**MODELS, THE DIVERSITY OF POPULATION FOR CROWD DYNAMICS 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 of data acquisition 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 of data acquisition that helps models predict crowd phenomena is very few. There is only studies (Moore, 2011, 2012) investigating on particle trajectories and measuring interaction forces of these particles through consecutive video frames. However, these studies only focus on the analysis of mutually interacting particles to detect anomalies in video recordings rather than the prediction of crowd behaviour emerging. Currently, there are also other studies focusing on image processing and computer vision to find the difference between consecutive video frames (Rao, 2014), (Greenewald, 2014). However, they still couldn’t answer how crowd behaviour is constructed.

Moreover, key information inside crowd when these phenomena unfold should be captured. It’s important for real-time modelling to make models can detect the change of crowd behaviour and potentially supporting effective and flexible disaster management. Specifically, in evacuation situation, information that can make evacuation faster when bottleneck phenomena occur should be collected for emergency response. Thus, this PhD study proposes two research questions towards data acquisition for crowd modelling.

**Question 1**: What data support to predict crowd’s self-organization phenomena?

* Why do these self-organization phenomena happen?
* What comparative combination of data can help to predict these phenomena?
* How to acquire these data effectively for real-time crowd modelling?

**Question 2**: What data should be captured for emergency response when crowd phenomena unfold?

* How to verify the importance of that data?
* How to collect that data for real-time crowd modelling?

Two proposed research questions aim to investigate unexplored data to predict crowd phenomena and give insightful data when these phenomena unfold. The questions are expected to give practical uses. With real-time crowd modelling capability to analyse real-time footage of crowd movements, areas around entrances and exits of the layout in mass events can be captured to prove foreseeing danger. Also, capturing key data from crowd phenomena in live events can give event organizers decisive minutes to try and restore the order of crowd before deteriorative situations can occur.

**2. Research Methodology**

This PhD project aims to investigate various data sources (video recording, mobile phone, and traffic flow) to extract useful data for real-time crowd modelling that supports prediction of crowd movements and planning of emergency response.

To address the question **Q1**, commonly crowd’s phenomena mentioned in the survey (Hoogendoorn, 2013) (e.g. bottleneck, stop-go-waves, lane formation, herding) are investigated. According to the survey, social force model (Helbing, 2000) is sufficiently to produce above phenomena; thus, firstly a simulation tool is developed based on the model in order to observe these phenomena. 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 crowd phenomena 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) accounting for the creation of these phenomena.

The comparative utilities of possible reasons are then investigated to trade off performance and accuracy. Also, they will be studied on different simulation scenarios (different layouts, and crowd population size, etc). This aims to enhance the predictive capability of crowd models for applying in different actual situations. For instance, to understand crowd bottleneck, we will construct simulation scenarios from a quantitative study of evacuation situations conducted in Finland (Rinne, Tillander, Gronberg, 2010). They include eighteen evacuation situations in different building types ranging from hospital to stadium were conducted in Finland in 2007 to 2010. These situations are detailed with floor layout information and total quantitative data including (total evacuation time, crowd population, and crowd speed). Other methods to predict crowd phenomena such as mutual information method used in complex, dynamical system of interacting particles (Vicsek, 1995) will be investigated as well. One of noticeable efforts in applying this method for detecting the early-stage formation of crowd crush analysis was studied on the disaster happened at the Station Nightclub in the year 2003, Rhode Island, USA, which caused 96 deaths over 440 people occupied (Harding, 2010).

After having comparative utilities from simulations, this study will address how to acquire them from available real-world video recordings of massive crowd events. They include real-world data of 1200 participants over five day experiment in Germany generated by International Partner Investigator Armin Seyfried (Lammel, Seyfried, Bernhard, 2014), and possible data from Sarvi’s studies (Sarvi, 2013). This study will analyse different approaches using pedestrian tracking and particle advection (Moore, 2011) to extract above comparative utilities for optimal performance purpose.

To address the question **Q2**,this study will focus on specific crowd phenomena that are useful for clear purposes (e.g. evacuation plan response when bottleneck occur, optimal lane separation response when crowd lanes emerge). A noticeable study (Moussaid, 2012) investigated “social dilemma” phenomena when crowd lanes created. This phenomena means fast-walkers in lane decrease the collective walking speed of the group. This information was then suggested for urban design as the author believes it’s important for reducing traffic jams.

In this study, idealised and actual scenarios in simulations are fundamentally compared on flowrate, escape rate, etc. Idealised scenarios mean that insightful information when phenomena unfold is detected in-time and emergency response takes action. Actual scenarios are original crowd behaviour without emergency response.

One of the disasters having clear evidences is the crush disaster happened at the Station Nightclub, USA (2003); its technical report was conducted by National Institute of Standards and Technology, USA and allowed for further investigation (Grosshander, 2005). The report includes layout information, time events in the disaster and positions of injured people. Thus, this study aims to construct the simulation of the disaster as the previous study (Harding, 2010) performed to measure the effectiveness of data that should be captured when crowd bottlenecks occur and how emergency response can take action to allow faster evacuation.

1. **Reference**

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