22. Parts Orienting

Mechanics of Manipulation

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Outline.

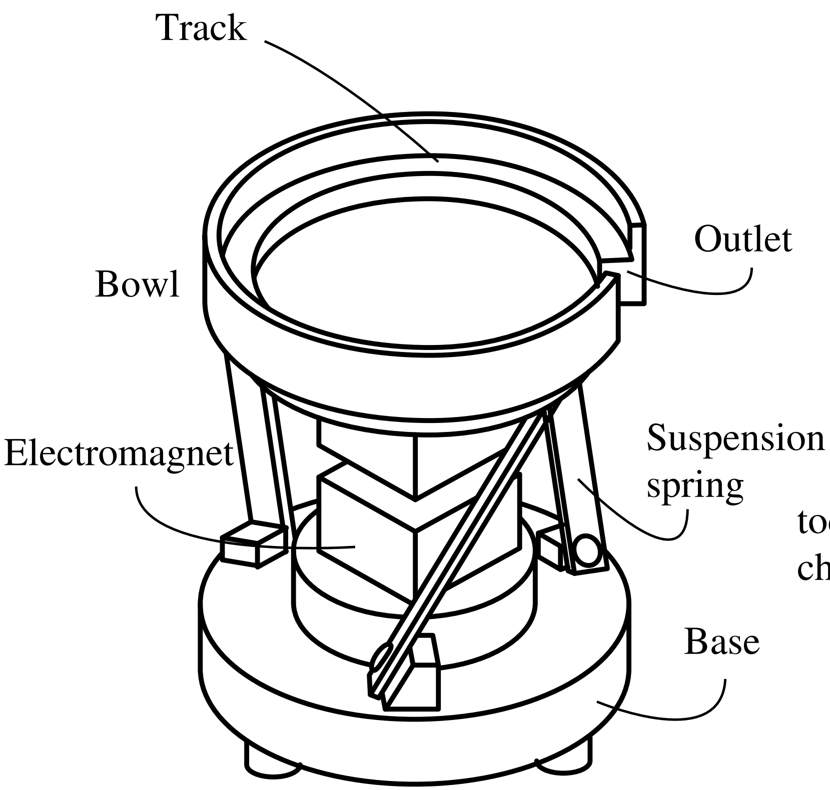
- Manufacturing
- Radius function and diameter function
- Push function
- Representing uncertainty
- Planning

