Pedestrian Behaviour Modelling & Simulation

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Outline

- Basic concepts
- Pedestrian modelling
- Pedestrian simulation
- Pedestrian behaviour
- Agent-based Modelling and Simulation
- Test, validation and calibration of pedestrian models
- Development of a simulation project

Pedestrian Simulation

There are three main reasons for developing computer simulation for pedestrian behaviours:

first to test scientific theories and hypotheses;

second, to test design strategies;

third, to create phenomena about which to theorize

(Pan, Han, Dauber, & Law, 2007).

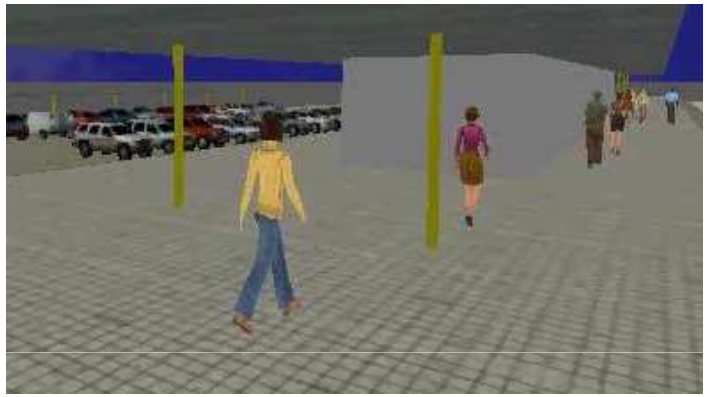
Pedestrian Simulation

Applications and scope

- Traffic: vehicles vs. pedestrians
- Urban Planning: indoor vs outdoor
- Games / Movies: Artificial Societies
- Emergency / Safety / Security

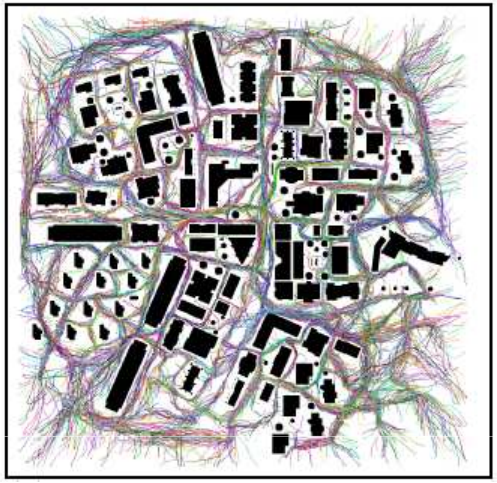
Basic Concepts: Vehicles vs. Pedestrians

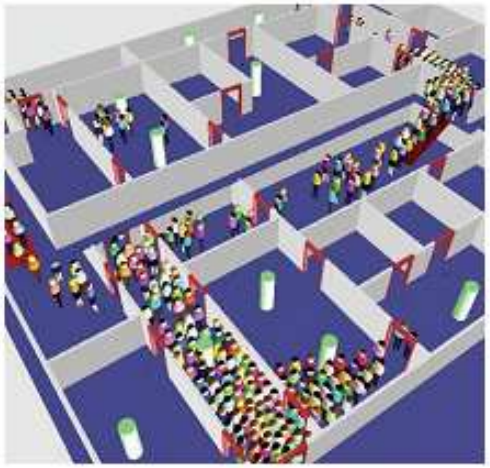
SimWalk, 2011



Yeh, Curtis, Patil et al., 2008

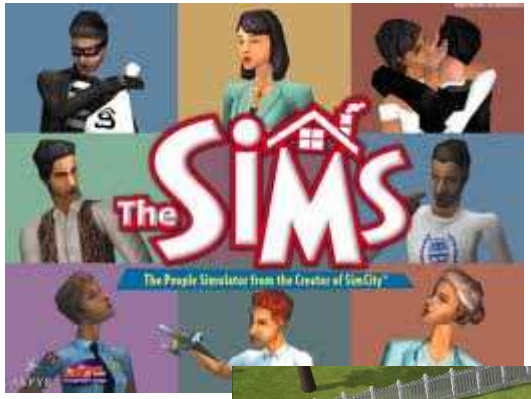
Basic Concepts: Urban Planning





Basic Concepts: Artificial Societies

Second Life, The Sims



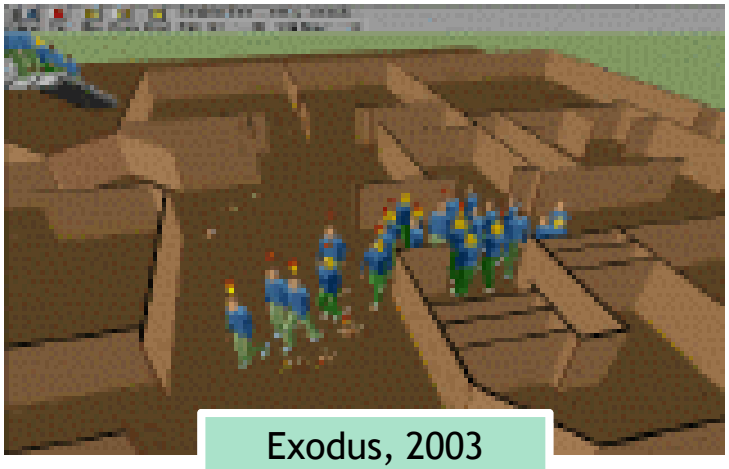
Basic Concepts: crowd safety/security

Models of anti-social behaviour (crowds, safety/security)

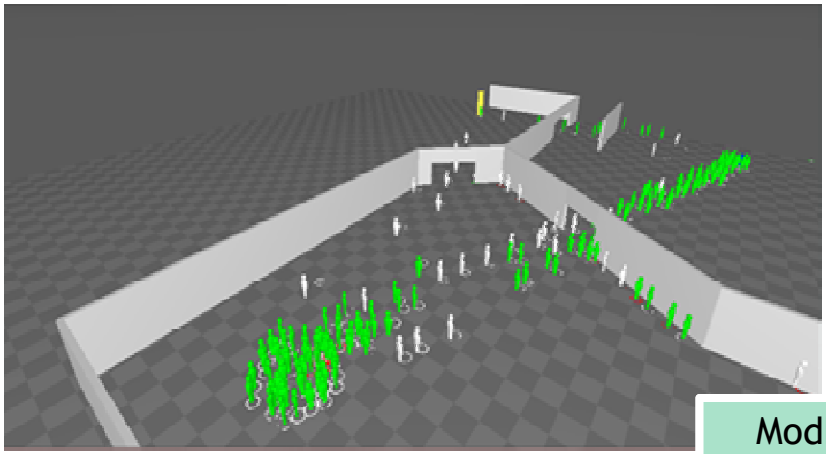
Yeh, Curtis, Patil et al., 2008

Basic Concepts: Buildings evacuation

Yeh, Curtis, Patil et al., 2008



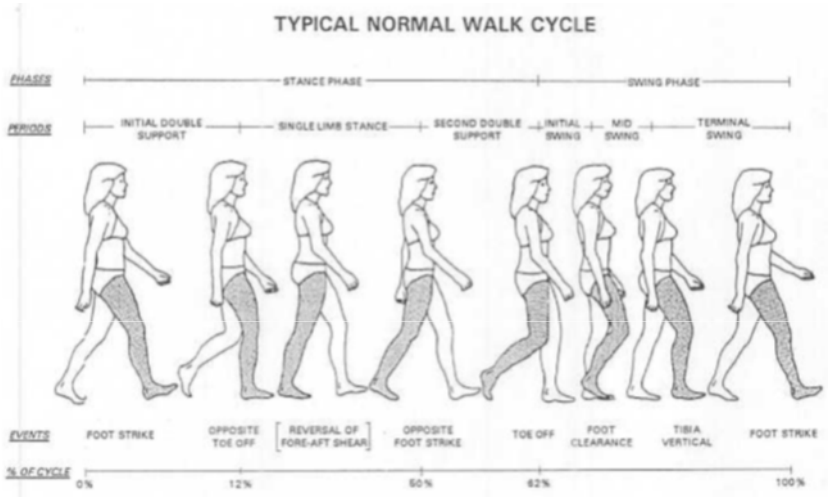
Exodus, 2003

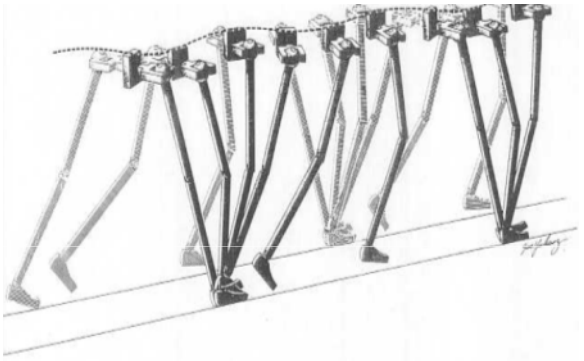


ModP - Aguiar, 2010

Basic Concepts: Mathematic and kinematic models

Walking movement: Walk or Gait Cycle

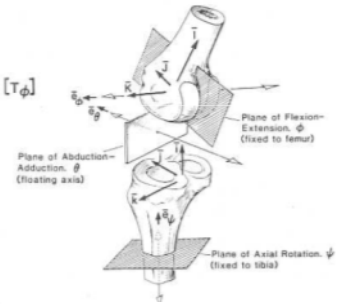


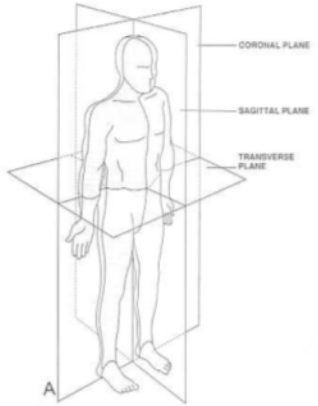


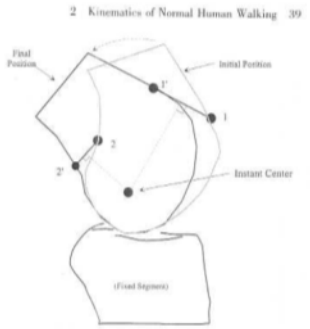
$$\bar{r}_1 = [T]\,\bar{\rho} + \bar{r}_0$$

