Dynamic Heterogeneous Crowd Behaviour Detection Framework for Evacuation Plan during Emergency Situation

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Summary
The crowd of people consist of various vital information that portrayed through their behaviour inside the group. Usually, the group of people mixed male and female, elderly, kids, adult and even baby. Its made the group is heterogeneous in term of agent composition. Studying the crowd is very important to make a plan and come up with proper action immediately. This research proposed a new frameworkthat combines emotion, aggression and response of the crowd. Afterwards,density-based counting which able to determine the estimated number of groupand determine how many evacuation routes that possibly created. The result ofexperiments shown that emotional face detection, such as smile successfullyconducted while the crowd counting still needs to be improved further. However,the overall framework depicts a great result to come up with an excellentevacuation plan. We believe the result of this research thought can bring a predictive plan for safety evacuation toward people.

Key words:
Crowd, density, emotion, face detection, evacuation.

1. Introduction

In some panic situation, the accurate and fast response is critical to help people overcome the dangers and dangerous situation. Studying crowd behaviour based on the personality of agents can imitate the habit of human when they are inside the crowd. The previous researcher has studied the effect of personality trait toward the behaviour of the group. They also proposed 2D factorisation for professed persona inside circle according to the statistical study of the user [1]. As mention before, the other researcher aims to provide simulation on evacuation performance when relinquishing from Theatre building. They focus on evacuation performance and visualisation process of the audience [2]. Most of the pedestrian characteristic inside crowd categorised as follow: cluster establishment, self-association, lead and follow group, queue creation has a significant impact on crowd dynamism [3]. This paper consists of several sections, section 1 introduce the work of crowd behaviour, followed by section 2 related works discussion. Section 3 focused on the methodology of the research, while chapter 4 will describe the result of the study. Finally, part 5 is the conclusion of the works.

Manuscript received December 5, 2019
Manuscript revised December 20, 2019

2. Related Works

Discrete Element Model (DEM) also introduced a technique to model the subgroup personality inside a crowd. The synchronisation between physical and psychological in the 2D environment will create a reflection of crowd behaviour to stick together with their family or friends [4]. The other design of crowd simulation is using new modular with parallel agent-based simulation to handle large scale of crowd simulation, they handling the memory management of the simulation in better ways [5]. The other researcher focuses on cellular discrete for simulating the pedestrian with social influence such as single vision, surrounding awareness, communiqué and transmission, and speed tuning of the agents [6]. The other research focuses on crowd simulation is collision avoidance, where it can make the crowd behave in realistic ways. It is known as “Boid” founded by Craig Reynold in 1987 and improved again by him in 1999. The method is quite simple when an agent is getting closed, and it will be pushed toward the opposite direction according to the forces that computed through velocity and obstacle friction [7,8]. Crowd simulation for multi-floor building that has multiple rooms also become a concern for crowd simulation. They focus on handling various agents for emergency for an agent that trapped in multiple-rooms and floors [9]. Furthermore, researcher also studied steering behaviour for an agent that manipulate movement of agent inside the crowd. They model an agent that can initiate change or respond toward the action [10].

Meanwhile, crowd counting also part of crowd research that essential on analysing the number and position of the crowd along with face detection. The crowd size will help the evacuation process with route prediction and estimation time. For example, Figure 1 shows the massive crowd in the stadium. stadium.

Fig. 1 The massive crowd in the stadium[11]

Zhang, Y. Et al. has proposed a unique solution for crowd counting Multi-column convolutional neural network. Their dataset consists of massive crowd people, as shown in Fig.2.

Fig. 2 The massive crowd in stadium[12]

They focused on the density map based to count the number of crowds. Their equation can be described as if Head position at pixel χi, it can be represented as a function of Delta δ(χ-χi). Therefore, the number of N Heads in an image can be computer through Equation 1[12]:

$$H(x) = \sum_{i=1}^{N} \delta(x - x_i) \qquad (1)$$

The group that pedestrian formed mostly share a common interest, such as socio-psychological and biological elements [13]. Fig.3 represents the crowd when they are moving toward the same destination. However, there is a particular situation that may force the group dynamically changed their trajectory and it will trigger by its stability [13].

