FANUC Robot series

R-30iB Plus/R-30iB Mate Plus/R-30iB Compact Plus CONTROLLER

iRVision 3D Laser Vision OPERATOR'S MANUAL

Original Instructions

Thank you very much for purchasing FANUC Robot.

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

- No part of this manual may be reproduced in any form.
- The appearance and specifications of this product are subject to change without notice.

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In this manual, we endeavor to include all pertinent matters. There are, however, a very large number of operations that must not or cannot be performed, and if the manual contained them all, it would be enormous in volume. It is, therefore, requested to assume that any operations that are not explicitly described as being possible are "not possible".

SAFETY PRECAUTIONS

This chapter must be read before using the robot.

For detailed functions of the robot operation, read the relevant operator's manual to understand fully its specification.

For the safety of the operator and the system, follow all safety precautions when operating a robot and its peripheral equipment installed in a work cell.

For safe use of FANUC robots, you must read and follow the instructions in "FANUC Robot series SAFETY HANDBOOK (**B-80687EN**)".

1 DEFINITION OF USER

The personnel can be classified as follows.

Operator:

- Turns the robot controller power ON/OFF
- Starts the robot program from operator panel

Programmer or Teaching operator:

- Operates the robot
- Teaches the robot inside the safety fence

Maintenance technician:

- Operates the robot
- Teaches the robot inside the safety fence
- Performs maintenance (repair, adjustment, replacement)
- Operator is not allowed to work in the safety fence.
- Programmer/Teaching operator and maintenance technician are allowed to work in the safety fence. Works carried out in the safety fence include transportation, installation, teaching, adjustment, and maintenance.
- To work inside the safety fence, the person must be trained on proper robot operation.

Table 1 (a) lists the work outside the safety fence. In this table, the symbol "O" means the work allowed to be carried out by the worker.

Table 1 (a) List of work outside the fence

	Operator	Programmer or Teaching operator	Maintenance technician
Turn power ON/OFF to Robot controller	0	0	0
Select operating mode (AUTO/T1/T2)		0	0
Select remote/local mode		0	0
Select robot program with teach pendant		0	0
Select robot program with external device		0	0
Start robot program with operator's panel	0	0	0
Start robot program with teach pendant		0	0
Reset alarm with operator's panel		0	0
Reset alarm with teach pendant		0	0
Set data on teach pendant		0	0
Teaching with teach pendant		0	0
Emergency stop with operator's panel	0	0	0
Emergency stop with teach pendant	0	0	0
Operator's panel maintenance			0
Teach pendant maintenance			0

In the robot operating, programming and maintenance, the operator, programmer/teaching operator and maintenance technician take care of their safety using at least the following safety protectors.

- Use clothes, uniform, overall adequate for the work
- Safety shoes
- Helmet

2 DEFINITION OF SAFETY NOTATIONS

To ensure the safety of users and prevent damage to the machine, this manual indicates each precaution on safety with "WARNING" or "CAUTION" according to its severity. Supplementary information is indicated by "NOTE". Read the contents of each "WARNING", "CAUTION" and "NOTE" before using the robot.

Symbol	Definitions	
⚠WARNING	Used if hazard resulting in the death or serious injury of the user will be expected to occur if he or she fails to follow the approved procedure.	
 ∴ CAUTION	Used if a hazard resulting in the minor or moderate injury of the user, or equipment damage may be expected to occur if he or she fails to follow the approved procedure.	
NOTE	Used if a supplementary explanation not related to any of WARNING and CAUTION is to be indicated.	

• Check this manual thoroughly, and keep it handy for the future reference.

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 *i*RVision.

1 ABOUT THIS MANUAL

This manual is desired to first refer to when starting up the robot system that performs a 3D offset using the 3D Laser Vision Sensor with *i*RVision. This manual describes the system startup procedures, program creation methods, caution, technical know-how, responses to various cases, etc. when performing a 3D offset using the 3D Laser Vision Sensor with *i*RVision.

This manual is directed to users who have taken the 3D Laser Vision Sensor course at FANUC Academy.

For details of each setting item, refer to "iRVision OPERATOR'S MANUAL (Reference) B-83914EN". For normal robot operations, refer to the "OPERATOR'S MANUAL (Basic Operation) B-83284EN". For other than above, refer to the manuals which are introduced in "2. RELATED MANUALS".

ACAUTION

This manual is based on the R-30*i*B Plus/R-30*i*B Mate Plus/R-30*i*B Compact Plus CONTROLLER with the software version 06 of 7DF3 series. Depending on the software version of your robot controller, there may not be some functions and settings that described in this manual, there may be some functions and settings that may not be described in this manual, or there may be some different notations.

Series	Chapter	Chapter title	Main content
Introduction	Chapter 1	ABOUT iRVision	This chapter describes the fundamental items of the vision system and the 3D Laser Vision Sensor such as the measurement principle of the 3D Laser Vision Sensor, types of camera mounting methods, types of offset modes, etc.
Setup	Chapter 1	FEATURES	This chapter describes the summary of four types of vision processes used for the 3D Laser Vision Sensor.
	Chapter 2	3DL SINGLE-VIEW VISION PROCESS	This chapter describes startup procedures and the teaching procedure of 3DL Single-View Vision Process.
	Chapter 3	3DL MULTI-VIEW VISION PROCESS	This chapter describes startup procedures and the teaching procedure of 3DL Multi-View Vision Process.
	Chapter 4	3DL CURVED SURFACE SINGLE VISION PROCESS	This chapter describes startup procedures and the teaching procedure of 3DL Curved Surface Single Vision Process.
	Chapter 5	3DL CROSS SECTION VISION PROCESS	This chapter describes startup procedures and the teaching procedure of 3DL Cross Section Vision Process.
Know-How	Chapter 1	FRAME SETTING	This chapter describes the frame setting using the touch-up pointer, and the frame setting method using the calibration grid frame setting function.
	Chapter 2	3DL SENSOR DATA SETTING	This chapter describes the data setting method of the 3D Laser Vision Sensor.
	Chapter 3	VISION APPLICATION	This chapter describes the method of using the 3D Laser Vision Sensor in combination with 2D vision processes, and the system in with multiple robots.
	Chapter 4	TROUBLESHOOTING	This chapter describes anticipated problems that may occur when using the 3D Laser Vision Sensor and how to deal with such problems.

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Indications in this manual

The symbol below is used in this manual. Refer to it when looking for information.

Symbol	Description
Memo	Gives information that will provide hints for performing screen operations, and information that
 ∅ INICITIO	will provide a reference for function explanations and setting details.

Explanation of teach pendant operation

This manual explains each procedure on the assumption that teaching is performed using a teaching PC. However, some procedures include a description of operation of the teach pendant. The teach pendant can be operated through touch panel operation, but the procedures using key input, for which the operations are more complex, are described in this manual.

Simple Mode and Advanced Mode

*i*RVision provides the simple mode to hide rarely used setting items and the advanced mode to display all the setting items. Unless otherwise specified, the screens and operations in the simple mode are shown in this manual. For details of the simple mode and advanced mode, refer to the "*i*RVision OPERATOR'S MANUAL (Reference) B-83914EN".

2 RELATED MANUALS

This section explains about related manuals for *i*RVision.

Manual Spec.	No.	Description
Manual Spec. OPERATOR'S MANUAL (Basic Operation)	No. B-83284EN	Description This is the main manual. Setting the system for manipulating workpieces Operating the robot Creating and changing a program Executing a program Status indications
MAINTENANCE MANUAL	B-83195EN	Backing up and restoring robot programs This manual is used on an applicable design, robot installation, robot teaching. This manual describes the maintenance and connection of the
MAINTENANCE MANUAL	B-83525EN	R-30iB/R-30iB Plus Controller. This manual describes the maintenance and connection of the R-30iB Mate/R-30iB Mate Plus Controller.
MAINTENANCE MANUAL	B-83555EN	This manual describes the maintenance and connection of the R-30iB Mate/R-30iB Mate Plus Controller (Open Air).
MAINTENANCE MANUAL	B-84035EN	This manual describes the maintenance and connection of the R-30iB Compact Plus Controller.
OPERATOR'S MANUAL (Alarm Code List)	B-83284EN-1	This manual provides a list of controller alarm codes. This manual describes the causes of alarm occurrence and the measures to be taken.
Sensor Mechanical/Control unit OPERATOR'S MANUAL	B-83984EN	This manual describes the method for connection between controller and sensors such as a camera or 3D Laser Vision Sensor used for <i>i</i> RVision and the maintenance method of sensors.
iRVision OPERATOR'S MANUAL (Reference)	B-83914EN	 This manual is the reference manual for iRVision. This manual describes each function which is provided by iRVision. When you would like to know the meanings (e.g. the items about the iRVision setup screen, the arguments of the instruction, and so on), refer to this manual.

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Manual Spec.	No.	Description
<i>i</i> RVision 2D Vision Application OPERATOR'S MANUAL	B-83914EN-2	 This manual is desired to first refer to when starting up robot systems that perform a 2D offset or a 2.5D offset using <i>i</i>RVision. This manual describes system startup procedures, program creation methods, caution, technical know-how, responses to various cases, etc. when performing a 2D offset or a 2.5D offset using <i>i</i>RVision.
<i>i</i> RVision Inspection Application OPERATOR'S MANUAL	B-83914EN-5	This manual is desired to first refer to when starting up a robot system that inspects whether workpieces are defective or not using <i>i</i> RVision. • This manual describes system startup procedures, program creation methods, caution, technical know-how, responses to various cases, etc. when performing non-defective/defective inspection of workpieces using <i>i</i> RVision.
<i>i</i> RVision Bin Picking Application OPERATOR'S MANUAL	B-83914EN-6	 This manual is desired to first refer to when starting up a robot system that performs bin picking using <i>i</i>RVision. This manual describes system startup procedures, program creation methods, caution, technical know-how, responses to various cases, etc. when performing bin picking using <i>i</i>RVision.
iRPickTool OPERATOR'S MANUAL	B-83924EN	This manual is desired to first refer to when starting up a robot system that performs visual tracking using <i>i</i> RVision. • This manual describes system startup procedures, program creation methods, caution, technical know-how, responses to various cases, etc. when performing visual tracking using <i>i</i> RVision.
Ethernet Function OPERATOR'S MANUAL	B-82974EN	This manual describes the optional network functions of robot controllers such as FTP, RIPE, and PC sharing.

PRECAUTIONS FOR 3D LASER VISION SENSOR

This chapter describes main precautions to be taken for the 3D Laser Vision Sensor before use.

3.1 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.

⚠ WARNING

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)

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3.2 LASER BEAM

The semiconductor laser beam is a visible optical laser with a wave length of 650 nm. It is necessary to pay attention to its operation though the maximum output power is at most 4.5 mW 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.

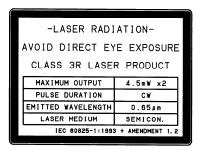
3.3 WARNING LABEL

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. 3.3 (a) and Fig. 3.3 (b) show the warning labels used.

① Explanatory label(for IEC/JIS)

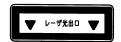


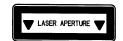
JIS (general type)



IEC (general type)

② Aperture label





LASER RADIATION IS EMITTED FROM THIS APERTURE.

JIS (general type) IEC (general type)

FDA (general type)

VOID EXPOSURE - VISIBLE

3 Warning label



IEC/JIS



FDA

Fig. 3.3 (a) Warning labels (1)

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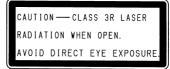
4 Address label (for FDA)

3580, Shibokusa Aza-Komanba. Oshino-mura, Minamitsuru-gun, Yamanashi Prefecture, Japan

5 Access panel label



JIS



IEC

DANGER
VISIBLE LASER RADIATION
WHEN OPEN.
AVOID DIRECT EYE EXPOSURE.

FDA

6 Certification label (for FDA)

- CERTIFICATION LABEL -

•This laser product complies with 21 CFR 1040.10 and 1040.11.

Fig. 3.3 (b) Warning labels (2)

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Introduction

ABOUT iRVision

Introduction

1

1 ABOUT iRVision

This chapter explains about offsetting the robot motion using iRVision (integral Robot Vision). iRVision is an image processing function integrated in a robot controller. It finds parts in an image snapped from a camera, offsets the robot motion and measures the features of the part. This chapter explains about offsetting the robot motion using iRVision (integral Robot Vision).

1.1 iRVision

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. A series of instructions that specify what robots are to do is called a robot program. The process of generating robot programs is called teaching.

And the act of executing the taught robot programs is called playback. 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. *i*RVision is a visual sensor system designed to eliminate such restrictions. *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.

*i*RVision is the vision function integrated into the FANUC robot controller. *i*RVision incorporates a 2D Camera that performs a 2D offset, and a 3D Vision Sensor, 3D Area Sensor, and 3D Laser Vision Sensor that perform a 3D offset.

1.2 BASIC CONFIGURATION

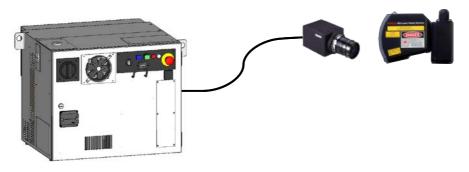
*i*RVision consists of the following components:

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



Basic configuration of iRVision

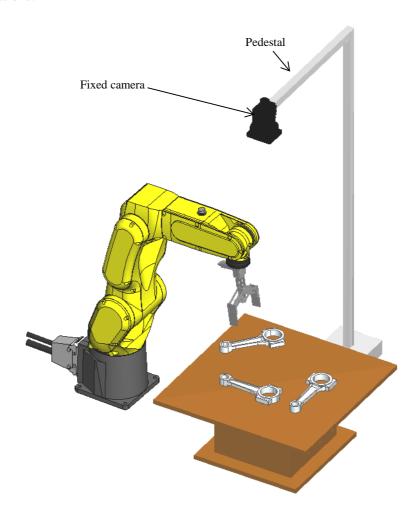
For how to connect the camera, the 3D Laser Vision Sensor and the robot controller, refer to "Sensor Mechanical Unit/Control Unit OPERATOR'S MANUAL B-83984EN". Since the camera and lens used for a 2D offset are also used for the 3D Laser Vision Sensor, 2D offset can be performed using the camera and lens for the 3D Laser Vision Sensor.

1.3 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

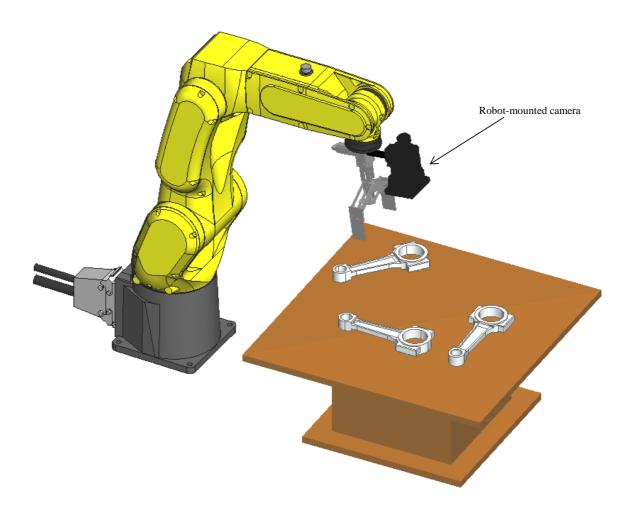
- A fixed camera is attached to the top of the pedestal or another fixed structure and a workpiece is detected.
- A fixed camera will always snap the same place from the same distance.
- As processes in *i*RVision can be done in parallel when the robot is carrying out other work, the whole cycle time can be shortened.
- For a stand for a fixed camera, use something that has enough durability that it will be unaffected by vibrations.



Fixed camera

Robot-mounted camera

- The robot-mounted camera is mounted on the wrist unit of the robot.
- By moving the robot, measurement can be done at different locations between the workpiece and the camera.
- When a robot-mounted camera is used, *i*RVision calculates the position of the workpiece while taking into account the camera movement resulting from the robot being moved.
- The camera cable moves according to the robot movement, so be careful so that the cables doesn't tangle.



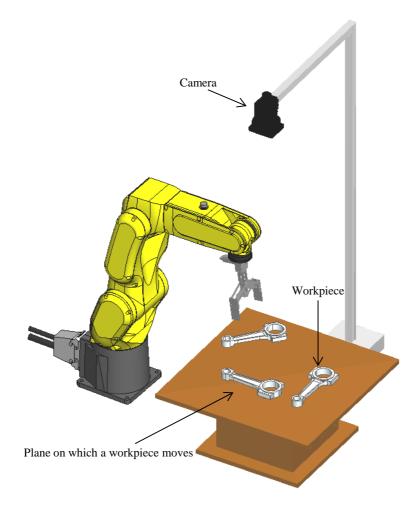
Robot-mounted camera

1.4 FIXED FRAME OFFSET AND TOOL OFFSET

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

Fixed frame offset

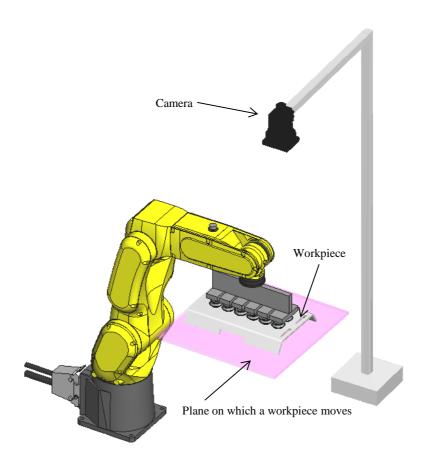
Fixed frame offset snaps an image of a workpiece placed on a table, etc. with the camera, measures the discrepancy, and corrects the operation of the robot so that it will work on (e.g., grip) the workpiece correctly.



Fixed frame offset

Tool offset

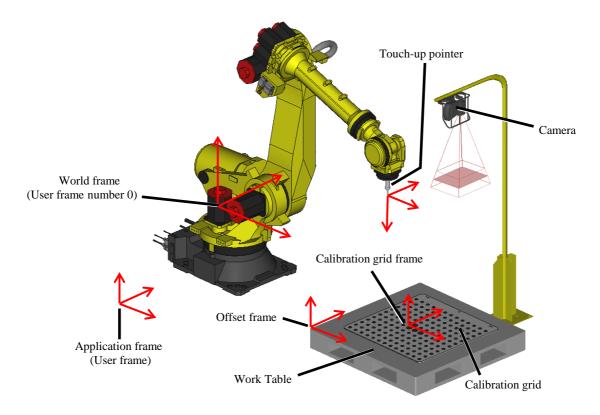
Tool offset snaps an image of a workpiece gripped by the robot that is off the reference position with the camera, measures the discrepancy, and corrects the operation of the robot so that it will work on (e.g., place) the workpiece correctly.



Tool offset

1.5 COORDINATE SYSTEMS USED FOR iRVision

It is necessary to set up some coordinate systems for iRVision.



Coordinate systems used for iRVision

Touch-up pointer with setting TCP

Set the TCP (tool frame) accurately on the touch-up pointer installed on the robot gripper. The touch-up pointer with TCP set is used for setting the application frame, installation information of the calibration grid, and the offset frame.

Offset frame

An offset frame is a coordinate system used for calculation of the offset data. A found position, etc. of the workpiece is outputted as a position on the frame set in the offset frame. Set the offset frame in such a way that the XY plane of the offset frame is parallel to the plane on which a workpiece moves. As shown in the above figure, if the workpiece moves on a work table, set the offset frame in such a way that it is parallel to the surface of the work table. If the plane on which a workpiece moves is not parallel to the XY plane of the offset frame, it can cause the offset accuracy to drop, so make sure to set it correctly. For the fixed frame offset, set the offset frame as a user frame. For the tool offset, set the offset frame as a tool frame.

Calibration grid frame

Set the information of 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 for calibration, set the installation information in a user frame. When the calibration grid is installed on the robot end of arm tooling for calibration, set the installation information in a tool frame.

The installation information of the calibration grid can be set by touch-up using the touch-up pointer with TCP set. When a robot-mounted camera is used or a calibration grid is mounted on a robot end of arm tooling, the calibration grid frame setting function can also be used for setting.

Introduction 1. ABOUT iRVision

ℳMemo

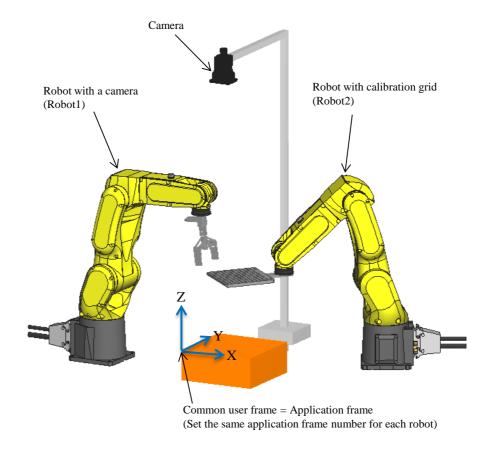
The calibration grid frame setting function sets the calibration grid frame using a camera. Compared with the manual touch-up setting method, the function offers a number of merits, including accurate setting of the frame without requiring user skills, no need for touch-up pointers or to set the TCP for touch-up setting, and semi-automatic easy-to-do operation. In calibration 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, refer to "Know-How: 1.2 FRAME SETTING WITH GRID FRAME SETTING FUNCTION".

Application Frame

Set the robot's user frame to be used as a reference for camera calibration. The camera is calibrated for the frame set in the application frame. In most cases, calibration is performed with reference to the world frame (user frame number 0) of the robot to be offset. Note that in the following cases, set the user frame, and then set the user frame number as the application frame.

- In the case the camera is mounted on a robot other than the robot to be offset.
- In the case the calibration grid is attached to a robot other than the robot to be offset.
- In the case the robot to be offset belongs to another motion group.

The following figure is an example of the calibration grid being mounted on a robot other than the robot to be offset. As shown in the following figure, when the robot with the camera mounted and the other robot with the calibration grid mounted are present, set the common plane as a user frame on both robots, and make it as the application frame (set the same user frame number for each robot). In this example, inter-controller communication is required between the two robots. For details of the communication between robot controllers, refer to the description of INTER-CONTROLLER COMMUNICATION in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".



Example of the calibration grid being mounted on a robot other than the robot to be offset

1.6 CAMERA CALIBRATION

iRVision finds parts in an image snapped from a camera. The position of the found part is available as the positional information in the image. However, in order to offset the robot based on the positional information that iRVision found, the positional information needs to be converted from the camera frame to a robot frame (user frame or tool frame). In order to perform such data conversion, data which describes where the camera is placed and where the camera is looking is required. The operation of setting up these data is called 'camera calibration'.

Calibrating cameras accurately is very important so that your robot can be offset accurately. To use the 3D Laser Vision Sensor, 3DL calibration using a calibration grid is required. For details of the 3DL calibration, refer to "Know-How: 2 3DL SENSOR DATA SETTING".

1.7 CALCULATION OF OFFSET DATA

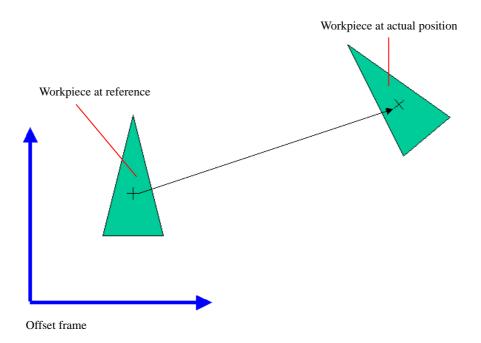
In this section, the calculation method of the offset data is explained.

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 as 'reference position setting'.

Offset data

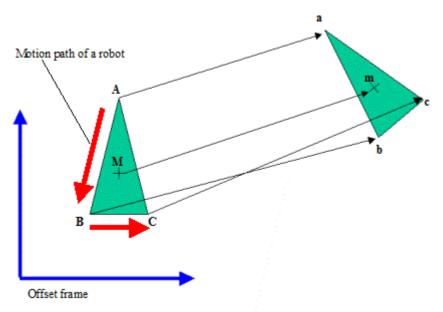
In the case of the following figure, the position of '+' mark is a found position of a workpiece. If a robot approaches only to the position of "+" mark, the offset data can be calculated by subtracting the value of actual position and reference position. Although it is easy to understand how to calculate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



Offset calculation by subtraction

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.

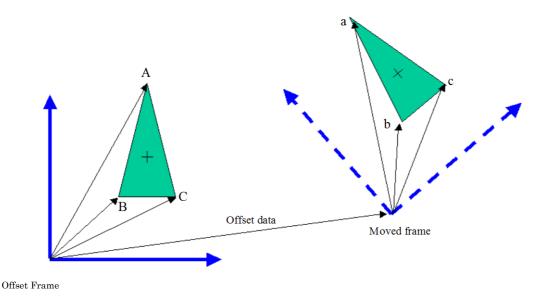
However, the movement of (a - A), (b - B), and (c - C) differ from the movement of the found position (m - M). So, it is necessary to calculate the offset data of a, b and c individually, which is not a trivial task using the found position. This task becomes more cumbersome as the number of taught points increases.



Position Information and movement amount

*i*RVision virtually shifts an offset frame so that the individual calculation of the offset amount at each point is not required.

Shifting the offset frame can offset the workpiece in such a way that the actual position of the workpiece is 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.



Offset calculation by shifting a frame

1.8 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.

1.8.1 Measurement Principle

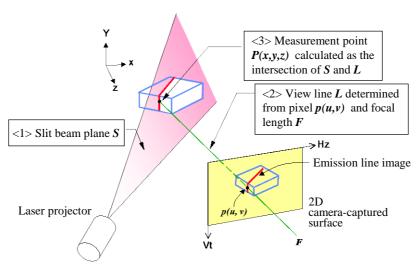
This sub section explains the measurement principle of the 3D Laser Vision Sensor.

Laser Deam projector Laser ON Laser OFF Laser OFF Laser Obtain the orientation and the distance of the plane Workpiece Fusion J D camera 2D image processing Obtain the 2D feature on the surface Fusion 3D position and orientation information

Measurement principle of the 3D Laser Vision Sensor

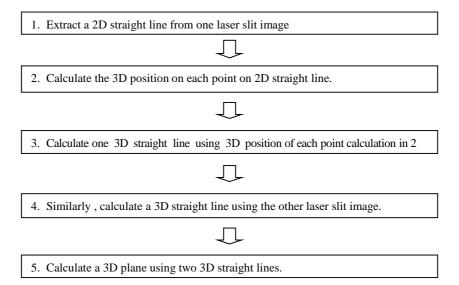
The 3D Laser Vision Sensor has a function to capture the laser slit beam directed to a workpiece from the laser slit projector into an image, and analyzes the image to measure the 3D position of the part to which the laser slit beam is directed. Combining this function with the 2D image processing function 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 slit beam is directed is obtained. Calibrating the 3D Laser Vision Sensor can calculate the formula to obtain view line L using the laser slit beam plane S < 1> and pixel p(u,v) < 2>. Specifying all pixels on the laser emission line on the 2D camera-captured surface (laser slit image) sequentially can obtain the 3D position of each point on the emission line on the actual workpiece.



Principle to obtain the 3D position

A 3D straight line can be calculated by obtaining a straight line on the laser slit image for one laser slit beam and obtaining the 3D position of each point on the emission line on the straight line. Because the 3D Laser Vision Sensor outputs two laser slit beams, two 3D straight lines can be obtained. A 3D plane can be calculated using the two 3D straight lines. The following figure shows the measurement flow of the 3D Laser Vision Sensor.



Measurement flow by the 3D Laser Vision Sensor

1.8.2 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 20 mm diameter area in the camera FOV to allow laser slit beams to be detected.

And workpieces should have features detectable by the 2D detection function in the camera FOV when measurement this plane.

1.8.3 Standoff

When the 3D Laser Vision Sensor measures a workpiece, the distance as reference between the workpiece and the 3D Laser Vision Sensor is called as 'Standoff'.

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

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

When taking out a workpiece from a deep container using the 3D Laser Vision Sensor, if you do not wish to put the 3D Laser Vision Sensor into the container when measuring or taking out, the 600 mm standoff 3D Laser Vision Sensor is available.

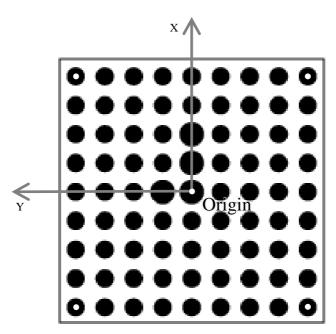
The 3D Laser Vision Sensor is usually adjusted at the FANUC factory to be focused for a 400 mm standoff.

To have the sensor adjusted to a standoff of 600 mm and shipped, a separate specification is necessary. If the 600 mm standoff sensor is necessary, please specify to FANUC SALES at the time of order.

1.9 CALIBRATION GRID

A calibration grid is a multi-purpose jig that is used for a variety of purposes, such as grid pattern calibration and calibration grid frame setting.

In *i*RVision, a calibration of a camera is performed using a calibration grid with a default pattern drawn. When the camera snaps an image of the grid as shown below, *i*RVision automatically recognizes the positional relationship of the calibration grid and the camera, lens distortion, the focal distance, etc.



Example of frame using calibration grid

All the black circles of the calibration grid are arrayed in a square lattice. There are four large black circles near the center that indicate the frame origin and direction as shown in the picture. The ratio of the diameter of a large black circle to that of other black circles is approximately 10:6.

For the five grid points arranged in the center and at the four corners, there is a white circle with a diameter of 1 mm placed at the center of the black circle. This white circle is used when setting the frame with touch-up using the robot's TCP.

Depending on the application, a calibration grid can be used by fixing it to a table or attaching it to the robot's gripper. In either case, it is necessary to set the arrangement position and direction (mounting information) of the calibration grid when performing calibration for the camera.

To set up the information for mounting the calibration grid, attach a pointer tool to the robot's gripper and set it up by physically performing touch-up (calibration grid setting using touch-up), or set it up automatically without any contact by using a camera and measuring a grid pattern (calibration grid frame setting).

1.10 MEMORY CARD PREPARATION

*i*RVision can save undetected images to a memory card or a USB memory inserted into the robot controller. It is recommended that at the time of system start-up and integration, a memory card or a USB memory be inserted to save undetected images to the memory card or a USB memory. By doing so, the locator tool parameter can be adjusted using undetected images. Moreover, when the system is reinstalled after being moved, e.g., 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, refer to the description of VISION CONFIG in "*i*RVision OPERATOR'S MANUAL (Reference) B-83914EN".

Note that even if "Log Failed Images" is set in the vision process, no un-detected images can be saved when no memory card or no USB memory is inserted.

When the free space of the memory device is less than the specified value (1 MB by default), old vision logs are deleted to make enough free space for writing a new vision log. Even if the free space of the memory card/USB memory is less than the specified value, files other than vision logs of the vision system are not deleted. If there are no vision logs which can be deleted, the 'CVIS-130 No free disk space to log' alarm is posted and the vision log will not be recorded.

⚠ CAUTION

1 As it takes a long time to delete the vision log, we recommend that you regularly transfer the data for the vision log to your PC and ensure you have sufficient free space in your memory card or USB memory. For details on how to export the vision log to an external device or to delete it, refer to the description of VISION LOG MENU in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

- 2 On a memory card or USB memory, data other than vision log for *i*RVision may be recorded. If the free space drops below the designated capacity, the next time a vision Process is executed, vision log will be deleted until the remaining capacity reaches the designated capacity. Depending on the amount of data that is deleted, it may take a while to get into a state in which execution of the next Vision Process can start. E.g., saving a backup to a memory card or USB memory corresponds to this case.
- 3 Do not insert a memory card in which vision log has been recorded using another robot controller. If you carry out line execution or test execution of a vision process with the memory card still inserted, the vision log that was recorded using the original robot controller may be overwritten.
- 4 Format devices such as memory card or USB memory to FAT16.
- 5 If you record images, it may take time to execute detection. Basically, set things up so that images will not be recorded after you have finished adjustment of the vision system. For details, refer to the description of VISION LOG in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

A memory card or a USB memory, when inserted, can be used to back up all data in the robot controller. If all data in the robot controller is backed up, the vision data can be backed up at the same time. Be sure to back up all data in the robot controller upon completion of startup or integration.

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

Setup

- 1 FEATURES
- 2 3DL SINGLE-VIEW VISION PROCESS
- 3 3DL MULTI-VIEW VISION PROCESS
- 4 3DL CURVED SURFACE SINGLE VISION PROCESS
- 5 3DL CROSS SECTION VISION PROCESS

Setup 1. FEATURES

1 FEATURES

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

- 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

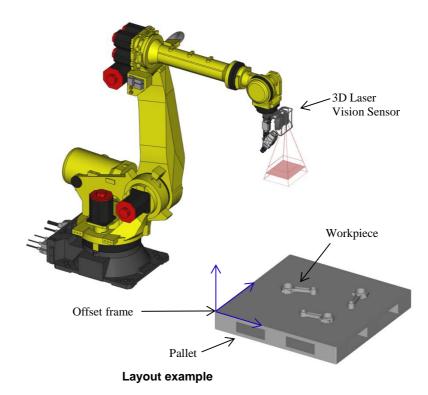
And there are the following robot position offset in each vision process.

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

Chapter 2 and subsequent chapters of this part describe the flow of the startup procedure and the details of the teaching procedure for each vision process. For details of each teaching item, refer to the description of VISION PROCESS and COMMAND TOOL in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

Layout example

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 camera.



Precautions

- 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.

1. FEATURES Setup

• 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 robot motion offset is performed, 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, accurate offset cannot be performed. The risk of displacement due to interference and so on can be reduced by installing a guard for the sensor.



3D Laser Vision Sensor protector

- 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 350 mm to 450 mm or from 550 mm to 650 mm (depending on the setup of the sensor). Check the following points when teaching.
 - 1 Whether the robot can reach all the measurement positions
 - Whether the hand and the 3D Laser Vision Sensor do not interfere with peripheral equipment during measurement.
 - 3 Whether an appropriate measurement distance can be secured
- 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.

2 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 offset for robotic handling of the workpiece.

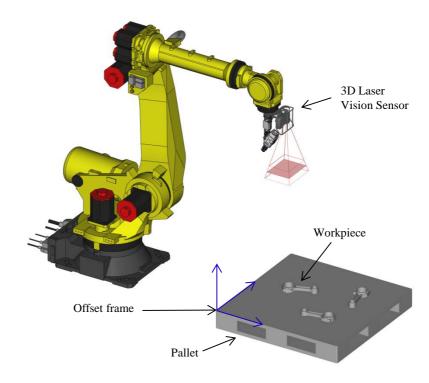
This chapter describes the startup procedure and teaching procedure using the following two application examples.

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

Unless otherwise specified, the screens and operations in the simple mode are shown in this chapter. For details of the simple mode and advanced mode, refer to the "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

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

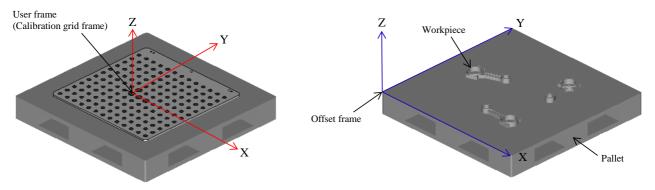
An example of layout for "robot-mounted camera + fixed frame offset" is given below.



Layout for "robot-mounted camera + fixed frame offset"

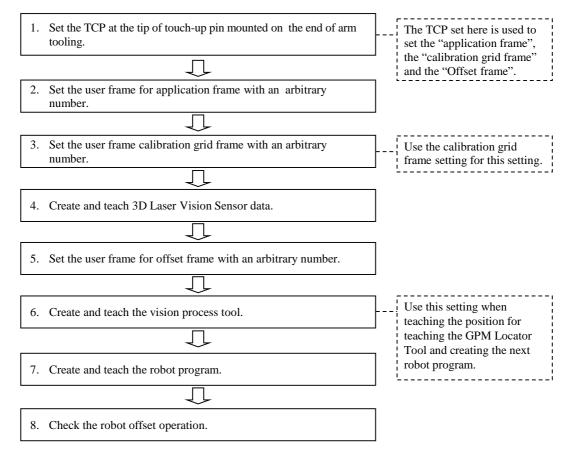
Setup for "robot-mounted camera + fixed frame offset" includes setting the "calibration grid frame" and the "Offset frame" in a user frame with an arbitrary number.

The "Calibration grid frame" can be set easily and correctly by using the camera of the 3D Laser Vision Sensor (calibration grid frame setting function).



Calibration grid frame and offset frame

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



Setup flow

2.1.1 Setting TCP of Robot

Setting the TCP of the robot is necessary to teach the application frame, the calibration grid frame and the offset frame. In general, 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]. For the setting method, refer to "Know-How: 1 FRAME SETTING".

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.

2.1.2 Setting Application Frame

Specify the robot's user frame to be used as a reference for 3DL calibration. In many cases, the base frame of the robot is set up in the world frame. However, in the following cases, set the user frame, and set the user frame number as the application frame.

- In the case the 3D Laser Vision Sensor is attached to a robot other than the robot to be offset.
- In the case the calibration grid is attached to a robot other than the robot to be offset.
- In the case the robot to be offset belongs to another motion group.

Refer to "Introduction: 1.5 COORDINATE SYSTEMS USED FOR iRVision".

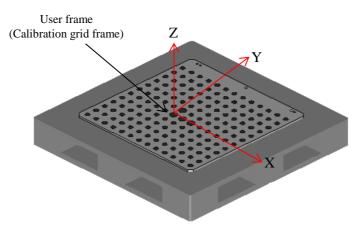
2.1.3 Setting Calibration Grid Frame

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 calibration grid frame setting function. After securing the calibration grid, execute the calibration grid frame setting function. For details of the calibration grid frame setting function, refer to "Know-How: 1.2 FRAME SETTING WITH GRID FRAME SETTING FUNCTION". Note that the user frame in the installation information of the calibration grid differs from the user frame used for offset described in the following subsection.

In addition to the method of using the calibration 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. Refer to "Know-How: 1.1 FRAME SETTING WITH POINTER TOOL". The TCP setting precision and touch-up precision directly affect the offset 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 details of the calibration recovery method, refer to "Know-How: 2.1.7 Automatic Re-Calibration".



Calibration grid installation information

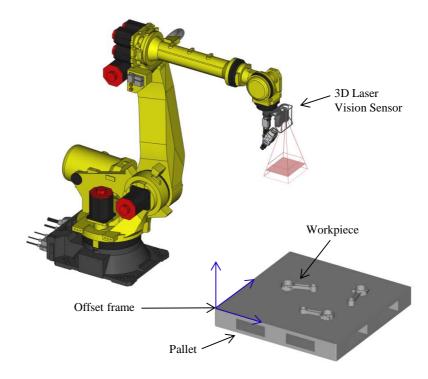
2.1.4 Creating and Teaching 3DL Sensor Data

To use the 3D Laser Vision Sensor, 3DL calibration using a calibration grid is required. For details of the 3DL calibration, refer to "Know-How: 2 3DL SENSOR DATA SETTING".

2.1.5 Setting Offset Frame

Set a user frame to be used as the reference for the robot offset 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. For details of the frame setting, refer to "Know-How: 1 FRAME SETTING".



User frame used for offset

Sharing user frame

When two or more robots work together for the same workpiece, it is necessary to physically set the same user frame for all the robots. 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.

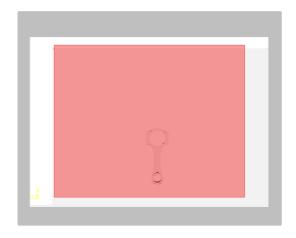
User frame sharing requires that all robots use the same user frame number. E.g., user frame 5 of robot 1 needs to be physically the same as user frame 5 of robot 2.

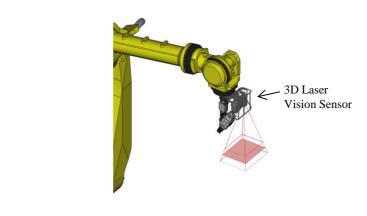
⚠ CAUTION

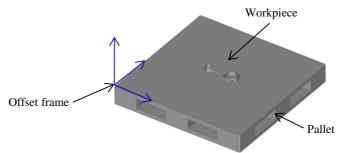
If robots share user frames of different numbers, *i*RVision cannot offset the robots correctly. Make sure that the robots share the same user frame number.

2.1.6 Creating and Teaching Vision Process

Create a vision process for the "3DL Single-View Vision Process". For fixed frame offset, 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.

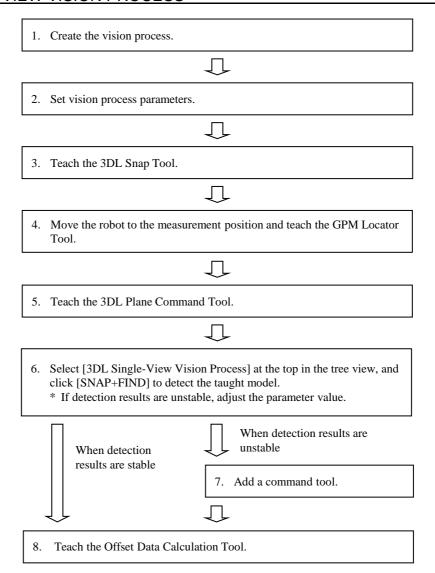






Workpiece setting example

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



Vision process teaching flow

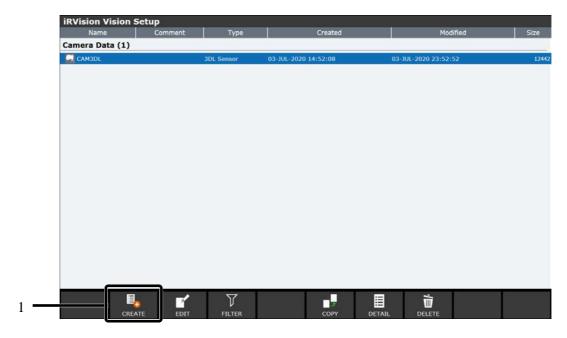
Placing reference workpiece

After it is confirmed that the calibration of the 3D Laser Vision Sensor has been correctly performed, workpiece picking is taught. This section explains the teaching to perform the fixed frame offset.

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.

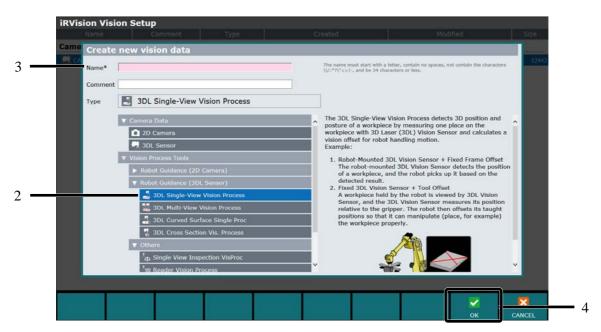
2.1.6.1 Creating vision process

After placing a reference workpiece, create a vision process.

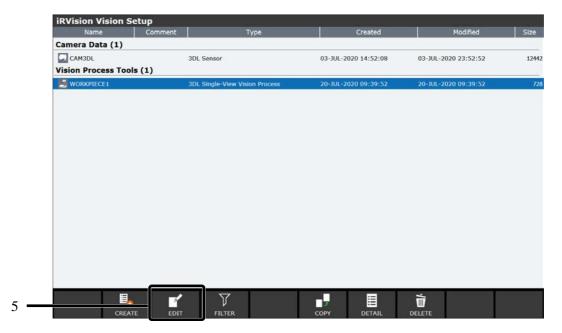


1 Click [CREATE].

The pop-up to create new vision data appears.



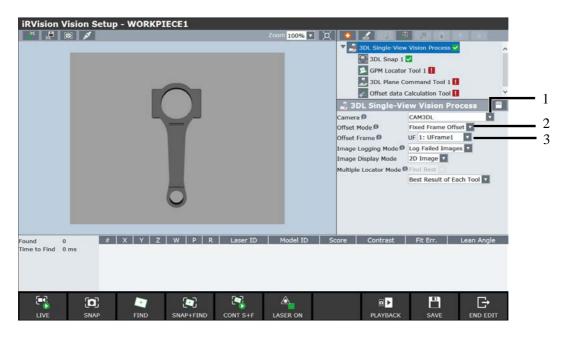
- 2 Select [3DL Single-View Vision Process].
- 3 Enter a name of vision process in [Name]. Assign a unique name to the vision process.
- 4 Click [OK].
 A new vision process is created.



5 Click [EDIT].

The setup screen for the vision process will appear.

2.1.6.2 Setting parameters of vision process

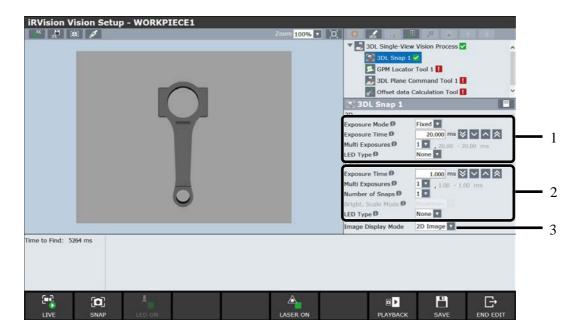


- Select the 3DL Sensor Data from the drop-down box. Select the name of the taught 3DL Sensor Data.
- Select [Fixed Frame Offset] from the [Offset Mode] drop-down box.
- 3 Select the user frame number set as [Offset Frame] from the drop-down box. An offset frame is a user frame used for calculation of the offset data. Select the user frame number set in "Setup: 2.1.5 Setting Offset Frame".

2.1.6.3 Teaching 3DL Snap Tool

Select [3DL Snap] in the tree view, and then set each item.

Setting parameters



1 Set parameters for 2D measurement.

Set parameters for snap of 2D measurement (detection and measurement of 2D features). For details of each parameter, refer to the description of COMMAND TOOL in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

2 Set parameters for laser measurement.

Set parameters for snap of laser measurement (detection and measurement of laser slit points). For details of each parameter, refer to the description of COMMAND TOOL in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

3 Select [Image Display Mode] from the drop-down box.

Select an image to show on the edit screen.

[2D Image]

An image snapped by the 2D camera appears.

[Laser Slit Image1]

An image of the laser slit 1 appears.

[Laser Slit Image2]

An image of the laser slit 2 appears.

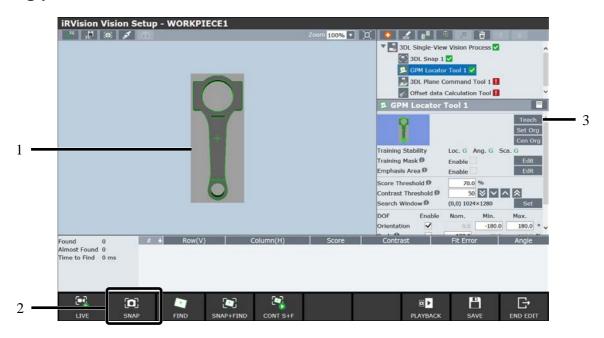
[Laser Composite Image]

An image that the image of the laser slit 1 and the image of the laser slit 2 are composited to 2D image appears.

2.1.6.4 Teaching GPM Locator Tool

Select [GPM Locator Tool] in the tree view, and then set each item.

Setting parameters



1 Jog the robot to the measurement area.

Move the robot position so that the laser beam is directed to the plane to be measured. Move the robot according to the following procedure.

Click [LIVE] to show a live image.

When the button is clicked, horizontal and vertical lines that show the center of the display screen appear. This is a guide when the plane to be measured is moved to the center of the screen. Jog the robot, and keep the distance of approx. 400 mm between the bottom surface of the 3D Laser Vision Sensor camera and the surface to be measured, in such a way that they almost directly face each other.

Next, jog the robot parallel to the surface to be measured so that the surface to be measured comes almost at the image center.

