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OPTIMIZATION OF CROWD EVACUATION SIMULATION MODEL IN EMERGENCY SITUATION

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ABSTRACT

Objectives

To develop the conceptual model based on the proposed hybrid optimization approach by optimizing the obstacles placement and exit path of decision-making elements in SFM crowd model to reduce the crowd evacuation time.

Methods / statistical analysis

The methods for this study mainly focusing on the use of the recent nature-inspired hybrid optimization namely Whale Optimization-Bat Optimization (WOA-BAT) algorithm and swarm-based to improve the SFM crowd model. The theoretical framework highlights on how the structure to be complied with the selected case study that will demonstrate the crowd evacuation process in public venue. The design for the crowd simulation environment is targeting to adjust one of the components of space, velocity, number of samples, annotation level, crowd density, type of scenarios and indoor environment in social force model based on the results from the latest work from the existing literature. The hybrid optimization will be the external unit before embedded in social force model under interaction component and will be run using Anylogic simulation tools.

Findings

The main outcome from this study is the conceptual model on how to optimize the crowd evacuation model, namely the SFM model. The proposed method is useful for simulation performance measurement analysis and to optimize the different setting of obstacle placement can help to reduce the evacuation time. The preliminary experiment will be done which includes the crowd evacuation simulation in public venue namely convention centre as its case study environment. As for the validation part, the validation of the developed crowd model will be based on the standard guidelines which are the Rimea-Standard and standard from other existing researchers' work.

Applications/improvements

An improved SFM with the integration of a new proposed hybrid optimization technique is expected to be the outcome in simulating the crowd evacuation.

INTRODUCTION

A crowd simulation focusing on evacuation management is very important nowadays. The evacuation procedure is necessary as a standard evacuation procedure. Thus, a pre-planning of building evacuation is essential that involved many occupants, mostly for simulating evacuation by the public attending events, masses of people gather, flow, and disperse at transportation centres, sporting events, and concerts [1].

Managing crowds in a large indoor facility are still challenging yet of critical importance in ensuring operational safety and efficiency. The need for simulation in this perspective may come as an excellent tool to demonstrate the crowd flow during any emergency evacuation event. The simulation should display particular emergent behaviour from the crowd that can correspond with good building layout designs during the evacuation process [2].

On the other hand, the study of crowd behaviour is also crucial in the simulation application. The crowd behaviour animation refers to a replication of human behaviour during emergencies. The research purpose in crowd simulation is to resemble the evacuation simulation by mimicking the real-life scenario of a fire emergency evacuation using the movement and behaviour of crowd models. In a case of a fire emergency evacuation, the model crowds will be able to move towards the emergency exits and avoid any static (such as walls) or incoming obstacles (such as other model crowds) to avoid a collision. The scenario also includes crowd behaviour, such as running towards the nearest exits [3]. Therefore, it is still a need to study on enhancing the facility in regards to the floor layout and placement of obstacle suitable towards the exit path [4].

Before further focusing on the specific models for crowd simulation, it is vital to understand the two main classes or group of models in describing the pedestrian's or agent's properties during crowd event namely as (i) macroscopic model and (ii) microscopic model. The macroscopic model is to describe the crowd model as a whole, whilst microscopic model describes the agent's description in the crowd as individual properties [5]. The microscopic model needs to be further research for more realistic simulation factor. s due to its

characteristic that study on one agent's properties i.e. the velocity of pedestrian's walking movement, agent's selection of exit (selection behaviour) and the agent's interaction behaviour. Under the microscopic model, there are various models for simulating crowd, and one of the most renowned models, namely Social Force Model, keep on improving till date.

After many decades, the Social Force Model (SFM) has become one of the most widely used models for basic mathematical formulas and an excellent ability to describe movement process. The enhancement of the social force model has been the current research topics in resolving realism issues [6]. It is more continuous in terms of agent movement's behaviour (more realistic) but needs more computational time (inefficient and low computation). In the context of crowd modelling and simulation, there are still some issues about decision making from the pedestrian or evacuee's side to find the exit ways. Modelling panic behaviour on evacuee is a critical challenge as the human movement is unpredictable [7].

