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Automation of Message Interchange Process in Maritime Transport

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ABSTRACT: The paper is focused on automation of data message interchange in maritime transport. A general concept of communication system is proposed. The authors deal with some issues of automatic communication in marine navigation. The principles and form of communication based on the use of maritime transport communication ontology with XML Schema are described.

1 INTRODUCTION

Some shipboard systems and equipment (AIS, GMDSS, ARPA, Navtex, and GPS) are used in the automation of information acquisition and exchange. However, these systems do not ensure exchange of information in complex situations, where co-operation between navigators (or coast station officers, helicopter pilots, etc.) has to be established.

The automation of the message interchange process in maritime transport could support navigators in this case. Moreover, such automation is a basis for further development of more complex, agent based navigation support system including an automated negotiation layer. Such automated negotiation systems are well known in e-business and trading environments and presented, among others, in Beam 1997, Paurobally 2003, Karp 2004.

Herein proposed is an approach to solve the automation of the message interchange process in maritime transport. This paper shows results of the research continued after the one described in Pietrzykowski et al. 2003, 2005, 2006. A general concept of communication system is shown. The ontological structure of messages is introduced and its description in XML Schema is proposed to formalize the format of message contents and is an extension of the navigational based ontology in Malyankar et al. 1999, Mingyang P. et al. 2003, Kopacz et al. 2004 and Pietrzykowski et al. 2006.

The proposed solutions are based on an analysis of a real process of communication between navigators presented as example in Pietrzykowski et al. 2006.

2 A CONCEPT OF AUTOMATION OF MESSAGE INTERCHANGE

The transformation of communication from human-to-human to fully automated one is a continuous process. Its purpose is not to provide the environment for fully automated communication between machines, but rather to allow communicating between:

- humans (system operators),
- machines (e.g. exchanging information between ships),
- humans and machines (in all possible combinations and proportions).

Figure 1 shows the scheme of the proposed communication between the sender and the receiver. A message built on sender's side can include information from the operator (e.g. navigator), even if their primary source is any of the available electronic systems. This information - sentences - can be put in manually by the operator. Besides, some information contained in a message is taken directly from external electronic systems (e.g. shipboard AIS). The aim of the communication system is to compose a valid message by means of the previously defined commonly understood syntax using the information contained in these sentences.

The receiver's system should be able to read this message and decompose it to small sentences shown directly to the operator, to store it or send to any of the available external systems. Moreover, the operator can obtain additional information from the external systems after they process any data from the message.

The proposed concept is a technical communication basis for further research in the following areas:

- visualization of information,
- automated negotiations between objects of communication in maritime transport,
- the latest systems on the market show the important role of efficient and ergonomic interface (e.g. visual interfaces of mobile devices). The interface for communication system in maritime transport should support the visualization of both source and destination objects of the communication. It should ensure that navigators understand who takes part in this process (visual verification of participants of the communication is provided as support for the operator).

