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DEVELOPING A PEDESTRIAN EVACUATION PLANNING TOOL FOR LIMITED ACCESS SITES USING EVOLUTIONARY ALGORITHM

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ABSTRACT

One of the evolving applications that heavily relies on pedestrian modeling is “emergency evacuation planning”. This research is focused on developing an emergency evacuation planning tool for urban sites with limited access points (entrance and exit gates). The evacuation problem is handled from an optimization perspective. Genetic Algorithms are used as a solution approach for the multivariable search based optimization problem in a simulation based modeling environment. In developing the evacuation tool a case study of the faculty of engineering campus at Cairo University, Egypt, has been adopted.

The Social Force Model is used to simulate the behavior of pedestrians in the evacuation process. The evacuation optimization problem has been efficiently mapped to a typical Genetic Algorithm framework. Simulation results revealed the potential of the developed tool in significantly reducing the evacuation time (44% reduction) and hence allowing for a safe and rapid evacuation process.

Keywords: Pedestrian simulation, Pedestrian evacuation, Genetic Algorithm based evacuation.

INTRODUCTION

Pedestrians constitute a major aspect of any transportation system. The planning and design of pedestrian facilities are essential for usage safety, efficiency and comfortability. One of the crucial planning applications for such facilities is the evacuation one. Emergency situations such as earthquakes, floods….etc or other human caused hazards such as fires, bombing threats….etc. are all accompanied with a rush in population movements in pedestrian paths causing serious injuries or possibly loss of life. To reduce potential risks, it is essential to prepare evacuation plans for the impacted individuals to properly flee the hazard location in a rapid and safe manner.

Emergency evacuation plans are generally based on the use of a number of transportation modes; private vehicles, public transit, pedestrians and so forth, according to the size and characteristics of the impacted area. This paper is focused on pedestrian emergency evacuation. Previous research efforts on pedestrian evacuation have been mostly focused on indoor evacuation such as buildings, shopping malls, transport terminals….etc. Pedestrian outdoor evacuation in larger areas such as stadiums, concerts, university campuses…..etc, have been rather limited. The objective of this research is to develop an emergency evacuation planning tool for limited-access, outdoor, sites (such as gated university campus, hospital center compound, small size residential compound…etc). The scope of this tool is limited to generating offline emergency evacuation plans for such sites, prior to the occurrence of any incident/emergency situation. The adoption of such plans will minimize the site evacuation time, which is the primary objective in emergency conditions.

The complexity of the transportation system challenges the adoption of an analytic solution approach to the problem in hand. Heuristic search techniques seem to offer an opportunity for achieving a satisfactory solution. In this paper Genetic Algorithms (GA) are adopted for the multivariable search based optimization problem in a simulation based modeling environment. In developing the emergency evacuation planning tool a microscopic simulation model for the study area (Cairo University Engineering campus) was used.

BACKGROUND

Several research efforts on pedestrian evacuation under various emergency situations have been published throughout the last decade. The characteristics of the evacuated area and the emergency severity play a main role in selecting the suitable solution approach. Georgiadou et al. (2007) introduced a mesoscopic model providing the temporal and spatial distribution of the population. This model incorporates stochastic and dynamic choices of evacuation routes based on a Markov process. The proposed model was used in simulating the evacuation of an area around a hazardous industrial facility. Lämmel et al. (2008) adapted a multi agent transportation simulation framework to simulate large-scale pedestrian evacuation. The model captures the congestion effects of bottlenecks and evacuation delays. Nana et al. (2008) used a simulation-based approach to study the optimum egress plan for the Beijing Olympic Games main stadium. Saadatseresht et al. (2009) defined the evacuation planning problem as a spatial multi-objective optimization problem, handled through a Geographic Information System (GIS) environment. Lämmel et al. (2010) adapted a large-scale pedestrian microscopic evacuation simulation platform for the city of Padang in Indonesia, as it faces high risks of tsunami.

A cornerstone in most pedestrian evacuation planning applications is the simulation of pedestrian movements. In contrast to vehicle movement, pedestrians interact simultaneously with each other and their surrounding environment, changing their direction and speed frequently rather than moving in continuous lanes. Many pedestrian simulation models have been developed in a variety of disciplines including computer graphics, robotics, and traffic. Simulating pedestrian movements can be grouped, similar to vehicles modeling, into three main methodologies; macroscopic, microscopic, and mesoscopic approaches.

