**THE DIVERSITY OF POPULATION FOR CROWD MODELLING IN EMERGENCY SITUATIONS**

**1. Motivation and Research Questions**

Rapid urbanization and population growth always are inevitable challenges for every country in the effort of planning infrastructure, estimating traffic needs and capacities, and increasing the safety of pedestrians since over 70% of the world population is predicted to live in cities by 2050 (Weidmann, 2012). With the increase in the number of events and the accidents often happen during these events (Evers, 2011), the prediction of congestion, planning of evacuation strategies, and the assessment of building layouts become important aims for risk management in urban design and crowd safety. The key to achieve these aims is the understanding of the mechanisms leading to the formation of crowd self-organization at different events and situations especially in emergency situations (Moussaid, Helbing, Johansson, Theraulaz, 2009). Commonly studied crowd’s self-organization include lane formation, herding, bottleneck, turbulence, stop-and-go waves (Hoogendoorn, 2013). Therefore, many models of pedestrian behaviour have been proposed to describe how pedestrians move and interact to produce the patterns emerging at the scale of crowd. Noticeable models are social-force models, Nomad model, cognitive-walking models, and cellular automata model.

To make these models are sufficient to simulate crowd behaviour in emergency situations, various efforts have been done. They are mainly categorized into three aims. First aim is the studies focusing on calibration processes to find realistic parameters of current models. Second aim is the works trying to extract useful information through particle-based approach that can detect anomalous situation. The last effort is the studies trying to understand specific behaviours which could be performed by pedestrians in panic situations such as herding, social group influence, visual information acquisition.

State of the art in the first aim is to find actual parameter values of crow models. Well-known models such as social-force model (Helbing, 2000), Nomad model (Hoogendoorn, 2003) were calibrated through video recordings of pedestrian’s trajectories in Germany and Netherland to find realistic data of model’s parameters such as average velocity, desired velocity, interaction strength of pedestrians (Johansson & Helbing 2007), (Daamen & Hoorgendoorn, 2012). Social-force model was then used to explain the LoveParade disaster happened in Germany, 2010 (Helbing, 2012). The report of survivors from another fire disaster occurred in the nightclub Lame Horse in Perm, Russia in the year 2010 was used to calibrate a panicking model’s parameters including velocity, crowd density on forward directions (Bratsun, 2013). Another recent study (Zeng, 2014) also performed acquiring actual parameters of social force model when simulating pedestrians at crosswalks. The study was performed and calibrated in Japan since more than 30% of fatal traffic accidents there were pedestrians.

State of the art in the second aim is to find data that help models predict abnormality. There is studies (Moore, 2011, 2012) investigating on particle trajectories and measuring interaction forces of these particles through consecutive video frames. There are also other studies focusing on image processing and computer vision to find the difference between consecutive video frames (Rao, 2014), (Greenewald, 2014).

For the last effort to understand human behaviour in panic conditions, Couzin and colleagues (Couzin, 2012) studied socially transmitted visual attention of pedestrians in different contexts of social group sizes and high-dense streets. The study found that pedestrians easily follow the gaze direction of other pedestrian groups because it may provide them relevant information about their current attention and environment information. Moussaid and colleagues (Moussaid, 2010) investigated on the impact of social interactions of group members on walking patterns. They found that group member tends to go side by side and V-like pattern in low and high dense places respectively.

However, above three efforts almost make the assumption that populations are homogeneous and well-mixed, which is not true for real population at different pedestrian-oriented places such as sport stadium, high schools, company venues (Johansson, 2012), (Leeson, 2014). A recent calibration work (Hoorgendoorn, 2012) found that pedestrian types, who are different in ages, interact very differently in congested or evacuation conditions than in normal condition. Therefore, the impact of different pedestrians in the same crowd on crowd dynamics hasn't yet been explored. It yields a fundamental consideration about whether or not a single model with single parameter set is sufficient to cover population's information in emergency situations. Moreover, understanding crowd dynamics in emergency situations of turning, merging, and diverging scenarios is necessary for evacuation plan in traffic networks containing different micro-flows (Shiwakoti, 2011).

Thus, this PhD study proposes two research questions to investigate heterogeneous information in the same population to build models in emergency situations.

**Question 1**: How to model the difference of pedestrian types in the same population in emergency situations?

* Is there a difference in escape rates and blockage occurrences between models using single and different parameter distributions in one-exit gate evacuation situation?
* What is the impact of different pedestrian types in merging, diverging, and turning situations?
* How to construct actual parameters for different pedestrian types in above situations?

**Question 2**: What data should be captured for emergency response when crowd phenomena unfold in the micro-flows of merging, diverging and turning scenarios?

* How to verify the importance of that data?

Two proposed research questions aim to construct a set of differential equations for pedestrians in same population in emergency situations and investigate insightful data for emergency response when these situations unfold. The questions are expected to give practical uses. It allows flexibility when performing real-time crowd modelling in different places. Also, it offers key information from crowd phenomena in live events which can give event organizers decisive minutes to try and restore the order of crowd before deteriorative situations can occur.

**2. Research Methodology**

To address the question **Q1** that aims to model the difference of pedestrians in different scenarios of merging, divering, and turning, social force model (Helbing, 2000) is used to perform simulations since it is sufficiently to produce commonly observable crowd phenomena (Hoogendoorn, 2013). A simulation tool is developed based on the model. Developing this tool will allow us to easily customize initial parameters of each pedestrian and environment, and monitor expected information from crowd.

Investigating what causes the difference in escape rate and blockage occurrences is then performed respectively on one and two dimensional simulations with simplified versions of social force model. It aims to understand the impact of possible reasons (e.g. parameter distribution, placements, velocities of pedestrians during simulation duration before phenomena occur).

Exploring the impact of pedestrian types in different scenarios is then investigated from real-world video recordings. They include real-world data of 1200 interchangeable participants over five day experiment in Germany generated by International Partner Investigator Armin Seyfried (Lammel, Seyfried, Bernhard, 2014) in turning, emerging, and diverging scenarios. This study will analyse different approaches using pedestrian tracking and particle advection (Moore, 2011) to extract the average distribution of parameters in social-force model used to simulate these scenarios. Since the data doesn’t comprise explicitly information of different pedestrian types, we then derive parameter distributions likely for different pedestrian types but make sure the constraint of average distribution parameters. The parameter distribution generation follows the comparison rules between interaction distributions of elders, adults and young pedestrians (Hoorgendoorn, 2012). Possible impacts such as the turbulence in crossings, how quickly they diver in multiple corridors are investigated.

Constructing actual parameters of pedestrian types in these scenarios is performed through game simulation. The key idea to collect data of pedestrian types in the scenarios is based on game simulation. An evacuation game will allow participants, who are different in ages, can join in a simultaneous network and interaction each other to escape fire disasters by using a pre-defined range distribution for each parameter in the social-force model. This approach will allow us to calibrate the model at different scenarios and help us know more about how adult, young, and elder people behave in emergency situation.

1. **Reference**

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