Statistical Techniques for Robotics: State Estimation for Coupled Geometric Systems

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Background

Goal: Localizing a machined part using touch probing using particle filtering. Industrial manufactured parts have tolerances along the dimensions and will not match CAD model.

Challenge: To divide the part into 2 sections or surfaces. Each surface has a 6DOF. Track a 12 DOF system by decoupling the surfaces to support manufacturing tolerances.

Framework: Simulated in RViz and ROS with a custom Raycasting library.

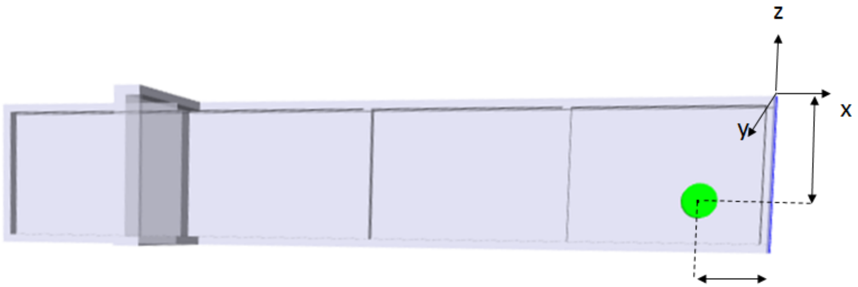
Prior Work

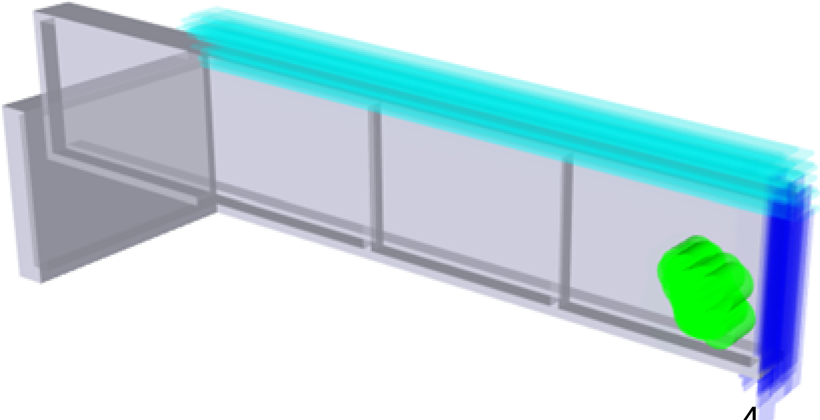
Rejection sampling without the relational linkage.

Cons: Could only model a single rigid object.

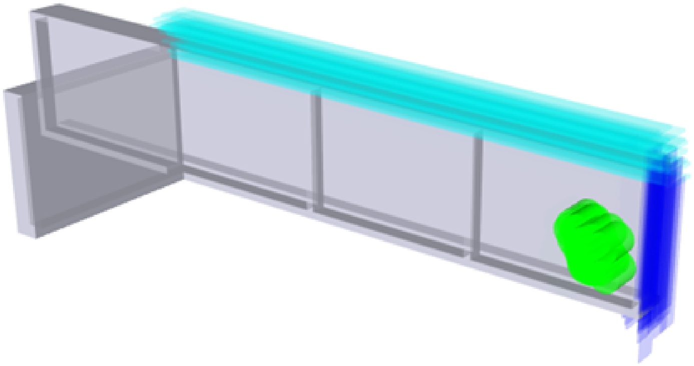
Datum Edge Surfaces ≠ Part

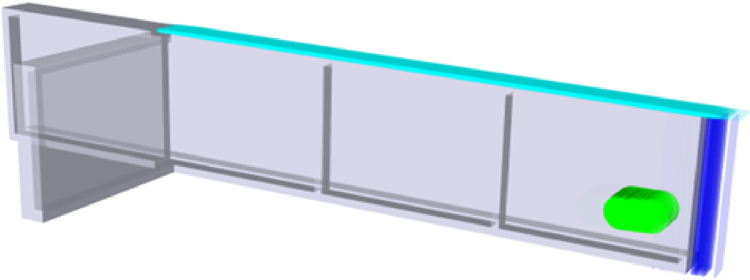
- Localizing the average CAD geometry does not localize the specific task, due to manufacturing error
- Specific tasks are based on reference features (datums)
- “Tasks” may be operations such as drilling holes

