Creating Robust Train Unit Shunting Plans using Probabilistic Programming

Author: G.B.J. van Zwienen (g.b.j.vanzwienen@student.tudelft.nl)

EEMCS, Delft University of Technology, The Netherlands

Background

- Train Unit Shunting Problem (TUSP)
  - Introduced by Freling et al.
  - Shunting yard
  - Routing, Matching, and Parking of trains
  - Match arriving and departing train units
  - Service tasks

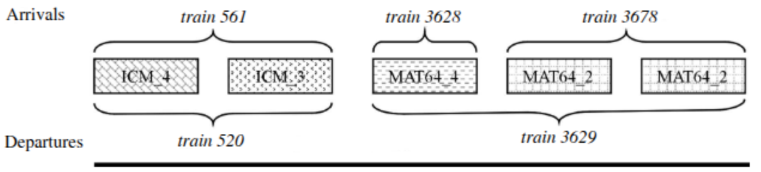

Figure 1: Shunting example by Freling et al.

- Robust planner
  - Uncertainties in the real-world
    - Delay in arrival time, closed off track, …
  - Robust: All trains operate, small departure delays
- Pursuing robustness
  - R.J. Gardos Reid
  - Probabilistic programming – Gen.jl
  - Generative model
  - Probabilistic inference
  - Distribution of robust solutions
  - Use algorithm as 'black box'
    - No in-depth planner knowledge necessary
    - Can be applied to any problem

Research question

How can one model uncertainties in the Train Unit Shunting Problem and use this to create a robust version of an existing planning algorithm?

Methods

- Model uncertainty
  - Arrival times/service durations
  - Gen.jl
  - Normal distribution
- Train shunting solver by Van den Broek
- Perform inference
  - Importance sampling
  - Weight on outgoing delay
- Output is distribution of plans

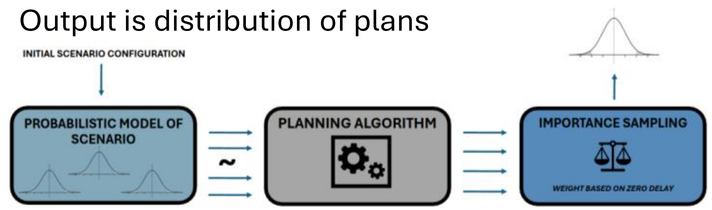

Figure 2: Workflow for robust shunting via probabilistic programming

Experimental Results

- Importance sampling on a large location
- Three incoming trains and three outgoing trains on a tight schedule
- Uncertainty: σ = 50 seconds
- 50 iterations

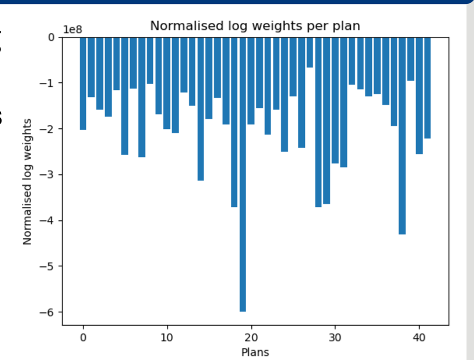

Figure 3: Weights of Importance Sampling

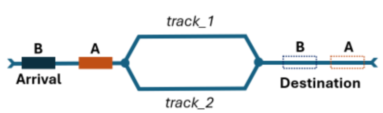

Figure 4: Simple shunting scenario

- Two trains
- No recombinations or service scheduling
- 50 iterations
- Arrivals: 2050 s, 2100 s
- σ of 60 seconds
- 38% use both tracks
- 62% use single track

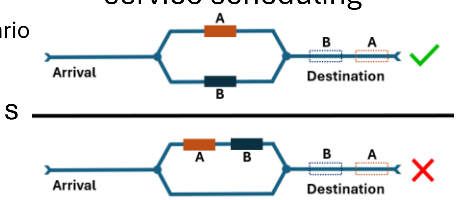

Figure 5: A robust plan and a fragile plan

- Service scheduling
- Train B waiting behind the cleaned train A
- Cleaning delay → train B gets delayed

Figure 6: Shunting scenario with service scheduling

Discussion

- Non-deterministic solver used
- F3: Likelihoods low, but relative values interesting
- F5: Output distribution contains robust plans dividing trains.
- F6: Output distribution contains delayed plans
  - Moves the same, times different
  - Uncertainty can cause problems later
  - Plans reveal weak points and how to improve plans (where to put margin)
- Sample from output distribution, assess plans, choose final plan/combination of plans

Conclusion and Future work

- Robust Train Unit Shunting using Probabilistic Programming
- Robust plans improvement over deterministic plan

- Inference techniques
  - Markov Chain Monte Carlo
- Other, more realistic distributions
- Other uncertainties
- Check method by using evaluator, simulate plan on uncertain scenarios, see how many pass, do larger scenarios

Train icon by www.arthurstreinenpagina.nl