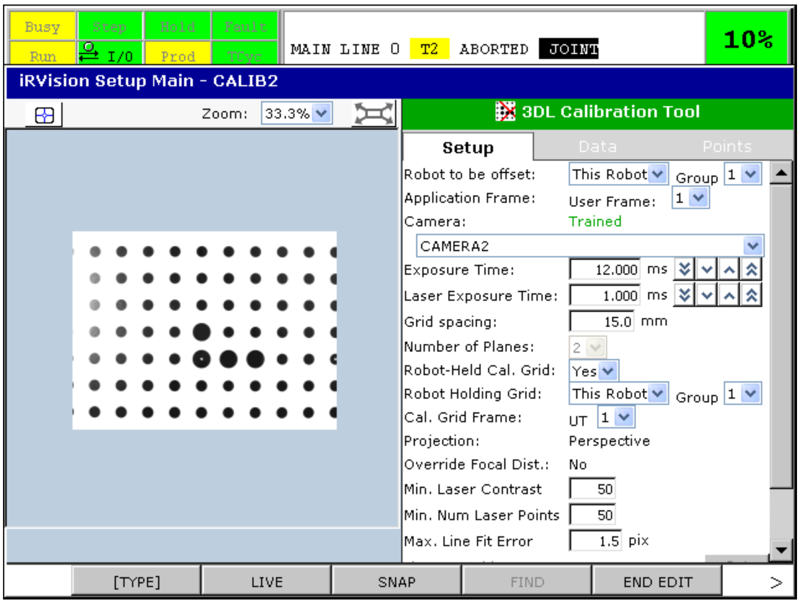
> ⚠ **CAUTION**
> If robots share user frames of different numbers, *i*RVision cannot offset the robots correctly. Make sure that the robots share the same user frame number.

7.2.4 Creating and Teaching Camera Calibration Tool

To use the 3D Laser Vision Sensor, 3DL calibration using a calibration grid is required. For a fixed sensor, perform 2-plane calibration by moving the robot end of arm tooling up and down as shown in the figure below. For calibration, the appropriate distances between the 3D Laser Vision Sensor and calibration grid are near 350 mm and 450 mm (near 550 mm and 650 mm if the standoff of the 3D laser sensor is 600mm). When the calibration grid is detected with the robot and is made to have the same posture as it does when the workpiece is detected, the precision is increased.



The teach screen for the 3DL calibration is shown below. A calibration grid image is displayed.



Select “application frame”. The world frame may be used. In this case, select 0. The example shows 1.

Enter [Exposure Time] to be applied for 2D measurement.

Enter [Laser Exposure Time] to be applied for laser measurement.

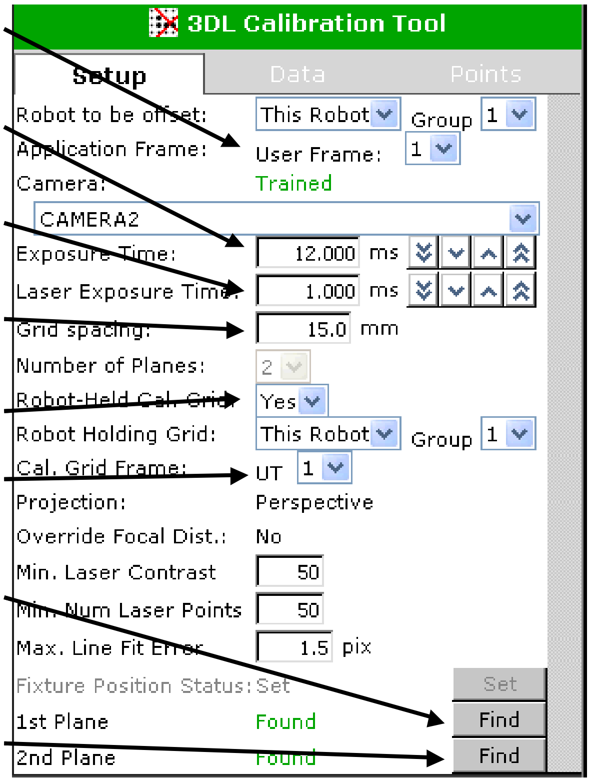
Enter [Grid Spacing] between grid points on the calibration grid.

Select [Yes].

Select the number of the “tool frame” in which “calibration grid frame” is set in [Tool Frame].

Move the camera from the calibration grid by a proper distance, then click the [Find] button for [1st Plane].

Change the distance between the camera and calibration grid, then click the [Find] button for [2nd Plane].

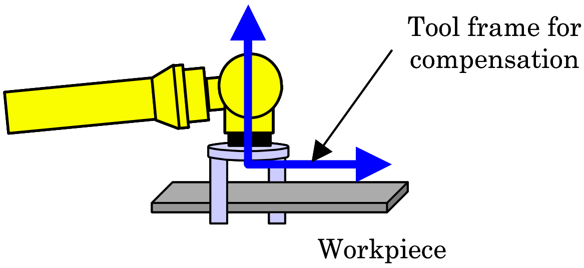


⚠ CAUTION

During calibration, how the camera of the 3D Laser Vision Sensor is positioned relative to the user frame (whose number is selected in [Application Frame]) is stored. This information is used for actual measurement. After calibration, do not change the number or the content of the application frame. If you change them, recalibrate the sensor. Then teach the reference positions of the vision processes which use the camera calibration tool.

