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Artificial intelligence methods in navigator decision support system

SUMMARY

The decision system in ship steering at sea should help the navigator to learn and enhance his intuition about a given decision. In the process computer modelling and simulation are preliminaries for decision making. The decision support system is a collection of procedures (data and parameters of the situation at sea, model of own ship, algorithms etc.) necessary to make decision.

One of the accepted ways of supporting in solving such problem is a multi-criterion and multi-level decision process. The navigator is supported during controlling the process of generating and evaluating various options of efficient decision in a multi-objective and optimum way.

Multi-criterion and multi-level decision problem of safe ship steering has to be based on the criterion of own ship's cost and the safe pass condition for own ship.

INTRODUCTION

Functions of the Decision Support System

A navigator, when making a decision during the process control takes into account the following objectives :

- to obtain the best possible effect as a result of the decision made
- to make a decision which is acceptable and rational.

A number of factors decides whether the objectives will be achieved or not in result of a decision. One of important factors is navigator's awareness of theoretical and analytical information about the process and the intuitive knowledge of the process, which is partly based on the experience [17].

A navigator can make proper decisions with high qualifications and experience. His experience most often results from earlier erroneous decisions and their consequences. A technical instrument which supports the decision making process is the Decision Support System (DSS) [2,6,16]. The task of the DSS is to select a subset of effective solutions out of a set of acceptable solutions.From this subset the navigator will then choose the most satisfactory solution.

The DSS should offer the following opportunities :

- to indicate alternative decisions
- to allow the navigator to assess the decisions with respect to his changing requirements.

The system which fulfils the conditions would be applied both as a teaching instrument for a navigator without enough experience, or without complex information about the decision process, and for looking for alternative solutions at different levels of realization of navigator's needs.

In most cases, the decision-making problem can be reduced to a task of multi-criterion optimization in which the task is defined by a criterion vector. The solution of the multi-criterion task determines a set of effective solutions which are satisfying with respect to the criterion vector. Then the navigator selects the final decision out of the set of effective solutions. The solution of the multi-dimensional optimization tasks is looked for on the basis of simulation models of the process in question. The correctness of the obtained solution depends on the process model precision and applied numerical optimization method. In the optimization task correct definition and verification of the model by means of the real process is a basic requirement for obtaining reliable solutions [16].

Any imposed simplification (for instance, neglecting essential limitations) may lead to erroneous results. However the use of optimization methods gives, even in the case of simplified models, important information and advice about :

- location of the solution area
- sensitivity of the solution to certain parameters
- consistence of the model with the real process and the range in which the solution of the task obtained on the basis of a simplified model can be applied to a practical problem.

Literature survey

Up to now, the available publications treat the problem of intelligent steering ship at sea rather one-sidedly and not in a general form.

A number of attempts were made to use expert systems [19] and the theory of fuzzy sets for solving the problem. M.K. James used the theory of fuzzy sets in the model of the ship steering for two ships approaching each other on the contra-course [5]. The decision model in which the approach of two ships at sea at good and poor visibility was modelled with the aid of fuzzy sets was presented in [18].

Time-description models using radar plots and distances to the traced object were worked out by K. Hara [3].

Determining the safe trajectory as a non-linear programming task was earlier formulated in [9,11] where a kinetic model of the own ship was applied. The criterion was defined as the deviation from a given course. The safety conditions were modelled as moving areas with non-linear admittance restriction. The problem was reduced to a finite-dimension, non-linear programming task by digitizing the trajectory, and solved by using gradient methods with a penalty function.

Another possible approach to the problem is the reduction of the solution space dimensions by creating the so-called digitized matrix of permissible manoeuvres for a given collision situation and a certain time instant [9].

In the digitized set of permissible solutions, a set of effective solutions satisfying the Pareto-optimum rule is determined with taking into consideration assumed values of the safe passing distance and course deviation. From the set of effective solutions, a solution is selected which best matches the minimum course change condition and at the same time satisfies the safety condition. The algorithm takes into account the dynamics of the own ship by determining the time of execution of a particular manoeuvre and estimating the coordinates of the ship location after the performed manoeuvre at a given ship speed, as well as load and the maximum rudder angle value.

In [12] the problem of avoiding collisions was formulated as the multi-criterion optimization task. Three separate criteria were applied, namely the collision risk minimization, cost of course deviation from a given value and approach distance maximization. A continuous task of the multi-criterion optimization was reduced to a static multi-dimensional task. The problem was solved for static and moving targets by using the DIDAS-N system [2,6].

