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

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Motivation

- Part 1
  - Introduce the concepts of object oriented Agent-Based Social Simulation (ooABSS)
- Part 2
  - Demonstrate the applicability of ooABSS to evaluate methods to reduce dwell times for rail passengers
- Part 3
  - Give you a brief overview of some other projects related to ooABSS

Part 1

Object Oriented Agent-Based Social Simulation

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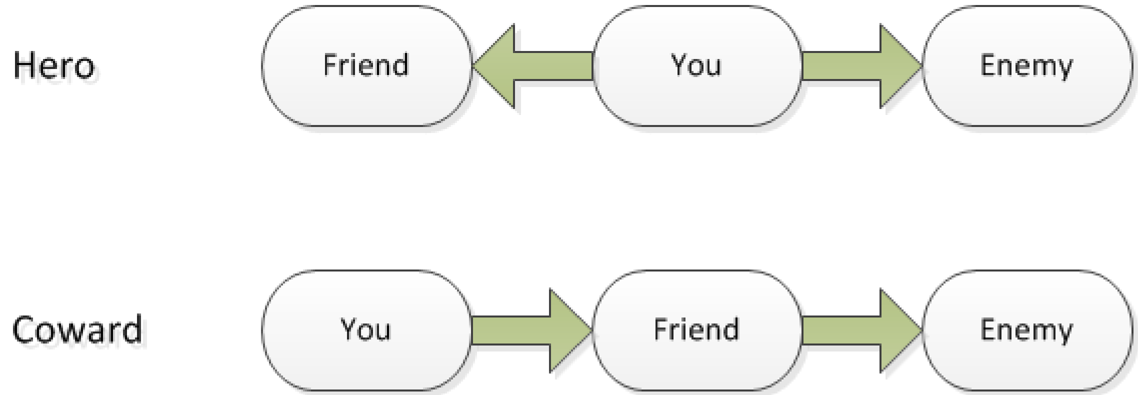
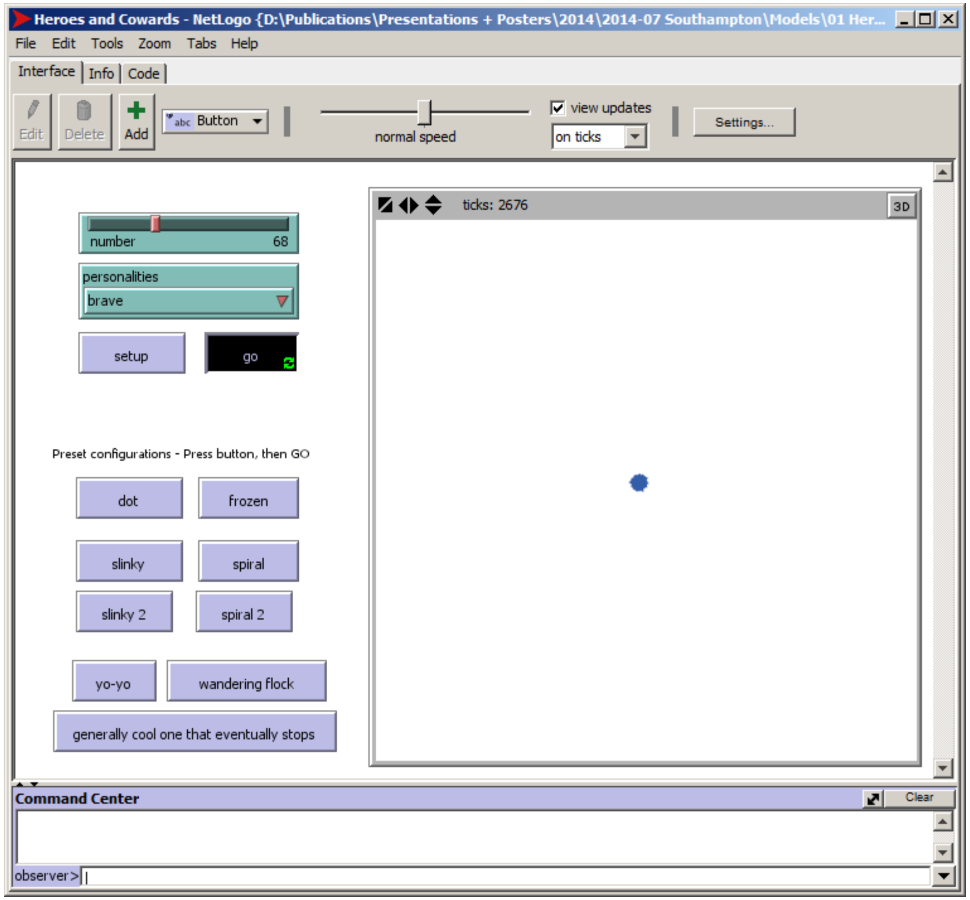
Agent-Based Modelling

- Heroes and Cowards Game [Wilensky and Rand 2013]



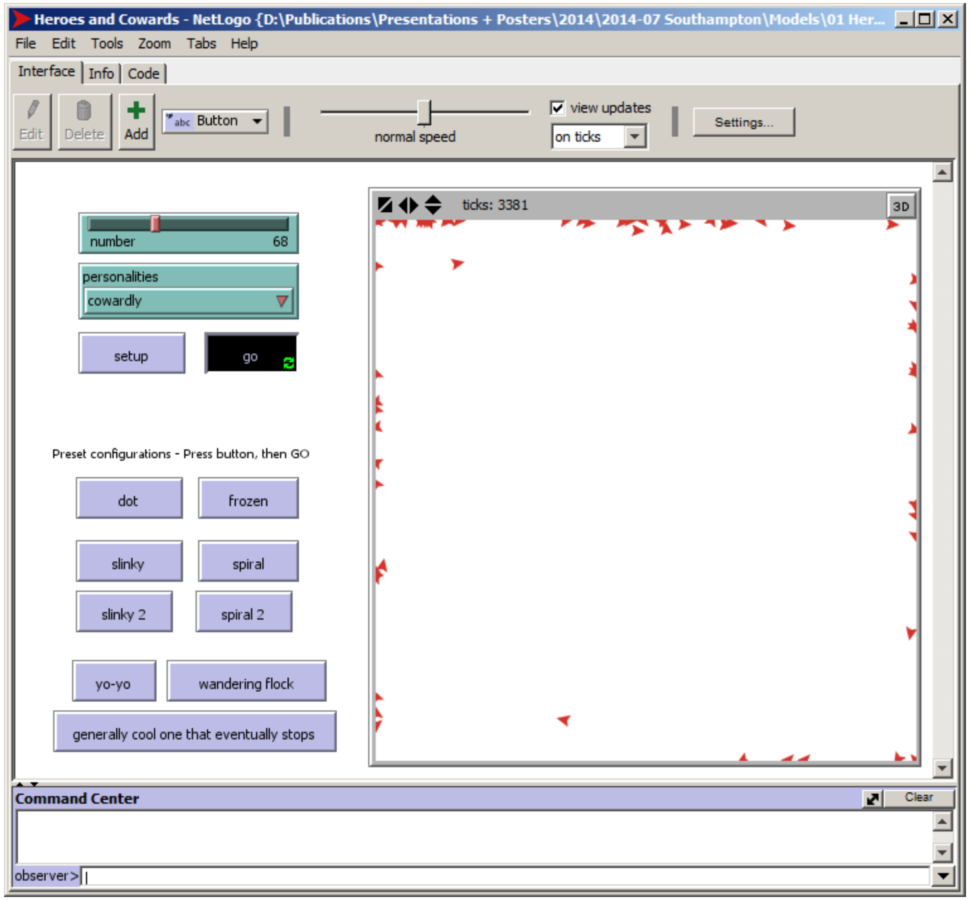
Agent-Based Modelling

- Heroes and Cowards Game : All heroes



Agent-Based Modelling

- Heroes and Cowards Game: All cowards



Agent-Based Modelling

- Heroes and Cowards Game: Source Code

Heroes and Cowards - NetLogo {D:\Teaching\Short Courses\ESM2013-Tutorial}

File Edit Tools Zoom Tabs Help

Interface | Info | Code

Find... Check Procedures ☑ Indent automatically

```
to setup
  clear-all

  ask patches [ set pcolor white ]  ;; create a blank background
  create-turtles number [
    setxy random-xcor random-ycor

    ;; set the turtle personalities based on chooser
    if (personalities = "brave")     [ set color blue ]
    if (personalities = "cowardly")  [ set color red ]
    if (personalities = "mixed")     [ set color one-of [ red blue ] ]

    ;; choose friend and enemy targets
    set friend one-of other turtles
    set enemy one-of other turtles
  ]
  reset-ticks
end

to go
  ask turtles [
    if (color = blue)  [ act-bravely ]
    if (color = red)   [ act-cowardly ]
  ]
  tick
end

to act-bravely
  ;; move toward the midpoint of your friend and enemy
  facexy ([xcor] of friend + [xcor] of enemy) / 2
         ([ycor] of friend + [ycor] of enemy) / 2
  fd 0.1
end

to act-cowardly
  ;; put your friend between you and your enemy
  facexy [xcor] of friend + ([xcor] of friend - [xcor] of enemy) / 2
         [ycor] of friend + ([ycor] of friend - [ycor] of enemy) / 2
  fd 0.1
end

; Copyright 2010 Uri Wilensky.
; See Info tab for full copyright and license.
```

Agent-Based Modelling

- In Agent-Based Modelling (ABM), a system is modelled as a collection of **autonomous decision-making entities** called agents. Each agent individually assesses its situation and makes decisions on the basis of a **set of rules**.
- ABM is **a mindset more than a technology**. The ABM mindset consists of describing a system from the perspective of its constituent units. [Bonabeau 2002]
- ABM is **well suited to modelling** systems with heterogeneous, autonomous and proactive actors, such as **human-centred systems**.