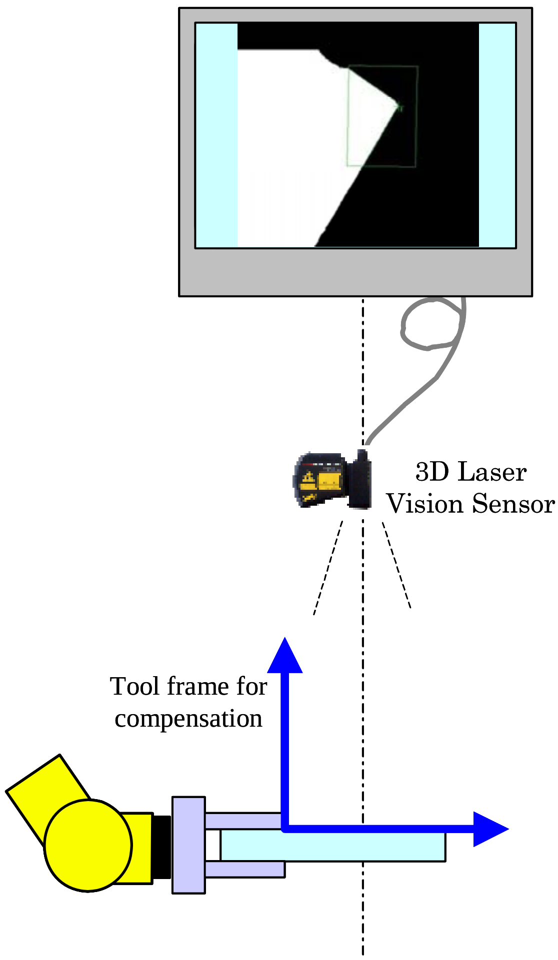
7.2.5 Setting a tool frame for compensation

Set a tool frame to be used as the reference of the tool offset compensation operation by the robot. The detection position to calculate tool offset compensation data is output as values in the tool frame. If a value of 0 is selected for the frame number, the robot face plate frame is used. If a value other than 0 is selected, set the tool frame. To set the tool frame, use [Tool Frame Setup / Six Point].



7.2.6 Creating and Teaching a Vision Process

Create a vision process for the “3DL Cross-Section Vision Process”.



Use the following procedure to teach a vision process for the 3DL Cross-Section Vision Process.

1. Set the tool frame for compensation with an arbitrary number.

⇩

2. Specify the calibration tool and set parameters.

⇩

3. Move the robot to the measurement position and teach the 3DL Cross-Section Vision Process

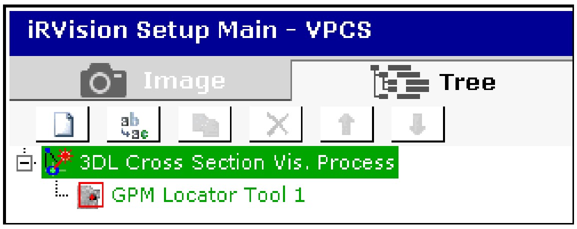
⇩

4. Generate a cross-section image and teach the GPM Locator Tool.

⇩

5. Select [3DL Cross-Section Vision Process], which is the top of the tree view, and press F3[SNAP] and F4[FIND] to detect taught model

Teaching the vision process

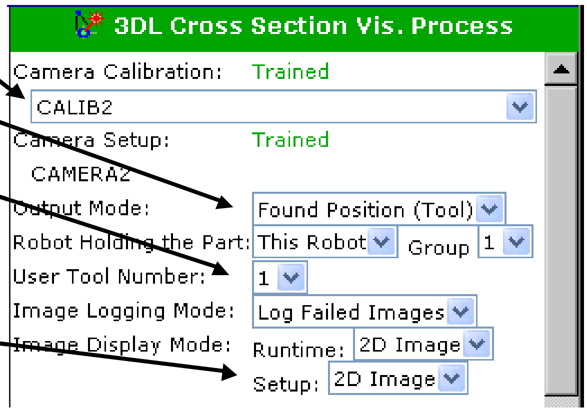


Select "calibration tool" of the camera.

Select [Found Position (Tool)].

A tool frame different from one set in [Calibration Grid Frame] must be selected here. Select the tool frame for compensation such as the TCP of the end of arm tooling.

[Image Display Mode]:
[Runtime]: Select an image to be displayed on the runtime monitor.
[Setup]: Select an image to be used for teaching.



Teach the measurement area for laser measurement.

If there is an unnecessary region in the measurement area, teach a mask.

Select [Laser Number] for generating a cross-section image. In a laser slit image, 1: From the lower left to the upper right, 2: From the upper left to the lower right

Enter [Effective Z Range] for laser measurement.

Enter [Exposure Time] for laser measurement.

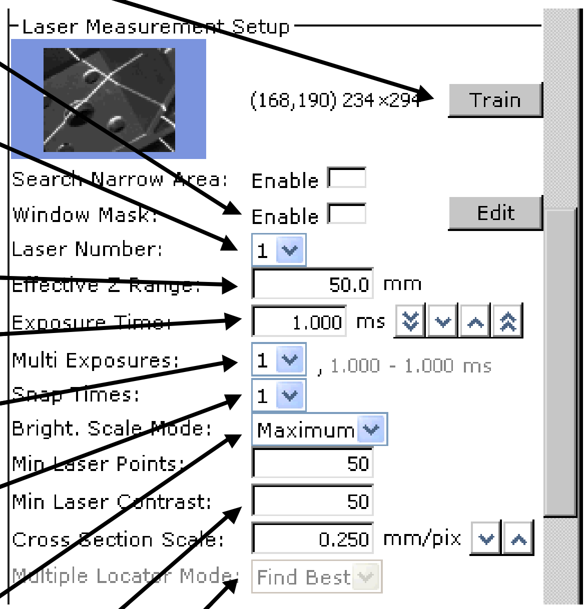
Select the number of images to be combined for "multi exposure" for laser measurement.

