Archives of
Transport System Telematics

Volume 10
Issue 1
February 2017

Analysis and generation of messages in an automatic communication system at sea

Z. PIETRZYKOWSKI, P. BANAŚ, P. HATŁAS, P. WOŁEJSZA
MARITIME UNIVERSITY OF SZCZECIN, Faculty of Navigation, Wały Chrobrego 1-2, 70-500 Szczecin, Poland
EMAIL: z.pietrzykowski@am.szczecin.pl

ABSTRACT
The development of unmanned remotely controlled and autonomous vehicles necessitates seeking new and improving existing systems of communications between such objects themselves and control or monitoring centers. This applies to maritime transport and other areas of transport. The article characterizes communication processes between the navigators on ships taking place via VHF in view of their automation. Some of the issues concerning analysis processes of message reception and generation of outgoing messages resulting from automatic reasoning are discussed. We also consider selected operations: message parsing, interpretation of data concerning the context and generation of outgoing message. An example is given of the analysis of the received message and corresponding answer.

KEYWORDS: automatic communication, message interpretation, navigation

1. Introduction

Increasing the scope of the automation of ship control and conduct is one of the actions aimed at reducing human error, a frequent cause of accidents at sea. The subprocesses subject to automation are: data acquisition, collection, processing and sharing. Increasingly, the automation also comprises the generation of solutions to collision situations in navigator's decision support systems. The automation of ship control processes applies to all modes of transport. It is particularly evident in air and land (road and rail) transport. One effect of automation is work on unmanned remotely operated vehicles and autonomous vehicles.

To make correct decisions, the decision maker has to have access to information, in this case navigational situation at sea. The sources of this information are both internal and external systems and devices. Internal systems, such as radar or ECDIS, make the operator independent of external sources, which is crucial for the security of vessels. External sources, complementing the available information, include GNSS, AIS, GMDSS. They can also serve to verify information from internal sources. These are systems and equipment gathering and providing information about vessels located within their coverage area. These systems and equipment for automatic data exchange acquire standardized sets of data in predefined formats (standardised scope and form of information). Solving a solution may require additional information or arrangements. In this approach, navigators on ships (with crew on board) are an additional important source of information. Voice communication provides a channel of communication allowing to obtain additional information, and to make arrangements, if necessary. The automation of verbal communication helps to avoid errors perpetrated by navigators such as mere lack of communication, or wrong communication, e.g. misunderstanding of a message. The same method of communication between vessels can be implemented on unmanned or autonomous vehicles. In this connection, an essential complement to the systems of automatic data exchange can be automatic communication systems based on the principles used in verbal communication.

2. The system of automatic communication at sea

2.1. The purpose and scope

Processes of communication can be considered as exchange of information, perception of a message and interaction, e.g. negotiations [1]. Communication occurs in various areas of human activity, also in navigation processes at sea. Processes of communication at sea include [2]:

- acquisition, processing, transmission and sharing of information by using standard navigational equipment and systems,
- selective acquisition of information for enhancing situational awareness through the determination or specification of description, interpretation, assessment of current and/or projected situation, and intentions of traffic participants,
- negotiations, including co-operation, to ensure safe ship conduct, avoid hazards and prevent or minimize consequences of accidents.

At present, the automation of communication involves mainly the first group of processes, whereas in the other two groups the process of automation is less advanced. This is partly due to difficulties in the automation of verbal communication. The basic premise herein assumed is that automatic communication system will be based on the principles obligatory in or characteristic of voice communications.

The principles of ship-to-ship and ship-to-shore communication are governed by regulations (SOLAS Convention, performance standards for AIS and GMDSS, Admiralty List of Radio Signals, Standard Marine Communication Phrases [3, 4]) as well as good sea practices. The need for automation of verbal communication stems from the fact that those principles and other factors do not eliminate dangerous situation from occurring, resulting from failure to establish communication or erroneous communication: incomprehension of received messages, wrong choice of message or bad interpretation of exchanged information. It has been accepted that for encounter situations, where only one vessel has the said system, its functionalities will be limited to selective information acquisition from other available sources of information.

The development of automatic communication system calls for working out, inter alia:

- the necessary ontology of the field concerned (marine navigation) for the unification and unambiguous interpretation of navigational information,
- ontology of communication, taking account of the principles, forms, standards of communication, including verbal communication,
- methods of generating and interpreting messages,
- user interface,
- methods of interference.

