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INTELLIGENT SUPPORT OF EVACUATION PLANNING OF SELECTED PUBLIC MASS EVENTS

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Due to the topical importance of the acts of terror, contemporary safety engineering must, among others, take on issues concerning the necessity of programming potential emergency evacuations concerning different kinds of mass events. These types of gatherings require preparing evacuation management programs in advance in case threatening information appears. These programs, apart from the conventional solutions based on binary logic and classical combinatorics methods, must also take into account the hybrid and fuzzy character of the course of the emergency evacuation accompanying occurrences. The article presents an example of implementing genetic algorithms, which are recognized as an artificial intelligence method. This example concerns the emergency evacuation of supporters in a stadium football match. The proposed method can also be applied in case of other mass events like: public concerts with the participation of show-business stars and rallies and political demonstrations.

Keywords: genetic algorithms, safety engineering

1. INTRODUCTION

Contemporary public safety engineering of organized events has an interdisciplinary character and in practice requires a methodological approach based on individual specialists' cooperation with knowledge engineers under the framework of so-called expert systems (Fig. 1). The main goal of this paper is a presentation of the methodological problems concerning an effective evacuation of large human communities concentrated in one place. Such communities have to face the threat of loss of health or life as a result of unpredictable, random incidents or acts of public terrorism. Solving such methodological problems has (from the viewpoint of formal requirements) the character of a mathematical combinatorial task. However,

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the degree of such problems' complexity depends on the complexity of the effective evacuation process as well as on the scientific degree recognizing dynamics regarding the course of the threat phenomenon (Pacholski, 2006).

