Planning Multi-Step Error Detection and Recovery Strategies

# Bruce Donald

## Abstract

**Background**

* Robots must perform tasks in the presence of uncertainty.
* Implement force/position control strategies even with some uncertainty.
* More complex for compliant motion strategies.
* Identified 3 kinds of uncertainty.
* 3 strategies:
  + Sensor-based gross motions
  + Compliant motions
  + Simple pushing motions

**Problem**

* Not always possible to find plans that are guaranteed to succeed
* Tolerance errors can render an assembly unfeasible

**Research Proposal**

* Investigate detection and recovery strategies (EDR).
  + EDR plans should succeed or fail recognizably.
  + *“EDR fills a gap when guaranteed plans cannot be found or do not exist; it provides a technology for constructing plans that might work,* but fail in a “reasonable” way when they cannot.

**Methodology**

* Present a “multi-step” strategy that consists of 3 approaches for their synthesis:
  + Push-forward algorithm
  + Failure-mode analysis
  + Weak EDR Theory
* Implemented the theory as an assembly planner called: “Limited.”

## Introduction

**Previous Work**

* Active compliance: enables robots to accomplish tasks even in the presence of significant sensing and control errors.
* How can we plan a motion and GUARANTEE that it will succeed as long as the errors lie within specified bounds?
  + I.e. peg-in-hole with tolerance parts.
* Attacked problem by
  + Adding additional dimensions to the configuration space
    - Each dimension represented a way in which the parts could parametrically vary. Called it “generalized configuration space.”
  + Also showed how to compute “pre-images” or LMT framework.
    - The pre-image of a goal is:
      * The set of generalized configurations from which a particular compliant motion is guaranteed to succeed.

**Guaranteed Success**

* There are times in which it’s not possible to find plans that are guaranteed to succeed. So the planner should stop and signal failure.

**EDR**

* That’s why they investigated the error detection and recovery strategies (EDR).
* EDR plans will fail or succeed recognizably.
* Geometric Definition of EDR:
  + For one-step strategy:
    - A force-position command that is fulfilled.
    - The system must also tell if it will succeed or fail.
* EDR is used both when there is a model of the system/environment and when there is not.
  + Remember, if you desire to command/know a position or force you only know that with limited accuracy.
  + For an example of meshing gears, LIMITED knows the following
    - 2 DOF of translational motion in gear A
    - 1 DOF translation motion in gear B with uncertainty error
    - Gear B can be rotated only if pushed by A
    - There is sensing and control uncertainty
    - The geometry of the gears is complicated
    - Quasi-static analysis is used to model the physics of interaction between the gears
* LIMITED employed EDR along with *failure mode analysis*
  + Humans may
    - Ram gears together, see if it worked.
    - If jam signal failure and try again.
    - Simple strategy and easy to generate.
* What if: Inaccurate position sensing?
  + Due to poor vision or occlusion from gears?
    - Cannot visually determine if gears are meshed.
    - Force sensing must be used to disambiguate the success of the motion from failure.
  + If force sensing is available, then the strategy could be:
    - Ram gears together.
    - Spin them to see if they mesh.
    - If A n B break contact or gears stick signal failure.
    - After 1st motion terminates, the planner cannot recognize whether or not the gears are meshed.
    - The 2nd motion, however, after it terminates, can provide a distinguishable result.
* This paper focuses on how to extend the 1st motion into a 2-step strategy.

**Peg-in-hole Model Error**

* Consider a plan generated by LIMITED with model error.
  + Help us understand how EDR works.
* Push motions are not involved here, so failure mode analysis won’t be used.
  + Uncertainty in the width of the hole within some tolerance.
  + Chamfers on side of hole of unknown depth.
  + Orientation of hole also not known.
    - These 3 unknowns are given to the planner as a 3-parameter family.
* If the width of the hole is narrower than the peg, then there can be no successful strategy.
* Or consider, the assembly can be successful but:
  + No vision system can see the assembly, or
  + No position-measuring devices
* Need an EDR that distinguishes between success and failure.
  + Take basic steps, assess possibilities.
  + Take a second step that tries to reach for the goal in all cases. Only at this stage can we tell if there is failure.
    - If the peg sticks and it is not in the goal position, then it is considered a failure.
  + LIMITED always stacks consecutive steps to develop its strategy.

**Push Forward**

* Simulate an action and record where it may terminate.
  + Termination prediction is complicated.
  + But made easier if sticking is considered termination.