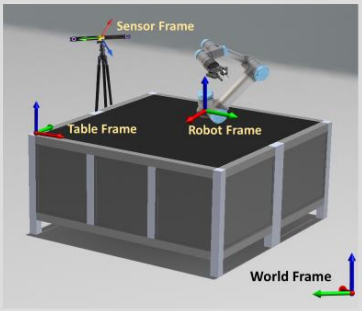
NIST's RRBC Method to Reduce Registration Error

What is Registration?

Registration is a process to transform one coordinate frame to another coordinate frame.

Point-based, rigid-body transformation is used in this presentation.

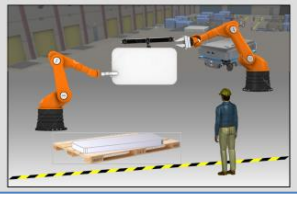
This type of registration requires a set of 3 or more common or registration points to determine the transformation matrix (***R***, ***t***).



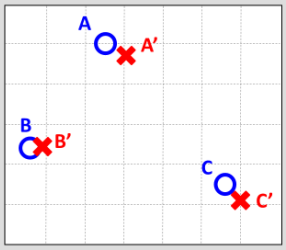
Why is registration needed?

It is required when locations of objects measured in one coordinate frame are needed in another frame. Examples:

1. Robots using sensors to determine location of work objects or obstacles need to register the sensor to the robot coordinate frame
2. Multiple robots carrying the same object need to register their respective coordinate frames
3. Applications:
   a. Automated assembly and pick-and-place tasks
   b. Humans/objects for collision avoidance and spatial awareness



Registration Error



○ = Points measured in Frame 1

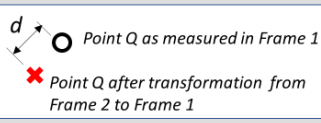
✖ = Points transformed to Frame 1

- After transforming to Frame 1, corresponding points are not mapped exactly onto each other.

  For example, A and A' should be in the same location after transformation of A'.

- The distances between any two points (e.g., AB & A'B') should be the same but are not.

What does the RRBC (restoration of rigid-body condition) method do?



Point Q is a target point (point of interest).

d, positional error:

1. Due to measurement error (e.g., robot, sensor, environment) of point location
2. Consists of measurement error and registration error
   a. If there is no measurement error, then registration error is zero.
   b. If there is measurement error, then (***R***, ***t***) will have errors which are propagated to **ALL** transformed points.

RRBC reduces *d*

Criteria for using RRBC Method

1. Need more positional accuracy
2. $\rho = \sigma_L/\sigma_{noise} > 2.5$

where

σ_L = sensor-robot differences*

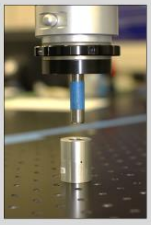
σ_{noise} = sensor noise from sensor spec

* See Franaszek, M. and Cheok, G. S., Improving Rigid-Body Registration Based on Points Affected by Bias and Noise," presented at the *8th Int. Precision Assembly Seminar*, Chamonix, France, 2018 on how to determine this variable.

Peg-in-Hole Experiments

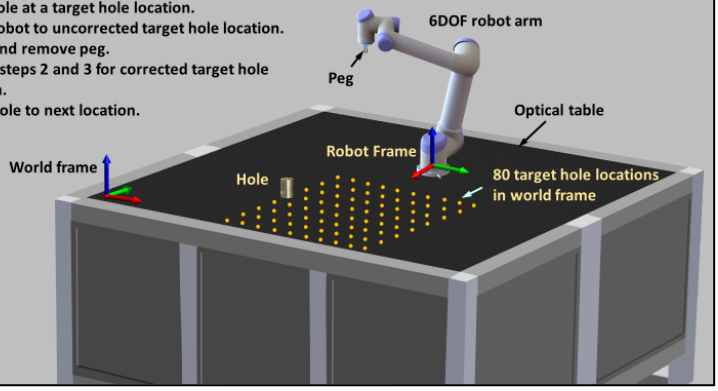
- **Three experiments**
  - Robot in position control (no active compliance control)
  - Seven runs (repeats) in each experiment
  - Each run = inserting a 12.7 mm peg into 80 holes
  - Two peg types
- **Metric**
  - Pass = Peg fully inserted
  - Fail
    - Peg not fully inserted or
    - Insertion force > 17 N

Exp. 1 Exp. 2 & 3



Experiment

1. Place hole at a target hole location.
2. Move robot to uncorrected target hole location.
3. Insert and remove peg.
4. Repeat steps 2 and 3 for corrected target hole location.
5. Move hole to next location.



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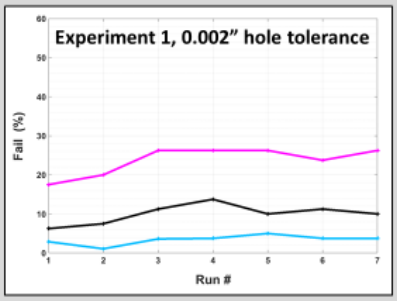
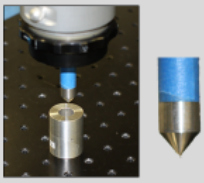
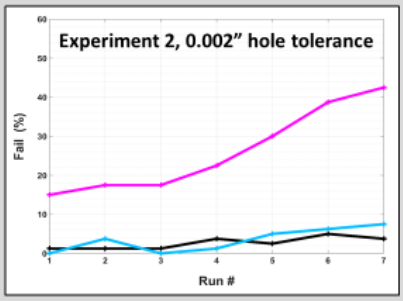


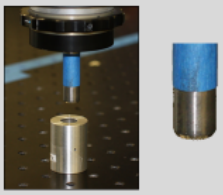


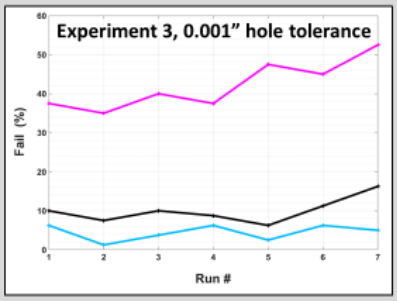
UNCORRECTED = Conventional registration

CORRECTED = Conventional registration w/ RRBC method applied

BASELINE = No registration applied







	Peg type	Peg-Hole tolerance (in.)	Failed Insertions[1, 2] (%)			
			Baseline[3]	Uncorrected	Corrected	Uncorrected / Corrected
Experiment 1 (7 runs)		0.002	3.4	23.8	10.0	2.4
Experiment 2 (7 runs)		0.002	3.4	26.3	2.7	11.0
Experiment 3 (7 runs)		0.001	4.5	42.1	10.0	4.5

1. Values are averages for 7 runs in a given experiment.
2. Failed insertion = # failed insertions in a run/total # of holes.
3. Baseline = failures in this category are due solely to measurement noise.

Target Registration Error

- **Target registration error (*TRE*)**
  - metric for registration quality
  - calculated for all 80 target hole locations in an experiment
- ***RMS*$_T$** = root mean square of *TRE*