THREE APPROACHES TO SOLVE THE PETROBRAS CHALLENGE
EXPLOITING PLANNING TECHNIQUES FOR SOLVING REAL-LIFE LOGISTICS PROBLEMS

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The PETROBRAS Problem

- one of the challenge problems at ICKEPS 2012
- transporting cargo items between ports and petroleum platforms while assuming limited capacity of vessels and fuel consumption during transport
- basic operations:
  - navigating, docking/undocking, loading/unloading, refueling
- objectives:
  - fuel consumption, makespan, docking cost, waiting queues, the number of ships

Classical Planning

- separate planning (which actions) from scheduling (when)
- planning part
  - only causal relations (no explicit time)
  - capacity constraints (vessels, fuel, ports)
  - core operators:
    - navigate-empty-vessel, navigate-nonempty-vessel
    - load-cargo, unload-cargo
    - refuel-vessel-platform, refuel-vessel-port
    - dock-vessel, undock-vessel
  - encoded in PDDL 3.0 (solved by SGPlan 6.0)
  - optimizing fuel consumption
Classical Planning (cont'd)

- scheduling (temporal) part
  - allocating actions to time
  - two stages:
    1. add durations and allocate actions to the earliest time after the actions giving the preconditions
    2. resolve resource conflicts and threats
      - shift actions to later times (action order in plan is preserved)
  - realized as post-processing in linear time (no exploration of alternatives)

Temporal/Resource Planning

- There already exist planners dealing with explicit time and resources.
  - encoding the problem in PDDL 3.1 (durative actions and numerical fluents)
- The Filuta planner:
  - resources (automatically deduced from fluents):
    - unary resource (docking/undocking)
    - consumable resource (fuel)
      - relative decrease (navigation), absolute increase (refueling)
    - reservoir (vessel and port capacity)
      - relative increase and decrease
  - optimizing makespan

Ad-hoc Method (MCTS)

- exploiting the Single Player Monte-Carlo Tree Search (MCTS) algorithm
  - state-space search algorithm (used in games)
  - requires finite branches to do random probes
  - state evaluation
    - expectation (for exploitation)
      - estimated value from the random probes
    - urgency (for exploration)
      - increases slowly when the node is not selected

Ad-hoc Method (MCTS) application to planning

- simulates forward planning
  - expanding state = adding action and allocating it to time
  - uses abstract actions to ensure finite plans
    - Load(Ship, Cargo)
    - Unload(Cargo)
    - Refuel(Ship, Station)
    - GoToWaitingArea(Ship)
  - abstract action unfolds to real actions based on the current state
    - Unload(Cargo) and ship not at target platform
      - translated to undock, navigate, dock, unload.
- plan evaluation
  \[ f(π) = usedFuel + 10*countOfActions + 5*makespan \]
Experimental Setting

- The challenge problem from ICKEPS 2012
  - 10 vessels with fuel capacity 600l, 15 cargo items
- Random problems
  - varying the number of vessels, fuel capacity:
    - Group A – 3 vessels, fuel tank capacity 600 liters
    - Group B – 10 vessels, fuel tank capacity 600 liters
    - Group C – 10 vessels, fuel tank capacity 800 liters
    - Group D – 10 vessels, fuel tank capacity 1000 liters
  - varying the number of items (1-15) in each group

Results (Challenge Data)

<table>
<thead>
<tr>
<th>Optimization Criteria</th>
<th>Fuel (l)</th>
<th>Vessels</th>
<th>Makespan (h)</th>
<th>Docking (Rs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SGPlan</td>
<td>1226 (1.38x)</td>
<td>2</td>
<td>467.0 (2.29x)</td>
<td>315k (1.01x)</td>
</tr>
<tr>
<td>Filuta</td>
<td>1989 (2.24x)</td>
<td>5</td>
<td>263.0 (1.29x)</td>
<td>333k (1.07x)</td>
</tr>
<tr>
<td>MCTS</td>
<td>887</td>
<td>4</td>
<td>203.5</td>
<td>311k</td>
</tr>
</tbody>
</table>

Results (Random Data)

Fuel consumption

- Filmatica
- SGPlan

Makespan

- Filmatica
- SGPlan
### Summary

- we solved the ICHEPS 2012 challenge problem using three approaches
  - ad-hoc (MCTS) approach is the best
  - temporal and resource planner Filuta not much worse
  - sequential planning less appropriate
- next steps
  - trying other classical planners
  - multi-criteria optimization in temporal and resource planner Filuta
  - generalizing the MCTS approach to other planning problems

### Results (Random Data)

- Docking cost, used vessels

![Graph showing docking cost and used vessels](chart)

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