Modelling and Simulation of Rail Passengers to Evaluate Methods to Reduce Dwell Times

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Content

- Introduction
- Modelling Theory
- Modelling Practice
- Model Implementation
- Experimentation
- Future Work

Introduction

Problem Statement

- The rail network in the UK is fast approaching maximum capacity and passenger numbers are growing 6-7% per year
- One relatively simple (and therefore cheap) way to increase capacity of the rail network is to reduce loading/unloading times (dwell time)

Aim and Approach

- Aim: Test the feasibility of using agent based modelling for assessing novel methods of reducing dwell times

- Approach: Using Xi's Extended Social Force Model (ESFM) together with a novel decision making algorithm for passengers' door choice


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Modelling Theory

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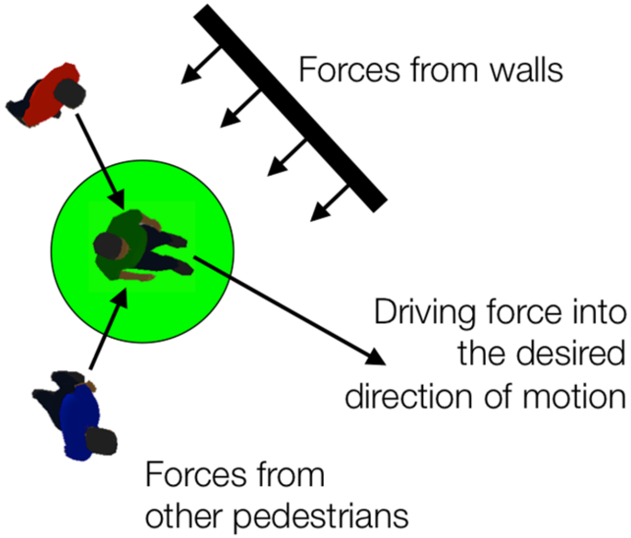
Social Force Model (SFM)

- The "social force model" (Helbing and Molnar 1995) assumes that the acceleration, deceleration and directional changes of pedestrians can be approximated by a sum of different forces, each capturing a different desire or interaction effect.



http://futurict.blogspot.it/2014/12/social-forces-revealing-causes-of.html

Agent-Based Modelling

- In Agent-Based Modelling (ABM) a system is modelled as a collection of autonomous interacting decision-making entities called agents.
- Each agent individually assesses its internal and external situation and makes decisions on the basis of a set of rules.
- ABM is well suited to modelling systems with heterogeneous, autonomous and proactive actors, such as human-centred systems.

Modelling Practice

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Base Model

- SFM was implemented by computing the force on an agent at each time step, using the model provided by Xi et al. (2010).

$$m_i \frac{d\boldsymbol{v}_i}{dt} = m_i \frac{v_i^0(t)\boldsymbol{e}_i^0(t) - \boldsymbol{v}_i(t)}{\tau_i} + \sum_{j(\neq i)} \boldsymbol{f}_{ij} + \sum_W \boldsymbol{f}_{iW}$$

$$\boldsymbol{f}_{ij} = \boldsymbol{f}_{ij}^{psy} + \boldsymbol{f}_{ij}^{phy}, \quad \boldsymbol{f}_{ij}^{psy} = A_i \exp\left(\frac{r_{ij} - d_{ij}}{B_i}\right)\boldsymbol{n}_{ij}$$

$$\boldsymbol{f}_{ij}^{phy} = kg\left(r_{ij} - d_{ij}\right)\boldsymbol{n}_{ij} + \kappa g(r_{ij} - d_{ij})\Delta v_{ji}^t \boldsymbol{t}_{ij}$$

Base Model

- To add some novelty we decided to incorporate the Extended Social Force Model (ESFM) proposed by Xi et al. (2010) which adds "vision" to the SFM.

- A simple way of considering vision is to use a "form factor" coefficient which modifies the psychological force felt by a passenger.

- We also developed a novel decision making algorithm which is based on a passenger's knowledge of the station, as well as their environment.

Base Model

- From this, the parameters used in the SFM could be calibrated in order to produce realistic behaviour (using trial and error).