Microscopic models describing the space time behavior of an individual pedestrian could be further divided into two main approach; Cellular Automata (CA) models and Social Force Models. Both models differ in their discretization methodology of space and time. The cellular automata (CA) approach describes the space under study as a uniform grid of cells with local states (Blue and Alder, 2000). Depending on a set of rules that describe the behavior of pedestrians, the movement of pedestrians is controlled. These rules compute the state of a particular cell as a function of its previous state and the states of the adjacent cells. Abdelghany et al. (2010) developed a simulation model for large-scale crowded pedestrian facilities during emergency evacuation using the cellular automata platform. This approach was applied to evaluate the evacuation of the new Masa'a in El-Haram El-Sharif mosque in Makkah, Saudi Arabia.

On the other hand, the Social Force model, adopted in this study, was introduced by Helbing and Molnár (1995). The model describes pedestrian behavior microscopically by virtual "physical" forces induced by the social behavior of the individuals. This study is based on the social force model concepts; where pedestrians move in reaction to a number of forces. These forces represent the effect of the environment (e.g. other pedestrians or borders) on the behavior of the moving pedestrian. Such forces describe the motivation resulting in an acceleration or deceleration as a reaction to perceived information that the pedestrian obtains about the environment (Helbing and Molnár, 1995). The driving force is a primary force in this context. This force describes the pedestrian desire to walk at a convenient speed to reach a certain destination. The driving force is affected by various inputs throughout the movement process, such as the desire to maintain a safety distance, not only to other pedestrians but also to obstacles or buildings. Obviously, the interaction between the driving force and other inputs varies according to the modeled situation (i.e. a panic movement is completely different than a normal walk). The Social Force model addresses these variations by manipulating the model parameter values. In the literature, the Social Force model was used in simulating several pedestrian movements in panic situations; such as the evacuation of Texas Medical Center with the hypothetical event of a toxic material leakage (Qiao et al., 2009).

SIMULATION-BASED PEDESTRIAN EVACUATION

Emergencies can be divided into large-scale ones that could cover a part or an entire city, which include hurricanes, volcanoes, tsunamis, land fires …etc., and relatively small-scale ones, which are often caused by terrorists' bombing threat, toxic material leakage…..etc. This study is focused on small scale emergencies that are characterized by short response time and high density populated areas. The conducted simulation-based evacuation planning procedure is organized in five main steps. In the first step the study area was identified together with the emergency situation. Second, data pertaining to the study area detailed geometric layout and buildings capacities was collected. Third, an estimation approach for the evacuation demand was adopted. Forth, PTV VISSIM was used to develop a microscopic simulation model of the study. In this step a sensitivity analysis was performed to guide the specification of the simulation model parameters. In the fifth step, the developed model was used as an evaluation test bed for the evaluation of potential evacuation plans in an attempt to identify the best one using a tailored GA-based optimization tool.

CASE STUDY AREA

The selected study area is the main campus of Cairo University Faculty of Engineering, Egypt. The study area is located in greater Cairo near the Cairo University main campus at the intersection of Nahdet Masr Street and Cairo University Street as shown in figure 1. The area is well-known with its high pedestrian and traffic volumes. The main campus extends over 50,000 m2 area with about 20,000 people entering and exiting the campus daily (students, teaching staff, and employees). The campus consists of 19 buildings, surrounded by a high fence with three access gates; for both vehicles and pedestrians, as shown in figure 1. The campus area is an outdoor urban area with open spaces and limited boundaries such as walls, corridors, parked cars, light posts….etc. Figures 3 and 4 are images displaying; one of the campus gates, and a within campus roadway dedicated for pedestrians movement, respectively.

