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APPLICATION OF MARITIME INFORMATION MARKUP LANGUAGE IN A SYSTEM OF SHIP COMMUNICATION AND COOPERATION

Most marine accidents are caused by human errors. These errors may occur at any stage of the ship movement control decision process. Accidents can also be due to improper communication and lack of coordination of actions between navigators conducting the ships involved. This article describes the principles and forms of communication between ships. It also discusses actions taken to improve navigational information exchange – standardization of contents and form of information.

ZASTOSOWANIE MORSKIEGO JĘZYKA ZNACZNIKÓW W SYSTEMIE KOMUNIKACJI I KOOPERACJI STATKÓW

Przyczyną większości wypadków morskich są błędy człowieka. Błędy te mogą wystąpić na każdym z etapów procesu decyzyjnego sterowania ruchem statku. Przyczyną wypadków może być także brak prawidłowej komunikacji i koordynacji działań między nawigatorami prowadzącymi statki. W artykule scharakteryzowano zasady i formy komunikacji między statkami. Omówiono działania mające na celu usprawnienie wymiany informacji nawigacyjnej - standaryzacji treści i postaci informacji.

1. INTRODUCTION

The number of information systems installed on board sea-going ships and at land-based centres is on the rise. These systems are used for the processing of data of various form and contents, essential from the point of view of participants of the transport process: navigators, shipowners, ship's agents, shipchandlers, buyers of goods and services, port and VTS operators and others. The diversification of physical properties, sources of navigational information, its kind and scope call for the standardization of the navigational information form. Actions taken are directed towards the development of a navigational information ontology. At the same time research is being done on formal languages that will enable recording (coding) of navigational information according to the accepted ontology.

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The definition of standards will allow to unequivocally interpret gathered and transmitted information.

The assurance of navigational safety, i.e. the safety of personnel, cargo and the environment requires that, apart from easy access to and automatic interpretation of data, there is a possibility of communication for the determination or specifying the interpretation and assessment of a present and forecast situation, as well as the intentions of transport process participants. In the case of maritime shipping the principles of communication between navigators steering their ships and between navigators and land-based centres are contained in appropriate regulations. These regulations impose certain obligations on vessel traffic participants, but they do not prevent ships from dangerous situations which result from failing to communicate or errors in communication. Examples of these are improper choice of the means of communication, wrong information, misunderstanding or wrong interpretation of exchanged information. One method of solving such problems may be the development of principles of automatic communication and cooperation, based on standards of navigational information presently in the stage of preparation. Therefore, there is a need to supplement the navigational ontology with a sub-ontology for communication processes, and to use an adequate formal language for information to be recorded. To begin with, it is advisable to analyse the presently observed principles of communication.

2. PRINCIPLES OF SHIP-TO-SHIP COMMUNICATION

The communications with shore-based centres and other ships are of utmost importance for the safety of life at sea and the ship itself. The functional requirements set forth in Regulation 4, chapter IV (Radiocommunication), part of the SOLAS Convention 1974 each ship at sea should be able to conduct **two-way inter-ship communication** [3].

Maritime communications witnessed a breakthrough in the 1990s. That was when the Global Maritime Distress and Safety System (GMDSS) was implemented. The system, defined and described in 1979, aimed at the standardization of means and principles of radiocommunications at sea. According to the system guidelines, every ship, regardless of the trading area, should be capable of maintaining communications for its own safety and the safety of other craft sailing in the vicinity. The advantages of the GMDSS are as follows: automation of safety communications, elimination of Morse Code radiotelegraphy and the introduction of common standards into existing systems [3].

The GMDSS system features strictly defined rules and procedures of priority communications, i.e.:

- distress communications (collisions, rescue of life and property),
- urgency communications (man overboard etc.),
- safety communications (e.g. navigational and meteorological warnings).

