IMPROVED SOCIAL FORCE MODEL FOR BUILDING EVACUATION SIMULATION

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改良社會力模型於建築物疏散模擬應用

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Abstract

Over the last few decades, there were numerous model developments in the field of pedestrian flow simulation. Most of these models try to simulate the pedestrian’s evacuation in buildings in case of fire or emergency situations. They also look at capacity issues at bottlenecks such as rail interchanges and bi-directional flow. A number of models for pedestrian movement have been developed in a variety of disciplines. There are two distinct groups of models in macroscopic and microscopic perspectives. The macroscopic models focus on the system as a whole, while microscopic models study the behaviour and decisions of individual pedestrians, their effect on other pedestrians around them, and the system as a whole.

There is a need to model the pedestrian behaviour for a range of applications including event planning, resource usage, and urban planning. For instance, the organizers of a large event in an exhibition hall require information on what areas are likely to be congested so that management strategies can be developed and tested before starting the event. Similarly, the designers of a shopping mall might be
interested in how people move around their intended design so that they can place
shop entrances and seating in useful locations.

Recently, computer based analysis for pedestrians movement in buildings is
widely adopted by the fire researchers or engineers in performance-based fire
engineering study. However, the pedestrians exhibit different behaviours depending
on their knowledge of the environment and other personal characteristics. Unlike the
rules that govern vehicular traffic, there are few formal procedures or rules that govern
the pedestrian movement, resulting in often complex and chaotic movements.
Pedestrians are not restricted to lanes or specific routes. In general, they are restricted
by the physical boundaries around them such as the width of doorways or presence of
walkways and also the movements of their neighbours. As a consequence, the
modelling of pedestrian movements presents some specific problems not encountered
in other forms of transport modelling.

A full understanding of crowd behaviours normally requires exposing real
people to the specific environment for obtaining empirical data, which is difficult
because of such environments are often dangerous in nature especially in emergency
situations. Moreover, the major deficiency of the existing pedestrians modelling is the
adaptation of crowd behaviour that is extremely difficult to be described by
mathematics.
In addition to studying the crowd behaviour based on the observations and the historical records, computer simulation may be a useful alternative that can provide valuable information to evaluate a building design, to help planning process, and for dealing with emergencies.

In this thesis, a modified computing pedestrian model, namely Improved Social Force Model, has been developed to simulate the perception and the cognition of a pedestrian in case of emergency evacuation. The algorithm of the model is implemented based on the Social Force Model introduced by Helbing and Molnar (1995). This model examines pedestrian movements as either positive or negative social fields, in which a pedestrian behaves as if acted upon by external forces.

However, the decisions and interaction between pedestrians is an extremely flexible and intelligent process. To provide more accurate results in pedestrian behaviours, the physical features of pedestrian movements such as walking speeds, acceleration, queuing, and herding behaviour must be accurately reproduced.

The motivation of this research comes from the need to understanding pedestrian psychology and modelling pedestrian behaviour accurately. Some parameters involving human behaviours will be introduced into the original Social Force Model in order to improve the accuracy for the computing modelling.
In summary, two human behaviours will be added into an individual’s walking performance: herding behaviour and visual angle. By adding a herding parameter into a pedestrian in an evacuation simulation is proved to be obtained a more accurate result. However, herding behaviour could not be the same in all age of pedestrians. In an Improved Social Force Model, the younger pedestrian, the larger herding behaviour; as younger pedestrians have lower judgement in the wayfinding (searching for a suitable escape route) so that they will follow the actions of others as a guide to determine how they might act. In addition, under evacuation situation, pedestrians will more concentrate on finding their destination (e.g. an exit) in order to leave the building as soon as possible. Therefore, applying a visual angle of $\pm 85^\circ$ to the pedestrians can achieve a more accurate simulation result.

Applying the concept into the algorithm of the proposed model, the predicted values for each pedestrian and time step are calculated. The model consists mainly of three terms. These terms are the desired velocity of motion of a pedestrian, the interactions between pedestrians, and the interactions between pedestrian and boundaries. Human behaviours, herding parameter and visual angle, are applied to the second term when processing the algorithm. Then the last step in the algorithm is to update of the position, velocity and acceleration of an individual for the next time step.
In proofing the performance of an Improved Social Force Model, two other computational pedestrian movement models, Social Force Model and Simulation of Transient Evacuation and Pedestrian MovementS (STEPS), were applied. Social Force Model is a well-known pedestrian movement modelling and it was published in the Journal of Nature in 2000 by Helbing et al.; Improved Social Force Model is proposed by the author in order to improve the prediction of pedestrian movement modelling which is based on the Social Force Model; STEPS is a commercial application of simulation in pedestrian movement and it is well-validated in academic and well-adopted in industry. Therefore, STEPS is being a benchmarking model in the research so as to evaluate the performance of the Improved Social Force Model.

