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# WALK THIS WAY

## A MULTI-AGENT BASED APPROACH TO PEDESTRIAN SIMULATION

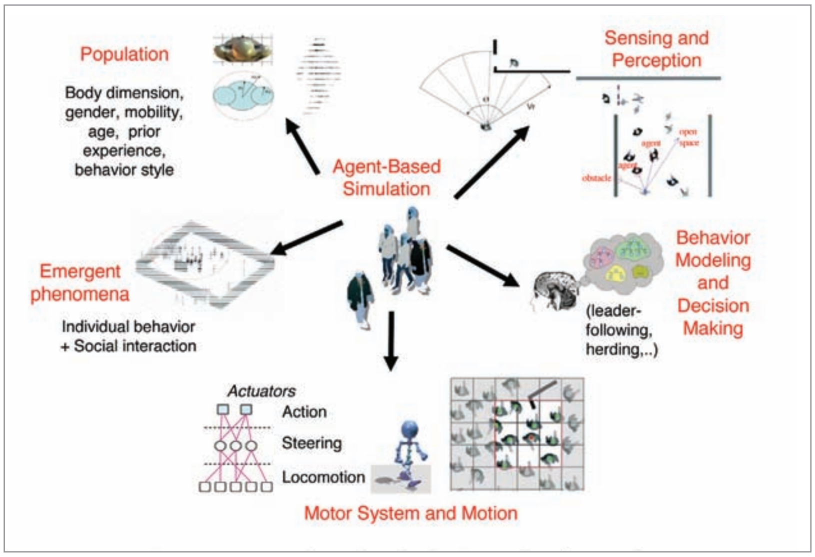
[ It is very difficult to develop realistic and robust models that account for complex human behaviours for a wide range of scenarios ]

Pedestrian modelling and simulation have attracted much interest from a wide range of disciplines, including architectural design, safety engineering, emergency planning, computer science, psychology and sociology. In computer games, automated generation of pedestrians can be used to enhance the realism of a virtual environment. In film making, computer-generated crowds, which consist of a large number of animated characters who can respond individually to their surroundings, have been popularly used to create impressive battle scenes.

In addition to entertainment, crowd and pedestrian simulations have been used to assist in the egress design of facilities such as airports and rail stations, and in safety engineering for emergency response training and disaster management. In social science, pedestrian simulation can be used to study group and crowd dynamics, and the collective social behaviour of people at gatherings, assemblies, protests, rebellions, concerts, sporting events and religious ceremonies. Pedestrian simulations enable human behaviour under extreme circumstances to be studied and experimented, providing insights that help save lives.

Even for normal situations, pedestrian simulation can help improve existing environments so that potential problems such as overcrowding can be eradicated in advance. One example is a recent pedestrian simulation study performed for London Euston station, which showed that changing the location of ticket gates and the hall layout could effectively reduce passenger flow congestion (Crowd Simulation Blog, 2010).

Despite the progress that has been made in the past several decades, pedestrian simulation remains challenging because it is very difficult to develop realistic and robust models that account for complex human and social behaviours for a broad range of scenarios. This




article introduces a multi-agent based modelling approach (sometimes referred to as Agent-Based Modelling, or ABM), which has emerged as the most widely accepted simulation approach in studying complex systems. A pedestrian simulation model, MASSEgress (Pan, 2006; Pan et al, 2007) is used to illustrate the approach.

**EXISTING APPROACHES** Computational tools for pedestrian simulation exist (Helbing et al, 2000; Thompson et al, 2003; AEA Technology, 2002; Halcrow Group Limited, 2003). Generally speaking pedestrian simulation models can be categorised into fluid or particle systems, matrix-based systems, or multi-agent based systems.

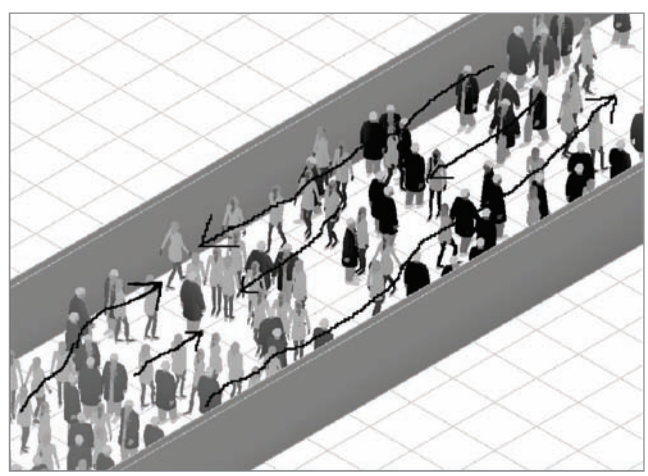
Considering the analogy between fluid and particle motion and pedestrian flow, systems have been developed to simulate and help design evacuation strategies. One approach, for example, is to pre-compute an evacuation map to represent the relative 'elevations' of spaces, where people would flow from higher to lower grounds. For matrix-based systems, floors and spaces are separated as cells, which represent open spaces, obstacles, areas occupied by pedestrians, or regions with other environmental attributes. People transit from cell to cell based on occupancy rules defined for the cells, thus creating pedestrian flows.

