Scientific Journals
Maritime University of Szczecin

Zeszyty Naukowe
Akademia Morska w Szczecinie

2012, 29(101) pp. 130–133

2012, 29(101) s. 130–133

Using genetic algorithms and genetic programming in solving problems related to safety and evacuation of people from ships and land facilities

Wykorzystanie algorytmów genetycznych i programowania genetycznego w rozwiązywaniu problemów związanych z bezpieczeństwem i ewakuacją ludzi ze statków i obiektów lądowych

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Key words: evolutionary calculations, optimization, passenger ship, the organization of the evacuation

Abstract
This article aims to present the principles of the method of genetic algorithms and examples of the use of this method for solving problems related to proper organization of evacuation both from ships and land buildings. The paper also proposes the use of genetic algorithms to search for the optimal distribution of evacuation. The problem of course was brought to the task of evacuation transport, which is so designated evacuation routes for different groups of people to get the shortest possible evacuation time. Application of genetic algorithms will determine the most preferred target as passengers from the premises where they are located at the start of the evacuation to the assembly. Describes how to encode the problem in the genetic algorithm and a simple calculation shows the distribution of escape routes and validate the assumed method of encoding.

Słowa kluczowe: obliczenia ewolucyjne, optymalizacja, statek pasażerski, organizacja ewakuacji

Abstrakt
Celem artykułu jest zaprezentowanie zasady działania metody algorytmów genetycznych oraz przykładów użycia tej metody do rozwiązywania problemów związanych z właściwą organizacją ewakuacji zarówno ze statków, jak i obiektów lądowych. W artykule przedstawiono ponadto propozycję zastosowania algorytmów genetycznych do poszukiwania optymalnego rozplanowania ewakuacji. Problem przebiegu ewakuacji sprowadzono do zadania transportowego, czyli takiego wyznaczenia tras ewakuacji dla poszczególnych grup osób, które pozwoli uzyskać jak najkrótszy czas ewakuacji. Zastosowanie metody algorytmów genetycznych ma na celu ustalenie, jak najkorzystniej kierować pasażerów z pomieszczeń, w których się znajdują w momencie rozpoczęcia ewakuacji do miejsc zbiórek. Opisano sposób zakodowania problemu w algorytmie genetycznym oraz przedstawiono obliczenia prostego przypadku rozkładu dróg ewakuacji, sprawdzające poprawność założonego sposobu kodowania.

Introduction-principle of genetic algorithm

Evolutionary calculations can fall into a group of artificial intelligence methods. Evolutionary methods including genetic algorithms allow to get good results (close to optimal), avoiding time-consuming calculations. Another important advantage of this method is the resistance to finding local extremes what is often encountered in other optimization methods. Because the objective function is considered as non-linear pieces, it can have multiple local optima, which is difficult to calculate in any gradient method. Figure 1 shows schematically the principle of the genetic algorithm.

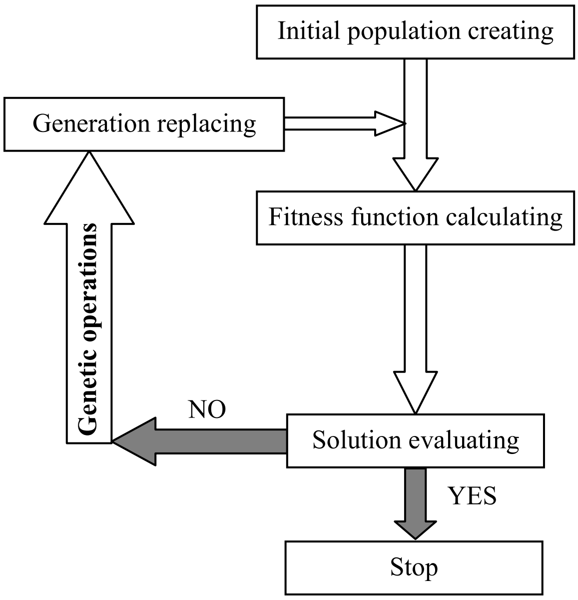

Fig. 1. Schematic of the genetic algorithm
Rys. 1. Schemat działania algorytmu genetycznego

Creating the initial population must be preceded by the adoption of the encoding method the parameters of the problem into a chromosome or a vector (usually binary) describing the task solution. Each of the chromosomes in the population is a potential solution. Chromosome consists of genes characteristic for describing the solution. Fitness function is a measure of fit of the chromosome in the population of chromosomes. On the basis of fitness function the individuals are evaluated and selected for further genetic operations. The next step of the genetic algorithm is the selection of the parental population, inspired by natural selection in nature. The simplest method is the method of selection by roulette, in which every chromosome receives a piece of the roulette wheel sized in proportion to the value of its fitness function. Then, this is drawing the parental population. Other method of selection – ranking or tournament can be chosen. Parental population is subjected to genetic operators. In the classical genetic algorithm two basic operators: crossover and mutation are used. Multi-crossover or inversion can also be used. Genetic operations introduce to the population of individuals completely new genetic material that contributes to the expansion of the search area. After the genetic operations, chromosomes that were created replacing the chromosomes of the previous generation. The algorithm stops, among other things beyond a certain number of iterations, the time limit or the limit of a function, or if further adaptation algorithm does not improve the best value. It should also determine the values of various parameters used in the genetic algorithm, namely population size, probability of mutation and crossover [1, 2, 3].

