**EXPLORING THE HETEROGENEITY** **INSIDE POPULATION**

**TO ENHANCE CROWD MODELLING ON SOCIAL GROUP DYNAMICS**

***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. Understanding crowd dynamics which unfolds in both of normal and emergency situations becomes the key for this effort since real-world emergency data is sparse. Social group dynamics has been approached in both of happened disasters and evacuation scenarios. However, the effect of social group dynamics constructed by different group members, who are different demographic traits, has not been investigated fully in both of evacuation simulations and real-world group data. It is caused by the fact that current crowd model studies make assumption that populations are homogeneous and the lack of a novel data collection technique which can distinguish different group members in crowd. Thus, this study will explore the effect of social group dynamics in evacuation scenarios through simulations and then collect a ~~novel~~ data collection framework for this social group dynamics to finally validate the effects of social group dynamics through crowd simulation models with actual group data.*

1. **Introduction**
   1. Chronological human crowd disasters and efforts in disaster prevention
   2. The contribution of this study towards human crowd modelling studies
2. **Background**
   1. Crowd motion flows and self-organization phenomena in human crowd
   2. Group cohesion in nature
   3. Human crowd modelling at different scopes and agent-based models
   4. 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 public 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). It aims to enhance crowd modelling in creating realistic crowd simulation models and providing useful information for real-time crowd management (Helbing, 2015). 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, cellular automata model, and behavioural heuristic rule model (Hoogendoorn, 2013).

To make these models are realistic when simulating crowd behaviour, two main efforts have been done. First effort is the studies focusing on calibration processes to find realistic parameters of current crowd models (Johansson & Helbing 2007), (Daamen & Hoorgendoorn, 2012), (Bratsun, 2013), (Zeng, 2014). Second effort is the studies trying to reproduce group dynamics (e.g. group cohesion, competitive) which can unfold in both of normal and emergency situations (Shiwakoti, 2010). In the second effort, several studies represented group behaviour through social-force model or agent-based model.

In social-force model, the latest study from Helbing and colleagues (Moussaid, 2010) suggested that an additional group influence force should be included in current social-force model which describes pedestrian’s acceleration over the time as in equation (1). An individuals in group continuously adjusts their position to facilitate communication, but also avoid group members each other.

(2)

However, this model and original social-force model 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) in recent studies (Leeson, 2014) and another Naturetechnical report (Gosce, 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).

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In agent-based model, (Pelechino, 2006) constructed a simulation environment and created different pedestrian roles (leader, untrained leader, group members) through agent-based model to simulate evacuation scenarios. (Aguirre, 2011) construct a simulation environment of the crush disaster happened at the Station Nightclub, USA (2003) and compared the difference in escape numbers of several prototypes constructed on agent-based model. The prototypes include individual behaviour, intermediate group (revert to individual behaviour while in duress), full group behaviour (follow group leader). The escape numbers are compared with actual survivor number. On social aspect, the author mentioned that a group leader can be selected by other through demographic traits such as age, gender and familiarity with environment. However, these studies did not investigated on situations in which group members might have different demographic traits and whether these group members behave similarly to generate the same escape numbers.

What is the escape rate when different group (group of children,

**The total field of forces which act on members to remain in the group Festinger, Schachter, & Back, 1950, p. 164**

Different Structure of group)? And escape rate?

Therefore, a study which explores the social group influence should be contributed in this area. It should investigate realistic the difference in escape numbers when varying group members who have different demographic traits:

* Its group members (e.g. how this influence makes group members move faster, slower)
* Other groups (e.g. become obstacles for other group’s movement in evacuation situations, or split other group’s members)
* Overall evacuation results (e.g. escape rates)

//contribution of study

**Question 1: What is the effect of leader-follower behaviour in evacuation situations?**

Firstly, it is questionable to differentiate group members inside crowd since current models only consider crowds are homogeneous. It will pave the way for further investigation of social influence between group members in different types. Thus, sub question Q1.1 is proposed to separate group members.

**Q.1.1**: **What information makes pedestrians inside crowd interact differently when moving individually in evacuation situations?**

Through the report of Station Nightclub disaster (Aguirre, 2011), the difference of age is one of factors that make a pedestrian might become follower or leader. Also, a recent calibration work through experiments imitating emergency situations found that children (<14 years old), adults, and elders (>60 years old) interact very differently in congested or evacuation conditions than in normal condition (Hoorgendoorn, 2012). A snapshot of these experiments is presented in Figure 1.

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. 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). Thus, to answer Question 1.1, this study proposes two case studies to investigate the effect of different pedestrians, who are different in ages, when they are escaping individually.