There are, however, many questions regarding the basic assumptions for the fluid or particle analogy and for matrix systems. People, unlike fluid or particles, "do not follow the laws of physics; they have a choice in their direction, have no conservation of momentum and can stop and start at will" (Still, 2000). Furthermore many of the matrix-based systems suffer from difficulties in simulating social behaviours and evacuation patterns, such as herding, multi-directional or cross flow and uneven crowd distributions, that contradict field observations (Still, 2000).

> [ Multi-agent based modelling has emerged as a popular approach for pedestrian simulation for good reasons ]

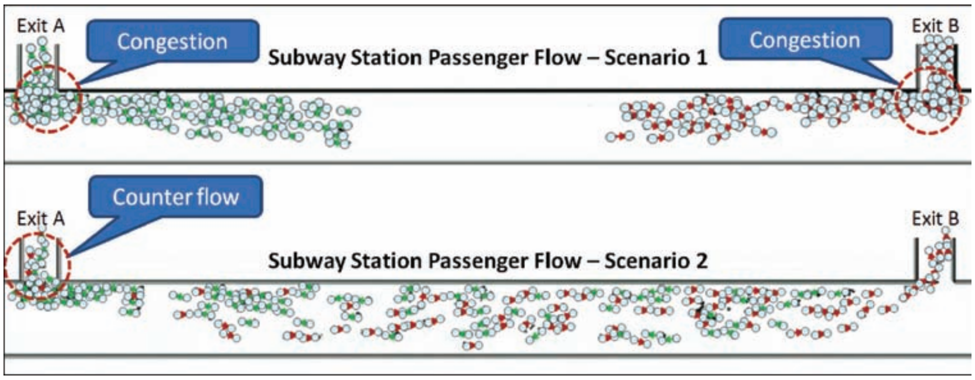
Multi-agent based modelling has emerged as a popular approach for pedestrian simulation for many good reasons. A crowd is a complex system and the collective behaviours of pedestrians in the crowd are often viewed as the emergent properties of the system. The multi-agent based approach is a dominant paradigm in social simulation due to a widely accepted view that suggests that complex systems emerge from the bottom up, are highly decentralised, and are composed of a multitude of heterogeneous parts called agents. Many researchers have adopted this approach to produce simulation models for pedestrian flows (Legion International, 2004; Narian et al, 2009).

While current agent-based simulation models are now able to simulate very large, dense crowds composed of up to a hundred thousand agents at near interactive rates on desktop computers, behavioural representation of individuals and groups remains simplistic. Current simulation tools focus on the modelling of spaces and crowd movements but rarely take



1. Figure 1: Agent-based approach for MASSEgress

2. Figure 2: Bidirectional pedestrian flow




into account human decision making and social behaviour (Kuligowski and Peacock, 2005; Santos and Aguirre, 2004). Including the sociological and psychological components of pedestrian behaviour is fundamental to developing pedestrian simulation models. The field is constantly making progress on this front; however much work remains to be done.

**MASSEGRESS SIMULATION FRAMEWORK** MASSEgress, or Multi-Agent Simulation System for Egress Analysis, is a research prototype that attempts to incorporate human behaviour, social interactions and group dynamics for pedestrian evacuation and design simulation. Figure 1 shows conceptually the agent-based approach for MASSEgress. Each agent is assigned its physical and social behaviour and is equipped with sensing and decision-making abilities to interact and react within a crowd and the environment. Using MASSEgress, the collective behaviours of pedestrians are simulated and emerged through modelling of individual physical and social behaviour and their interactions.

The system architecture of MASSEgress consists of six basic modules: a Geometric Engine, a Population Generator, a Global Database, a Crowd Simulation Engine, an Events Recorder and a Visualiser.

• The Geometric Engine generates the geometries representing a facility, such as a building or a train station, and its physical environment. Spatial information, including obstacles, exits, spatial layouts, exit signs, etc, can be conveniently defined using CAD tools such as Autodesk's AutoCAD or Architectural Desktop.

• The Population Generator generates the occupants based on a distribution of age, mobility, physical size, facility type and other human and social factors. This module allows the system to generate groups and random populations to study individual human and crowd behaviours.

• The Global Database maintains all the information about the physical environment and the agents during a simulation. It maintains the state information (mental tension, behaviour level, location, etc) of the individuals. The database is also used to support interactions and reactions among the individuals and groups.

The events captured can also be used for comparison with known scenarios

• The Events Recorder captures the simulated events for retrieval and playback. The results are recorded for further use, such as to derive evacuation patterns via statistical analysis. The events captured can also be used for comparison with known and archived scenarios.

