Pedestrian Dynamics: Models of Pedestrian Behaviour

John Ward
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- Macro-scale sketch plan model
- Micro-scale agent based model for pedestrian movement
- Development of JPed
- Results
- Extensions

Macro-scale sketch plan model

- used to estimate existing and future pedestrian volumes

- multiple regression analysis of independent variables representing pedestrian attractors such as adjacent land use, or quantifying characteristics of the environment and indicators of transport trip generators, such as directly observed pedestrian data.

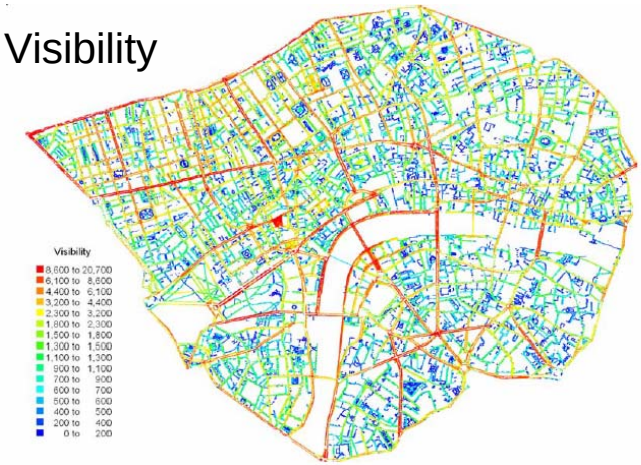
- 4 models made
  - 2 MRA individual pavement models
  - 1 MRA street segment model
  - 1 Panel model incorporating 10 years of pedestrian data

Macro-scale sketch plan model : dependent variables

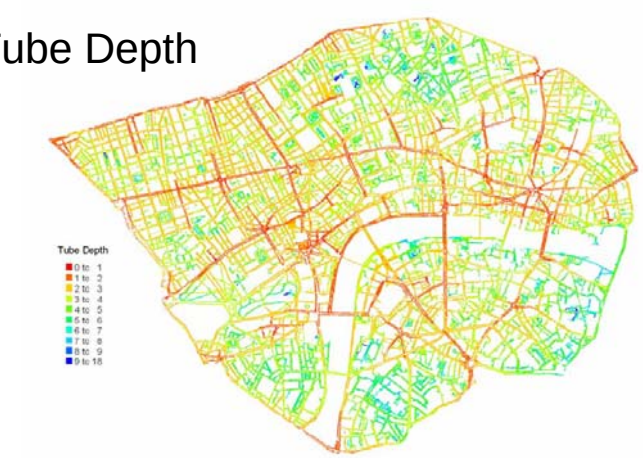
5 – 6 minute pedestrian observations

Macro-scale sketch plan model : independent variables

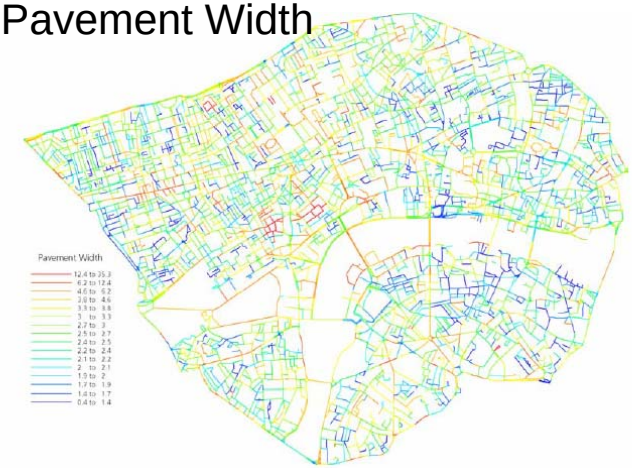
Visibility



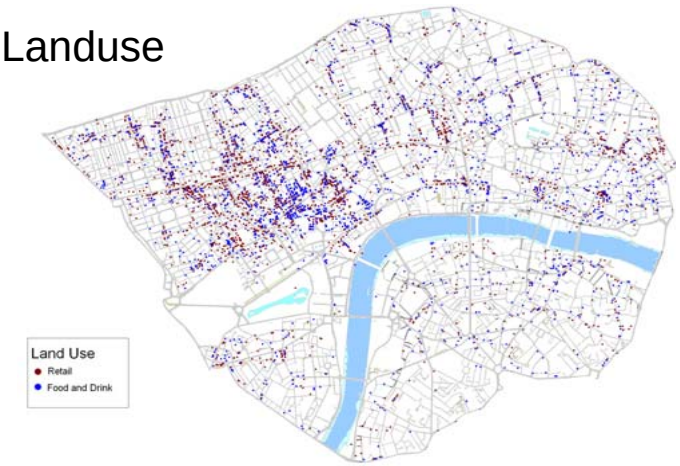
Tube Depth



Pavement Width



Landuse



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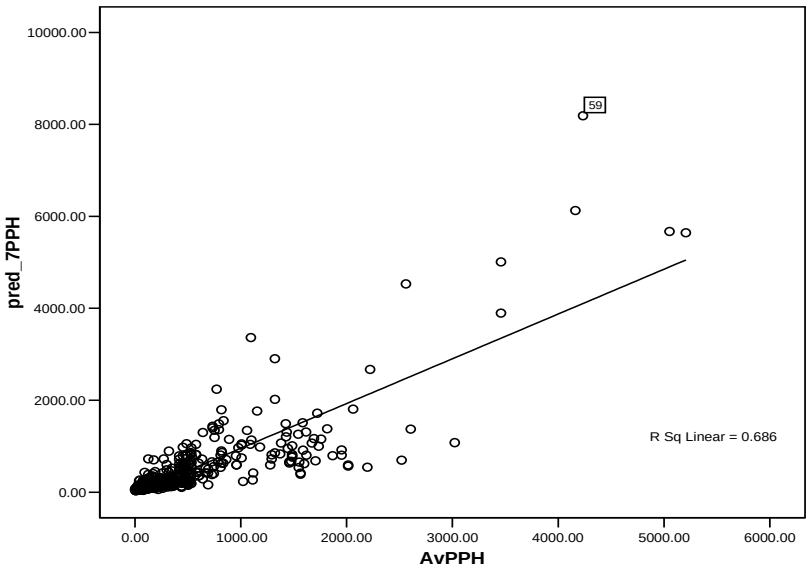
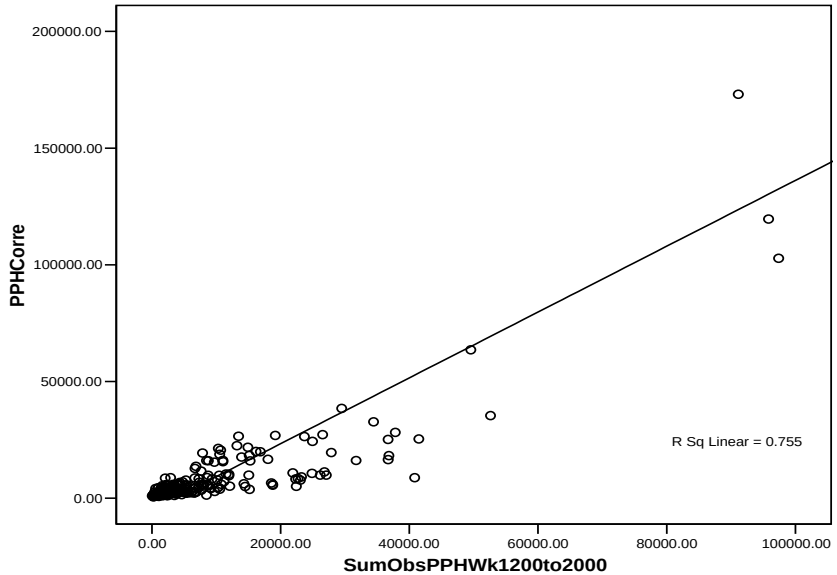
Results



Individual Pavement Volume



Street Segment Volume

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Micro scale agent based models- why use them?

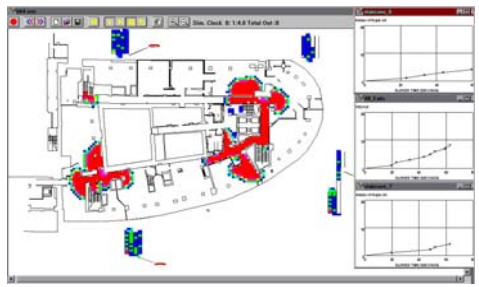
- Simulation of pedestrian movement for low and high density Scenarios.

Traditional models (regression, logit, 4 stage transport...)

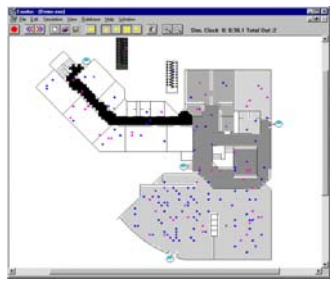
not well suited for:

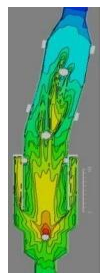
- Buildings or spaces with exceptional architecture
- Microscale dynamic effects such as crowding and subsequent re-routing
- Effects of changes in environment
  - Pedestrian zones (creation of pedestrians)
- Extreme conditions such as escape