Next, jog the robot vertically to the surface to be measured so that the laser beam intersection comes almost at the center of the surface to be measured of the workpiece.

*M***emo**

To adjust the laser irradiation position for the workpiece, select [3DL Single-View Vision Process] in the tree view area, and click [LASER ON] to irradiate the laser, and then click [LIVE] for adjustment. Then, select [3DL Snap] in the tree view area, and adjust the parameters.

2 Click [SNAP].

After determining the measurement position, click [SNAP] to capture an image.

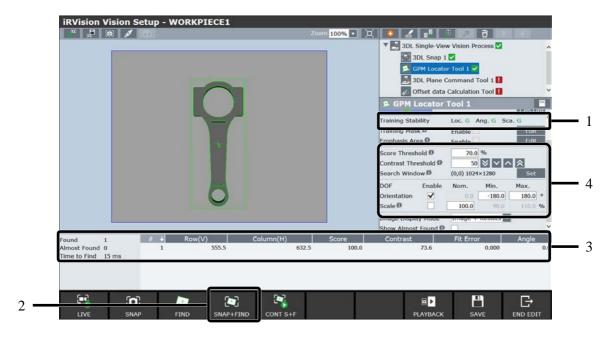
3 Click the [Teach] button.

The GPM Locator Tool model setup screen appears. 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 Mask] can be set to exclude them from the teach model. For details of teaching 2D features, refer to "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

4 Teach the robot position in the robot program. Teach the robot program the position here as a workpiece measurement point.

Detection test

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



Check [Training Stability].

This item provides a guideline indicating whether the position, angle, and size are detected correctly in the taught model. Evaluations are indicated with [G] (good), [P] (poor) and [N] (none). [N] indicates that stable detection of the model may be impossible. In such a case, change the model, or uncheck [Enable] of the parameter in question in [DOF] to make the parameter invalid.

- Click [SNAP+FIND].
 - An image is captured, and detection is performed.
- Check the detection results.
 - Check that the workpieces 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 area. If the score and contrast values are higher than the set thresholds by at least 10 points, there is no problem.
- Adjust parameters. Adjust the parameters of the GPM Locator Tool as necessary.

2.1.6.5 Teaching 3DL Plane Command Tool

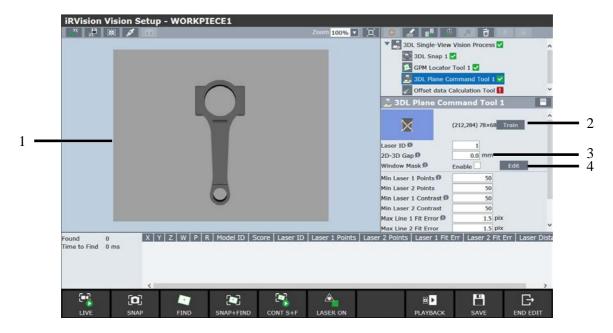
Select [3DL Plane Command Tool] in the tree view, and then set each item.

Setting parameters



↑ CAUTION

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



I Jog the robot to the measurement area.

Click [LASER ON], and jog the robot in such a way that the laser beam is directed to the plane to be measured of the workpiece. Move the robot according to the following procedure.

Although it is desirable that a measurement be made at the teaching position for the GPM Locator Tool, however, if necessary, jog the robot in the same way as the GPM Locator Tool adjustment so that the laser beam is directed to the plane to be measured of the workpiece. In this case, teach the found position of the robot program again.

2 Click the [Train] button.

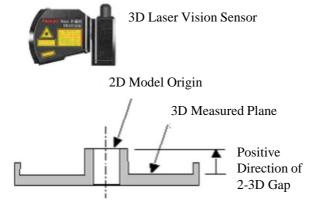
The measurement area teaching screen for plane measurement appears. Inside of the red frame shown in the image indicates the area for laser measurement. The area can be modified, and a line being modified is shown in purple.

Once the training of measurement area is completed, a thumbnail of the image used for training appears, and the area position and size appear.

If the GPM Locator Tool is present in the vision process, the GPM Locator Tool model must be taught in advance. If the GPM Locator Tool is not taught, the measurement area for plane measurement cannot be taught. Also, the measurement area must be taught again if the model origin of the GPM Locator Tool is changed or the detection model is taught again after teaching the measurement area.

3 Set [2D-3D Gap].

When there is a difference in height between the planes 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.

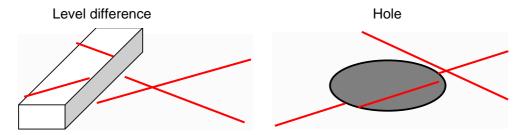


Section of the workpiece(example)

Height difference between laser measurement plane and 2D measurement plane

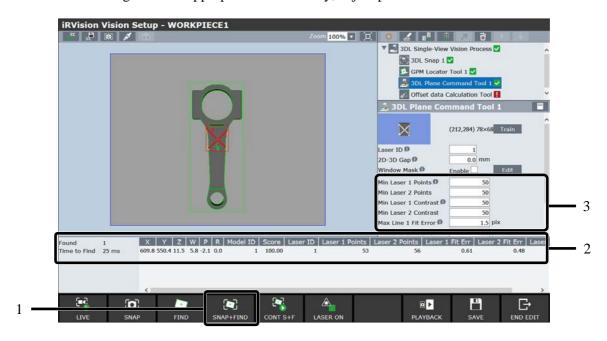
4 Click the [Edit] button of [Window Mask].

When there is an area to be excluded from the measurement area because the measurement area includes planes with level difference to which the laser beam is directed or for other reasons, click the [Edit] button of [Window Mask], and train the mask. Even if the mask is taught, 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.



1 Click [SNAP+FIND].

An image is captured, and detection is performed.

2 Check the detection results.

Check that laser points are detected correctly on the image. Then, check the results output on the test execution result display area. By comparing the values of the results with set thresholds, determine whether stable detection can be performed. When detection fails, laser slit measurement results appear. Its measurement result can be used to determine the cause of the non-detection.

If the checked LL distance is close to 3.0 mm, the measurement area may contain different planes or calibration data may be incorrect. Review the measurement area for plane measurement and check the calibration data.

If the GPM Locator Tool is set, the precondition to perform laser measurement is that the GPM Locator Tool detection was successful.

3 Adjust parameters.

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

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. To change the parameters, refer to the description of COMMAND TOOL in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN", and make changes with caution.

↑ CAUTION

Before changing the detection parameters of laser points, check whether the laser measurement exposure time of the 3DL Snap Tool has been adjusted properly.

2.1.6.6 Running a test

Run a test to check whether the vision process operates as taught. Before running the test, select [3DL Single-View Vision Process] in the tree view.

Running a test

Click [SNAP+FIND] to snap an image and detect workpiece. If the workpiece is not detected, change the parameter for the undetected image, click [FIND] and run the test without snapping the image again. If the parameter change is valid, the workpiece is detected. Click [CONT S+F] to snap images and detect workpiece repeatedly. During this continuous execution, [CONT S+F] is changed to [STOP]. Click [STOP] to stop the continuous execution.

Time to find

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.

Checking found result

When the test detection is successful, the results appear. The measured position and posture of the workpiece are output using the values in the offset frame selected for the vision process. [Laser ID] and [Model ID] indicate which command tool resulted in successful detection.



When the score and contrast values are higher than the set thresholds by at least 10 points and therefore detection results are stable, proceed to "Setup: 2.1.6.8 Teaching the offset data calculation tool". If the detection results are still unstable even after adjusting parameters of each command tool, proceed to "Setup: 2.1.6.7 Adding command tools", and change the setting to achieve a stable results.

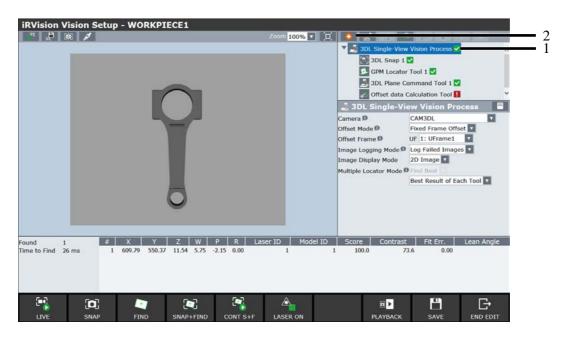
2.1.6.7 Adding command tools

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

ℳMemo

The reasons why command tools are added

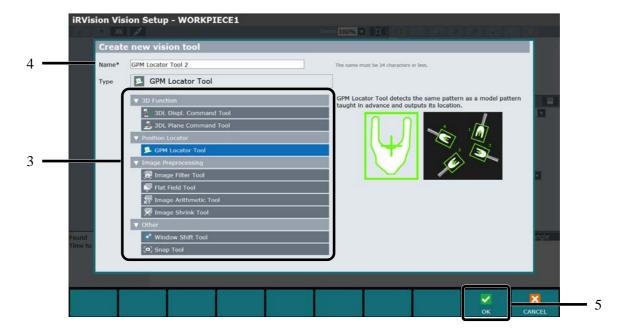
Due to individual differences of workpieces and change of illumination intensity by time of day, an undetected situation tends to occur with only one set of detection parameter. In this case, preparing multiple command tools meeting the conditions can improve detection robustness.



- 1 Select [3DL Single-View Vision Process].
 - When a vision process for [3DL Single-View Vision Process] is created, one GPM Locator Tool and one 3DL Plane Command Tool are added. To add another command tool to a vision process, at first, select [3DL Single-View Vision Process] in the tree view.
- 2 Click the **button**.
 - A new command tool setting can be added.

∕Memo

To copy an existing command tool, select the command tool to copy and click the button.



3 Click a type of command tool to be added. From the drop-down box, select [3DL Displ. Command Tool], [3DL Plane Command Tool], or [GPM Locator Tool].

- 4 Enter a name in [Name].
 Assign a unique name to the command tool.
- 5 Click [OK].
 The command tool is added.

Adding 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, the robot offset data cannot be correctly 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.

Adding 3DL Displacement Command Tool

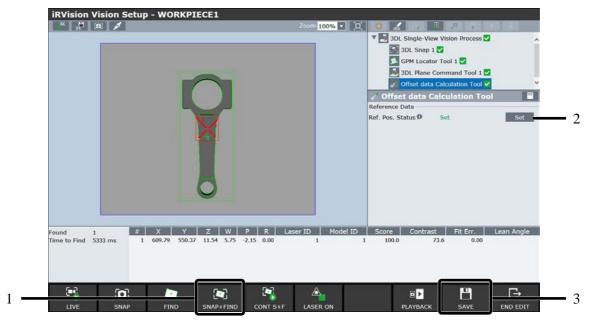
Because robot offset motion differs between [3DL Displ. Command Tool] and [3DL Plane Command Tool], when [3DL Displ. Command Tool] is added to a vision process, it is recommended to delete 3D measurement tools other than [3DL Displ. Command Tool].

[3DL Displ. Command Tool] is taught in the same manner as [3DL Plane Command Tool]. Note that the output position and posture of a workpiece, and parameter setting items differ between them. For details, refer to "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

2.1.6.8 Teaching the offset data calculation tool

In this section, place a workpiece in a reference position, run a test, and set the detection result as the reference position XYZWPR.

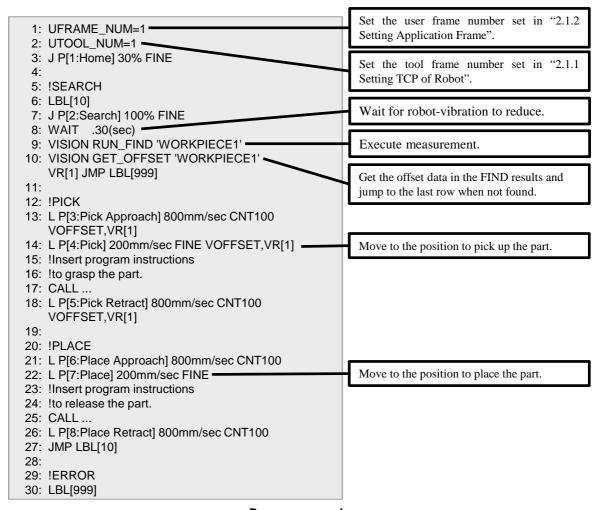
When the vision process is performed after the setting, the vision process calculates the offset data by comparing the actual position where the workpiece is detected and this reference position. Select [Offset data Calculation Tool] in the tree view, and then set each item.



- 1 Click [SNAP+FIND].
- 2 Check that the workpiece is properly detected and click the [Set] button of [Ref. Pos. Status].
- 3 Click [SAVE] and then [END EDIT].

2.1.7 Creating and Teaching Robot Program

In the sample program below, a vision process for the 3DL Single-View Vision Process named "WORKPIECE1" is used. The sample program is a program to pick up, a pile of sheet metals one by one. The robot offsets the picking motion according to the measurement result, and picks the workpiece as taught. After supplying the workpiece to the next process, the robot tries to detect another workpiece. Teach the measurement position specified with the robot program when creating the vision process. Refer to "Setup: 2.1.6.4 Teaching GPM Locator Tool".



Program example

ℳMemo

Measurement is performed after the robot reaches the taught position on the last motion. If there is no residual vibration in the robot, measurement can be performed immediately after positioning. However, depending on the robot's setting condition, residual vibration may occur in the robot's motion or rail axis, which may affect the accuracy of measurement. In such cases, giving the wait command or the acceleration override command to reduce the speed slowly may be required for adjustment.

In the sample program above, the vision process 'WORKPIECE1' is executed, one vision offset is calculated, and the robot position is offset by the vision offset. If no workpiece is detected, it jumps to the label [999] without offset operation.

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

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

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 at 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.

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, 14th, and 17th lines, the robot motion such like as the workpiece handling is offset 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 that is offset with a vision offset data in a specified vision register.

For details of each command above and other commands, refer to the description of PROGRAM COMMAND in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

2.1.8 Checking Robot Offset Operation

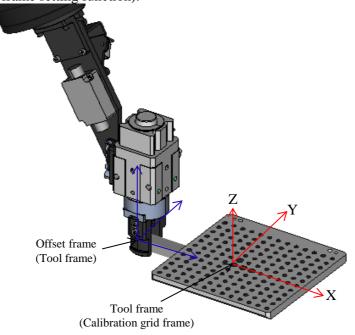
Check that a workpiece gripped by the robot can be detected and positioned at a desired location exactly. At first, decrease the override of the robot to check that the logic of the program is correct. Next, increase the override and cycle the program again to check its operation.

2.2 SETUP FOR "FIXED CAMERA + 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 offset so that the robot places the gripped workpiece at the predetermined position exactly.

For setup of 'fixed camera + tool offset', specify a tool frame with an arbitrary number to 'calibration grid frame' and 'offset frame' respectively, and set necessary data to the tool frame.

The "Calibration grid frame" can be set easily and correctly by using the camera of the 3D Laser Vision Sensor (calibration grid frame setting function).



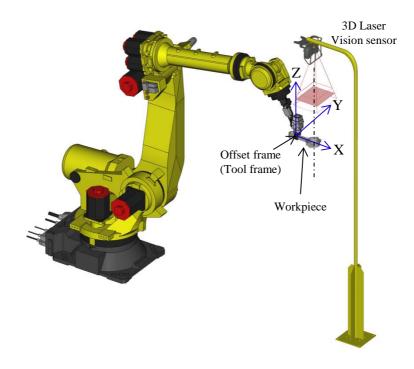
Tool frame used for offset

Use the following setup procedure for "fixed camera + tool offset". 1. Set an application frame as required. Set the calibration grid frame in a tool frame with an arbitrary Use the calibration grid frame setting for this setting. number. 3. Create and teach 3D Laser Vision Sensor data 4. Set the offset frame in tool frame with an arbitrary number. 5. Create and teach the vision process. Use this setting when teaching the position for 6. Create and teach the robot program. teaching the GPM Locator Tool and creating the next robot program. 7. Check the robot offset operation.

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Setup flow

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

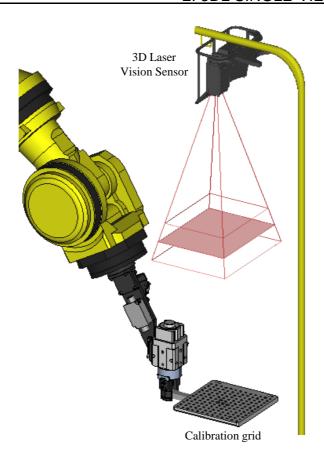


Fixed camera + tool offset layout example

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.



Calibration grid mounting example

2.2.1 Setting Application Frame

Specify the robot's user frame to be used as a reference for 3DL calibration. In many cases, the base frame of the robot is set up in the world frame.

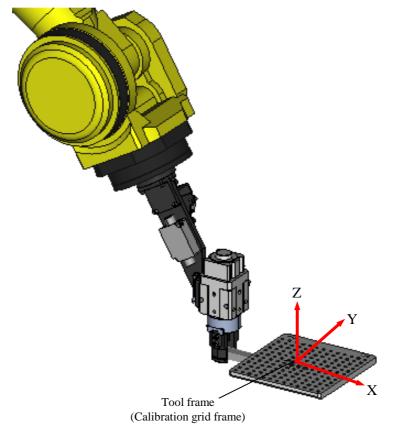
Refer to "Introduction: 1.5 COORDINATE SYSTEMS USED FOR iRVision".

2.2.2 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 calibration grid frame setting function. After securing the calibration grid, execute the calibration grid frame setting function. For details of the calibration grid frame setting function, refer to "Know-How: 1.2 FRAME SETTING WITH GRID FRAME SETTING FUNCTION".

In addition to the method of using the calibration 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, and then set a tool frame as shown in the figure below. Refer to "Know-How: 1.1 FRAME SETTING WITH POINTER TOOL". Touch up the grid precisely since the touch-up precision directly affects the offset precision.

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 details of the calibration recovery method, refer to "Know-How: 2.2.7 Automatic Re-Calibration".



Calibration grid installation information

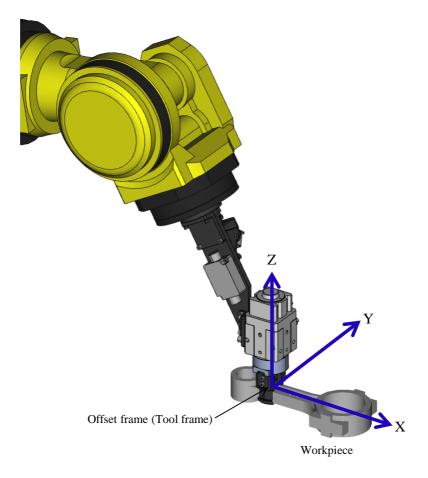
2.2.3 Creating and Teaching 3DL Sensor Data

To use the 3D Laser Vision Sensor, 3DL calibration using a calibration grid is required. For details of the 3DL calibration, refer to "Know-How: 2 3DL SENSOR DATA SETTING".

2.2.4 Setting Offset Frame

Set a tool frame to be used as the reference of the tool offset operation by the robot. The measurement results (tool offset data) are output as values in the tool frame set here.

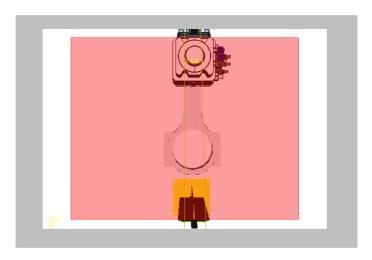
To set the tool frame, use [Tool Frame Setup / Six Point]. For details of the frame setting, refer to "Know-How: 1 FRAME SETTING".

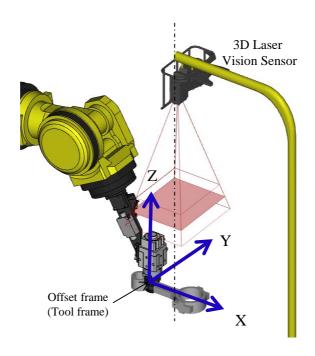


Tool frame used for offset

2.2.5 Creating and Teaching Vision Process

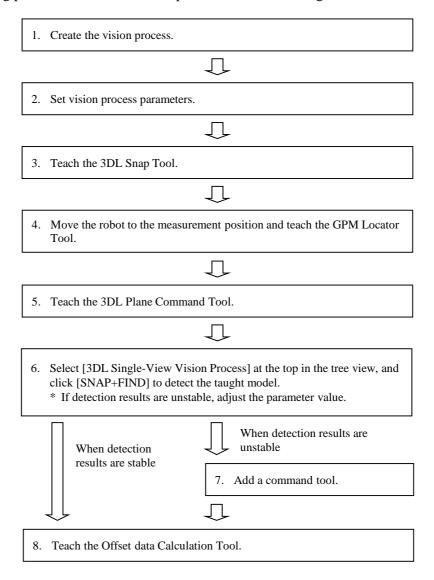
Create a vision process for the "3DL Single-View Vision Process". For tool offset, first make the end of arm tooling hold the workpiece to be picked up to teach the reference position. If how the end of arm tooling holds the workpiece can be reproduced with precision, detection models can be added or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





Workpiece setting example

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



Vision process teaching flow

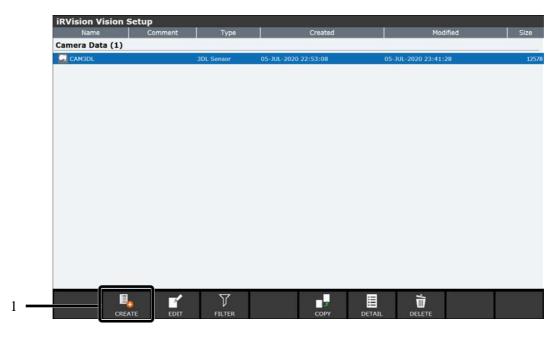
Placing reference workpiece

After it is confirmed that the calibration of the 3D Laser Vision Sensor has been correctly performed, workpiece picking is taught. This section explains the teaching to perform a tool offset.

First, hold the target workpiece for measurement by the end of arm tooling. If a reproducible position is set as the reference position, detection models can be added or changed easily.

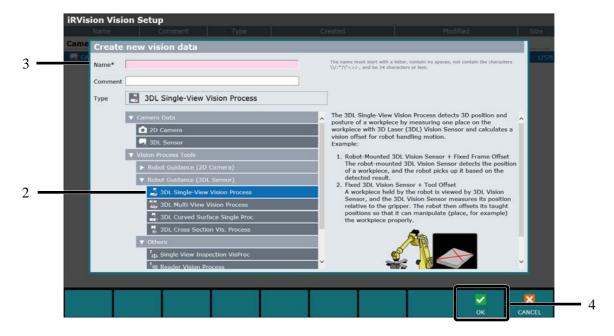
2.2.5.1 Creating vision process

After placing a reference workpiece, create a vision process.

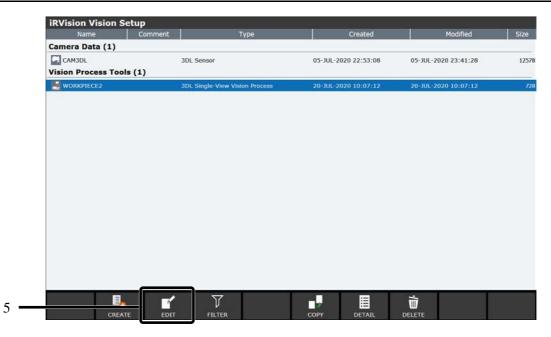


1 Click [CREATE].

The [Create new vision data] screen appears.

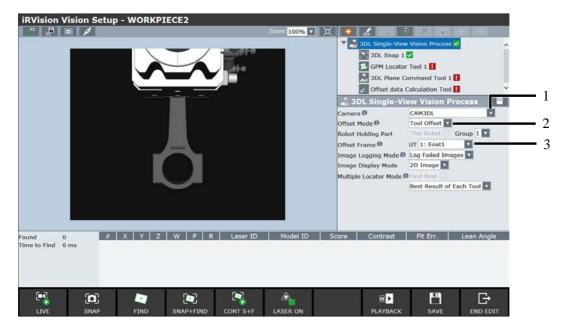


- 2 Select [3DL Single-View Vision Process].
- 3 Enter a name of vision process in [Name]. Assign a unique name to the vision process.
- 4 Click [OK].
 A new vision process is created.



5 Click [EDIT].
The vision process setup screen appears.

2.2.5.2 Setting parameters of vision process

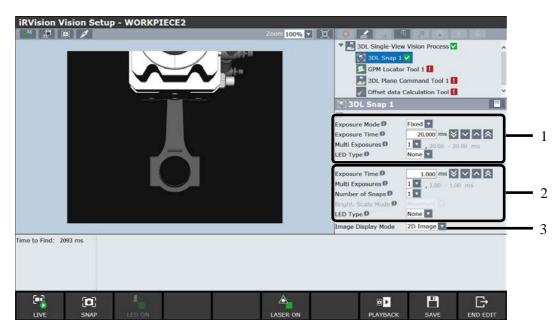


- Select the 3DL Sensor Data from the drop-down box. Select the name of the taught 3DL Sensor Data.
- 2 Select [Tool Offset] from the [Offset Mode] drop-down box.
- 3 Select the tool frame number from the [Offset Frame] drop-down box. An offset frame is a tool frame used for calculation of offset amount. Select the tool frame number set in "Setup: 2.2.4 Setting Offset Frame".

2.2.5.3 Teaching 3DL Snap Tool

Select [3DL Snap] in the tree view, and then set each item.

Setting parameters



1 Set parameters for 2D measurement.

Set parameters for snap of 2D measurement (detection and measurement of 2D features). For details of each parameter, refer to the description of COMMAND TOOL in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

2 Set parameters for laser measurement.

Set parameters for snap of laser measurement (detection and measurement of laser slit points). For details of each parameter, refer to the description of COMMAND TOOL in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

3 Select [Image Display Mode] from the drop-down box.

Select an image to show on the edit screen.

[2D Image]

An image snapped by the 2D camera appears.

[Laser Slit Image1]

An image of the laser slit 1 appears.

[Laser Slit Image2]

An image of the laser slit 2 appears.

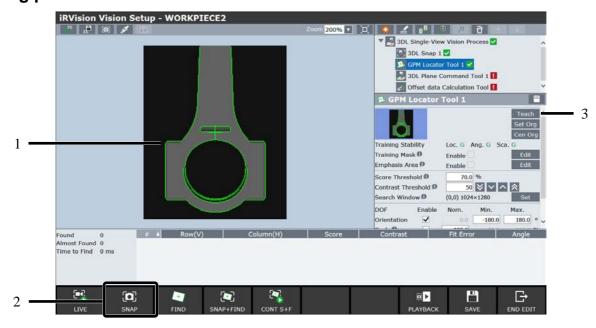
[Laser Composite Image]

An image that the image of the laser slit 1 and the image of the laser slit 2 are composited to 2D image appears.

2.2.5.4 Teaching GPM Locator Tool

Select [GPM Locator Tool] in the tree view, and then set each item.

Setting parameters



1 Jog the robot to the measurement area.

Move the robot position so that the laser beam is directed to the plane to be measured. Move the robot according to the following procedure.

Click [LIVE] to show a live image.

When the button is clicked, horizontal and vertical lines that show the center of the display screen appear. This is a guide when the plane to be measured is moved to the center of the screen. Jog the robot, and keep the distance of approx. 400 mm between the bottom surface of the 3D Laser Vision Sensor camera and the plane to be measured in such a way that they almost directly face each other. Next, jog the robot parallel to the surface to be measured so that the surface to be measured comes almost at the image center.

Next, jog the robot vertically to the surface to be measured so that the laser beam intersection comes almost at the center of the surface to be measured of the workpiece.

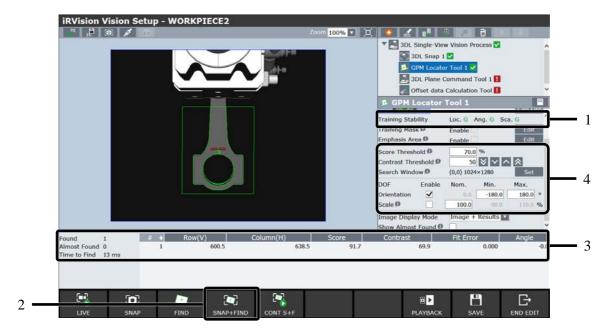
ℳMemo

To adjust the laser irradiation position for the workpiece, select [3DL Single-View Vision Process] in the tree view area, and click [LASER ON] to irradiate the laser, and then click [LIVE] for adjustment. Then, select [3DL Snap] in the tree view area, and adjust the parameters.

- 2 Click [SNAP].
 - After determining the measurement position, click [SNAP] to capture an image.
- 3 Click the [Teach] button.
 - The GPM Locator Tool model setup screen appears. 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 Mask] can be set to exclude them from the teach model. For details of teaching 2D features, refer to "*i*RVision OPERATOR'S MANUAL (Reference) B-83914EN".
- Teach the robot position in the robot program.
 Teach the robot program the position here as a workpiece measurement point.

Detection test

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



1 Check [Training Stability].

This item provides a guideline indicating whether the position, angle, and size are detected correctly in the taught model. Evaluations are indicated with [G] (good), [P] (poor) and [N] (none). [N] indicates that stable detection of the model may be impossible. In such a case, change the model, or uncheck [Enable] of the parameter in question in [DOF] to make the parameter invalid.

- 2 Click [SNAP+FIND].
 - An image is captured, and detection is performed.
- 3 Check the detection results.
 - Check that the workpieces 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 area. If the score and contrast values are higher than the set thresholds by at least 10 points, there is no problem.
- 4 Adjust parameters.
 Adjust the parameters of the GPM Locator Tool as necessary.

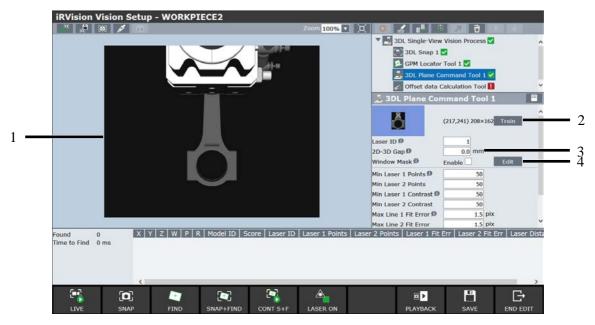
2.2.5.5 Teaching 3DL Plane Command Tool

Select [3DL Plane Command Tool] in the tree view, and then set each item.

Setting parameters



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



1 Jog the robot to the measurement area.

Click [LASER ON], and jog the robot in such a way that the laser beam is directed to the plane to be measured of the workpiece. Move the robot with the following procedure.

Although it is desirable that a measurement be made at the teaching position for the GPM Locator Tool, however, if necessary, jog the robot in the same way as the GPM Locator Tool adjustment so that the laser beam is directed to the plane to be measured of the workpiece. In this case, teach the found position of the robot program again.

2 Click the [Train] button.

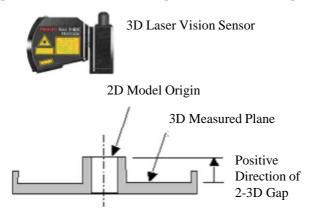
The measurement area teaching screen for plane measurement appears. Inside of the red frame shown in the image indicates the area for laser measurement. The area can be modified, and a line being modified is shown in purple.

Once the training of measurement area is completed, a thumbnail of the image used for training appears, and the area position and size appear.

If the GPM Locator Tool is present in the vision process, the GPM Locator Tool model must be taught in advance. If the GPM Locator Tool is not taught, the measurement area for plane measurement cannot be taught. Also, the measurement area must be taught again if the model origin of the GPM Locator Tool is changed or the detection model is taught again after teaching the measurement area.

3 Set [2D-3D Gap].

When there is a difference in height between the planes 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.



Section of the workpiece(example)

Height difference between laser measurement plane and 2D measurement plane

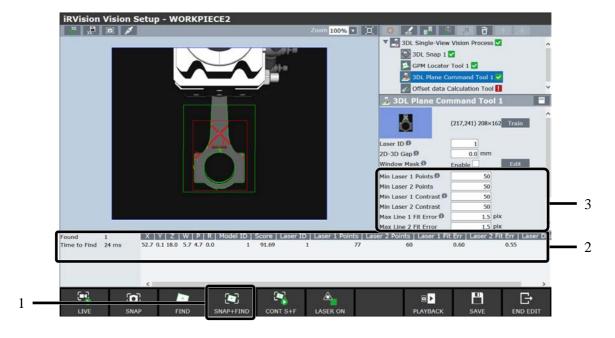
4 Click the [Edit] button of [Window Mask].

When there is an area to be excluded from the measurement area because the measurement area includes planes with level difference to which the laser beam is directed or for other reasons, click the [Edit] button of [Window Mask], and train the mask. Even if the mask is taught, 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.



1 Click [SNAP+FIND].

An image is captured, and detection is performed.

2 Check the detection results.

Check that laser points are detected correctly on the image. Then, check the results output on the test execution result display area. By comparing the values of the results with set thresholds, determine whether stable detection can be performed. When detection fails, laser slit measurement results appear. Its measurement result can be used to determine the cause of the non-detection.

If the checked LL distance is close to 3.0 mm, the measurement area may contain different planes or calibration data may be incorrect. Review the measurement area for plane measurement and check the calibration data.

If the GPM Locator Tool is set, the precondition to perform laser measurement is that the GPM Locator Tool detection was successful.

3 Adjust parameters.

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

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. To change the parameters, refer to the description of COMMAND TOOL in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN", and make changes with caution.

⚠ CAUTION

Before changing the detection parameters of laser points, check whether the laser measurement exposure time of the 3DL Snap Tool has been adjusted properly.

2.2.5.6 Running a test

Run a test to check whether the vision process operates as taught. Before running the test, select [3DL Single-View Vision Process] in the tree view.

Running a test

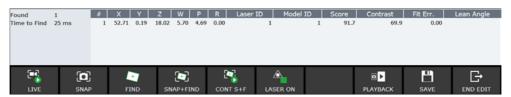
Click [SNAP+FIND] to snap an image and detect workpiece. If the workpiece is not detected, change the parameter for the undetected image, click [FIND] and run the test without snapping the image again. If the parameter change is valid, the workpiece is detected. Click [CONT S+F] to snap images and detect workpiece repeatedly. During this continuous execution, [CONT S+F] is changed to [STOP]. Click [STOP] to stop the continuous execution.

Time to find

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.

Checking found result

When the test detection is successful, the results appear. The measured position and posture of the workpiece are output using the values in the offset frame selected for the vision process. [Laser ID] and [Model ID] indicate which command tool resulted in successful detection.



When the score and contrast values are higher than the set thresholds by at least 10 points and therefore detection results are stable, proceed to "Setup: 2.2.5.8 Teaching the offset data calculation tool". If the detection results are still unstable even after adjusting parameters of each command tool, proceed to "Setup: 2.2.5.7 Adding command tools", and make a necessary setting for stable results.

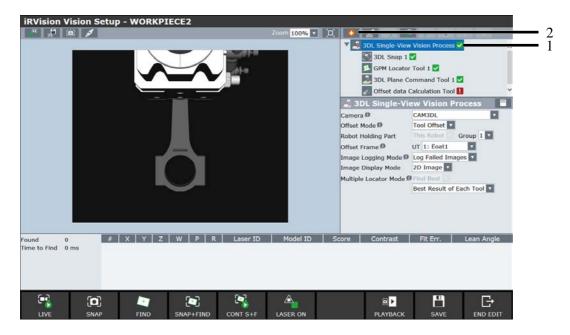
2.2.5.7 Adding command tools

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

*M***emo**

The reasons why command tools are added

Due to individual differences of workpieces and change of illumination intensity by time of day, an undetected situation tends to occur with only one set of detection parameter. In this case, preparing multiple command tools meeting the conditions can improve detection robustness.

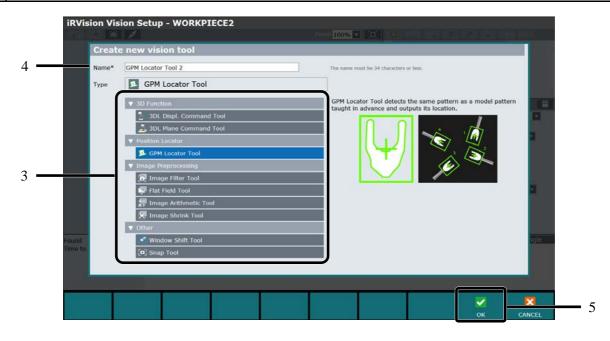


- 1 Click [3DL Single-View Vision Process].
 - When a vision process for [3DL Single-View Vision Process] is created, one GPM Locator Tool and one 3DL Plane Command Tool are added. To add another command tool to a vision process, at first, select [3DL Single-View Vision Process] in the tree view.
- 2 Click the button.

A new command tool setting can be added.



To copy an existing command tool, select the command tool to copy, then click the button.



- 3 Click a type of command tool to be added. From the drop-down box, select [3DL Displ. Command Tool], [3DL Plane Command Tool], or [GPM Locator Tool].
- 4 Enter a name in [Name].
 Assign a unique name to the command tool.
- 5 Click [OK].
 The command tool is added.

Adding 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, the robot offset data cannot be correctly 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.

Adding 3DL Displacement Command Tool

Because robot offset motion differs between [3DL Displ. Command Tool] and [3DL Plane Command Tool], when [3DL Displ. Command Tool] is added to a vision process, it is recommended to delete 3D measurement tools other than [3DL Displ. Command Tool].

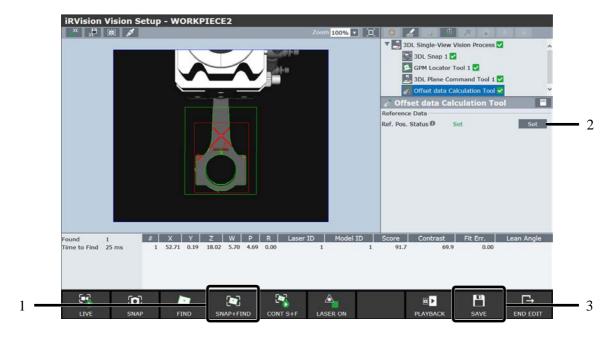
[3DL Displ. Command Tool] is taught in the same manner as [3DL Plane Command Tool]. Note that the output position and posture of a workpiece, and parameter setting items differ between them. For details, refer to "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

2.2.5.8 Teaching the offset data calculation tool

In this section, place a workpiece in a reference position, run a test, and set the detection result as the reference position XYZWPR.

When the vision process is performed after the setting, the vision process calculates the offset data by comparing the actual position where the workpiece is detected and this reference position.

Select [Offset data Calculation Tool] in the tree view, and then set each item.

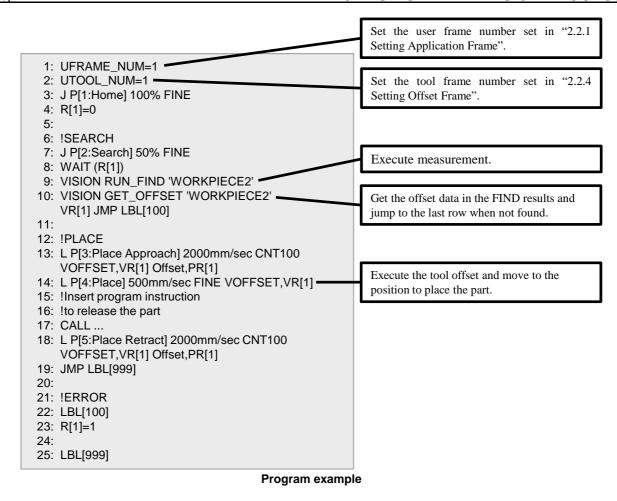


- 1 Click [SNAP+FIND].
- 2 Check that the workpiece is properly detected and click the [Set] button of [Ref. Pos. Status].
- 3 Click [SAVE] and then [END EDIT].

2.2.6 Creating and Teaching Robot Program

In the sample program below, a vision process for the 3DL Single-View Vision Process named "WORKPIECE2" is used. The sample program is a program to place, e.g., an unprocessed casting gripped by the robot in the position and posture determined beforehand. The robot performs a tool offset according to the measurement result. After supplying the workpiece to the processing machine, the robot tries to detect another workpiece.

Teach the measurement position specified with the robot program when creating the vision process. Refer to "Setup: 2.2.5.4 Teaching GPM Locator Tool".



ℳMemo

Measurement is performed after the robot reaches the taught position on the last motion. If there is no residual vibration in the robot, measurement can be performed immediately after positioning. However, depending on the robot's setting condition, residual vibration may occur in the robot's motion or rail axis, which may affect the accuracy of measurement. In this case, adjustment such as giving the wait command or the acceleration override command to reduce the speed slowly may be required.

In the sample program above, the vision process 'WORKPIECE2' is executed, only one piece of offset data is obtained, and the position where the workpiece is placed is offset. If no workpiece is detected, it jumps to the label [999] without offset operation.

The command for iRVision used in the sample program is explained.