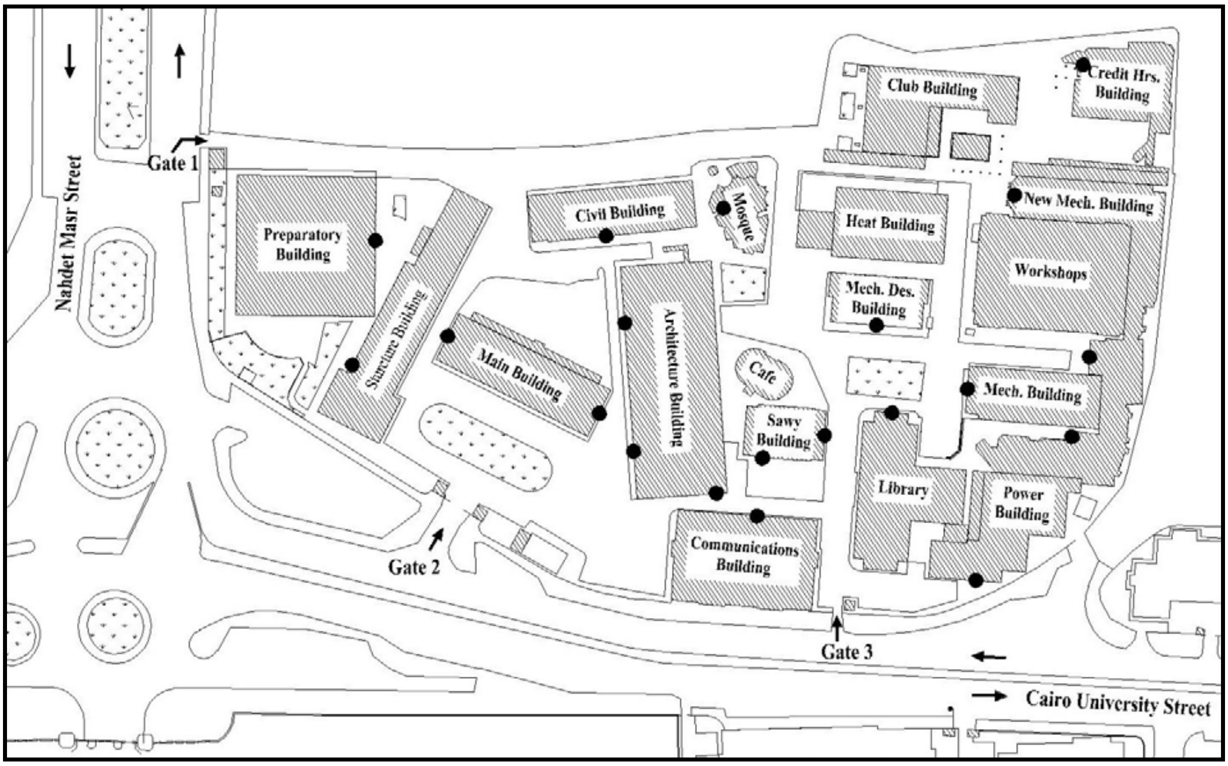

Figure 1: Cairo University - Engineering campus overview

DATA COLLECTION

The geometric layout of the study area components were captured via a detailed survey map together with field measurements. The map depicts the locations of buildings, streets, features, gates…..etc. The collected field measurements included; doorways widths, passageways widths, and stairs dimensions……etc. The spatial location of pedestrians depends on the students/staff distribution among all buildings. As such, data pertaining to the number and capacities of lecture rooms and classes was collected per building to assist in estimating the evacuation demand on campus. The destination selection behavior of pedestrians is primarily dependent on the availability of evacuation routes and exits location. As such, data pertaining to on-campus transportation infrastructure and access locations were collected.

Figure 2: Main entrance/exit gate -Cairo University - Engineering campus

Figure 3: Within campus pedestrian walkway -Cairo University - Engineering campus

EVACUATION DEMAND ESTIMATION

Specification of the evacuation demand is a crucial step in any simulation model development. Evacuation demand refers to the number of people within the campus area that are expected to exit a specific building doorway or a specific outdoor area throughout the evacuation process. As expected, estimated peak volumes are required. The normal daily on-campus pedestrians are basically students, teaching staff and employees. Accordingly, the peak demand was estimated in relation to the number of lecture rooms, classes and offices located in each building. A pilot field study revealed that maximum 80% of classes' capacities are reached during a normal weekday. On the other hand, the number of teaching staff and employees was considered according to their office location. The total pedestrian input distribution is shown in table 1.

Table 1: Evacuation Demand per Building

No.	Building Name	Estimated no. of students	Estimated no. of staff/employees	Total
1	Preparatory Building	1891	30	1921
2	Structure Building	640	30	670
3	Main Building	480	100	580
4	Civil Building	606	30	636
5	Architecture Building	5062	60	5122
6	The Mosque	490	10	500
7	El Sawy Building	288	5	293
8	Communications Building	467	30	497
9	Library	430	30	460
10	Power Building	96	30	126
11	Mechanical Design Building	192	30	222
12	Heat Building	-	10	10
13	Mechanical Building	141	30	171
14	New Mechanical Building (1)	714	10	724
15	New Mechanical Building (2)	570	10	580
16	New Mechanical Building (3)	227	10	237
17	Credit Hours Building	482	30	512
18	Workshops	-	10	10
19	Club Building	-	30	30
Total		12776	525	13300

SIMULATION MODEL DEVELOPMENT

Physical Model Development

PTV VISSIM was used as the microscopic simulation platform for model development. Building the network model requires assigning all physical features on the model such as walking areas, obstacles, ramps, stairways, traffic lights and levels. First, the detailed map was used as a background image to assist in creating the geometry where pedestrian areas and obstacles are assigned. Ramps or stairs also were modeled to capture changes in levels. The model is concerned with outdoor evacuation, and hence, the movement of people inside the building was not captured.