The methods of generation and interpretation of messages are considered.

2.2. Modes of communication

Given the scope of the automation of communication, in particular selective information acquisition and negotiations, and the tasks necessary for (Chapter 2.1) the transformation of man-to-man communication to fully automatic communication between systems on ships and in land-based centres can be done in different modes (Fig. 1):

- man-to-man via a computer system; applies to manned vessels
- man-computer system (in both directions, any range); applies to encounters of vessels, in which only one is equipped with the system under consideration.
- computer system-computer system; applies to all types of vessels, including manned, unmanned, autonomous.

The modes of communication for the proposed system of communication for the sender - recipient relation is shown in Figure 1.

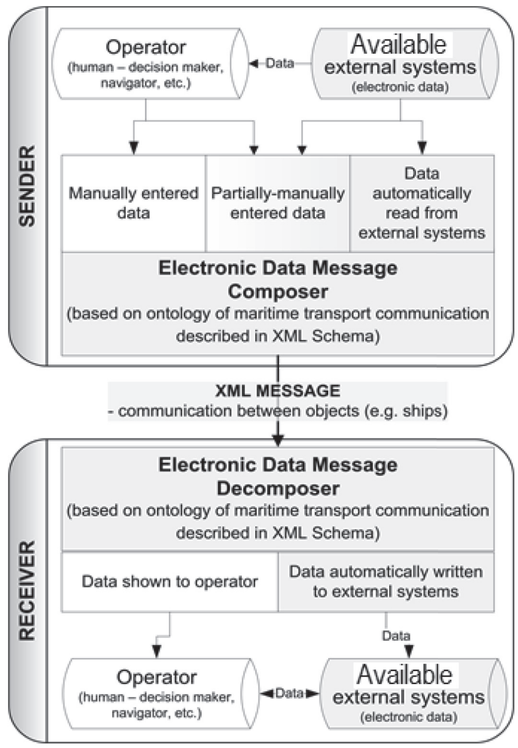

Fig. 1. Modes of communication between two objects (e.g. ships). [5]

3. Processes of communication

3.1. The scope and form of messages

Determining the scope and form of messages, we adopted the division used in the Global Maritime Distress and Safety System (GMDSS). It includes rules and procedures of priority communication: distress (collisions, fire, grounding, man overboard etc.), urgency (technical failure, ice damage etc.) and safety (navigational and meteorological reports and warnings, environmental protection etc.). GMDSS System also enables routine communication. This applies, for example, to situations, when ships report their position in traffic separation schemes or reporting system areas. Routine communication, unlike priority messages, has no specific structure or defined circumstances, in which communication must or should be performed. The attention was also drawn to messages formulated by navigators during VHF communication.

In [6] the authors proposed this message format: a header with a unique identifier, sender, recipient, body of message transmitted to the recipient. We assumed that transmissions consist of either a single message or a sequence of messages.

Three basic forms of communication:<Question>, <Answer> and statement <Tell>) and their attributes, defining what a single message refers to: 'Warning', 'Information', 'Request', 'Intention', 'Expectation', 'Demand' and 'Permission'. The message body is supplemented with items of the message, specifying the message content (Fig. 2).

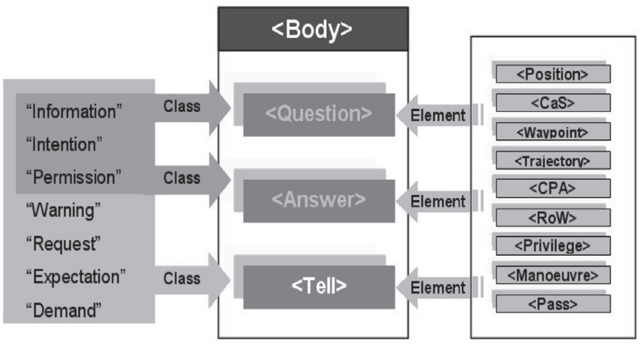

Fig. 2. Structure of message body [6]

It is assumed that these elements are defined in the ontology of the field concerned (marine navigation) for the unification and unambiguous interpretation.

3.2. Ontology in the system of automatic communication at sea

Ontology deals with discovering and describing 'what is"- in reality, in our minds, or observations. It is ontology that allows us to formalize knowledge and describe concepts hierarchically in order to establish the semantic relations within the field [7].

