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Subontology of communication in the automation of negotiating processes in maritime navigation

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Abstract
The lack of proper communication between navigators is one of the many causes of dangerous situations in maritime transport. Automation of communication processes, in particular negotiation processes, can help either avoid such situations or, when they do occur, deal with them more promptly and effectively. We have characterized inference processes in maritime communication and the communication subontology used to describe these processes. The negotiating processes involving two or more parties are considered. An example is given of an encounter by three ships that requires communication (including negotiations) between the three navigators. We also present how the described communication processes can be automated using the developed subontology of communication.

Introduction

Access to information is the basis for making right decisions. Such information should be up-to-date, reliable, and relevant. Navigational systems and equipment available on board are the primary sources of information, besides observation of the environment carried out by the navigator. A large quantity of information, compounded by its diverse types and scopes, results in the need for information processing, integration, and selection. However, when a navigational situation changes dramatically so that the navigators need access to additional information or need to agree on joint actions, they may require the exchange of information by communicating verbally.

The replacement of verbal communication by automatic communication based on the principles characteristic of verbal exchanges can significantly streamline the decision-making process. This is especially true of complex and dangerous (e.g. collision) situations. A special case is a close-quarters situation which in order to avoid a collision or reduce its consequences, it is imperative that the navigators concerned co-operate (last minute manoeuvre). Additional information obtained in the process of automatic communication, including negotiations (such as co-operation), may be later directly utilized by the same navigators or, in the future, by navigational decision support systems. Today, navigational decision support systems ships are carried by more than ten ships, and are being developed and expected to be commonly implemented on ships of the global fleet.

Communication processes

Situations requiring decision-making in marine navigation may require communication to be established between the navigators for two reasons: to exchange information and to negotiate a common standpoint via cooperation or competition.

Communication is the transfer of information from a sender to a receiver and is implemented in several stages. First, the sender encodes information by means of conventional symbolic messages, such as sounds, letters, or gestures. In the second stage, a signal containing information is prepared and transmitted to the receiver either verbally or non-verbally. The next step is the receipt of a message by the receiver and the reproduction of the content of the message (decoding). Communication can be one-way (when the sender does not expect feedback from the receiver) or two-way (when feedback is expected as confirmation of the receipt or as an answer to a question asked).

Navigators are strongly recommended to use Standard Marine Communication Phrases developed by the International Maritime Organization. The excess of information, problems with concentration, and the incorrect interpretation of information received carry a risk of making wrong decisions.

Many decision-making situations require negotiations aimed at finding a solution in cases of divergent interests and different criteria used. In the processes of negotiation, the parties use different techniques and methods for finding a compromise or persuading the other party to change their decision. From this perspective, the automation of communication processes relates to successful acquisition, analysis, and interpretation of information and the execution of negotiation processes.

The process of automatic communication is shown in Figure 1 (Wójcik, Banaś & Pietrzykowski, 2014). The message formulated in natural language is interpreted and recorded by means of the ontology of navigational information, part of which is communication subontology. The resulting formal record of the message is the basis for inference (communication inference), which results in conclusions.

On the basis of the conclusion(s), an answer is formulated, then sent back. The answer may be further processed, to develop an answer in natural language, or used directly by shipboard navigational systems.

The ontology of navigational information

Ontology is created to provide the hierarchy and order in a given data set. It is defined as *inter alia*, as conceptualisation (Gruber, 2008). In Gruber (Gruber, 1993), the author lays down five criteria for the evaluation of ontology systems: coherence, extendibility, minimal encoding bias, minimal ontological commitment, and the most important – clarity. The term clarity suggests that ontology should communicate the intended meaning of the data concepts effectively. In attempting to create an ontology of navigational information, we have to design a common vocabulary − basic terminology. The Malyankar paper (Malyankar, 1999) has described issues arising in the creation and formalization of a marine navigation ontology, research issues in this domain, the sources of ontological knowledge and means of extracting this ontological knowledge, and problems encountered to date.