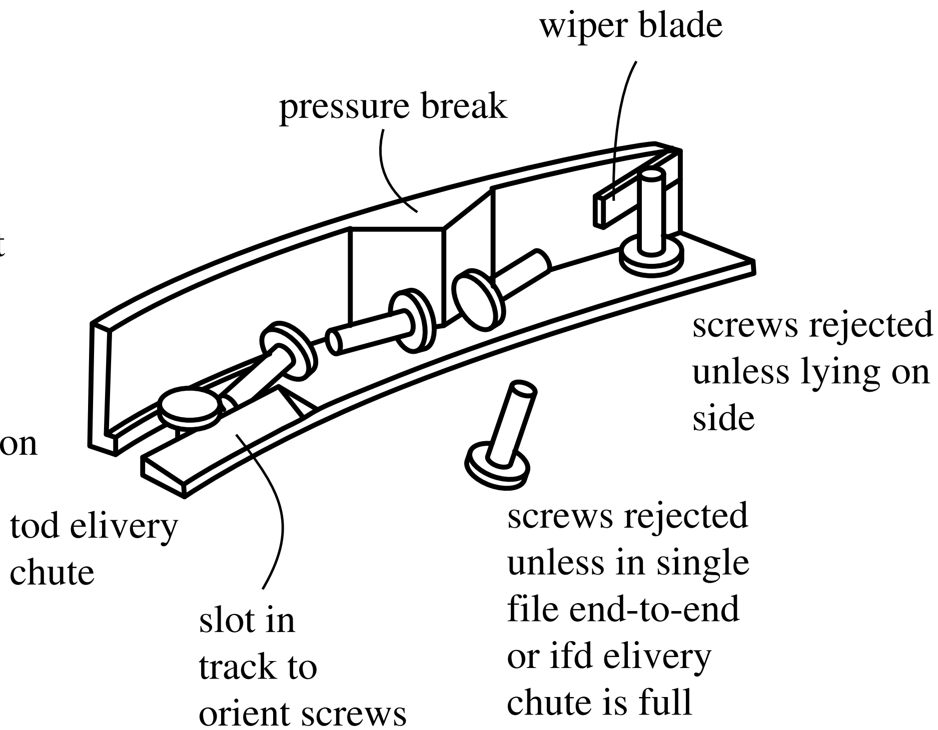
Automation and parts orienting

Assembly systems need oriented parts

Recall SONY Smart cell and APOS

Most common example: bowl feeder





Orienting by pushing

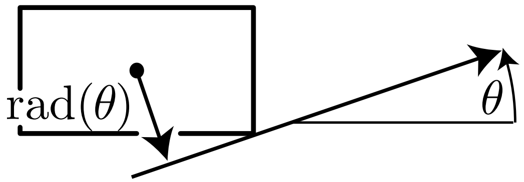
Pushing is a good way to orient a part.

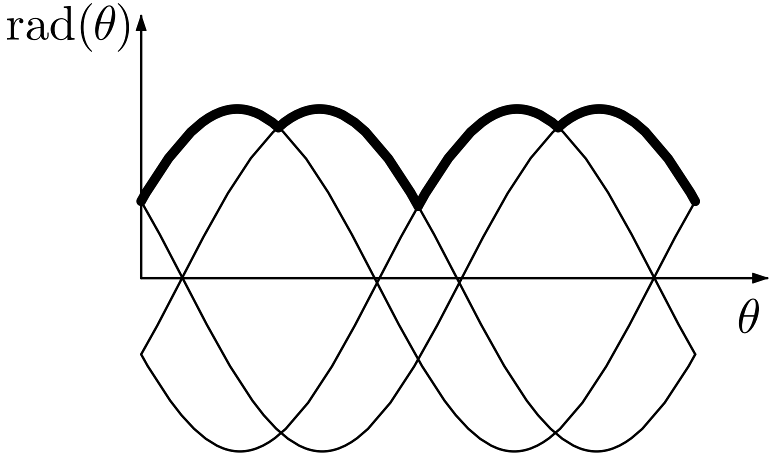
- Generic and flexible: with a flat support surface and a flat pusher, the same hardware can be used for a very broad variety of parts.
- An important problem: to find a sequence of motions that will orient a given part.

Assumptions

1. Isolated rigid planar polygon, on a planar support surface.
2. Coulomb's law, uniform coefficient of friction.
3. Square pushing: pusher translates along its normal.
4. The part makes contact only with the face of the pusher. Each push proceeds until the part reaches a stable orientation.
5. Quasistatic: a balance of contact forces and gravity determines the object motion with sufficient accuracy.

Radius function





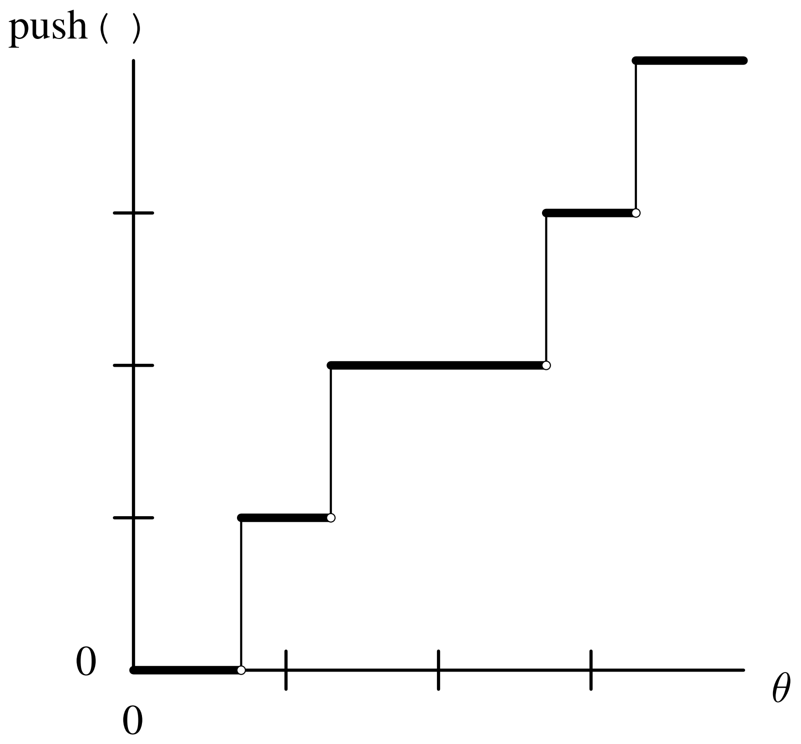
Definition of the radius function.

