**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 a data collection framework to finally contribute a crowd model integrating this dynamics.*

1. **Introduction**
   1. Human chronological crowd disasters and disaster prevention
   2. The contribution of this study
2. **Background**
   1. Crowd motion flows and self-organization phenomena in human crowd
   2. Crowd modelling at different scopes, agent-based models
   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 describe agents follow other people, they can’t represent how the group force is integrated 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 and human studies of Couzin and colleagues. (Couzin, 2013) realize that individual fish have to balance personal information, potentially conflicting social information, and maintain group cohesion to minimize isolation risk. In human crowd, (Dyer & Helbing & Couzin, 2009) also realize that pedestrians always seek a potential leader in sudden situations. Thus, to address the social group dynamics in crowd motion models, 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), the difference of age is one of factors that make pedestrians might become follower or leader. Also, a recent calibration work through experiments imitating emergency situations (Hoorgendoorn, 2012) found that children (<14 years old), adults, and elders (>60 years old) interact very differently in congested or evacuation conditions than in normal condition. Therefore, this yields a fundamental consideration about whether or not a single crowd motion model with single parameter set is sufficient to cover the different parameter distributions of these pedestrian types.

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| --- |
|  |
| Figure 1. Differen pedestrians in ages distinguished by color cap are escaping invidivually through bottleneck in slop-whoop signal condition (Hoorgendoorn, 2012) |

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

**-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 is continuously investigating to understand more about the difference through simplified models in 1 and 2 dimensional simulations.

**- Do these two prototypes (heterogeneous and homogeneous population) 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 three case studies. 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 the group cohesion can become obstacles to other group’s movement, and how group is sunk and stretched because of other group’s pedestrians in these situations. It is also expected to see the impact when changing group size, such as how a pedestrian moves when intersecting with a group moving in a turning situation. Different network layouts are constructed from 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.

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

Recently, real-world data for crowd research becomes more important because of the demand in calibrating models and constructing new agent-based rules (Helbing, 2011). The currently largest accessible dataset in this area is from real-world data constructed by 1200 participants over five-day experiment in Germany (Lammel & Seyfried & Bernhard, 2014). However, conventional data acquisition techniques, which rely on camera-based approach, make pedestrians interchangeable. Thus, it raises a need for acquiring data which can distinguish pedestrians inside group. Human-sensing based approaches are recommended in recent studies. (Kjargaard, 2012) used accelerometer and compass sensors on mobile device and Wifi to detect flock of pedestrians. (Seer, 2014) used Kinect sensors to calibrate social force model. (Claudio, 2014) used Bluetooth to scan nearby device to propose proximity graphs for lane formation and bottleneck detections. Thus, this study proposed two sub-questions to acquire data of different pedestrian types and group influence:

**-What is the technique to collect movement data of groups?**

This study will develop a downloadable mobile application to allow pedestrians in the same group register information (name, age, and group ID: is assigned to distinguish with pedestrians in other groups) and track their positions on an indoor map when moving in the same group. When the application is enabled by pedestrians, it will collect periodically nearby MAC addresses and Bluetooth signal strength of surround devices and transfer to server. To infer pedestrian’s locations, predefined devices (mobile devices or iBeacon devices with known MAC Address) are placed at known positions in Cartesian coordinator. Inferring locations is performed commonly through triangulation and trilateration techniques .It was successfully applied in previous study (Wang, 2013). Mobile-based data collection framework offers a lightweight method comparing to lab-controlled experiments using camera-based approach because of time, cost, and pedestrian identification. Also, this method takes advantages of existed floor layouts (corridor, turning, merging, and diverging situations) rather constructing experimental obstacles, and captures pedestrian’s natural movement.

Status: A mobile application is almost finished. It allows pedestrians register information and scans surrounding devices (iBeacons and mobile devices) for each 30-second interval and then transfers to server. When deploying the application in different venues, their corresponding digital map will be downloaded on mobile. The server side development is in progress.

Expected Outcome: A sufficient data collection framework to collect vast data of large crowd

**-How to deploy the data collection framework in social aspect?**

(group, talk a little bit, 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?

* + Easy to test in different situations places.
    - A simulation 2D of FIT floor is constructed,
  + Deploy in other place as conference in Melbourne
  1. *mobile phone at different places*
  2. *build by above scenarios in Monash FIT, workshop in Floor6*
  3. *mass up in chadstone, crossing places*

**Question 4: How to calibrate and validate model**?

(Swakoti).//helbing formula

**Parameter such as movement speed, group size,** …

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

**Question 5**: adaptive simulate change from move individually to following

**Question 6**: Leader relationship in herding

**3. Project Trajectory**

**3.1 Project components**

The proposed research questions in this study can be separated into the core and peripheral elements, and the associated probability of non-completion.

**Table 1**- Importance and probability of failure of proposed research questions

|  |  |  |
| --- | --- | --- |
| **Research Questions** | **Importance level** | **Probability of Failure** |
| 1)What fundamental information makes pedestrians interact differently in emergency situations when only moving individually? | Core Element | Nil |
| 2)What is the impact of social group influence in evacuation situations? | Core Element | Nil |
| 3)How to acquire actual data for different pedestrian types and group influence in above situations? | Core Element | Nil |
| 4) How to calibrate and validate model? | High | Low |
| 5) |  |  |
| 6) |  |  |

**3.2 Workflow**

**-The figure illustrate** //figure here show included 1D, 2D

//final outcome (data collection for further studies, parameter distribution for pedestrian types, (moving individually to group, different places when know pedestrian type percentage)

*Generally, the model can be adapted in different pedestrian-oriented venues and with the change of crowd behaviour from moving individually to following.*

**3.3 Project Timeline**

**3.4 Project progress**

*//simulation environments capture*

*//blockage frequency*

*//mobile activity snapshot*

1. **Coursework and professional development**

As required from our faculty, I completed the course FIT 5143 in the first semester 2015. I am attending the course FIT6021 from 31 July, 2015. I also completed 115 research training hours as in Table 1.

**Table 2**- List of professional development undertaken

|  |  |
| --- | --- |
| **Activity** | **Hours counted towards coursework goal** |
| Faculty Induction | 4 |
| Research Integrity | 12 |
| FIT 5143 Course | 48 |
| FIT 6021 |  |
| FIT 4012 | 15 |
| Monash Seminar/workshop attendance | 21 |
| Participation at Monash Bootcamp Commercialisation workshop | 15 |

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