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Analysis of selected methods for building an ontology for a system of automatic communication at sea

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Abstract
Automatic communication can help reduce errors in communication between navigators, and, consequently, increase the level of navigation safety. This article reviews some methods for the development of an ontology and looks into processes for communication at sea. Three basic elements of ontology can be distinguished: navigational information, communication and interface. The possibility of applying these methods for the construction of ontology was analyzed for a system of automatic communication at sea.

Introduction

One of the main tasks in navigation is to ensure its safety by avoiding dangers throughout an entire voyage. One of the causes of dangerous situations in maritime transport is the lack of proper communication between navigators. The most common cause of navigational accidents is human error. The 80/20 rule (Harrald et al., 1998) states that 80% of accidents are due to human error, and 20% are technical incidents. Automation of communication processes, particularly negotiation, may contribute to the prevention of navigationally dangerous situations, or if they occur, to more prompt and effective solutions. IT systems are increasingly used to support processes that characterize maritime transport. In addition, the emergence of new technologies in the IT services market forces changes in IT solutions designed to support management. It is necessary to adjust the best possible IT solutions to current information needs (Gładysz, 2015) and to implement automation in two shipboard areas: the acquisition, selection, processing and presentation of information, and communication processes. So far, these tasks have been mainly by navigators conducting their ships and land-based center personnel (Pietrzykowski et al., 2014). The automation of these processes requires the development of a relevant communication ontology.

Methods of constructing an ontology

Ontology is a theory that may be applied to any area, in which concepts are described in a hierarchical manner to determine the semantic relations in a given domain. One of its characteristics is a logical theory that introduces limits to logical models. According to one of its definitions, ontology can be viewed as conceptualization (Gruber, 2008). Ontology should effectively convey the intended meaning of its concepts. There are several basic approaches to ontology (Basser, 2004):

- Inductive approach − using the generalization of a particular case. Although it is characterized by relatively low costs, the resultant ontology may not be applicable to other cases;
- Deductive approach − using general, universally accepted rules and principles derived from the

analyzed field. It gives rise to the considerably large, work-intensive ontology;
- Inspirational approach − characterized by individual approach to the modelled field. The created ontology is not necessarily universally accepted, but revolutionary in the way of understanding the field;
- Synthetic approach − uses the synthesis of several ontologies, each one describing a part of the modelled field;
- Co-operation-based approach − ontology is created in the mode of group work, based on the experiences of designers and future users.

The analysis of ontology construction methods presented by Sobczak (Sobczak, 2004) indicates that within a few years highly diversified versions were created. The user wishing to implement an IT system must adapt it to his requirements. In order to streamline this process, one can use the methods already available for building an ontology.

There are various attempts to organize ontology construction methods and work out a methodology associated with the formation of ontology. Although the so-called 'from scratch' approach is frequently proposed, it is usually suggested to use existing ontologies. Attempts to partially automate the process of acquiring knowledge for the ontology are also often made. The literature on the subject proposes many solutions, some of which are presented below.

Uschold and King Method

M. Uschold and M. King, later joined by M. Grüninger (Uschold & Grüninger, 1996) presented the guidelines for the construction of an enterprise knowledge-oriented ontology. The procedure to build an ontology can be described through three steps:
1. Capture – identification of the key concepts, generalization and specialization in order to derive the remaining hierarchy of concepts.
2. Coding – explicit representation of the conceptualization captured in the previous stage in some formal language.
3. Integrating existing ontologies – the issue of reuse of existing ontologies.

CYC method

The method was developed by Microelectronics and Computer Technology Corporation.

The key features of this method of building an ontology are:
- Common-sense knowledge as a source of information;
- Manual coding of this knowledge;
- Simplified processes of knowledge feeding and updating.

Grüninger and Fox method

The method was created using the experience and M.Grüninger and M. Fox (Grüninger & Fox, 1995) under the TOVE project. Providing the Design and Engineering Enterprise environment, it allows users to build a wide range of projects in the IT industry. In the process of building an ontology it is important to:
- Create motivational scenarios that will permit the description of the set of requirements for ontology verification;
- Develop informal competency questions, on the basis of which the ontology completeness can be verified during the final construction stage.