The attempt to estimate the safe trajectory by using genetic algorithms was presented in [1]. A collision situation was modelled as a fuzzy process with many inputs. The authors applied a multi-dimensional digitized model of the collision situation in which the rules were defined at each stage of steering of the own ship. A fuzzy classifier system was used for selecting the steering rules. A problem which is in a sense similar to that of planning ship trajectory at sea is the steering of a mobile robot by using evolutionary algorithms [7].

The main goal of the present paper is to discuss the problem of avoiding collisions at sea : application of a intelligent method - evolutionary computation considered as an adaptive evolutionary task of estimating the own ship trajectory in an unsteady environment. A modified version of the intelligent system has been developed on the basis of the planning concept, which takes into account specific character of the process of steering ship at sea.

The main innovation of the modified version is the use of different types of static and moving constraints to model the real environment of moving targets and their dynamic characteristics.

THE STRUCTURE OF OWN SHIP GUIDANCE AT SEA

The problem of ship voyage can be shown as a set of tasks with different time horizons. The most general sub-problem with the longest time horizon (extending to a number of days) is planning the voyage - starting from the beginning way point up to the end way point („Route Planning R_{-0}"). The route is selected according to the economic factors such as the minimum fuel oil consumption and ship maintenance cost. Moreover, navigation constraints and long range sea weather forecast should be taken into account.

The next sub-problem is the selection of particular stages of the route where the time horizon lasts up to twenty hours. Here, the short-range sea weather forecast should be taken into account. Parameters describing the safety of the ship are the vital quality factor. In practice, it leads to corrections of the earlier selected, planned route due to the limitations imposed by safety requirements.

Third problem are navigation limitations, for example the existence of restricted zones, canals, and others. The optimization factor here is the safety of navigation and environment protection. Moreover, the actual position and draught of the ship are very important.

In the next step the safe trajectory or manoeuvre should be selected in the case of meeting a number of other targets, both steady and moving (so-called „Planning Safe Trajectory). This is the optimization task with the approximate time horizon not exceeding half an hour. In this task the ARPA information is used [4]. The steering decision of a manoeuvre, or its sequence making a trajectory is obtained depending on the form of the model and the method applied.

The process of safe guidance of the own ship in a collision situation was divided into three phases (Fig.1). In the first off-line phase the optimum safe trajectory of the ship is estimated by intelligence methods (here the evolutionary computation is applied) for certain navigation conditions [3]. The navigation data are obtained from the ARPA system [4]. These data are the input data to the procedures which compute the trajectory in „Adaptive Control".

In the next phase the ship is guided along the estimated trajectory and the distance and time preservation rule is observed. The phase is connected with the direct control of the ship movements in real time. The controlling instruments, e.g., main engine governor and autopilot, are used to follow the earlier selected trajectory. The actual locations of the ship on the estimated trajectory must be correlated with the time of the manoeuvre execution because of the presence of other moving targets.

In the third and last phase the development of the situation is controlled in an on-line manner, and in the case of changes of motion parameters of other targets the actual trajectory is corrected. The current location of the own ship and current parameters of motion of the remaining targets constitute the actual starting conditions for correcting the trajectory.

The last level is the direct control of the ship movements in real time. Here, the control instruments such as main engine governor and autopilot are used to follow the earlier selected trajectory.