Examples of the use of genetic algorithms

Genetic algorithms are used in a wide number of disciplines. Establishment of methods for genetic algorithms was initiated by the use of computers for simulation of genetic processes. For the first time genetic algorithms were used in the non-biological context by Holland in 1962. He applied quasi--genetic methods in problems of artificial adaptation.

According to Goldberg [3] the most important historical applications of genetic algorithms were:

- an adaptive program to play made by Bagley 1967,
- simulation of single-celled organisms made by Rosenberg in 1967,
- using a genetic algorithm to identify the shapemade by Cavicchio in 1970,
- optimization function made by Hollstein in 1971,
- management method for the decision-making activities made by Box in 1957.

Genetic algorithms have been also used in problems of evacuation. The movement of people during the evacuation depends heavily on the geometry of the environment. It can be simulated in a computer already in the design phase. Environment shapes can be optimized using evolutionary algorithms [4, 5, 6]. During the optimization the location and shape of building, distribution of corridors, emergency exits, stairwells, elevators, the shape of rooms, corridors, exits, and function rooms are determined. The proposed procedures are used not only to design but also to reduce existing refinements through appropriate treatment.

Using multi-criteria optimization evolutionary algorithms is proposed in [7] for solution the problem of evacuation of the cities in the event of threats such as earthquakes or floods. The first step is the selection of safe areas. Then, for each building algorithm is looking for the optimal distribution of people to safe areas.

The paper [8] drew attention to the problem of narrow passages (e.g. doors), which constitute the evacuation dangerous point. The authors propose to reduce the pressure of crowd for the emergency exit by intentionally setting obstacles in the way of escape. They would slow down the people and realizing their flow through the narrow passage. In order to optimize the flow of people through emergency exits the method of genetic algorithms is used.

Genetic algorithms have been applied to design the spatial layout of streets in towns, shops, shopping centers, based on human decision-making process for planning purchases [9].

Selection and application examples presented above show the versatility of genetic algorithms using methods of genetic algorithms.

Using of genetic algorithms to search the optimum evacuation planning

Escape routes should meet certain requirements, but also to effectively be able to fulfill their function, should have adequate capacity, marking and lighting. One of the important factors that may influence the effectiveness of evacuation is the proper organization of the evacuation. Escape routes can be properly designed, however, if the distribution of passengers in them will be inadequate due to incorrect directing the evacuation may cause blockages, which increase the risk of panic. The problem of the evacuation process can be reduced to the transport task, that is so designated evacuation routes for different groups of people to get the shortest evacuation time (to determine the most preferred direct passengers to the premises where they are located at the start of the evacuation to the assembly stations).

Based on the general arrangement of the ship, which includes evacuation routes, plan of organization of evacuation is formed. This is a scheme of distribution of passengers from places where they can be alarmed at the start of the evacuation (for a fixed scenario of initial distribution) to the assembly stations (or safe areas). For such plan the actual time of evacuation is calculated. For the calculation of evacuation time, the simplified method recommended by the IMO or to one of the methods of computer can be used. Optimization method should be chosen for the problem being solved and should take into account the accepted way of encoding the input parameters. As a method of optimization it is proposed to apply the method of genetic algorithms.

The following formula describes the proposed manner of encoding the problem. We assume that the gene encodes a number of people in a particular stream of people who follow the evacuation route.

$$\{x_1, x_2, \ldots, x_i, \ldots, x_p\}$$

Let's consider developing a plan of escape of N passenger from n initial spaces $PP[1]$, $PP[2]$, ..., $PP[n]$. Passengers have the choice of p evacuation routes with different difficulty levels (stairs, different length and width of corridors), which lead to the assembly points $DP[1]$, $DP[2]$, ..., $DP[k]$.

The number of persons is described as a $N_{PP[1]}$, $N_{PP[2]}$, ..., $N_{PP[j]}$, ..., $N_{PP[n]}$ and for every room the initial streams of people x_i, is given.

