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Ship's optimum safe trajectory in a collision situation of passing many moving targets in fuzzy environment

SUMMARY

Ship safe sailing consists in continuous observation of the situation at sea, determination the anticollision manoeuvre, if necessary, the realisation of it and safe voyage to a point of destination. So it is necessary to determine ship safe trajectory as a sequence of ship course changing manoeuvres. Each manoeuvre is undertaken on the basis of information obtained from the anticollision system.

In this paper safe ship control in a collision situation is presented with taking into account passing many moving objects, considered as multistage decision-making process in a fuzzy environment. A branch-and-bound method is used to determine optimum safe trajectory of the ship according to the International Rules of the Road at Sea.

INTRODUCTION

Ship safety is one of the most important problems in the marine navigation. It is more and more difficult to make correct decision in a collision situation because of growing size, velocity and number of ships taking part in the maritime transport.

A contemporary tendency in ship control is automation of choosing optimum manoeuvre or optimum safe trajectory, based on the information from the anticollision system.

In the paper a solution is discussed of the basic task of the ship's optimum course (position) determination at every stage of ship trajectory, based on a kinematic model of the process. The straight-line and uniform motion of encounter targets is assumed.

An optimum safe trajectory in collision situation is considered to be a multistage decision-making process in fuzzy environment [1], because of the fuzziness caused by the subjective role of the officer-navigator in decision-making process as well as due to uncertainty of estimation of safe approach distance and time to make collision avoidance manoeuvre.

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PROCESS KINEMATIC MODEL

A ship safe trajectory in a collision situation can be presented as a multistage decision-making process in a fuzzy environment [2]. Suppose that ship's real motion equation is as follows:

$$f\colon XxU \to X$$

$$\underline{X}(t) = f[\underline{X}(t-1), \underline{u}(t-1)] \qquad (1)$$

$$x(t) = x(t-1) + V(t).t.\sin\psi(t)$$
$$y(t) = y(t-1) + V(t).t.\cos\psi(t) \qquad (2)$$

where:

- $x, y \in X$ - ship position coordinates
- t - time
- $\bar{u}$ - control vector
- V - ship speed
- $\underline{X}(t)$ - vector of real ship position coordinates which belongs to the set of states X:

$$X = \{s_1, s_2, \ldots, s_{p-1}, s_p, s_{p+1}, \ldots, s_n\} \qquad (3)$$

whereas:

- s - ship position state
- p - state number
- n - maximum number of states
- $\psi(t)$ - ship course which belongs to the set of admissible controls U determined in accordance with the International Rules of the Road at Sea:

$$U = \{c_1, c_2, \ldots, c_n\} \qquad (4)$$

- c - control state

The process comes to an end when a ship attains for the first time back points (final points) called the final states W:

$$W = \{s_{p+1}, s_{p+2}, \ldots, s_n\} \qquad (5)$$

The set of final states must satisfy the following condition:

$$\langle \Psi_{opt} = \Psi_Z \quad \mu_R \leq \mu_{Rsafe} \rangle$$

where:

Ψ_Z - initial course of the „own" ship
μ_R - membership function of fuzzy set of the collision risk R, R⊆XxU, which can be expressed in the form of (6)
μ_{Rsafe} - a value of μ_R at which the process is assumed safe

$$\mu_R(t,j) = exp[-\lambda_{Rd}(t,j)DCPA^2 - \lambda_{Rt}(t,j)TCPA^2(k,j)]$$

$$if\ TCPA \geq 0 \tag{6}$$

$$\mu_R(t,j) = 0 \qquad if\ TCPA < 0$$

where:

DCPA - distance of closest point of approach
TCPA - time to distance of closest point of approach
j - ship number
k - manoeuvre phase

Let the fuzzy sets of goals and constraints be defined as G and C, G⊆XxU, C⊆XxU respectively, then the fuzzy decision is determined as the fuzzy set D, D⊆XxU , in result of the aggregation „*" of the G and C sets [4,6]:

$$D = G * C \tag{7}$$

or in the form of the fuzzy decision membership function :

$$\mu_D(.,.) = \mu_G(.,.) * \mu_C(.) \tag{8}$$

where:

$$\mu_G(t,j) = 1 - \exp[-\lambda_d(t,j)DCPA^2] \qquad if\ TCPA \geq 0$$
$$\mu_G(t,j) = 0 \qquad if\ TCPA < 0 \tag{9}$$

$$\mu_C(t) = \exp\{-\lambda_c(t)[V\cos\psi_{opt}(t) - V\cos\psi_{opt}(t-1)]t\} \tag{10}$$

and:

$\lambda_c, \lambda_d, \lambda_{Rd}, \lambda_{Rt}$ - officer-navigator's subjective parameters [4,6]

ALGORITHM

A fuzzy decision is the result of a compromise between the sets G and C. If the trajectory is assumed to be a sequence of the attained states then the membership function of decision fuzzy set can be defined as follows:

$$\mu_D[x(0),x(1),...,x(n)] =$$
$$= \mu_C[u(0)/x(0)] * \mu_G[u(1)/x(1)] * ... \tag{11}$$
$$... * \mu_C[u(n-1)/x(n-1)] * \mu_G[u(n)/x(n)]$$

where:

μ_C, μ_D, μ_G - membership function of constraint fuzzy set, decision fuzzy set, goal fuzzy set, respectively

To maximize the membership function of decision fuzzy set the optimum decision can be obtained by using the minimum type of it „ ∧ " [5]:

$$\mu_D[x^*(0),x^*(1),...,x^*(n)] = \max_{x(0),x(1),...,x(n)} \{\mu_C[u(0)/x(0)] \wedge$$
$$\wedge \mu_G[u(1)/x(1)] \wedge \mu_C[u(1)/x(1)] \wedge ... \tag{12}$$
$$... \wedge \mu_C[u(n-1)/x(n-1)] \wedge \mu_G[u(n)/x(n)]\}$$

A branch-and-bound algorithm is used to solve this problem [2,3,5].

The decision process can be conveniently presented in the form of a decision tree, the root of it is the initial state x(0). The process is started from x(0) and while looking for an optimum decision it is put under the control u(0) and then passed to the state x(1). The optimum decision u(1) is now determined and the process passed again to the next state until the final state is attained. In this manner a sequence of states which present a ship's optimum safe trajectory is obtained [3].

The algorithm block diagram is shown in Fig. 1.

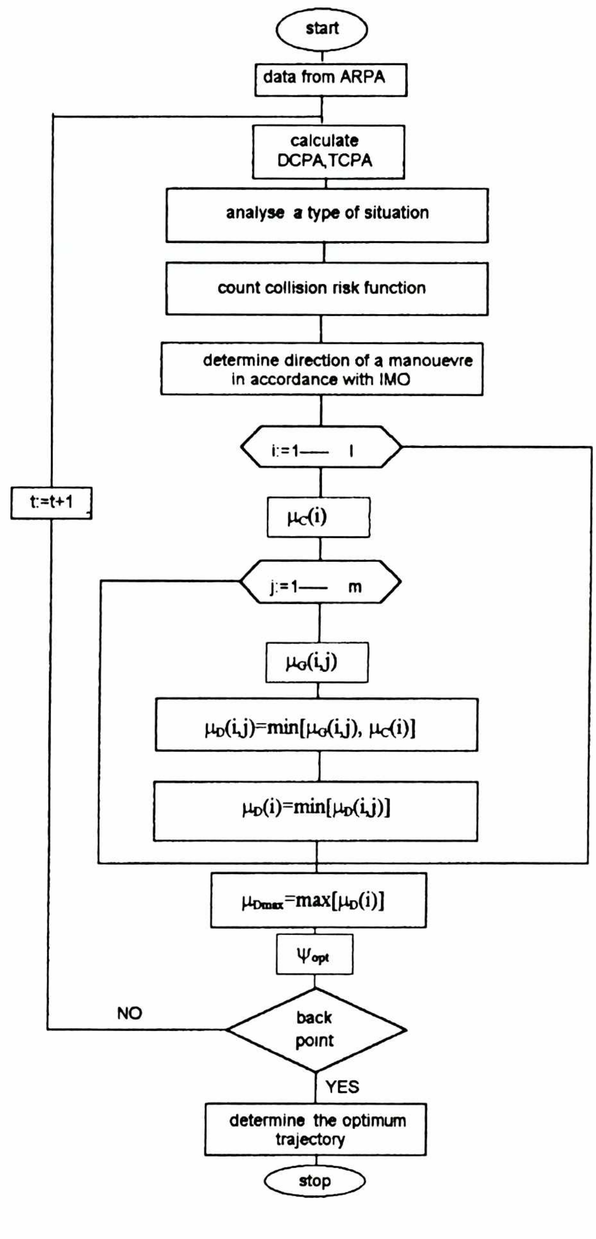

Fig. 1. The algorithm block diagram to determine the optimum safe trajectory of a ship in collision situation

