FUZZY PRODUCTION MODEL FOR INITIAL EVALUATING OF THE RISK OF COLLISIONS

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ABSTRACT

Modern assessment of collision risk has a distinct value for safe shipping. Upon detection of a target vessel, that is, a vessel with which it is necessary to avoid collision, a ship driver shall promptly determine whether a situation of close approach to them is developing [1], and if it is so to decide on the best maneuver to prevent a possible threat.

This paper proposes a fuzzy production model of the initial assessment of collision risk on computed distance and time of approach, in which a mentioned disadvantage is eliminated.

Based on the theory of fuzzy sets an assessment model of collision risk is developed. Linguistic variables, used in it, are presented and universal sets for each of them are defined. Implementation of the model was carried out in a software environment FuzzyTECH, performance of the system on several test examples is demonstrated.

Keywords: safety of navigation, shipping, risk of collision, approach distance, approach time, linguistic variable, fuzzy production rule.

Background. *In [2] the primary hazard assessment of collisions at sea is determined by three different methods:*

1. The nature of changes in bearing and approach distance.

2. By mutual location of vessels.

3. By calculated distance and time of the closest approach.

For the first two methods A. S. Maltsev [2] presents auxiliary tables, and for the third method it is stated that ship drivers subjectively, based on personal experience, identify the best parameters of distance and time of approach, which the actual circumstances on the water dictate (suggest) them. Earlier attempts to develop a universal system to sum up experience of ship drivers, for example, in [3–5], but they have a disadvantage that lies in the complex interpretation of the output parameter.

Objective. *The objective of the author is to present a model of collision risk assessment.*

Methods. *The author uses analysis, mathematical methods, comparative method, evaluation method.*

Results.

Description of a model

Fuzzy production model consists of two input linguistic variables and one output variable.

The first input variable «Approach distance» corresponds to the distance between a target vessel, with which it is necessary to avoid collision, and a vessel- operator, which maneuvers. Since a reliable detection of a target vessel by radar occurs at around 15 miles, the universal set for the first linguistic variable is defined in the range from 0 to 15 miles.

Linguistic variable «Approach distance» is characterized by a basic term-set: short, control, resolve, decision, rating, detection. And the term «short» corresponds to the situation of excessive approach, the term «control» corresponds to the zone of control when additional actions are possible to correct errors, «resolve» – the ability to perform maneuvers for avoidance, «decision» – area for decision-making on the avoidance maneuver, «rating» – area to assess the situation, and the term «detection»- zone of medium-range detection of the target vessel [1].

Membership functions for the terms of the first input linguistic variable are shown in Pic. 1A.

The second input linguistic variable «Approach time» is defined by the interval of time from target detection to performance of required avoidance maneuver. This variable has a universal set [0, 30] minutes, and a basic term-set is divided into several types: very_little, little, allowable, sufficient, no_problem.

Membership functions for the terms of the second input linguistic variable are indicated in Pic. 1B.

Output linguistic variable «Hazard level» is characterized by a basic term-set: very_low, low, medium, high, very_high, a universal set for this variable is taken in the range of 0 to 100 (the higher it is, the more dangerous it is).

Membership functions for the terms of the output linguistic variable are shown in Pic. 1C.

Used in the fuzzy production model of the initial hazard assessment of collisions on computed distance and time of approach membership functions to set the terms of input and output linguistic variables are triangular, linear Z-shaped and linear S-shaped.

