Jurnal Teknologi

Full paper

Modification of Physical Force Approach for Simulating Agent Movement with Collective Behavior

Nurulaqilla Khamis[a], Hazlina Selamat[b*], Rubiyah Yusof[a]

[a]Centre for Artificial Intelligence and Robotics, Malaysia – Japan International Institute of Technology, Universiti Teknologi Malaysia, 54100 Kuala Lumpur, Malaysia

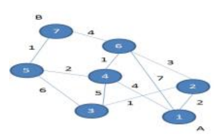
[b]Centre for Artificial Intelligence and Robotics, Faculty of Electrical Engineering, Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor, Malaysia

*Corresponding author: hazlina@fke.utm.my

Article history

Received :15 June 2014
Received in revised form :
15 September 2014
Accepted :15 October 2014

Graphical abstract



Abstract

Crowd modelling is a simulation study to know how crowd will behave in the environment. This simulation will contribute general knowledge and insight especially for safety engineers and architectural designers in assessing safety of crowd movement in buildings. There are many existing crowd models. However, these models neglect the details of agent characteristics and intelligence on how the agent will behave in the real environment. Therefore, in this study, the aim is to present heterogeneous agent characteristics and to include intelligence in the model in order to produce collective types of agent behaviour by modify the existing physical force approach.

Keywords: Agent characteristics; intelligence; physical force approach

1.0 INTRODUCTION

Crowd modelling has attracted tremendous research area especially in computer graphics, animation, robotics and urban or building planning. In crowd modelling, the entities in the crowd, also known as an agent, are embedded with certain levels of intelligence to interact and react in the virtual environment in order to imitate human movement. Normally in computer graphics and animation this area will specialized crowd modelling for a movie or game production [1] by imitate how human behave in a real situation into virtual environment. Meanwhile, for urban or building planning [2] this model is used as an important tool for architectural engineers and designers as well as safety engineers to assist or revitalize their design emergency exit structure inside the building if emergency cases happen and crowd management plan before the actual implementation.

Before developing crowd models, the modelers must know which type of models approach is compatible with their objective of crowd research studies. There are two types of models approach available in this research area which is macroscopic and microscopic levels. In macroscopic, agents in the model will be treated homogenously by omitting individual internal and external characteristics such as their speeds, masses and positions. By using this approach normally their scope of research studies is to analyze flow of the crowd as been done in [3, 4]. Therefore, the macroscopic approach is more suitable in modelling large crowds, and if the modelers insist to include details agent characteristics using this approach, it will require high computational demand that may affect simulation runtime performance.

Meanwhile in microscopic approach mainly modelers will consider heterogeneous type of agent internal and external characteristics. The modelers were able to assign different agent details such as positions, speeds, navigation appearance and also intelligence features. There are two types of microscopic approach commonly used in this research area, cellular based model and physical force model. For cellular based model were known as Cellular Automata (CA) that has been introduced by [5] and mainly used in others research work such as [6, 7], and [8]. By using CA, runtime performance will be represented in discrete time. Since the environment of this model segmented into grid, agent movement will hop from one cell to another based from state of transition probability [5]. Implementation by using this concept is simple and fast, scant agent interaction can be studied as the agent movement seems roughly to be visualized.

For physical force model, previous research work [9, 10] has been inspired by Dirk Helbing [11] model where in this model, movement of an agent were based on the summation of interaction forces. These forces will consider the agent motivational force to move towards target destination and repulsion forces between agents and obstacles. In Helbings work, the model developed has successful to represent the interaction of agent movement in emergency or panic situation by including additional forces of body force counteracting body compression and sliding friction force. This model has successfully simulated plausible agent movement in the virtual environment. However, there are scant agent details characteristics have been detailed out in this model where the agent in the model were treated most likely a particle movement. The simulation also gave no guarantee that the agents will not overlap with each other.

In this paper, modified version of agent based movement by using physical approach has been proposed including agent details characteristics and intelligent features. In Section 2 of this paper will consist the development of agent model using proposed method meanwhile in Section 3 will justify how the results will be based on proposed model. In the last section of this paper will emphasize the conclusion and propose future work to improve current develop model.