- Four behaviours are to be expected: (Helbing and Molnar, 1995; Helbing et al. 2000)
  - Clogging at bottlenecks
  - Lane formation
  - Oscillations at doorways
  - Freezing by heating (pedestrians' high desired velocity resulting in slower overall movements)

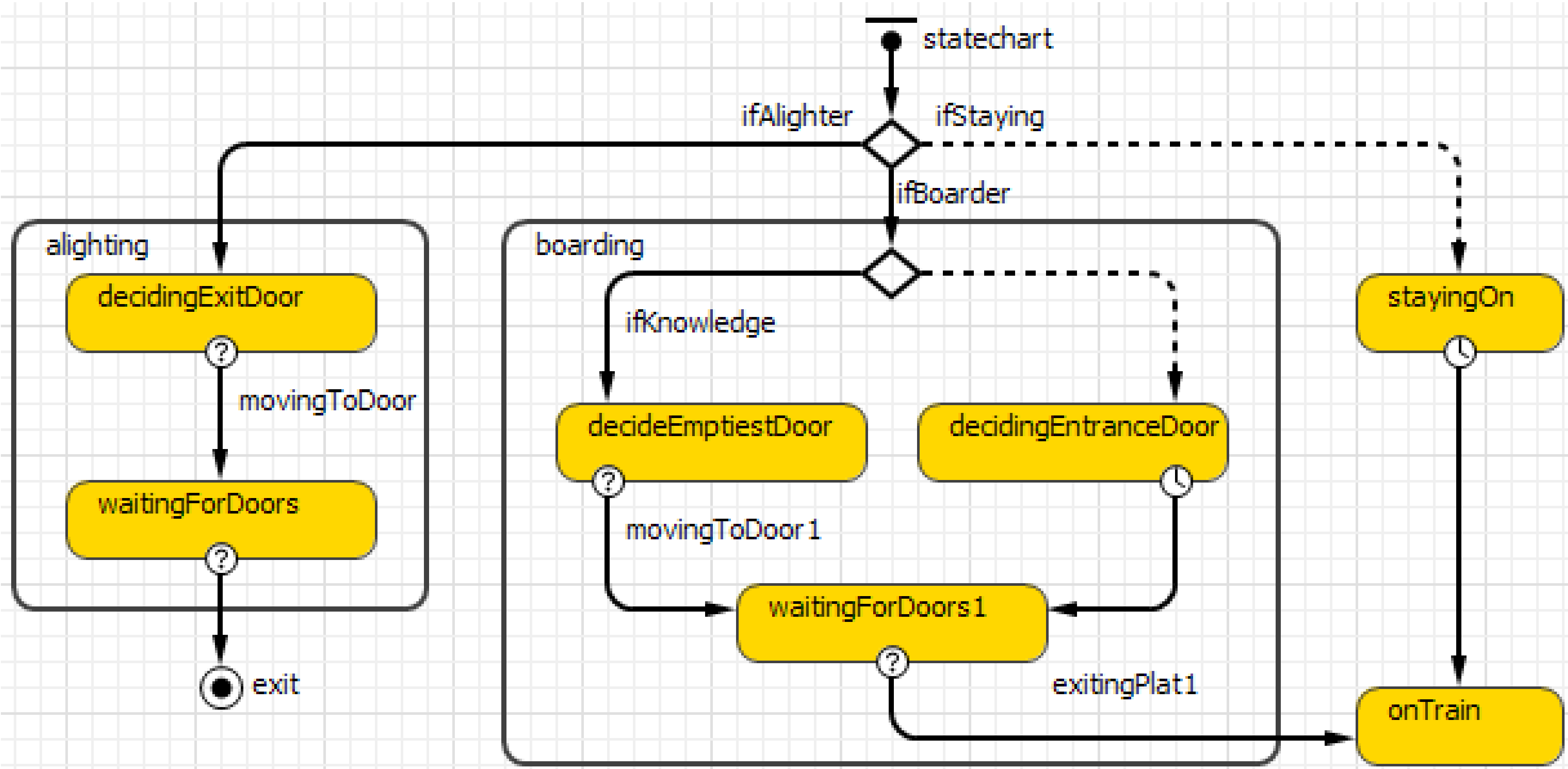
Passenger Types

- Passenger decision-making process depends on "knowledge"
  - If a passenger has knowledge of the station they base their decision on the least crowded door.
  - If a passenger does not have knowledge of the station, there are two different decision-making processes, depending on their arrival time relative to the train's arrival time.
    - Early arrivals will move towards the nearest anticipated door area.
    - Late arrivals pass by each door in turn. If the crowdedness at a door is under a specified threshold, the passenger will choose that door to enter.