Square pushing and radius function

For square pushing, radius function behaves like a potential function.

- For a square push, the contact normal is the line of pushing, which splits the votes of the friction cone edges.
- So decision can switch when center of friction crosses contact normal (peak of radius function)
- . . . or when we switch from one vertex to another (valley of radius function).

Push function



Define the push function mapping given object orientation θ to orientation resulting from square push.

Uncertainty

- The push function maps area between two maxes to a min.
- One push can eliminate a little bit of orientation uncertainty.
- Can a sequence of pushes eliminate a lot?

We represent uncertain orientation as a closed interval $\Theta = [\alpha, \beta]$. Define $\bar{p}(\Theta)$ to return the smallest interval containing $\{\mathrm{push}(\theta) | \theta \in \Theta\}$.

Possibilism

Possibilistic approach: Representing uncertainty by set of possibilities.

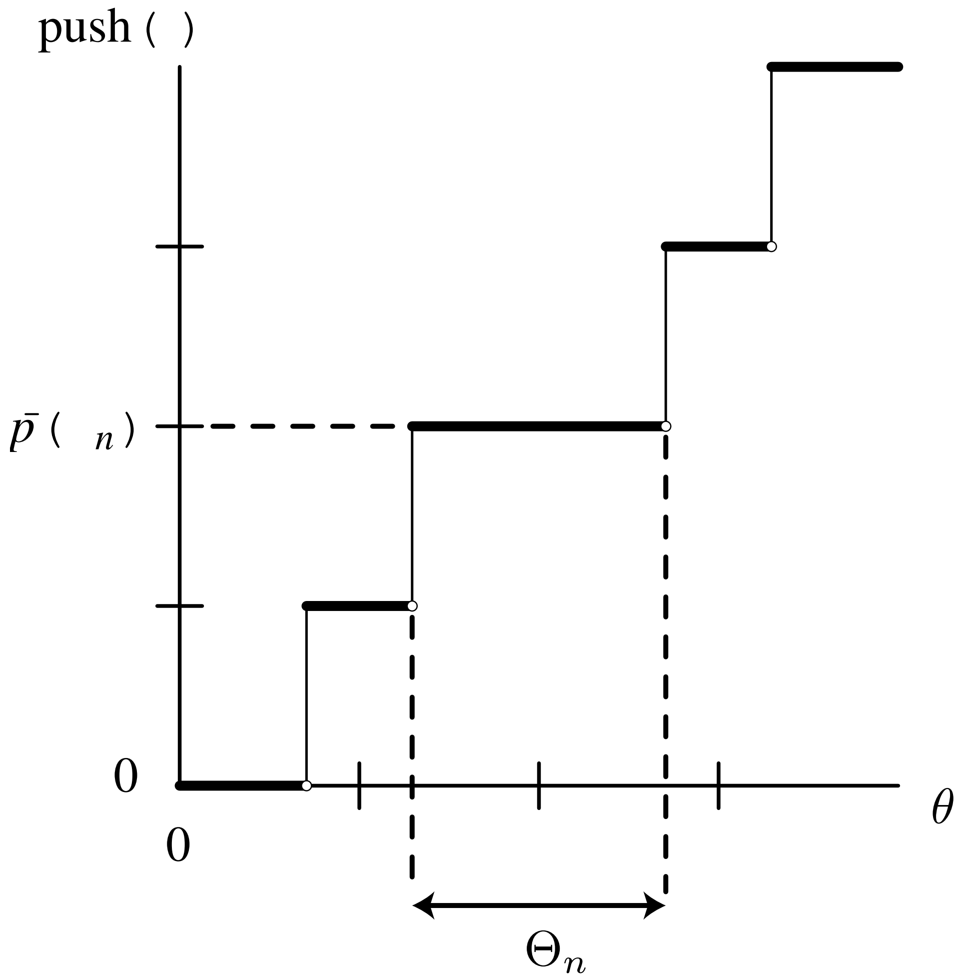
Conservative approximation: approximating the set of the possible states by a superset. (A plan that works for the approximation will work for the actual possibilities.)