2.0 METHODOLOGY

2.1 Development of Agent Model

To develop agent model based on modification of physical force approach, this work has been categorized into 2 stages; the basic agent movement model in Stage 1 and integration of intelligent features in Stage 2. In Stage 1, details agent characteristic such as agent physical appearance will be emphasized including interaction of an agent to move towards target destination and repulsion force to evade other agents and obstacles. Meanwhile in Stage 2, proposed intelligent features such as agent path finding towards target destination and social interaction behaviour will be proposed in this stage.

2.1.1 Basic Agent Movement

This work has been inspired by [11] and the agent dynamics movement will be represented by using Newton Second Law as shown in Equation (1).

$$F(t) = m\frac{dv(t)}{dt} \tag{1}$$

Where m and $v(t)$ is the agent mass and velocity in respective time. The agent movement will be influenced by summation of three main forces $F(t)$, motivational forces to move towards target destination $F^0(t)$, repulsion forces to evade agents $F_{ij}(t)$ and obstacles, $F_w(t)$ as shown in Equation (2).

$$F(t) = F^0(t) + \sum_{i\neq j} F_{ij}(t) + \sum_{w} F_w(t) \tag{2}$$

$F^0(t)$ in Equation (2) is given as:

$$F^0(t) = m\frac{v^o(t)e^o(t) - v(t)}{t} \tag{3}$$

Where, m is agent mass followed by agent desired speed, $v^0(t)$ and direction, $e^0(t)$ to move towards target destination including agent actual speed, $v(t)$ adapted in time, t. For repulsion force between agent and obstacle has been modified in this paper based from Helbings work by using simpler concept of magnetic model represent in Equation (4).

$$F_{ij}(t) = k_r\frac{M_i M_j}{x^2} n_{iw} \tag{4}$$

Where, M_i and M_j are the agent social mass defined as unity as to prove initial assumption of modified model perform similar operation with original model. Meanwhile, k_r and x will represent as a repulsion constant and distance between agent respectively considering agent body radius, $R_{i/j}$. The agent distance will be calculated based on Equations (5) and (6) as depicted in Figure 1 before repulsion force will be exerted.

$$D_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \tag{5}$$

$$x = D_{ij} - R_i - R_j \tag{6}$$

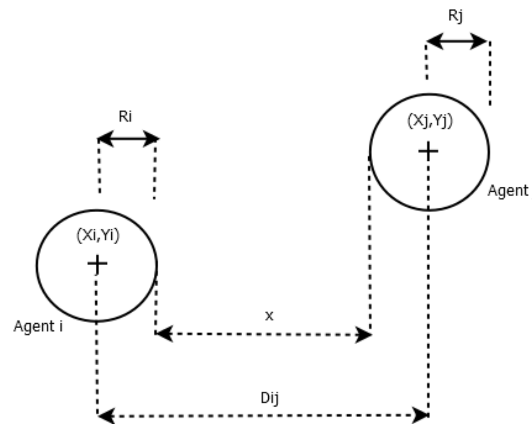


Figure 1 Agent distance (top view)

According to Helbings model, he has successfully represented panic situation by including additional forces in agent model. However, Helbings model cant encounter flow of agent movement in bi – directional or counterflow direction in a normal situation. Therefore, modified original model will represent collective of agent movement including social interaction tendency to follow others with variety of agent physical characteristics. By using modified force model given in Equations (5) and (6), the conditions for the agent to repulse will be based on comfort space [12] where in this model distance for an agent to repulse, x other will be 7 m. This will include the agent Field of View (FoV), θ before exerting repulsion force. The agent will repulse other agents when the other agent are within FoV and distance to repulse range as depicted in Figure 2, labelled with ‘1’ ($F_{ij} \neq 0$). If the other agent outside of both ranges, i.e in Figure 2 labelled with ‘2’, no repulsion force will be exerted ($F_{ij} = 0$) as in this region agent will normally ignores others. Furthermore, by considering this factor will utilized computing processing more effectively.