Implementation of a model scheme

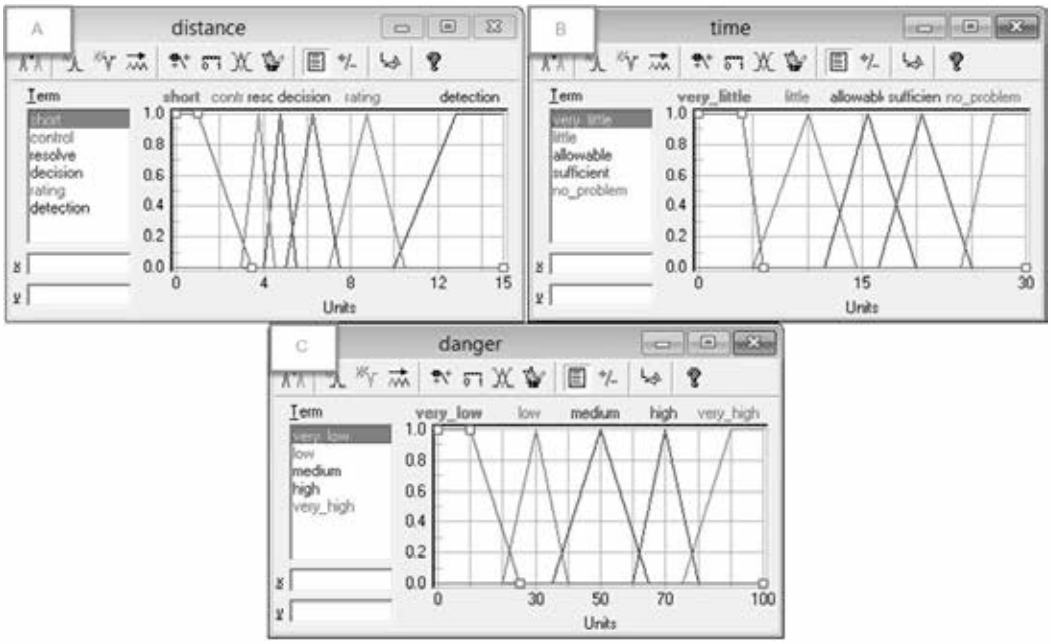
Pic. 2 shows a general scheme of fuzzy production model of the primary assessment of the collision risk. As an algorithm of a fuzzy inference method Mamdani method is used [6].

The rule base of fuzzy model products includes 30 positions; their implementation was carried out using the software environment FuzzyTECH [7] (3D surface of a fuzzy interference is shown in Pic.3).

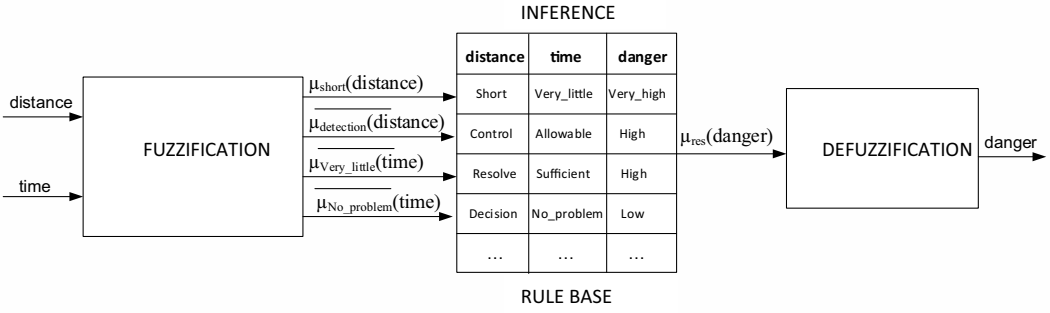
Let's consider work of the model on a few typical examples.

Example № 1. Let's assume that a situation of excessive approach occurs when the distance to the oncoming vessel is one mile, the time to approach is equal to 2,5 minutes. This situation corresponds to a high degree of risk, as time is enough only for actual execution of the maneuver. We enter this information in the fuzzy production system (Pic. 4A), it gives the degree of danger 91,6, which confirms the presence of a very high level of threat.