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

```
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 at 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.

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, 14th, and 18th lines, robot motion such as placing the workpiece is offset 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 that is offset with a vision offset data in a specified vision register.

For details of each command above and other commands, refer to the description of PROGRAM COMMAND in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

2.2.7 Checking Robot Offset 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.

3 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 offset 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 startup procedure and teaching procedure using the following two application examples.

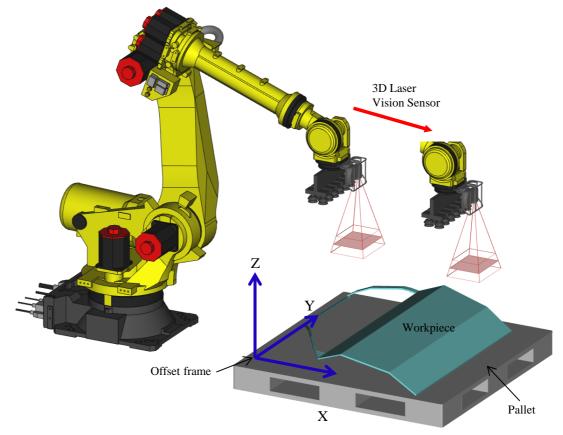
- (1) Robot-mounted camera + fixed frame offset
- (2) Fixed camera + tool offset

ℳMemo

Unless otherwise specified, the screens and operations in the simple mode are shown in this chapter. For details of the simple mode and advanced mode, refer to the "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

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

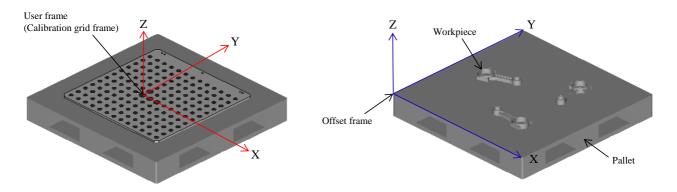
A layout example of 'robot-mounted camera + fixed frame offset' for '3DL Multi-View Vision Process' is given below.



Layout example of robot-mounted camera + fixed frame offset

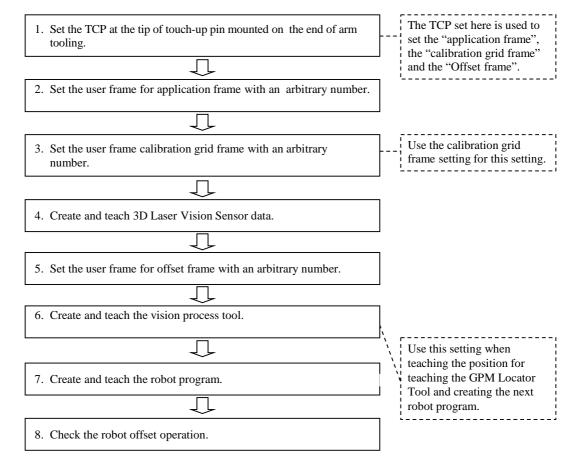
For setup of 'robot-mounted camera + fixed frame offset', specify a user frame with an arbitrary number to 'installation information of the calibration grid' and 'offset frame' respectively, and make necessary settings for the user frame.

The "Calibration grid frame" can be set easily and correctly by using the camera of the 3D Laser Vision Sensor (calibration grid frame setting function).



Calibration grid frame and offset frame

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



Setup flow

3.1.1 Setting TCP of Robot

Setting the TCP of the robot is necessary to teach the application frame, the calibration grid frame and the offset frame. In general, 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]. For the setting method, refer to "Know-How: 1 FRAME SETTING".

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.

3.1.2 Setting Application Frame

Specify the robot's user frame to be used as a reference for 3DL calibration. In many cases, the base frame of the robot is set up in the world frame. However, in the following cases, set the user frame, and set the user frame number as the application frame.

- In the case the 3D Laser Vision Sensor is attached to a robot other than the robot to be offset.
- In the case the calibration grid is attached to a robot other than the robot to be offset.
- In the case the robot to be offset belongs to another motion group.

Refer to "Introduction: 1.5 COORDINATE SYSTEMS USED FOR iRVision".

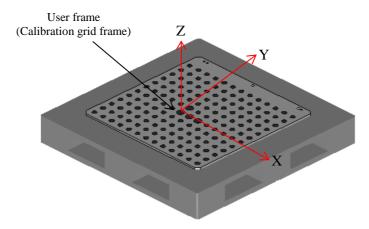
3.1.3 Setting Calibration Grid Frame

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 calibration grid frame setting function. After securing the calibration grid, execute the calibration grid frame setting function. For details of the calibration grid frame setting, refer to "Know-How: 1.2 FRAME SETTING WITH GRID FRAME SETTING FUNCTION". Note that the user frame in the installation information of the calibration grid differs from the user frame used for offset described in the following subsection.

In addition to the method of using the calibration 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. Refer to "Know-How: 1.1 FRAME SETTING WITH POINTER TOOL". The TCP setting precision and touch-up precision directly affect the offset 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 details of the calibration recovery method, refer to "Know-How: 2.1.7 Automatic Re-Calibration".



Calibration grid installation information

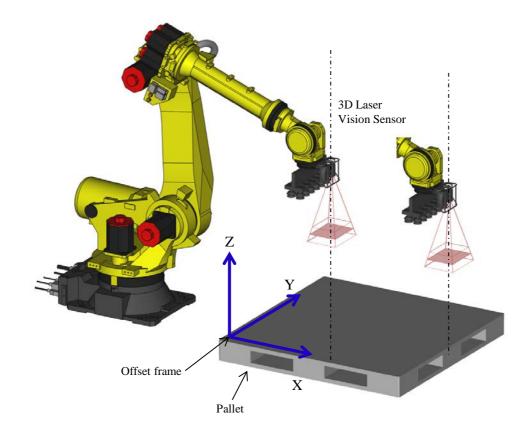
3.1.4 Creating and Teaching 3DL Sensor Data

To use the 3D Laser Vision Sensor, 3DL calibration using a calibration grid is required. For details of the 3DL calibration, refer to "Know-How: 2 3DL SENSOR DATA SETTING".

3.1.5 Setting Offset Frame

Set a user frame to be used as the reference for the robot offset 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. For details of the frame setting, refer to "Know-How: 1 FRAME SETTING".



User frame used for offset

Sharing user frame

When two or more robots work together for the same workpiece, it is necessary to physically set the same user frame for all the robots. 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. E.g., user frame 5 of robot 1 needs to be physically the same as user frame 5 of robot 2.

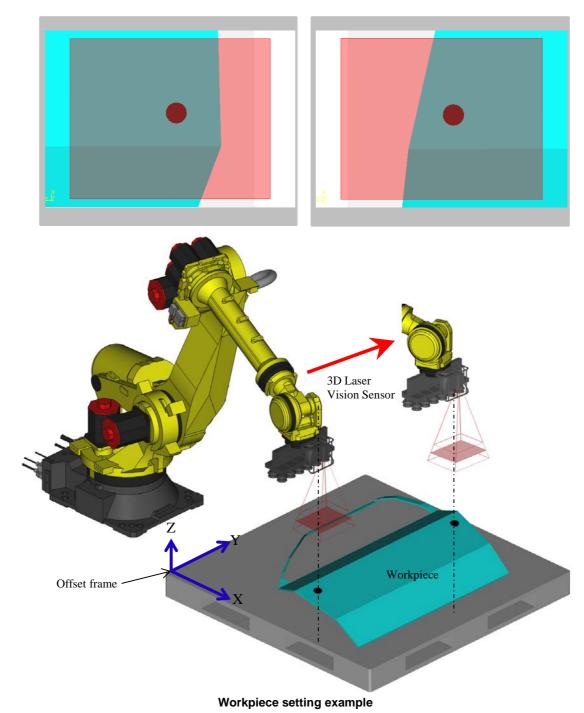


⚠ CAUTION

If robots share user frames of different numbers, iRVision cannot offset the robots correctly. Make sure that the robots share the same user frame number.

3.1.6 Creating and Teaching 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 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. Create the vision process.
2. Set vision process parameters.
3. Select a plane camera view and specify the 3D Laser Vision Sensor data.
4. Teach the 3DL Snap Tool.
\Box
5. Move the robot to the measurement position and teach the GPM Locator Tool.
\Box
6. Teach the 3DL Plane Command Tool.
\Box
7. Return to the plane camera view and click [SNAP+FIND] to detect the taught model. * If detection results are unstable, adjust the parameter value of the command tool.
When detection results are unstable
When detection results are stable 8. Add a command tool.
9. Perform the steps 3 to 7 for all the camera views.
\Box
10. Teach the Offset data Calculation Tool.

Vision process teaching flow

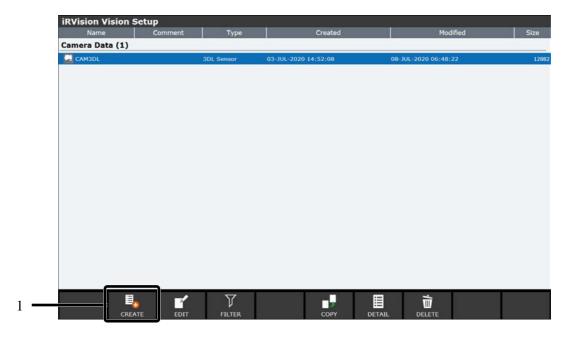
Placing reference workpiece

After it is confirmed that the calibration of the 3D Laser Vision Sensor has been correctly performed, workpiece picking is taught. This section explains the teaching to perform the fixed frame offset.

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.

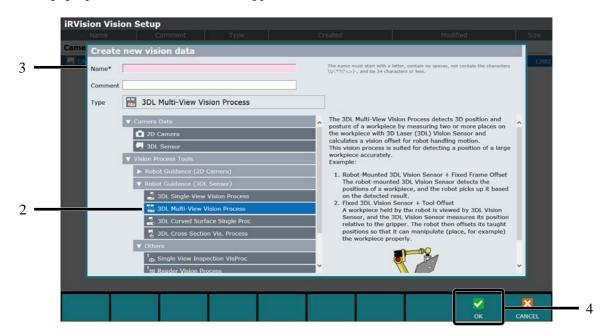
3.1.6.1 Creating vision process

After placing a reference workpiece, create a vision process.

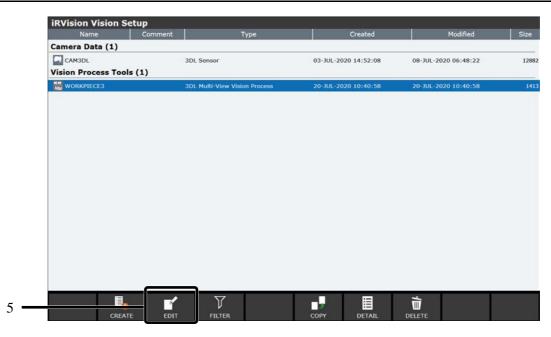


1 Click [CREATE].

The pop-up to create new vision data appears.



- 2 Select [3DL Multi-View Vision Process].
- 3 Enter a name of vision process in [Name]. Assign a unique name to the vision process.
- 4 Click [OK].
 A new vision process is created.



5 Click [EDIT].
The vision process setup screen appears.

3.1.6.2 Setting parameters of vision process

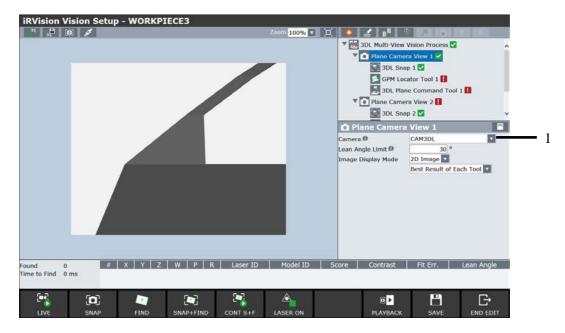


- 1 Select [Fixed Frame Offset] from the [Offset Mode] drop-down box.
- 2 Select the user frame number set as [Offset Frame] from the drop-down box. An offset frame is a user frame used for calculation of the offset data. Select the user frame number set in "Setup: 3.1.5 Setting Offset Frame".

3.1.6.3 Teaching plane camera view

Select [Plane Camera View] in the tree view area, and then set each item.

Setting parameters



Select the 3DL Sensor Data from the drop-down box. Select the name of the taught 3DL Sensor Data.

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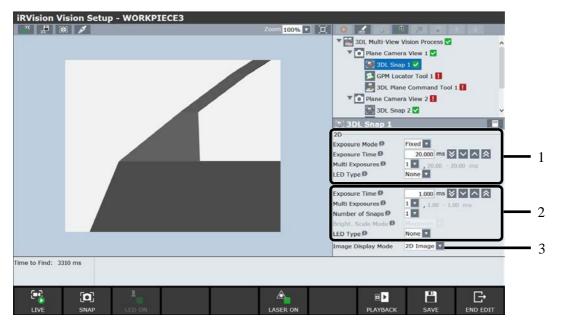
Adding plane camera views

Plane camera views can be added as necessary. Consider adding plane camera views when adequate offset precision cannot be achieved with two-point plane camera views due to a large workpiece. Up to four points can be added. To add, select [3DL Multi-View Vision Process] in the tree view area, and click the button.

3.1.6.4 Teaching 3DL Snap Tool

Select [3DL Snap] in the tree view area, and then set each item.

Setting parameters



1 Set parameters for 2D measurement.

Set parameters for snap of 2D measurement (detection and measurement of 2D features). For details of each parameter, refer to the description of COMMAND TOOL in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

2 Set parameters for laser measurement.

Set parameters for snap of laser measurement (detection and measurement of laser slit points). For details of each parameter, refer to the description of COMMAND TOOL in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

3 Select [Image Display Mode] from the drop-down box.

Select an image to show on the edit screen.

[2D Image]

An image snapped by the 2D camera appears.

[Laser Slit Image1]

An image of the laser slit 1 appears.

[Laser Slit Image2]

An image of the laser slit 2 appears.

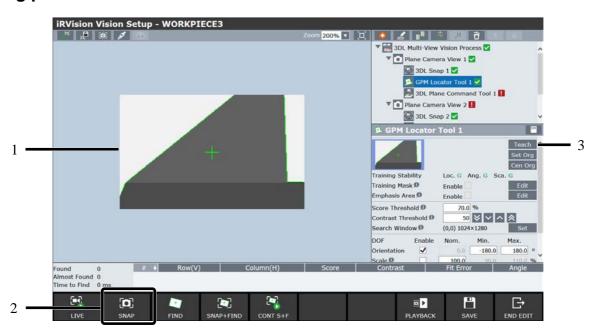
[Laser Composite Image]

An image that the image of the laser slit 1 and the image of the laser slit 2 are composited to 2D image appears.

3.1.6.5 Teaching GPM Locator Tool

Select [GPM Locator Tool] in the tree view area, and then set each item.

Setting parameters



1 Jog the robot to the measurement area.

Move the robot position so that the laser beam is directed to the plane to be measured. Move the robot according to the following procedure.

Click [LIVE] to show a live image.

When the button is clicked, horizontal and vertical lines that show the center of the display screen appear. This is a guide when the plane to be measured is moved to the center of the screen. Jog the robot, and keep the distance of approx. 400 mm between the bottom surface of the 3D Laser Vision Sensor camera and the plane to be measured in such a way that they almost directly face each other. Next, jog the robot parallel to the surface to be measured so that the surface to be measured comes

almost at the image center.

Next, jog the robot vertically to the surface to be measured so that the laser beam intersection comes almost at the center of the surface to be measured of the workpiece.

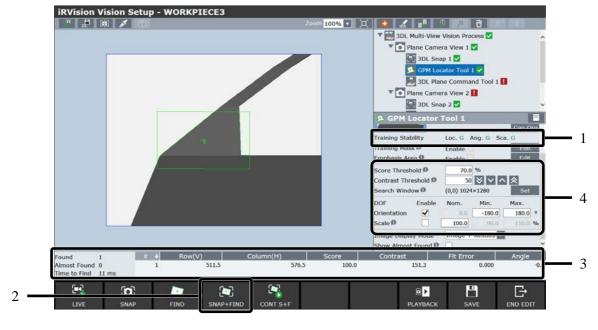
ℳMemo

To adjust the laser irradiation position for the workpiece, select [Plane Camera View] in the tree view area, and click [LASER ON] to irradiate the laser, and then click [LIVE] for adjustment. Then, select [3DL Snap] in the tree view area, and adjust the parameters.

- 2 Click [SNAP].
 - After determining the measurement position, click [SNAP] to capture an image.
- 3 Click the [Teach] button.
 - The GPM Locator Tool model setup screen appears. 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 Mask] can be set to exclude them from the teach model. For details of teaching 2D features, refer to "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".
- Teach the robot position in the robot program.
 Teach the robot program the position here as a workpiece measurement point.

Detection test

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



1 Check [Training Stability].

This item provides a guideline indicating whether the position, angle, and size are detected correctly in the taught model. Evaluations are indicated with [G] (good), [P] (poor) and [N] (none). [N] indicates that stable detection of the model may be impossible. In such a case, change the model, or uncheck [Enable] of the parameter in question in [DOF] to make the parameter invalid.

- 2 Click [SNAP+FIND].
 - An image is captured, and detection is performed.
- 3 Check the detection results.
 - Check that the workpieces 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 area. If the score and contrast values are higher than the set thresholds by at least 10 points, there is no problem.

4 Adjust parameters.

Adjust the parameters of the GPM Locator Tool as necessary.

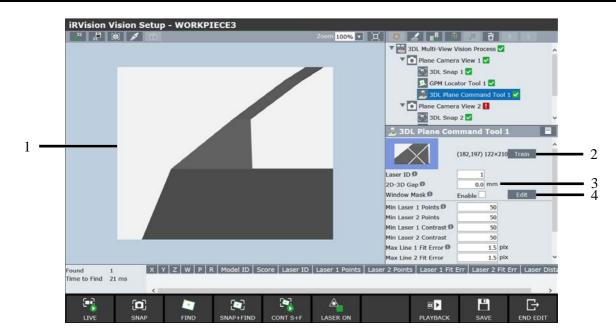
3.1.6.6 Teaching 3DL Plane Command Tool

Select [3DL Plane Command Tool] in the tree view area, and then set each item.

Setting parameters

⚠ CAUTION

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



1 Jog the robot to the measurement area.

Click [LASER ON], and jog the robot in such a way that the laser beam is directed to the plane to be measured of the workpiece. Move the robot according to the following procedure.

Although it is desirable that a measurement be made at the teaching position for the GPM Locator Tool, however, if necessary, jog the robot in the same way as the GPM Locator Tool adjustment so that the laser beam is directed to the plane to be measured of the workpiece. In this case, teach the found position of the robot program again.

2 Click the [Train] button.

The measurement area teaching screen for plane measurement appears. Inside of the red frame shown in the image indicates the area for laser measurement. The area can be modified, and a line being modified is shown in purple.

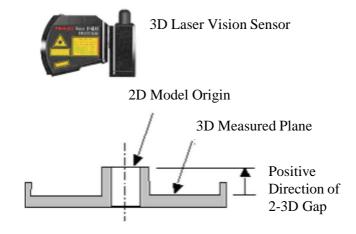
Once the training of measurement area is completed, a thumbnail of the image used for training appears, and the area position and size appear.

If the GPM Locator Tool is present in the vision process, the GPM Locator Tool model must be taught in advance. If the GPM Locator Tool is not taught, the measurement area for plane measurement cannot be taught. Also, the measurement area must be taught again if the model origin of the GPM Locator Tool is changed or the detection model is taught again after teaching the measurement area.

3 Set [2D-3D Gap].

When there is a difference in height between the planes 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.

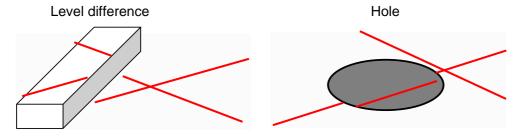


Section of the workpiece(example)

Height difference between laser measurement plane and 2D measurement plane

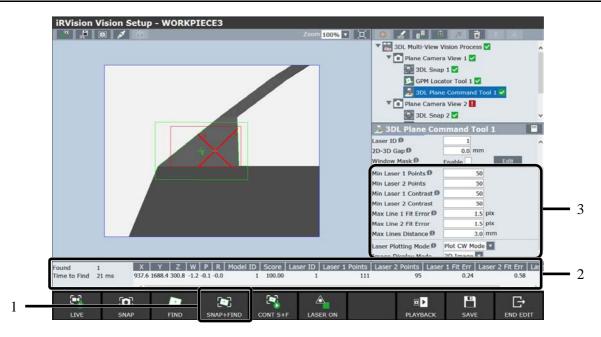
4 Click the [Edit] button of [Window Mask].

When there is an area to be excluded from the measurement area because the measurement area includes planes with level difference to which the laser beam is directed or for other reasons, click the [Edit] button of [Window Mask], and train the mask. Even if the mask is taught, 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.



- Click [SNAP+FIND].
 - An image is captured, and detection is performed.
- Check the detection results.
 - Check that laser points are detected correctly on the image. Then, check the results output on the test execution result display area. By comparing the values of the results with set thresholds, determine whether stable detection can be performed. When detection fails, laser slit measurement results appear. Its measurement result can be used to determine the cause of the non-detection.
 - If the GPM Locator Tool is set, the precondition to perform laser measurement is that the GPM Locator Tool detection was successful.
- Adjust parameters.
 - Parameters can be adjusted so that stable detection of laser points is enabled. When changing parameters, read the description in the following subsection, "Parameters for laser points detection", and carefully change them.

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. To change the parameters, refer to the description of COMMAND TOOL in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN", and make changes with caution.

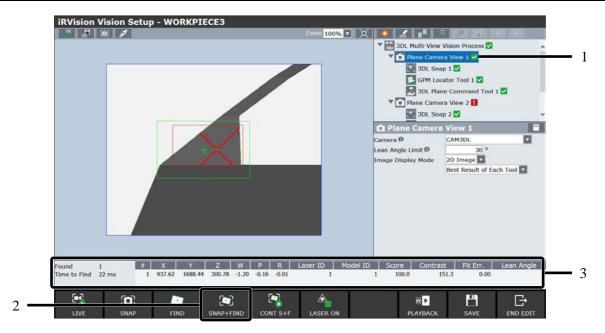


↑ CAUTION

Before changing the detection parameters of laser points, check whether the laser measurement exposure time of the 3DL Snap Tool has been adjusted properly.

3.1.6.7 Running a test

Run a detection test to check whether the plane camera view operates as taught.



- 1 Click [Plane Camera View].
- 2 Click [SNAP+FIND].

An image is captured, and detection is performed. If the workpiece is not detected, change the parameter for the undetected image, click [FIND] and run the test without snapping the image again. If the parameter change is valid, the workpiece is detected. Click [CONT S+F] to snap images and detect workpiece repeatedly. During this continuous execution, [CONT S+F] is changed to [STOP]. Click [STOP] to stop the continuous execution.

3 Check the detection results.

Time to find

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.

Checking found result

When the test detection is successful, the results appear. The measured position and posture of the workpiece are output using the values in the offset frame selected for the vision process. [Laser ID] and [Model ID] indicate which command tool resulted in successful detection.

When the score and contrast values are higher than the set thresholds by at least 10 points and therefore detection results are stable, return to "Setup: 3.1.6.3 Teaching plane camera view", and set the next plane camera view. If detection results are unstable, proceed to "Setup: 3.1.6.8 Adding command tool", and make a necessary setting for stable results. When the settings for all the plane camera views are completed, proceed to "Setup: 3.1.6.9 Teaching the offset data calculation tool".

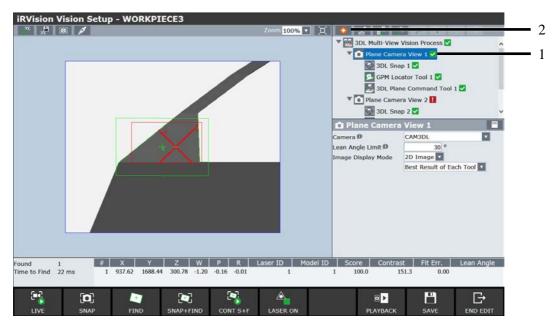
3.1.6.8 Adding command tools

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

ℳMemo

The reasons why command tools are added

Due to individual differences of workpieces and change of illumination intensity by time of day, an undetected situation tends to occur with only one set of detection parameter. In this case, preparing multiple command tools meeting the conditions can improve detection robustness.



- 1 Click [Plane Camera View].
 - One GPM Locator Tool and one 3DL Plane Command Tool are added in [Plane Camera View]. To add another command tool to a vision process, select [Plane Camera View] in the tree view.
- 2 Click the button.

A new command tool setting can be added.

ℳMemo

To copy an existing command tool, select the command tool to copy and click the button.



- 3 Click a type of command tool to be added.
 - From the drop-down box, select [3DL Plane Command Tool] or [GPM Locator Tool].
- 4 Enter a name in [Name].
 - Assign a unique name to the command tool.
- 5 Click [OK].
 - The command tool is added.

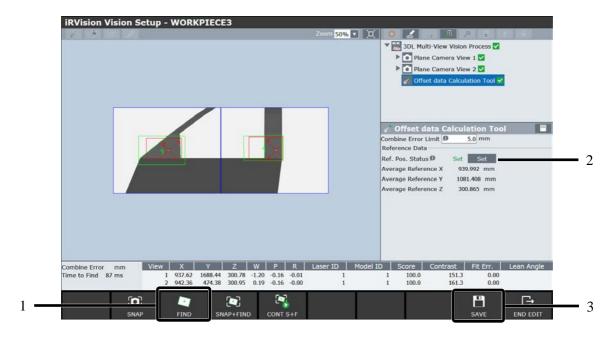
Adding GPM Locator Tool

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, the robot offset data cannot be correctly 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.

3.1.6.9 Teaching the offset data calculation tool

In this section, place a workpiece at a reference position, and set the reference position according to the detection results of each plane camera view.

When the vision process is performed after the setting, the vision process calculates the offset data by comparing the actual position where the workpiece is detected and this reference position. Select [Offset data Calculation Tool] in the tree view, and then set each item.



↑ CAUTION

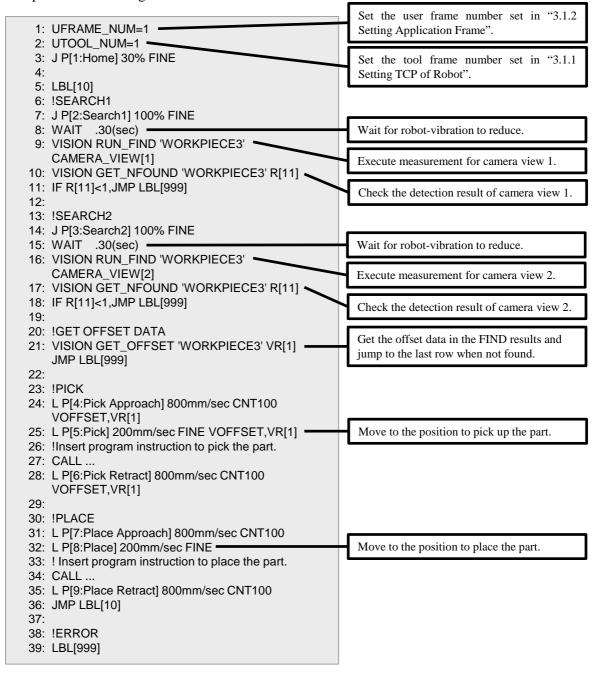
Afterward, do not click [SNAP] and [SNAP+FIND] until creation and teaching of the robot program is completed. If you click them, images are snapped at the current camera position in all the camera views and you must train the camera views again. In addition, do not move the workpiece.

- 1 Click [FIND].
- 2 Check that the workpiece is properly detected and click the [Set] button of [Ref. Pos. Status].
- 3 Click [SAVE] and then [END EDIT].

3.1.7 Creating and Teaching Robot Program

In the sample program below, the vision process for the 3DL Multi-View Vision Process is named as 'WORKPIECE3'. The sample program is a program to pick up, e.g., a pile of sheet metals one by one. The robot offsets the picking motion according to the measurement result, and picks the workpiece as taught. After supplying the workpiece to the next process, the robot tries to detect another workpiece. Note that R [11] is used here to obtain number of detected workpieces (= check the detection result) in each view.

Teach the measurement position specified with the robot program when creating the vision process. Refer to "Setup: 3.1.6.5 Teaching GPM Locator Tool".



Program example

ℳMemo

Measurement is performed after the robot reaches the taught position on the last motion. If there is no residual vibration in the robot, measurement can be performed immediately after positioning. However, depending on the robot's setting condition, residual vibration may occur in the robot's motion or rail axis, which may affect the accuracy of measurement. In such cases, giving the wait command or the acceleration override command to reduce the speed slowly may be required for adjustment.

In the sample program above, the vision process 'WORKPIECE3' is executed, one vision offset is calculated, and the robot position is offset by the vision offset. If no workpiece is detected, it jumps to the label [999] without offset operation.

The command for iRVision used in the sample program is explained.

The commands at the 9th and 16th lines execute the specified vision process, snap an image from a camera, perform image processing and store 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 at the 21st 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.

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 24th, 25th, and 28th lines, the robot motion such like as the workpiece handling is offset 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 that is offset with a vision offset data in a specified vision register.

For details of each command above and other commands, refer to the description of PROGRAM COMMAND in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

3.1.8 Checking Robot Offset Operation

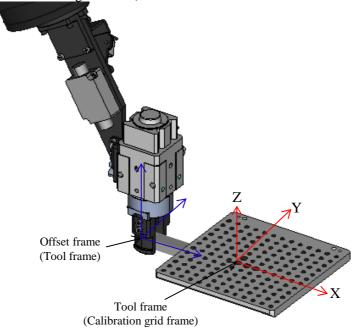
Check that a workpiece gripped by the robot can be detected and positioned at a desired location exactly. At first, decrease the override of the robot to check that the logic of the program is correct. Next, increase the override and cycle the program again to check its operation.

3.2 SETUP FOR "FIXED CAMERA + 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 offset so that the robot places the gripped workpiece at the predetermined position exactly.

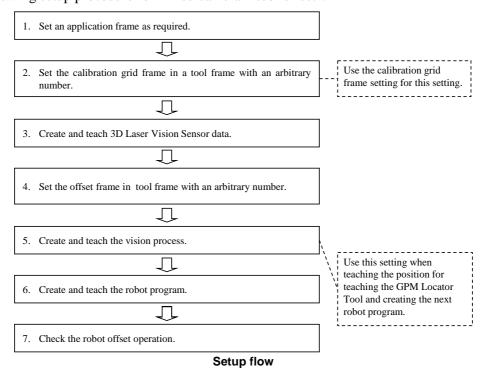
For setup of 'fixed camera + tool offset', specify a tool frame with an arbitrary number to 'installation information of the calibration grid' and 'tool frame used for offset' respectively, and set necessary data to the tool frame.

The "Calibration grid frame" can be set easily and correctly by using the camera of the 3D Laser Vision Sensor (calibration grid frame setting function).

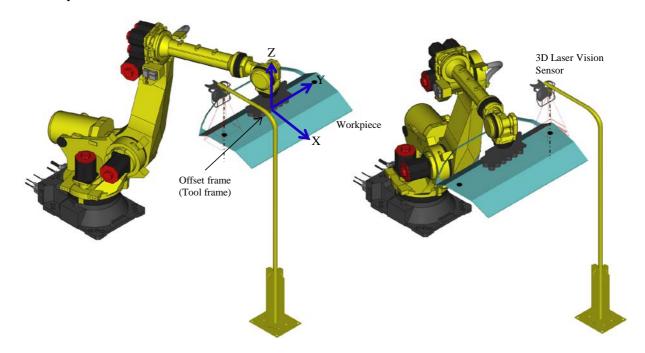


Tool frame used for offset

Use the following setup procedure for "fixed camera + tool offset".



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

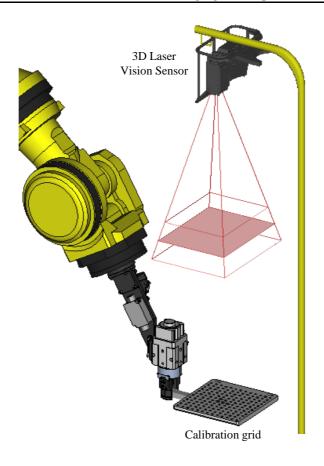


Fixed camera + tool offset layout example

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.



Calibration grid mounting example

3.2.1 Setting Application Frame

Specify the robot's user frame to be used as a reference for 3DL calibration. In many cases, the base frame of the robot is set up in the world frame.

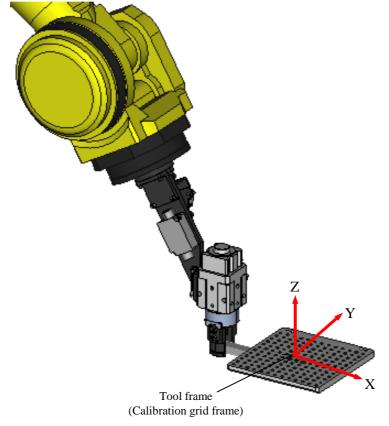
Refer to "Introduction: 1.5 COORDINATE SYSTEMS USED FOR iRVision".

3.2.2 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 calibration grid frame setting function. After securing the calibration grid, execute the calibration grid frame setting function. For details of the calibration grid frame setting function, refer to "Know-How: 1.2 FRAME SETTING WITH GRID FRAME SETTING FUNCTION".

In addition to the method of using the calibration 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, and then set a tool frame as shown in the figure below. Refer to "Know-How: 1.1 FRAME SETTING WITH POINTER TOOL". In this case, touch up the grid precisely since the touch-up precision directly affects the offset precision.

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 details of the calibration recovery method, refer to "Know-How: 2.2.7 Automatic Re-Calibration".



Calibration grid installation information

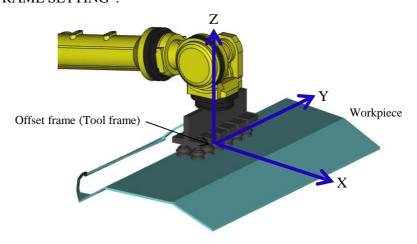
3.2.3 Creating and Teaching 3DL Sensor Data

To use the 3D Laser Vision Sensor, 3DL calibration using a calibration grid is required. For details of the 3DL calibration, refer to "Know-How: 2 3DL SENSOR DATA SETTING".

3.2.4 Setting Offset Frame

Set a tool frame to be used as the reference of the tool offset operation by the robot. Tool offset data is output as values in the tool frame set here.

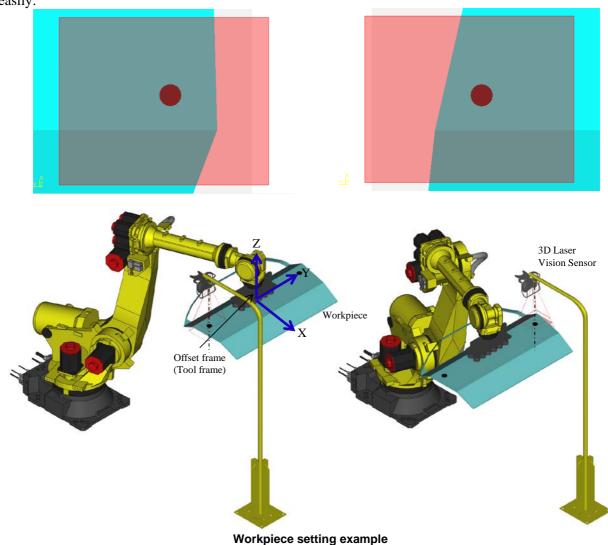
To set the tool frame, use [Tool Frame Setup / Six Point]. For details of the frame setting, refer to "Know-How: 1 FRAME SETTING".



Tool frame used for offset

3.2.5 Creating and Teaching 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.

Create the vision process.
Γ.
2. Set vision process parameters.
3. Select a plane camera view and specify the 3D Laser Vision Sensor data.
\Box
4. Teach the 3DL Snap Tool.
\Box
5. Move the robot to the measurement position and teach the GPM Locator Tool.
Ţ.
6. Teach the 3DL Plane Command Tool.
Ţ
7. Return to the plane camera view and click [SNAP+FIND] to detect the taught model. * If detection results are unstable, adjust the parameter value of the command tool.
When detection results are unstable
results are stable 8. Add a command tool.
9. Perform the steps 3 to 7 for all the camera views.
10. Teach the Offset data Calculation Tool.

Vision process teaching flow

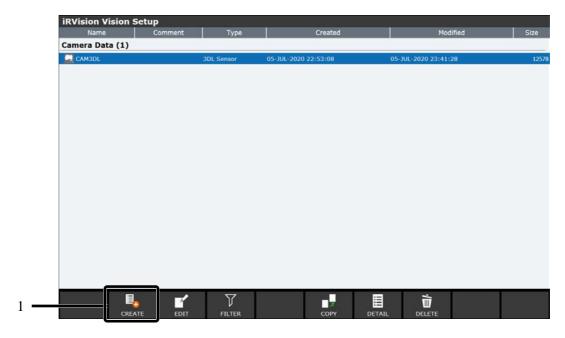
Placing reference workpiece

After it is confirmed that the calibration of the 3D Laser Vision Sensor has been correctly performed, workpiece picking is taught. This section explains the teaching to perform a tool offset.

First, hold the target workpiece for measurement by the end of arm tooling. If a reproducible position is set as the reference position, detection models can be added or changed easily.

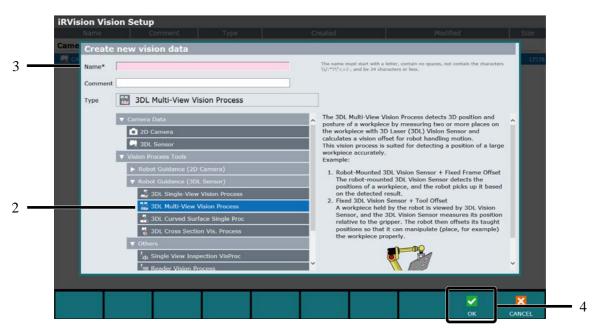
3.2.5.1 Creating vision process

After placing a reference workpiece, create a vision process.



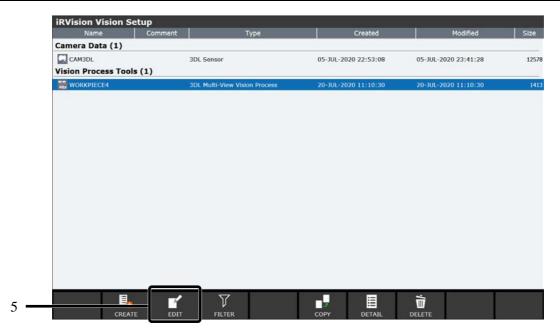
1 Click [CREATE].

The pop-up to create new vision data appears.



- 2 Select [3DL Multi-View Vision Process].
- 3 Enter a name of vision process in [Name]. Assign a unique name to the vision process.
- 4 Click [OK].

A new vision process is created.



5 Click [EDIT].
The vision process setup screen appears.

3.2.5.2 Setting parameters of vision process

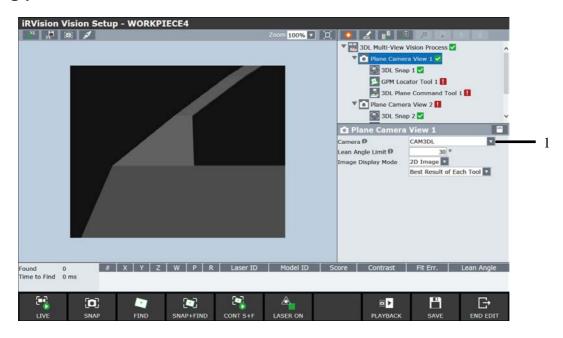


- 1 Select [Tool Offset] from the [Offset Mode] drop-down box.
- 2 Select the tool frame number from the [Offset Frame] drop-down box. An offset frame is a tool frame used for calculation of offset amount. Select the tool frame number set in "Setup: 3.2.4 Setting Offset Frame".

3.2.5.3 Teaching plane camera view

Select [Plane Camera View] in the tree view area, and then set each item.

Setting parameters



Select the 3DL Sensor Data from the drop-down box. Select the name of the taught 3DL Sensor Data.

*M***Memo**

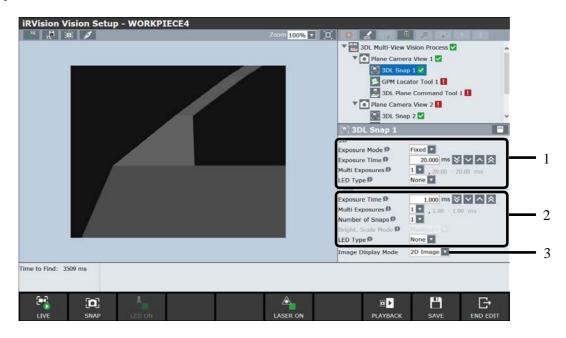
Adding plane camera views

Plane camera views can be added as necessary. Consider adding plane camera views when adequate offset precision cannot be achieved with two-point plane camera views due to a large workpiece. Up to four points can be added. To add, select [3DL Multi-View Vision Process] in the tree view area, and click the button.

3.2.5.4 Teaching 3DL Snap Tool

Select [3DL Snap] in the tree view area, and then set each item.

Setting parameters



1 Set parameters for 2D measurement.

Set parameters for snap of 2D measurement (detection and measurement of 2D features). For details of each parameter, refer to the description of COMMAND TOOL in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

2 Set parameters for laser measurement.

Set parameters for snap of laser measurement (detection and measurement of laser slit points). For details of each parameter, refer to the description of COMMAND TOOL in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

3 Select [Image Display Mode] from the drop-down box.

Select an image to show on the edit screen.

[2D Image]

An image snapped by the 2D camera appears.

[Laser Slit Image1]

An image of the laser slit 1 appears.

[Laser Slit Image2]

An image of the laser slit 2 appears.

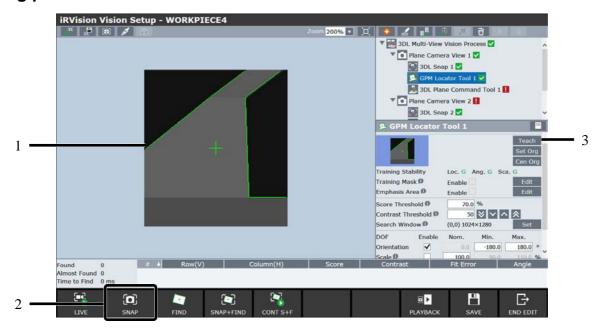
[Laser Composite Image]

An image that the image of the laser slit 1 and the image of the laser slit 2 are composited to 2D image appears.

3.2.5.5 Teaching GPM Locator Tool

Select [GPM Locator Tool] in the tree view area, and then set each item.

Setting parameters



1 Jog the robot to the measurement area.

Move the robot position so that the laser beam is directed to the plane to be measured. Move the robot according to the following procedure.

Click [LIVE] to show a live image.

When the button is clicked, horizontal and vertical lines that show the center of the display screen appear. This is a guide when the plane to be measured is moved to the center of the screen. Jog the robot, and keep the distance of approx. 400 mm between the bottom surface of the 3D Laser Vision Sensor camera and the plane to be measured in such a way that they almost directly face each other. Next, jog the robot parallel to the surface to be measured so that the surface to be measured comes

almost at the image center.

Next, jog the robot vertically to the surface to be measured so that the laser beam intersection comes almost at the center of the surface to be measured of the workpiece.

∕ Memo

To adjust the laser irradiation position for the workpiece, select [Plane Camera View] in the tree view area, and click [LASER ON] to irradiate the laser, and then click [LIVE] for adjustment. Then, select [3DL Snap] in the tree view area, and adjust the parameters.

2 Click [SNAP].

After determining the measurement position, click [SNAP] to capture an image.

3 Click the [Teach] button.

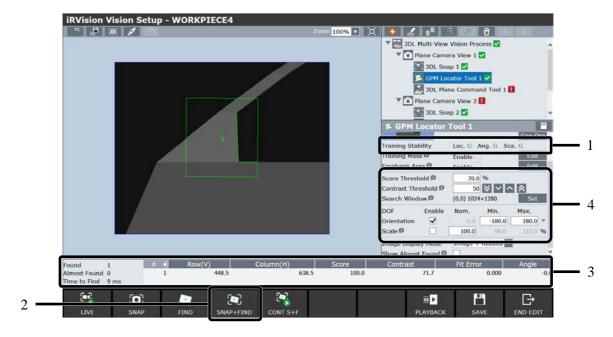
The GPM Locator Tool model setup screen appears. Teach 2D features used for position detection. As the features of a model, select features on the same plane to reduce the effects of changes in shape due to parallax. For features that need not be included in the model, [Training Mask] can be set to exclude them from the teach model. For details of teaching 2D features, refer to "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

4 Teach the robot position in the robot program.

Teach the robot program the position here as a workpiece measurement point.

Detection test

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



1 Check [Training Stability].

This item provides a guideline indicating whether the position, angle, and size are detected correctly in the taught model. Evaluations are indicated with [G] (good), [P] (poor) and [N] (none). [N] indicates that stable detection of the model may be impossible. In such a case, change the model, or uncheck [Enable] of the parameter in question in [DOF] to make the parameter invalid.

- 2 Click [SNAP+FIND].
 - An image is captured, and detection is performed.
- 3 Check the detection results.
 - Check that the workpieces 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 area. If the score and contrast values are higher than the set thresholds by at least 10 points, there is no problem.
- 4 Adjust parameters.

 Adjust the parameters of the GPM Locator Tool as necessary.

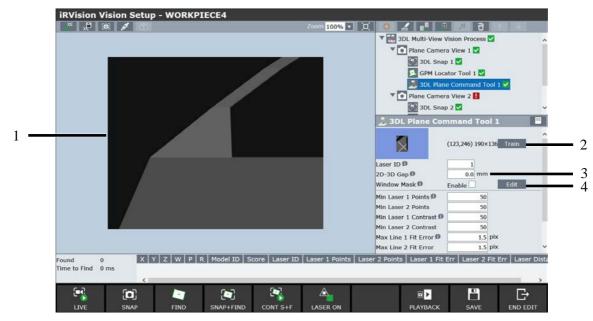
3.2.5.6 Teaching 3DL Plane Command Tool

Select [3DL Plane Command Tool] in the tree view area, and then set each item.

Setting parameters



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



1 Jog 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. Move the robot according to the following procedure.

Although it is desirable that a measurement be made at the teaching position for the GPM Locator Tool, however, if necessary, jog the robot in the same way as the GPM Locator Tool adjustment so that the laser beam is directed to the plane to be measured of the workpiece. In this case, teach the found position of the robot program again.

2 Click the [Train] button.

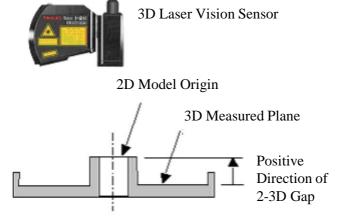
The measurement area teaching screen for plane measurement appears. Inside of the red frame shown in the image indicates the area for laser measurement. The area can be modified, and a line being modified is shown in purple.

Once the training of measurement area is completed, a thumbnail of the image used for training appears, and the area position and size appear.

If the GPM Locator Tool is present in the vision process, the GPM Locator Tool model must be taught in advance. If the GPM Locator Tool is not taught, the measurement area for plane measurement cannot be taught. Also, the measurement area must be taught again if the model origin of the GPM Locator Tool is changed or the detection model is taught again after teaching the measurement area.

3 Set [2D-3D Gap].

When there is a difference in height between the planes 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.

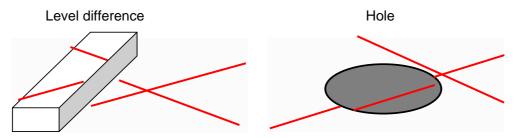


Section of the workpiece(example)

Height difference between laser measurement plane and 2D measurement plane

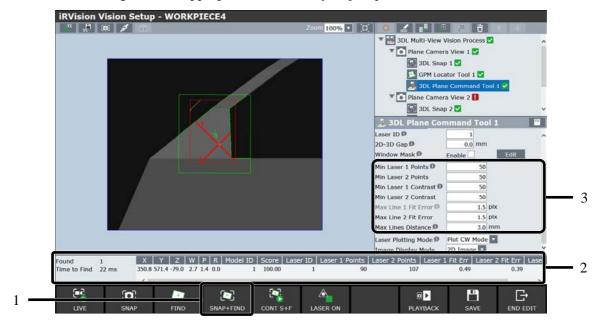
Click the [Edit] button of [Window Mask].

When there is an area to be excluded from the measurement area because the measurement area includes planes with level difference to which the laser beam is directed or for other reasons, click the [Edit] button of [Window Mask], and train the mask. Even if the mask is taught, 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.



- 1 Click [SNAP+FIND].
 - An image is captured, and detection is performed.
- Check the detection results.
 - Check that laser points are detected correctly on the image. Then, check the results output on the test execution result display area. By comparing the values of the results with set thresholds, determine whether stable detection can be performed. When detection fails, laser slit measurement results appear. Its measurement result can be used to determine the cause of the non-detection. If the checked LL distance is close to 3.0 mm, the measurement area may contain different planes or calibration data may be incorrect. Review the measurement area for plane measurement and check the calibration data. If the GPM Locator Tool is set, the precondition to perform laser measurement is that the GPM
 - Locator Tool detection was successful.
- Adjust parameters.
 - Parameters can be adjusted so that stable detection of laser points is enabled. When changing parameters, read the description in the following subsection, "Parameters for laser points detection", and carefully change them.

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. To change the parameters, refer to

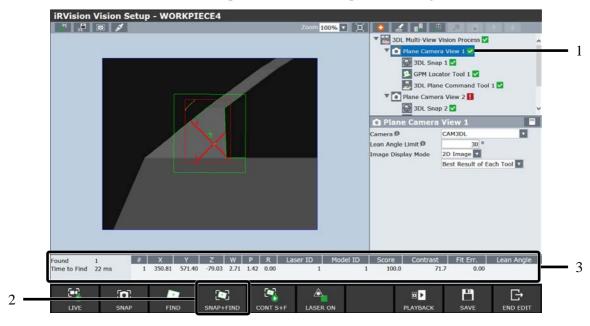
the description of COMMAND TOOL in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN", and make changes with caution.

⚠ CAUTION

Before changing the detection parameters of laser points, check whether the laser measurement exposure time of the 3DL Snap Tool has been adjusted properly.

3.2.5.7 Running a test

Run a detection test to check whether the plane camera view operates as taught.



- 1 Click [Plane Camera View].
- 2 Click [SNAP+FIND].

An image is captured, and detection is performed. If the workpiece is not detected, change the parameter for the undetected image, click [FIND] and run the test without snapping the image again. If the parameter change is valid, the workpiece is detected. Click [CONT S+F] to snap images and detect workpiece repeatedly. During this continuous execution, [CONT S+F] is changed to [STOP]. Click [STOP] to stop the continuous execution.

3 Check the detection results.

Time to find

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.

Checking found result

When the test detection is successful, the results appear. The measured position and posture of the workpiece are output using the values in the offset frame selected for the vision process. [Laser ID] and [Model ID] indicate which command tool resulted in successful detection.

When the score and contrast values are higher than the set thresholds by at least 10 points and therefore detection results are stable, return to "Setup: 3.2.5.3 Teaching plane camera view", and set the next plane camera view. If detection results are unstable, proceed to "Setup: 3.2.5.8 Adding command tool", and make a necessary setting for stable results. When the settings for all the plane camera views are completed, proceed to "Setup: 3.2.5.9 Teaching the offset data calculation tool".

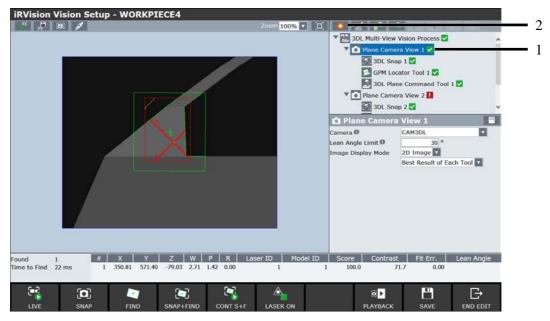
3.2.5.8 Adding command tools

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

ℳMemo

The reasons why command tools are added

Due to individual differences of workpieces and change of illumination intensity by time of day, an undetected situation tends to occur with only one set of detection parameter. In this case, preparing multiple command tools meeting the conditions can improve detection robustness.



- 1 Click [Plane Camera View].
 - One GPM Locator Tool and one 3DL Plane Command Tool are added in [Plane Camera View]. To add another command tool to a vision process, select [Plane Camera View] in the tree view.
- 2 Click the button.

A new command tool setting can be added.

ℳMemo

To copy an existing command tool, select the command tool to copy, then click the button.



- 3 Click a type of command tool to be added. From the drop-down box, select [3DL Plane Command Tool] or [GPM Locator Tool].
- 4 Enter a name in [Name].
 Assign a unique name to the command tool.
- 5 Click [OK].
 The command tool is added.

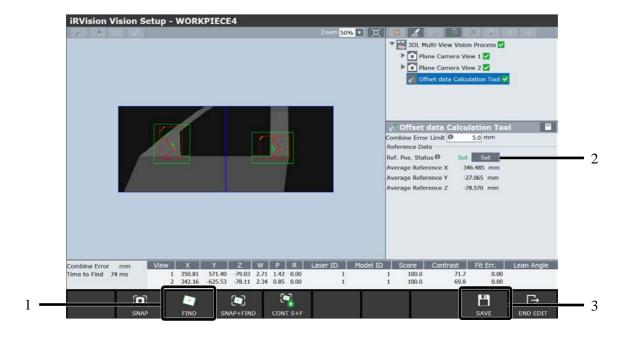
Adding GPM Locator Tool

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, the robot offset data cannot be correctly 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.

3.2.5.9 Teaching the offset data calculation tool

In this section, place a workpiece at a reference position, and set the reference position according to the detection results of each plane camera view.

When the vision process is performed after the setting, the vision process calculates the offset data by comparing the actual position where the workpiece is detected and this reference position. Select [Offset data Calculation Tool] in the tree view, and then set each item.



A CAUTION

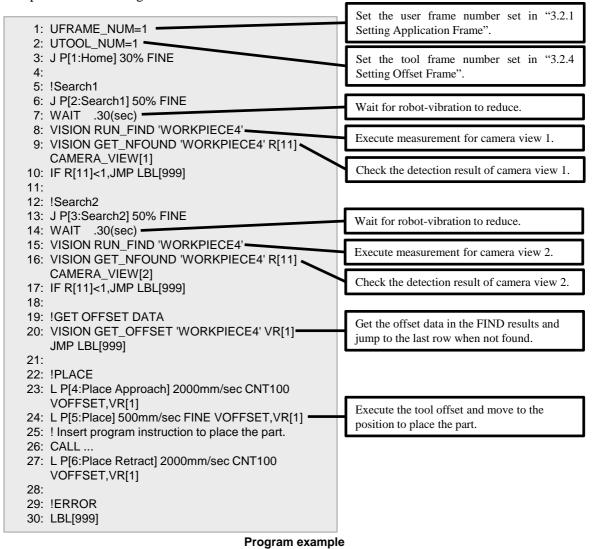
Afterward, do not click [SNAP] and [SNAP+FIND] until creation and teaching of the robot program is completed. If you click them, images are snapped at the current camera position in all the camera views and you must train the camera views again.

- 1 Click [FIND].
- 2 Check that the workpiece is properly detected and click the [Set] button of [Ref. Pos. Status].
- 3 Click [SAVE] and then [END EDIT].

3.2.6 Creating and Teaching Robot Program

In the sample program below, the vision process for the 3DL Multi-View Vision Process is named as 'WORKPIECE4'. The sample program is a program to place, e.g., an unprocessed casting gripped by the robot in the position and posture determined beforehand. The robot performs a tool offset according to the measurement result. After supplying the workpiece to the processing machine, the robot tries to detect another workpiece. Note that R [11] is used here to obtain number of detected workpieces (= check the detection result) in each view.

Teach the measurement position specified with the robot program when creating the vision process. Refer to "Setup: 3.2.5.5 Teaching GPM Locator Tool".



ℳMemo

Measurement is performed after the robot reaches the taught position on the last motion. If there is no residual vibration in the robot, measurement can be performed immediately after positioning. However, depending on the robot's setting condition, residual vibration may occur in the robot's motion or rail axis, which may affect the accuracy of measurement. In such cases, giving the wait command or the acceleration override command to reduce the speed slowly may be required for adjustment.

In the sample program above, the vision process 'WORKPIECE4' is executed, only one piece of offset data is obtained, and the position where the workpiece is placed is offset. If no workpiece is detected, it jumps to the label [999] without offset operation.

The command for iRVision used in the sample program is explained.

The command at the 8th and 15th lines execute the specified vision process, snap an image from a camera, perform image processing and store 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 at the 20th 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.

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 23rd, 24th, and 27th lines, the robot motion such as placing the workpiece is offset 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 that is offset with a vision offset data in a specified vision register.

For details of each command above and other commands, refer to the description of PROGRAM COMMAND in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

3.2.7 Checking Robot Offset 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 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 performs offset for robotic handling of the workpiece.

This function cannot measure a plane. For it, use the 3DL Single-View Vision Process. For the 3DL Single-View Vision Process, refer to "Setup: 2 3DL SINGLE-VIEW VISION PROCESS".

This chapter describes the startup procedure and teaching procedure using the following two application examples.

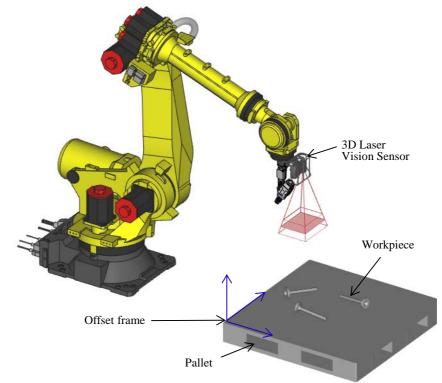
- (1) Robot-mounted camera + fixed frame offset
- (2) Fixed camera + tool offset

*№***Memo**

Unless otherwise specified, the screens and operations in the simple mode are shown in this chapter. For details of the simple mode and advanced mode, refer to the "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

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

A layout example of 'robot-mounted camera + fixed frame offset' for '3DL Curved Surface Single Vision Process' is given below.

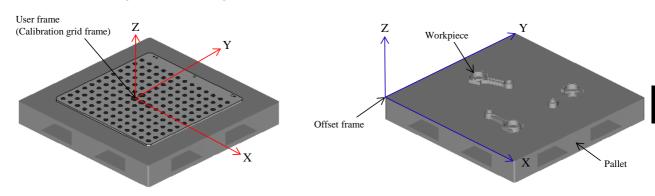


Layout example of robot-mounted camera + fixed frame offset

For setup of 'robot-mounted camera + fixed frame offset', specify a user frame with an arbitrary number to 'installation information of the calibration grid' and 'offset frame' respectively, and make necessary

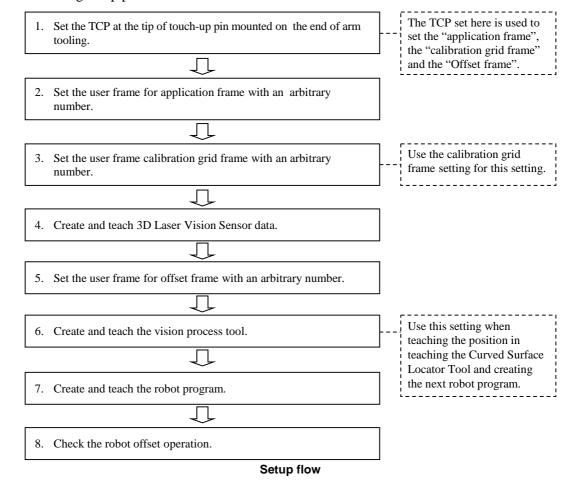
settings for the user frame.

The "Calibration grid frame" can be set easily and correctly by using the camera of the 3D Laser Vision Sensor (calibration grid frame setting function).



Calibration grid frame and offset frame

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



4.1.1 Setting TCP of Robot

Setting the TCP of the robot is necessary to teach the application frame, the calibration grid frame and the offset frame. In general, 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]. For the setting method, refer to "Know-How: 1 FRAME SETTING".

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.

4.1.2 Setting Application Frame

Specify the robot's user frame to be used as a reference for 3DL calibration. In many cases, the base frame of the robot is set up in the world frame. However, in the following cases, set the user frame, and set the user frame number as the application frame.

- In the case the 3D Laser Vision Sensor is attached to a robot other than the robot to be offset.
- In the case the calibration grid is attached to a robot other than the robot to be offset.
- In the case the robot to be offset belongs to another motion group.

Refer to "Introduction: 1.5 COORDINATE SYSTEMS USED FOR iRVision".

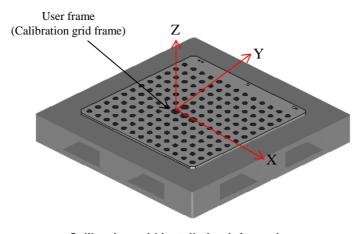
4.1.3 Setting Calibration Grid Frame

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 calibration grid frame setting function. After securing the calibration grid, execute the calibration grid frame setting function. For details of the calibration grid frame setting function, refer to "Know-How: 1.2 FRAME SETTING WITH GRID FRAME SETTING FUNCTION". Note that the user frame in the installation information of the calibration grid differs from the user frame used for offset described in the following subsection.

In addition to the method of using the calibration 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. Refer to "Know-How: 1.1 FRAME SETTING WITH POINTER TOOL". The TCP setting precision and touch-up precision directly affect the offset 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 details of the calibration recovery method, refer to "Know-How: 2.1.7 Automatic Re-Calibration".



Calibration grid installation information

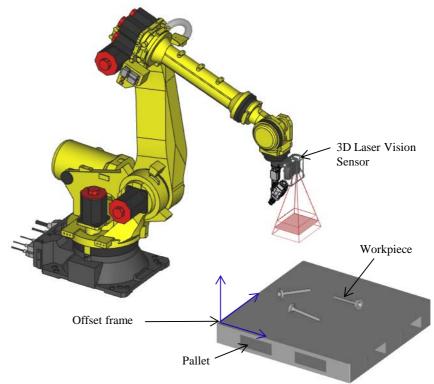
4.1.4 Creating and Teaching 3DL Sensor Data

To use the 3D Laser Vision Sensor, 3DL calibration using a calibration grid is required. For details of the 3DL calibration, refer to "Know-How: 2 3DL SENSOR DATA SETTING".

4.1.5 Setting Offset Frame

Set a user frame to be used as the reference for the robot offset 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. For details of the frame setting, refer to "Know-How: 1 FRAME SETTING".



User frame used for offset

Sharing user frame

When two or more robots work together for the same workpiece, it is necessary to physically set the same user frame for all the robots. 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.

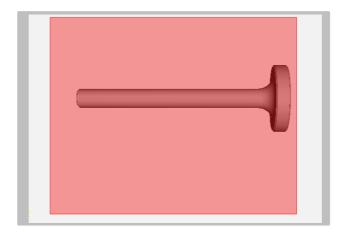
User frame sharing requires that all robots use the same user frame number. E.g., user frame 5 of robot 1 needs to be physically the same as user frame 5 of robot 2.

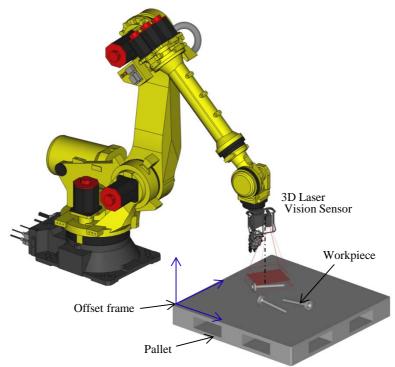
↑ CAUTION

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.

4.1.6 Creating and Teaching Vision Process

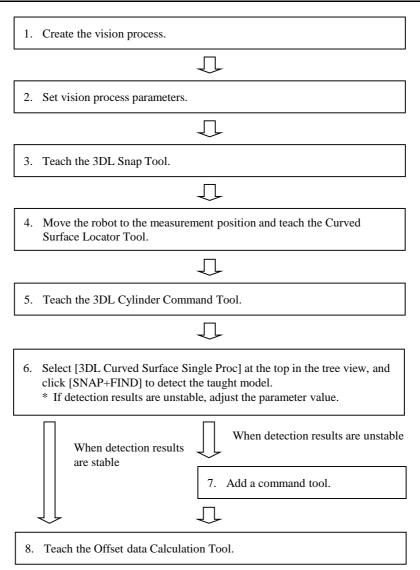
Create a vision process for the '3DL Curved Surface Single Vision Process'. For fixed frame offset, place the workpiece to be picked up at the reference position to teach the reference position. If a reproducible position is set as the reference position, detection models can be added or changed easily.





Workpiece setting example

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



Vision process teaching flow

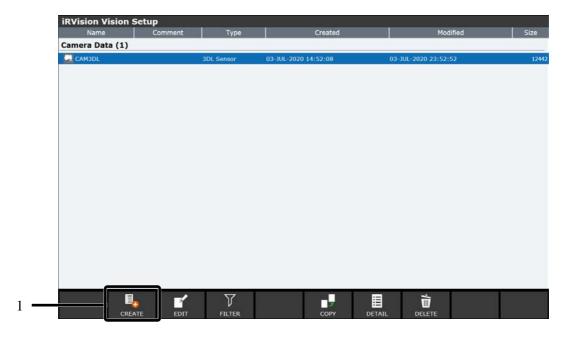
Placing reference workpiece

After it is confirmed that the calibration of the 3D Laser Vision Sensor has been correctly performed, workpiece picking is taught. This section explains the teaching to perform the fixed frame offset.

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.

4.1.6.1 Creating vision process

After placing a reference workpiece, create a vision process.

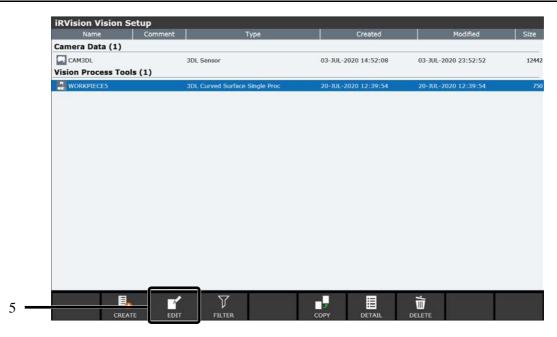


1 Click [CREATE].

The pop-up to create new vision data appears.

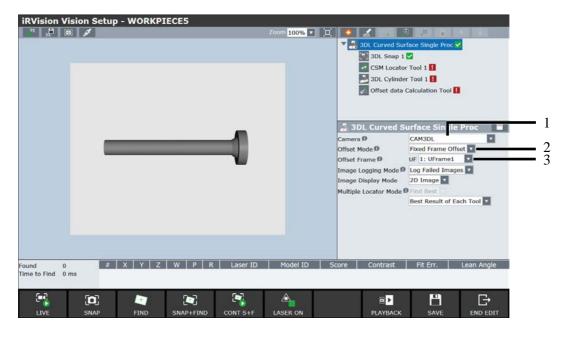


- 2 Select [3DL Curved Surface Single Proc].
- 3 Enter a name of vision process in [Name]. Assign a unique name to the vision process.
- 4 Click [OK].
 A new vision process is created.



5 Click [EDIT].The vision process setup screen appears.

4.1.6.2 Setting parameters of vision process

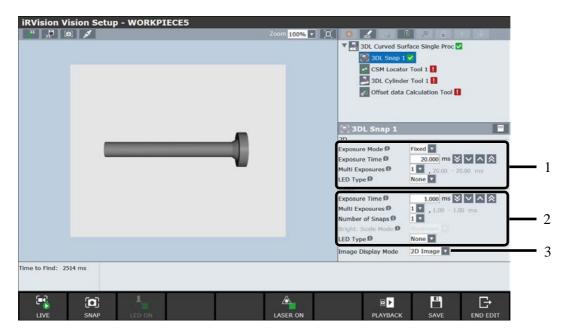


- Select the 3DL Sensor Data from the drop-down box. Select the name of the taught 3DL Sensor Data.
- 2 Select [Fixed Frame Offset] from the [Offset Mode] drop-down box.
- 3 Select the user frame number set as [Offset Frame] from the drop-down box. An offset frame is a user frame used for calculation of the offset data. Select the user frame number set in "Setup: 4.1.5 Setting Offset Frame".

4.1.6.3 Teaching 3DL Snap Tool

Select [3DL Snap] in the tree view area, and then set each item.

Setting parameters



1 Set parameters for 2D measurement.

Set parameters for snap of 2D measurement (detection and measurement of 2D features). For details of each parameter, refer to the description of COMMAND TOOL in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

2 Set parameters for laser measurement.

Set parameters for snap of laser measurement (detection and measurement of laser slit points). For details of each parameter, refer to the description of COMMAND TOOL in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

3 Select [Image Display Mode] from the drop-down box.

Select an image to show on the edit screen.

[2D Image]

An image snapped by the 2D camera appears.

[Laser Slit Image1]

An image of the laser slit 1 appears.

[Laser Slit Image2]

An image of the laser slit 2 appears.

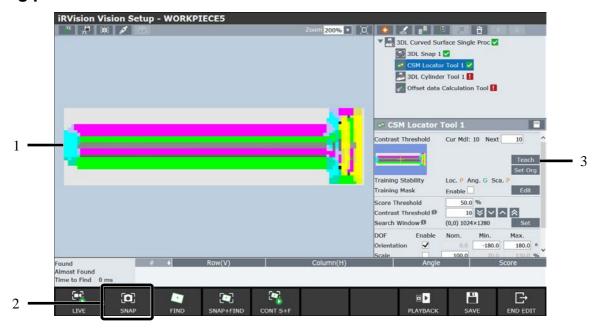
[Laser Composite Image]

