Adaptive Behaviour of Intelligent Agents under Schedule Disturbances in Rail Systems

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Motivation

The Real World has Problems

"...on the Dutch rail network (more than 5,000 daily trains), on average 10 disruptions of a route occur per day. Delays occur more frequently: On average 450 trains experience one or more delays ($>$ 3 minutes) per day. These delays lead to removal of on average 10 train services per day" (Abbink et al., 2009)

Importance

- Importance of public, mass transportation systems
- Operational problems have a significant impact on services and, thus, society

Solution

- Intelligent management and utilisation of resources
- Adaptive monitoring and rescheduling of services
- Smart modelling, intelligent agents and simulation

Challenges

Dynamism

- Environment subject to change
- Preconditions for action change before or during action realisation

Complexity

- Numerous entities to coordinate
- Competing objectives
- Constraints on time for action

Uncertainty

- Environmental events cannot be predicted
- Incomplete or uncertain information

Solution Approach

- Multi-agent model based on Intelligent agents suitable for complex, adaptive systems
- Simulated rail environment
- Interaction between agents and environment
- *Monitoring* for disturbances and *adaptive*, real-time rescheduling

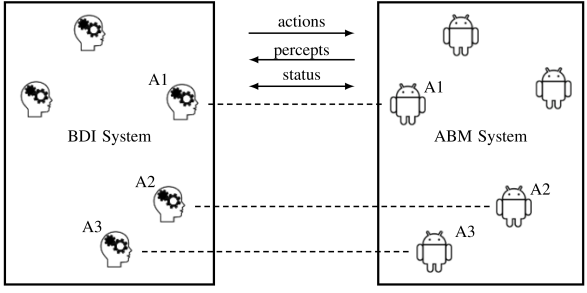

Figure: Padgham et al. (2014)

Elements

Domain Formalisation

- Domain description
- Mathematical formulation

Mechanism Model

- Protocols and agent data interchange
- Core algorithms

Conceptual Model

- Description of agent model
- Agent environment model

Detailed Agent Model

- Objectives, behaviours and knowledge for agent types
- Properties, state transitions, goal-plan trees, elaboration of agent plans

Agent Based Simulation Model

Rail Network

Schedule

Wollongong	03:20	04:14	-	04:36	04:48
North Wollongong	03:22	04:16	-	04:38	04:50
Fairy Meadow	03:24	04:18	-	–	04:52
Towradgi	03:26	04:20	-	–	04:54
Corrimal	03:28	04:22	-	–	04:56
Bellambi	03:30	04:24	-	–	04:58
Woonona	03:33	04:27	-	–	05:01
Bulli	03:35	04:29	-	–	05:03
Thirroul	03:39	04:32	-	04:47	05:06

Trains
- Current position, that is track segment or station, on journey
- Expected arrival next station
- Expected departure current track segment
- Expected dwell time next station
- Number of carriages
- Load factor or number of passengers
- Dynamics eg speed

Tracks
- Track segments connect nodes
- Possible parallel track segments between nodes
- Status of track segment by time period eg occupied, available

Stations
- Number of platforms
- Status of each platform eg occupied, free
- Number of passengers waiting

For each train journey (or service):
- Scheduled arrival and departure times for each station on a journey
- Origin and departure station with relevant departure and arrival times.
- Track and platform allocations
- Varies depending on peak or off-peak, weekday or weekend

Environment

Society of Agents

Structure and status of the rail network, status of trains, current fixed schedule information

Query

Percepts

Actions

Directions to alter schedules, train journey, train status, routing.

Train Agent

Line Agent

Track Segment Agent

Station Agent

Model Considerations

Delays, Disturbances and Disruptions

A *disturbance* is considered a relatively small incident while a *disruption* is a relatively large, external incident. Initial focus on delays introduced through disruptions.

Remedial Actions

Options include re-routing, re-timing, reordering, changed speed profile, service modification, bridging services or combinations thereof.

Characteristics

- Decentralised control
- Decentralised knowledge; no global knowledge
- Cooperative agent behaviour with negotiation for decision-making
- Multi-Agent System interacting with Environment Simulation

Component Interaction

Multi-Agent System

- Agent behaviour; proactive and reactive
- Continual perception of changes in the environment
- Agent decision-making to determine course of action required to achieve goals
- Initiation of actions in the environment based on changes in the agent's knowledge base

Environment Simulation

- Move trains through space and time
- Provide agents with updates ie position of a train
- Inject specified or randomly generated disturbances
- Interface with visualisation

Platform

Platform provided by *Jadex*, a (BDI) agent system based on *Jade*. Component development is undertaken in Java.

Train Agents

Goals and Objectives

- Complete a trip according to schedule
- Adapt to any disturbances or disruptions

Knowledge

- An itinerary denoted as a sequence of stops with associated arrival and departure times
- The current position in space and time
- The schedule status, that is one of $\{onTime, early, late\}$

Plans and Actions

- Travel at normal, increased or reduced speed
- Arrive, wait at and depart from a station
- Stop between stations
- Negotiate with station agents to vary itinerary

Station Agents

Goals and Objectives

- Facilitate flow of trains through station according to schedule
- Adapt to disturbances or disruptions
- Manage traffic flow within safety constraints

Knowledge

- Scheduled services denoted by the sequence of arrivals and departures with associated times
- Services pending arrival and departed
- Resources at station such as the number of platforms
- Available track resources for entry and exit from station

Plans and Actions

- Manage train arrivals and departures
- Negotiate with trains and stations to vary schedule

Status and the Future

Status

- Single train on single track traversing multiple stations on a trip
- Extending to multiple trains in both directions
- Injection of simple disturbances
- Ongoing experimental work

Future

- Increase complexity of scenarios - coordinated agent actions
- Extend design accordingly
- Extend experimental work and analysis of results

Conclusion

Why?

- Importance of public, mass transportation systems
- Operational problems have a significant impact on services and society

What?

- Intelligent management and utilisation of resources
- Adaptive monitoring and rescheduling of services
- Smart modelling, intelligent agents and simulation

How?

- Staged research
- Incremental increase in complexity with stages
- Stepwise development and refinement of solution
- Application to real transport network

Questions

References

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