Evaluating PDDL for programming production cells: – a case study

Christoph Mayr-Dorn, Alexander Egyed (Johannes Kepler University, Linz)
Mario Winterer, Christian Salomon, (Software Competence Center Hagenberg GmbH)
Harald Fürschuß, (ENGEL Austria GmbH)
Motivation

Manufacturing companies are required to *quickly/easily adapt* their *production* to changing demands and innovation.

- Need to **frequently reprogram robots** and machines on the shop floor
- Involves defining the **interaction with other shop floor participants** (robots/machines/humans).
- (Re)programming is often done **by end-users** (e.g., domain engineers)
- Complex interactions/sequences require **extensive handling of edge-cases**
  - Hard to get right
  - Hard to understand
  - Hard to reuse
Research Questions

• How can we enable engineers to focus on their domain knowledge and limit detailed implementation work?
  • Engineers have detailed product know-how
  • Are aware of production stages, goals
  • Pre and post conditions of production steps

• Are planning languages such as PDDL and/or HDDL practical to this end?
  • RQ1: To create efficient production sequences?
  • RQ2: How easy are they to be extended for changing production scenarios?
Case Study: multi-stage molding

- Multi-stage sequence C:
  - Pick solidified part
  - Place for cooling
  - Take cooled insertion component
  - (Pick solidified final part from previous run)
  - (Pick solidified intermediary part from previous run)
  - Insert component into mold
  - Place solidified final part

- Complexity due to distinction between initial and subsequent runs, failures of picking/placing, and restarting from previous run in unknown state: multiple cooling locations, two mold forms, amount of grippers
Results – Support for adaptation

3 modeling variants: PDDL+ for time-aware sequences, PDDL cost for some optimization, HDDL for hierarchical task structuring

<table>
<thead>
<tr>
<th>Structure</th>
<th>PDDL+ based</th>
<th>PDDL cost based</th>
<th>HDDL based</th>
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<tbody>
<tr>
<td>LoC:</td>
<td>~300</td>
<td>~205</td>
<td>~490</td>
</tr>
<tr>
<td>Structure</td>
<td>10 actions, 3 proc., 6 events</td>
<td>11 actions</td>
<td>11 actions, 10 tasks, 23 methods</td>
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<tr>
<td>LoC:</td>
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<td>~280</td>
<td>~660</td>
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<tr>
<td>Structure</td>
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<td>14 actions</td>
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<tr>
<td>New/diff LoC</td>
<td>65/15</td>
<td>70/20</td>
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**Similar actions/predicates across the variants**

**Same type and extent of adaptation across the variants**
Problem scenarios with increasing product instances and starting conditions.

Models for optimal sequences (i.e., considering time) don’t scale.
RQ1: feasible but not practical yet

- HDDL/PDDL require tracking each product individually → need to obtain a cyclic plan for continuous production (without constant replanning)
- Difficult transition from start-up to continuous phase
- Planning duration is not practical for efficient (i.e., time aware) sequences
- HDDL solver is sensitive to problem order
- Perhaps process mining (BPM community) can bring some inspiration here

RQ2: advanced engineering support needed

- Changes have cascading effects (not just adding of code),
  - limiting impact/scoping difficult to achieve
  - difficult to understand what is impacted
  - HDDL: Difficult to understand applicable constraints in each step
- Support for testing: wrong logic, wrong test setup, solver limits?
- Support for deadlock detection
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