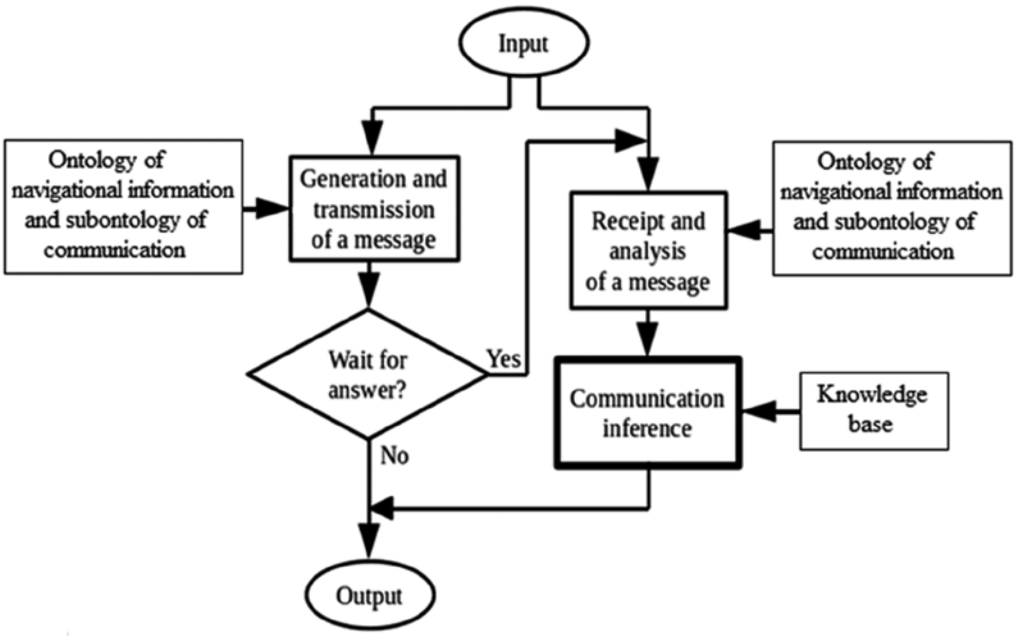

Figure 1. The process of automatic communication (Wójcik, Banaś, & Pietrzykowski, 2014)

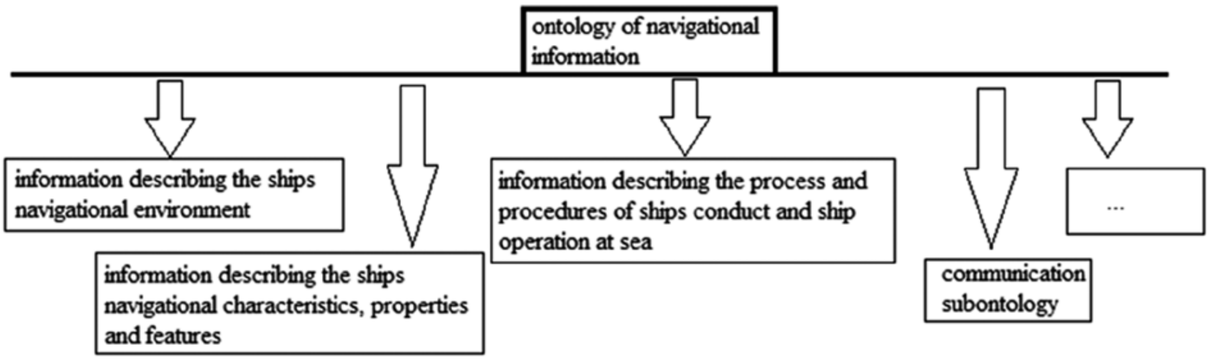

Figure 2. Ontology of navigational information (fragment)

In Pietrzykowski et al. (Pietrzykowski et al., 2014), the authors presented selected issues of the ontology of information, in particular the ontology of navigational information and its use for communication between navigators steering their ships. The authors suggested extending the ontology of communication to elements of negotiations (cooperation, competition). For some decision-making situations, particularly encounters of two ships, communication processes between the navigators are presented.

The following three main types of navigational information proposed in Pietrzykowski et al. (Pietrzykowski et al., 2011) were adopted as the starting point in defining the ontology of navigational information:

- information describing the ships navigational environment (operational, legal, geographic information);
- information describing the ships navigational characteristics (ship sea-keeping ability, dimensions, stability, ship maneuvering characteristics, navigational equipment and information systems);
- information describing the process and procedures of ship conduct and operations at sea (ship's navigation, standards and procedures, ship's measurement data and observations).