Passenger Types

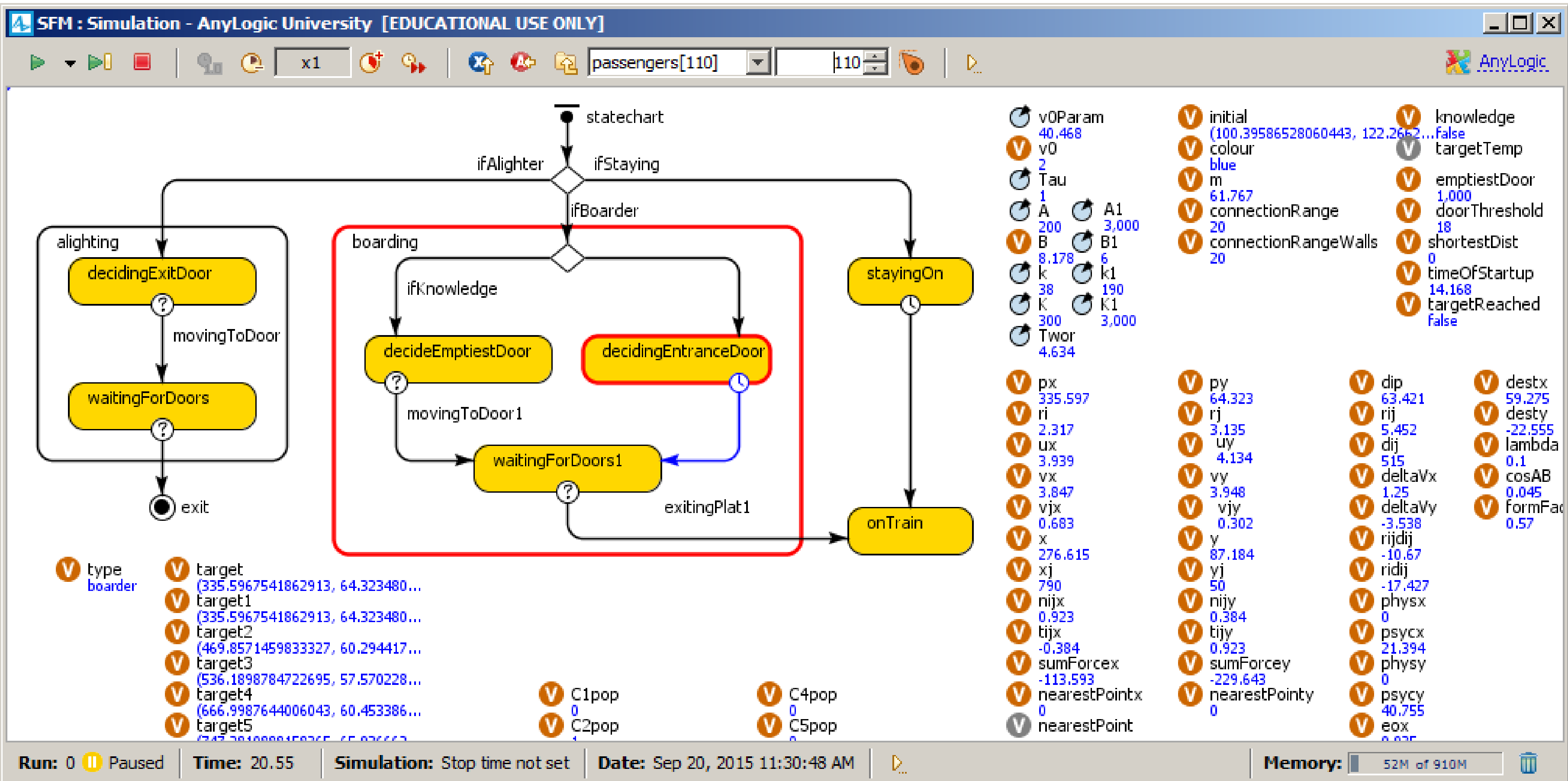
- For simplicity, it was also assumed that boarders do not wait for alighters before they start moving, and instead it is left to the social force to decide which group moves, hopefully oscillating, depending on relative group sizes.