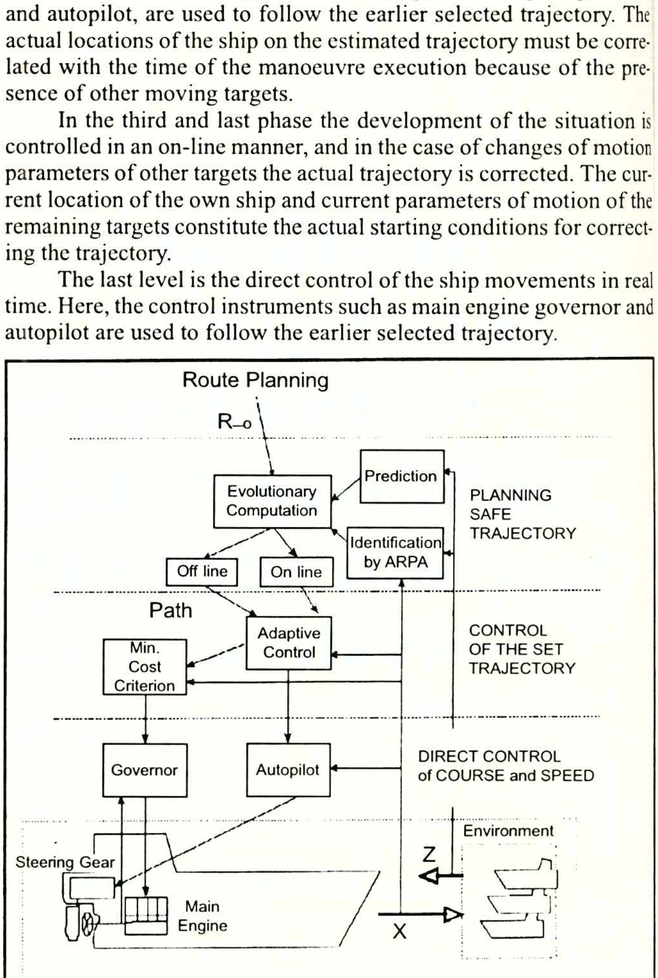


Fig.1. Structure of evolutionary own ship guidance in collision situation

This paper deals with the phase of evolutionary estimation of the near optimum trajectory in a well-known environment modelled by navigation constraints and moving targets. The resulting trajectory which represents the passing path consists of a number of line segments between the assumed starting and final states.

MODEL DEFINITION OF ENVIRONMENT AND CONSTRAINTS

Ship motion in the used model is approximated by the following status variables (Fig. 2.A)[8] :

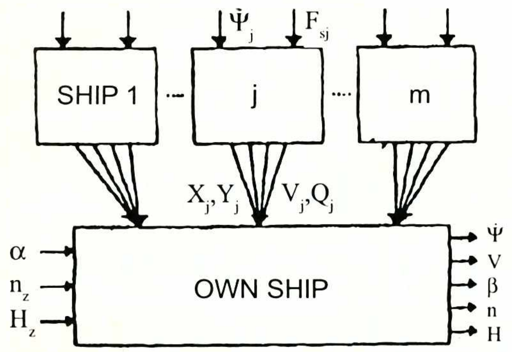
$\dot{\Psi}$ - angular speed of the own ship
V - speed of the own ship
β - drifting angle of the own ship
n - rotating speed of the propeller of the own ship
H - pitch of the adjustable propeller of the own ship

X_j - position co-ordinate x of the j-th ship relative to the own ship
Y_j - position co-ordinate y of the j-th ship relative to the own ship
Q_j - relative course angle to the j-th ship
V_j - speed of the j-th ship.

The steering values are represented by the following values:

α - rudder angle of the own ship
Ψ - course of the own ship
$\dot{\Psi}$ - angular speed of the own ship
n_z - predetermined rotating speed of the own ship's propeller
F_{sj} - propeller thrust of the j-th ship
V - speed of the own ship
H_z - pitch of the own ship's adjustable propeller
Ψ_j - course of the j-th ship encountered
$\dot{\Psi}_j$ - angular speed of the j-th ship encountered.

A)



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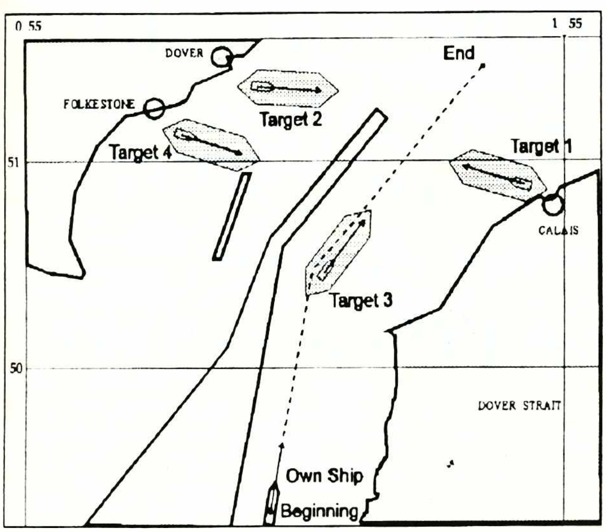


Fig.2. A - block diagram of a basic model. B - navigation situation in Dover Straits

The applied reduced description of the own ship's dynamics, dynamics of the j-th encountered ship and their movement kinematics leads to the following approximate models [10]: model of the differential game, dynamic model, kinematic model of the actual or relative movement, fuzzy model, static model, model of a speed triangle, evolutionary model.

In the evolutionary model the ship sails [13÷15] in the environment with natural constraints (land, canals and shallow waters) or those resulting from formal regulations (traffic restricted zones, fairways, etc.) (Fig.2B). It is assumed that the constraints are stationary and they can be defined by polygons, in the same way as the electronic maps are created.