In the context of optimization issues, a traditional evacuation system indicates only a fixed direction and may mislead people to a dangerous or wrong place. Optimization-based evacuation models calculate the shortest path by using Dijkstra algorithm, simulated annealing, genetic algorithm and others. The limitation of this model is that it does not take into account the dynamics of real-life situations which caused congestion situation.

Why optimization approach is beneficial for improving the social force model? Problems in evacuation can be defined as optimization problem. The purpose of the optimization is to maximize and minimize the outcome of the classical problems [8]. Nevertheless, the optimization is crucial for retrieving a minimal evacuation time.

For simulating crowd evacuation that incorporate optimization, the problems involve computation wise such as pedestrian's navigation, avoiding obstacles, decision variables and searching of exit path.

In recent trend of crowd evacuation simulation system, there is a need to optimized using different optimization algorithms (hybrid). This is to help finding the best location of the exit door of evacuation area. Some may say that shortest distance towards exit is crucial but optimization can help decide to find the best or near optimal solution (exit) through better estimation on exit capacity (EC) [9].

In this paper, the main contribution will be the conceptual and theoretical model as shown in Figure 1. It describes the overall structures of the proposed enhancement of SFM crowd model using hybrid WOA-BAT and swarm-based optimization algorithm. This will allow a more accurate simulation work in searching and selecting different exit route (optimizing exit capacity computation) thus minimizing the evacuation time without losing the elements of realistic crowd behavior.

The following section of this paper is organized as follows: Section 2 reviews the related work pertaining to the research, Section 3 describe the research methodology, Section 4 discusses the research outcome and Section 5 highlights on the conclusion of this paper as well as recommendation for future work.

RELATED RESEARCH WORK

The effectiveness of pedestrian evacuation in many public premises is highly important as any latency that occurs during exit point can cause in human fatal [10]. Numerous studies have been carried out on pedestrian flow at bottlenecks over past decades such as [11][12][13][14][15][16].

Research scope

In past decades, Helbing and Monar [17] has contributed a tremendous work in simulating crowd behavior which based on physics named Social Force Model. Basically, the work is reproduced from Agent Based Model. Since then, their work has open-up for further research activities in modeling crowd based on physics to describe individual (also known as the agent) or pedestrian movement in 2D basis. The reason is nonetheless to simulate the crowd escaping from panic situation in realistic manner.