From the computational results of the pedestrian simulation for various scenarios, it was found that the simulated escaping time of pedestrians in the proposed model from the fire room is longer than the original Social Force Model by comparing to the results from STEPS. The agreement of the proposed model is not expected to be perfect since there are important variations among collected by different authors under different layouts, situations, and cultures. However, an improvement is clearly visible.
# TABLE OF CONTENTS

- **Abstract**  
  i
- **Acknowledgments**  
  vi
- **Table of Contents**  
  vii
- **List of Figures**  
  xi
- **List of Tables**  
  xiv
- **Nomenclature**  
  xv

**CHAPTER ONE Introduction**  
1. **Preliminaries**  
1.1 Preliminaries  
1
1.2 Motivations and Objectives for the Research  
1.3 Achievements for the Research  
1.4 Thesis Outline  
5

**CHAPTER TWO Literature Review**  
2. **Models for the Simulation of Pedestrian Flow**  
2.1 Models for the Simulation of Pedestrian Flow  
9
2.2 Cellular Automata Models  
2.2.1 Related Works  
2.2.2 Discussion  
10
2.3 Lattice Gas Models  
2.3.1 Related Works  
2.3.2 Discussion  
16
2.4 Social Force Models  
2.4.1 Related Works  
2.4.2 Discussion  
21
2.5 Fluid Dynamics Models  
2.5.1 Related Works  
2.5.2 Discussion  
25
2.6 Agent-based Models  
28
### Table of Contents

2.6.1. Related Works 28
2.6.2. Discussion 33

2.7 **Game Theoretic Models** 35
2.7.1. Related Works 35
2.7.2. Discussion 36

2.8 **Approaches based on Experiments with Animals** 37
2.8.1. Related Works 37
2.8.2. Discussion 38

2.9 **Combined Models** 39

2.10 **Commercial Pedestrian Evacuation Models** 39
2.10.1. Spatial-grid Evacuation Model (SGEM) 39
2.10.1.1 Background 39
2.10.1.2 Structure of Model 40
2.10.1.3 Occupant Behaviour 43
2.10.1.4 Movement of Occupant 43
2.10.1.5 Formula for Walking Speed 46
2.10.1.6 Output 47
2.10.2. Simulation of Transient Evacuation and Pedestrian movements (STEPS) 48
2.10.2.1 Background 48
2.10.2.2 Perspective of Model 48
2.10.2.3 Movement of Occupant 49
2.10.2.4 Output 52
2.10.2.5 Limitations 53

**CHAPTER THREE Social Force Model and its Development** 54

3.1 **General** 54

3.2 **Governing Equations** 54
3.2.1. Driving Force 55
3.2.2. Interactions between Pedestrians 56
3.2.3. Interactions between Boundaries 60
3.2.4. Attractive Interaction 61
3.2.5. Summary 62

3.3 **Previous Modifications to the Social Force Model** 62
3.3.1. Overlapping Elimination among Pedestrians 63
3.3.2. One-dimensional Movement of a Pedestrian 64
3.3.3. Self-stopping Mechanism 64
TABLE OF CONTENTS

CHAPTER FOUR Development of an Improved Social Force Model 66

4.1 Introduction 66

4.2 Implementation of an Improved Social Force Model 66

4.2.1 Introduction 66

4.2.2 Herding Behaviour 67

4.2.2.1 Formulation 67

4.2.2.2 Mathematical Model 69

4.2.3 Visual Angle 79

4.2.3.1 Formulation 79

4.2.3.2 Mathematical Model 81

4.2.4 Summary 84

CHAPTER FIVE Numerical Simulations of an Improved Social Force Model 87

5.1 Introduction 87

5.2 Scope of the Model 87

5.2.1 Assumptions 87

5.2.2 Input of Geometries 89

5.2.2.1 Baseline Model 89

5.2.3 Input of Pedestrians 90

5.2.4 Modelling Process 91

5.2.4.1 Concept of Modelling 91

5.2.4.2 Implementation of Modelling 91

5.3 Simulation Results 94

5.3.1 Background 94

5.3.2 Scenario A: 8m x 8m Test Room with One Exit (1.5m width) and 12 Pedestrians 95

5.3.2.1 Enclosure Configurations 95

5.3.2.2 Interpretation of Results 96

5.3.3 Scenario B: 8m x 8m Test Room with Two Exits (1.5m width) and 12 Pedestrians 101

5.3.3.1 Background 101

5.3.3.2 Enclosure Configurations 102

5.3.3.3 Interpretation of Results 103

5.3.4 15 Additional Tests: 8m x 8m Test Room with Two Exits (1.5m width) and 12 Pedestrians 110

