**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. 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 cohesion dynamics has been approached in both of happened disasters and evacuation scenarios. Various models have been proposed to describe this dynamics. However, the effect of this dynamics constructed by different group members, who are different demographic traits, has not been investigated fully on escape results 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. Thus, this study will explore the effect of social group dynamics in evacuation scenarios through crowd simulation model and 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
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). This caused by the fact that pedestrians rarely escape individually (Aguirre, 2011), they almost are influenced by other pedestrians (e.g. family, friends, groups of pedestrians have the same interests). In the second effort, several studies represented group cohesion behaviour through social-force model, cellular automata or agent-based model.

In social-force model, the latest study from Moussaid 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). This force aims to describe that an individual in group continuously adjusts its position to reduce its head direction and maintain group’s centre of mass, but also avoid group members each other as in equation (2). //Group formation V, inverse

(1)

(1)

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).

//CA, vizzari, and in survey. Formulate of group cohesion and dispersion, group formation

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. A group member follows leader if they are in the leader’s line of sight. In general, by using agent-based model approach, one of the most clearest limitation mentioned in the future work of the study (Weijmen, 2013) is the lack of a standard mechanism to validate the effects of agent’s parameters in the pedestrian’s acceleration calculation. Another to see group formation

Although various models have been proposed, these models did not investigated group cohesion behaviour in situations in which group members have different demographic traits and whether these group members behave similarly to generate the same escape numbers. Therefore, a study which explores the social group influence should be contributed in this area. It should investigate the difference in overall escape numbers when group members are different in ages. This work is inspired by a recent calibration work (Hoorgendoorn, 2012). Through experiments imitating emergency situations, this study found that children (<14 years old), adults, and elders (>60 years old) interact very differently in congested or evacuation conditions than in normal condition. Among well-known models such as cellular automata, multi-agent based model, or social force model, this study uses social force model to explore the influence of group cohesion behaviour on escape rate since the model is highly recommend to simulate sufficiently crowd’s self-organization phenomena (Hoorgendoor, 2013).

//contribution of study should move individually or with group in exit gate. Live-event organizer restores order of group, or move individually to enhance escape rate. **Re-order group before they transform shapes in density places**

Parameter for group, adapt ?

1. What is the difference in escape rates when the group of different group members, who are different in ages, changes group structure?
   1. How to simulate a crowd of three different pedestrians using social-force model move individually, simple model?

Two approach, 1-large distrubtion, or 3 parameter sets

1.2: Escape rate group interact another crow people move individually?

hypothesis: children > adult> elder velocity or low parameters ,become obstacles to other groups through structure

purpose:

Look at the relationship between group cohesion, and group dispersion degree? Group cohesion degree when various this parameter, t-test between centroid of this results when varying group member types.

Look at possible group formation generate this difference from this parameter set?

In Moussaid, in high density-place auto form to minimize group maintain, .model has parameter beta fixed let produce V-like, in V-like, river,breast, (for small group size < 4 ped ),in high places, in river by order if larger than 4.

1. How to verify this difference in escape rate by actual data?

Two groups are invited and move, a camera

Experiment 1: 9ped move individually

Experiment 1: same size, 9 pedestrians in gate floor 6, not interact with other group

Change percentage: well-mixed (30,30,30), dominant of each pedestrian type, move individually

Hypothesis: move individually faster, children move faster, adult, elderly. Kknow background, and how they order to escape

Experiment 2: interact with another crow people move individually, who move individually.

Compare escape rate with case study1.

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.

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).

**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

|  |  |
| --- | --- |
| **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.

|  |
| --- |
|  |
| **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).

**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

|  |  |
| --- | --- |
| **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? |
| * 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? | |

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

**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

|  |  |  |
| --- | --- | --- |
| **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

|  |  |
| --- | --- |
| **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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