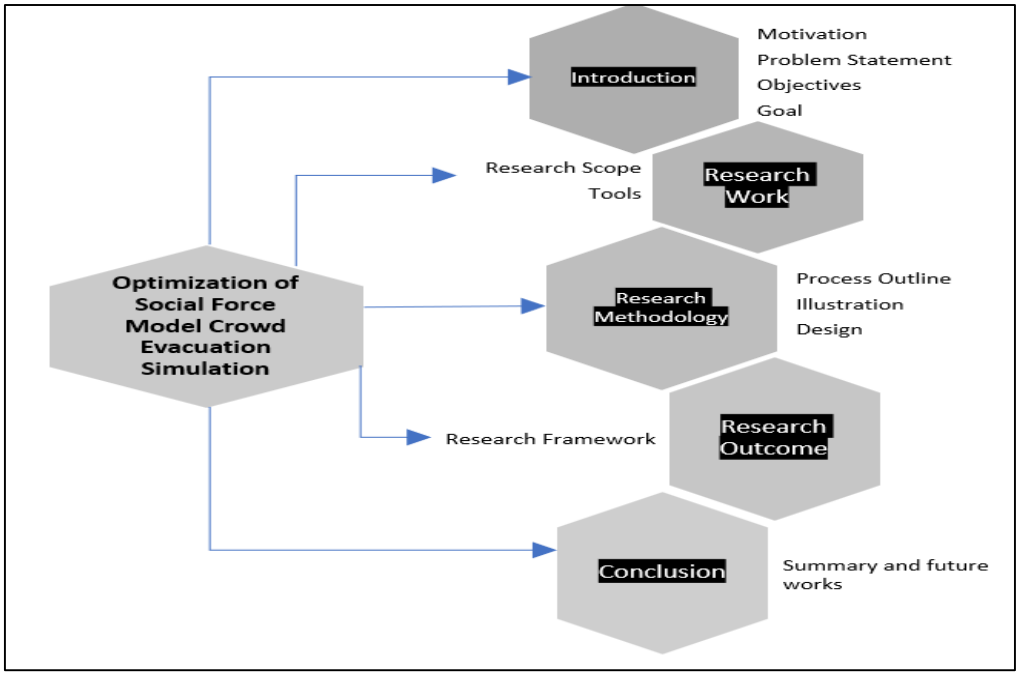

Figure 1 The conceptual model for optimizing SFM for crowd evacuation simulation structures.

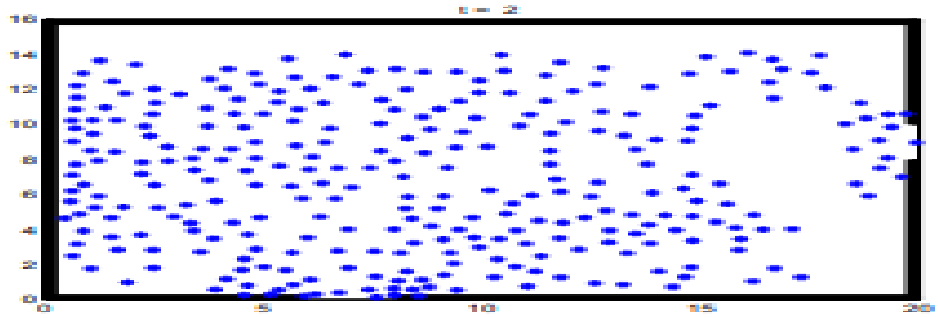

Figure 2 Example of social force particle (crowd) movement in simulation [17].

Figure 2 depicts how particle movement based on the social force of the particles that moves toward the exit. It rather looks like a natural flow and seemingly realistic on real crowd movement behavior.

The process of evacuation that shows the crowd move to the same goal of egress whereby it may result in clogging and bottleneck scene need to be analyse using SFM as a microscopic model in the pedestrian dynamic and it is called "faster-is-slower" effect [18]. The SFM current studies still lacks of precise computation of exit capacity (EC). Wrong EC computation can lead to faulty in the action of choosing exit selection. The SFM also still has unreal situation i.e. constant gap of one person leaving from the group while waiting to be evacuated [19].

The social force model also can be expressed in Equation (1) introduced by Helbing and Monar [17].

$$\underbrace{m_i \frac{d\vec{v}_i(t)}{dt}}_{Acceleration} = \underbrace{\frac{m_i}{\tau_i}(v_i^0 \vec{e}_i(t) - \vec{v}_i(t))}_{DrivingForce} + \underbrace{\sum_{j(\neq i)} \vec{F}_{ij}^{wwe}(t)}_{Interactions} + \underbrace{\vec{F}_i^b(t)}_{Borders,\ Fire} + \underbrace{\sum_k \vec{F}_{ik}^{att}(t)}_{Attraction} + \underbrace{\vec{\xi}_i(t)}_{Fluctuations} \quad (1)$$

As what has been followed by other researcher, in their work shows that the social force model can calculate actual forces in the simulations and describe all kinds of different behaviours such as pushing and following others towards the exits. However, the social force model lacks features that can represent more detailed individual characteristics and realistic movement when dealing with multi-room environment [20]. Another researchers have suggested that this model has redundant issues and do not have the properties of selecting many exits [21].

On the other hand, nature inspired optimization has become one of the appealing approaches to be help improved in many applications, including crowd simulation. Nonetheless, hybrid is one of the strategies to aid the improvement process. The recent optimization approaches which is the hybrid whale-bat algorithm (WOA-BAT) [22], as well as the latest swarm-based optimization will be integrated as an approach to optimize and enhance the SFM crowd model.