An image that the image of the laser slit 1 and the image of the laser slit 2 are composited to 2D image appears.

4.1.6.4 Teaching Curved Surface Locator Tool

Select [CSM Locator Tool] in the tree view area, and then set each item.

Setting parameters



1 Jog the robot to the measurement area.

Move the robot position so that the laser beam is directed to the plane to be measured. Move the robot according to the following procedure.

Click [LIVE] to show a live image.

When the button is clicked, horizontal and vertical lines that show the center of the display screen appear. This is a guide when the plane to be measured is moved to the center of the screen. Jog the robot, and keep the distance of approx. 400 mm between the bottom surface of the 3D Laser Vision Sensor camera and the surface to be measured, in such a way that they almost directly face each other.

Next, jog the robot parallel to the surface to be measured so that the surface to be measured comes almost at the image center.

Next, jog the robot vertically to the surface to be measured so that the laser beam intersection comes almost at the center of the surface to be measured of the workpiece.

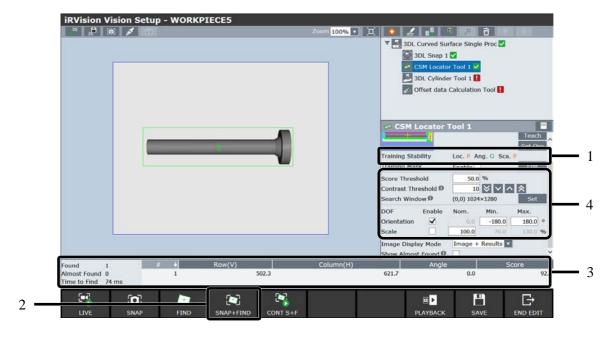
∲Memo

To adjust the laser irradiation position for the workpiece, select [3DL Curved Surface Single Proc] in the tree view area, click [LASER ON] to irradiate the laser, and then click [LIVE] to adjust. Then, select [3DL Snap] in the tree view area, and adjust the parameters.

- 2 Click [SNAP].
 - After determining the measurement position, click [SNAP] to capture an image.
- 3 Click the [Teach] button.
 - The model setup screen for the Curved Surface Locator Tool appears. 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 Mask] can be set to exclude them from the teach model.
- 4 Teach the robot position in the robot program.
 - Teach the robot program the position here as a workpiece measurement point.

Detection test

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



1 Check [Training Stability].

This item provides a guideline indicating whether the position, angle, and size are detected correctly in the taught model. Evaluations are indicated with [G] (good), [P] (poor) and [N] (none). [N] indicates that stable detection of the model may be impossible. In such a case, change the model, or uncheck [Enable] of the parameter in question in [DOF] to make the parameter invalid.

- 2 Click [SNAP+FIND].
 - An image is captured, and detection is performed.
- 3 Check the detection results.
 - Check that the workpieces taught with the model are detected correctly on the image display screen. Then, check score, etc. in the test execution result display area. If the score and contrast values are higher than the set thresholds by at least 10 points, there is no problem.
- 4 Adjust parameters.
 - Adjust the parameters of the GPM Locator Tool as necessary.

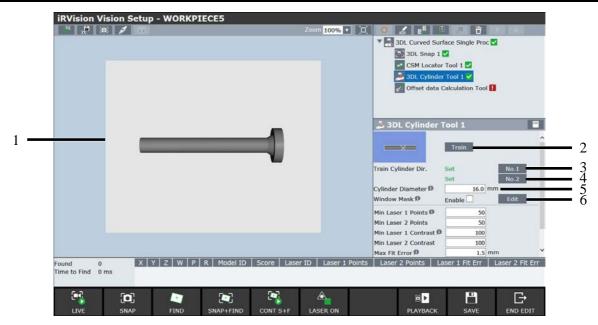
4.1.6.5 Teaching 3DL Cylinder Command Tool

Select [3DL Cylinder Tool] in the tree view area, and then set each item.

Setting parameters

⚠ CAUTION

When GPM Locator Tools or Curved Surface Locator Tools have been set in the same vision process, teach all the GPM Locator Tools or Curved Surface Locator Tools before teaching the 3DL Cylinder Command Tool.



1 Jog the robot to the measurement area.

Click [LASER ON], and jog the robot in such a way that the intersection point of the laser beam is directed to near the center of the cylinder. Move the robot according to the following procedure. Although it is desirable that a measurement be made at the teaching position for the Curved Surface

Locator Tool, however, if necessary, jog the robot in the same way as the Curved Surface Locator Tool adjustment so that the laser beam is directed to the surface to be measured of the workpiece. In this case, teach the found position of the robot program again.

2 Click the [Train] button.

The measurement area training screen for cylinder measurement appears. Inside of the red frame shown in the image indicates the area for laser measurement. The area can be modified, and a line being modified is shown in purple.

Once the training of measurement area is completed, a thumbnail of the image used for training appears, and the area position and size appear.

If the Curved Surface Locator Tool is present in the vision process, the model teaching of the Curved Surface Locator Tool must be done in advance. If the Curved Surface Locator Tool is not taught, the measurement area for cylinder measurement cannot be taught. Also, the measurement area must be trained again if the model origin of the Curved Surface Locator Tool is changed, or the detection model is taught again after teaching the measurement area.

3 Click [No.1].

An image and a line segment in the measurement area appear. Arrange the line segment along either end of the curved surface of the cylinder.

4 Click [No.2].

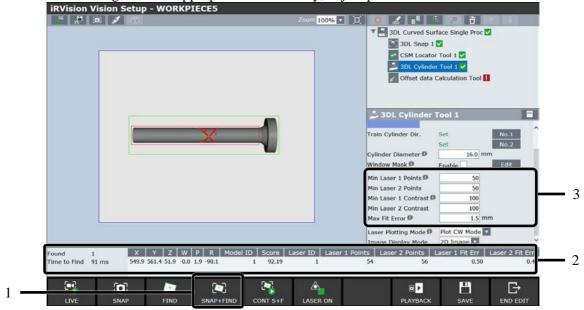
An image and a line segment in the measurement area appear in the same way as for [No.1]. Arrange the line segment along the other end of the curved surface of the cylinder.

- 5 Input [Cylinder Diameter].
 Set the diameter of the part taught the cylinder direction.
- Click the [Edit] button of [Window Mask].

 When there is an area to be excluded from the measurement area because the measurement area includes planes with level difference to which the laser beam is directed or for other reasons, click the [Edit] button of [Window Mask], and teach the mask. Even if the mask is taught, 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.



- 1 Click [SNAP+FIND].
 - An image is captured, and detection is performed.
- 2 Check the detection results.
 - Check that laser points are detected correctly on the image. Then, check the results output on the test execution result display area. By comparing the values of the results with set thresholds, determine whether stable detection can be performed. When detection fails, laser slit measurement results appear. Its measurement result can be used to determine the cause of the non-detection.
 - If the Curved Surface Locator Tool is set, the precondition to perform laser measurement is that the Curved Surface Locator Tool detection must be successful.
- 3 Adjust parameters.
 - Parameters can be adjusted so that stable detection of laser points is enabled. When changing parameters, read the description in the following subsection, "Parameters for laser points detection", and carefully change them.

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. To change the parameters, refer to the description of COMMAND TOOL in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN", and make changes with caution.

⚠ CAUTION

Before changing the detection parameters of laser points, check whether the laser measurement exposure time of the 3DL Snap Tool has been adjusted properly.

4.1.6.6 Running a test

Run a test to check whether the vision process operates as taught. Before running the test, select [3DL Curved Surface Single Proc] in the tree view area.

Running a test

Click [SNAP+FIND] to snap an image and detect workpiece. If the workpiece is not detected, change the parameter for the undetected image, click [FIND] and run the test without snapping the image again. If the parameter change is valid, the workpiece is detected. Click [CONT S+F] to snap images and detect workpiece repeatedly. During this continuous execution, [CONT S+F] is changed to [STOP]. Click [STOP] to stop the continuous execution.

Time to find

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.

Checking found result

When the test detection is successful, the results appear. The measured position and posture of the workpiece are output using the values in the offset frame selected for the vision process. [Laser ID] and [Model ID] indicate which command tool resulted in successful detection.



When the score and contrast values are higher than the set thresholds by at least 10 points and therefore detection results are stable, proceed to "Setup: 4.1.6.8 Teaching the offset data calculation tool". If the detection results are still unstable after adjusting parameters of each command tool, proceed to "Setup: 4.1.6.7 Adding command tools", and make a necessary setting for stable results.

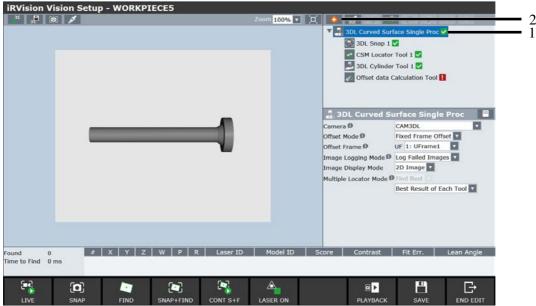
4.1.6.7 Adding command tools

Command tools such as a Curved Surface Locator Tool or 3DL Cylinder Command Tool can be added as necessary.

ℳMemo

The reasons why command tools are added

Due to individual differences of workpieces and change of illumination intensity by time of day, an undetected situation tends to occur with only one set of detection parameter. In this case, preparing multiple command tools meeting the conditions can improve detection robustness.



1 Click [3DL Curved Surface Single Proc].

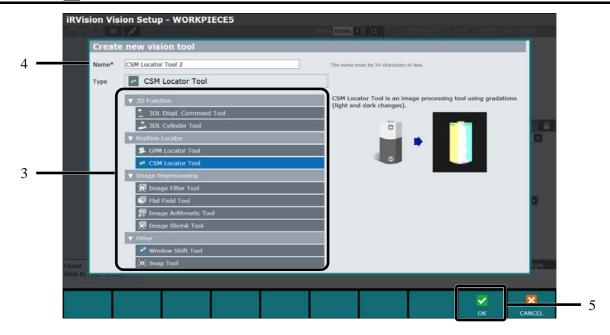
When a vision process for [3DL Curved Surface Single Proc] is created, one Curved Surface Locator Tool and one 3DL Cylinder Command Tool are added. To add another command tool to a vision process, select [3DL Curved Surface Single Proc] in the tree view.

2 Click the button.

A new command tool setting can be added.

*M*Memo

To copy an existing command tool, select the command tool to copy, then click the button.



3 Click a type of command tool to be added.

Select any one of [3DL Displ. Command Tool], [3DL Cylinder Tool], [GPM Locator Tool] and [CSM Locator Tool].

4 Enter a name in [Name].

Assign a unique name to the command tool.

5 Click [OK].

The command tool is added.

Adding Curved Surface Locator Tool

The laser measurement area window automatically moves depending on the Curved Surface Locator Tool detection results. Therefore, if separate model origins are set for more than one Curved Surface Locator 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, the robot offset data cannot be correctly calculated with the detection results of command tools having different model origins. To prevent these problems, when multiple Curved Surface Locator Tools are set in a vision process, the model origins of all the Curved Surface Locator Tools must match. The best way is to copy an existing command tool.

Adding 3DL Displacement Command Tool

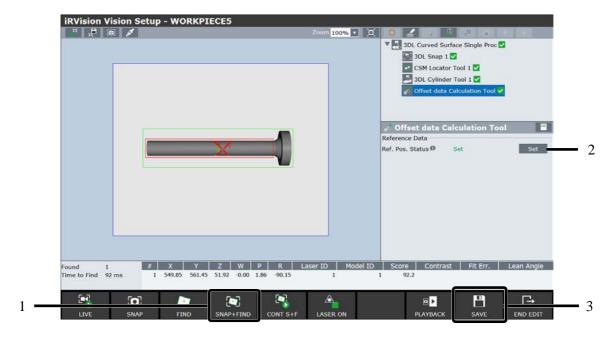
Because robot offset motion differs between [3DL Displ. Command Tool] and [3DL Plane Command Tool], when [3DL Displ. Command Tool] is added to a vision process, it is recommended to delete 3D measurement tools other than [3DL Displ. Command Tool].

[3DL Displ. Command Tool] is taught in the same manner as [3DL Cylinder Tool]. Note that the output position and posture of a workpiece, and parameter setting items differ between them. For details, refer to "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

4.1.6.8 Teaching the offset data calculation tool

In this section, place a workpiece in a reference position, run a test, and set the detection result as the reference position XYZWPR.

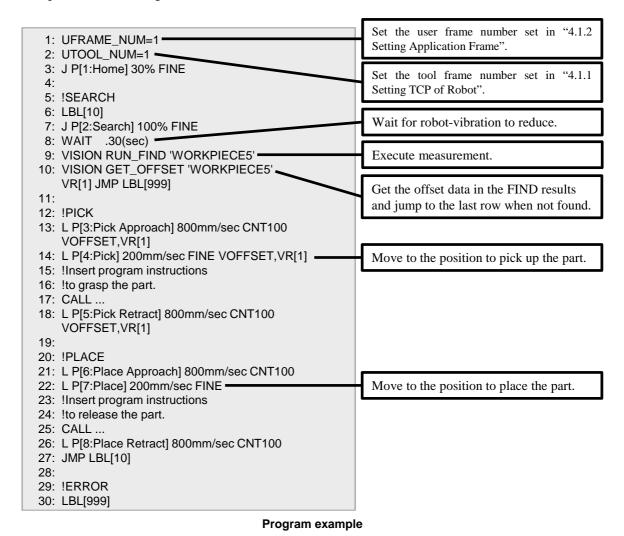
When the vision process is performed after the setting, the vision process calculates the offset data by comparing the actual position where the workpiece is detected and this reference position. Select [Offset data Calculation Tool] in the tree view, and then set each item.



- 1 Click [SNAP+FIND].
- 2 Check that the workpiece is properly detected and click the [Set] button of [Ref. Pos. Status].
- 3 Click [SAVE] and then [END EDIT].

4.1.7 Creating and Teaching Robot Program

In the sample program below, the vision process for the 3DL Curved Surface Single Process is named as 'WORKPIECE5'. The sample program is a program to pick up, e.g., cylinder shaped workpieces one by one. The robot offsets the picking motion according to the measurement result, and picks the workpiece as taught. After supplying the workpiece to the next process, the robot tries to detect another workpiece. Teach the measurement position specified with the robot program when creating the vision process. Refer to "Setup: 4.1.6.4 Teaching Curved Surface Locator Tool".



∕∕Memo

Measurement is performed after the robot reaches the taught position on the last motion. If there is no residual vibration in the robot, measurement can be performed immediately after positioning. However, depending on the robot's setting condition, residual vibration may occur in the robot's motion or rail axis, which may affect the accuracy of measurement. In such cases, giving the wait command or the acceleration override command to reduce the speed slowly may be required for adjustment.

In the sample program above, the vision process 'WORKPIECE5' is executed, one vision offset is calculated, and the robot position is offset with the vision offset. If no workpiece is detected, it jumps to the label [999] without offset operation.

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

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

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 at 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.

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, 14th, and 18th lines, the robot motion such like as the workpiece handling is offset 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 that is offset with a vision offset data in a specified vision register.

For details of each command above and other commands, refer to the description of PROGRAM COMMAND in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

4.1.8 Checking Robot Offset Operation

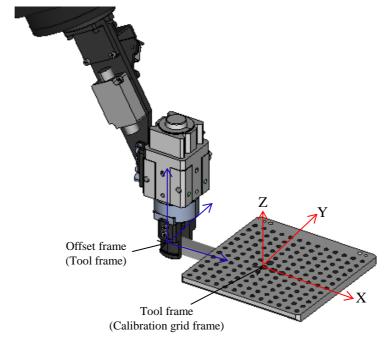
Check that a workpiece gripped by the robot can be detected and positioned at a desired location exactly. At first, decrease the override of the robot to check that the logic of the program is correct. Next, increase the override and cycle the program again to check its operation.

4.2 SETUP FOR "FIXED CAMERA + 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 offset so that the robot places the gripped workpiece at the predetermined position exactly.

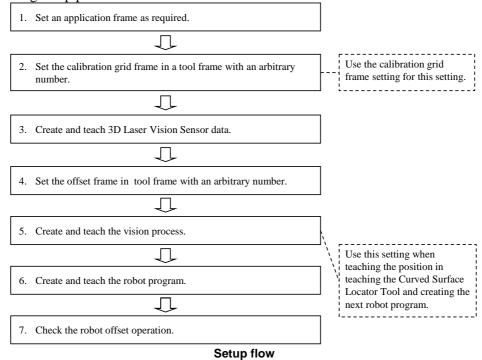
For setup of 'fixed camera + tool offset', specify a tool frame with an arbitrary number to 'installation information of the calibration grid' and 'tool frame used for offset' respectively, and set necessary data to the tool frame.

The "Calibration grid frame" can be set easily and correctly by using the camera of the 3D Laser Vision Sensor (calibration grid frame setting function).

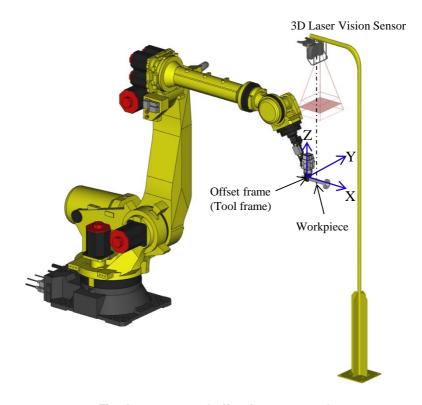


Tool frame used for offset

Use the following setup procedure for "fixed camera + tool offset".



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

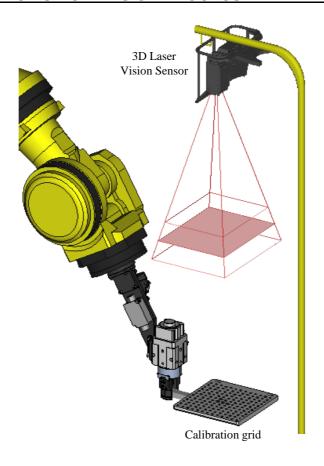


Fixed camera + tool offset layout example

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.



Calibration grid mounting example

4.2.1 Setting Application Frame

Specify the robot's user frame to be used as a reference for 3DL calibration. In many cases, the base frame of the robot is set up in the world frame.

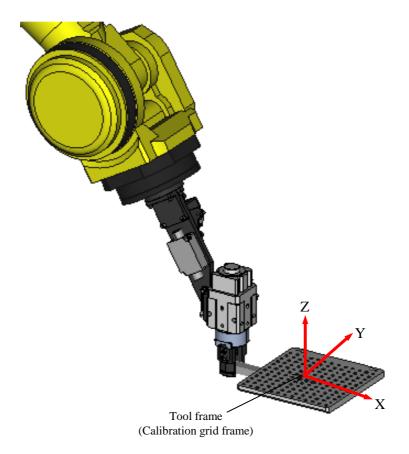
Refer to "Introduction: 1.5 COORDINATE SYSTEMS USED FOR iRVision".

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 calibration grid frame setting function. After securing the calibration grid, execute the calibration grid frame setting function. For details of the calibration grid frame setting function, refer to "Know-How: 1.2 FRAME SETTING WITH GRID FRAME SETTING FUNCTION".

In addition to the method of using the calibration 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, and then set a tool frame as shown in the figure below. Refer to "Know-How: 1.1 FRAME SETTING WITH POINTER TOOL". Touch up the grid precisely since the touch-up precision directly affects the offset precision.

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 details of the calibration recovery method, refer to "Know-How: 2.2.7 Automatic Re-Calibration".



Calibration grid installation information

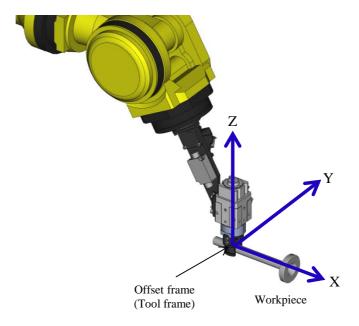
4.2.3 Creating and Teaching 3DL Sensor Data

To use the 3D Laser Vision Sensor, 3DL calibration using a calibration grid is required. For details of the 3DL calibration, refer to "Know-How: 2 3DL SENSOR DATA SETTING".

4.2.4 Setting Offset Frame

Set a tool frame to be used as the reference of the tool offset operation by the robot. The measurement results (tool offset data) are output as values in the tool frame set here.

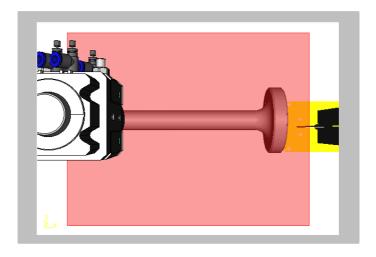
To set the tool frame, use [Tool Frame Setup / Six Point]. For details of the frame setting, refer to "Know-How: 1 FRAME SETTING".

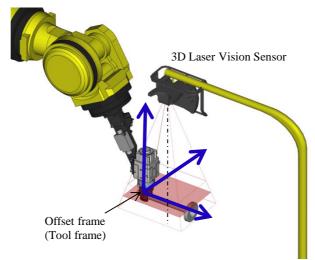


Tool frame used for offset

4.2.5 Creating and Teaching Vision Process

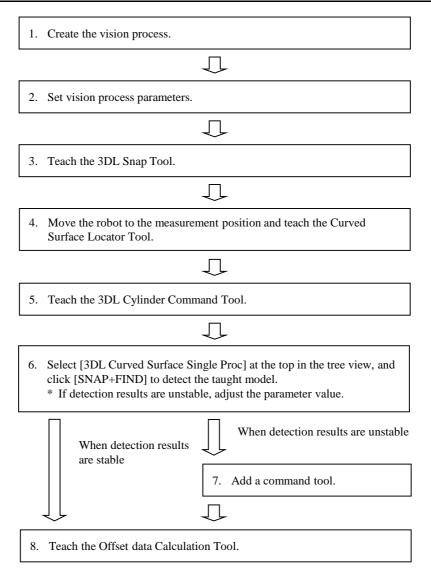
Create a vision process for the '3DL Curved Surface Single Vision Process'. For tool offset, first make the end of arm tooling hold the workpiece to be picked up to teach the reference position. If how the end of arm tooling holds the workpiece can be reproduced with precision, detection models can be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





Workpiece setting example

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



Vision process teaching flow

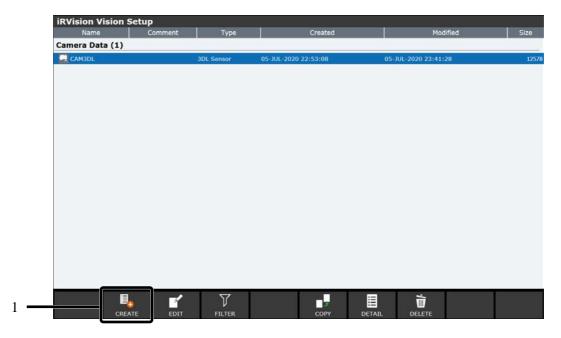
Placing reference workpiece

After it is confirmed that the calibration of the 3D Laser Vision Sensor has been correctly performed, workpiece picking is taught. This section explains the teaching to perform a tool offset.

First, hold the target workpiece for measurement by the end of arm tooling. If a reproducible position is set as the reference position, detection models can be added or changed easily.

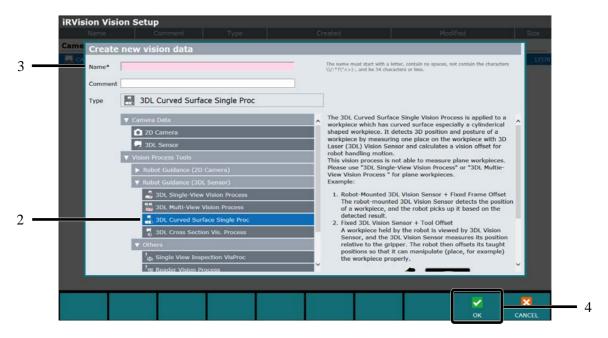
4.2.5.1 Creating vision process

After placing a reference workpiece, create a vision process.



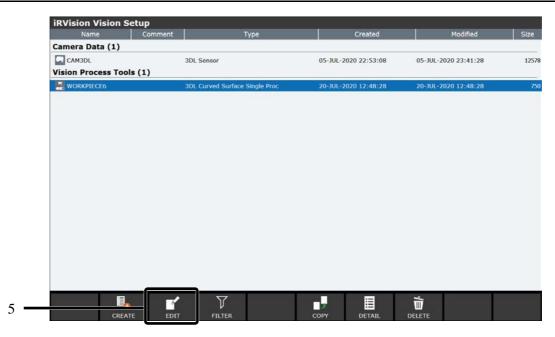
1 Click [CREATE].

The pop-up to create new vision data appears.



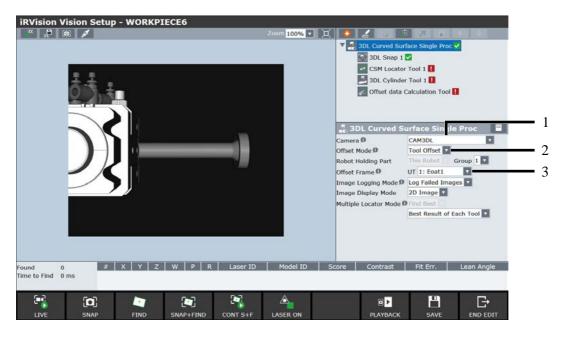
- 2 Select [3DL Curved Surface Single Proc].
- 3 Enter a name of vision process in [Name]. Assign a unique name to the vision process.
- 4 Click [OK].

A new vision process is created.



5 Click [EDIT].
The vision process setup screen appears.

4.2.5.2 Setting parameters of vision process

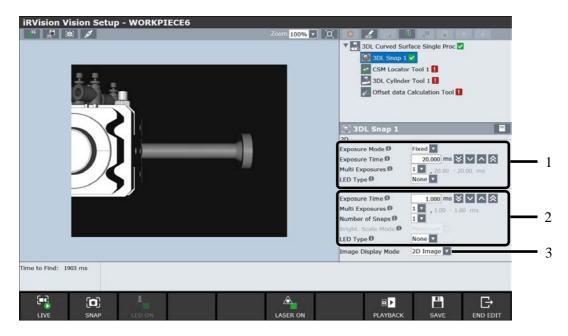


- 1 Select the 3DL Sensor Data from the drop-down box. Select the name of the taught 3DL Sensor Data.
- 2 Select [Tool Offset] from the [Offset Mode] drop-down box.
- 3 Select the tool frame number from the [Offset Frame] drop-down box. An offset frame is a tool frame used for calculation of offset amount. Select the tool frame number set in "Setup: 4.2.4 Setting Offset Frame".

4.2.5.3 Teaching 3DL Snap Tool

Select [3DL Snap] in the tree view area, and then set each item.

Setting parameters



1 Set parameters for 2D measurement.

Set parameters for snap of 2D measurement (detection and measurement of 2D features). For details of each parameter, refer to the description of COMMAND TOOL in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

2 Set parameters for laser measurement.

Set parameters for snap of laser measurement (detection and measurement of laser slit points). For details of each parameter, refer to the description of COMMAND TOOL in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

3 Select [Image Display Mode] from the drop-down box.

Select an image to show on the edit screen.

[2D Image]

An image snapped by the 2D camera appears.

[Laser Slit Image1]

An image of the laser slit 1 appears.

[Laser Slit Image2]

An image of the laser slit 2 appears.

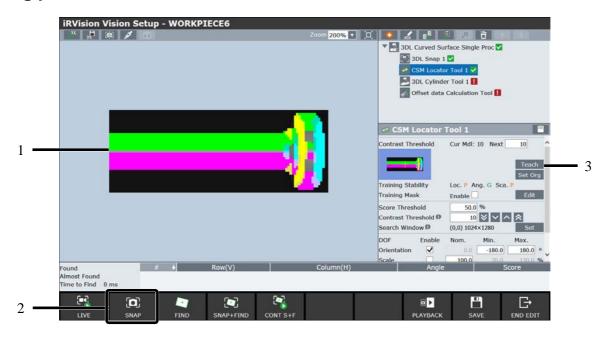
[Laser Composite Image]

An image that the image of the laser slit 1 and the image of the laser slit 2 are composited to 2D image appears.

4.2.5.4 Teaching Curved Surface Locator Tool

Select [CSM Locator Tool] in the tree view area, and then set each item.

Setting parameters



1 Jog the robot to the measurement area.

Move the robot position so that the laser beam is directed to the plane to be measured. Move the robot according to the following procedure.

Click [LIVE] to show a live image.

When the button is clicked, horizontal and vertical lines that show the center of the display screen appear. This is a guide when the plane to be measured is moved to the center of the screen. Jog the robot, and keep the distance of approx. 400 mm between the bottom surface of the 3D Laser Vision Sensor camera and the surface to be measured, in such a way that they almost directly face each other.

Next, jog the robot parallel to the surface to be measured so that the surface to be measured comes almost at the image center.

Next, jog the robot vertically to the surface to be measured so that the laser beam intersection comes almost at the center of the surface to be measured of the workpiece.

∦Memo

To adjust the laser irradiation position for the workpiece, select [3DL Curved Surface Single Proc] in the tree view area, click [LASER ON] to irradiate the laser, and then click [LIVE] to adjust. Then, select [3DL Snap] in the tree view area, and adjust the parameters.

2 Click [SNAP].

After determining the measurement position, click [SNAP] to capture an image.

3 Click the [Teach] button.

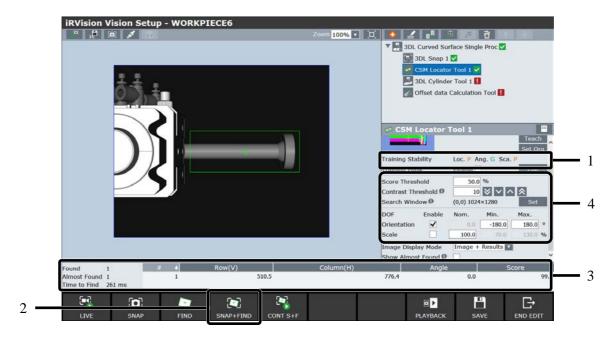
The model setup screen for the Curved Surface Locator Tool appears. Teach 2D features used for position detection. As the features of a model, select features on the same plane to reduce the effects of changes in shape due to parallax. For features that need not be included in the model, [Training Mask] can be set to exclude them from the teach model.

4 Teach the robot position in the robot program.

Teach the robot program the position here as a workpiece measurement point.

Detection test

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



1 Check [Training Stability].

This item provides a guideline indicating whether the position, angle, and size are detected correctly in the taught model. Evaluations are indicated with [G] (good), [P] (poor) and [N] (none). [N] indicates that stable detection of the model may be impossible. In such a case, change the model, or uncheck [Enable] of the parameter in question in [DOF] to make the parameter invalid.

- 2 Click [SNAP+FIND].
 - An image is captured, and detection is performed.
- 3 Check the detection results.
 - Check that the workpieces taught with the model are detected correctly on the image display screen. Then, check score, etc. in the test execution result display area. If the score and contrast values are higher than the set thresholds by at least 10 points, there is no problem.
- 4 Adjust parameters.
 - Adjust the parameters of the GPM Locator Tool as necessary.

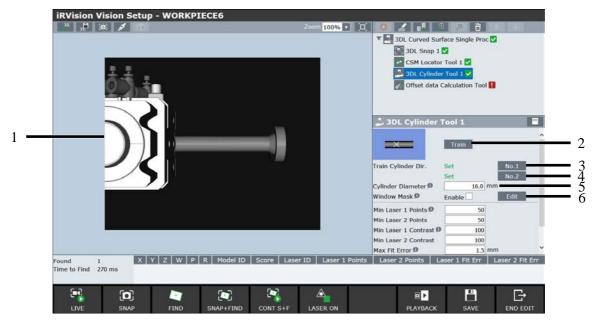
4.2.5.5 Teaching 3DL Cylinder Command Tool

Select [3DL Cylinder Tool] in the tree view area, and then set each item.

Setting parameters

⚠ CAUTION

When GPM Locator Tools or Curved Surface Locator Tools have been set in the same vision process, teach all the GPM Locator Tools or Curved Surface Locator Tools before teaching the 3DL Cylinder Command Tool.



1 Jog the robot to the measurement area.

Click [LASER ON], and jog the robot in such a way that the intersection point of the laser beam is directed to near the center of the cylinder. Move the robot according to the following procedure. Although it is desirable that a measurement be made at the teaching position for the Curved Surface Locator Tool, however, if necessary, jog the robot in the same way as the Curved Surface Locator Tool adjustment so that the laser beam is directed to the surface to be measured of the workpiece. In this case, teach the found position of the robot program again.

2 Click the [Train] button.

The measurement area training screen for cylinder measurement appears. Inside of the red frame shown in the image indicates the area for laser measurement. The area can be modified, and a line being modified is shown in purple.

Once the training of measurement area is completed, a thumbnail of the image used for training appears, and the area position and size appear.

If the Curved Surface Locator Tool is present in the vision process, the model teaching of the Curved Surface Locator Tool must be done in advance. If the Curved Surface Locator Tool is not taught, the measurement area for cylinder measurement cannot be taught. Also, the measurement area must be trained again if the model origin of the Curved Surface Locator Tool is changed, or the detection model is taught again after teaching the measurement area.

3 Click [No.1].

An image and a line segment in the measurement area appear. Arrange the line segment along either end of the curved surface of the cylinder.

4 Click [No.2].

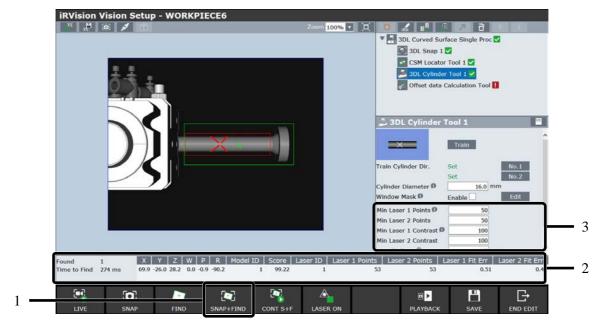
An image and a line segment in the measurement area appear in the same way as for [No.1]. Arrange the line segment along the other end of the curved surface of the cylinder.

- 5 Input [Cylinder Diameter].
 Set the diameter of the part taught the cylinder direction.
- Click the [Edit] button of [Window Mask].

 When there is an area to be excluded from the measurement area because the measurement area includes planes with level difference to which the laser beam is directed or for other reasons, click the [Edit] button of [Window Mask], and teach the mask. Even if the mask is taught, 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.



- 1 Click [SNAP+FIND].
 - An image is captured, and detection is performed.
- 2 Check the detection results.
 - Check that laser points are detected correctly on the image. Then, check the results output on the test execution result display area. By comparing the values of the results with set thresholds, determine whether stable detection can be performed. When detection fails, laser slit measurement results appear. Its measurement result can be used to determine the cause of the non-detection.
 - If the Curved Surface Locator Tool is set, the precondition to perform laser measurement is that the Curved Surface Locator Tool detection must be successful.
- 3 Adjust parameters.
 - Parameters can be adjusted so that stable detection of laser points is enabled. When changing parameters, read the description in the following subsection, "Parameters for laser points detection", and carefully change them.

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. To change the parameters, refer to the description of COMMAND TOOL in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN", and make changes with caution.

↑ CAUTION

Before changing the detection parameters of laser points, check whether the laser measurement exposure time of the 3DL Snap Tool has been adjusted properly.

4.2.5.6 Running a test

Run a test to check whether the vision process operates as taught. Before running the test, select [3DL Curved Surface Single Proc] in the tree view area.

Running a test

Click [SNAP+FIND] to snap an image and detect workpiece. If the workpiece is not detected, change the parameter for the undetected image, click [FIND] and run the test without snapping the image again. If the parameter change is valid, the workpiece is detected. Click [CONT S+F] to snap images and detect workpiece repeatedly. During this continuous execution, [CONT S+F] is changed to [STOP]. Click [STOP] to stop the continuous execution.

Time to find

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.

Checking found result

When the test detection is successful, the results appear. The measured position and posture of the workpiece are output using the values in the offset frame selected for the vision process. [Laser ID] and [Model ID] indicate which command tool resulted in successful detection.



When the score and contrast values are higher than the set thresholds by at least 10 points and therefore detection results are stable, proceed to "Setup: 4.2.5.8 Teaching the offset data calculation tool". If the detection results are still unstable after adjusting parameters of each command tool, proceed to "Setup: 4.2.5.7 Adding command tools", and make a necessary setting for stable results.

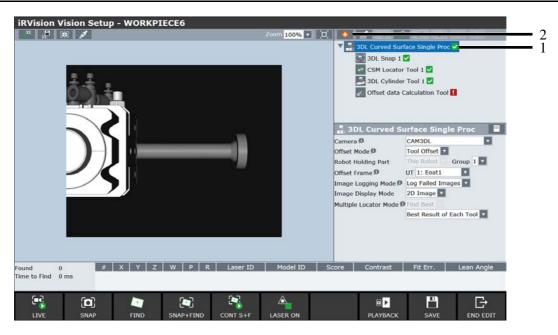
4.2.5.7 Adding command tools

Command tools such as a Curved Surface Locator Tool or 3DL Cylinder Command Tool can be added as necessary.



The reasons why command tools are added

Due to individual differences of workpieces and change of illumination intensity by time of day, an undetected situation tends to occur with only one set of detection parameter. In this case, preparing multiple command tools meeting the conditions can improve detection robustness.



- 1 Click [3DL Curved Surface Single Proc].
 - When a vision process for [3DL Curved Surface Single Proc] is created, one Curved Surface Locator Tool and one 3DL Cylinder Command Tool are added. To add another command tool to a vision process, select [3DL Curved Surface Single Proc] in the tree view.
- Click the button.A new command tool setting can be added.

*M***emo**

To copy an existing command tool, select the command tool to copy, then click the button.



- 3 Click a type of command tool to be added. Select any one of [3DL Displ. Command Tool], [3DL Cylinder Tool], [GPM Locator Tool] and [CSM Locator Tool].
- 4 Enter a name in [Name].
 Assign a unique name to the command tool.

5 Click [OK].
The command tool is added.

Adding Curved Surface Locator Tool

The laser measurement area window automatically moves depending on the Curved Surface Locator Tool detection results. Therefore, if separate model origins are set for more than one Curved Surface Locator 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, the robot offset data cannot be correctly calculated with the detection results of command tools having different model origins. To prevent these problems, when multiple Curved Surface Locator Tools are set in a vision process, the model origins of all the Curved Surface Locator Tools must match. The best way is to copy an existing command tool.

Adding 3DL Displacement Command Tool

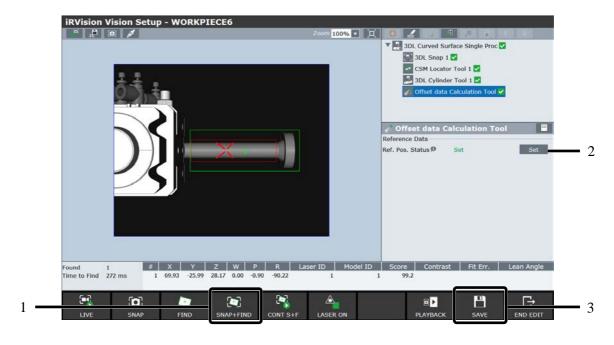
Because robot offset motion differs between [3DL Displ. Command Tool] and [3DL Plane Command Tool], when [3DL Displ. Command Tool] is added to a vision process, it is recommended to delete 3D measurement tools other than [3DL Displ. Command Tool].

[3DL Displ. Command Tool] is taught in the same manner as [3DL Cylinder Tool]. Note that the output position and posture of a workpiece, and parameter setting items differ between them. For details, refer to "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

4.2.5.8 Teaching the offset data calculation tool

In this section, place a workpiece in a reference position, run a test, and set the detection result as the reference position XYZWPR.

When the vision process is performed after the setting, the vision process calculates the offset data by comparing the actual position where the workpiece is detected and this reference position. Select [Offset data Calculation Tool] in the tree view, and then set each item.

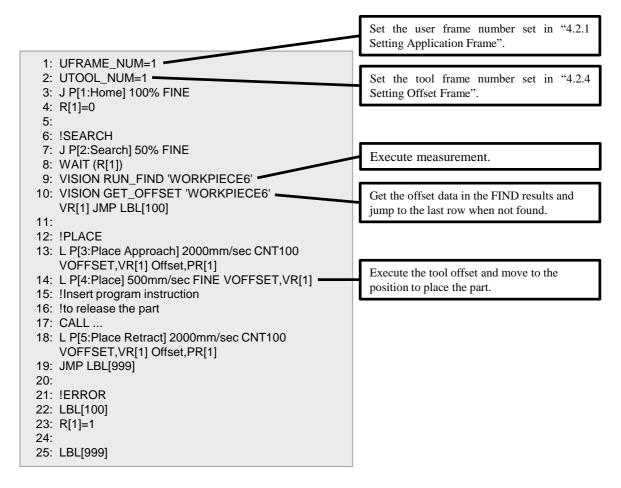


- 1 Click [SNAP+FIND].
- 2 Check that the workpiece is properly detected and click the [Set] button of [Ref. Pos. Status].
- 3 Click [SAVE] and then [END EDIT].

4.2.6 Creating and Teaching Robot Program

In the sample program below, the vision process for the 3DL Curved Surface Single Process is named as 'WORKPIECE6'. The sample program is a program to place, e.g., an unprocessed casting gripped by the robot in the position and posture determined beforehand. The robot offsets the picking motion according to the measurement result, and picks the workpiece as taught. After supplying the workpiece to the next process, the robot tries to detect another workpiece.

Teach the measurement position specified with the robot program when creating the vision process. Refer to "Setup: 4.2.5.4 Teaching Curved Surface Locator Tool".



Program example

∦Memo

Measurement is performed after the robot reaches the taught position on the last motion. If there is no residual vibration in the robot, measurement can be performed immediately after positioning. However, depending on the robot's setting condition, residual vibration may occur in the robot's motion or rail axis, which may affect the accuracy of measurement. In such cases, giving the wait command or the acceleration override command to reduce the speed slowly may be required for adjustment.

In the sample program above, the vision process called 'WORKPIECE6' is executed, only one piece of offset data is obtained, and the position where the workpiece is placed is offset. If no workpiece is detected, it jumps to the label [999] without offset operation.

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

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

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 at 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.

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, 14th, and 18th lines, robot motion such as placing the workpiece is offset 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 that is offset with a vision offset data in a specified vision register.

For details of each command above and other commands, refer to the description of PROGRAM COMMAND in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

4.2.7 Checking Robot Offset 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 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.

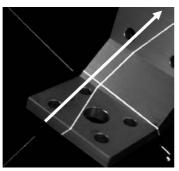
This function can be used particularly when the target workpiece does not meet the condition that 'workpieces should have the same plane where stable irradiation of laser beams is possible in the distance of about at least 20 mm in the camera FOV, and have a feature that detection is possible by the 2D detection function in the field of view of the camera when a plane is measured', which is required by other 3D Laser Vision Sensor measurement functions.

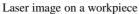
However, this function can output the measurement position only while other 3D Laser Vision Sensor measurement functions can output offset data for offsetting robot operation.

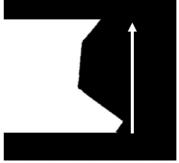
To offset robotic handling of the workpiece, it is necessary to perform measurements as many times as required to calculate offset data, synthesize the measurement results with the robot program, and calculate offset data.

Contact FANUC to inquire about whether the 3D Laser Vision Sensor is applicable for a specific application, and also inquire about the offset mode for the robot.

A cross-section image is created by projecting information consisting of 3D points on the laser plane. The information is obtained by irradiating the laser on a workpiece. 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.







Cross-section image

Laser irradiation and cross-section image

This chapter describes the procedure to set up and teach the 3DL Cross Section Vision Process using the following two application examples.

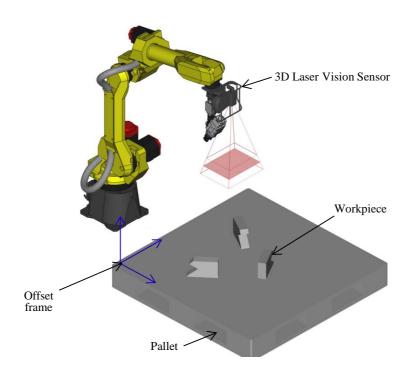
- (1) Robot-mounted camera + fixed frame offset
- (2) Fixed camera + tool offset

∕Memo

Unless otherwise specified, the screens and operations in the simple mode are shown in this chapter. For details of the simple mode and advanced mode, refer to the "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

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

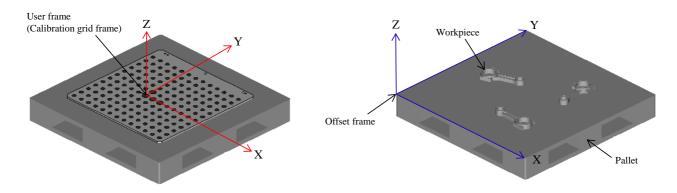
A layout example of 'robot-mounted camera + fixed frame offset' for '3DL Cross Section Vis. Process' is given below.



Layout example of robot-mounted camera + fixed frame offset

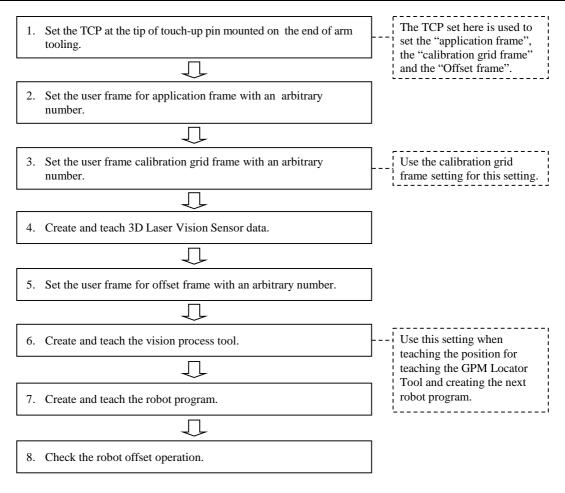
For setup of 'robot-mounted camera + fixed frame offset', specify a user frame with an arbitrary number to 'installation information of the calibration grid' and 'offset frame' respectively, and make necessary settings for the user frame.

The "Calibration grid frame" can be set easily and correctly by using the camera of the 3D Laser Vision Sensor (calibration grid frame setting function).



Calibration grid frame and offset frame

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



Setup flow

5.1.1 Setting TCP of Robot

Setting the TCP of the robot is necessary to teach the application frame, the calibration grid frame and the offset frame. In general, 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]. For the setting method, refer to "Know-How: 1 FRAME SETTING".

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.

5.1.2 Setting Application Frame

Specify the robot's user frame to be used as a reference for 3DL calibration. In many cases, the base frame of the robot is set up in the world frame. However, in the following cases, set the user frame, and set the user frame number as the application frame.

- In the case the 3D Laser Vision Sensor is attached to a robot other than the robot to be offset.
- In the case the calibration grid is attached to a robot other than the robot to be offset.
- In the case the robot to be offset belongs to another motion group.

Refer to "Introduction: 1.5 COORDINATE SYSTEMS USED FOR iRVision".

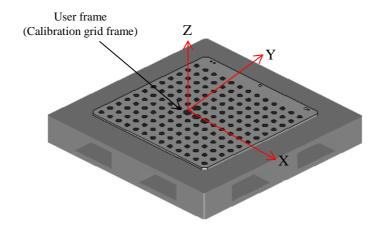
5.1.3 Setting Calibration Grid Frame

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 calibration grid frame setting function. After securing the calibration grid, execute the calibration grid frame setting function. For details of the calibration grid frame setting function, refer to "Know-How: 1.2 FRAME SETTING WITH GRID FRAME SETTING FUNCTION". Note that the user frame in the installation information of the calibration grid differs from the user frame used for offset described in the following subsection.

In addition to the method of using the calibration 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. Refer to "Know-How: 1.1 FRAME SETTING WITH POINTER TOOL". The TCP setting precision and touch-up precision directly affect the offset 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 details of the calibration recovery method, refer to "Know-How: 2.1.7 Automatic Re-Calibration".



Calibration grid installation information

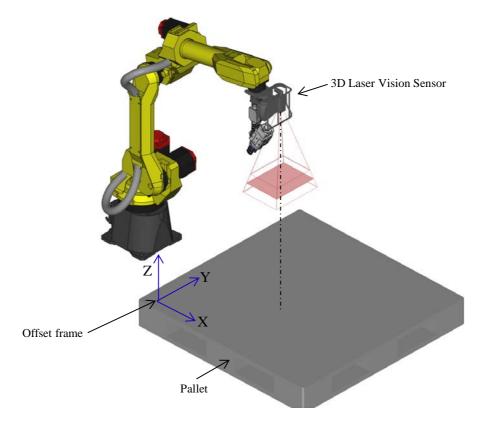
5.1.4 Creating and Teaching 3DL Sensor Data

To use the 3D Laser Vision Sensor, 3DL calibration using a calibration grid is required. For details of the 3DL calibration, refer to "Know-How: 2 3DL SENSOR DATA SETTING".

5.1.5 **Setting Offset Frame**

Set a user frame to be used as the reference for the robot offset 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. For details of the frame setting, refer to "Know-How: 1 FRAME SETTING".



User frame used for offset

Sharing user frame

When two or more robots work together for the same workpiece, it is necessary to physically set the same user frame for all the robots. 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. E.g., user frame 5 of robot 1 needs to be physically the same as user frame 5 of robot 2.

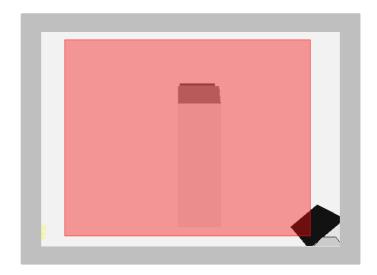


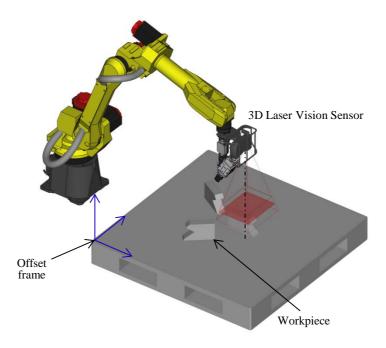
↑ CAUTION

If robots share user frames of different numbers, iRVision cannot offset the robots correctly. Make sure that the robots share the same user frame number.

5.1.6 Creating and Teaching Vision Process

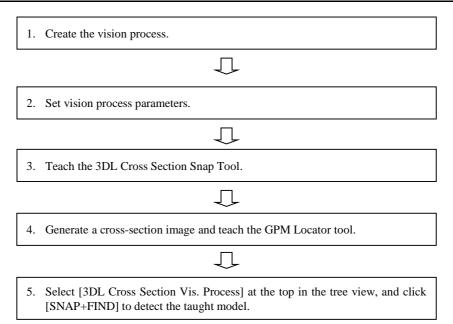
Create a vision process for the '3DL Cross Section Vision Process'.





Workpiece setting example

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



Vision process teaching flow

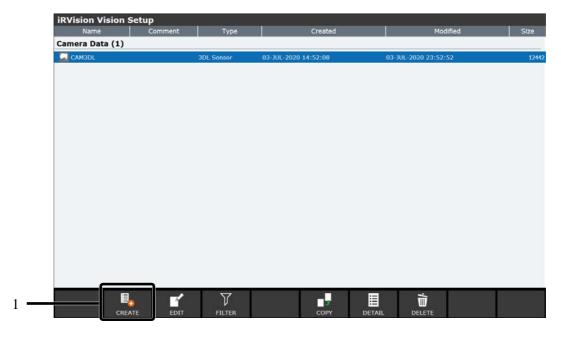
Placing reference workpiece

After it is confirmed that the calibration of the 3D Laser Vision Sensor has been correctly performed, teaching to measure the 3D position specified on the workpiece is performed.

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

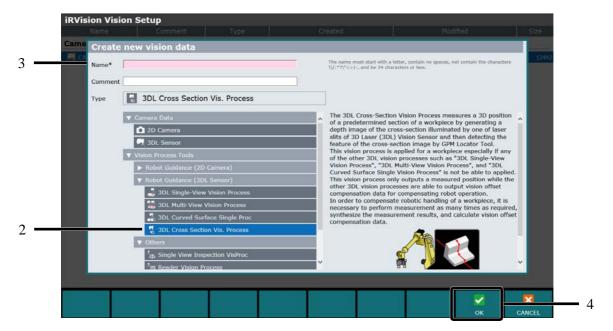
5.1.6.1 Creating vision process

After placing a reference workpiece, create a vision process.

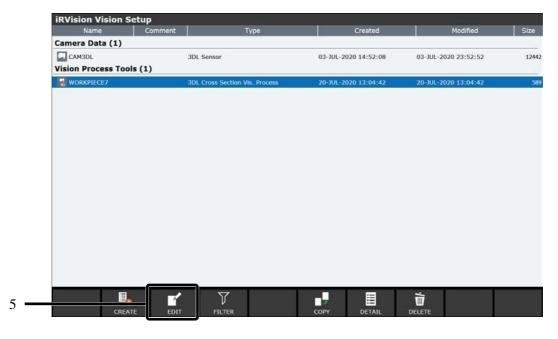


1 Click [CREATE].

The pop-up to create new vision data appears.



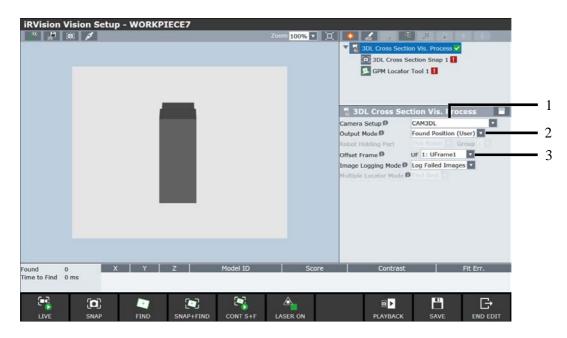
- 2 Select [3DL Cross Section Vis. Process].
- 3 Enter a name of vision process in [Name]. Assign a unique name to the vision process.
- 4 Click [OK].
 A new vision process is created.



5 Click [EDIT].

The vision process setup screen appears.

5.1.6.2 Setting parameters of vision process

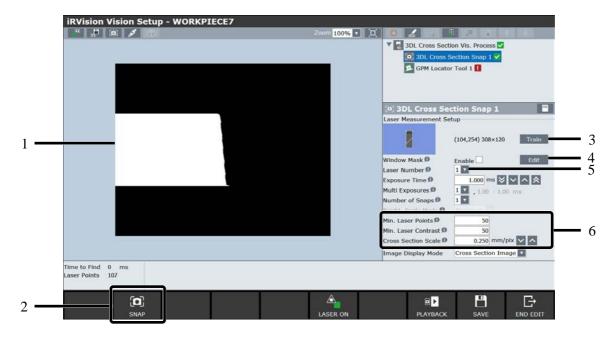


- 1 Select the 3DL Sensor Data from the drop-down box. Select the name of the taught 3DL Sensor Data.
- 2 Select [Found Position (User)] from the [Output Mode] drop-down box.
- 3 Select the user frame number set as [Offset Frame] from the drop-down box. An offset frame is a user frame used to calculate a measured 3D position. Select the user frame number set in "Setup: 5.1.5 Setting Offset Frame".

5.1.6.3 Teaching 3DL Cross Section Snap Tool

Select [3DL Cross Section Snap] in the tree view area, and then set each item.

Setting parameters



1 Jog the robot to the measurement area.

Move the robot position so that the laser beam is directed to the plane to be measured. Move the robot according to the following procedure.

When the button is clicked, horizontal and vertical lines that show the center of the display screen appear. This is a guide when the plane to be measured is moved to the center of the screen. Jog the robot, and keep the distance of approx. 400 mm between the bottom surface of the 3D Laser Vision Sensor camera and the surface to be measured, in such a way that they almost directly face each other.

Next, jog the robot parallel to the surface to be measured so that the surface to be measured comes almost at the image center.

Next, jog the robot vertically to the surface to be measured so that the laser beam intersection comes almost at the center of the surface to be measured of the workpiece.

To adjust the laser irradiation position for the workpiece, select [3DL Cross Section Vis. Process] in the tree view area, click [LASER ON] to irradiate the laser, and then click [LIVE]. Then, select [3DL Cross Section Snap] in the tree view area, and adjust the parameters.

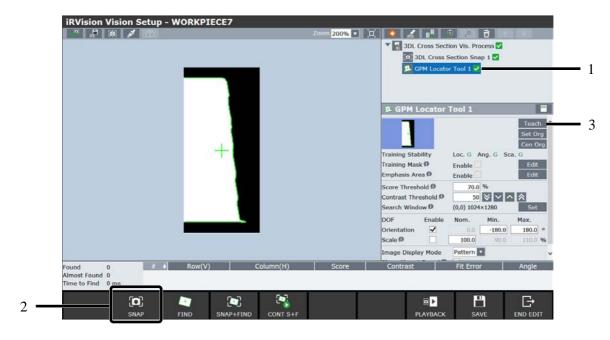
- 2 Click [SNAP].
 - After determining the measurement position, click [SNAP] to capture an image.
- 3 Click [Train]. The measurement area teaching screen appears. Inside of the red frame shown in the image indicates the area for laser measurement. The area can be modified, and a line being modified is shown in purple. Once the training of measurement area is completed, a thumbnail of the image used for training appears, and the area position and size appear.
- 4 Click the [Edit] button of [Window Mask].
 - When there is an area to be excluded from the measurement area because the measurement area includes planes with level difference to which the laser beam is directed or for other reasons, click

- the [Edit] button of [Window Mask], and teach the mask. Even if the mask is taught, the mask is ignored if the [Enable] check box is not checked.
- Select a laser number to snap a cross section from the [Laser Number] drop-down box. Select 1 for lower left - upper right, and select 2 for upper left - lower right on the laser slit image.
- 6 Set parameters for laser measurement. Set parameters for snap of laser measurement (detection and measurement of laser slit points). For details of each parameter, refer to the description of COMMAND TOOL in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

5.1.6.4 Teaching GPM Locator Tool

After showing the cross-section image of the workpiece with laser, set each item for the GPM Locator Tool.

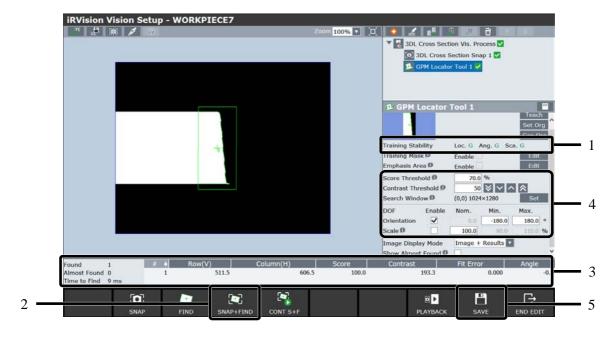
Setting parameters



- 1 Click [GPM Locator Tool] in the tree view area. The GPM Locator Tool setup screen appears.
- 2 Click [SNAP].
 - After determining the measurement position, click [SNAP] to capture an image.
- 3 Click the [Teach] button.
 - The GPM Locator Tool model setup screen appears. Teach 2D features used for position detection. Select a cross section feature to detect as a model in the cross-section image. For features that need not be included in the model, [Training Mask] can be set to exclude them from the teach model. For details of teaching 2D features, refer to "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".
- Teach the robot position in the robot program.
 Teach the robot program the position here as a workpiece measurement point.

Detection test

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



1 Check [Training Stability].

This item provides a guideline indicating whether the position, angle, and size are detected correctly in the taught model. Evaluations are indicated with [G] (good), [P] (poor) and [N] (none). [N] indicates that stable detection of the model may be impossible. In such a case, change the model, or uncheck [Enable] of the parameter in question in [DOF] to make the parameter invalid.

- 2 Click [SNAP+FIND].
 - An image is captured, and detection is performed.
- 3 Check the detection results.
 - Check that the workpieces 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 area. If the score and contrast values are higher than the set thresholds by at least 10 points, there is no problem.
- 4 Adjust parameters.
 - Adjust the parameters of the GPM Locator Tool as necessary.
- 5 Click [SAVE].
 - The set contents are saved.

5.1.6.5 Running a test

Run a test to check whether the vision process operates as taught. Before running the test, select [3DL Cross Section Vis. Process] in the tree view area.

Running a test

Click [SNAP+FIND] to snap an image and detect workpiece. If the workpiece is not detected, change the parameter for the undetected image, click [FIND] and run the test without snapping the image again. If the parameter change is valid, the workpiece is detected. Click [CONT S+F] to snap images and detect workpiece repeatedly. During this continuous execution, [CONT S+F] is changed to [STOP]. Click [STOP] to stop the continuous execution.

Time to find

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.

Checking found result

When the test detection is successful, the results appear. The measured position and posture of the workpiece are output using the values in the offset frame selected for the vision process. [Model ID], which is displayed when you enable the advanced mode, indicates which command tool resulted in successful detection.



5.1.7 Creating and Teaching 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 "WORKPIECE7" to "WORKPIECE10", respectively. Offset data calculated by the robot program is used not with the vision offset command, but with the position offset command. How many measurement points are required differs depending on the actual application.

Teach the measurement position specified with the robot program when creating the vision process. Refer to "Setup: 5.1.6.4 Teaching GPM Locator Tool".

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.

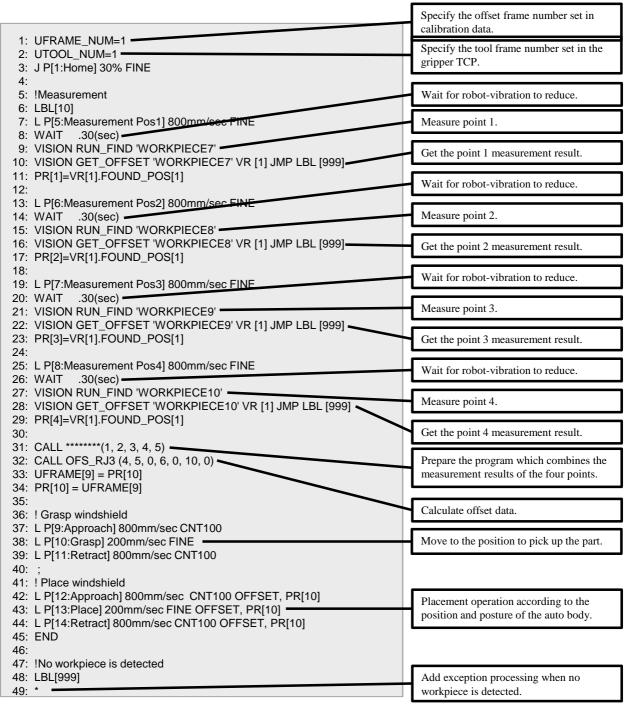
PR[10]: Contains offset data.

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 offset method, contact FANUC.



Program example

≫ Memo

Measurement is performed after the robot reaches the taught position on the last motion. If there is no residual vibration in the robot, measurement can be performed immediately after positioning. However, depending on the robot's setting condition, residual vibration may occur in the robot's motion or rail axis, which may affect the accuracy of measurement. In such cases, giving the wait command or the acceleration override command to reduce the speed slowly may be required for adjustment.

In above sample program, the vision processes 'WORKPIECE7' to 'WORKPIECE10' are executed, only one piece of offset data is obtained, and the robot position is offset. If no workpiece is detected, it jumps to the label [999] without offset operation.

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

The commands at the 9th, 15th, 21st and 27th lines execute the specified vision process, snap an image from a camera, perform image processing and store the position information of the detected workpiece.

