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Challenges in Simulation of Pedestrians and Motorised Traffic

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Background

- The analysis of pedestrian interaction with motorized traffic in urban areas may allow to understand the behaviour of road users and their response to various strategies or interventions, to more efficient planning of pedestrian facilities and traffic control, and more accurate estimation of pedestrian safety level.
- The complex and dynamic nature of pedestrians movement can not be easily addressed by algebraic models, and simulation often appears to be a more appealing modelling approach.
- However, simulation models of pedestrian movement have been criticised for lacking the explanatory power required to enable their exploitation for planning and engineering purposes.

Objectives

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- The analysis of the state of the art in pedestrian simulation models
- The identification of key issues for further research

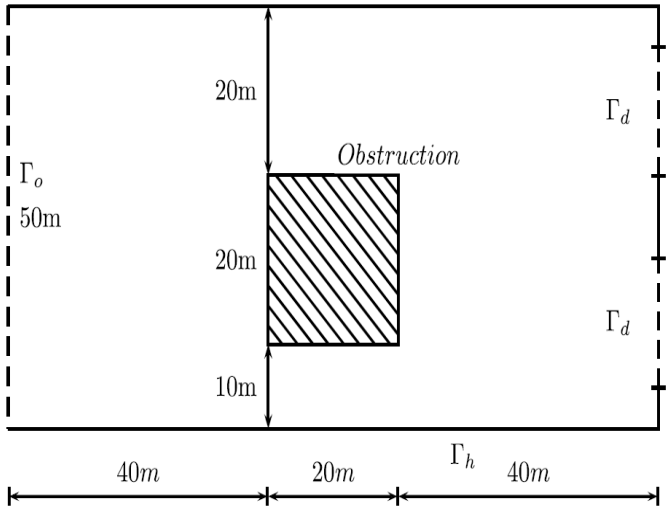
- With particular focus on the modelling of pedestrians and motorised traffic.

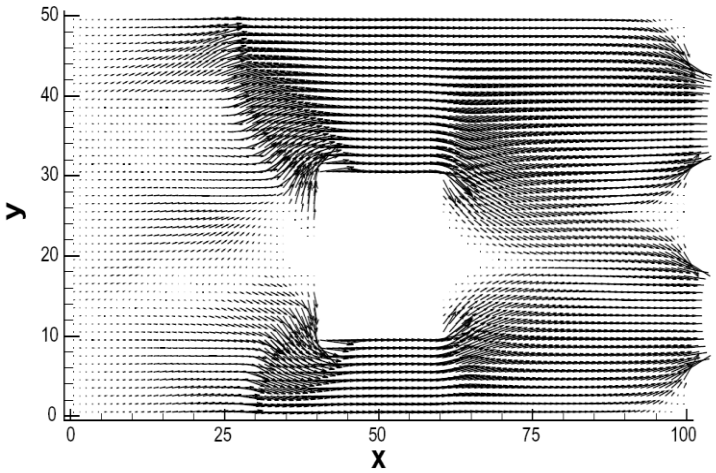
- **Outline**
- Review of pedestrian simulation models
- Challenges in pedestrian simulation
- Discussion

Review of pedestrian simulation models

- **Macroscopic models**
- Earlier models
- Based on traffic flow and queuing theory, or in fluid or continuum mechanics

		Problem			Simulation framework							Interactions				
					Time model		System Transition		Rules							
Author	**Year**	traffic flow	crowd / evacuation	route choice	Continuous	discrete	time-based	event-based	traffic / kinematic	logical / literature	Models driven	Other pedestrians	Road environment	obstacles	Traffic	Observational Data
Hunt and Griffiths	1991	●			●		●			●	●		●		●	●
Mitchel and Smith	2001	●			●			●	●		●	●	●			
Hughes	2002	●										●	●			
Daamen et al.	2005	●										●		●		●
Huang et al.	2009	●										●				
Jiang et al.	2012	●	●		●		●		●			●	●	●		●
Bergman et al.	2011	●											●		●	●





Source: Huang et al. (2009)