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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) |

Case study 1: Understanding the difference in escape rates and blockage occurrence between a population having different pedestrians in ages and a population having uniform pedestrians.

Case study 2: Understanding the effect of two above prototypes in merging, turning, and diverging scenarios when pedestrians move individually.

To perform these case studies, a simulation tool is developed based on the social-force model as in equation (1). 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).

(1)

Status: Simulation to be continued

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. In merging, turning, and diverging scenarios, possible impacts such as the turbulence in crossings, how quickly they diver in multiple corridors will be investigated.

**Q.1.2: What is the effect of group cohesion in evacuation scenarios when group members are different in ages?**

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) in equation (2). 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 interaction between groups in three case studies. Their results will be compared with the result of pedestrians escaping individually.

Case study 1: Understanding the effect of group cohesion when performing simulations of different groups escaping through one-exit gate, merging, diverging, and turning situations.

Case study 2: Understanding the effect in above situations when group size is changed and group members are placed sparsely.

Case study 3: Understanding the effect when simulating in networks of merging, diverging, and turning layouts.

Status: Simulations to be performed. Three prototypes as bellow will be compared to each other.

* Crowd of pedestrians moving individually (by using equation (1))
* Crowd of pedestrians following a leader in a group (by using equation (2))
* Crowd of pedestrians maintain a certain distance to the group’s centre of mass (by using equation (2)). This prototype considers group don’t have leader.

Expected outcome: Proposed case studies aim to understand whether group cohesion can become obstacles to other group’s movement (non-moving objects or moving upstream), and how group is sunk and split 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 and the interaction between pedestrians in group and out-group pedestrians. 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 2: How to acquire actual data of group members 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 group members and group influence as in Table 1:

**Table 1**- Data acquisition of group member and group information to infer group cohesion

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| --- | --- |
| **Scope level** | **Acquired Data** |
| Group (meso level) | Percentage of pedestrian types in group  Total population size  Average speed at a certain time  Centre point of mass at a certain time |
| Individual (micro level) | Pedestrian type  Environment familiarity level  Pedestrian trajectory  Distance to other group members at a certain time  Distance to group’s centre of mass  Heading direction at a certain time  Average speed over the time  Speed at a certain time  Desired speed |

Table 1 represents required data to understand the effect of group cohesion towards different pedestrian inside group and other groups.

**Q.2.1: What is the technique to collect movement data of group members in turning, diverging and merging scenarios?**

This study will develop a downloadable mobile application to allow pedestrians in the same group register information (name, age, environment familiarity, and group ID- assigned to distinguish with pedestrians in other groups) and track their positions 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, a unique identifier) 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. This method takes advantages of existing floor layout design (corridor, turning, merging, and diverging situations) rather than constructing experimental obstacles, and it also easily captures natural movement of different pedestrian types even in public events. A full data collection framework is represented in below figure.

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| **Figure 2**. Proposed group member data collection framework |

Status: An Android mobile application is almost finished. It allows pedestrians register information and scans surrounding devices (iBeacons and mobile devices) for each 1-second interval and then transfers to server. The server side development is in progress. It also allows tracking real-time indoor position of pedestrians on server side.

Expected outcome: A data collection framework is developed to collect vast data of large crowd in public events. A Hadoop distributed file system is used to store raw data, inquiring group information and pedestrian’s trajectory over the time is developed as scripts to access these files.

**Q.2.2: How to deploy the data collection framework in social aspect?**

Take advantages of this lightweight data collection framework, this study will perform case studies:

Case study 1: Two groups with different sizes start together at NICTA area and go in the same direction to the kitchen at Floor 6, Building H, Monash Caulfield.

Case study 2: Two groups go in the same direction from NICTA area and turn right to exit gate at elevator at Floor 6, Building H, Monash Caulfield.

Case study 3: A population is mixed from above two groups. The population starts at the exit gate and then diverge into two escaping directions (NICTA area, kitchen area).

Case study 4: Members of two groups are placed at NICTA and kitchen areas respectively, they go to emerge and escape at main exit gate of the floor.

Above four case studies aim to understand group cohesion of adult pedestrian type and all of them have equal layout design familiarity level. Each above case studies is repeated two times (one for maintaining certain distance to group centre of mass, last for following an informed leader).

Case study 5: It is also expected to perform experiment at workshops hold at SensiLab, Monash University. A workshop’s common agenda means that a population of participants who have different topic attention often gather at the welcome area at the beginning time of the workshop and then split into different rooms of majors. This case study will provide a compound data of various pedestrians, who are different in design layout familiarity and age, and groups which are avoid each other simultaneously at turning, merging, diverging layouts.