The hybrid of WOA-BAT algorithm takes place in order to get better results with less iteration incurred during running time. This means it will get to solution fast or fast computation in achieving the solution [23]. This hybrid optimization is recommended to be applied in crowd evacuation in certain perspectives that can improve the crowd model simulation by integrating it with other optimization approach.

The recent swarm-based optimization is efficient in selecting parameters and good in exploration phase in finding the optimal solution, it is recommended to hybrid with existing optimization which is in this case to hybrid with WOA-BAT in order to improve the accuracy of searching and finding for exit path during evacuation process when the number of agent is higher (particle). Another reason for improvement is the definition of weight function (wf) in each iteration of each agent once the solution has been found makes the swarm algorithm able to avoid the unnecessary exploitation process.

The newly hybrid of WOA-BAT and swarm-based optimization algorithms also needed to help in accuracy(exploring) matter in crowd evacuation such as optimizing the obstacles placement in building and to optimize the computation efficiency (cost effective) using the appropriate parameters for iteration adjustment.

The SFM generally served as to simulate the crowd behavior in realistic manner as it has interaction component but need improvement to make the model achieve better simulation results while maintain the realism issues. The hybrid optimization is then plugged into SFM (Interaction) module as stated in equation (1) to further exploit (exploitation) of the pace or velocity parameter which work together to overcome the unrealistic scenario in SFM model such as people tend to leave behind from the group when in clogging at exit point. The precise exit capacity calculation based on force model is needed with the help of hybrid technique to lead to a better selection of exit by the particles(agent) in the crowd.

The overall proposed method designed and including its purposes. The hybrid optimization is to help in dealing with obstacle's placement and agent searching path accuracy for selecting the nearest exit point. This illustration shows how the component in research stage to reflect the research objectives can be achieved.

Simulation tools

The selected simulation tool is using any logic software. Any logic software is the well-known simulation tools that can support many crowd model for example Agent Based. Since SFM is derived from agent-based model [17], therefore the simulation work will be done using any logic software. From the simulation, the setting of the particle interaction with building layout with obstacles and exit selection can be observed and expected to produce realistic

and minimize the simulation time.

RESEARCH METHODOLOGY AND FRAMEWORK

This section will discuss on general research stages and the setting up of the crowd evacuation optimization-based framework, research activities, the experiments and expected results from the experiments.

Figure 3 shows the research methodology for this optimization of crowd evacuation simulation work stages. The design for the crowd simulation environment and components will be proposed based on the results from the latest approach from literature e.g. space, velocity, number of samples, annotation level, crowd density, type of scenarios and indoor environment. In design stage will reflect of how the research objectives stated earlier will be achieved via illustration of the overall proposed method and the simulation performance measurements. The rest of the research stages
will be elaborated in next subsection.

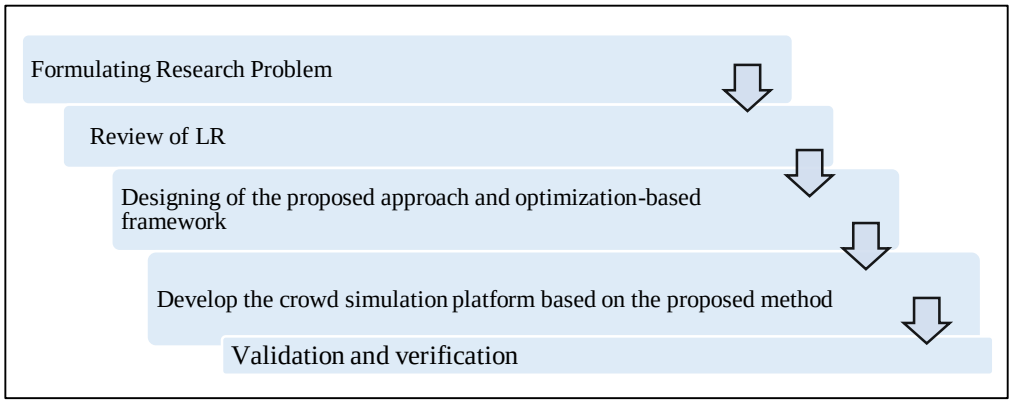

Figure 3 The research methodology.