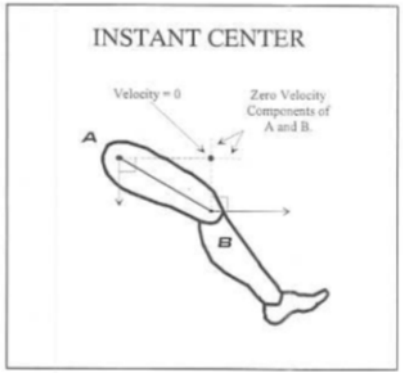
where

$$[T] = [T_\psi]\,[T_\theta]\,[T_\phi]$$





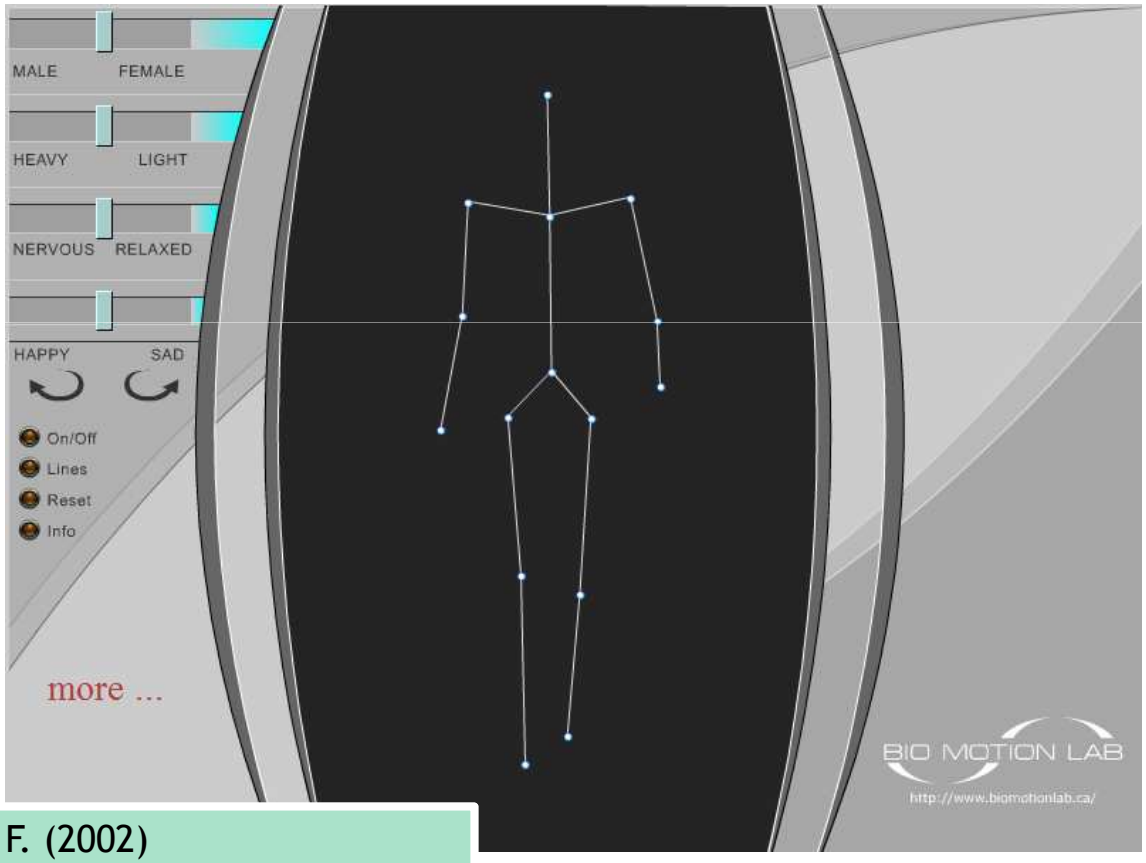




Sutherland, Kaufman, & Moitoza, 1994

Basic Concepts: human movement

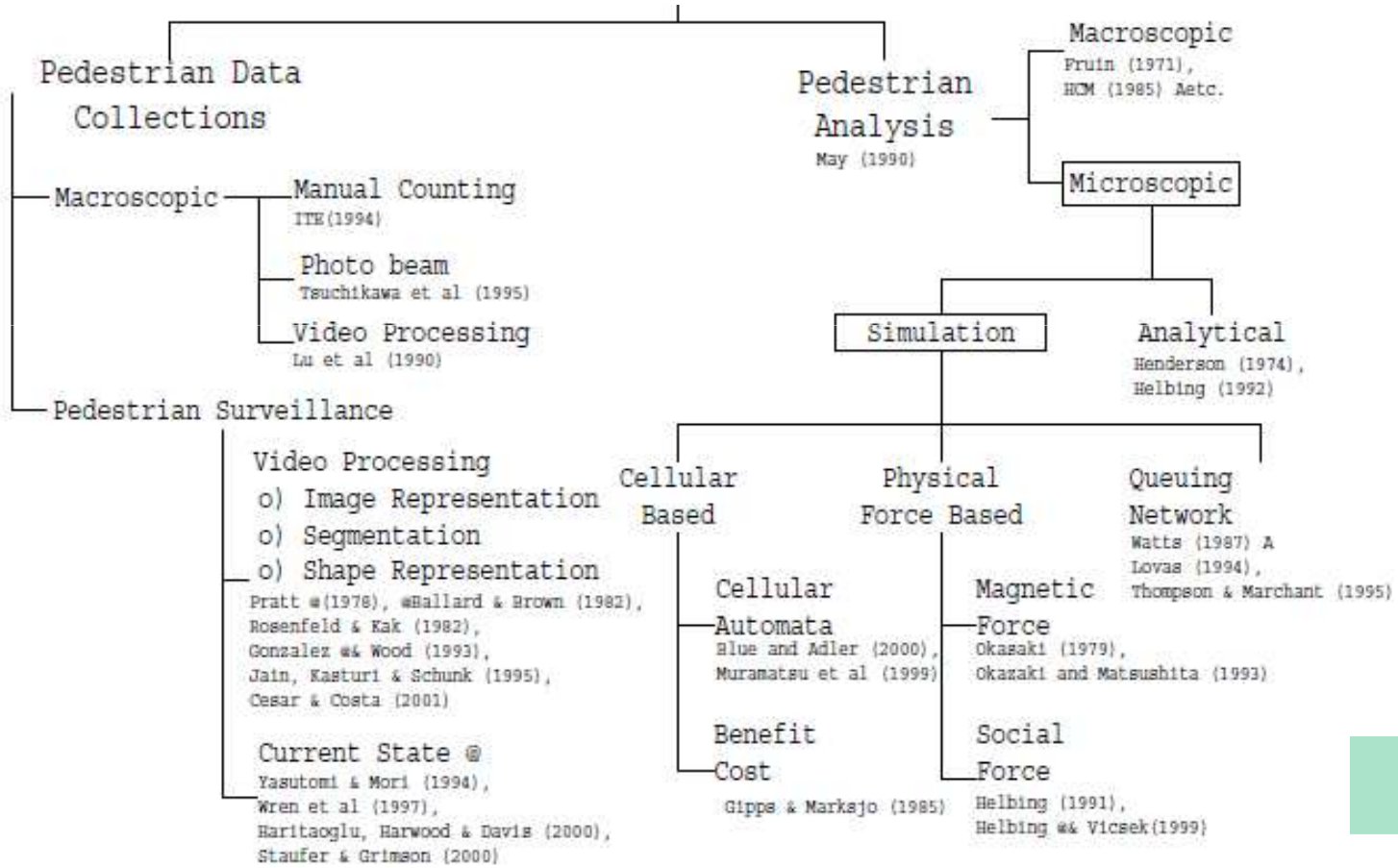
Walking movement: Gait Cycle



Troje, N. F. (2002)
http://www.biomotionlab.ca/Demos/BMLwalker.html

Basic Concepts: an introduction

Pedestrian Studies: a classification



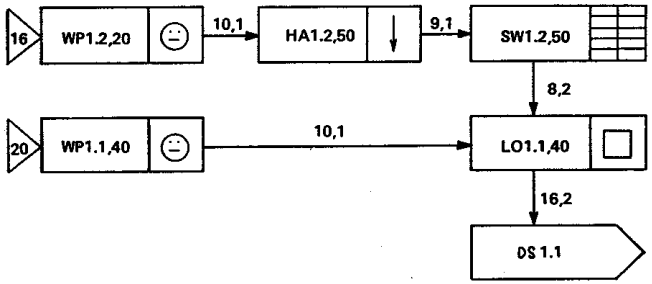
Pedestrian Studies
(Teknomo, 2002)

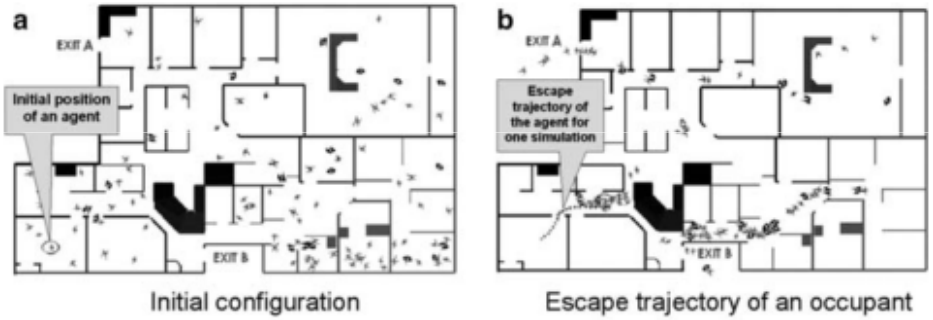
Basic Concepts: Microscopic, Macroscopic, Mesoscopic

Macroscopic

Microscopic

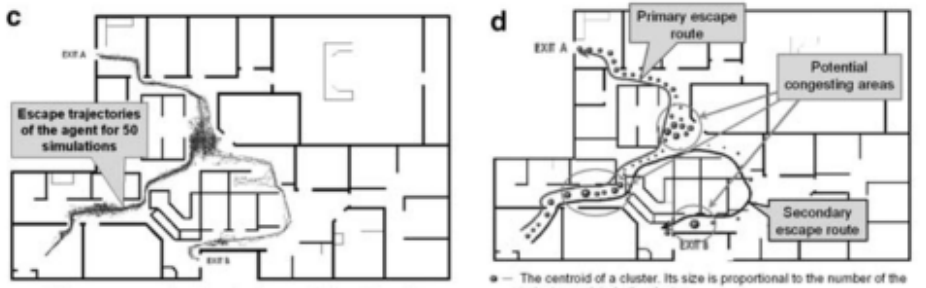
Mesoscopic





Initial configuration

Escape trajectory of an occupant



50 escape trajectories of the 'test' occupant

Plot of cluster centroids and analysis

Pedestrian Modelling

The more common representation models:

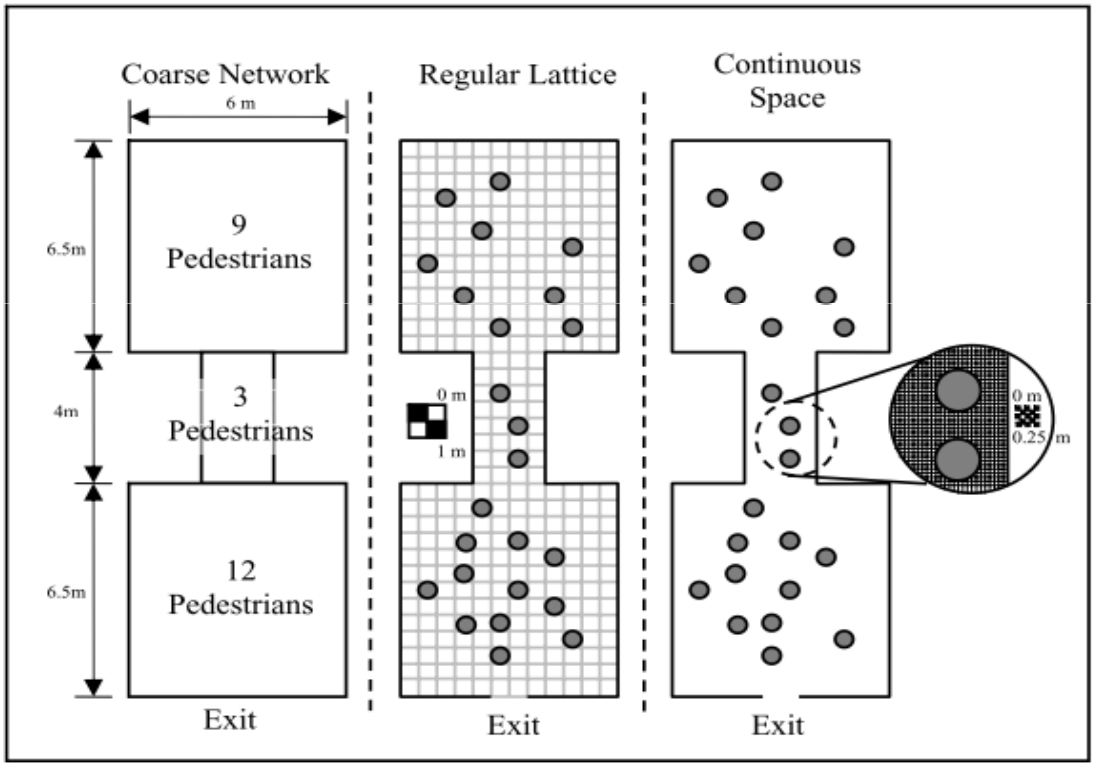
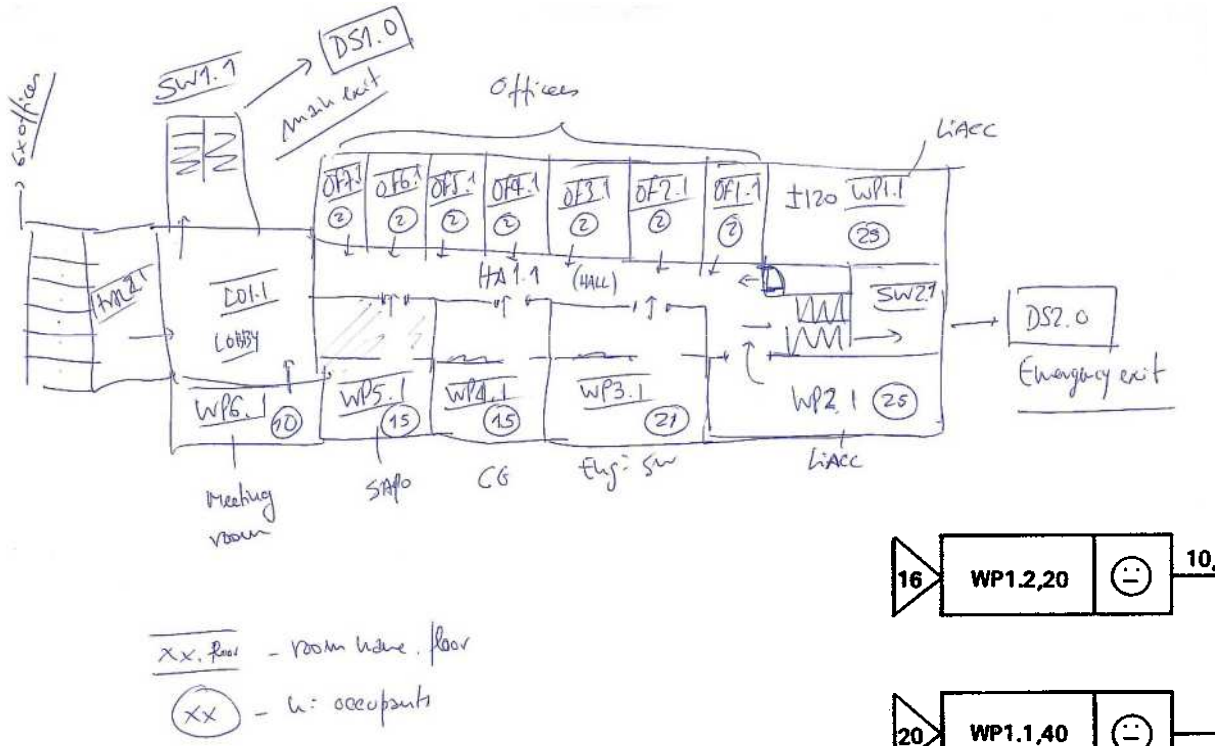
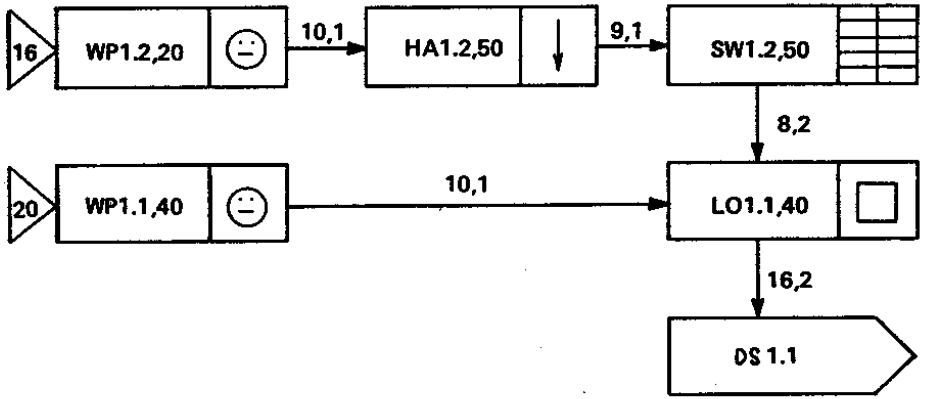


Illustration of the three more common representation models (Castle, 2007)

Pedestrian Modelling

Flow-based models (macroscopic models)





Evacnet4

Pedestrian Modelling

Cellular Automata models (microscopic models)

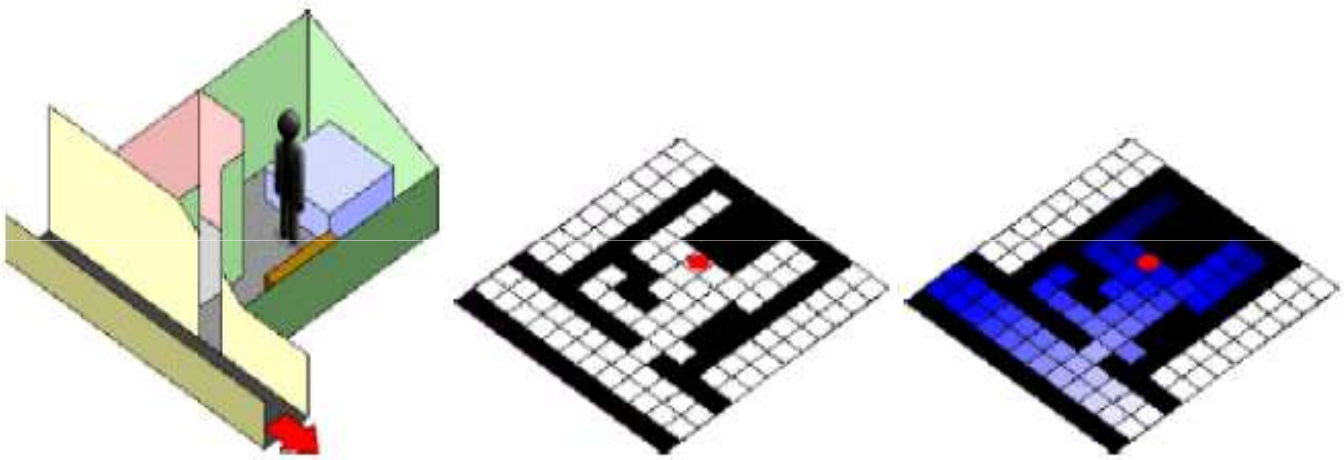
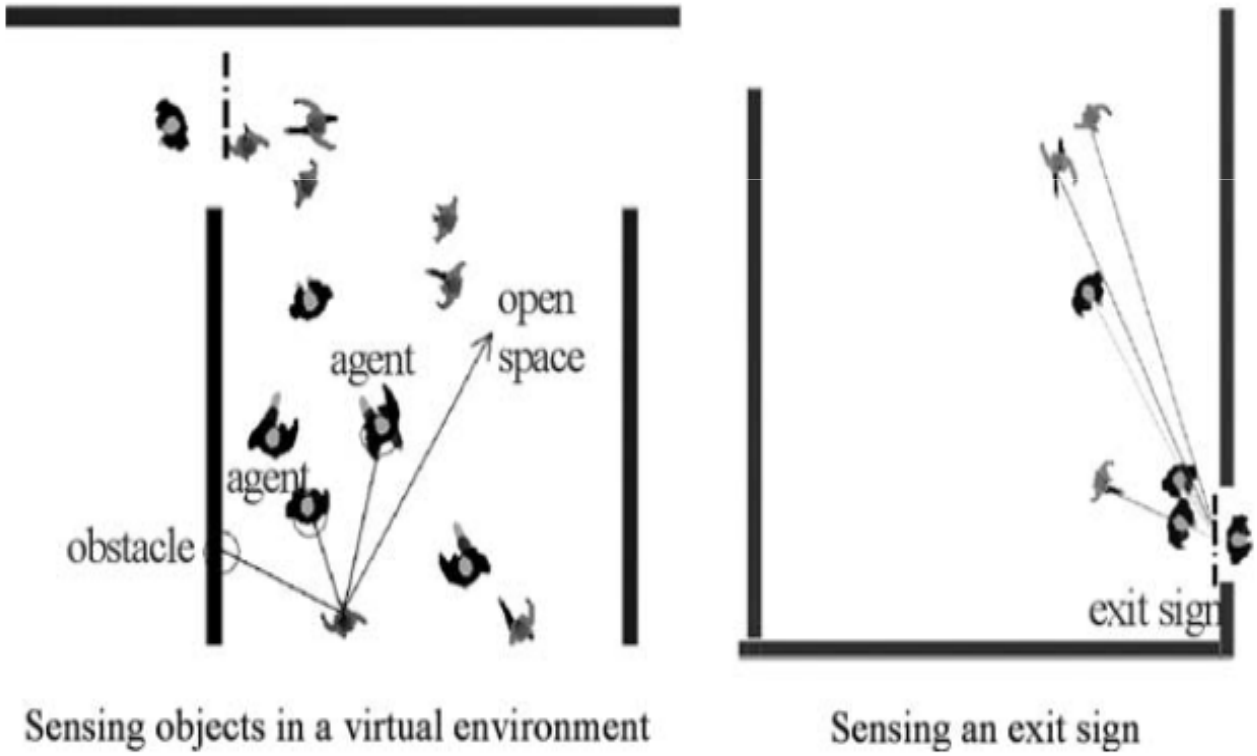


