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THE APPLICATION OF EVOLUTIONARY ALGORITHMS FOR MINIMUM-TIME CALCULATIONS OF VESSEL OCEAN ROUTES

The planning of an ocean-going vessel voyage is aimed at determining the shortest time route that satisfies the vessel and navigational safety requirements. Various computation methods and procedures, including evolutionary algorithms, are used for the purpose.

ZASTOSOWANIE EWOLUCYJNYCH ALGORYTMÓW DLA MINIMALNO-CZASOWYCH OBLICZEŃ DLA STATKÓW NA TRASACH OCEANICZNYCH

W programowaniu trasy statku na oceanie wykorzystywane są algorytmy optymalizacyjne dla określenia trasy minimalno - czasowej. Rodzaj zastosowanych algorytmów i szczegółowość obliczeń uzależnione są od dostępnych danych pogodowych i oprogramowania. Zaprezentowano zastosowanie programu komputerowego opartego na działaniu algorytmu ewolucyjnego obliczania trasy minimalno - czasowej statku na oceanie.

1. INTRODUCTION

Genetic algorithms constitute a method, modelled on natural evolution, for solving mainly optimization problems. These are procedures of searching based on the processes of natural selection and inheritance. The procedures use the evolutionary principle of survival of best fit individuals. Genetic algorithms utilize a number of notions used in genetics, such as genes, chromosomes, populations, individuals, genotypes or phenotypes. These algorithms differ from traditional optimization methods in that:

- they do not process directly parameters of the problem, but their encoded form,
- they search starting not from a single point, but from a population,
- they use the objective function only, not its derivatives or other auxiliary information,
- they use probabilistic rules of selection, not deterministic ones.

Genetic algorithms serve solving problems for which it is possible to design a function evaluating the fitness of solutions to the required conditions.

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Evolutionary programs make up a generalization of genetic algorithms. The classical algorithm works on a fixed-length binary strings. Evolutionary programming enables using a wider set of data structures, e.g. a floating point representation of chromosomes. According to [3] an evolutionary program is a probabilistic algorithm operating on a population of individuals

$$P(k) = \{x_1^k, x_2^k, \ldots, x_n^k\}$$

for the iteration k. Each individual represents a potential solution to the problem. In an evolutionary program it is represented in the form of a data structure. Each solution x_i^k is evaluated by its fitness to the problem being solved. Then a new population is produced (iteration k+1) by selecting best fit individuals (selection). The individuals of the population are manipulated by means of genetic operators – crossover and mutation – producing new solutions. Mutations create new individuals by changing an individual, while the crossover operator produces new individuals by combining fragments of two or more individuals.
The structure of an evolutionary program can be presented by means of a code [4]:

```
procedure evolutionary_program
begin
  k=0
  initialize population P(k)
  evaluate the individual's fitness in P(K)
  while (not termination condition) do
    begin
      k=k+1
      select individuals from P(k-1) to P(k)
      apply genetic operators
      evaluate individuals in  P(k)
    end
end
```

The authors have attempted at adapting an evolutionary program to the specific search for an time-optimal vessel route. Each individual in the evolutionary program represents a potential solution to the problem, in this case the vessel ocean route coordinates. The initial population P(0) is chosen from allowable climatic routes and a number of randomly generated routes proposed by a navigator. This population is a starting point for the evolutionary program. The fitness function is the value of sailing time of a vessel covering a selected route in preset navigational and meteorological conditions. The function can be determined by using standard navigational procedures (position coordinates, speed, course, etc). The function determines the fitness of each route indicating better and worse individuals. Crossover operators have been designed for the recombination of randomly selected routes, accounting for constraints resulting from certain navigational requirements that have to be met. Additional constraints are due to the need for maintaining navigational safety (keeping clear of land and ice, the safety of vessel and its cargo (keeping clear of land and ice-covered areas, avoding storm damage, maintaining the safety of vessel and its cargo). The mutation operator has also been applied to transform the coordinates of a single route. The mutation operator has also to take into account for the above mentioned constraints. A few versions of the algorithm for various crossover and mutation operators have been examined. The sailing time of a vessel navigating along the great circle or the time of a recommended route calculated by other optimization methods can be used as a time reference in a program test. The evolutionary program is particularly suitable for solving optimization problems featuring a large parameter space and unknown analytical solution. Thanks to mutation the program is resistant to local extremes and finds approximated solutions.