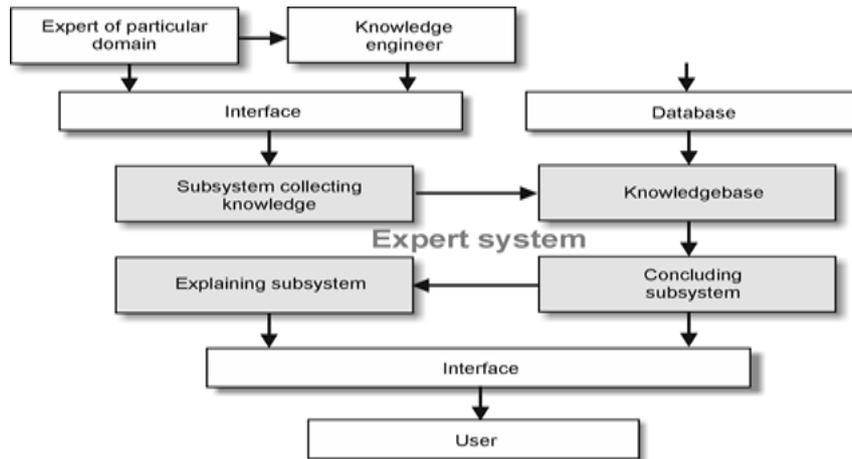


Fig. 1. The Expert System model

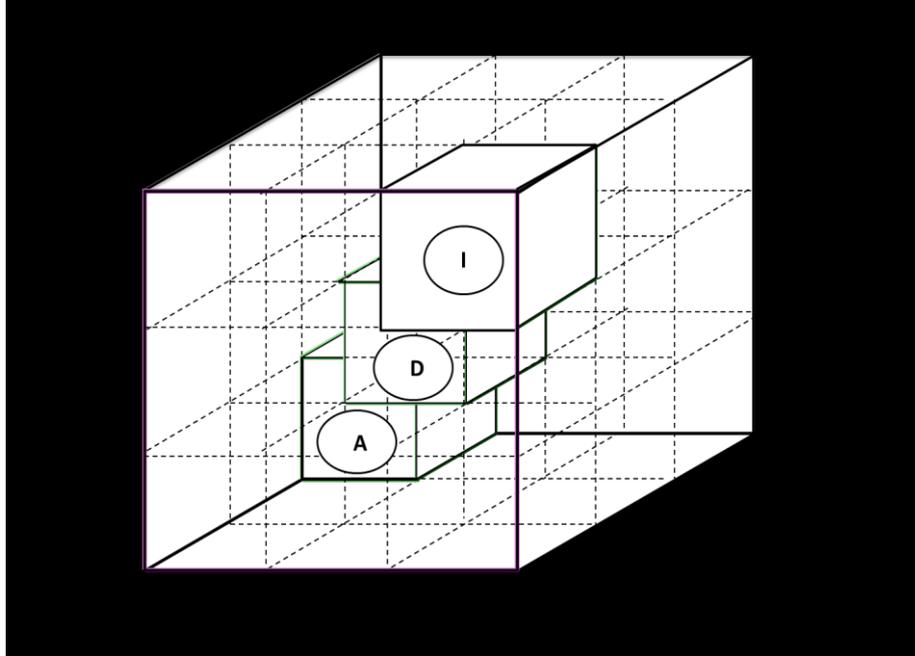


Fig. 2. Selection of the problem solving methodology in regard to the formal complexity of the phenomenon and stage of understanding the dynamics of its course

These two issues determine the type of the selected methodology concerning the planning and programming of the evacuation process. At present, our society is functioning in a turbulent period from an economic cycles viewpoint (long waves), i.e. in a transition from the “fifth wave” (information society) to the “sixth wave” (conceptual society). This transition (concerning planning engineering and process programming) is characterized by the abuse of the algorithmic models based on binary logic typical for the deterministic phenomena representative of the fourth wave (industrial society). This problem is presented in Figure 2. Reasoning A (Fig. 2) is used in cases in which there is a possibility of a precise understanding and describing of the phenomenon (there is knowledge enabling the creation of a model of a particular phenomenon in the form of clearly defined and determined dependencies). The methodology of solving the problem according to model of reasoning A is typical for the period of industrial society.

Reasoning D (Fig. 2) can be applied to a phenomenon that we can't precisely describe in a mathematical form, yet based on direct observation we can find some stable patterns of a determined phenomenon (there is knowledge enabling the creation of a model of a particular phenomenon on the basis of expert systems or parametric regression). The methodology for solving the problem according to model of reasoning D is typical for the period of informational society. Reasoning I (Fig. 2) is used when there is no possibility of directly and precisely determining constant patterns of the course of a particular phenomenon. There is knowledge enabling the creation of a model of a particular phenomenon on the basis of methodological tools like: non-parametric regression, artificial neural networks, adaptive fuzzy systems or evolutionary algorithms (Pacholski, 1998; Khwang H. Lee, 2006; Kałkowska, Kozlov, 2015). The methodology of solving the problem according to model of reasoning I is typical for the period of conceptual society.

2. GENETIC ALGORITHMS

Models of algorithms of evolutionary processing solve optimizational problems and searching tasks with the help of a method similar to the rules of real evolutionary mechanisms, i.e. Darwin's strategy of survival of the most adapted individuals. Such algorithms might be used in practical tasks for difficult questions of optimization and for research in cases when numeric or heuristic solutions are not possible to obtain or if those solutions lead to unsatisfactory results. The three basic streams of evolutionary algorithms concern: genetic algorithms, evolutionary strategies and evolutionary programming (Miranda, Proenca, 1995; Pacholski, 2015). The strategy of an evolutionary algorithm consists of translocating from one population of solutions into another one, next to the preceding population, in accordance with certain rules that have been established. The genetic algorithm generates the next

population and searches it and selects a new generation through the following genetic operators: selection, crossing or mutation. From the viewpoint of operations research, genetic algorithms are a subcategory of strategies of local research and they co-create a class of so-called metaheuristic optimizational algorithms (among