Overall design process flow and illustration of panic crowd simulation

Figure 4 shows the illustration of overall concept of hybrid optimization algorithm is to help in dealing with obstacle's placement and agent searching path accuracy for selecting the nearest exit point by enhancing the component in SFM for this crowd evacuation simulation work. Figure 5 shows the process flow and working algorithm incorporating the steps on particles(agent) that act as a crowd in evacuation simulation.

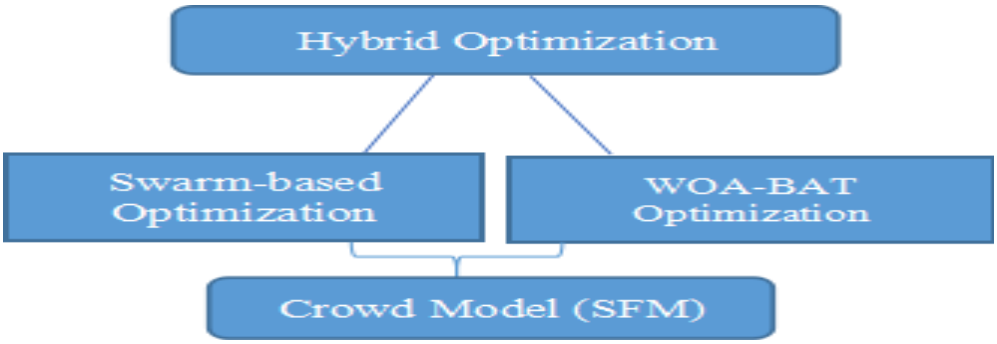

Figure 4 The overall proposed method designed.