One of the first definitions was introduced by T. Gruber, who characterized ontology as a specification of a conceptualization [8]. For any broad field we can create different ontologies, describing that field in a different way.

The ontology referring to marine navigation may be used to describe communication between participants of the transport process, e.g. ship navigators. The need arises to comprehend a specific fragment of reality, and the said ontology, understood as the formalization of the knowledge of marine navigation, permits to unify the meanings of the concepts used.

The description of vessel traffic and communication between vessels makes use of the ontologies of navigation and communication and an interface. The ontologies were built with the Protégé program, which is used for object modeling, and supports designing of ontologies, data bases and complex formal models (Fig. 3).

The ontology of navigation distinguishes navigational information, manoeuvres, events, wheel and engine orders and objects created on the basis of Standard Marine Communication Phrases [4]. They make up main classes, to which instances, containing appropriate values, are assigned.

Communication ontology takes into account actual information acquisition and sharing processes and negotiations between traffic participants. It defines the message structure, distinguishing a header and message body.

The interface contains functions for interpreting messages, and semantic criteria. One of the functions is function f, responsible for generating messages (1). Function f combines elements of set X with one element from set Y, creating the message body.

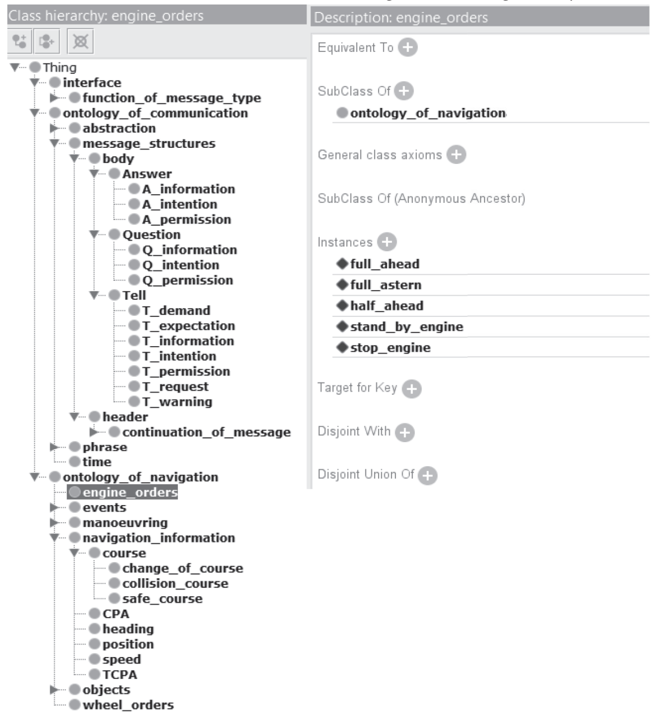

Fig. 3. Fragment of the developed ontology created by using Protégé software [own study]

Function g is responsible for message interpretation, understood as the identification of the meaning of the information sent and of actions that must be undertaken in conjunction with the received message (2). This function assigns to the received message K_i a combination of entities from sets X and Y. The functions f and g are expressed by the formulas:

$$f : X \times Y \rightarrow K \quad (1)$$

$$g : K \rightarrow X \times Y \quad (2)$$

where:

X - a set of navigational concepts (entities contained in the navigation ontology),

$X_k = \{x_{k1}, x_{k2,} ..., x_{kj}\}$ - set of entities in k-th sequence of messages

k - numeral of a message sent ($k \in N$),

Y - a set of types of messages,
K - a set of messages,
K_i - i-th message from set K,
$K_i = \{s_{i1}, s_{i2}, ..., s_{ij}\}$ - individual words in a message, where:
s_j - j-th word in message K_i,
$i, j \in N$

Function g can be described by the following algorithm:

1. For every word si contained in message K, its assignment should be searched for in one of the defined ontologies: navigation or communication,
2. Words assigned to the ontology of navigation are collected in a set X,
3. The words attributed to the ontology of communication are collected in a set Y,
4. If the cardinality of set Y is more than one, the words contained in this set should be examined for contradiction; if they are contradictory, and one of them is not a word requesting for information, the function returns an error indicating a wrongly worded (unintelligible, ambiguous) message, otherwise it returns the pair of sets (X, Y).