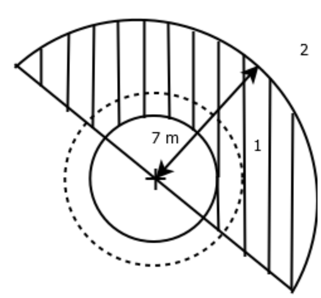


Figure 2 Agent operation to repulse

On the other hand, force interaction between agent and obstacle to repulse, F_w is given by Equations (7) and (8).

$$F_w = \frac{k_w}{x_w^2} n_{iw} \tag{7}$$

$$x_w = \sqrt{(x_i - x_w)^2 + (y_i - y_w)^2} \tag{8}$$

Where, k_w is a obstacle repulsion constant and x_w is distance between agent position and obstacle. n_{iw} is a normalized vector point perpendicular from the obstacle. The condition for an agent to repulse obstacle perform similar operation, described previously.

2.1.2 Intelligent Features

In this work, the intelligent features have been integrated such as how the agent will navigate the environment and choose suitable path to move towards their desired destination and social behaviour to show how the agent tendency to follow others in the simulated model.

For path finding features, dijkstra algorithm has been proposed in this work. Dijkstra algorithm is one of established algorithm used in computational science and this algorithm has broadly used for problem solving model. Therefore, this algorithm aims used in this model is to find shortest path agent from an origin to a destination by performing simple nodes calculation in all directions. For example, in Figure 3 node A and B are assigned as initial and target node. The number in each circle will represent as nodes and the interconnecting lines will represent distance between each node.

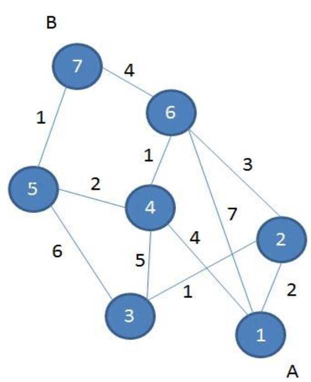


Figure 3 Node assigns

In order for agent to move from A to B via the shortest path, the distance between each node will be calculated from node A and the shortest distance will be chosen. From Figure 3 selected node is from node 1 to 7 via node 4 and 5. The chosen nodes will be marked as visited node and this visited node will not be checked again. By apply this algorithm, it also guarantees that the agent will bypass these agents or obstacles in the shortest path in its waypoint towards the target point as shown in Figure 4 where the black circle and red star represent the agent and target destination respectively.

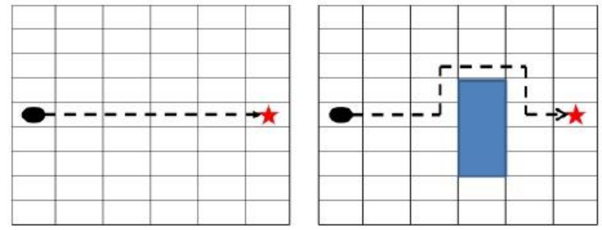


Figure 4 (Left) agent without obstacle, (right) agent with obstacle

Another intelligent features included in this work is how the agent will interact, tendency to follow others by considering their social range and Field of View (FoV) and how the agent will evade pedestrian ahead with inverse velocity as shown in Figures 5 and 6.

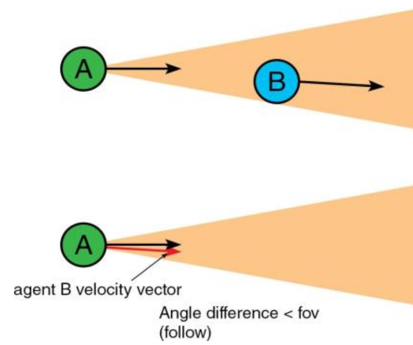


Figure 5 Following other agents

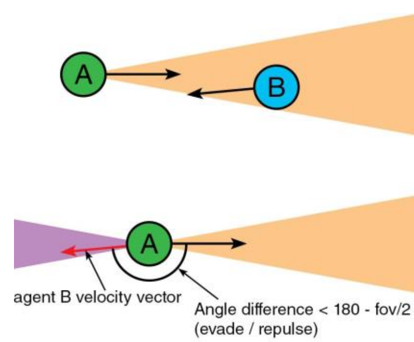


Figure 6 Repulse agent ahead

The conditions for an agent to perform both movements were based on their Field of View (FoV) and angle difference between velocity vectors. By including this concept in the agent model, agent can encounter bi – directional movement in the simulation program. For agent social interactions to follow other agents, agent range are set with 3 m based from human inter – personal space area [12].