Sometimes probabilistic approach would be better.

Planning the last step

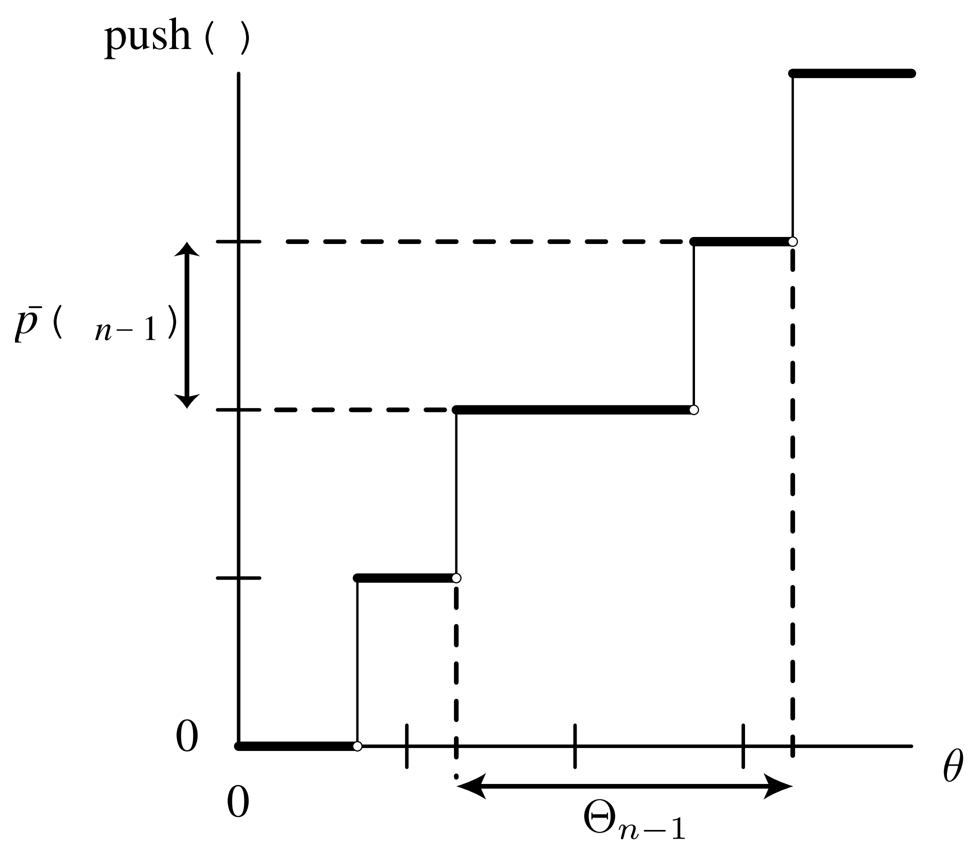
To plan *last* step of n-step plan:

- Θ_n: set of orientations before step n.
- What is the largest set that can be oriented in one push? I.e. what is the largest Θ such that $\bar{p}(\Theta)$ is a single point?



Planning the next-to-last step

- Result must be at least as large as Θ_n.
- To find Θ_{n-1}:
  - What is the largest interval Θ that can be oriented in two pushes? I.e. what is the largest Θ such that $\bar{p}(\Theta)$ is smaller than Θ_n?



The planning algorithm

1. Construct the push function.
2. Find the widest step in the push function. Call it Θ_n, and set i to 1.
3. Set Θ_{n-i} to the largest interval Θ such that $|\bar{p}(\Theta)| < |\Theta_{n-i+1}|$. If $|\Theta_{n-i}| = |\Theta_{n-i+1}|$ then set n to i and terminate. Otherwise increment i and repeat step 3.