To snap multiple images during one exposure time for laser measurement, select a number in [Snap Times].

Select [Brightness Scaling Mode] when the value in [Multi Exposures] or [Snap Times] for laser measurement is 2 or greater.

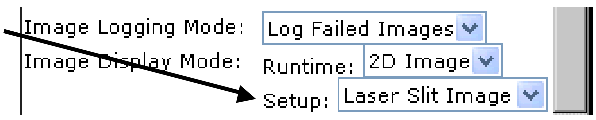
Set [Min Num Laser Points], [Min Laser Contrast], and [Scale of Cross Section] for laser measurement as required.

Select [Multiple Locator Find Mode] if two or more GPM Locator Tools are taught.

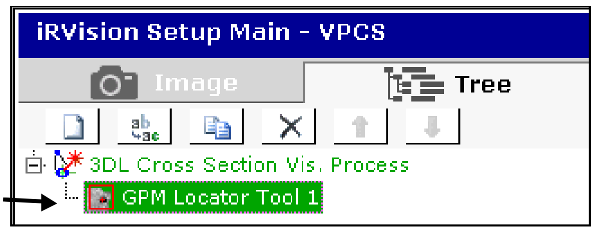


After the completion of the above setting, select [Cross Section Image] for [Setup] in [Image Display Mode]. A cross-section image of the workpiece generated by the laser selected in [Laser Number] is displayed. In this state, teach the GPM Locator Tool.

[Image Display Mode]:
[Setup]: Select [Cross Section Image] to be used for teaching.



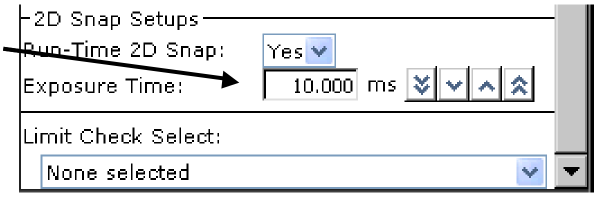
Select [GPM Locator Tool].



SUPPLEMENT

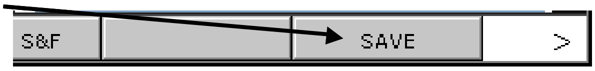
Set the model origin correctly because the position of the model origin specified by the GPM Locator Tool is used as the final detection position.

When [Fixed] is selected for the 2D image, enter [Exposure Time].



Finally, configure the 2D image settings. These 2D image settings are used only for obtaining an image to be displayed. Changing them does not affect the actual measurement result.

After the setting is complete, be sure to press F10[SAVE] to save the modifications.



7.2.7 Creating and Teaching a Robot Program

This example is used to measure four points on a windshield using the fixed 3D Laser Vision Sensor and put the panel on an auto body. Four vision processes using the 3DL Cross-Section Vision Process are prepared and named “VPCS1” to “VPCS4”, respectively. Calibration tool calculated by the robot program is used not with the vision offset command, but with the position compensation command. How many measurement points are required differs depending on the actual application.

This sample uses the following registers:
R[4]: Reference execution flag
PR[1] to PR[4]: Contains measurement points 1 to 4.
PR[5]: Contains the combined result of measurement points 1 to 4.
PR[6]: Contains the combined result of reference execution.
PR[10]: Contains compensation data.
VR[1]: Temporarily contains the result of each measurement.

In This sample, the program which combines the measurement results of the four points is prepared according to the actual application.
For whether the 3D Laser Vision Sensor is applicable for a specific application and the required robot compensation method, contact FANUC.

```
 1:  UFRAME_NUM=1
 2:  UTOOL_NUM=1
 3:J P[1:Home] 30% FINE
 4:
 5:  ! Grasp windshield
 6:  LBL[10]
 7:L P[2:Approach] 800mm/sec CNT100
 8:L P[3:Grasp] 200mm/sec FINE
 9:L P[4:Retract] 800mm/sec CNT100
10:  ;
11:  !Measurement
12:  LBL[10]
13:L P[5:Measurement Pos1] 800mm/sec FINE
14:  WAIT    .30(sec)
15:  VISION RUN_FIND 'VPCS1'
16:  VISION GET_OFFSET 'VPCS1' VR[1] JMP LBL[999]
17:  PR[1]=VR[1].FOUND_POS[1]
18:
19:L P[6:Measurement Pos2] 800mm/sec FINE
20:  WAIT    .30(sec)
21:  VISION RUN_FIND 'VPCS2'
22:  VISION GET_OFFSET 'VPCS2' VR[1] JMP LBL[999]
23:  PR[2]=VR[1].FOUND_POS[1]
24:
25:L P[7:Measurement Pos3] 800mm/sec FINE
26:  WAIT    .30(sec)
27:  VISION RUN_FIND 'VPCS3'
28:  VISION GET_OFFSET 'VPCS3' VR[1] JMP LBL[999]
29:  PR[3]=VR[1].FOUND_POS[1]
30:
31:L P[8:Measurement Pos4] 800mm/sec FINE
32:  WAIT    .30(sec)
33:  VISION RUN_FIND 'VPCS4'
34:  VISION GET_OFFSET 'VPCS4' VR[1] JMP LBL[999]
35:  PR[4]=VR[1].FOUND_POS[1]
36:
37:  CALL ******** (1, 2, 3, 4, 5)
38:  CALL OFS_RJ3 (4, 5, 0, 6, 0, 0, 10)
39:
40:  ! Place windshield
41:L P[6:Approach] 800mm/sec CNT100 Tool_Offset,, PR[10]
42:L P[7:Place] 200mm/sec FINE Tool_Offset,, PR[10]
43:L P[8:Retract] 800mm/sec CNT100 Tool_Offset,, PR[10]
44:  JMP LBL[10]
45:
46:  !No workpiece is detected
47:  LBL[999]
48:  *
```