Agent-Based Modelling

- What do we mean by "agent"?
  - Agents are **objects with attitude**!
- Properties:
  - Discrete entities
    - With their own goals and behaviours
    - With their own thread of control
  - Autonomous decisions
    - Capable to adapt
    - Capable to modify their behaviour
  - Proactive behaviour
    - Actions depending on motivations generated from their internal state

Agent-Based Modelling

- The agents can represent individuals, households, organisations, companies, nations, … depending on the application.

- ABMs are essentially **decentralised**; there is no place where global system behaviour (dynamics) would be defined.
- Instead, the individual agents **interact** with each other and their environment **to produce complex collective behaviour** patterns.

Agent-Based Modelling

- Benefits of ABM
  - ABM provides a natural description of a system
  - ABM captures emergent phenomena
- Emergence
  - Emergent phenomena result from the interactions of individual entities. **The whole is more than the sum of its parts** [Aristotle BC] because of the interactions between the parts.
  - An emergent phenomenon can have properties that are decoupled from the properties of the part (e.g. patterns appearing).
  - Example: Traffic Jam Dynamics

Agent-Based Modelling

- When to use ABM? [Siebers et al. 2010]
  - When the problem has a **natural representation as agents** - when the goal is modelling the behaviours of individuals in a diverse population
  - When agents have relationships with other agents, especially **dynamic relationships** - agent relationships form and dissipate, e.g., structured contact, social networks
  - When it is important that individual agents have **spatial or geo-spatial aspects** to their behaviours (e.g. agents move over a landscape)
  - When it is important that agents **learn or adapt**, or populations adapt
  - When agents engage in **strategic behaviour**, and anticipate other agents' reactions when making their decisions
  - ...

Agent-Based Simulation

- The Sims: Interactive Organisational Agent-Based Simulation

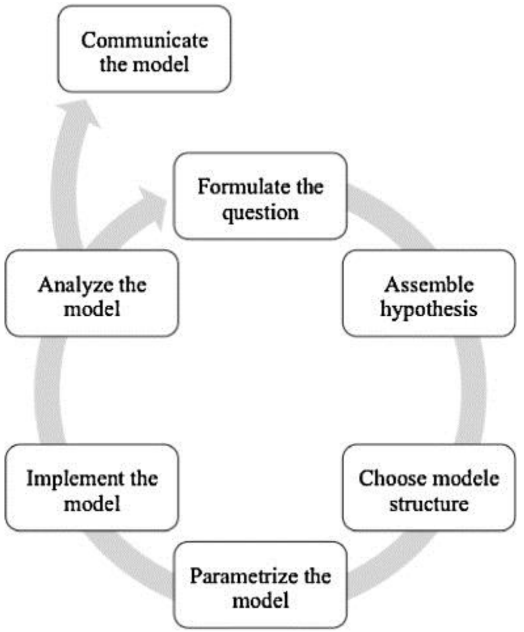
Agent-Based Simulation

- Building an ABS model (OR/MS)
  - Identify active entities (agents)
  - Define their states and behaviour
  - Put them in an environment
  - Establish connections
  - Test the model

AnyLogic Help (2013)

- Validating an ABS model
  - System behaviour is an emergent property
  - Validation on a micro level

- Alternative (e.g. Ecology)



Grimm and Railsback (2005)

Agent-Based Simulation

- Simulation facts in different disciplines

Operations Research	Business, Economics, Social Science
Empirical basis	Theoretical basis
Improving the real world	Thinking about the real world
Data collection and analysis	Dynamic hypothesis
Validation: Sufficient accuracy for purpose	Plausibility: Seeming reasonable or probable
Implementing findings	Learning + understanding

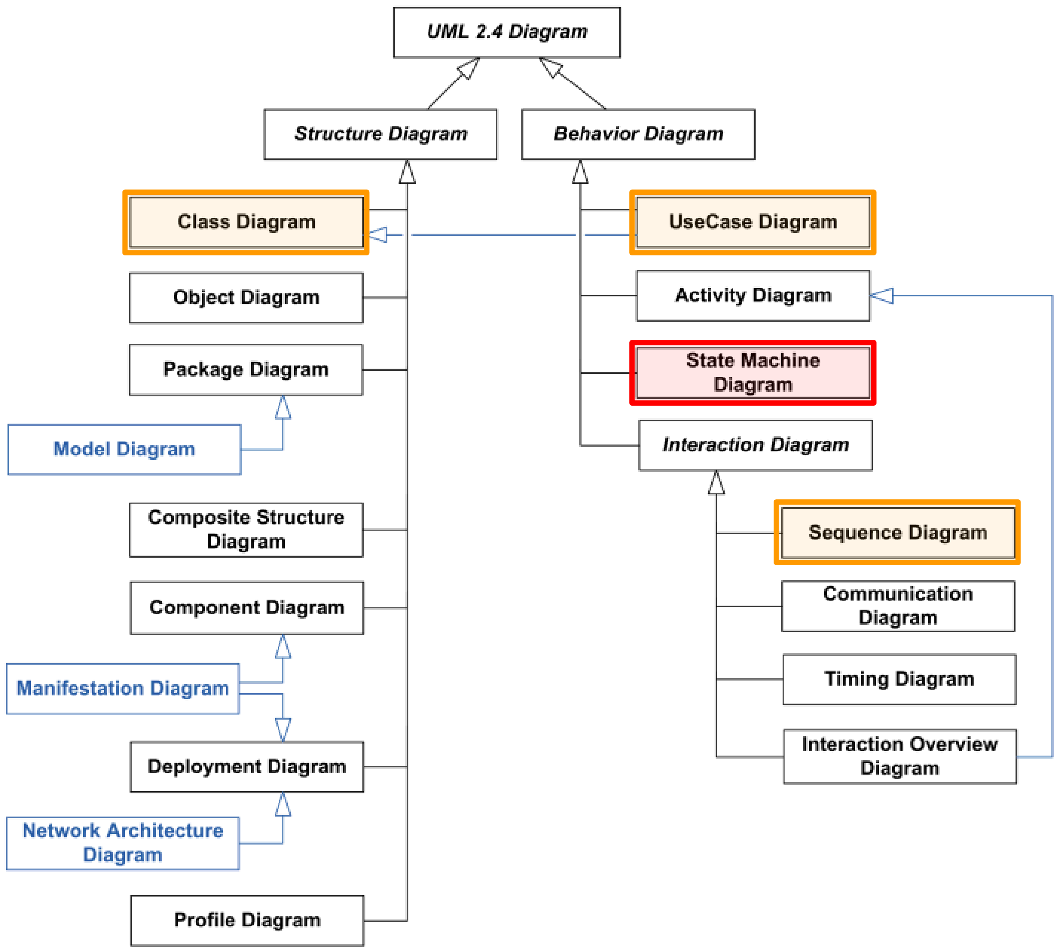
after Robinson (2010)

Agent-Based Simulation

- Synchronous approach [Macal 2013]
  - Loop over time horizon
    - Loop over randomised list of agents. For each **agent A** in list:
      - Execute **agent A** behaviour
      - Update state of **agent A** (based on **agent A**'s state, the states of agents that interact with **agent A**, and the state of the environment).
      - Update other agents states and the environment (if appropriate)
    - End loop over randomized list of agents
  - Increment t in time loop and repeat until end of simulation time horizon

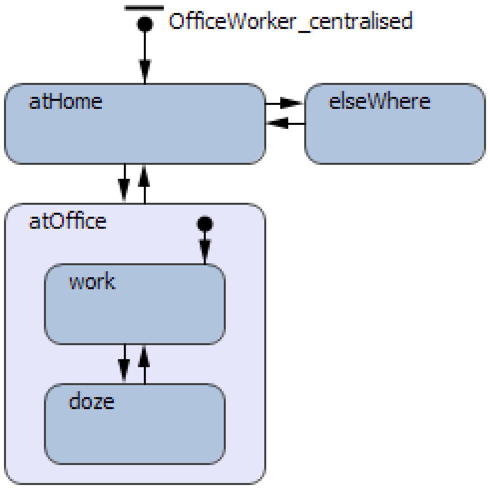
- Asynchronous approach [openABM.org 2014]
  - Event driven
    - An action of one agent may trigger the updating of another agent
      - Example: An **agent A** sending messages to an **agent B**