A theorem, without a proof

Theorem (Goldberg):
The algorithm produces plans that orient any planar polygon up to symmetry in the push function.
Related systems:

- Squeezing (Goldberg)
- Not-square pushing (Brost)
- Sequences of fences (Peshkin)
- 1JOC (Actuated fence over conveyor) (Akella et al)

Diatribe on factories and uncertainty

Some think there is no uncertainty in the factories. E.g., found on the web, http://www.abc.net.au/rn/science/buzz/stories/s1130271.htm): "Most of the robotic systems that are currently in industrial applications like factory automation, the primary objective is to minimise that uncertainty. So rather than making the robot smart enough to deal with the uncertainty you structure the environment so there is no uncertainty."
Flame on:

1. Frustration. Some of us are interested in factory manipulation *specifically* because of uncertainty.
2. Which is the environment, and which the robot?
3. Even *after* parts oriented, uncertainty is central issue.
4. Perhaps the factory is *just* smart enough to deal with the uncertainty.
5. Still there is a difference between factories and museum tour guides. The best word is not *uncertainty* but *unstructured*.

Sanderson: 1984 IEEE ICRA

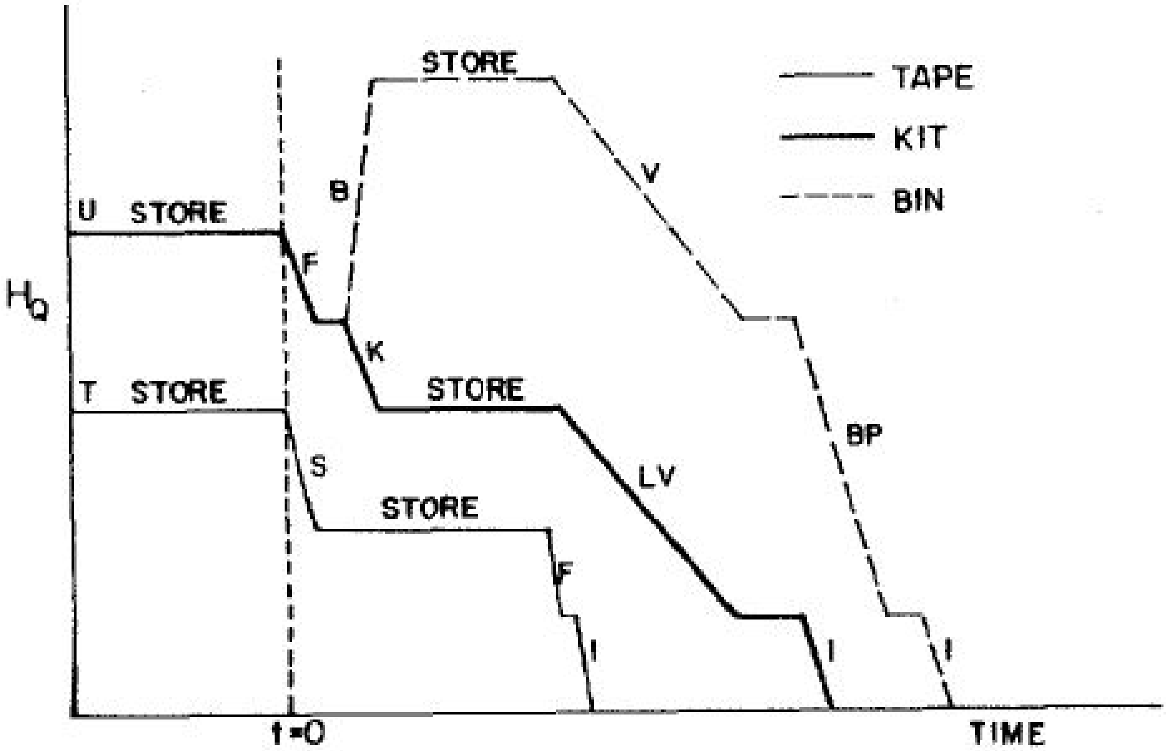


Figure 4-3: Parts entropy sequences for three different electronics assembly strategies:
(1) Taped (T) and Sequenced (S) components, forming (F) and automatic insertion (I),
(2) Formed (F), Kitted (K) components,lead visualization, (LV), and insertion (I)