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Using genetic algorithm method for improving evacuation analysis at passenger ship

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It is necessary to prepare the methods and tools for the analysis of evacuation time at passenger ships because designing of evacuation routes should be still improving. Safety evacuation process is very important in case the fire growth. Evacuation routes should be correctly designed in order to enable the passengers to leave danger areas. The paper describes an application of genetic algorithm to random search of combinations of initial distribution of the passengers, evacuation routes blocked by fire and the flow of the passengers. Calculated evacuation time is a fitness function. Parameters of evacuation routes topology should be coding as non-binary chromosomes. Genetic operators (selection, crossover, mutation or inversion) should be suitable for such type of problems to avoid inadmissible solutions. There are a lot of models that simulate eventual people evacuation. Influence of different factors for human behaviour and movement is analysed. The papers shortly describes the methods of estimating evacuation time.

Key words: *evacuation, genetic algorithm, passenger ship, optimisation.*

1. Introduction

Nowadays at the world there is tendency to build great passenger ships. Ferries are larger and larger, furnishings are richer and richer. There are a lot of different spaces such as cafeterias, restaurants, shops, cinemas, fitness, swimming pools, etc. Modern arrangements of passenger ships make them attractive for spending free time. The giants such as "Carnival Triumph", "Carnival Victory", "Explorer of the Seas" or "Galaxy" have length about 300 m and carry about 4 thousand passengers [12].

These numbers convey an idea how complicated can be furnishing, corridors and cabins arrangement at such type of ferries. It is necessary to prepare the methods and tools for the analysis of evacuation time in case collision or fire growth. Evacuation routes should be correctly designed in order to permit the passengers to leave endangered areas.

2. The methods for estimating evacuation time

Evacuation process can be analysed by full trials at similar ships. Results do not often agree with reality, because participants of the trials can not be exposed to fear, heat, smoke and toxic gases.

There are a lot of computer models, which simulate eventual people evacuation. Influence of different factors for human behaviour and movement is analysed. Evacuation models can be divided into macroscopic or microscopic [3].

Macroscopic models treat people as a homogeneous mass without individual characteristics. People evacuate as quick as possible, direction and speed of evacuation are fixed by physical values (population size, speed of persons, etc.).

Microscopic models take into account consideration not only physical conditions, but each person is treated individually. Passengers react for outside impulses resulting from the fire spread. BYPASS [10] can be an example of a microscopic model.

3. IMO requirements referring evacuation time analysis

According to the rules evacuation routes design should be preceded by evacuation time analysis. Maritime Safety Committee (belonging to IMO) prepared guidelines for the estimation of evacuation time of ro-ro passenger ships. The method is described in MSC/Circ.909. The method is temporary and further research is recommended.

The analysis identifies "bottle-necks" that can appear during passengers and crew members movement but the method is based on some simplifications:

- all passengers start evacuation process in the same time and do not disturb each others;
- passengers and crew evacuate by main evacuation routes;
- initial speed of persons depends on their density;
- number of persons and their initial distribution is fixed according to the rules given by FSS Code.

Additionally it is recommended to consider four scenarios (night; day; only 50% of stairways capacity previously used within the identified main vertical zone; 50% of the persons in one main vertical zone neighbouring the identified main vertical zone are forced to move into the zone and proceed to the assembly station through that zone), cf. [5].

But a lot of different scenarios can appear during real evacuation. Calculated evacuation time depends on the factors such as an initial distribution of the passengers, evacuation routes blocked by the fire and the flow of the passengers (they can choose different routes).

4. Model of the problem solved by genetic algorithm

The paper describes an application of a genetic algorithm to the random search of a lot of combinations of the initial distribution of the passengers and their flow. The calculated evacuation time is connected with a fitness function. Parameters of evacuation routes topology should be coded as non-binary chromosomes. Genetic operators (crossover, mutation or inversion) should fit to such type of problems to avoid inadmissible solutions.

The objective of the proposed method is to find the evacuation time in case of the worst scenarios. The method can contributes to the evacuation time analysis recommended by IMO.

5. Genetic algorithms as an optimisation method

The method of genetic algorithm was inspired by Darwin's evolution theory. The method imitates alive organisms, which fit to changing natural conditions during such processes as natural selection and heredity. Every next generation is better then preceding.

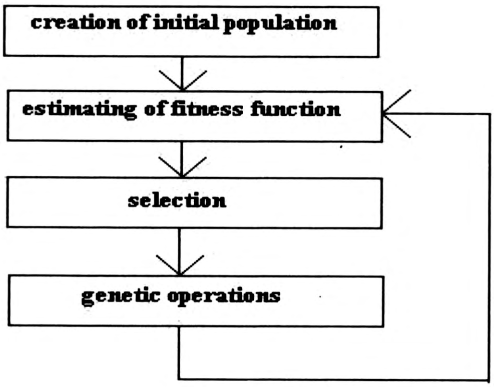

FIGURE 1. Schematic diagram of genetic algorithm.

At first step genetic algorithm creates initial population, composed of some chromosomes. Then for every chromosome the fitness function is calculated. Next step is selection. During this operation chromosomes with better fitness function should have grater probability to be drawn to new generation then others. Parent's population is subjected to genetic operations (crossover, mutation, inversion, etc.). Offspring's population becomes current population, for which fitness function is calculated again [11].

6. Method of coding the evacuation routes

Evacuation routes at a ship are described as the graph G(N,E), where rooms are the nodes of graph and the connections between them are represented by graph's edges (see Fig. 3).