```
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 commands at the 10th, 16th, 22nd and 28th lines import the offset data of the workpiece into 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.

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.

The commands at the 42nd to 44th lines offset the actual robot motion such as workpiece handling by using the detection position stored in the obtained offset data.

```
L P[1] 800mm/sec FINE OFFSET. PR[a]
```

OFFSET is an optional operation command that is added to a robot motion statement. This command moves the robot to a position calculated with a vision offset data in position register [10].

For details of each command above and other commands, refer to the description of PROGRAM COMMAND in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

5.1.8 Checking Robot Offset Operation

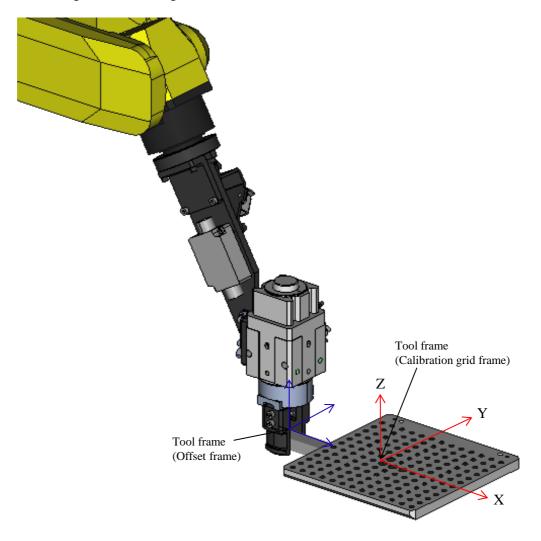
Check that as many points as required are measured, offset data is calculated using the robot program, and the robot can handle the workpiece exactly. At first, decrease the override of the robot to check that the logic of the program is correct. Next, increase the override and cycle the program again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

5.2 SETUP FOR "FIXED CAMERA + 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 offset so that the robot places the gripped workpiece at the predetermined position exactly.

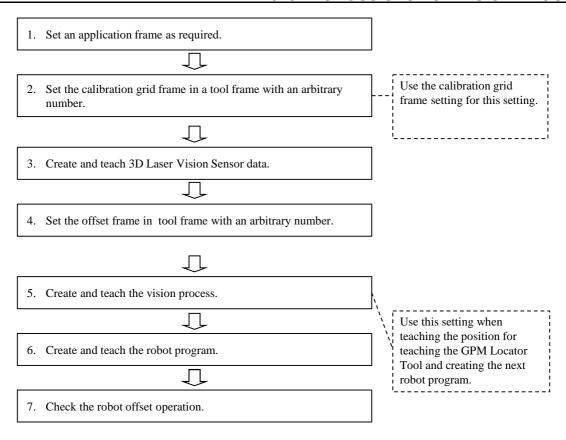
For setup of 'fixed camera + tool offset', specify a tool frame with an arbitrary number to 'installation information of the calibration grid' and 'tool frame used for offset' respectively, and set necessary data to the tool frame.

The "Calibration grid frame" can be set easily and correctly by using the camera of the 3D Laser Vision Sensor (calibration grid frame setting function).



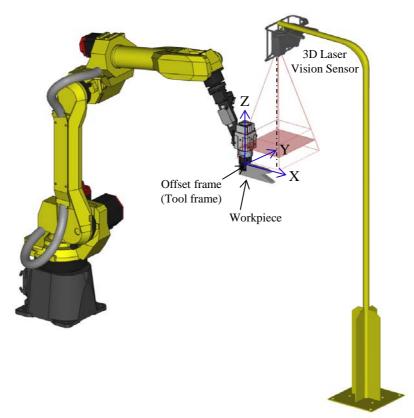
Tool frame used for offset

Use the following setup procedure for "fixed camera + tool offset".



Setup flow

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

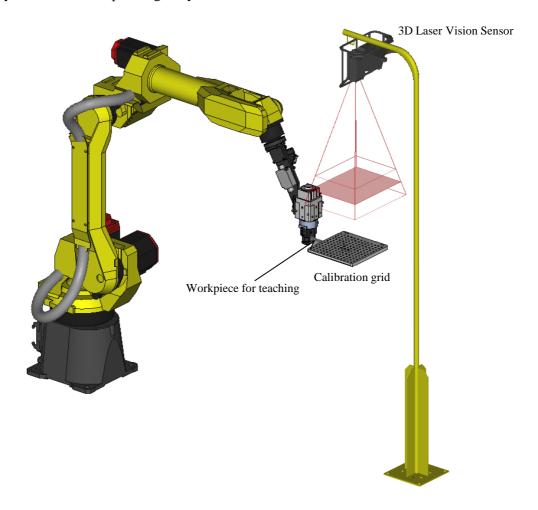


Fixed camera + tool offset layout example

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.



Calibration grid mounting example

5.2.1 Setting Application Frame

Specify the robot's user frame to be used as a reference for 3DL calibration. In many cases, the base frame of the robot is set up in the world frame.

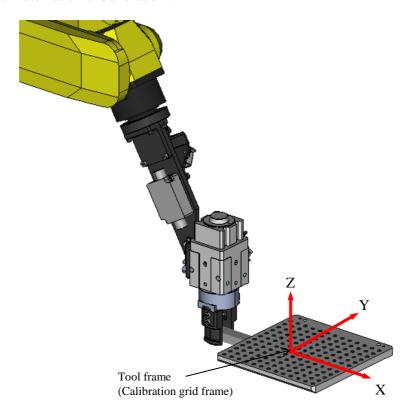
Refer to "Introduction: 1.5 COORDINATE SYSTEMS USED FOR iRVision".

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 calibration grid frame setting function. After securing the calibration grid, execute the calibration grid frame setting function. For details of the calibration grid frame setting function, refer to "Know-How: 1.2 FRAME SETTING WITH GRID FRAME SETTING FUNCTION".

In addition to the method of using the calibration 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, and then set a tool frame as shown in the figure below. Refer to "Know-How: 1.1 FRAME SETTING WITH POINTER TOOL". Touch up the grid precisely since the touch-up precision directly affects the offset precision.

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 details of the calibration recovery method, refer to "Know-How: 2.1.7 Automatic Re-Calibration".



Calibration grid installation information

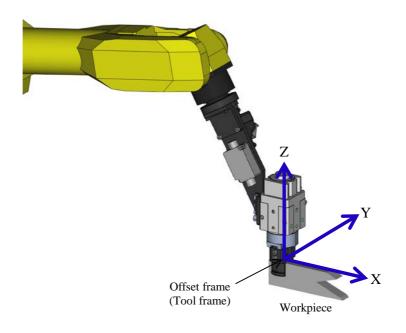
5.2.3 Creating and Teaching 3DL Sensor Data

To use the 3D Laser Vision Sensor, 3DL calibration using a calibration grid is required. For details of the 3DL calibration, refer to "Know-How: 2 3DL SENSOR DATA SETTING".

5.2.4 Setting Offset Frame

Set a tool frame to be used as the reference of the tool offset operation by the robot. Tool offset data is output as values in the tool frame set here.

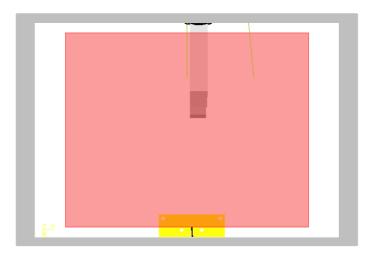
To set the tool frame, use [Tool Frame Setup / Six Point]. For details of the frame setting, refer to "Know-How: 1 FRAME SETTING".

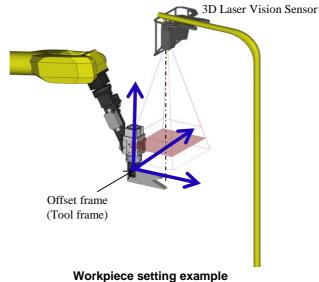


Tool frame used for offset

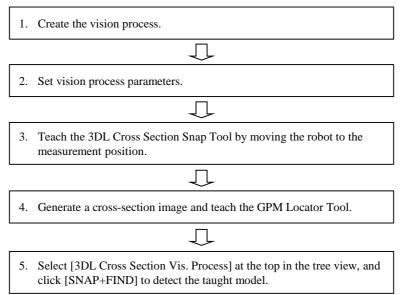
5.2.5 Creating and Teaching Vision Process

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.



Vision process teaching flow

Placing reference workpiece

After it is confirmed that the calibration of the 3D Laser Vision Sensor has been correctly performed, teaching to measure the 3D position specified on the workpiece is performed.

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

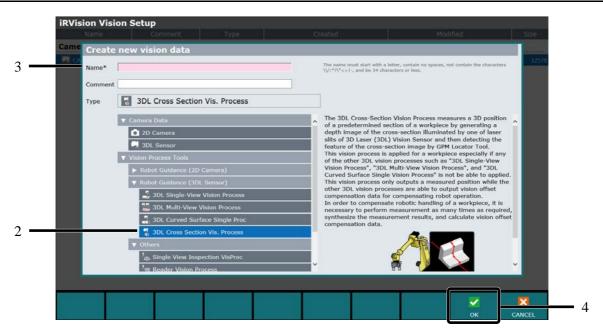
5.2.5.1 Creating vision process

After placing a reference workpiece, create a vision process.

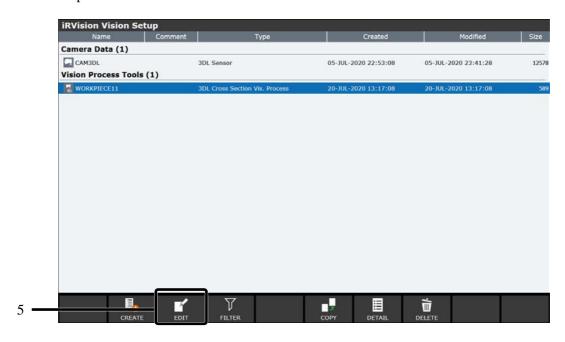


1 Click [CREATE].

The pop-up to create new vision data appears.



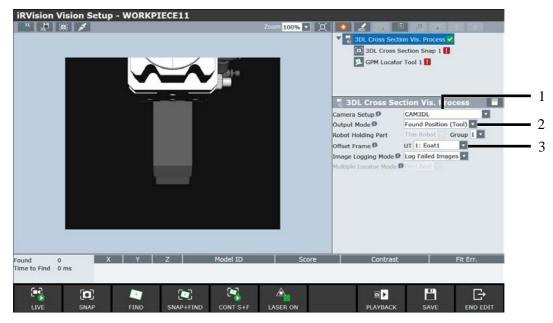
- 2 Select [3DL Cross Section Vis. Process].
- 3 Enter a name of vision process in [Name]. Assign a unique name to the vision process.
- 4 Click [OK].
 A new vision process is created.



5 Click [EDIT].

The vision process setup screen appears.

5.2.5.2 Setting parameters of vision process

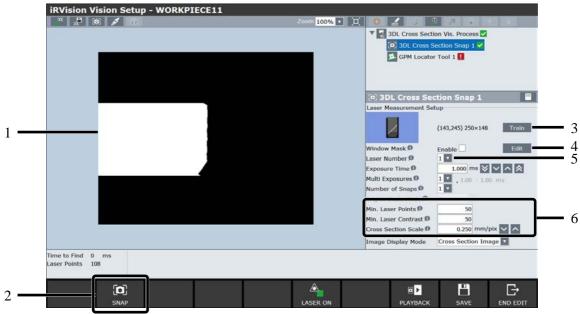


- Select the 3DL Sensor Data from the drop-down box. Select the name of the taught 3DL Sensor Data.
- 2 Select [Found Position (Tool)] from the [Output Mode] drop-down box.
- 3 Select the tool frame number from the [Offset Frame] drop-down box. An offset frame is a tool frame used to calculate a measured 3D position. For example, select the tool frame number set as TCP of the hand.

5.2.5.3 Teaching 3DL Cross Section Snap Tool

Select [3DL Cross Section Snap] in the tree view area, and then set each item.

Setting parameters



Jog the robot to the measurement area.

Move the robot position so that the laser beam is directed to the plane to be measured. Move the robot according to the following procedure.

 When the button is clicked, horizontal and vertical lines that show the center of the display screen appear. This is a guide when the plane to be measured is moved to the center of the screen. Jog the robot, and keep the distance of approx. 400 mm between the bottom surface of the 3D Laser Vision Sensor camera and the surface to be measured, in such a way that they almost directly face each other. Next, jog the robot parallel to the surface to be measured so that the surface to be measured comes almost at the image center.

Next, jog the robot vertically to the surface to be measured so that the laser beam intersection comes almost at the center of the surface to be measured of the workpiece.

∕ Memo

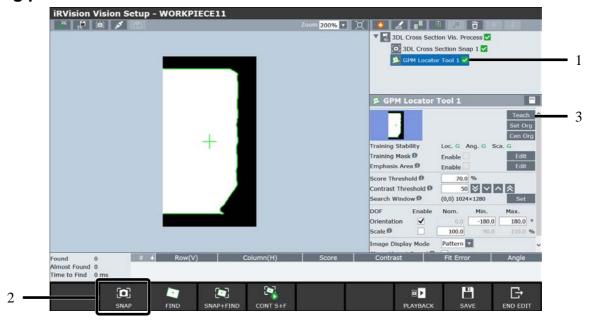
To adjust the laser irradiation position for the workpiece, select [3DL Cross Section Vis. Process] in the tree view area, click [LASER ON] to irradiate the laser, and then click [LIVE]. Then, select [3DL Cross Section Snap] in the tree view area, and adjust the parameters.

- 2 Click [SNAP].
 - After determining the measurement position, click [SNAP] to capture an image.
- 3 Click [Train]. The measurement area teaching screen appears. Inside of the red frame shown in the image indicates the area for laser measurement. The area can be modified, and a line being modified is shown in purple. Once the training of measurement area is completed, a thumbnail of the image used for training appears, and the area position and size appear.
- 4 Click the [Edit] button of [Window Mask].
 - When there is an area to be excluded from the measurement area because the measurement area includes planes with level difference to which the laser beam is directed or for other reasons, click the [Edit] button of [Window Mask], and teach the mask. Even if the mask is taught, the mask is ignored if the [Enable] check box is not checked.
- Select a laser number to snap a cross section from the [Laser Number] drop-down box. Select 1 for lower left - upper right, and select 2 for upper left - lower right on the laser slit image.
- 6 Set parameters for laser measurement. Set parameters for snap of laser measurement (detection and measurement of laser slit points). For details of each parameter, refer to the description of COMMAND TOOL in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

5.2.5.4 Teaching GPM Locator Tool

After showing the cross-section image of the workpiece with laser, set each item for the GPM Locator Tool.

Setting parameters



- 1 Click [GPM Locator Tool] in the tree view area. The GPM Locator Tool setup screen appears.
- 2 Click [SNAP].
 - After determining the measurement position, click [SNAP] to capture an image.
- 3 Click the [Teach] button.
 - The GPM Locator Tool model setup screen appears. Teach 2D features used for position detection. Select a cross section feature to detect as a model in the cross-section image. For features that need not be included in the model, [Training Mask] can be set to exclude them from the teach model. For details of teaching 2D features, refer to "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".
- 4 Teach the robot position in the robot program.

 Teach the robot program the position here as a workpiece measurement point.

Detection test

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



1 Check [Training Stability].

This item provides a guideline indicating whether the position, angle, and size are detected correctly in the taught model. Evaluations are indicated with [G] (good), [P] (poor) and [N] (none). [N] indicates that stable detection of the model may be impossible. In such a case, change the model, or uncheck [Enable] of the parameter in question in [DOF] to make the parameter invalid.

- 2 Click [SNAP+FIND].
 - An image is captured, and detection is performed.
- 3 Check the detection results.

Check that the workpieces 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 area. If the score and contrast values are higher than the set thresholds by at least 10 points, there is no problem.

- 4 Adjust parameters.
 - Adjust the parameters of the GPM Locator Tool as necessary.
- 5 Click [SAVE].

The set contents are saved.

5.2.5.5 Running a test

Run a test to check whether the vision process operates as taught. Before running the test, select [3DL Cross Section Vis. Process] in the tree view area.

Running a test

Click [SNAP+FIND] to snap an image and detect workpiece. If the workpiece is not detected, change the parameter for the undetected image, click [FIND] and run the test without snapping the image again. If the parameter change is valid, the workpiece is detected. Click [CONT S+F] to snap images and detect workpiece repeatedly. During this continuous execution, [CONT S+F] is changed to [STOP]. Click [STOP] to stop the continuous execution.

Time to find

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.

Checking found result

When the test detection is successful, the results appear. The measured position and posture of the workpiece are output using the values in the offset frame selected for the vision process. [Model ID], which is displayed when you enable the advanced mode, indicates which command tool resulted in successful detection.