The above ontology has been extended and supplemented with the subontology of communication (Figure 2).

Subontology of communication

The Global Maritime Distress and Safety System defines rules and procedures for communications at sea. However, additional information or amendment of the decision made is often required by way of communication between navigators on board ships and/or shore-based personnel. This involves supplementary information or data acquisition through dialogue. In the automation of both selective acquisition of information and negotiation processes, the contents of dialogues have to be analyzed and interpreted. In order to do these two things successfully, humans need to know the methods of inference and be able to extend the subontology of communication. Intelligent communication will rely on automating both information interpretation and negotiation process. The development of IT and ICT provides such opportunities, nevertheless the communication subontology has yet to be designed.

There is a need to understand a specific aspect of reality that is to be implemented. Different scenarios require different communication models, including negotiations (cooperation and competition). The communication subontology is presented below, in Table 2 and schematically in Figure 4.

The novel element of the communication subontology that is in the process of creation is the message type function.

Communication (as a message) is understood as a piece of information to be conveyed, while a message consists of one or more instances of navigational terms, including the type of message.

The above refers to partial or complete automation of the communication process: from system to system or navigator to system, where communication recognition is necessary.

The function of message type allows combining instances of terms (attributes), and determines whether the communication is a question, request, intention etc. On this basis, the system identifies the type of communication.

$$f : X \rightarrow Y \tag{1}$$

where: X is a set of instances of navigational terms (attributes) (Kopacz, Morgaś & Urbański, 2004):

$$X = \{n_1(\mathrm{CPA}), n_2(\mathrm{CPA}), ..., n_1(\mathrm{K}), n_2(\mathrm{K}), ...\} \tag{2}$$

where: $n(x)$ – instance of a navigational term x.

Set Y is a type of message $Y = \{\mathrm{Q, A, I, Re}, ...\}$.

Function *f* permits to automatically connect a series of instances of a navigational concept to the type of communication.

Further studies will aim at developing the function's principles of operation and verifying its suitability for the automation of negotiation processes in marine navigation. Computing with Words is one methodology that can be used for constructing this function.

For example, a sample of information ontology (Table 1) and distinct types of messages (Table 2) can be schematically depicted by a graph (Figure 3).

A diagram illustrating the assignment of navigational information to the type of message is presented in Figure 4.

Table 1. Ontology of information (scrap) (Kopacz, Morgaś & Urbański, 2004)

Term	Notation
Types of navigational information	
CPA – closest point of approach	CPA
TCPA – time to closest point of approach	TCPA
Possible collision	K
Ship's heading	SH
Ship's speed	SV
Direction	WAY
Port, to port, port side	L
Starboard, to starboard, starboard side	R
Bow, forward, ahead, ahead of	F
Stern, aft, astern, astern of	A
Time	TM
Types of manoeuvres	
Passing	S_P
Overtaking	O
Course alteration	CA
Crossing course	Cr_C
Speed reduction	S_Vd
Speed increase	S_Vi
Ship is (We are) standing on (maintaining course and speed)	S_U

Table 2. Subontology of communication – types of messages

Type of message	Notation
Answer	ANS
Demand	De
Intention	I
Question	Q
Request	Re
Warning	W