Vissim



Exodus





Myriad

Development of Microscale simulation model

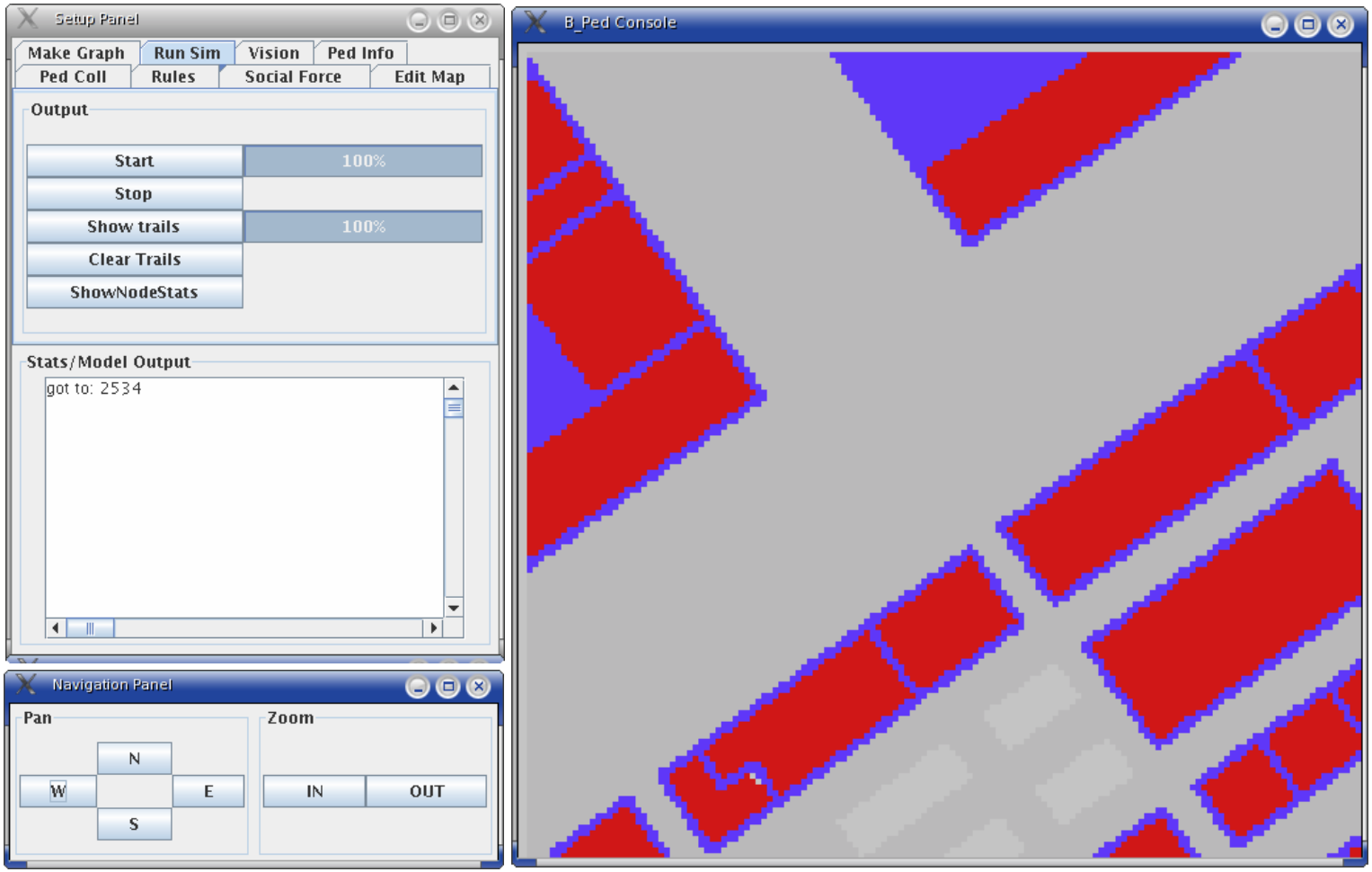
- Use both as a research and potential design tool.
  - urban planners/event managers to test the effects of any design changes on pedestrian behavior before their implementation.
- Flexible
  - Previous micro scale pedestrian models fit for purpose but have narrow range of applications.
  - Include both Low/high density situations.
  - Normal Shopping Behaviour/Emergency Egress
- Expandable design
  - inclusion of additional aspects which affect the routes pedestrians take until a sufficiently close approximation of the corresponding situation in the real world is achieved.

There is very little standard software out there that someone who hasn't designed the model and written the software could easily use – that is the state of the art in these kinds of models and may well remain like this [M. Batty]

Choice of language

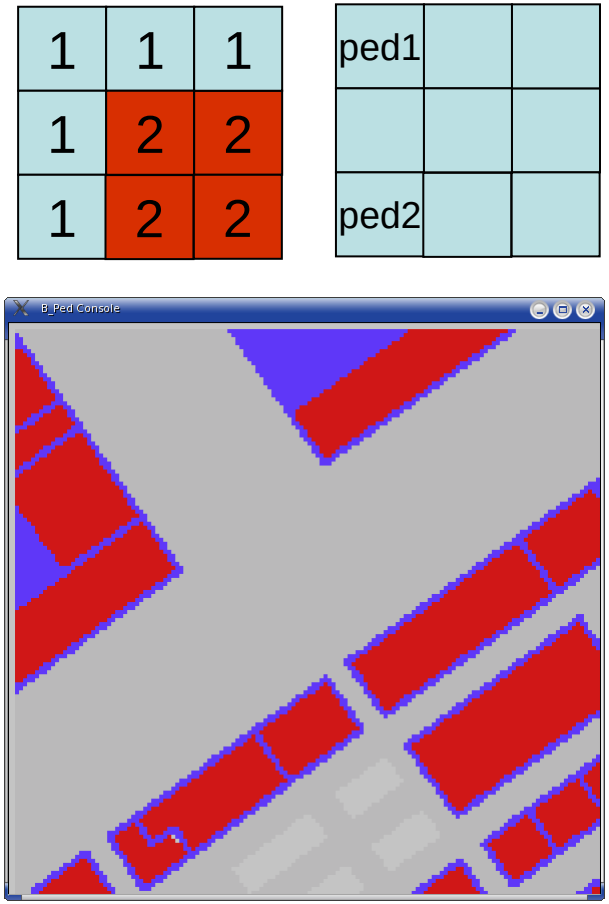
- Large scale agent based sims are processor and RAM intensive
- Java
  - portable
  - automatic garbage collection
  - strict type checking
  - Object Orientated Language – abstraction
  - Becoming language of choice for mainstream and commercial applications (more money on development)
  - 0 to 15% less performance than c++ (Esp small gap using Linux + IBM Java)
- Mapinfo GIS system with MapBasic scripts
  - Too much time required to implement GIS functionality within program

GUI – Graphical User Interface



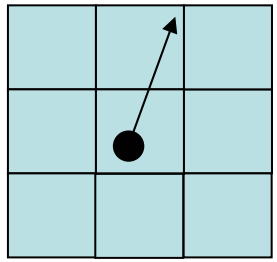
Representation of Pedestrian Environment

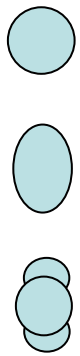
- Raster Map (fast)
- 40cm square mesh
- Multiple Layers
- Geometry
  - Pavement
  - Road space
  - Shop
  - Restaurant/Bar
  - Pedestrian Crossing
  - Doorway/Gate
- Networks
  - Waypoints
- Pedestrian Objects
- Vehicle Objects
- Floor fields



Representation of pedestrian

- Speed
- X coordinate
- Y coordinate
- Type (tourist, local…)
- Goals (shops, restaurants, office..)
- Knowledge of environment
- Perception
- Assets (time, money, energy..)
- Internal states (low on time or money…)
- Size – Currently circular

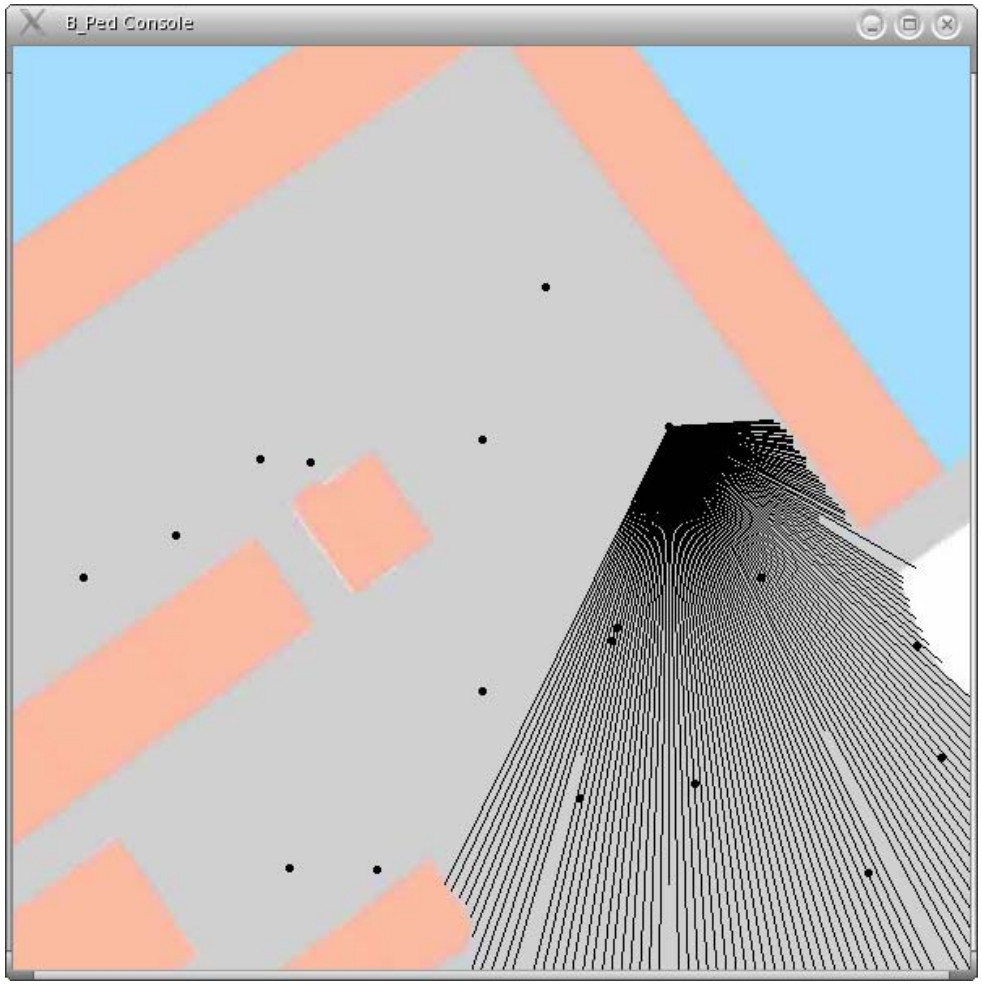




Pedestrian Sensing Environment

- Pedestrian uses ray tracing type technique to take a snapshot of the visual environment for processing
  - Way points, doorways,
  - Other pedestrians
  - Possible targets

- Important nodes can be stored in memory
- Reinforced learning?