EXAMPLE

Results of the simulation of the ship collision situation of passing three moving targets are exemplified in Fig. 2. The"own" ship moves at V_0 = 14 [Kn.] , $\psi_z = 0^0$. Motion parameters of three target ships are as follows:

target	V [Kn]	$\psi_z[^0]$	$N[^0]$	D[Nm]
1	19	90	315	4.24
2	14	182	1.9	3.01
3	17	175	18.5	3.16

N - ship (target) course bearing
D - ship (target) distance

The optimum course angles $\psi_{opt}[^0]$ are given in the table attached to Fig. 2.

k	1	2	3	4	5	6
$\psi_{opt}[^0]$	24	15	6	1	0	0

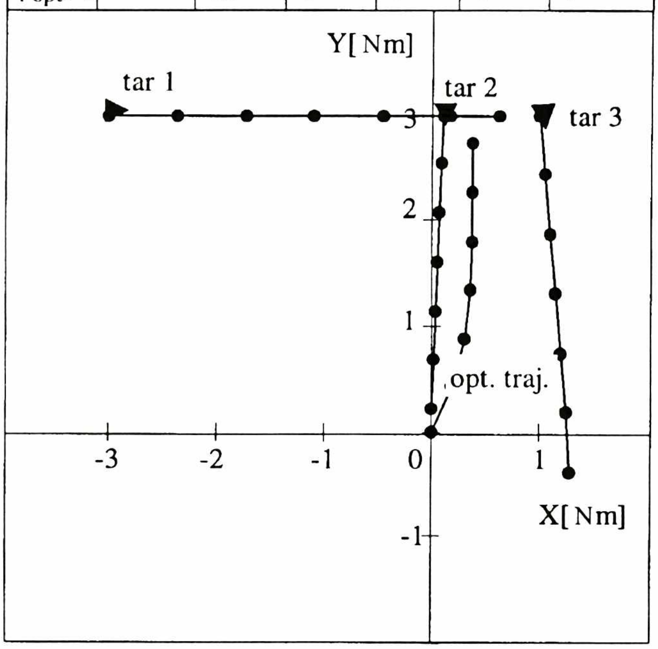

Fig. 2 Results of the simulation of the ship collision situation of passing

CONCLUSIONS

The presented results showed that the proposed concept of the determination of ship's optimum safe trajectory, based on the fuzzy set theory, is a promising way to solve the considered task and design a novel anticollision system on its basis in the future.

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Conferences

Corrosion Conference

KOROZJA '96
GDAŃSK

The V domestic conference on corrosion problems, organized within the „Gdańsk 997÷1997" celebration program of Gdańsk 1000-year anniversary, was held on 17,20 September 1996. It was arranged by the Chair of Corrosion Protection Technology, Chemical Faculty, Technical University of Gdańsk, headed by Prof. Romuald Juchniewicz. The main building of the almost 100 year old University hosted the conference and accompanying events.

A large extent of the scientific event may be evidenced by the following data:

- 53 papers (a dozen or so of them prepared by specialists from abroad)
- large poster session of more than 100 items
- about 400 participants.

Eight topic sessions were devoted to the main, scientific part of the Conference:

I	Corrosion processes	- 7 papers
II	Measurement techniques	- 6 papers
III	Electro-chemical protection	- 6 papers
IV	Surface engineering	- 6 papers
V	Corrosion in engineering	- 7 papers
VI	Environment technology	- 5 papers
VII	Anticorrosion coatings I	- 7 papers
VIII	Anticorrosion coatings II	- 5 papers

The topic sessions were preceded by the plenary session (of 4 papers) opening the Conference, and ended by the round table meeting on: „The corrosion protection strategy in the Polish economy". A very wide scope of topics, both of the theoretical area and corrosion fighting practice in various environment conditions, were presented. The Conference was very carefully prepared, and supplemented by the product exposition of 20 firms engaged in manufacturing anti-corrosion chemicals and devices.

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SAFE SHIP International Conference cancelled

The earlier announced Conference which had to be held in Gdańsk in September 1996 was cancelled because of too low number of persons interested to participate in it.