5 Calibration

Why Calibration is Necessary

Calibration of the ORCA system arm is a necessary and important procedure to ensure proper operation. Calibration serves two purposes:

a) It determines the origin of the robot's coordinate system (i.e., defines the origin of the "null frame");

b) It positions the arm segments (i.e., the joint angles) relative to one another in a consistent manner.

Calibration is a critical operation. Once completed, all taught positions will be referenced to the calibration point (the null frame). The arm will move through space in a manner dictated by the orientation of each of the arm segments relative to each other established during the calibration procedure. *Therefore, it is crucial to calibrate the arm carefully and as consistently as possible. If it is not, the arm may not return to taught locations in the work space within its precision specification.*

Calibration Conventions

The controller expects the arm segments to be in a particular orientation (level) with respect to each other after the calibration procedure has been completed. SAGIAN recommends the following conventions.

1. Remove all fingers and tools from the hand before beginning the calibration process.
2. Because the wrist joint can rotate >360 degrees, it can have two distinct level positions.
    a. The wrist can rotate approximately + 100 degrees before hitting a hard stop, but can rotate in the *negative* direction more than one full revolution.
    b. The wrist can rotate approximately -100 degrees before hitting a hard stop, but can rotate in *the positive* direction more than one full revolution.

The wrist *must always* be calibrated to the same level position. SAGIAN recommends that prior to beginning the calibration procedure, the robot is powered

down (using the emergency stop button is fine), the hand is rotated in either the positive or negative direction until the hard stop is encountered, then the hand is rotated back to approximately the desired level position.

3. The pinch rack *must* be oriented such that the latch lids are facing up.
4. The rail calibration point should *always* be approached from the same direction (i.e., either left-to-right or right-to-left). An appropriate location should be selected where: the arm can be fully extended in the work space; the arm can move about 1 cm to the right while fully extended; and can be precisely repositioned at the selected rail calibration location (e.g., use the side edge of a mini-platform).
5. The arm segments are leveled with respect to the work surface.

CAUTION

The digital level will drift over time! ***If the arm segments are leveled to zero rather than to the level of the work surface, the digital level itself MUST ALWAYS be calibrated before calibrating the arm. Failure to do so could result in poor calibration results and poor robot performance. See Appendix A for the proper way to calibrate the digital level.***

6. The level of the work surface *must* be measure in the y direction (perpendicular to the rail) for the upper arm segment (shoulder joint), forearm segment (elbow joint), and hand segment (wrist joint) and then in the x direction (parallel to the rail) for the pinch rack segment (the twist joint).
7. The work surface angles *must* be measured consistently over time. SAGIAN recommends defining a permanent location on the work surface to make these measurements.
8. When calibrating the arm, the orientation of the level sensor on each arm segment must be the same as that used to measure the corresponding work surface angle (see no. 6 above). In other words, the level sensor must not be rotated 180 degrees.
9. Each arm segment should be positioned slightly above the level position and moved down to its calibration position (the measured y angle of the work surface).
10. The pinch rack should be rotated slightly clockwise and move counter-clockwise to the calibration position (the measured x angle of the work surface).
11. If the rail position is overshot, reverse the arm back beyond the desired calibration point by about 2-3 cm then re-approach the desired location from the adopted direction. Repeat this as often as necessary until the target position is achieved.
12. If any arm segment position is overshot, reverse that segment back up beyond the desired calibration point by about at least 0.5 degrees then the segment back down towards the calibration position until target value + 0.02 degrees is achieved.

Consistency is Critical

☒ *Remember:* when calibrating the arm, consistency is crucial.

- *Always* remove tools and fingers from the arm before calibrating.
- *Always* rotate the wrist to the proper level position before calibrating.
- *Always* rotate the pinch rack such that the latch lids are facing up.
- *Always* measure the work surface angles with the level sensor oriented the same way and in the same location.
- *Always* put the level sensor on the arm in the same orientation used to measure the work surface angles.
- *Always* move the arm towards the calibration position in the same direction.
- *Always* calibrate the arm segments to within + 0.02 degrees of the measured work surface angles.
- *Always* reverse the arm back beyond the calibration position and approach from the same direction if the calibration position is overshot.
- *Always* go back and recheck each segment after calibrating the entire arm to ensure that no segment has been unintentionally moved.

When to Calibrate

The ORCA system arm is calibrated prior to shipment. It is strongly recommended to recalibrate immediately after installation (before operation). Calibration is also required:

a) after the robot has undergone a repair or preventive maintenance;

b) if the controller PCB or communications processor on the controller PCB is replaced;

c) if the arm encounters resistance or an obstacle that causes an internal belt to slip.

The Calibration Procedure

1. Remove any object that the robot may be holding.
2. Power down the arm by depressing the emergency stop button.
3. Remove any fingers that are attached to the arm.
4. Rotate the hand to the desired hard stop, then back to the nearest level position.
5. Access the MDS robot module software main window.
6. Click on **Calibrate** under the **Control** menu.
7. Click once on **Enable Pendant**.

