LCAMP

Learner Centric Advanced Manufacturing Platform

FANUC INDUSTRIAL ROBOT PROGRAMMING (EXCERCISES)

WP6 COLLABORATIVE LEARNING FACTORY

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Summary of the document

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Document description	During the exercises, students learn how to work safely with an industrial robot, learn about the structure of an industrial robotic system and know how to program a robot for a selected robotic application. The exercises are suitable for operators and maintainers of industrial robots and candidates who want to learn how to work and program industrial robots.
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CONTENT TABLE

EXECUTIVE SUMMARY

During the exercises, students learn how to work safely with an industrial robot, learn about the structure of an industrial robotic system and know how to program a robot for a selected robotic application. The exercises are suitable for operators and maintainers of industrial robots and candidates who want to learn how to work and program industrial robots.

EXERCISE 1: MANUAL CONTROL OF AN INDUSTRIAL ROBOT AND CONSTRUCTION OF A ROBOT CELL IN THE FANUC ROBOGUIDE SIMULATION PROGRAM

In this exercise, you'll be able to:

- learn to take safety precautions when working with an industrial robot,
- learn about the structure and operation of an industrial robot,
- manually guided industrial robot,
- know how to use a gripper,
- depending on the given situation, we were able to choose the appropriate coordinate system and in the simulation program RoboGuide learned:
- to produce a new robotic cell (RC),
- work with the mouse (zoom in/out, flip view, move view, etc.),
- manually guide the robot,
- install and set up the basic tool – gripper, and
- make a backup copy of the RC (compressed file, type *.rgx).

After completing the exercise, submit three files:

- Scanned and handwritten report on the completed exercise (PDF type – all pages in one document, orientation of the portrait document, pages arranged in order from 1 onwards)
- screen image (jpg, pdf, doc... appropriately oriented) robotic cell from which the following can be seen:
    - the name of the robotic cell,
    - a robot with a gripper installed and TCP set (TCP should be displayed) and placed in the center of the full-size RG screen – across the entire screen, and
    - the included learning unit placed on the right side of the screen on which the UTILITIES Hints – MENU/1 UTILITIES/1 Hints screen with software version V8.30 should be visible),
- a backup of a robot cell, of the *.rgx type, made in RoboGuide.

All submitted files must have meaningfully the same names as the name of the robot cell, only the backup copy must have a creation date at the end of the name in the form -YYYY_MM_DD.

Minimum standard of knowledge:

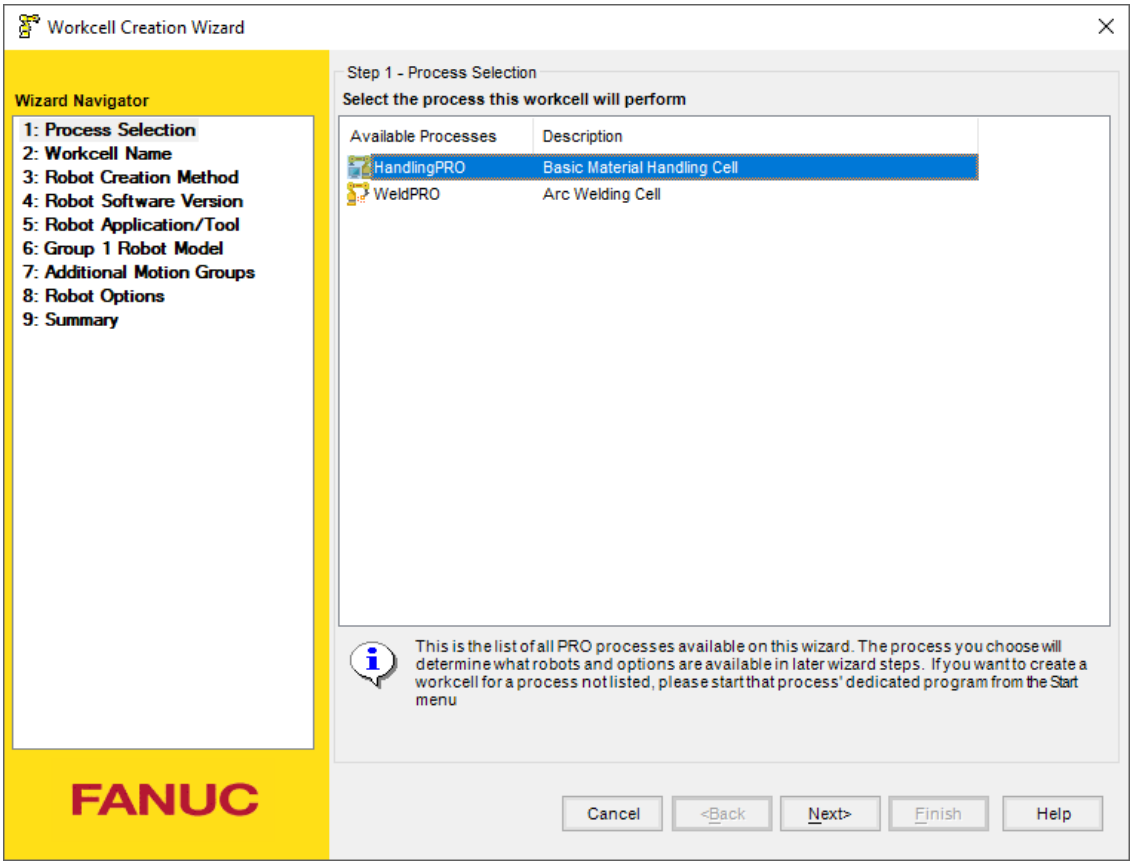
- explain where the greatest dangers are when working with robots and who they threaten,
- list and describe the hazards when working with robots,
- lists and knows how to use essential safety measures when working with an industrial robot (safe work in a robot cell, completion of work with a robot),
- lists and draws the structure of an industrial robotic system and describes the essential components (robotic arm, controller, learning unit),
- knows how to use each mode of operation of the system (T1, T2, AUTO),
- knows how to use the learning unit (TP) and manually guide the robot (jogging) and activate the gripper,
- knows how to correctly choose the appropriate mode of movement – coordinate system,
- v RoboGuide knows how to set the gripper (open/close, TCP),
- in RoboGuide knows how to make a backup, name it appropriately, and store it in a safe place.

MANUAL ROBOT CONTROL – WORK ON AN INDUSTRIAL ROBOT

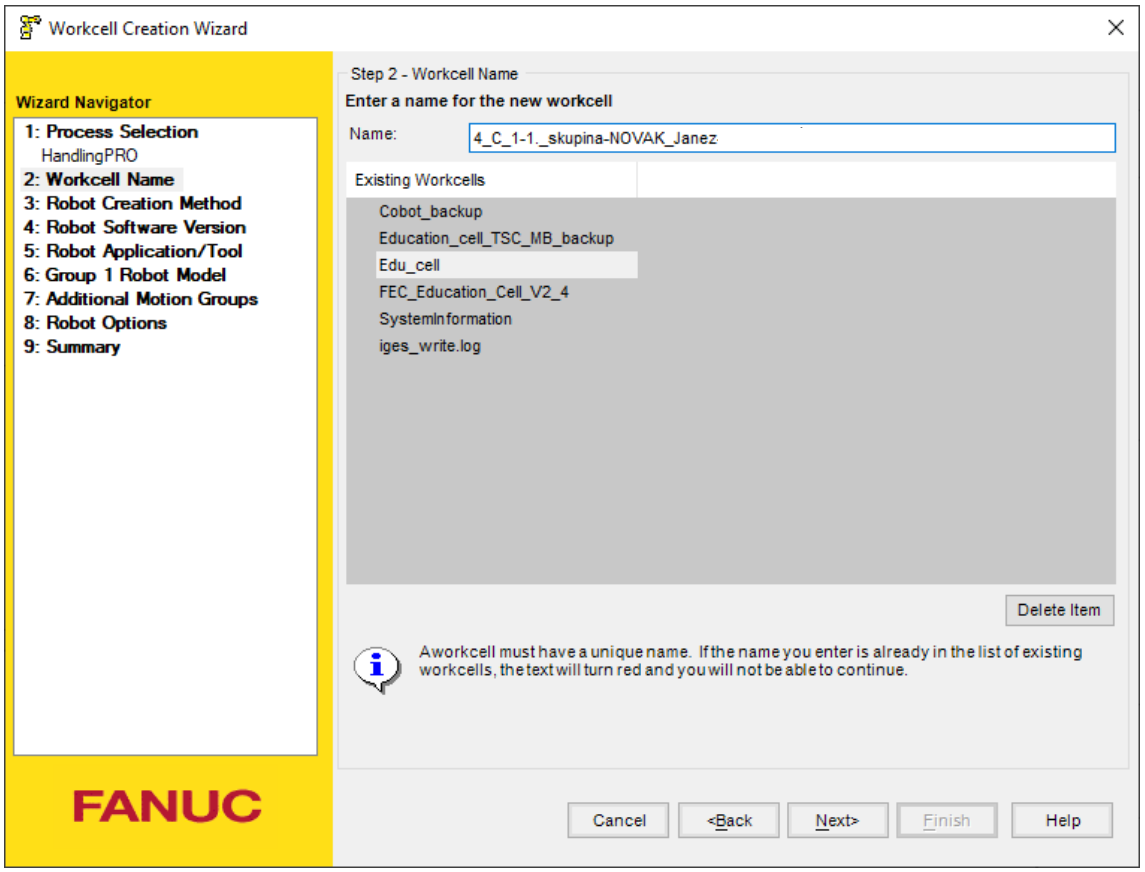
1. Familiarize yourself with the safety precautions when working with industrial robots.
2. Learn about the structure of an industrial robot and the use of coordinate systems.
3. Manually guide an industrial robot (jog – jogging) in different coordinate systems:
   - axisally characteristic or along individual axes:
     - move each axis separately (J1, J2, J3, J6, J5 and J6),
     - check the gripper (closing/opening),
   - Cartesian, TCP linear and rotation:
     - transfer the object from point A (horizontal) to point B (horizontal), and
     - transfer the object from point A (horizontal) to point B (slant) and / or vice versa.

CREATING A ROBOT CELL IN THE FANUC ROBOGUIDE SIMULATION PROGRAM

1. You start Roboguide.
2. Step 1: In the Workcell Creation Wizard window, select **HandlingPRO** (for manipulating products) and confirm with Next.



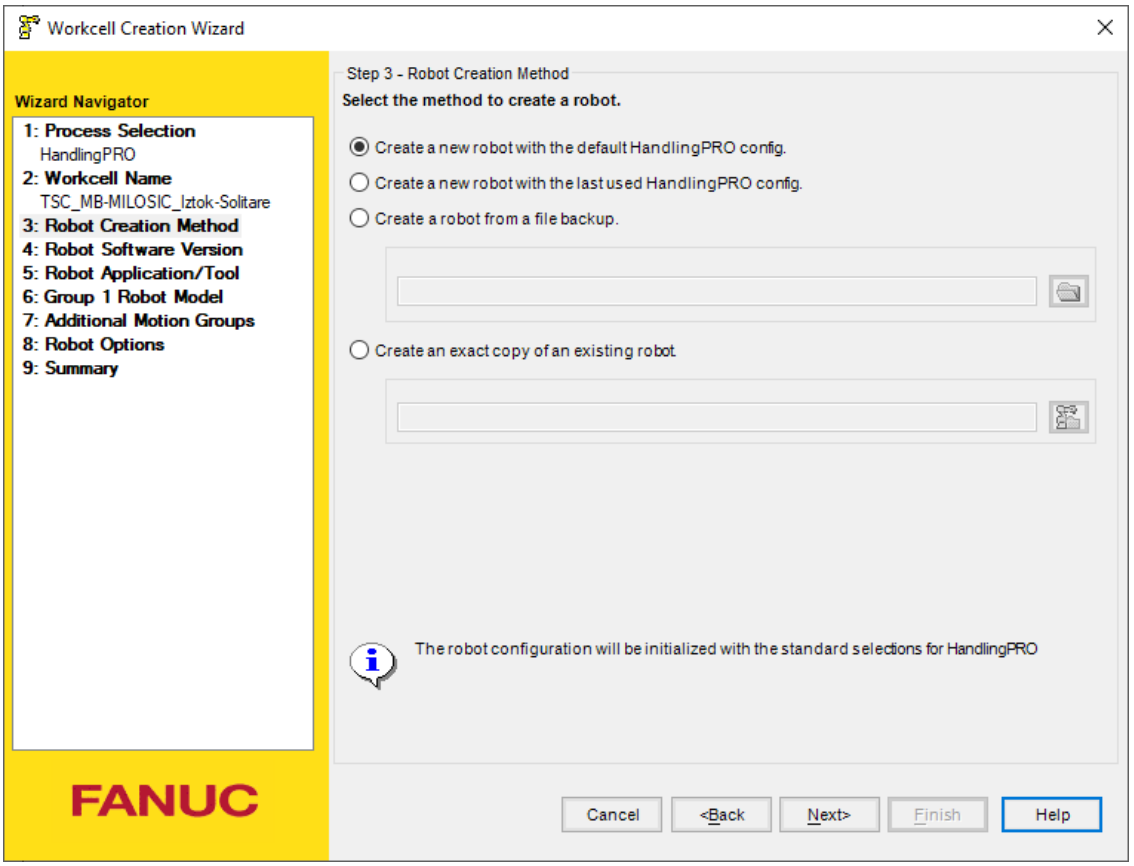
3. Step 2: Type in the name of the RC. You enter the name according to the system: **class-group-PRIIMEK_Ime**, confirm with Next. **Allowed characters are letters of the alphabet (without noises, umlauts, etc.), numbers, periods (.) and underscores (_), and hyphens (-). Everything else is not allowed** (spaces, noises, umlauts, special characters...) because there may be errors in the RC.
Example: **4._C_1-1._skupina-NOVAK_Janez**



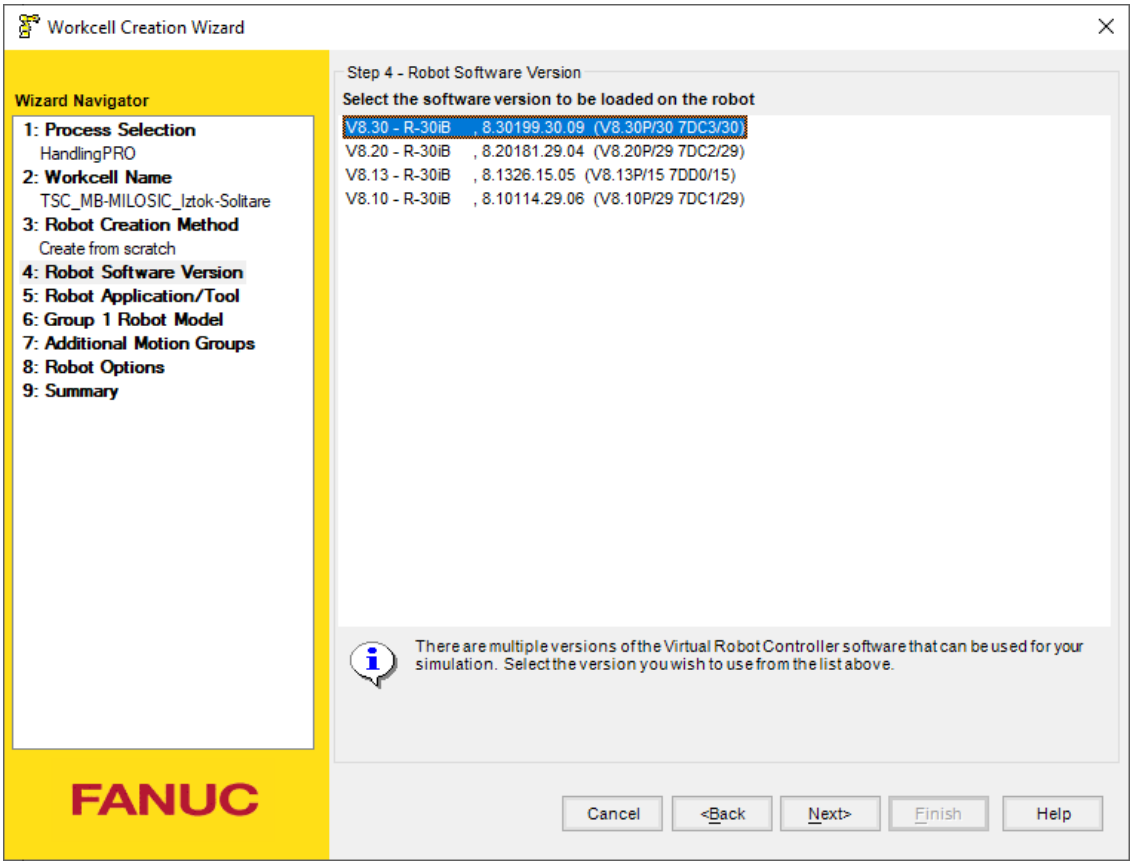
4. Step 3: Choose the appropriate method:

   - Create a new robot with the default HandlingPRO config, a new cell with default settings,
   - Create a new robot with the last HandlingPRO config, a new cell with the latest settings,
   - Create a robot from a file backup, a copy of a cell from a robot controller,
   - Create an exact copy of an existing robot, a copy of an existing cell.

   For our example, we want to create a new RC with the default values, select the first choice, **Create a new robot with the default HandlingPRO config**, confirm with Next.

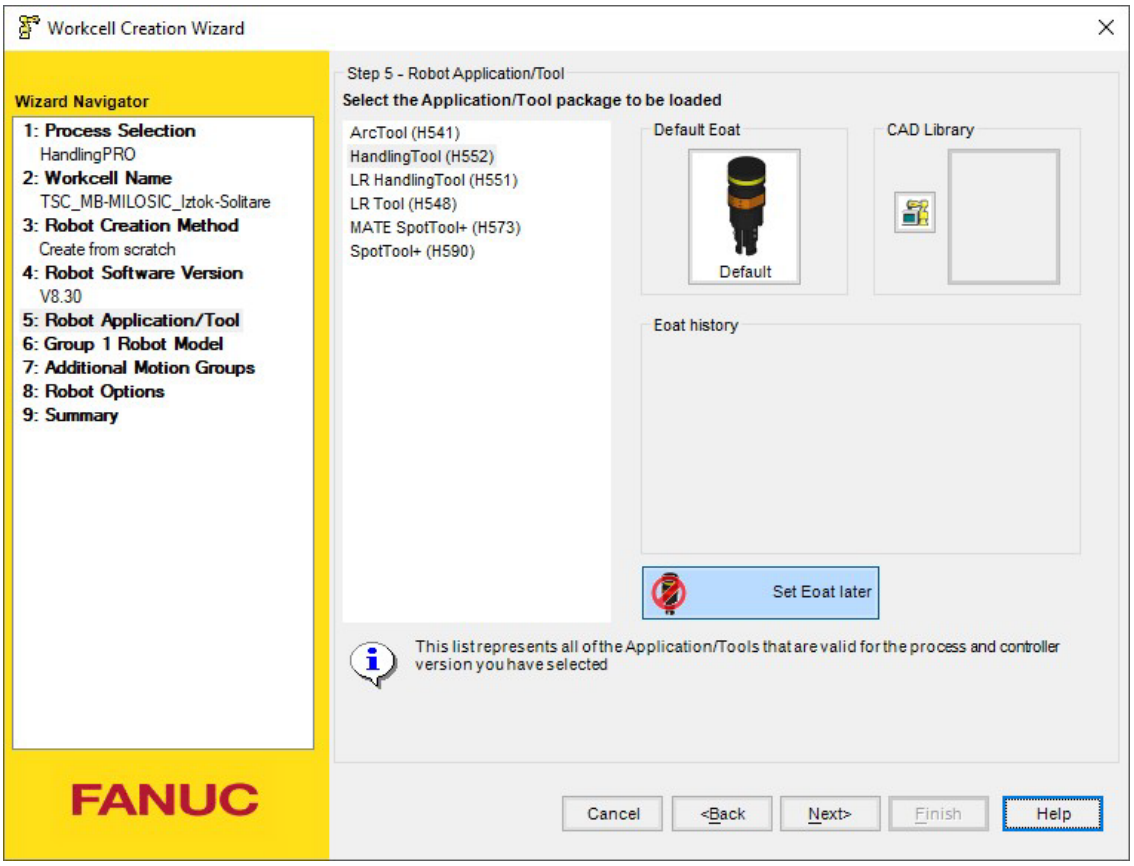


5. Step 4: Select the system software version.
   For our example, **V8.30 – R-30iB**, since our robot has the same software version, then confirm with Next.

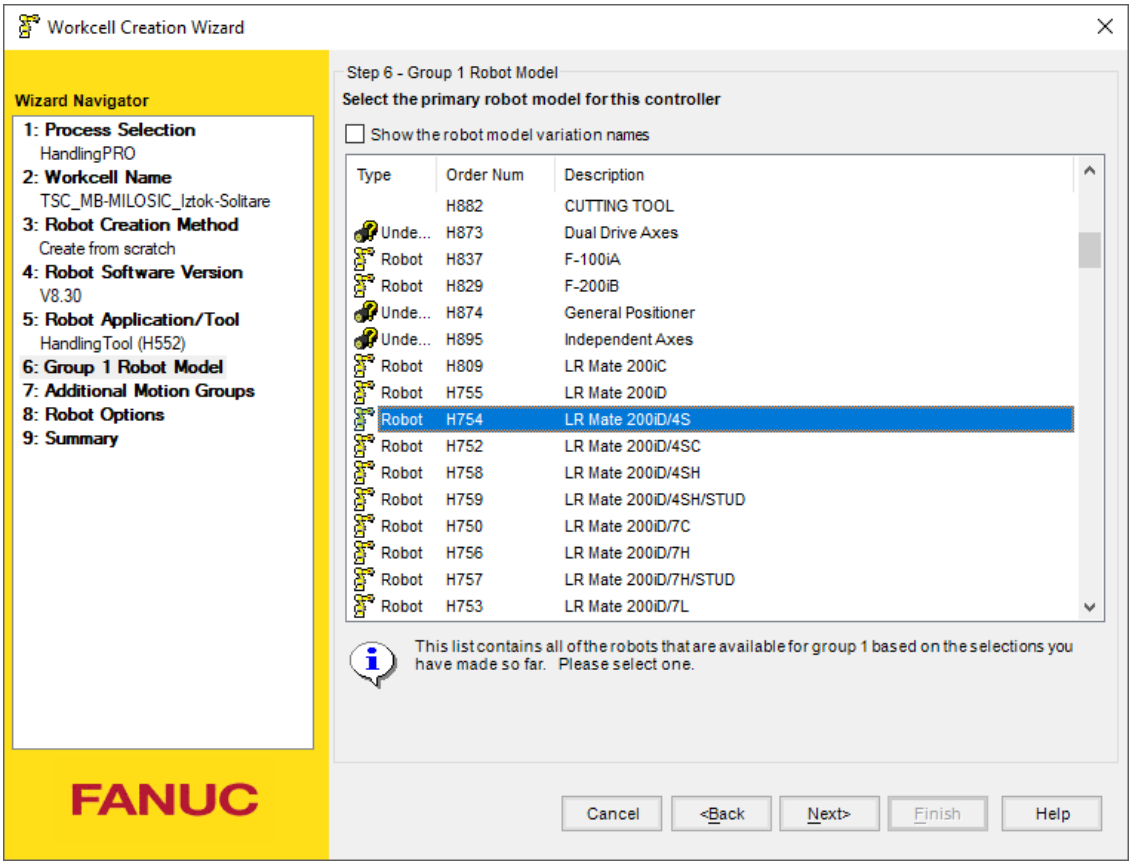


6. Step 5: Proceed with the Eoat (End Of Arming Tool) tool. You can select a default tool (Default Eoat), a tool from the CAD Library, or set it later (Set Eoat later).

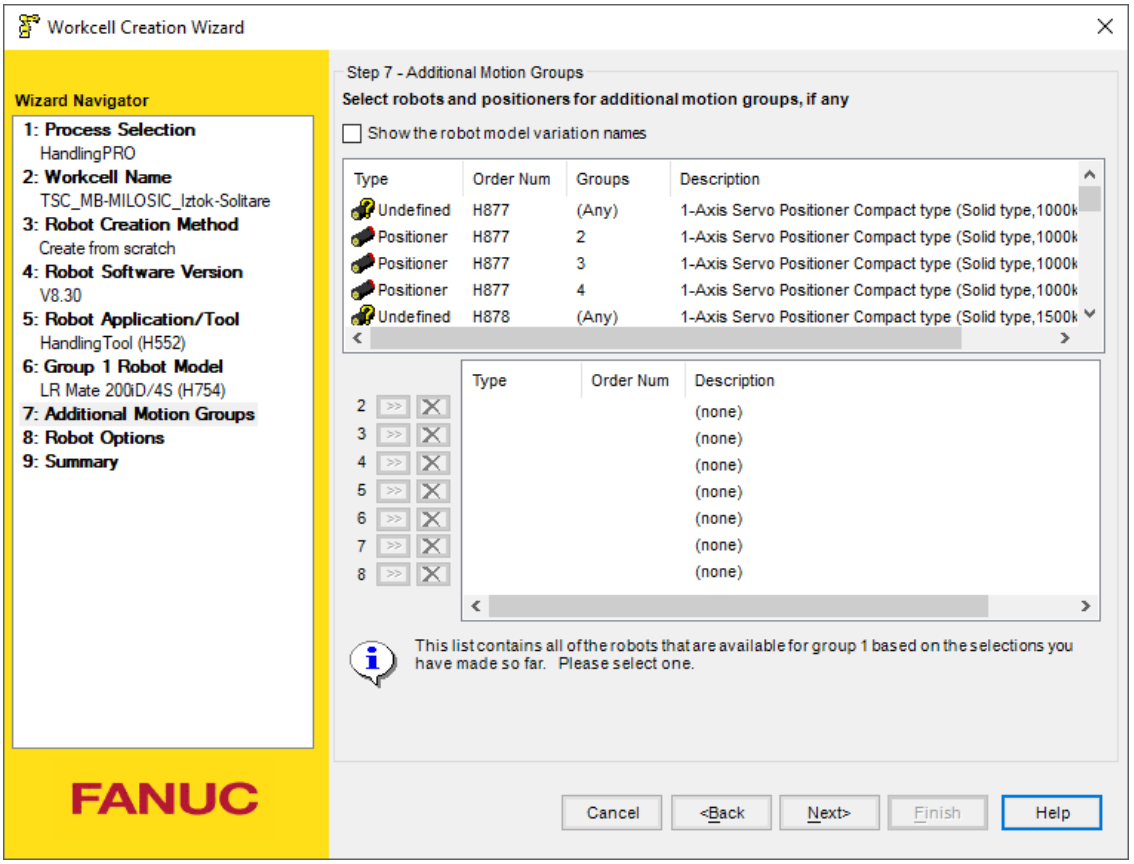
   Since you will set up the tool later, select **Set Eoat later**, confirm with Next.



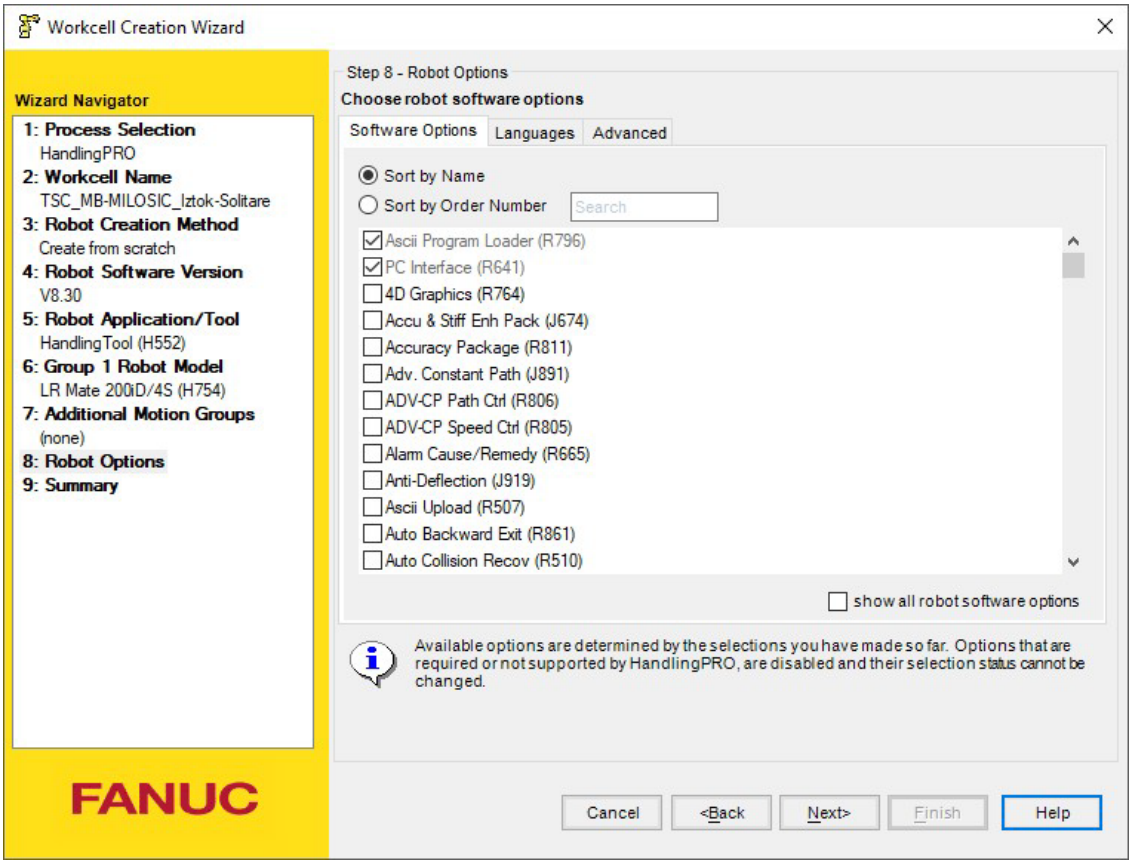
7. Step 6: Choose the appropriate robot arm model.
   For our example**, the LR Mate 200iD/4S**, and in the case of the participating robot**, CR-4iA**, confirm with Next.



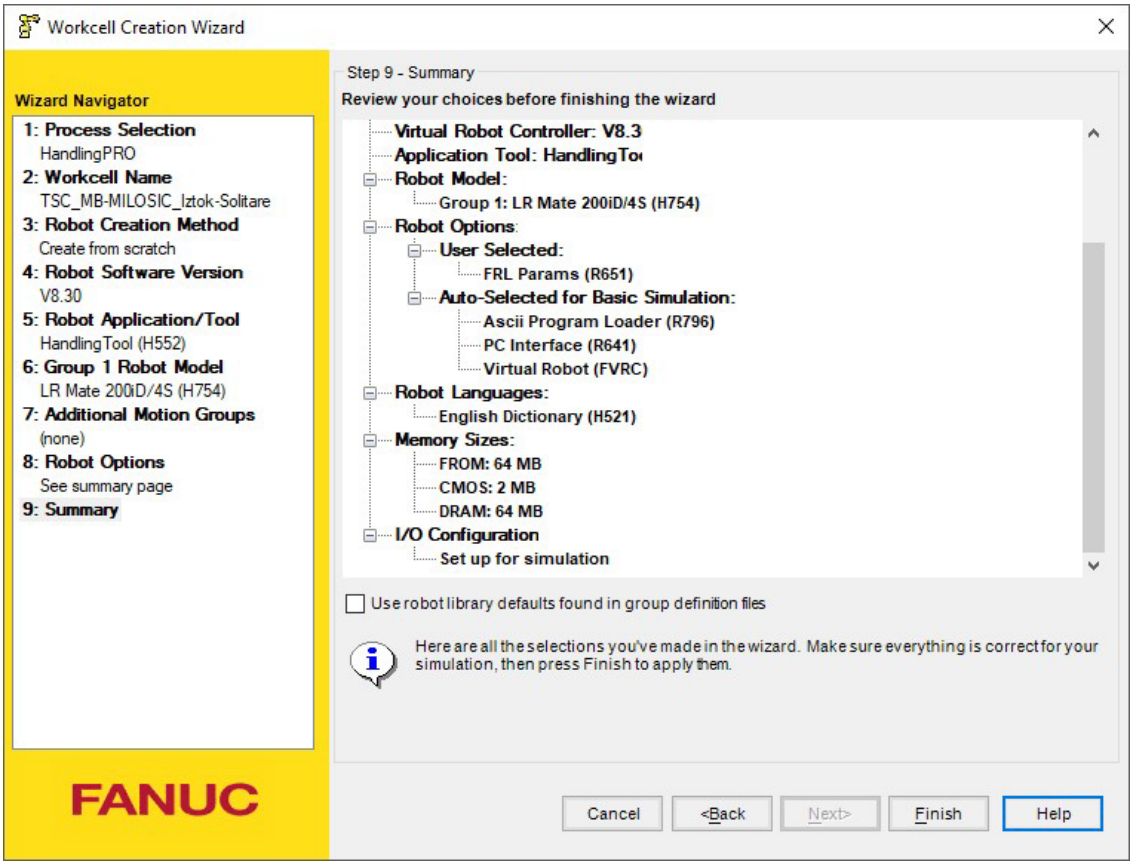
8. Step 7: If necessary, select additional axes (welding table, rails, etc.). If you have none of these, **do not mark anything**, confirm with Next.



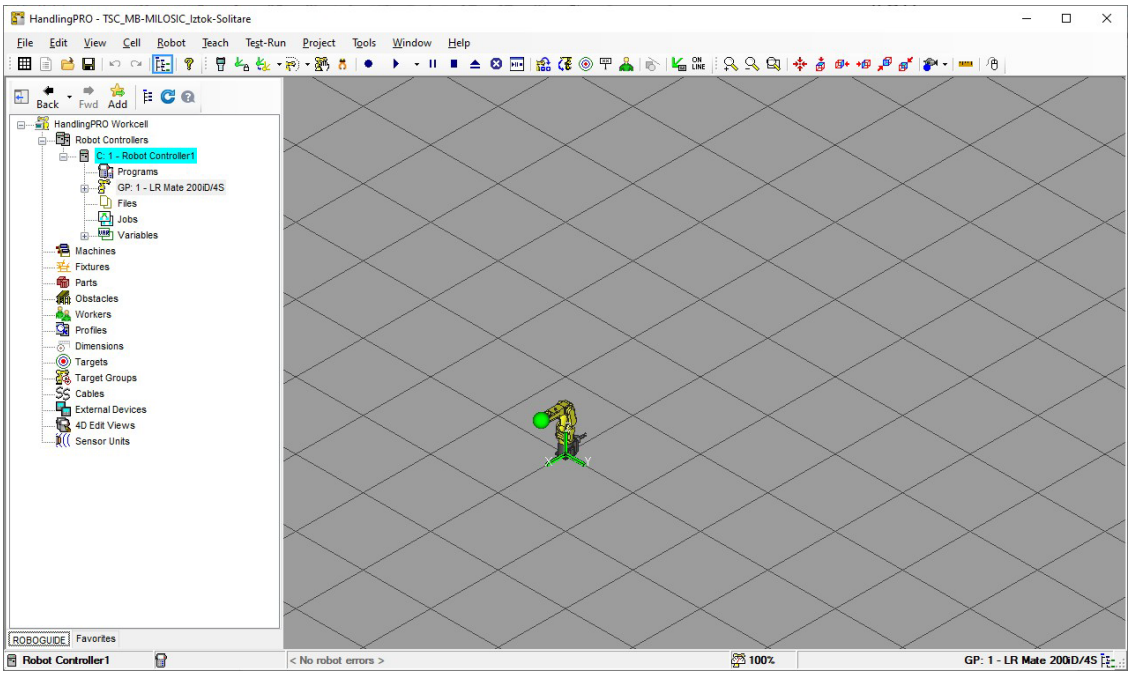
9. Step 8: If necessary, select the optional software (DCS, iRVision ...). If you don't need any of these for the time being, **don't tick anything**, confirm with Next.



10. Step 9: Summary, check in detail if you have set up/selected everything correctly (RC name, controller software version, robotic arm, tool...). If you need to fix something, press the Back key to return to the appropriate step and correct, otherwise confirm with Finish.

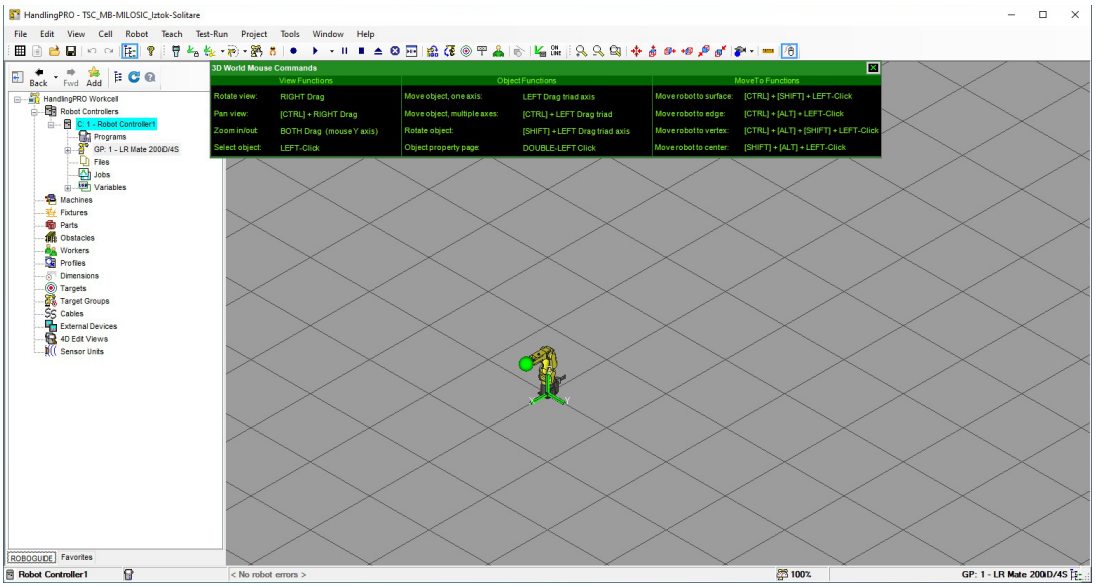


11. Wait for the RC to appear to you.



WORK WITH THE MOUSE

1. Turn the mouse help on/off in View/Mouse Commands (move/rotate view, zoom in/out...).



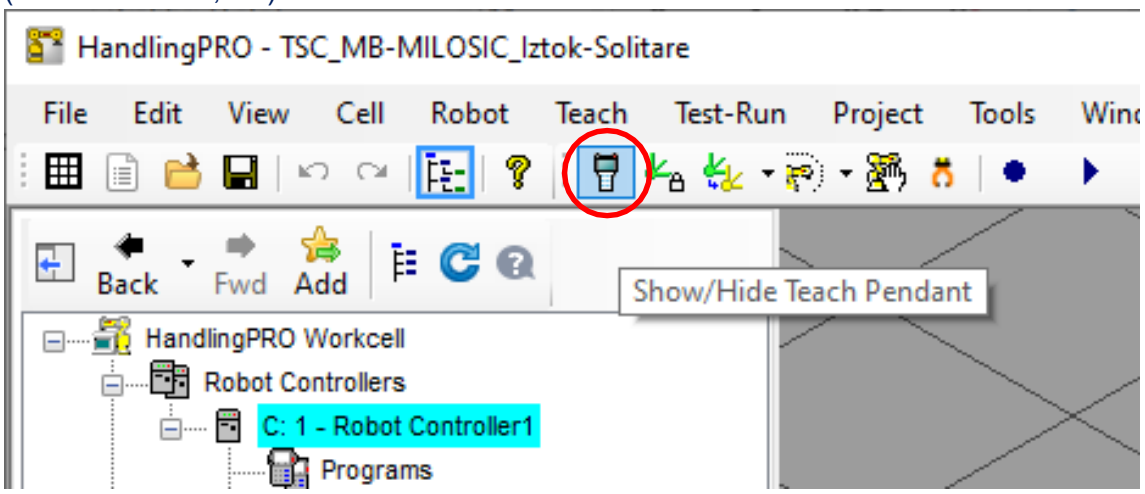
Test:

- ZOOM IN/OUT – turn the wheel on the mouse,
- ROTATE – click and hold the right mouse button and move the mouse and
- MOVE your view of the robot – Click the mouse wheel and move the mouse.

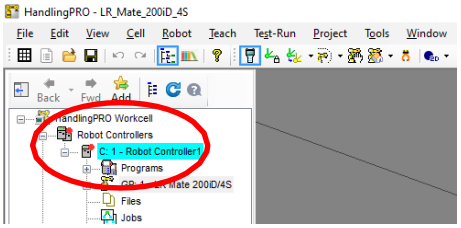
MANUAL ROBOT CONTROL WITH THE HELP OF UE

1. On a real robot, we take care of safety with manual control:
    a. T1 mode of operation (only T2 and AUTO are available in RG),
    b. the permission key (deadman switch) and
    c. Emergency stop button (E-stop).

   You don't need all these security mechanisms in RG, because you are working on a computer simulation and the robot cannot hurt you. You can switch between the T2 and AUTO modes using the switch on the learning unit (ON – T2, OFF – AUTO).
2. You can manually guide a robot in the same way as a real robot, with a learning unit, UE (Teach Pendant, TP). TP Show/Hide on the Show/Hide Teach Pendant icon.

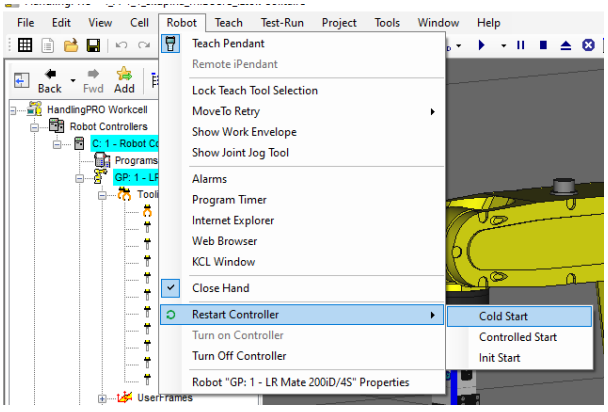


3. If the UE doesn't load, or if you have a red dot next to the Robot Controller in the tree structure, the virtual controller needs to be restarted.