Review of pedestrian simulation models

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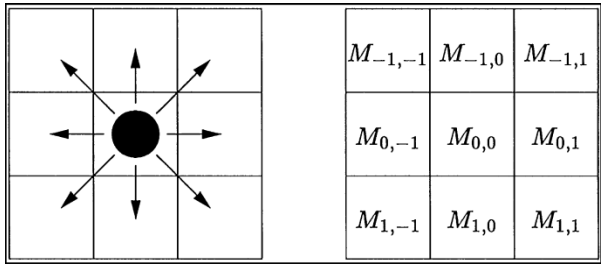
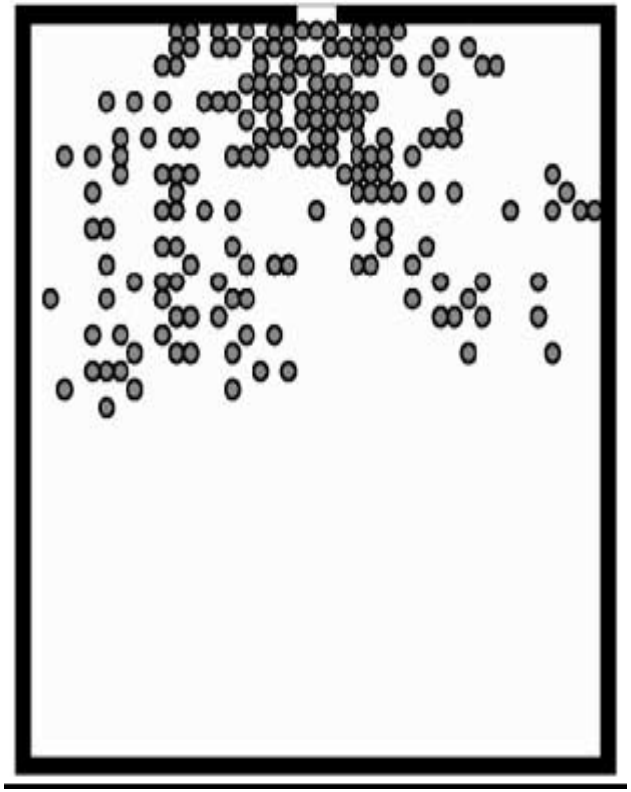
- **Microscopic models: Cellular automata**



- Pedestrians move on a grid of cells
- A set of rules defines the state / occupation of a cell in relation to the neighbourhood of the cell
- A transition matrix is used to update the cell states in successive time steps.

		Problem			Simulation framework: Time model		Simulation framework: System Transition		Simulation framework: Rules			Interactions				
Author	Year	traffic flow	crowd / evacuation	route choice	Continuous	discrete	time-based	event-based	traffic / kinematic	logical / literature	Models driven	Other pedestrians	Road environment	obstacles	Traffic	Observational Data
Gipps and Markjo	1985			●		●	●		●	●		●		●		
Borgers and Timmermans	1986			●		●	●			●	●		●			●
Lóvås	1994		●			●		●	●			●		●		
Blue and Adler	2001		●			●	●			●		●		●		
Burstedde et al.	2001		●		●	●	●		●	●		●		●		
Weifeng et al .	2003		●			●	●			●		●				
Liu et al.	2000	●		●		●	●			●	●	●	●		●	
Wakim et al.	2004			●		●	●			●					●	
Lee and Lam	2008			●		●	●		●	●		●				●
Yue et al.	2010		●			●	●		●	●		●				●
Feng et al.	2013		●			●	●		●	●		●	●			●



Source: Burstedde et al. (2001)

Review of pedestrian simulation models

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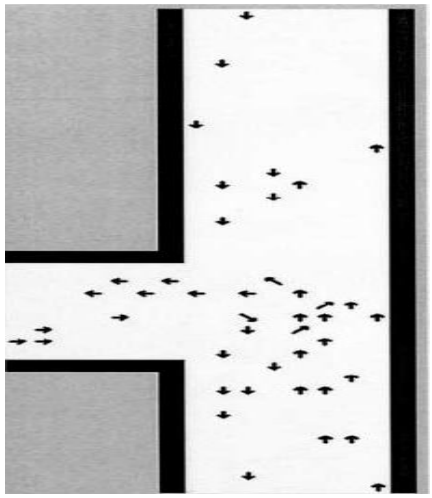
- **Microscopic models: Multi-agent simulation**

- Based on artificial intelligence techniques.
- Pedestrians are treated as fully autonomous entities with cognitive and learning abilities.



		Problem			Simulation framework							Interactions				
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Author	Year	traffic flow	crowd / evacuation	route choice	Continuous	discrete	time-based	event-based	traffic / kinematic	logical / literature	Models driven	Other pedestrians	Road environment	obstacles	Traffic	Observational Data
Batty and Jiang	1999		●	●		●	●		●	●		●	●	●		●
Kukla et al.	2001		●	●		●	●		●	●		●	●	●		●
Dijkstra and Timmermans	2002			●		●	●			●		●	●	●		
Teknomo	2006		●			●	●		●		●	●		●		●
Osaragi	2004		●			●	●		●		●	●		●		●
Kitazawa and Batty	2004			●		●		●			●	●	●	●		●
Hoogendoorn	2004		●		●		●		●		●	●		●		
Hoogendoorn and Bovy	2004			●		●	●		●		●	●	●	●		●
Antonini et al.	2006			●		●	●		●		●	●		●		●
Airault et al.	2004	●		●		●	●		●	●		●	●		●	
Godara et al.	2007	●		●		●	●		●	●			●		●	
Gaud et al.	2008			●		●	●		●	●		●	●		●	
Guo et al.	2010		●		●	●	●		●	●	●	●				●
Dai et al.	2013		●		●		●		●			●	●			●
Usher and Strawderman	2010			●	●		●			●		●	●			