Using Software Engineering Tools

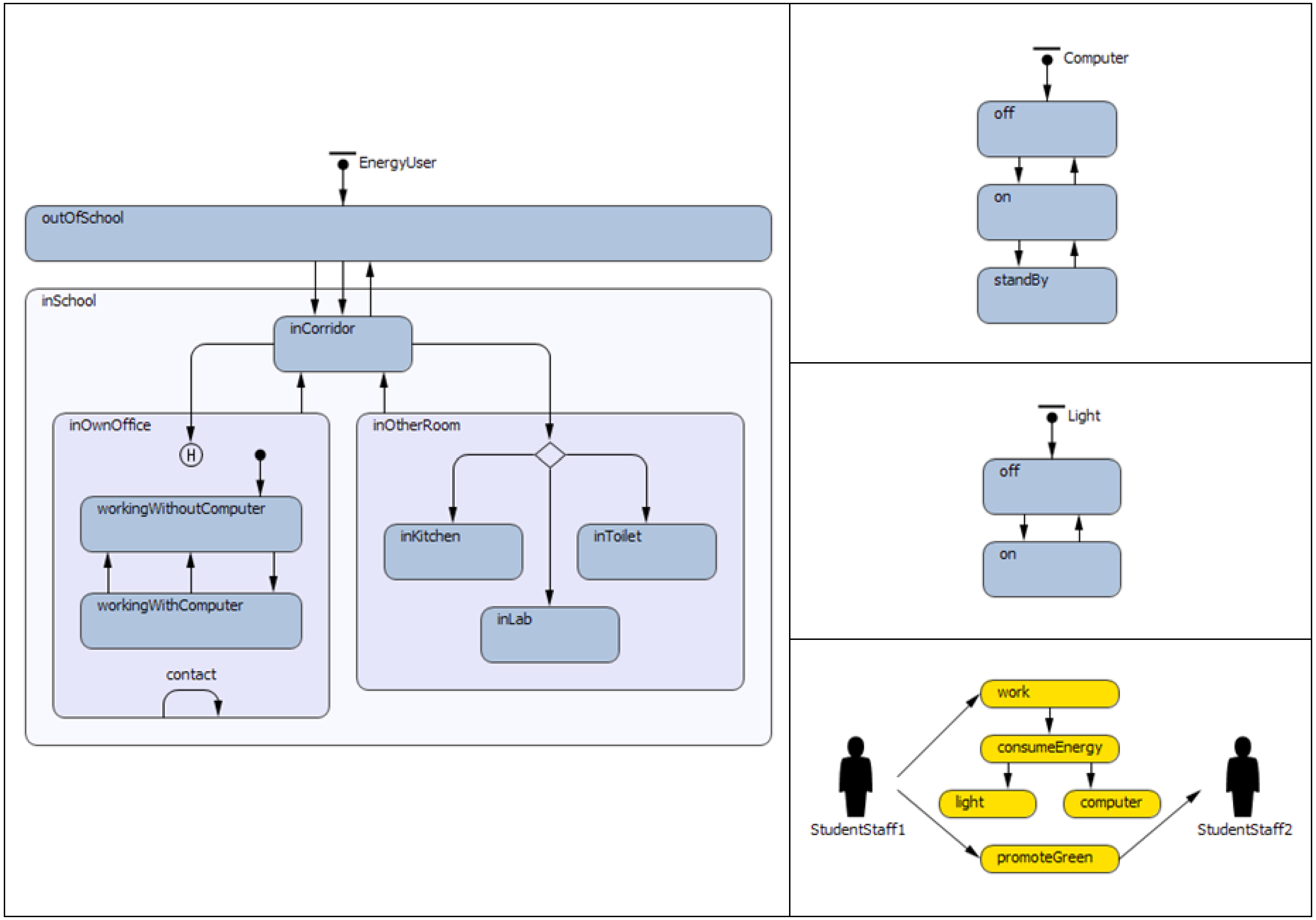


Using Software Engineering Tools

- Building a state chart step-by-step
  - Who are the actors?
  - What are the key locations you can find them?
  - What are key time consuming activities they get involved in?



Case Study: Office Energy Consumption [Zhang et al 2011]



Part 2

Case Study: Simulation of Rail Passengers to Evaluate Methods to Reduce Dwell Times

[Perkins et al 2015]

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Introduction

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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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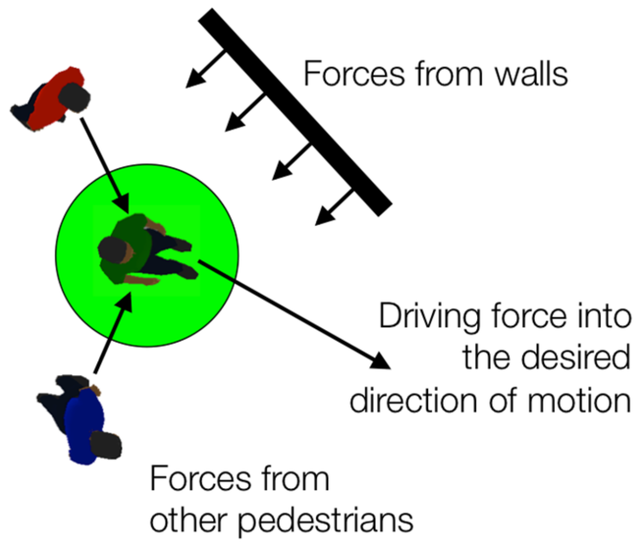
Modelling Theory

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

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)