KACTUS method

The method was developed by Amay Bernarc, who aimed at examining the use of knowledge of complex information systems and the role of ontologies in these systems. Ontology in this case represents the knowledge required for a specific IT system.

SENSUS method

The approach adopted in the SENSUS method promotes knowledge sharing because it implies acceptance of the same base ontology for all newly created domain ontologies. An interesting feature of the method is the simplicity of creating ontology processes.

ON-TO-KNOWLEDGE method

The purpose of creating this method was to facilitate knowledge management in large distributed organizations. Three main processes were identified: knowledge meta process, human resource management, and software engineering. It consists of five main phases: feasibility study, kick-off (start), refinement, evaluation, and application and evolution.

This method refers to knowledge management, therefore ontologies created by using it are strongly dependent on their future use.

Methontology

The method enables dynamic control of interconnected ontologies and supports the process of reengineering (i.e. recovery and mapping of the conceptual model of implemented ontology to another appropriate model).

The presented overview of some methods is not exhaustive of the topic under consideration. The use of properly chosen methods for the construction of ontology may contribute to faster and more effective development of navigational information ontology, enabling automation of data analysis processes and the creation of a system for automatic communication at sea.

Ontology of communication

An important aspect of management in marine navigation is to ensure an appropriate level of safety for people, cargo, ship and environment. Today the GMDSS (Global Maritime Distress and Safety System) provides a foundation for maritime communication throughout the world. The system sets out rules and procedures for standardized communication; however, situations frequently arise in which additional information is required or a decision has to be made through intership or shore-ship communication. This involves supplementary information or acquiring data through dialogue. That is why the creation of communication ontology is mostly needed for the shipboard system (Pietrzykowski et al., 2015).

So far, research has covered the processes of communication performed between navigators using IMO-recommended standard marine communication phrases (SZPM, 2009). The examined aspects include the exchange of information, message perception and interaction, e.g. negotiations. Their description uses ontologies of navigational information and communication supplemented by elements of the protoform theory. The processes of inference have been studied in the context of acquisition of (additional) information and conducting negotiations. Computing with words has been used for the modelling of communication processes, including inference processes of inference.

The automation of the selective acquisition of information and negotiation processes requires the analysis and interpretation of the content of navigators' exchanges (dialogues). These tasks, in turn, have two requirements: the knowledge of inference methods and the extension of communication ontology. Intelligent communication should consist in automating both information interpretation and negotiations. Although developments in IT and ICT create such opportunities, there is an additional requirement, namely building the ontology of navigational information, including the ontology of communication.

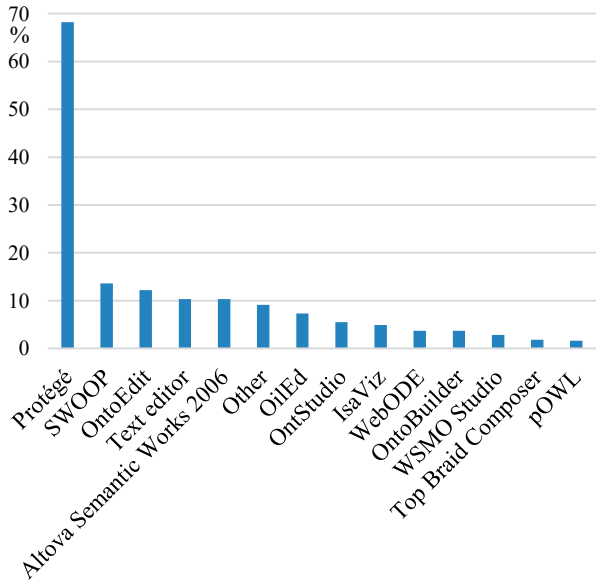

Figure 1. Respondents' use of ontology editors (Cardoso, 2007)

The construction of ontology includes navigational information, communication, and so-called interface (Wójcik, Hatłas & Pietrzykowski, 2016). These aspects are summarized in Table 1.

Ontology is built in the Protégé environment (Figure 2). Statistical data (a questionnaire composed of 14 questions, where the respondent may give more than one answer) gathered for the IEEE Intelligent Systems (Cardoso, 2007) have allowed to conclude that the Protégé is the most frequently used editing program, as depicted in Figure 1.