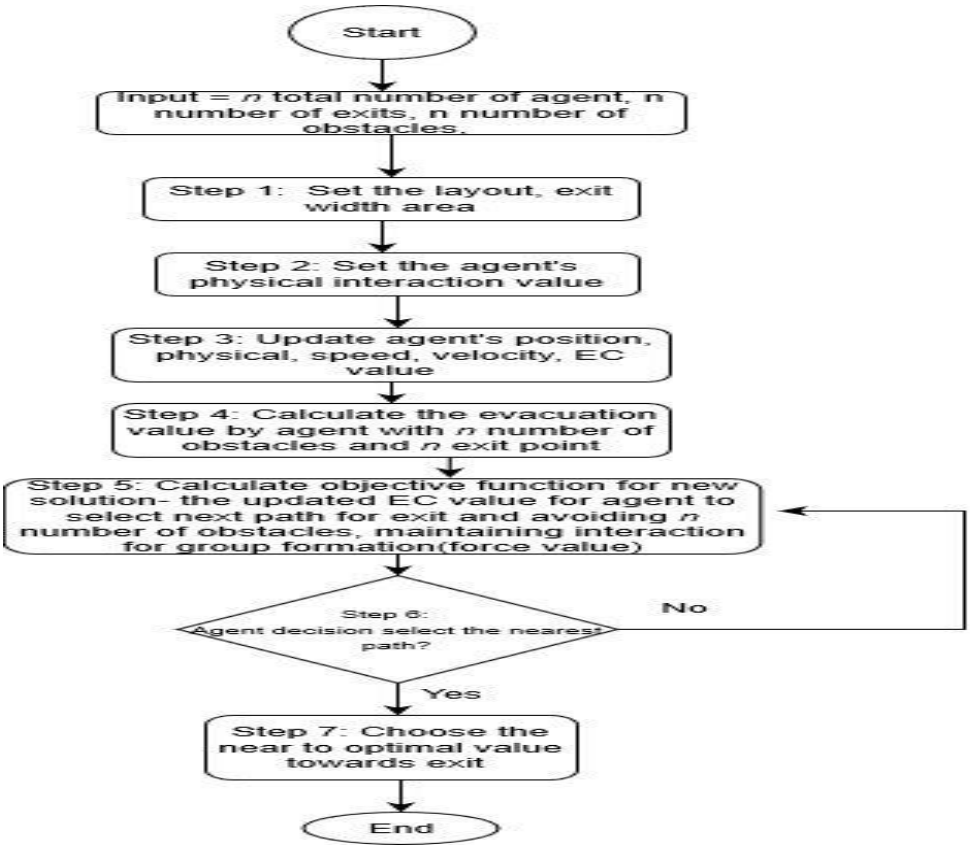

Figure 5 The process flow for optimizing crowd evacuation simulation.

The illustration of crowd behavior during evacuation in panic situation can be seen in Figure 6 and Figure 7. Figure 6 shows the simulation without obstacles [24]. The clogging behavior can be observed and panic level arises. The clogging caused the agents (particles) to move slower and thus increase the evacuation time. As compared to Figure 7, the simulation is done with obstacles being placed in various positions near exit door. From observation, it can be seen clogging behavior emerged and cause the delay and time consuming during evacuation procedure. Thus, the optimization on obstacles layout and placement can further help alleviate the situation.

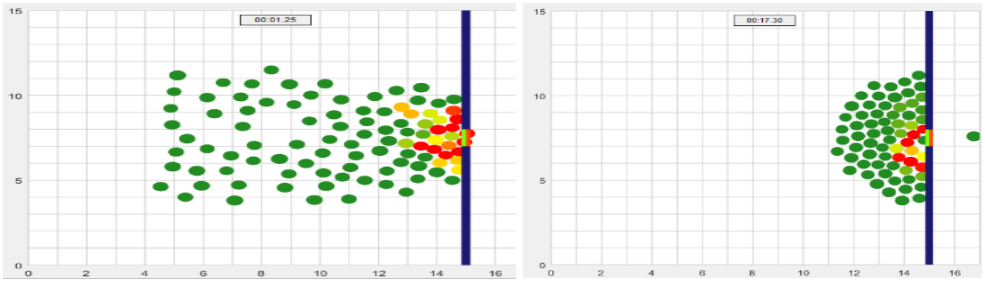

Figure 6 The simulation without obstacles. The clogging behavior can be observed and panic level arises [24].

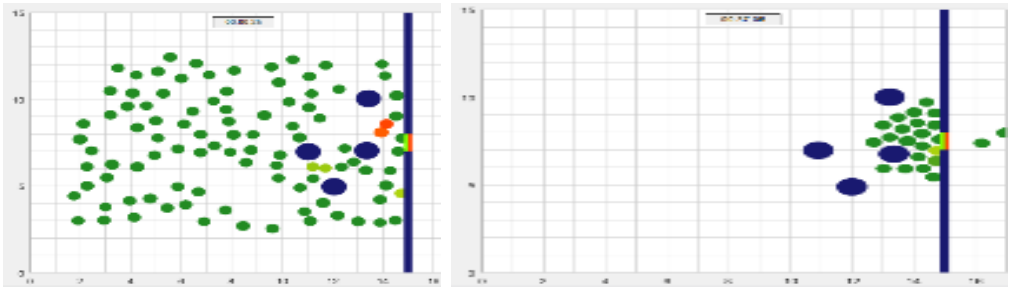

Figure 7 In this simulation, the environment has been populated and obstacles (blue colored circle) has been put into several position near exit way [24].

The optimization of crowd evacuation simulation conceptual model

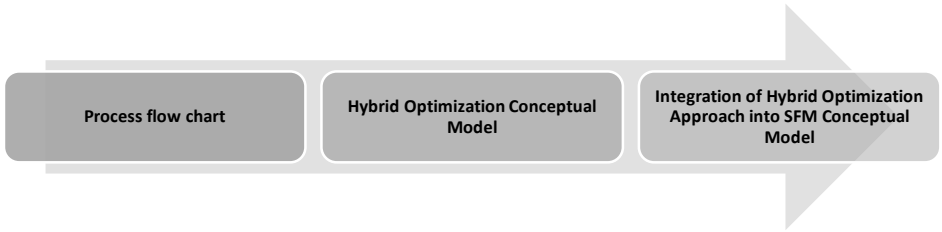

Figure 8 The development of conceptual model for optimization of crowd evacuation simulation.