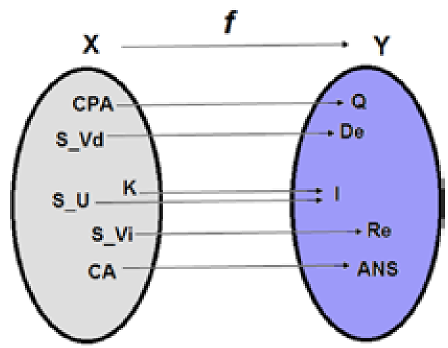

Figure 3. Graph representing the construction of function *f*

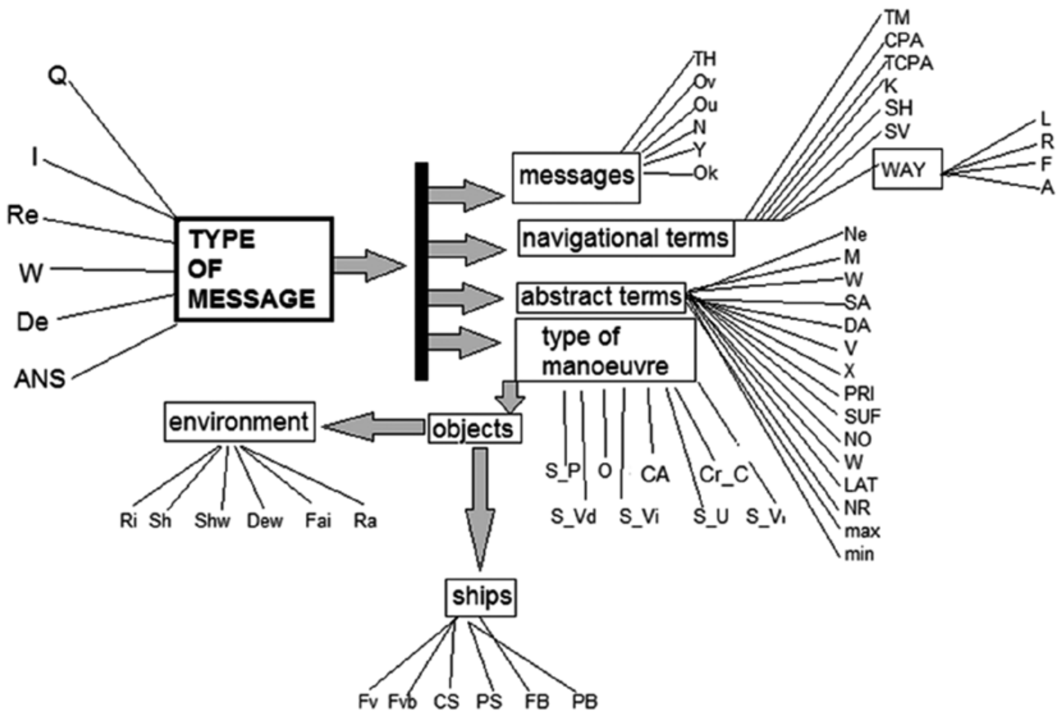

Figure 4. A diagram illustrating the assignment of navigational information to the type of message (subontology of communication)

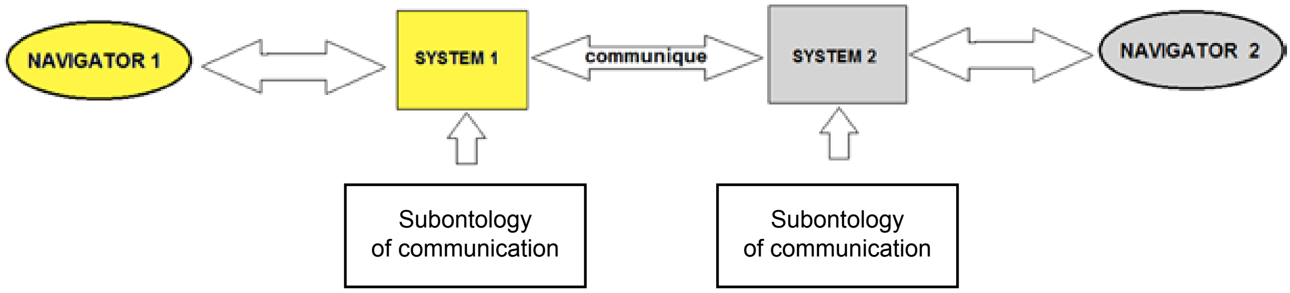

Figure 5. The negotiation process of automatic communication with the navigator using the subontology of communication

The process of automatic communication between navigators (shipborne systems) is shown in Figure 5.

Inference

In the automatic communication system being developed for maritime transport, decisions result from inference processes. These processes include effective acquisition, analysis, and interpretation of information, including negotiations.