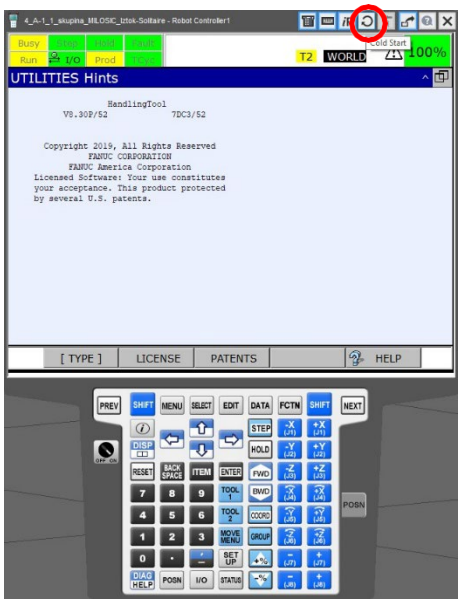
You can restart the virtual controller:

- Click on the menu Robot/Restart controller/Cold Start

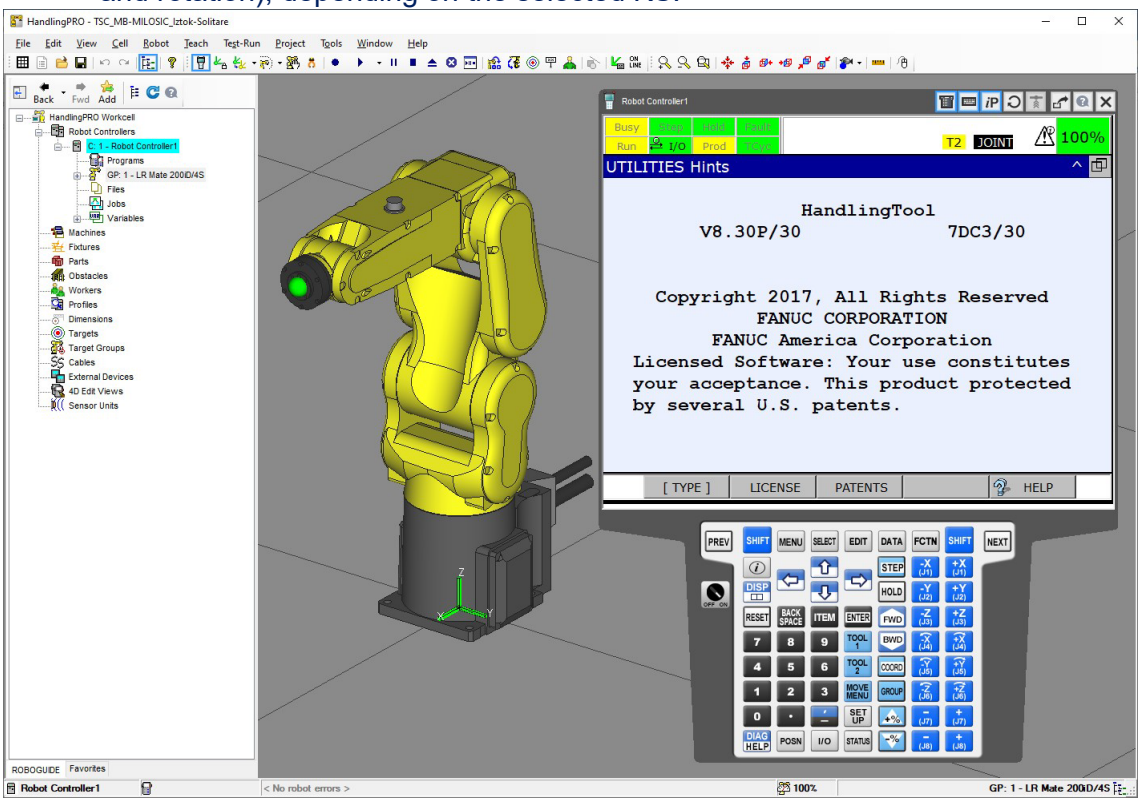


or

- Click on the Cold Start icon and confirm the question with YES to the question: "Do you want to Cold Start the controller?".



4. Manual guide procedure from UE to RG:
    a. Select the coordinate system (COORD).
    b. Set the speed (+% / -%).
    c. You activate the SHIFT key.
    d. Using the manual control keys, you can move individual axes or TCP (translation and rotation), depending on the selected KS.



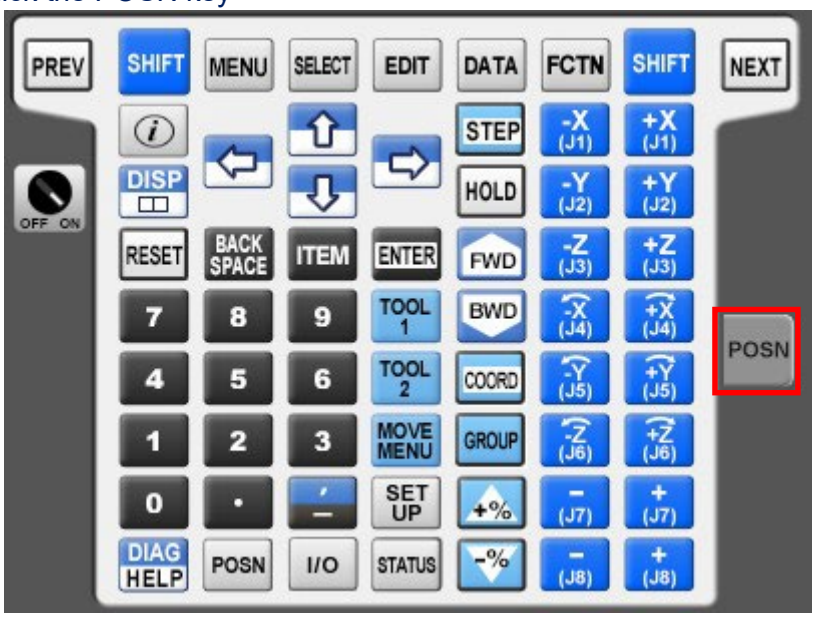
Manually guide the robot to KS using UE:

- JOINT (each axis of the robot separately, J1, J2, J3, J4, J5 and J6).
- WORLD:
    - Move TCP linearly.

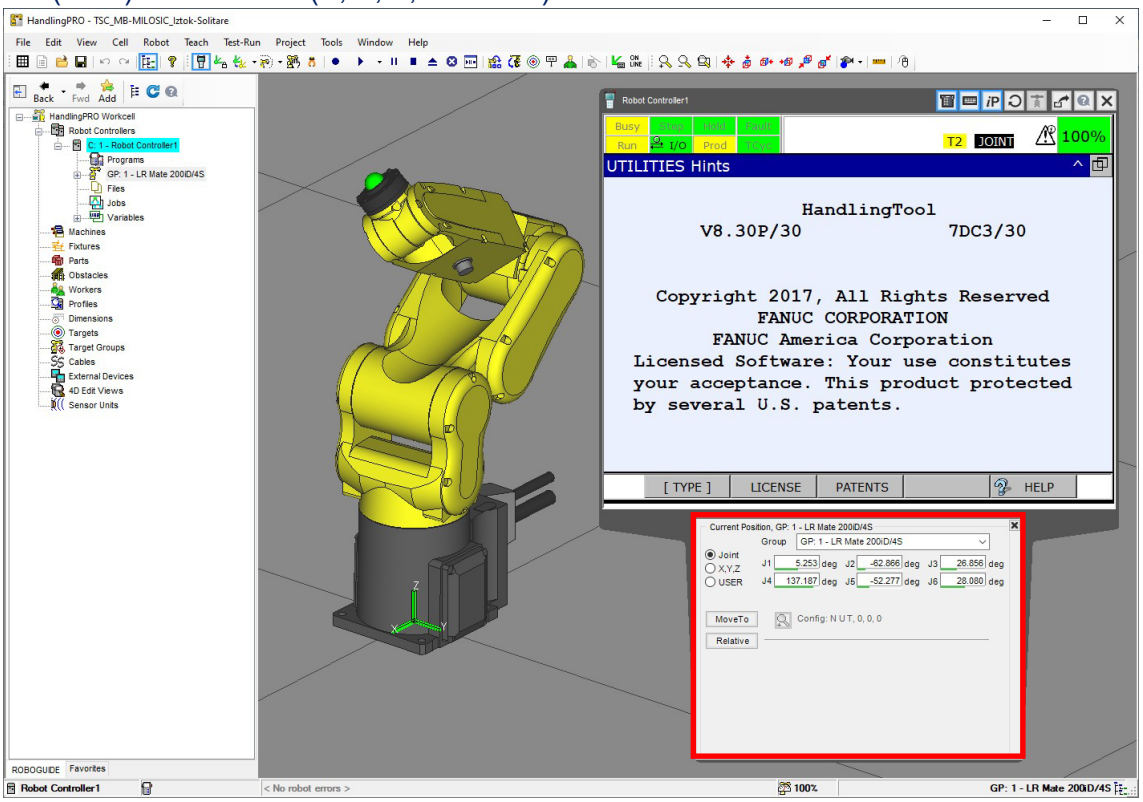
- Rotate the tool around TCP.

- TOOL:
  - Move TCP linearly.
  - Rotate the tool around TCP.

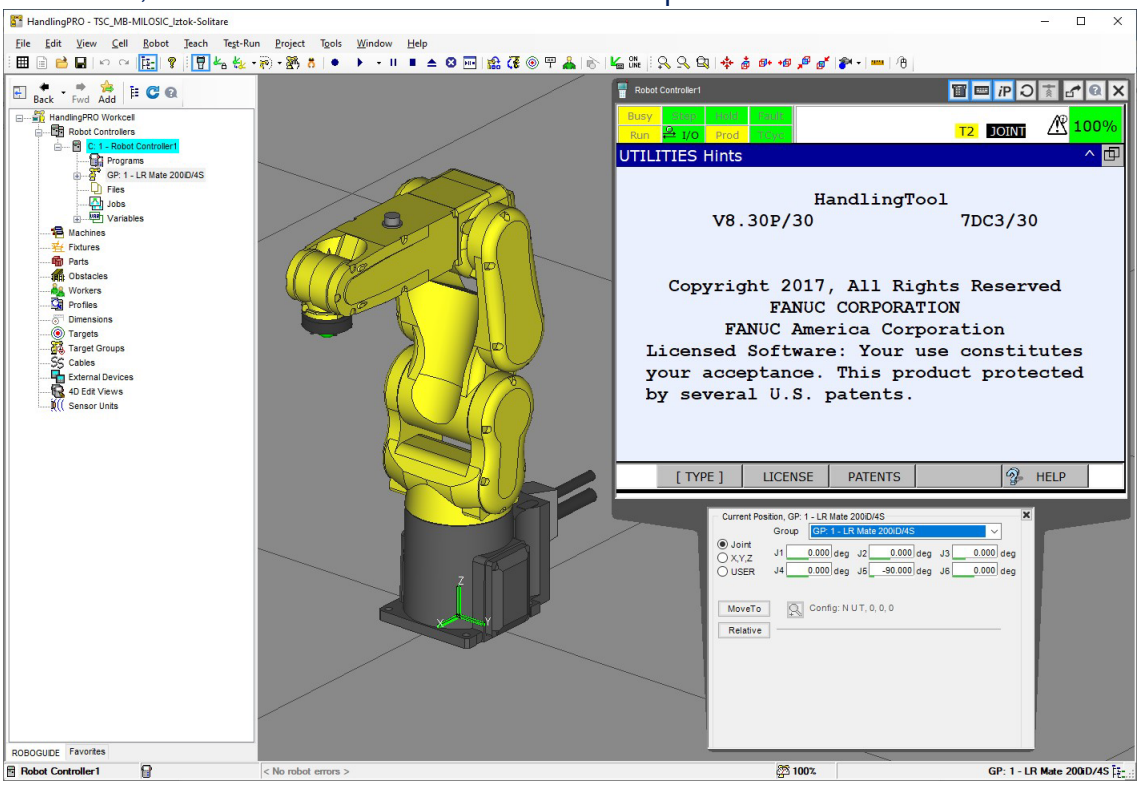
5. You can place the robot directly in any coordinates.
   a. Right-click on the bottom of UE (the gray area from the UE keyboard), a menu will open from which you can select Current Position or
   b. On UE, click the POSN key



- From the Current Position window that appears, ... choose whether you want polar (Joint) or Cartesian (X, Y, Z, or USER) coordinates.

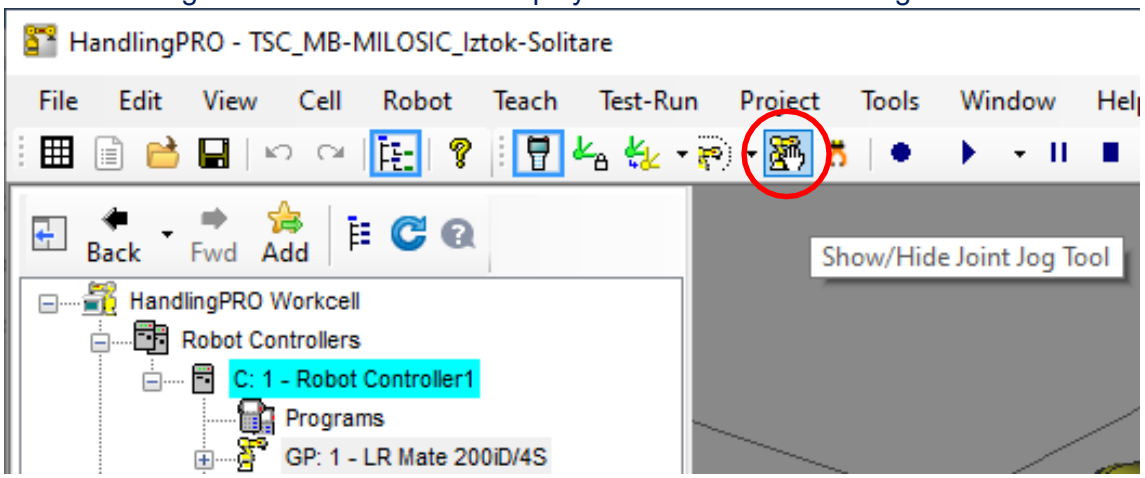


- Select the polar (Joint) coordinates, type J1 = 0°, J2 = 0°, J3 = 0°, J4 = 0°, J5 = - 90°, J6 = 0° and click MoveTo. The robot is placed in the desired coordinates.

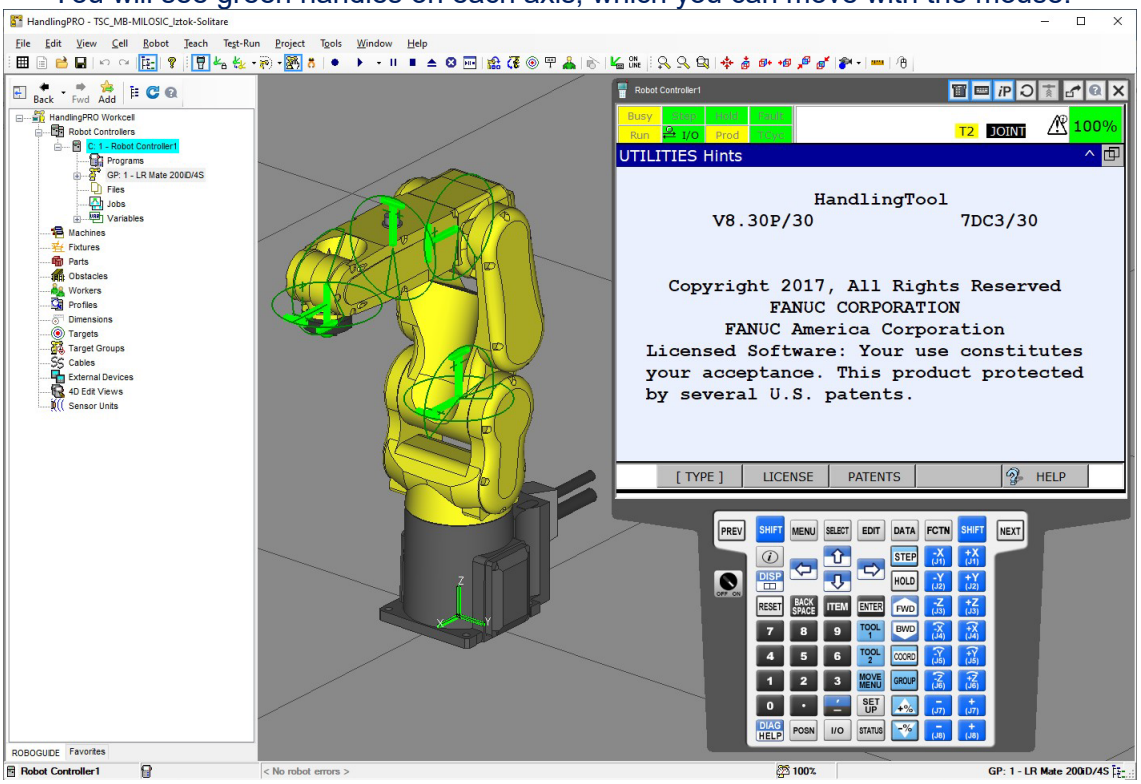


MANUAL GUIDANCE TYPICAL OF RG

1. You can also guide individual axes to display the Show/Hide Joint Jog Tool icon.

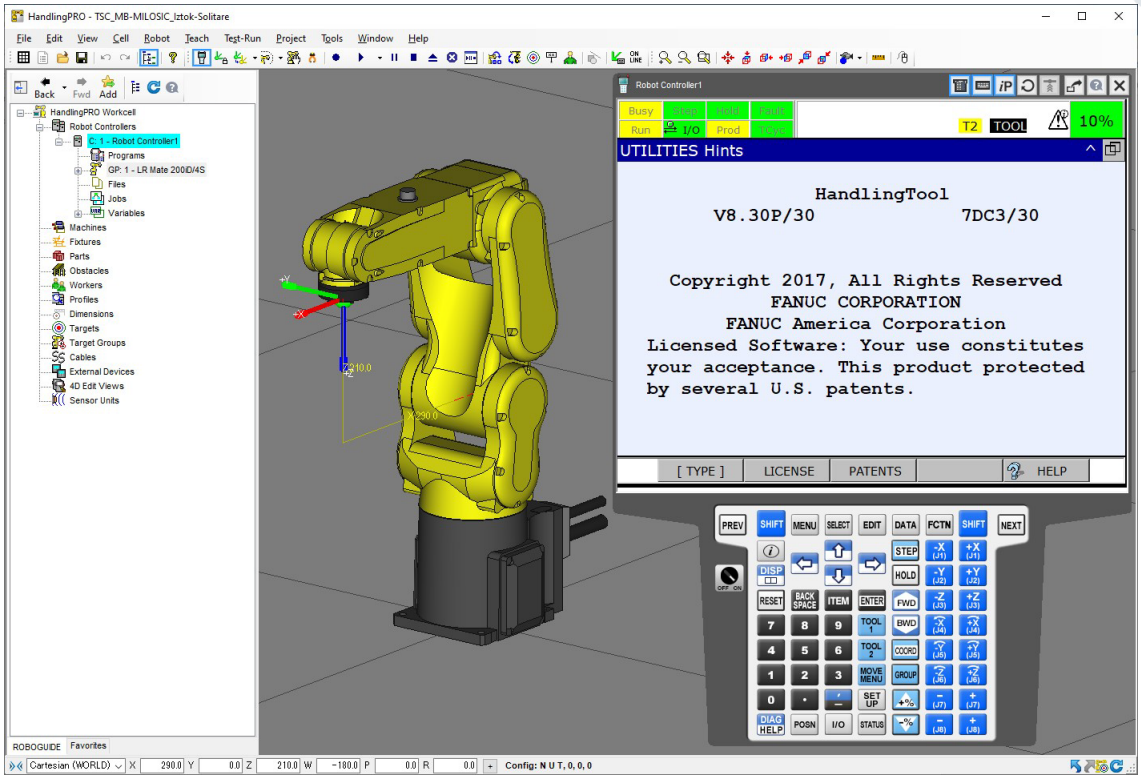


- You will see green handles on each axis, which you can move with the mouse.



- Use the green handles to move all six axes (J1, J2, J3, J4, J5 and J6).

2. You can move the TCP of the robot linearly (Cartesian), click on TCP (green dot) and KS will appear on it. Place the mouse on the desired coordinate axis (X, Y or Z), an icon will appear, click and hold the L button on the mouse and drag in the appropriate direction.

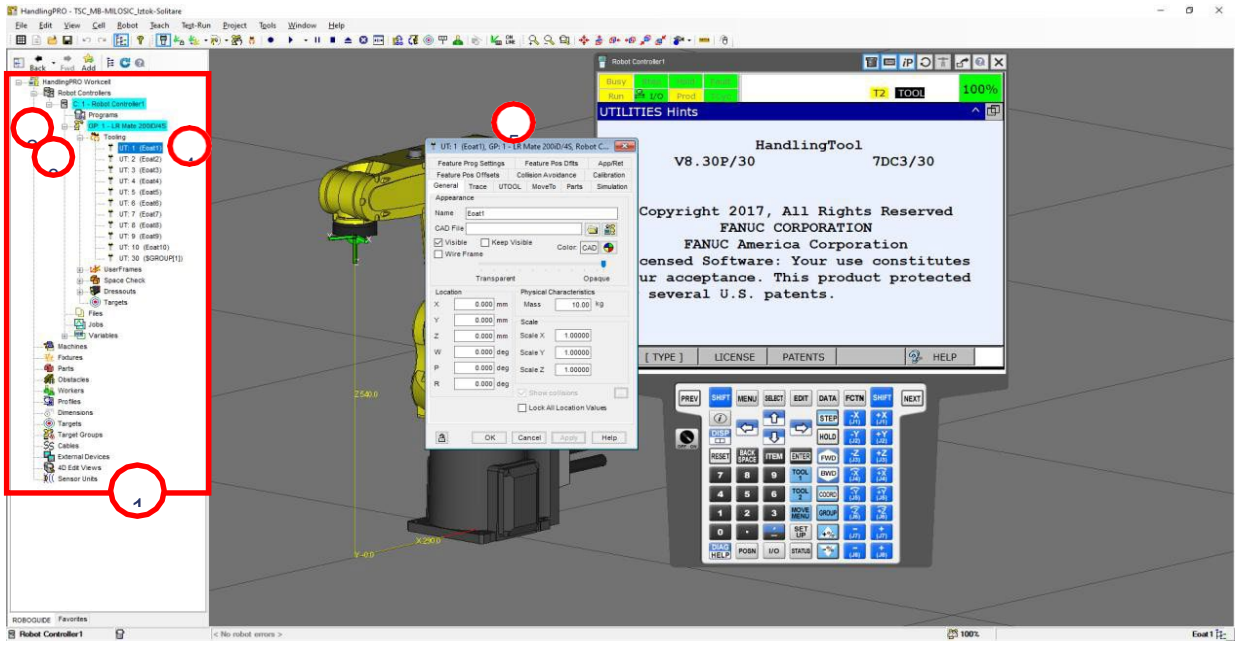


3. You can rotate the tool around TCP, click on TCP (green dot) and KS will appear on it. You have two options:
   - Place the mouse on the desired coordinate axis (X, Y or Z), the icon appears , click and hold SHIFT and the L key on the mouse and drag the mouse in the appropriate direction.
   - Place the mouse at the end of the corresponding coordinate axis, an icon appears, click and hold the L key on the mouse and drag in the appropriate direction.

   Manually guide the robot:
   - Move TCP linearly (Cartesian) along all three axes (X, Y, and Z).
   - rotate the top of the robot (tool) around the TCP around all three axes, X (W), Y (P) and Z (R).

INSTALLING THE TOOL

1. Place the robot in the starting position with the end of the robot facing down (J1 = 0°, J2 = 0°, J3 = 0°, J4 = 0°, J5 = - 90°, J6 = 0°).
2. In the tree structure (1), click on + GP: 1 – LR Mate 200iD/4S (2), click on + Tooling (3) and then double-click on UT: 1 (Eot1) (4) to show you the tool settings window (5).

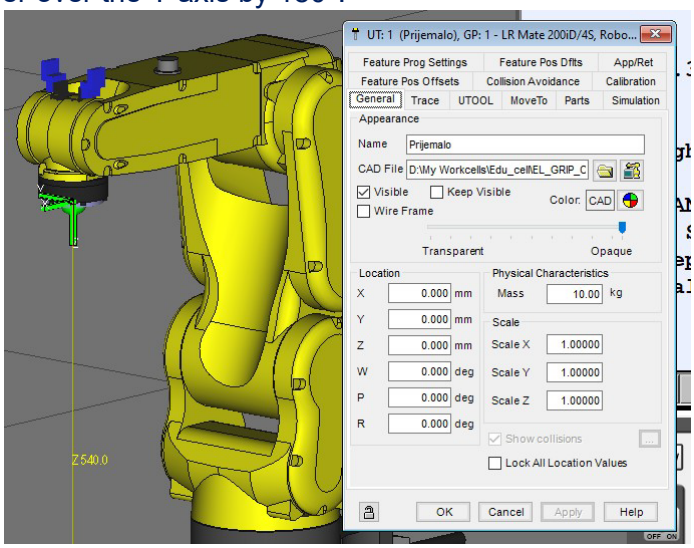


- On the General tab, in the Name box, type a name for the tool, such as Gripper.
- In the CAD File field, click on the icon and find the CAD file named **EL_GRIP_O.igs**. Confirm your selection with Apply.

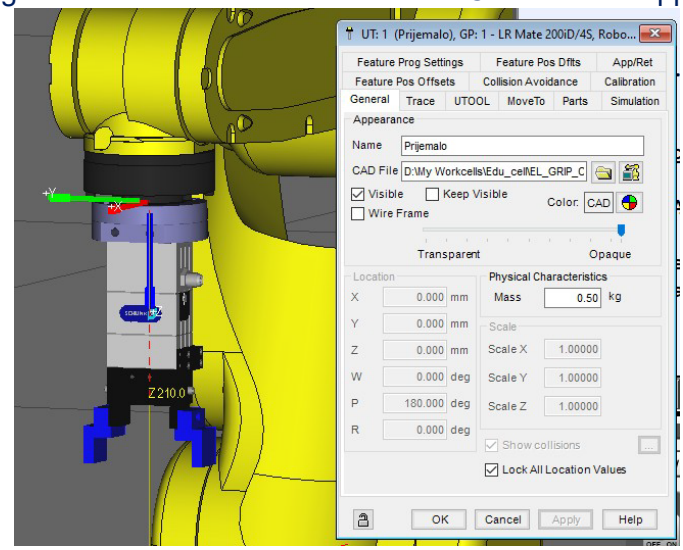
Hint:

- Find the file in the assignment attachment,
- save the file to a folder with your RC,
- The folder with your RC is usually located in the Documents/My Workcells folder...

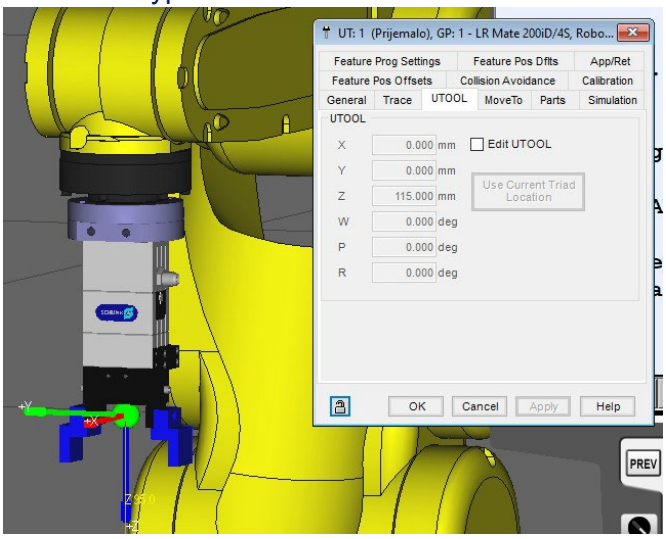
- Since the gripper has a different KS position than the KSO, the gripper is turned inwards and you need to turn it outwards. If you compare the two KS, you can see that you have to turn the gripper over the Y axis by 180°.



- In the Location field, the value of P (rotation around Y), type 180 and confirm with Apply. If necessary, in the Scale, Scale X, Scale Y, and Scale Z fields, you can zoom in or out of the tool to fit the size of the robot.
- In the Mass field, set the mass of the gripper. From the technical data you can see (search online for the SHUNK 40 N-N-B) that the gripper has a mass of 0.32 kg. To this mass you still need to add the mass of your fingers. Thus, a total weight of 0.5 kg can be taken into account for grippers. You can still lock all values before changing them by checking the Lock All Location Values box. Confirm with Apply.

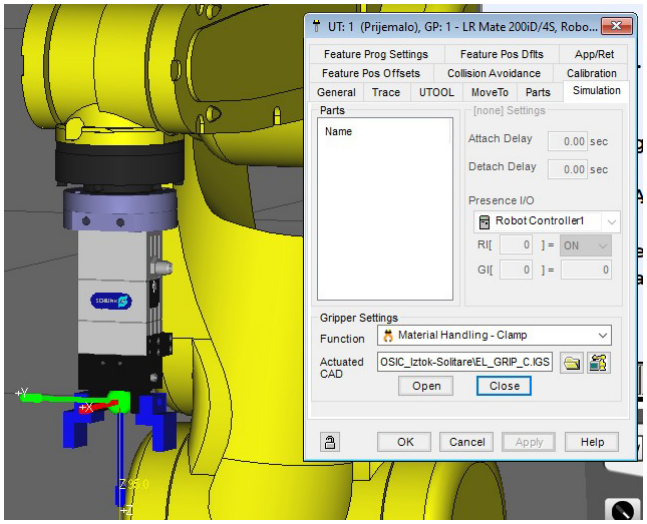


3. You still need to set up TCP to match the gripper. In the receiver settings, open the UTOOL tab. Check Edit UTOOL. Since you will be gripping small objects with the gripper, you can set TCP in the center of the gripper. For larger grippers and workpieces, TCP is better set to one corner of the gripper. This makes it easier to align the object, align the corner with TCP first, and then align the other sides. For our example, move the TCP in the direction of the + Z axis by 115 mm. You type this value in the Z box and confirm it with Apply.



- Use tool rotations to test the correct TCP setup.

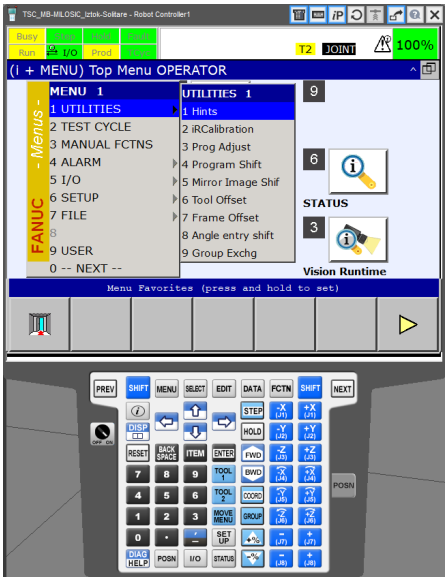
4. To simulate the operation or closing and opening of the gripper, open the Simulation tab in the gripper settings. In the Gripper Settings, Function field, select Material Handling – Clamp and in the Actuated CAD field, select the closed gripper CAD file **EL_GRIP_C.igs**. Confirm your selection with Apply.
   Hint:
   - Find the file in the assignment attachment,
   - save the file to a folder with your RC,
   - The folder with your RC is usually located in the Documents/My Workcells folder... Check the gripper simulation using the Open/Close buttons.

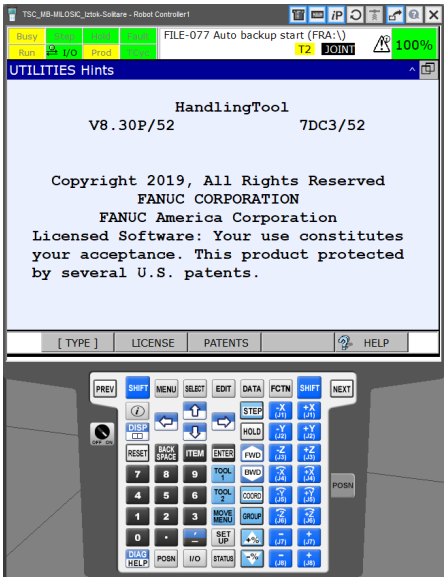


   Close the receiver settings window with OK. You can also check the grip by clicking on the Open/Close Hand icon  .

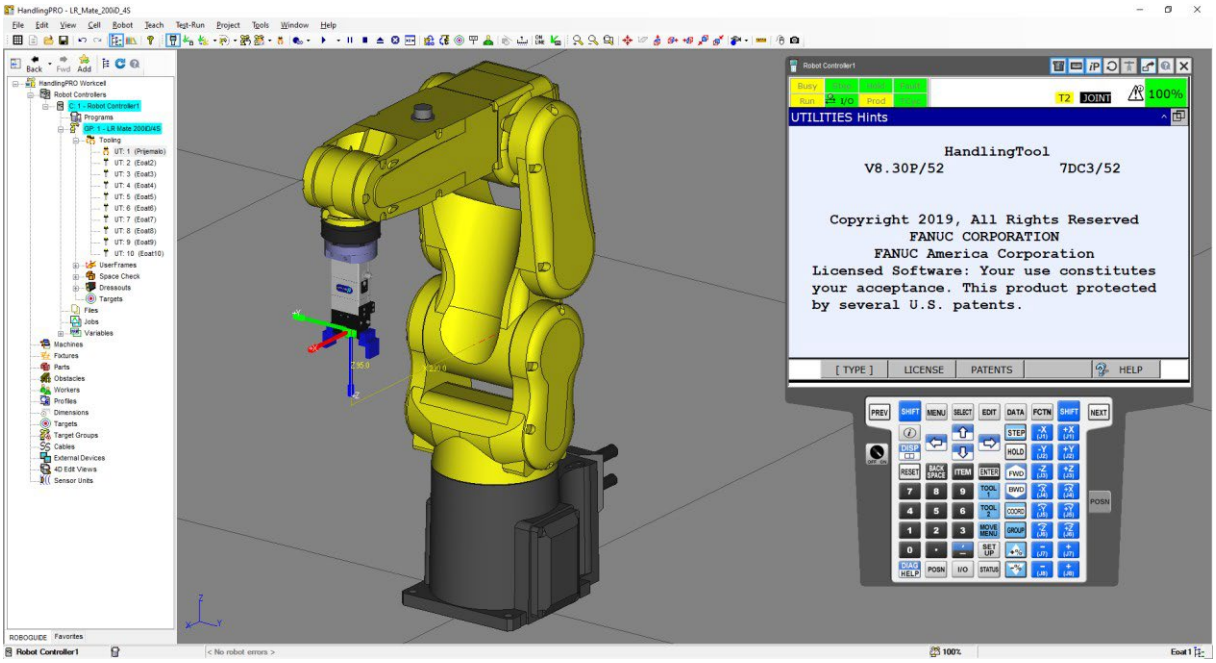
DISPLAY OF THE UTILITIES HINTS SCREEN WITH THE UE VERSION OF THE SOFTWARE

On UE, click MENU/1 UTILITIES/1 Hints. The HandlingTool, V8.30 window appears...



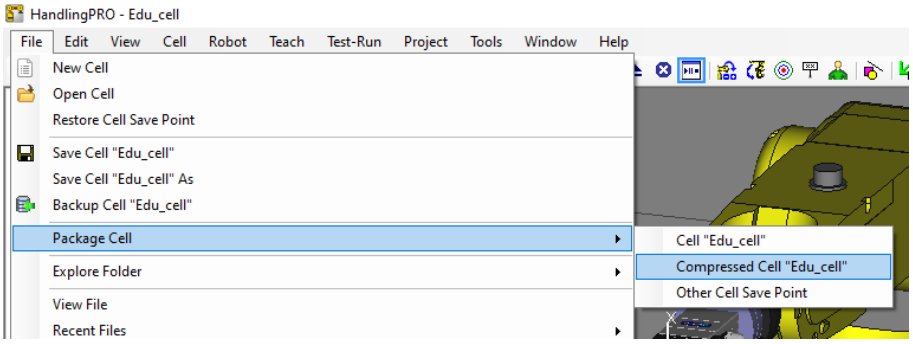


EXAMPLE OF RC DISPLAY FOR BROADCAST

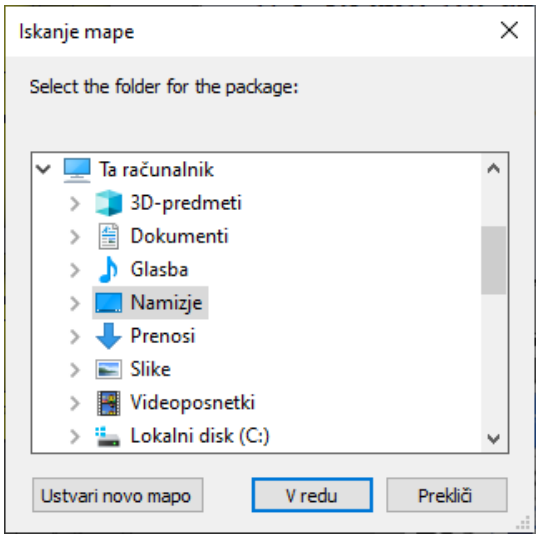


BACK UP YOUR FILES OR SAVE YOUR WORK

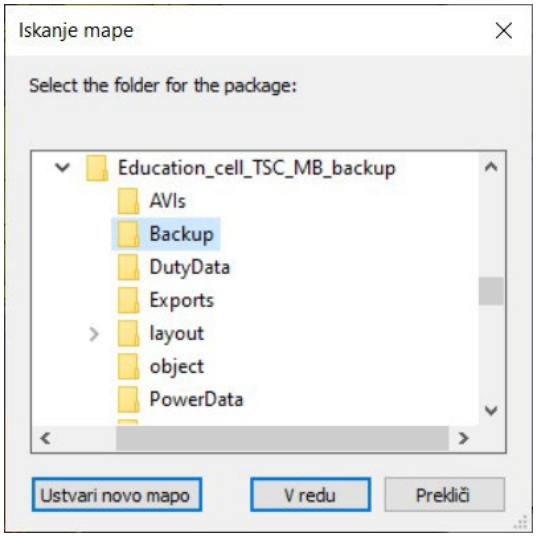
Back up the robot cell in RoboGuide, select the command File/Package Cell/Compressed Cell ...



The Folder Search window appears, in which you select the folder where you want to save the RC backup.

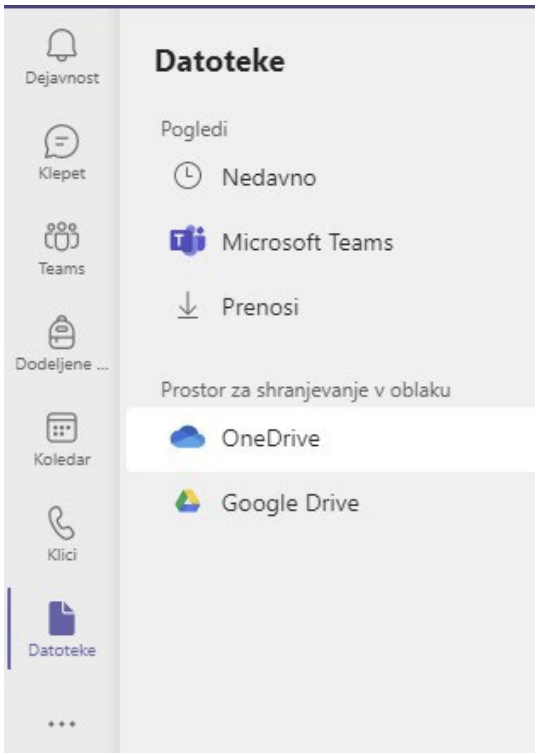


Save the backup to the folder with the contents of your RC. In the Search Folder window, find your folder. As a rule, the folder is located in **D:/My Workcells/Ime_vase_robotske_celice**. Create a new folder in your folder named **Backup** (click on the Create New Folder button and type the name **Backup** and confirm with ENTER). To make a backup, click on the OK button.



The RC backup is saved as a compressed file, of type *.rgx. Use the explorer to go to the D:/My Workcells/Ime_vase_robotske_celice/Backup folder and rename the backup sensibly by adding a date at the end of the name (e.g. **Ime_vase_robotske_celice-2021_11_**21.rgx). This will give you your own backup for each appointment.

Save your backups to your computer or to your OneDrive cloud that you have in your Microsoft Office environment. You can also access it with MST.



You can transfer files from the remote to your computer and from your computer to the remote computer by using the Windows Copy and Paste function.

TRANSFER FILES FROM A REMOTE COMPUTER TO YOUR COMPUTER AND VICE VERSA USING THE WINDOWS FUNCTION (RECOMMENDED)

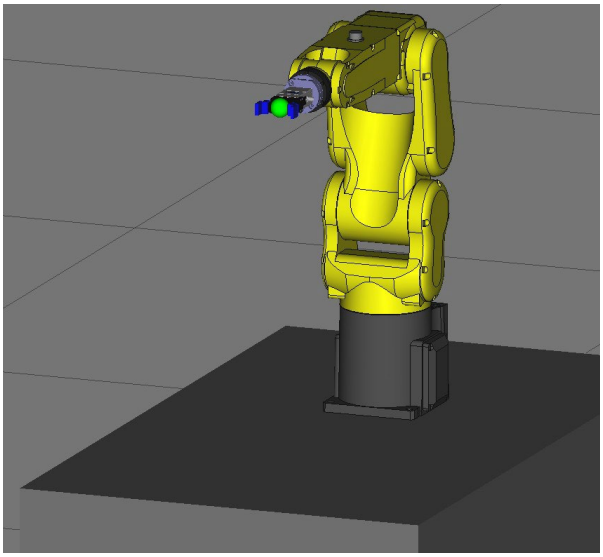
To copy files, open File Explorer remotely and on your computer and use Windows Copy & Paste to copy files on both sides.

ADDITIONAL VIDEO INSTRUCTION

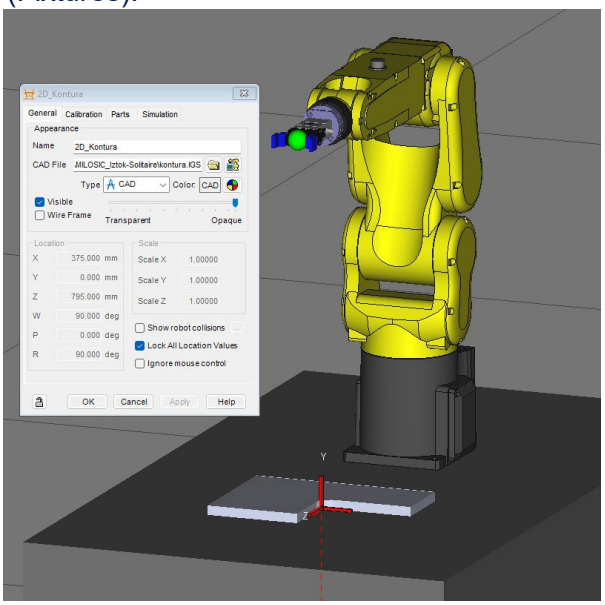
1. WILLEA, Adam: FANUC Roboguide Tutorial, available at: https://www.youtube.com/watch?v=neAFHplKu-Y, used: January 2021.