■3.0 RESULTS AND DISCUSSIONS

Matlab has been used to simulate agents movement. Results will show comparison between proposed model and original Social Force (SF) model. To proof effectiveness by including path finding features in the simulated model, Figure 7 will show the experiment setting on how the agent will represent in the virtual environment. There are 5 number of agents allocated in one area where the agent will pass through the small door opening to reach their target destination. The interaction between the agent and obstacle will be analyzed including how fast the agent will reach their target by using proposed and original model.

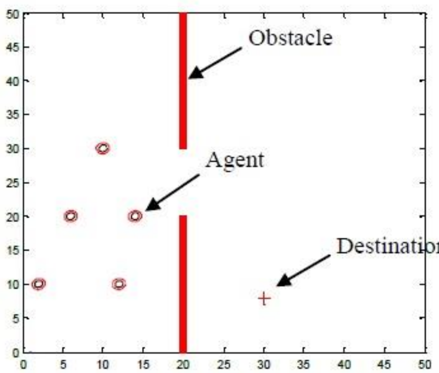


Figure 7 Experiment setting

Figures 8 and 9 show the trajectories of all agents from their initial positions towards target destination using Social Force (SF) model and proposed model respectively.

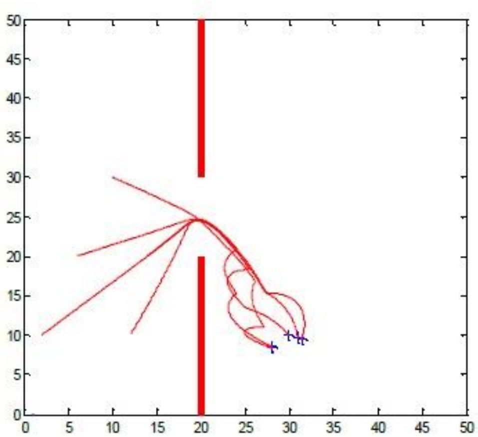


Figure 8 Agent trajectory using social force model

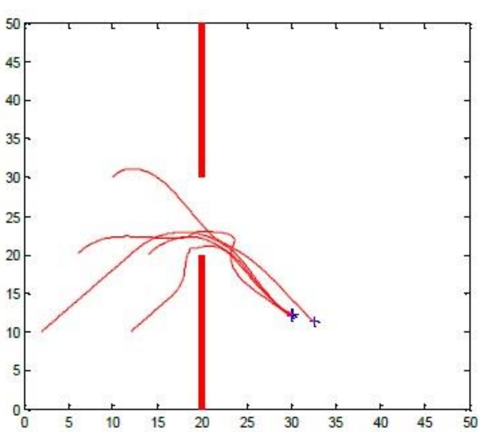


Figure 9 Agents trajectory using modified model

By comparing both trajectories, time taken from Table 1 for agent to reach their destination, 60% of the agents in the proposed model take shorter time to reach destination. This may caused by the optimal path finding features that have been integrated in the proposed model.

Table 1 Time taken to reach destination

Agent	Original Model, (s)	Modified Model, (s)
Agent 1	36.12	34.08
Agent 2	32.64	40.64
Agent 3	27.64	29.44
Agent 4	27.20	25.12
Agent 5	21.64	18.40

These comparisons show that our result by using proposed model is successful to simulate more realistic and smooth agent trajectory compared to the original model.

For bi–directional, this model be able to produce this type of behaviour in the simulated model in early stages of work by using proposed method and intelligent features. There are 20 agents were allocated randomly in the simulated environment with specified destination. In Figures 10 and 11 will show the simulated environment and trajectory generated when agent try to evade or follow pedestrian ahead to reach their target destination. There are two trajectories generated in opposite direction and the interaction for agent to repulse will be calculated and checked based on their conditions. The pathway width for an agent to move is set to 10 m wide.