Pedestrian inputs are manipulated through the specification of pedestrian flows from each doorway and its respective flow time. Pedestrian flows are modeled based on the following equations (Kanok-kantapong and Sirkul, 2009):

$$Q_i = \frac{N_i}{T} \qquad \text{Eq. 1}$$

Where, Qi : The pedestrian flow from the doorway i in the building which is expressed by a function of the doorway width (per/hr)

Ni : An estimate of the number of pedestrians passing through doorway i existing in the building under consideration (individulas)

T : The time interval to traverse doorway (sec)

$$Q_i = q * b_i \qquad \text{Eq. 2}$$

Where, bi : The width of the doorway i in a building (meters)

q : The pedestrians passage flow per unit width of the doorway (per/m/sec)

The pedestrian flow per unit width (q) of the doorway is assumed constant and taken as 1.33 person per second per meter of the effective width of each doorway (Gwynne et al., 2009). Since the doorways of all buildings are completely opened during working time, the effective width of each is considered equal to its original width. Using the estimated flow values from Eq. 2 assigned to each doorway input and the estimated number of pedestrians inside each building a definite time interval is specified for each doorway flow according to Eq. 1. Also individuals located in the outdoor areas are assumed to evacuate rapidly within the first 5 minutes of the evacuation time frame.

Route choice behavior also characterizes the evacuation model. Evacuation routes for pedestrians are assigned in relation to available exits. Evacuation routes starts from buildings exits and ends by one of the three available exit gates. The network clearance time represent the evacuation time of the campus bearing in mind that the response time for evacuees and time spent inside buildings is excluded.

Parameters Specification

The dynamical features of escape panic was studied before by Helbing et al., (2000) who analyzed the characteristic features of pedestrians in escape panic. Such behavioral aspects increase evacuation times. To simulate the features of pedestrians in emergency several model parameters needs to be altered from the normal pedestrian movement situation. McGuire, (2005) also used an emergency pedestrian safety system model, modifying Helbing model (indoor setting), to simulate the urban settings (outdoor settings) for pedestrians evacuation.

The credibility of any simulation model depends to a great extent on the adopted parameters values. Usually, parameters estimation and model calibration are performed on the basis of comparing the simulation model performance to reality. In case of an emergency evacuation application, it is extremely difficult to get people to demonstrate a realistic reaction during a crisis rehearsal. Alternatively, obtaining a video footage of a pedestrian evacuation during past emergencies seems more credible. In our case study, given the absence of such videos, using previous calibration results of the social force model in pedestrian emergency evacuations was an appealing option, and hence was adopted. The rationale behind this adoption relies on the argument that human behavior in escape panic situation is mainly impacted by the severity of the emergency situation; subsiding the culture-based variations.

The default values of model parameters are based on movement behavior of pedestrians naturally i.e. the movement of pedestrians in a normal day situations. Parameters of the social force model are divided into three types according to VISSIM user manual, (2009): parameters of the original model, parameters of the model extension for VISSIM, and implementation-specific global parameters. The parameters candidates for modification are mainly the original model parameters that deal with the social force model. The impact on the other model parameters, by the emergency scenario, is rather limited. Studying the effect of changing parameters values in the model operation was performed through a sensitivity analysis; where the evacuation time was recorded for different parameter values. Results of the conducted sensitivity analysis revealed the high sensitivity of the model operation, in panic situations, to the following four parameters:

1- The relaxation time tau τ_α which relates to the reaction time or response inertia; as it couples the difference between the desired speed and direction v0 and the current speed and direction v to the acceleration (Eq. 3). Smaller values of the relaxation parameter stimulate more aggressive walking behavior (Helbing et al., 1998). To test the model sensitivity to τ_α value, a number of simulation runs were performed with different values of the relaxation time. The clearance time of the network (evacuation time) was recorded with the change of τ_α value as shown in figure 4. It is obvious that the evacuation time increases with the increase in the τ_α value. This result confirms that small values of τ_α force pedestrians to walk more aggressively; decreasing their total evacuation time. Based on the simulation results a τ_α value of 0.1 was adopted for the developed simulation model as taken by Nakatsuji and Shiwakoti (2006).

