**THE HETEROGENEITY** **INSIDE POPULATION TO ENHANCE CROWD MODELLING IN EMERGENCY SITUATIONS**

***Abstract:***

*Nowadays, crowd modelling becomes more important in the effort of disaster prevention due to the increase in the number of public events and rapid urbanization. Various approaches have been proposed to make crowd models more realistic in emergency situations. Investigating crowd dynamics which unfold in both of normal and emergency situations is the key to make current models more realistic since real-world emergency data is sparse. Social group dynamics has been approached in both of happened disasters and evacuation scenarios. However, integrating social group influence into crowd motion models has not been explored fully since these models make assumption that populations are homogeneous. Thus, this study will explore the impact of social group dynamics in evacuation scenarios of different pedestrian types, who are different in ages, and then propose the data collection framework to finally contribute an adaptive crowd model integrating this dynamics. It aims to allow crowd models represent group dynamics influence between pedestrian types inside crowd. Generally, the model can be adapted in different pedestrian-oriented venues and with the change of crowd behaviour from moving individually to following.*

1. **Introduction**
   1. Human crowd disaster through chronological evidences
   2. Efforts in crowd disaster prevention
   3. Crowd modelling importance
2. **Background**
   1. Crowd motion flows and self-organization phenomena in human crowd
   2. Crowd modelling at different scopes
   3. Crowd model enhancement

**3. 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 crowd dynamics leading to the formation of crowd self-organization at different events and situations especially in emergency situations (Moussaid, Helbing, Johansson, Theraulaz, 2009). Observable studied crowd’s self-organization include lane formation, herding, bottleneck, turbulence, stop-and-go waves. 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. Highly recommended model are social-force models, Nomad model, and cellular automata model, behavioural heuristic rule model (Hoogendoorn, 2013).

To make these models are sufficient to simulate crowd behaviour in emergency situations, two main efforts have been done. First effort is the studies focusing on calibration processes to find realistic parameters of current crowd models. Second effort is the studies trying to understand and simulate uncontrolled behaviours (leader-follower, competitive) in emergency situations (Shiwakoti, 2010).

State of the art in the first effort is to find actual parameter values of crowd 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. Another study, (Aguirre, 2011), used agent-based model to simulate the crush disaster happened at the Station Nightclub, USA (2003) through the technical report technical conducted by National Institute of Standards and Technology, USA.

In the second effort, various social factors describing leader-follower behaviour have been investigated and then integrated into agent-based models to replay known disasters and simulate various evacuation scenarios. By using the timeline-event report of the disaster Station Nightclub, (Aguirre, 2011) categorized leaders based on age, gender, environment familiarity and then defined ‘what-if’ rules for group members when following leaders to replay the disaster. The study was validated by comparing escape numbers of different prototypes (moving with group influence, moving individually) with actual survivor number. (Pelechino, 2006) also constructed a simulation environment and created different pedestrian roles (leader, untrained leader, group members) through agent-based model to simulate evacuation scenarios.

In the survey (Hoogendoorn, 2013), representing social group dynamics to produce herding phenomena hasn’t been explored in current motion models. It is caused by the fact that these models almost make assumption that populations are homogeneous and well-mixed, which is not true for real population at different pedestrian-oriented places (e.g sport stadium, high schools, working places) (Johansson, 2012) (Leeson, 2014). It is also explained that the earliest models including Reynold’s model (Reynolds,1987) and Social Force model (Helbing & Molnar,1995) averaged out potential influences to produce smooth flow of pedestrian movement (Collin, 2014).

In emergency situations, pedestrians almost do not move individually to escape. They are influenced by other pedestrian’s information (age, gender, environment familiarity) as justified through disasters occurred (Aguirre, 2011); they might become obstacles to other people in the worst case because they are waiting their expected leader. Although agent-based rules have been investigated variously to represent how agents follow other people, they can’t represent the group force in pedestrian’s desired motion (Wijermans, 2013) (Sun, 2014). The latest study from Helbing and colleagues (Moussaid, 2010) suggested that an additional group influence force should be included in current social-force model. However, they still made the fundamental assumption that populations are homogeneous and yet considered evacuation scenarios. Therefore, a study which explores the social influence should be contributed in this area. It should represent sufficiently the influence between different pedestrians inside group and how this influence makes pedestrians move faster or slower in emergency situations. This work is inspired by biological studies (Couzin, 2013) when they realize that individual fish have to balance personal information, potentially conflicting social information, and maintain group cohesion to minimize isolation risk. To address this problem, this PhD study proposes main questions:

**Question 1**: **What fundamental information makes pedestrians interact differently in emergency situations when only moving individually?**

It is questionable to differentiate types of pedestrians inside crowd since current crowd models only consider crowds are homogeneous. It will pave the way for further investigation of social influence on these types. Through the report of Station Nightclub disaster (Aguirre, 2011), pedestrians, who are different in ages, is one of physical factors make pedestrian might follow other. Also, a recent calibration work through experiments imitating emergency situations (Hoorgendoorn, 2012) found that children, adults, and elders interact very differently in congested or evacuation conditions than in normal condition. Therefore, this yields a fundamental consideration about whether or not a single model with single parameter set is sufficient to cover the different parameter distributions of pedestrian types.