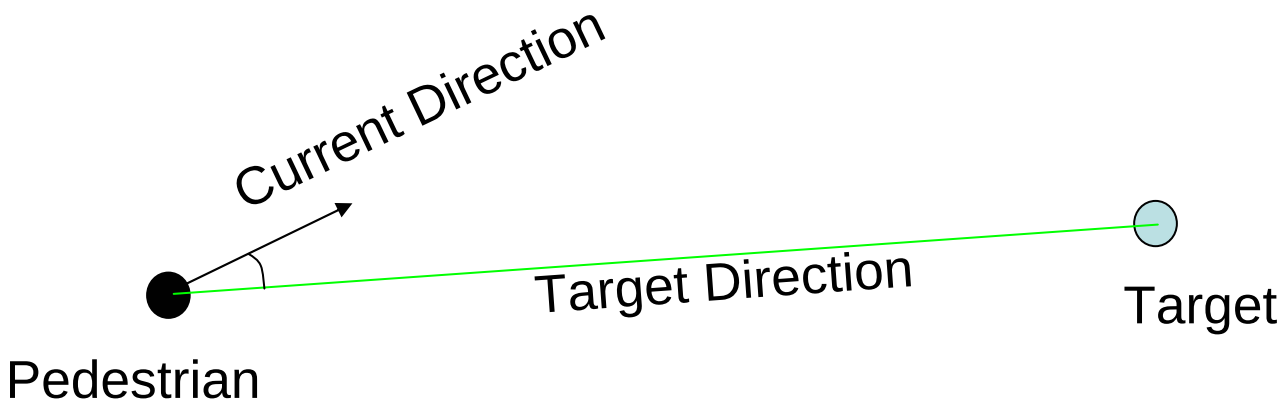
Pedestrian Behaviour

Multi Level Behaviour

1. Reflex
2. Reactive
3. Motivated
4. Reasoned behaviors
5. Social behaviour

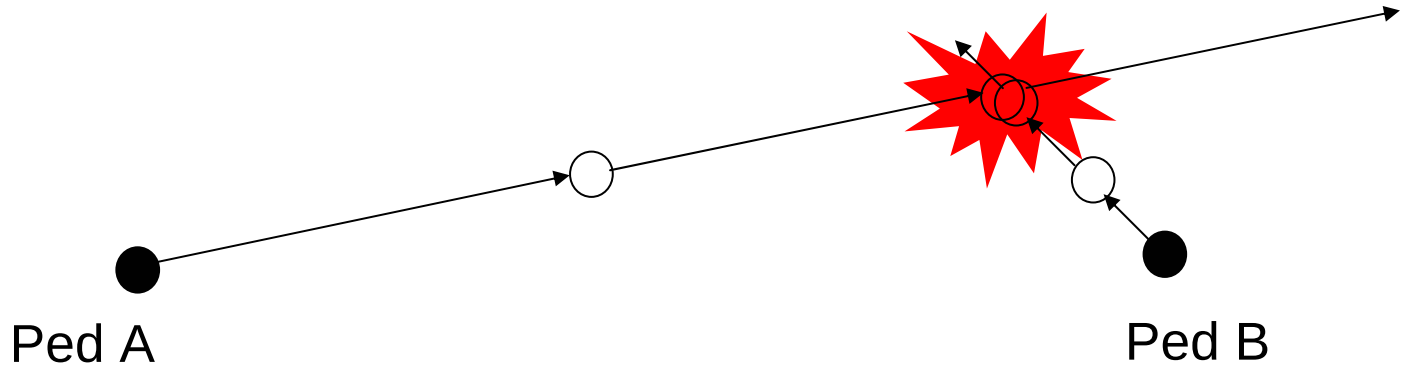
1. Reflex Behaviour

- Reflex
  - Locamotive, motion behaviour
  - The action at this level does not require any input – external perception and internal state of motivation.
  - Walk forward at a given speed
  - Pedestrians calculate the trajectory of there current target and turn to face the direction of the target (limited turning per time step), hence tending towards the shortest path from local origin to destination.



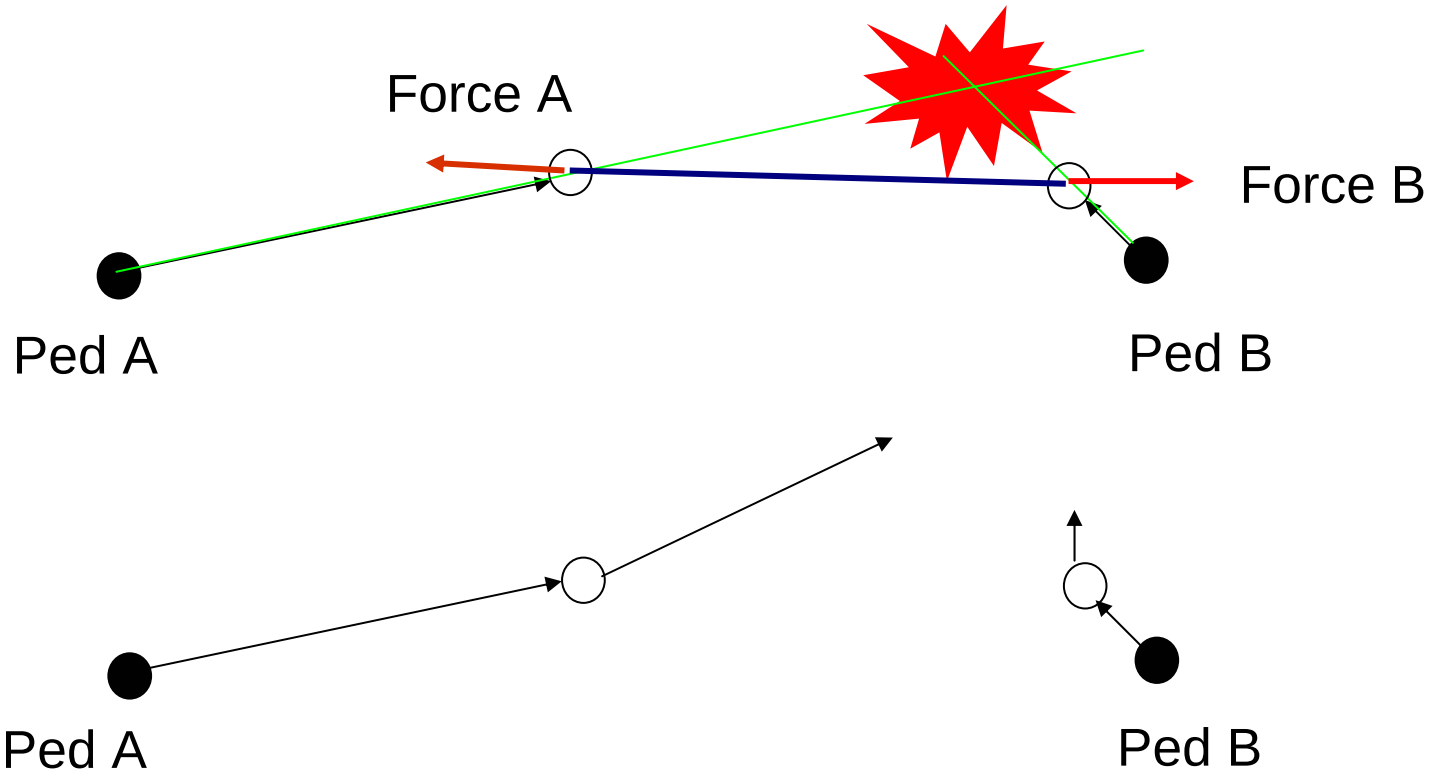
2. Reactive Behaviour

- This level of behaviour shows complete dependence of "external perception"
- Reactive behaviour from external signals – steering behaviour
- When obstacles get in our way (pedestrian, vehicle, wall)



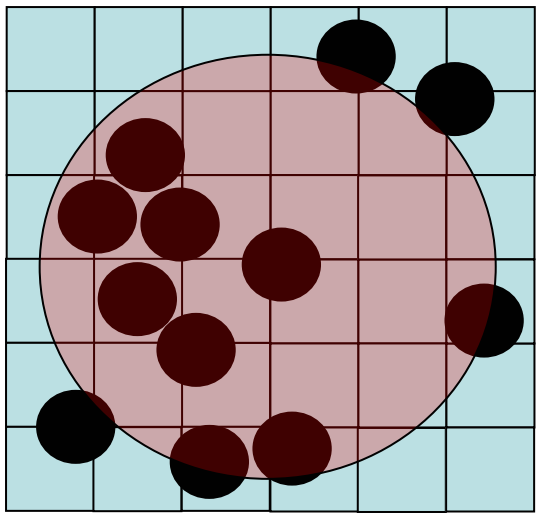
2. Reactive behaviour- Pedestrian Collision

Sense Neighbours –Test for future intersections-Closest Threat-Location of collision



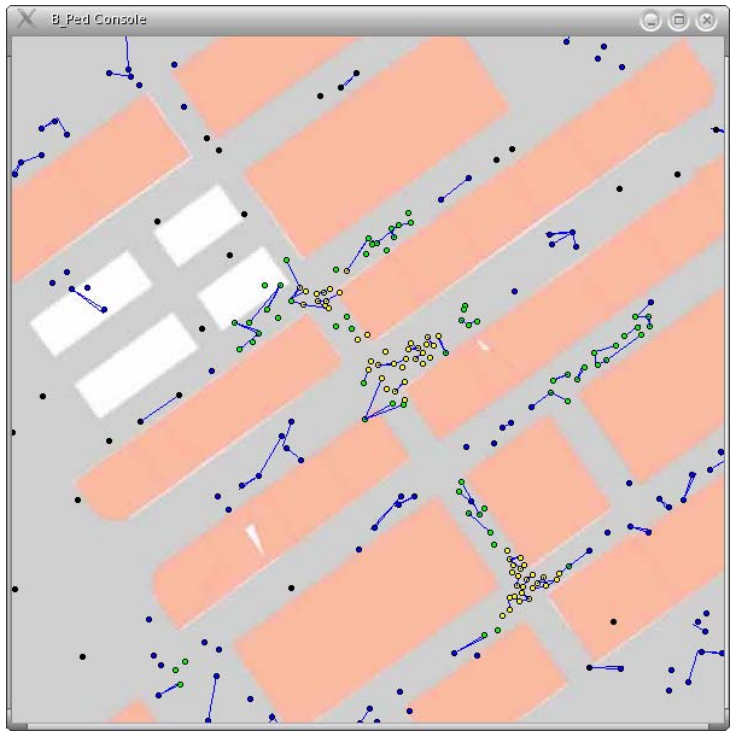
2. Reactive Behaviour – Density Speed Relations

- Each pedestrian senses the number of neighbouring pedestrians in the area and adjusts there velocity according to the local pedestrian density.