$$a = \frac{(v_\alpha^0 - v_\alpha)}{\tau_\alpha} \quad \text{Eq. 3}$$

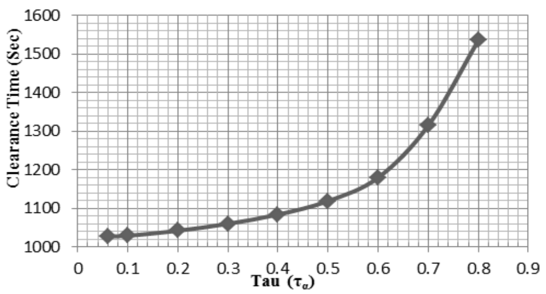

Figure 4-a: Senstivity of tau (τ_α)

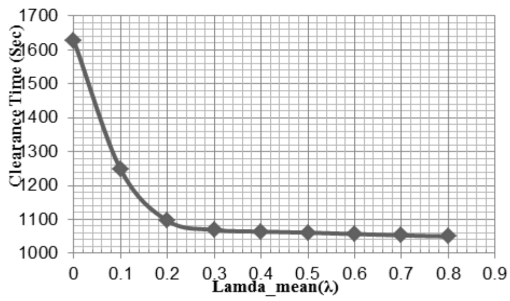

Figure 4-b: Senstivity of lambda (***λ***)

Figure 4: Model Sensitivity to changing tau (τ_α) and lambda (λ) values

2- Lambda (λ_mean) that governs the amount of anisotropy of the forces. This factor is based on the belief that events and phenomena behind the back of a pedestrian do not influence him/her as much as if they were in his sight i.e. repulsion effect of back pedestrians and obstacles. From lambda and the angle φ between the current direction of an agent and the source of a force a factor w for all social forces is calculated; suppressing the force shown in Eq.4 (Helbing and Molnár, 1995).

$$w = \lambda + \frac{(1-\lambda)(1+\cos\phi)}{2} \qquad \text{Eq. 4}$$

It is expected that the movement of pedestrian in an evacuation situation incorporates more crowding and pushing and that's why pedestrian reaction towards the backward events (such as moving following other pedestrian) will have a less effect (i.e. repulsive effect) on their movement than in normal situations. In evacuation situations, pedestrians are expected to move in bottlenecks and crowded spaces; accepting other near pedestrians. Simulation results indicate that the evacuation time decreases with the increase in λ values, as shown in figure 2-b. The default value of lambda_mean in the model is 0.4; however a value of 0.1 is adopted in the evacuation situation based on a research effort by Kretz et al. (2008).

3- Noise parameter; concerned with the effect of the fluctuations in the social force model equation that account for the general random force. These random variations of behavior arise from accidental or deliberate deviations from the usual motion forcing the pedestrian to move slower than desired. In panic situations the noise value is expected to increase to accommodate the differences in the individuals' behavior in an evacuation situation. A value of 2 is adopted compared to 1.2 in normal conditions.

4- Routing_large_grid parameters; the only global parameter subjected to change. This parameter is manipulated to simulate a relatively large pedestrian area. The routing_large_grid defines the topological grid size that is handled as one cell in VISSIM simulation. This parameter affects the speed of running of the simulation depending on the PC memory capability. There is no global value that fits best in all case. The recommendation is typically to increase the parameter value with the increase in the simulated area. A judgmental-based value of 100 is adopted in this study.

GENETIC ALGORITHM BASED EVACUATION OPTIMIZATION

Genetic Algorithm Model Framework

The introduction of heuristic-based techniques, such as Evolutionary Algorithms (EA), has created opportunities for solving complex optimization problems. Genetic Algorithms (GA), one of the EA categories, has been successfully used for solving a wide range of optimization problems. A GA-based optimization tool was tailored for the evacuation problem of a closed site with limited access. The problem in hand was mapped to a typical GA framework, where the developed simulation model was used as an evaluation test-bed for each potential solution. Typically, GA starts its search with randomly chosen chromosomes from the search space to create an initial population. Each chromosome represents a potential solution to the problem.

The initial population evolves towards better chromosomes, i.e. better solutions, by applying genetic operations such as selection, crossover and mutation (Shopova, et. al. 2006).