This research work aims to produce the framework based on the proposed crowd evacuation model. Figure 8 shows the development of conceptual model of hybrid optimization and integration of the hybrid optimization into SFM model as part of the enhancement process. The research is targeting to adjust one of the components in social force model by plugging in the hybrid optimization model. Figure 9 shows the proposed crowd simulation framework, whilst the optimization unit is explained in Figure 10.

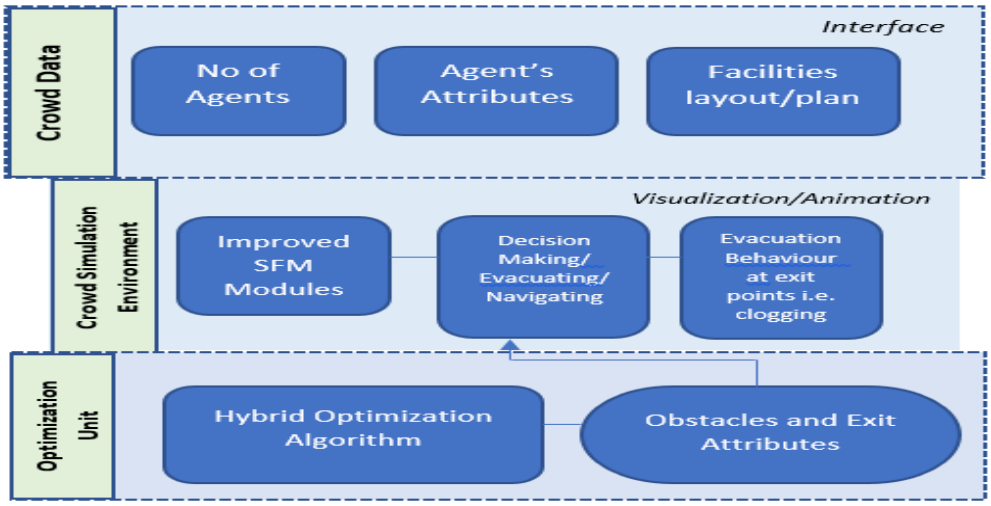

Figure 9 The framework for the proposed crowd simulation and behaviour analysis.

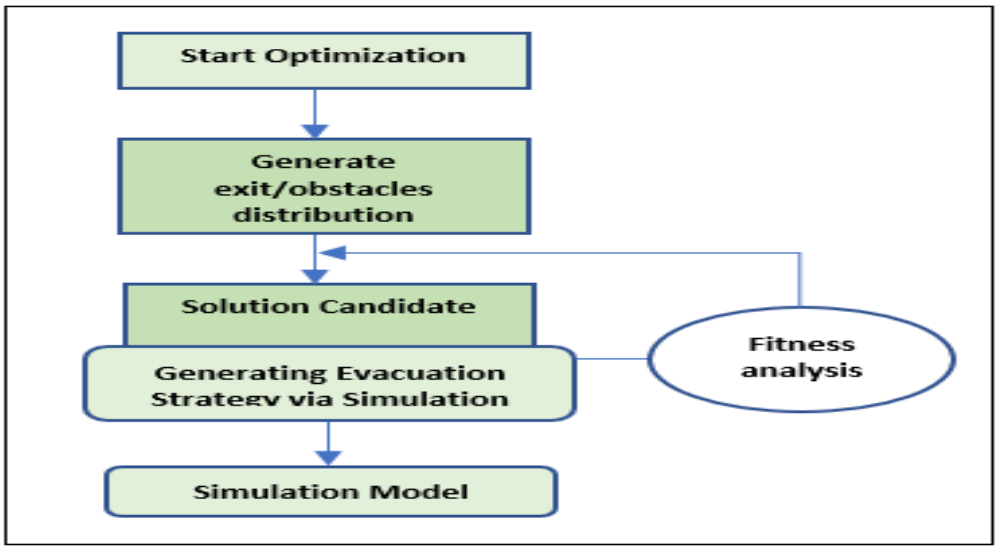

Figure 10 The Optimization Unit analysis.