Apart from the above three modes of communications, the GMDSS system enables routine communication, e.g. in situations when ships have to coordinate manoeuvres to be performed to pass each other safely. However, this mode of communication, unlike the priority communications, is not strictly defined in terms of procedure and circumstances in which to use it within the GMDSS. This results from a lack of legal regulations for this mode of communications.

The navigator's legal basis for communication with other ships to establish a manner and time of passing each other is Regulation 2a, part A of collision regulations (COLREGs) [16]. The regulation reads: "*none of the provisions of these regulations does not exempt ... Master nor the crew from the consequences of any ... negligence in taking precautions that* *may be required by both seamanship and particular circumstances of a given accident.*". Therefore, the regulation does not impose directly the necessity to establish communication, it only obliges the navigator to take proper precautions.

One such precaution is VHF radiotelephony (VHF RT) which has a range of dozens of nautical miles. Although quite often used in routine communications between ships, it often to be careless, incorrect or just given up. Examples of improper use of radiotelephony can be found in the verdicts of maritime courts, which in many cases indicate improper communication or its lack as an indirect reason for marine accidents.

Causes of improper or no communication, in turn, can be as follows:

- language barrier (difficulties in formulating messages in English, or limited capability of understanding them),
- various aspects of human behaviour, such as negligence, fear, embarrassment or others,
- technical reasons, e.g. failure of VHF equipment, poor audibility etc.

Language barrier has been on the rise over the last decades as the number of nationalities represented by seafarers has increased. The problem of overcoming the language barrier was undertaken by the International Maritime Organization in 1973 [5]. Its aim has always been the standardization of maritime English for communication and working out rules for simple, precise and unequivocal communication. The first outcome of the standardized maritime language was known as Standard Marine Navigational Vocabulary and was issued in 1977, while a revised version was published in 1985. The Standard Marine Communication Phrases (SMCP) in a book form appeared in 1997. Revised in 2001, the phrases have been recommended for use till now. Although the SMCP puts emphasis on the rules of information exchange and specifies the marine register in on board, inter-ship and ship-to-shore priority communications, safety communication between ships seems to be of secondary importance [6].

Human behaviour with its wide spectrum has, obviously, an important influence on the quality of marine communication. The conduct of a navigator who does not care much for correct communication is a topic of a separate analysis. The reasons for navigator's inadequate behaviour may be due to insufficient training or continuously advancing automation of navigation [1]. The consequences, however, are similar to those caused by language barrier.

3. STANDARDIZATION OF NAVIGATIONAL INFORMATION

The standardization and unequivocal interpretation of navigational information is of key importance for the effective ship-to-ship and ship-shore communication. Some standards for the exchange of maritime information have already been developed, others are being prepared. These standards are based on the existing, constantly enriched navigation ontology. These include:

- CML (Coastal Mark-up Language); Oregon State University (USA),
- MIML (Maritime Information Mark-up Language); US Coastguard – Waterways Information Network,
- MarineXML (EU project).

The above projects of maritime information standardization make use of the eXtensible Mark-up Language (XML) for information recording. The extensible mark-up language derived from the World Wide Web Consortium (W3C) as a semi-structural format of data exchange contains both data and their descriptions in a single "package".

The CML language is being built in order to extend metadata in the XML format, according to a Federal Geographic Data Committee (FGDC) standard, for the construction of interactive maps for data display and analysis.

The MIML is a standard of maritime information used by the US Coastguard. The MIML is being developed for the WIN (Waterways Information Network) belonging to the RDC (Coast Guard Research and Development Center), with the objective of using the XML for the description of the format of data transfer mechanism and structure of various data available at the WIN.

MarineXML (pre-standardized marine language based on XML, still being developed) is a project created by the European Commission. The project demonstrates capabilities offered by the XML technology in marine navigation, particularly as a support in marine observation systems. The MarineXML has four basic goals: the construction of a prototype structure of marine information ontology, the creation of operational demonstrations of data exchange structure, the development of the MML specification prototype and the advancement of Marine Mark-up Language standard. In the future, the MarineXML will join US teams developing CML and MIML standards.