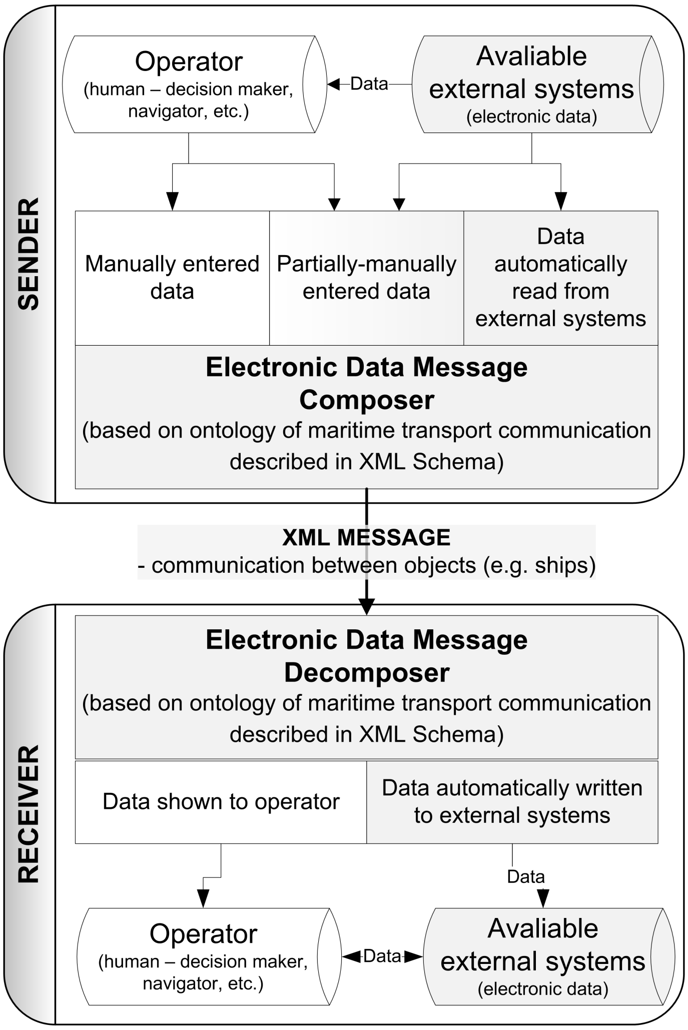

Figure 1. Scheme of proposed communication between two objects (e.g. ships). Note: a gray marked elements show automated data processing.

The proposed system concept can be regarded as a basis for an automated negotiation system in maritime transport, which can be used, for instance, as an expert system helping to optimize navigation issues. In that case the automated or semi-automated negotiation support system requires at least the following functionalities: information sharing among objects (e.g. ship positions, speeds, courses) and auto-negotiation between them (e.g. implemented as agents).

In Beam 1997 it is acknowledged, with a support of several examples, that building an automated negotiation system is a challenging and difficult task. Both the need for ontology and the need for a negotiation strategy are highlighted that study. Ontology is a way of categorizing objects in such a way that they are semantically meaningful to a software agent. The negotiation strategy in the navigational environment should be clear in maritime transport (while the strategy is a secret in known trading systems).

However, the functionalities indicated above cannot be realized without automated communication. The sections that follow present an ontology and its implementation in XML Schema required to provide for automated communication.

3 THE ONTOLOGICAL STRUCTURE OF MESSAGES IN MARITIME TRANSPORT

Ontology plays a major role in supporting the information exchange processes in maritime transport. In general, it provides a shared and common understanding of the domain of knowledge, communication, etc. The problem of ontology for maritime transport is mentioned, among others, in Malyankar et al. 1999, Mingyang P. et al. 2003, Kopacz et al. 2004 and Pietrzykowski et al. 2006.

One of the ways of message interchange is the use of radiotelephone VHF communication. The basic element of radiotelephone dialogs between objects such as ships, coast stations, etc., is a single message. Each message consists of at least one sentence. In practice sentences are usually simple ones and contain one piece of navigational information, e.g. for ship encounter situation (Fig. 2.):

- Alpha: ‘Our CPA is close to 0’,
- Alpha: ‘Is it possible that we pass starboard to starboard?’

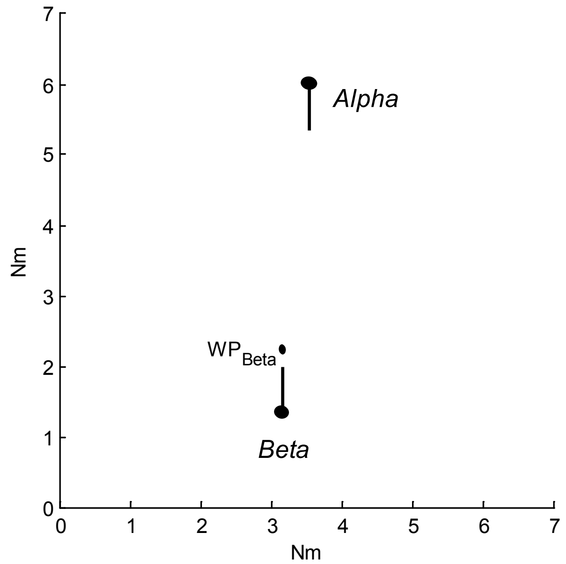

Figure 2. Ship encounter situation.