Illustration of the three more common representation models (Castle, 2007)

Pedestrian Modelling

Continuous Space / Spatial Behavioural models

(macro / microscopic models)



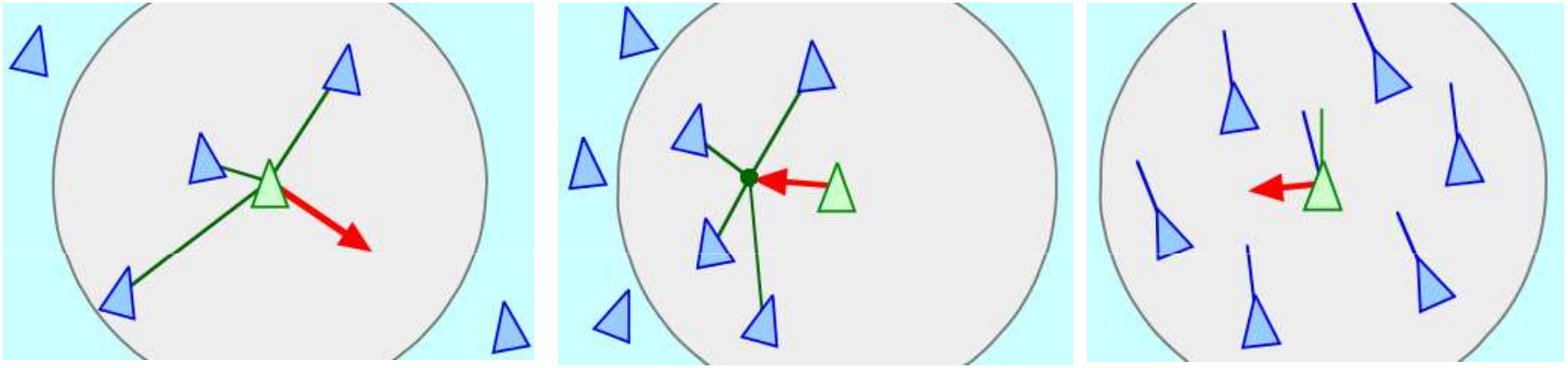
Sensing objects in a virtual environment

Sensing an exit sign

Visual sensors using the ray tracing method
(Pan et al., 2007)

Pedestrian Behaviour

Rules based Models: eg Boyds (Reynolds 1987)



Separation, Cohesion, Alignment:

by combining just these 3 group behaviors we can simulate flocking

"Steering Behaviors For Autonomous Characters" Craig Reynolds

Pedestrian Behaviour

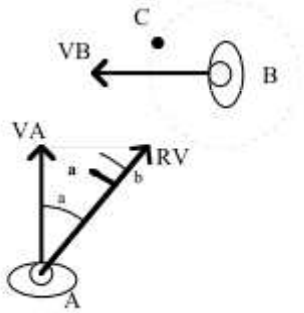
Magnetic Forces Model (MFM) - Okazaki & Matsushita 1993

$$F = (k*q_1*q_2 / r^3)*r$$

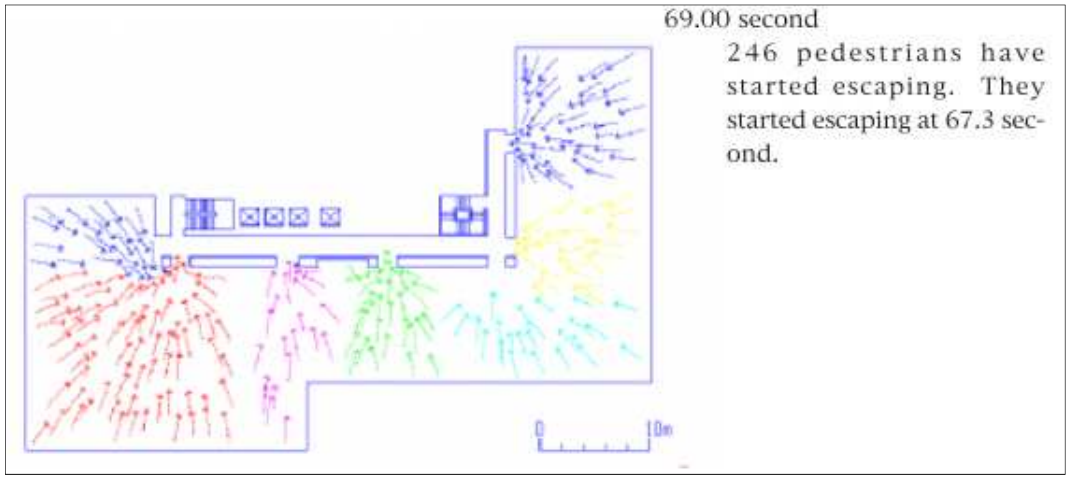
F : magnetic force (vector)
k : constant value
q_1: intensity of magnetic load of a pedestrian
q_2: intensity of a magnetic pole
r : vector from a pedestrian to a magnetic pole
r : length of r

$$\mathbf{a} = \mathbf{VA}*\cos a*\tan b \qquad (2)$$

In Figure 1, Acceleration **a** acts on pedestrian A to modify the direction of **RV** to the direction of Line **AC**. Line **AC** is a contacting line from the position of Pedestrian A to the circle around Pedestrian B. This circle is the Pedestrian Area Module of which the radius is set to 60cm (4).



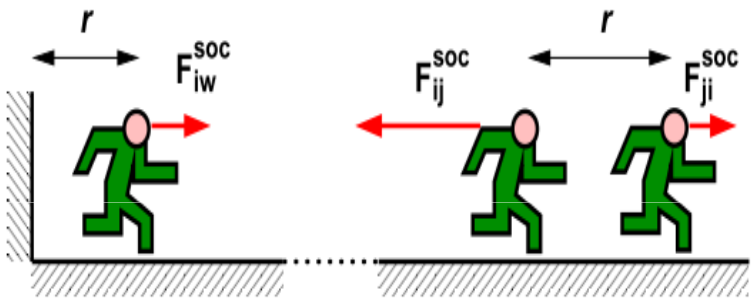
A: a pedestrian
B: a pedestrian
VA: velocity of pedestrian A
VB: velocity of pedestrian B
RV: relative velocity of pedestrian A to pedestrian B
a: angle between **RV** and **VA**
b: angle between **RV** and **AC**

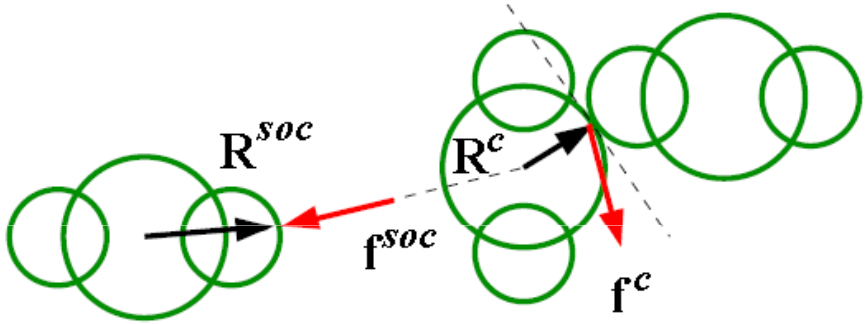


Pedestrian Behaviour

Models of escape, egress and panic behaviour:

Social Forces Model (SFM) Helbing & Molnar 1995



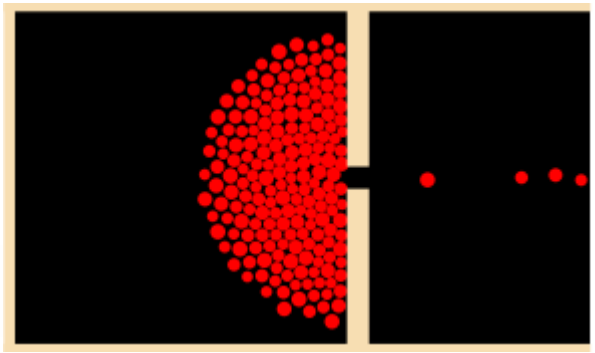


The force on the agent i has many components:

$$f_i = \frac{m_i}{\tau_i}\left(v_i^0 - v_i\right) + \sum_{j \neq i}\left(f_{ij}^{soc} + f_{ij}^{c} + f_{ij}^{att}\right) + \sum_{w}\left(f_{iw}^{soc} + f_{iw}^{c}\right) + \sum_{k} f_{ik}^{att}, \qquad (2)$$

$$f_{ij}^{soc} = A_i e^{-(d_{ij} - r_{ij})/B_i}\left(\lambda_i + (1-\lambda_i)\frac{1+\cos\varphi_{ij}}{2}\right) n_{ij}, \qquad (3)$$

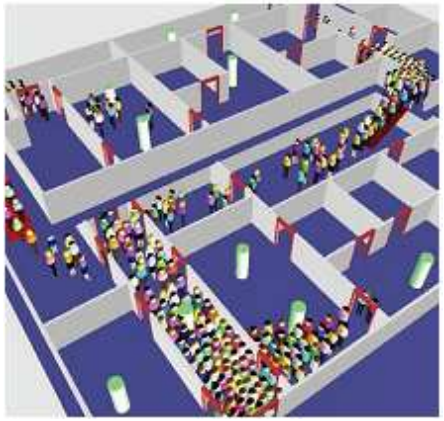
$$f_{ij}^{c} = \left(k_{ij}(r_{ij} - d_{ij}) + a_d \Delta a_{ij}^{t}\right) n_{ij} + \kappa_{ij}(r_{ij} - d_{ij})\Delta a_{ij}^{t}\, t_{ij}, \qquad (4)$$

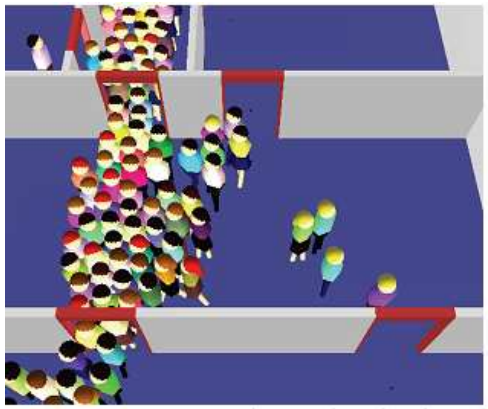


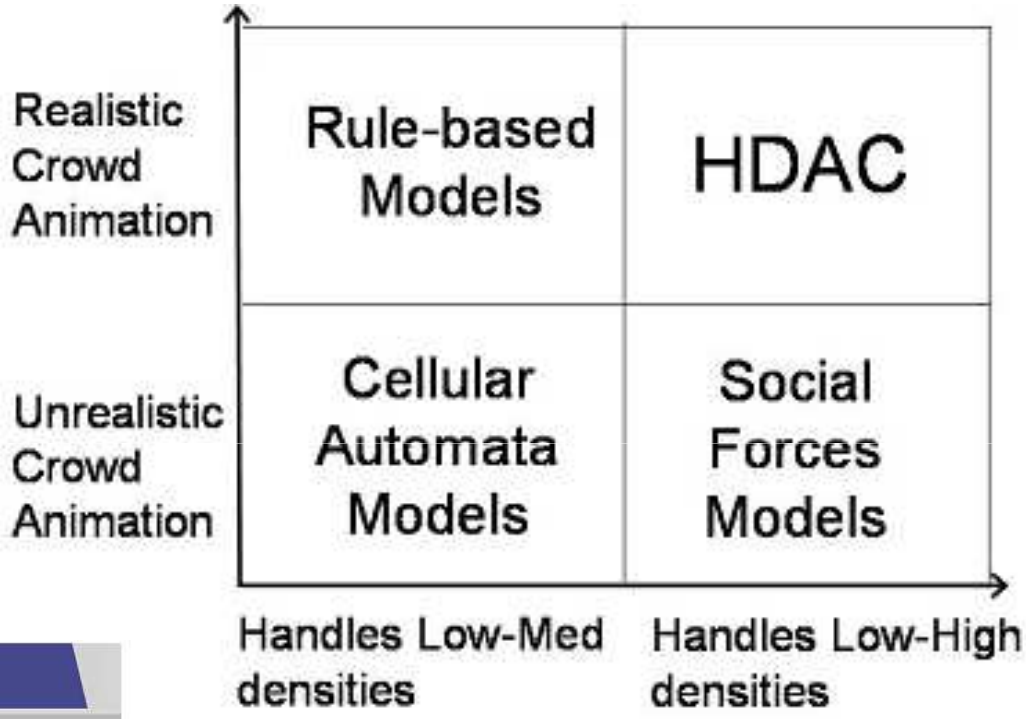
Pedestrian Modelling

A model for High Density Autonomous Crowds (HiDAC)

- Natural, realistic crowd simulation
- Handle high density
- Adapt to dynamic changes