EXERCISE 2: CONTOUR OF THE LOOP

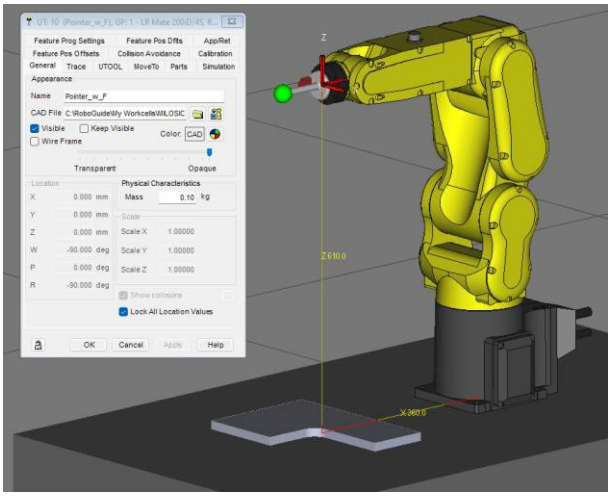
1. Hide elements, obstacle, panel.

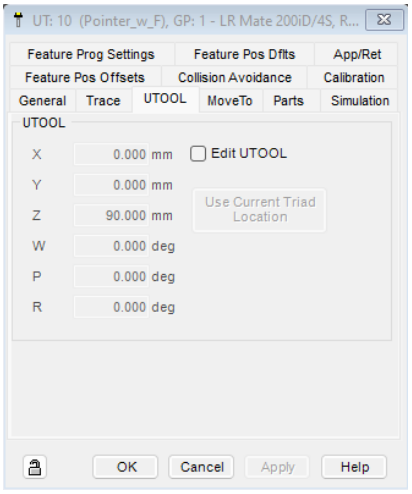


2. Insert a 2D contour (Fixtures).



3. Install the tool tip with the flag at number 10.





4. Create an application in which the tool will follow the outer contour, with the tool flag always located on the inside of the contour. Divide the application into a main program and a subprogram.
    a. In the CONTOUR subroutine, you have only the points that are located on the contour. You name the points T1, T2 ...
    b. Everything else is in the main program KONTURA_G.
5. Copy the main program to KONTURA_G_NESK and change it so that the tool repeats the contour an infinite number of times.

```
12:   !Zacetek ponavljanja
13:   LBL[1:ZANKA]
14:
15:   !Kontura
16:   CALL KONTURA
17:
18:   !Konec ponavljanja
19:   JMP LBL[1]
```

6. Copy the main program to the KONTURA_G_POGOJ_DI and change it so that the tool repeats the contour as long as the switch connected to digital input 102 is turned on.

```
12:   !Zacetek ponavljanja 5 x
13:   LBL[1]
14:
15:   !Kontura
16:   CALL KONTURA
17:
18:   !Konec ponavljanja
19:   IF DI[102]=ON,JMP LBL[1]
```

7. Copy the main program to KONTURA_G_IF_5_X and change it so that the tool repeats the contour for 5 ×. Do the repetition with an IF clause.

```
12:   !Postavitev stevca in
13:   !zacetek ponavljanja 5 x
14:   R[1:Stevec]=1
15:   LBL[1]
16:
17:   !Kontura
18:   CALL KONTURA
19:
20:   !Konec ponavljanja
21:   R[1:Stevec]=R[1:Stevec]+1
22:   IF R[1:Stevec]<=5,JMP LBL[1]
```

8. Copy the main program to KONTURA_G_FOR_5_X and change it so that the tool repeats the contour for 5 ×. Do the repetition with the FOR clause.

```
12:   !Zacetek ponavljanja 5 x
13:   FOR R[1:Stevec]=1 TO 5
14:
15:   !Kontura
16:   CALL KONTURA
17:
18:   !Konec ponavljanja
19:   ENDFOR
```

EXERCISE 2A: PREPARING THE ROBOT CELL FOR PROGRAMMING IN THE ROBOGUIDE SIMULATION PROGRAM

In this tutorial, you'll use the RoboGuide simulation program:

- prepare a robotic cell for programming:
  - set up the base of the robot,
  - inserted a Solitaire panel,
  - put up an obstacle,
  - set up rollers to simulate movement on the Solitaire board and in the gripper.

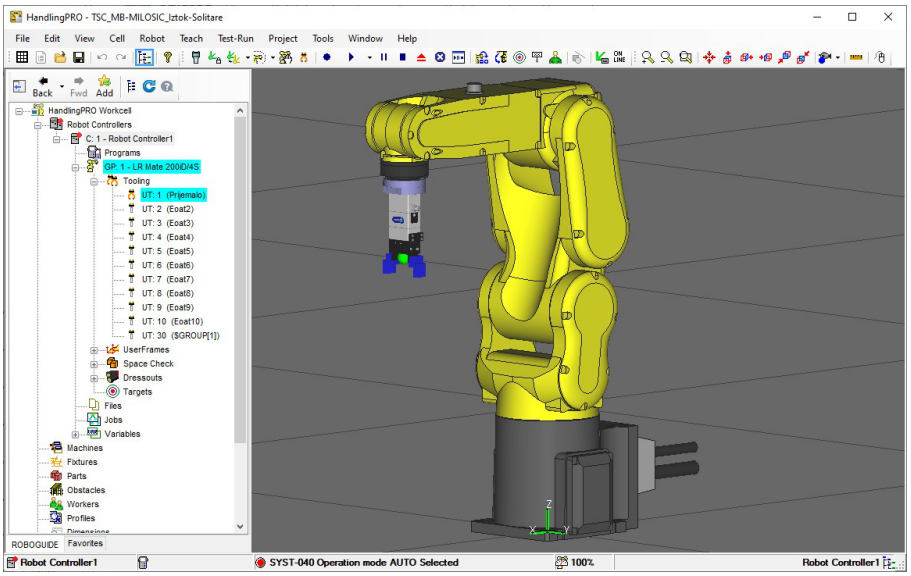
When the exercise is complete, submit the files:

- screen image (pdf, doc ... appropriately oriented) of its robotic cell from which it can be seen:
  - the name of the robotic cell,
  - all RC elements (robot, gripper, pedestal, plate, obstacle, rollers...) on the panel must be visible both halves – L and D from the obstacle) and placed in the middle of the RG screen in full size – across the entire screen, and
  - the included learning unit placed on the right side of the screen, on which the UTILITIES Hints – MENU/1 UTILITIES/1 Hints screen with software version V8.30) should be visible, and
- a backup of a robot cell, of the *.rgx type, made in RoboGuide.

All submitted files must have meaningfully the same names as the name of the robot cell, only the backup copy must have a creation date at the end of the name in the form -YYYY_MM_DD.

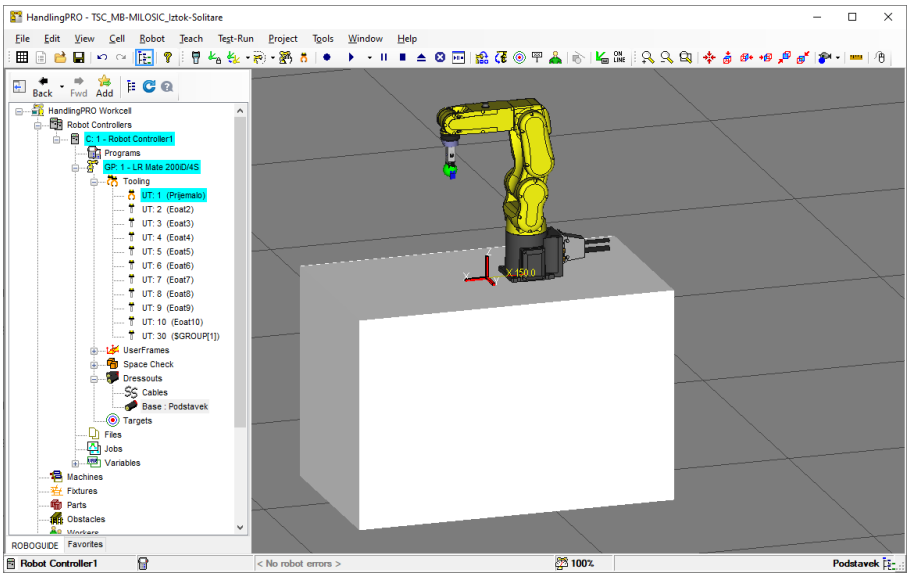
PLACEMENT OF ELEMENTS IN RC

A prerequisite for starting this exercise is that you have a basic RC, with an appropriate robot and gripper, and a properly set gripper (TCP) – see the figure below.



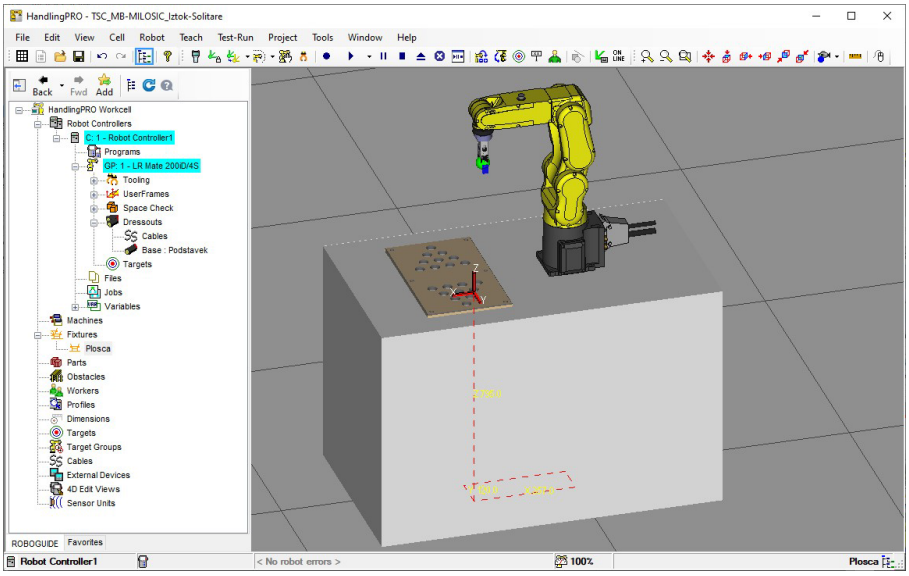
TO ADD A COASTER:

1. On the tree structure, right-click on GP: 1: - LR Mate 200iD/4S -> Add Dressout/Base/Box, place the pedestal.
2. In the Name box, type the name Pedestal.
3. In the Scale field, set the base size, XYZ: 1200 mm, 700 mm, 795 mm, and confirm with Apply and OK. You can't see the pedestal because the robot is on the floor.
4. Raise the robot by the height of the base, double-click on the robot and set the height Z 795 mm in the Location field, and lock the location, Lock All Location Values, confirm with Apply and OK.
5. Place the robot on the pedestal 150 mm back, double-click on the base, enter the value X 150 mm in the Location field and lock the location of the pedestal, Lock All Location Values and confirm with Apply.
6. Select gray, confirm with Apply and OK.



TO ADD A PANEL TO A PEDESTAL:

1. You will add an already drawn panel from a CAD file. In the tree structure, right click on Fixture/Add Fixture/Single CAD File, select the file named SolitairTrayT4_1.csb.
   Hint:
   - Find the file in the assignment attachment,
   - save the file to a folder with your RC,
   - The folder with your RC is usually located in the Documents/My Workcells folder...
2. In the Name field, type a name: Board.
3. In the Location field, set the location of the plate on the base, XYZ: 357mm, 120mm, 795mm, lock the location of the panel, Lock All Location Values, confirm with Apply and OK.

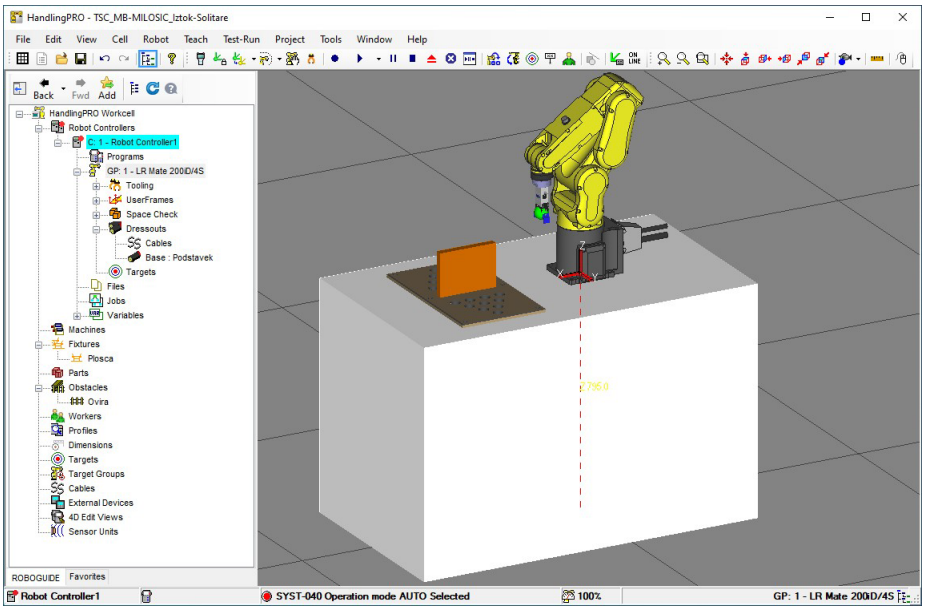


TO ADD AN OBSTACLE:

1. On the tree structure, right-click on Obstacle/Add Obstacle/Box to add an obstacle.
2. In the Me field, enter a name: Obstruction and set it to orange/brown.
3. In the Scale field, set the size XYZ: 200 mm, 25 mm, 150 mm.
4. In the Location field, place the obstacle on the base, XYZ: 410 mm, 0 mm, 957 (795 + 12 + 150) mm, lock the location of the obstacle, Lock All Location Values, confirm with Apply and OK.

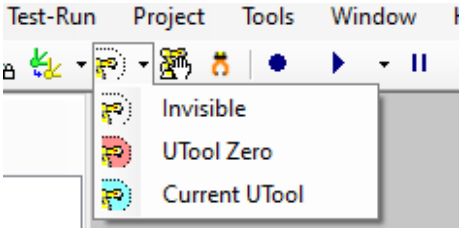
TO ADD A PRODUCT:

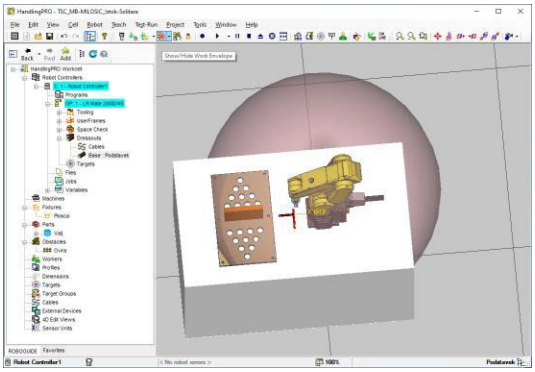
1. On the tree structure, right-click on Parts/Add Parts/Cylinder to add a cylinder shaped product.
2. Set Name: Cylinder, Weight: 0.1kg, Size Diameter: 25mm, Height 40mm, White color, confirm with Apply and OK.
3. We zoom out of the RC view to see if we have a cylinder in place. Leave the cylinder in a remote place and zoom in on the view.

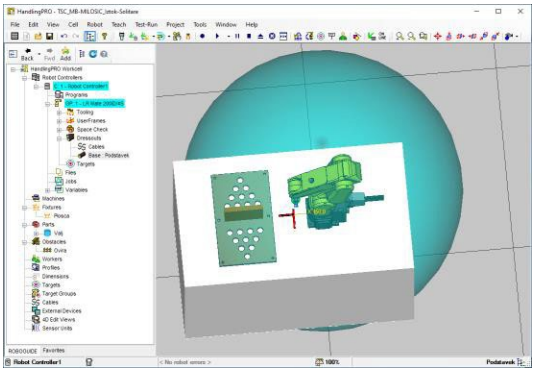


With the Show/Hide Work Envelope button, you can view the workspace or the range if the gripper reaches our space:

- Invisible – hide the workspace,
- UTool Zero – show the workspace with the default tool (on the flange of the robot),
- Current UTool – Show the workspace with the active tool set.







If the workspace matches, hide the workspace, Invisible.

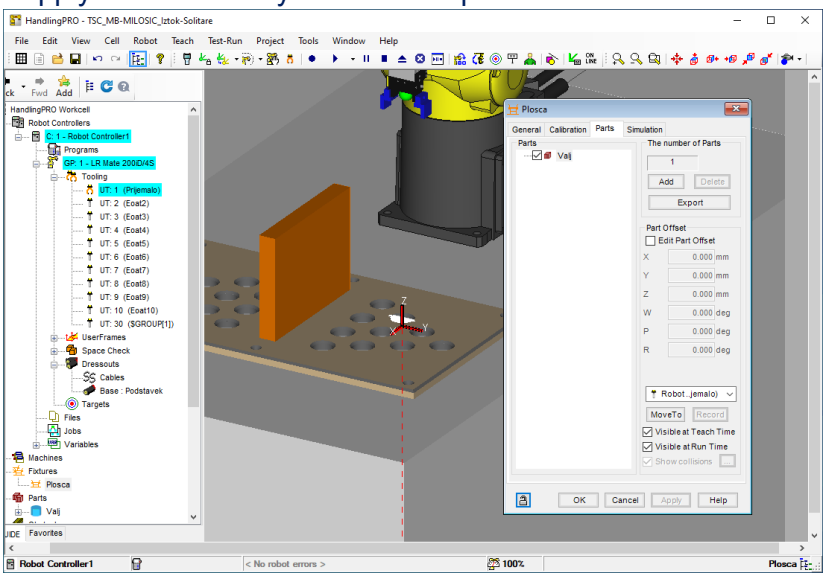
SETTING UP THE ROLLER FOR THE PICK & PLACE APPLICATION (SIMULATION)

In RG, we don't actually move objects, but we simulate the movement of objects; This means showing/hiding them at the right time in a certain place.

Therefore, you need to set up two rollers on the board, one for picking up, the other for dumping, and set the right parameters for them, when they are shown/hidden and how long they are shown/hidden. Also in the grip it is necessary to set when it is shown/hidden in the grip.

ROLLER SETTINGS TO BE PICKED UP

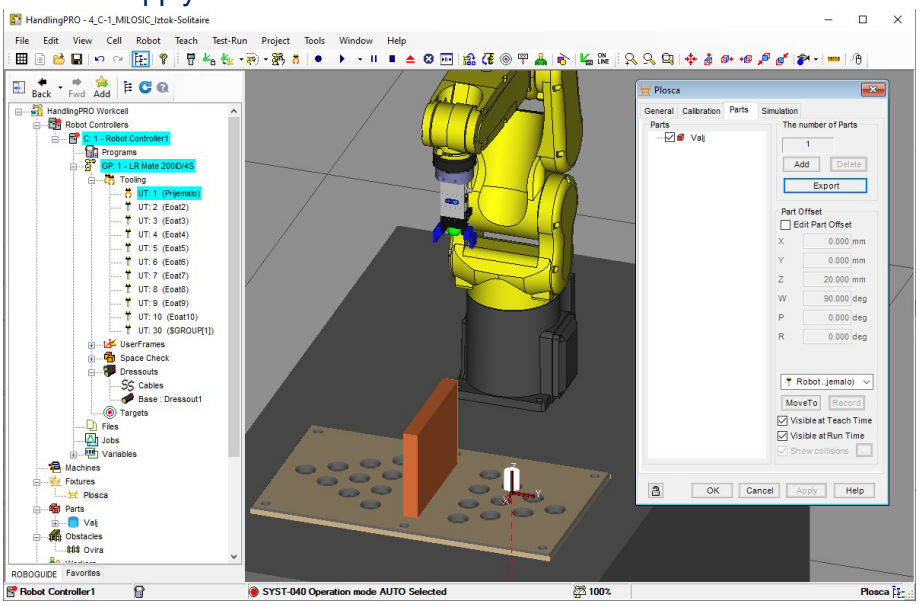
1. Double-click on the panel, the Parts tab, check the Cylinder with the check mark, confirm with Apply and see the cylinder on the panel.



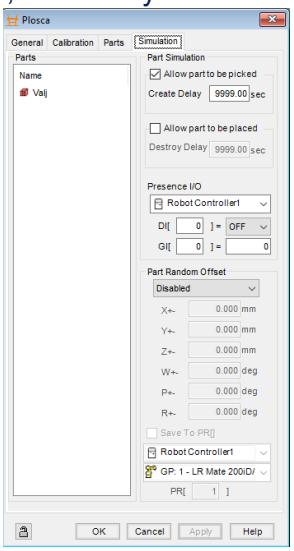
2. Place the roller in the desired place with the desired orientation. In the Part Offset box, check Edit Part Offset and type the values XYZWPR: 0, 0, 20, 90, 0, 0, confirm with Apply.
3. Since you want the Cylinder you are picking up to be visible during the learning and execution of the program, check the following:

a. Visible at Teach Time,
b. Visible at Run Time

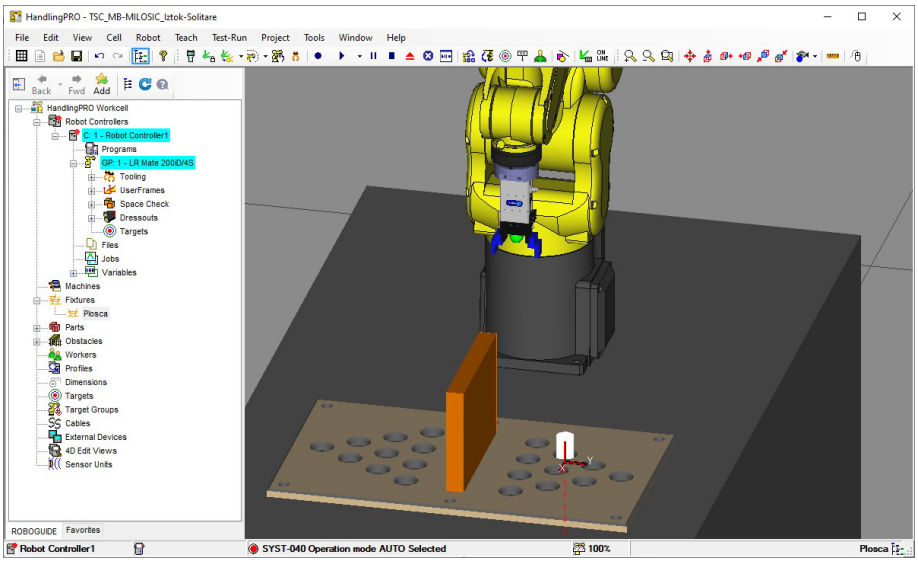
and confirm with Apply.



4. In the Simulation tab:
   a. check Allow Parts to be picked up – enable the cylinder to be picked up and type Create Delay 10.00 s – the time before the cylinder appears before the pick command.
   b. tick Allow Parts to be placed, because you won't be putting this cylinder down.

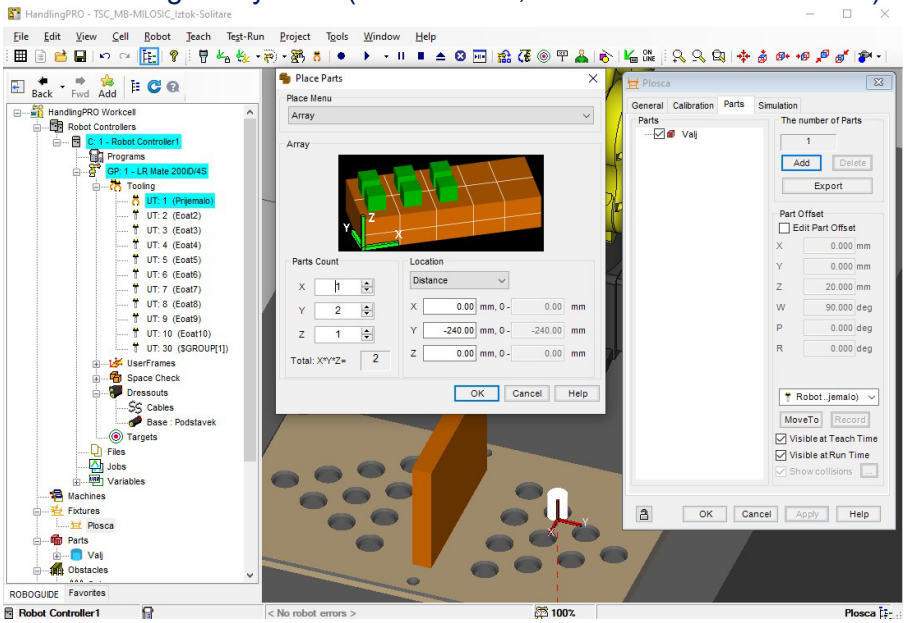


Confirm with Apply and OK.

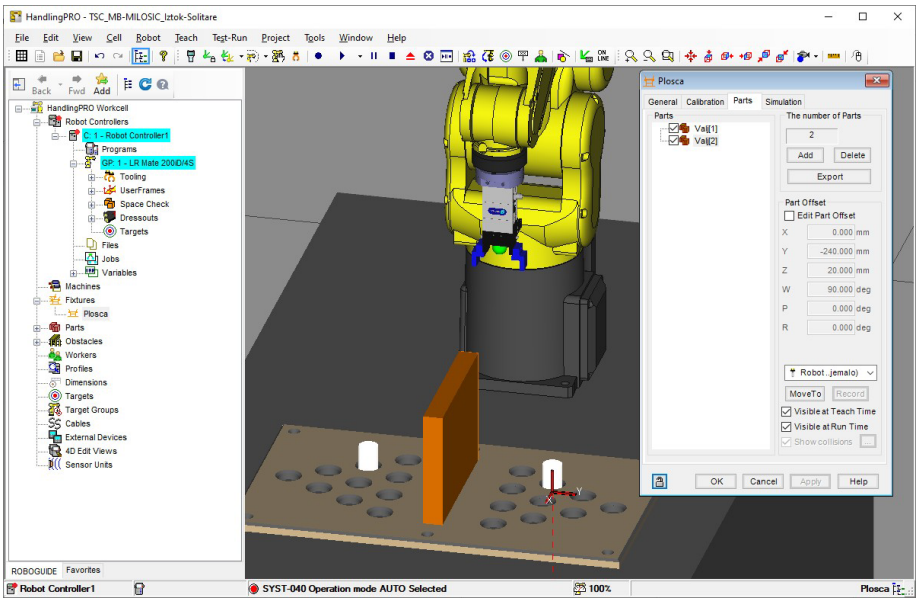


SETTINGS OF THE CYLINDER TO BE DEPOSITED

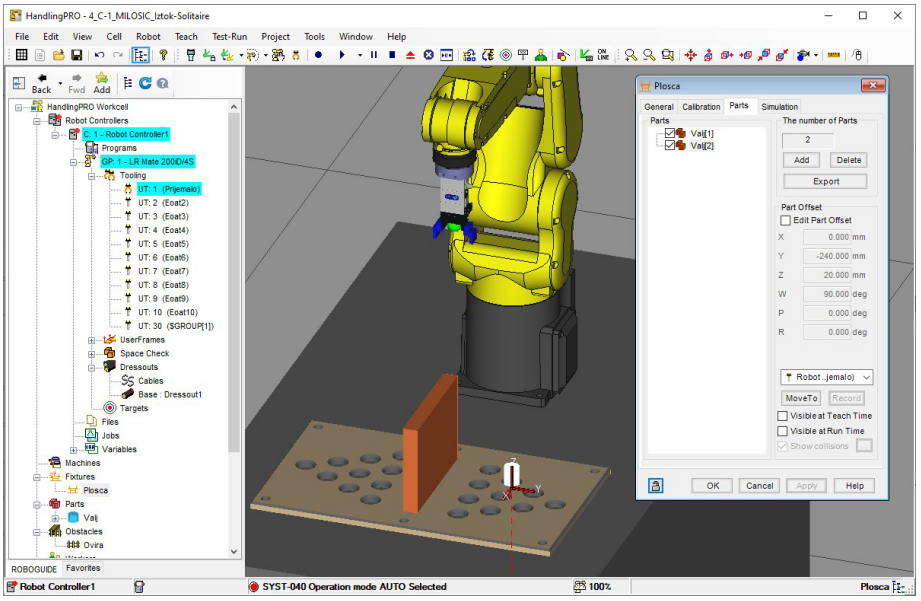
1. Double-click the panel, the Parts tab, in the The number of Parts box, click Add.
2. The Place Parts window appears. In it, set that you want another cylinder in the Y direction (in the Parts Count field, set the Y value to 2). In the Location field, set the distance from the original cylinder (in the Y field, set the value to – 240 mm).



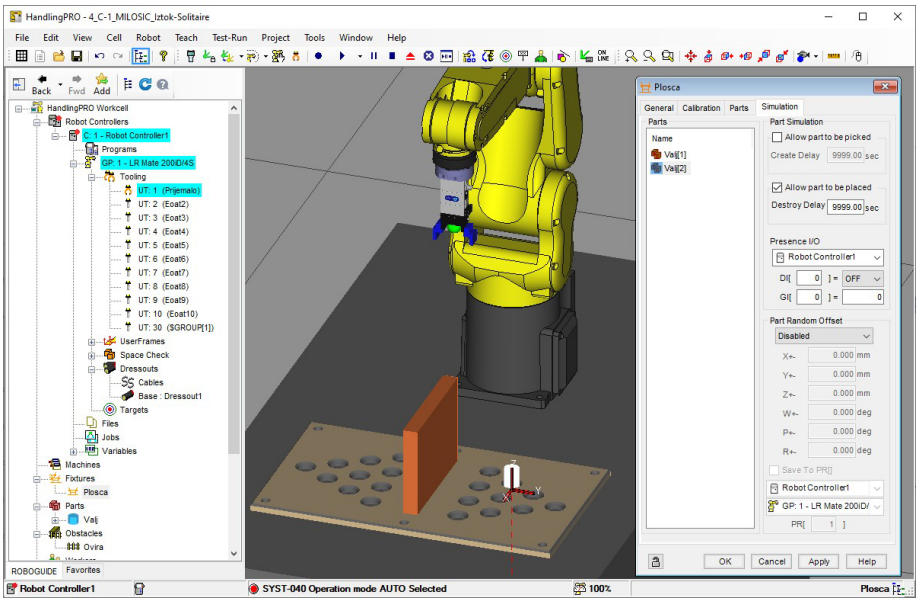
Confirm with OK.



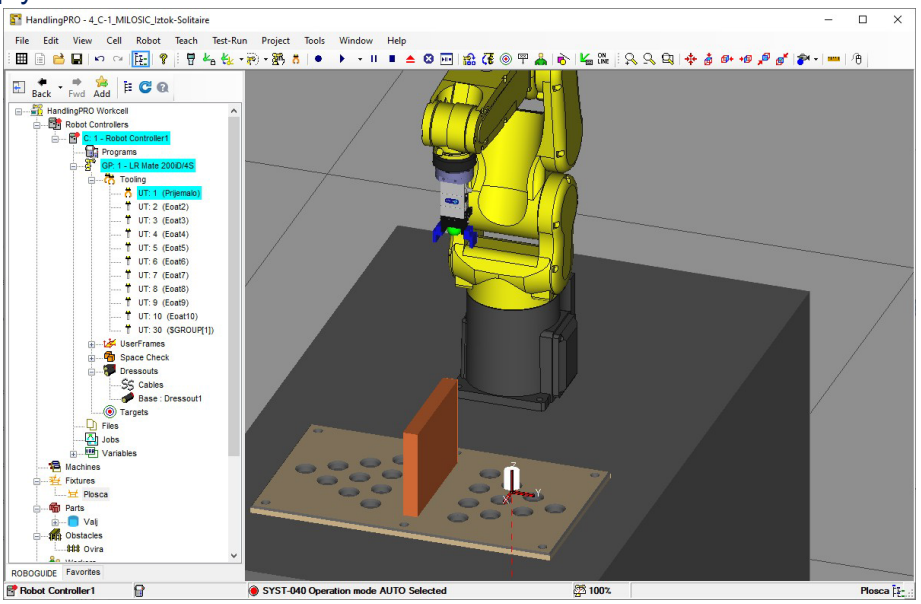
3. Place the cylinder[2] in the desired location with the desired orientation. In the Panel window, on the Parts tab, click Cylinder[2], and in the Part Offset box, check Edit Part Offset, and then type the appropriate values for XYZWPR. For our example, the Cylinder[2] is already standing in the appropriate place.
4. Since you want the Roller you are depositing not to be visible during the learning and execution of the program, but only after dumping, tick off:
    a. Visible at Teach Time,
    b. Visible at Run Time and confirm with Apply.



5. On the Simulation tab, in the Parts field, click on Cylinder[2] and set:
    a. tick Allow Parts to be picked – disable because you won't pick up this cylinder.
    b. check Allow Parts to be placed – allow the cylinder to be delayed and enter Destroy Delay 10.00 s – the time for which the cylinder is displayed after it has been delayed.

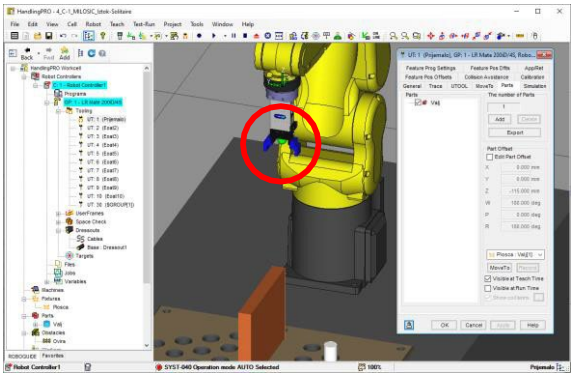


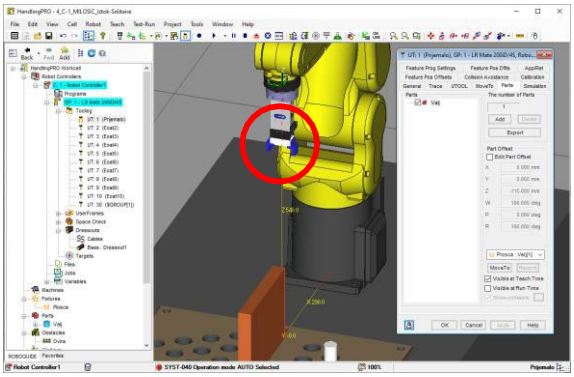
Confirm with Apply and OK.



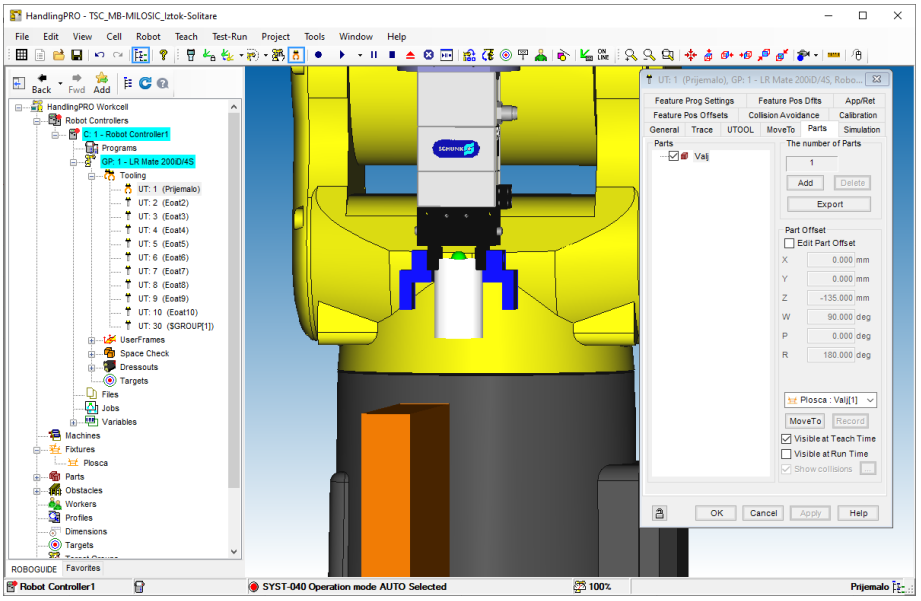
CYLINDER SETTINGS IN THE GRIPPER

1. Double-click on the handle, on the Parts tab, check Cylinder and confirm with Apply.
2. Check the gripper close/open icon  to see if the cylinder is displayed when the gripper is closed and if it is invisible when it is opened.

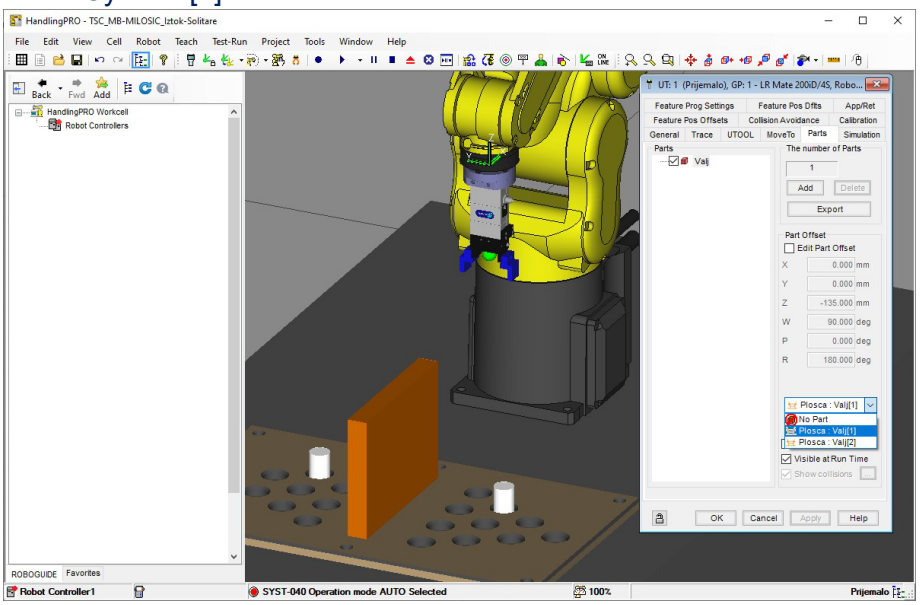




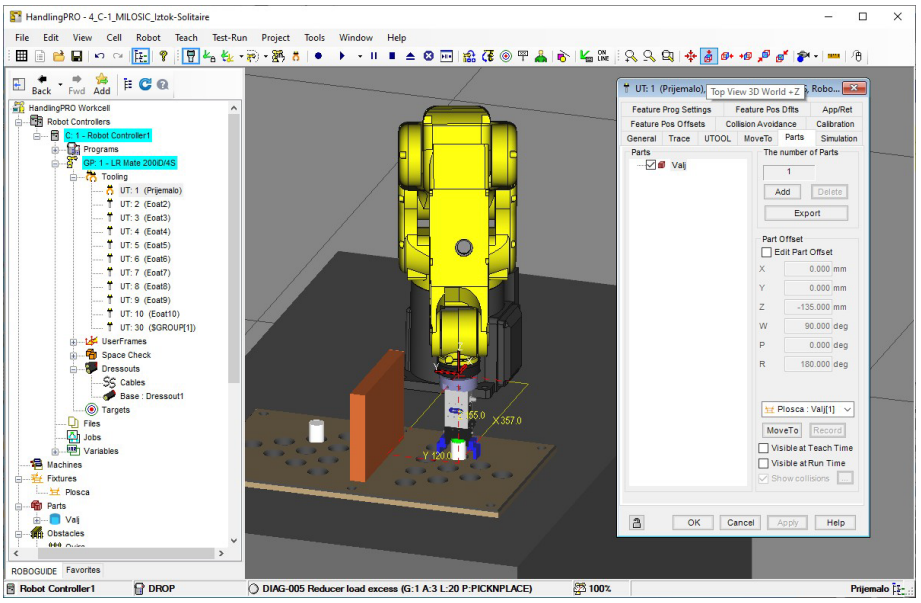
3. The cylinder is not properly positioned in the gripper, so you need to correct its location and orientation accordingly. In the Part Offset field, set the location and orientation of the cylinder and set the XYZWPR values: 0, 0, -135, 90, 0, 180.
4. Check the gripper close/open icon  to make sure that the cylinder is positioned correctly.



5. Check that the tool is properly positioned when picking up or putting down the roller. In the Parts tab, select which Cylinder you want to check on from the drop-down menu. Select Panel: Cylinder[1].

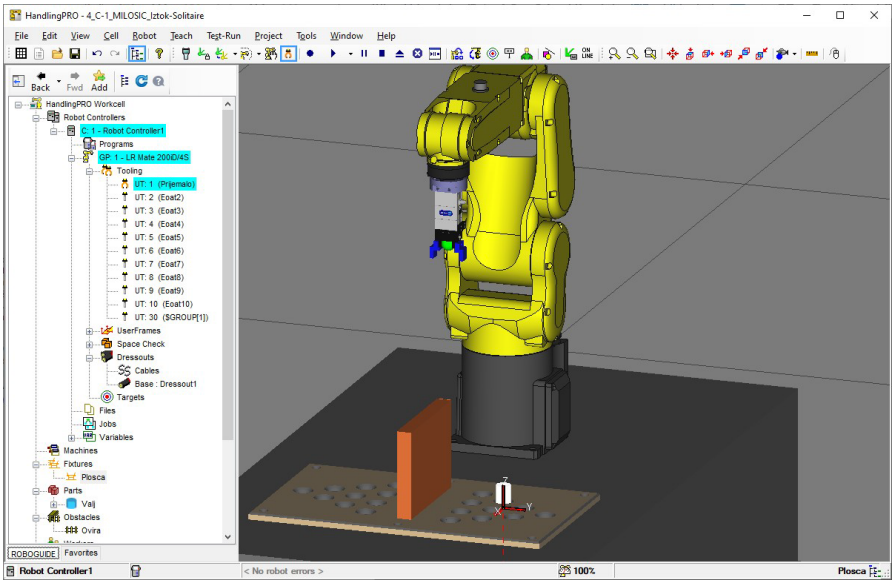


Click MoveTo and the robot will move to the selected product.