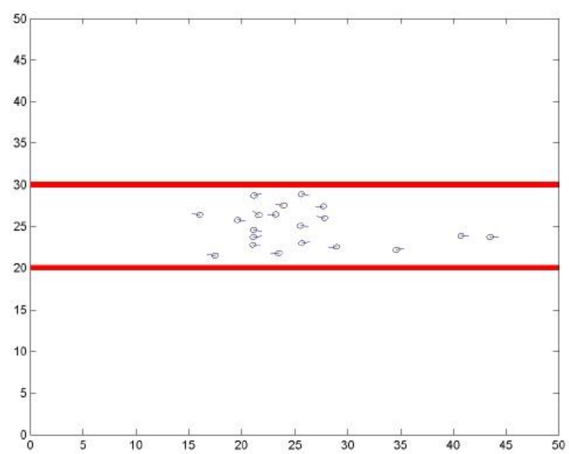


Figure 10 Experiment setting for bi–directional movement

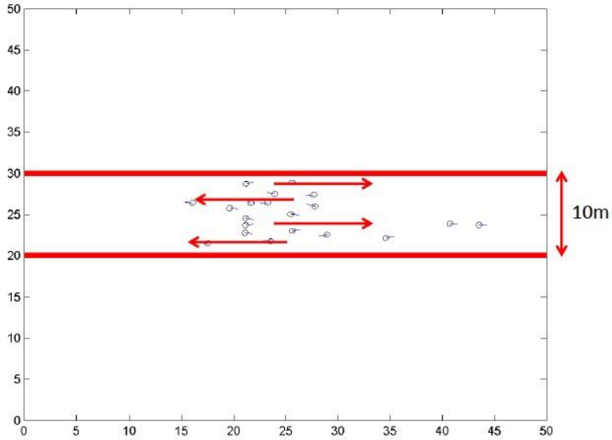


Figure 11 Trajectory for bi–directional movement

■4.0 CONCLUSION AND FUTURE WORKS

This paper compares agent movement that based from physical force approach. In our modified model, we have included the agent intelligent features for path finding to guide agent movement towards target destination and how the agent will try to react to follow or evade other agents ahead in the simulated model. To make our simulation performance efficient and realistic, decision for an agent to evade agent ahead, left or right will be included in our future works. Even in a real life of human walking, each of individual have their own characteristics tendency which side (left or right) should they choose in order to evade individual in front.

Acknowledgement

The authors would like to thank the Ministry of Education Malaysia and Universiti Teknologi Malaysia for their support. This project is supported by Research University Grant 00G19.

References

[1] Terozopoulos, D. 1999. Artificial Life for Computer Graphics. *Commun. ACM*. 42(8): 32–42.

[2] Waldau, N., Gattermann, P., Knoflacher, H. and Schreckenberg, M. 2007. *Pedestrian and Evacuation Dynamics 2005*. Springer Verlag.

[3] Chenney, S. 2004. Flow tiles. *Proceedings of the 2004 ACM SIGGRAPH/Eurographics Symposium on Computer Animation.* Eurographics Association. 233–242.

[4] Kisko, T. M., Francis, R. and Nobel, C. 1998. *Evacnet4 Users Guide.* University of Florida.

[5] Blue, V. J. and Adler, J. L. 1999. Cellular Automata Microsimulation of Bidirectional Pedestrian Flows. *Transportation Research Record: Journal of the Transportation Research Board*. 1678(1): 135–141.

[6] Zarita, Z. and Lim, E. A. 2012. Refined Cellular Automata Model for Tawaf Simulation.

[7] Peng, Y. C. and Chou, C. I. 2011. Simulation of Pedestrian Flow Through A T-Intersection: A Multi Floor Field Cellular Automata Approach. *Computer Physics Communications*. 182(1): 205–208.

[8] Shao, P. 2009. A More Realistic Simulation of Pedestrian Based on Cellular Automata. *Open-source Software for Scientific Computation (OSSC), 2009 IEEE International Workshop on.* IEEE. 24–29.

[9] Moussaid, M., Perozo, N., Garnier, S., Helbing, D. and Theraulaz, G. 2010. The Walking Behavior of Pedestrian Social Groups and Its Impact on Crowd Dynamics. *PloS* one. 5(4): 10047.

[10] Teknomo, K. 2002. Microscopic Pedestrian Flow Characteristics: Development of an Image Processing Data Collection and Simulation Model. Diss. Tohoku Univ.

[11] Helning, D., Farkas, I. and Vicsek, T. 2000. Simulating Dynamical Features of Escape Panic. *Nature*. 407(6803): 487–490.

[12] Hall, E. T. and Hall, E. T. 1969. *The Hidden Dimension.* Anchor Books New York.