- Specify the application frame number set in calibration data. (line 1)
- Specify the tool frame number set in the vision processes. (line 2)
- Wait for robot-vibration to reduce. (line 14)
- Measure point 1. (line 15)
- Get the point 1 measurement result. (line 16)
- Wait for robot-vibration to reduce. (line 20)
- Measure point 2. (line 21)
- Get the point 2 measurement result. (line 22)
- Wait for robot-vibration to reduce. (line 26)
- Measure point 3. (line 27)
- Get the point 3 measurement result. (line 28)
- Wait for robot-vibration to reduce. (line 32)
- Measure point 4. (line 33)
- Get the point 4 measurement result. (line 34)
- Prepare the program which combine the measurement results of the four points. (line 37)
- Calculate compensation data. (line 38)
- Placement operation while compensating for the tool offset of the windshield (lines 41–43)
- Add exception processing when no workpiece is detected. (line 48)

NOTE

Measurement is performed after the robot reaches the taught position on the last motion. If there is vibration in the robot left, it might cause a negative effect on the accuracy of the measurement. In such cases, please use 'WAIT' or 'acceleration override' to minimize the vibration.

7.2.8 Checking Robot Compensation Operation

Check that the robot grips the workpiece (as many points as required are measured), compensation data is calculated using the robot program, and that the robot can perform the placement operation exactly. At first, decrease the override of the robot to check that the logic of the program is correct. Next, increase the override and cycle the program again to check its operation.

8 VISION APPLICATION

8.1 AUTOMATIC RE-CALIBRATION

If the 3D Laser Vision Sensor hits the peripheral equipment or workpiece by mistake, the sensor's relative position to the robot is displaced from the position at which calibration has been performed, or the relative positions of the laser unit and camera unit of the 3D Laser Vision Sensor are displaced, which can prevent compensation values from being calculated correctly. In such cases, the line can be recovered by automatic re-calibration without performing teaching again.
The automatic re-calibration can be performed by using the robot program
The automatic re-calibration can be performed by making simple modifications to the robot program described in “3.2.5 Creating and Teaching Camera Calibration Tool” and executing.

If the 3D Laser Vision Sensor is used as a robot-mounted camera and the calibration grid is in a fixed location, fix the calibration grid to the same position in the system as the first calibration.
If the 3D Laser Vision Sensor is used as a fixed camera and the calibration grid is attached to the robot end of arm tooling, fix the calibration grid to the same position on the robot end of arm tooling as the first caribration.

The sample robot program is shown as below.
Execute the program with fixed calibration grid, so the 2-plane calibration is performed automatically.

```
 1:   UFRAME_NUM=1 ;
 2: J P[1] 100% FINE    ;
 3:   PR[99]=LPOS
 4:   PR[99, 1]=0
 5:   PR[99, 2]=0
 6:   PR[99, 4]=0
 7:   PR[99, 5]=0
 8:   PR[99, 6]=0
 9:
10:   !Remove Backlash ;
11:   PR[99, 3]=60
12: L P[1] 800mm/sec FINE    ;
  :   Offset,PR[99]
13:
14:   !1st Plane ;
15:   PR[99, 3]=50
16: L P[1] 800mm/sec FINE Offset,PR[99]
17:   VISION CAMERA_CALIB 'CALIB' Request=1 ;
18:    ;
19:   !2nd Plane ;
20:   PR[99, 3]=(-50)
21: L P[1] 800mm/sec FINE Offset,PR[99]
22:   VISION CAMERA_CALIB 'CALIB' Request =2 ;
23:   END
```

Specify calibration name.
Request code is equivalent to calibration plane No.

By using the automatic re-calibration, there are following merits.

- The automatic re-calibration can be performed by executing the robot program automatically. So the system can be recoverd without manual operation, for example, when changing camera.
  The automatic re-calibration can be recovered the system more quickly than the case where the usual camera calibration is used. Moreover, an operator's operation mistake etc. are avoidable.

- By using the automatic re-calibration, touch-up operation to the calibration grid by a robot is unnecessary. So the accuracy error by touch-up operation is avoidable.
  In the many case to need re-teaching with usual re-calibration, the accuracy error by touch-up operation is the cause. So, for the application with severe accuracy, the automatic re-calibration should be used.