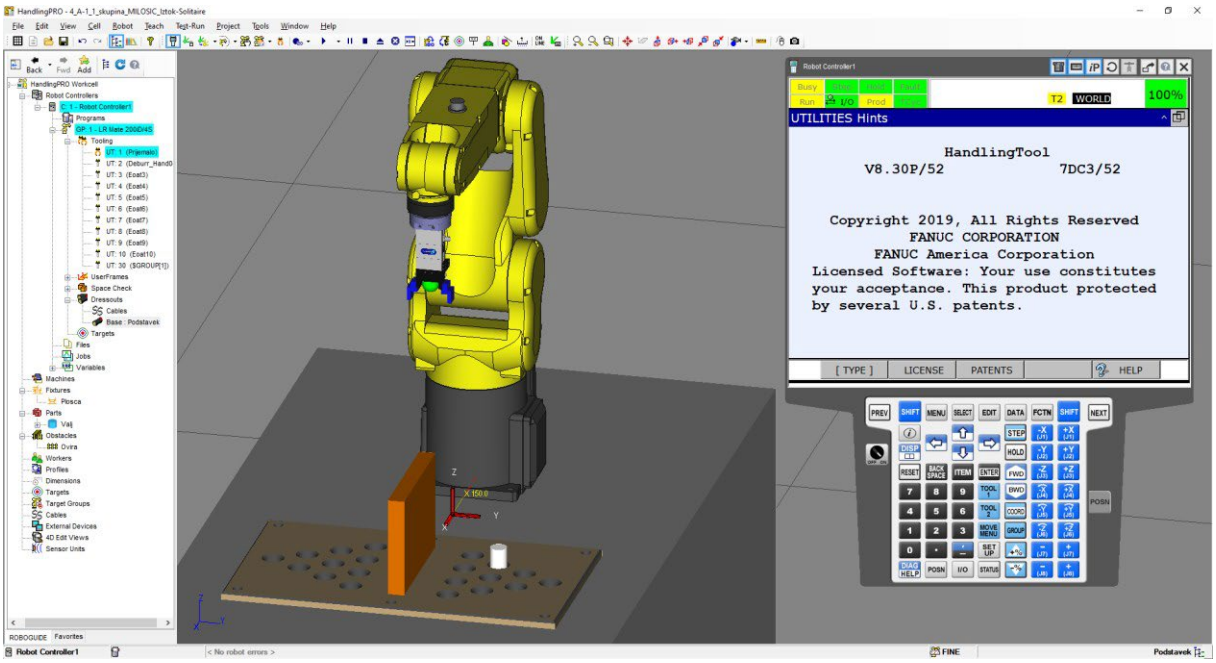


If the tool is not positioned correctly (location and orientation), correct the location and orientation in the Part Offset / Edit Part Offset field.

6. Check that the tool is positioned correctly, also for the rest of the rollers. Repeat the procedure indicated in the previous point.
7. Tick Visible at Teach Time so that the cylinder is not displayed during programming (learning) and tick Visible at Run Time so that the cylinder is not displayed during program execution. Confirm with Apply and OK.



EXAMPLE OF RC DISPLAY FOR BROADCAST



ADDITIONAL VIDEO INSTRUCTION

1. WILLEA, Adam: FANUC Roboguide Tutorial, available at: https://www.youtube.com/watch?v=neAFHplKu-Y, used: January 2021.

EXERCISE 2B: LEARNING (PROGRAMMING) AN INDUSTRIAL ROBOT IN THE ROBOGUIDE SIMULATION PROGRAM AND TRANSFERRING THE PROGRAM TO A REAL ROBOT

In this tutorial, you'll use the RoboGuide simulation program:

- developed a program for picking and unloading the cylinder (Pick & Place),
  - TF = 1 and UF = 1 were used,
  - enter a meaningful description of the program (comment) in the program details,
  - make meaningful comments about the robotic program and write the author(s) in the first lines
  - the robot starts at the starting point (J1 = 0°, J2 = 0°, J3 = 0°, J4 = 0°, J5 = 0° and J6 = 0°) and finally returns here,
  - use J, L and C movements and point termination (FINE/CNT) sensibly,
  - name all points sensibly (HOME, APP, RT, PICKUP, DROP, VIA ...),
  - use a maximum speed of 50% in free movements; however, in the case of Cartesian movements, the empty gripper moves in/from the pick-up/unloading point at a speed of 200 mm/s and the full gripper at 100 mm/s,
  - set the general speed of the program (override) to 50%,
  - rearrange the programme as the main programme and meaningful sub-programmes;
  - tested in T1/T2 mode of operation
  - optimize the operation of the program (shorter cycle of operation without collisions, continuous and smooth movement of the robot without unnecessary stopping ...) and
  - run the program in AUTO mode, and
- on a real robot:
  - transfer a proven program from the RoboGuide simulation environment to a real robot,
  - test the program in T1/T2 mode, and
  - run the program in AUTO mode.

When the exercise is complete, submit the files:

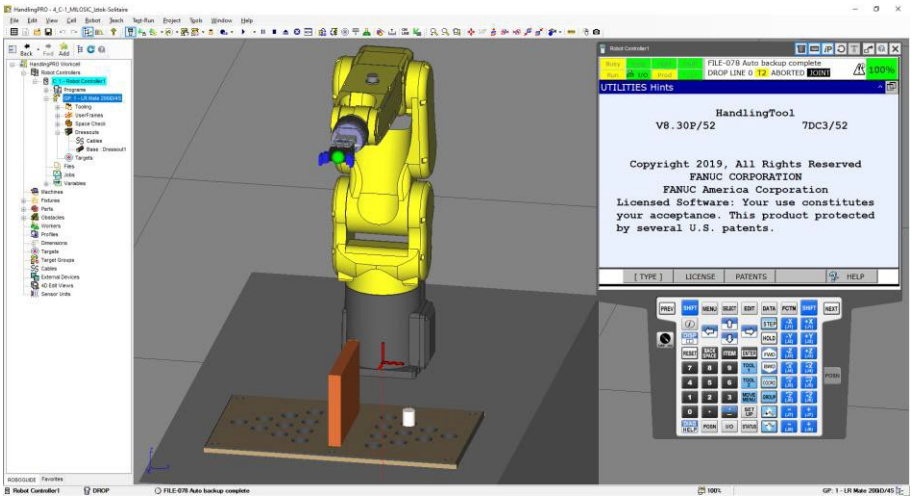
- a scanned and handwritten report on the completed exercise (PDF type – all pages in one document, orientation of the portrait document, pages arranged in order from 1 onwards),
- screen image (pdf, doc ... appropriately oriented) of its robotic cell from which it can be seen:
  - the name of the robotic cell,
  - all RC elements (robot, gripper, pedestal, plate, obstacle, rollers...) on the panel must be visible both halves – L and D from the obstacle) and placed in the middle of the RG screen in full size – across the entire screen, and
  - the included learning unit placed on the right side of the RG screen,
  - the full code of the program and all subroutines used (except the gripper closing and opening subprograms) – divide the UE screen into three (3) parts and display the main program in the left part, the pickup subprogram on the right and the dump subprogram on the right, and the dump subprogram below,
- video of the operation of the program, type *.avi, size 1,920 × 1,080 and

- a compressed robot cell file, type *.rgx, made in RoboGuide.

All submitted files must have meaningfully the same names as the name of the robot cell, only the backup copy must have a creation date at the end of the name in the form -YYYY_MM_DD.

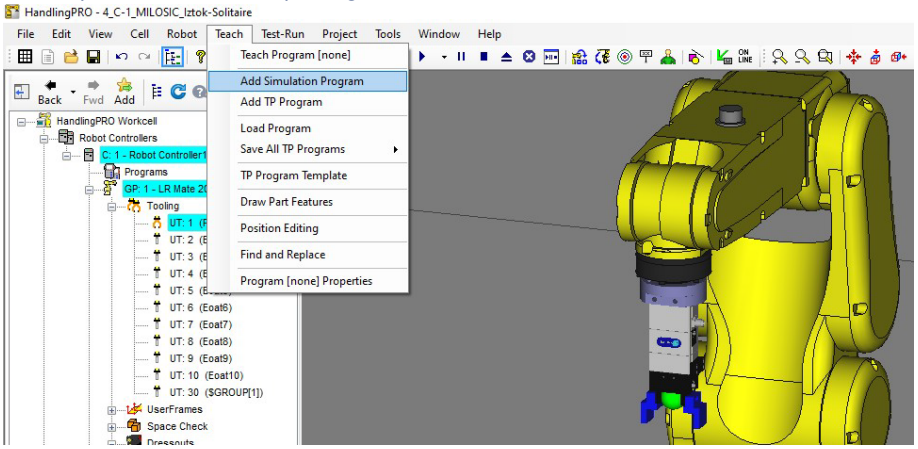
Learning (programming) of a robot or application for product manipulation (Pick & Place)

A prerequisite for starting this exercise is that you have made a preliminary exercise – see the picture below.



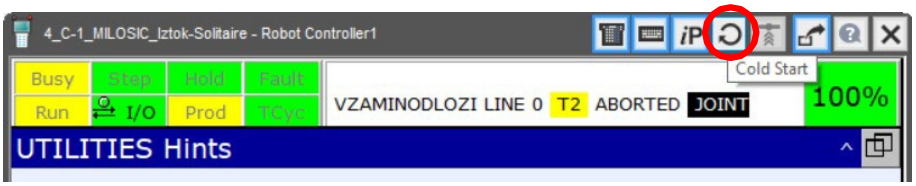
CREATING A NEW PROGRAM

In this part, you will create a program (application) for moving the cylinder and point A over the obstacle to point B. In RG, we can program in several ways. We can create a simulation program or a TP (Teach Pendant) program.

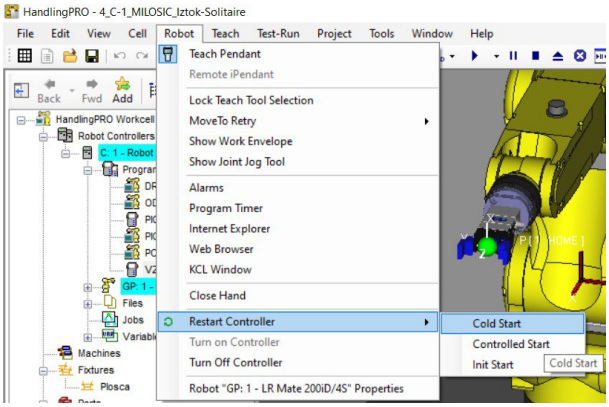


The simulation program is typical only for RG, while the TP program is the same program as the program on the actual robot. You will create a TP program. To simulate the opening and closing of the gripper and the movement of the cylinder, you will need to create a simulation (sub)program that you will call to the main TP program.

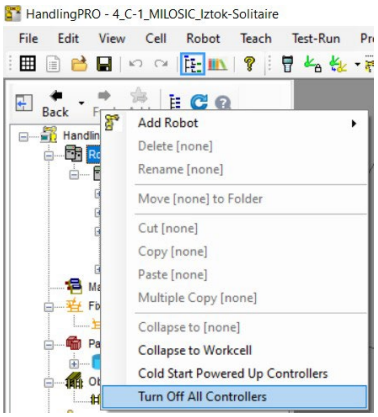
1. Include a learning unit, UE, in the RG. If the UE does not turn on, restart the virtual controller. This can be done in several ways:
    a. On UE, click on the Cold Start icon and confirm the question: "Do you want to Cold Start the controller?".

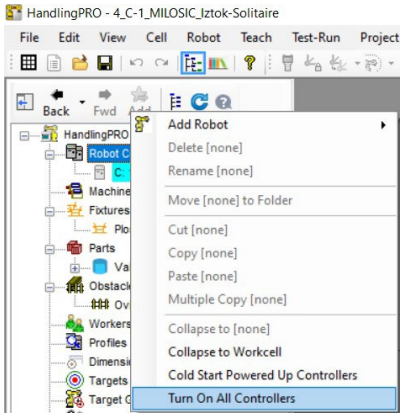


b. From the Robot/Restart Controller menu, select the Cold Start command.

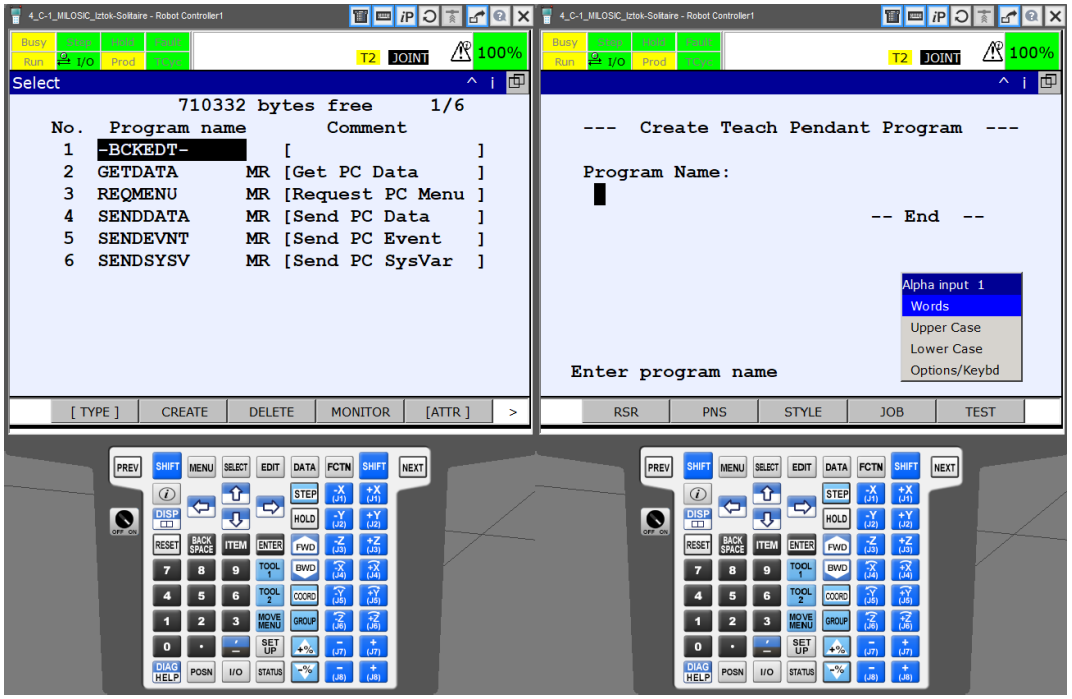


c. In the tree structure, right-click on Robot Controllers and select Turn Off All Controllers from the menu. When the virtual controller is turned off, right-click again in the tree structure on Robot Controllers and select Turn On All Controllers from the menu.

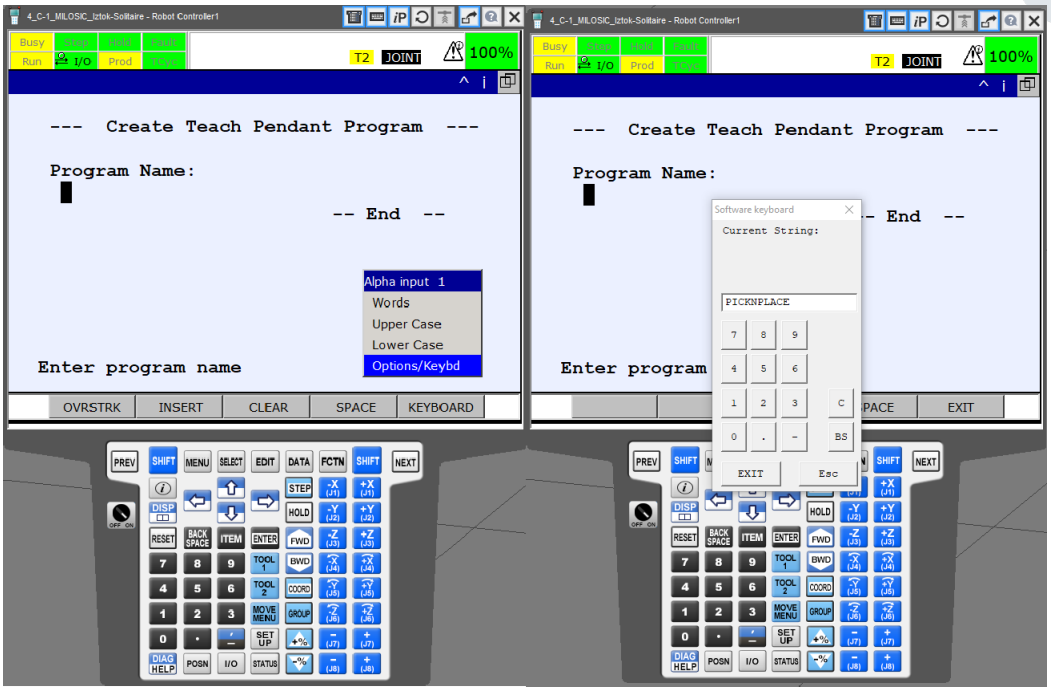




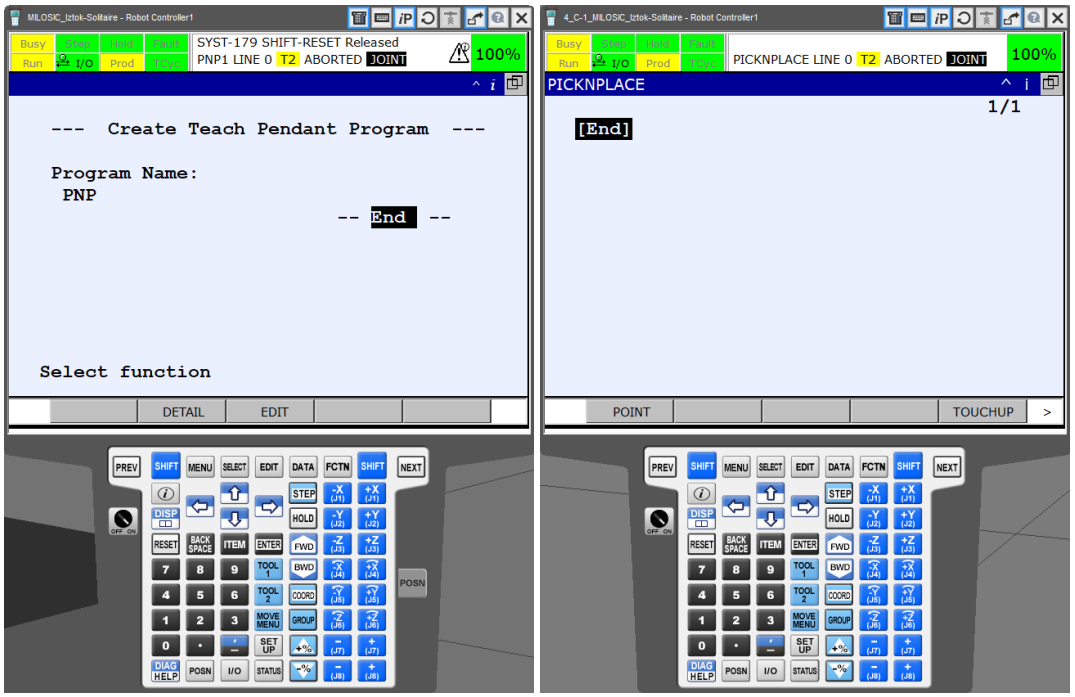
2. On UE, click SELECT/CREATE and enter the name of the PNP (Pick aNd Place) program.



To make typing easier, turn on the Options/Keyb/F5 KEYBOARD software keyboard.

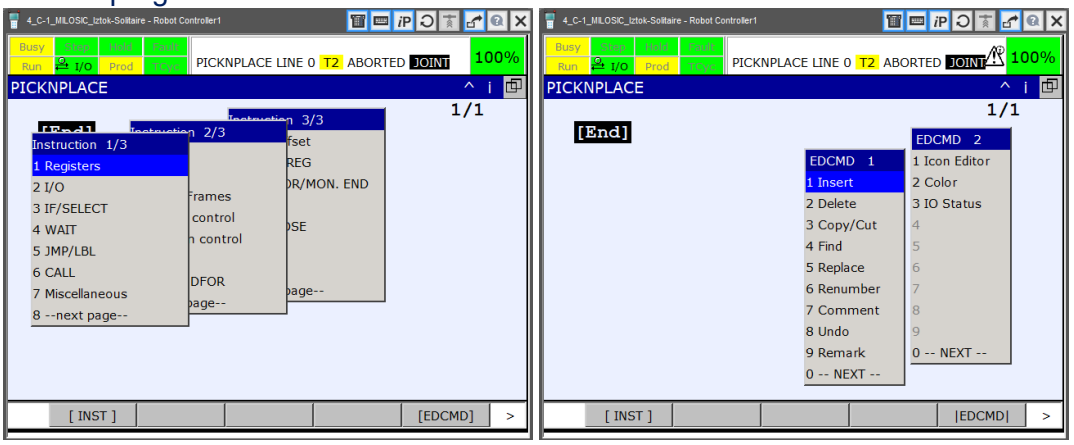


After typing the name, confirm with EXIT or ENTER on the computer keyboard. To enter the program editor, on UE, click EDIT or ENTER.

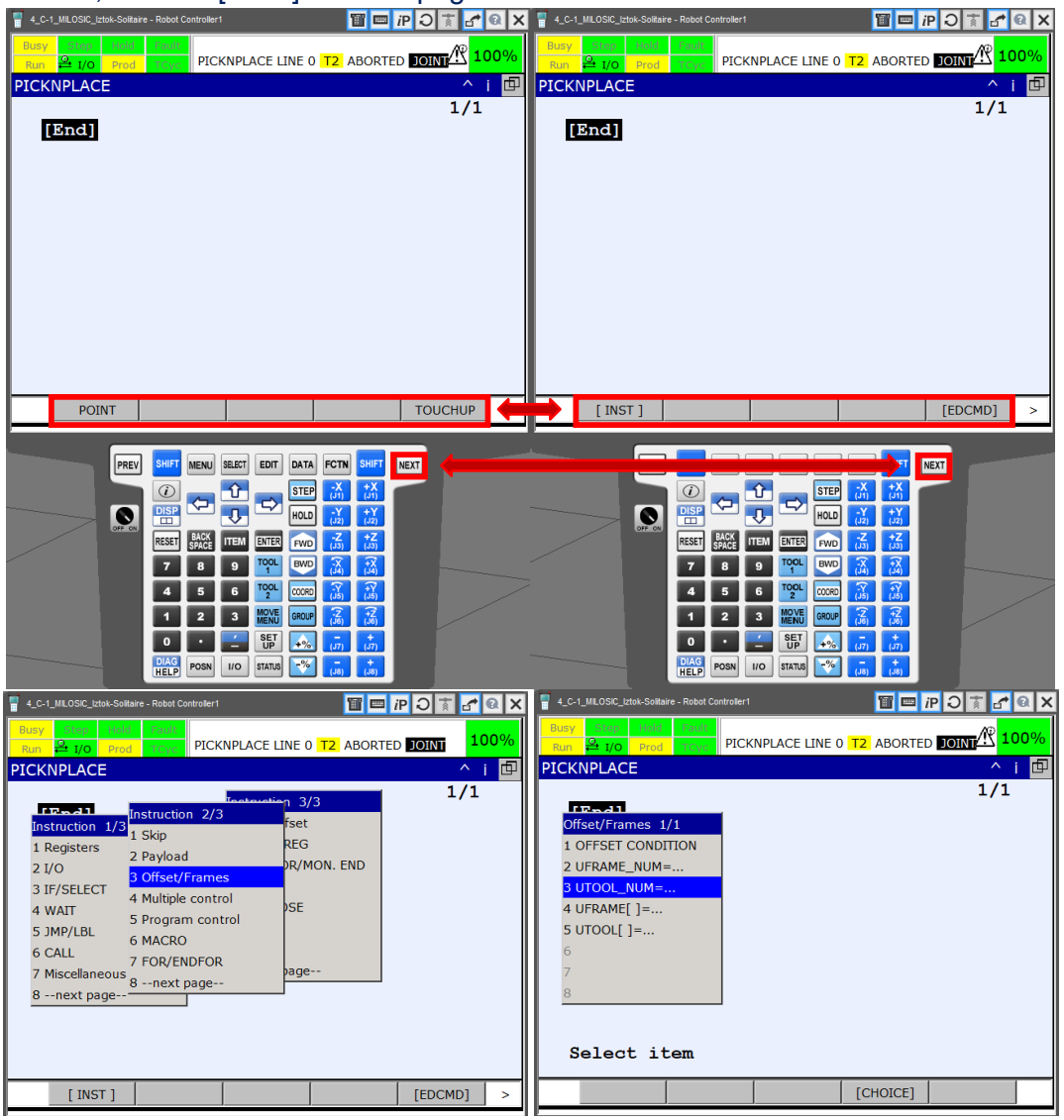


3. At the beginning of the program, set which tool (KSO – TF) you will work with and in which room (UKS – UF) you will work. You can also set the speed at which you will run the program. You'll be using TF = 1 (since we've already set this up), UF = 1 (it's set to equal WF), and a speed of 50% (half the speed of running the program).
4. In the program editor, you have commands at the bottom of the TP screen, or function keys F1 through F5. You can switch between the different menus by pressing the NEXT key to TP.

The F1 POINT and F5 TOUCHUP commands are motion commands and are made as shortcuts. They are used in combination with the SHIFT key (F1 POINT can also be used without SHIFT).
In F1 [INST] there are other commands for programming, and in F5 [EDCMD] there are commands for the program editor.

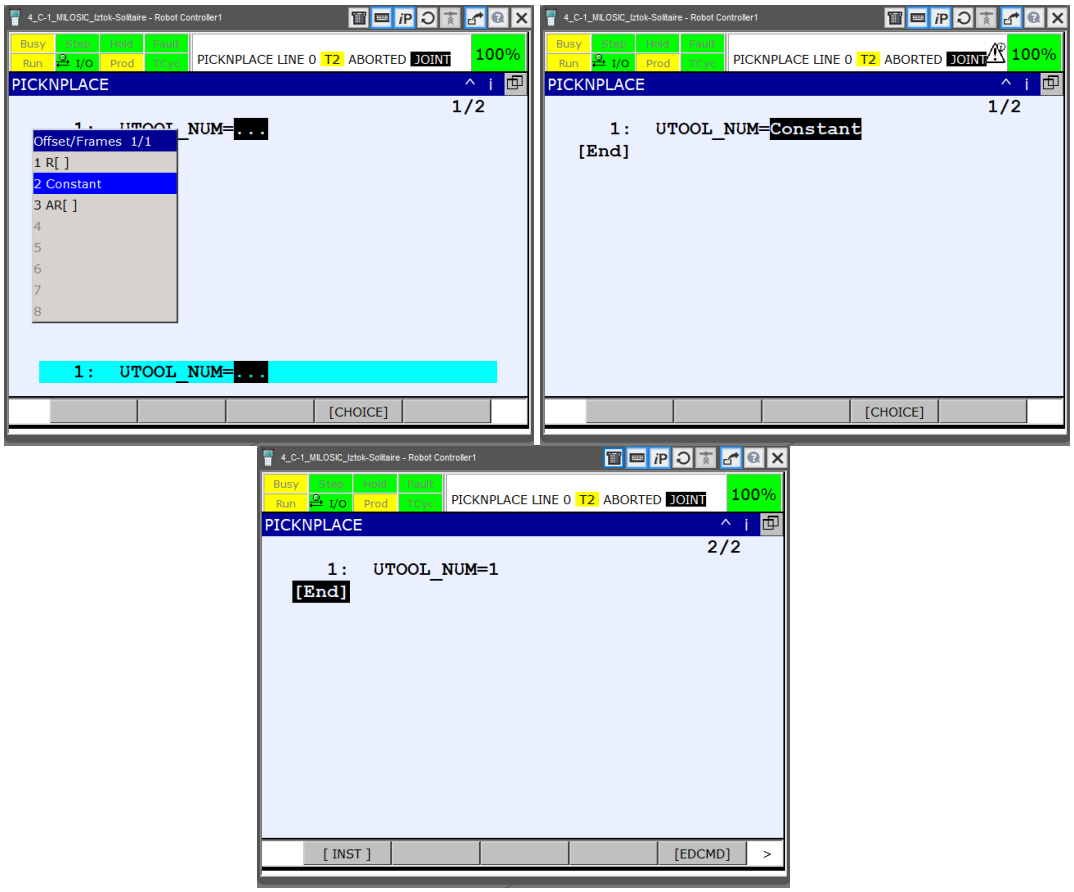


5. Insert TF, click F1 [INST]/8—next page--/3 Offset/Frames.

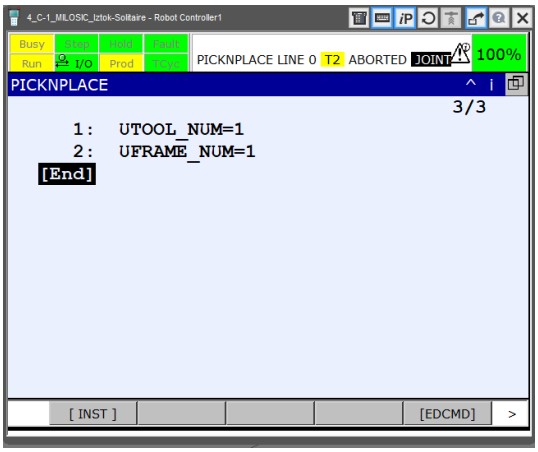


Select 3 UTOOL_NUM=.../2 Constant and confirm with ENTER.

In **Constant,** type 1 and confirm with ENTER.

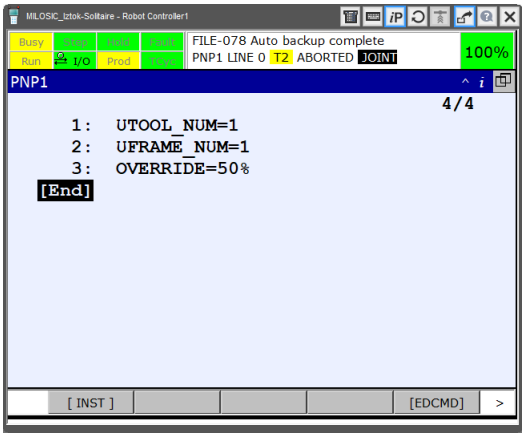


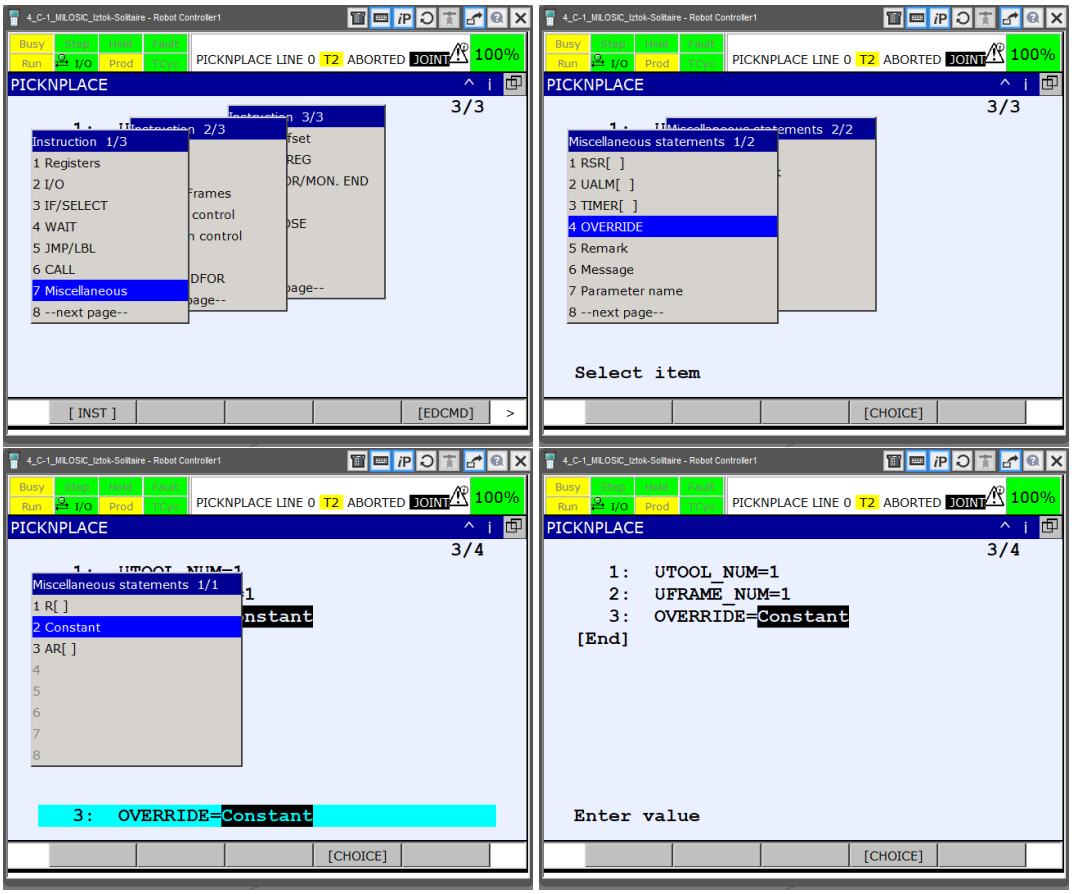
6. Do the same process on UF, except that instead of 3 UTOOL_NUM=... You choose 2 UFRAME_NUM=...



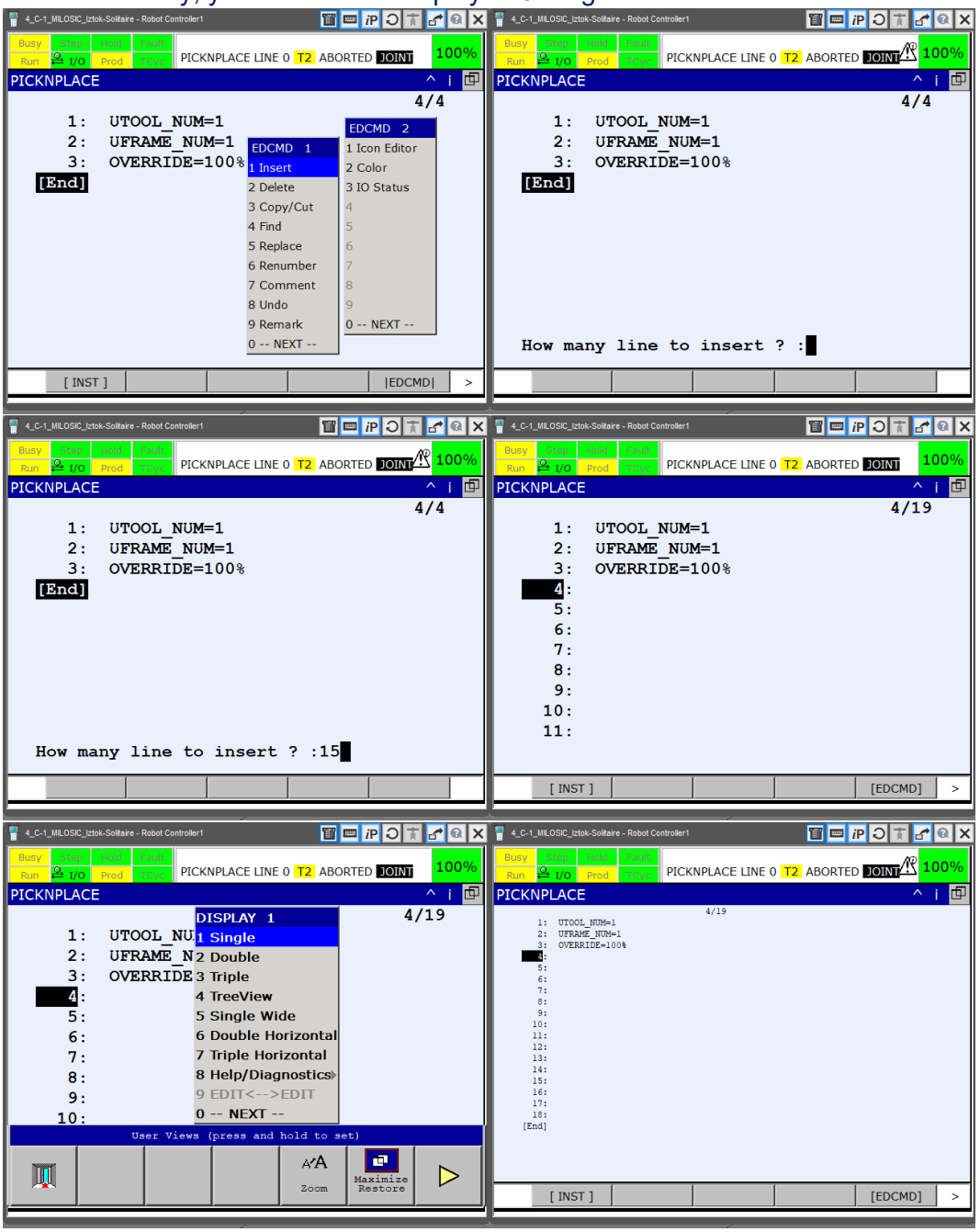
7. Set the program speed, F5 [INST]/7 Miscellaneous/4 OVERRIDE/2 Constant, and confirm with ENTER.

In **Constant** , type 50 and confirm with ENTER.





8. Make a few blank lines for the program lines. Click F5 [EDCMD]/1 Insert. When asked how many lines do you want to insert?, type e.g. 15 and confirm with ENTER. For better visibility, you can set the display to 5 Single Wide with SHIFT + DISP.



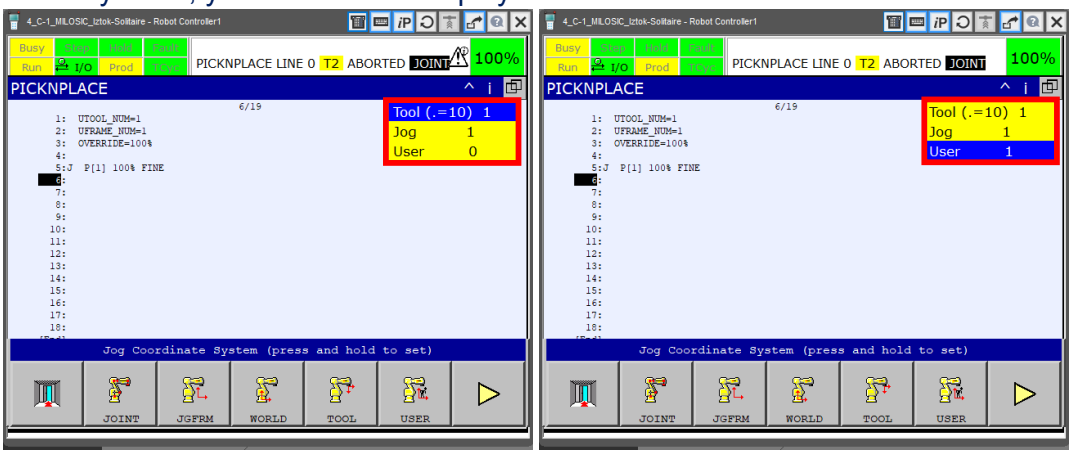
9. For better clarity of the program code, leave the line blank. Place the robot or TCP in the desired position. The first is the HOME or starting position. This is the position where the robot starts and returns to it after the program ends. It is presumably placed in the middle above the workplace so that the robot has the fastest path to the work-space and at the same time is so far away that the robot does not "disturb" the work-space at rest.

You can place the robot or TCP in the desired position in several different ways:

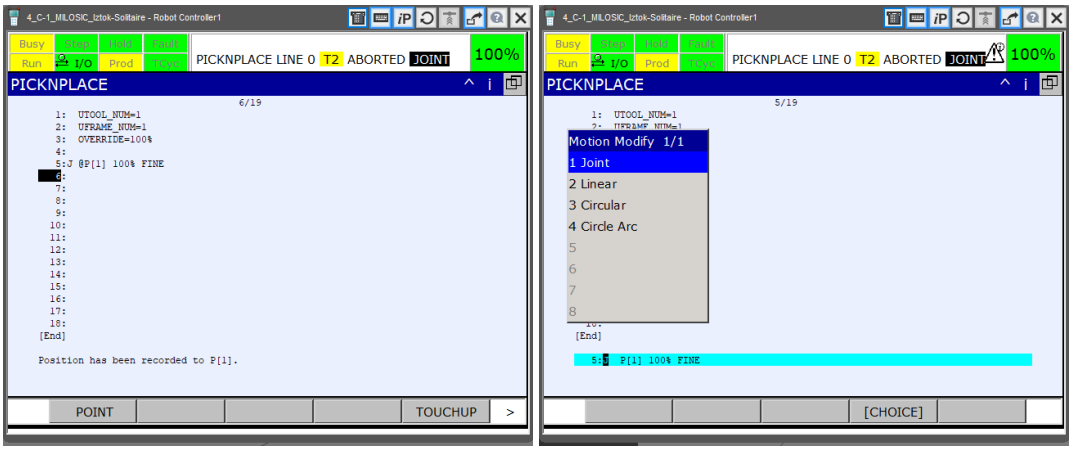
- with UE (COORD, speed setting, RESET, SHIFT + manual control keys),
- with RG-specific movement (turning on the green handles and moving the individual axes and/or clicking on the TCP and moving the TCP in the X, Y or Z directions or rotating around the X, Y or Z axes),

- on the keyboard, click and hold CTR + SHIFT and move the mouse to a specific object and click the L key on the mouse,
- Double-click on the gripper, select the object you want to move the robot to in the Parts tab, and confirm with MoveTo.

10. For the HOME position, it doesn't matter where the robot is standing, because we will enter the coordinates manually (only possible if you know the coordinates). Before the first movement command, ALWAYS check if you have the corresponding KS active, i.e. TF = 1 and UF = 1. On UE, click SHIFT + COORD and check both KS; TF = 1, UF = 0. You need to fix the UF. Use the scroll arrows to place yourself on User and type 1 on your keyboard. Use SHIFT+COORD to check KS again. With PREV on TP or Esc on the keyboard, you hide the KS display.

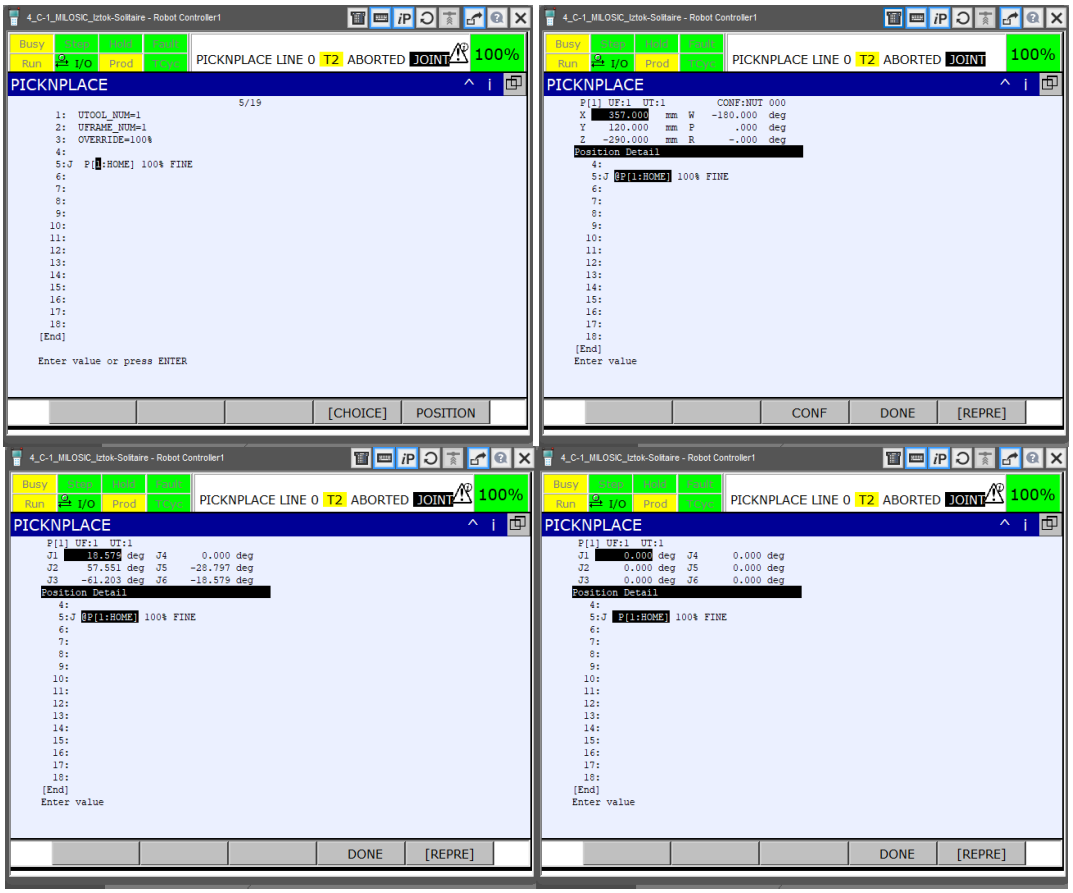


11. Insert the first motion command, click SHIFT + F1 POINT. Correct the parameters for movement. Place yourself on the 1st parameter, the motion mode, and click F4 [CHOICE] and select the appropriate motion mode (J, L, C...). For our example, you choose J.

