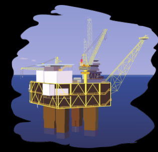
Daniel Toropila, Filip Dvořák, Otakar Trunda, Martin Hanes, Roman Barták
(Charles University in Prague, Czech Republic)

THREE APPROACHES TO SOLVE THE PETROBRAS CHALLENGE

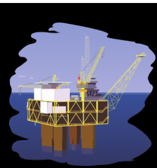
EXPLOITING PLANNING TECHNIQUES FOR SOLVING REAL-LIFE LOGISTICS PROBLEMS

The PETROBRAS Problem

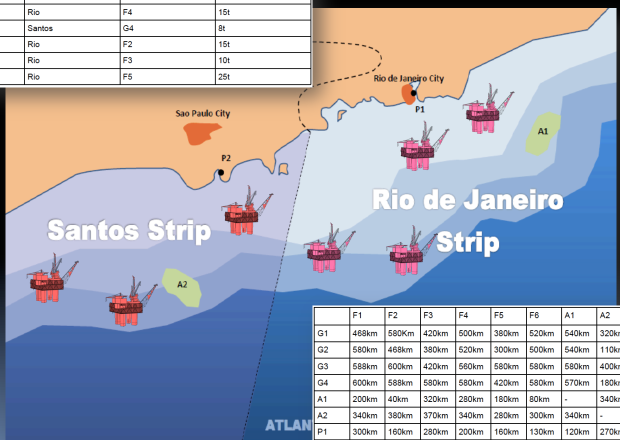


- one of the challenge problems at ICKEPS 2012
- transporting **cargo** items between **ports** and petroleum **platforms** while assuming limited capacity of **vessels** and fuel consumption during transport
- basic operations:
  - navigating, docking/undocking, loading/unloading, refueling
- objectives: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

The PETROBRAS Problem



cargo specification	loading port	delivering point	weight
C1	Rio	F1	20t
C2	Rio	F6	5t
C3	Rio	F4	15t
C4	Santos	G4	8t
C5	Rio	F2	15t
C6	Rio	F3	10t
C7	Rio	F5	25t



	F1	F2	F3	F4	F5	F6	A1	A2	P1	P2
G1	468km	580Km	420km	500km	380km	520km	540km	320km	350km	300km
G2	580km	468km	380km	520km	300km	500km	540km	110km	400km	180km
G3	588km	600km	420km	560km	580km	580km	580km	400km	450km	280km
G4	600km	588km	580km	580km	420km	580km	570km	180km	420km	140km
A1	200km	40km	320km	280km	180km	80km	-	340km	120km	270km
A2	340km	380km	370km	340km	280km	300km	340km	-	270km	100km
P1	300km	160km	280km	200km	160km	130km	120km	270km	-	200km
P2	380km	290km	320km	340km	270km	300km	270km	100km	200km	-

Approach 1

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

Approach 1

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)

Approach 2

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

Approach 3

Ad-hoc Method (MCTS)

background

- 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

Approach 3

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**

  $f(\pi) = usedFuel + 10 * countOfActions + 5 * makespan$

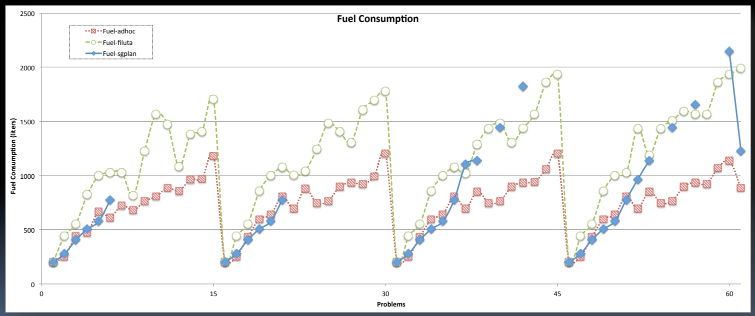
Experimental Setting

- The challenge problem from ICKEPS 2012
  - 10 vessels with fuel cacity 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

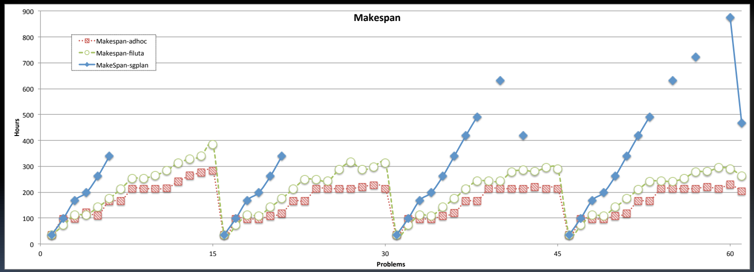
Results (Challenge Data)

	Optimization Criteria			
	Fuel (l)	Vessels	Makespan (h)	Docking (R$)
SGPlan	1226 (1.38x)	**2**	467.0 (2.29x)	315k (1.01x)
Filuta	1989 (2.24x)	5 (2.5x)	263.0 (1.29x)	333k (1.07x)
MCTS	**887**	4 (2.0x)	**203.5**	**311k**

Results (Random Data)
fuel consumption

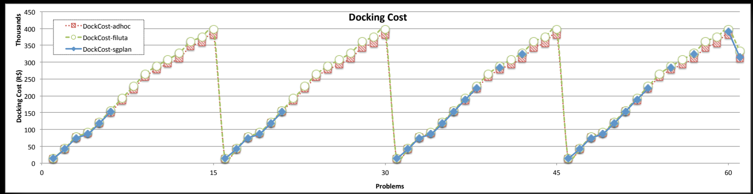


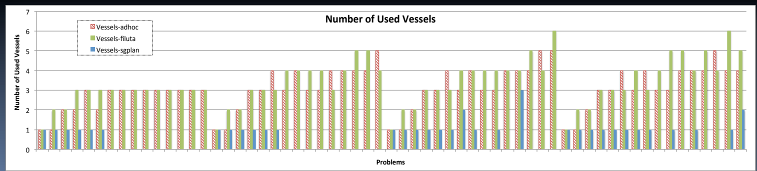
Results (Random Data)
makespan



Results (Random Data)

docking cost, used vessels





Summary

- we solved the ICKEPS 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

Daniel Toropila, Filip Dvořák, Otakar Trunda, Martin Hanes, Roman Barták
(Charles University in Prague, Czech Republic)

THREE APPROACHES TO SOLVE THE PETROBRAS CHALLENGE

EXPLOITING PLANNING TECHNIQUES FOR SOLVING REAL-LIFE LOGISTICS PROBLEMS