Passenger States

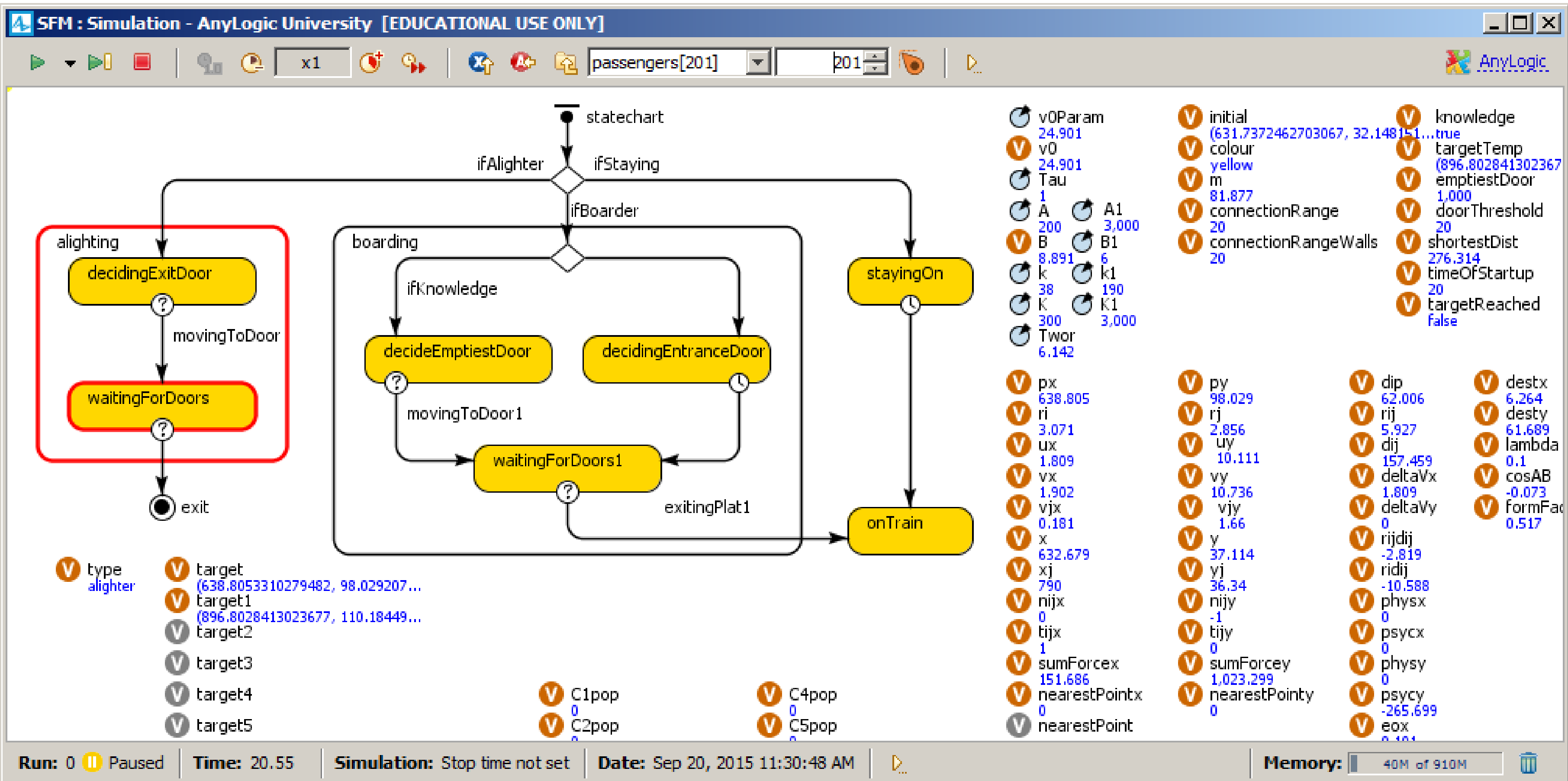


Model Implementation

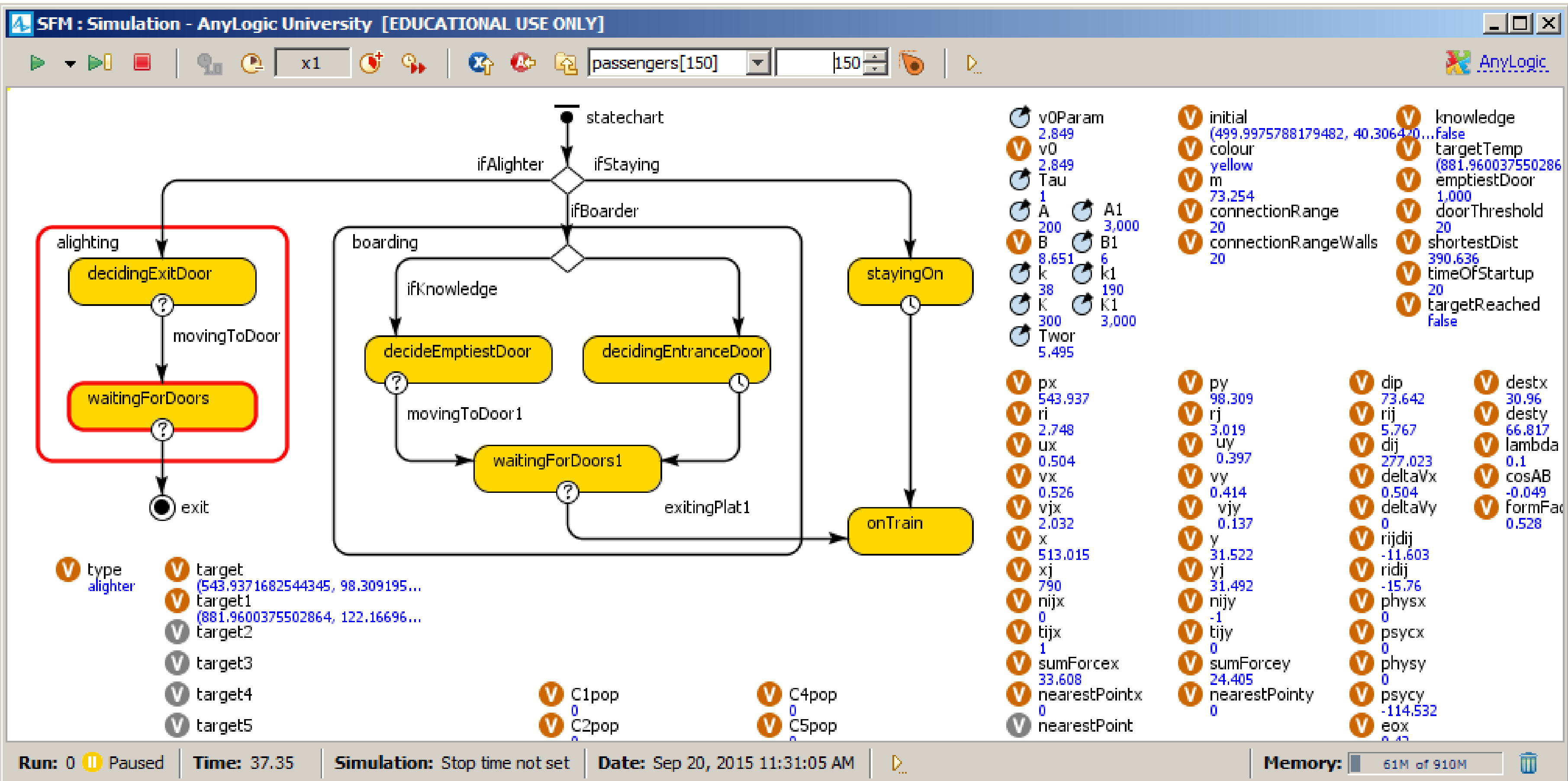
Pre Train Arrival



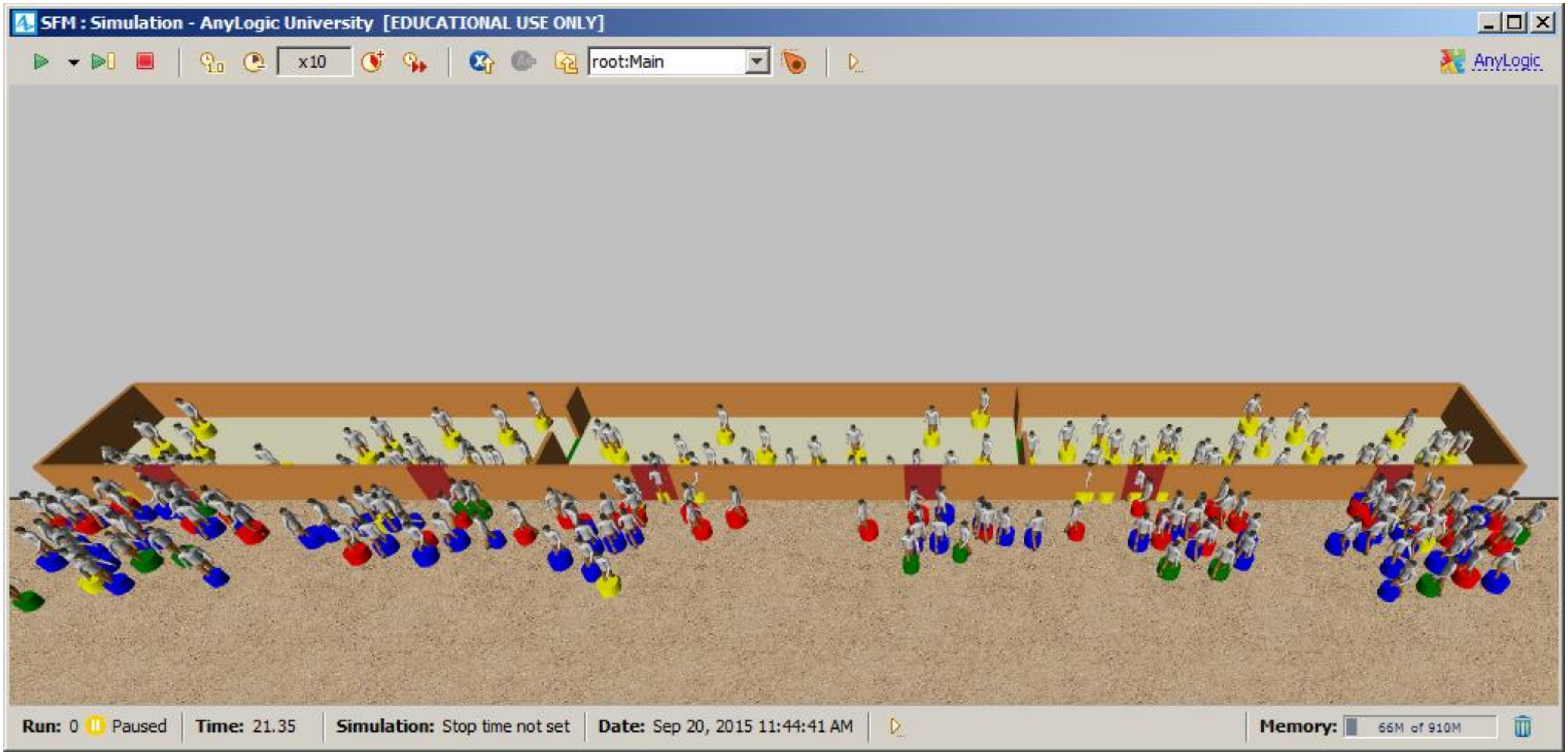
Train arrival



Train Stop Time



3D Display



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Experimentation

Experimentation

- Four scenarios are considered
  - Scenario 1: The "standard" generic scenario.
    - 600 passengers (split evenly between boarders, alighters, and stayers)
    - Normal distribution of desired walking speeds (mean = 1.3m/s; standard deviation = 0.2m/s)
    - 10% of passengers have "knowledge" of emptiest door
  - Scenario 2: The "rush hour" scenario in which the majority of the passengers are expected to be middle-aged commuters.
    - 1200 passengers (split equally between boarders, alighters and stayers)
    - Normal distribution of desired walking speeds (mean = 1.47m/s; standard deviation = 0.2m/s)
    - 50% of passengers have "knowledge" of the emptiest door

