

Intera 5.2.2 Robot Positioning System (RPS) Guide for Success

March 2018

Robot Positioning System (RPS) is a technology that allows the robot to manage and adapt to ever-changing, real-world environments. The Robot Positioning System helps users to more quickly and easily re-deploy the robot after common plant-floor variations occur, such as tables being bumped, fixtures being moved, and more.

This system adjusts more readily to changing work environments by using visual reference markers, called Landmarks™, in conjunction with its embedded vision system. The robot is able to recognize the original locations of the markers, and, when those locations change slightly, can observe the changes in orientation to the new locations and adjust its movements accordingly.

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Robot Positioning System Testing Protocol and Relative Accuracy Results

This portion of the document provides characterization information for the level of accuracy the user should expect when using the Robot Position System (RPS). After registering a Landmark, either the robot or the Landmark (if it's on a cart for example) may move, so the user would re-register the Landmark. Even if the original registered Landmark location is not perfectly accurate, the *relative* accuracy of the re-registration is the most important factor. That is, if the robot moves 5mm to the left, we would expect to see the Landmark move precisely 5mm to the right in robot base frame.

The test conditions to measure and collect accuracy data consisted of a system where a Landmark is attached to a third party testing mechanism at a precisely measured location. This system precisely measures the Landmark location and uses the arm to estimate the Landmark location via RPS. Using the initial measurements as a reference, the difference in position measurements between RPS and the third party system derives the error.

This test follows established best practices regarding the lighting, settings, and position of the camera relative to the Landmark at the time of registration. Best practices also dictate that the same arm pose be used for registration and all subsequent re-registrations and that the user try to move the robot or Landmark as close as possible to its original location before attempting re-registration.

Results Summary

If the user follows the RPS best practices guide and the Landmark is “close to the original location”, which is defined as the Landmark being within 20 mm (x/y) and 5 mm (z) of its original position and 4 deg (roll/pitch) and 10 deg (yaw) of its original orientation, the user can expect the following accuracy:

X / Y	Z	Roll / Pitch	Yaw
±0.4 mm	±0.4 mm	±1.5 deg	±0.2 deg

If the same arm pose is *not* used or a different robot is used, the user can expect the following accuracy:

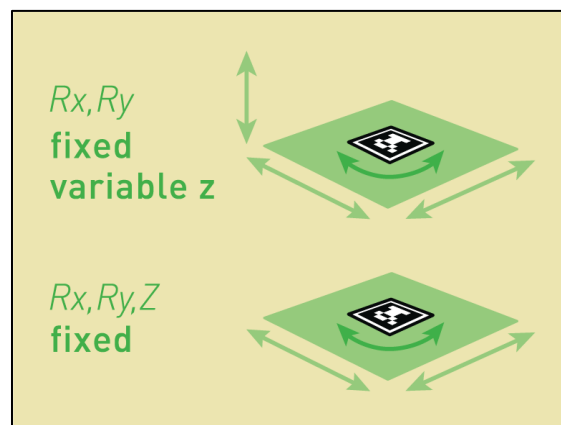
X / Y	Z	Roll / Pitch	Yaw
±2.0 mm	±1.5 mm	±1.5 deg	±0.2 deg

Landmark Registration Options

Users should consider the application and identify the potential for variability of the equipment in the work cell to determine the Landmark re-registration requirements. There are three Landmark surface type options that define the axes that are updated when a Landmark is re-registered. The user may select options that maximize the repeatability and accuracy of the Landmark re-registration.

Robot Positioning System -Landmark Surface Type options:

- **All** - Landmark registration will update the position of all axes (X, Y, Z, Rx, Ry, Rz) of the Landmark surface frame upon re-registration. This option is subject to the most registration error, but should be used when the parallel movement and distance to the original Landmark location, or the Landmark relative to the robot arm camera cannot be controlled, or guaranteed. This is the default setting.
- **Fixed, Variable Z** - The position of Rx and Ry axes of the Landmark surface frame are fixed upon establishing the Landmark and will not be updated upon a Landmark re-registration. A Landmark re-registration will update the positions of the X, Y, Z, and Rz axes of the Landmark surface frame. This option helps to reduce re-registration error due roll and pitch variations.
- **Fixed** - The position of Rx, Ry, and Z axes of the Landmark surface frame are fixed upon establishing the Landmark and will not be updated upon a Landmark re-registration. A Landmark re-registration will update the position of the X, Y, and Rz axes of the Landmark surface frame. This option should be used if there is a constant distance between the Landmark surface frame and the robot arm camera but can move parallel and relative to a consistent surface. For example, this option is suggested if the robot arm camera distance (Z) will remain consistent relative to a surface (e.g. table), but where something on a table (e.g. fixture) may move in one plane only. This option is subject to the least re-registration error.