Inference processes, taking place in the communication between navigators steering their respective ships, can be divided into three stages (Wójcik, Banaś & Pietrzykowski, 2014). The first is preliminary inference. This stage allows the navigator to assess whether the encounter situation carries a risk of collision. The next stage, inference proper, consists in determining manoeuvres to be performed while complying with the rules of the road. The final inference, which takes place directly with communication, is based on **messages** received from the other ship. This inference allows finding solutions and generating a feedback (Figure 6). In the communication block, where the inference applies to messages received and to creating feedback for the other ship, inferences will be based on the following:

1. A knowledge base for recognizing navigational situations and generating solutions consistent with the COLREGs.

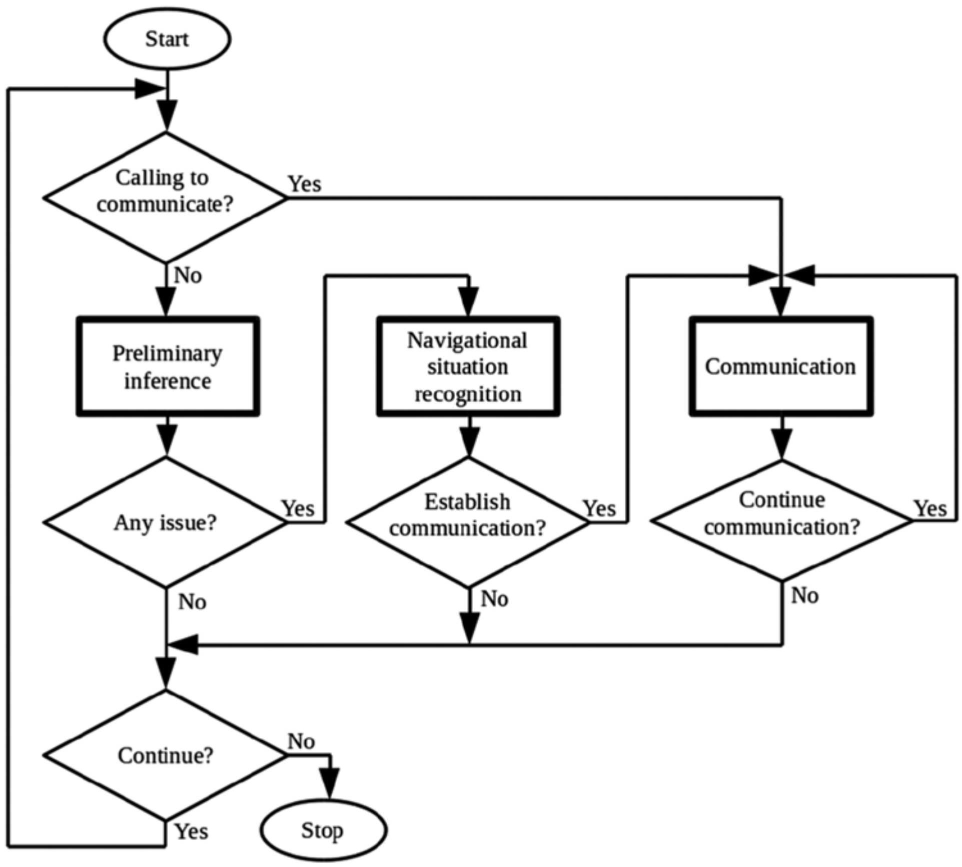

Figure 6. Inference processes in an automatic maritime communication system (Wójcik, Banaś & Pietrzykowski, 2014)

2. A knowledge base for communication, with a particular focus on the processes of negotiations taking place between navigators.

The inferences drawn are based on simple principles of two-valued logic and on a knowledge base containing the rules of inference. When interpreting the received message, we recognize that there is additional information which is inaccurate due to vague terms used, such as *far* or *safely*. In such case, inferences will be made using the protoform theory and fuzzy logic (Computing with Words).

At sea, when ships seek a convenient solution to an encounter situation, the need may arise to include another participant in the negotiations, for other verbal exchanges between three or more parties, or to introduce additional restrictions to the solution being sought.

Further in this article, we will discuss example negotiations between two and three parties, aimed at developing a solution (compromise) beneficial for all parties involved in the encounter.

Case study

One possible situation regarding the encounter of three vessels (A, B, C) is shown in Figure 7 below. Shallow water is an additional difficulty in this situation. Lack of communication between navigators is recommended; they should follow the rules, but in practice, the navigators may establish contact in case of doubt.

In the example, vessel C should keep its course and speed. Vessel A should give way to vessel C, and pass astern of C. Vessel C should keep its course and speed in relation to B. Vessel B should give way to not obstruct vessel A, and pass astern of C.