5.3.4.1 Background 110

5.3.4.2 Interpretation of Results 111

5.3.5 Scenario C: 8m x 8m Test Room with One Exit (2m width) and 12 Pedestrians 114

5.3.5.1 Enclosure Configurations 114
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.3.5.2 Interpretation of Results</td>
<td>115</td>
</tr>
<tr>
<td>5.3.6. Scenario D: 8m x 8m Test Room with Two Exits (2m width) and 12 Pedestrians</td>
<td>118</td>
</tr>
<tr>
<td>5.3.6.1 Enclosure Configurations</td>
<td>118</td>
</tr>
<tr>
<td>5.3.6.2 Interpretation of Results</td>
<td>119</td>
</tr>
<tr>
<td>5.3.7. Scenario E: 8m x 8m Test Room with Two Exits (2.5m width) and 12 Pedestrians</td>
<td>126</td>
</tr>
<tr>
<td>5.3.7.1 Background</td>
<td>126</td>
</tr>
<tr>
<td>5.3.7.2 Enclosure Configurations</td>
<td>126</td>
</tr>
<tr>
<td>5.3.7.3 Interpretation of Results</td>
<td>127</td>
</tr>
<tr>
<td>5.3.8. Summary</td>
<td>131</td>
</tr>
<tr>
<td>5.4 Model Validation</td>
<td>133</td>
</tr>
<tr>
<td>5.4.1. Experimental Set-up and Results</td>
<td>133</td>
</tr>
<tr>
<td>5.4.2. Simulation Results by Improved Social Force Model</td>
<td>135</td>
</tr>
<tr>
<td><strong>CHAPTER SIX Conclusions and Recommendations</strong></td>
<td>137</td>
</tr>
<tr>
<td>6.1 Conclusions</td>
<td>137</td>
</tr>
<tr>
<td>6.2 Limitations</td>
<td>143</td>
</tr>
<tr>
<td>6.3 Suggestions for Further Works</td>
<td>144</td>
</tr>
<tr>
<td>References</td>
<td>147</td>
</tr>
<tr>
<td>List of Publications</td>
<td>156</td>
</tr>
<tr>
<td>Appendix I - Part of Computer Codes of Simulation Model</td>
<td>158</td>
</tr>
</tbody>
</table>
LIST OF FIGURES

Figure 2 - 1  A grid of cells in zone simulated by SGEM...................................44
Figure 2 - 2  8 possible directions in grid cell simulated by STEPS ...............49
Figure 3 - 1  Distance between pedestrians....................................................57
Figure 3 - 2  Crushing force between pedestrians..........................................58
Figure 3 - 3  Interaction force between pedestrians.......................................59
Figure 3 - 4  Interaction force with boundary..................................................61
Figure 4 - 1  Relationship between the body diameter of pedestrian and the
herding parameter .........................................................................................70
Figure 4 - 2  x-y coordination of pedestrians in a room....................................71
Figure 4 - 3  A desired direction of an individual without herding behaviour for
a next time-step ............................................................................................73
Figure 4 - 4  A desired direction of an individual with herding behaviour for a
next time-step ...............................................................................................73
Figure 4 - 5  Snapshots of the simulation. A pedestrian’s (red dot) moving
direction under herding behaviour..............................................................78
Figure 4 - 6  Angle of view in 170° .................................................................79
Figure 4 - 7  Angle of view in 120° .................................................................80
Figure 4 - 8  Angle between pedestrian’s desired direction and the current
position of the neighbour pedestrians ........................................................81
Figure 4 - 9  Visual zone ....................................................................................82
Figure 4 - 10 Awareness range .........................................................................83
Figure 4 - 11 Flowchart of the algorithm of an Improved Social Force Model ..86
Figure 5 - 1  Baseline mode: Test room of area 8 m x 8 m with a 1.5m-wide exit
door................................................................................................................89
Figure 5 - 2  Step 1 – Pedestrian setup..............................................................92
Figure 5 - 3  Step 2 – Determine the neighbours within an awareness range ....93
Figure 5 - 4  Simulation of 12 pedestrians towards the 1.5m width exit of a room
of size 8m x 8m ............................................................................................96
Figure 5 – 5  Snapshots of the simulation of an 8m x 8m room with one exit
(1.5m width) compared among three models .............................................98
Figure 5 – 6  Cumulative outflows of pedestrians leaving the room as a function
of time among three models (with one exit – 1.5m width) .................101
Figure 5 – 7  Simulation of 12 pedestrians towards two 1.5m width exits of a room of size 8m x 8m .................................................................103