The hybrid optimization will be the external unit before embedded in social force model under interaction component. Optimization algorithm of WOA-BAT and swarm-based optimization will be used for the hybrid purposes. Figure 11 shows the design of the conceptual model based on the described method discussed earlier.

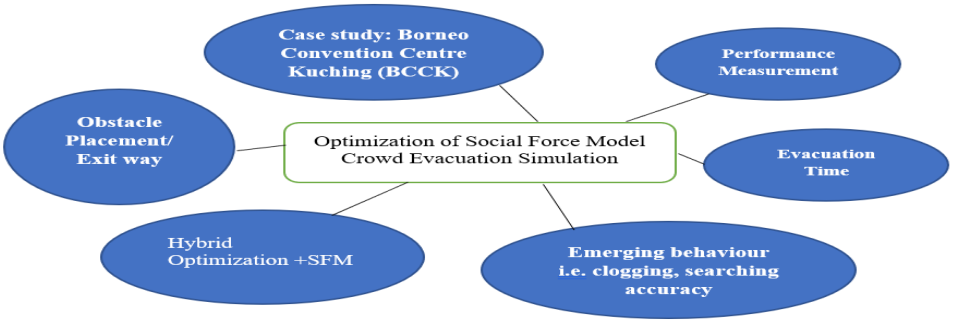

Figure 11 The conceptual model component.

Facilities layout design

For this simulation, it intends to simulate the public indoor facilities such as in convention center. One of the convention centers has been chosen Borneo Convention Center Kuching (BCCK) [25]. The layout has been presented as the preliminary experiment purposes in Figure 12. In this cropped image, the highlight is on the exit way from the main hall which the circular object act as a pillar (obstacles) in order to show the evacuation process.

RESEARCH OUTCOME

In this paper, the main contribution has been highlighted by presenting the conceptual model of optimization in crowd evacuation model comprising of latest nature-inspired hybrid optimization as main approach. An experimental study will follow suit on the selected case study which complies with the theoretical structure to demonstrate the crowd behaviour during public event i.e. during exhibition and how the evacuation process can take place. Apart from that, the new proposed method is useful for simulation performance measurement analysis and to optimize the different setting of obstacle placement can help to reduce the evacuation time. As for the validation part, the validation of the developed crowd model will be based according to the technical and guidelines for emergency evacuation scenarios Rimea-Standard [26] and other validation standards adopted from other researcher method [27].

The results of evacuation time is supposed to be minimal or following the standard of evacuation procedure for at least 3 minutes in building evacuation according to standard from The Fire & Rescue Service Department and Occupational, Health and Safety Environment whilst the minimum exit time for evacuation from Seagate Convention Center (large public space) take 10 to 12 minute for approximately 6000 people capacity for [28].

Figure 12 The cropped layout of the selected convention centre (BCCK) with obstacles illustrated along the exit path.

CONCLUSION

This paper is aim to discuss the conceptual model of the optimization of crowd evacuation model research work. It presents the new proposed hybrid optimization algorithm to be integrated in the crowd behavior model in order to produce the expected simulation output. The approach of hybrid technique has been claimed by many researchers to be applied in simulation model due to its flexibility and powerful technique [29]. In general, it describes the process of the research stages on how to appropriately select the technique based on literature review. Consequently the details for each of the research stages also been discussed especially on how the technique can be applied and the possible outcome of the research stages for this research study. The proposed research work is also targeting to analyze the evacuation time and to better estimate the exit capacity estimation upon improvement that has been made to the SFM model.

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