Source: Dijkstra & Timmermans (2002)

Assessment of existing models

- **Scope of analysis**
- Mostly pedestrian flow, crowd and evacuation
- The interaction of pedestrians and traffic is explored to a much smaller extent.

- **Pedestrians movement algorithms**
  - basic kinematic or traffic flow equations.
  - 'social forces' rules (crowd analysis)
  - utility maximization (cost minimization, shortest path etc.)
- None of them is realistic enough, each one may be adequate under specific conditions.

- **Simulation Models**
- Mostly fully stochastic ones (i.e. random draws)
- Occasional use of probabilistic or deterministic sub-models
- Do not adequately take into account the effects of various determinants (roadway, traffic, crowd, and individual pedestrian's characteristics)

Challenges in pedestrian simulation

- **Methodological and practical difficulties in modelling pedestrians and motorised traffic**
  - Larger number of restrictions in pedestrian movement on a road network, compared to pedestrian movement in a ‘dedicated’ pedestrian facility;
  - Baseline differences in the structure and type of pedestrian and vehicle networks;
  - The different behavioural ‘levels’ involved in pedestrian movement;
  - A lack of knowledge and understanding of pedestrian strategies, tactics and operational decisions on the road network.

The Hierarchical Model of Pedestrian Behaviour

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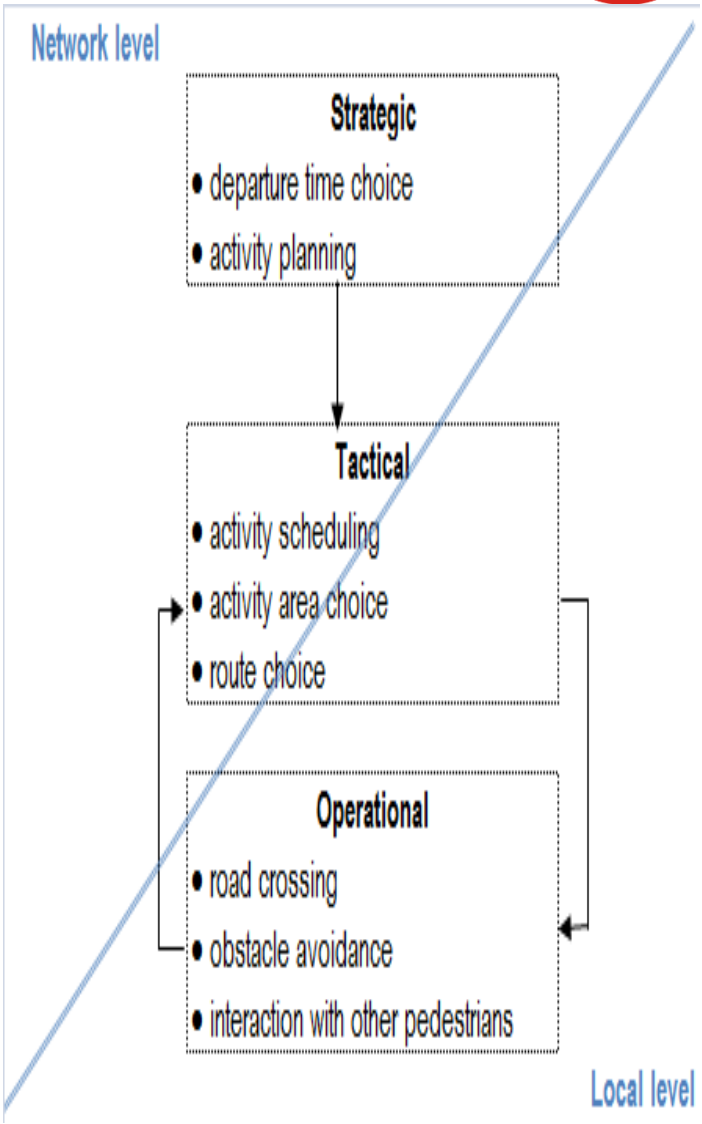
- **Hierarchical model of behaviour** (strategic / tactical / operational)
- Strategic and tactical choice models are developed at network level, while some of the tactical choice models and all of the operational choice models are developed at local level
- No general consensus as regards the specific components of each behavioral level
  - road crossing and route choice may be assigned to either the tactical or the operational level depending on the scale of analysis
- The interaction of choices taken at the upper level with choices taken at the lower level should be addressed.
- All types of choice are largely based on the balancing of pedestrian's risk acceptance vs. delay acceptance.