Actions taken are aimed at the development of marine information ontology, including navigational information. There is a certain quantity of overlapping ontological information from various sources. It has been found that different independent sources present various parts of taxonomy in the overall domain of maritime information that are duplicated. Therefore, there is a need for the combination of sub-ontologies, that is the construction of an ontology which will contain all the terms and combine discrepancies into a single whole. The combination and mapping of various ontologies are now subject to research. The following ontologies have been considered in the MIML:

1. The S57-IHO standard. S-57 describes a standard used for the exchange of digital hydrographic data between hydrographic institutions and for the distribution of digital data and products among producers, seafarers and other users.
2. The GML standard (Geographical Mark-up Language), which is being developed by the OpenGIS consortium. Its basic function is the presentation of simple shapes (lines, polygons).
3. A standard of communicative (sub)language for the description of information connected with communication itself (information on VHF channels, call signs, telephones, etc.).
4. A standard of (sub)language of services for the description of port facilities, information on repairs to small ships.
5. A standard of weather (sub)language for the description of sea state, wind force and weather forecast.

The development of navigational information ontology starts with its analysis and taxonomy accounting for the kind and scope of information. The works [8, 9, 17] include definitions of the structure of navigational information sets and relations between them.

Apart from information standardization (standardization of contents and form) it is essential for information exchange and processing to standardize the communication: making it automatic – communication based on adopted standards.

4. SUB-ONTOLOGY OF NAVIGATIONAL INFORMATION FOR INTERSHIP COMMUNICATION

Ontology is a description of the structure and hierarchy of notions, symbols and objects of the world or its part. The concept of navigational information ontology is understood as a meta-language describing the structure and form of navigational information and relations between the elements of this information [11, 12]. Ontology has to be expressed in a certain formal language, corresponding to the language of logic (e.g. KIF – Knowledge Interchange Format), to semantic networks (e.g. RDF – Resource Definition Format, connected with XML) or another language [10].

The previously discussed MIML is derived from the XML language. Probably the simplest example of information ontology defined in a language based on the XML is a Document Type Definition (DTD). The ontology written in a DTD is poor as it does not specify links between the elements of knowledge structure.

The following should be taken into account while constructing a navigational information sub-ontology for inter-ship communication:

- recommendations and legal regulations relating to communication between ships (GMDSS, SMCP),
- conditions resulting from sea practice,
- set of information that is (should be) exchanged in the process of communication.

To comply with these guidelines, the following format of a message has been established, consisting of four basic fields: **header** (with such data as transmission time and a unique identifier of a ship-to-ship dialogue), **sender** (sender's details, such as: ship's name, call sign, etc.), **receiver** (details, as above, of one or more receivers, or, among others, geographical area), **body** (message sent from the sender to receiver(s).

The basic problem to be solved, i.e. the construction of ontology, focuses on the last part – the message itself (Fig.1). Tasks formulated by navigators during VHF communications have three basic forms (<Question>, <Answer> and statement <Tell>). These forms of sentences represent an indirect goal that is to be achieved after one single message consisting of one or several sentences is transmitted. Therefore, typically for real verbal communication, after asking a question we expect an answer (or possibly a question, if it changes, e.g. the form of a navigational problem) etc.