Fig. 3 Crowd behaviour with Intra and inter behaviour[13]

Crowd behaviour that shown in the Fig.3 has four main properties such as collectiveness, stability, uniformity and conflict. Sometimes the pedestrian crowd can have a different goal when joined together, such as crossing the road for two groups with different direction [13].

Study of the crowd for the last decades mainly focused on crowd behaviour analysis: crowd segmentation and crowd counting. The technique that mostly used for crowd behaviour analysis is image-based analysis [13].

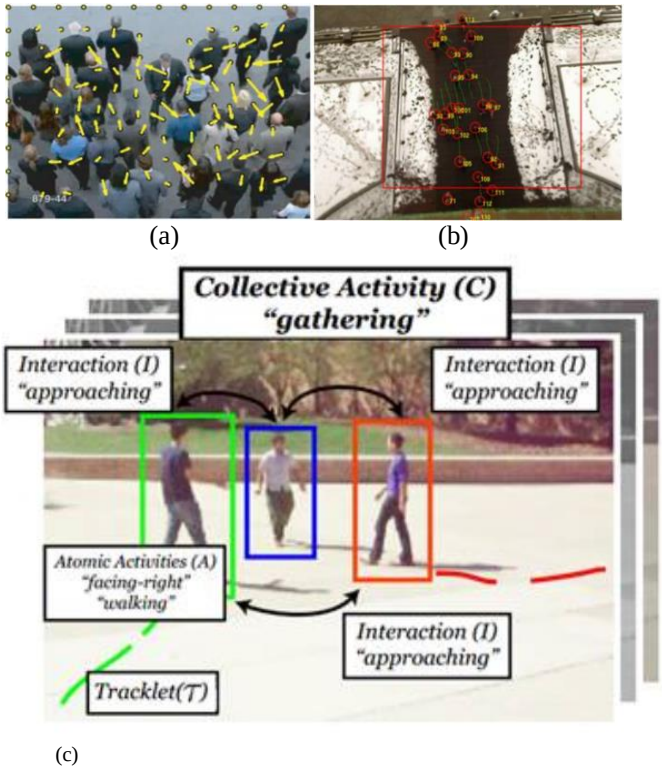

Fig. 4 Typical crowd behaviour analysis: a) Social Force model [14], Tracking for a multi-target with different behaviour [15], multilayer activity [16].

The other researcher focused on the study the velocity of an agent during collision avoidance[17], then how the character is walked via brain controller [18]. ALjahdali, M.A (2019) focused on how to treat the parent-child relationship of crowd agent when a panic situation emerged[19]. Besides motion of an agent and navigation with augmented reality also studied as well to achieve better agent performance[20-22]. Not only focused on the behaviour, the external appearance such as hair, cloth of the agents also being considered as an important factor in the character animation[23-28].

3. Research Method and Material

The focused of this research is to combine the crowd counting method to suggest an evacuation plan if an emergency occurred. The process of the whole framework described in Fig.5.

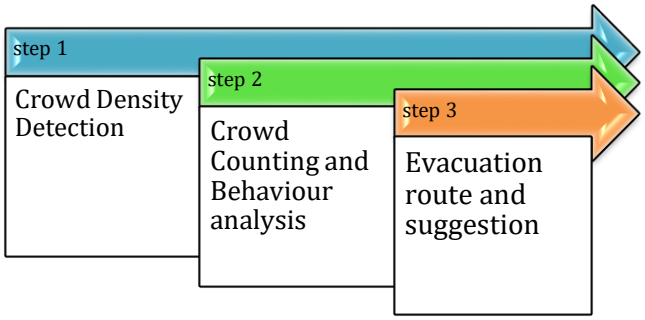

Fig. 5 Framework of crowd counting and evacuation plan

To detect the density of the crowd, we adopt the density map using geometry-adaptive kernels that initiate by mapping the human head to the plan for crowd density, as described in equation 1. Zhang et al. proposed a method to measure the average distance of each head person toward their neighbourhood, as described in equation 2. The length for each head to k nearest block can be represented as $\{d_1^i, d_2^i, d_m^i\}$, then average distance can be computed as:

$$\bar{d}^i = \frac{1}{m}\sum_{j=1}^{m} d_j^i \qquad (2)$$

Therefore, for each pixel of xi around region should resemble with a distance of $\bar{d}^i$. The crowd density estimation near xi, by adjusting the $\delta(x - x_i)$ with Gaussian kernel variance σ_i to $\bar{d}^i$. The density of F calculated using equation 3[12]:

$$F(x) = \sum_{i=1}^{N} \delta(x - x_i) * G_{\sigma_i}(x), with\ \sigma_i = \beta \bar{d}^i \ (3)$$