The combination of communication and navigation ontologies with an interface (in the oval structure) is shown in Fig. 4)

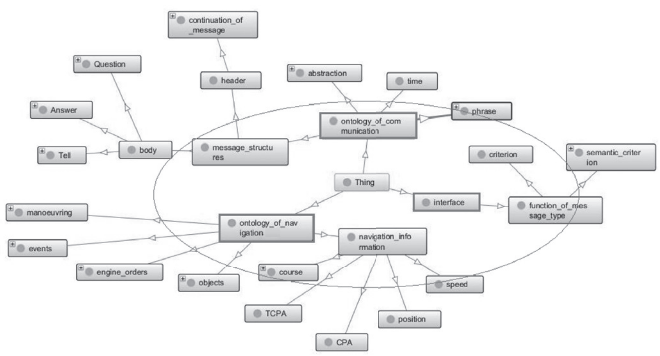

Fig. 4. Fragment of an ontology in the oval structure [own study]

This ontology construction allows its extension to other modes of transport (Fig. 5).

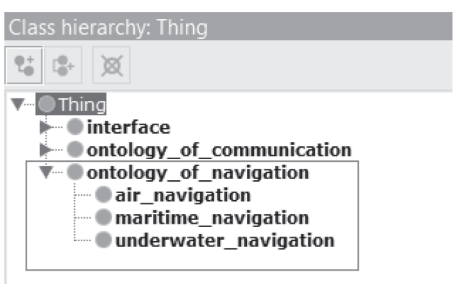

Fig. 5. Fragment of the ontology of navigation [own study]

A graphical display of the process of communication at sea is shown in Figure 6. It encompasses the discussed earlier assumptions, scope, modes and forms of communication in the system of automatic communication at sea and a description the message built on the created ontology.

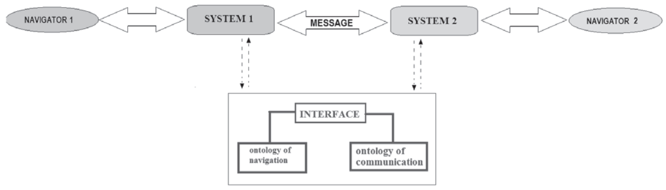

Fig. 6. A diagram of automatic communication [9]

3.3. Representation (record) of a message

In the presented solution, transmitted messages are encoded using the XML language. A single message consists of two basic parts: a header containing control information and the body encoding the message proper. Its components are shown in Figure 7.

<?xml version=”1.0” encoding=”UTF-8”?>	A tag (markup) of an XML file
<ontology xmlns=”http://am.szczecin.pl/zitm” xmlns:xsi=”http://www.w3.org/2001/XMLSchema-instance” xsi:schemaLocation=”http://am.szczecin.pl/zitm ontology.xsd”>	A reference to the XML schema describing the ontology used
<message>	Start of message
<header MessageID=”13AD129E” MessageReapeted=”0” ConfirmationRequired=”true”>	The header defining message parameters: MessageID - unique identifier of the message, MessageRepeated - a tag of second transmission of message, ConfirmationRequired - obligation to acknowledge the message receipt
<sender>	Definition of message sender
<vessel MMSI=”9213911” name=”GDYNIA”/> </sender>	Identification of the sender’s ship
<receiver>	Definition of message recipient
<vessel MMSI=”9056002” name=”FU SHAN HAI”/> </receiver>	Identification of the recipient’s vessel
<sent date=”2003-05-31” time=”12:09:02”/>	Date and time of message transmission

<continuation_ of_message MessageID=”13AD129D”>	tags of relations with other messages creating a series of messages: parameter MessageID - identifier of preceding message;
False	tag value indicates the appearance of subsequent single messages
</continuation_of_ message> </header>	
<body>	The message content consisting of the tags defined in the XML schema defining the ontology used
<tell>	Indication of the fragment of the ontology used
<t_intention>	Type of message
<course>355</ course> </t_intention> </tell> </body> </message> </ontology>	Name and value of the information sent

Fig. 7 Message example in XML form with explanations [own study]

The tags used are defined in the ontology written in the XML-schema, divided into the communication and navigation ontologies.

4. Generation, analysis and interpretation of messages

4.1. Collision at sea – case study

The case concern a collision of two ships [10], where one of the recognized causes was lack of VHF communication between the ships' navigators. The collision between the m/v Fu Shan Hai and the m/v Gdynia occurred on 31st May 2003 north of Bornholm in daylight, with visibility over 10 Nm. The distance from the place of collision to the nearest navigational danger, shallow water, was about 3 Nm. There were also a few fishing vessels in the area, the traffic parameters of which did not constitute immediate threat of collision with any of the vessels.