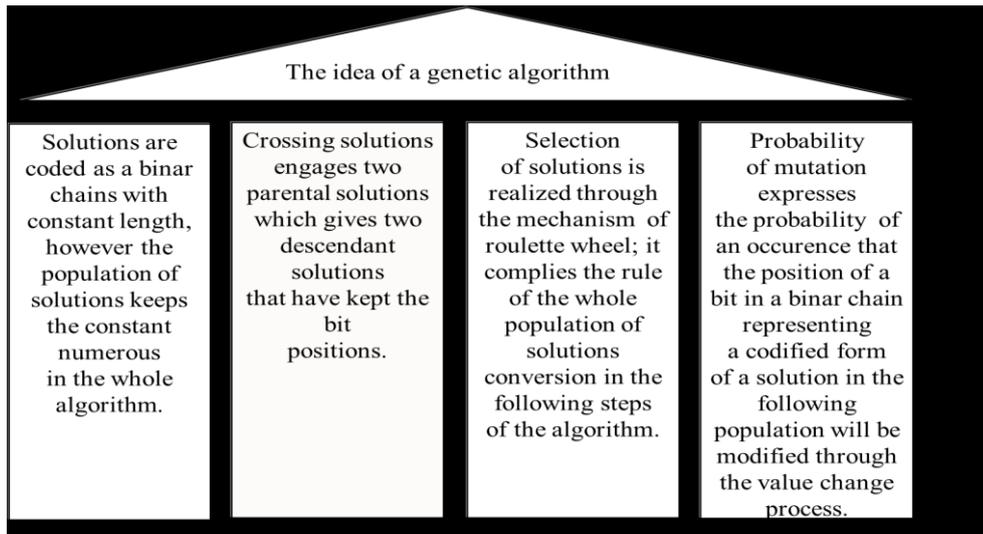


Fig. 3. Four foundations of the idea of genetic algorithms

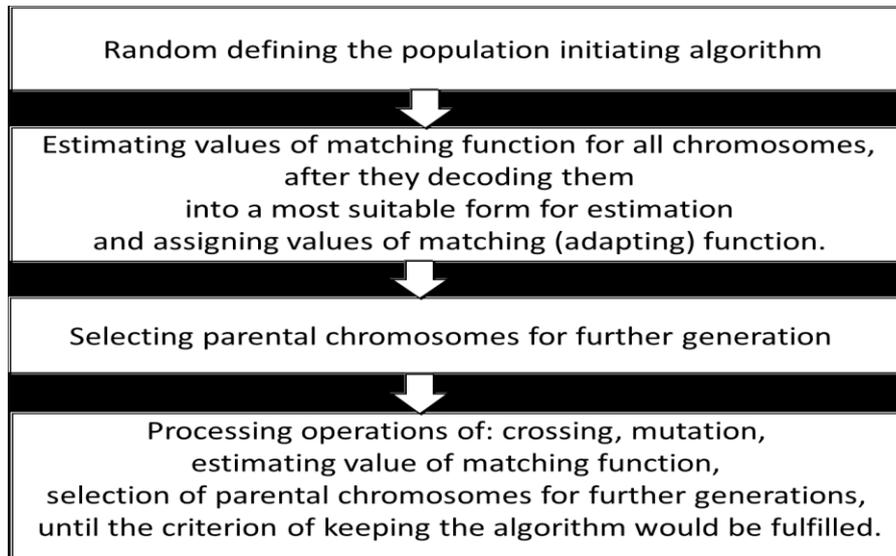


Fig. 4. Four steps of a regular genetic algorithm

others, inaccurate heuristics) (Kałkowska, 2016). The strategy of local searching uses the space of solutions to search through a trajectory determined by the next solutions selected from the proximity of solutions directly preceding them. The genetic algorithm is an adaptive procedure of research for optimization solutions that functions in a coded space of solutions and uses random processes for determining research directions. The set of parameters of an optimization task is coded in a form of a definite sequence of symbols from a particular to a genetic algorithm definite alphabet and it is called an individual or chromosome. The idea of genetic algorithms is based on four foundations presented in Figure 3 (Pacholski, 2015).

The regular genetic algorithm concerns the four following steps presented in Figure 4 (Pacholski, 2015).

3. EVACUATION TASKS SCHEDULING

The application of genetic algorithms in safety engineering most often includes combinatorial optimization regarding the distribution and the allocation in the context of evacuation tasks scheduling. One of them can concern the need for sudden and unexpected departure from stadium sectors while at asports event. Figure 5 presents the view at a stadium football match and gives some impression concerning the possible danger.