5.2.6 Creating and Teaching 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 "WORKPIECE11" to "WORKPIECE14", respectively. Offset data calculated by the robot program is used not with the vision offset command, but with the tool offset command. How many measurement points are required differs depending on the actual application.

Teach the measurement position specified with the robot program when creating the vision process. Refer to "Setup: 5.2.5.4 Teaching GPM Locator Tool".

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.

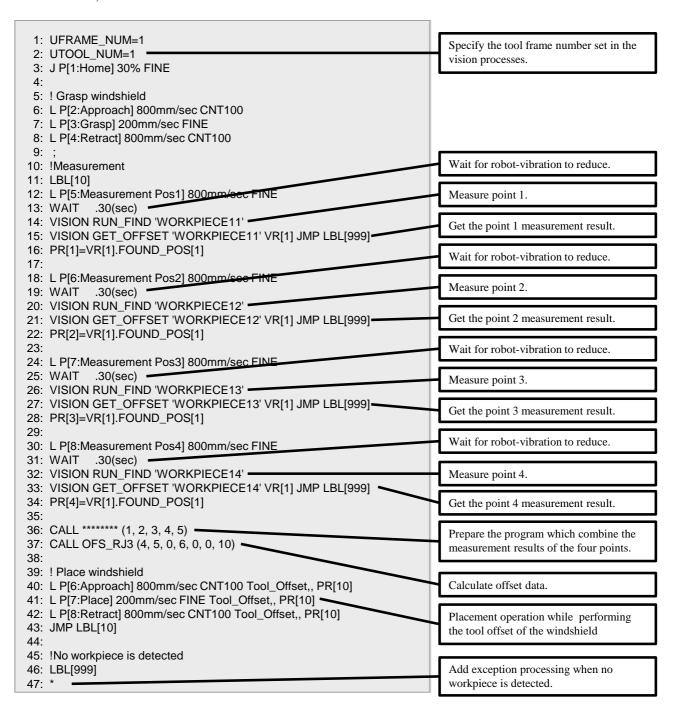
PR[6]: Contains the combined result of reference execution.

PR[10]: Contains offset 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 offset method, contact FANUC.



Program example

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Measurement is performed after the robot reaches the taught position on the last motion. If there is no residual vibration in the robot, measurement can be performed immediately after positioning. However, depending on the robot's setting condition, residual vibration may occur in the robot's motion or rail axis, which may affect the accuracy of measurement. In such cases, giving the wait command or the acceleration override command to reduce the speed slowly may be required for adjustment.

In above sample program, the vision processes 'WORKPIECE11' to 'WORKPIECE14' are executed, only one piece of offset data is obtained, and the robot position is offset. If no workpiece is detected, it jumps to the label [999] without offset operation.

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

The commands at the 14th, 20th, 26th and 32nd lines execute the specified vision process, snap an image from a camera, perform image processing and store the position information of the detected workpiece.

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 commands at the 15th, 21st, 27th and 33rd lines import the offset data of the workpiece into 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.

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.

The commands at the 40th to 42nd lines offset the actual robot motion such as placing the workpiece by using the found position stored in the obtained offset data.

L P[1] 800mm/sec FINE Tool_Offset, PR[a]

With reference to the position taught to the operation command, the Tool_Offset command moves the robot to a position offset with the amount of offset data stored in position register [10].

For details of each command above and other commands, refer to the description of PROGRAM COMMAND in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

5.2.7 Checking Robot Offset Operation

Check that the robot grips the workpiece (as many points as required are measured), offset 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.

Know-How

- 1 FRAME SETTING
- 2 3DL SENSOR DATA SETTING
- 3 VISION APPLICATION
- 4 TROUBLESHOOTING

1 FRAME SETTING

This chapter explains the setting method for the user frame and tool frame. In *i*RVision, the following frames are used.

World frame

The frame that is defined in the robot from the start. A specified location is defined for each model of robot. It cannot be changed.

User frame

A frame that is defined by a user. It is expressed using a relative position from the world frame. It will be the same as the world frame when it is not set.

Tool frame

A frame that shows the tool center point (TCP) and orientation of a tool. It needs to be set up in accordance with each tool.

In iRVision, the above frames need to be setup in [Application Frame] or [Offset Frame].

For details on the general method for frame setting, refer to the description of FRAME SETTING in "OPERATOR'S MANUAL (Basic Operation) B-83284EN".

There are two methods for frame setting. Refer to the following for each setting method.

- Setting with a pointer tool
 - For the setting method, refer to "Know-How: 1.1 FRAME SETTING WITH POINTER TOOL".
- Setting with the calibration grid frame setting function For the setting method, refer to "Know-How: 1.2 FRAME SETTING WITH GRID FRAME SETTING FUNCTION".

1.1 FRAME SETTING WITH POINTER TOOL

This is a method for setting a user frame or tool frame by physically performing touch-up with a pointer tool.

This section explains a user frame and tool frame with the following configuration.

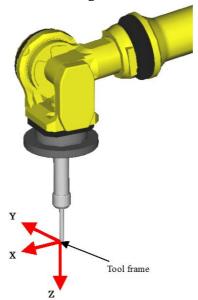
- For details of the user frame setting, refer to "Know-How: 1.1.1 User Frame Setting".
- For details of the tool frame setting, refer to "Know-How: 1.1.2 Tool Frame Setting".

1.1.1 User Frame Setting

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

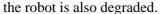
1.1.1.1 TCP set up

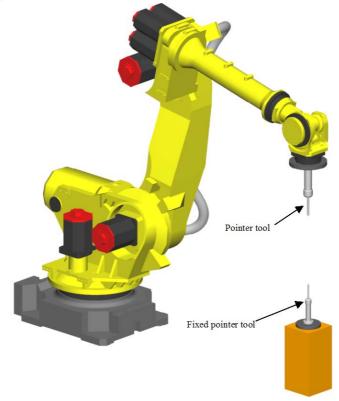
Attach a pointer tool on the robot end of the arm tooling, and set TCP to an arbitrary tool frame number.



Pointer tool and tool frame

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



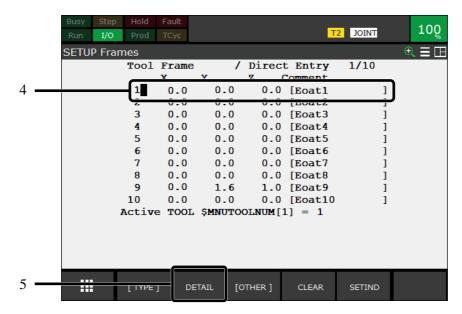


Example of a layout for pointer tool and fixed pointer tool

Three point method

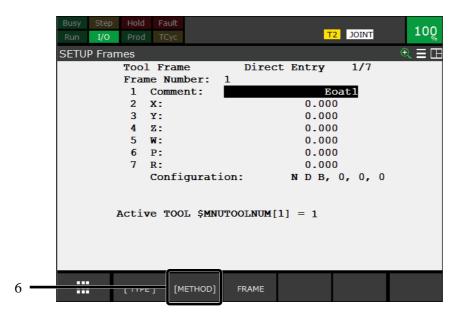
Use the three point method to define the tool center point (TCP). The three approach points must be taught with the tool touching a common point from three different approach statuses. As a result, the location of TCP is automatically calculated. To set the TCP accurately, three approach directions had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

- On the teach pendant, after selecting the [MENU] key \rightarrow [SETUP], place the cursor over [Frames] and press the [ENTER] key.
- 2 Press F3 [OTHER].
- 3 Place the cursor over [Tool Frame] and press the [ENTER] key. The list screen for tool frames will appear.



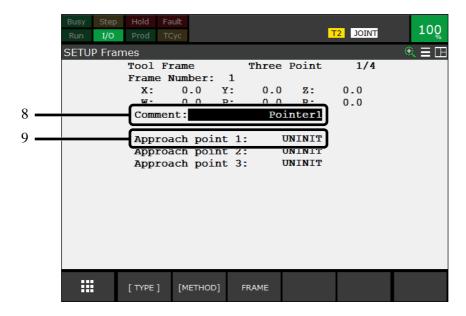
- 4 Place the cursor over the line of the tool frame number to be set.
- 5 Press F2 [DETAIL].

The setup screen for the tool frame for the selected frame number will appear.

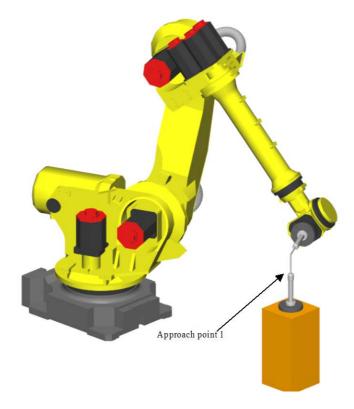


- 6 Press F2 [METHOD].
- Place the cursor over [Three Point] and press the [ENTER] key.

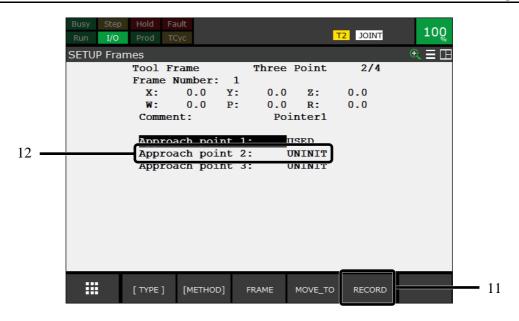
 A screen for tool frame setting using the three point teaching method will appear.



- 8 Enter a comment in the [Comment] field as required.
 A comment to distinguish this frame from other frames is recommended.
- 9 Place the cursor over [Approach point 1].
- 10 Jog the robot and touch up the fixed pointer tool pin with the robot pointer tool pin.

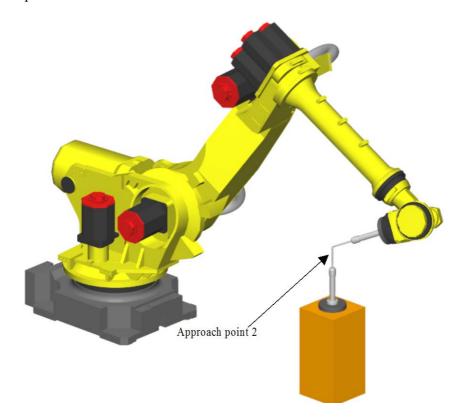


Touch-up of approach point 1

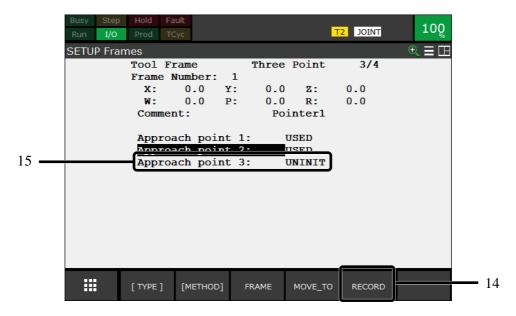


- While holding down the [SHIFT] key, press F5 [RECORD]. The current value's data will be input as approach point 1. For the taught [Approach point 1], [Used] will appear.
- 12 Place the cursor over [Approach point 2].
- Jog the robot and touch up the fixed pointer tool pin with the robot pointer tool pin.

 Touch up the same point as the approach point 1. However, change the robot attitude from that of the approach point 1.

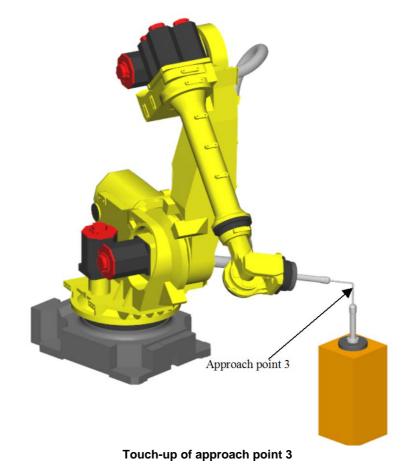


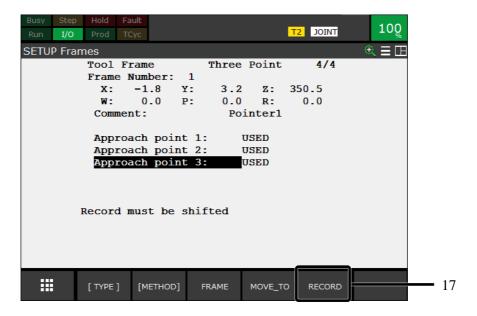
Touch-up of approach point 2



- While holding down the [SHIFT] key, press F5 [RECORD]. The current value's data will be input as approach point 2. For the taught [Approach point 2], [Used] will appear.
- 15 Place the cursor over the [Approach point 3].
- Jog the robot and touch up the fixed pointer tool pin with the robot pointer tool pin.

 Perform touch-up of the same point as for approach point 1 and approach point 2. However, make the orientation of the robot different from that for approach point 1 and approach point 2.





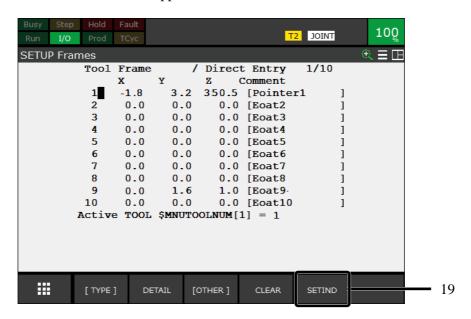
While holding down the [SHIFT] key, press F5 [RECORD].

The current value's data will be input as approach point 3.

When all the approach points are taught, [Used] will appear. The tool frame has been set.

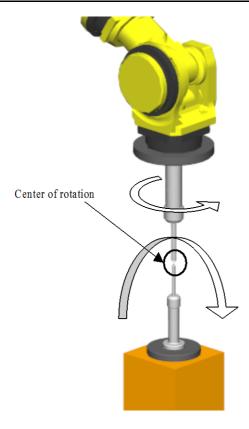
18 Press the [PREV] key.

The list screen for tool frames will appear.



19 Check that the TCP is set accurately. Press F5 [SETIND] and enter a frame number. The tool frame that has been set will be set as the currently enabled tool frame.

20 Operate the robot by jog operation to move its pointer tool close to the tip of the fixed pointer tool.



Check by moving the pointer tool close to the tip of the fixed pointer tool

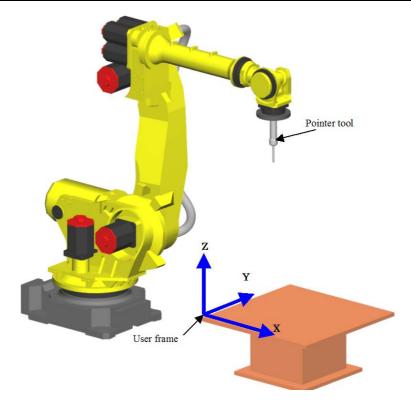
Operate the robot by jog operation around the tool frame, and change the orientation of the tool (w, p, r). If the TCP is accurate, the tip of the pointer tool will always point toward the tip of the fixed pointer tool.

1.1.1.2 Setting method types and procedures

To set a user frame, there are three methods that are "Three point method", "Four point method" and "Direct list method". For settings of the three point method and four point method, use the touch-up pointer set in "Know-How: 1.1.1.1 TCP set up". Moreover, the accuracy of user frame setting becomes better as the distance of each taught points is far. When setting the calibration grid frame, the distance of each taught point by using the "Four point method" becomes longer than when using the "Three point method". When setting the calibration grid frame, the "Four point method" is recommended. The "Three point method" and "Four point method" are explained as shown below.

Three point method

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



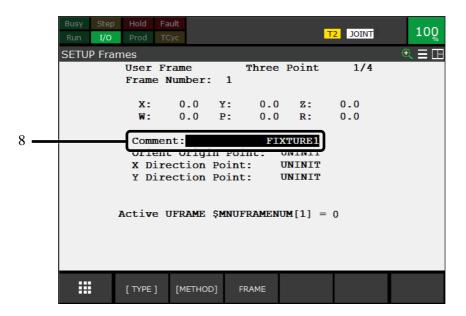
Example for setting a user frame that is parallel with a work table plane

- On the teach pendant, after selecting the [MENU] key \rightarrow [SETUP], place the cursor over [Frames] and press the [ENTER] key.
- 2 Press F3 [OTHER].
- Place the cursor over [User Frame] and press the [ENTER] key. The following list screen for user frames will appear.

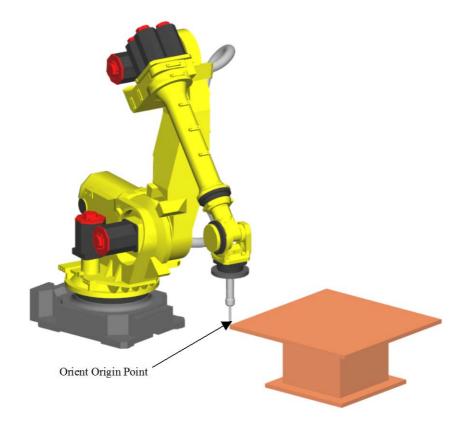


- 4 Place the cursor over the line of the user frame number to be set.
- 5 Press F2 [DETAIL].
 - The setup screen for the user frame for the selected frame number will appear.
- 6 Press F2 [METHOD].
- Place the cursor over [Three Point] and press the [ENTER] key.

 A screen for user frame setting using the three point teaching method will appear.

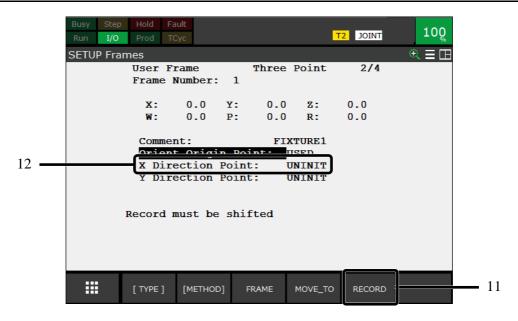


- 8 Enter a comment in the [Comment] field as required.
 A comment to distinguish this frame from other frames is recommended.
- 9 Place the cursor over the [Orient Origin Point].
- 10 Jog the robot and touch up the origin of the frame with the pointer tool pin.



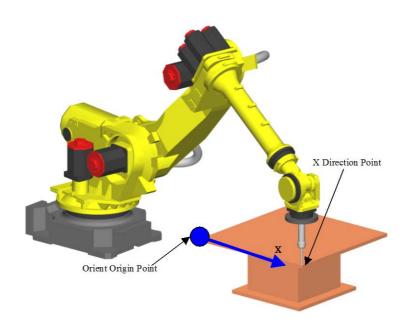
Touching up the system origin

While holding down the [SHIFT] key, press F5 [RECORD].
The current position data will be recorded as the orient origin of the frame.
[USED] will appear for the taught [Orient Origin Point].

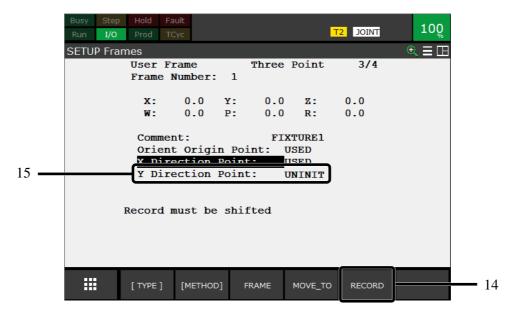


- 12 Place the cursor over the [X Direction Point].
- Jog the robot and touch up the X direction point with the pointer tool.

 A line drawn between the orient origin point and the touched up X direction point will be the X-axis of the frame.

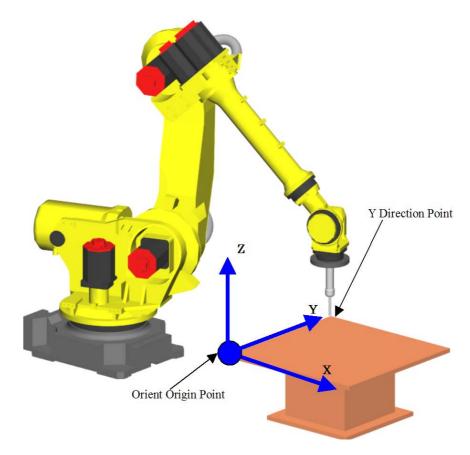


Touch-up of X direction point

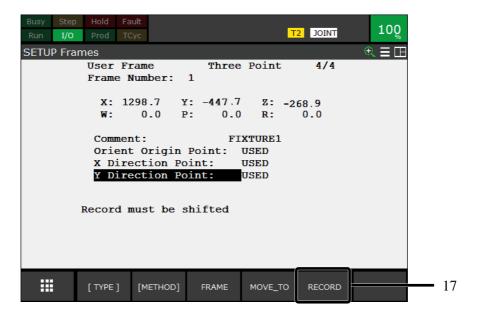


- While holding down the [SHIFT] key, press F5 [RECORD].
 The current position data will be recorded as the X direction point.
 [USED] will appear for the taught [X Direction Point].
- 15 Place the cursor over the [Y Direction Point].
- Jog the robot and touch up the Y direction point with the pointer tool.

 Touching up the Y-axis direction will determine the X and Y plane of the frame.



Touch-up of Y direction point

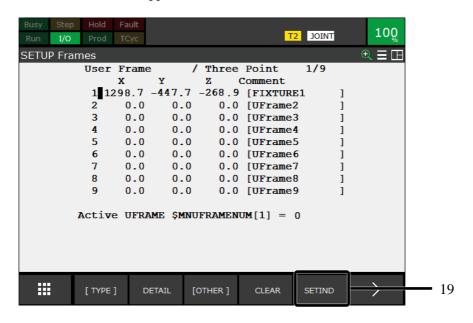


- While holding down the [SHIFT] key, press F5 [RECORD].

 The current position data will be recorded as the Y direction point.

 When all the touch-up points are taught, [Used] will appear. The user frame will be set.
- 18 Press the [PREV] key.

 The User Frame list screen will appear.

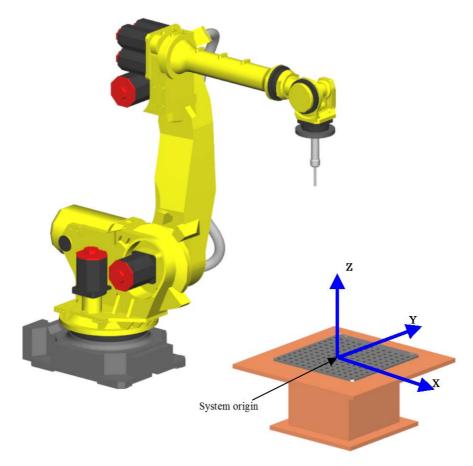


19 Press F5 [SETIND] and enter a frame number.

The user frame that has been set will be set as the currently enabled user frame.

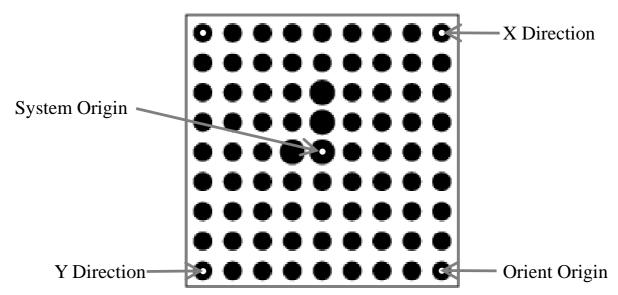
Four point method

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



Example of setting a user frame on a fixed calibration grid

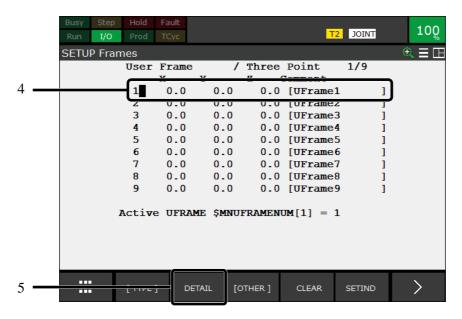
The following figure is a calibration grid. When perform the Grid Pattern Calibration for camera calibration, it is necessary to set up a user frame such as shown in the following figure. Since it is necessary to set a System origin on the center of a calibration grid, when the "Three point method" is used, the distance from the System Origin to the X Direction Point or the Y Direction Point is near. By using "Four point method", the accuracy of user frame setting becomes better.



Four point teaching method touch-up points for a calibration grid

On the teach pendant, after selecting the [MENU] key \rightarrow [SETUP], place the cursor over [Frames] and press the [ENTER] key.

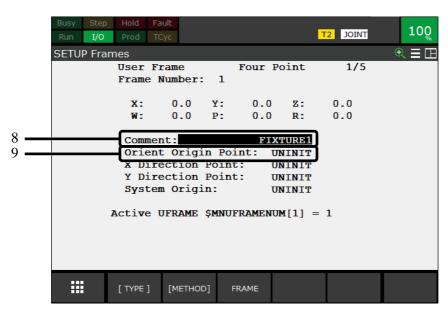
- 2 Press F3 [OTHER].
- 3 Place the cursor over [User Frame] and press the [ENTER] key. The list screen for user frames will appear.



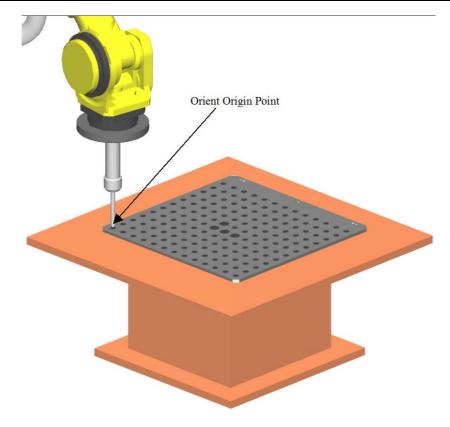
- 4 Place the cursor over the line of the user frame number to be set.
- 5 Press F2 [DETAIL].

 The setup screen for the user frame for the selected frame number will appear.
- 6 Press F2 [METHOD].
- Place the cursor over [Four Point] and press the [ENTER] key.

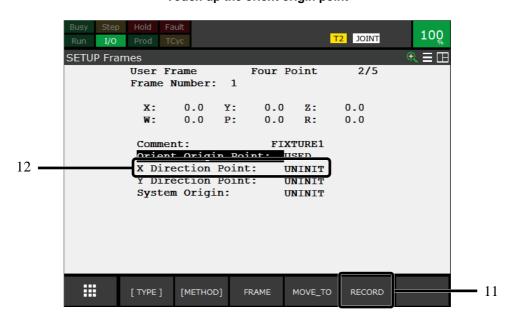
 A screen for user frame setting using the four point teaching method will appear.



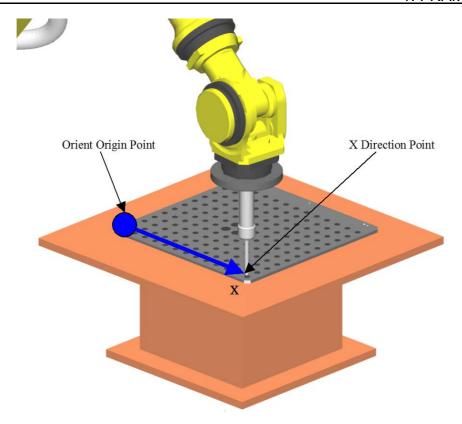
- 8 Enter a comment in the [Comment] field as required.
 A comment to distinguish this frame from other frames is recommended.
- 9 Place the cursor over [Orient Origin Point].
- 10 Jog the robot and touch up the X direction origin point with the pointer tool.



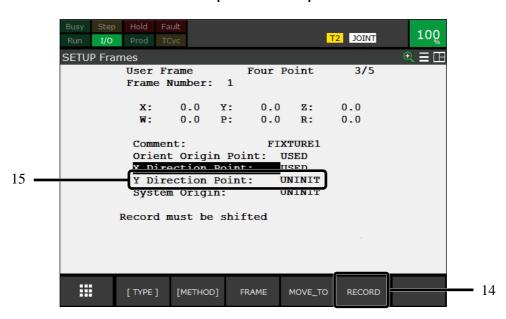
Touch up the orient origin point



- While holding down the [SHIFT] key, press F5 [RECORD].
 The current position data will be entered as the X-axis origin point.
 For the taught [Orient Origin Point], [Used] will appear.
- 12 Place the cursor over the [X Direction Point].
- Jog the robot and touch up the X direction point with the pointer tool.
 A line drawn between the orient origin point and the touched up X direction point will be the X-axis of the frame.

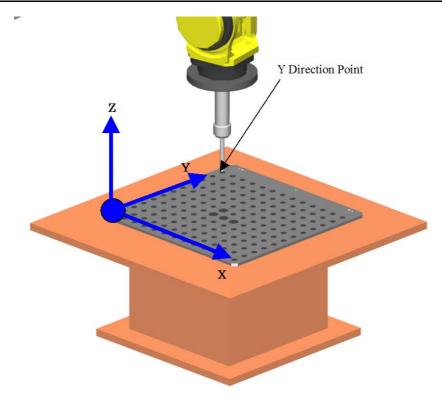


Touch-up of X direction point

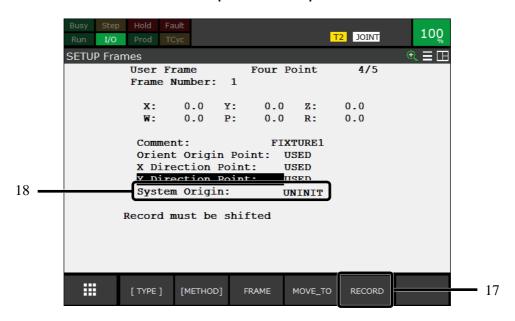


- While holding down the [SHIFT] key, press F5 [RECORD].
 The current position data will be recorded as the X direction point.
 [USED] will appear for the taught [X Direction Point].
- 15 Place the cursor over the [Y Direction Point].
- Jog the robot and touch up the Y direction point with the pointer tool.

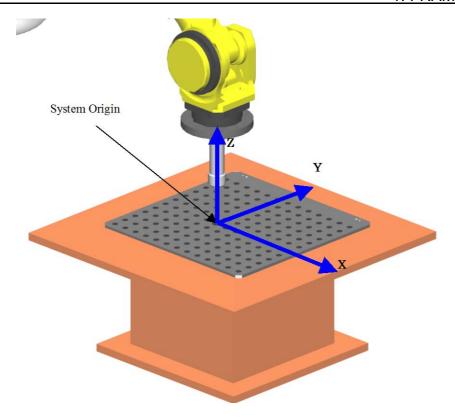
 Touching up the Y-axis direction will determine the X and Y plane of the frame.



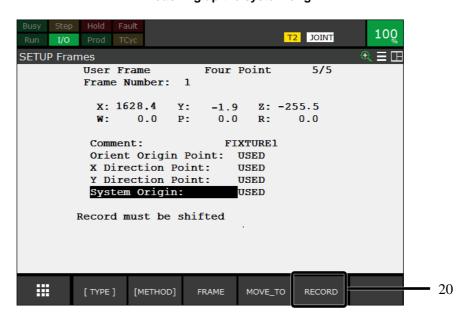
Touch-up of Y direction point



- While holding down the [SHIFT] key, press F5 [RECORD].
 The current position data will be recorded as the Y direction point.
 [USED] will appear for the taught [Y Direction Point].
- 18 Place the cursor over [Orient Origin Point].
- 19 Jog the robot and touch up the orient origin point of the frame with the pointer tool.



Touching up the system origin



- While holding down the [SHIFT] key, press F5 [RECORD].

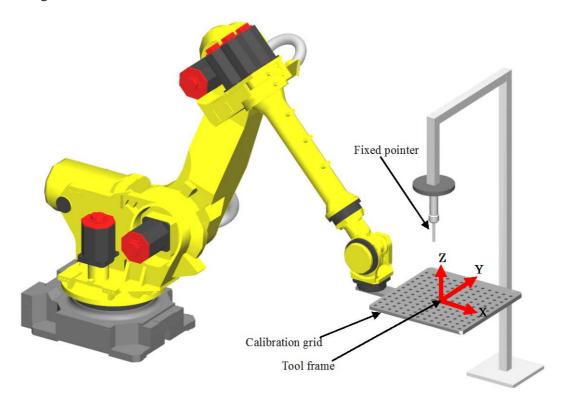
 The current position data will be recorded as the orient origin of the frame.

 When all the touch-up points are taught, [Used] will appear. The user frame will be set.
- 21 Press the [PREV] key.
 - The User Frame list screen will appear.
- Press F5 [SETIND] and enter a frame number.

 The user frame that has been set will be set as the currently enabled user frame.

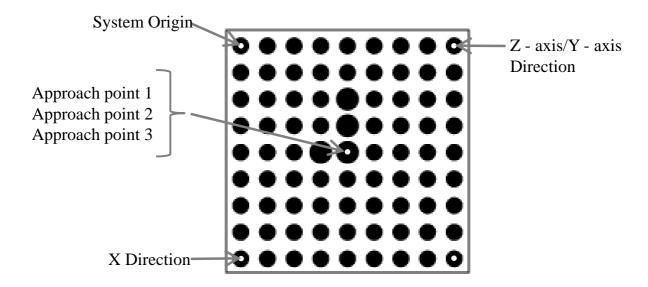
1.1.2 Tool Frame Setting

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



Example of tool frame setting with a pointer tool

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

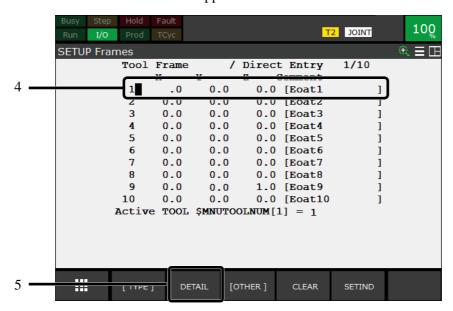


Six point teaching method touch-up points for a calibration grid

The tool frame set using the "Tool Frame Setup / Six Point(XZ)" method is rotated by 90 degrees about the X-axis with respect to a desired frame. Upon completion of setting the tool frame by touch-up operation, manually enter the value of W plus 90.

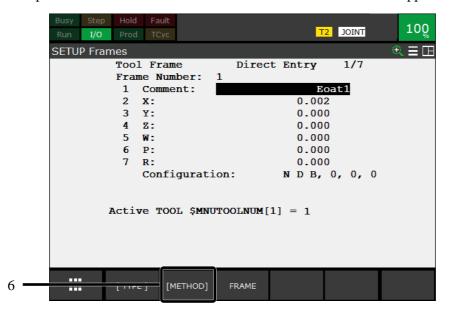
In the example of this subsection, "Tool Frame Setup / Six Point(XY)" is explained. Make sure that the calibration grid is fixed securely to the robot end of arm tooling so that it remains in place while the robot moves. It is recommended that positioning pins or other appropriate means may be used so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

- On the teach pendant, after selecting the [MENU] key \rightarrow [SETUP], place the cursor over [Frames] and press the [ENTER] key.
- 2 Press F3 [OTHER].
- 3 Place the cursor over [Tool Frame] and press the [ENTER] key. The list screen for tool frames will appear.

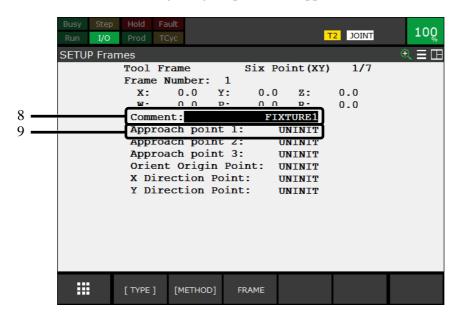


- 4 Place the cursor over the line of the tool frame number to be set.
- 5 Press F2 [DETAIL].

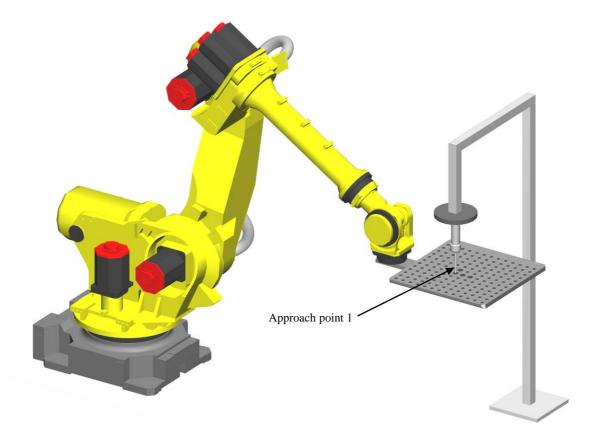
The setup screen for the tool frame for the selected frame number will appear.



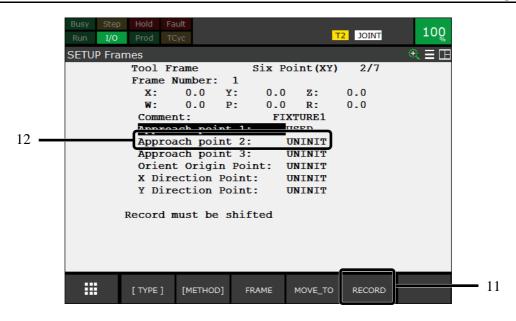
- 6 Press F2 [METHOD].
- Place the cursor over [Six Point (XY)] and press the [ENTER] key. A screen for tool frame setting using six points will appear.



- 8 Enter a comment in the [Comment] field as required.
 A comment to distinguish this frame from other frames is recommended.
- 9 Place the cursor over [Approach point 1].
- 10 Jog the robot and touch up the reference point 1 with the pointer tool.

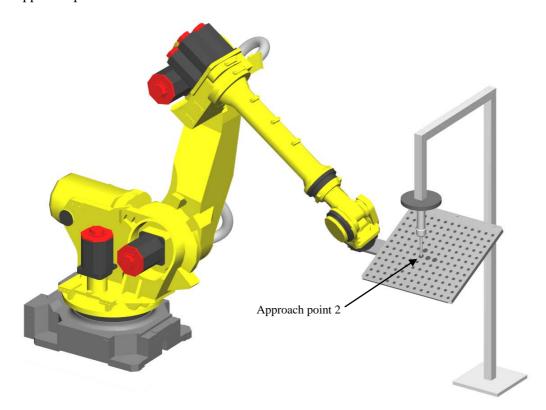


Touch-up of approach point 1

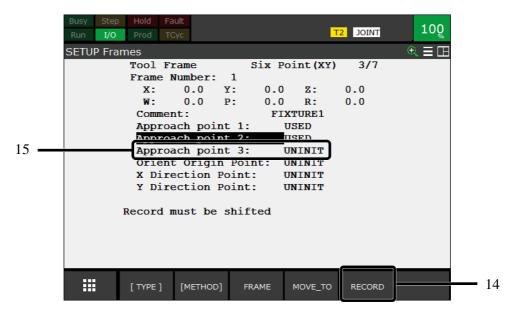


- While holding down the [SHIFT] key, press F5 [RECORD]. The current value's data will be input as approach point 1. For the taught [Approach point 1], [Used] will appear.
- 12 Place the cursor over [Approach point 2].
- Jog the robot and touch up the approach point 2 with the pointer tool.

 Touch up the same point as the approach point 1. However, change the robot attitude from that of the approach point 1.

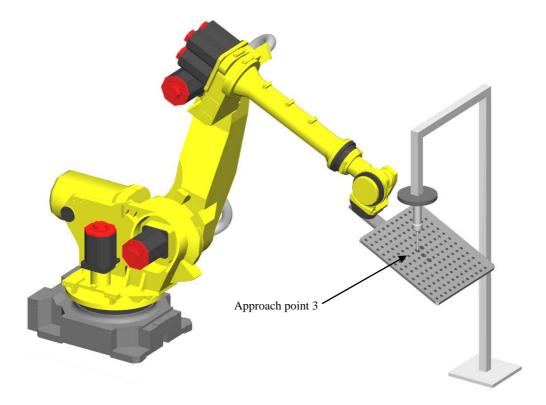


Touch-up of approach point 2

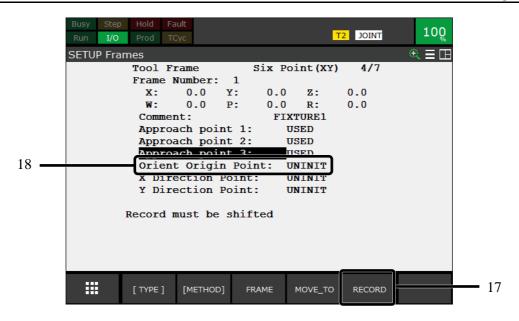


- While holding down the [SHIFT] key, press F5 [RECORD]. The current value's data will be input as approach point 2. As for the [Approach point 2], [USED] will appear.
- 15 Place the cursor over the [Approach point 3].
- Jog the robot and touch up the approach point 3 with the fixed pointer.

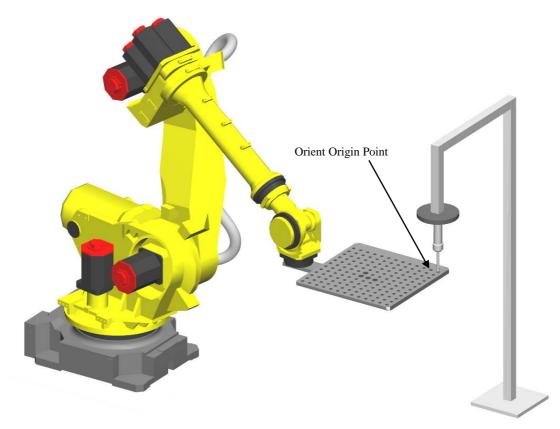
 Perform touch-up of the same point as for approach point 1 and approach point 2. However, make the orientation of the robot different from that for approach point 1 and approach point 2.



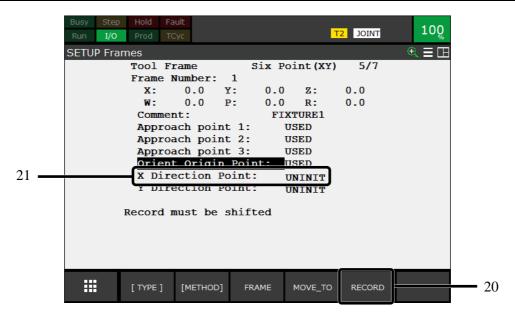
Touch-up of approach point 3



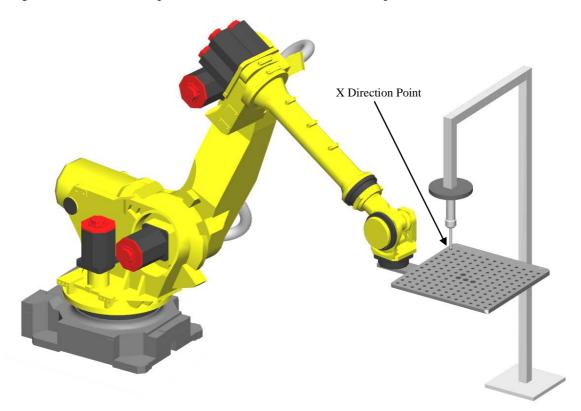
- While holding down the [SHIFT] key, press F5 [RECORD]. The current value's data will be input as approach point 3. As for the taught [Approach point 3], [USED] will appear.
- 18 Place the cursor over [Orient Origin Point].
- 19 Jog the robot and touch up the Orient Origin Point with the fixed pointer.



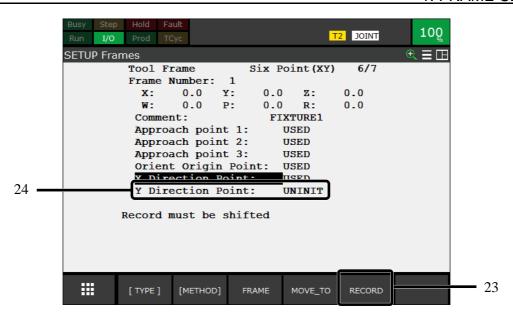
Touch-up of the point for the Orient Origin Point



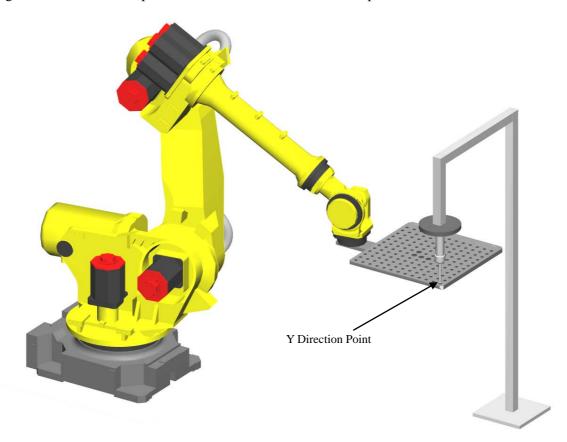
- While holding down the [SHIFT] key, press F5 [RECORD].
 The current position data will be recorded as the orient origin of the frame.
 [USED] will appear for the taught [Orient Origin Point].
- 21 Place the cursor over the [X Direction Point].
- 22 Jog the robot and touch up the X Direction Point with the fixed pointer.



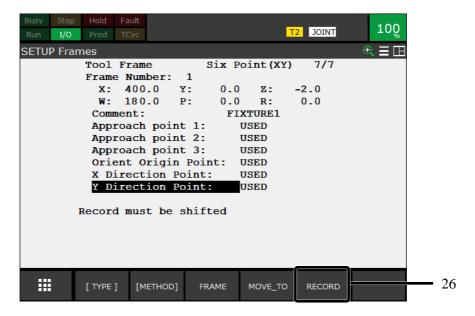
Touch-up of X direction point



- While holding down the [SHIFT] key, press F5 [RECORD].
 The current position data will be recorded as the X direction point.
 [USED] will appear for the taught [X Direction Point].
- 24 Place the cursor over the [Y Direction Point].
- 25 Jog the robot and touch up the Y Direction Point with the fixed pointer.



Touch-up of Y direction point

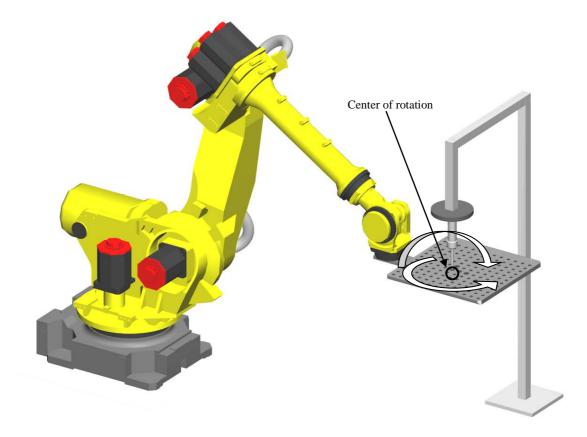


- While holding down the [SHIFT] key, press F5 [RECORD].

 The current position data will be recorded as the Y direction point.

 When all the touch-up points are taught, [Used] will appear. The tool frame has been set.
- 27 Press the [PREV] key.

 The list screen for tool frames will appear.
- 28 Check that the TCP is set accurately. Press F5 [SETIND] and enter a frame number. The tool frame that has been set will be set as the currently enabled tool frame.
- 29 Jog the robot to move the origin point of the calibration grid close to the tip of the fixed pointer tool.



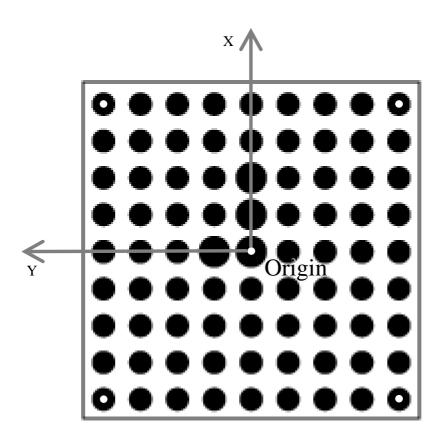
Check by moving the origin point of the calibration grid close to tip of fixed pointer tool

30 Operate the robot by jog operation around the tool frame, and change the orientation of the calibration grid (w, p, r). If the TCP is accurate, the tip of the pointer tool will always point toward the origin point of the calibration grid.