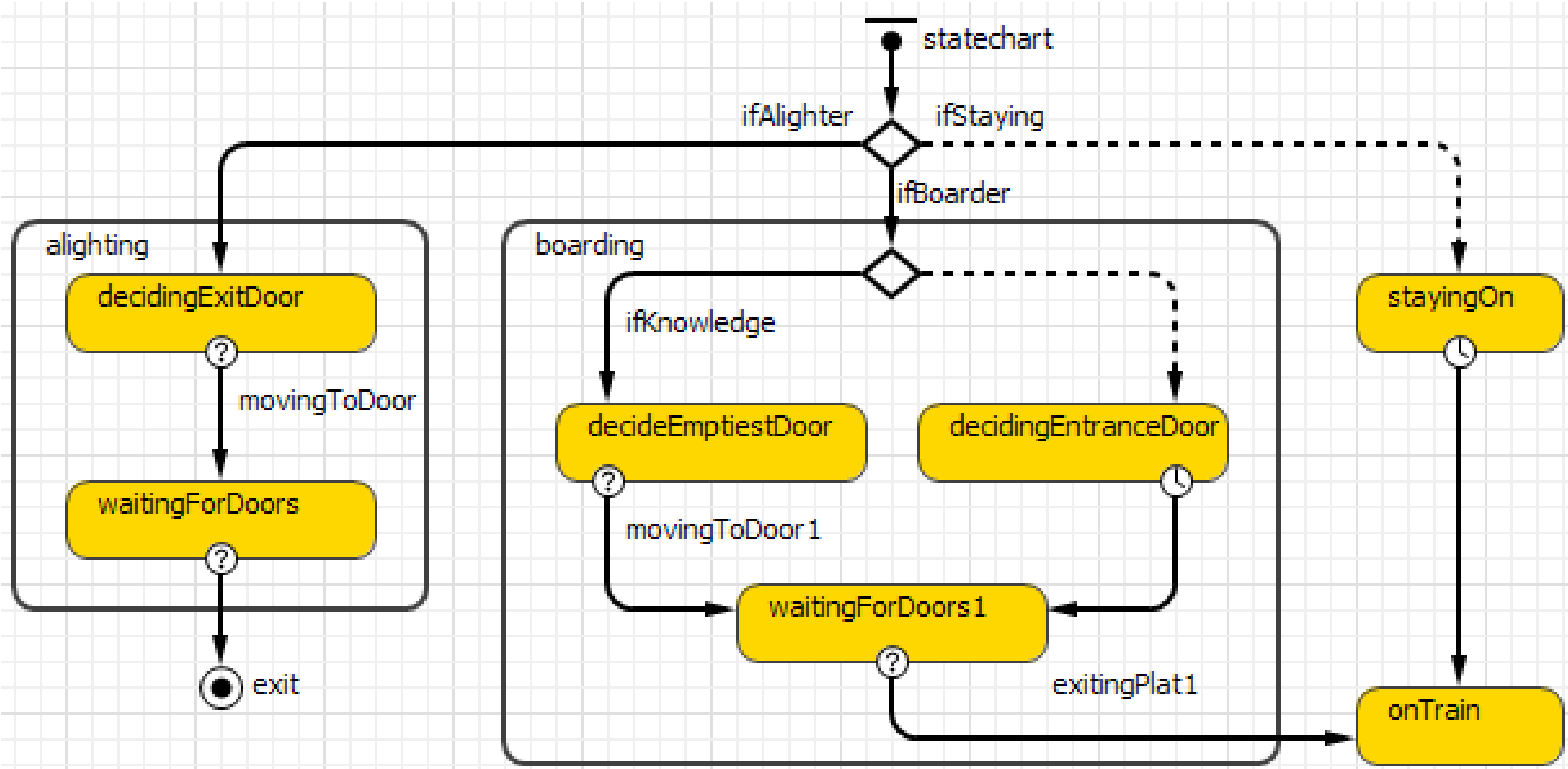
Passenger Types

- 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

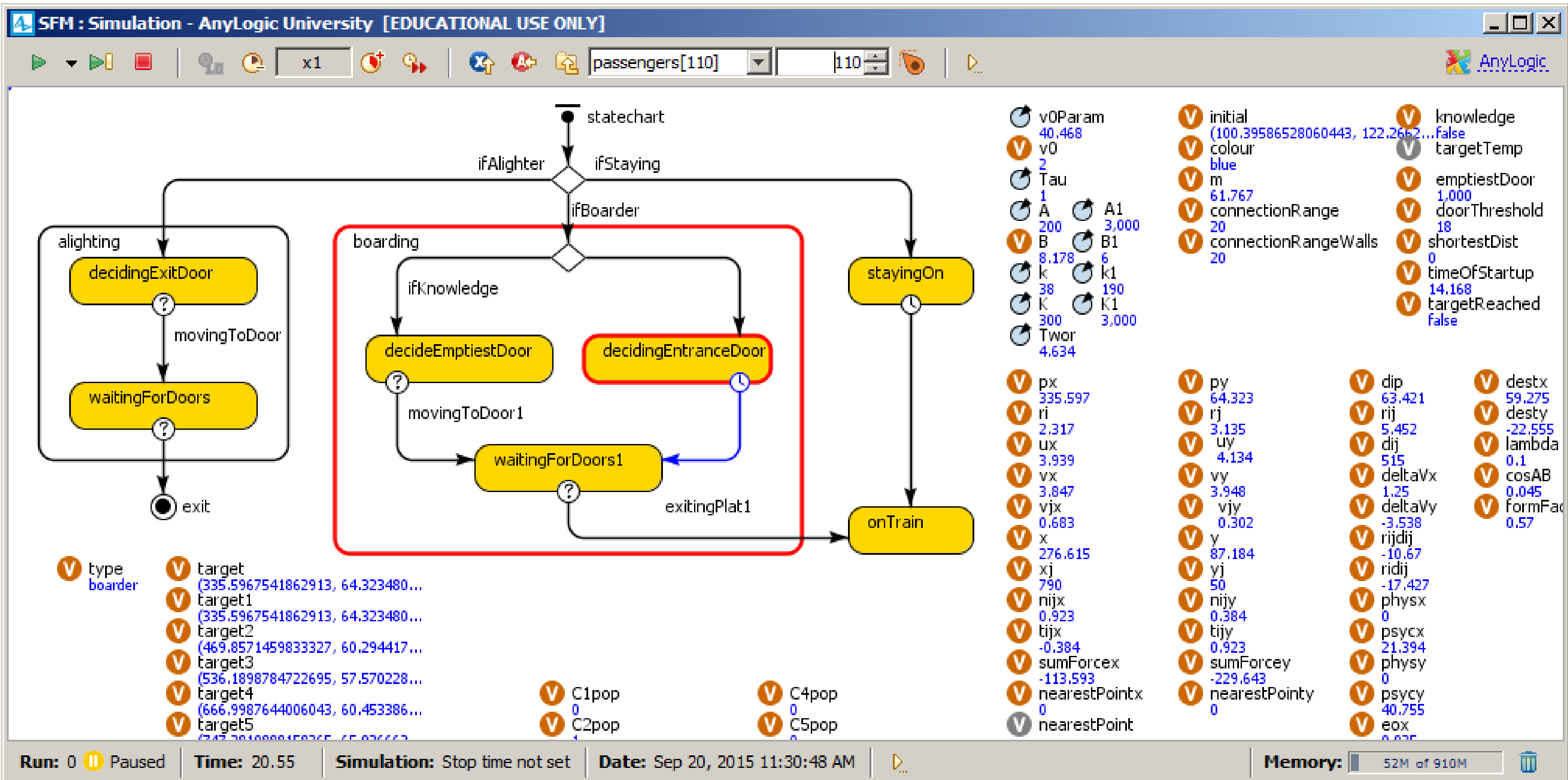
- For simplicity, it was also assumed that boarders do not wait for alighters before they start moving, and instead it is left to the social force to decide which group moves, hopefully oscillating, depending on relative group sizes.