Fig. 5. The stadium football match

Let's assume that N is a number of evacuation tasks P_i , where $i = 1, \dots, N$ with a given completion time which must be performed with the use of M entrance/exit gates to the stadium unit. Furthermore, let's also assume that in the determined time T there are performed simultaneously M operations on M entrance/exit gates, which together create the evacuation task. Each task can be perceived as a sequence of a particular number of evacuations, for example W . Therefore timing concerns planning $N = M \times W$ of evacuation tasks that should be performed. Then an optimization task consists of finding a permutation N of evacuation tasks, which considers the minimum completion time of all operations. It is equal to determining a permutation of numbers $1, 2, \dots, N$ divided into M parts by numbers KW , where $K = 1, \dots, N : W$, by multiplicity W . It should be noticed that each part of the permutation represents a solution of the problem for an individual entrance/exit gate. It is possible to distinguish between two variants of the problem of timing of evacuation tasks. The first one assumes that tasks of a particular work can be performed in an optional sequence, i.e. there is no special requirement for the performance of tasks in any determined sequence. The second variant assumes that tasks in each evacuation must be performed in a determined sequence and in accordance with special requirements (for example: children and women first, or elderly people first). In the case, when this usage of entrance/exit gates must be performed in a sequence resulting from special requirements, it is acceptable to apply a different scheme of permutation (Bierwith 1995; Bierwith et al., 1995), without division into M parts but with M repetitions of numbers of the use of entrance/exit gates. In that case: K -sequence of appearance of the number of the use of entrance/exit gates refers to the K -operation in the special requirements order of this gate usage. For example, let's assume that the task concerns three evacuations performed with the use of three entrance/exit gates in the section. Evacuations appear in a sequence determined by special requirements in the third work the following tasks appear: seventh, eighth and ninth (Fig. 6). A Gantt chart illustrates this situation. Operations that are usually performed with the use of the same entrance/exit gate are colored with the same color in Figure 6.

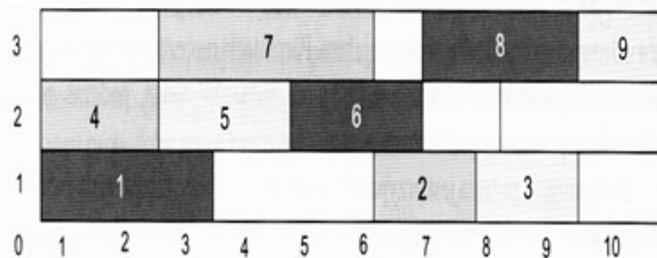


Fig. 6. Gantt chart

Let's notice that permutation consisting works that are not works no. 7, 4 or 1 represent solutions, which are unacceptable from the special requirements point of view. Using the modified scheme of permutation with $M = 3$ repetitions of numbers of the use of entrance/exit gates we can obtain the following table (Table 1).

Table 1. Table of indications of the special requirements limitations

| | | | | | | | | | |
|-------------------------|---|---|---|---|---|---|---|---|---|
| Permutation of work | 1 | 2 | 2 | 3 | 1 | 2 | 3 | 1 | 3 |
| Indicator of occurrence | 1 | 1 | 2 | 1 | 2 | 3 | 2 | 3 | 3 |
| Attributed task | 1 | 4 | 5 | 7 | 2 | 6 | 8 | 3 | 9 |

In a defined scheme two types of operators of grading have been introduced: sequential (GOX) and partially projecting (GPMX). Both operators create one descendant chromosome from two parental chromosomes. One of the parental chromosomes is called a donor, the second is called a recipient. For example:

| | | | | | | | | | |
|-----------|---|---|---|---|---|---|---|---|---|
| Donor | 1 | 2 | 2 | 3 | 1 | 2 | 3 | 1 | 3 |
| Recipient | 1 | 1 | 3 | 2 | 2 | 1 | 2 | 3 | 3 |

Both operators of grading use a so-called component chain, which is selected from the chromosome of the donor. Let's assume that it would be the exemplary chain : 2 2 3 1.