1.2 FRAME SETTING WITH GRID FRAME SETTING **FUNCTION**

Function overview

The calibration grid frame setting function sets the calibration grid frame using a camera. In the calibration grid frame setting function, the robot holding the camera or the robot holding the calibration grid automatically moves repeatedly to change the relative position between the camera and the calibration grid, and find the grid pattern. Finally, the position of the calibration grid frame relative to the robot base frame or the robot mechanical interface frame (the robot face place) is identified. When the calibration grid frame setting function is executed, a frame is set on the calibration grid, as shown in the following figure.



Example of frame using calibration grid

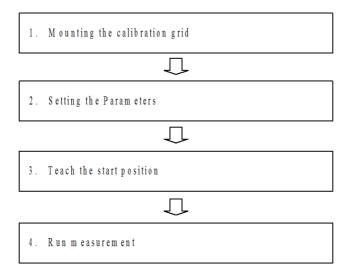
Compared with the manual touch-up setting method, the function offers a number of merits, including accurate setting of the frame without requiring user skills, no need for touch-up pointers or to set the TCP for touch-up setting, and semi-automatic easy-to-do operation.

↑ CAUTION

The calibration grid frame setting function is usable with 6-axis robots only. The function cannot be used with 4-axis robots and 5-axis robots.

1.2.1 Setting Procedure

Use the following setup procedure for the calibration grid frame setting function:

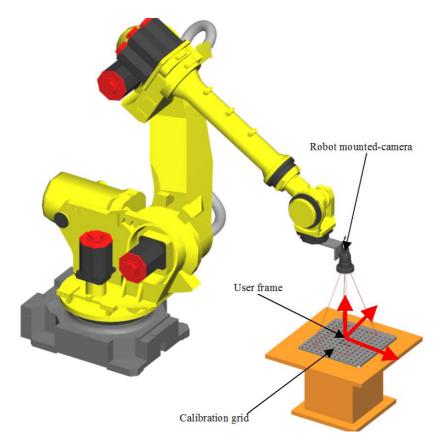


Setup flow

1.2.1.1 Mounting calibration grid

When the calibration grid is secured to a fixed surface

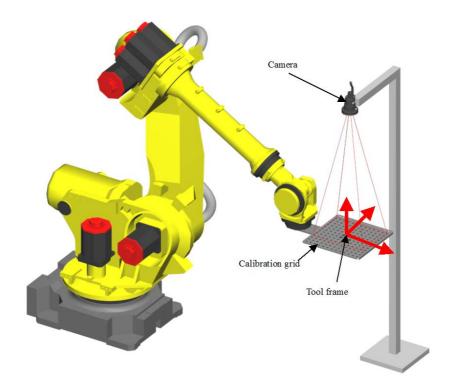
When the calibration grid is secured to fixed surface, a camera mounted on the robot end of arm tooling is used to measure the position of the calibration grid frame. The calibration grid frame setting function identifies the position of the calibration grid frame relative to the robot base frame (world), and sets the results in a user specified user frame. When use a robot-mounted camera, the calibration grid frame setting function can be performed with the camera currently used. When use a fixed camera, prepare another camera for the calibration grid frame setting function separately. Then, perform the calibration grid frame setting function using the camera attached to the arbitrary positions of the robot end of arm tooling.



Example of a fixed calibration grid

When the calibration grid is mounted on the robot

When the calibration grid is mounted on the robot, a fixed camera is used to measure the position of the calibration grid frame. The robot moves the calibration grid within the field of view of the fixed camera. The calibration grid frame setting function identifies the position of the calibration grid frame relative to the robot mechanical interface frame (the robot face plate), and the results is written in a user defined tool frame. The calibration grid frame setting function can be performed with the camera currently used. When there is not sufficient space to perform calibration grid frame setting function with the camera currently used, prepare another fixed camera and calibration grid frame setting function can be performed.



Example of a calibration grid attached to the robot hand

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



To prevent unnecessary circles from being found, check that the calibration grid is free of dirt and flaws. Spreading a plain sheet in the background is effective. Also, make sure to cover the printed text on the calibration grid.

1.2.1.2 Setting parameters

Setup the parameters on [iRVision Utilities] screen of the teach pendant.

On the teach pendant, after selecting the [MENU] key → [iRVision], place the cursor over [Vision Utilities] and press the [ENTER] key.

The [iRVision Utilities] screen will appear.



2 Place the cursor over [Automatic Grid Frame Set] and press the [ENTER] key. The [Grid Frame Set] screen will appear.



↑ CAUTION

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

The following items will appear on the [Grid Frame Set] screen.

[Robot Group Number to Use]

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

[Set UFrame or UTool?]

Select the frame to be set with the calibration grid frame setting function - user frame or tool frame. To set the tool frame with the calibration grid mounted on the robot, select F4 [UTOOL]. To set the user frame with the calibration grid secured to a table or other fixed surface, select F5 [UFRAME].

[User Frame Number to set]

Specify the number of the user frame to be set. The range of specifiable user frame numbers is 1 to 9. This will only appear if [UFRAME] is selected in [Set UFrame or UTool?].

[Tool Frame Number to set]

Specify the number of the tool frame to be set. The range of specifiable tool frame numbers is 1 to 10. This will only appear if [UTOOL] is selected for [Set UFrame or UTool?].

[Camera Name]

Select a camera to use in the measurement. Place the cursor over the line of [Camera Name], then press F4 [CHOICE], and a list of cameras will appear. By selecting from the list, specify the camera to use for the measurement.

[Exposure Time]

Specify the exposure time for the camera to capture an image (Shutter speed). The larger the value, the brighter the images that will be snapped.

Adjust the exposure time so that the black circles of the calibration grid are clearly visible.

[Start Position]

Teach the position where measurement is to be started. If the position has been taught already, [Recorded] will appear, and if it hasn't been, [Not Recorded] will appear.

In the case of [Not Recorded], measurement cannot be executed. Be sure you always teach the start position before measurement.

For the procedure to teach the start position, refer to "Know-how: 1.2.1.3, Teaching start position".

[Grid Spacing]

Set the grid spacing of the calibration grid in use.

[Setting Result]

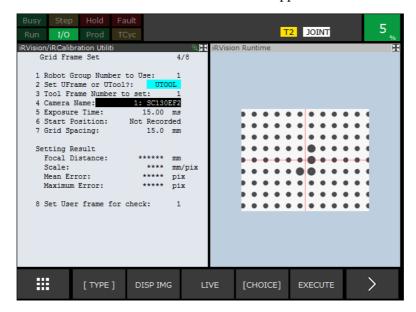
This item is displayed when measurement is complete.

[Set User frame for check]

This item can be set after measurement is complete. This item cannot be set until measurement is complete. For details, refer to "Setup: 7.1.4 Checking the Measurement Result" in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

F2 [DISP IMG]

The Grid Frame Set screen and Vision Runtime screen will appear as follows.



F3 [LIVE]

A live image for the selected camera will appear on the Vision Runtime screen. When a live image appears, it changes to F3 [STOPLIVE] and if F3 [STOPLIVE] is pressed, live image display will be stopped.

F4 [FIND]

Performs detection of a grid pattern. The detection result will be displayed on the Vision Runtime screen.

F7 [DEFAULT]

The set values will be changed to the initial values. [Camera Name] and [Start Position] will be returned to their initial values so that you can set them again.

F8 [LED TYPE]

The LED light setting screen will appear.

F9 [MOVE_LIM]

The move amount limit setting screen will appear.

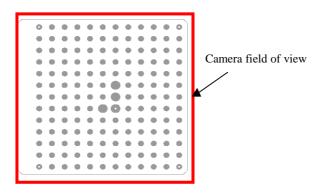
1.2.1.3 Teaching start position

Teach the start position using the following procedure.

- 1 If Vision Runtime does not appear, press F2 [DISP IMG].
- 2 Place the cursor over [Start Position].
- Jog the robot so that the camera's optical axis is approximately perpendicular to the plate surface of the calibration grid and that all of the four large black circles of the calibration grid are inside the camera's field of view. The distance between the calibration grid and the camera should be appropriate for the grid to come into focus, which is, under normal circumstances, roughly the same as the distance at which camera calibration is performed.

ℳMemo

For Automatic Grid Frame Set, measurement is performed by panning and rotating the camera attached to the robot's gripper or the calibration grid. It is recommended that you set the field of view to something quite large in relation to the calibration grid, so that the four large black circles will not be outside of the field of view.



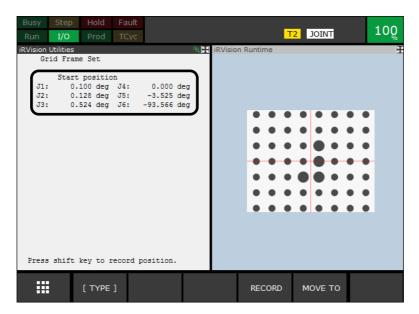
Camera field of view

While holding down the [SHIFT] key, press F4 [RECORD].

The start position will be recorded, and [Start Position] changes to [Recorded].

1. FRAME SETTING Know-How

5 To check the trained start position, press F3 [POSITION].
The value of each axis of the start position will appear, as shown below.



To return to the previous menu, press the [PREV] key.

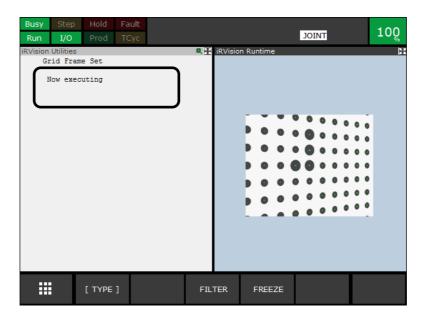
6 When moving the robot to the taught start position, press F5 [MOVE TO] while pressing the [SHIFT] key.

1.2.1.4 Running measurement

Perform measurement as follows, using the taught start position as a reference.

- 1 If Vision Runtime does not appear, press F2 [DISP IMG].
- 2 Check the parameter setup on the [Automatic Grid Frame Set] screen.
- 3 Check that the robot is at the start position.
- While holding down the [SHIFT] key, press F5 [EXECUTE].

 The robot will start the operation, and measurement will be executed. A message saying 'Now executing' will appear during the operation.

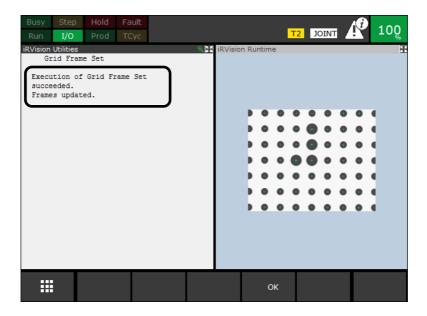


↑ CAUTION

1 The measurement will stop if you release the [SHIFT] key during measurement. In such cases, redo the measurement. The measurement can be resumed from where it was stopped.

- 2 The measurement will stop if you perform an operation that moves to another screen during measurement, such as pressing the [SELECT] key on the teach pendant. In such cases, open the [Automatic Grid Frame Set] screen and redo the measurement. The measurement can be resumed from where it was stopped.
- 3 Although the robot will perform the decided motion to some extent, depending on the settings, it is possible that it will move with an unexpected motion range. When executing measurement, check that the setup of parameters is correct, and be careful to lower the override so that the robot will not interfere with devices.
- 4 The robot may not be able to operate if other programs are in a paused state. In such cases, press the [FCTN] key and end the programs.

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



5 If you press F4 [OK], you will return to the Automatic Grid Frame Set screen.

Checking measurement result

The calibration grid frame will be set depending on the measurement. The set frame can be checked using the following procedure.

- Set the manual feed frame as the frame for automatic grid frame set.

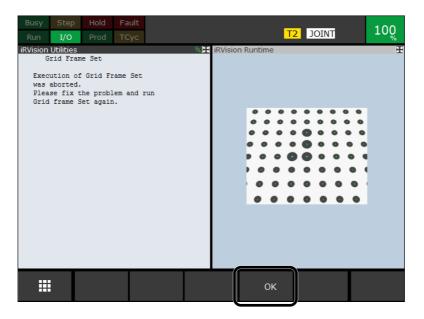
 For a tool frame, press the [COORD] key and switch to [Tool].

 For a user frame, press the [COORD] key to switch to [User], and specify the tool frame number that was specified in [Camera User Tool Number] in [Tool] under the jog menu, using the number keys.
- 2 Press F3 [LIVE] to start the display of a live image, and move the robot by jog operation around the WPR of the selected tool frame. There will be no problem unless the center position of the grid pattern is significantly far from the center line of the image.

1. FRAME SETTING Know-How

In the event of failure to measure

If measurement fails, the following message will appear.



If F4 [OK] is pressed, the screen will return to the original screen.

After changing the setup parameters, measurement can be redone by pressing F5 [EXECUTE] while holding down the [SHIFT] key.

2 3DL SENSOR DATA SETTING

This chapter explains the settings for 3DL sensor data.

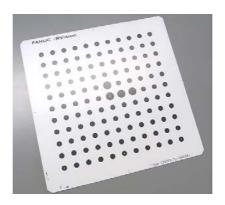
Create 3DL sensor data and perform camera setup and calibration. Camera calibration is the work of setting where the camera is installed as seen from the robot. Complete calibration before teaching a vision process. There are two types of calibration methods for camera used for the 3D Laser Vision Sensor. This chapter explains them using the following structure.

- "Know-How: 2.1 3DL CALIBRATION WITH ROBOT-MOUNTED CAMERA"
- "Know-How: 2.2 3DL CALIBRATION WITH FIXED CAMERA"

Unless otherwise specified, the screens and operations in the simple mode are shown in this chapter. For details of the simple mode and advanced mode, refer to the "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

2.1 3DL CALIBRATION WITH ROBOT-MOUNTED CAMERA

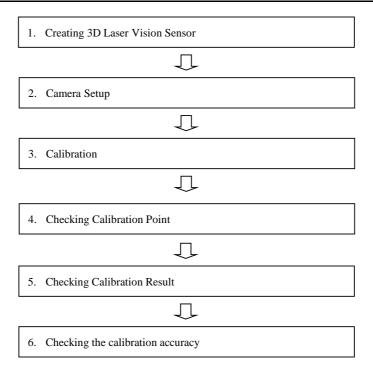
To use the 3D Laser Vision Sensor, 3DL calibration using a calibration grid is required. When using 3DL calibration, prepare a calibration grid in advance. Normally, use a calibration grid one-size larger than the size of field of view. Several sizes of standard calibration grids by FANUC are available. It is recommended that you order a calibration grid at the same time when ordering a camera and lens.



Calibration grid

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

Use the following setup procedure for 3DL calibration with a robot-mounted camera:



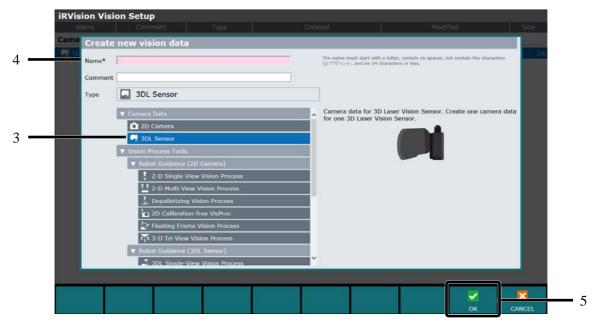
Setup flow of the 3DL calibration

2.1.1 Creating 3DL Sensor Data

To create new 3DL sensor data, perform the following steps:

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

 After setting the application frame and the user frame used for the installation information of the calibration grid, place the 3D Laser Vision Sensor at a distance of about 400 mm (when the standoff distance is 400 mm) from the calibration grid and set the orientation of the sensor visually so that the sensor and grid face each other.
- 2 Click [CREATE] on the vision data list screen. The pop-up to create new vision data appears.
- 3 Click the type of vision data you want to create. Select [3DL Sensor] in [Camera Data].



In [Name], enter the name of the vision data you are going to create.

The name can be up to 34 alphanumeric characters in length. The name must not contain spaces or symbols other than underscore, and must start with a letter.

In [Comment], enter any character string providing additional information about the vision data if necessary. The comment can be up to 50 one-byte or 25 two-byte characters. Entry is optional.

5 Click [OK].

New vision data will be created.

Clicking [CANCEL] will cancel creating a vision data.

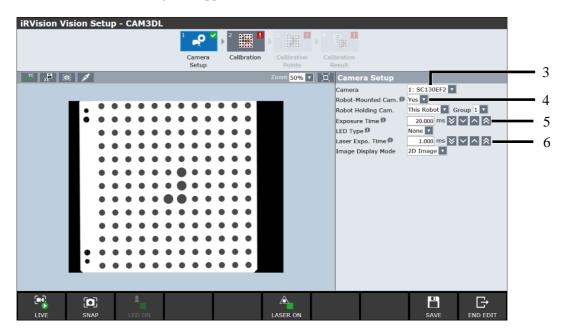
↑ CAUTION

The following names are not usable as the name of the vision data: CON, PRN, AUX, NUL, COM1, COM2, COM3, COM4, COM5, COM6, COM7, COM8, COM9, LPT1, LPT2, LPT3, LPT4, LPT5, LPT6, LPT7, LPT8, LPT9.

2.1.2 Camera Setup

Set the camera to be used for the 3DL Sensor Data that has been created.

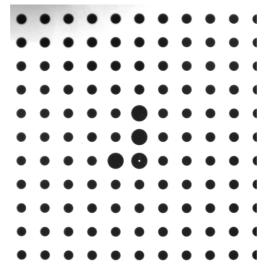
- On the vision data list screen, select the 3DL Sensor Data that has been created, and click [Edit]. The 3DL Sensor Data edit screen appears.
- 2 Click [1 Camera Setup] in the navigation area. A screen like the following will appear.



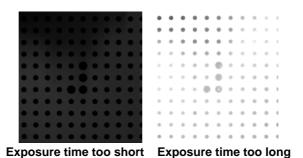
3 Select [Camera] from the drop-down box.

When a camera to be used is selected, the camera automatically snaps an image, and the image appears in the image view area.

- 4 Select the camera mounting method from the drop-down box.
 - If a camera has been attached to the robot end of arm tooling, select [Yes] for [Robot-Mounted Cam.].
- 5 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, an image snapped with the changed exposure time appears.



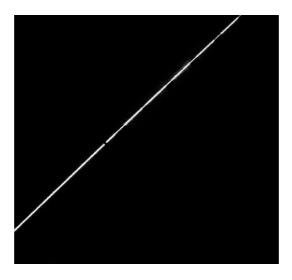
Example of an image with appropriate exposure time



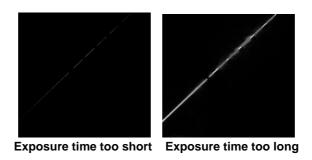
Examples of images with inappropriate exposure time

6 Set [Laser Expo. Time] to be applied for laser measurement.

Adjust [Laser Expo. Time] so that the laser slits can be seen clearly in the same way as the exposure time used for 2D measurement is adjusted. When [Laser Expo. Time] is changed, an image is automatically snapped with a new exposure time, and a laser slit image appears in the image view area. The following figures of 'Examples of images with inappropriate exposure time' shows that the laser slit faints with too short exposure time and blurs with too long exposure time.



Example of an image with appropriate exposure time

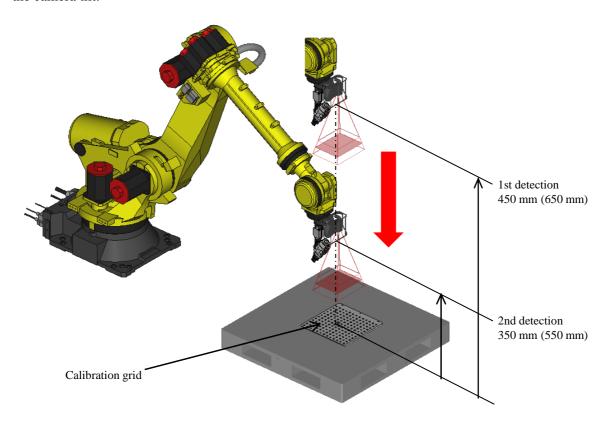


Examples of images with inappropriate exposure time

2.1.3 Calibration

When using a robot-mounted camera, 2-plane calibration is performed by moving the robot 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 600 mm).

The detection accuracy is increased when the robot's posture to detect the calibration grid is the same as the posture to detect a workpiece. When moving the camera up and down, jog the robot without changing the camera tilt.



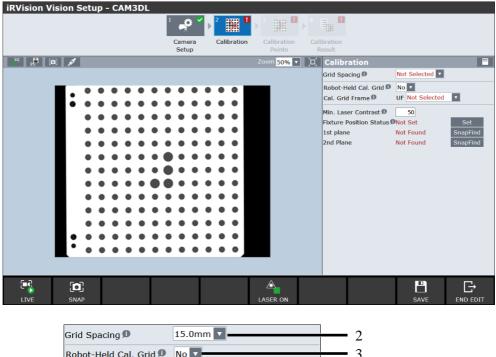
Example of two-plane calibration when installing the 3D Laser Vision Sensor on the robot end of arm tooling

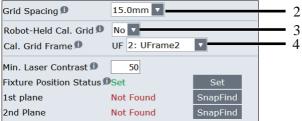
After one set of calibration tool is created with 3DL vision calibration, another set of calibration tool does not need to be created even after the camera Measurement Position is changed. This is because *i*RVision uses the current robot position when calculating the position of the workpiece.

Calibration setting procedure

The calibration setting for when a 3D Laser Vision Sensor is attached to the robot end of arm tooling is as follows.

1 Select [2 Calibration] in the navigation area. The 3DL calibration setting screen appears.





ℳMemo

In the following cases, enable the advanced mode before setting the application frame although you usually do not have to change the mode because you can use the world frame of the robot to be offset as the calibration standard.

- In the case the camera is mounted on a robot other than the robot to be offset.
- In the case the calibration grid is attached to a robot other than the robot to be offset. For details of the application frame, refer to "Setup: 2.1.2/3.1.2/4.1.2/5.1.2 Setting Application Frame".
- 2 From the [Grid Spacing] drop-down box, select the grid spacing for the calibration grid.
- From the [Robot-Held Cal. Grid] drop-down box, select [No].
- 4 From the [Cal. Grid Frame] drop-down box, select the number of the user frame in which the calibration grid installation information was recorded.

 Specify the user frame number set in "Setup: 2.1.3/3.1.3/4.1.3/5.1.3 Setting Calibration Grid Frame".

∕Memo

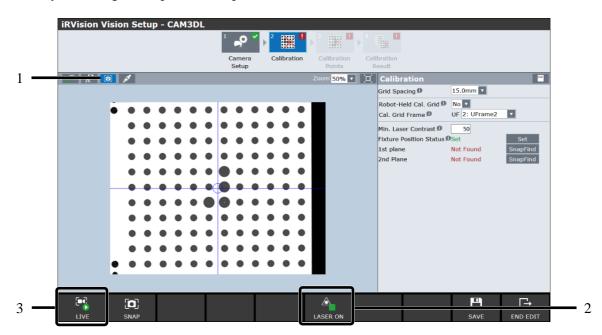
Note that the frame for calibration grid installation information is different from [Application Frame] and [Offset Frame].

⚠ CAUTION

Detection parameters ([Min. Laser Contrast], [Min. Num Laser Points] and [Max. Line Fit Error]) for laser points should be adjusted only when correct detection cannot be made just by adjusting the exposure time. ([Min. Laser Points] and [Max. Line Fit Error] are displayed when you enable the advanced mode.) Note that calibration may not complete appropriately if the laser points are detected forcibly by changing the parameter values carelessly.

Moving robot to appropriate position

When the setting of 3DL calibration described so far is completed, move the robot to an appropriate position by following the steps below to perform calibration.



Click the button.

A vertical line and a horizontal line appear in the image view area to indicate 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.

- Click [LASER ON].
 - The laser is irradiated on the actual calibration grid.
- 3 Click [LIVE].

The live image of the selected camera appears in the image view area.

The laser does not appear in the image view area. When adjusting the robot position, check the calibration grid where the laser actually hits.

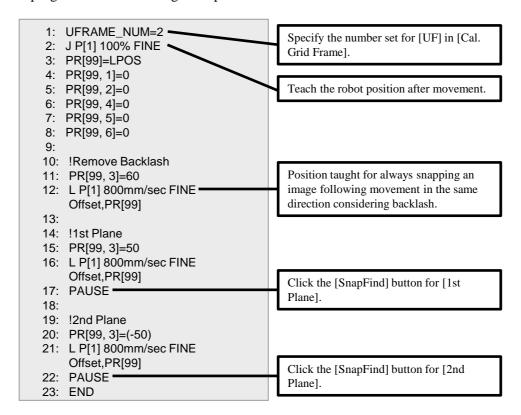
Jog the robot so that the laser beam intersection and the center of the calibration grid come almost at the center of the image view area.

The bottom surface of camera of the 3D Laser Vision Sensor faces the calibration grid almost straight with the distance of about 400 mm (when the standoff distance is 400 mm). Next, jog the robot in the XY direction of the calibration grid so that the center of the calibration grid comes almost at the center of the image view area. 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.

Performing 3DL calibration

1 Teach the robot program the position where the laser beam intersection and the center of the calibration grid come almost at the center of the image view area.

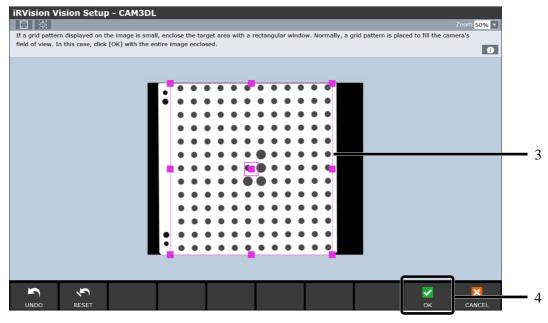
Create a program as the following example.



Program example

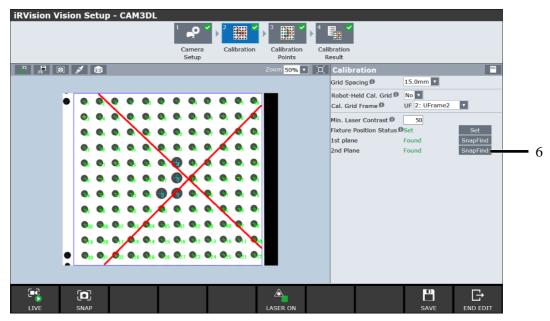
Specify the 'user frame' number set for [Cal. Grid Frame]. Jog the robot to teach the position for P[1] in the condition that the laser beam intersection and the center of the calibration grid come almost at the center of the image view area. In the above sample robot program, the 'Set new ID?' message appears on the teach pendant, select F5 [NO]. The calibration grid is actually detected at the position where the taught position is offset, so carefully operate the robot end of arm tooling and camera not to cause them to interfere with the peripheral equipment and workpiece.

- 2 Execute the robot program, and keep the 3D Laser Vision Sensor away from the calibration grid with appropriate distance (approx. 450 mm for the 3D Laser Vision Sensor with a standoff of 400 mm, and approx. 650 mm for the 3D Laser Vision Sensor with a standoff of 600 mm), and then click the [SnapFind] button of [1st Plane].
 - Execute the robot program for calibration. After pausing at the first measurement position, click the [SnapFind] button of [1st Plane] to detect the first calibration plane.



- Teach the search window to enclose only the perfect circles on the calibration grid. When the area outside the calibration grid is included in the search range, a grid detection error may occur. Therefore, teach the search window to enclose only the calibration grid. Also, if the grid pattern is not fit in the camera FOV, do not allow imperfect circles present around the circumference of the camera FOV to be included within the search range.
- 4 Click [OK].
 - Check that all circles are detected and that the laser slits are detected clearly in the image view area. If the detection is successful, [1st Plane] shows [Found].
- 5 Restart the program, and change the distance between the 3D Laser Vision Sensor and the calibration grid.
 - The program is paused at the second measurement position (approx. 350 mm for the 3D Laser Vision Sensor with a standoff of 400 mm, and approx. 550 mm for the 3D Laser Vision Sensor with a standoff of 600 mm).
- 6 Click [SNAP+FIND] button for [2nd Plane], and teach the search window.

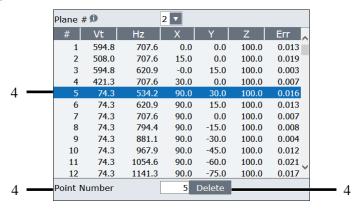
 Detect the second calibration plane. Check that all circles are detected and that the laser slits are detected clearly in the image view area. If the detection is successful, [2nd Plane] shows [Found].



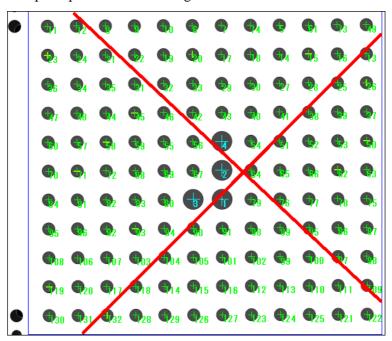
When [Fixture Position Status] shows [Set], and both [1st Plane] and [2nd Plane] show [Found], the 3DL calibration is completed.

2.1.4 Checking Calibration Point

Check the calibration point found in "Know-How: 2.1.3 Calibration".



- 1 Click [3 Calibration Points] in the navigation area.
 - The screen display changes, and the laser slit detection image appears in the image view area, and the detection point list appears in the setting item area.
- 2 Check the detection point positions in the image view area.



Example of an image showing appropriate detection points

The results of 1st Plane and 2nd Plane can be switched by switching the plane numbers. Check in the image view area that there is no detection point at a position other than the circle positions on the calibration grid and that all the circles in the search window are correctly detected. Also check that the detected laser slits are clearly shown within the search window.

- 3 Check the detection point details in the detection point list.
 When checking the detection points, pay particular attention to [Err] of each detection point.
 Normally, when circles on the calibration grid are detected with high accuracy, the maximum error is 1 pixel or less.
- 4 Delete invalid detection points.

 If there is a detection point at a position other than the circle positions on the calibration grid, select

the invalid detection point in the detection point list, or enter its detection point number in the [Point Number] text box, and click the [Delete] button.

2.1.5 Checking Calibration Result

Check the calculated calibration data.

Essel Dist			12.00						
Focal Dista									
Standoff Di	stand	æ 🞾	491.5		mm				
Lens Distor	0	-0.00000							
Max Lens D	istor	tion 🗩	0.0		pix				
Scale 🗩			0.217		mm/pix				
Mean error	value	e D	0.016		pix				
Maximum e	error	value 🛭	0.048		pix				
Position of Camera Relative to Cal. Grid 🕮									
X 1	14.4	Υ	11.8	Z	491.5				
W	-0.0	P	-0.0	R	0.0				
Laser1 Plane Relative to Calibration Grid									
Px 3	32.9	Ру	0.0	Pz	z 0.0				
Vx 0.	706	Vy	0.699	Vz	z 0.113				
Laser2 Plane Relative to Calibration Grid									
Px	-3.8	Ру	0.0	Pz	z 0.0				
Vx -0.	705	Vy	0.699	Vz	z 0.113				
Position of	Position of Cal. Grid Relative to App. UFrame								
X 200	0.00	Υ	0.0	Z	-510.0				
W	0.0	Р	0.0	R	0.0				
Position of Robot Holding Camera 🛭									
					43.5				
W -18	30.0	Р	-0.0	R	-0.0				
Camera Frame Relative to Robot 🕕									
X 13	30.0				512.1				
W 18	30.0	P	0.0	R	-0.0				
Laser Frame Relative to Robot 🛭									
X 13	30.1	Υ	-58.0	Z	512.1				
W -17	70.8	Р	0.0	R	0.0				

- 1 Click [4 Calibration Result] in the navigation area.
 The screen display changes, and the calibration data details appear.
- 2 Check the calibration data details.
 - If the calculated value in [Focal Distance] is approximately \pm 5% from the focal distance of the lens used, the value is considered to be permissible.
 - [Standoff Distance] is a distance along the optical axis from the center of length direction of the lens to the top surface of the grid pattern. Check the value is appropriate, and matches the actual standoff.
 - [Scale] depends on the field of view at the time of calibration and the space between grids on the calibration grid. When calibration is performed for a 3D Laser Vision Sensor equipped with an 8 mm lens of analog camera (or a 12 mm lens of digital camera), the value between 0.35 and 0.45 mm/pixel is normally obtained if the 1st Plane is about 450 mm away from the sensor and the 2nd Plane is about 350 mm away from the sensor. When calibration of a 3D Laser Vision Sensor equipped with a 12 mm lens of analog camera (or a 16 mm lens of digital camera) is performed in the same conditions, the value between 0.25 and 0.30 mm/pixel is obtained.

ℳMemo

For the digital camera, lenses with focal distances of 12 mm and 16 mm are provided. The field-of-view ranges of the 12 mm lens and 16 mm lens of the digital camera are equivalent to those of the 8 mm lens and 12 mm lens of the analog camera respectively.

• [Image Center] indicates the center of the image calculated by calibration. The center of the screen is around the position (240, 256), and if the calculated value is in the range approximately ± 10 % of this value, it is considered to be permissible.

If the value is not appropriate, check the calibration procedure, and perform calibration again.

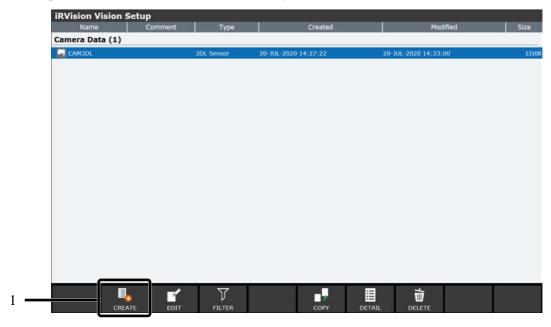
3 Click [SAVE] to save the setting, and then click [END EDIT] to close the edit screen of the 3DL Sensor Data.

2.1.6 Checking Calibration Accuracy

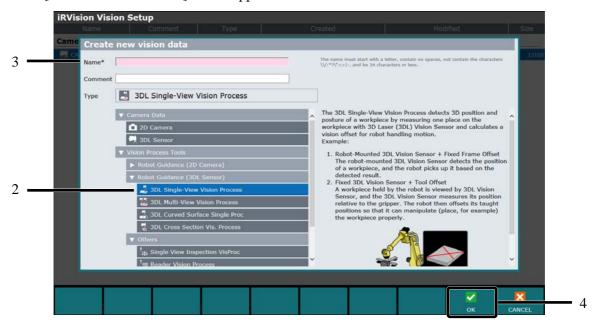
Change the robot position and posture, repeat measurements of the vision process, and check whether the calibration of the 3DL Sensor Data is correctly performed.

2.1.6.1 Creating vision process

Create a vision process to check the calibration accuracy.



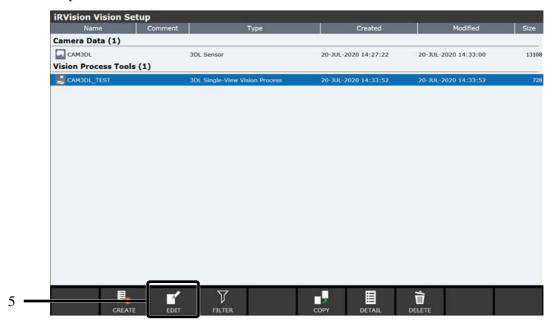
1 Click [CREATE] on the vision data list screen. The [Create new vision data] screen appears.



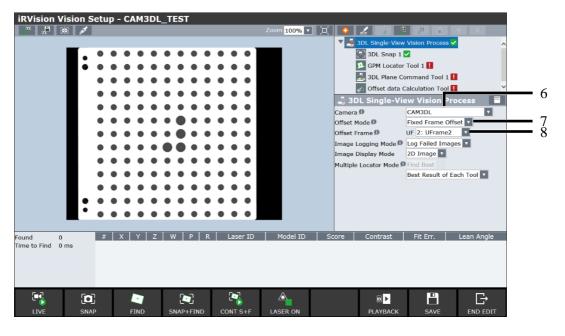
2 Select [3DL Single-View Vision Process].

- 3 Enter a name of vision process in [Name]. Assign a unique name to the vision process.
- 4 Click [OK].

A new vision process is created.



5 Select the created vision process and click [Edit]. The vision process setup screen appears.

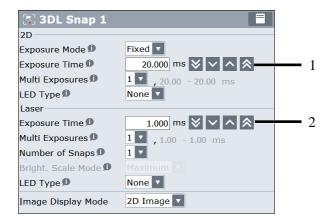


- 6 Select the 3DL Sensor Data from the [Camera] drop-down box. Select the name of the taught 3DL Sensor Data.
- 7 Select [Fixed Frame Offset] from the [Offset Mode] drop-down box.
- 8 Select the user frame number from the [Offset Frame] drop-down box.

 An offset frame is a user frame used for calculation of the offset data. To check the accuracy, in this step, select the user frame number selected for [Cal. Grid Frame] in "Know-How: 2.1.3 Calibration".

2.1.6.2 Teaching 3DL Snap Tool

Select [3DL Snap] in the tree view, and then set each item.

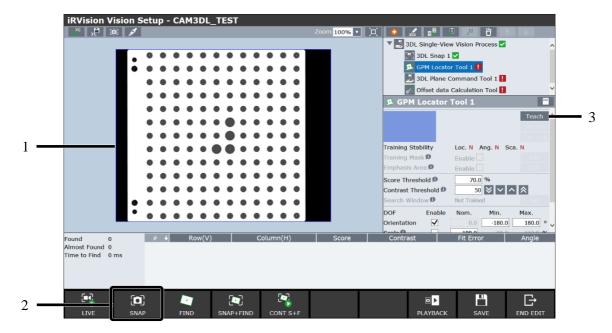


- Input [Exposure Time] for [2D].
 Set the same exposure time as the one used when the calibration of the 3D Laser Vision Sensor was performed.
- Input [Exposure Time] for [Laser].

 Set the same exposure time as the one used when the calibration of the 3D Laser Vision Sensor was performed. In the same way as in calibration, check that an image with appropriate exposure time is snapped in the image view area.

2.1.6.3 Teaching GPM Locator Tool

Select [GPM Locator Tool] in the tree view, and then set each item.



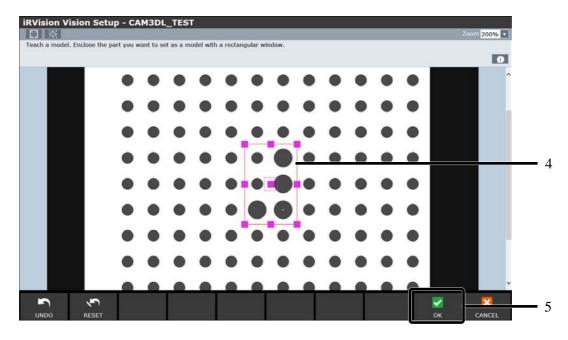
1 Jog the robot to the measurement area.

Jog the robot to the position taught in the robot program created for calibration. In the same way as in calibration, check that the laser beam intersection and the center of the calibration grid come almost at the center of the image view area.

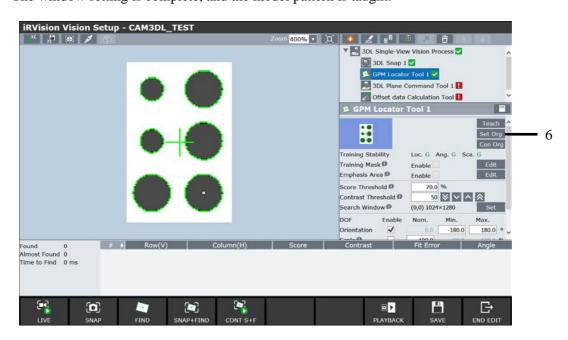
2 Click [SNAP].

After determining the measurement position, click [SNAP] to capture an image.

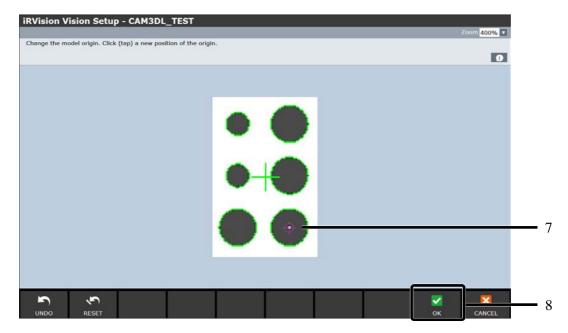
3 Click the [Teach] button.
The model setup screen for the GPM Locator Tool appears.



- 4 Enclose the large circles of the calibration grid.
 While operating the control points of the rectangle window on the screen, change the area so that the four large circles of the calibration grid are enclosed.
- 5 Click [OK].
 The window setting is complete, and the model pattern is taught.



6 Click [Set Org].
The model origin setup screen appears.

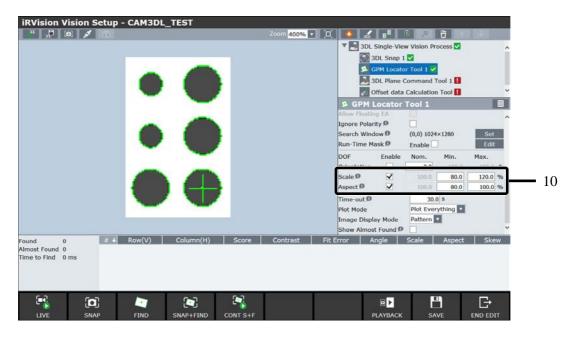


7 Move the origin.

Move the model origin target to the center of the calibration grid. The model origin can be set more correctly by enlarging the screen using the [Zoom] drop-down box.

8 Click [OK].

A new model origin is set.

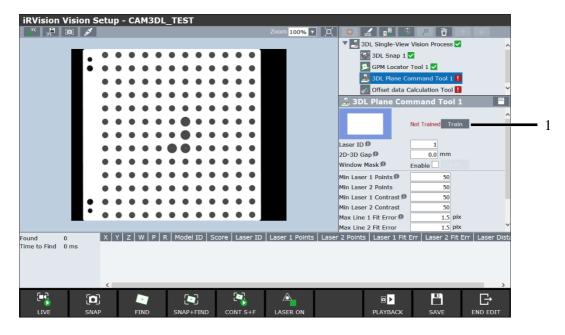


- 9 Click to enable the advanced mode.
- 10 Set [Scale] and [Aspect] in [DOF].

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

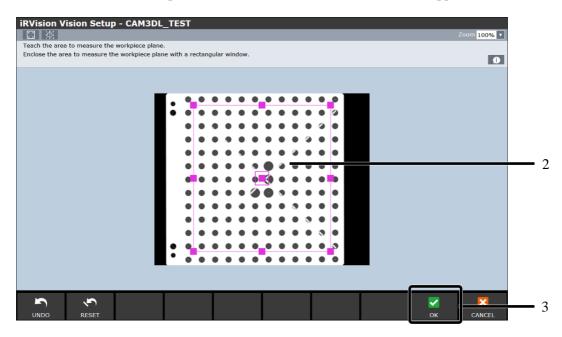
2.1.6.4 Teaching 3DL Plane Command Tool

Select [3DL Plane Command Tool] in the tree view, and then set each item.



1 Click the [Train] button.

The measurement area setup screen for 3DL Plane Command Tool will appear.



2 Enclose the grids on the calibration grid.

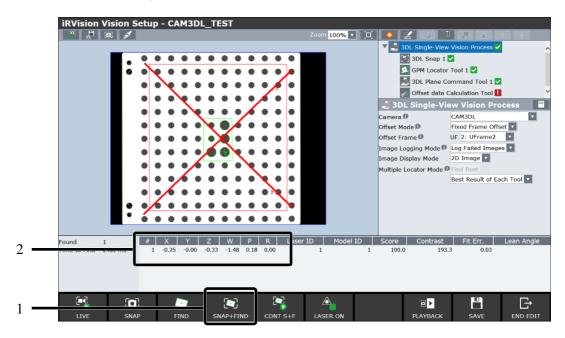
While operating the control points of the rectangle window on the screen, change the measurement area so that only the calibration grid is enclosed.

3 Click [OK].

The window setting is complete, and the measurement area is taught.

2.1.6.5 Running a test

Select [3DL Single-View Vision Process] in the tree view, and then execute the test of the vision process to check the calibration accuracy.



1 Click [SNAP+FIND].

The image is snapped and detected. When the detection is successful, the measurement results appear in the result display area.

2 Take a note of measurement results.

Write down the values for 'X, Y, Z, W, P and R' that appear in the result display area.



3 Move the robot position.

Jog the robot to change the robot position and posture as far as the calibration grid is seen within the field of view of the camera. Click [LIVE], and a live image appears in the image view area.

- 4 Click [SNAP+FIND].
 - The image is snapped and detected. When the detection is successful, the measurement results appear in the result display area.
- 5 Compare the measurement results.
 - Compare the results with the measurement results written down in step 2, and check that they almost match. Also check the values for 'X, Y and Z' are close to '0'.
- 6 Change the robot position and posture, and repeat measurements.
 - Repeat the sequence of operations from steps 3 to 5. If differences in results comprehensively resulted from 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, and 1 degree or less for the W, P and R elements, it can be determined that the calibration has been performed normally. If the differences in results are large, check the calibration procedure, and perform the calibration again.

2.1.7 Automatic Re-Calibration

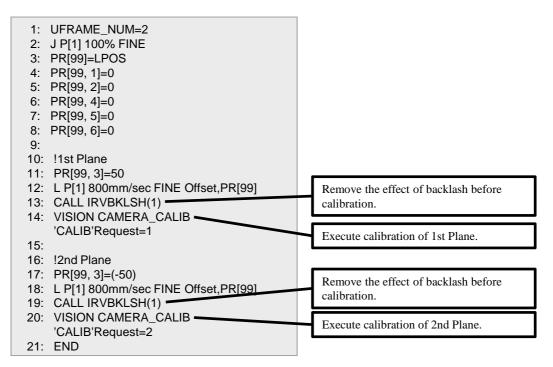
The workpiece cannot be measured correctly if the mounting position or direction of the 3D Laser Vision Sensor relative to the robot is displaced, or the relative positions of the laser unit and camera unit of the 3D Laser Vision Sensor are displaced because the 3D Laser Vision Sensor has accidentally hit the peripheral equipment. In such cases, the line can be recovered by automatic re-calibration without performing teaching again.

To perform automatic re-calibration, the robot program for executing automatic re-calibration needs to be added beforehand to the robot program for calibration created in "Know-How: 2.1.3 Calibration".

If the 3D Laser Vision Sensor is used as a robot-mounted camera, and the calibration grid is installed in a fixed installation, securely fix the calibration grid to the location where the calibration was performed first, and do not move it.

The sample robot program is shown as below.

If the program is executed with the calibration grid fixed, the 2-plane calibration is automatically performed.



Program example

By using the automatic re-calibration, there are following merits.

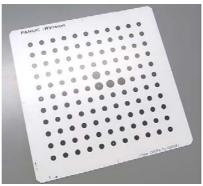
- Since this can be performed from the robot program, the system can be recovered without manual operation, e.g., when replacing the camera.

 Since the system can be recovered more quickly than performing the normal 3DL calibration, operation error by the operator, etc. can be avoided.
- Since the robot's touch-up of the calibration grid is unnecessary, accuracy errors by touch-up operation can be avoided. In many cases, the reason for teaching correction required in normal re-calibration is accuracy errors resulted from touch-up operation. Because of this, for applications requiring strict accuracy, it is desired to use automatic re-calibration.

In almost cases, e.g., 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.