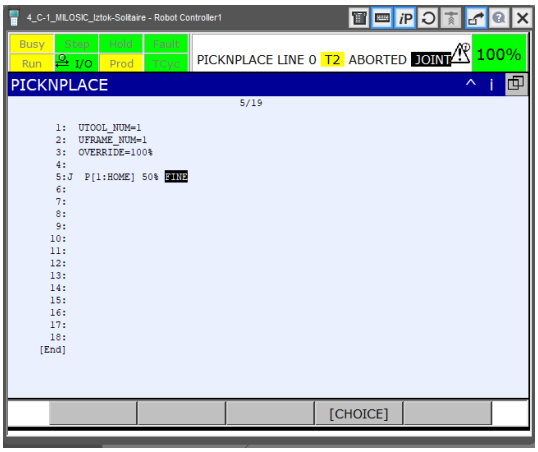


Set yourself to the 2nd parameter, location. Type the name of the item, click ENTER, select Options/Keybd/F5 KEYBOARD and type the name HOME and confirm with ENTER.
Go back to the 2nd parameter and click F5 POSITION.

Set the coordinates of the HOME point to J1 = 0°, J2 = 0°, J3 = 0°, J3 = 0°, J5 = 0°, J6 = 0°. Since the current coordinates are written in Cartesian form, you must first change them to polar (**SINGULARITY).** Click F5 [REPRE] and select 2 Joint and confirm with ENTER. Enter the values J1 = 0° + ENTER, J2 = 0° + ENTER, J3 = 0° + ENTER, J3 = 0° + ENTER, J5 = 0° + ENTER,
J6 = 0° + ENTER and confirm with F4 DONE.

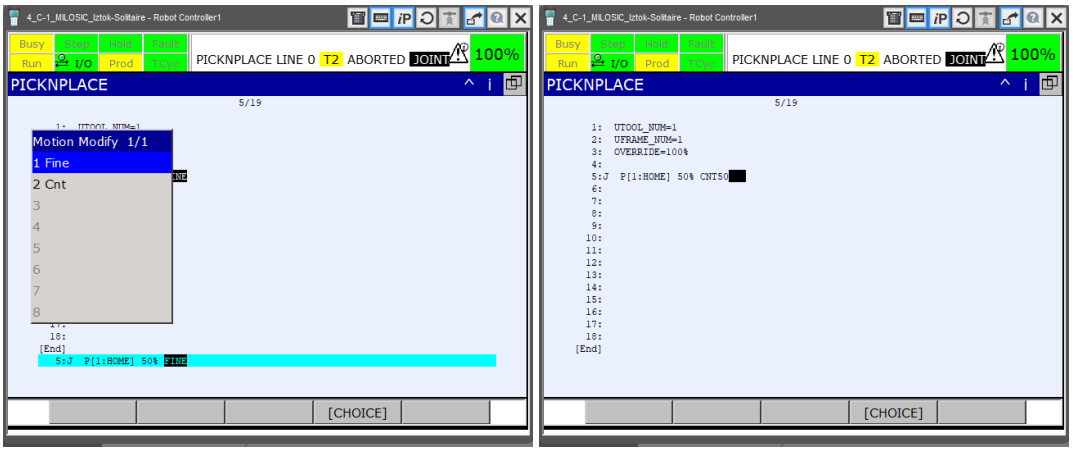


Place yourself on the 3rd parameter, speed and click F4 [CHOICE] and select a different speed unit if necessary. To change the speed value, type a new value, and then confirm with ENTER. For our example, enter 50%.

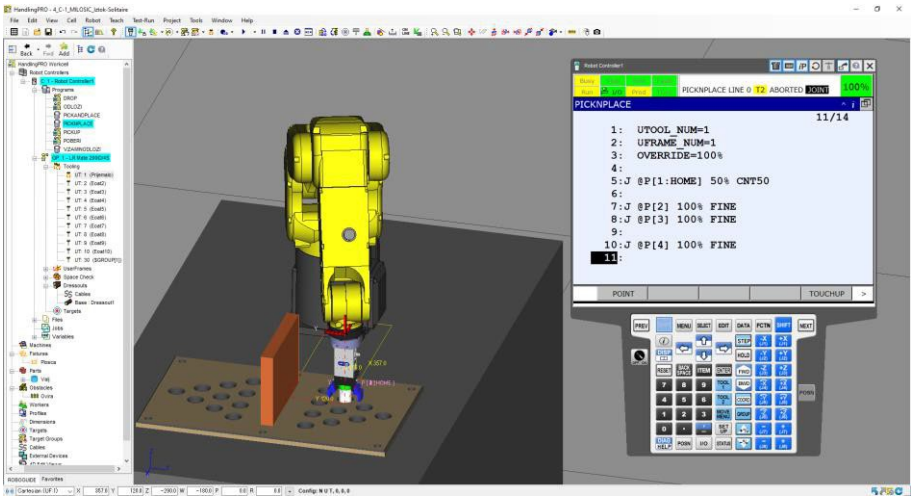


Set yourself to Parameter 4, Point Termination (FINE) or No Stop (CNT). By clicking on F4 [CHOICE], you can choose between FINE or CNT. If you select CNT, you must also type a value between 0 and 100, and then confirm with ENTER. For our example, enter CNT50.

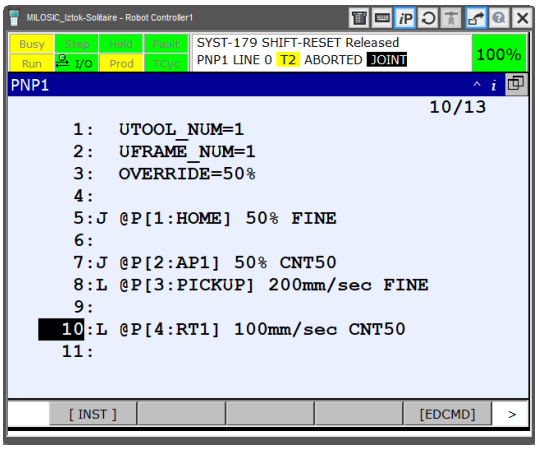
12. Move the robot or TCP to the next position. This is the point before the grip of the cylinder or the point of approach (APPROACH), followed by the point of grip (PICKUP), then the command/line for closing the gripper and the point of return (RETREAT). Since the approach and return points are always perpendicular to the grip point, you create a grip point first, then move TCP higher by just the Z coordinates to create an approach point and a return point. **The height of the approach or return point is higher (farther away) with a full grip than the approach or return point with an empty gripper**.



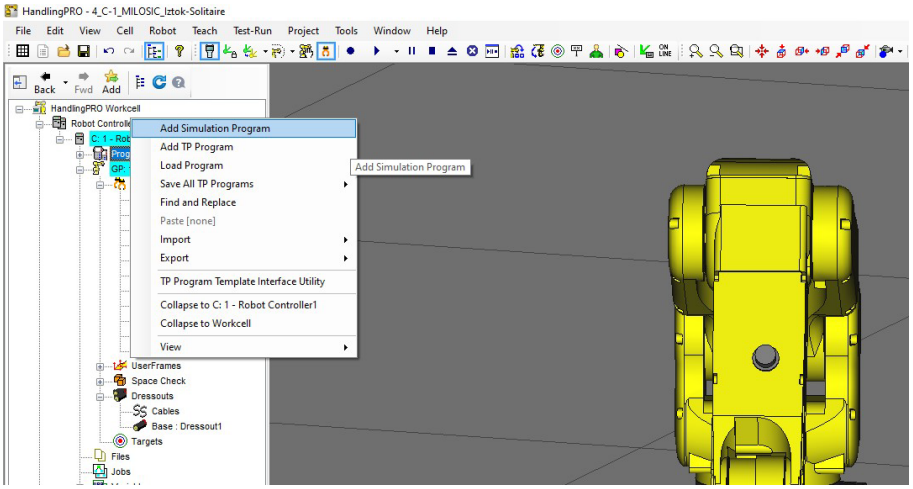
For our example, move the TCP to the cylinder (hint: double-click on the grip, select the object to which you want to move the TCP in the Parts tab and confirm with MoveTo, close the gripper window). Insert two (2) motion commands, SHIFT + POINT (for the approach point and the grip point), leave one (1) blank line to close the gripper, and make a 3rd motion command for the return point.



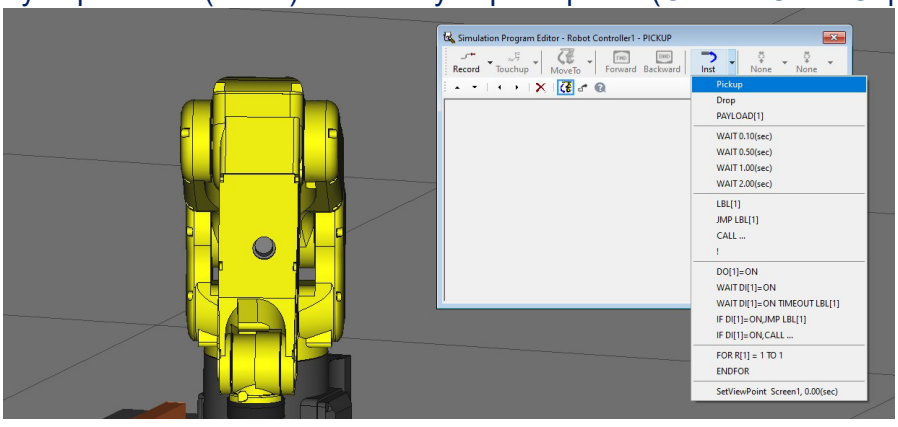
13. Set the appropriate motion parameters in the approach point line: free movement, point name APP1, set the coordinates of the point exactly 50 mm higher than the grip point (as close as possible to the grip point), half speed (50 %) and no stop (CNT50).
14. In the line with the grip point, set the appropriate parameters of movement: linear movement, the name of the PICKUP point, the coordinates of the point are already correct, the speed (200 mm/s, because we have an empty gripper) and with a stop at the point (FINE).
15. In the row with the return point, set the appropriate motion parameters: linear movement, the name of the RT1 point, set the coordinates of the point exactly 100 mm higher than the grip point (as close as possible to the grip point and higher than at the approach point, at least for the height of the cylinder), speed (100 mm/s, since we have a full gripper) and without stopping (CNT50).

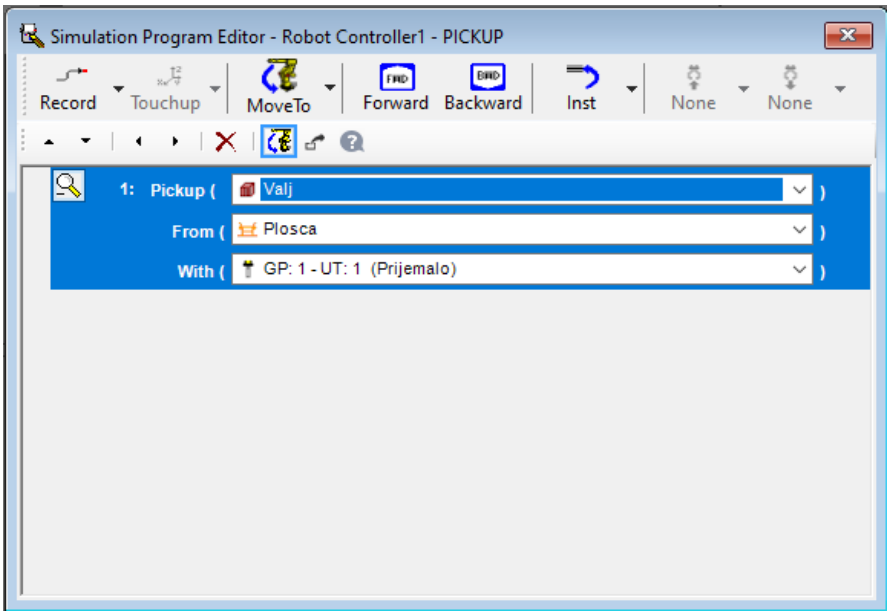


16. Also set the grip bar. There is no command for this, but you need to make a simulation program in the RG. In the tree structure, click on Programs with the D key on the mouse and select Add Simulation Program. Type the name of the HAND_CLOSE program and confirm with OK.

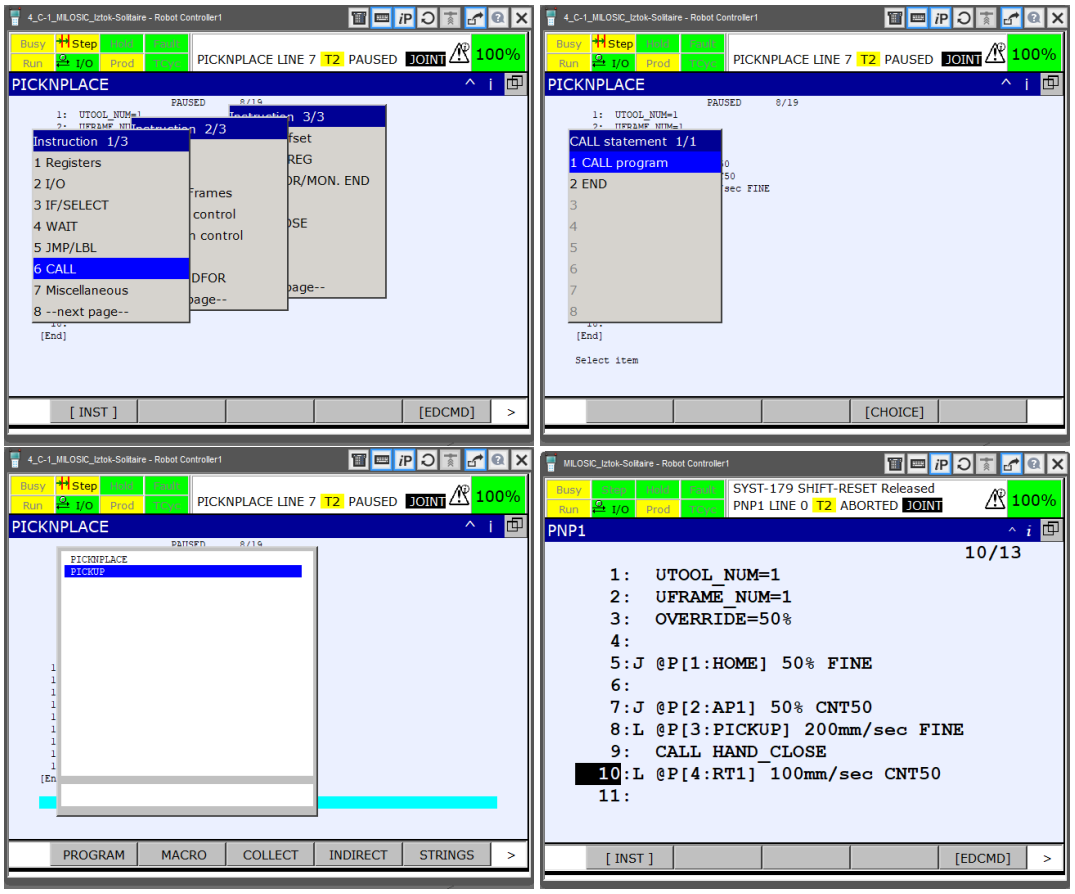


The Simulation Program Editor window appears, and then click the Inst. From the menu, select the Pickup command. You get 3 drop-down menus from which you set what you pick up (Cylinder), where you pick from (Panel) and what you pick up with (GP: 1 – UT: 1 Grip).





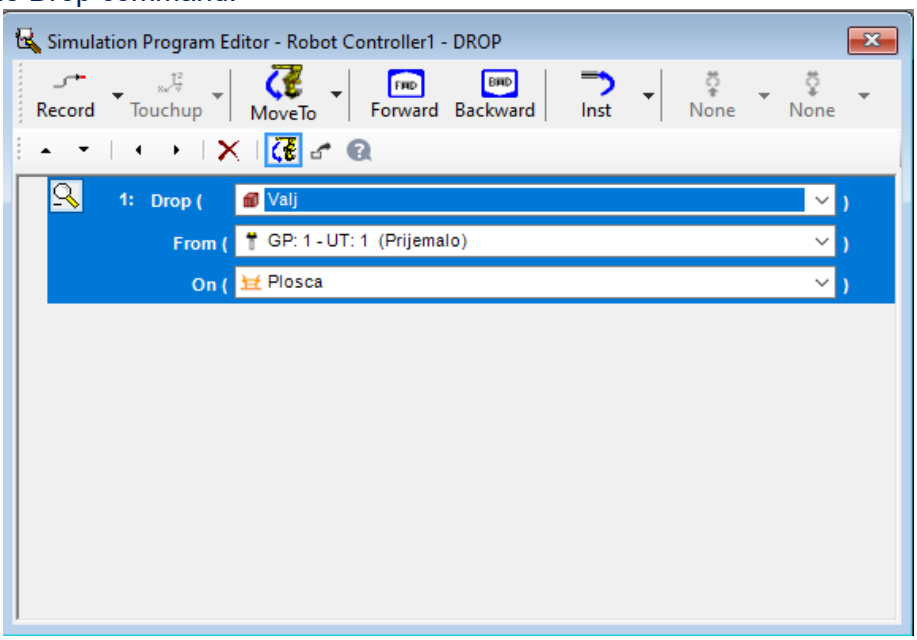
Use the cross at the top right of the Simulation Program Editor window to close it.
On the TP in the pickup bar, click F1 [INST]/6 CALL/CALL program and search for the previously made simulation program HAND_CLOSE and confirm with ENTER



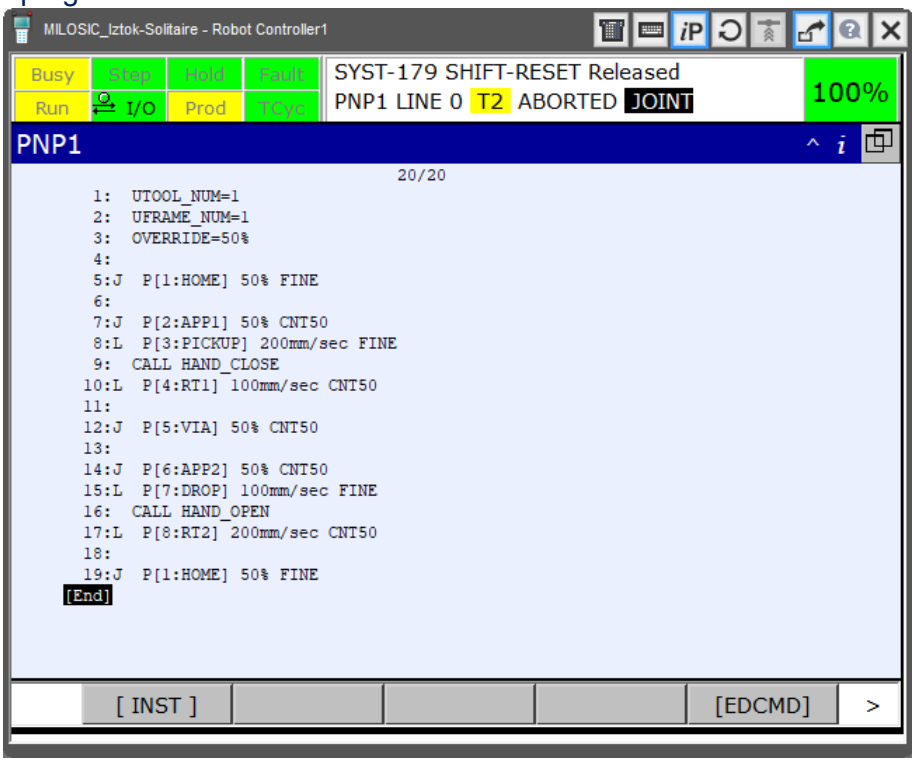
17. Following the same procedure, do the following:
    a. points of retreat over an obstacle, one or two points (free movement, name VIA1, VIA2 ..., speed 50 %, no stopping CNT50),
    b. the approach point for cylinder deposition (free movement, name APP2, 100 mm above the deposition point, speed 100 mm/s, without stopping CNT50),

c. the deposition point (linear motion, name of the DROP point, speed 100 mm/s, precision stop FINE, and
d. return point (linear motion, point name RT2, 50 mm above the deposition point, speed 200 mm/s, no stopping CNT50).

18. To dump, make the simulation program HAND_OPEN, similar to picking up, just by using the Drop command.



19. Finished program.

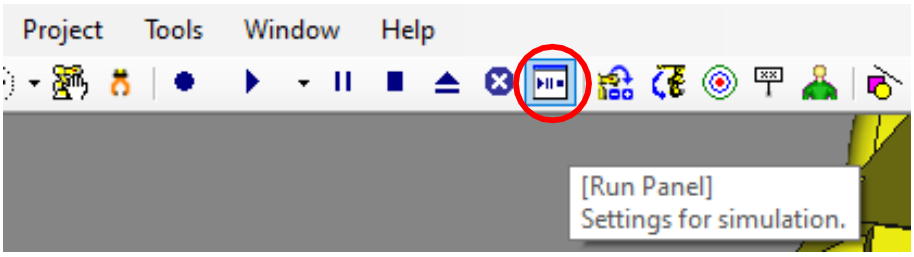


TEST AND RUN THE PROGRAM

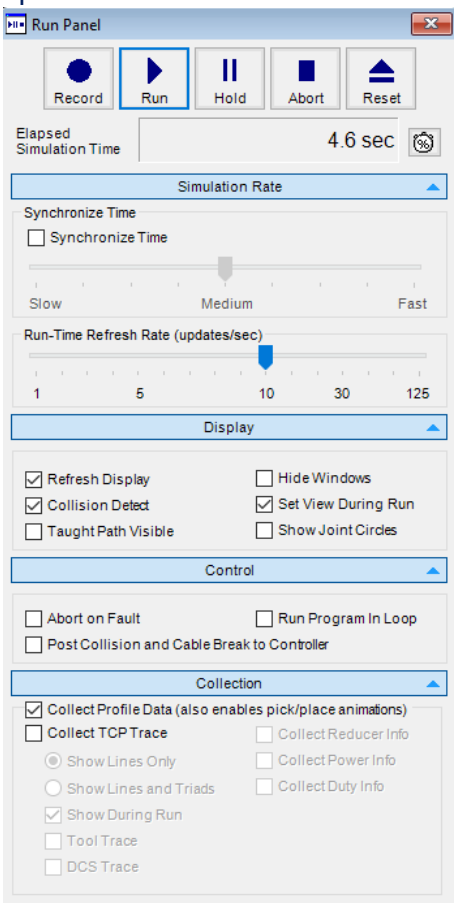
1. You can test the program in the same way as on an actual robot, i.e. with UE. Open the program, place yourself in the desired program line, set STEP/NO STEP, click RESET, click SHIFT and hold it, and use the FWD key to test the program forward and BWD back. This method is

equivalent to testing in T1/T2 mode and does not allow the demonstration (simulation) of cylinder movement and the closure/opening of the gripper. For simulation, it is necessary to run the program in simulation mode, which is equivalent to running the program in AUTO mode.

2. To run the program or simulate the roller shifting, you must run the program in simulation mode (AUTO). Enable this in the [Run Panel] Settings for simulation icon.

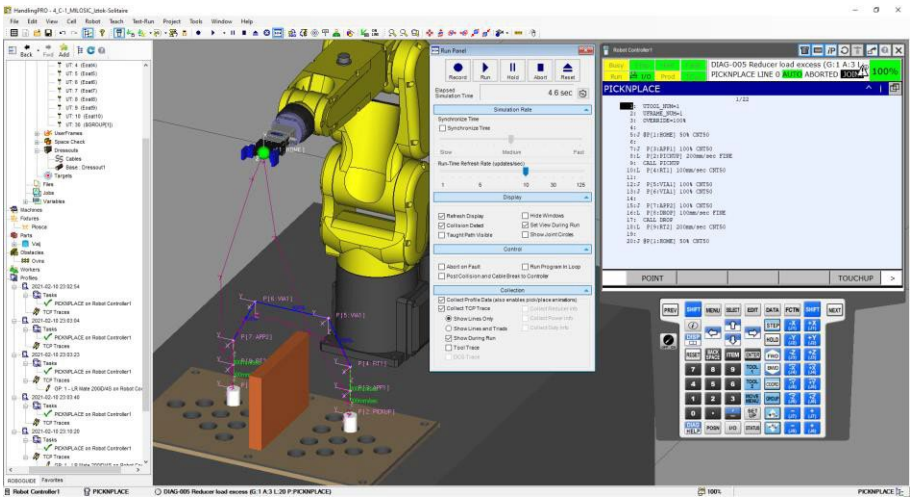


On the Run Panel, expand all the options.



Useful options:

- Display, Taught Path Visible – shows/hides the programmed TCP path in the performance simulation.
- Collection, Collect TCP Trace – shows/hides and stores the actual TCP path in the performance simulation.



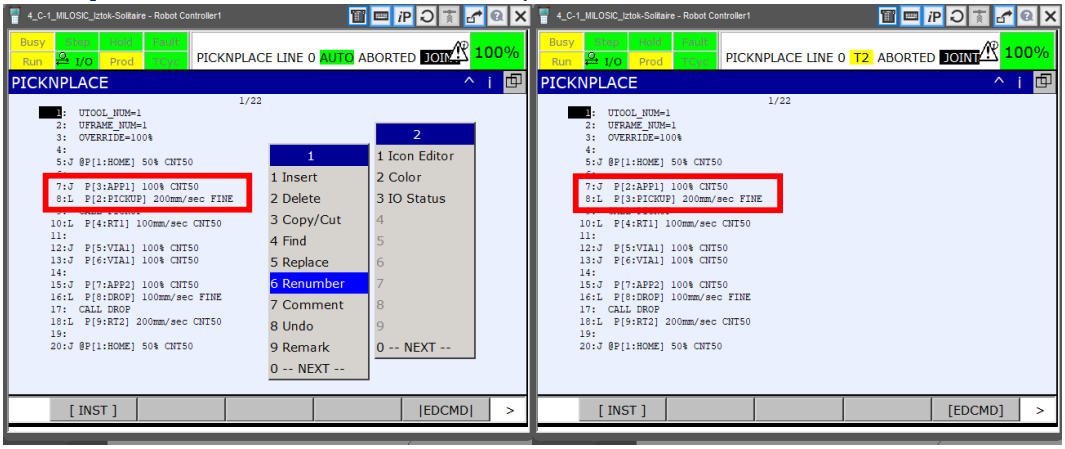
3. Based on the recording of TCP paths and the display of saved points, optimize the operation of the program so that you achieve the shortest possible operating cycle time and without collisions and without unnecessary shaking of the robot (change the execution speed and CNT parameter of individual motion commands, use CNT instead of FINE, move points...).
4. Use time logging to optimize (reduce time). Use the TIMER[...] command and enter its value in R[33].

```
6:  !ZACETNA POZICIJA
7:J @P[1:HOME] 50% FINE
8:  TIMER[1]=RESET
9:  TIMER[1]=START
```

```
42:  !KONCNA POZICIJA
43:J @P[1:HOME] 50% FINE
44:  TIMER[1]=STOP
45:  R[33]=TIMER[1]
```

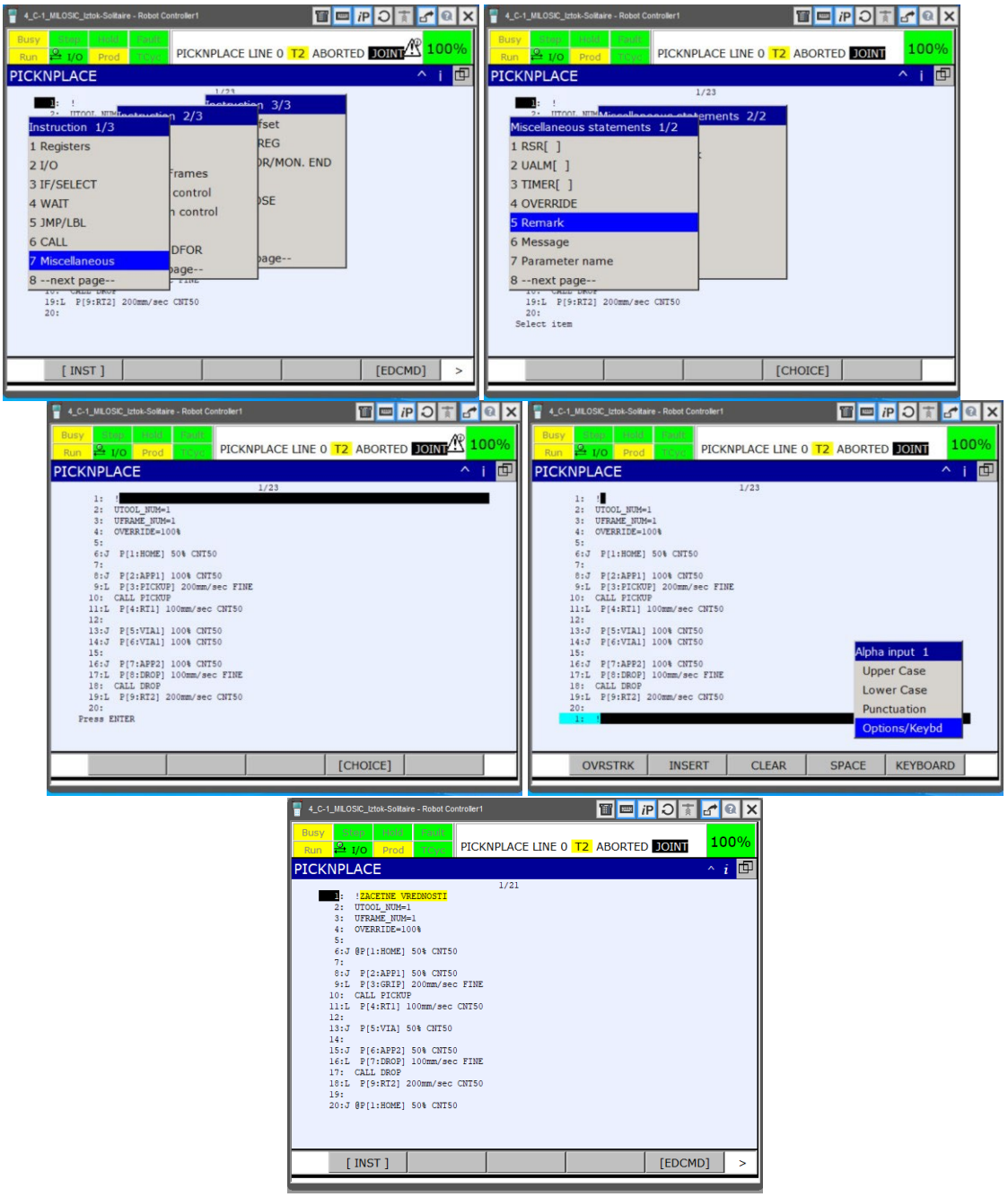
EDIT AND COMMENT ON AN APP

1. You can edit the sequence of IDs of stored points in the program in order using the F5 [EDCMD]/6 Renumber command. To the question Renumber OK? confirm F4.

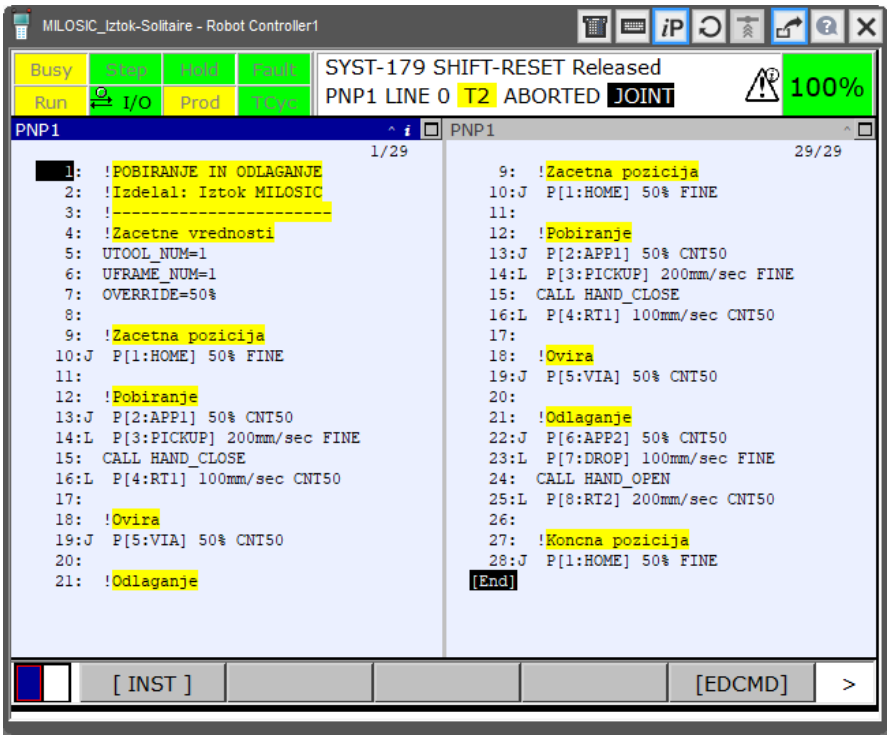


2. For better clarity of the program code, we add blank lines (F5 [EDCMD]/1 Insert ...), and for better understanding, we add program comments. Comment (**in a blank line!!**) is added with F1 [INST]/7 Miscellaneous/5 Remark.

You get a line with an exclamation point at the beginning of the line. On this line, click ENTER and select the comment input method, Options/Keybd/KEYBOARD, use the keyboard to enter text and confirm with EXIT or ENTER.

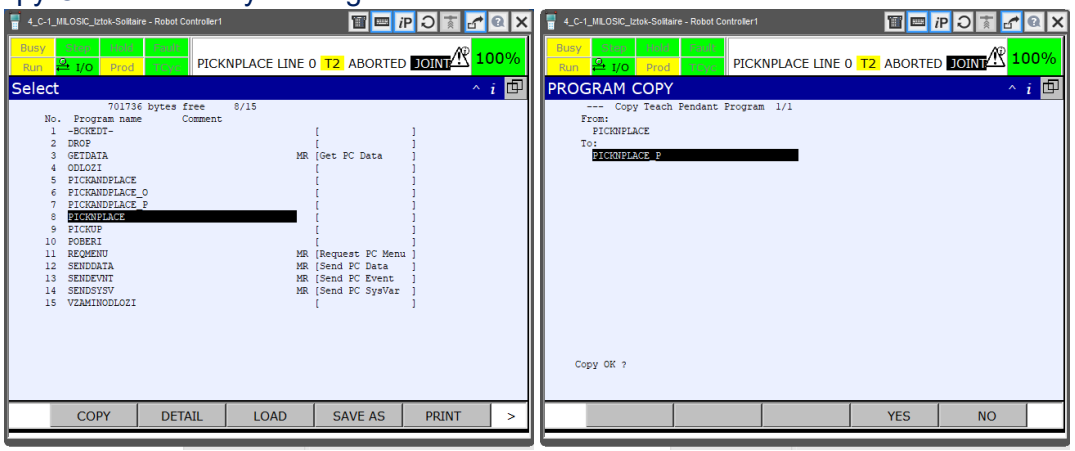


Comment on the rest of the lines.



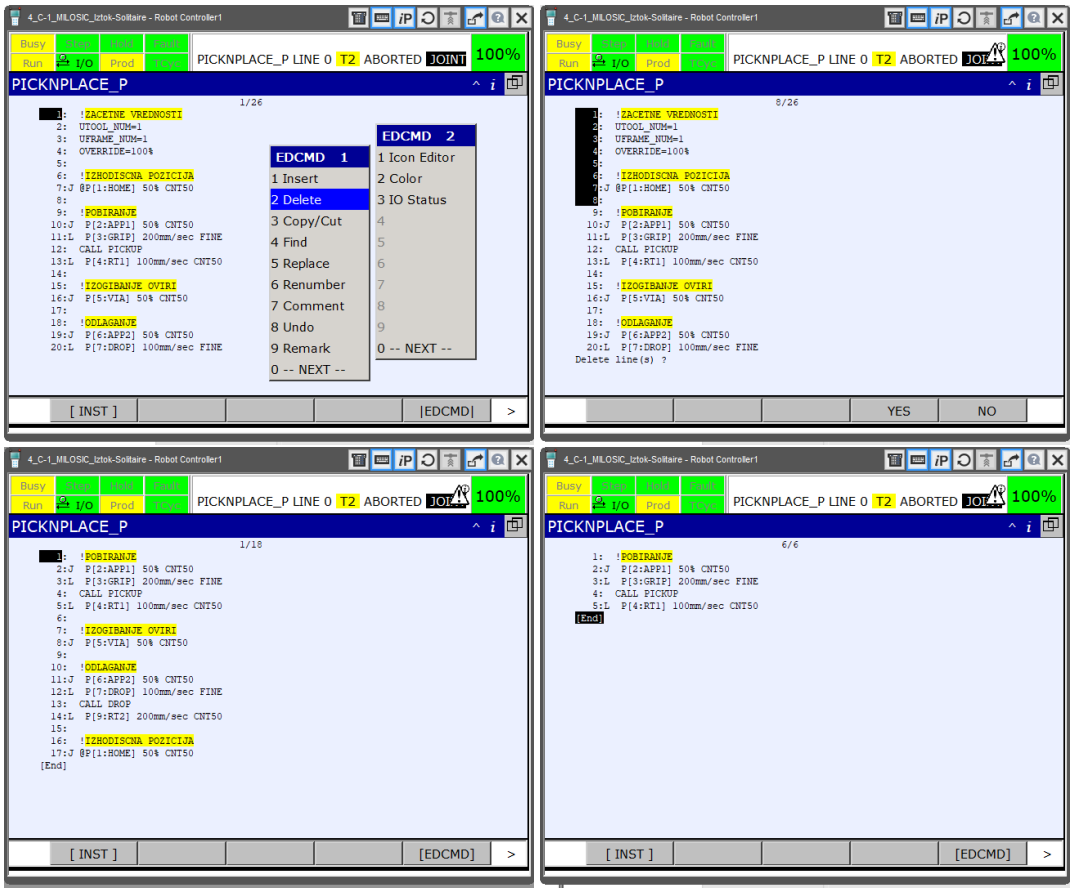
SUBPROGRAMS

1. For better transparency, we divide longer programmes into shorter, meaningful subprogrammes. You will divide the program into the main program, in which you will have the initial values, the starting position, the subroutine for picking, obstacle avoidance, the subroutine for dumping, and finally the starting position. You will make two subroutines, one for picking up, the other for dumping. Since you already have the entire program written, it is best to copy the already created PNP program into three (sub)programs with the names PNP_G (main), PNP_P (collection) and PNP_O (disposal). In all three (sub)programs, we edit the program code accordingly (delete redundant lines). We leave the original PNP program original, fix only PNP_G, PNP_P and PNP_O.
2. To copy a PNP program: On UE, click SELECT, press NEXT to toggle the menu at the bottom of the screen (F1 to F5) to locate the COPY command, locate and highlight the PNP program, and click F1 COPY. In the To: field, type the name PNP_G and then ask Copy OK? confirm by clicking on F4 YES.

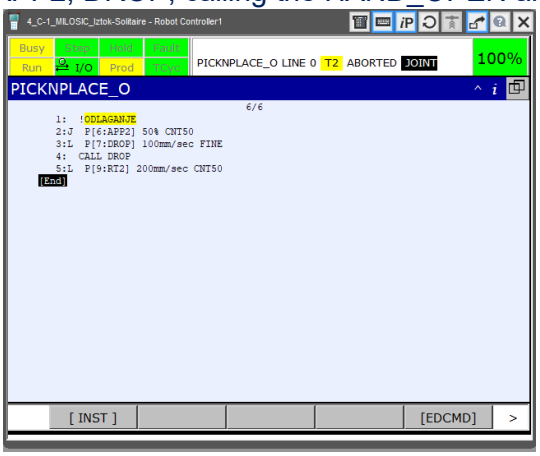


3. Copy the PNP program with the name PNP_P and PNP_O.
4. Open the PNP_P subroutine and rearrange it accordingly. Delete all rows except the pickup lines (remains: APP1, PICKUP, calling subroutine HAND_CLOSE and RT1). To delete rows, use the F5 [EDCMD] command. In the program, place yourself in the first

line to delete, click F5 [EDCMD] and select the command 2 Delete from the window, use the up/down arrows to mark the lines you want to delete and to the question Delete line(s)? confirm by clicking on F4 YES. Delete the rest of the unnecessary lines.