The sentences shown above contain one piece of navigational information – such piece is called an attribute in this context. Complex sentences - containing more than one attribute - may also be heard, e.g. two-attribute sentence: *Beta: „I intend to alter my course to starboard soon and cross ahead of you at a safe distance.*" In this particular example one navigator informs of his intention to alter his ship's course to starboard and of the closest point of approach after the maneuver is completed.

In each sentence more than one attribute can be placed if they have the same simple sentence form when expressed separately. In other words, we cannot announce one piece of information in a sentence and ask about another piece of information in the same sentence.

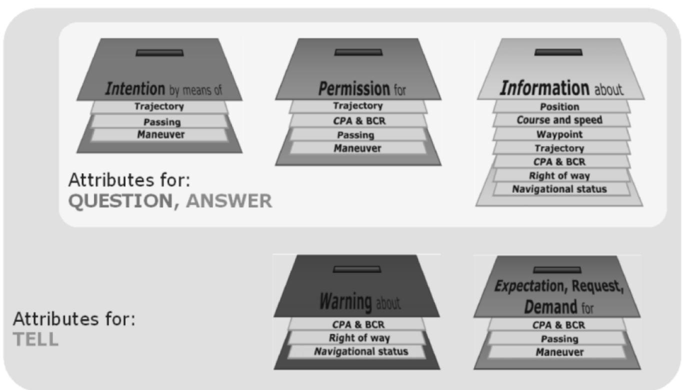

Figure 3. Sentence attributes divided into sentence forms.

Source: Pietrzykowski et al. 2006

Source: Pietrzykowski et al. 2006

Considering the forms of sentences, we should note that they significantly affect the meaning of formulated messages. A single message can be expressed as an interrogative and positive sentence. However, according to the accepted rules and using the recommendations concerning communication at sea (IMO 2002, IMO 2005) information is designed here as a group of attributes that can be linked to all possible types of sentences: Questions, Answers and Tells (statements).

Figure 3 shows that all information about intentions, permissions, information, warnings and requests can be expressed in the form of statements (Tell). The set of attributes related to intentions, permissions and information can be also provided in form of a Question (when we ask about e.g. permission for maneuver) or Answer (when we receive the permission for this maneuver).

The ontological structure of a message (Fig. 4) in the proposed automatic communication results from the structure of verbal communication and technical conditions:

- Header – supplemental data placed at the beginning of a block of data being transmitted, includes:
  - Sender – object sending a message (ship, coast station),
  - Receiver – object(s) getting the message from sender (ships(s), coast station(s), objects located in circle- or square-shaped area),
  - Sent – time of message casting,
  - Other control information such as validity time, communication ID, information about message repetition.
- Body – information content of the message.

It is assumed that a message can be transmitted from the sender to a single destination (precisely defined address - unicast addressing), any group of interested destinations (multicast) or finally geocasted – to destinations identified by their geographical locations.