2. ALGORITHM AND PROGRAM DESCRIPTION

The computation procedure begins with a selection of the initial population of individuals. These are possible ocean routes of a vessel, extending from a starting point to a destination point defined by geographical coordinates (φ, λ). It is recommended that the selection of routes includes a climatic, great circle and rhumbline routes. The run of each route is defined by a set of points located at an identical distance between two consecutive points. The initial route population should be of possibly large size and cover an ocean area in which a vessel can sail.

Therefore, apart from the three routes other routes, randomly selected, are introduced. Crossover and mutation operations are executed on the initial population of , e.g. 100, routes. In the simplest case, crossover consists in the selecting a pair of routes and creating new routes by mutual exchange of randomly selected sections. In this way routes may have better properties (short sailing time) and will be taken for further processing. Similarly, better properties of routes can be obtained by mutations of the initial route population (small modification of a route run) thus creating a new population. After each stage of computations, the individuals are evaluated by the sailing time of a vessel proceeding along a preset track. Weather conditions (waves, wind, currents, ice conditions) and speed characteristics of a given vessel are an essential part of the computations. The algorithm produces subsequent populations and evaluates them a certain number of times depending on the distance of the starting and destination points of the calculated route. The block diagram below presents the program (Figure 1).

The results of calculations obtained from thus created program are presented in Figures 3-5. The results have been compared with the time-optimal route obtained by the graph method shown in Figure 2. [2] The results of tests done so far show that in order to obtain results similar to those for the optimal route, the number of initial routes, the number of crossovers, percentage of mutations and the number of generations for which the shortest voyage time is calculated are very large (hundreds, even thousands of repetitions).

The results shown in the enclosed diagrams illustrate the actual state which differs from the reference. However, in some cases they can be satisfactory for practitioners checking various versions of the routes (differences up to five hours of ocean voyage between Europe and the American mainland.