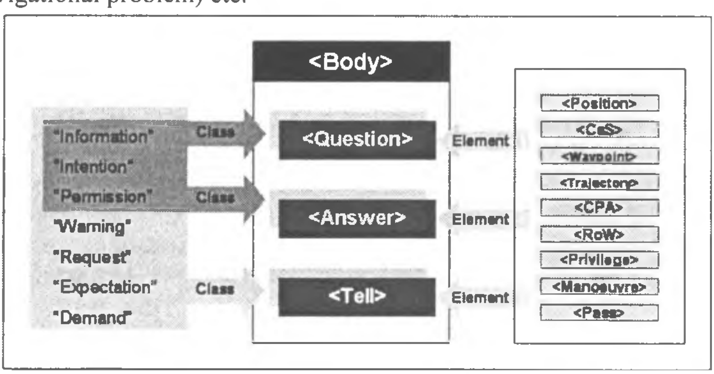

Fig.1. Diagram of a message body

Another element in the ontology being built is an attribute of a single sentence in a transmitted message. The attribute defines what we ask about, what we answer to and the subject our statement is concerned with. Each sentence in a message has one attribute named <Class>, and among its values the following can be distinguished: "Warning", "Information", "Request", "Intention", "Expectation", "Demand" and "Permission". These values are strictly connected with IMO recommendations for communication [5, 6]. They have a key importance during encounter situations and determining the right of way according to the Collision Regulations [16].

It is worth noting that for such forms as <Question> and <Answer> the attribute <Class> can only have the value of: "Information", "Intention" or "Permission". The principles and goals of hereby proposed communication do not predict a question about expectation or an answer to a warning.

After a sentence template is constructed in a specific form for a given class, we have to add the body contents expressing the data we require or warn against etc. These data include the following items:

- <Position> – given as latitude and longitude coordinates, or bearing and range,
- course and speed <CaS> – basic parameters of ship's movement,
- <Waypoint> – position of ship's next turn and new course to be taken,
- <Trajectory> – waypoints describing the trajectory, e.g. of a ship giving way,
- <CPA> – closest point of approach to another ship, and the time to the CPA (TCPA),
- <RoW> – right of way according to the COLREGs,
- <Privilege> – degree of ship's privilige according to the COLREGs,
- <Manoeuvre> – type of manoeuvre and its parameters,
- <Pass> – manner of passing another ship and associated parameters.

Obviously, these elements of sentence contents have always the same meaning, regardless of which context (sentence) they have been included in. The elements have a definite structure and types of data.

5. IMPLEMENTATION IN A SHIP COMMUNICATION AND COOPERATION SYSTEM

The presented proposal of formal communication can be implemented in a ship communication and cooperation system. The system proposed in works [13, 14], based on the multi-agent technology [15], makes up one possible realization of tasks including automatic exchange of information, coordination and negotiations between vessels. Each ship is represented by a group of program agents (Fig.2).

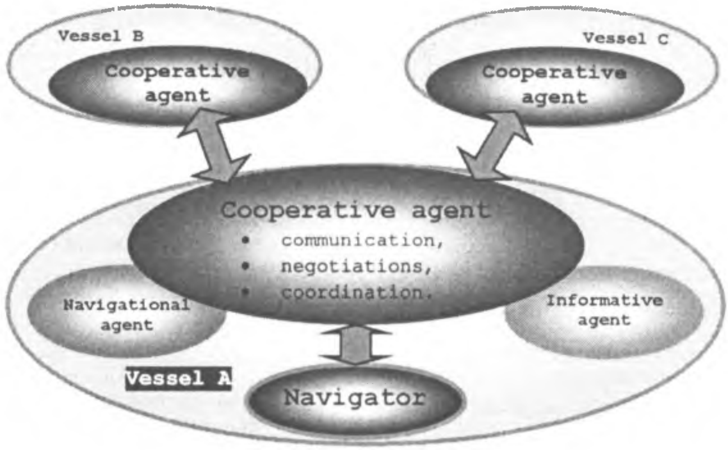

Fig.2. Group of intelligent ship agents

The concept of intelligent program agent is understood as computer programs designed to independently execute tasks ordered by the user in the network environment. The programs feature internal properties (autonomy, capability of learning, mobility, reactivity, initiative/orientation to solve problems, inference) and external properties (ability to communicate, coordinate actions and cooperate).

Tasks of the informative agent are to acquire, select and verify navigational data from the equipment and systems available on board (ARPA, AIS, GPS, ECDIS) and making the obtained information accessible to the other agents.

The navigational agent analyses and assesses a navigational situation. The agent works out decisions, specifies and optimizes manoeuvres.