The situation shown in Figure 7 is often encountered in practice. It is extremely stressful for the navigator on board vessel A, who at the same time has to keep clear of vessel C and maintain proper movement parameters relative to vessel B. The best solution to this situation is for vessels A and B to establish contact, coordinate, and both alter course to starboard, passing astern of vessel C.

The situation becomes complicated when vessel B cannot alter its course to starboard because of shallow water (Figure 7). It is also complicated if vessels A and B are moving in a Traffic Separation Scheme. In such a situations, the best manoeuvre is to reduce speed. If for operational reasons the manoeuvre cannot be performed in time, the execution of a turning circle to port by vessel A will solve the situation. For the latter manoeuvre to be considered, the

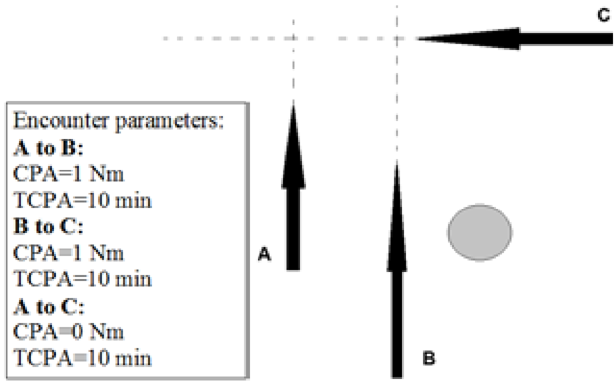

Figure 7. An example encounter situation of three ships: A, B, C

water area to the port side of vessel A must be free from dangers. In a Traffic Separation Scheme, such a manoeuvre is not recommended due to the crossing of the traffic lanes and entry into the separation zone, along with associated violations.

When vessel A's speed reduction or turning circle to port is not possible, and vessel B cannot alter course to starboard, the solution may be the method of 'small steps'. This method involves course alteration by a few degrees by both A and C (Figure 7). Even though Vessel A will then approach vessel B, this manoeuvre will not cause a close-quarters situation. To increase the passing distance, vessel C will alter course to starboard, even if it should maintain its course. From the COLREGs viewpoint, small course alterations, hardly noticeable, are not recommended. However, if such alteration is agreed upon in advance, the two ships will effectively solve a collision situation and the vessels will safely pass each other at a pre-determined CPA.

An example scenario of communication

C to A: Vessel A, this is Vessel C, we are on collision course, please alter your course a few degrees to starboard. Over.

A to C: Vessel C this is Vessel A, I cannot alter my course to starboard, and Vessel B is overtaking me on my starboard side. Please increase your speed. Over.

C to A: ...., I am proceeding at my full speed, I cannot increase my speed. Over.

A to B: ...., Please alter your course to starboard, I am on collision course with Vessel C, I must alter course to starboard. Over.

B to A: ...., There is a shallow water on my starboard side. I am constrained by draft. I will keep my course and speed. Over.

Ontology	Inference
from C to A: S(K) Re(CA: R) S(Ov) from A to C: NO(CA:R), S(Vessel B: O:R) Re(S_Vi) S(Ov) from C to A: S(SVfull) NO(S_Vi) S(Ov)	<u>Premises:</u> * $CPA(A,C) < CPA_L$ 1. A is to give way to vessel C 2. A is to pass astern of vessel C 3. A is to maintain course and speed relative to B 4. *Proposition for vessel A to alter course a few degrees to starboard* <u>Conclusion:</u> 5. A cannot satisfy the request (3 and 4 are contradictory) 6. Proposition for vessel C to increase speed <u>Vessel A receives information from vessel C:</u> 7. C is moving at maximum speed and cannot increase speed
from A to B: Re(CA: R) S(Vessel C: K) NEE(CA: R) S(Ov) from B to A: S(Sh: R) S(Ra) S(S_U: SH,SV) S(Ov)	<u>Premises:</u> * $CPA(A,C) < CPA_L$ 1. A is to give way to vessel C 2. A is to pass astern of vessel C 7. C is moving at maximum speed and cannot increase speed <u>Conclusion:</u> 8. Request to B to alter course to starboard, because A is on collision course with C and must alter course <u>Premises:</u> 9. B has an obstruction on starboard side and will maintain course and speed <u>Conclusion:</u> 10. Request to C to alter course.
from A to C: NO(CA: R) Re(CA) S(Ov) from C to A: AG(CA: R) INS(CA: R) Ov from A to C: S(Ok) S(CA: 5^o R) S(PPP) S(Ov) from C to A: S(TH) S(Ou)	<u>Premises:</u> 11. C will alter course a few degrees to starboard 12. C requests A to alter course a few degrees to starboard as well to increase CPA <u>Conclusion:</u> A will alter course 5 degrees to starboard and in five or six minutes will return to our previous course.