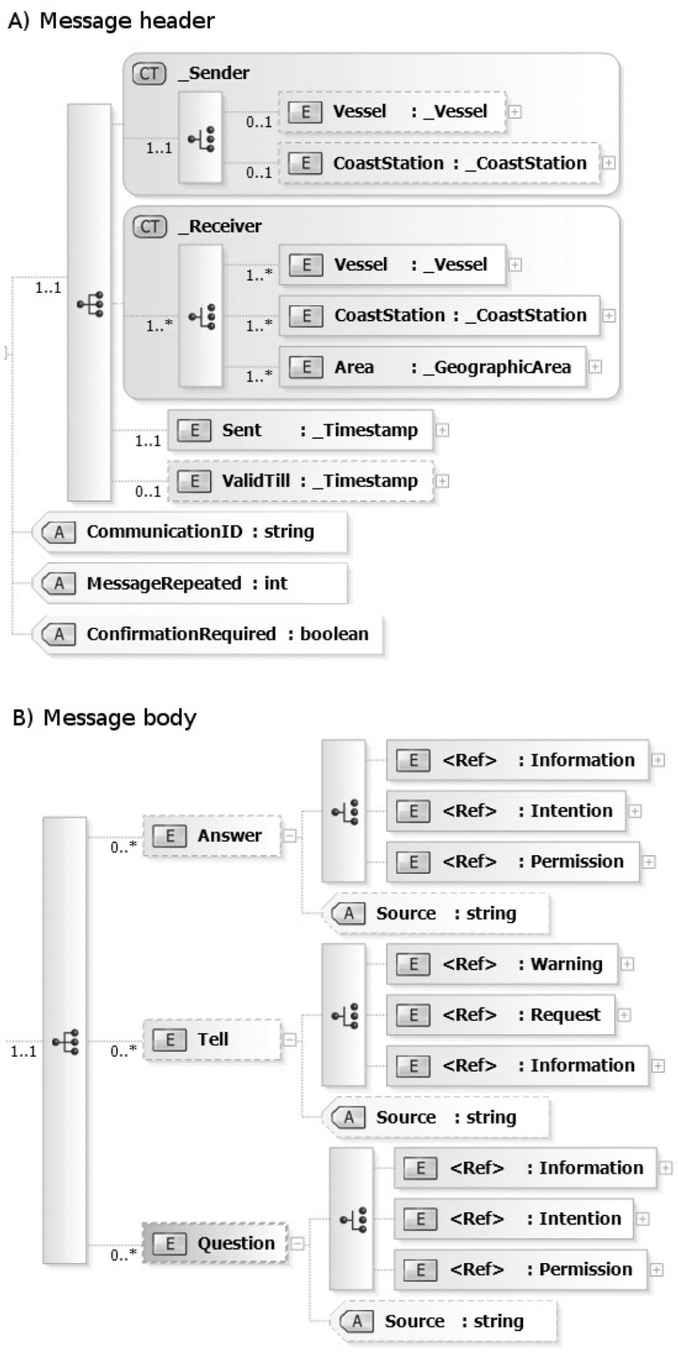

Figure 4. Structure of a message for automatic communication.

In the last case the location is pointed by rectangular or circular area described with geographical coordinates, where elevation is an optional parameter.

The body of the message consists of three groups of data related to all possible types of sentences: questions, answers and tells.

4 USE OF XML SCHEMA TO DESCRIBE ONTOLOGY

The process of developing the ontology and its result in the form of technical description of message syntax is a cyclic one. In each iteration of this model the following steps are required: updating requirements and analysis, design of ontology, implementation-testing of technical description of messages, maintenance. The result of the cycle is the richer version of both ontology and document description.

When the ontology for maritime transport communication is defined (the step of designing ontology is successfully made), it has to be described more precisely with constraints on the syntax and structure. It will allow generating and validating XML messages in an applied telecommunication system. XML Schema or DTDs can be used for that purpose. The XML Schema recommendation describes the content and structure of XML documents in XML. It includes the full capabilities of Document Type Definitions (DTDs), so that existing DTDs can be converted to XML Schema. Compared to DTDs, XML Schemas have additional capabilities.

According to the World Wide Web Consortium (W3C), XML Schema is itself represented in an XML vocabulary and uses namespaces, substantially reconstructs and considerably extends the capabilities found in XML document type definitions (DTDs).

XML Schema is itself represented in an XML vocabulary, whereas DTDs document is described in a unique syntax borrowed from SGML DTDs.

The size of message generated according to the description in XML Schema is about 50% larger than that based on DTDs. However, it does not seem to be a serious disadvantage, while its typical size is still several hundreds of characters and, if necessary, it can be compressed during transmission.

Finally, in some cases DTDs do not support the functionality required for XML documents, i.e. they do not ensure the compatibility with new XML products, do not support data types, and provide less complex constraints on the validity of XML documents. W3C recommend using XML Schema.