8. Move each arm segment (each joint) so that the upper arm is slightly above the level of the work surface, the forearm is slightly above the level of the upper arm, and the hand is slightly above the level of the forearm (i.e., the hand is pointing up). Rotate the pinch rack a few degrees clockwise with respect to the level position.
9. Move the robot to a point on the rail about 2-3 cm to the left (or right) of the chosen calibration position.
10. Move the robot to the right (or left) until the calibration position is achieved.

NOTE! It is not necessary to tap or bump the teach pendant joystick. To achieve small, slow movements of the arm, simply apply slight but steady pressure to the joystick and be patient.

NOTE! If the calibration position is overshot, move the arm back 2-3 cm to the left (or right) of the desired position and try again. Repeat this procedure as necessary until you are satisfied with the calibration position.

11. Place the level sensor at the measurement location on the work surface such that it is perpendicular to the rail. Allow the reading to stabilize then note the value, *including the sign.* This is the y angle of the work surface that will be used to calibrate the upper arm, forearm, and hand segments.
12. Center the level sensor on the calibration pads on the top surface of the upper arm. Align the edge of the level sensor base with the edge of the upper arm cover.

NOTE! The orientation of the level sensor on the upper arm must match the orientation of the level sensor used to measure the y inclination angle of the work surface. If the sensor is rotated 180 degrees, the robot may be calibrated incorrectly resulting in reduced performance.

NOTE! To calibrate the arm segments properly, please refer to the laminated card that shows the correct orientation of the teach pendant required to control each individual joint in calibration mode.

13. Using the teach pendant, move the upper arm (shoulder joint) until the angle of this arm segment matches the measured y angle of the work surface in step 11.

NOTE! The angle of the upper arm must be within + 0.02 degrees of the measured y angle of the work surface. If this value is overshot, move this segment back up beyond the target value by at least 0.5 degrees then move back down towards the calibration position. Repeat this procedure as necessary until the angle of the upper arm segment equals the measured y angle of the work surface + 0.02 degrees.

14. Center the level sensor on the calibration pads on the forearm. Align the edge of the level sensor base with the edge of the forearm cover.

NOTE! The orientation of the level sensor on the forearm must match the orientation of the level sensor used to measure the y inclination angle of the work surface. If the sensor is rotated 180 degrees, the robot may be calibrated incorrectly resulting in reduced performance.

15. Using the teach pendant, move the forearm (elbow joint) until the angle of this arm segment matches the measured y angle of the work surface in step 11.

NOTE! The angle of the forearm must be within + 0.02 degrees of the measured y angle of the work surface. If this value is overshot, move this segment back up beyond the target value by at least 0.5 degrees then move back down towards the calibration position. Repeat this procedure as necessary until the angle of the forearm segment equals the measured y angle of the work surface + 0.02 degrees.

16. Center the level sensor front-to-back on the hand box. Align the edge of the level sensor base with the edge of the hand cover (i.e., the level sensor should be positioned near the wrist joint).

NOTE! The orientation of the level sensor on the hand must match the orientation of the level sensor used to measure the y inclination angle of the work surface. If the sensor is rotated 180 degrees, the robot may be calibrated incorrectly resulting in reduced performance.

17. Using the teach pendant, move the hand (wrist joint) until the angle of this arm segment matches the measured y angle of the work surface in step 11.

NOTE! The angle of the hand must be within + 0.02 degrees of the measured y angle of the work surface. If this value is overshot, move this segment back up beyond the target value by at least 0.5 degrees then move back down towards the calibration position. Repeat this procedure as necessary until the angle of the hand segment equals the measured y angle of the work surface + 0.02 degrees.

18. Place the level sensor at the measurement location on the work surface such that it is parallel to the rail. Allow the reading to stabilize then note the value, *including the sign.* This is the x angle of the work surface that will be used to calibrate the pinch rack segment.

NOTE! Make sure that the latch lids on the pinch rack are facing up.

19. Center the level sensor on the pinch rack.

NOTE! The orientation of the level sensor on the pinch rack must match the orientation of the level sensor used to measure the x inclination angle of the work surface. If the sensor is rotated 180 degrees, the robot may be calibrated incorrectly resulting in reduced performance.

20. Using the teach pendant, move the pinch rack (twist joint) until the angle of this arm segment matches the measured x angle of the work surface in step 18.

NOTE! The angle of the pinch must be within + 0.02 degrees of the measured x angle of the work surface. If this value is overshot, rotate this segment beyond the target value clockwise by at least 0.5 degrees then move back counter-clockwise towards the calibration position. Repeat this procedure as necessary until the angle of the hand segment equals the measured x angle of the work surface + 0.02 degrees.

NOTE! The grip axis is self-calibrating.

21. Move the level sensor back to each arm segment, from the upper arm through the pinch rack in the same order as above, to ensure that no joint has been inadvertently moved. If necessary, give the digital readout a moment or two to stabilize. Re-calibrate any arm segment that requires adjustment
22. Remove the level sensor from the arm.
23. Disable the teach pendant by turning it upside-down for 1 second.
24. In the calibration window, click once on **Finish Calibrating**.
25. When the arm stops moving, click once on **OK**.

The robot is now calibrated and ready to operate.

Warning

Failure to calibrate the robot after a repair or preventive maintenance will cause unexpected results that can lead to damage to the robot and/or other equipment in the work space.