For the problem in hand, the objective is simply to minimize the total evacuation time of the network by assigning each pedestrian input (doorway flow) to one of the three exit gates. First the optimization problem must be mapped to shape a genetic chromosome defining the problem parameters, constrains and variables. Binary encoding was used in this representation such that each flow Q_n (flow Q of doorway n) is assigned three bits in the chromosome genes one for each exit j (where j is from 1 to 3, representing the 3 exit gates). Each bit takes either a value of 1 if Q_n exits through its respective gate or 0 if it doesn't. It's noteworthy that each doorway flow could exit from only one gate.

After defining the genetic representation, a measure of the solution fitness is mandatory. The fitness function provides a numerical representation of the goodness-of-fit of the evaluated solution. Equation 5 represents the adopted function.

Fitness Function $f_i = \frac{1}{T_i}$ Eq. 5

Where fi: The fitness function of each evacuation solution i
Ti: The objective function which is the evacuation time Ti for each run no. i

Selection is the first genetic operator taking place in the selection process of a proportion of the existing population to breed a new generation. The selection schemes used is based on the Roulette-wheel selection. This selection scheme maintains the selection of higher fitness solutions in the following generations since they will have a higher selection probability, as shown in equation 6 (Shopova, et. al. 2006).

$$P(i) = \frac{\text{fitness}(\vec{x}_i)}{\sum_{i=1}^{N} \text{fitness}(\vec{x}_i)}$$ Eq. 6

Where N is the size of the population

The crossover is the second genetic operator; it combines, the features of two selected parent chromosomes forming children. Based on available literature, high crossover probabilities are typically recommended for single point cross-over (Shopova, et. al. 2006); a value of 80% was considered in the developed tool. Mutation is the third genetic operator used to maintain genetic diversity from one generation of a population to the next. The mutation process is generally controlled by a mutation probability; typically a low probability value of 5% is adopted (Shopova, et. al. 2006).The last genetic operator is the elitism where the best (elite) solutions in the generation is determined and copied to survive in the new generation. The cycle of genetic operations is repeated until convergence.

Genetic Algorithm Based Optimization Tool Development

The software was developed using Visual Basic programming language. Briefly, the software links the optimization operations to the developed simulation model. The simulation model serves as the test-bed for the proposed solutions. The software loads the network model on VISSIM; performing several simulation runs as dictated by the GA operators. A screen shot of the software interface is provided in figure 6.

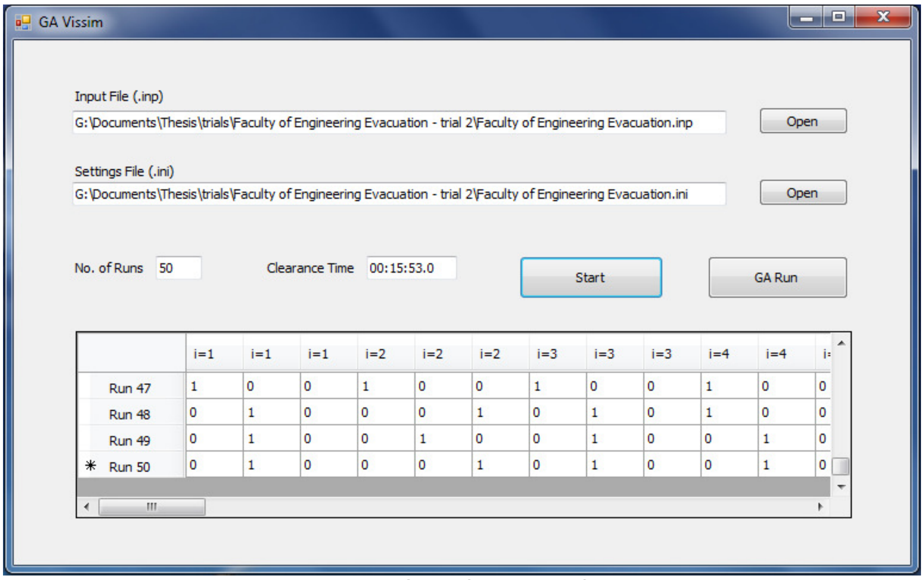

Figure 5: GA software interface

In terms of processing capabilities, when dealing with multiple simulation runs, cluster computers are more efficient. Cluster computers are composed of a network of computers working in parallel to harness the cumulative power of the entire network in which a specific area in the model is divided into smaller blocks (McGuire, 2005). This makes the system handles more entities than the possible in case of individual computer. Without using a cluster computer, running successive simulations is sometimes slow. In this study only one computer was used, and hence, successive iteration of the GA operators where phased to avoid the collapse of the processor. It's worth mentioning that at this stage only offline operation of this tool is feasible (for planning activities). The use of cluster computers is expected to speed up the process; allowing for online operation.