Therefore, in the following discussion it is assumed that XML Schema applies to the ontology in the way that allows automating building, validating and understanding of messages for communication in maritime transport.

```
<?xml version="1.0" encoding="utf-8"?>
<xs:schema elementFormDefault="qualified"
                  xmlns:xs="http://www.w3.org/2001/XMLS
               chema">
 <xs:element name="Message">
  <xs:complexType>
   <xs:sequence>
    <xs:element name="Header">
     <xs:complexType>
      <xs:sequence minOccurs="1" maxOccurs="1">
     <xs:element name="Sender" type="_Sender"/>
     <xs:element name="Receiver" type="_Receiver">
```

```
<xs:element name="Sent" type="_Timestamp" />
<xs:element name="ValidTill" type="_Timestamp" />
</xs:sequence>
<xs:attribute name="CommunicationID" type="xs:string"
use="required" />
<xs:attribute name="MessageRepeated" type="xs:int"/>
<xs:attribute name="ConfirmationRequired" type="xs:boolean" />
</xs:complexType>
</xs:element>
<xs:element name="Body" minOccurs="1" maxOccurs="1">
<xs:complexType>
<xs:choice minOccurs="1" maxOccurs="1">
<xs:sequence minOccurs="1" maxOccurs="1">
<xs:element name="Answer" minOccurs="0" maxOccurs="255">
<xs:complexType>
<xs:choice>
<xs:element ref="Information" />
<xs:element ref="Intention" />
<xs:element ref="Permission" />
</xs:choice>
<xs:attribute name="Source">
<xs:simpleType>
<xs:restriction base="xs:string">
<xs:enumeration value="Automatic" />
<xs:enumeration value="Human" />
</xs:restriction>
</xs:simpleType>
</xs:attribute>
</xs:complexType>
</xs:element>
[...]
</xs:schema>
```

Figure 5. Fragment of the ontology written in XML Schema.

Figure 5 shows the fragment of the more detailed ontology for maritime transport communication written in XML Schema. It is the technical form of message structure description for automatic communication that is shown in Figure 3. Its application in the real system allows to generate and validate messages.

A note is required about some XML Schema demands. All time stamps (type="_Timestamp") consist of combined date, time and time zone description. However, the time format is strictly required by XML Schema definitions. It requires storing time value in form of *hh:mm:ss.ff* (*hh*-hours, *mm*-minutes, *ss*-seconds, *ff* –hundredths of a second).

We assume that some sentences can be fully-automatically exchanged between the sender and the receiver. Therefore, for each sentence additional information should be provided to indicate if a human or machine is the source of information. It is important when the communication is not only between system operators (humans) but is semi- or fully-automatic (between machines).

One of the results of the maritime transport ontology development is the message structure – a universal envelope that allows exchanging information among objects of the communication process (ships and all other types of watercraft, aircraft, coast stations, land vehicles). Although in the example mentioned in the next section the communication between two ships is described, more general communication can be processed (Fig. 6: note <Vessel> tags in both sender and receiver related lines in message headers).

5 APPLICATION

Let the dialog between two ships: *Alpha and Beta*, presented in the paper by Pietrzykowski at al. 2006, be an example – a case study – showing the communication described by XML messages generated according to the ontology described by XML Schema.

A situation. Both ships - *Alpha* and *Beta* - (Fig. 2) are in a situation that COLREGs qualify as "ships are on opposite courses or nearly opposite courses" – see Rymarz 1995. In this case, both ships are obliged to alter course to starboard (pass each other port-to-port) in order to safely pass each other. However, in certain conditions the regulations allow ships to alter their courses to port side, so that they pass each other on starboard sides.

Verbal communication. In our case, the ship *Alpha* suggested to the ship *Beta* that both ships pass on their starboard sides, as passing to port might have caused a dangerous situation due to the presence of another ship. In response, the *Alpha* received information that the *Beta* is about to alter course to starboard (because she approaches her waypoint), which will result in passing ahead of *Alpha* at a safe distance and the encounter situation will be solved. The *Alpha* accepts this solution.

Messages used in automated communication. The above dialog can be described in the form of XML messages built according to the ontology structure described in XML Schema (Figure 6).