Case study 6: The application will be installed on prepared devices. This case study aims to collect data of pedestrians in other public places rather than in Monash area. A shopping area is expected. Random group of pedestrians visiting the area is invited to use the application and moving naturally to capture their movement. It aims to collect data from different pedestrian types (in ages and environment familiarity). Group leader is selected by averaging out the highest years old and most familiar with design layout.

**Question 3: What qualitative effects of group cohesion occur in both of simulation environment and observed data?**

The effect of group cohesion is investigated in group members and with other groups in turning, merging, and diverging scenarios especially in high-density places. Thus, this question is divided into these scales.

**Q.3.1: What is the impact of group cohesion on group members?**

Through collected data in Question 2, this sub question aims to understand the effect of group cohesion caused by different group member types. Table 2 proposes sub questions to scrutinize the effect of group cohesion on group members.

**Table 2**- Group cohesion effect on group members according group leader existence

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| --- | --- |
| **Group leader existence** | **Group cohesion effect on group members** |
| No | * Which group (uniformed individuals of children, elder, adult, or well-mixed) move faster in turning, merging, and diverging scenarios? * Which pedestrian type inside group more often accelerates and decelerates to maintain a certain distance to group’s centre of mass? * Which pedestrian type inside group keeps the furthest distance to group’s centre of mass? |
| Yes | * Which group type moves faster in turning, merging, diverging scenarios? * What is the position of group leader to achieve the highest group’s average speed in these scenarios? * Which group member type more often follows relative positioning of group leader? |
| * How do above effects change when group size is changed? * Which scenario in which group should have a group leader? * Which scenario in which group should maintain a group cohesion without following informed leader? | |

**Q.3.2: What is the impact of group cohesion on other group’s movement and overall evacuation results?**

This question aims to understand realistic effects (such as group’s average speed, distance to leader or group’s centre point) when a group of different pedestrians interacts with another group in turning, merging and diverging scenarios. In macro level, it aims to understand the crowd density, escape rate, and turbulence occurrence in these scenarios. The below table categorizes these effects according the existence of group leaders.

**Table 3**- The effect on two interacting groups in turning, merging, and diverging scenarios

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| **Group leader existence** | **Effect on the remaining group** | **Effect on macro level** |
| Both two groups have leaders | * Which group member type in this group more often accelerates/ decelerates/become obstacles in these scenarios?      * Which group member type keep the closest distance to its group’s centre of mass? | * Which case of group leader existence generates the least turbulence frequency? * Which case of group leader existence generates the highest escape rate? |
| Only one group has leader |
| Both two groups don’t have leader |
| * How do above effects change when group sizes of two groups are changed? | | |

**4. Project Trajectory**

**4.1 Project components**

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

**Table 4**- Importance and probability of failure of proposed research questions

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| --- | --- | --- |
| **Research Questions** | **Importance level** | **Probability of Failure** |
| 1)What is the effect of leader-follower group behaviour in evacuation situations? | Core Element | Nil |
| 2)How to acquire actual data for different pedestrian types and group influence in above situations? | Core Element | Nil |
| 3) What qualitative effects of group cohesion occur in both of simulation environment and observed data? | Core Element | Nil |

**4.2 Workflow**

The figure in this section illustrates how questions incorporate and finally return outcome. Question 1 is investigated in order to understand comprehensively the effects of different group behaviours (moving with leader, moving individually, moving to maintain group’s centre of mass) in which group members are different in ages. These effects are investigated in different network layouts. Question 2 aims to collect data to infer group cohesion from meso and micro information as in Table 1. Question 3 aims to verify the effect of group cohesion in different scenarios according the existence of group leader through actual data.

The practical outcome of this project is at three points:

* It offers a better data collection framework and collected data (pedestrian type, trajectory, environment information) for further studies which aim to calibrate and validate current models to produce herding phenomena.
* In live events, it offers key information for leader-follower behaviour which can give event organizers decisive minutes to try and restore the order of crowd in different network layouts before deteriorative situations can occur.
* In normal situations, it offers a comprehensive understanding for different group member types in order to improve group behaviour guidance in pedestrian-oriented places (children school, elder house, or working places).

**4.3 Project Timeline**

**4.4 Project progress**

-Crowd simulation screen, escape rats, blockage frequency results of Question 1

-Snapshot of data collection mobile application of Question 2

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 116 research training hours as in Table 3.

**Table 5**- List of professional development undertaken

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| **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 | 22 |
| Participation at Monash Bootcamp Commercialisation workshop in the year 2015 | 15 |

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