Best Practices

In order to receive sub-millimeter accuracy post-registration, please keep these best practices in mind:

- The arm position has to be exactly the same during initial registration and during every subsequent re-registration:
 - Verify the gripper is attached and the center of mass has been configured correctly
 - Verify the gripper mass and/or design does not change between Landmark registrations
 - Verify the gripper is not holding a part because the mass of the part will affect the arm position due to compliance in the arm
 - If a navigator has to be used for reregistration, use navigator on back of the robot so that the arm does not move during registration
- Arm camera to Landmark relationship is extremely important:
 - Use the AUTO set feature to automatically move the arm to the optimal Landmark pose
 - Verify the Landmark and arm camera are parallel to each other
 - Verify the distance between Landmark and center of camera is ~20 cm
 - Verify the Landmark is as close to the center of the camera field of view as possible
- Do not forget to associate the parent frame of the action(s) to their respective Landmarks
- Reregistration works best when the Landmark is within +/- 20 mm in the X-Y plane and +/- 5mm in Z axis (arm camera) relative to the original Landmark location.
- Setting the Camera exposure helps to improve accuracy:
 - The exposure on the camera should be lowered as much as possible to a level where the Landmark is still consistently recognized by the software before the registration happens
 - Use of the strobe light is not recommended because it may overexpose the image of the Landmark. However, the strobe light is recommended when lighting conditions vary greatly or when the robot is in an environment with fluorescent lights.
- Considerations for Landmark mounting:
 - Landmarks should be fixed in a place relative to where the action will take place
 - The Landmark mounting orientation should be consistent relative to the "important" axes of the actions associated with that Landmark. For example, in the case of loading a part into a horizontal CNC machine lathe chuck, it is most important to have the lateral positioning well controlled to ensure insertion of the part into the chuck. It is less important to control the position of the part relative to the chuck in the Z axes. Therefore, it's recommended that the Landmark be placed such that its surface is normal to the lathe chuck. In this case errors in Landmark Z axis registration are less influential on performance.
 - Landmark mounting orientation and Landmark surface frame type relative to the "important" axes of the action should also be considered when selecting the Landmark Surface frame type "Fixed" or "Fixed, Variable Height" options for re-registering because the position of some axis will not be updated.
- Landmark placement- design considerations:
 - In a scenario where a Landmark is being used to register a box with tall edges, sometimes users place the landmark in the bottom of the box. Since the arm may not be able to

position the hand camera inside the tall box and close enough for the optimal distance from the camera to the Landmark, the registration height would have to be really high and could potentially impact the repeatability. Instead of placing a Landmark at the bottom of a tall box try building a small fixture with an L-bracket to mount the Landmark on the side of the box.

- Landmark Registration Frequency:
 - Create your task in a way that Landmark registration frequency makes sense. For example, registering your Landmarks at the beginning of a task (in the Initialize node) is recommended to make sure the task will run correctly every time. Also, in some cases it may be a good idea to register certain Landmarks after a few cycles or when catching an error. However, it is not recommended to register a Landmark every single cycle. This will cause performance issues and cycle time delays.
- If you have ANY suspicions, it's best to start over:
 - If there is a suspicion that robot may have moved during training and after initial Landmark registration, it's best to delete all Landmarks and perform registration and association again
 - Test the task first to verify everything is still working as expected

FAQs

- I re-registered and my action is way off, what should I do?
 - Make sure the node(s) parent frame is associated to correct Landmark
 - Make sure robot and/or surface did not move while creating the nodes and registering the Landmark
 - Make sure the gripper conditions are replicated between registrations
 - Make sure you have set the best option for Landmark Surface type
 - Make sure the robot base and pedestal assembly are securely mounted and do not shift during operation. Check the tightness of the pedestal assembly mounting rods, remove the robot from the pedestal and torque the mounting rods to 30 N-m.
- I placed the Landmark in a location that is different than where the action takes place, when I re-register that Landmark the position of my actions are off. What do I do?
 - Any action that is far away from the Landmark location can be subject to greater error. Verify the mounting location of the Landmark, it should be as close as possible to where the action occurs and use of the new Landmark surface type options to improve performance. If not, suggest alternative Landmark mounting locations.
- I have a high-precision task with a lot of part presentation variability and may not have ideal Landmark mounting conditions or settings. What else can I do to improve the task reliability?
 - In combination with Landmarks, try taking advantage of the robots compliance and force control features to adapt to variability in tooling or fixtures.
 - Use force control to respond to measured forces, change activity or behaviors based on force input, and apply or limit a specified force while placing or inserting parts.

RPS Best Practices Checklist

Exact Arm Pose and Configuration:

- ☐ Gripper attached and configured correctly
- ☐ Gripper configuration is same as during original Landmark registration
- ☐ Gripper is not holding on to the part
- ☐ Use the navigator on the robot base, not the navigator on the arm

Arm to Landmark Relationship:

- ☐ Use AUTO set feature to automatically move the arm to the optimal Landmark pose, otherwise verify:
 - ☐ Landmark is parallel to the robot arm camera
 - ☐ Distance of the Landmark to the camera is ~20cm
 - ☐ Landmark is in center of the camera's field of view

Other:

- ☐ Camera exposure is set low and robot can continuously recognize the Landmark
- ☐ Only use the strobe when ambient lighting conditions vary greatly or fluorescent lights are present
- ☐ During re-registration, the location of the Landmark is within +/- 20 mm in X or Y plane, +/- 5 mm in Z axis from the original location
- ☐ Node(s) parent frames are correctly set to the appropriate Landmark
- ☐ Landmark is placed so that most important axes are consistent to X/Y frame of Landmark surface frame
- ☐ Ensure the robot base and pedestal assembly are securely mounted
- ☐ If the user is confident that nothing in the work cell has shifted position since the initial Landmark registration and actions were trained, its best to start from the beginning and retrain the Landmark and use the best practices