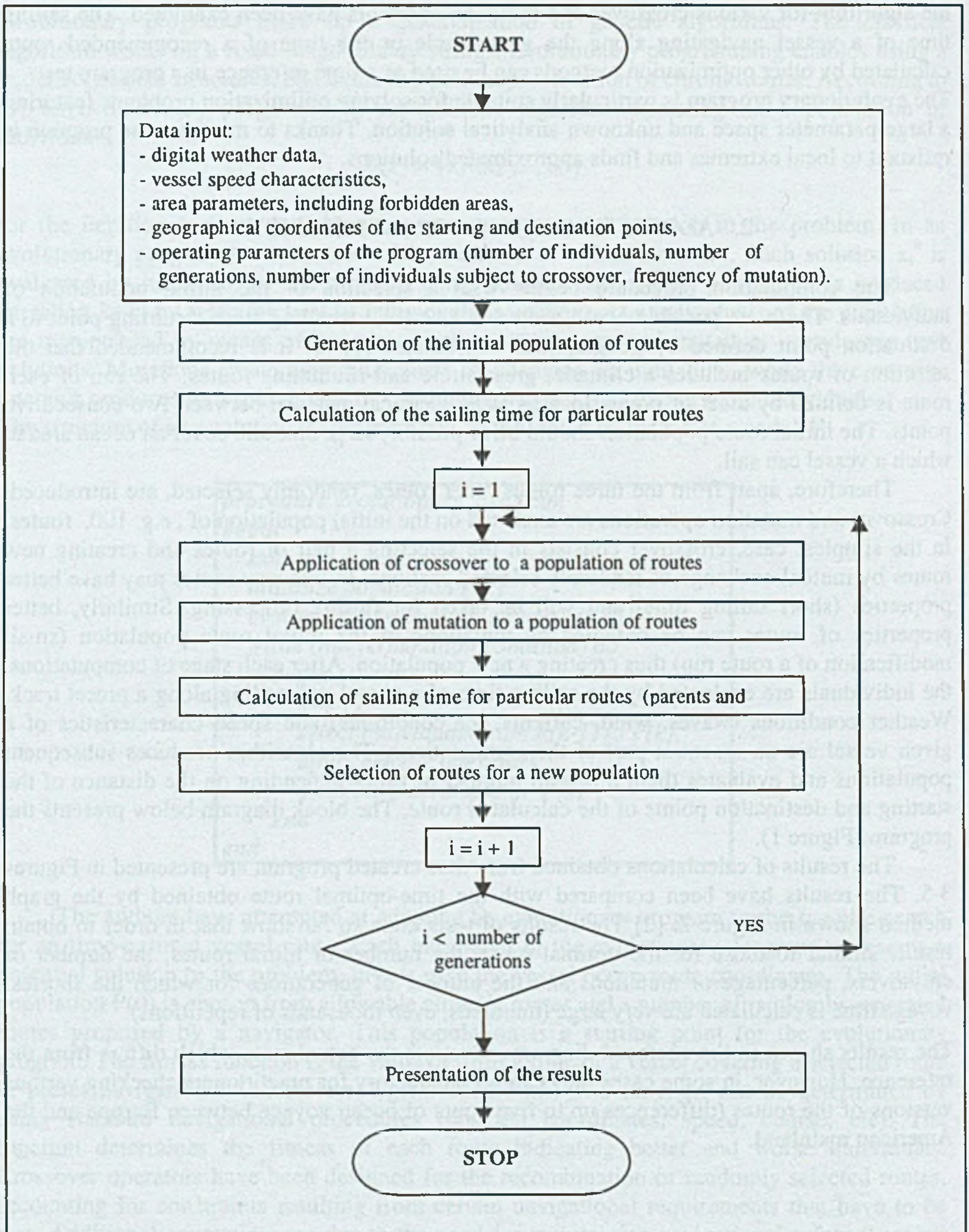

Fig.1. Block diagram of a program for searching minimum-time route, based on an evolutionary algorithm

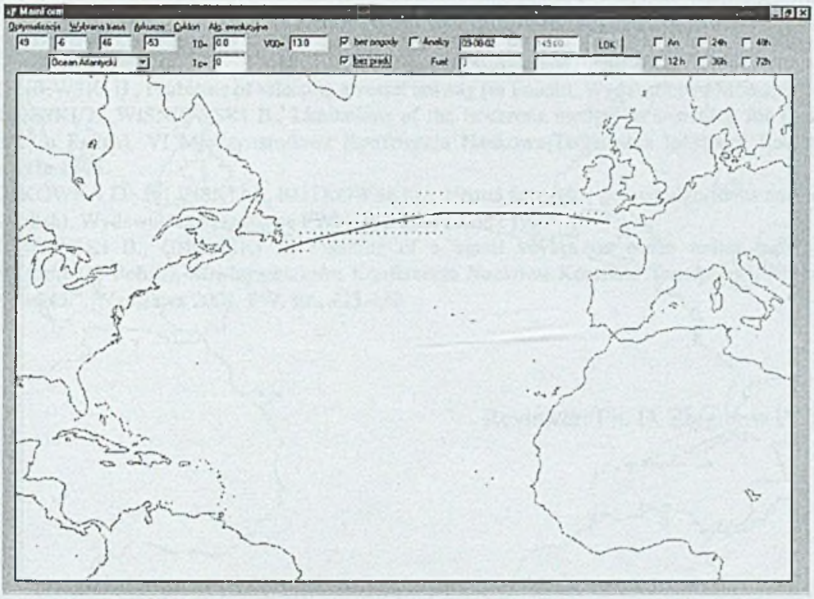

Fig.2. Graphic illustration of the optimal route from the English Channel (49 N, 006 W) to Cabot Strait (46 N, 050 W) – graph method T=145 hours