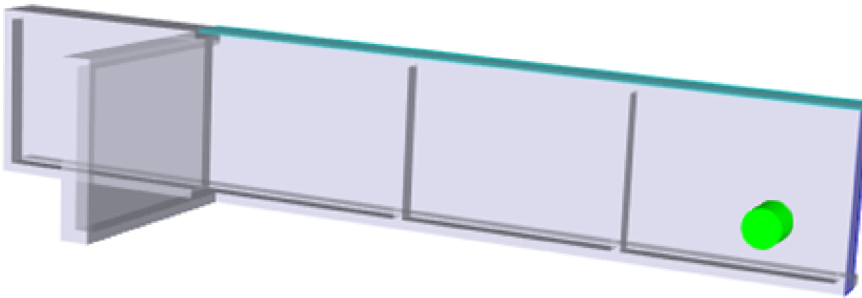




Localize Edge Surface

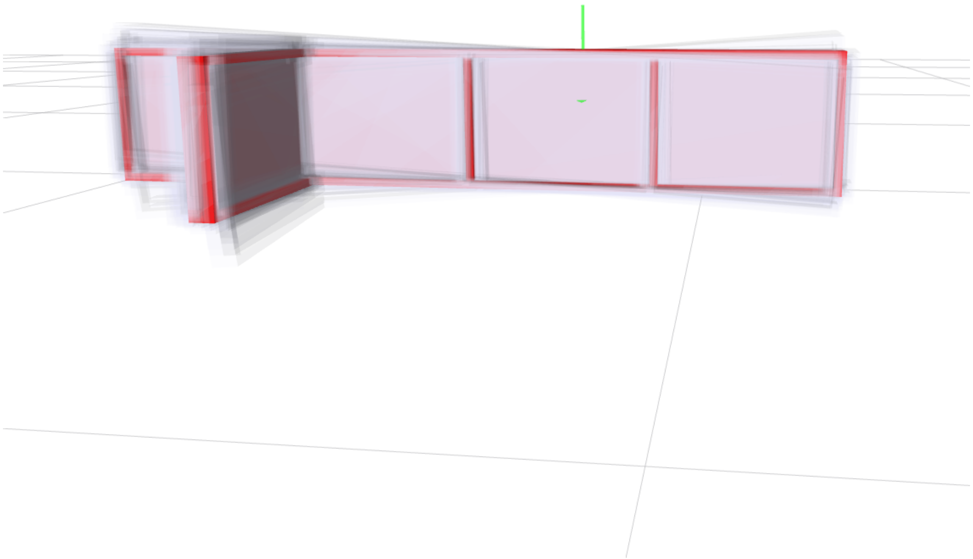






Measurement and Belief

- Model belief distribution by particle filter
- Observer part using linear touch measurements



Red = True State

Gray = Belief

Rejection Sampling a Rigid Object

Particle filters often use importance sampling. For this case rejection sampling because importance sampling fails - with very accurate measurements, particles tend to converge very quickly on the incorrect state.

Rejection Sampling:

1. a ~ prior [bel(x_t)]
2. Accept with probability p(measurement | a)
3. Continue until accepted enough particles

VIDEO: 01_importance_sampling_problems

Assuming Independence Loses Information

- We are not making it independent as we will end up not exploiting the data across two transforms.
- If complete independence assumed, we lose too much information
- VIDEO: 02_assuming_independence

Sampling probabilistic transforms

- Uniform sampling
- Gaussian sampling - more realistic

Our particle update algorithm

1. Randomly sample s_{sample} from the prior belief
2. Randomly sample t_{sample} from the prior distribution of transformations
3. Apply t_sample to s_{sample} to create s'_{sample}
4. Compute the agreement between the measurement m_o and the geometry o in frame s'_{sample}, and accept with probability $p(m_o | s'_{sample})$
5. Repeat until the desired number of particles have been accepted

Demo video

- VIDEOS:
- 03_relationshipLocalization
- 04_relationshipLocalization