The only signal transmitted during the collision situation was five short blasts (doubt signal) from the Fu Shan Hai.

At 1205 hrs local time the vessels were in a distance of 2.9 nm from each other and the CPA according to ARPA was 0.4 nm. In the subsequent (06-08) minutes CPA rose to 0.5 nm, although it was actually on the level of 0.3 nm. Only at 1209 hrs, when the CPA started decreasing, did vessel "Gdynia" begin to alter course to starboard. At 1210 hrs vessel "Fu Shan Hai" issued 5 short blasts; she must have not noticed that "Gdynia" started altering course. At 1213 hrs, when "Gdynia" had altered her course by about 150 this fact went unnoticed on vessel "Fu Shan Hai", which is why the master decided to stop engine. He did not notify other vessels about it; the manoeuvre could not be noticed neither visually nor by radar. At 1215 hrs the vessels were at a distance of 1.1 nm from each other. Two minutes before the collision "Gdynia" continued turning to starboard and was on a course of 3220. "Fu Shan Hai" was decreasing her speed. A minute before the collision "Gdynia" continued altering course to starboard (at the moment of collision she was on a course of 3500), and "Fu Shan Hai" continued to reduce her speed. From collision avoidance point of view both manoeuvres were neutralizing each other and eventuated in "Gdynia" striking the port of the other vessel making it sink.

Figure 8 presents both vessels' position from 1200 hrs up to the moment of collision.

Table 1 Reconstruction of collision situation parameters [11]

GDYNIA			FU SHAN HAI (data from ARPA plot on board GDYNIA)					
Time local	Course	Speed	Distance	Bearing	Course	Speed	CPA	TCPA
1205	280°	13.5 kts.	2.9 n.m.	356°	237°	13.4 kts.	0.4 n.m.	
1206	280°	13.5	2.6	357°	236°	13.3	0.5	15.4 min
1207	280°	13.5	2.5	357°	236°	13.4	0.5	14.8
1208	279°	13.6	2.3	358°	236°	13.5	0.5	13.9
1209	279°	13.6	2.2	358°	238°	13.6	0.4	13.3
1210	280°	13.7	2.0	359°	237°	13.9	0.4	12.4
1211	282°	13.7	1.9	002°	236°	13.3	0.4	10.8
1212	295°	13.6	1.7	003°	230°	9.9	0.7	7.2
1213	295°	13.9	1.5	006°	234°	12.0	0.5	6.3
1214	301°	13.6	1.3	008°	236°	12.4	0.4	5.5
1215	305°	13.6	1.1	010°	241°	11.3	0.3	4.5
1216	313°	13.6	0.8	013°	237°	11.1	0.2	3.0
1216.5	322°	13.6	0.6	016°	241°	9.3	0.2	2.2
1217	326°	13.6	0.5	018°	241°	8.3	0.1	1.8
1217.5	335°	13.6	0.4	021°	238°	6.6	0.1	1.3
1218	350°	13.6	0.3	027°	231°	5.1	0.1	0.7
1218.5	Collision							

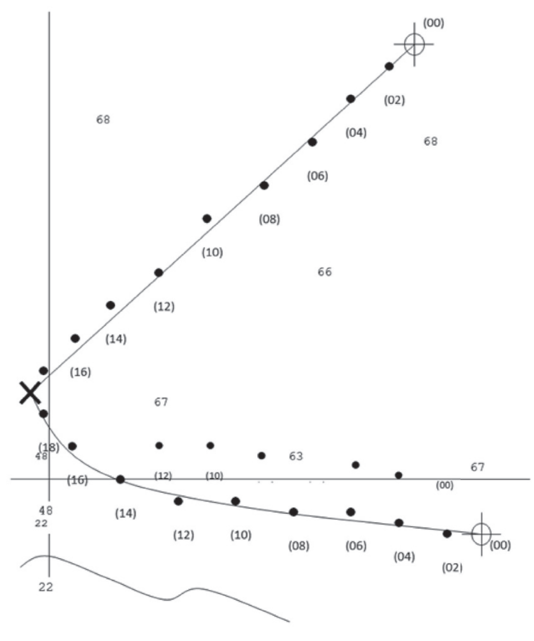

Fig 8. Reconstruction of the vessels' location based on DMA data [10]

The give way vessel did not undertaking proper measures according to the situation (non-compliance with rules 8, 15, and 16 of COLREG). This may have been due to erroneous estimation of the situation, based mainly on ARPA information (breaking rules 5 and 7), which eventuated in undue nervousness of the other party, resulting in miss-judged decisions (action non-complying with rule 17) and leading to collision.