Moreover, understanding crowd dynamics in situations of turning, merging, and diverging scenarios is necessary for evacuation plan in traffic networks containing different micro-flows (Shiwakoti, 2011). To answer Question 1, this study proposes two sub-questions:

**1.1 Does a population having different pedestrian types in ages generate different escape rate and blockages than a homogeneous population does in one-exit gate?**

To answer this sub question, a simulation tool is developed based on the social-force 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).

Status: Simulation completed

Expected outcome: The difference result in escape rate and blockages between two prototypes

**1.2 Do these two prototypes generate different escape rates, blockages and turbulence phenomena in merging, turning, and diverging scenarios?**

Possible impacts such as the turbulence in crossings, how quickly they diver in multiple corridors will be investigated.

Status: Simulation to be performed

Expected outcome: The impact of pedestrian types in evacuation scenarios will be quantitatively investigated.

**Question 2: What is the impact of social group influence in evacuation situations**?

After distinguishing pedestrians based on ages, this question aims to understand the impact when adding social group influence. From here, a social force model separated for three above pedestrian types will be used for this question. Social group influence force will be added into this model as Helbing’s suggestion (Moussaid, 2010). A population contains different groups inside (adult group, children group, elder group, and a group of three pedestrian types) will be investigated to understand group cohesion and the impact of group to each other in four experiments. Their results will be compared with the result of pedestrians escaping individually.

Case study 1: What is the impact when performing simulations of different groups escaping through one-exit gate, merging, diverging, and turning situations?

Case study 2: What is the impact in above situations when group size is changed and pedestrians in the same group are placed sparsely?

Case study 3: What is the impact when simulating pedestrian groups in a network of merging, diverging, and turning layouts?

Status: Simulations to be performed

Expected outcome: Proposed case studies aim to understand whether or not the group cohesion can generate obstacles to other groups and the impact of different group size. Moreover, a quantitative investigation on

* 1. Simulate Test with 18 scenarios of fire to see the different (corver from stadium, hospital)

maintain cohesion (Couzin , 2011), and delay, effect on other group size, People could lost their individualities and adopt the behaviour of stimulus group, meso, macro levels, crowd density. Will firstly, show the impact comparing between different types , to understand how they increase move forward into their group and become obstacles to other friends

**Questions 3: How to acquire actual data for different pedestrian types in above situations**?

3.1Technically?

3.2 Social aspect?

(group, talk a littlebbit, and then move, identify to meet there friend), what is cohesion between pedestrian types) different venues? An application is to collect data understand whether they are familiar with environment, age, group leader?

* 1. *mobile phone at different places (), group member,*

**Question 4:** How to measure and integrate with current force model, Uncertainty data?

Scope: pedestrian different in ages because previous disaster mentioned that, also allow to pedestrian-oriented venues.

Finally, integrate with social force is possibility (Swakoti).

collective behaviour during emergence/panic. When crowd changes its behaviour, how intergration behaviour force is good, how to define model this changes (dependence on speed, distance of current agent with leader, with other members), moving fast or low because of group leader, group size, weight role of leaders, in different, for different pedestrian types (follows by which),. How these changes under panic/ emergency situations, how current between pedestrian types , avoid other groups (competitive-disease).

**Question 5: How to calibrate and validate**?

* 1. Simulate Test with stationNight club bar, with group, individual, and ages
  2. Test with group sparse of data collection

**Question 6: Adapt when pedestrians stay at a places and disasters dynamically change?**

The questions are expected to give practical uses. It allows flexibility when performing real-time crowd modelling in different places, also allow change

**3.** **Thesis Structure**

**4. Project Trajectory**

**Project components**

**Workflow**

//figure here show 1D, 2D explaination

**Project Timeline**

**Project progress**

**Summary of Required Data**

1. **Coursework and professional development**
2. **References**

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)..

Constructing actual parameters of pedestrian types in these scenarios is performed through

With the potential of human sensing nowdays (2013), (Leeson,2014) and MIT calibrate social force (,2014)

* 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?
  + Turbulence,
  + Crowd pressure
* How to acquire actual data for different pedestrian types in above situations in technical and social aspects?
  + Fit construct different scenarios, workshop, ibeacon, indoor , an application will be downloaded , put into pocket, Bluetooth will record their indoor position. Lightweight (time, cost) method, pedestrians move naturally rather than in lab-controlled experiment. Easy to test in different situations placees.
    - A simulation 2D of FIT floor is constructed,
    - Evolutionary in different scenarios after collecting data
  + Deploy in other place as conference in Melbourne
  + An application on device will added on and need volunteer in naturally boxing day
    - At same scenario, derive maximum desired speed of children, adult, elderly. They don’t have to participate at same time. Information will be collected and then put in 2d dimension simulation to derive other information
  + Framework to manage that data
  + Velocity, and surrounding information let us know herding, follow, group social, different pedestrian types, aim to measure the difference between models of social forces
* How to calibrate and validate model in these micro flow? Log-likelihood estimation, evolution?

MOBILE APP lication screenshot, architecture server side

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