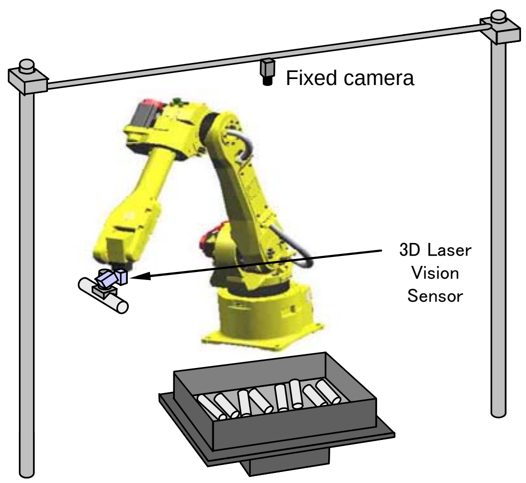
In almost cases, for example, when the 3D Laser Vision Sensor hits something by mistake and the broken sensor is replaced, the system can be recovered without re-setting of reference position or re-teaching of robot position.
But when the 3D Laser Vision Sensor is attached to shifted position from original, if a search window for 2D detection or laser is narrow, the 2D feature or laser is out of the range and not detected. In such a case, re-attach the 3D Laser Vision Sensor or adjust the position and posture of the 3D Laser Vision Sensor to detect the workpiece correctly.

8.2 COMBINATION OF 3D LASER VISION SENSOR AND 2D VISION

The view size of the 3D Laser Vision Sensor is not so large. When the standoff of the 3D Laser Vision Sensor is 400mm and the focal distance of the lens is 12mm, the size is 172.4 x 129.4mm.
And both 2 laser slits must be applied in the laser search window

For a measurement of the 3D Laser Vision Sensor, it is necessary that two laser slit beams should exist in the laser search window, but not necessary that a intersection of laser slit beams exists in it.
The relative relation between the camera view of the 3D Laser Vision Sensor and the position where two laser slit beams is applied is decided by distance between a workpiece and the 3D Laser Vision Sensor.
To apply two laser slit beams on the measurement plane of a workpiece, the workpiece should exists within the limited area. Therefore, the variation of the workpiece position should be with in the area which the 3D Laser Vision Sensor can apply two laser skit beams to the workpiece.

When the variation of the position of a workpiece is larger than the measuring range of the 3D Laser Vision Sensor, detect the workpiece position roughly by using a camera fixed over the system, move the 3D Laser Vision Sensor close to the workpiece by using the detected result, and detect with applying two laser slit beams by the 3D Laser Vision Sensor.



The sample robot program is shown as below.

```
  1: J P[1] 50% FINE
  2:   VISION RUN_FIND ‘ZENTAI'
  3:   VISION GET_OFFSET ‘ZENTAI' VR[1] JMP LBL[999]
  4: L L[2] 1000mm/sec FINE  VOFFSET,VR[1]
  5:   VISION RUN_FIND ‘RITTAI'
  6:   VISOIN GET_OFFSET ‘RITTAI' VR˝[2] JMP LBL[999]
  7: L P[3] 800mm/sec CNT100  VOFFSET,VR[2]
  8: L P[4] 200mm/sec FINE  VOFFSET,VR[2]
  9: L P[5] 800mm/sec CNT100 VOFFSET,VR[2]
       :
 23:   !NOT FOUND
 24:   LBL[999]
 25:   *
```

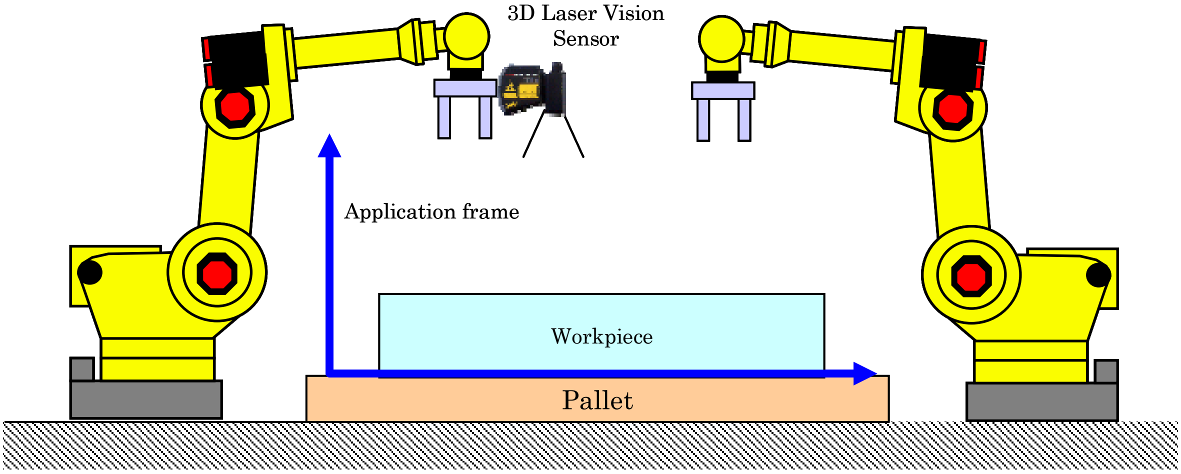
Line 1 The robot moves to starting position.
Line 2-3 Detect a workpiece in a container by using a camera fixed over the system, and output the offset data as a detection result to vision register [1].
Line 4 By using vision register [1], shift the position of the 3D Laser Vision Sensor to detect the workpiece.
Line 5-6 The 3D Laser Vision Sensor detects a workpiece, and outputs the offset data as detection result to vision register [2].
Line 7-9 By using the offset data, the robot motion is compensated.

8.3 SYSTEM WITH TWO OR MORE ROBOTS

Two or more robots may work together. Specifically, it may be as follows.

- Multiple robots are offset with a single set of offset data.
- The robot to be offset is different from the robot that has the camera.