Massages, which enable to avoid collision:

Gdynia:

At 1209 "I'm altering course to starboard. My final course is……" – or one short blast on siren/whistle

Fu Shan Hai:

At 1213 "I stopped my engine" – or three short blasts on siren/whistle

Fu Shan Hai did not perform a proper lookout and radar observation, this is why she did not noticed that Gdynia was altering course to starboard.

In short, if ships had notified each other of their intentions, they would not have carried out ineffective manoeuvres that neutralized each other.

4.2. Generating a message

In the case described above the two ships collided (with each other). One of the identified causes was a lack of communication between the ships' navigators. We have examined the possibility of preventing that collision by using a system of automatic communication at sea. We have formulated messages that, if exchanged, could lead to collision avoidance.

Let us skip the phase of interference during message creation, and present the processes of message generation and interpretation in the system.

Here is how the collision could have been avoided:

Gdynia: 'I am altering course to starboard. The final course is ……'

Fu Shan Hai: 'I stopped my engine'

Figures 9 and 10 illustrate those messages written in the ontology (oval structure).

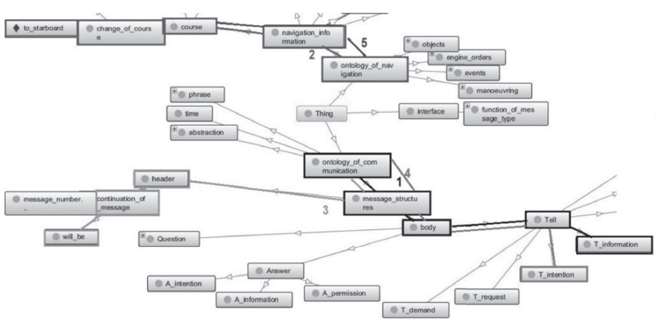

Fig. 9. Message from the ship Gdynia in an ontological record [own study]

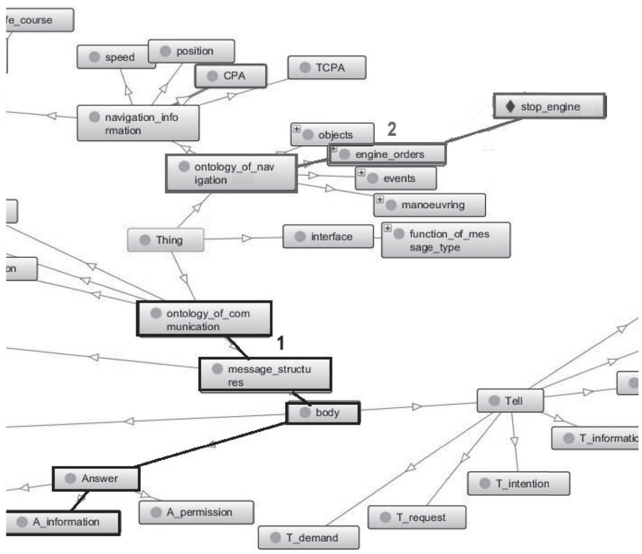

Fig. 10. Message from the ship Fu Shan Hai in the ontological record [own study]

Listed below are the messages generated on the basis of the ontology and formula (1).

The ship Gdynia

<u>Message:</u>

$f(X_1, Y_1) = K_1$

$X_1 = \{x_{11}, x_{12}, x_{13}\}$

$X_1 = \{(course),\ (change), (to\ starboard)\}$,

where : $x_{11} = course \quad x_{12} = change \quad x_{13} = to\_starboard$

$Y_1 = \{T\_information\}$

$f(X_2, Y_2) = K_2$

$X_2 = \{x_{21}\}$

$X_2 = \{(course)\}$, where : $x_{21} = course$

$Y_2 = \{T\_intention\}$

The ship „Fu Shan Hai"

<u>Message:</u>

$f(X_1, Y_1) = K_1$

$X_1 = \{(engine\_orders), (stop\_engine)\}$,

where : $x_{11} = engine\_orders \quad x_{12} = stop\_engine$

$Y_1 = \{A\_information\}$

As mentioned in Chapter 2.2 messages may be generated in different modes. It has been adopted that the process of message generation is carried out in the manual mode.