An additional, slightly modified, version of this software was developed to enable producing an evacuation plan for specific building/s. In certain cases, only one building could be affected by an emergency situation, thus, the plan need to focus on building and the neighboring ones only; without evacuating the entire campus. As such, the modified version of the software operates in the basis of having a variable chromosome length. This length is case-specific. The length in determined based on the number of doorways of the affected buildings.

CASE STUDY RESULTS

Testing the developed evacuation planning tool based on the adopted case study of the faculty of engineering campus evacuation was achieved through the comparison of the evacuation plans formulated using the developed tool and the random evacuation case "no plan case". The total evacuation time was used as a measure of effectiveness to the evaluation procedure. Testing was performed for two evacuation scenarios;

1- Application (1): Evacuation of the entire campus.
2- Application (2): Evacuation of a particular building and the immediate surrounding ones.

Application (1): Evacuation of the entire campus

This scenario requires the evacuation of the entire campus under a hypothetical emergency situation such as bomb threat, earthquake…..etc. The evacuation time of the entire campus is estimated under two evacuation plans. First, the "no plan case" is studied, where evacuees are instructed to evacuate without any guidance. This case was simulated using the developed network simulation model, where pedestrian flows were distributed among available routes with percentages inversely proportional to routes length. This approach leaves a large percent of evacuees using near exits and a smaller percent using far exits when nearby ones are overcrowded. This simulation scenario showed a network evacuation time of about 1679 seconds.

Second, the "planned evacuation case" where pedestrians are guided through a published emergency evacuation plan. Evacuation paths/exits were defined using the developed evacuation planning tool. Such plans are to be posted beside each building exit/entrance doorway. Students are to be asked to familiarize themselves with such plans, in normal conditions, as a safety measure. The developed tool attempts to minimize the evacuation time using the GA-based approach. The developed tool based on a population size of 50 chromosomes produced a plan with a total evacuation time of 942 seconds. This result illustrates the potential of the developed tool, achieving a significant reduction in the evacuation time of about 44%.

Application (2): Evacuation of a particular building and the immediate surrounding ones

This scenario is a limited evacuation one, where a limited number of buildings are to be evacuated if an emergency happens in one building and only the endangered building and the neighboring ones need to be evacuated. Similar to application (1), two evacuation plans are to be compared; the "unplanned case" and the "planed case". For the adopted case study the structure building no.2 and its neighboring ones are subjected to evacuation.

First, in the "unplanned case", the evacuees are left to evacuate the building and the neighboring ones without guidance with a clearing time of about 1142 seconds. Secondly, the GA evacuation planning tool generated a plan resulting in a total evacuation time of 904 seconds. A significant reduction in the evacuation time of about 21% was achieved.

CONCLUSIONS

This research aimed at introducing the EA search-based techniques in the organizational evacuation planning of urban closed sites with limited access by developing an emergency evacuation optimization planning tool. Genetic Algorithms were used as a solution approach for the multivariable search optimization problem within the simulation modeling environment that simulates the evacuation process. Simulation of the evacuation process was modeled using VISSIM microscopic traffic simulator, based on the social force model concepts.

DEVELOPING A PEDESTRIAN EVACUATION PLANNING TOOL FOR LIMITED ACCESS SITES USING EVOLUTIONARY ALGORITHMS

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A case study of Cairo University - Engineering campus was adopted throughout the study to evaluate the proposed evacuation modeling/planning approaches. The social force model introduced by (Helbing and Molnár, 1995), showed high potential in simulating the behavior of pedestrians when evacuating a site in emergency situations. Nonetheless, the values of model parameters need to be adjusted to reflect the simulated situation. The conducted sensitivity analysis on changing parameters values revealed the necessity of specifying appropriate values for the following parameters; the relaxation time (Tau), the lambda mean value and the noise parameter. Based on relevant literature, the following parameters values were considered appropriate for the current investigation; 0.1, 0.1 and 2 respectively. As such, the developed simulation is realized to be a test bed for simulating pedestrian movement under different evacuation strategies and plans for the adopted case study.

A GA-based optimization tool was developed for evacuation planning purposes. The pedestrian evacuation problem was efficiently mapped into a GA framework. The adopted algorithm was implemented in a software for testing purposes. Simulation-based testing was conducted in two stages. First, in application (1), the entire campus was evacuated. The evacuation time of the whole campus was significantly reduced by about 44% when using the developed software in comparison to the “no plan” case. Similarly, for application (2): partial campus evacuation, the evacuation time of building no. 2 and the neighboring ones was significantly reduced by about 21%.