In These cases, the sharing of the user frame and the transmission of offset data are necessary.



Sharing User Frame

When two or more robots work together, it is necessary to configure the system so that these robots share physically the same user frame. This is called the sharing of the user frame.
*i*RVision calculates the offset data by comparing the current workpiece position and the reference position taught beforehand.
The offset data in the fixed frame offset is outputted as the value on the user frame set as the application frame.

Therefore, if the same user frame is not set up between the robot with *i*RVision and the robot which compensates the motion, the offset data calculated by the robot with *i*RVision is not correct for the robot which compensates the motion.
The same user frame should be set up to all robots which use the same offset data.

User frame sharing requires that all robots use the same user frame number. For example, user frame 10 of robot 1 needs to be physically the same as user frame 10 of robot 2.

For example, in the case of the above figure, the application frame shown by blue line should be set up to both the left-side robot “A” with the 3D Laser Vision Sensor and the right side robot “B” which compensates the motion.
If the user frame No.10 is shared, the robot “A” should calculate the offset data with the user frame No.10, and the robot “B” should teach the motion with the user frame No.10.

> ⚠ **CAUTION**
> If robots share user frames of different numbers, *i*RVision cannot offset the robots correctly. Make sure that the robots share the same user frame number.

Transmission of offset data

The offset data calculated by the robot with *i*RVision should be transmitted to all robots which compensate the motion.
The Data Transfer Between Robots function is used for the transmission of offset data.
The Data Transfer Between Robots function is an option which sends and receives a data of register and position register between robots over Ethernet. The data is transmitted by executing the KAREL program.

For details of each KAREL program, please refer to “12.2 DATA TRANSFER BETWEEN ROBOTS” in “*i*RVision OPERATOR’S MANUAL (Reference)” and “R-30*i*B CONTROLLER Software Optional Function OPERATOR’S MANUAL”.

The sample robot program is shown as below.

Sending robot

```
 1:  VISION RUN_FIND 'VPLS'
 2:  VISION GET_OFFSET 'VPLS' VR[1] JMP LBL[999]
 3:  PR[10]=VR[1].OFFSET
 4:  CALL RSETPREG(ROBOT2,20,1,10,1,1)
 5:  R[5]=1
 6:  CALL RSETNREG(ROBOT2,15,5,1)
     :
23:  !NOT FOUND
24:  LBL[999]
25:  *
```

Line 1-2	The vision process “VPLS” is executed, and the offset data as the execution result is outputted to vision register [1].
Line 3	The content of the offset data in the vision register [1] is copied to position register [10].
Line 4	The content in position register [10] is transmitted to position register [20] of the receiving robot with specifying the name of the receiving robot [ROBOT2].
Line 5-6	As a signal which transmitted position register [15], the sending robot transmits the content of register [5] to the register [15] of receiving robot.

Receiving robot

```
 1:   UFRAME_NUM=10
 2:   R[15]=0
      :
17:   WAIT  R[15]=1
18: L P[6:Approuch] 800mm/sec CNT100  Offset,PR[20]
19: L P[7:Place] 200mm/sec FINE  Offset,PR[20]
20: L P[8:Retract] 800mm/sec CBT100 Offset,PR[20]
      :
```

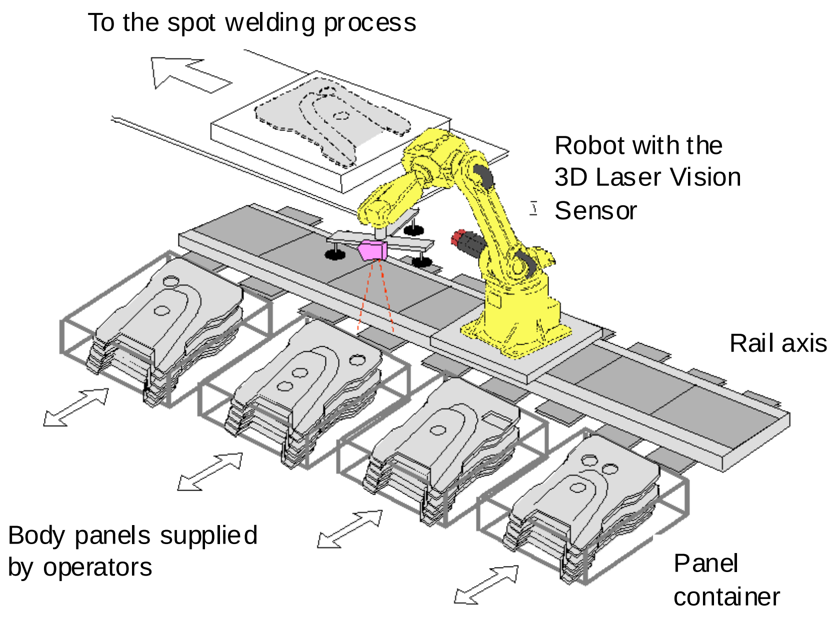
Line 1	The number of the sharing user frame is specified.
Line 17	The content in register [15] which is a signal of the completion of transmission is set to 0, and the robot waits until it is set to 1.
Line 18-20	By using the received offset data in position register[20], the robot motion is compensated.

8.4 SAMPLE APPLICATIONS

This section shows the sample applications with the 3D Laser Vision Sensor.