With β as additional parameters.
The previous researcher, Zhang et al. has achieved density estimation using equation 3 as shown in Fig.6.

Fig. 6 Crowd density calculation based on involving geometry-adaptive Gaussian kernels[12]

After density estimation, we continued with crowd counting and behaviour analysis by adopting the Convolutional Neural Network (CNN) using regression-based which is adopting from Li, Y et al. (2018). The sample of convolution net based different dilation is shown by Fig.7[29].

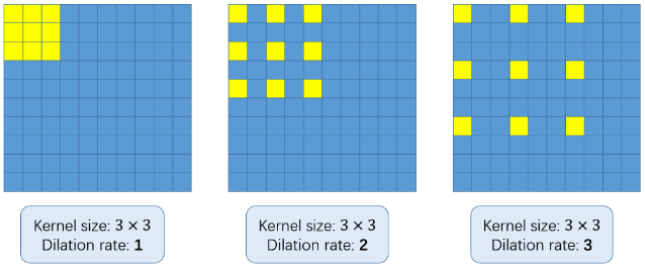

Fig. 7 Convolution kernel with size 3x3 and various dilation rate[29]

The lost function created by Li, Y et al. (2018) is defined as equation 4:

$$L(\theta) = \frac{1}{2N}\sum_{i=1}^{N} \left\| Z(X_i;\theta) - Z_i^{GT} \right\|_2^2 \qquad (4)$$

N represents the size of training iteration, while the output is $Z(X_i;\theta)$ with θ as the parameter. Xi is the input and Z_i^{GT} used as ground truth to validate the image input of Xi.
The main contribution of this paper is providing the alternative evacuation route plan based on the density number dynamically after counting the crowd and analyze their behaviour. The process is initiated based on the default evacuation plan then continued by scoring estimation of the group. The emotional condition of crowd can be a hindrance during evacuation. The algorithm for the whole framework is described in Fig.8.

Algorithm

```
Initiate
while not stop do
read image I;
Set face detection ϕ
Counting
do detection
end
stop Tracking;
```

Fig. 8 Algorithm for crowd detection and counting

4. Result and Discussion

The process of face detection inside the crowd focused on the smile detection for each human based on open cv library. Fig.9 successfully detect the face and smile; however, there is one person that closed to camera missed. While Fig10 can identify the even farthest face image.

Fig. 9 Face with Smile detected inside crowd-1

Fig. 10 Face with Smile detected inside crowd-2

The face detection includes several processes such as change the colour space, equalise brightness to capture skin region, grayscale conversion based on a particular threshold, and convert binary imaged based on a computed threshold. Fig.11 is the result of colour space conversion from RGB to CMYK, it's intended for device-independent colour space. It is continued with brightness adjustment to detect skin area as shown in Fig.12.

Fig. 11 Colour space conversion

Fig. 12 Brightness balancing

While Fig.13 is binary mode resulted from gray threshold which is computed previously. Its global threshold by Otsu's method to diminish intraclass variance.

Fig. 13 Threshold binary based image

Fig. 14 Bounding box detected face

The final result of the tracking is detected face with a bounding box, even though some face still missed as shown in Fig.14. The training method yet required for better accuracy.

For a massive crowd, we adopt the method of Adam, S et al. (2019), even though their way still inferior compared to density-based counting, for regular dataset its quite affordable plan. Fig.15 and 16 show the result of their tracking method.