The achieved evaluation results highlight the potential of the developed software as an offline emergency evacuation planning tool, for limited access open sites. The next step in this research endeavor will be to develop an online version, for real time operations. Such development requires expediting the simulation process. Parallel processing will be investigated for this purpose.

REFERENCES

Abdelghany, A., Abdelghany, K., Mahmassani, H. Al- Ahmadi, H., and Alhalabai, W. (2010). Modeling the evacuation of large-scale crowded pedestrians facilities. In: proceedings of the 89th Transportation Research Board Annual Meeting (TRB), 2010, Washington, D.C.

Blue, V. J. and Adler, J. L. (2000). Cellular Automata Microsimulation of Bidirectional Pedestrian Flows. In Transportation Research Board 1678, p.135-141.

Georgiadou, P. S., Papazoglou, I. A., Kiranoudis, C. T., and Markatos, N. C. (2007). Modeling emergency evacuation for major hazard industrial sites. Reliability Engineering and System Safety, 92, p. 1388-1402.

Gwynne, S.M.V., Kuligowski, E.D., Kratchman J., and Milke J.A. (2009). Questioning the linear relationship between doorwaywidth and achievable flow rate. Fire Safety Journal, 44, p. 80-87.

Helbing, D., and Molnár, P. (1995). Social force model for pedestrian dynamics. Physical Review E, 51(5).

Helbing, D., Farkas, I. J., and Vicsek, T. (2000). Simulating dynamical features of escape panic. Nature, 407.

Kretz, T., Hengst, S., Vortisch, P. (2008). Pedestrian flow at bottlenecks validation and calibration of vissim social force model of pedestrian traffic and its emperical foundations. In the International Symposium of Transport Simulation 2008 (ISTS08) in Gold Coast, Australia

Lämmel, G., Rieser, M., and Nagel, K. (2008). Bottlenecks and congestion in evacuation scenarios: A microscopic evacuation simulation for large-scale disasters. Presented at the 5th Workshop on Agents in Traffic and Transportation at the Autonomous Agents and Multiagent Systems (AAMAS 2008), Estoril, Portugal.

Lämmel, G., Grether, D., and Nagel, K. (2010). The representation and implementation of time-dependent inundation in large-scale microscopic evacuation simulations. Transportation Research Part C, 18, p. 84-98.

McGuire, J. M. (2005). Crowd management and evacuation modeling system. Proceedings of the South west Decisions Sciences Institute 2005.
http://www.swdsi.org/swdsi05/Proceedings05/paper_pdf/Crowd%20Management%20by%20J_McGuirel%20(F4D2).pdf

Nana, Z., Jiangyan, W., and Jiangang, S. (2008). Application of pedestrian simulation in Olympic Games. Journal of Transportation Engineering and Information Technology, 8(6), p. 85-90.

Nakatsuji, T., and Shiwakoti, N. (2006). Simulation of pedestrian dynamics in case of emergency evacuation in a community. 2th ISSOT Symposium, Nov. 14-16, 2006, Bangkok, Thailand.

Kanok-kantaong, C., and Sirikul, N. (2009),Escape Movement Speeds, Evacuation Rate and Time of Thai People from Buildings.
http://oldweb.eng.psu.ac.th/enghome/media/65/File/July/Microsoft%20Word%20-%20Safety2009.pdf

Qiao, F., Ge, R., and Yu, L. (2009). Evacuation modeling in small and dense area. In: proceedings of the 88th Transportation Research Board Annual Meeting (TRB), 2009, Washington, D.C, 09-1172.

Reeves, C. R., and Rowe, J.E. (2003). Genetic Algorithms: Principles and Perspectives A Guide to GA Theory. Kluwer Academic Publishers.

Saadatseresht, M., Mansourian A., and Taleai, M. (2009). Evacuation planning using multiobjective evolutionary optimization approach. European Journal of Optimization Research, 198, p. 305-314.

Shopova, E. G., and Vaklieva-Bancheva, N. G. (2006). Basic genetic algorithm for engineering problems solution. Computers and Chemical Engineering, 30, p. 1293-1309.

VISSIM version 5.20 User Manual, PTV Planung Transport Verkehr AG, 2009. http://www.ptvag.com/software/transportation-planning-traffic-engineering/software-system-solutions/vissim-pedestrians/