Parameterisation of vehicle and pedestrian networks

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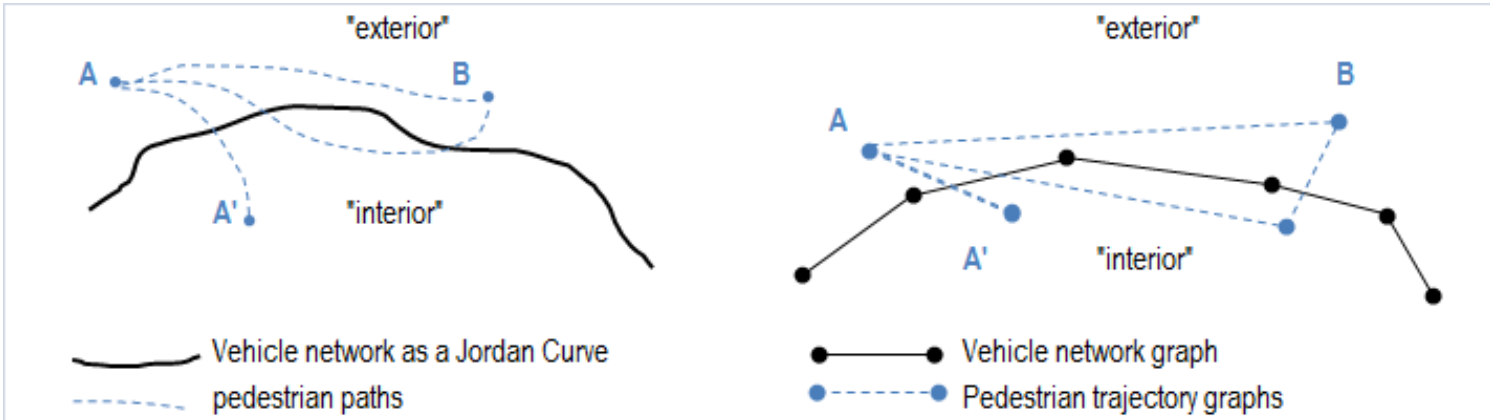
- Vehicle networks are easily represented by links and nodes, but pedestrian trajectories are not situated on these links and nodes
- Vehicle networks and pedestrian trajectories intersect while road crossing
- In most of existing simulation models, pedestrians are either allowed to cross roads randomly in an ‘empty’ road network, or constrained to cross at dedicated locations
- The networks description should allow to simulate a shared space, to simulate pedestrians who cross the street at any point along the sidewalk etc.
- The relationship between vehicle and pedestrian networks and trajectories needs to be formalized
  - Topological concepts (‘interior’, ‘exterior’ and ‘neighbourhood’ of an object)
  - Graph theory concepts (nodes, links, dual graph, ‘adjacency’)



Integration of probabilistic models and simulation

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- Integration of models-driven rules in the simulation should be envisaged.
- In most microscopic models, rules are mostly derived from existing literature results or observational data.
- There is increasing evidence that pedestrian behaviour and choices are probabilistic, and the effects of the various determinants can be quantified in statistical analyses.
- The exploitation of probabilistic models in pedestrian simulation may lead to better exploitation of the advantages of both approaches

Conclusions

- Pedestrian simulation is a very popular research topic, examining important aspects of pedestrian behaviour and providing useful insights on pedestrian movement in various conditions.
- Existing simulation tools focus on crowd, evacuation or route choice in an ‘empty’ network.
- The different aspects and levels of pedestrian behaviour are examined separately and not consistently.
- Three main challenges for the simulation of pedestrians and motorized traffic in urban areas were identified:
  - depart from and account for the hierarchical behavioural model of road users
  - description and parameterization of vehicle and pedestrian networks exploit in the simulation the results of statistical and probabilistic models

Conclusions

- The simulation of pedestrians and motorized traffic involves methodological and practical difficulties possibly to a greater extent compared to the simulation of pedestrians alone.
- The new approaches for the management of urban systems, such as the “safe systems” approach and the “shared space” concepts, bring forward the need to take into account the interactions between pedestrians and traffic within the system.
- The simulation of pedestrians and motorized traffic should receive more attention in future research, in order to address the current difficulties and limitations, and eventually provide researchers and policy makers better tools to assess the mobility and safety implications of pedestrian movement in urban systems.

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