The component chain is next placed in the chromosome of the recipient; for the GOX operator from the position, in which occurred the first gen of the component chain in the recipient's chromosome, for the GPMX operator from the position in which occurred the first gen of the component chain in the donor's chromosome. Simultaneously, in accordance with the indicator of appearance in the donor's chromosome, all genes from the chromosome of the recipient that refer to genes of the component chain are being erased sequentially. Therefore, the following example includes:

| | | | | | | | | | |
|-----------------|---|---|---|---|---|---|---|---|---|
| Recipient | 1 | 1 | 3 | 2 | 2 | 1 | 2 | 3 | 3 |
| GOX descendant | 1 | 1 | 2 | 2 | 2 | 3 | 1 | 1 | 3 |
| GMPX descendant | 1 | 3 | 2 | 2 | 3 | 1 | 2 | 1 | 3 |

Let's notice that for both operators the component chain is not being modified while the recipient's chromosome is being pulled apart. It is assumed that the length of the component chain reaches $1/3$ to $1/2$ of the length of the chromosome.

Descendant chromosomes resulting from the procedure of grading carried out with the use of the GOX and GPMX operators, represent solutions acceptable from the point of view of the special requirements limitations.

4. CONCLUSIONS

The contemporary life of democratic consumer societies is connected with using transport centers (airports, underground and long-distance railway stations) enabling the mass migration of people, as well as organizing leisure time, among others, by the participation in different kinds of mass events (like concerts with the participation of show-business stars, football, basketball and volleyball matches, track-and-field meets, Olympic Games, rallies and political demonstrations). Participation in these events is connected with the need for physical and mental regeneration, determined by the search for aesthetical and spiritual experiences, with demonstrating political sympathies as well as social, ethnic and religious favors. Managers responsible for solving mass transportation issues as well as organizers of the mentioned public mass events have to (both for their own business as well as due to social need) provide safety during travel and participation in such events for large gatherings of people. Safety includes not only technological/operational and managerial aspects but is also connected with counteracting the threats generated by the authors of acts of terror from the one hand undertaken by certain political, religious and ethnic social organizations based on sociopathic degeneration and from the other hand by individuals of a psychopathic personality. The article presents an example of implementing genetic algorithms, which are recognized as an artificial intelligence method. This example concerns the emergency evacuation of supporters from a stadium football match and distinguishes between two variants of the timing of evacuation tasks. The first one assumes that tasks of particular work can be performed in an optional sequence, i.e. there is no special requirement for the performance of tasks in any determined sequence. The second variant assumes that tasks in each evacuation must be performed in a determined sequence and in accordance with special requirements (for example: children and women first, or elderly people first). When the use of entrance/exit gates in a section must be performed in a sequence resulting from the above requirements, it is acceptable to apply a different scheme of permutation. The proposed method can also be applied in case of other mass events like the above-mentioned: track-and-field meets, the Olympic Games, concerts with the participation of show-business stars, rallies and political demonstrations as well as basketball and volleyball matches.

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**INTELIĞENTNE WSPOMAGANIE PROGRAMOWANIA EWAKUACJI
W PRZYPADKU WYBRANYCH IMPREZ MASOWYCH****Streszczenie**

W wyniku analizy aktualnej problematyki związanej z coraz częściej pojawiającymi się aktami terroru, współczesna inżynieria bezpieczeństwa wykorzystuje między innymi wspomaganie programowania potencjalnej konieczności ewakuacji ludności uczestniczącej w różnego typu imprezach masowych. Imprezy te wymagają uprzedniego przygotowania programu zarządzania ewakuacją na wypadek potencjalnego zagrożenia. Takie programowanie, niezależnie od konwencjonalnych rozwiązań bazujących na logice binarnej i klasycznej kombinatoryce, powinny uwzględniać również hybrydowy i rozmyty charakter towarzyszących okoliczności. W artykule przedstawiono przykład wykorzystania algorytmów genetycznych uznawanych za metodę sztucznej inteligencji. Przykład ten dotyczy konieczności przeprowadzenia nagłej ewakuacji uczestników i publiczności meczu piłki

nożnej. Proponowana metoda może również zostać wykorzystana w przypadku organizacji innych imprez masowych takich jak: koncerty gwiazd estrady lub mityngi i zorganizowane demonstracje polityczne.

Słowa kluczowe: algorytmy genetyczne, inżynieria bezpieczeństwa