Figure 5 - 8  Simulated snapshots of an 8m x 8m room with two exits (1.5m width) compared among three models.................................105

Figure 5 – 9  Cumulative outflows of pedestrians leaving the room as a function of time among three models (with two exits – 1.5m width)........107

Figure 5 – 10 Cumulative outflows of pedestrians leaving the room through the door ‘Exit 1’ (1.5m width) as a function of time among three models.................................................................109

Figure 5 – 11 Cumulative outflows of pedestrians leaving the room through the door ‘Exit 2’ (1.5m width) as a function of time among three models....................................................................................... 110

Figure 5 - 12 Simulated leaving time of pedestrians against simulation number among three models.................................................................112

Figure 5 – 13 Averaged cumulative outflows of pedestrians to leave a room as a function of time among three models (with two exits – 1.5m width)114

Figure 5 - 14 Simulation of 12 pedestrians towards the 2m width exit of a room of size 8m x 8m ........................................................................ 115

Figure 5 – 15 Snapshots of the simulation with an 8m x 8m room with one exit (2m width) compared among three models.................................................................117

Figure 5 – 16 Cumulative outflows of pedestrians leaving the room as a function of time among three models (with one exit – 2m width) ...................... 118

Figure 5 – 17 Simulation of 12 pedestrians towards two 2m width exits of a room of size 8m x 8m........................................................................ 119

Figure 5 - 18 Simulated snapshots of an 8m x 8m room with two exits (2m width) compared among three models.................................................................121

Figure 5 – 19 Cumulative outflows of pedestrians leaving the room as a function of time among three models (with two exits – 2m width)...........122

Figure 5 – 20 Cumulative outflows of pedestrians leaving the room through the door ‘Exit 1’ (2m width) as a function of time among three models 125

Figure 5 – 21 Cumulative outflows of pedestrians leaving the room through the door ‘Exit 2’ (2m width) as a function of time among three models 125

Figure 5 – 22 Simulation of 12 pedestrians towards two 2.5m width exits of a room of size 8m x 8m ........................................................................ 126

Figure 5 - 23 Simulated snapshots of an 8m x 8m room with two exits (2.5m width) compared among three models.................................................................128

Figure 5 – 24 Cumulative outflows of pedestrians leaving the room as a function of time among three models (with two exits – 2.5m width)...........129
**Figure 5 – 25** Cumulative outflows of pedestrians leaving the room through the door ‘Exit 1’ as a function of time among three different door widths simulated by an Improved Social Force Model...............132

**Figure 5 – 26** Cumulative outflows of pedestrians leaving the room through the door ‘Exit 2’ as a function of time among three different door widths simulated by an Improved Social Force Model...............132

**Figure 5 - 27** Schematic illustration of the experimental set-up for the evacuation of crawlers. (Extracted from a research paper by Nagai et al. (2006)) ......................................................................................134

**Figure 5 - 28** Time evolution of the experiment at $t = 0, 10, 20, \text{ and } 30s$ for exit width of 0.4m and 25 crawlers (Extracted from a research paper by Nagai et al. (2006)) ......................................................................................135

**Figure 5 - 29** Patterns of 25 crawlers obtained at $t = 0, 10, 20, \text{ and } 30s$ simulated by Improved Social Force Model. ..............................136
LIST OF TABLES

Table 4 - 1  Summary of mathematical formulation of an Improved Social Force Model........................................................................................................85

Table 5 - 1  Parameters of the Improved Social Force Model and their value used in the model..................................................................................90

Table 5 - 2  Assumptions used by STEPS.................................................................................................................................95

Table 5 - 3  Exiting pattern for 2 exits (1.5m width) situation among three models ........................................................................................................108

Table 5 - 4  Simulated leaving time of 15 tests among three models..........111

Table 5 – 5  Exiting pattern for 2 exits (2m width) situation among three models ........................................................................................................124

Table 5 – 6  Exiting pattern for 2 exits (2.5m width) situation among three models ........................................................................................................131