Density Increase = V decrease

Fruin



3. Motivated Behaviour

- This behavior depends on internal state of motivation and the external stimuli that correspond to the internal needs

  - Set target for shop
  - Run out of money
  - Need a cash machine- set target to cash machine
  - Get cash via shortest route
  - Return to shop

4. Reasoned Behaviours

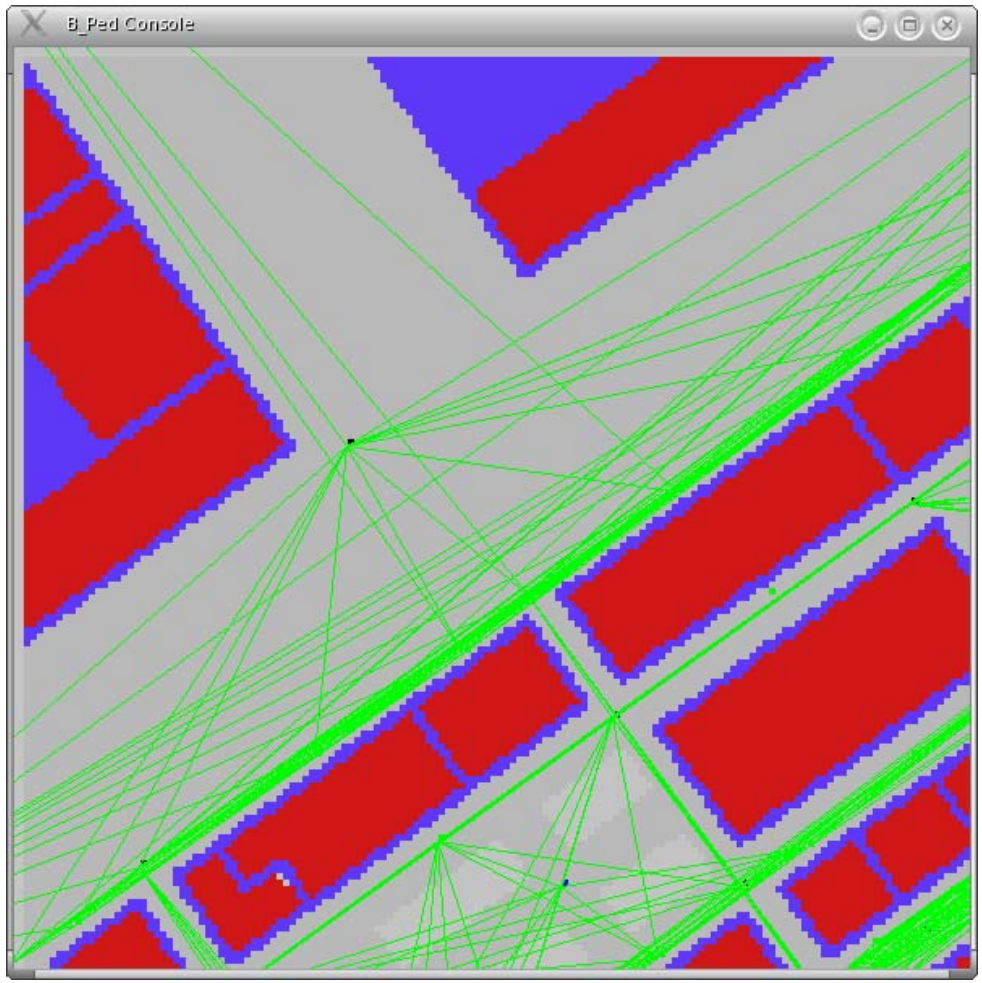
- Reasoned behaviors involve more intelligent behaviors.
  - Does the pedestrian know where to find a cash machine?
  - Can the pedestrian explore to find a cash machine?
  - Can a pedestrian ask directions/obtain information to find a cash machine?

- They require concepts and logic in selecting action.
- The conscious level represents more complex thinking process such as the recognition of layout of spaces, before sending signals down to the less complex levels to execute actions.

4. Reasoned Behaviours - Way finding

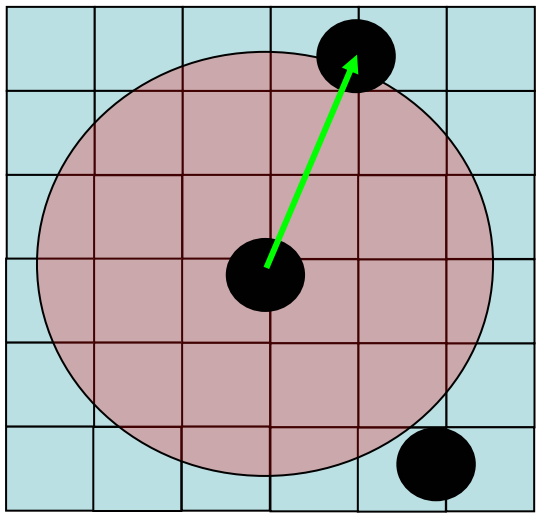
- Visibility Type Graph
- If the pedestrian knows the environment enough to find target
  - Calculate shortest distance to target
  - Walk in general direction of target

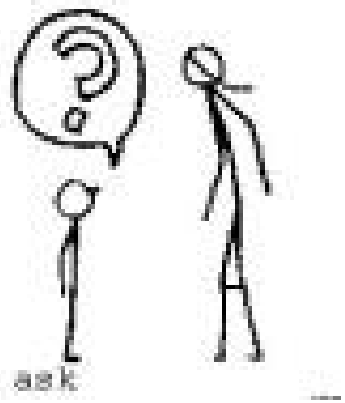
  Else
  - Randomly search for target
  - Walk in a popular direction
  - Ask for info from another pedestrian



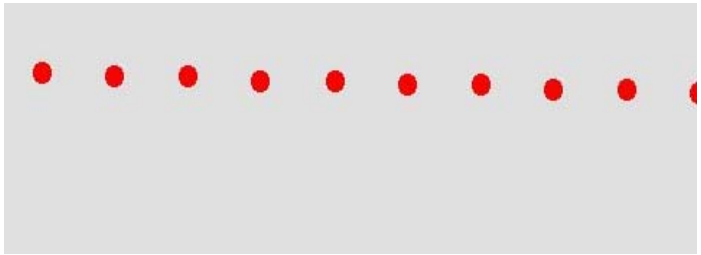
5. Social Behaviour

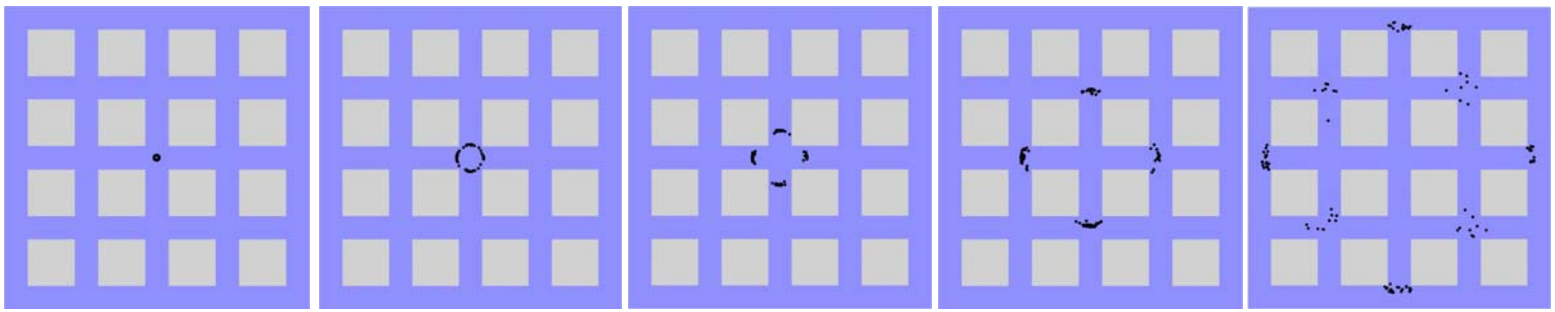
- The interaction of individuals sharing a moment in a same space.
- Pedestrians are members in societies because they interact not only with elements in space but also with other people, whether they intend to or not.
- Pedestrian social behaviors can range from perceiving or being aware of each other to having a conversation or any form of communication.