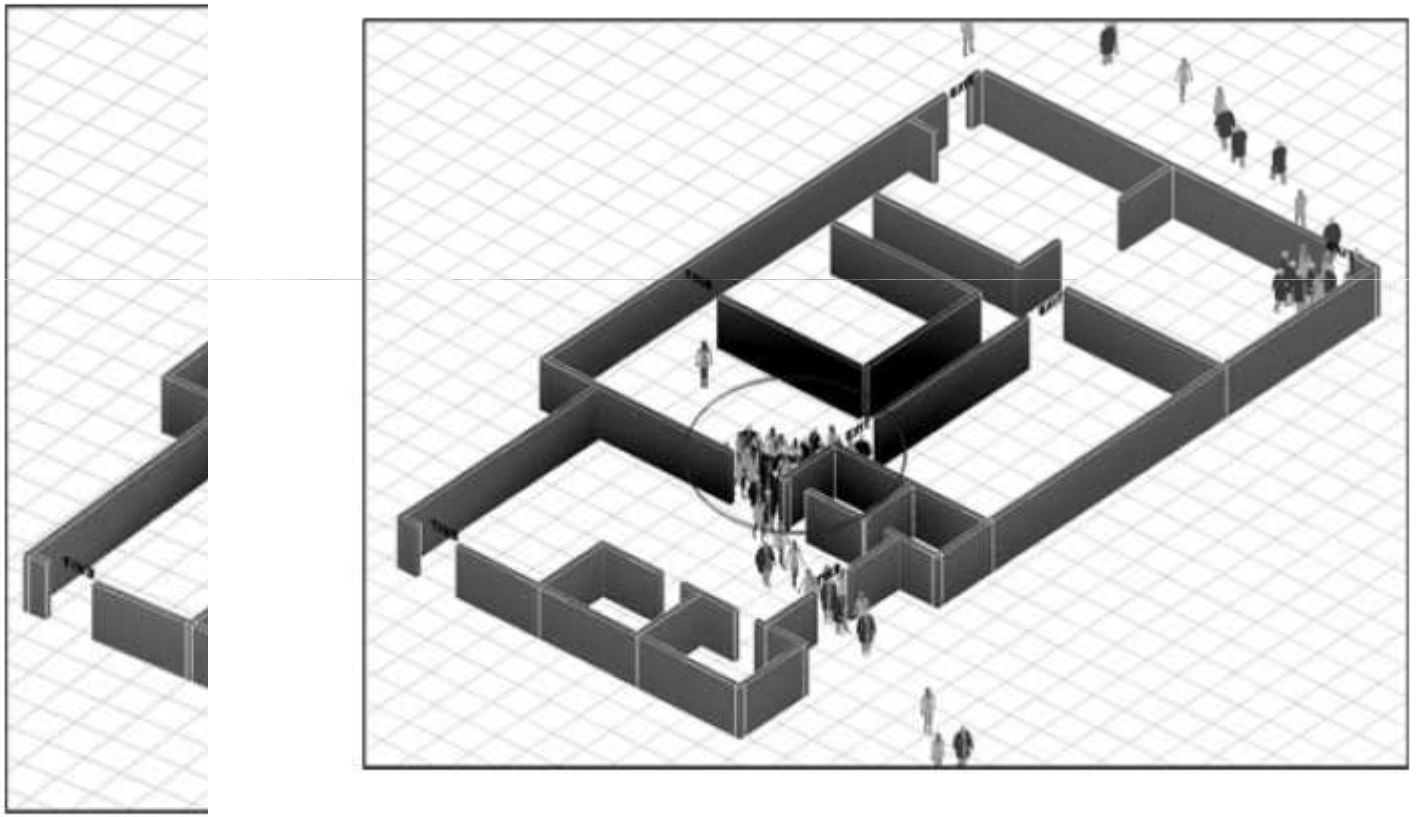




(Pelechano, 2007)

Types of Behaviour

Xiaoshan Pan, Charles S. Han, Ken Dauber, Kincho H. Law



He

Competitive behavior

Queuing behavior

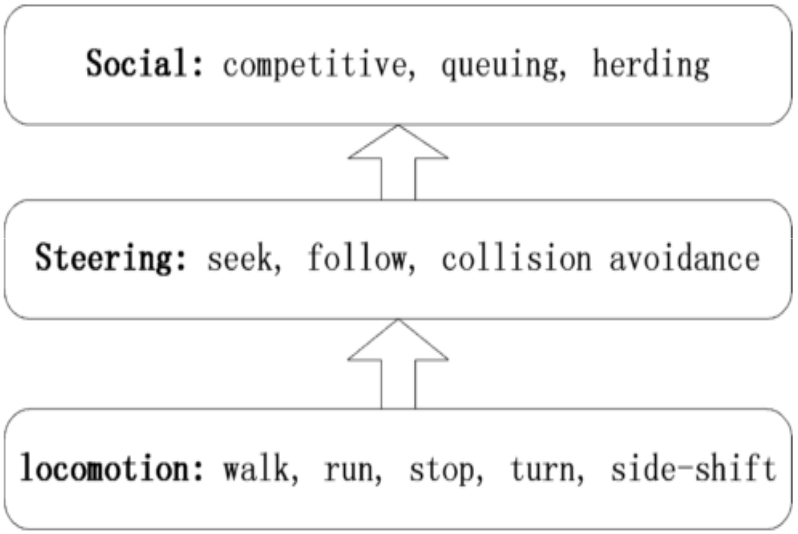
Pedestrian Behaviour

Heuristics for pedestrian motion and planning (Shao, 2005)

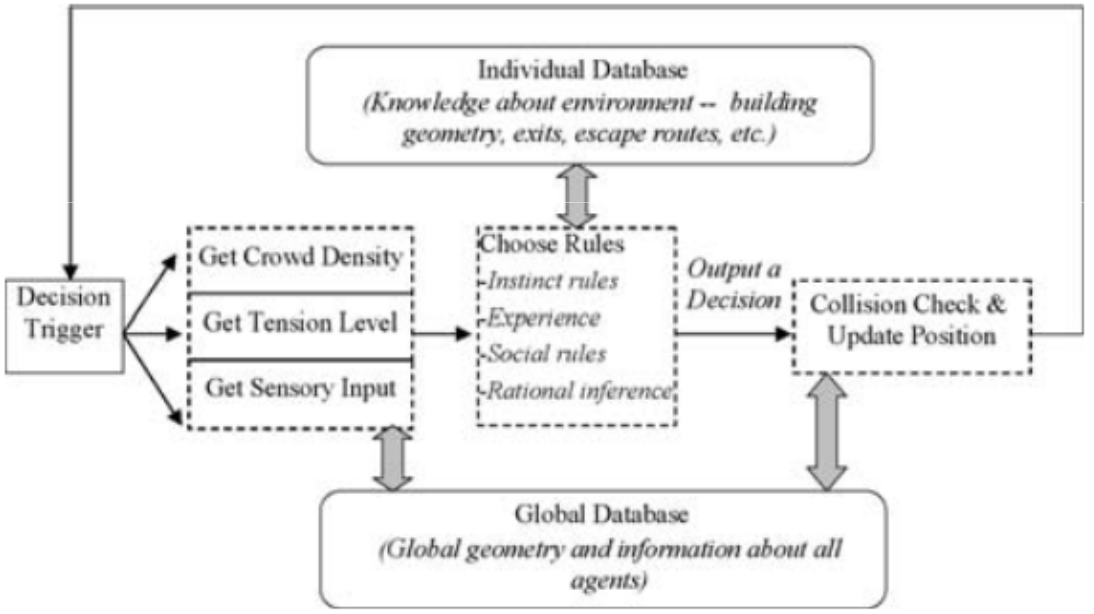
- Static obstacle avoidance;
- Static obstacle avoidance in a complex turn;
- Maintain separation in a moving crowd;
- Avoid oncoming pedestrians.
- Avoid dangerously closed pedestrians
- New directions relative to obstacles

Pedestrian Modelling

Behavioural models: a hierarchy of agent behaviour



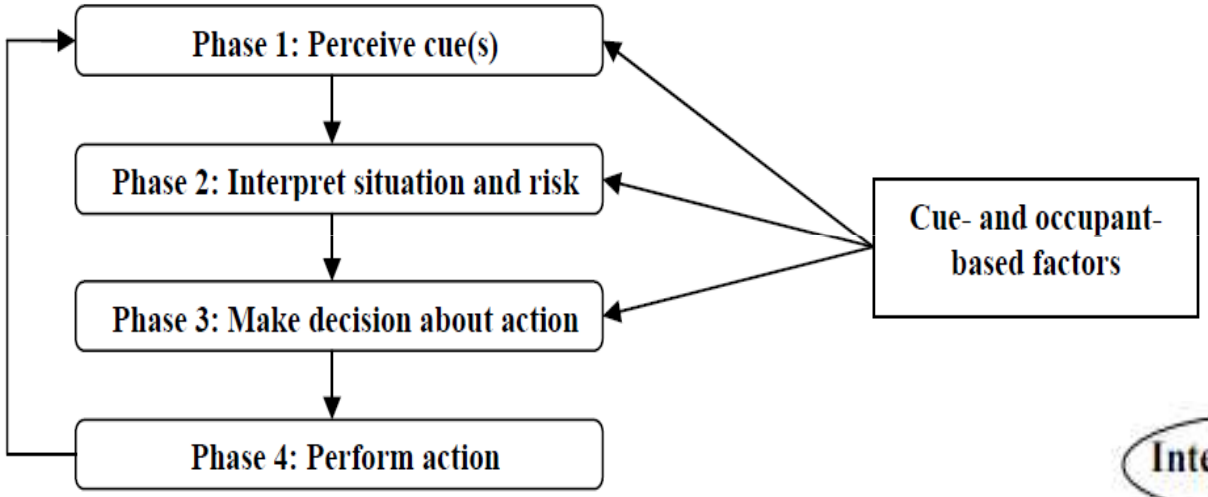
Hierarchy of agent behaviour
(Pan et al., 2007)

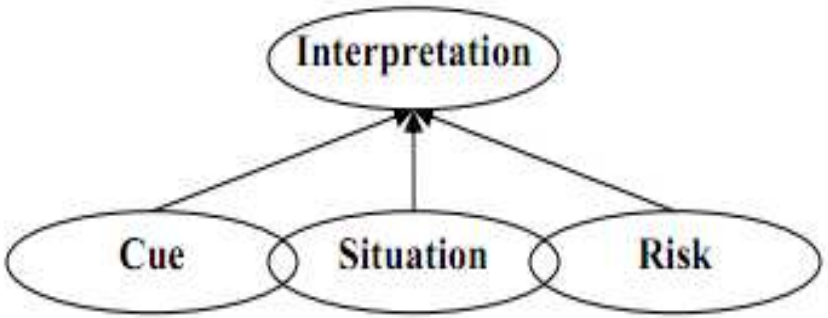


Individual behaviour model
(Pan et al., 2007)

Pedestrian Behaviour

Kuligowski model (NIST, 2008/11) – Behavioural models

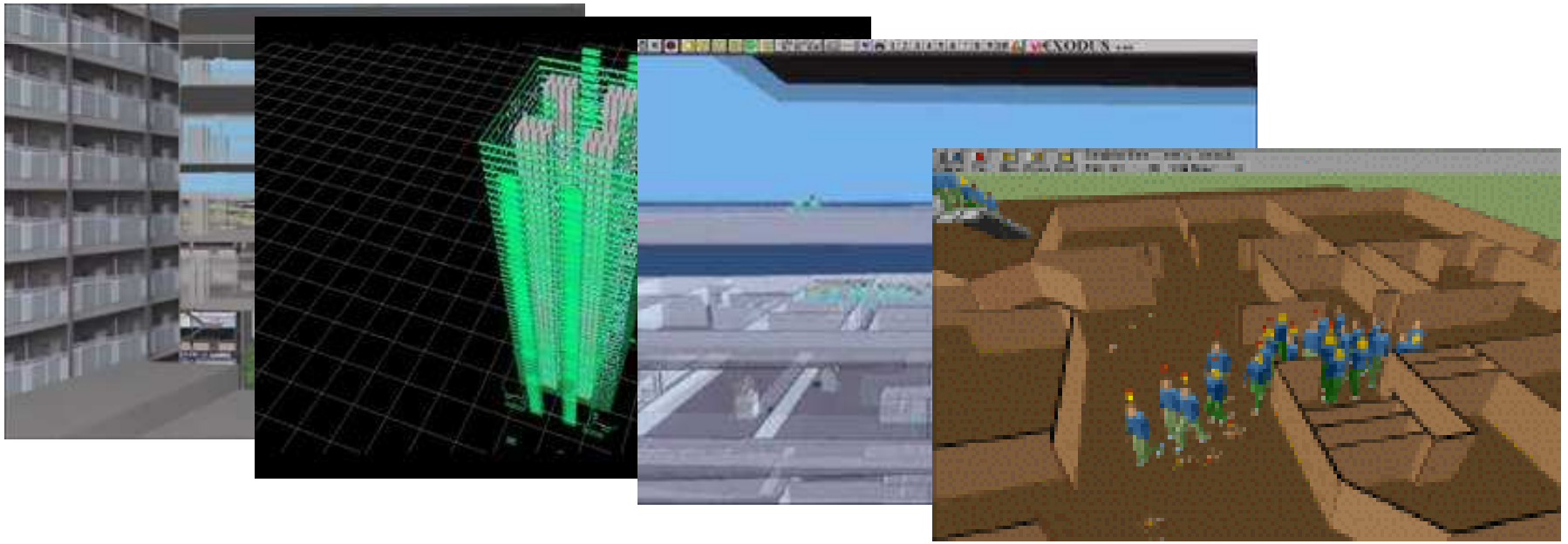




Evacuation Simulators

Exodus

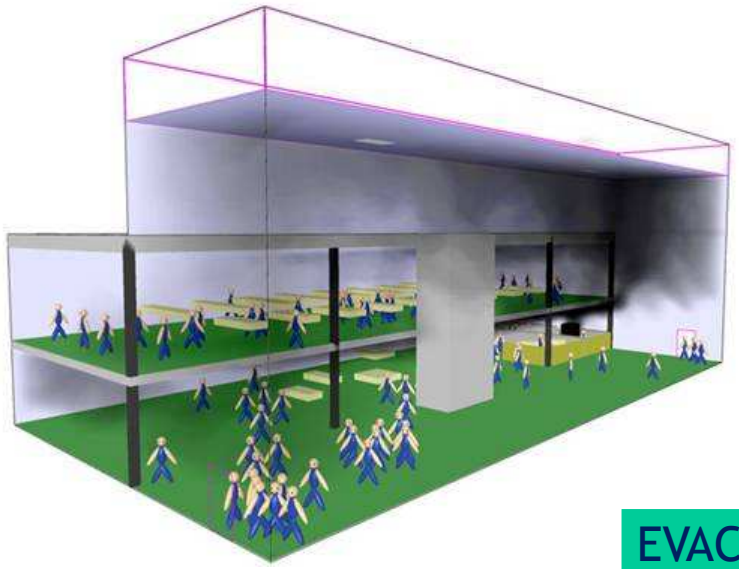
Developed by the **Fire Safety Engineering Group** at the **University of Greenwich** since 1993, EXODUS comprises a suite of software packages, tailored to the building, maritime and aircraft environments. A rail version of the EXODUS software is currently under development.



Evacuation Simulators

FDS+EVAC

Building and Fire Research Lab (BRFL) at National Institute of Standards and Technology (NIST), USA



VTT (Finland): VTT Technical Research Centre of Finland is the biggest multitechnological applied research organisation in Northern Europe.