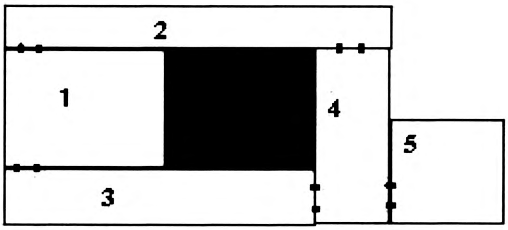

FIGURE 2. Example of arrangement of the evacuation routes.

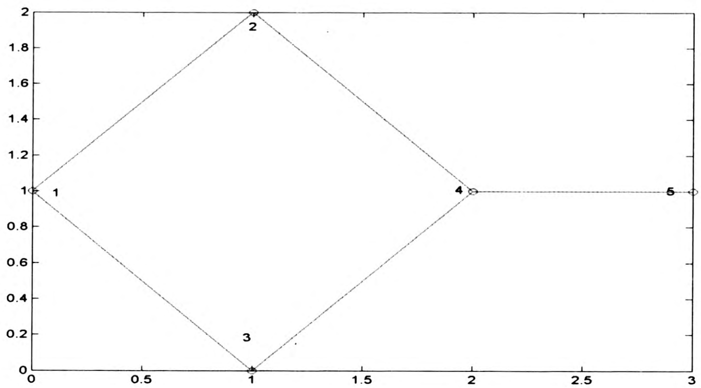

FIGURE 3. Example of describing the evacuation routes.

Graph in Fig. 3 has the following adjacency matrix:

$$A = \begin{bmatrix} 0 & 1 & 1 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 1 & 0 \\ 0 & 1 & 1 & 0 & 1 \\ 0 & 0 & 0 & 1 & 0 \end{bmatrix} \tag{6.1}$$

and the set of nodes:

$$k = (k_1, k_2, k_3, k_4, k_5). \tag{6.2}$$

For every k_i a random number of passengers is imputed from compartment $(0, k_{i\,\max})$, where $k_{i\,\max}$ is the maximal capacity of the node. Additionally the sum of k_i should be equal to the total number of passengers.

7. Estimation of the evacuation time

The time needed for passing the node by x passengers can be described by simplified formula:

$$T_n = \frac{L}{S} + \frac{x}{F_s W_c} \tag{7.1}$$

where:

L is the corridor's length,

S is the mean speed of a person,

F_s is the specific flow,

W_c is clear width of the corridor,

x is the number of persons passing though the room.

The total evacuation time from the node k_1 to the node k_n is the sum of T_{in}. In case of parallel connections the maximum of T_{in} should be chosen. For example:

$$T = T_{n1} + \max(T_{n2}, T_{n3}) + T_{n4} + T_{n5}; \tag{7.2}$$

- for T_{n1}:

$$x = k_1 \quad \text{(randomly chosen)};$$

- for T_{n2}:

$$x = s\,k_1 + k_2,$$

  where s randomly describes what percentage of people from the room k_1 passed to the room k_2;

- for T_{n3}:

$$x = (1 - s)\,k_1 + k_3;$$

- for T_{n4}:

$$x = k_1 + k_2 + k_3 + k_4;$$

- for T_{n5}:

$$x = k_1 + k_2 + k_3 + k_4 + k_5.$$

The total evacuation time is needed for creating the fitness function for the estimating chromosomes in genetic algorithm.

8. Application of genetic algorithm method for solving the problem

The initial population is created by some number of chromosomes consisting of the following strings:

$$\begin{aligned} k_1 &= (k_{11}, k_{12}, k_{13}, \dots, k_{1i}, \dots, k_{1n}), \\ k_2 &= (k_{21}, k_{22}, k_{23}, \dots, k_{2i}, \dots, k_{2n}), \\ k_3 &= (k_{31}, k_{32}, k_{33}, \dots, k_{3i}, \dots, k_{3n}), \\ &\vdots \\ k_j &= (k_{j1}, k_{j2}, k_{j3}, \dots, k_{ji}, \dots, k_{jn}), \\ &\vdots \\ k_m &= (k_{m1}, k_{m2}, k_{m3}, \dots, k_{mi}, \dots, k_{mn}). \end{aligned} \tag{8.1}$$

For every chromosome the fitness function should be estimated. The fitness function for the chromosome k_j is following:

$$F_j = \frac{T_j}{\sum\limits_{j=1}^{m} T_j}. \tag{8.2}$$

During the next step the chromosomes to parent's population are chosen by roulette wheel selection. Some chromosomes of this population are mutated with a fixed probability. Mutation changes all genes in such chromosome.

The genetic algorithm was tested on simple example showed in Fig. 2. Thirty persons where distributed in five rooms. The worst time obtained after several generations was about 39 seconds.

9. Conclusions

In the above simple example the calculated evacuation time was strongly dependes on the initial distribution of passengers. The range of the results was about 8 seconds (20%). The evacuation time was estimated by a simplified formula. IMO gives a more complicated method for the calculation of the evacuation time with regard to effects of ship motion, restricted visibility, counter flow, etc. In the future the fitness function should be improved. Additionally the doors between rooms should be added to the set of graph nodes. The method should also simulate blocking by the fire of some rooms and corridors.

The presented method could help to design safer evacuation routes thus letting the passenger to leave danger areas in case of the worst scenarios of initial distribution of passengers, their flow and fire spread.

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