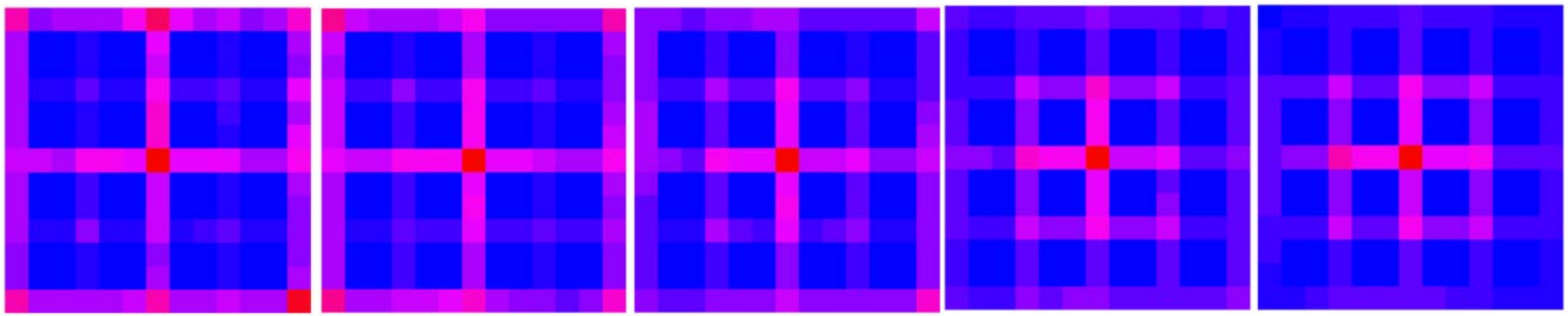




Evaluation Process







Model Application to Covent Garden Market

- Investigate pedestrian movement within Covent Garden Market

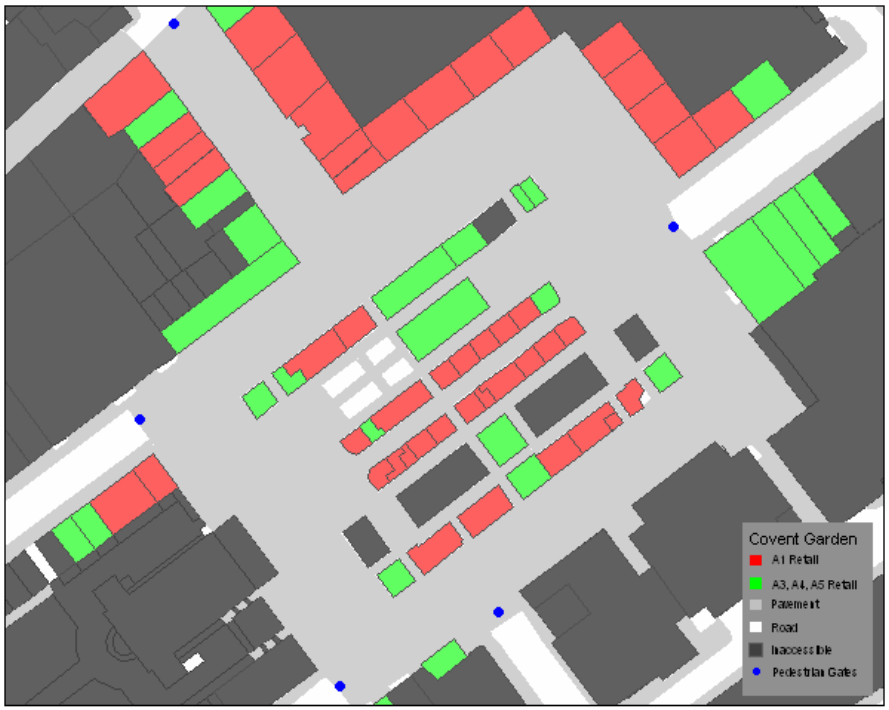
- Try to find approximation with real flows
- different navigation techniques
- Interaction
- Change retail layout

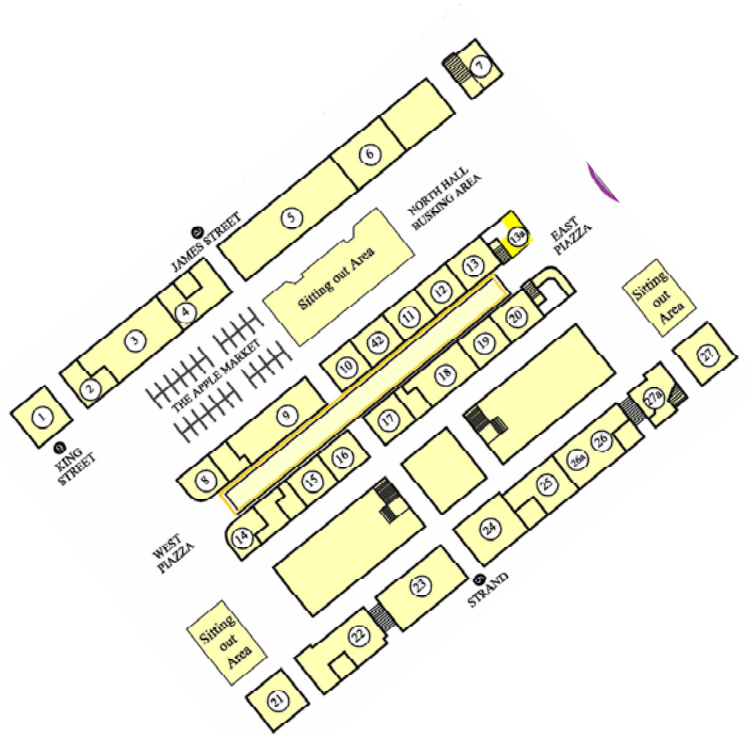
Model Set Up

- The model aims to simulate pedestrians at both low to medium densities.
- Assume pedestrian flow is made of locals and tourists

- Tourist pedestrians
  - initially assumed to know nothing about the geographical layout of the environment.
  - hence navigate by sight. (no pocket maps, signposts e.t.c)
- Local Pedestrian
  - have good knowledge of the environment
  - use 'memory map' type graphs for navigation.
  - require waypoints to be set by the user.
  - waypoints combined with targets are used to create a network

Covent Garden Market





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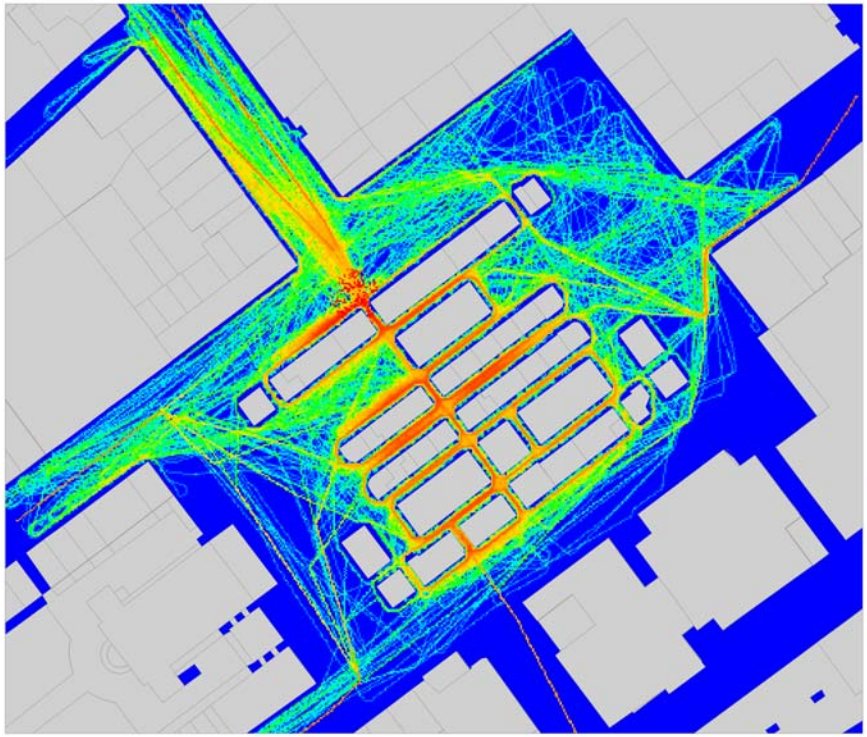
Initial Tests

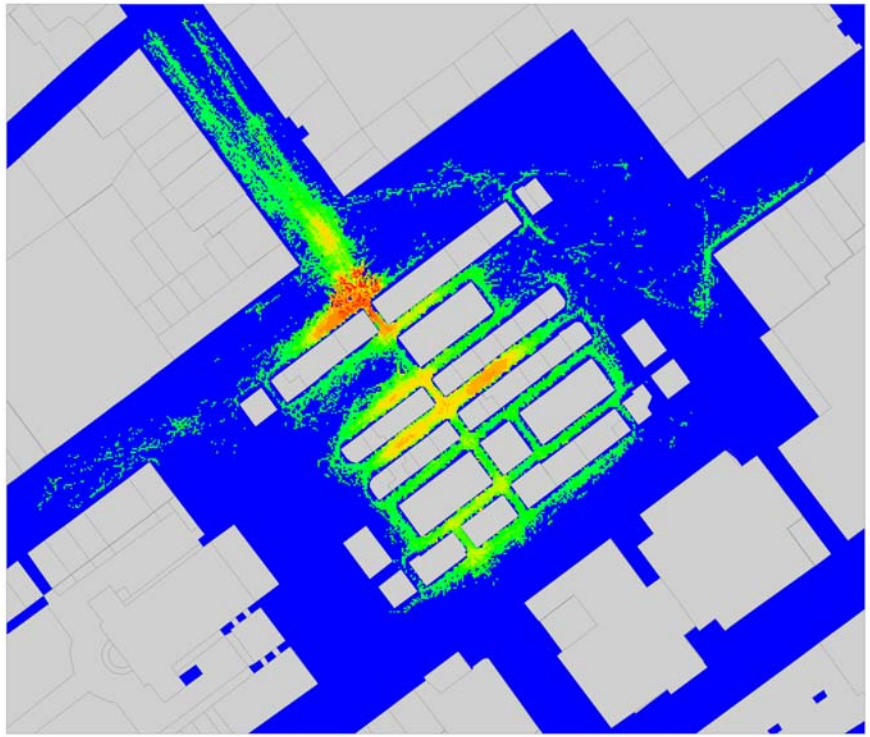
- Model run for three test cases :
  1. All pedestrians are assumed to be local,
  2. All pedestrians are assumed to be tourists randomly searching the environment with no specific goals.
  3. 50% of pedestrians are local, 50% are tourist. The tourist pedestrians are randomly searching the environment with no specific goals.