FDS=Fire Dynamic Simulator
Smokeview=3D visualization SW for FDS

EVAC=Agent-Based Egress Simulator for FDS

Pedestrian Simulation

Existing models

STEPS

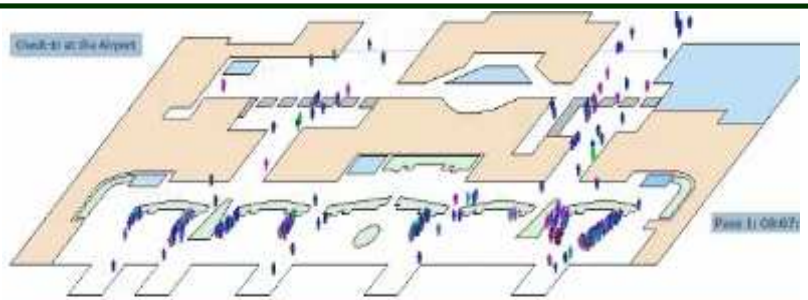
- All-purpose
- + 20 develop.
- the Mott MacDonald's Group
- examples:
  - London Heathrow Terminal 5
  - Minneapolis Light Rail Transit, USA;
  - Rotterdam Metro, The Netherlands;
  - Delhi metro, India;
  - KCRC Shatin-Central Link, Hong Kong;
  - Luton Network Rail station, UK;

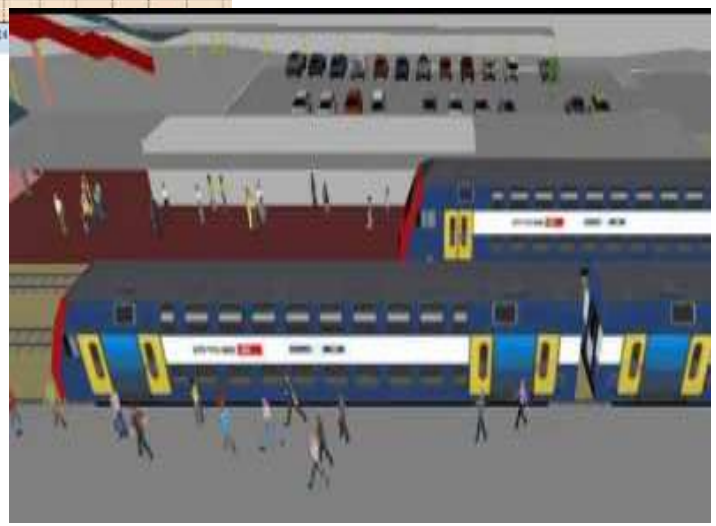
Pedestrian Simulation

Existing models:

SimWalk

- Transport
- Airport

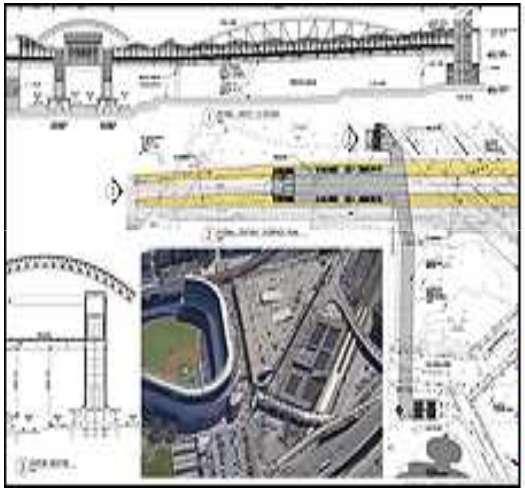


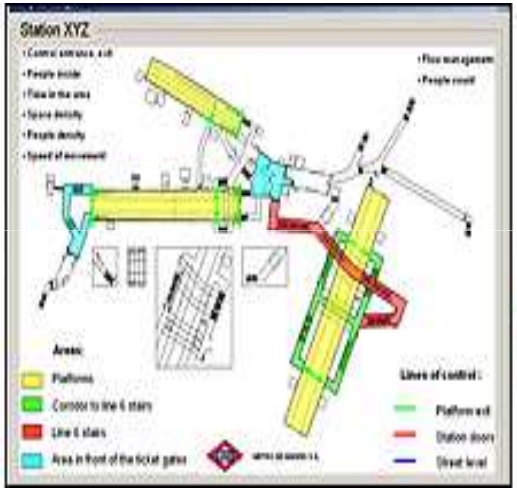


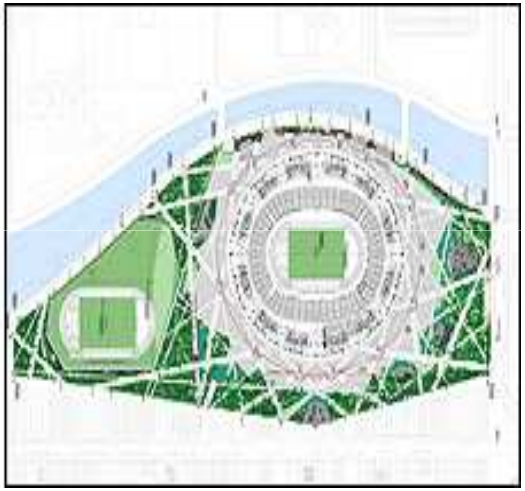
Pedestrian Simulation

Existing models

Legion



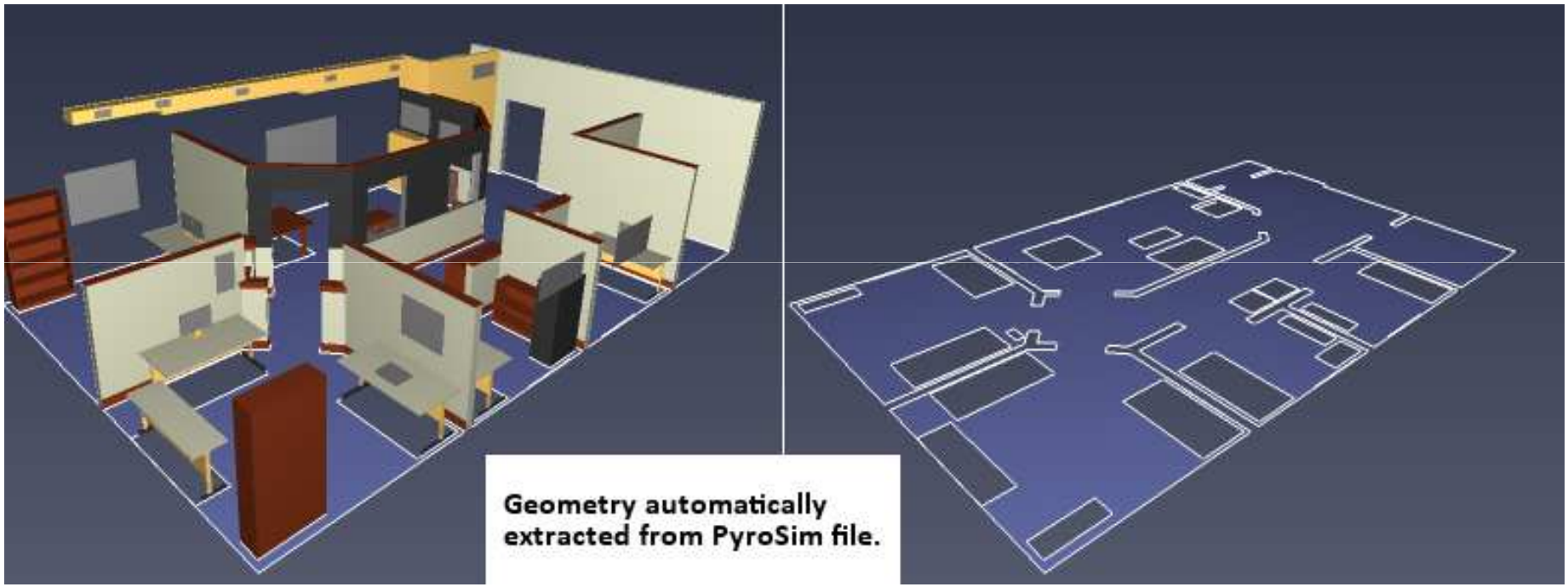




- All-purpose
- examples:
  - London Underground;
  - Luton Airport (London);
  - New York's 34th Street Pennsylvania Station
  - Olympic Stadiums in Athens, Greece, Sidney and Beijing

Pedestrian Simulation

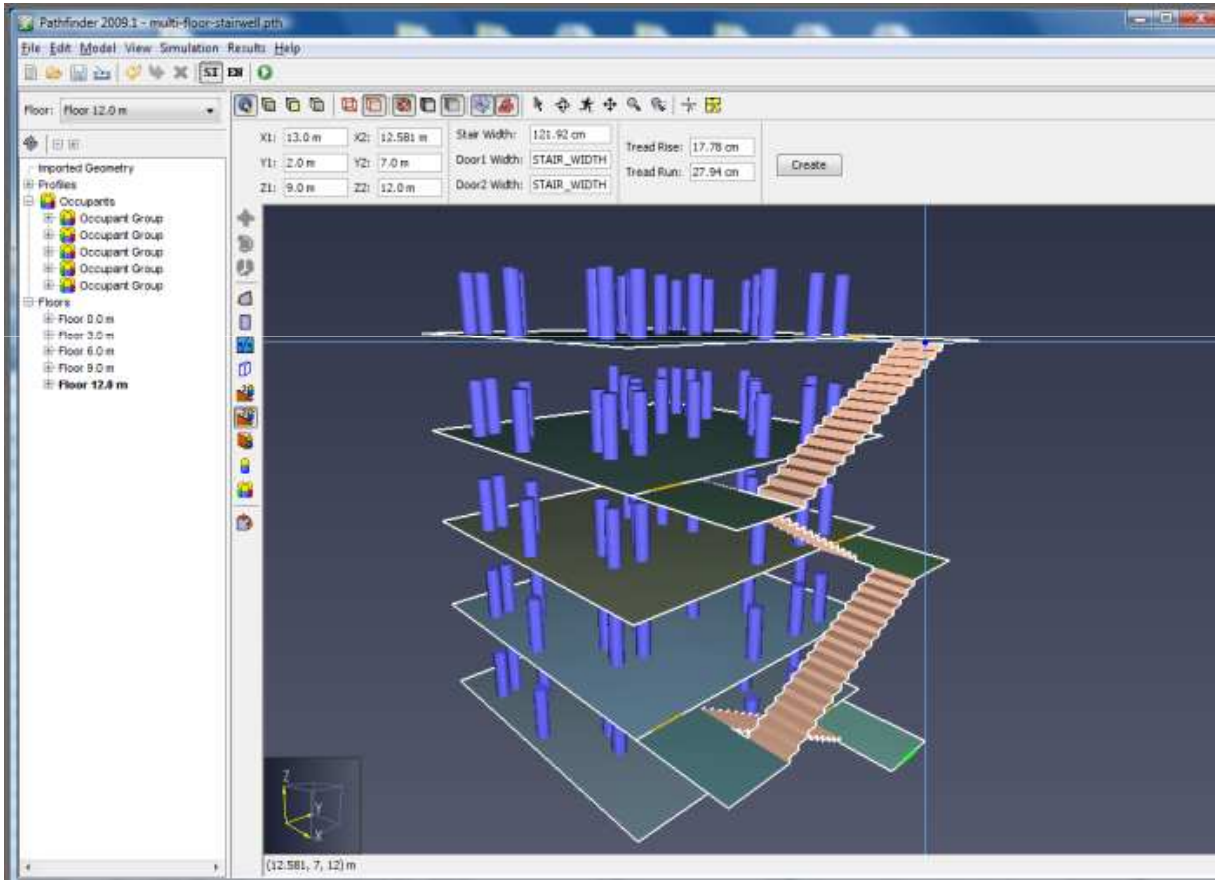
Pathfinder (newest evacuation simulator, 2012)



Scenario editor based on AutoCAD architectural files

Pedestrian Simulation

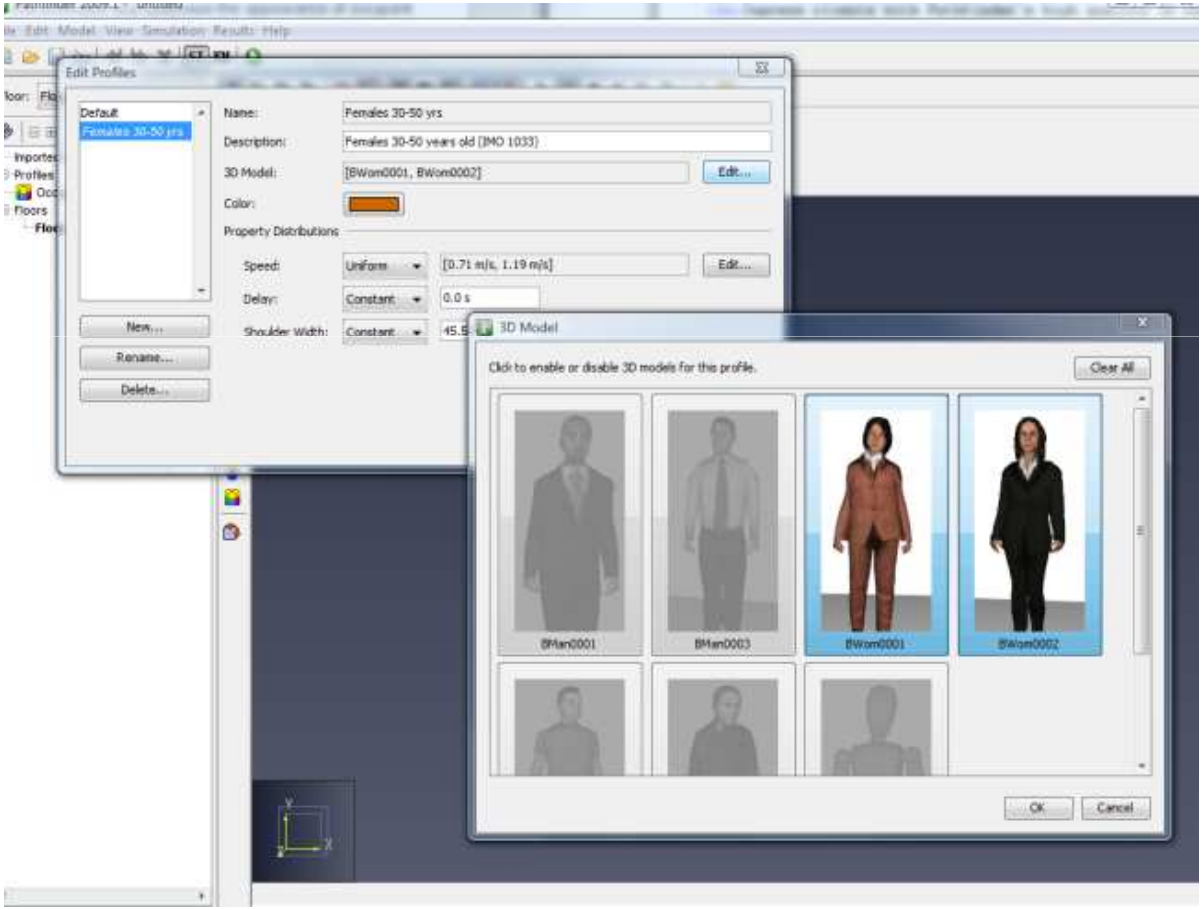
Pathfinder (newest evacuation simulator, 2012)



Multi-Floor

Pedestrian Simulation

Pathfinder



Profile editor:

- gender
- age
- cinematic & physics
- CG
- behaviour
- …

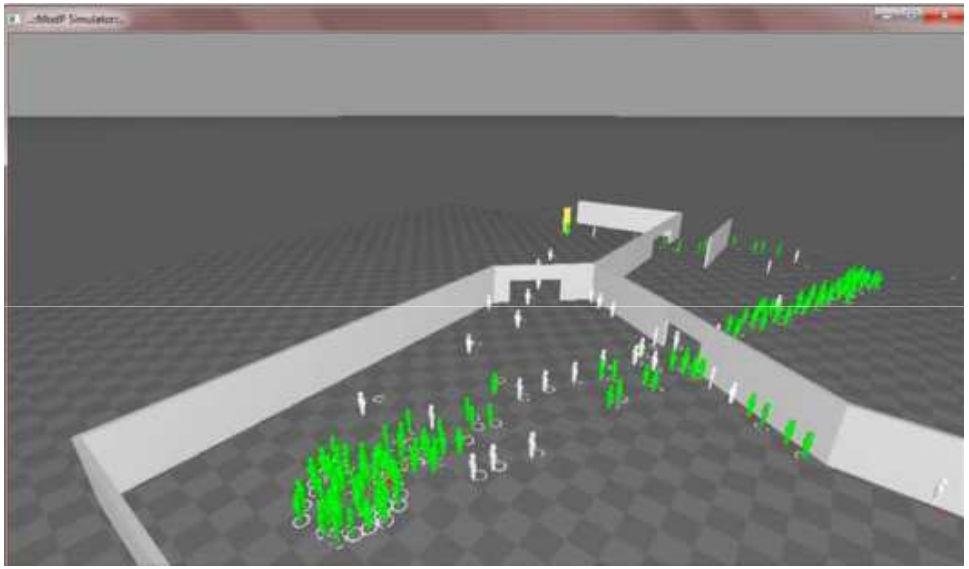
Pedestrian Simulation

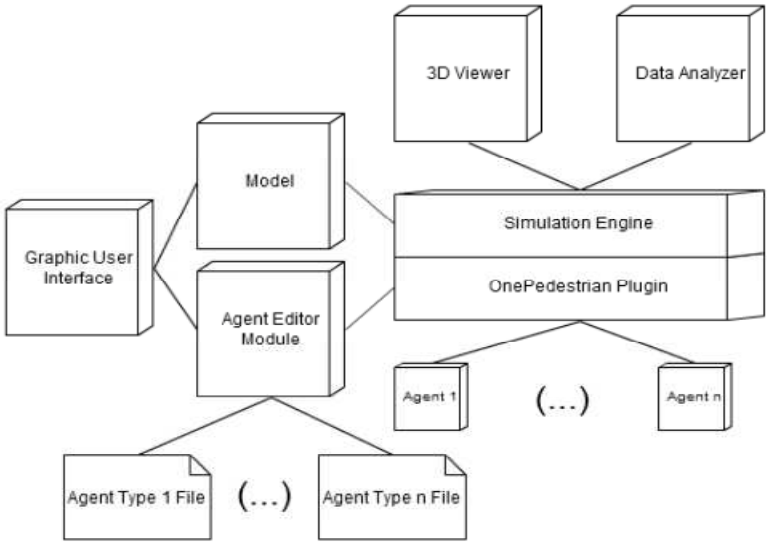
Pathfinder

High definition Computer Graphics

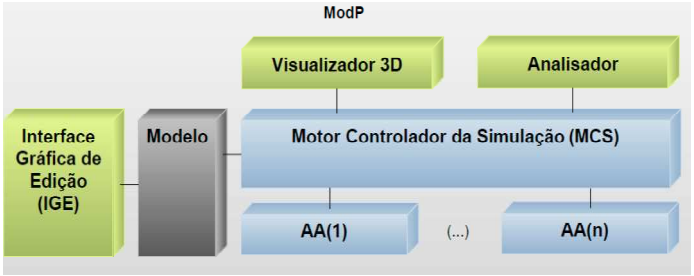
Pedestrian Simulation - LIACC

ModP - Simulador Pedonal

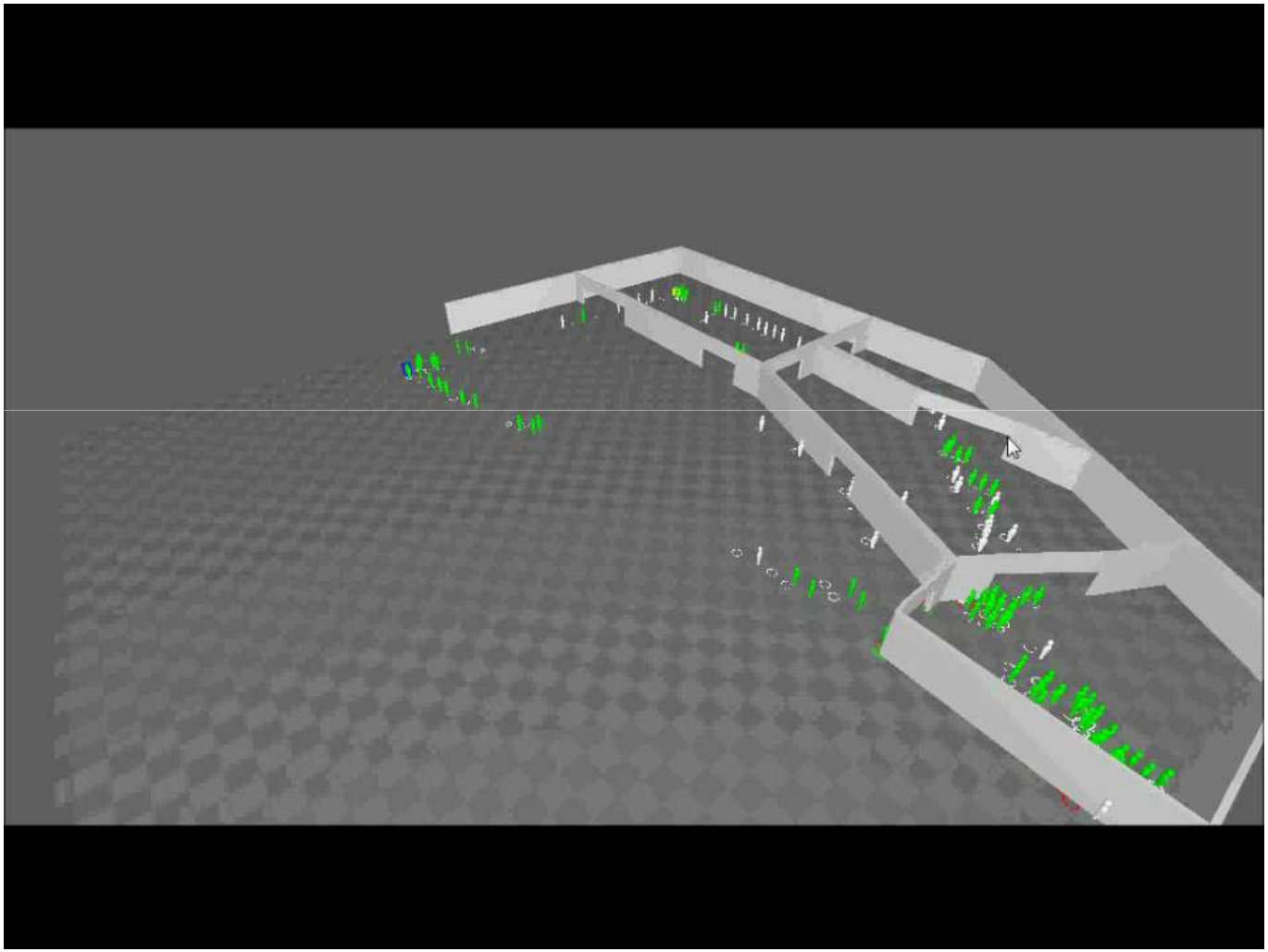




- LIACC
- OpenSteer + C++

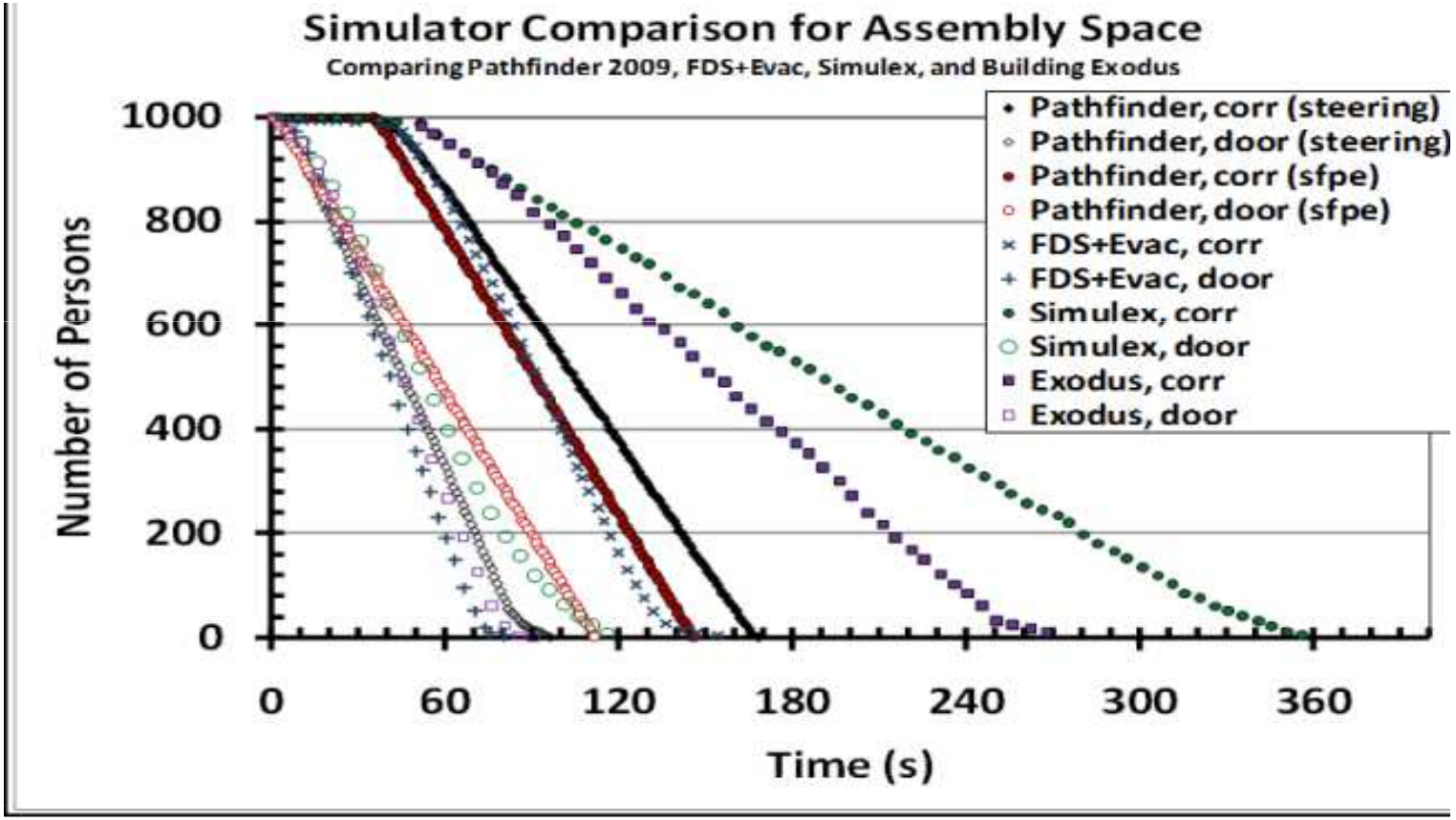


Pedestrian Simulation: ModP



Simulators Comparison

Results varies within simulators!



Comparison data based on results presented in "Fire Dynamics Simulator with Evacuation: FDS+Evac, Technical Reference and User's Guide" (Korhonen and Hostikka, 2009).

Validation & Verification of movement with other simulators

Pedestrian Simulation

Characteristics of pedestrian simulators:

- Availability and access
- Purpose / background
- Nature: microscopic, macroscopic or mesoscopic
- Enclosure representation
- Occupant enclosure perspective
- Occupant movement
- Behavioural perspective of occupant
- Validation
- Support

Simulators characteristics (Castle, 2007)

Pedestrian Simulators comparison – Kuligowski 2009

Table 1. Main features of egress models

Model	*Available to public*	*Modeling Method*	*Purpose*	*Grid/ Structure*	*Perspective of M/O*	*Behavior*[a]	*Movement*[a]	*Fire data*	*CAD*	*Visual*	*Valid*
EVACNET4	Y	M-O	1	C	G	N	UC	N	N	N	FD
WAYOUT	Y	M	5	C	G	N	D	N	N	2-D	FD
STEPS[c]	Y	B	1	F	I	C, P	P, E	Y1,2	Y	2,3-D	C,FD,PE
PEDROUTE	Y	PB	3	C	G	I	D	N	Y	2,3-D	N
Simulex[b]	Y	PB	1	Co.	I	I	ID	N	Y	2-D	FD,PE, 3P
GridFlow	Y	PB	1	Co.	I	I	D	N	Y	2,3-D	FD, PE
FDS+Evac[c]	Y	PB	1	Co.	I	I, C, P	ID	Y3	N/Y	2,3-D	FD,PE,OM
Pathfinder 2009[c]	Y	PB	1	Co.	I/G	I	D,ID	N	Y	2,3-D	C,FD,PE,OM
SimWalk[c]	Y	PB	1,3	Co.	I	C, P	P	N	Y	2,3-D	FD,PE,3P
PEDFLOW[c]	Y	B	1	Co.	I	C, P	ID	Y2	Y	2,3-D	PE
PedGo[c]	Y,N1	PB/B	1	F	I/I,G	I/C, P	P,E (CA), C	Y2	Y	2,3-D	FD,PE,OM,3P
ASERI[c]	Y	B-RA	1	Co.	I	C, P	ID	Y1,2	Y	2,3-D	FD, PE
BldEXO[b]	Y	B	1	F	I	C, P	P, E	Y1,2	Y	2,3-D	FD,PE,OM,3P
Legion[c]	Y,N1	B	1	Co.	I	AI, P	ID, C	Y1	Y	2,3-D	C,FD,PE,3P
SpaceSensor[c]	Y	B	3	Co.	I	C, P	C, Ac_K	N	Y	2,3-D	FD,OM
EPT[c]	Y,N1	B	1	F	I	AI	UC,C	Y2	Y	2,3-D	FD
Myriad II[c]	Y, N1	B	1	C, F, Co.	I	AI	D, UC, IP, Ac_K	Y1	Y	2,3-D	PE, 3P
MassMotion[c]	Y, N1	B	1	Co.	I/I,G	AI,P	C	N	Y	2,3-D	C,FD,PE,OM
PathFinder	N1	M	1	F	I/G	N	D	N	Y	2-D	N
ALLSAFE	N1	PB	5	C	G	I	Un_F	Y1,2	N	2-D	OM
CRISP	N1	B-RA	1	F	I	C, P	E,D	Y3	Y	2,3-D	FD
EGRESS 2002	N1	B	1	F	I	C, P	P,D (CA)	Y2	N	2-D	FD
SGEM[c]	N1	PB	1	Co.	I	I	D	N	Y	2-D	FD,OM
EXIT89[c]	N2	PB	1	C	I	I/C, P	D	Y1	N	N	FD,3P
MASSEgress[b]	N2	B	1	Co.	I	C, AI	C	N	Y	2,3-D	PE,OM
EvacuatioNZ[c]	N2	B	1	C	I/I,G	I, C, P	D, UC	Y2	Y	2-D	FD, PE,OM

[a]Only the underlying methods used by the algorithm are listed. In some instances users can define other options

[b]Model developers/NIST provided an update on the model's development in Spring 2009.