The cooperative agent executes the following tasks:

- communication (information exchange),
- cooperation (processes of negotiation and actions coordination).

The solutions of a navigational situation worked out by program agents on a given ship have to be agreed on and coordinated with the solutions of agents representing other ships. The coordination of actions is understood as the present supervision of the realization of negotiation results and the initiating of corrective measures when deviations are found.

The situation examined in computer simulation was an encounter of ships in an open sea area covered by the system of ship communication and cooperation. The ships' dynamics was simulated by means of the verified analytical model [2, 4]. The regulations in force [16] for good visibility conditions have been taken into account.

Encounters of ships on various headings were simulated. According to the regulations, in the presented collision situation the ship A is obliged to give way to the ship B. Obeying the regulations and following good sea practice the ship A performs a preventive manoeuvre. Navigating in open seas, the ships, having performed a collision avoiding manoeuvre often return to their original course.

Having analysed a navigational situation and recognizing a collision situation, the ship B sends a message to the ship A informing it has recognized a collision situation, stating that ship A is to give way and asking ship A for the trajectory of avoiding manoeuvre (Fig.3). Ship A is planning the avoiding manoeuvre and the return to its original trajectory. Then it acknowledges the right of way of ship B and provides it with the points of its movement trajectory (Fig.4). The ship A starts the manoeuvre – sails following the determined safe trajectory. The ship B monitors the manoeuvre performed by ship A and communicates if there is any departure.

In order to implement the determined ship movement trajectory the authors used a modified cascade fuzzy controller based on the model presented in [7].


```
<?xml version="1.0" ?>
<!DOCTYPE Message (View Source for full doctype...)>
- <Message>
  <Call Type="Individual" Time="125000UTC" CommunicationID="BA01" />
  <From Name="B" MMSI="2310023" />
  - <To>
    <Receiver Name="A" MMSI="2629987" />
  </To>
  - <Body>
    - <Tell Class="Information">
      - <Position>
          <LatLon Lat="..." Lon="..." Time="124950UTC" />
        </Position>
        <RoW Whose="Mine" Who="You" Action="MustGiveWay" />
      </Tell>
    - <Question Class="Intention">
        <Trajectory />
      </Question>
    </Body>
</Message>
```


Fig.3. Message from ship B


```
<?xml version="1.0" ?>
<!DOCTYPE Message (View Source for full doctype...)>
- <Message>
  <Call Type="Individual" Time="125100UTC" CommunicationID="BA01" />
  <From Name="A" MMSI="2629987" />
  - <To>
    <Receiver Name="B" MMSI="2310023" />
  </To>
  - <Body>
    - <Tell Class="Information">
      - <Position>
          <LatLon Lat="..." Lon="..." Time="125056UTC" />
        </Position>
        <RoW Whose="Yours" Who="I" Action="WillGiveWay" />
      </Tell>
    - <Answer Class="Intention">
      - <Trajectory No="12">
          <Point Time="125500UTC" Lat="..." Lon="..." Speed="14.5kn" />
          <Point Time="125530UTC" Lat="..." Lon="..." Speed="14.3kn" />

          <Point Time="131210UTC" Lat="..." Lon="..." Speed="14.1kn" />
        </Trajectory>
      </Answer>
    </Body>
</Message>
```


Fig.4. Message from ship A

6. SUMMARY

Ship-to-ship communication aiming at avoiding a collision situation, by agreeing on proper manoeuvres to be performed, has not been appropriately regulated, i.e. there are no strictly specified principles and procedures. In spite of this fact, institutions determining the reasons for marine accidents find navigators guilty of improper communication or of failing to communicate at all.

This work presents a proposal of the formalization and automation of the process of communication between ships within a ship communication and cooperation. The proposal concerning automatic communication is in line with present trends in the field (XML, construction of the ontology) and is a supplement to solutions proposed in MIML and MarineXML projects now in progress.

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