The constraints are described by following formulas:

1. $\sum_{i=1}^{p} x_i = \sum_{j=1}^{n} N_{PP[j]} = N$
2. If the stream $x_{N_{PP[i]}} \in N_{PP[j]}$
   then $x_{N_{PP[j]}} = \{0, N_{PP[j]}\}$
3. If the streams
   $\{x_{N_{PP[s]}}, \ldots.., x_{N_{PP[i]}}, \ldots\ldots., x_{N_{PP[t]}}\} \in N_{PP[j]}$
   then $\sum_{i=s}^{t} x_{PP[i]} = N_{PP[j]}$

The first constraint means that the sum of all the streams of people should be equal to the total number of passengers. The second defines the maximum size of the stream leading from the initial room. It can take it from zero to the total number of people in the room, but it can also set it to another level, so that e.g. distribution of people was more proportional to the width of the exits. The third constraint requires that the sum of the streams coming out of the room was equal to the total number of people in the room. The fitness function is the time to evacuate all passengers for their distribution withdrawing on the individual streams. Traveling time of x passengers through the arc (corridor, room) is given by formula:

$$T_c = \frac{L}{S_{śr}} + \frac{x}{(F_s \cdot W_c)} \text{ [s]}$$

where

- $S_{śr}$ – average speed of people, it may be about 0.5 [m/s] [10],
- L – length of the corridor [m],
- W_c – width measured between the handrails for stairs and corridors and the width of the door in position when they are completely open [m],
- F_s – specific flow, we assume:
  1.1 [person / m·s] – steps down,
  0.88 [person / m·s] – steps up,
  1.3 [person / m·s] – corridors,
  1.3 [person / m·s] – the door,
  based on data contained in [11].

The resulting time should be increased by taking into account factors: age of passengers, the unavailability of corridors, limited visibility, movement of people in the opposite direction, and other factors that could delay the evacuation. Factors that increase is set at 2.3 [12].

The following is a simple calculation of the distribution of the escape routes for establishing the validation of coding.

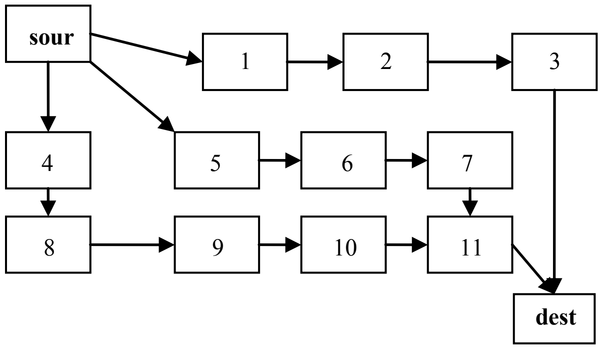

Fig. 2. Schematic distribution of the escape routes
Rys. 2. Schemat rozkładu dróg ewakuacji

The initial presence of 900 people is assumed. The calculations were performed for the case of dividing the total number of persons in three equal groups (300 people) and assign them to different evacuation routes.

The following dimensions of corridors [m] is assumed:

D = {15; 10; 8; 10; 11; 3; 7; 10; 12; 5; 7}
W_c = {2,4; 3; 2; 3; 3; 4; 2; 3; 1; 5; 2,4}

For such a case the calculated evacuation time was 1273 s (about 21 min).

Then the evacuation time calculations were made using a genetic algorithm. Obtained the shortest evacuation time 907 s (about 15 minutes) with the following distribution of passengers on each route: $g_1 = 265$ persons, $g_2 = 438$, $g_3 = 197$ people. The calculation results are shown in the graph (Fig. 3).

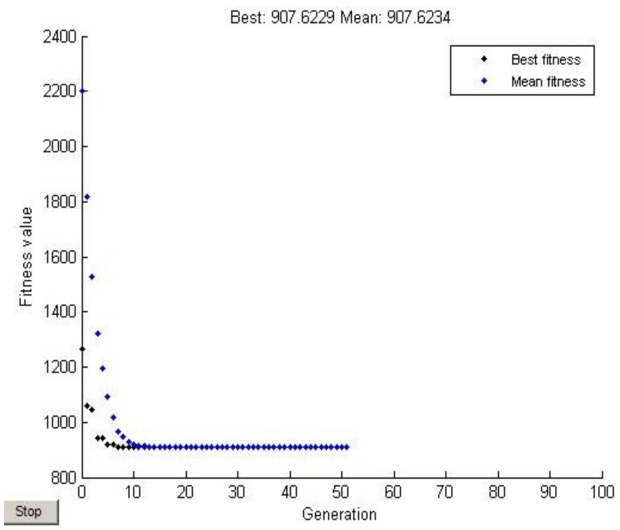

Fig. 3. The calculation results of the genetic algorithm
Rys. 3. Wyniki obliczeń algorytmu genetycznego

Conclusions

Genetic algorithms are a method inspired by Darwin's theory of evolution. The procedure is the imitation of living organisms that through evolutionary processes such as natural selection and inheritance adapt to changing natural conditions. Each subsequent generations are better suited than the previous, weaker animals are less likely to survive and reproduce. Currently, many tasks to be solved requires a lot of time and resources to calculate, to obtain a satisfactory result. Due to the fact that genetic algorithms using simple methods of encoding and reproduction tend to be very effective tool, used this method to optimization the evacuation organization. Proper organization of the evacuation is the major factor that may affect the safety of the people.

Sample calculations are presented for simple distribution of rooms and a small number of people. The simulation results seem to indicate however that this method is also effective in the search for the optimal evacuation organization in real buildings with complex arrangement. The above example shows that using a genetic algorithm can avoid having to search all possible solutions to find the optimum.

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