Passenger States

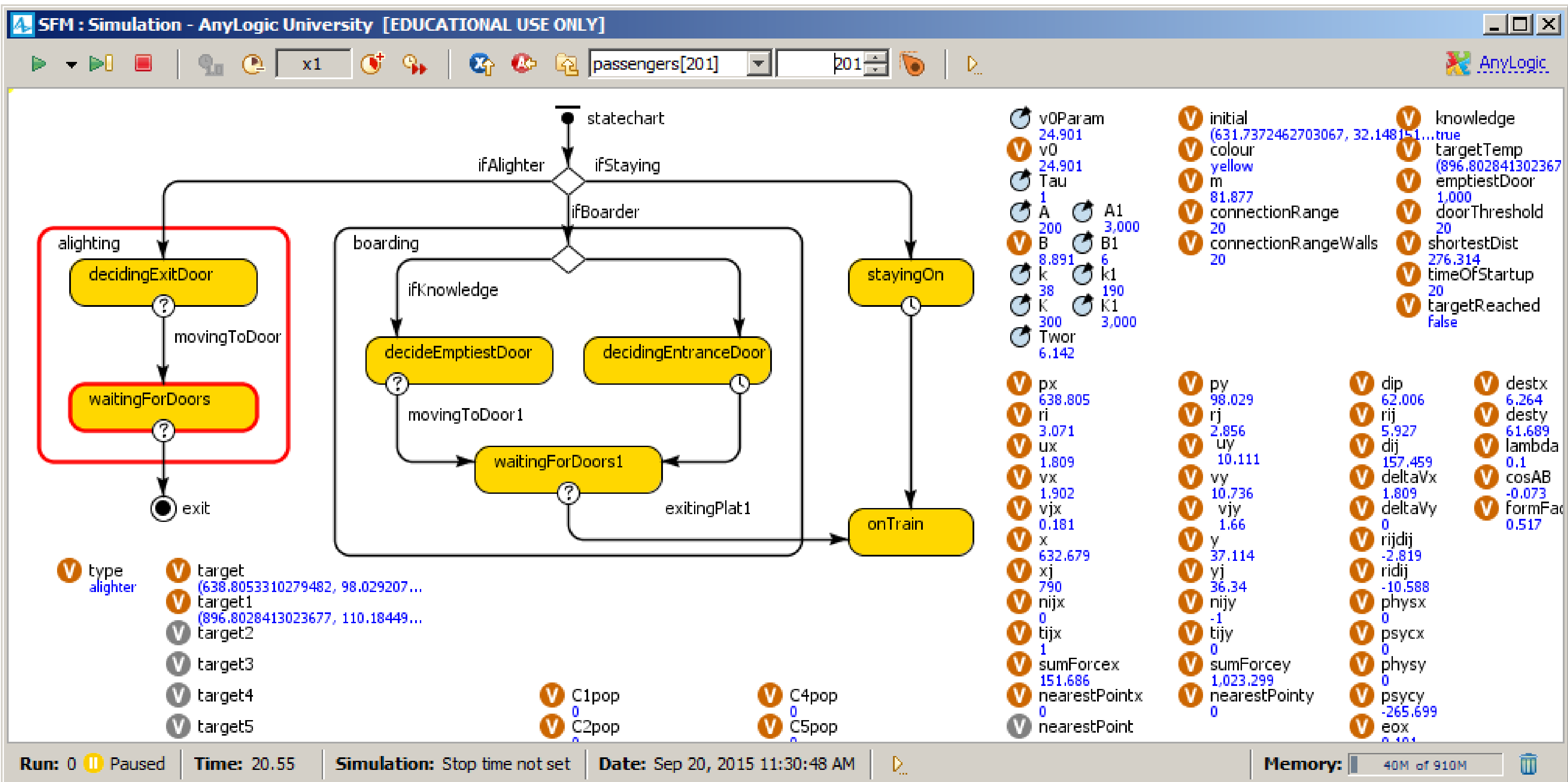


Model Implementation

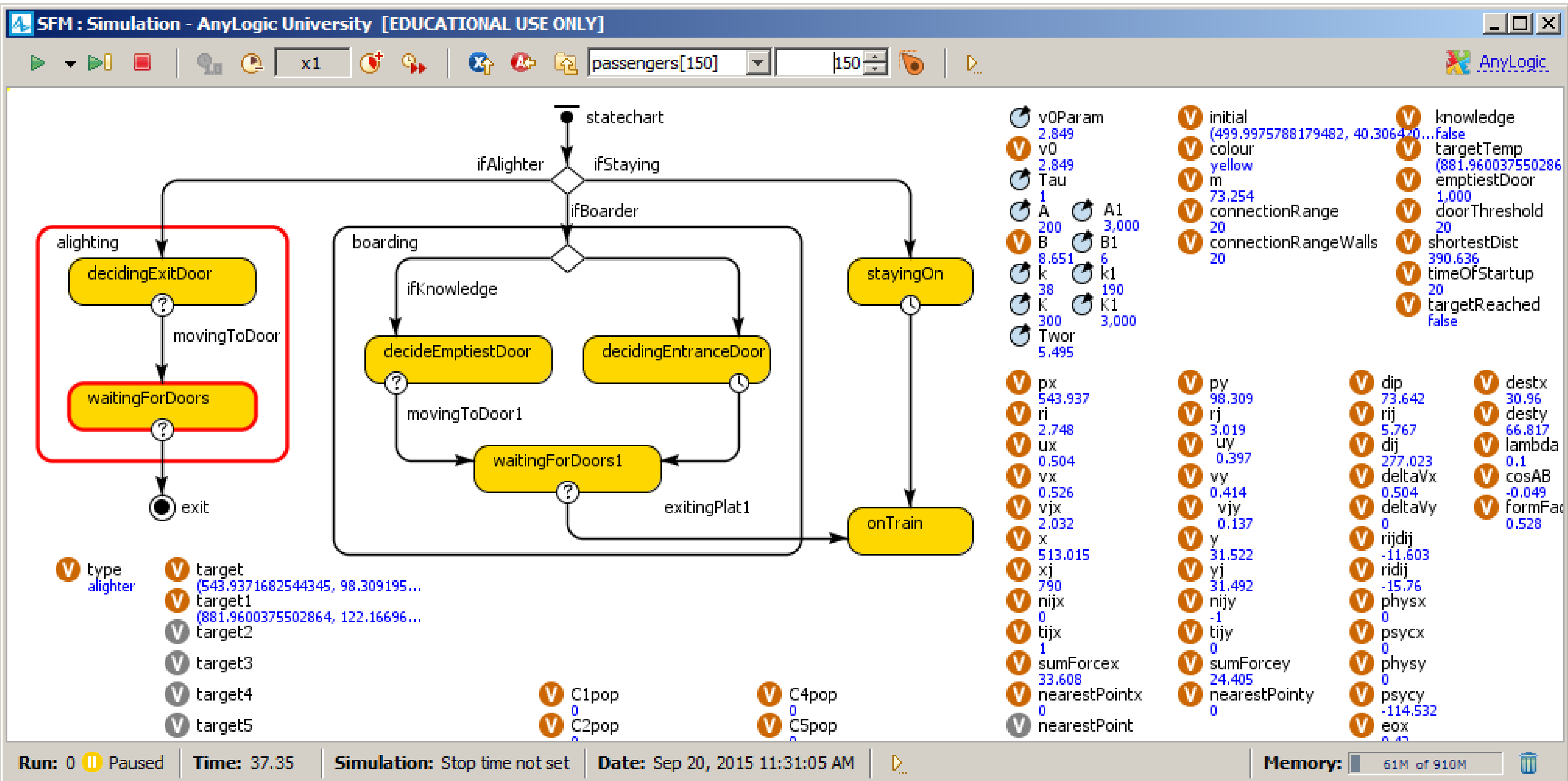
Pre Train Arrival



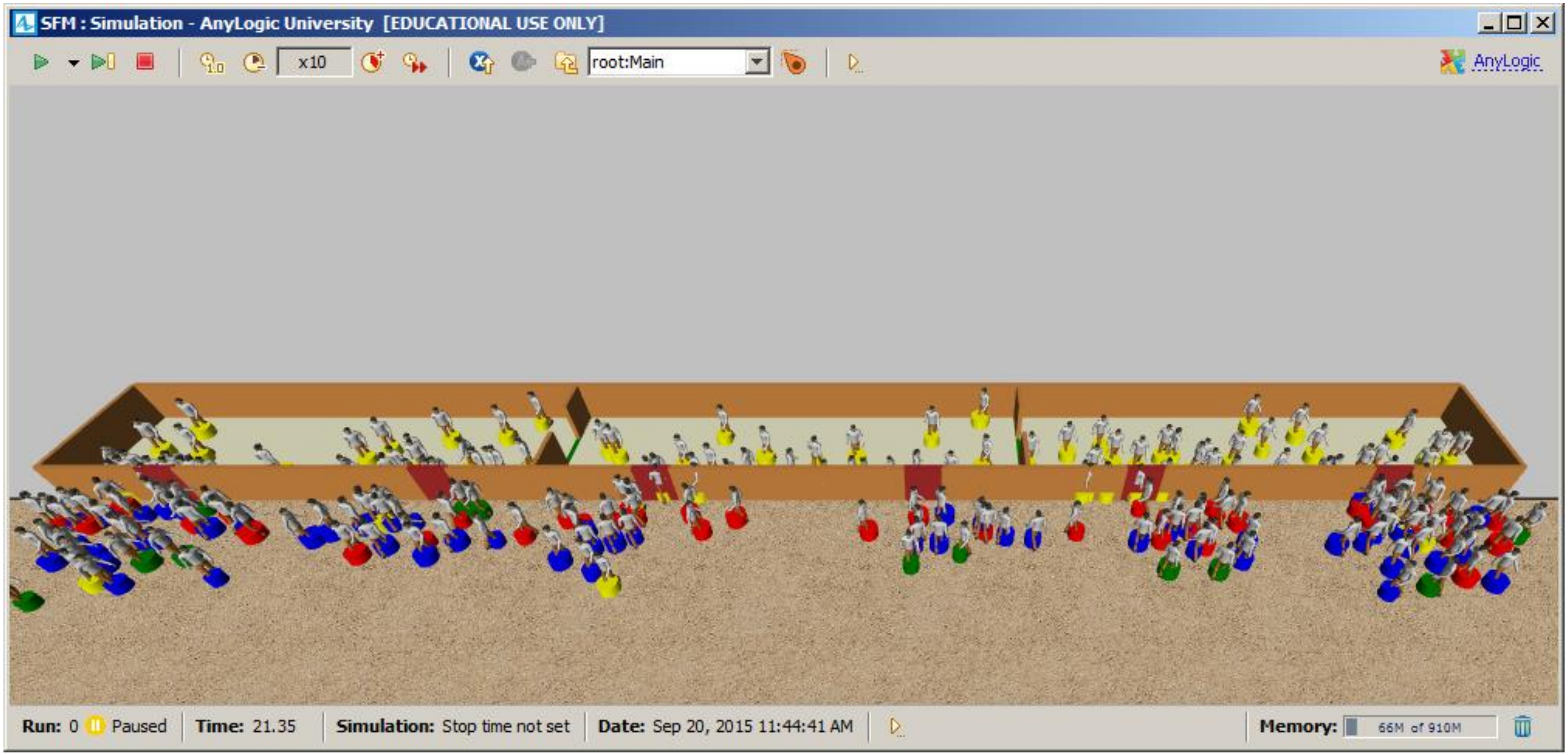
Train arrival



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

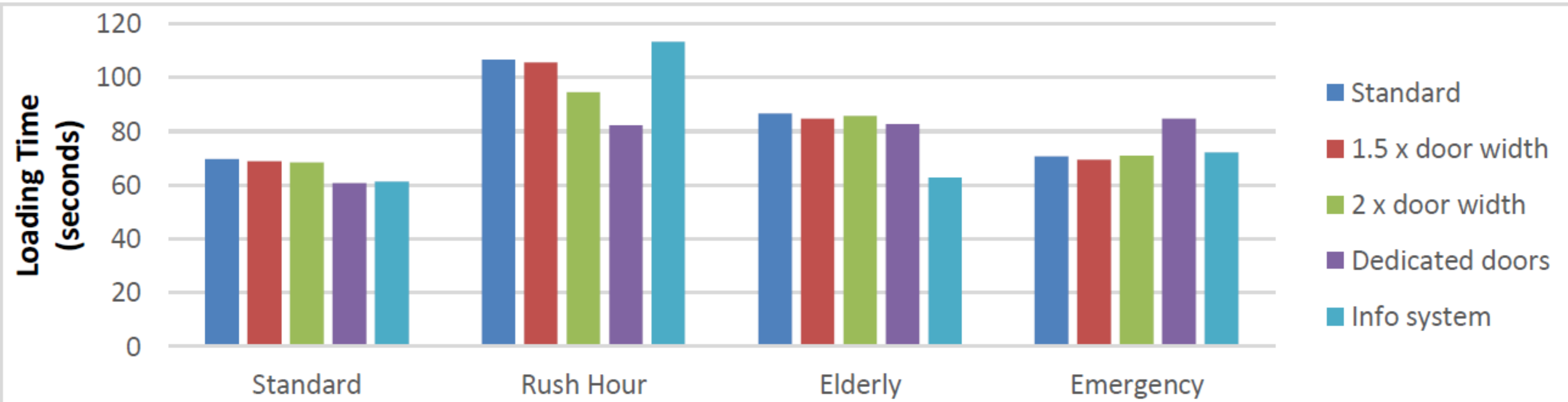
– Scenario 4: The "Emergency" scenario, to assess how well the train and platform can be cleared, including a higher desired velocity representing panic.
    - 400 passengers (all of which being alighters)
    - Normal distribution of desired walking speeds (mean = 3.0m/s; standard deviation = 1.0m/s)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