- 600 Pedestrians are used in each case (max 15,000)
- Field of vision 120 degrees
- 2500 iterations

Results :Test 1 (100% local)

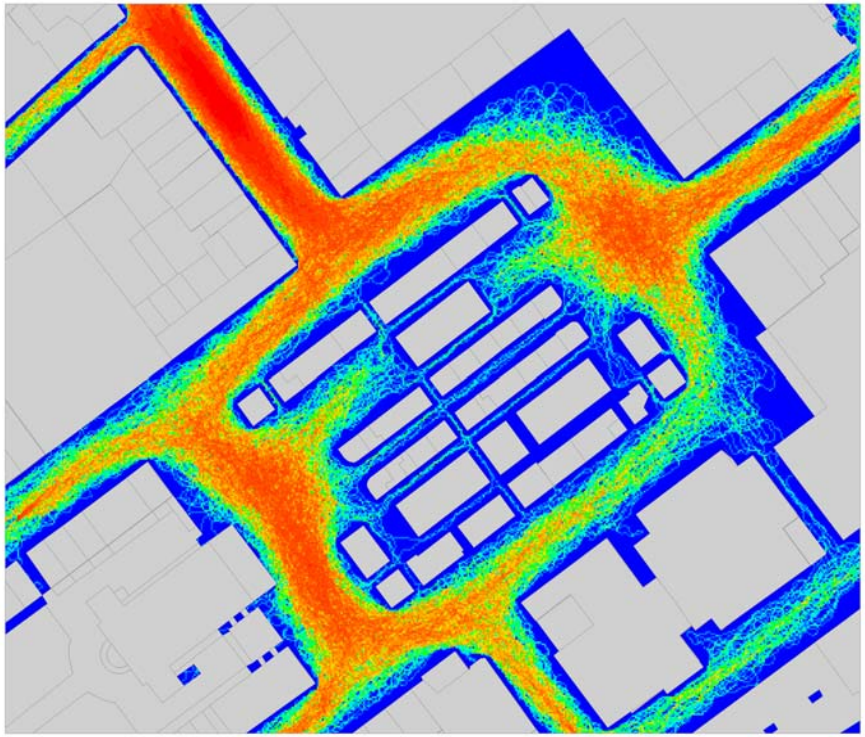


Density

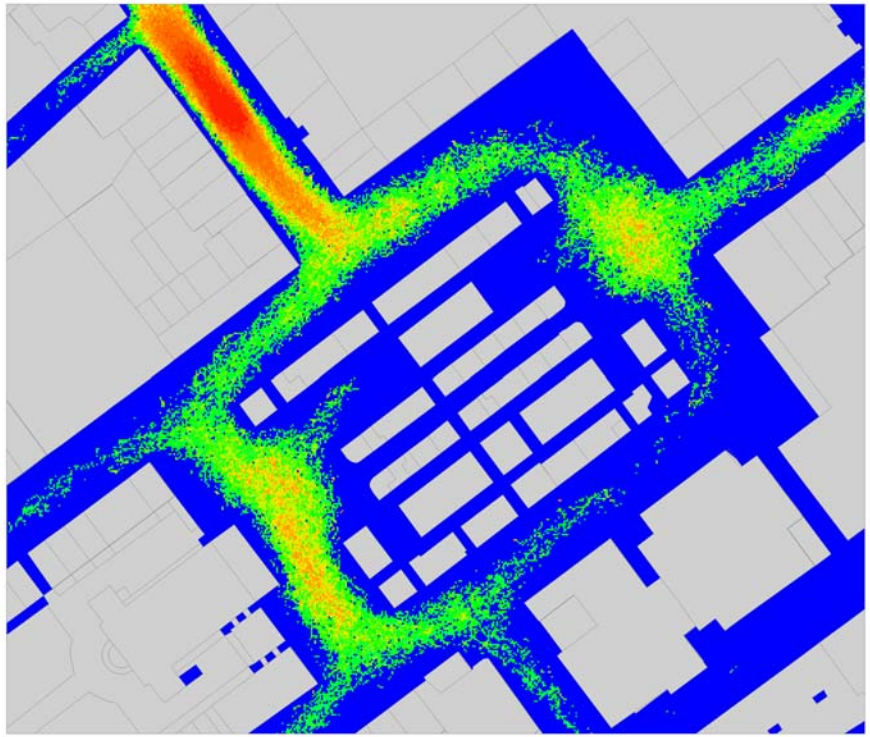


Speed

Results :Test 2 (100% Tourist)

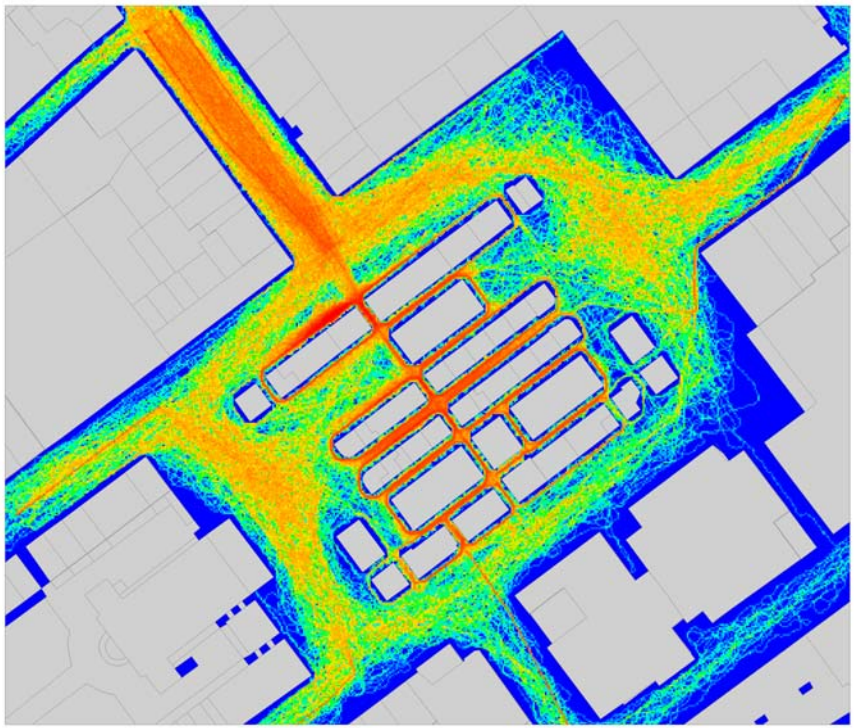


Density

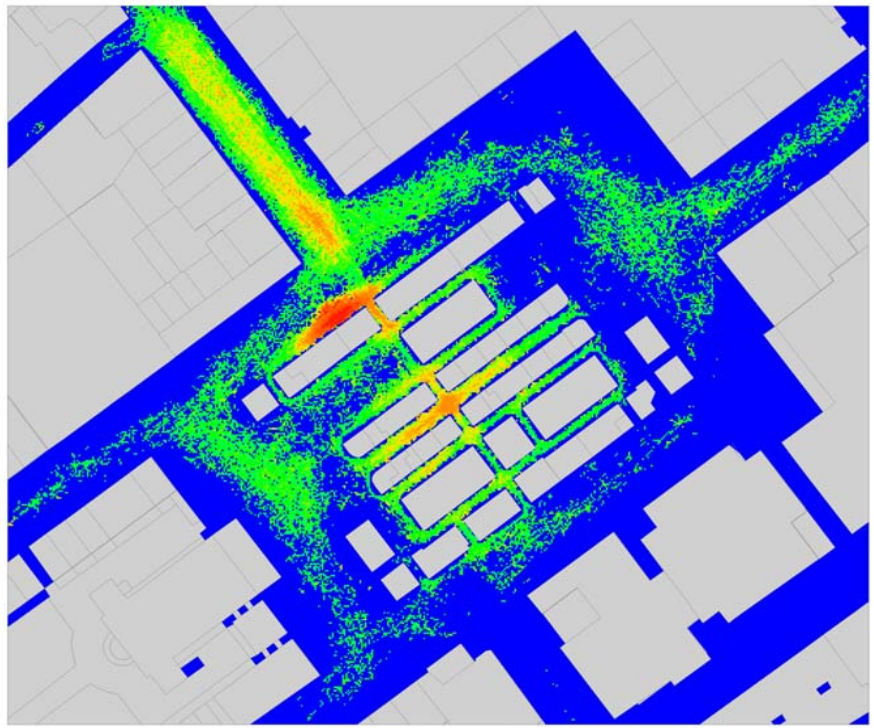


Speed

Results :Test 3 (50% local, 50% Tourist)

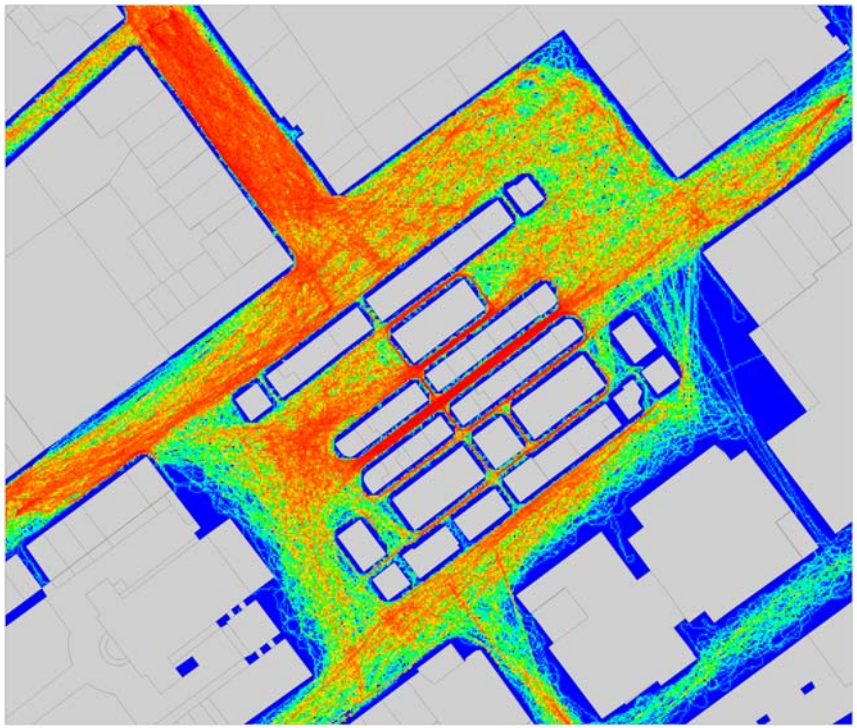


Density

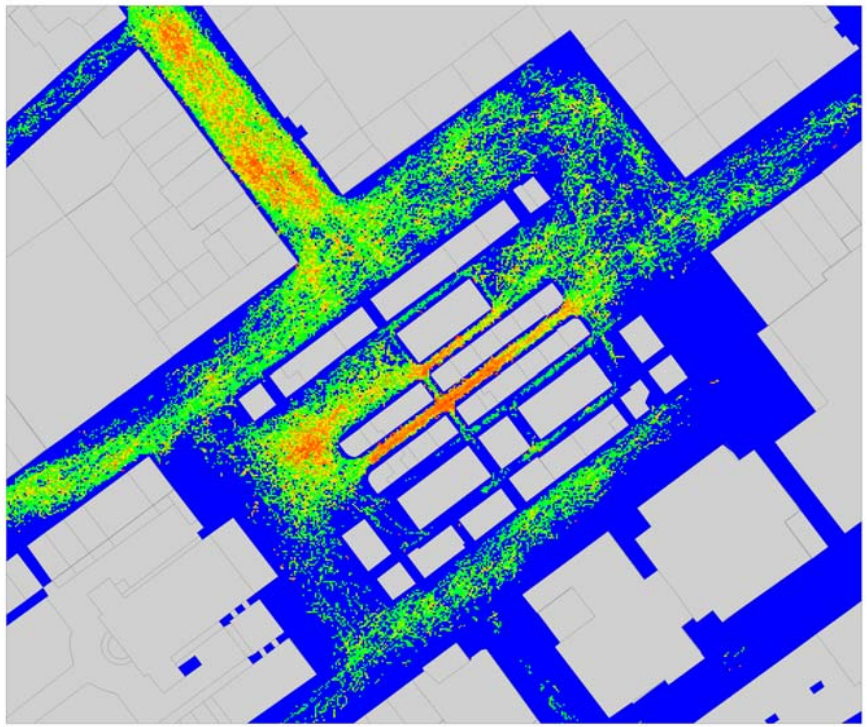


Speed

Results :Test 4 (100% Tourist, directed vision)