2.2 3DL CALIBRATION WITH FIXED CAMERA

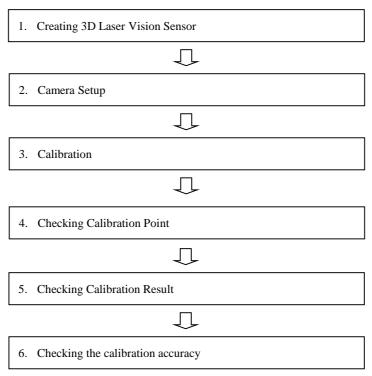
To use the 3D Laser Vision Sensor, 3DL calibration using a calibration grid is required. When using 3DL calibration, prepare a calibration grid in advance. Normally, use a calibration grid one-size larger than the size of field of view. Several sizes of standard calibration grids by FANUC are available. It is recommended that you order a calibration grid at the same time when ordering a camera and lens.



Calibration grid

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

Set up the 3DL calibration (fixed camera) with the following procedure.



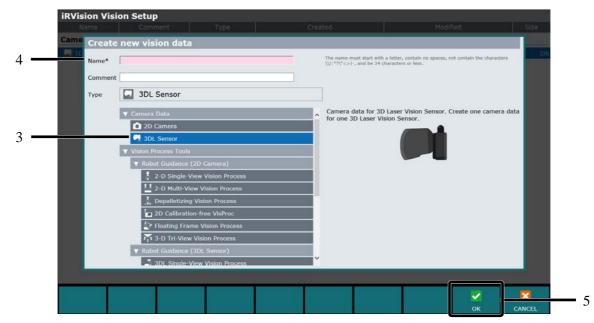
Setup flow of the 3DL calibration

For a robot system with multiple 3D Laser Vision Sensors, create the 3DL Sensor Data for each 3D Laser Vision Sensor, and perform calibration.

2.2.1 Creating 3DL Sensor Data

To create new 3DL sensor data, perform the following steps:

- Place the calibration grid so that it faces the 3D Laser Vision Sensor.
 - After setting the application frame and the user frame used for the installation information of the calibration grid, place the calibration grid at a distance of about 400 mm (when the standoff distance is 400 mm) from the 3D Laser Vision Sensor, and set the orientation of the sensor visually so that the sensor and grid face each other.
- 2 Click [CREATE] on the vision data list screen.
 - The pop-up to create new vision data appears.
- 3 Click the type of vision data you want to create. Select [3DL Sensor] in [Camera Data].



- In [Name], enter the name of the vision data you are going to create.
 - The name can be up to 34 alphanumeric characters in length. The name must not contain spaces or symbols other than underscore, and must start with a letter.
 - In [Comment], enter any character string providing additional information about the vision data if necessary. The comment can be up to 50 one-byte or 25 two-byte characters. Entry is optional.
- 5 Click [OK].
 - New vision data will be created.
 - Clicking [CANCEL] will cancel creating a vision data.

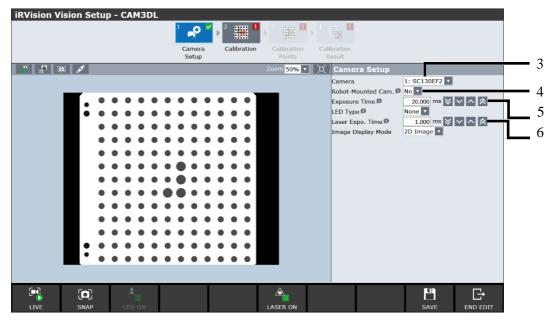
⚠ CAUTION

The following names are not usable as the name of the vision data: CON, PRN, AUX, NUL, COM1, COM2, COM3, COM4, COM5, COM6, COM7, COM8, COM9, LPT1, LPT2, LPT3, LPT4, LPT5, LPT6, LPT7, LPT8, LPT9.

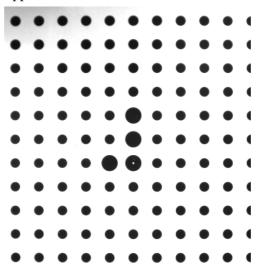
2.2.2 Camera Setup

Set the camera to be used for the 3DL Sensor Data that has been created.

- On the vision data list screen, select the 3DL Sensor Data that has been created, and click [Edit]. The 3DL Sensor Data edit screen appears.
- 2 Click [1 Camera Setup] in the navigation area. A screen like the following will appear.



- 3 Select [Camera] from the drop-down box.
 - When a camera to be used is selected, the camera automatically snaps an image, and the image appears in the image view area.
- 4 Select the camera mounting method from the drop-down box. For a fixed camera, select [No] for [Robot-Mounted Cam.].
- 5 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, an image snapped with the changed exposure time appears.



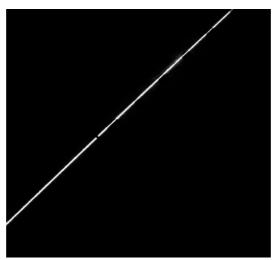
Example of an image with appropriate exposure time



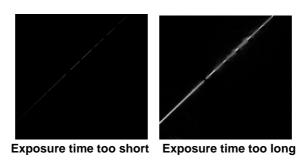
Exposure time too short Exposure time too long Examples of images with inappropriate exposure time

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

Adjust [Laser Expo. Time] so that the laser slits can be seen clearly in the same way as the exposure time used for 2D measurement is adjusted. When [Laser Expo. Time] is changed, an image is automatically snapped with a new exposure time, and a laser slit image appears in the image view area. The following figures of 'Examples of images with inappropriate exposure time' shows that the laser slit faints with too short exposure time and blurs with too long exposure time.



Example of an image with appropriate exposure time

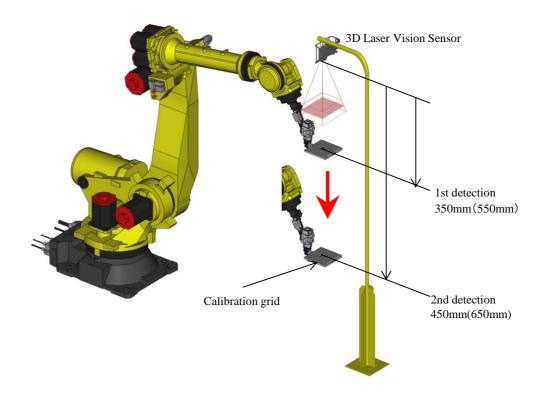


Examples of images with inappropriate exposure time

2.2.3 Calibration

For a fixed 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 350 mm and 450 mm (near 550 mm and 650 mm if the standoff of the 3D laser sensor is 600 mm).

The detection accuracy is increased when the robot's posture to detect the calibration grid is the same as the posture to detect a workpiece.



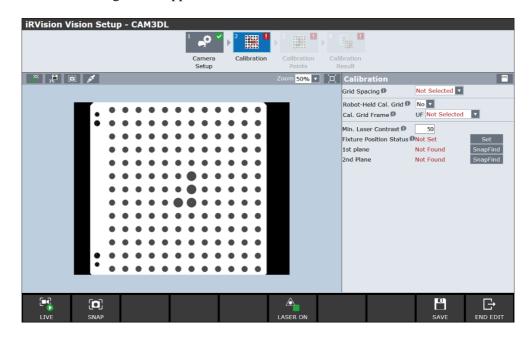
Example of calibration using two planes when installing a calibration grid on the robot's gripper

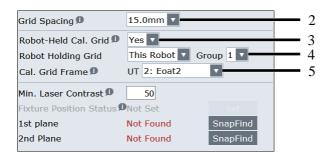
When moving the calibration grid up and down, jog the robot without changing the calibration grid posture. Make sure that the calibration grid is fixed securely to the robot end of arm tooling so that it remains in place while the robot moves. It is recommended that positioning pins or other appropriate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

Calibration setting procedure

Calibration setting for when installing the calibration grid on the robot's gripper is as follows.

1 Select [2 Calibration] in the navigation area. The 3DL calibration setting screen appears.





ℳMemo

In the following cases, enable the advanced mode before setting the application frame although you usually do not have to change the mode because you can use the world frame of the robot to be offset as the calibration standard.

- In the case the camera is mounted on a robot other than the robot to be offset.
- In the case the calibration grid is attached to a robot other than the robot to be offset. For details of the application frame, refer to "Setup: 2.1.2/3.1.2/4.1.2/5.1.2 Setting Application Frame".
- 2 From the [Grid Spacing] drop-down box, select the grid spacing for the calibration grid.
- 3 From the [Robot-Held Cal. Grid] drop-down box, select [Yes].
- From the [Robot Holding Grid] drop-down box, select the name of the robot controller for the robot with the calibration grid attached to it and the motion group number.
- From the [Cal. Grid Frame] drop-down box, select the number of the tool frame in which the calibration grid installation information was recorded.

 In the tool frame, set the information for where the calibration grid is installed. Specify the tool frame number set in "Setup: 2.2.2/3.2.2/4.2.2/5.2.2 Setting Calibration Grid Frame".

∕Memo

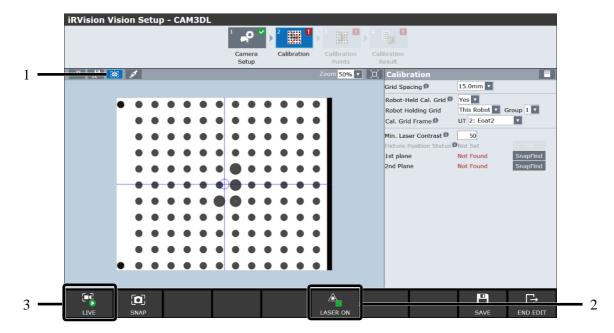
Note that the frame for [Cal. Grid Frame] is different from the [Application Frame] or the [Offset Frame] setting.

↑ CAUTION

Detection parameters ([Min. Laser Contrast], [Min. Num Laser Points] and [Max. Line Fit Error]) for laser points should be adjusted only when correct detection cannot be made just by adjusting the exposure time. ([Min. Laser Points] and [Max. Line Fit Error] are displayed when you enable the advanced mode.) Note that calibration may not complete appropriately if the laser points are detected forcibly by changing the parameter values carelessly.

Moving robot to appropriate position

When the setting of 3DL calibration described so far is completed, move the robot to an appropriate position by following the steps below to perform calibration.



1 Click the 🔯 button.

A vertical line and a horizontal line appear in the image view area to indicate 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.

- 2 Click [LASER ON].
 - The laser is irradiated on the actual calibration grid.
- 3 Click [LIVE].

The live image of the selected camera appears in the image view area.

ℳMemo

The laser does not appear in the image view area. When adjusting the robot position, check the calibration grid where the laser actually hits.

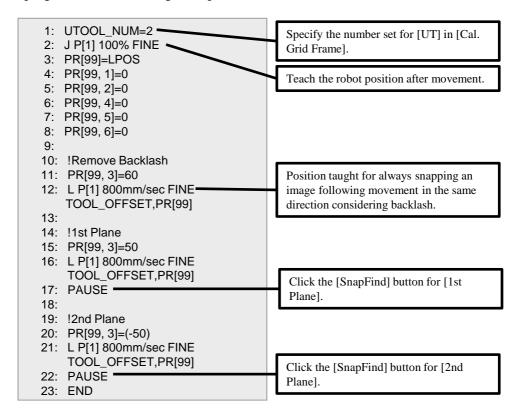
4 Jog the robot so that the laser beam intersection and the center of the calibration grid come almost at the center of the image view area.

The bottom surface of camera of the 3D Laser Vision Sensor faces the calibration grid almost straight with the distance of about 400 mm (when the standoff distance is 400 mm). Next, jog the robot in the XY direction of the calibration grid so that the center of the calibration grid comes almost at the center of the image view area. 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.

Performing 3DL calibration

1 Teach the robot program the position where the laser beam intersection and the center of the calibration grid come almost at the center of the image view area.

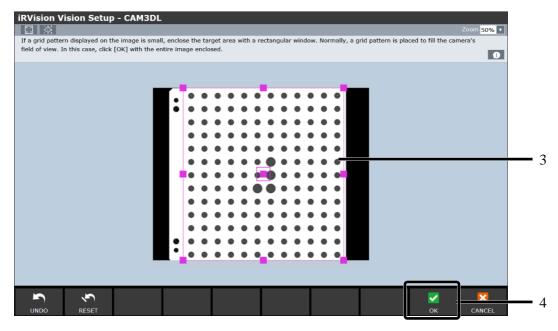
Create a program as the following example.



Program example

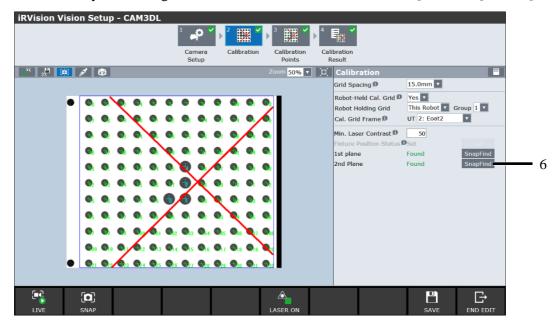
Specify the 'tool frame' number set for [Cal. Grid Frame]. Jog the robot to teach the position for P[1] in the condition that the laser beam intersection and the center of the calibration grid come almost at the center of the image view area. In the above sample robot program, the 'Set new ID?' message appears on the teach pendant, select F5 [NO]. The calibration grid is actually detected at the position where the taught position is offset, so carefully operate the robot end of arm tooling and camera not to cause them to interfere with the peripheral equipment and workpiece.

- 2 Execute the robot program, and keep the calibration grid away from the 3D Laser Vision Sensor with appropriate distance (approximately 350 mm for the 3D Laser Vision Sensor with a standoff of 400 mm, and approximately 550 mm for the 3D Laser Vision Sensor with a standoff of 600 mm), and then click the [SnapFind] button of [1st Plane].
 - Execute the robot program for calibration. After pausing at the first measurement position, click the [SnapFind] button of [1st Plane] to detect the first calibration plane.



- Teach the search window to enclose only the perfect circles on the calibration grid. When the area outside the calibration grid is included in the search range, a grid detection error may occur. Therefore, teach the search window to enclose only the calibration grid. Also, if the grid pattern is not fit in the camera FOV, do not allow imperfect circles present around the circumference of the camera FOV to be included within the search range.
- 4 Click [OK].
 Check that all circles are detected and that the laser slits are detected clearly in the image view area.
 If the detection is successful, [1st Plane] shows [Found].
- Restart the program, and change the distance between the 3D Laser Vision Sensor and the calibration grid.
 - The program is paused at the second measurement position (approx. 450 mm for the 3D Laser Vision Sensor with a standoff of 400 mm, and approx. 650 mm for the 3D Laser Vision Sensor with a standoff of 600 mm).
- 6 Click [SNAP+FIND] button for [2nd Plane], and teach the search window.

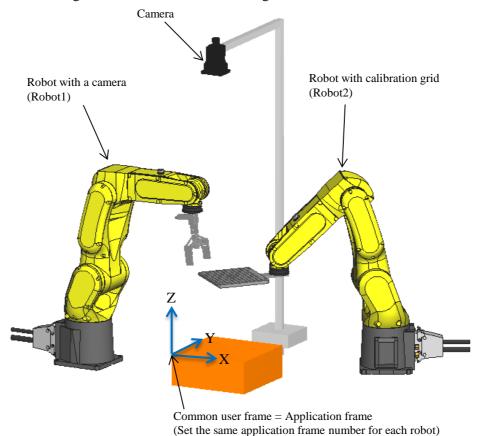
 Detect the second calibration plane. Check that all circles are detected and that the laser slits are detected clearly in the image view area. If the detection is successful, [2nd Plane] shows [Found].



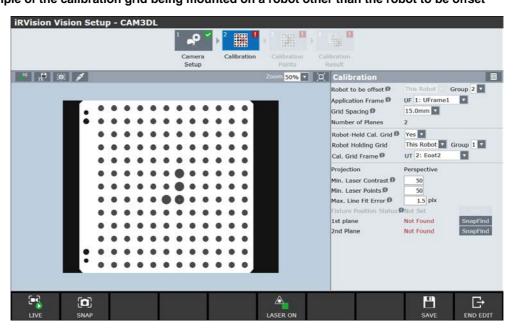
When [Fixture Position Status] shows [Set], and both [1st Plane] and [2nd Plane] show [Found], the 3DL calibration is completed.

When two or more robots are used

If the robot that has a camera attached to it and the robot that has a calibration grid attached to it are different as shown in the figure below, for the [Robot Holding Grid], select the robot controller for the robot with the calibration grid attached to it on the teaching screen for calibration.



Example of the calibration grid being mounted on a robot other than the robot to be offset



- Enable the advanced mode and select a frame for the robot that will be the reference for calibration from the [Application Frame] drop-down box. Specify the same user frame number for the two robots.
- From the [Robot Holding Grid] drop-down box, select the name of the robot controller for the robot with the calibration grid attached to it, and the motion group number.

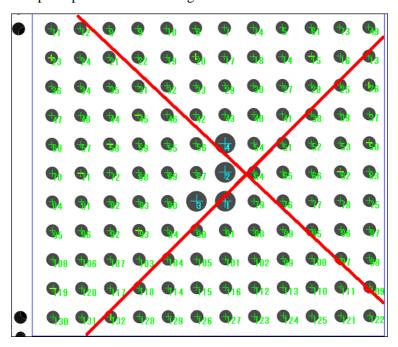
2.2.4 Checking Calibration Point

Check the calibration point found in "Know-How: 2.2.3 Calibration".

	Plane # ወ			2 🔽				
	#	Vt	Hz	Х	Υ	Z	Err	
	1	581.3	686.1	0.0	0.0	-100.0	0.019	
	2	511.4	686.1	15.0	0.0	-100.0	0.017	
	3	581.3	616.2	0.0	15.0	-100.0	0.013	
	4	441.5	686.1	30.0	0.0	-100.0	0.011	
1 —	5	92.1	546.4	105.0	30.0	-100.0	0.024	
	6	92.1	616.2	105.0	15.0	-100.0	0.014	
	7	92.2	686.1	105.0	0.0	-100.0	0.034	
	8	92.2	756.0	105.0	-15.0	-100.0	0.011	
	9	92.2	825.8	105.0	-30.0	-100.0	0.011	
	10	92.1	895.7	105.0	-45.0	-100.0	0.011	
	11	92.2	965.6	105.0	-60.0	-100.0	0.003	
	12	92.2	1035.5	105.0	-75.0	-100.0	0.032	
_	Point N	lumber		5	Delete			

- 1 Click [3 Calibration Points] in the navigation area.

 The screen display changes, and the laser slit detection image appears in the image view area, and the detection point list appears in the setting item area.
- 2 Check the detection point positions in the image view area.



Example of an image showing appropriate detection points

The results of 1st Plane and 2nd Plane can be switched by switching the plane numbers. Check in the image view area that there is no detection point at a position other than the circle positions on the calibration grid and that all the circles in the search window are correctly detected. Also check that the detected laser slits are clearly shown within the search window.

Check the detection point details in the detection point list.

When checking the detection points, pay particular attention to [Err] of each detection point.

Normally, when circles on the calibration grid are detected with high accuracy, the maximum error is 1 pixel or less.

4 Delete invalid detection points.

If there is a detection point at a position other than the circle positions on the calibration grid, select the invalid detection point in the detection point list, or enter its detection point number in the [Point Number] text box, and click the [Delete] button.

2.2.5 Checking Calibration Result

Check the calculated calibration data.

Focal D	istance¶		12.00	m	ım			
Standof	f Distan	ce 🗩	386.0	m	ım			
Lens Di	stortion	D	-0.000	00				
Max Lei	0.0	р	ix					
Scale 🗩)		0.170	m	m/pix			
Mean e	0.013	р	ix					
Maximum error value 🗩 0.040 pix								
Position of Camera Relative to Cal. Grid								
X	15.0	Υ	10.0	Z	386.0			
W	-0.0	P	-0.0	R	0.0			
Laser1 Plane Relative to Calibration Grid								
Px	12.0	Ру	0.0	Pz	0.0			
Vx	0.705	Vy	0.691	Vz	0.154			
Laser2 Plane Relative to Calibration Grid								
Px	17.9	Ру	0.0	Pz	0.0			
Vx	-0.705	Vy	0.691	Vz	0.154			
Position of Cal. Grid Relative to App. UFrame								
X	1985.0	Υ	-10.0	Z	432.0			
W	0.0	P	-0.0	R	-0.0			

1 Click [4 Calibration Result] in the navigation area.

The screen display changes, and the calibration data details appear.

- 2 Check the calibration data details.
 - If the calculated value in [Focal Distance] is approximately \pm 5% from the focal distance of the lens used, the value is considered to be permissible.
 - [Standoff Distance] is a distance along the optical axis from the center of length direction of the lens to the top surface of the grid pattern. Check the value is appropriate, and matches the actual standoff.
 - [Scale] depends on the field of view at the time of calibration and the space between grids on the calibration grid. When calibration is performed for a 3D Laser Vision Sensor equipped with an 8 mm lens of analog camera (or a 12 mm lens of digital camera), the value between 0.35 and 0.45 mm/pixel is normally obtained if the 1st Plane is about 450 mm away from the sensor and the 2nd Plane is about 350 mm away from the sensor. When calibration is performed for a 3D Laser Vision Sensor equipped with a 12 mm lens of analog camera (or a 16 mm lens of digital camera) in the same conditions, a value between 0.25 and 0.30 mm/pixel is obtained.

ℳMemo

For the digital camera, lenses with focal distances of 12 mm and 16 mm are provided. The field-of-view ranges of the 12 mm lens and 16 mm lens of the digital camera are equivalent to those of the 8 mm lens and 12 mm lens of the analog camera respectively.

• [Image Center] indicates the center of the image calculated by calibration. The center of the screen is around the position (240, 256), and if the calculated value is in the range approximately ± 10 % of this value, it is considered to be permissible.

If the value is not appropriate, check the calibration procedure, and perform calibration again.

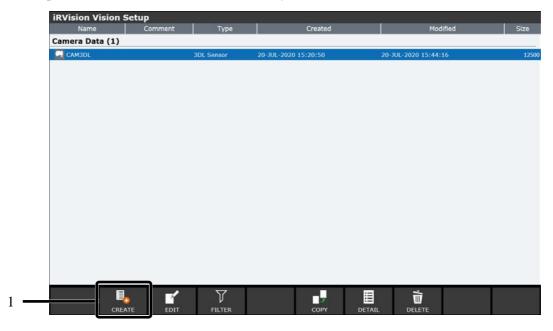
3 Click [SAVE] to save the setting, and then click [END EDIT] to close the edit screen of the 3DL Sensor Data.

2.2.6 Checking Calibration Accuracy

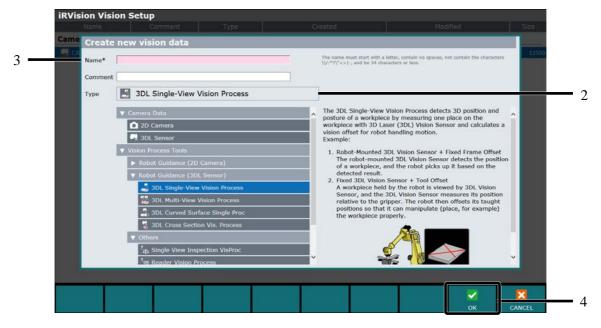
Change the robot position and posture, repeat measurements of the vision process, and check whether the calibration of the 3DL Sensor Data is correctly performed.

2.2.6.1 Creating vision process

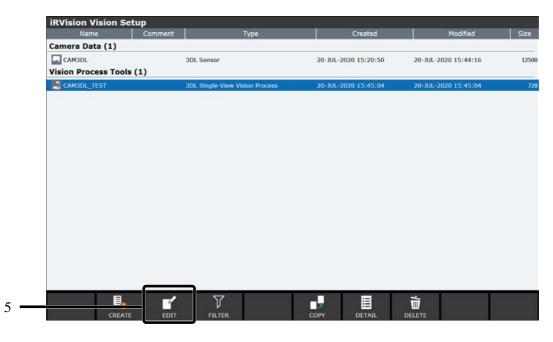
Create a vision process to check the calibration accuracy.



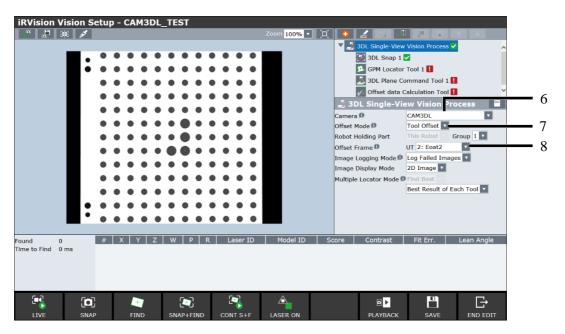
1 Click [CREATE] on the vision data list screen. The [Create new vision data] screen appears.



- 2 Select [3DL Single-View Vision Process].
- 3 Enter a name of vision process in [Name]. Assign a unique name to the vision process.
- 4 Click [OK].
 A new vision process is created.



5 Select the created vision process and click [Edit]. The vision process setup screen appears.

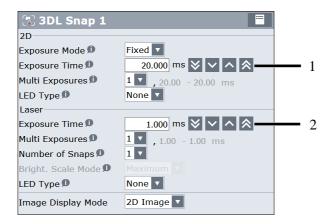


- 6 Select the 3DL Sensor Data from the [Camera] drop-down box. Select the name of the taught 3DL Sensor Data.
- 7 Select [Tool Offset] from the [Offset Mode] drop-down box.
- 8 Select the tool frame number from the [Offset Frame] drop-down box.

 An offset frame is a tool frame used for calculation of offset amount. To check the accuracy, in this step, select the tool frame number selected for [Cal. Grid Frame] in "Know-How: 2.2.3 Calibration".

2.2.6.2 Teaching 3DL Snap Tool

Select [3DL Snap] in the tree view, and then set each item.

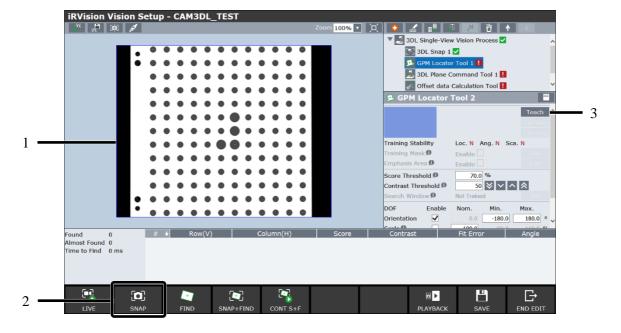


- Input [Exposure Time] for [2D].
 Set the same exposure time as the one used when the calibration of the 3D Laser Vision Sensor was performed.
- Input [Exposure Time] for [Laser].

 Set the same exposure time as the one used when the calibration of the 3D Laser Vision Sensor was performed. In the same way as in calibration, check that an image with appropriate exposure time is snapped in the image view area.

2.2.6.3 Teaching GPM Locator Tool

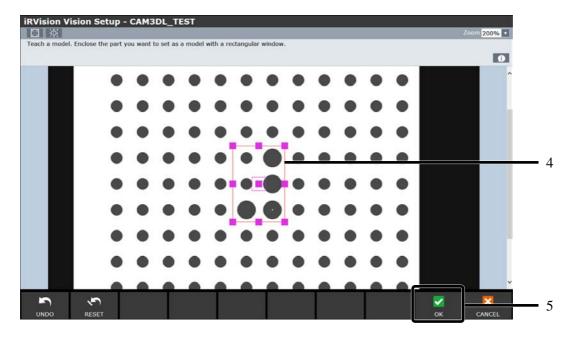
Select [GPM Locator Tool] in the tree view, and then set each item.



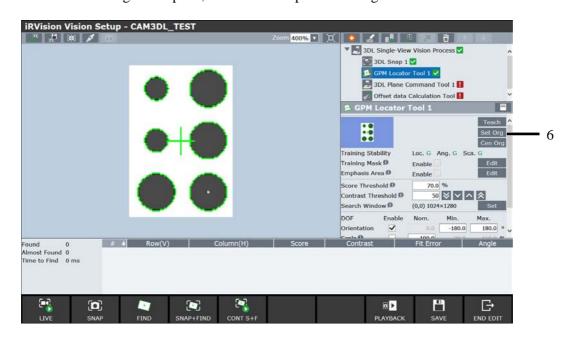
- 1 Jog the robot to the measurement area.
 - Jog the robot to the position taught in the robot program created for calibration. In the same way as in calibration, check that the laser beam intersection and the center of the calibration grid come almost at the center of the image view area.
- 2 Click [SNAP].

 After determining the measurement position, click [SNAP] to capture an image.

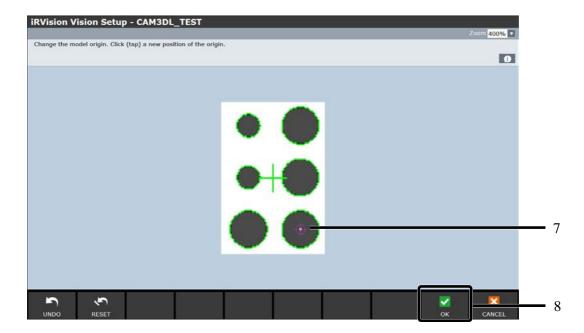
3 Click the [Teach] button.
The model setup screen for the GPM Locator Tool appears.



- 4 Enclose the large circles of the calibration grid.
 While operating the control points of the rectangle window on the screen, change the area so that the four large circles of the calibration grid are enclosed.
- 5 Click [OK].
 The window setting is complete, and the model pattern is taught.



6 Click [Set Org].
The model origin setup screen appears.

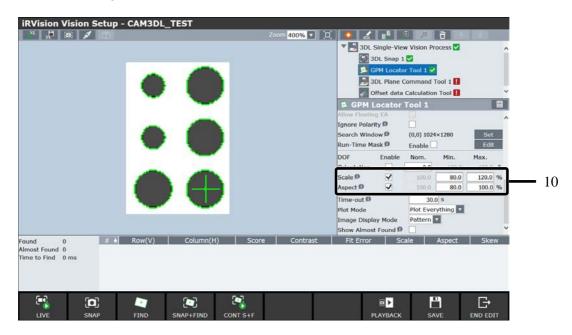


7 Move the origin.

Move the model origin target to the center of the calibration grid. The model origin can be set more correctly by enlarging the screen using the [Zoom] drop-down box.

8 Click [OK].

A new model origin is set.

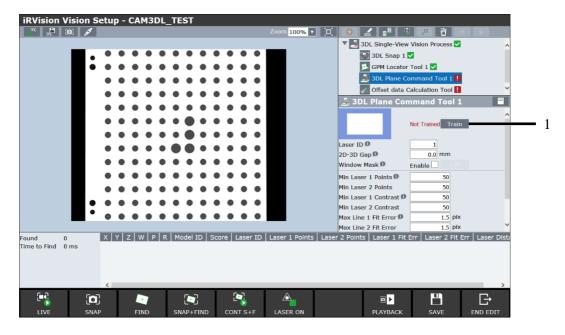


- 9 Click to enable the advanced mode.
- 10 Set [Scale] and [Aspect] in [DOF].

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

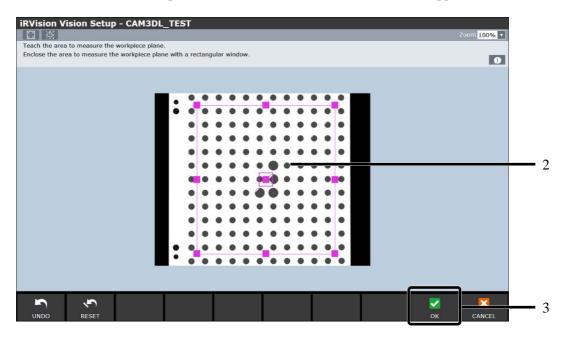
2.2.6.4 Teaching 3DL Plane Command Tool

Select [3DL Plane Command Tool] in the tree view, and then set each item.



1 Click the [Train] button.

The measurement area setup screen for 3DL Plane Command Tool will appear.



2 Enclose the grids on the calibration grid.

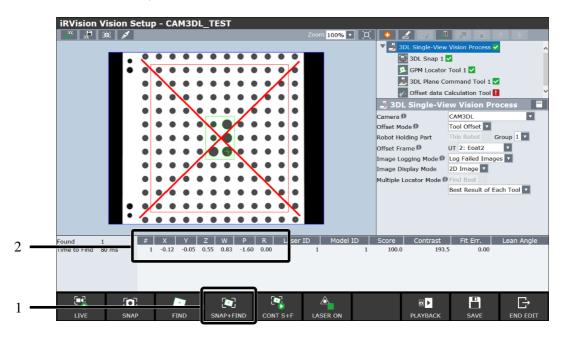
While operating the control points of the rectangle window on the screen, change the measurement area so that only the calibration grid is enclosed.

3 Click [OK].

The window setting is complete, and the measurement area is taught.

2.2.6.5 Running a test

Select [3DL Single-View Vision Process] in the tree view, and then execute the test of the vision process to check the calibration accuracy.



1 Click [SNAP+FIND].

The image is snapped and detected. When the detection is successful, the measurement results appear in the result display area.

2 Take a note of measurement results.

Write down the values for 'X, Y, Z, W, P and R' that appear in the result display area.



3 Move the robot position.

Jog the robot to change the robot position and posture as far as the calibration grid is seen within the field of view of the camera. Click [LIVE], and a live image appears in the image view area.

4 Click [SNAP+FIND].

The image is snapped and detected. When the detection is successful, the measurement results appear in the result display area.

5 Compare the measurement results.

Compare the results with the measurement results written down in step 2, and check that they almost match. Also check the values for 'X, Y and Z' are close to '0'.

6 Change the robot position and posture, and repeat measurements.

Repeat the sequence of operations from steps 3 to 5. 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 differences in results are large, check the calibration procedure, and perform the calibration again.

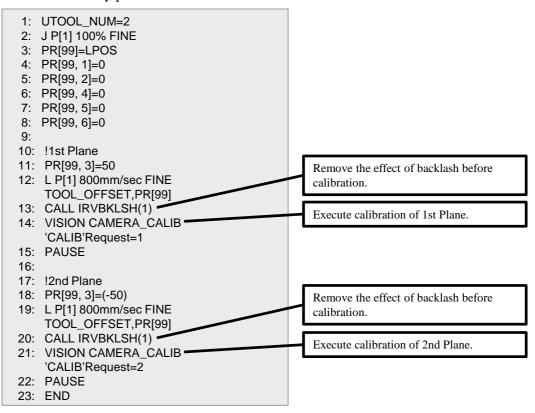
2.2.7 Automatic Re-Calibration

The workpiece cannot be measured correctly if the mounting position or direction of the 3D Laser Vision Sensor relative to the robot is displaced, or the relative positions of the laser unit and camera unit of the 3D Laser Vision Sensor are displaced because the 3D Laser Vision Sensor has accidentally hit the peripheral equipment. In such cases, the line can be recovered by automatic re-calibration without performing teaching again.

To perform automatic re-calibration, the robot program for executing automatic re-calibration needs to be added beforehand to the robot program for calibration created in "Know-How: 2.2.3 Calibration".

When the fixed camera is mounted on the 3D Laser Vision Sensor, and the calibration grid is mounted on the robot end of arm tooling, do not rewrite the values of the tool frame for which the installation information of the calibration grid is set. The values of the tool frame are referred to during re-calibration. The sample robot program is shown as below.

If the program is executed with the calibration grid mounted on the robot end of arm tooling, the 2-plane calibration is automatically performed.



Program example

By using the automatic re-calibration, there are following merits.

• Since this can be performed from the robot program, the system can be recovered without manual operation, e.g., when replacing the camera.

Since the system can be recovered more quickly than performing the normal 3DL calibration, operation error by the operator, etc. can be avoided.

• Since the robot's touch-up of the calibration grid is unnecessary, accuracy errors by touch-up operation can be avoided. In many cases, the reason for teaching correction required in normal re-calibration is accuracy errors resulted from touch-up operation. Because of this, for applications requiring strict accuracy, it is desired to use automatic re-calibration.

In almost cases, e.g., 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.

3 VISION APPLICATION

This section describes general application examples of the 3D Laser Vision Sensor.

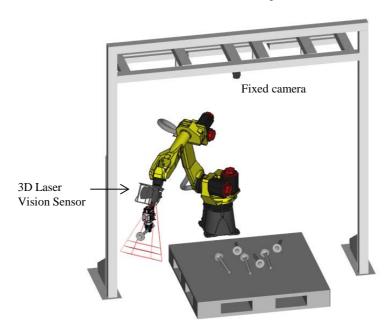
3.1 COMBINATION OF 3D LASER VISION SENSOR AND 2D VISION

The view size of the 3D Laser Vision Sensor is not so large. When the standoff distance is 400 mm and the focal distance of the lens is 12 mm, the field of view of the analog camera is 172.4 x 129.4 mm (For the digital camera, the similar field of view is obtained with the focal distance of 16 mm.).

Also 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 an intersection of laser slit beams exists in it. The relative relation between the camera FOV of the 3D Laser Vision Sensor and the position where two laser slit beams are applied is decided by distance between a workpiece and the 3D Laser Vision Sensor.

To irradiate two laser slit beams on the measurement part of a workpiece, it is necessary to minimize the positional variability in the workpiece within the range where the laser can be irradiated.

When the positional variability in the workpiece is larger than the measuring range of the 3D Laser Vision Sensor, it is effective to use the method to allow the laser slit beams to be irradiated by detecting the workpiece position with a fixed camera mounted on the upper part of the 3D Laser Vision Sensor system and moving the 3D Laser Vision Sensor close to the workpiece based on the result.



COMBINATION OF 3D LASER VISION SENSOR AND 2D VISION

The sample robot program is shown as below.

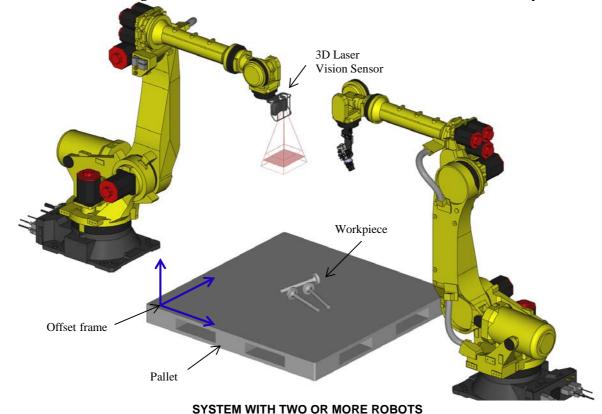
- 1: J P [1] 50% FINE
- 2: VISION RUN_FIND 'ZENTAI'
- 3: VISION GET_OFFSET 'ZENTAI' VR[1] JMP LBL[999]
- 4: L L[2] 1000mm/sec FINE VOFFSET,VR[1]
- 5: VISION RUN FIND 'RITTAI'
- 6: VISION GET_OFFSET 'RITTAI' VR[2] JMP LBL[999]
- 7: L P[3] 800mm/sec CNT100 VOFFSET, VR[2]
- 8: L P[4] 200mm/sec FINE VOFFSET, 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 To measure the workpiece with the taught 3D Laser Vision Sensor mounted on the robot end of arm tooling, offset the robot position by using vision register [1], and move the 3D Laser Vision Sensor to almost directly above 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 The robot is offset by using the offset data.

3.2 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 'sharing of user frame'.

iRVision 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 offset frame. Therefore, if the same user frame is not set for the robot with the 3D Laser Vision Sensor mounted and the robot to offset the operation, the offset data calculated by the robot with the 3D Laser Vision Sensor mounted cannot instruct the correct offset amount and direction to the robot to offset the operation.

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. E.g., user frame 10 of robot 1 needs to be physically the same as user frame 10 of robot 2.

In the example of the above figure, it is necessary to set the 'user frame used for offset' indicated with the blue line to be the user frame with the same number for the robot A at left with the 3D Laser Vision Sensor mounted, and the robot B at right in which to offset the motion.

For example, if the user frame No. 10 is shared, the robot A should be taught to calculate the offset data using the user frame No. 10, and the robot B should be taught to offset the operation using the user frame No. 10.



⚠ CAUTION

If robots share user frames of different numbers, iRVision 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 the 3D Laser Vision Sensor mounted needs to be transferred to all the robots to offset the operation.

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, refer to the description of ETHERNET COMMUNICATION FUNCTION BETWEEN ROBOTS in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN" and "Optional Function OPERATOR'S MANUAL B-83284EN-2".

The sample robot program is shown as below.

Sending robot

- 1: VISION RUN_FIND 'WORKPIECE'
- 2: VISION GET_OFFSET 'WORKPIECE' 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]

Line 1–2 The vision process 'WORKPIECE' 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 vision register [1] is copied to position register [10].

The content in position register [10] is transmitted to position register [20] of the receiving robot with the name of the receiving robot specified as [ROBOT2].

Line 5–6 As a signal that transmitted position register [15], the sending robot transmits the content of register [5] to register [15] of receiving robot.

Receiving robot

1: UFRAME_NUM=10

2: R[15]=0

17: WAIT R[15]=1

18: L P[6:Approach] 800mm/sec CNT100 Offset, PR[20]

19: L P[7:Place] 200mm/sec FINE Offset, PR[20]

20: L P[8:Retract] 800mm/sec CNT100 Offset , PR[20]

:

Line 1 The number of the shared 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.

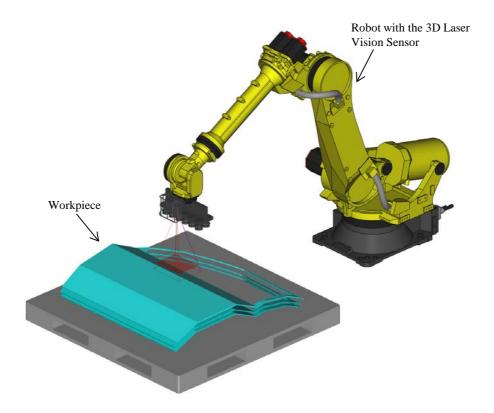
Line 18–20 The robot is offset by using the received offset data in position register [20].

3.3 SAMPLE APPLICATIONS

This section shows the sample applications with the 3D Laser Vision Sensor.

3.3.1 Body Panel Pickup (Robot-Mounted Camera + Fixed Frame Offset)

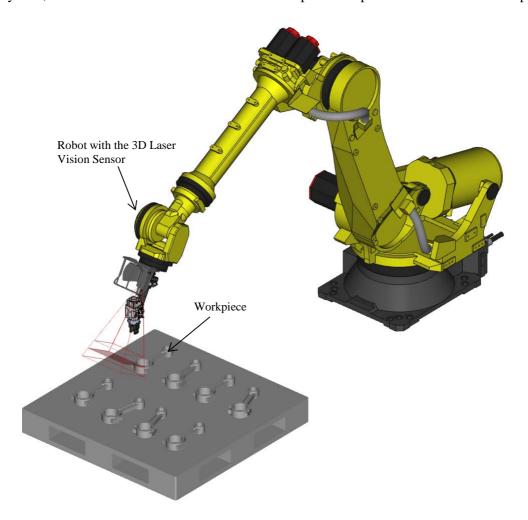
In this system, the 3D Laser Vision Sensor detects the position and inclination of body panels on a pallet and the robot supplies the panels one by one to the spot welding process.



Example of picking up sheet metal (robot-mounted camera + fixed frame offset)

3.3.2 Small Part Pickup (Robot-Mounted Camera + Fixed Frame Offset)

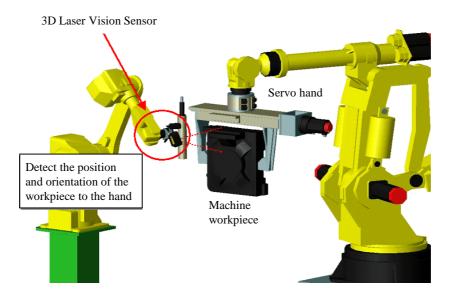
In this system, the 3D Laser Vision Sensor detects a workpiece in a pallet or box and the robot picks it up.



Example of picking up small parts (robot-mounted camera + fixed frame offset)

3.3.3 Loading Machine Part (Robot-Mounted Camera + Tool Offset)

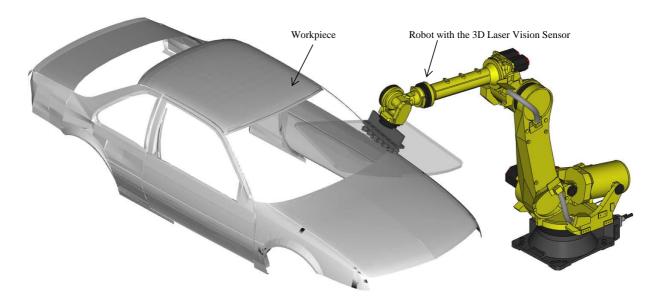
The 3D Laser Vision Sensor mounted on the small robot measures the machine workpiece to calculate the tool offset of the workpiece. The large robot receives the offset data for operation from the small robot, offsets the placing operation, and sets the machine workpiece onto the fixture.



Example of attaching and removing the part to and from the machine tool (robot-mounted camera + tool offset)

3.3.4 Mounting Windshield onto 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 calculate 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 calculate the tool offset of the panel together with the fixed frame offset of the body.



Example of mounting the glass to the car body (robot-mounted camera + fixed frame offset)

4

TROUBLESHOOTING

Method of restoring vision data

Prepare the memory card backed up in "Introduction: 1.10 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

If a workpiece is not found by executing a vision process, measures can be taken using vision log or logged images. By setting as shown below, *i*RVision can record a vision log of the execution of 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 [Image Logging Mode] for a vision process.

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 [Show 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, refer to the description of VISION LOG in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

Retry finding

When a workpiece 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, refer to the description of VISION OVERRIDE in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

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. In theory, these two straight lines intersect at the laser beam intersection point of the plane of the workpiece, and the distance between both straight lines is 0. In actuality, however, the distance between the two lines rarely becomes 0 because of calibration error or measurement error.

The LL distance is the distance between these two straight lines, and the Max LL distance is the upper limit threshold for the LL distance.

The Max LL distance is set to 3.0 mm as default. If the LL distance is longer than this threshold value, the 3D Laser Vision Sensor changes the detection result into failure.

If the LL distance is longer than 3.0 mm, the cause may be the following:

- The workpiece plane where the laser is irradiated is uneven.
- The plane is not flat, but curved.

Another cause may be that the calibration for the 3D Laser Vision Sensor is not correct. When the calibration of the 3D Laser Vision Sensor is performed, the relative positions of the camera of the 3D Laser Vision Sensor and the laser unit are recognized. However, if the 3D Laser Vision Sensor hits the peripheral equipment, etc., the relative positions recognized during the calibration are displaced from the current status. In this case, 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, although the offset operation may be correct when the workpiece moves in parallel against the reference position, the offset operation may be shifted when the workpiece rotates, and larger the amount of rotations, larger the amount of shift may be.

In many cases, it is because the user frame specified for [Offset Frame] or [Cal. Grid Frame] is not set correctly.

When the user frame recognized by the robot is shifted from the user frame recognized by iRVision, 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 used for the installation information of the calibration grid, robot TCP or user frame to be offset was not set correctly.
- There is a mistake in the 3DL calibration setting or procedures.

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 calculated 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 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 have variation or the workpiece size has variation, the workpiece position may not be calculated correctly.

In this case, when the workpiece position and posture are calculated by using the vision support tool MERGE3DV2, the workpiece position can be determined at the detection position of one specific location, and the workpiece posture can be determined at the detection position of another location. For details, refer to the description of VISION SUPPORT TOOLS in "iRVision OPERATOR'S MANUAL (Reference) B-83914EN".

Notes for 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 workpiece.
- When the inclination of workpiece is large and the shape of workpiece is not simple (e.g., like a circle, a square, etc.), teaching of multiple models for multiple inclinations is recommended.
- 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 cannot accept bad offsets by specifying the range of the offset elements in the limit check function.

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