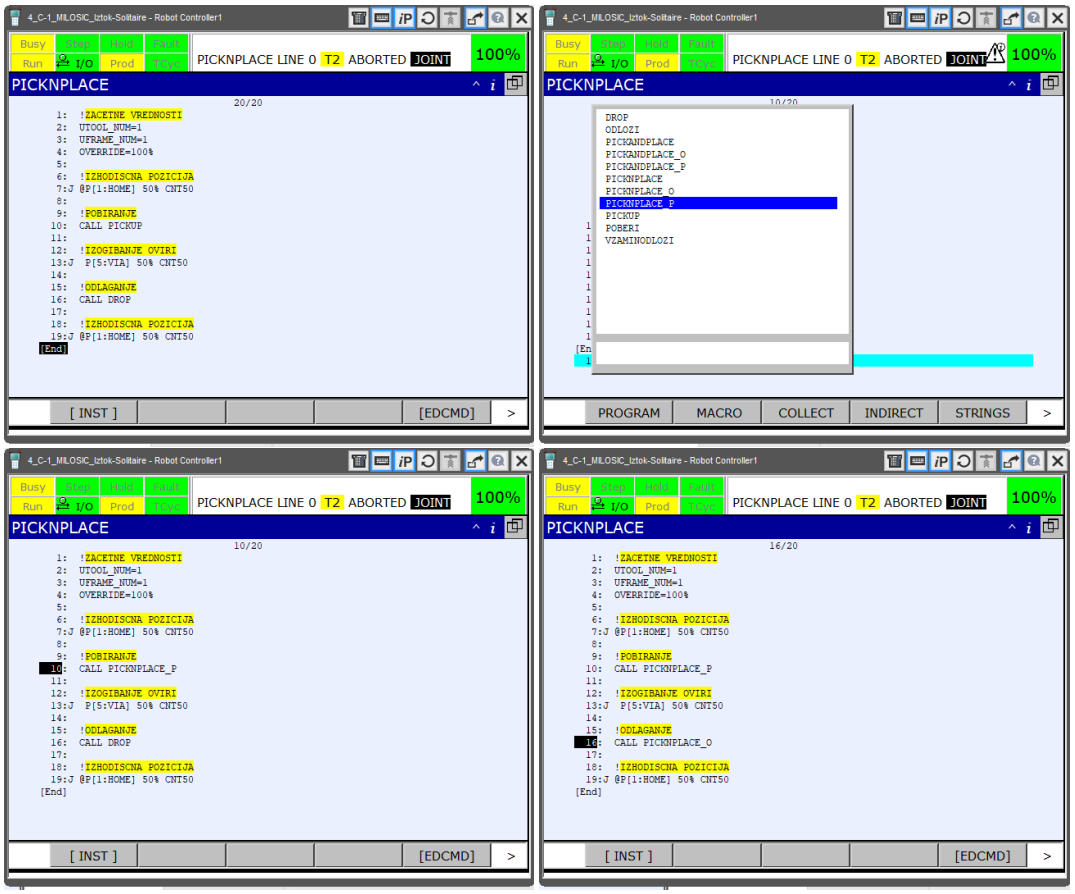


5. Open the PNP_O subroutine and rearrange it accordingly. Delete all lines except the dump lines (remains: APP2, DROP, calling the HAND_OPEN and RT2 subroutines).



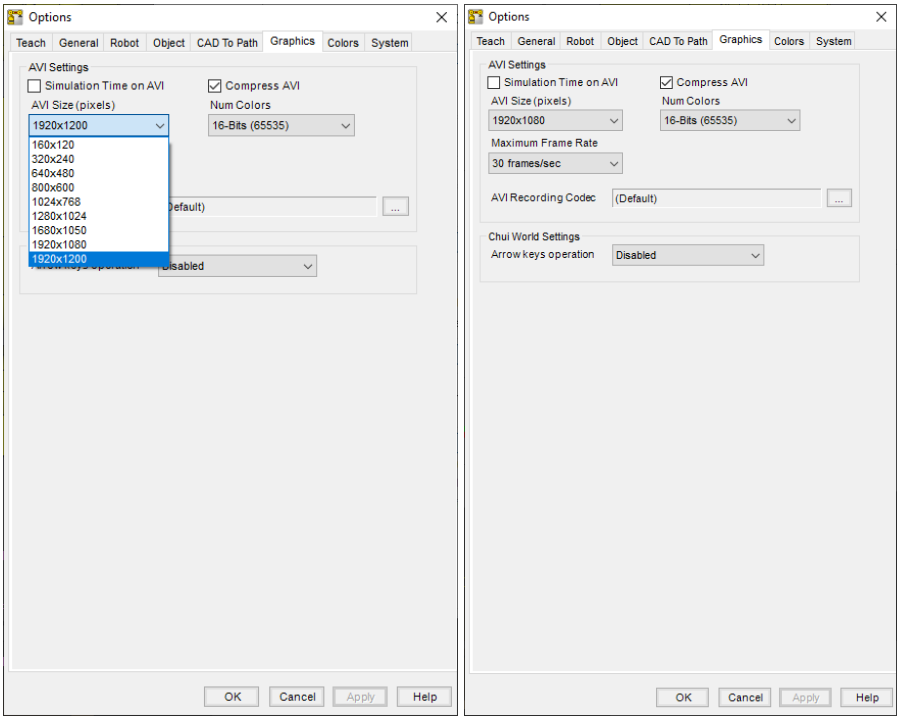
6. Open the main program PNP_G and rearrange it accordingly, i.e. delete the pickup lines (APP1, PICKUP and RT1, except CALL HAND_CLOSE) and the dump lines (APP2, DROP and RT2, except CALL HAND_OPEN). Leave comments. Instead of the pick and dump lines, insert the commands to call the PNP_P and PNP_O subroutines. At the CALL HAND_CLOSE line on the HAND_CLOSE, click F4 [CHOICE] to find and select the PNP_P pickup subroutine. Do the same for the PNP_O dump subroutine.

Check the performance of the program (testing and running).

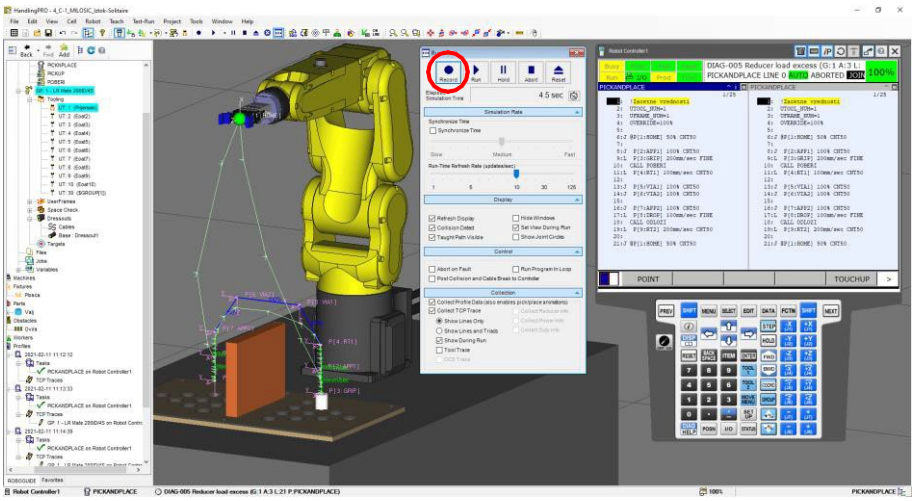


VIDEO OF HOW IT WORKS

1. Record the operation or simulation of the operation of the program in a video recording *.avi. Before recording, set the quality and size of the video. If you have a short program runtime, increase the quality, otherwise decrease it. You can set the quality in the RG in the Tools/Options menu. In the window that appears, open the Graphics tab and in the AVI Settings field, set the AVI Size (pixels) to, for example, 1920 × 1080 and the frame rate to 30 and confirm with Apply and OK.



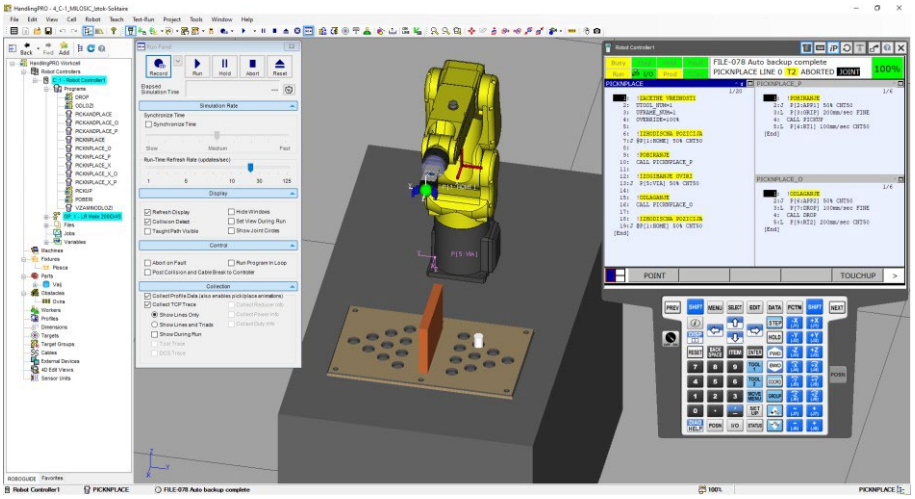
2. In the Run Panel window, instead of the Run button, click Record. The simulation will start up and record to video at the same time. When the recording is complete, you will be shown the location of the saved video.



OTHER INFORMATION

1. Robot cells are usually stored locally in the folder: Documents/My Workcells/Mapa_z_imenom_vase_robotske_celice.
2. The videos are stored in your robot cell folder, subfolder AVIs.

EXAMPLE OF DISPLAYING AN RC SCREEN IMAGE FOR BROADCAST



ADDITIONAL VIDEO INSTRUCTION

1. WILLEA, Adam: FANUC Roboguide Tutorial, available at: https://www.youtube.com/watch?v=neAFHplKu-Y, used: January 2021.

EXERCISE 3: SETTING UP THE COORDINATE SYSTEM OF THE TOOL

In this tutorial, you'll use the RoboGuide simulation program:

- prepare a robotic cell to set up the coordinate system of the tool,
  - hide items you don't need,
  - install a simple tool (tip),
  - install a more complex tool (welding gun) and
  - set a fixed point,
- for a simple tool (tip), set the coordinate system of the tool according to the 3-point method and check the correct setting of the coordinate system of the tool,
- for a more complex tool (welding gun), set the coordinate system of the tool according to the 6-point method and check the correct setting of the coordinate system of the tool, and

on a real robot in the same way as in RG:

- set up the coordinate system of the tool for an easy gripper and welding gun.

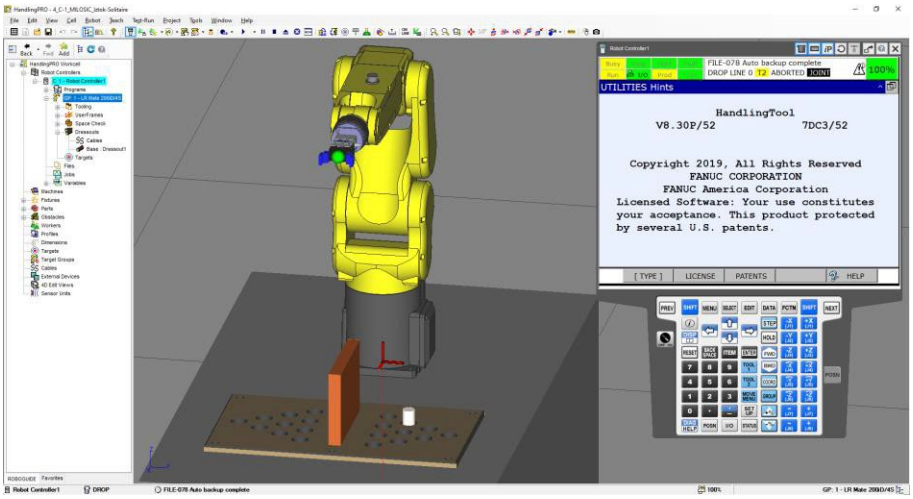
When the exercise is complete, submit the files:

1. a scanned and handwritten report on the completed exercise (PDF type – all pages in one document, orientation of the portrait document, pages arranged in order from 1 onwards),
2. Screenshot 1 (PDF, Doc... appropriately oriented) of its robotic cell from which it can be seen:
   - the name of the robotic cell,
   - all RC elements (robot, tool, tip, pedestal) on the panel should show a fixed point, all placed in the center of the full-size RG screen – across the entire screen, and
   - the included learning unit placed on the right side of the RG screen on which the TF settings screen (method, TF number, coordinates of the set TF, comment and all points) should be visible,
   - TF must be active on UE to see the correctly set TCP and TF on the tool,
3. Screenshot 2 (PDF, Doc... appropriately oriented) of its robotic cell from which it can be seen:
   - the name of the robotic cell,
   - all RC elements (robot, tool, welding gun, pedestal) on the panel should be visible at a fixed point, all placed in the center of the full-size RG screen – across the entire screen, and
   - the included learning unit placed on the right side of the RG screen on which the TF settings screen (method, TF number, coordinates of the set TF, comment and all points) should be visible,
   - TF must be active on UE to see the correctly set TCP and TF on the tool,
4. a compressed robot cell file, type *.rgx, made in RoboGuide.

All submitted files must have meaningfully the same names as the name of the robot cell, only the backup copy must have a creation date at the end of the name in the form -YYYY_MM_DD.

Preparation of the robot cell for setting up the coordinate system of the tool

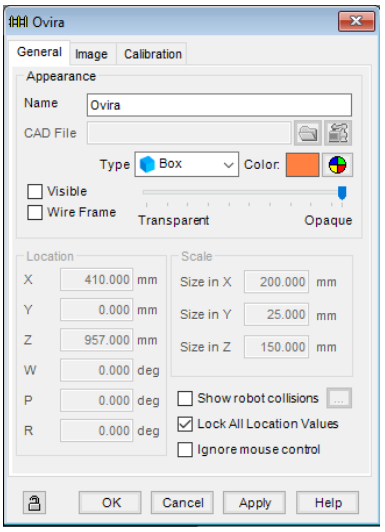
A prerequisite for starting this exercise is that you have a robotic cell built – see the image below.



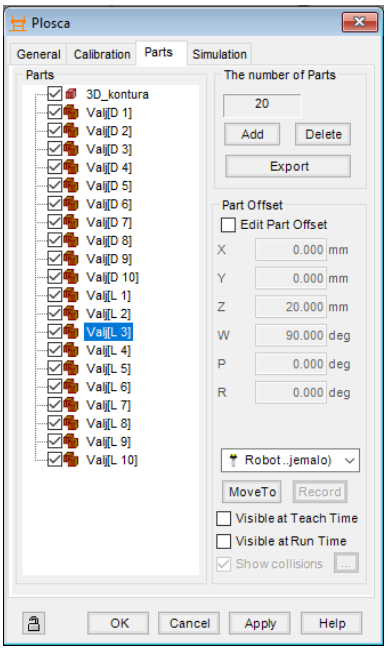
PREPARATION OF THE ROBOT CELL

Hide the elements you don't need in the robot cell:

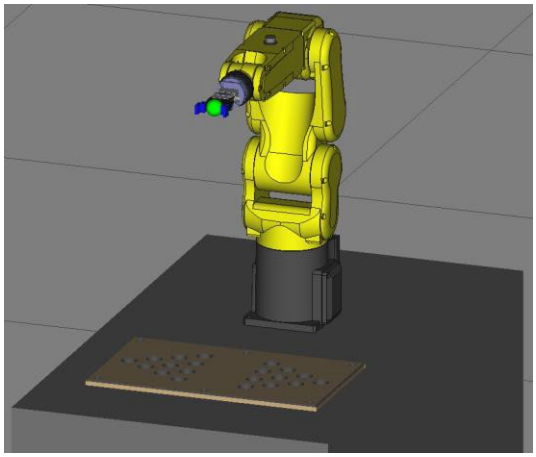
1. Barrier:
    a. Double-click on the obstacle and you will see a window to set up the obstacle.
    b. In the pop-up window, check the Visible setting.



    c. Confirm to Apply and OK.
2. Cylinder:
    a. Double-click on the panel and the panel setup window will appear.
    b. On the Parts tab, click on the cylinder and tick:
        i. Visible at Teach Time in
        ii. Visible at Run Time.



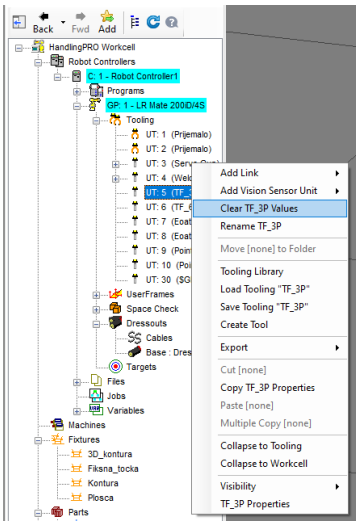
iii. Confirm to Apply and OK. The appearance of a robotic cell by hidden elements.



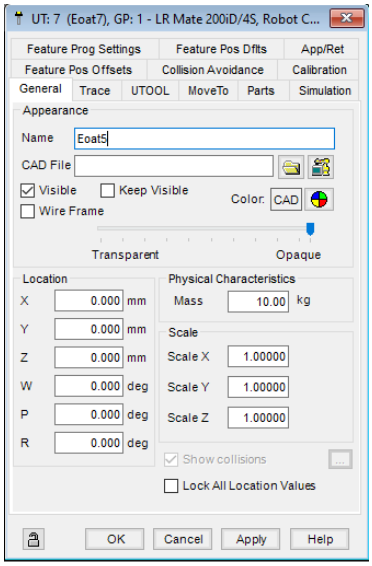
INSTALLATION OF A SIMPLE TOOL, TIP

First of all, you will install a simple tool, the tip.

1. In the tree structure, under Tooling, look for tool No. 5 or UT: 5.
2. On UT: 5 right click and by clicking on Clear... Values to delete the settings of this tool.

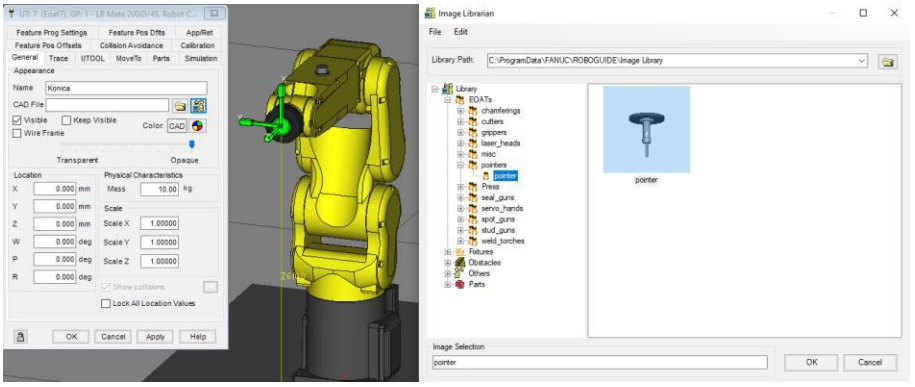


3. Double-click on UT: 5 and you will see a window with the settings or properties of this tool.

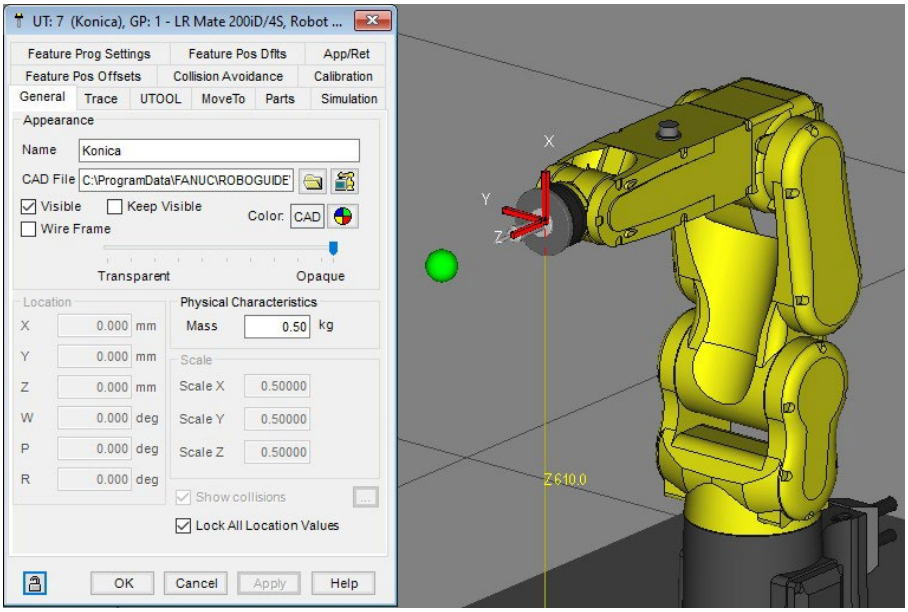


4. In the Name box, type the name Spike.

5. Click on the icon  to the right of the CAD File field. The Image Librarian library window will open.
6. In the library, in the EOATs/pointers group, locate the pointer tool and confirm it with OK.



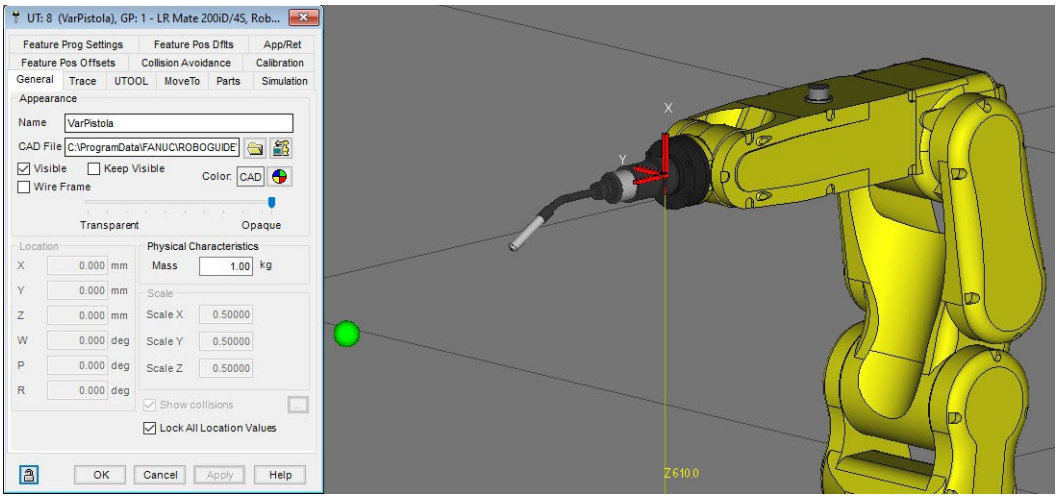
7. Set the mass in the Mass field to 0.5 kg and reduce the tool in the Scale field after all three coordinates by a factor of 0.5.
8. Lock the settings with Lock All Location Values and confirm with Apply and OK.



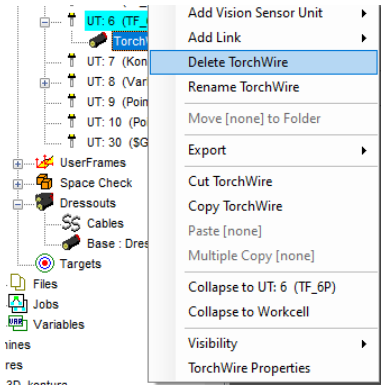
INSTALLATION OF A MORE COMPLEX TOOL

Install the tool on UT: 6.

The installation process for a more complex tool is the same as for a simple tool, only select the tool BINZEL_ABIROB_350_GC_30L _GasNozzle_Straight from the CAD library in the EOATs/weld_torches group. Set all other parameters as in the window below.

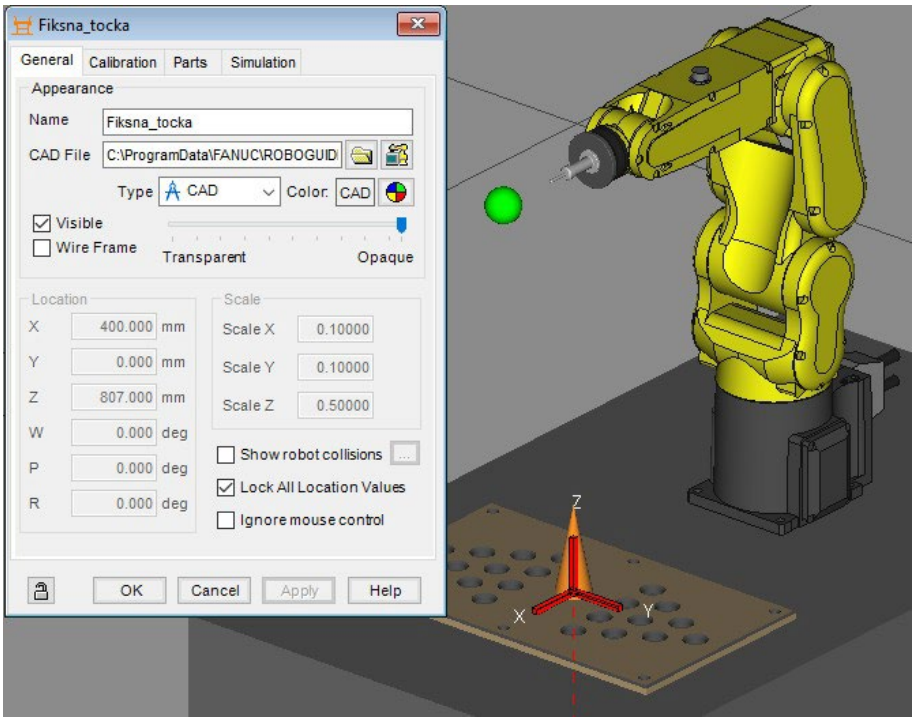


A TorchWire appears (remains) on the tool, which you can delete by clicking on TorchWire in the tree structure at/under UT: 6 on the right and selecting Delete TorchWire from the pop-up window.



FIXED POINT PLACEMENT

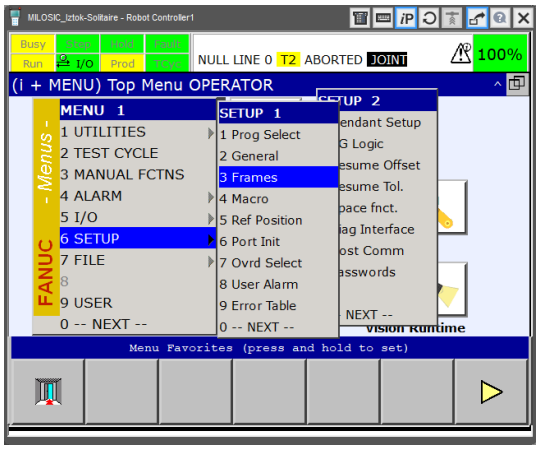
1. In the tree structure, right-click on Fixture, select Add Fixture and CAD Library.
2. In the Image Librarian pop-up window, click + to expand the Parts group, and click + to expand the workpiece subgroup and select the zone object. Confirm with OK.
3. In the properties window, type Name, Location, and Scale, as shown in the image below. Lock all values and confirm with Apply and OK.



SETTING THE TOOL COORDINATE SYSTEM, TIP

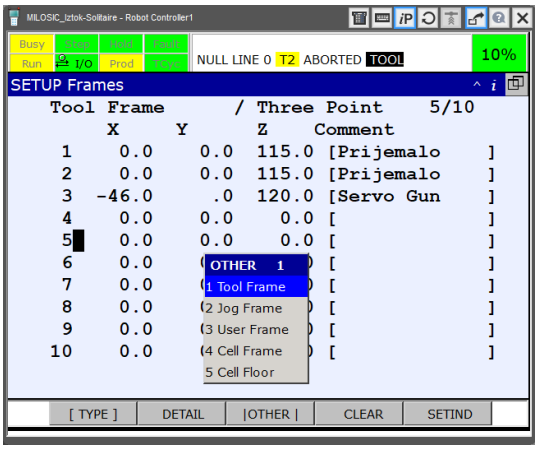
Set the TF for the tool tip to UT: 5.

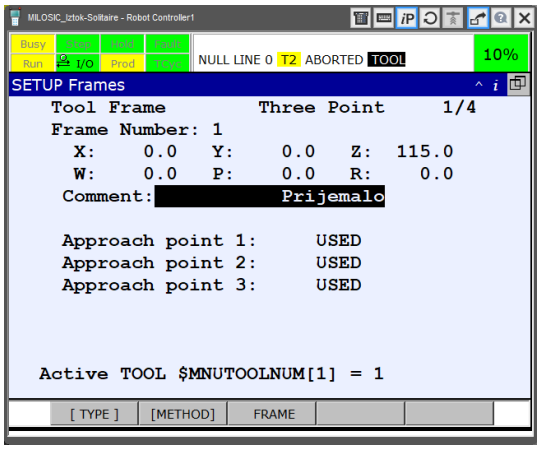
1. 6 FRAMES AND 3 FRAMES.



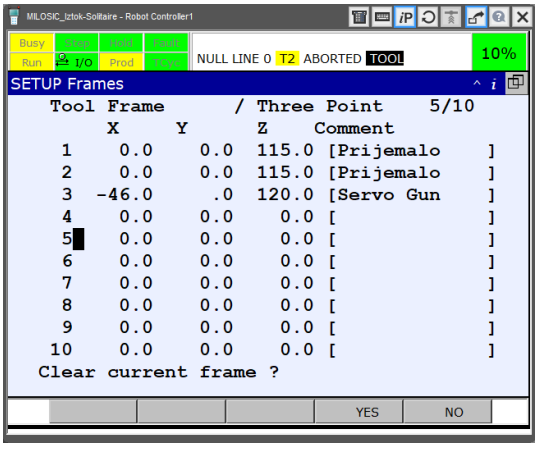
2. If you do not have Tool Frames displayed, switch to the Tool Frame settings, F3 [OTHER] and select Tool Frame (image left).

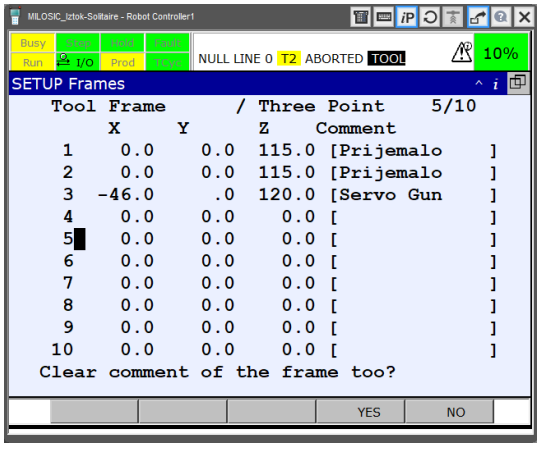
If you do not see all KS in the coordinate system settings, click the PREV key and then switch to the desired KS, F3 [OTHER] (image on the right).



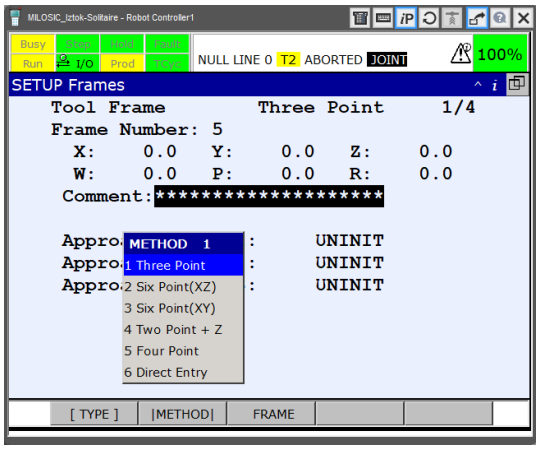


3. Place yourself on TF: 5 and delete it by clicking the F4 CLEAR key (values and comment)

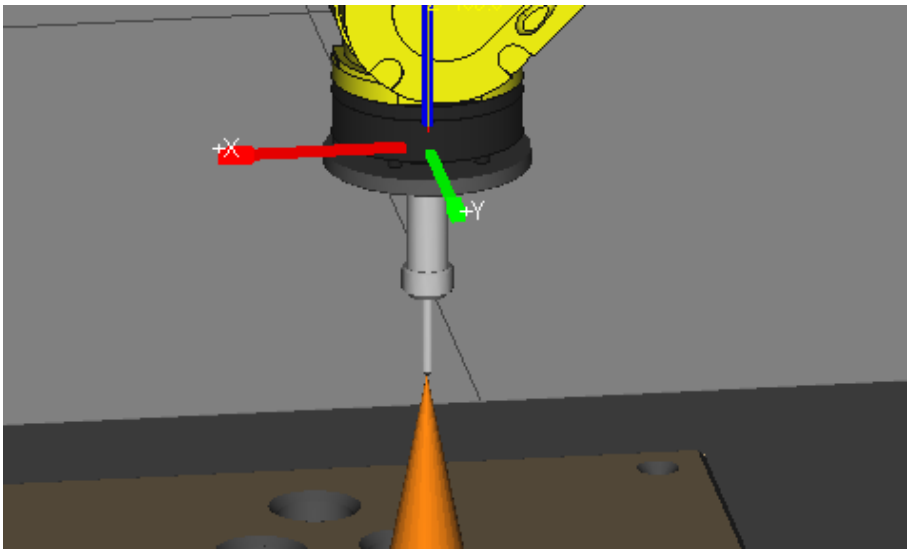




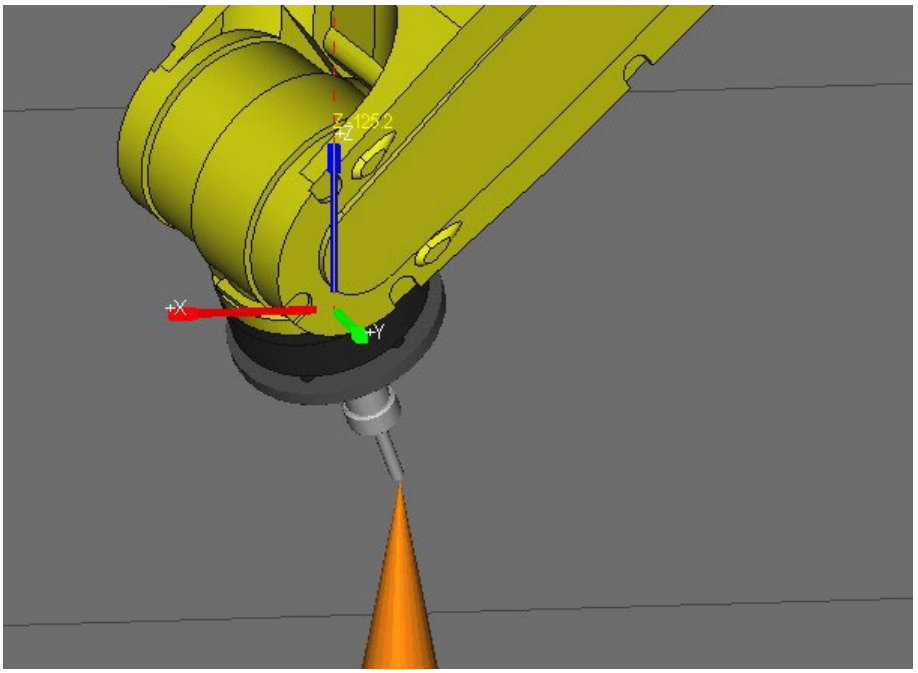
4. Enter the settings by clicking on F2 DETAIL.
5. Select the method at F2 [METHOD], 1 Three Point.



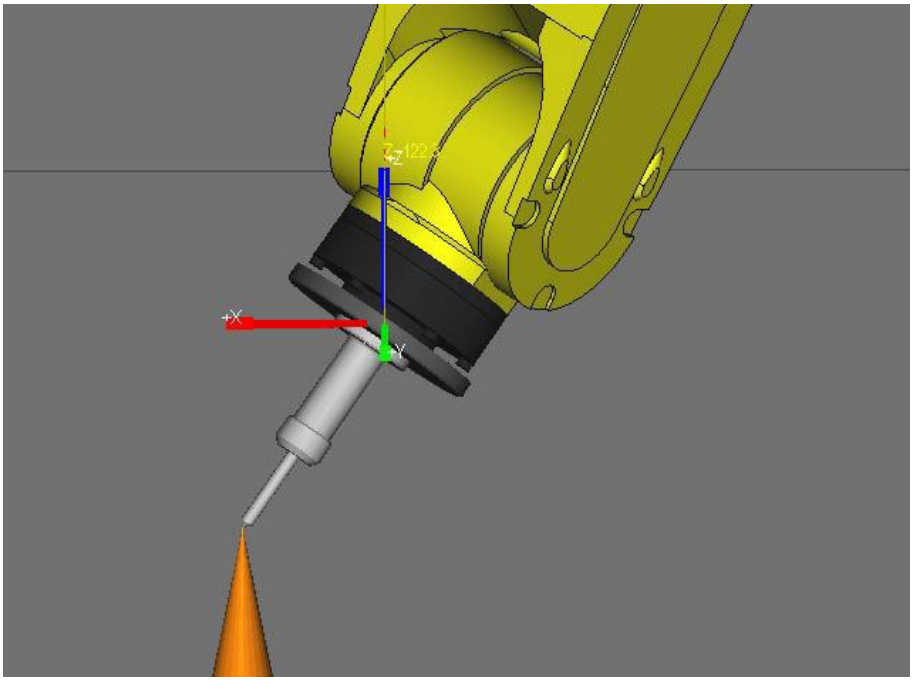
6. Use the typing pad to place yourself in the Comment field, click ENTER and type a comment, e.g. TF_3P or Spike, confirm with ENTER.
7. Use the input to position yourself at Approach point 1 and touch the top of the fixed point (WORLD) with the tip of the tool. Save the point with SHIFT+RECORD.



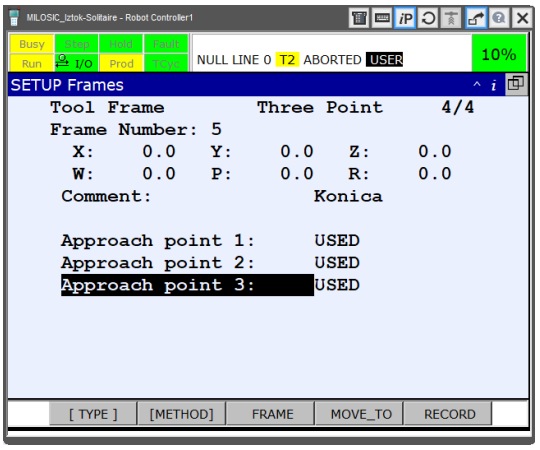
8. Use the input to position yourself on Approach point 2, move the tool away from the fixed point (WORLD), rotate J4, J5, and J6, each 90° or at least 45° (JOINT), and touch the tip of the tool to the top of the fixed point (WORLD). Save the point with SHIFT+RECORD.



9. Position yourself on Approach point 3 with the input, move the tool away from the fixed point (WORLD), rotate J4, J5 and J6, each 90° or at least 45° (JOINT) in the opposite direction to AP2, and touch the tip of the tool to the top of the fixed point (WORLD). Save the point with SHIFT+RECORD.



10. When you save point 3 (AP3), the result is calculated and the coordinates of your TF, X, Y, Z, W, P and R are printed.



11. Check or test the appropriately set TF. Switch to KS TF (COORD) and activate your TF (SHIFT+COORD and your TF number, for your case No. 5).
    a. Place yourself on one saved point, Approach point 1, 2, or 3, by placing yourself on this field with the input and pressing SHIFT+MOVE_TO. TCP is placed on top of the fixed point.
    b. Use rotations to verify the adequacy of the TCP location. Use translations to check the adequacy of the TF orientation or tool.

SETTING THE COORDINATE SYSTEM OF THE TOOL, WELDING GUN

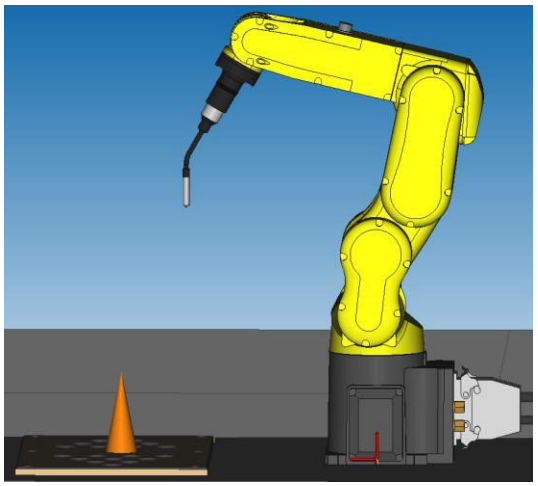
The procedure in the first part is exactly the same as for the 3-point method, except that:

- in point 5, select the 6 point method, F2 [METHOD], 2 Six Point (XZ) or 3 Six Point (XY); choose the variant that is more suitable for your tool, i.e. which direction of the tool (Z or Y) you can point with the tool in the last, 6th point;
- write a comment in point 6, e.g. TF_6P or VarPistola.

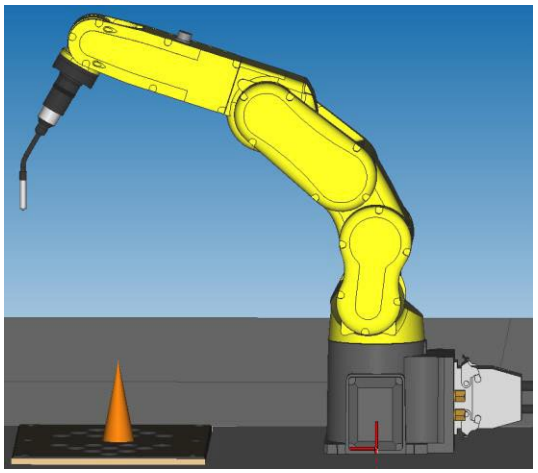
Once you have done the first three points (AP1, AP2 and AP3), proceed to the next, 4th point.

1. Use the feeder to place yourself at the Orient Origin Point and place the tool so that your TF is parallel to the WF:
    a. Place the X axis TF parallel to the X axis WF;
    b. Place the Z (or Y) axis TF parallel to the Z (or Y) axis WF, with the Z axes facing opposite each other;
    c. the tip of the tool does not have to touch the tip of a fixed point;
    d. position the tool so that you still have at least 250 mm of space (reach) with the tool in the X and Z (or Y) directions.

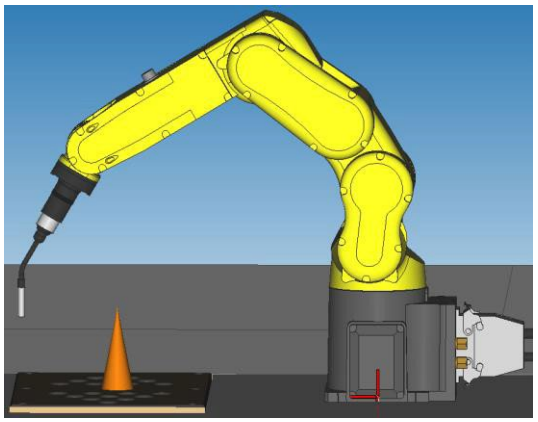
    Save the point with SHIFT+RECORD.



2. Use the feeder to position yourself at the X Direction Point and move the tool in the X TF direction, which is equal to the X direction in the WF by at least 250 mm. Save the point with SHIFT+RECORD.



3. Place yourself on the Z Direction Point with the feeder and move the tool in the Z TF direction, which is equal to the Z to WF direction by at least 250 mm. Save the point with SHIFT+RECORD.