Experimentation

- Scenario 3: "OAP day out" in which a large number of passengers are elderly passengers.
  - 600 passengers (split evenly between boarders, alighters, and stayers)
  - Normal distribution of desired walking speeds (mean = 1.0m/s; standard deviation = 0.5m/s)
  - 10% of passengers have "knowledge" of emptiest door

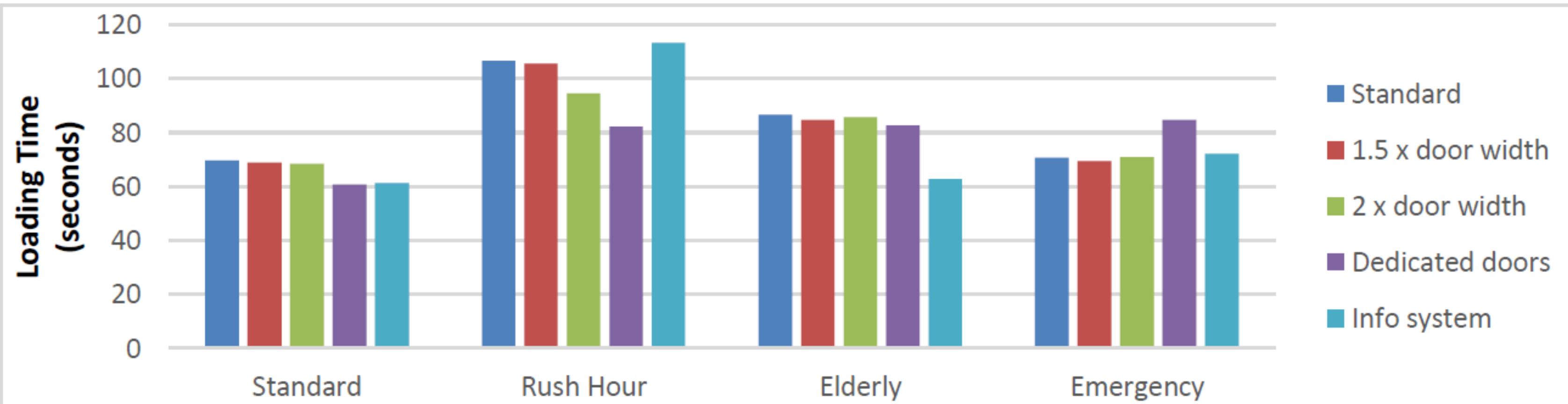
- Scenario 4: The "Emergency" scenario, to assess how well the train and platform can be cleared, including a higher desired velocity representing panic.
  - 400 passengers (all of which being alighters)
  - Normal distribution of desired walking speeds (mean = 3.0m/s; standard deviation = 1.0m/s)
  - 10% of passengers have "knowledge" of emptiest door

Experimentation

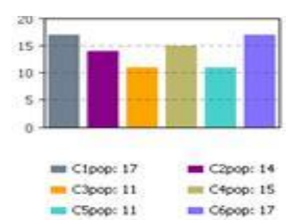
- For the four scenarios we compare five strategies:
  - Base case
  - 1.5x wider doors
  - 2x wider doors
  - Designated boarding and alighting door
  - An active passenger information system

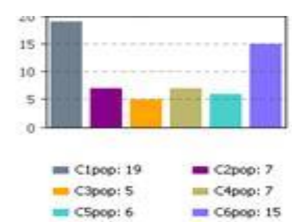
Results

- The quantitative output was total loading time



- There are a number of other numerical outputs available
  - Separation of Boarding and alighting times
  - Door utilisation dynamics





Future Work

Future Work

- This was just a feasibility study!
  - There are still bugs

- Next steps:
  - Modelling the interior of the train
  - Modelling groups: The ESFM also includes a socially attractive force between members of a group
  - Adding rules to let alighters off first (as it is the rule in Britain)
  - Adding agent learning

References

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