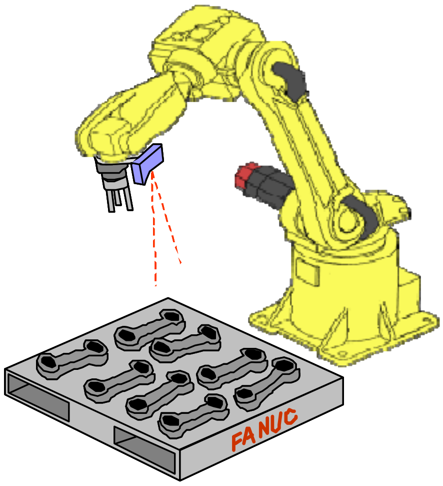
8.4.1 Body Panel Pickup (Robot-Mounted Camera + Fixed Frame Offset)

In this system, the 3D Laser Vision Sensor detects the position and inclination of body panels in the container and the robot supplies the panels one by one to the spot welding process.



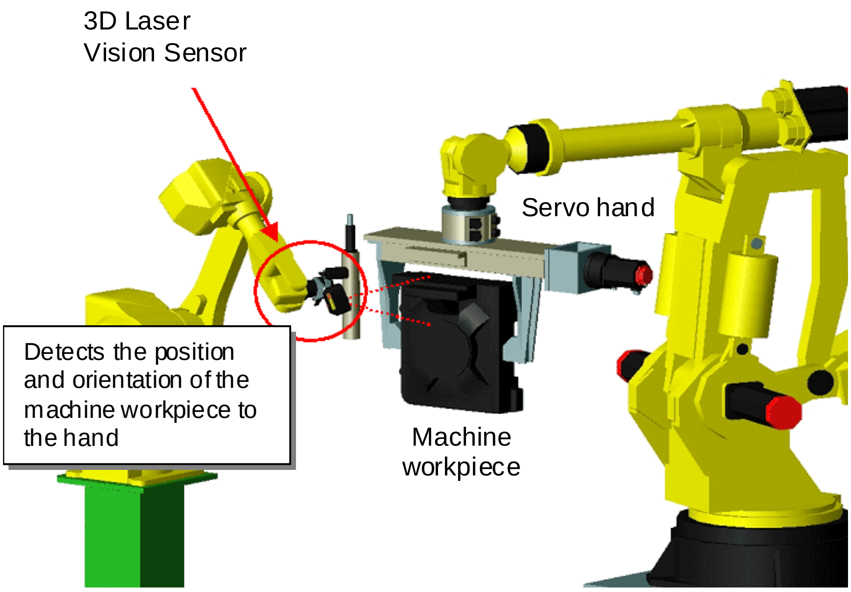
8.4.2 Small Part Pickup (Robot-Mounted Camera + Fixed Frame Offset)

In this system, the 3D Laser Vision Sensor detects a workpiece in a pallet or box and the robot picks it up.



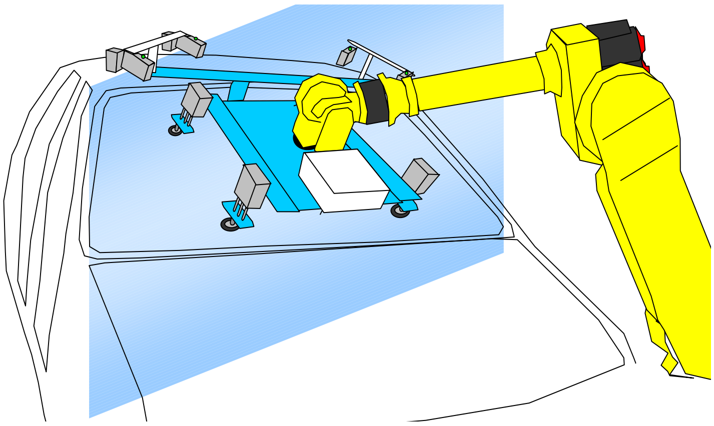
8.4.3 Loading of a Machine Part (Robot-Mounted Camera + Tool Offset)

The 3D Laser Vision Sensor mounted on the small robot measures the machine workpiece to calculate the tool offset of the workpiece. The large robot receives compensation data for operation from the small robot and sets the machine workpiece onto the fixture.



8.4.4 Mounting of a Windshield onto a Body (Robot-Mounted Camera + Fixed Frame Offset)

The 3D Laser Vision Sensor mounted on the end of tooling measures several points on the body to compensate the fixed frame offset of the body and mount a windshield. This system can also measure the windshield simultaneously depending on the sensor layout conditions to compensate the tool offset of the panel together with the fixed frame offset of the body.



8.4.5 Bin Picking of Circular Cylindrical Parts (Robot-Mounted Camera + Fixed Frame Offset)

Use a fixed camera above a bin and detect roughly some parts in the bin. Then, measure one of the detected parts finely and pick it. The 3DL Cylinder Command Tool enables circular cylindrical parts to be measured.

9 TROUBLESHOOTING

Method of restoring vision data

Prepare the memory card for data back-up described in “2.9 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.

Not Found

by setting as below, *i*RVision can record a vision log of executing a vision process and save a processing image.

- Insert the memory card into the slot on the MAIN board.
- Check the [Enable Logging] check box on the Vision Config screen.
- Select [Log Failed Images] or [Log All Images] in the edit screen for a vision process.