Table 1. Elements of the ontology (Wójcik, Hatłas & Pietrzykowski, 2016)

No.	Element	Comment
1	NAVIGATIONAL INFORMATION	The ontology of navigational information is under construction according to the IMO's standard marine communication phrases and divided into external and on-board communication. Navigation terms are divided into entities (main classes) and instances (elements belonging to specific sets).
2	COMMUNICATION	The ontology of communication is being developed based on fuzzy logic and the protoform theory. Using fuzzy logic, imprecise and ambiguous terms can be formally defined. These terms are often used in verbal language, such as *low risk*, *safe situation*.
3	INTERFACE	The interface is intended as a merger of navigational information and the ontology of communication. It includes message markers, such as QUESTION, REQUEST.

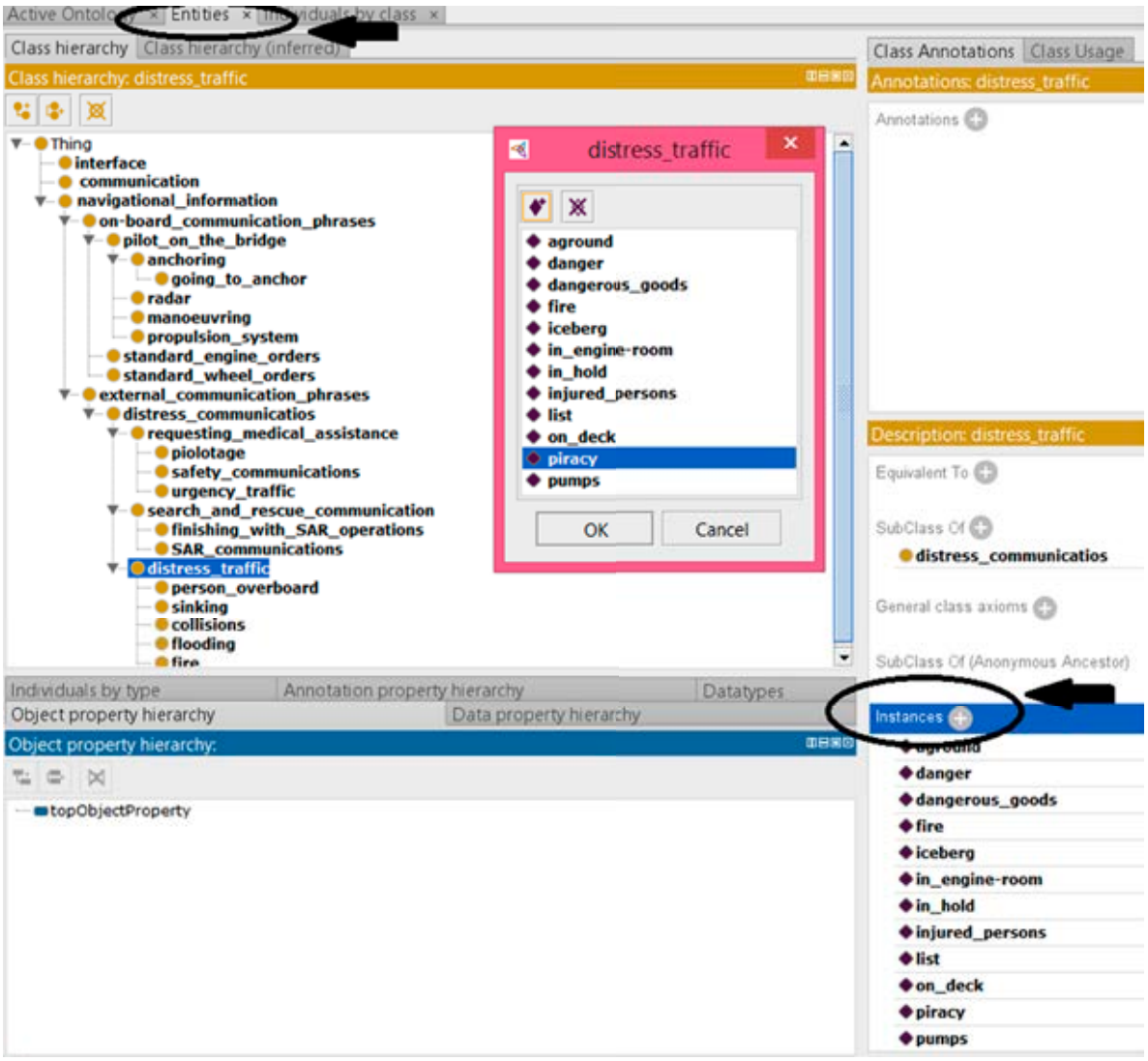

Figure 2. A screenshot displaying communication ontology created in the Protégé program (Wójcik, Hatłas & Pietrzykowski, 2016)

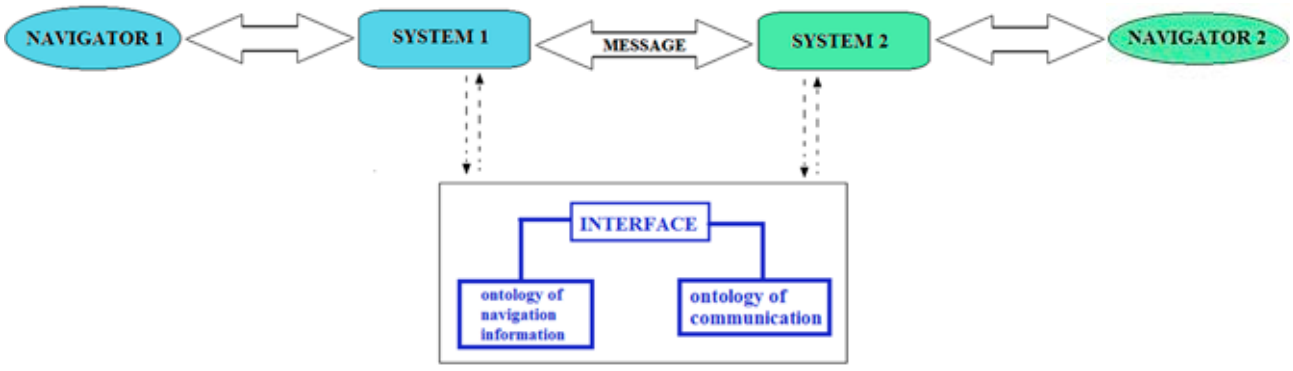

Figure 3. The automatic communication at sea (Pietrzykowski et al., 2015)

The aim of this work is to develop an ontology of communication and knowledge base covering inference processes associated with communication at sea. This will enable the acquisition of additional information and conducting negotiations to solve problematic navigational situations, involving explanations and agreeing on actions to be taken. Constructing such a system (Figure 3) can significantly contribute to the enhancement of safety at sea.

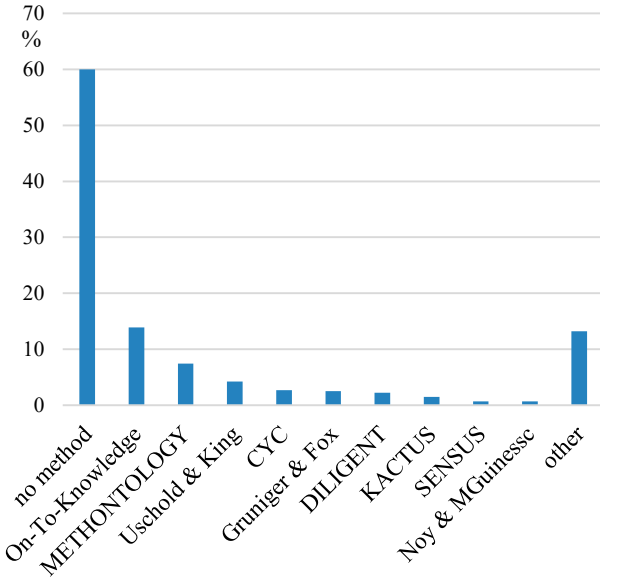

Figure 4. The methods of the ontology and the frequency of their use as a percentage (Cardoso, 2007)