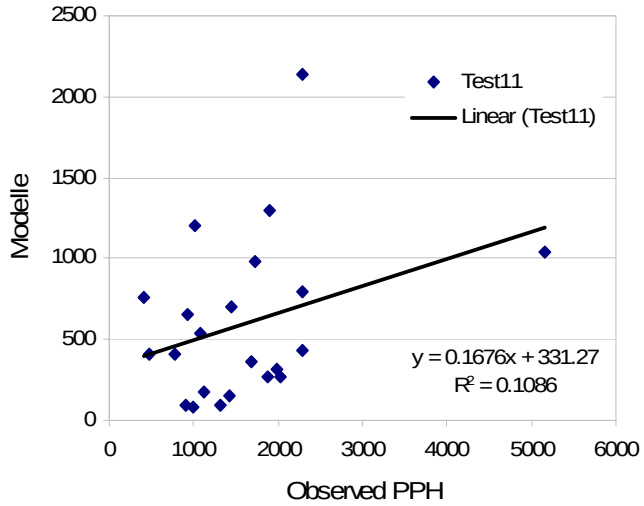
Density



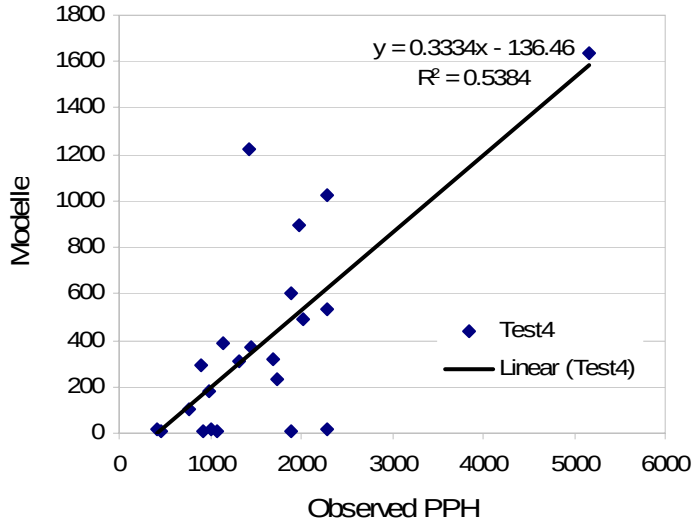
Speed

Results

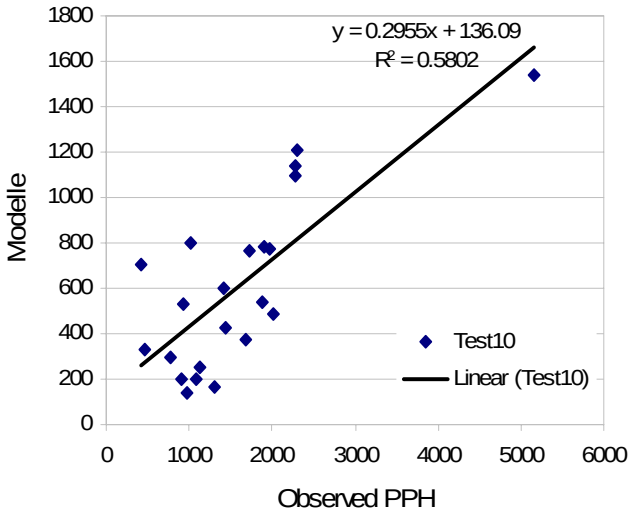
M1



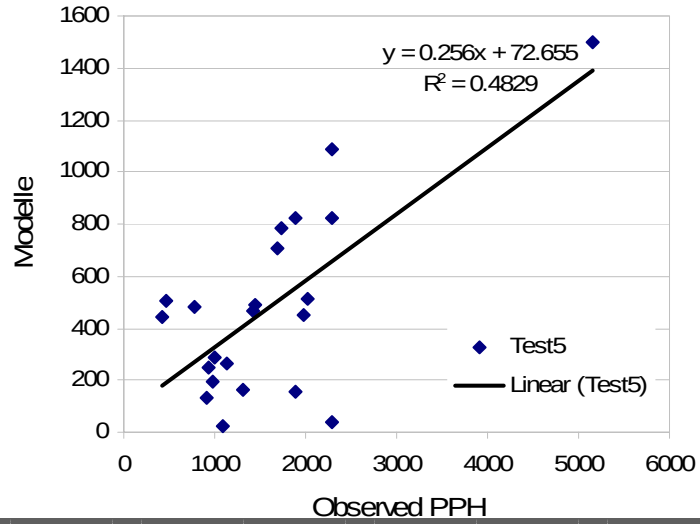
M2



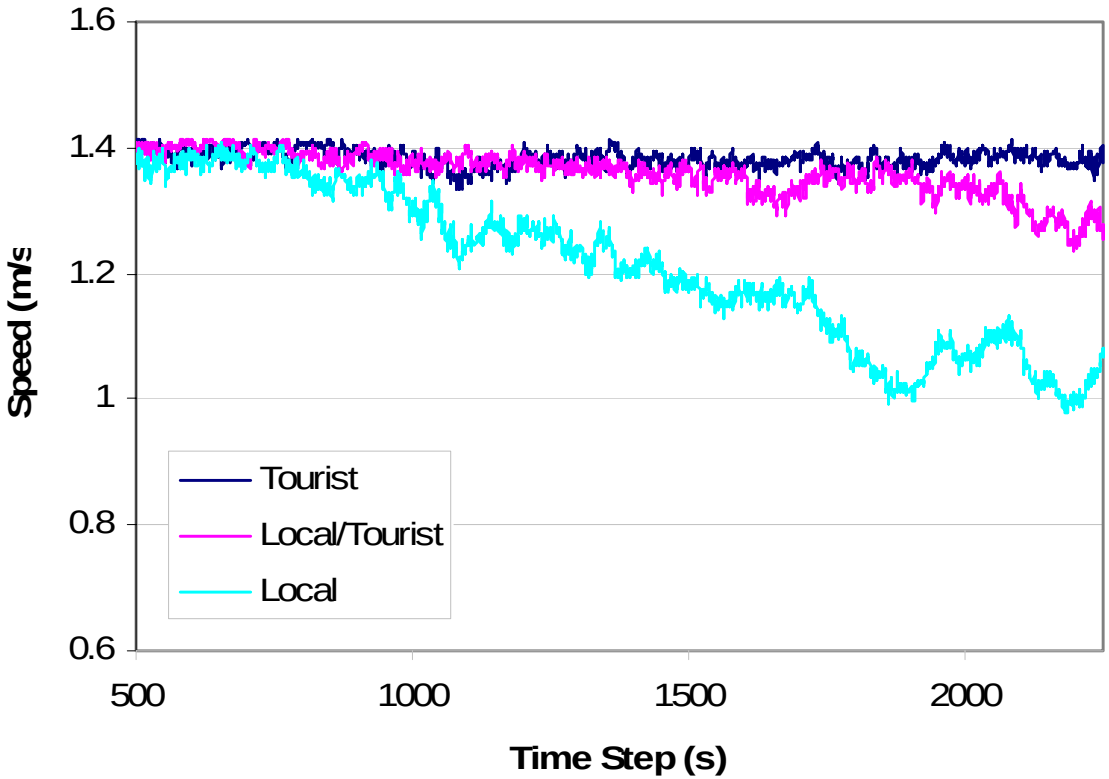
M3



M4

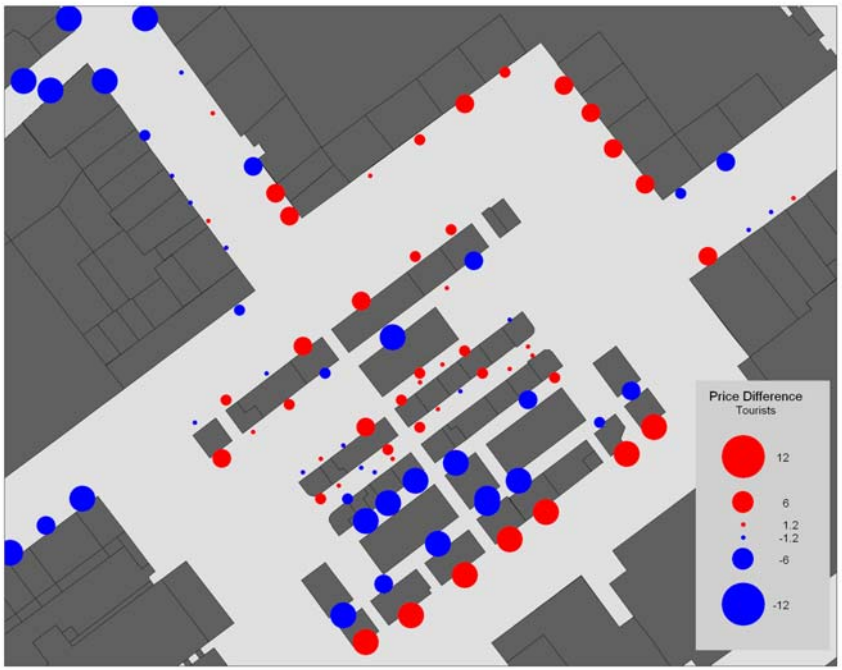


Results : Average Speed Comparison

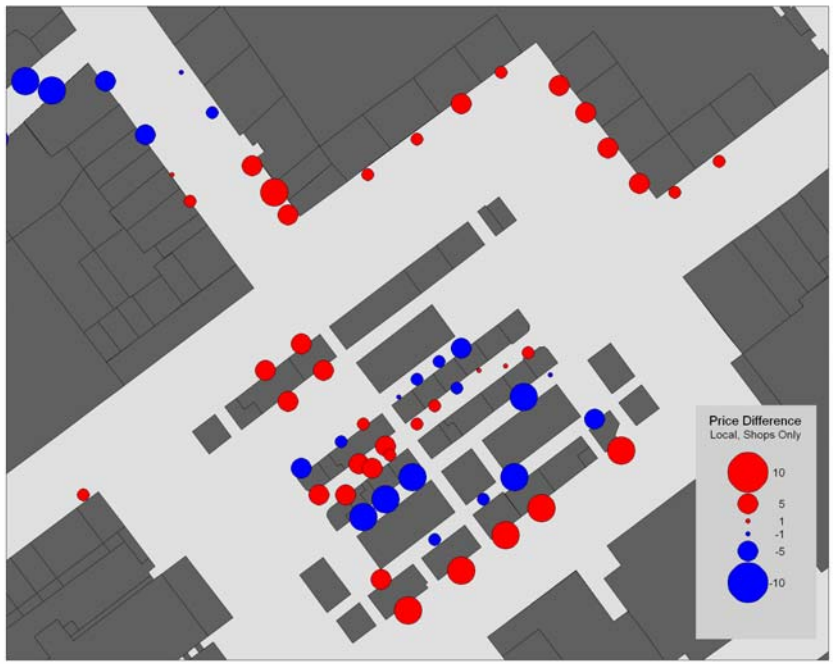


Spatial Micro Economics

- Shopkeepers with uniform expectation
- Tourist shoppers with 25% probability of choosing shop sighted
- Prices updated every 300t
- No feedback.. will be included



Shops + Retaurants



Retaurants

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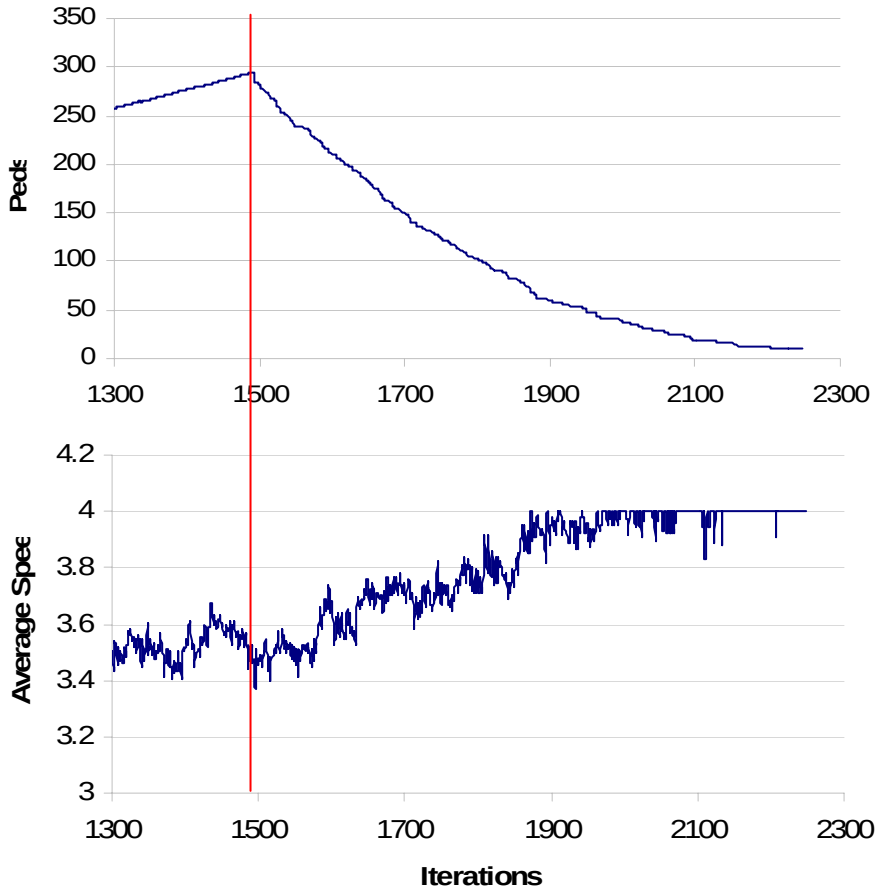
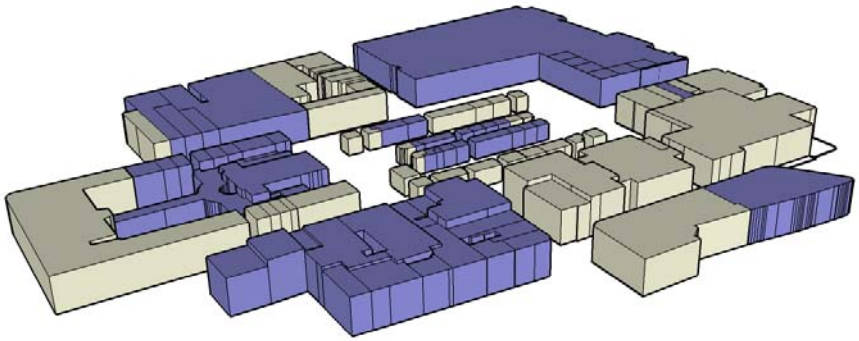
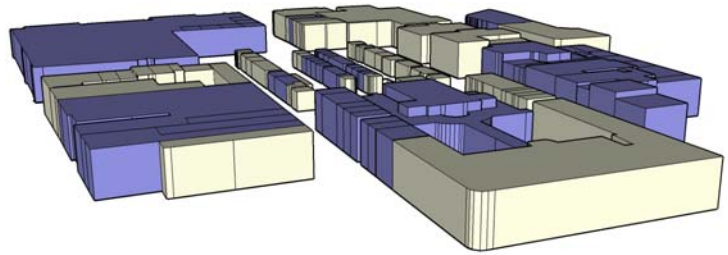
Emergency Egress

- Return to origin
- Straight line wayfinding (Golledge 1992)
- Nearest exit?
- Shortest path?
- Building evacuation?

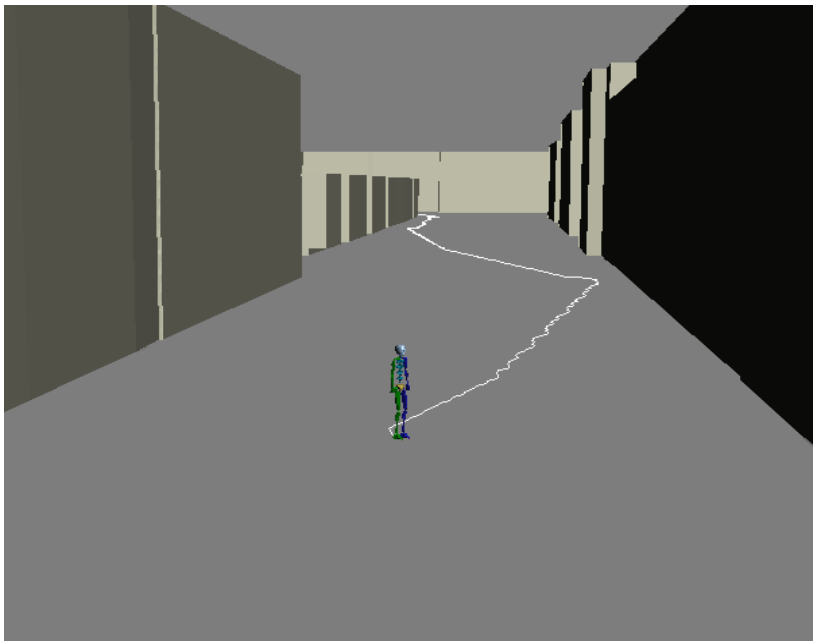


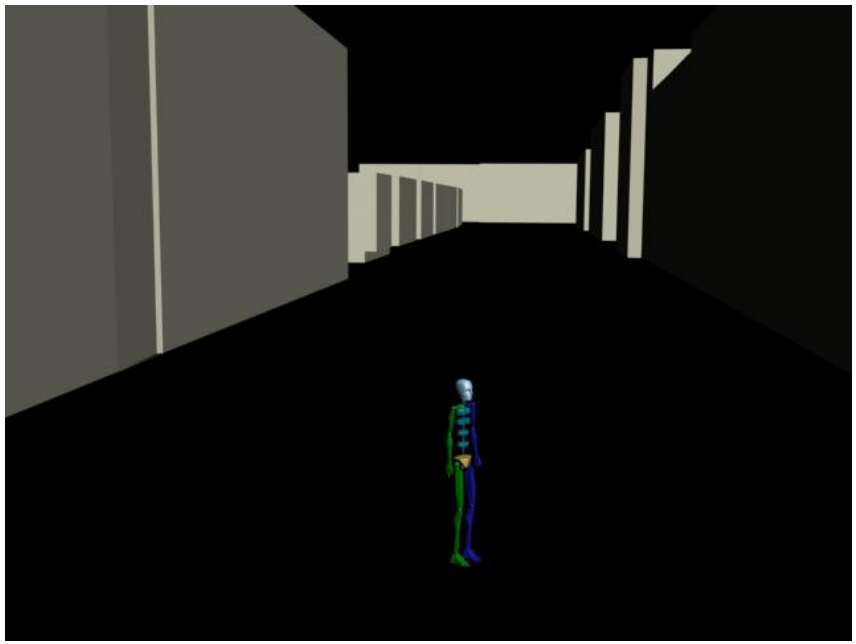
3D - Visualisation





3D - Animation





Conclusions

- Macro sketch plan and Micro agent based pedestrian models provide useful techniques for predicting pedestrian volume and movement.
- Few agent based micro-scale models are appropriate for low to medium density conditions - Rule sets derived for high density situations, not so useful for low density conditions.
- Micro-scale models can suffer from scale gaps, and rules need to be devised to allow transition between scales
- Construction of normal density agent based models uses subjective behaviour which is difficult to calibrate and validate.
- Scalability of agent based micro models using direct vision a issue.

Further work

- Pedestrians behaviour governed by internal states in the form of energy and money.
- Attractiveness of economic unit varies with success
- Vary parcels sold in each economic unit.
- Vary shop/shopkeeper behaviour.

- More complex interaction of wayfinding and memory maps and resulting influence on navigation

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