The record also illustrates the membership of information kinds which are related to a given attribute. For example, attributes "Expectation", "Request" and "Demand" may be related to the same kind of information.

a)
```
<?xml version="1.0" encoding="utf-8"?>
<Message
xmlns:xsi="http://www.w3.org/2001/XMLSchema-
instance" (View source...)>
<Header CommunicationID="AB02"
MessageRepeated="0" ConfirmationRequired="0">
```

```
      <Sender><Vessel Name="Alpha" MMSI="231002300" /></Sender>
      <Receiver><Vessel Name="Beta" MMSI="262998700" /></Receiver>
      <Sent Date="2010-11-01" Time="18:00:01.00" Zone="UTC" />
    </Header>
    <Body>
      <Tell Source="Automatic">
        <Information>
          <Position Latitude="50'49,1'N" Longtitude="01'03,1'W" Altitude="0" />
        </Information>
      </Tell>
      <Tell Source="Human">
        <Warning>
          <CPA Value="0.1NM">Dangerous</CPA>
          <RightOfWay Whose="Indefinite" Who="We" Action="MustGiveWay" />
        </Warning>
      </Tell>
      <Question Source="Human">
        <Permision>
          <Passing Type="Opposite" Side="Starboard" Berth="0.5NM" />
        </Permision>
      </Question>
    </Body>
</Message>
```

b)

```
<?xml version="1.0" encoding="utf-8"?>
<Message xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" (View source...)>
    <Header CommunicationID="AB02" MessageRepeated="0" ConfirmationRequired="0">
      <Sender><Vessel Name="Beta" MMSI="262998700" /></Sender>
      <Receiver><Vessel Name="Alpha" MMSI="231002300" /></Receiver>
      <Sent Date="2010-11-01" Time="18:00:51.00" Zone="UTC" />
    </Header>
    <Body>
      <Answer Source="Human">
        <Intention>
          <Maneuver>
            <AC Dir="Stbd" Value="40">
              <Time Date="2010-11-01" Time="18:02:00.00" Zone="UTC" />
            </AC>
          </Maneuver>
        </Intention>
      </Answer>
      <Question Source="Human">
        <Permision>
          <Passing Type="Cross" Side="Ahead" Berth="1.2NM" />
        </Permision>
      </Question>
    </Body>
</Message>
```

c)

```
<?xml version="1.0" encoding="utf-8"?>
<Message xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" (View source...)>
    <Header CommunicationID="AB02" MessageRepeated="0" ConfirmationRequired="0">
      <Sender><Vessel Name="Alpha" MMSI="231002300" /></Sender>
      <Receiver><Vessel Name="Beta" MMSI="262998700" /></Receiver>
      <Sent Date="2010-11-01" Time="18:01:22.00" Zone="UTC" />
    </Header>
    <Body>
      <Answer Source="Human">
        <Permision>
          <Passing Type="Cross" Side="Ahead" Berth="1.2NM" />
        </Permision>
      </Answer>
    </Body>
</Message>
```

Figure 6. A dialog between two ships written in XML – all massages validated with the ontology described in XML Schema.

Message a) is sent by the ship *Alpha*, and its body consists of two positive sentences (position and warning against a dangerous situation) and one interrogative sentence (permission for passing). Responding, the ship *Beta* sends message b), in which she declares an intention of making a turning maneuver to starboard soon and asks for permission to pass ahead of *Alpha* at a safe distance. The ship *Alpha* sends an answer (message c)) which includes the permission for the proposed passing.

6 CONCLUSIONS

A general concept of communication system for maritime transport was introduced. The cyclic development process of ontology and its result – technical description of message syntax (XML Schema) – allow to build the solution in iterative steps. Therefore, these authors proposed an ontological structure of messages and its description in XML Schema to formalize format of contents of messages. The general form of message envelope was developed to support communication among watercraft, aircraft, coast stations and land vehicles. It is a basis for the development of the general ontology for maritime transport.

XML messages validated with partial maritime ontology described in XML Schema were shown as the example of implementation of communication between two ships.

Further research will be focused on defining and implementation of detailed ontology parallel to the development of automatic negotiation system based upon proposed automated communication system.

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