4. When you save the last point (ZDP), the result is calculated and the coordinates of your TF, X, Y, Z, W, P and R are printed.
5. Check or test the appropriately set TF in the same way as with the 3-point method.

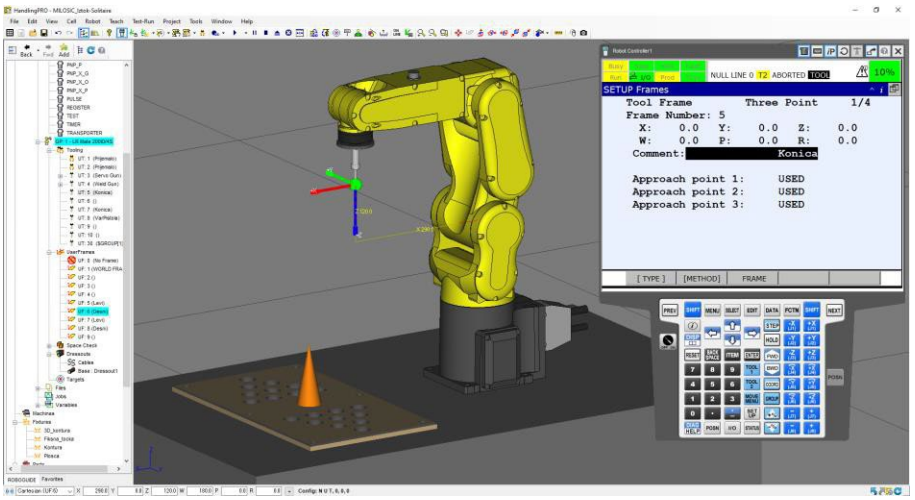
TF SETTING ON A REAL ROBOT

In the same way as in RG, set the TF for the tools on a real robot:

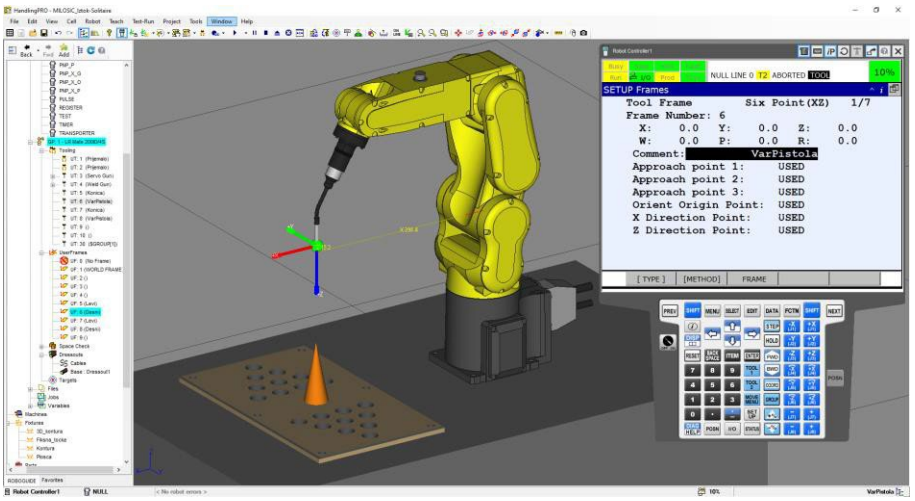
- SHUNK and
- welding gun.

EXAMPLE OF DISPLAYING AN RC SCREEN IMAGE FOR BROADCAST

Screenshot 1:



Screenshot 2:



ADDITIONAL VIDEO INSTRUCTION

1. MEHRING, Timothy: TOOL FRAMES AND FANUC'S ROBOGUIDE SOFTWARE, accessed at: https://www.youtube.com/watch?v=rPI2DVJKo-8, used: November 2023.
2. STAIFER, Dan: Creating a Tool Frame Using the Three Point Method, accessed at: https://www.youtube.com/watch?v=c1kNBFBDbIY, used: November 2023.

EXERCISE 4: SETTING UP A USER COORDINATE SYSTEM

In this tutorial, you'll use the RoboGuide simulation program:

- prepare a robot cell for setting up the user coordinate system:
  - hide items you don't need,
  - place all the rollers in the holes and mark them accordingly,
- set up the user coordinate system for picking up the rollers and check the correct setting of the user coordinate system,
- set up the user coordinate system for cylinder disposal and check the correct setting of the user coordinate system, and

on a real robot in the same way as in RG:

- set the user coordinate systems on the panel.

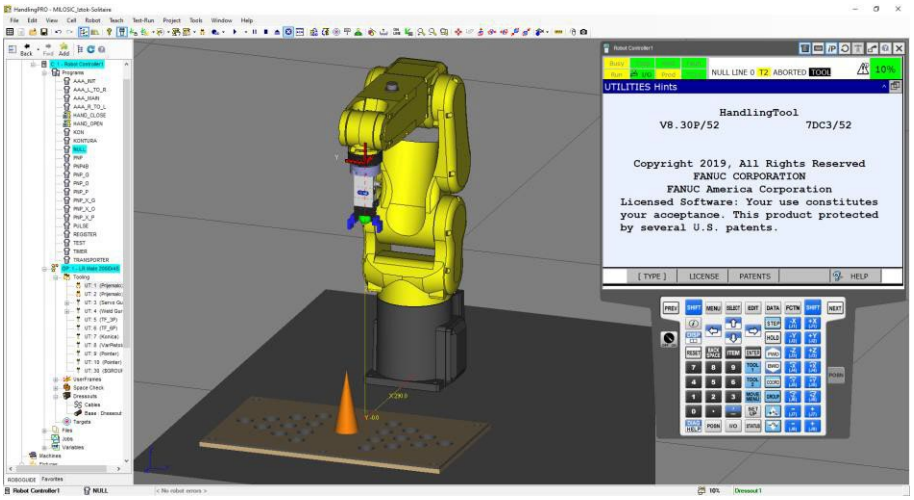
When the exercise is complete, submit the files:

1. a scanned and handwritten report on the completed exercise (PDF type – all pages in one document, orientation of the portrait document, pages arranged in order from 1 onwards),
2. Screenshot 1 (PDF, Doc... appropriately oriented) of its robotic cell from which it can be seen:
   - the name of the robotic cell,
   - all RC elements (robot, gripper, base, rollers...) the required rollers must be visible on the panel, all placed in the center of the full-size RG screen – across the entire screen, and
   - the included learning unit placed on the right side of the RG screen on which the screen with the UF settings (method, UF number, coordinates of the set UF, comment and all points should be visible),
   - the UE must have an active UF in order to see the correctly set UF on the board,
3. Screenshot 2 (PDF, Doc... appropriately oriented) of its robotic cell from which it can be seen:
   - the name of the robotic cell,
   - all RC elements (robot, gripper, base, rollers...) the required rollers must be visible on the panel, all placed in the center of the full-size RG screen – across the entire screen, and
   - the included learning unit placed on the right side of the RG screen on which the screen with the UF settings (method, UF number, coordinates of the set UF, comment and all points should be visible),
   - the UE must have an active UF in order to see the correctly set UF on the board,
4. a compressed robot cell file, type *.rgx, made in RoboGuide.

All submitted files must have meaningfully the same names as the name of the robot cell, only the backup copy must have a creation date at the end of the name in the form -YYYY_MM_DD.

Preparation of the robot cell for setting up the coordinate system of the tool

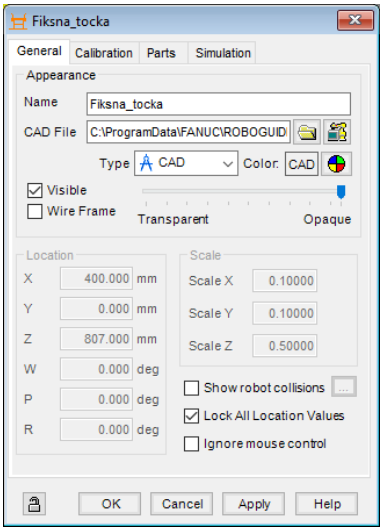
A prerequisite for starting this exercise is that you have a robotic cell built – see the image below.



PREPARATION OF THE ROBOT CELL

Hide the elements you don't need in the robot cell:

1. Barrier:
    a. Double-click on a fixed point and you will see a window to set a fixed point.
    b. In the pop-up window, check the Visible setting.

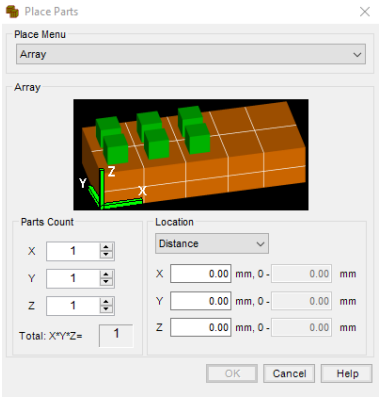


    c. Confirm to Apply and OK.

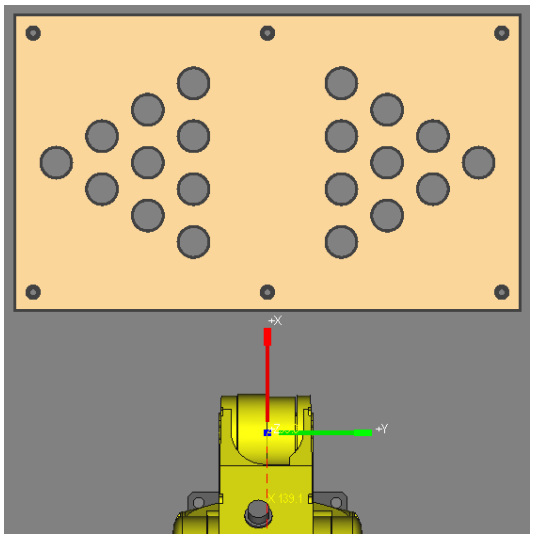
On the plate, add all the rollers on the L side (10) and all the rollers on the right side (10) of the plate.

1. Double-click on the panel and the panel setup window will appear.
2. In the Parts tab, click on the cylinder and click on Add. In the displayed window, in the Parts Count field, enter the appropriate number of cylinders (in the X, Y and Z directions) to be added and set the Distance or distance between them in the Location field (In the X, Y and Z directions). Confirm with OK.

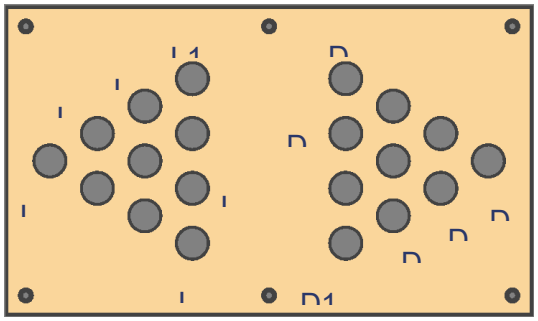
   Three rollers form an equilateral triangle, the distance between the rollers (side of the triangle) is 53 mm. However, calculate the distance between the adjacent cylinders that form the height of the triangle using the Pythagorean theorem.



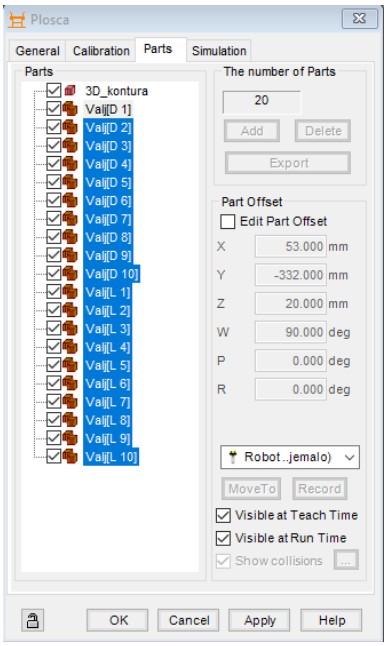
3. Place the robot in position J1 = 0°, J2 = -25°, J3 = -35°, J4 = 0°, J5 = -55°, J6 = 0° and set the view from above or to look at the panel from above in the direction of the robot.



4. Double-click the panel, click each cylinder on the Parts tab, and then check Edit Part Offset in the Part Offset box. A cylinder is marked on the panel and a green KS is drawn on it. Click on the coordinate axis with the mouse and drag the cylinder as accurately as possible to the hole in the board. In the Edit Part Offset box, fine-tune the roller to be positioned exactly in the middle of the platter hole (a multiple of the number of spacing between the rollers or heights between the rollers).
   Name the cylinders from L1 to L10 on the left and D1 to D10 on the right, as shown in the figure below.



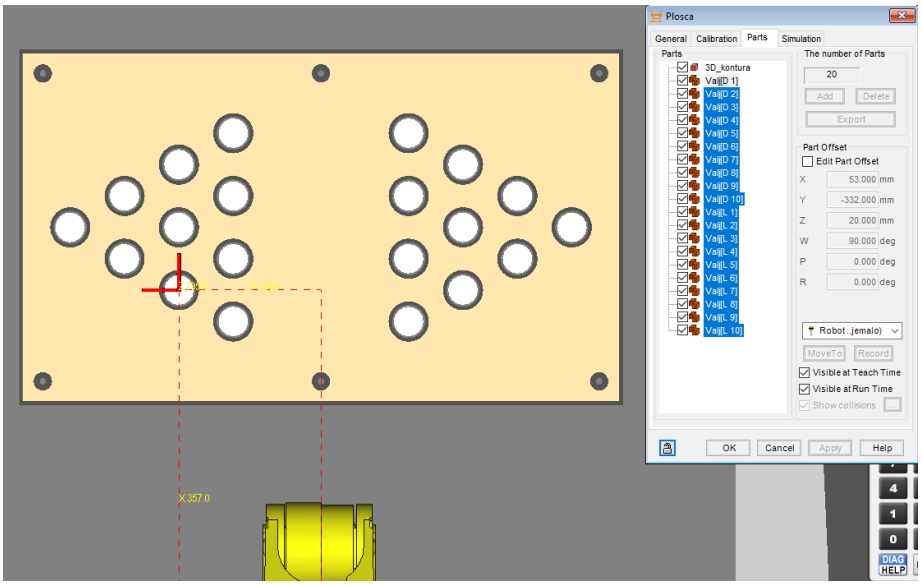
5. On all cylinders, in the Parts box, check:
   a. Visible at Teach Time in
   b. Visible at Run Time.



Confirm on Apply.

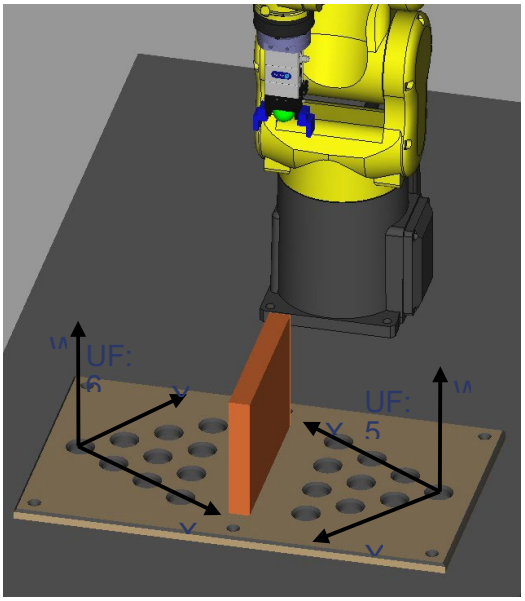
6. On the Simulation tab, on all cylinders, highlight:
    a. Allow parts to bi picked, Create Delay 9999.00 sec in
    b. Allow parts to bi placed, Destroy Delay 9999.00 sec. Confirm to Apply and OK.

The appearance of the plate with properly placed rollers.

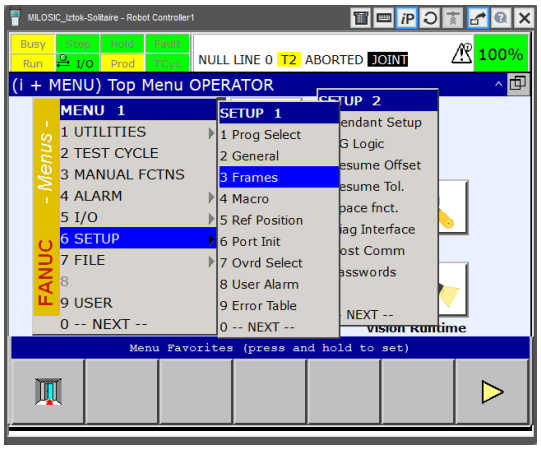


SETTING UP THE USER COORDINATE SYSTEM

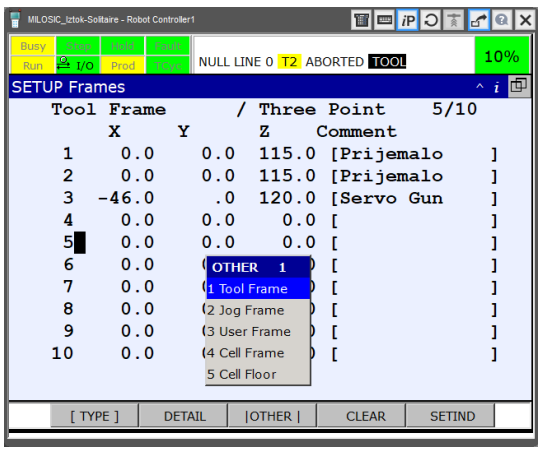
You will set two UFs, left and right. You'll place it sensibly so that you can pick up cylinder L1 and put it down on D1, then L2 on D2, and so on to L10 on D10.

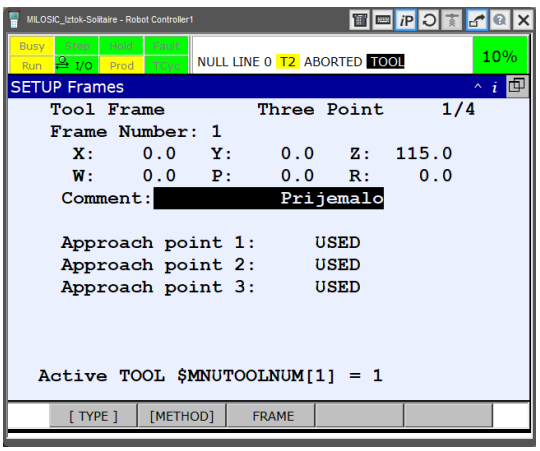


1. 6 FRAMES AND 3 FRAMES.



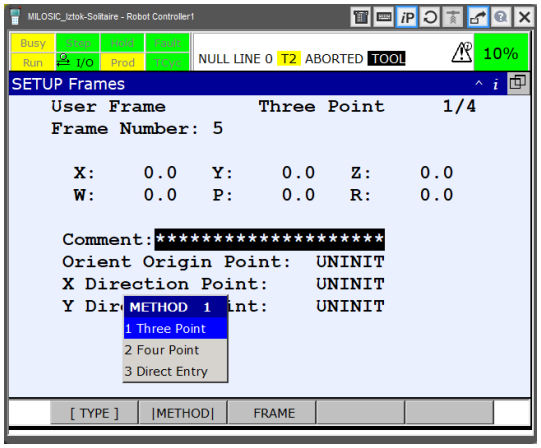
2. If you don't have User Frames displayed, switch to User Frame settings, F3 [OTHER], and select 3 User Frames (image left).
   If you do not see all KS in the coordinate system settings, click the PREV key and then switch to the desired KS, F3 [OTHER] (image on the right).



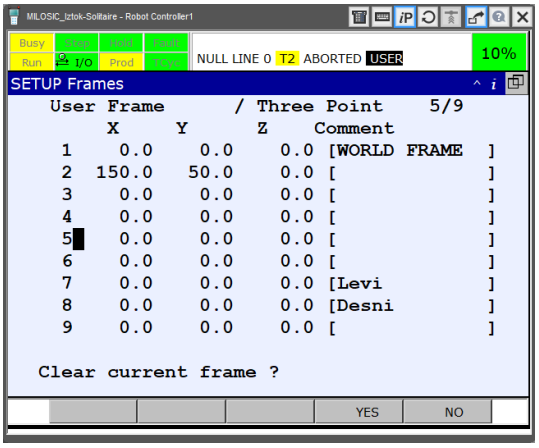


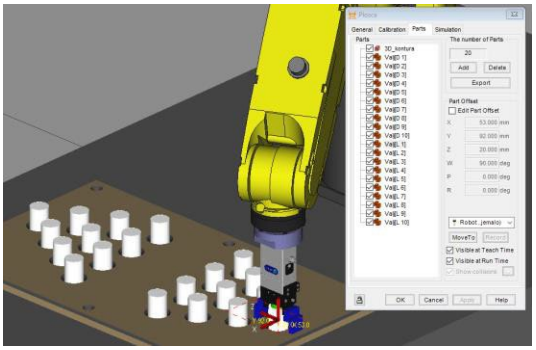
3. Stand at UF:5 and delete it by clicking the F4 CLEAR key (values and comment)

4. Enter the settings by clicking on F2 DETAIL.
5. Select the method at F2 [METHOD], 1 Three Point.

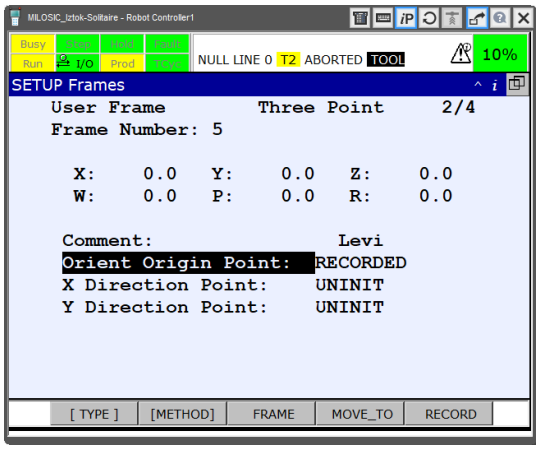


6. Use the typing pad to place yourself in the Comment field, click ENTER and type a comment, e.g. Left, confirm with ENTER.
7. Place yourself at the Orient Origin Point with the input and place yourself with TCP at the coordinate starting point, i.e. cylinder L1. Position yourself on L1 by double-clicking on the panels, highlighting cylinder L1 in the Parts tab, and clicking Move To.

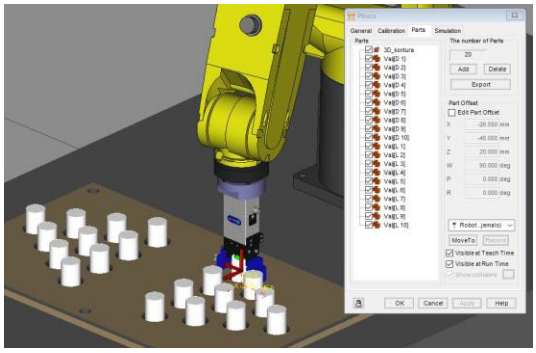




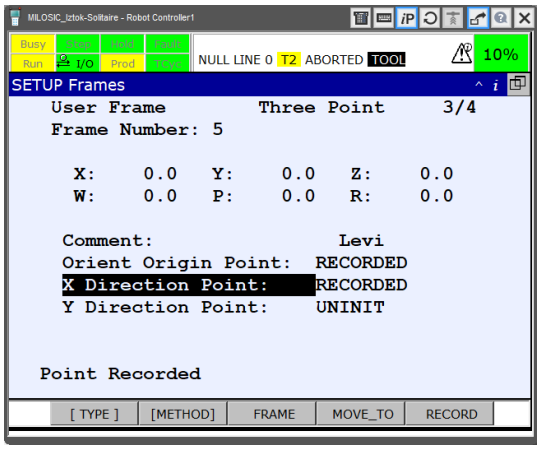
Save the point with SHIFT+RECORD.



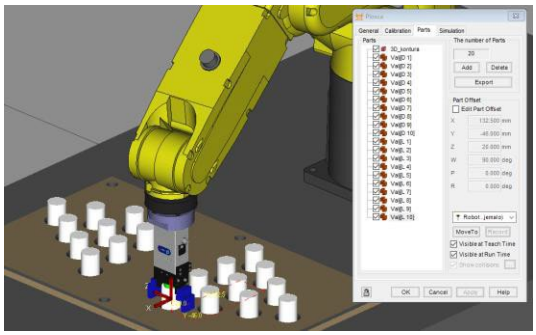
8. Place yourself at the X Direction Point with the feeder and place yourself on the farthest cylinder on the X-axis with TCP, i.e. cylinder L4. Position yourself on L4 by double-clicking on the panels, highlighting cylinder L4 in the Parts tab, and clicking Move To.



Save the point with SHIFT+RECORD.

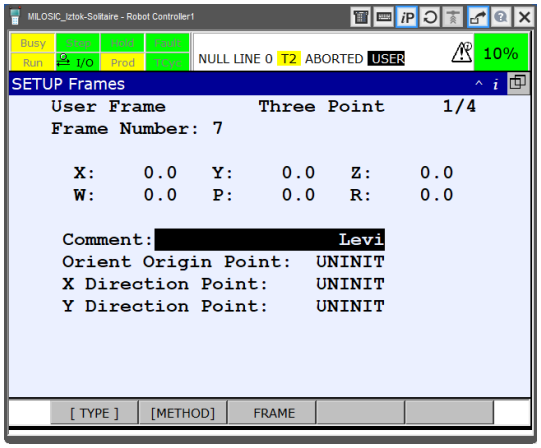


9. Place yourself on the Y Direction Point with the input and place yourself on the farthest cylinder on the + X + Y plane with TCP, i.e. the L10 cylinder. Position yourself on L10 by double-clicking on the panels, highlighting the L10 cylinder in the Parts tab, and clicking Move To.



Save the point with SHIFT+RECORD.

10. When you save point 3, your score is calculated and the coordinates of your UF, X, Y, Z, W, P, and R are plotted.



11. Check or test the appropriately tuned UF. Switch to KS UF (COORD) and activate your UF (SHIFT+COORD and your UF number, for your case No. 5).
    a. Place yourself on one saved point, Orient Origin Point, by placing yourself on this field with the input and pressing SHIFT + MOVE_TO. The TCP is placed at the coordinate starting point.
    b. Use translations to check the corresponding TCP movement in all directions (X, Y, and Z) of your UF: 5.

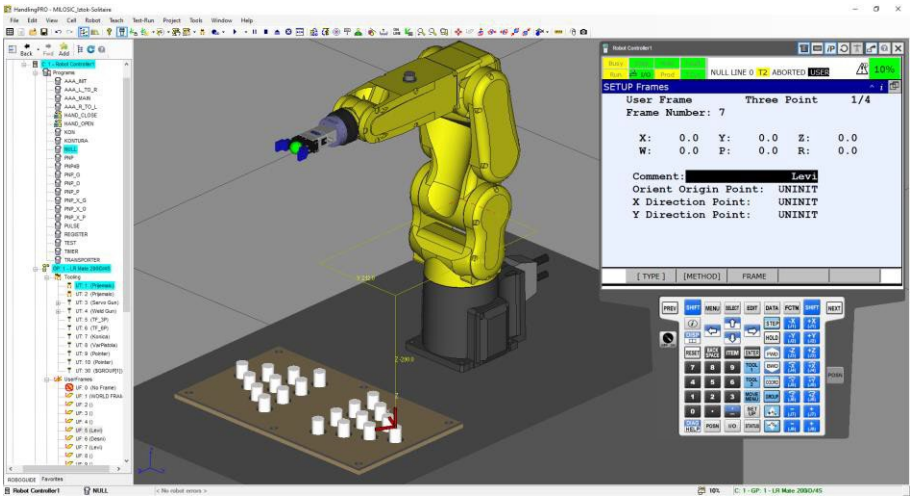
Sensibly set the user coordinate system on the right and test it (UF: 6, comment: Right).

SETTING UF ON A REAL ROBOT

In the same way as in RG, on a panel on a real robot, set the user coordinate systems.

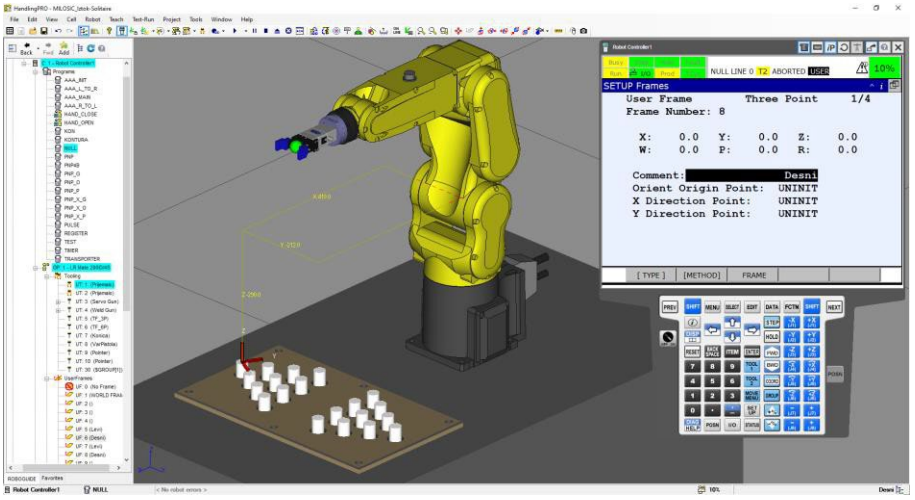
Place the robot at the starting point. In the tree structure, open Groups on + to find the UserFrames group and click on UF: 5. You will be shown UF with its coordinates. On UE, have the setting for UF displayed: 5.

Screenshot 1:



Also display UF: 6 and on UE setting for

UF: 6. Screenshot 2:



ADDITIONAL VIDEO INSTRUCTION

1. WILLEA, Adam: FANUC User Frame Setup and Strategy, accessed at: https://www.youtube.com/watch?v=LVjTjpxZV50, used: November 2023.
2. WILLEA, Adam: FANUC User Tool Setup Tips, available at: https://www.youtube.com/watch?v=TxvqeOsj4tU, used: November 2023.

EXERCISE 5: PICKING UP AND UNLOADING THREE ROLLERS PLACED IN A LINE WITH POSITION CALCULATION

In this tutorial, you'll use the RoboGuide simulation program:

- create a program for picking up and unloading three rollers, in which you will:
  - declare and initialize variables (registers),
  - declare and initialize position variables (position registers),
  - perform mathematical operations with registers and position registers, and
  - apply the final loop (final repetition) and
- on a real robot:
  - transfer a proven program from the RoboGuide simulation environment to a real robot,
  - test the program in T1/T2 mode, and
  - run the program in AUTO mode.

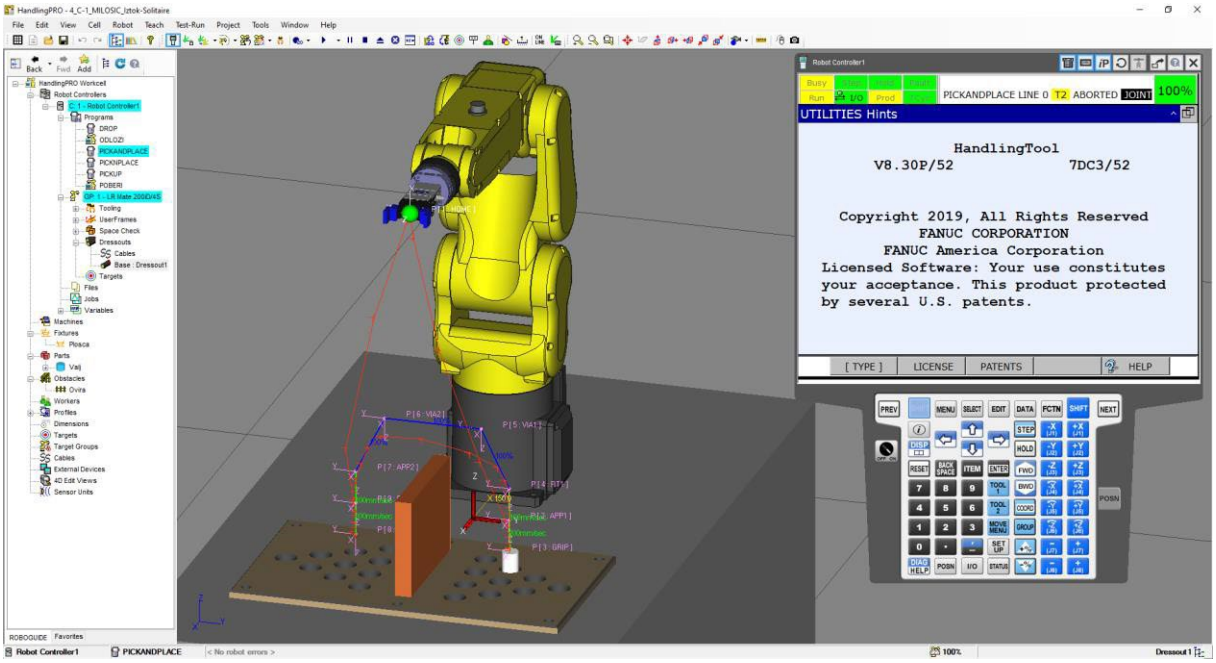
When the exercise is complete, submit the files:

- a scanned and handwritten report on the completed exercise (PDF type – all pages in one document, orientation of the portrait document, pages arranged in order from 1 onwards),
- screen image (pdf, doc ... appropriately oriented) of its robotic cell from which it can be seen:
  - the name of the robotic cell,
  - all RC elements (robot, gripper, pedestal, plate, obstacle, rollers...) on the panel must be visible both halves – L and D from the obstacle) and placed in the middle of the RG screen in full size – across the entire screen, and
  - the included learning unit placed on the right side of the RG screen,
  - The full code of the program and all subroutines used (except the gripper closing and opening subroutines) – divide the UE screen into several parts appropriately and display the main program, the pickup subprogram and the dump subprogram.
- video of the operation of the program, type *.avi, size 1,920 × 1,080 and
- a compressed robot cell file, type *.rgx, made in RoboGuide.

All submitted files must have meaningfully the same names as the name of the robot cell, only the backup copy must have a creation date at the end of the name in the form -YYYY_MM_DD.

Programming an application for picking and dropping products placed in a line, Pick & Place

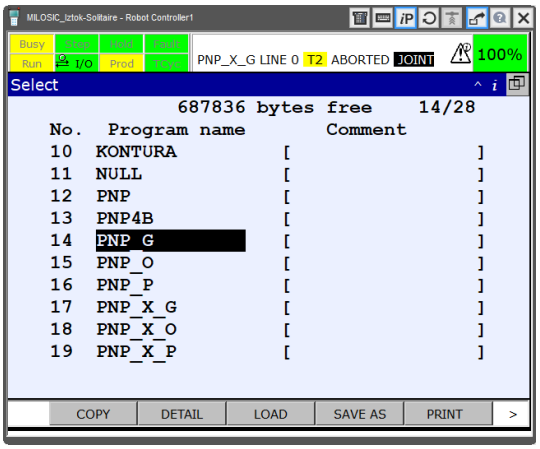
A prerequisite for starting this exercise is that you have completed exercise 2 (see image below).

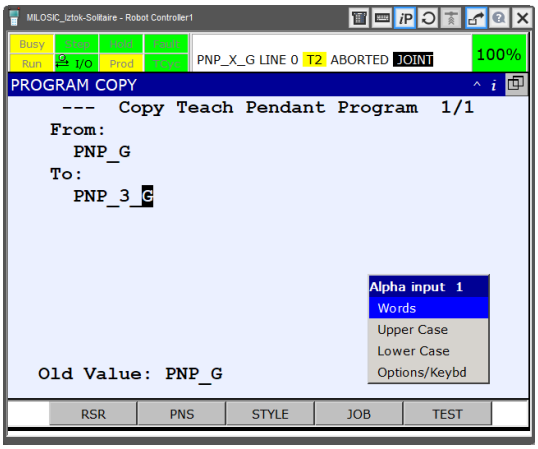


PREPARATION OF THE PROGRAM

1. First, make a copy of the existing (sub)programs:
   - Copy PNP_G program to PNP_3_G.
   - Copy the PNP_P subprogram to PNP_3_P and
   - Copy the PNP_O subroutine into PNP_3_O.

   You can make a copy in two ways, on the learning unit, UE or in the tree structure of the RoboGuide program, RG.
   Copying a program to UE:
   - Click SELECT and select the program you want to copy,
   - use the NEXT key on UE to switch the menu keys (F1 to F5),

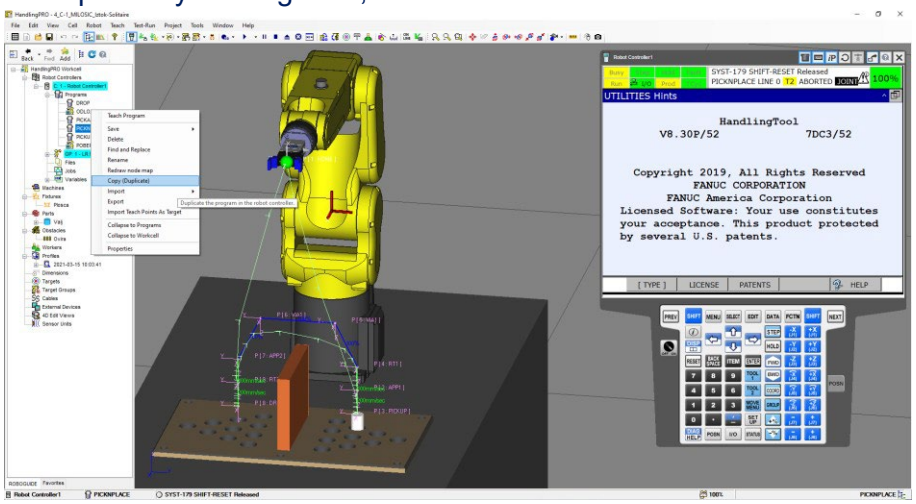




   - click F1 COPY, type a new name for the program, and then confirm with F4 YES to the question "Copy OK?".

To copy a program in the RG tree:

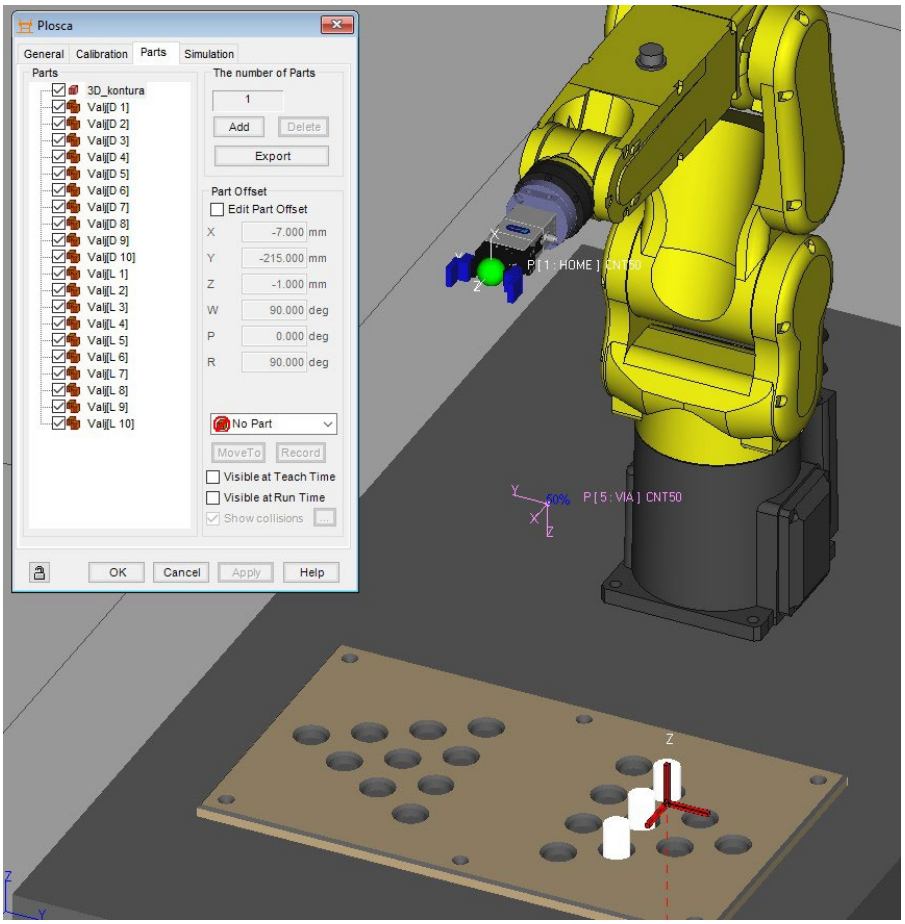
- in the tree structure by clicking on + Robot Controllers, find the Programs group and open it by clicking on +,



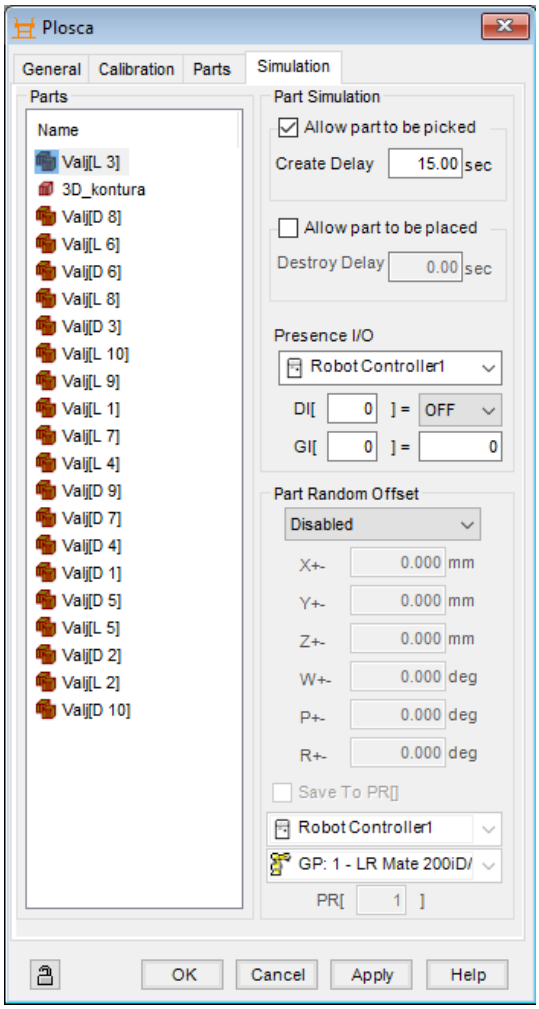
- find the program you want to copy, click on it with the D key on the mouse, select the Copy (Duplicate) command from the displayed menu and enter a new name, confirm with OK.