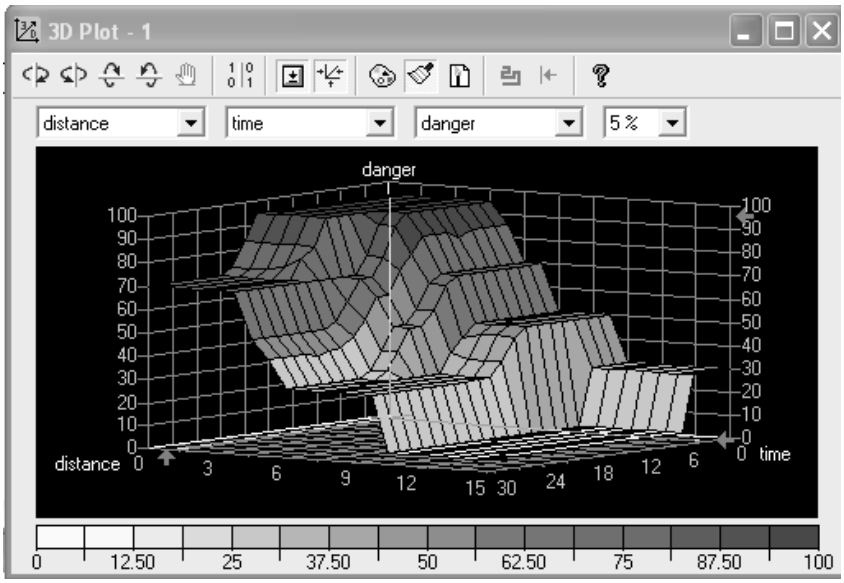
Example № 2. There is a situation when a target vessel is detected at a distance of five miles, and time to approach is 20 minutes. Despite the fact that the target vessel is close, the position is not critical because the degree of hazard is reduced by sufficient time, which is enough to solve the problem of vessel collision avoidance action and to perform an appropriate maneuver. Therefore, the degree of danger is less than average, so



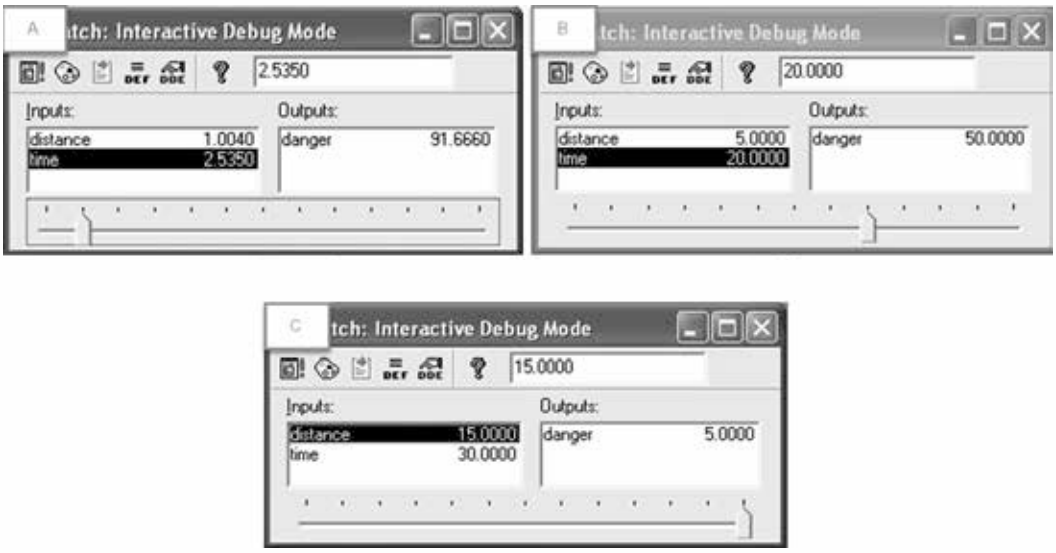
Pic. 1. A – input LV «Approach distance"; B – input LV «Approach time"; C – output LV «Hazard level».



Pic. 2. General scheme of fuzzy production model.



Pic. 3. Dependence of output linguistic variable from input linguistic variables.



Pic. 4. Examples of initial assessment of collision risk.

time to approach is 20 minutes. Despite the fact that the target vessel is close, the position is not critical because the degree of hazard is reduced by sufficient time, which is enough to solve the problem of vessel collision avoidance action and to perform an appropriate maneuver. Therefore, the degree of danger is less than average, so entering background information in the fuzzy production system, we obtain the results shown in Pic. 4B.

Example № 3. Let's imagine that a target vessel is detected at a distance of 15 miles, approach time is 30 minutes. This situation is not dangerous in time, or in the distance, which allows us to get additional information, to process it, to decide and to perform a necessary maneuver. Consequently, the level of threat will be minimal. We enter information in the fuzzy production system and get the confirmation of minimal risk (Pic. 4C).

Conclusions. *Having tested the fuzzy production model of initial assessment of collision risk in different situations, the author has a right to conclude on its working capacity. Taking into account the accumulated research material [8 et al.], such a model, in the author's opinion, can be a basis for creation of an automated system for determining a hazard level during ships' approaching and for selection of the best avoidance maneuver.*

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