4.3. The analysis and interpretation of the message

If we use the previously introduced message format using XML language, the interpretation of a message consists in the parsing of received messages in accordance with the indicated types of messages. Since the defined message types clearly indicate a context, further interpretation of the message content is unambiguous: depending on the indicated type of message, it is interpreted as sending information on the present situation (information) or its probable change (intention), which requires updating of the knowledge base (data base) on navigational situation. When another type of message is identified (permission, question, request), the message is interpreted as the need of performing operations using indicated navigational data, e.g. sending indicated information or performing a manoeuvre.

An interesting issue in this context is the interpretation of messages transmitted in the form of a simple text, which should be analyzed in terms of syntax and semantics, and not in the coded form using XML.

Interpreted messages, displayed in the program window, have the form as shown in Figure 11.

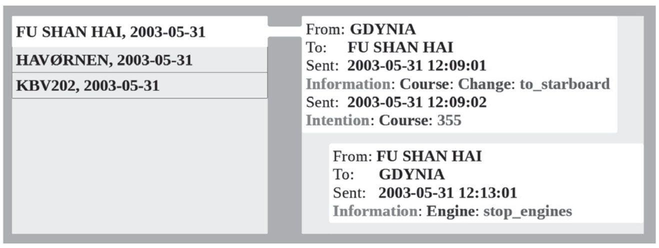

Fig. 11. Interpreted messages in GUI [own study]

5. Conclusion

The automation of communication processes, including verbal communication between navigators on board ships, can be one of the ways to reduce the number of collisions at sea.

The authors have presented the assumptions, modes and forms of automatic communication at sea and some problems of outgoing messages generation, resulting from the automatic inference, analysis and interpretation of incoming messages. One specific case of ships' collision is given, where the navigators failed to establish contact on VHF radio. One of the ways to prevent that collision could have been sending messages about actions taken by both ships. The authors also describe the process of generation and interpretation of messages coming in the automatic system of communication specifically for the collision case considered.

The automation of communication processes, including verbal communication, is crucial for ships with crews as well as unmanned and autonomous vessels. The same observation applies to other types of transport.

Bibliography

[1] PIETRZYKOWSKI Z., et al.: Inference processes in an automatic communication system in marine navigation, Scientific Works Warsaw University of Technology, no 95, Transport, 2013, pp. 421 – 432 (in Polish).
[2] WÓJCIK A., HATŁAS P., PIETRZYKOWSKI Z.: Modeling Communication Processes In Maritime Transport Using Computing With Words, Archives of Transport System Telematics, Vol. 9, Issue 4, 2016, pp. 47-51.
[3] International Maritime Organization (IMO), Resolution A.918(22) adopted 29.11.2001, IMO Asembly 22-nd Session 25.01.2002.
[4] International Maritime Organization (IMO): Standard Marine Communication Phrases (English-Polish edition), Maritime University of Szczecin, Szczecin, 2005.
[5] PIETRZYKOWSKI Z., et al.: Automation of Message Interchange Process in Maritime Transport. TransNav, The International Journal on Marine Navigation and Safety of Sea Transportation, Vol. 5, No. 2, 2011, pp. 175-181.
[6] PIETRZYKOWSKI Z., et al.: Exchange and Interpretation of Messages in Ships Communication and Cooperation System. In: Advanced in Transport Systems Telematics, Ed. J. Mikulski, Publisher Jacek Skalmierski Computer Studio, Katowice 2006, pp. 313-320.
[7] PIETRZYKOWSKI Z., et al.: Subontology for communication in automation of information exchange and negotiations processes at sea, Logistyka 6/2014; pp. 8654-8665 (in Polish)
[8] GRUBER T.R.: Toward Principles for the Design of Ontologies Used for Knowledge Sharing, Stanford Knowledge Systems Laboratory, 1993.
[9] PIETRZYKOWSKI Z., et al.: Subontology of communication in the automation of negotiating processes in maritime navigation, Scientific Journals Maritime University of Szczecin 2016, 46(118), pp. 209-216.
[10] WOŁEJSZA P., BANACHOWICZ A.: Advances in marine navigation and safety of sea transportation, pt. The analysis of possibilities how the collision between m/v Gdynia and m/v Fu Shan Hai could have been avoided, Gdynia 2007
[11] Danish Maritime Administration, Casualty investigation reports. www.dma.dk.