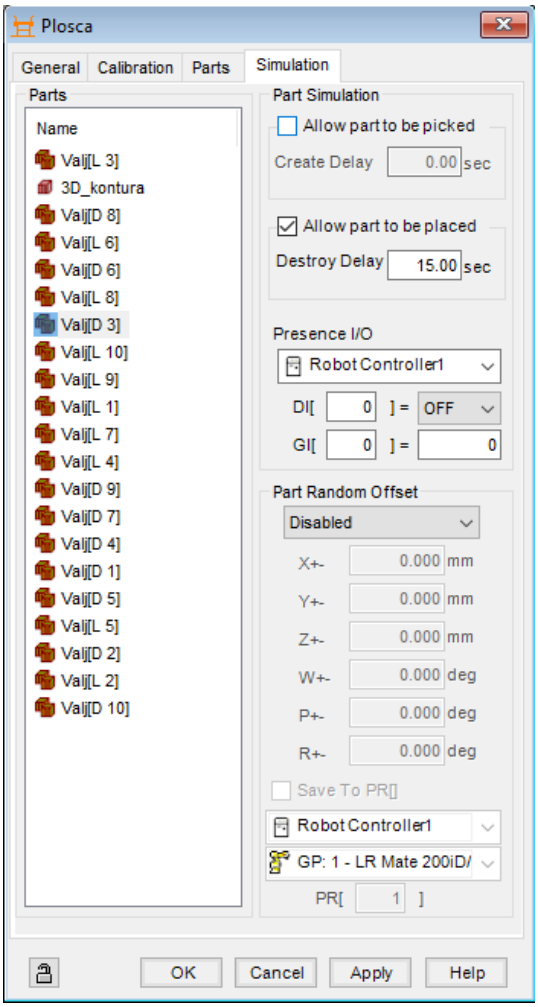
PREPARATION OF ROLLERS

If you already have all 20 rollers placed on the panel (visible/hidden), show the three (3) rollers on the left for picking and hide all rollers on the right side of the plate (robot direction) as shown in the figure below.



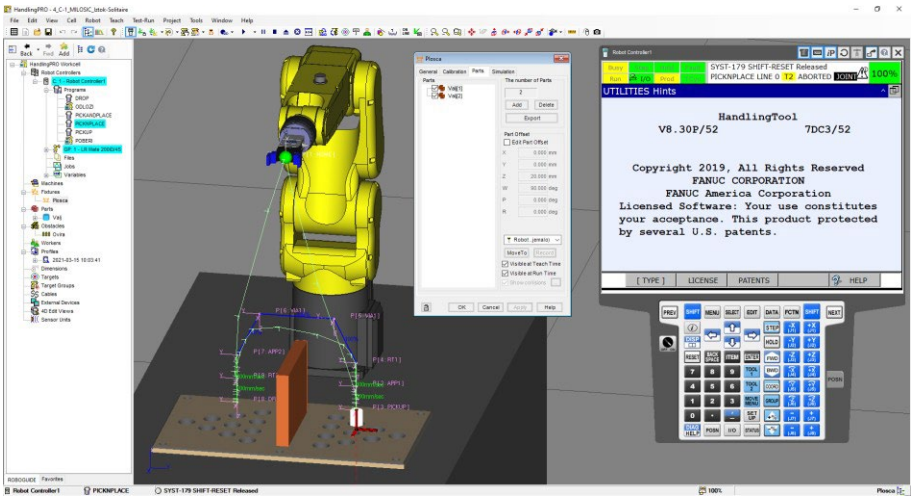
To properly simulate the movement of the rollers (show/hide), set the time before the pick command and the time after the drop command to 15 s as shown in the figure below.





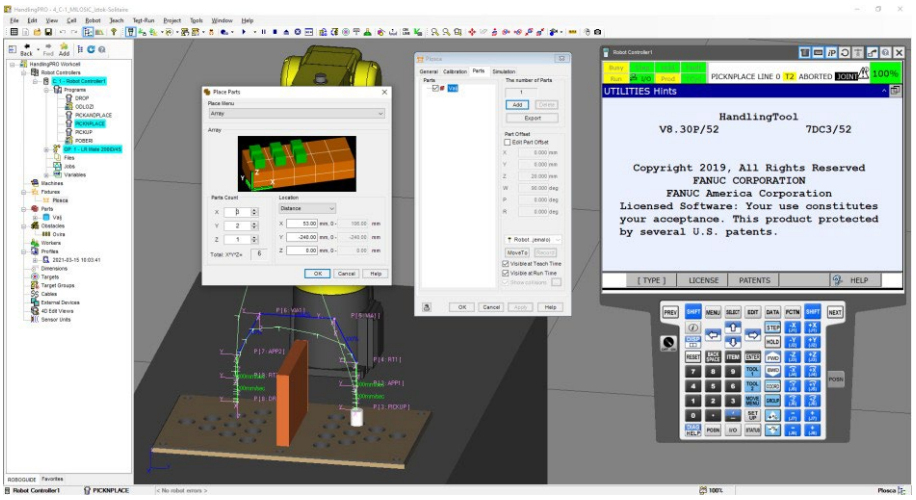
If you do not have the cylinders ready yet, continue with the next procedure for preparing the cylinders, otherwise proceed to the next section.

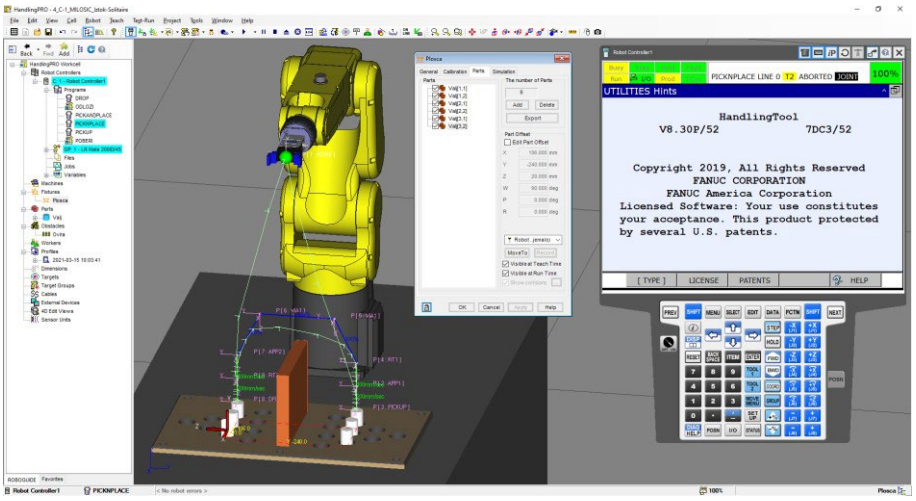
1. To prepare the rollers, double-click on the panel. In the Parts tab, we add more cylinders.



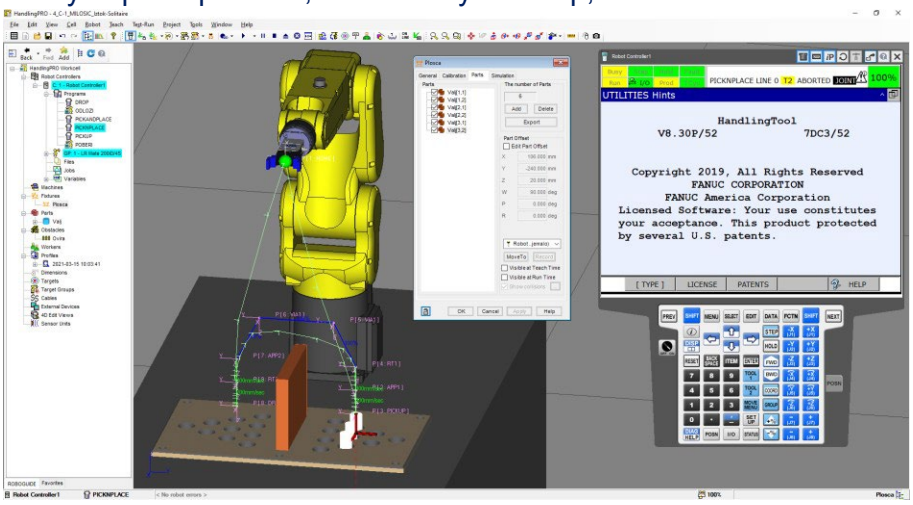
2. By clicking on the Add button, we add the required number of cylinders. I recommend deleting the rollers first, and then adding them. Click on the Cylinder[2] and click on the Delete button to delete it.

3. Click on Add again and set the appropriate number of cylinders in the X and Y directions and place them at the appropriate distance. For our example, in the X direction, there will be 3 rollers at a distance of 53 mm, and in the Y direction, 2 rollers at a distance of 240 mm.

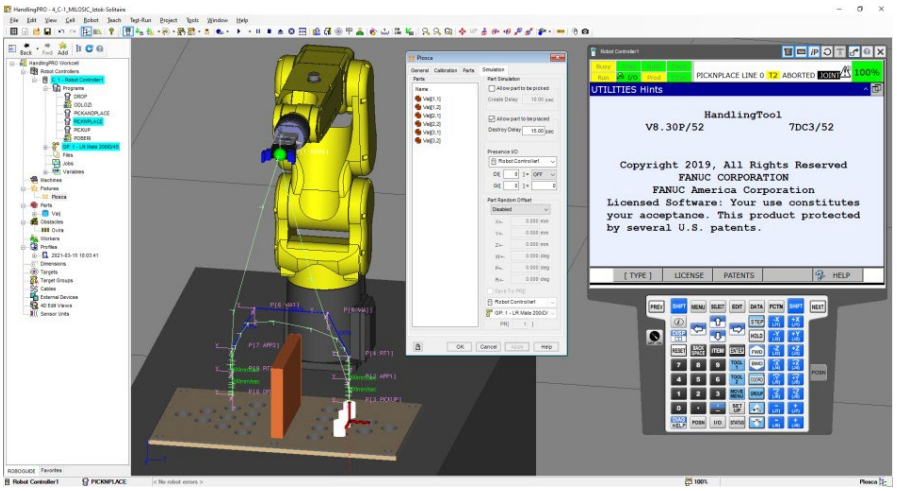




4. Set the rollers you pick up visible, the rollers you dump, set the invisible.

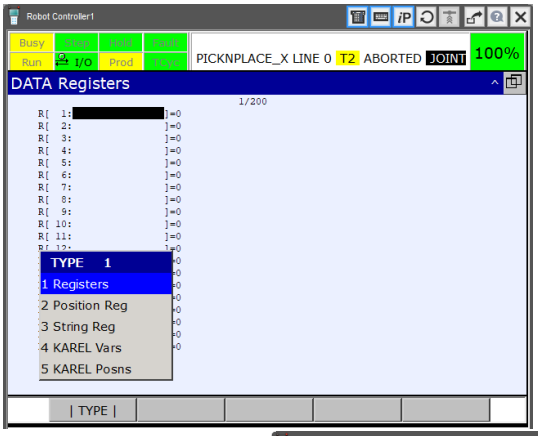


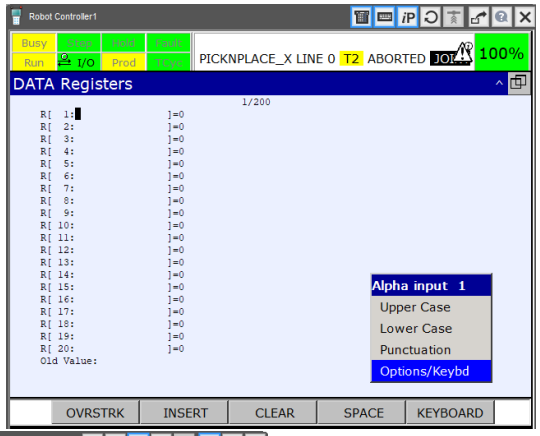
5. In the Simulation tab, set the visibility of the cylinders to be picked up 15 s before the grip command and the visibility of the rollers to be dumped, 15 s after the dump command.

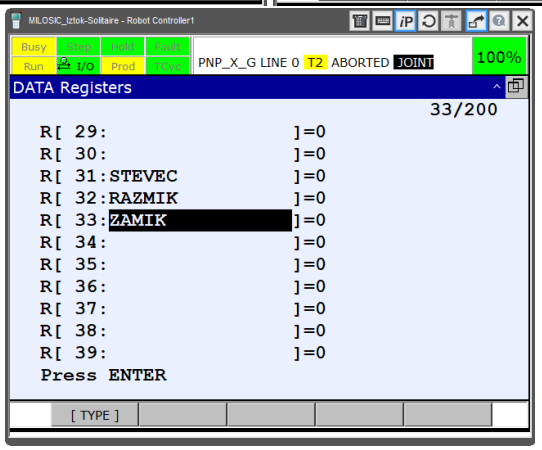


EDIT AN APP

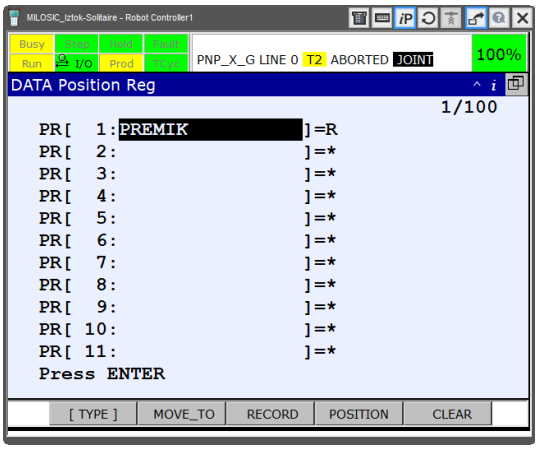
1. In the program, you will need some variables or registers:
   - R[31:COUNTER] – counter for the number of repetitions of picking up and putting away, for our example 3 repetitions,
   - R[32:SPACING] – the value of the cylinder spacing, 53 mm for our example,
   - R[33:MENTION] - Calculating the value by how much the pick-up/drop-off point should move,
   - PR[1:SHIFT] - Enter coordinates for how much the pick-up/drop-off point should move.
2. Declare variables or registers by entering a comment or the name of the register. On UE, click DATA/F1 [TYPE] and select 1 Registers. Use the directional arrows to place yourself in the registry comment box, and then press ENTER. Select Options/Keyb and F5 KEY-BOARD. For the first register, enter the name NUMERATOR, for the second register IN-TERVAL and for the third ZAZAM.





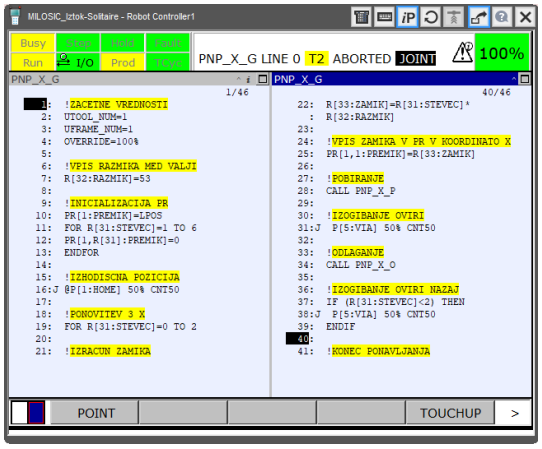


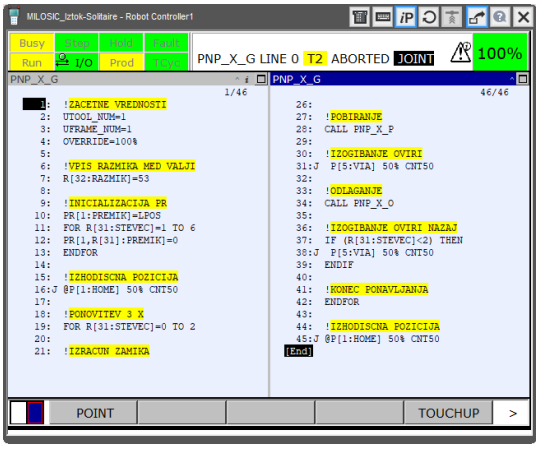
3. Similarly, set up for PR[i] position registers. On UE, click DATA/F1 [TYPE] and select 2 Position Reg. Use the directional arrows to position yourself in the position register comment box and press ENTER. Select Options/Keyb and F5 KEYBOARD. PR[1] add a name or comment MOVE.



4. In UE, open the previously copied main PNP_3 program and edit in it:
   - initialize the variables or enter the spacing between the cylinders in the numerical register,
     - R[32:SPACING] = 53,
   - initialize the position register or set all Cartesian coordinates to 0,
     - PR[1:SHIFT] = LPOS
     - FOR R[31:STEVEC] = 1 TO 6
     - PR[1,R[1]:P RUMIK] = 0
     - ENDFOR,
   - insert the FOR loop for 3 × repetitions of picking and putting away,
     - FOR R[31:STEVEC] = 0 TO 2
     - …
     - ENDFOR,
   - calculate the offset and enter it in the position register in the X coordinate,
     - R[33:SPACE] = R[31:NUMBER] * R[32:SPACE],
   - in the pick-up and unloading sub-programs, correct the program so that the points move by the distance between the rollers,
     - J P[2:APP1] 50 % CNT50 Offset, PR[1:APP1],
   - that at the last repetition from the point of return (RETREAT), TCP does not return to the starting position (HOME) via the point of avoiding the obstacle back (VIA),
     - IF R[31:STEVEC] < 2 THEN
     - J P[5:VIA] 50 % CNT50
     - ENDIF.

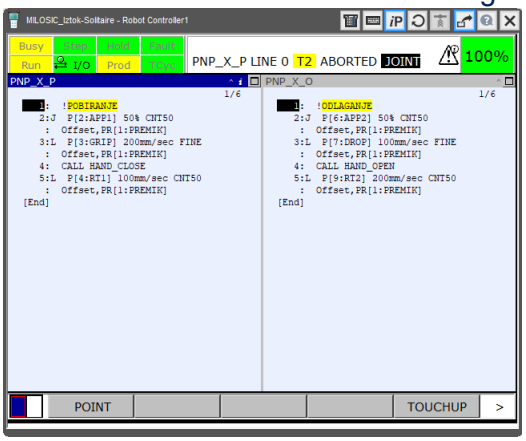
The main program can be seen from the following figures:



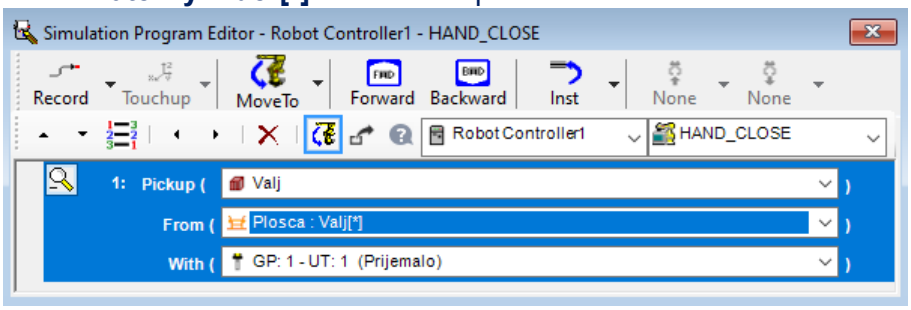


5. In UE, open the previously copied subprogram PNP_3_P and add an indent with the position register at all points. The subroutine can be seen in the figure.

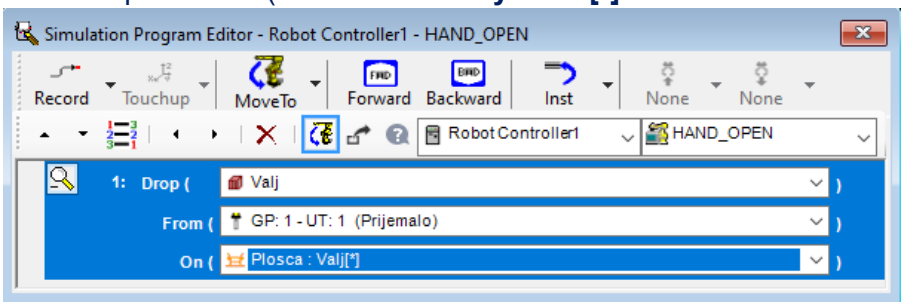
6. In UE, open the previously copied subprogram PNP_3_O and add an indent with the position register at all points. The subroutine can be seen in the figure.



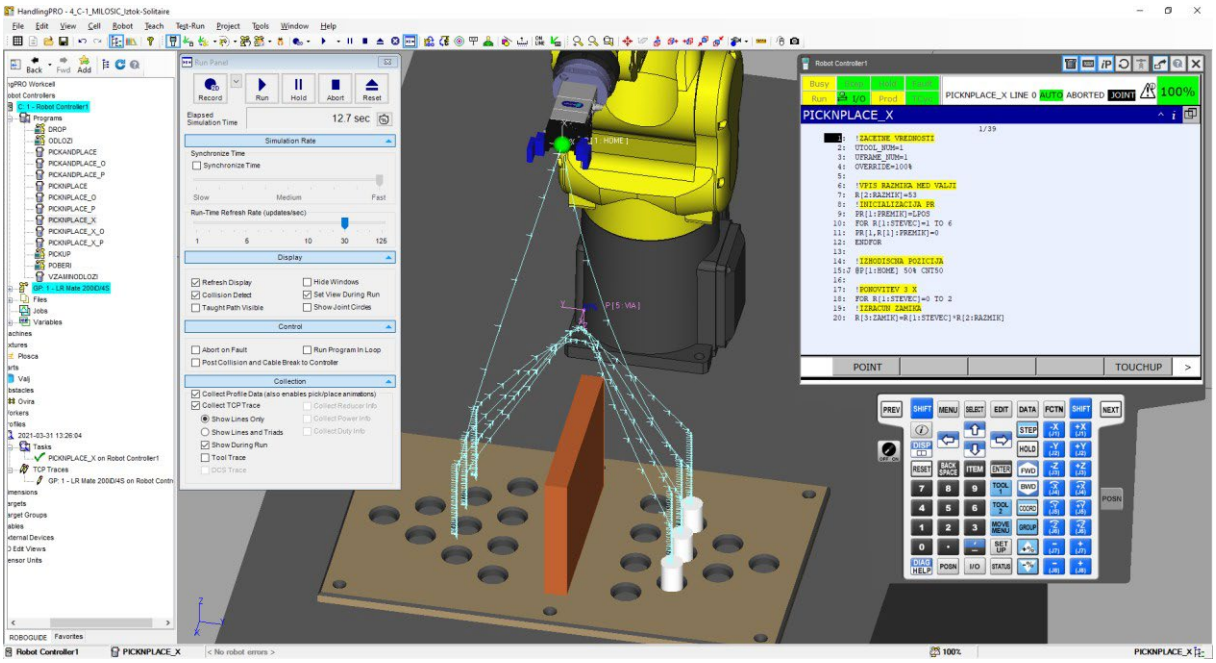
7. Change the simulation subroutines for closing and opening grippers, HAND_CLOSE and HAND_OPEN, to pick up and put down all cylinders, not just the first cylinder.
    - In the tree structure, double-click on the simulation subroutine HAND_CLOSE and select **Plate:Cylinder[*]** in the From parameter.

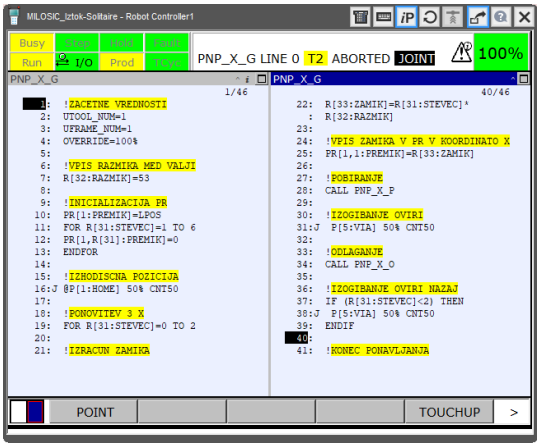


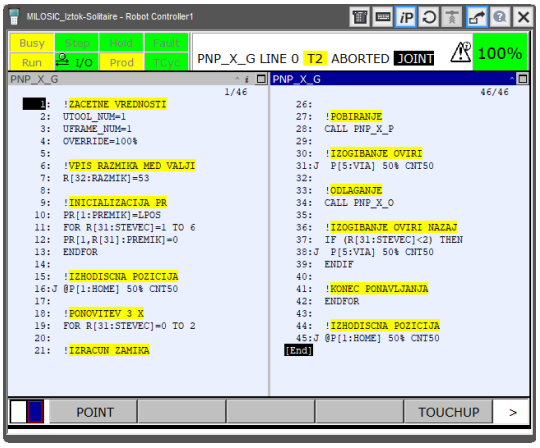
    - In the tree structure, double-click on the simulation subroutine HAND_OPEN and in the On parameter (select **Board: Cylinder[*]**.

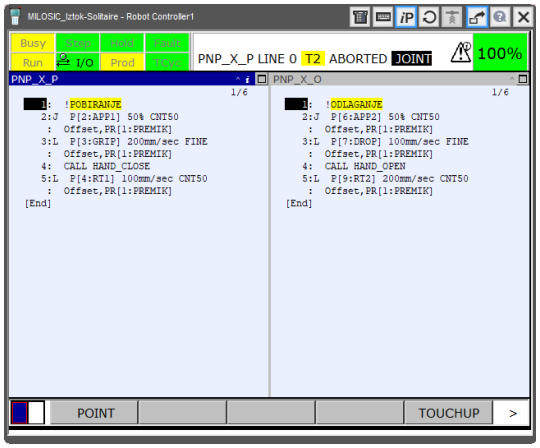


EXAMPLE OF DISPLAYING AN RC SCREEN IMAGE FOR BROADCAST









ADDITIONAL VIDEO INSTRUCTION

1. WILLEA, Adam: FANUC Roboguide Tutorial, available at: https://www.youtube.com/watch?v=neAFHplKu-Y, used: January 2021.

EXERCISE 6: PICKING UP AND UNLOADING ALL 10 CYLINDERS PLACED IN THE PLANE OF THE SHAPE OF AN EQUILATERAL TRIANGLE BY CALCULATING POSITIONS

In this tutorial, you'll use the RoboGuide simulation program:

- create a robotic program that will move 10 cylinders over an obstacle to the other side,
- develop a subroutine for initialization and subroutines for picking and dumping,
- on the left side of the board (pick-up/dump) use TF1 and UF5,
- on the right side of the plate (deposit/pick-up) use TF1 and UF6,
- in other cases (main program) use TF1 and UF1,
- make an application 2 to continuously stack the program back and forth, between repetitions should be 3 s pause in the starting (HOME) position,
- Create an application 3 so that the robot with a sensor will find the cylinders and just move them back and forth always to the same pick-up and unloading positions (the 1st cylinder always puts down to the 1st place ... 3rd to 3rd place...),
- make an application 4 so that the robot with the sensor will look for the cylinders and just pick them up and put them on the other side in the first empty spaces (1. the found cylinder, which does not necessarily stand in the 1st place, can be in the 3rd place and put it in the 1st empty place, 2. the found cylinder, which does not necessarily stand in the 2nd place, can be in the 6th place and put it in the 2nd empty place ...),
- on a real robot:
    - transfer a proven program from the RoboGuide simulation environment to a real robot,
    - test the program in T1/T2 mode, and
    - run the program in AUTO mode.

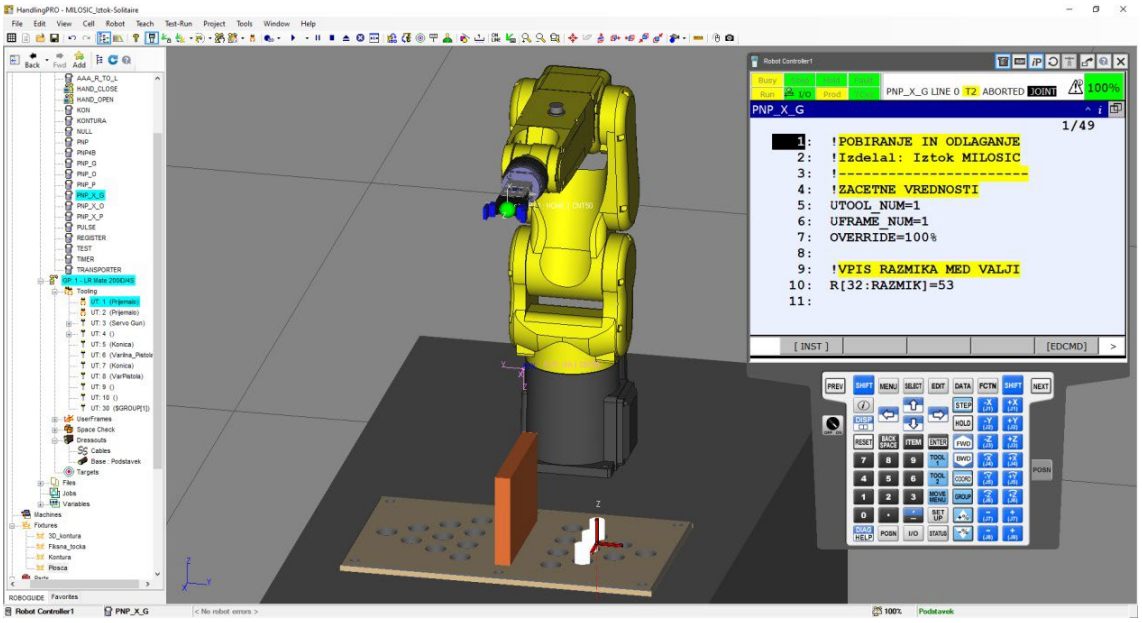
When the exercise is complete, submit the files:

- a scanned and handwritten report on the completed exercise (PDF type – all pages in one document, orientation of the portrait document, pages arranged in order from 1 onwards),
- screen image (pdf, doc ... appropriately oriented) of its robotic cell from which it can be seen:
    - the name of the robotic cell,
    - all RC elements (robot, gripper, pedestal, plate, obstacle, rollers...) on the panel must be visible both halves – L and D from the obstacle) and placed in the middle of the RG screen in full size – across the entire screen, and
    - the included learning unit placed on the right side of the RG screen,
    - The full code of the program and all subroutines used (except the gripper closing and opening subroutines) – divide the UE screen into several parts appropriately and display the main program, the pickup subprogram and the dump subprogram.
- a video of the operation for each application separately, of type *.avi, size 1,920 × 1,080 and
- a compressed robot cell file, type *.rgx, made in RoboGuide.

All submitted files must have meaningfully the same names as the name of the robot cell, only the backup copy must have a creation date at the end of the name in the form -YYYY_MM_DD.

Programming an application for picking up and unloading products placed in the plane of the shape of an equilateral triangle, Pick & Place

A prerequisite for starting this exercise is that you have completed exercise 4 and exercise 5 (see image below).

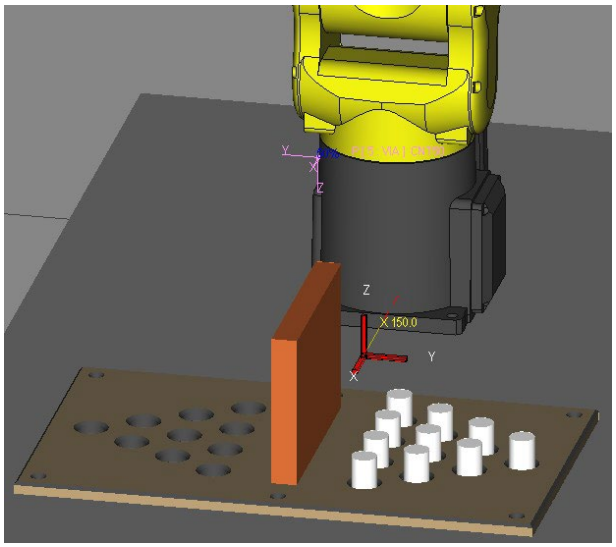


PREPARATION OF THE PROGRAM

1. First, make a copy of the existing (sub)programs:
    - Copy PNP_3_G program to PNP_10_G.
    - Copy the PNP_3_P subroutine to PNP_10_P, and
    - Copy PNP_3_O subroutine to PNP_10_O.

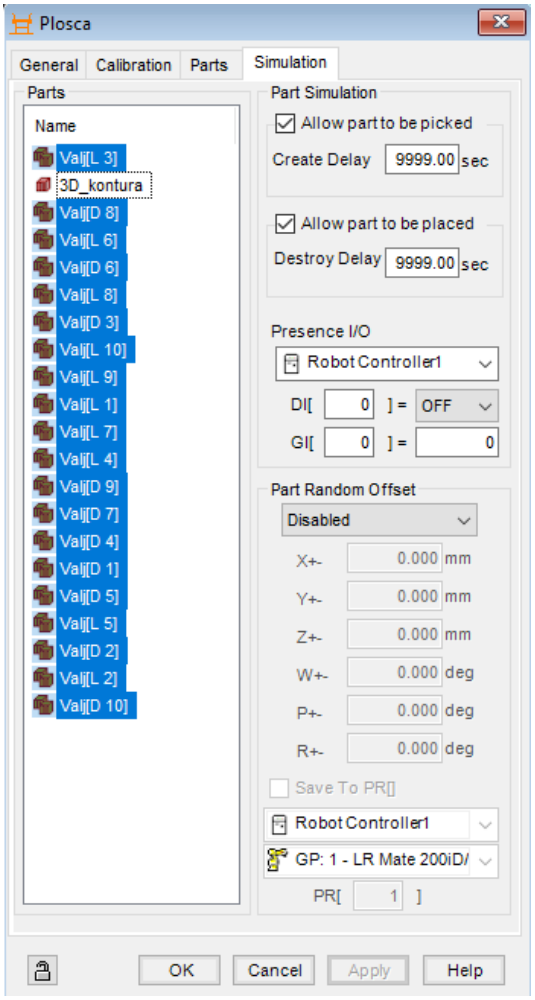
PREPARATION OF ROLLERS

Display all ten (10) rollers on the left side of the pickup plate on the panel, and hide all rollers on the right side of the dump plate (robot direction) as shown in the figure below.



To properly simulate the movement of the rollers (show/hide), set the time before the pick command and the time after the drop command to 9999 s.

If you are going to pick up the rollers on the left and dump on the right, and repeat the pick-up on the right and the drop-off on the left (repeat), then set the time before the pick-up command and the time after the drop-off command for all rollers to 9999 s, as shown in the figure below.



EDIT AN APP

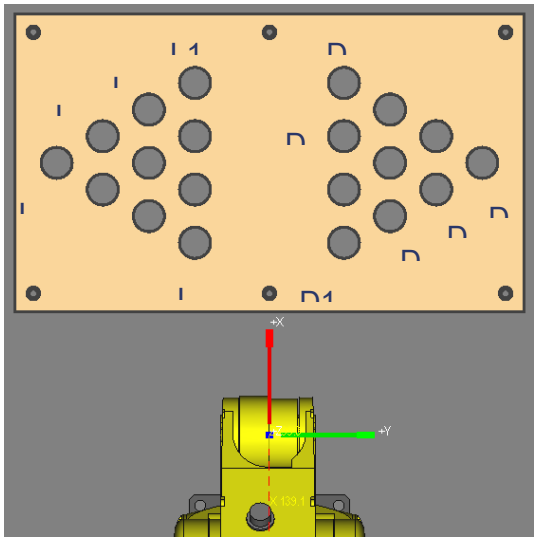
1. Declare and initialize the necessary variables or registers (counter in X and Y directions, dimensions or spacing between cylinders in X and Y directions ...). To initialize, make a subprogram named PNP_INIT, which you call from the main program PNP_10_G. The following illustration shows an example:

```
 1:  !Postavitev zacetnih vrednosti
 2:  R[20:Stevec_X]=0
 3:  R[21:Stevec_X2]=3
 4:  R[22:Stevec_Y]=0
 5:  R[23:Razmik_X]=53
 6:  R[24:Razmik_X2]=26.5
 7:  R[25:Razmik_Y]=45.9
 8:
 9:  !Brisanje poz. registra
10:  PR[1]=LPOS
11:  FOR R[20:Stevec_X]=1 TO 6
12:  PR[1,R[20]]=0
13:  ENDFOR
[End]
```

To indent or calculate positions, make a calculation that you include in the main program and is shown in the image below:

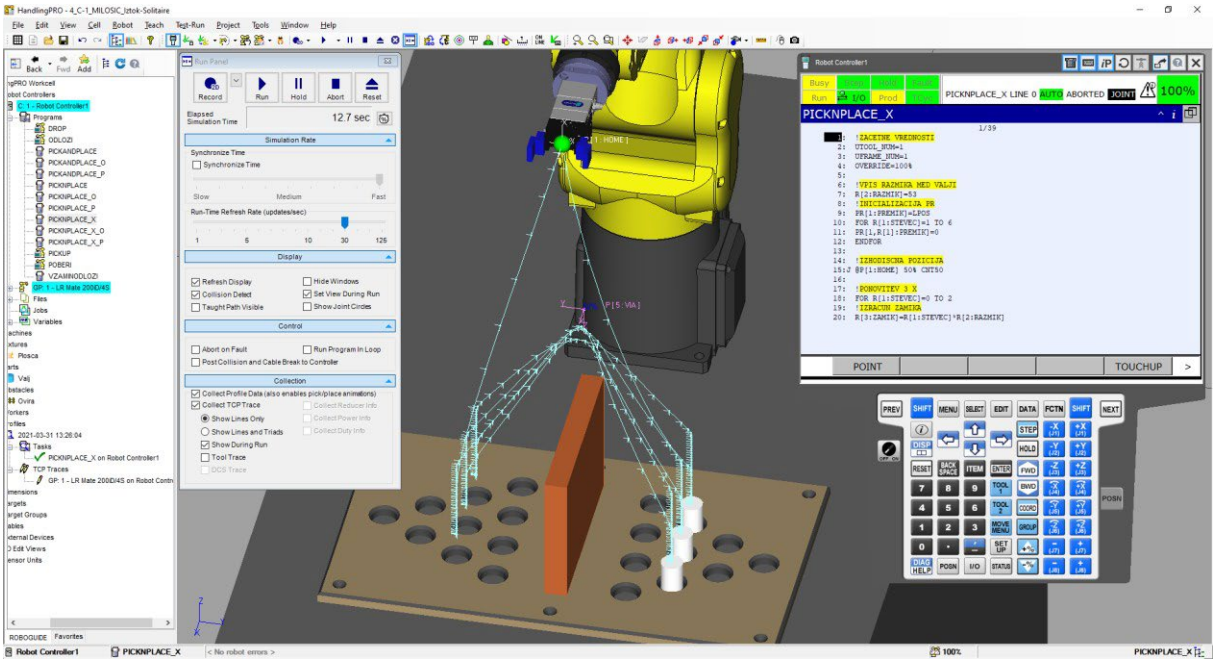
```
21:  !Izracun Y koordinate
22:  FOR R[22:Stevec_Y]=0 TO 3
23:  R[28:Izracun_Y]=R[22:Stevec_Y]*R[25:Razmik_Y]
24:  !Vpis Y koordinate v poz. reg.
25:  PR[1,2]=R[28:Izracun_Y]
26:  !Izracun X koordinate
27:  FOR R[20:Stevec_X]=0 TO R[21:Stevec_X2]
28:  R[26:Izracun_X]=R[20:Stevec_X]*R[23:Razmik_X]
29:  R[27:Izracun_X2]=R[22:Stevec_Y]*R[24:Razmik_X2]
30:  !Vpis X koordinate v poz. reg.
31:  PR[1,1]=R[27:Izracun_X2]+R[26:Izracun_X]
32:  !Poberi in Odlozi
33:  CALL PNP_10_PRENESI
34:  ENDFOR
35:  !Zmanjsa st. ponovitev v X smeri
36:  R[21:Stevec_X2]=R[21:Stevec_X2]-1
37:  ENDFOR
```

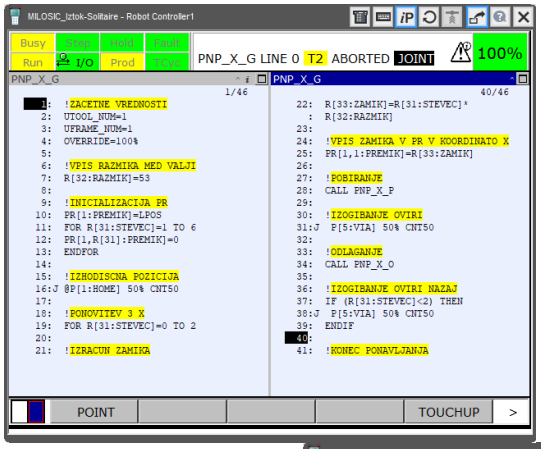
2. In the pick-up/dump subroutine on the left side of the panel, use user coordinate system No. 5 (left). Therefore, correct the initial pick-up/dump positions (APP1, PICKUP, RT1) on the first roller L1 in UF5 (TOUCHUP).
3. In the Dump/Pick subroutine on the right side of the panel, use the user coordinate system No. 6 (right). Therefore, correct the initial deposit/pick up positions (APP2, DROP, RT2) on the first roller D1 in UF6 (TOUCHUP).

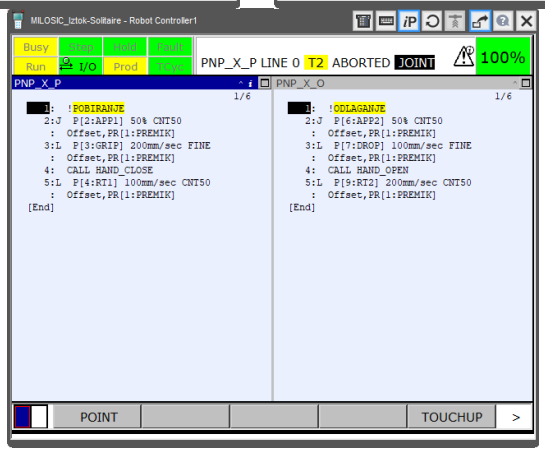


4. Make a copy of the application (the main program and all subroutines), e.g. PNP_10_P_G ... Fix the application so that the robot continuously stacks the rollers back and forth, with 3 pauses between repetitions in the HOME position.
5. Make a copy of the application (the main program and all subroutines), e.g. PNP_10_PS_G ... Fix the application so that the robot looks for rollers on the panel (not necessarily all of them are placed, but randomly placed any number less than or equal to 10) continuously stacks the rollers back and forth, between repetitions there should be 3 s pause in the starting (HOME) position.
6. Make a copy of the application (the main program and all subroutines), e.g. PNP_10_PS_G ... Fix the application by having the robot look for cylinders on the board (not necessarily all of them are placed, but randomly placed any number less than or equal to 10), pick it up and put it in the first empty place (the 1st cylinder found, which does not necessarily stand in the 1st place, can be in the 3rd place and put it in the 1st empty place, the 2nd cylinder found, who doesn't necessarily stand in 2nd place, can be in 6th place and put it on the 2nd empty spot ...). The app continuously stacks the rollers back and forth, with 3 breaks between repetitions in the HOME position.

EXAMPLE DISPLAY FOR RC ELEPHANT PAINTINGS FOR SUBMISSION







ADDITIONAL VIDEO INSTRUCTION

1. WILLEA, Adam: FANUC Roboguide Tutorial, available at: https://www.youtube.com/watch?v=neAFHplKu-Y, used: January 2021.

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