Industrial-Scale Environments With Bounded Uncertainty: A Productivity Maximisation Challenge

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What Ocado Technology does

- Provide end-to-end e-commerce logistics platform
- Tech powers 4 automated warehouses in the UK
- Expanding to other retailers in Canada, France, Sweden, USA
- Fulfil online grocery orders for Ocado’s retail arm and Morrisons
- Grocery deliveries come with several constraints
  - Temperature regime - chilled, ambient, frozen
  - Hard shipping deadlines, 24/7 operation
  - Shelf-life / freshness requirements
  - Storage / handling requirements
  - Low profit margins demand high efficiencies
OSP video

https://www.youtube.com/watch?v=iogFXDWgDak (Ocado Tech)
https://www.youtube.com/watch?v=EeMTZd68fOU (Ocado Tech)
https://www.youtube.com/watch?v=4DKrcpa8Z_E (Tech Insider)
Warehouse automation

- Warehouse is artificial, controlled environment
- Large numbers of robots, conveyors, lifts - high redundancy
- Several sources of uncertainty
  - Mechanical wear and tear
  - Manufacturing variations
  - Human performance (and human errors)
  - Radio communications performance
  - Dirt and contamination
- Uncertainty limited to these known categories
- No single point of failure
A Comparison

- Ocado Smart Platform
- Kiva (Amazon)
- Autostore
- London DLR
- Production Line Robot
- STRIPS / Shakey
- Roomba
- Mars rover
- UAV
- Autonomous Car
- Perdix swarm
- RoboCup
Coping with uncertainty

- Warehouse control systems allocate work to robots/conveyors
  - E.g. move a storage container to specific location
  - New work arrives continually throughout the day

- Actuator assumed to operate within performance envelope without failures

- When failure occurs, one or more local plans are invalidated

- Failure and recovery is usually **localised** - majority of actuators can continue operating
Recovery process

Invalidation
Detect which plans no longer valid

Fault quarantine
Alert hardware engineers

Book-keeping
Adjust preference functions

Plan recalculation
- Remedial steps that undo previous actions (correct mistakes)
- Steps that resolve ambiguity in system state (scanning barcodes)
Results (i)

Global Plan Reset
- Significant impact
- Quick recovery
  - Due to low-overhead planning

Local Plan Reset
- Minor impact
  - A: 18 tasks naturally complete
  - B: 11 tasks plans invalidated
Results (ii)

- Very few in-progress tasks cancelled at the same time
  - Typically <3%, but often < 1%
- Replanning comparable to natural planning for new work entering system
Summary

- Ocado OSP warehouses are an industrial-scale instance of a highly controlled environment
- “Planning for Failure” less critical in highly controlled environments
- “Just-in-time Planning” useful when unpredictable but continuous stream of work enters system
- Logistics is a rich domain with many challenging aspects
  - Many diverse constraints
  - Many degrees of freedom within which to optimise for throughput
  - Controlled environment allows us to consider it a perfect-information problem (with chance)
  - Doing it all in (near) real-time is critical
P.S. We’re hiring

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http://rainbow-senior.oca.do
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