Experimentation

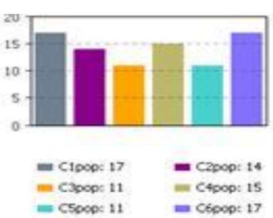
- For the four scenarios we compare five strategies:
  - Base case
  - 1.5x wider doors
  - 2x wider doors
  - Designated boarding and alighting door
  - An active passenger information system

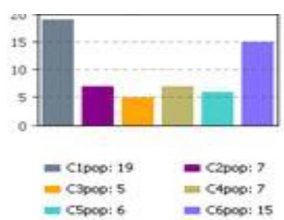
Results

- 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





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Future Work

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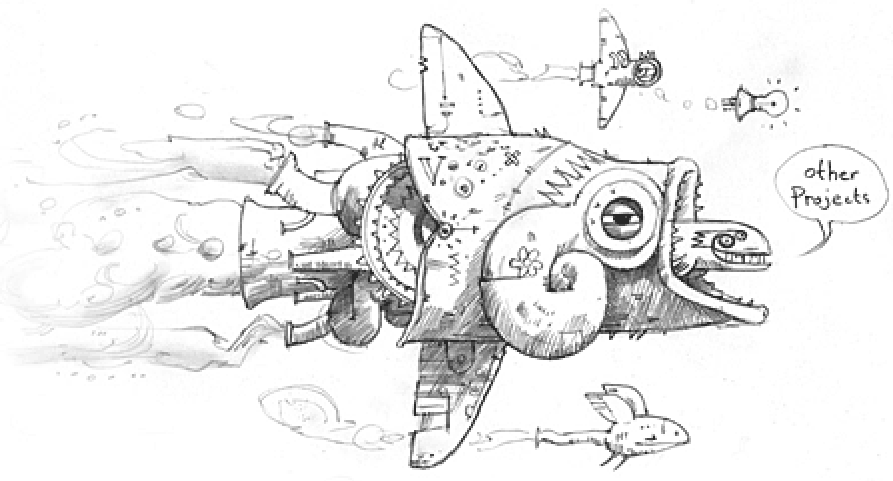
Future Work

- 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

Part 3

Other Projects



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LUCAS is a cross-faculty interdisciplinary team directed by Darren Robinson (Chair in Building and Urban Physics), working to better understand how cities function, socially and physically, and how this functioning and its consequences for social, economic and environmental sustainability can be improved upon.

At the core of our activities is the Leverhulme Research Programme Grant

"Sustaining urban habitats: an interdisciplinary approach"

The Leverhulme Trust

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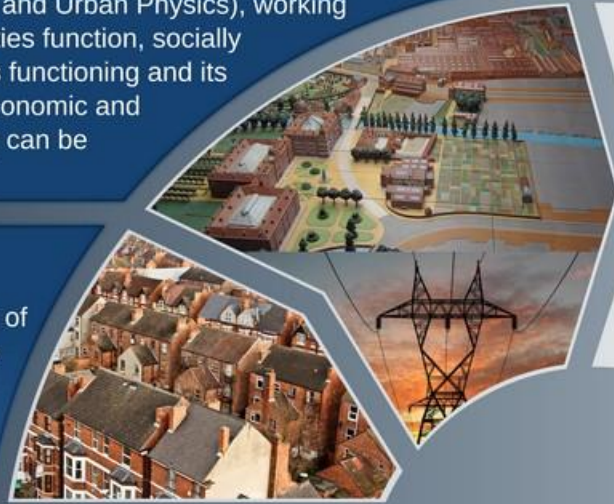

LUCAS is a key component of the University's Sustainable and Resilient Cities Research Priority Area

Research themes

Environmental: realistic measures of urban sustainability and options for improving resilience and resource flows

Social and Cultural: patterns of consumption by different groups and social perspectives on measures and scenarios for improving sustainability

Economic: factors shaping economic activity and migration, and prospects for balancing economic and social capital with environmental capital

Measurement and Data: effective ways of managing the different forms of data from themes 1, 2 and 3 to develop appropriate indicators of sustainability

Modelling and Optimisation: minimising resource demands in response to underlying stimuli and constraints

Policy and Governance: the role of public policies and policy-maker perspectives on the indicators and scenarios that we develop

LABORATORY OF URBAN COMPLEXITY AND SUSTAINABILITY

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Director - Professor Darren Robinson
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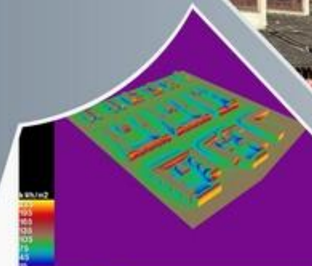
InSMART:

Integrative Smart City Planning project

brings together cities and scientific organizations in order to establish a methodology for enhancing sustainable planning for both the current and future city needs through an integrative and multidisciplinary planning approach.



CINERGY

CiNERGY:

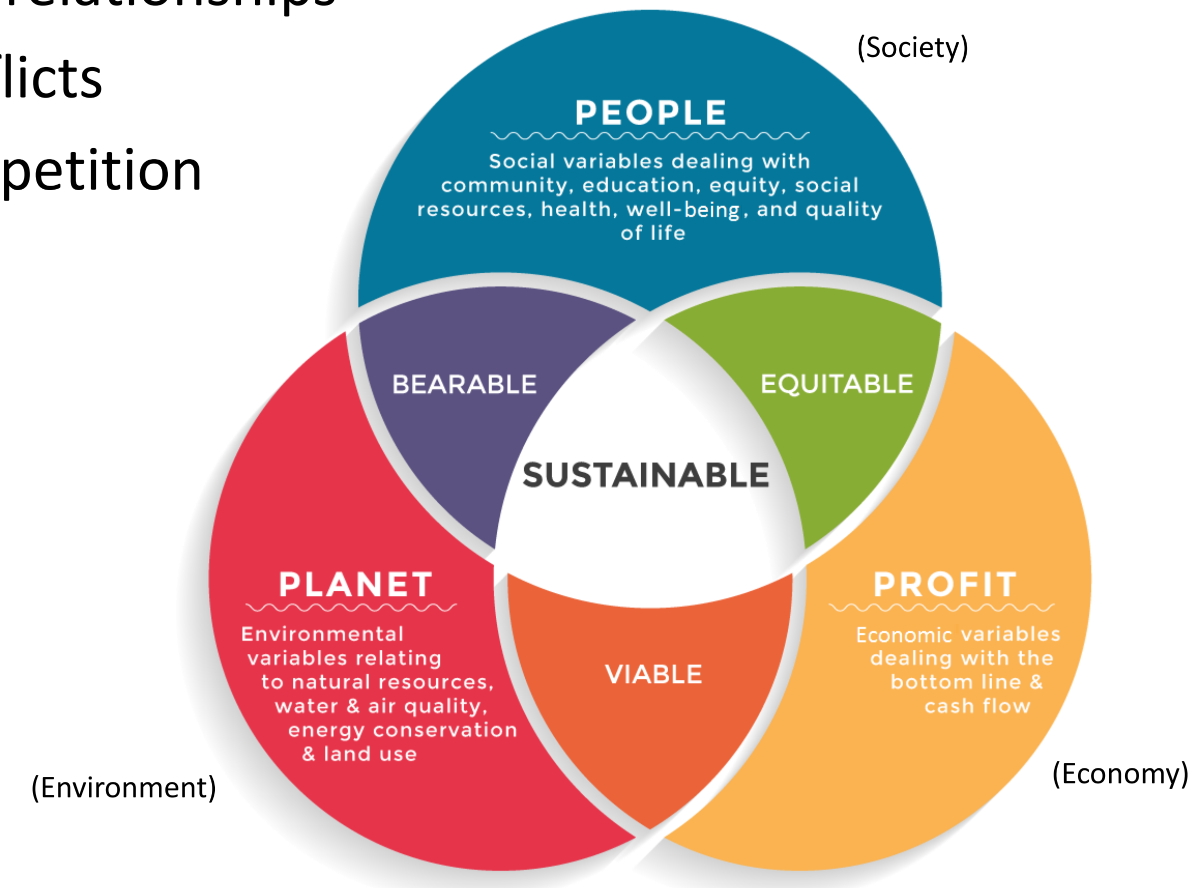
Smart cities with sustainable energy systems

Marie Curie International Training Network (ITN) project is training young scientists to develop urban decision-making and urban energy system models that help decision makers to maximise energy efficiency and renewable energy integration toward a low carbon urban future.