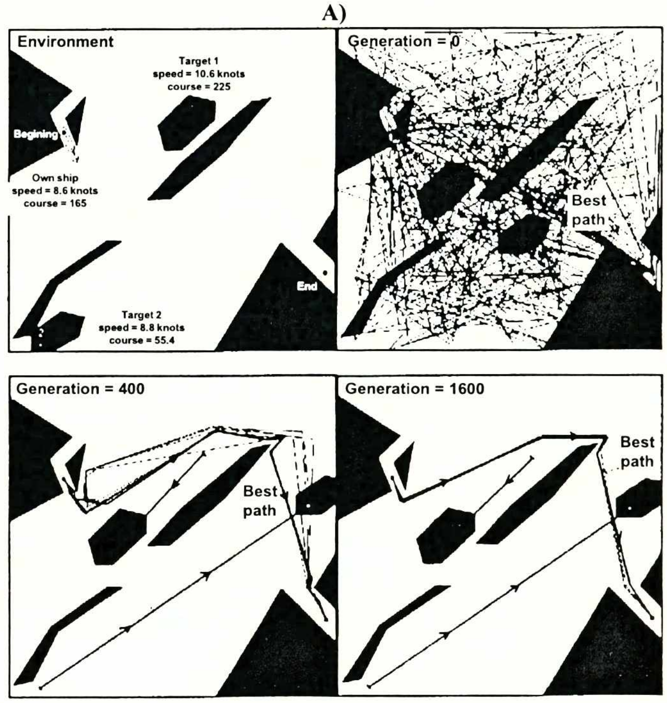
When sailing in a stationary environment, the own ship meets other sailing ships, i.e. moving targets. A part of the targets creates a collision threat while the rest does not influence the safety of motion of the own ship. It is assumed that the dangerous target is that which has appeared in the area of observation and can cross the estimated course of the own ship at a dangerous distance.

In the evolutionary task the targets threatening with collision are interpreted as the moving areas of danger having the shapes and speeds corresponding to the data obtained from the ARPA system. Actual shapes of the areas depend on the safety conditions: the assumed safe distance, D_{safe}, ship speed ratios and bearings.

EXAMPLES OF SAFE TRAJECTORY PLANNING BY EVOLUTIONARY COMPUTATION

The own ship is assumed to move with the constant speed V along the passing path S from the starting point to the final point. At the initial instant t_0 the motion of the strange ships (targets) is assumed constant. Motion of each target is represented by the following parameters: bearing, distance, speed, and course given by the

A)



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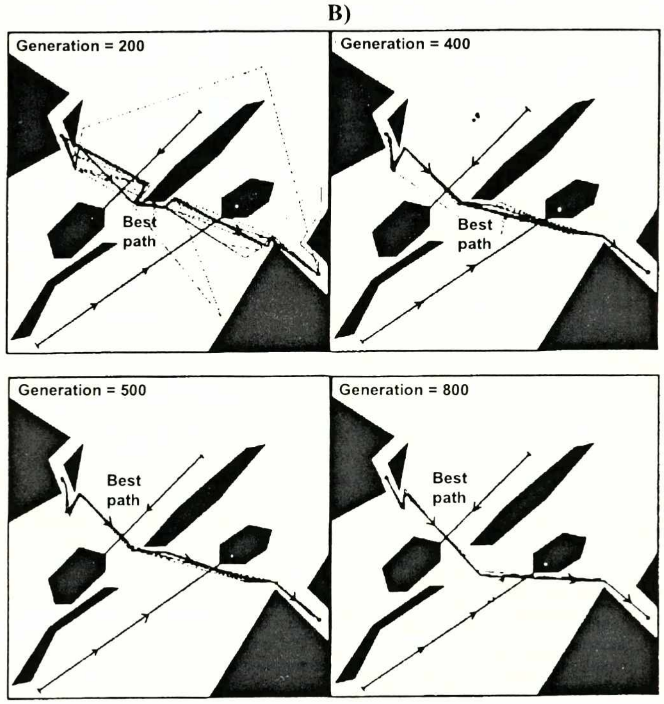

Fig.3. A - trajectory evolution for two moving targets and static navigational constraints (population of 40 trajectories). Speed of own ship (ferry) V=8,6 knots. B - trajectory evolution for two moving targets and static navigational constraints (population of 40 trajectories). Speed of own ship (ferry) V=5,6 knots

ARPA system. Each path S (individual) is first generated in a random way. Then a set of the dynamic areas of danger corresponding to particular targets is attributed to the passing path. The locations of the dynamic areas with respect to the passing path depend on the time t determined from the first crossing point between the own ship path S and the trajectory of the target of concern.