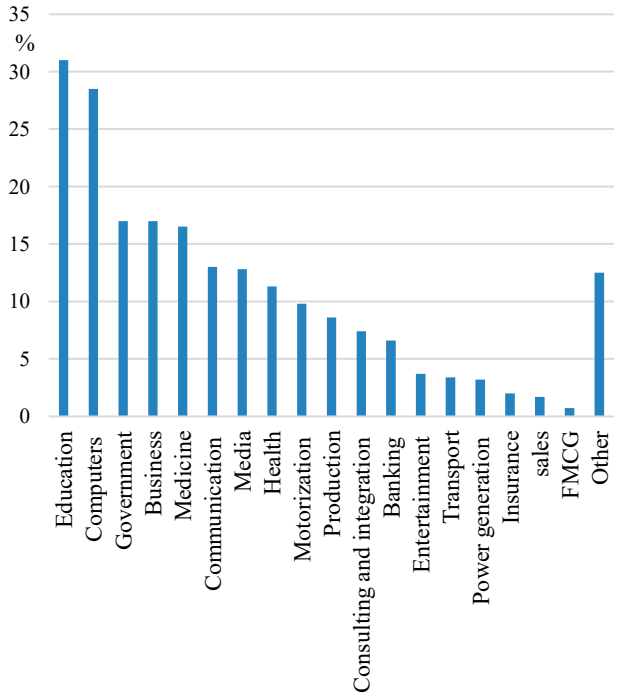

Figure 5. Development of ontologies depending on the field of economic activity (Cardoso, 2007)

The proposed method ontology

One of the propositions (Abramovich, Stolarski & Tomaszewski, 2010) emphasized that the use of ontologies and starting operations on semantic models will broaden possibilities relating to the collection and processing of information. However, it is important to choose the appropriate method for the given domain. Figure 4 implies that 60% of companies do not use any particular method, and are constructing an ontology on an individual basis.

The most commonly chosen method is that of ON-TO-KNOWLEDGE (Figure 4). This method was created under the project, bearing its same name, implemented by Y. Sure, S. Staab and R. Studer (Sure, Staab & Studer, 2004) and aimed at facilitating knowledge management in large distributed organizations. Bearing that in mind, we chose to use the On- To- Knowledge method to build an ontology for a system of automatic communication at sea (Figure 5, Table 2).

Conclusions

The construction of a communication ontology based on the ON-TO-KNOWLEDGE method may contribute to the development of automatic communication systems to be used in shipping, an important link in the global transport chain. This method is

Table 2. Analysis of ON-TO-KNOWLEDGE method applications for a system of automatic communication at sea (Sure, Staab & Studer, 2004)

No.	Stage		COMMENT
1	**Refinement** – aimed to produce mature application – oriented ontology following the specifications given in the initial process. It consists of two sub-processes:		Knowledge and experience of navigators (*method of case studies: analysis of selected dialogues and methods used to formulate utterances*) to create terminology to be used in the word resource of the ontology; recorded in the Protégé program
	knowledge acquisition by domain experts – iterative process used by many experts, who fill in (add details) their skeletal version of the ontology in specific areas of their expertise	formalization – process of recording knowledge in a particular ontology language chosen to suit specific requirements the ontology has to meet	
2	**Evaluation** – process repeated in multiple cycles allows continuous improvement of ontology, at the same time verifies and evaluates the base ontology by subprocesses:		*Experimental method: simulation of the negotiation process* (*simulators at the Maritime University of Szczecin*)
	checking the requirements and competency questions	testing of the ontology in the environment of the target application	
3	**System care** – determines who will be responsible and how the administration of ontology will be provided, including the updating of the knowledge contained therein		

most frequently used by respondents who in practice expect a tool that facilitates knowledge management in large distributed organizations. The primary advantages of the proposed method are its three final phases: refinement, evaluation, and application and evolution. For this reason, ontologies created using this method heavily depend on their future use.

The article analyses selected applications of ontology. The authors present an overview of approaches and methods of ontology construction and consider processes of communication at sea. Based on an analysis of the methods' applicability, the ON-TO-KNOWLEDGE method has been chosen for building the ontology system for automatic communication at sea.

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