[c]Model developers/NIST provided an update on the model's development in Fall 2010.

Some major problems…

Traditional pedestrian simulation:

-> lacks appropriate behavioural representation (basic models)

-> might cause simulation results to bear much noise and biases

-> Focused in movement issues (obstacle avoidance, path finding)

-> little reasoning and interpretation of cues (Kuligowski work)

-> Social simulation lacks appropriate Calibration, V & V

-> traditional approaches, e.g. fire risk analysis rely very much on questionnaires and fire drills; these methods are expensive, complex and also subject to much noise and bias

New Simulator

- Development of a simulation project:
  - Problems to tackle
  - Framework overview
  - Architecture, Implementation
  - Serious Games use for elicitation of human behaviour and mimicking real scenarios of social simulation)
  - Testing and Validation & Calibration

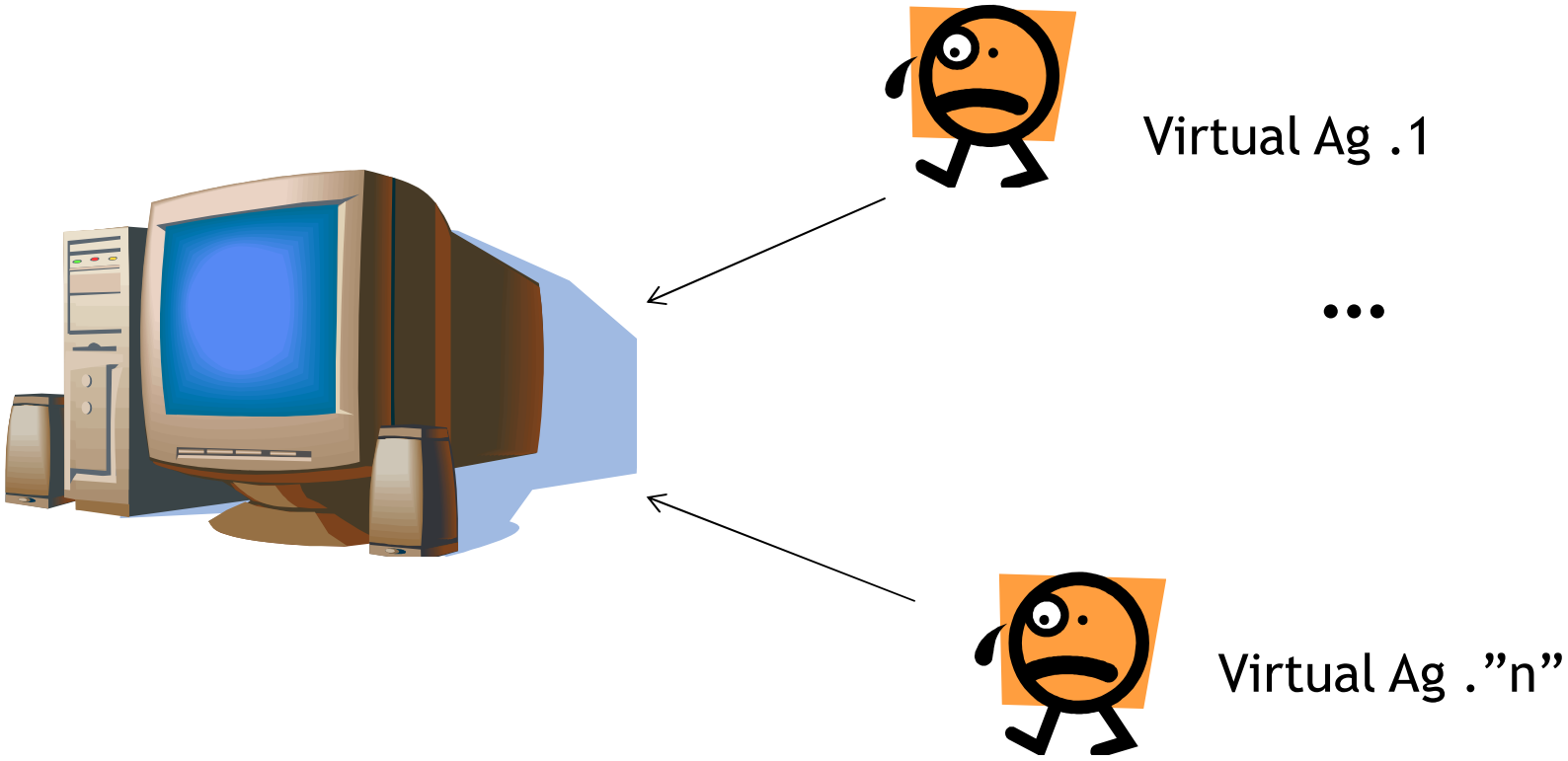
Some Questions

Is it possible to mix virtual agents (as traditionally approached in pedestrian simulation) with avatars controlled by one or more human subjects?

Would the human-in-the-loop simulation concept allow us to synthesise behaviour, so that we could improve the behavioural representation of traditional virtual agents?

Can short-term repeated strategies result in assimilated long-term reactive behaviour of humans?

ABMS / MAS / Agents

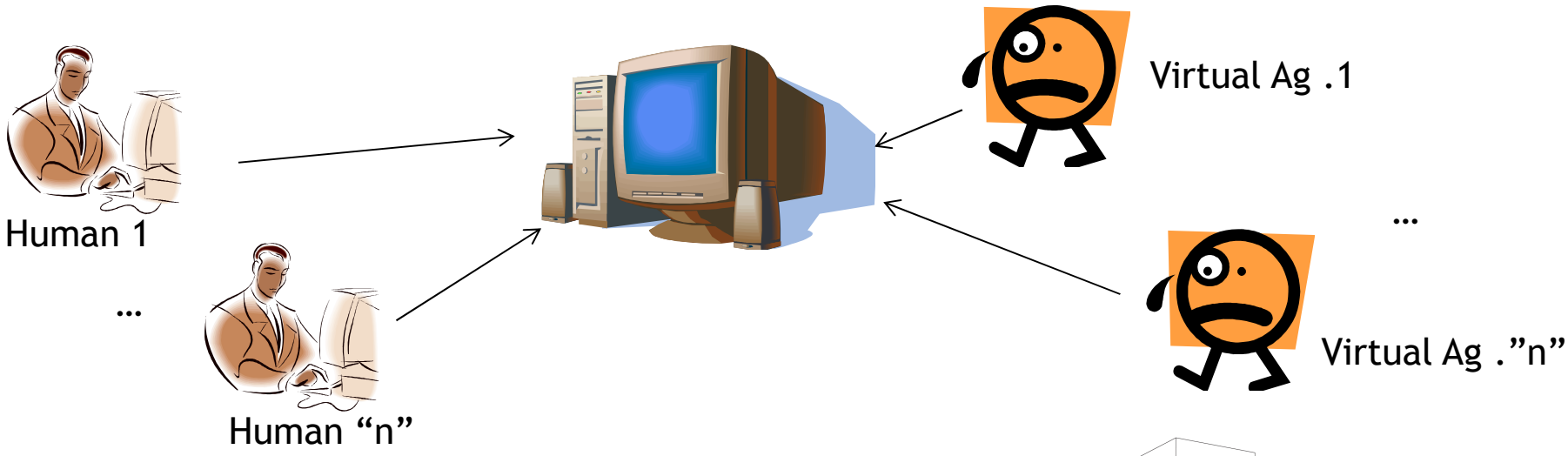


Methodology

Human-in-the-Loop (HITL)

HITL: A model that requires human interaction (DoD M&S Glossary, 1998, USA)

Simulations where the human might influence the outcome in such a way that it is difficult to reproduce exactly.

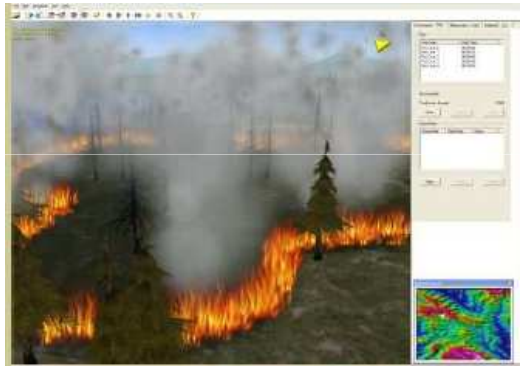


Serious Games Concept

Serious Games

Serious Games:

- Military used to call “war games” in order to train strategic skills (Kriegsspiel, Prussian Army game, von Reisswitz, 1824)
- "Serious Games: Games That Educate, Train,and Inform" by David Michael,Sande Chen (Thompson Course Technology, 2005)

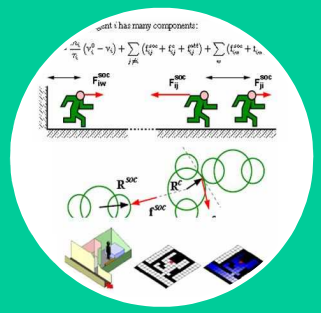


Applications:

- Medicine (Oral health, Speech, therapy, …)
- Education (Maths, Geography, Physics…)
- Military
- Industry
- …

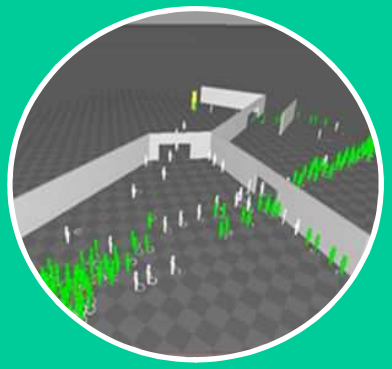
Uses: training and education

Goals



1

- Identify related work, research background, scientific and technological challenges of the areas of study



2

- Specify and implement an experimental prototype for crowd simulation using serious games

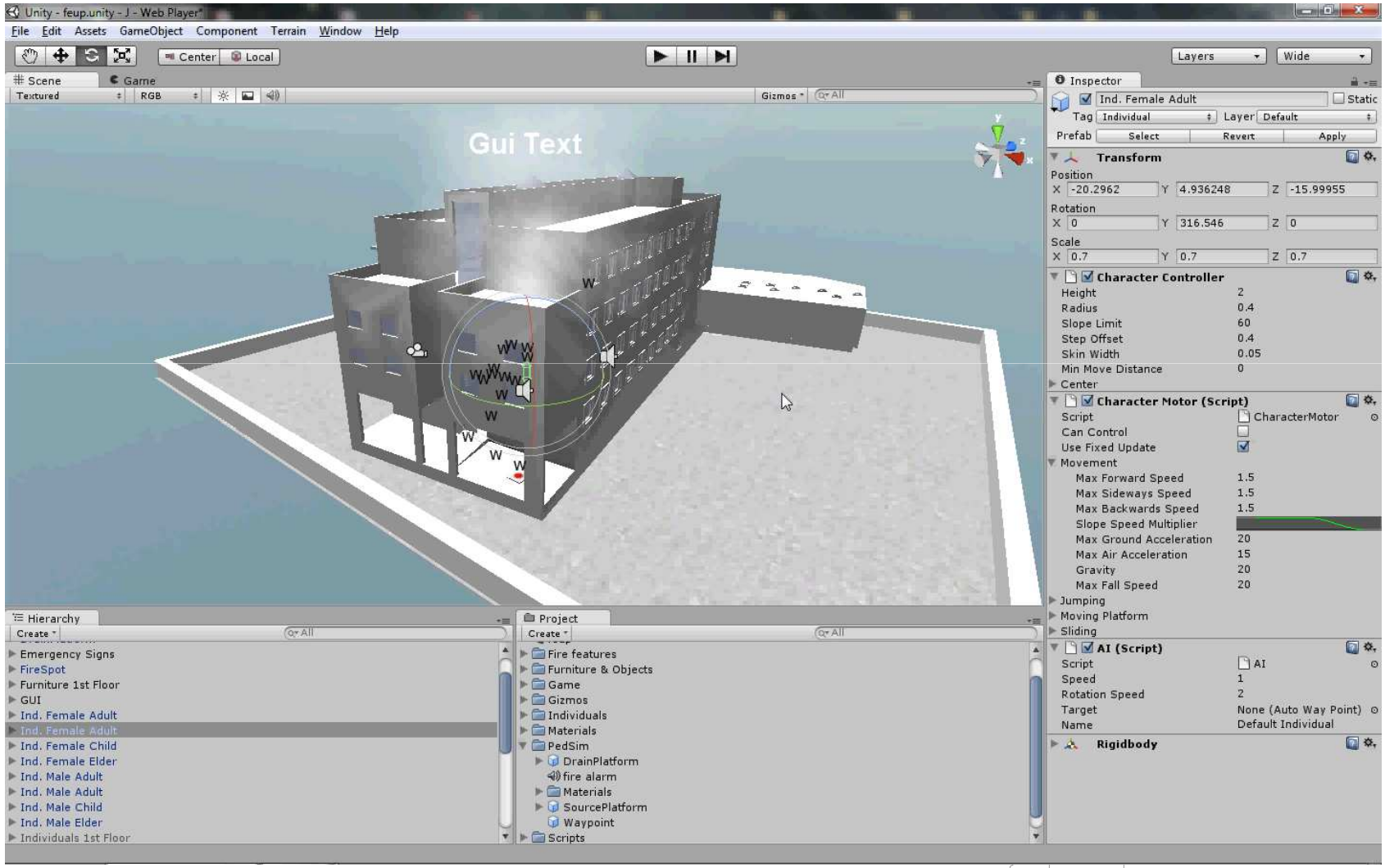
3

- Devise and implement means for social behaviour elicitation, validation and assimilation

4

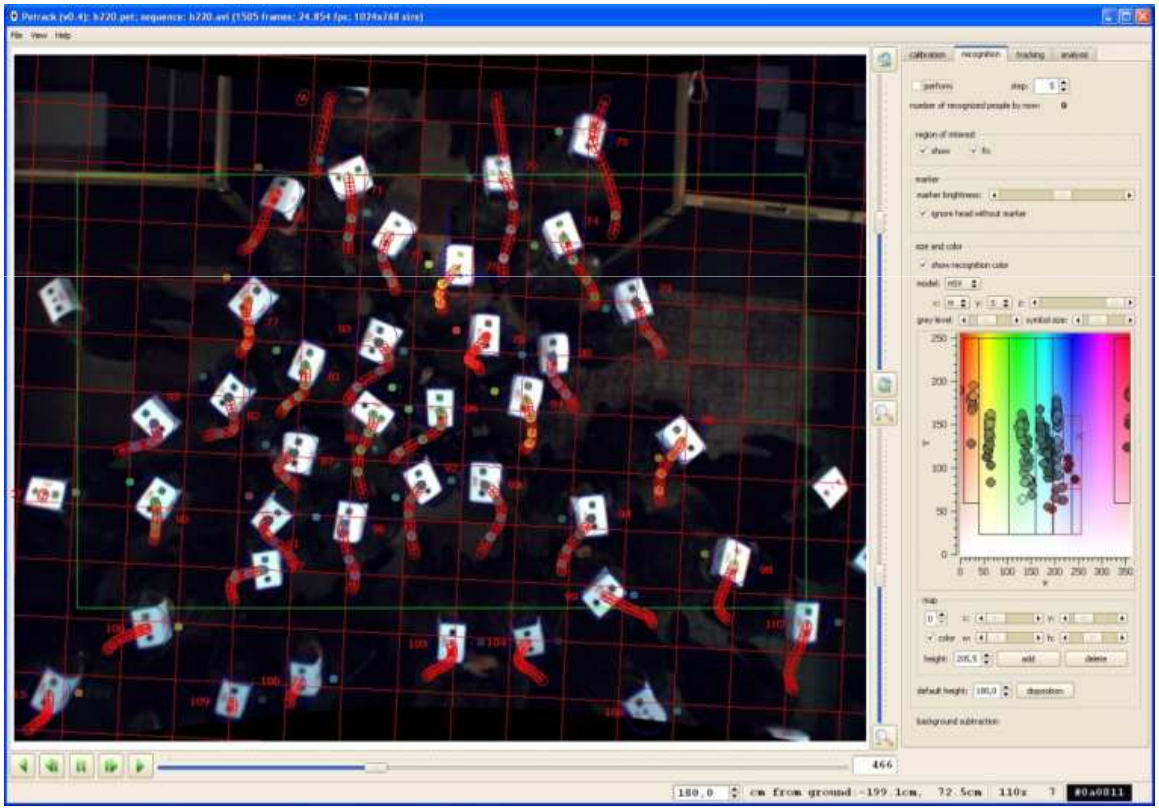
- Specify real-life scenarios, model and validate simulation experiments