Thanks to Anthony Beck (LUCAS) for the poster!

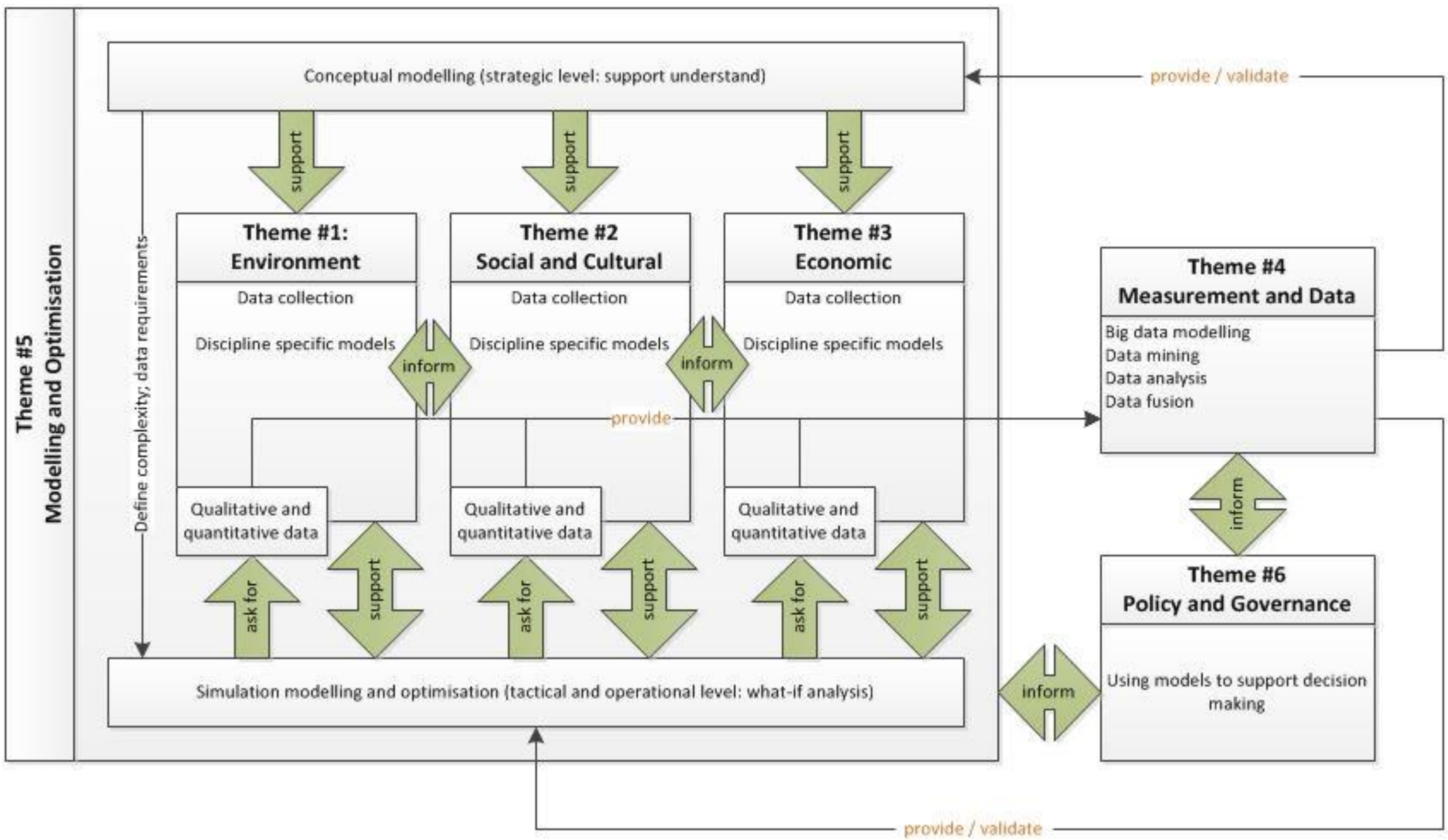
Sustaining Urban Habitats

- Interrelationships
- Conflicts
- Competition

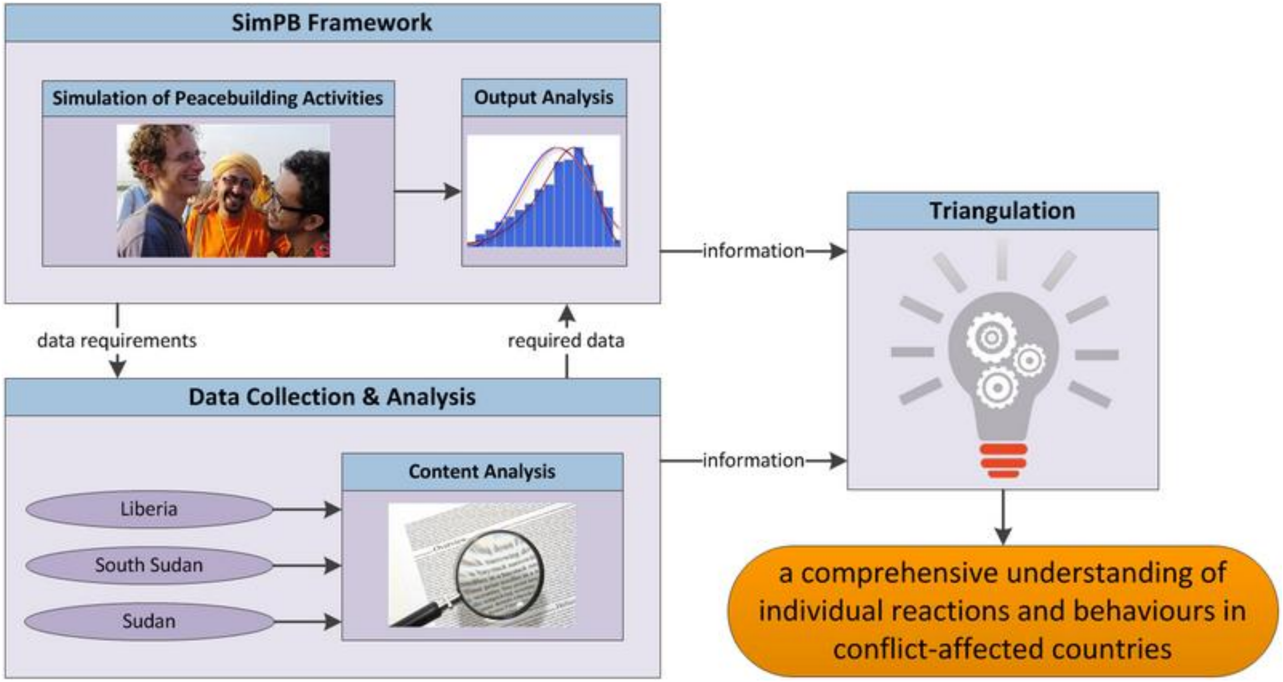


http://www.fourewesdesign.com/about

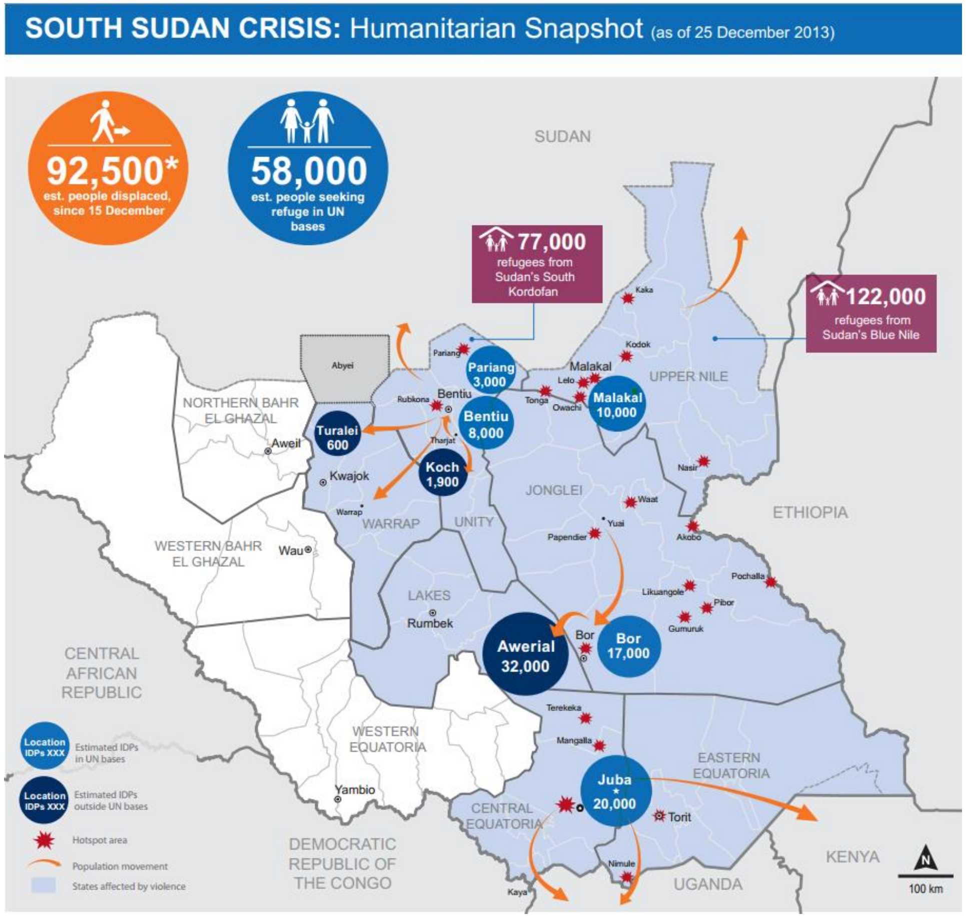
Sustaining Urban Habitats



Simulating Peace Building