The diagrams shown in Fig.3A [14,15] present the solution of the problem of ferryship communication, obtained by using the evolutionary algorithm version with trajectory modification. The situation presents the own ship, a ferry, sailing between two islands while approaching two moving targets; it has to pass two fixed navigational constraints which makes the situation more difficult.

The trajectory population consists of 40 individual trajectories. The own ship speed is constant and equal to V=8,6 knots. Due to Target 1 sailing between the islands, the own ship is to pass round the island in such a way as to reach the destination point without collision.

In the computation process, after 600 generations (computing time 36 s), no trajectory changes in the populations were observed. The own ship moving along the determined trajectory with the assumed speed will pass the moving targets and static constraints at a safe distance.

In the above mentioned case, a more effective manoeuvre of the own ship would be the simultaneous change of course and speed reduction. The next two cases show the same navigational situation, the only difference consists in the speed reduction (Fig.3B), where the own ship speed was equal to V=5,6 knots. Reducing speed of the own ship makes it possible to pass the approaching targets behind their sterns and sail between the islands without significant course changes. This is the shortest trajectory of the own ship between the starting and final point.

Acknowledgement

The research reported in this paper was financially supported by The State Committee for Scientific Research (the grant No 8 T11A 004 14).

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Conference

S/s SOŁDEK

Polish historic coal-ore carrier

S/s SOŁDEK, the ship reminding the post-war beginnings of Polish shipbuilding industry, converted now to museum, stays afloat close to the headquarters of the Central Maritime Museum in Gdańsk. It is the ship which opens the list of more than 1000 sea-going ships built by three largest Polish shipyards of Gdańsk, Gdynia and Szczecin after the World War II.

Her keel was laid in Gdańsk Shipyard on 3 April and hull was launched on 6 November 1948. Round 50 years just passed from the day, and on the occasion a symposium was held at the Central Maritime Museum on 6 November 1998 under the heading:

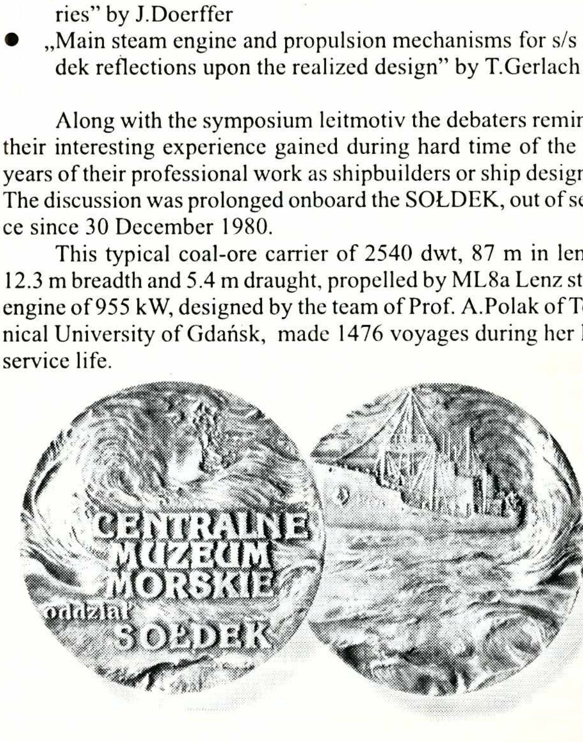
„Polish sea-going steam ships of 1938÷1998"

Many attendants of the jubilee took part in presentation of 5 papers prepared by the authors merited to development of Polish shipbuilding :

- „Beginnings of steam cargo ships in Poland" by E.Gill
- „Sea fishing vessels with steam propulsion plant" by J.Staszewski
- „Development trends of steam propulsion for modern cargo ships" by J.Krępa
- „Construction of B-30 coal-ore carriers handful of memories" by J.Doerffer
- „Main steam engine and propulsion mechanisms for s/s Sołdek reflections upon the realized design" by T.Gerlach

Along with the symposium leitmotiv the debaters reminded their interesting experience gained during hard time of the first years of their professional work as shipbuilders or ship designers. The discussion was prolonged onboard the SOŁDEK, out of service since 30 December 1980.

This typical coal-ore carrier of 2540 dwt, 87 m in length, 12.3 m breadth and 5.4 m draught, propelled by ML8a Lenz steam engine of 955 kW, designed by the team of Prof. A.Polak of Technical University of Gdańsk, made 1476 voyages during her long service life.



The medal issued by the Central Maritime Museum, SOŁDEK division