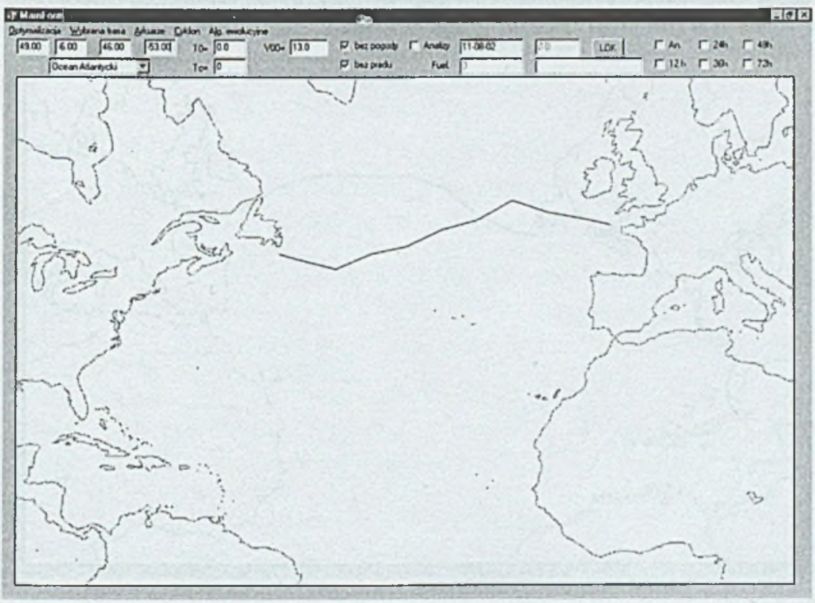

Fig.3. Graphic illustration of the route evaluated as the best after a crossover T_c=154.97 hours for a population of 100 routes, 50 crossovers and 50th generation

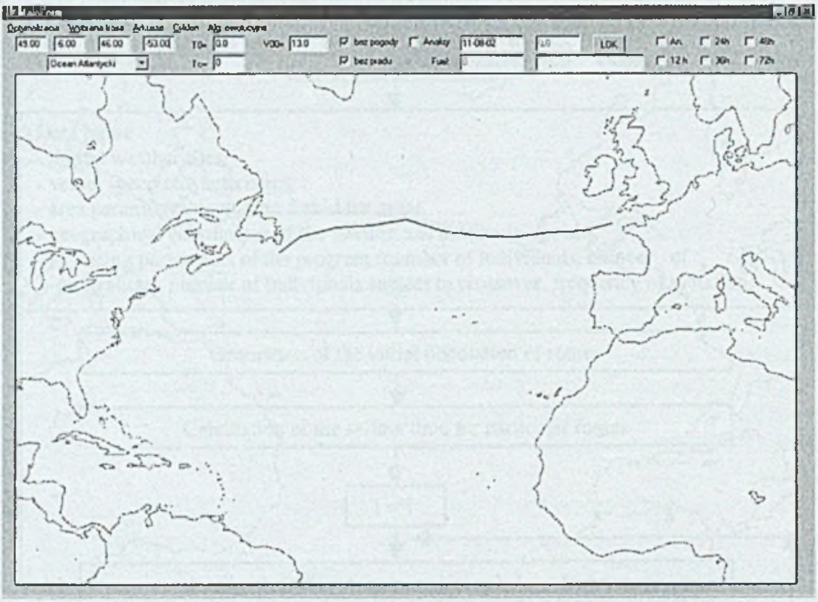

Fig.4. Graphic illustration of the route evaluated as the best after a mutation $T_m = 149.48$ hours for a population of 100 routes, 50th generation and the mutation of all routes

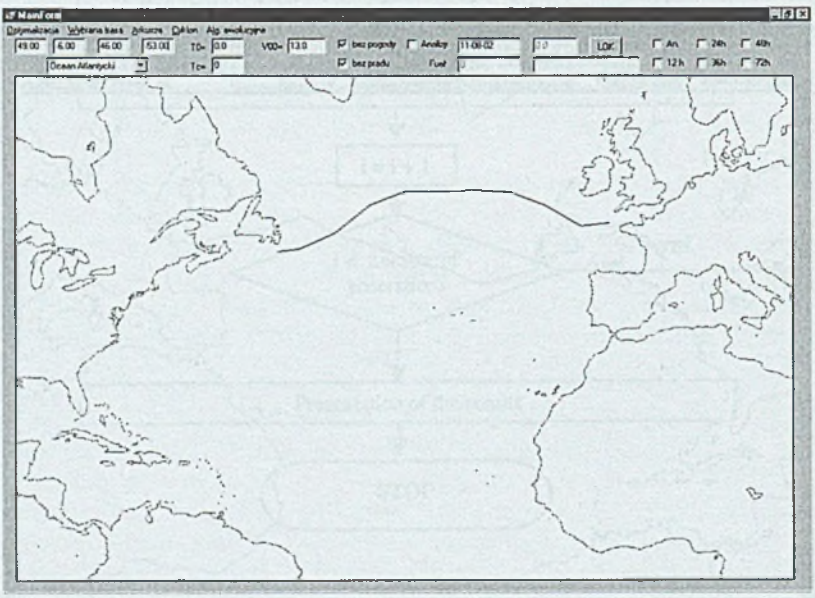

Fig.5. Graphic illustration of the route evaluated as best after the application of both crossover and mutation operators $T_{c,m}$=150.93 hours for a population of 100 routes, 50 crossovers, 50 generations, the mutation of all individuals

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