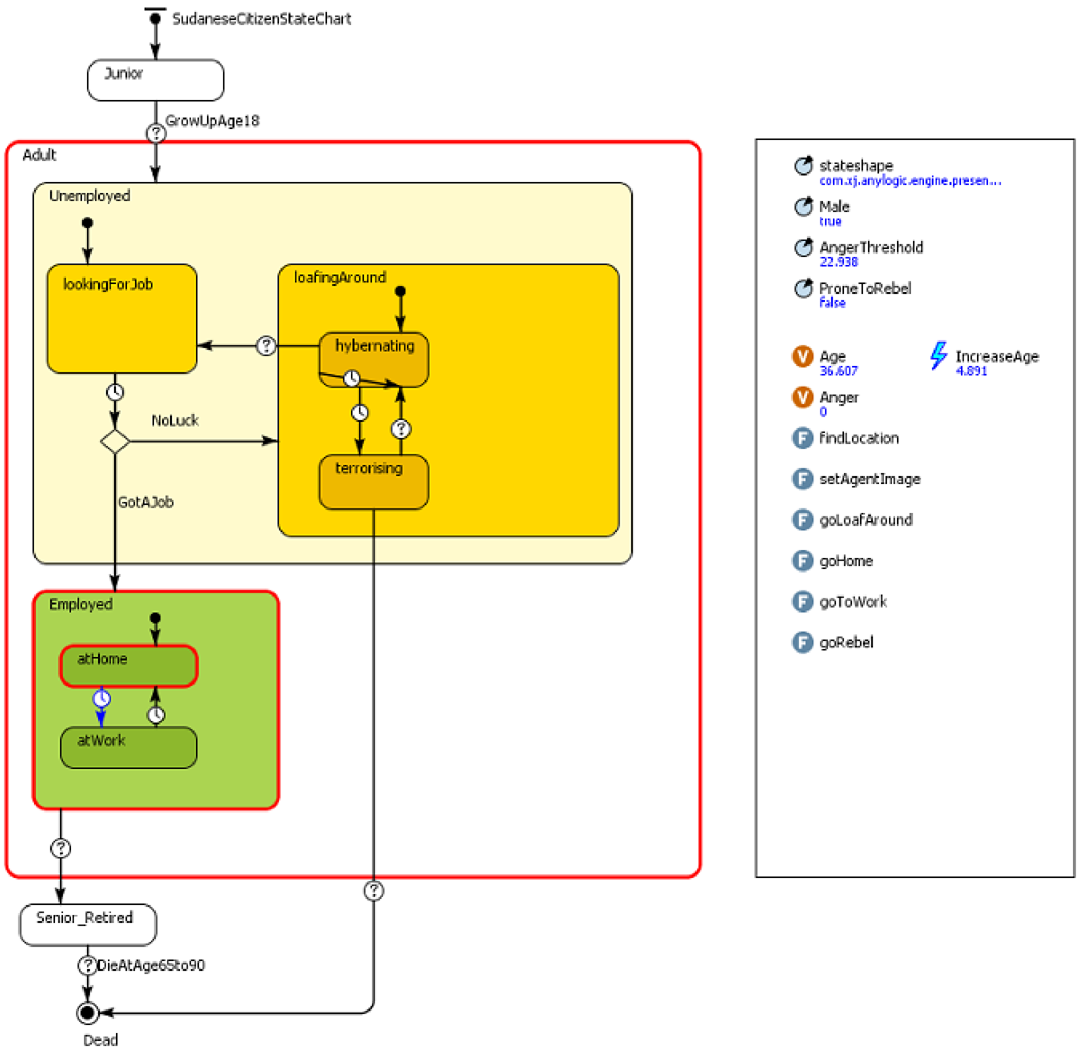


SimPB: Simulating Peace Building



www.techchange.org

SimPB: Simulating Peace Building



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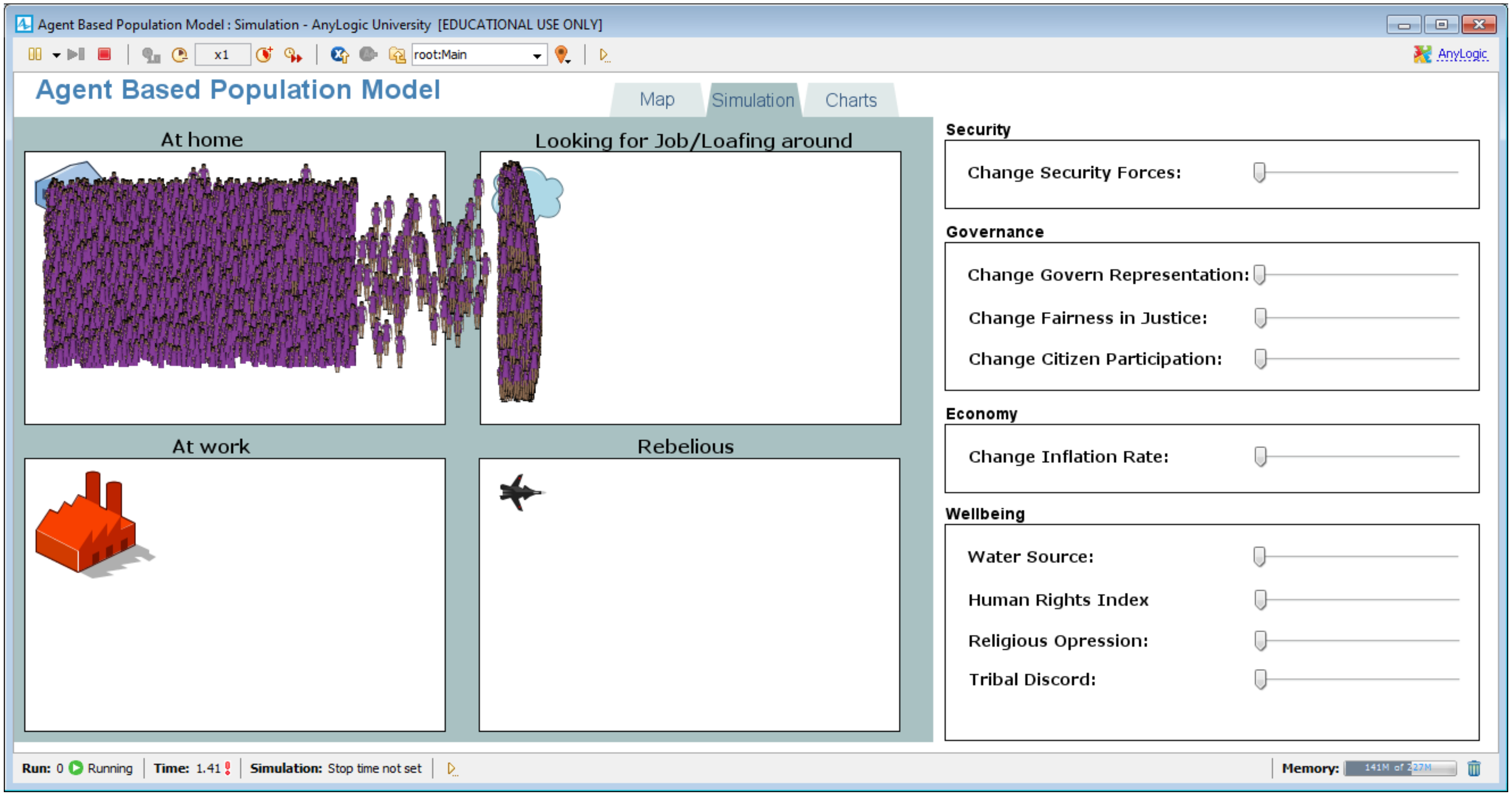
SimPB: Simulating Peace Building



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The End