For details, please refer to “3.3 VISION LOG“ in “*i*RVision OPERATOR’S MANUAL (Reference)”

You can perform a test run of a vision process by using the vision logs and the logged images.
When a vision process is executed and a workpiece is not found, you can take measures for the not found workpiece by performing a test run with adjusting the parameters.
If you check [Displaying almost found] check box of the location tools when the test run is performed, you can know the reasons which the workpiece is not found.
For details, please refer to “3.7.12 Image Playback“ in “*i*RVision OPERATOR’S MANUAL (Reference)”

Retry founding

When a worlpiece is not found, you can retry a vision process with changing the parameters by using the vision override function. For details of the vision override function, please refer to “8.1 VISION OVERRIDE“ in “*i*RVision OPERATOR’S MANUAL (Reference)”

In the 3D Laser Vision Sensor system, when the workpiece is tilted, the 2D feature or the laser slits becomes out of a search window, so the workpiece is not found.
In such a case, by retrying with changing the posture of 3D Laser Vision Sensor, the workpiece may be found.

Max. Lines Distance

The 3D Laser Vision Sensor applies two laser slits on the workpiece plane. The applied laser points form each straight line. Theoretically, the two straight lines intersect at the intersection point of the laser applied to the workpiece plane. In actuality, however, the distance between the two lines rarely becomes 0 because of calibration error or measurement error.

The LL distance is the shortest distance of the straight line orthogonal to the two straight lines, and the maximum LL distance is the threshold for the distance.
The initial value of the maximum LL distance is set to 3.0mm. If the LL distance is longer than this value, the 3D Laser Vision Sensor changes the detection result into failure.

If LL distance is longer than 3.0mm, the workpiece plane to be illuminated with the laser may be uneven, or the 3D Laser Vision Sensor might not have been calibrated properly.

When the 3D Laser Vision Sensor calibration is performed, the relative positions of the laser unit and camera unit are recognized. But If the 3D Laser Vision Sensor hits the peripheral equipment or workpiece by mistake, the positions are displaced. So, the LL distance becomes longer.

Although the maximum LL distance can be increased on a temporary basis as long as the position offset of the robot is within the required accuracy range, it is recommended to perform automatic re-calibration as appropriate.

Offset data is not correct

When the robot works to the workpiece detected by the 3D Laser Vision Sensor, the robot may move to shifted position from the correct workpiece position.
At this time, the robot may move correctly when the workpiece moves with only parallel movement from a reference position, the robot may move incorrectly when the workpiece moves with rotated movement, and the amount of shift may become large if the amount of rotations becomes large.
In many cases, it is because the user frame such like as application frame, offset frame, and calibration grid frame is not set up correctly.
When the user frame recognized by the robot is shifted from the user frame recognized by *i*RVision, the above phenomenon appears

There are following reasons that a user frame is not set up correctly.

- The robot TCP used when the frame is set up was not correct.
- The selected number of tool frame of TCP was wrong.
- The installed calibration grid was shifted.

Measurement accuracy improvement

When the measurement accuracy of the 3D Laser Vision Sensor is wrong, the following causes can be considered.

- The user frame as calibration grid was not set up correctly
- The user frame as application frame was not set up correctly
- The user frame as offset frame was not set up correctly
- The robot TCP used when the frame set up was not set up correctly
- There is a mistake in the procedures of camera calibration.

When above causes do not correspond, the measurement accuracy can be improved if the 3D Laser Vision Sensor measures with the posture confronting directly to the workpiece.

Even if the measurement position of the 3D Laser Vision Sensor was taught with the posture confronting directly to the workpiece when the reference position was taught, the sensor may be unable to measure with the posture confronting directly to the workpiece when the workpiece is tilted,

In such a case, the 3D Laser Vision Sensor measures again with the measurement position compensated by the offset data. So, the measurement position becomes with the posture confronting directly to the workpiece, and the measurement accuracy can be improved.

The cycle time may become long. But if you need to improve the measurement accuracy, please inquire above method.

Two or more detections on a workpiece

In the 3D Laser Vision Sensor system, the sensor can detect two or more parts on a workpiece, compound these results to one, and recognize it as the position and posture of whole workpiece.
The position and posture of whole workpiece is calculated by using the center-of-gravity position (centroid) calculated from two or more detection results. So, the offset data is calculated and outputted.
When two parts on a workpiece are detected, the inclination component is calculated by averaging the inclination components of each part

This method calculates by using center-of gravity position (centroid) as the position and posture of whole workpiece. So, when the relative positions of detected parts has variation or the workpiece size has variation, the workpiece position may not be calculated correctly. If the user for example wants one view to be the part center and the other views to be used for calculating tilt and roll, they should consider using “merge3dv”.

The “merge3dv” routine is in the vision support tools and can determine the position from one detected part, and the posture from other parts.
For details of the vision support tools, please refer to “12.1 VISION SUPPORT TOOLS“ in “*i*RVision OPERATOR’S MANUAL (Reference)”

Notes for the 3D Laser Vision Sensor

- When the 3D Laser Vision Sensor is to be mounted on the robot and used as a robot-mounted camera, mount it in such a place that the sensor does not touch a workpiece, container, or peripheral equipment when the robot finds and picks the worlpiece

- When the inclination of workpiece is large and the shape of workpiece is not simple (like a circle, a square, etc.), the teaching of multiple models for multiple inclinations is effective.

- It may be difficult for 3D Laser Vision Sensor to measure a workpiece with a specular reflection (such as shining aluminum material). This is because the surface reflects the laser slit beams.

- The incorrect measurement of the distance to the workpiece can be prevented defining a search window with a runtime mask. Moreover, the user can not accept bad offsets by specifying the range of the offset elements in the offset limit function.

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