Fig. 15 Face detection for massive crowd-1[30]

Fig. 16 Face detection for massive crowd-2[30]

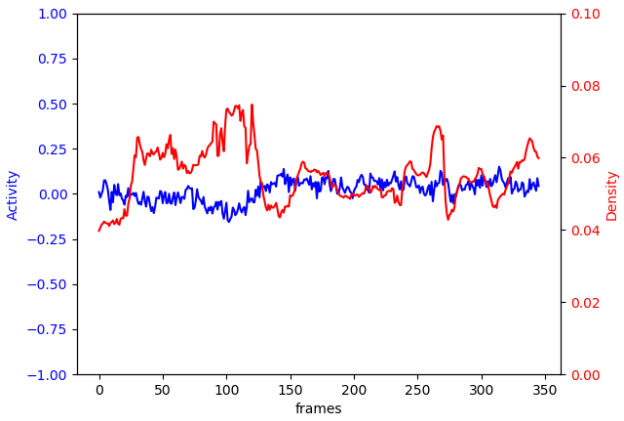

Fig. 17 Correlation graph between activity and density-1

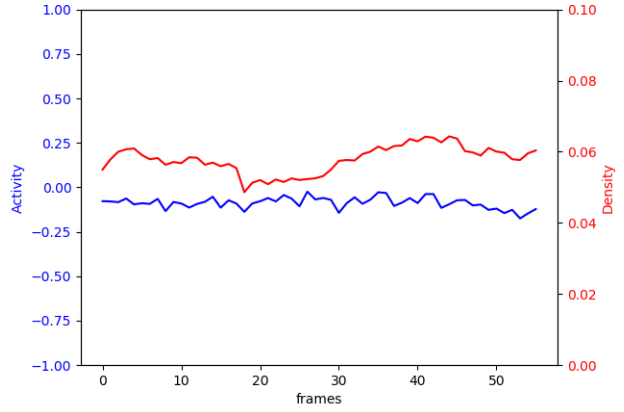

Fig. 18 Correlation graph between activity and density-2

Fig.17 and 18 describe the correlation between the activity of agents inside the crowd with density. If exercise increases the frequency of the group also raised, due to the masses will tend to make pools near-certain area. Therefore, our framework is designed to give an alternative solution by adding extra exit routes in case the density passing the certain threshold.

Finally, the evacuation plan for a particular case can be simulated through the density map as shown in Fig. 19. The Orange-Red colour illustrates the highest density of the crowd going through multiple exit doors. If the counting method for the massive people succeeded then the evacuation route will be triggered based on the density level of crowd dynamically.

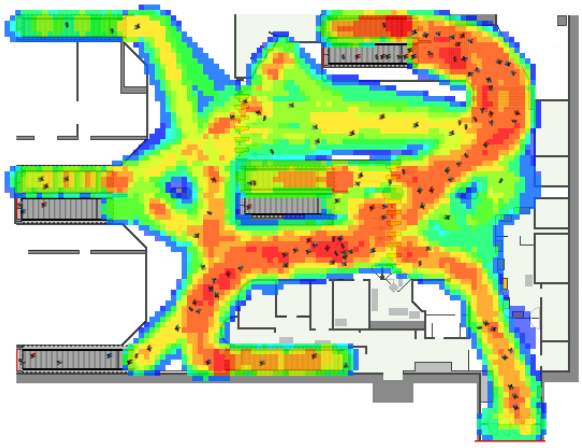

Fig. 19 Density map of crowd going through multiple exit doors

5. Conclusion

Crowd behaviour analysis indeed essential and popular research that being studied for the past decades. The proposed research. The idea of the study is providing the general framework for people safety inside the crowd. The initial process started by detecting the density of people in some area then followed by face and behaviour detection to capture current situation of masses. In case the crowd scene becomes chaos due to some factors, it will initiate the emergency routes plan. The plan carried out by considering the number of crowd density that already calculated using density-based image counting. The result of this research is significant for hazard prevention, and it can be improved further by analysing the thickness of the crowd in a more detail manner.

Acknowledgements

This work was supported by the Deanship of Scientific Research (DSR), King Abdulaziz University, Jeddah Saudi Arabia. The authors, therefore, gratefully acknowledge the DSR technical and financial support under grant no. G:209-611-39.

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