Pedestrian Simulation: Modp3D



Pedestrian Modelling: data collection

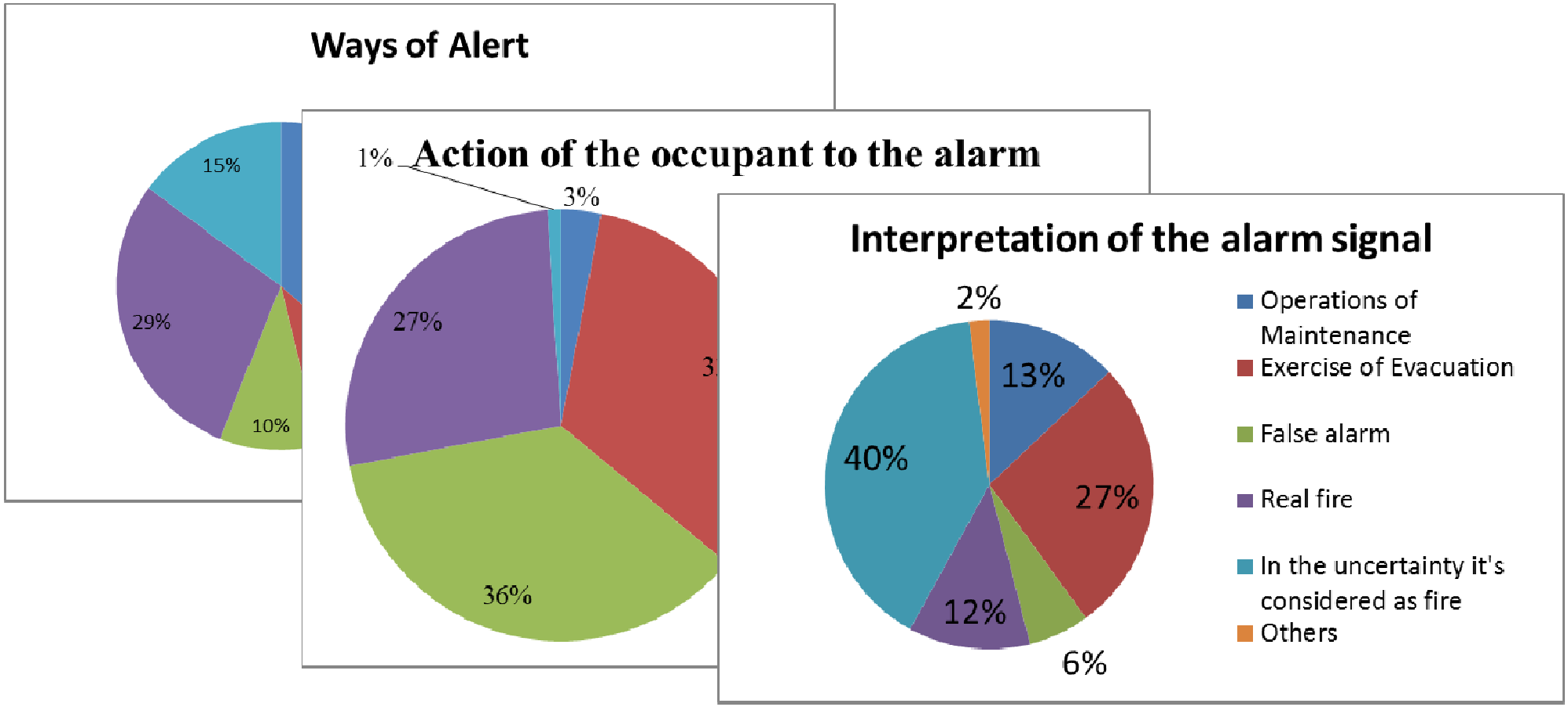
Using video to capture pedestrian models



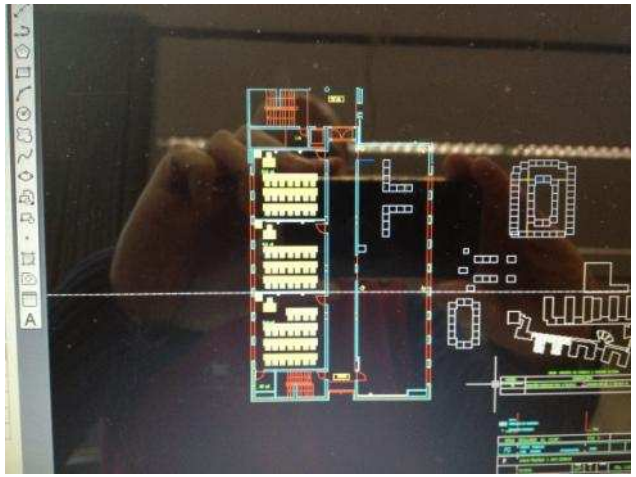
PeTrack, Hermes Project (BMBF, GermanyTeknomo, 2002)

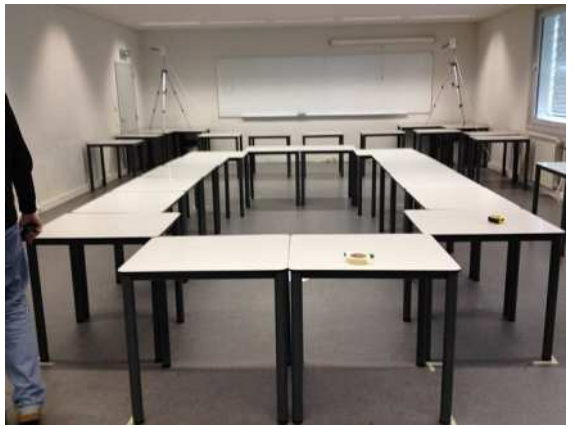
Pedestrian Modelling: data collection

E.Cordeiro, Coelho studies (U.Coimbra): Data Collection (surveys)

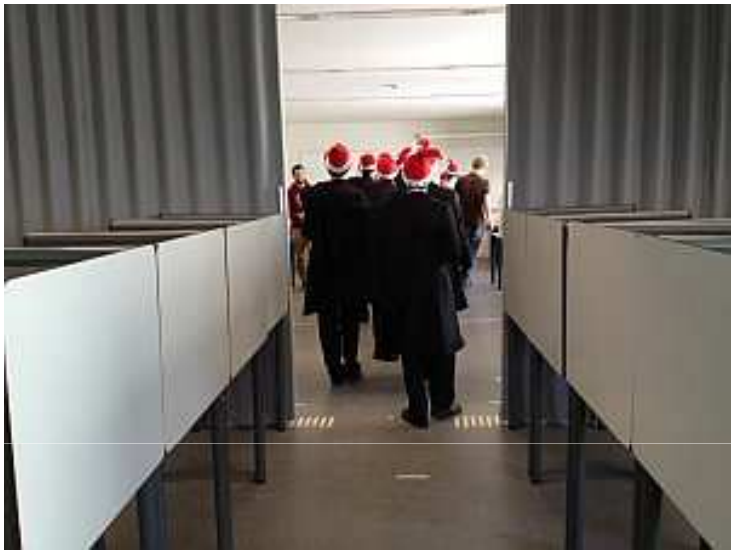


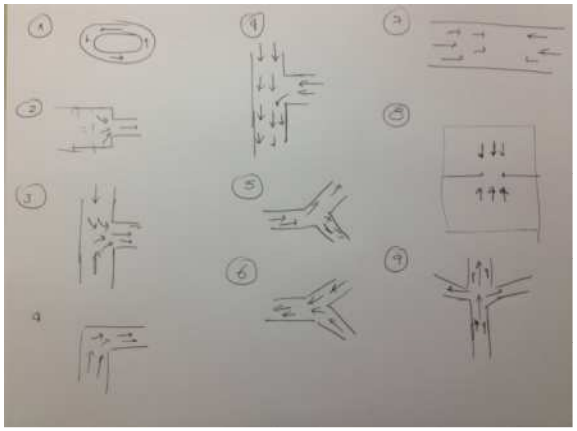
Pedestrian Simulation: using RIFD



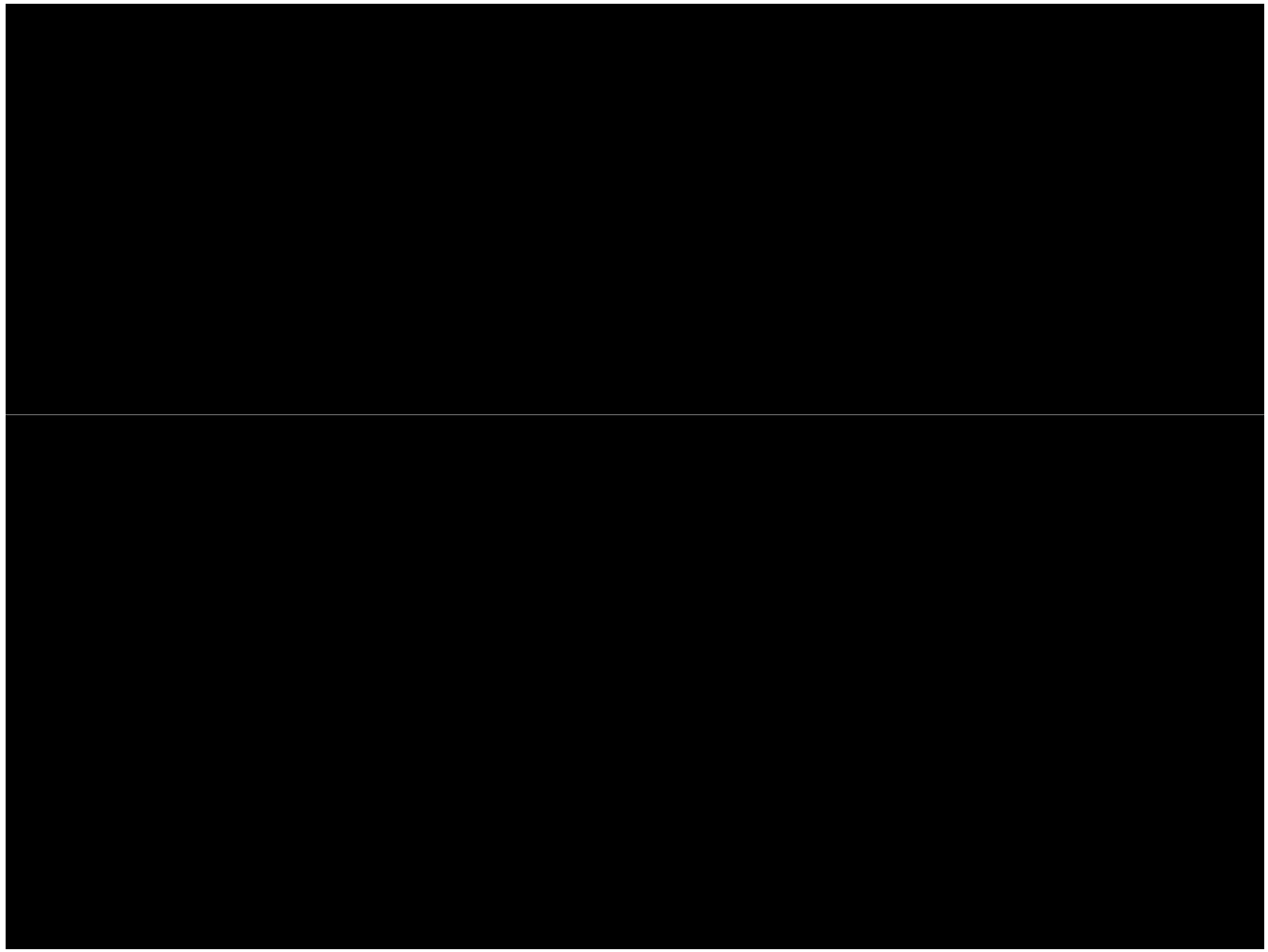


Pedestrian Simulation: using RIFD





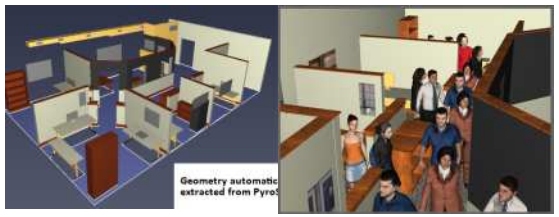
Pedestrian Simulation: using RIFD



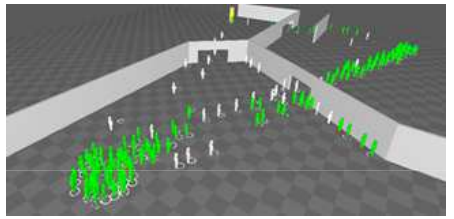
Pedestrian Simulation: using RIFD

Methodology

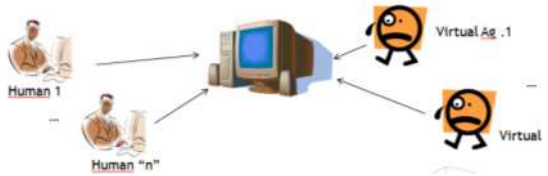
Select state-of-the-art game engines (for scenario construction, avatar specification, and appealing 3D computer graphics)



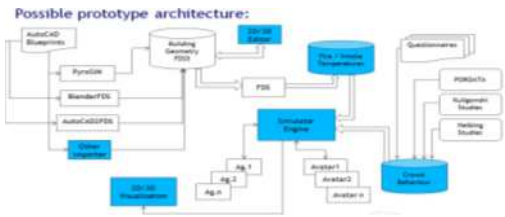
Select state-of-the-art pedestrian simulator (in-house ModP?) to allow for appropriate analysis of social interaction parameters



Combine Serious Games and Simulation to implement behaviour elicitation and assimilation



Implement appropriate verification and validation techniques of social behavioural models



Pedestrian Behaviour Modelling & Simulation

Future work:

- Serious games simulator
- More data collection
- Data elicitation
- Peer Design Agents
- ?

Thank You!

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Thank You!

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