• The Visualiser, currently implemented using OpenGL, receives the positions of agents and then dynamically generates and displays simulation results as 2D/3D visual images.

• The Crowd Simulation Engine is the key module of MASSEgress. Each agent is assigned physical and behaviour models according to the Population Generator. The simulation follows a perception-interpretation-action approach where each agent perceives the information (such as sensory input, crowd density, tension) about the situation, interprets and chooses individual, social and group behaviour rule(s), and executes the decision through its motor skill.

The modular design of MASSEgress allows investigation of pedestrian dynamics and incorporation of behaviour models. Diverse individual behaviours can be modelled and collective social behaviour simulated through the processes of sensing, behaviour selection and decision making, and execution of individual movements. Social behaviours are complex phenomena that emerge from interactions among individuals; they are sensitive to individual behaviour, group size, heterogeneity of individual agent behaviours. MASSEgress is able to simulate many typical social behaviours, such as like competition, queuing, herding and others. For example, Figure 2 shows a screenshot of bidirectional pedestrian flow from a simulation using MASSEgress.

By defining different behaviours and goals of individual agents, the resulting pedestrian flow patterns can be quite different. Figure 3 illustrates two evacuation scenarios for a subway station where the passenger platform has two exits that lead to the ground level. A population of 200 pedestrians were distributed randomly on the platform where agents marked with green arrows seek to exit at Exit A and those with red arrows seek to exit at Exit B.

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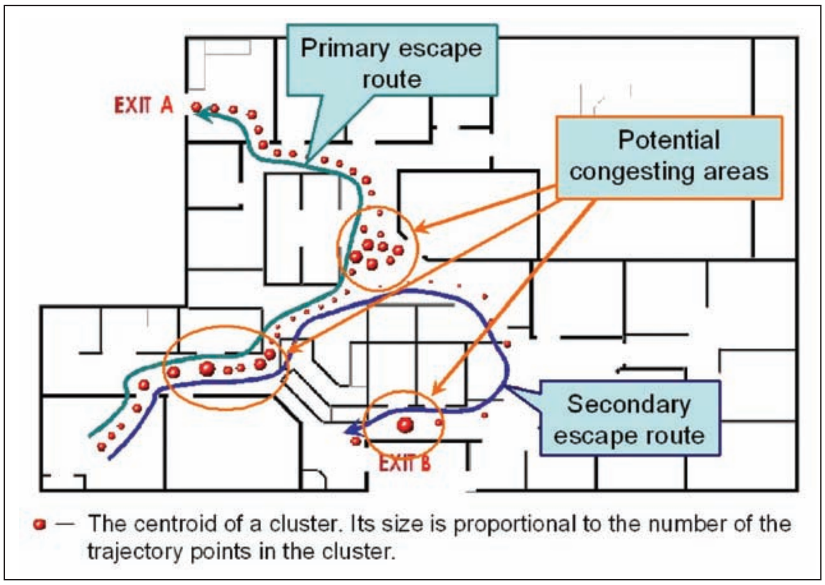
1. Figure 3: Pedestrian flow simulation for a subway station




Both the screenshots shown in Figure 3 were taken 30 seconds after the simulations began.

Scenario 1 assumes that all pedestrians would seek the nearest exit and then compete to leave the station. As a result congested areas emerged at both exits. For scenario 2, half of the pedestrians are randomly assigned to use Exit A while the other half use Exit B. A congested area emerged at Exit A, which was primarily caused by a counter flow initiated by a few pedestrians (with red arrows) attempting to travel to Exit B all the way from Exit A.

These two scenarios illustrate that, under the same physical environment, the collective behaviour patterns can be very different, depending on individual pedestrian behaviour and goal. MASSEgress can be used to study a variety of behaviour types and scenarios. For example, evacuation patterns, which may be useful for design evaluation and for identifying potentially congested areas (see Figure 4), can be discovered by statistically analysing a series of simulated events (Pan et al, 2007).

**CONCLUDING REMARKS** Pedestrian modelling and simulation find many applications in computer games, film-making, building and facility design, emergency planning, and crowd management. Multi-agent based simulation systems such as MASSEgress are now able to simulate some complex social behaviours such as herding, competition, queuing and bidirectional flow through modelling individual pedestrian behaviour and interactions among pedestrians. As psychologists and social scientists gain better understanding of human behaviour and crowd dynamics, more sophisticated pedestrian behaviour models will emerge.

Continuing advances in computer simulation methods and computer hardware will allow hundreds of thousands of pedestrians, each driven by sophisticated human behaviour models, to be simulated. An agent based simulation framework that can incorporate the characteristics of individual and group behaviours can help provide safer public environments, advance the state of practice in safety engineering, facility design and management, and facilitate knowledge transfer between technology and social science research.

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**1. Figure 4: Discovering potentially congested areas – applying a K-mean clustering algorithm on 50 pedestrian flow simulations on an office floor plan (Pan et al, 2007)**