A to C: ...., I cannot alter my course to starboard; please alter <u>your</u> course. Over.
C to A: ...., I will alter my course a few degrees to starboard. Try to do the same to increase CPA. Over.
A to C: ...., OK, I will alter course 5 degrees to starboard for a few minutes and then will return to my previous course. Over.
C to A: ...., Thank you, have a nice watch. Out.

Conclusions

One way to reduce the human error and the consequences of these errors is to automate the processes controlled or supervised by people. This also applies to communication processes at sea. The automation of information acquisition and exchange, meeting accepted standards, is progressing quickly. The research in the field of verbal communication automation is expanding to include verbal exchange of information and negotiations.

Automatic acquisition of information previously available through verbal communication between navigators can contribute to prompter and more effective prevention of dangerous situations. If they do occur, these situations can be dealt with earlier and more effectively, thus enhancing the safety of maritime transport. This requires the development or extension of:

- ontology of navigational information;

- subontology of communication;
- formal description of inference processes.

The basic aim of navigation is the vessel's efficient and safe passage on an assumed trajectory. Taking this as the vantage point, a navigational decision support system has to implement two basic tasks: conduct the vessel on an assumed trajectory and avoid collisions. First task can be executed by any vessel equipped with autopilot connected to ECDIS or GPS. Challenge arises, when other vessels obstruct our smooth sailing along determined route. To ensure fully Autonomous Navigation, vessels have to be equipped with automatic communication systems.

The lack of proper communication between navigators is one of the causes of dangerous situations in maritime transport. Automation of communication processes, in particular negotiation processes, can help either avoid dangerous situations or, when they do occur, deal with them more promptly and effectively. Inference processes in maritime communication and the communication subontology used to describe these processes were characterized above. The negotiating processes involving two or more parties were considered. An example of the encounter of three ships was given that required communication including negotiations between the three navigators. We also presented how the described communication processes can be automated using the developed subontology of communication.

The authors present examples of how communication processes may take place, including processes of negotiation, in an encounter situation involving two or more ships.

Further research will concentrate on:

- developing the ontology of navigational information and communication subontology;
- construction of a knowledge base on the processes of communication, including negotiation processes;
- implementation of the continually developed concept of automation of communication in shipping.

References

1. Gruber, T. (2008) Ontology. Entry in the *Encyclopedia of Database Systems*. Ling Liu and M. Tamer Özsu (Eds.), Springer-Verlag.
2. Gruber, T.R. (1993) *Toward Principles for the Design of Ontologies Used for Knowledge Sharing*. Stanford Knowledge Systems Laboratory.
3. Kopacz, Z., Morgaś, W. & Urbański, J. (2004) Information of maritime navigation: Its kinds, components and use. *European Journal of Navigation* 2, 3. pp. 53–60.
4. Malyankar, R. (1999) Creating a Navigation Ontology. In *Workshop on Ontology Management*. Menlo Park, CA. AAAI Pres.
5. Pietrzykowski, Z., Banaś, Z., Wołejsza, P. & Hatłas P. (2014) Subontologia komunikacji w automatyzacji procesów wymiany informacji i negocjacji na morzu. *Logistyka* 6. pp. 8654–8665.
6. Pietrzykowski, Z., Hołowiński, G., Magaj, J. & Chomski, J. (2011) Automation of Message Interchange Process in Maritime Transport. *TransNav* 5, 2. pp. 175–181.
7. Wójcik, A., Banaś, P. & Pietrzykowski, Z. (2014) Schema of inference processes in a preliminary identification of navigational situation in maritime transport. Springer, Telematics – Support for Transport, *Communications in Computer and Information Science* 471. pp. 130–136.