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A SEA-GOING VESSEL IN AN INTELLIGENT MARINE TRANSPORT SYSTEM

The paper presents a concept and preliminary implementation of an intelligent system of communication and co-operation of vessels. The system makes up a component of an intelligent marine transport system. The technology of intelligent agents, used in the construction of the system, has been characterised. Some elements of the intelligent marine transport system have been discussed. A prototype of vessel communication and co-operation system has been presented.

STATEK PEŁNOMORSKI W SYSTEMIE INTELIGENTNEGO TRANSPORTU MORSKIEGO

W referacie przedstawiono koncepcję i wstępną realizację inteligentnego systemu komunikacji i kooperacji statków. Stanowi on element inteligentnego morskiego systemu transportowego. Scharakteryzowano technologię inteligentnych agentów, wykorzystaną w budowie tego systemu. Omówiono wybrane elementy inteligentnego morskiego systemu transportowego. Przedstawiono prototyp systemu komunikacji i kooperacji statków.

1. INTRODUCTION

Marine transport constitutes a link of the entire transport chain. Like in other modes of transport, its basic task is to carry cargo and passengers. Therefore, apart from economic issues, the safety of people, cargo and the environment has to be taken into account.

In order to boost the safety and effectiveness of transport services in shipping, more and more modern tools and systems are introduced to support the process of vessel management. The quantity, scope and kind of information available onboard a vessel is on the rise. Part of the information, obtained from a variety of sources, refers to the same objects or their parameters. It becomes necessary to efficiently manage the information, i.e. gather, select, verify and make it accessible. It is also essential that the information is appropriately used by the navigator, automated shipboard equipment and systems and land-based centres.

One way of finding solutions to this problem is an implementation of intelligent transport systems. These are understood as a combination of advanced information and

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telecommunications technologies and vehicles and networks of routes created for the carriage of people and cargo [2]. Over the past years actions have been taken to build a Marine ITS [4]. These actions have to account for existing Vessel Traffic Service systems and to supplement them with the so called virtual VTS systems in areas not covered by the former. Apart from these actions, the construction of an ultra-automated vessel has been in progress. In the project, what comes first is a concept of a vessel control system based on autonomous co-operating modules, whose designs utilise artificial intelligence tools.

In areas where VTS and VVTS are not in operation, systems of automatic intelligent communication and co-operation of vessels can be applied. The operation of these systems is based on the use of shipboard systems of control and management and the use of methods and tools of scattered artificial intelligence – the technology of intelligent agents.

2. INTELLIGENT AGENTS TECHNOLOGY

More and more attempts are made to apply artificial intelligence in solving various practical problems, including those of the safety of navigation. Applications are mainly connected with tools of traditional artificial intelligence that deals with closed systems, representing complex and detailed knowledge of one particular field, and using defined methods of knowledge representation. An alternative approach is a distributed artificial intelligence (DAI). One of the DAI methods features agents [13]. These computer programs are to autonomously perform, ordered by the user, in the network environment. Their characteristics include internal properties (autonomy, learning ability, mobility, reactivity, initiative / problem-solving orientation, reasoning) and external properties (ability to communicate, activity co-ordination and co-operation).

Hence three basic areas of operation are distinguished together with the classification into informative, co-operative and transactional agents. The architecture of intelligent agents plays an important role in this context. Reactive and deliberative agents are distinguished. The former respond to certain defined events through the observation of the environment. If a situation known to them occurs, they will take action (agent's reaction). They do not have explicit knowledge on the environment.

Due to the fact that, as a rule, implementation of certain diversified activities requires that a group of intelligent agents must exist, systems of multi-agents are created. Various methods and designs of the system structure are used. The ones most frequently mentioned are the blackboard principle, the contract nets principle and the system of partial global planning. In the case of the blackboard principle, the communication of modules, including the gathering and exchange of knowledge is performed exclusively through the so-called blackboard. With contract nets principle, the coordination of modules is carried out through a distinguished module - manager. The third method does not feature a manager. Each of the modules is responsible for solving its problem and has insight into communication and interaction processes between the other modules.

The use of the technology of intelligent agents with their various types, depending on the task to be executed, enables a complex solution of problems relating to the implementation of shipboard control and management systems, vessel communication and co-operation systems, VVTS construction and the upgrading of VTS operation. These systems make up components of the marine intelligent transport system. It is worthy of noting that systems based on intelligent agents technology are open systems. This means that one or more

systems can be extended with additional modules while the structure of the entire system remains unchanged.

3. MARINE INTELLIGENT TRANSPORT SYSTEM (MITS)

Intelligent transport systems, including all modes of transport, aim at performing a number of services. As far as the marine transport is concerned, these services can be specified as follows:

- Traffic management,
  - access control,
  - dynamic speed adjustment,
  - management of traffic environment and its requests,
  - accident management,
  - route changes,
  - traffic monitoring
- information for passengers, vessel commanders, shipowners, marine agents,
  - information before and during a voyage,
  - navigational advice and assistance
- payment systems,
  - harbour dues
  - pilotage dues
  - freight and charter charges, others
- safety and emergency management,
  - emergency and extraordinary situations alarms
  - collision avoidance
  - rescue services management
- freight and fleet management.
  - coordinated port logistics
  - fleet and resources management
  - freight management
  - dangerous goods management
  - operational planning management

The execution of the above mentioned services requires fast and efficient exchange of information and its effective management (gathering, selection, verification and access) and its appropriate use. The task is difficult and complicated if we take into account the fact that the amount of available information is constantly increasing while the time to process the accessible data and take proper action is limited [6, 11, 8].

The notion of information exchange comprises both the acquisition of accessible data and requests to provide extra information. This belongs to the problem of communication and co-operation between elements (objects) of an intelligent transport system. As particular objects have to execute their own objectives and tasks, it is necessary for them to negotiate specific solutions between one another. Figure 1 presents an example of a MITS configuration, based on intelligent agents technology.

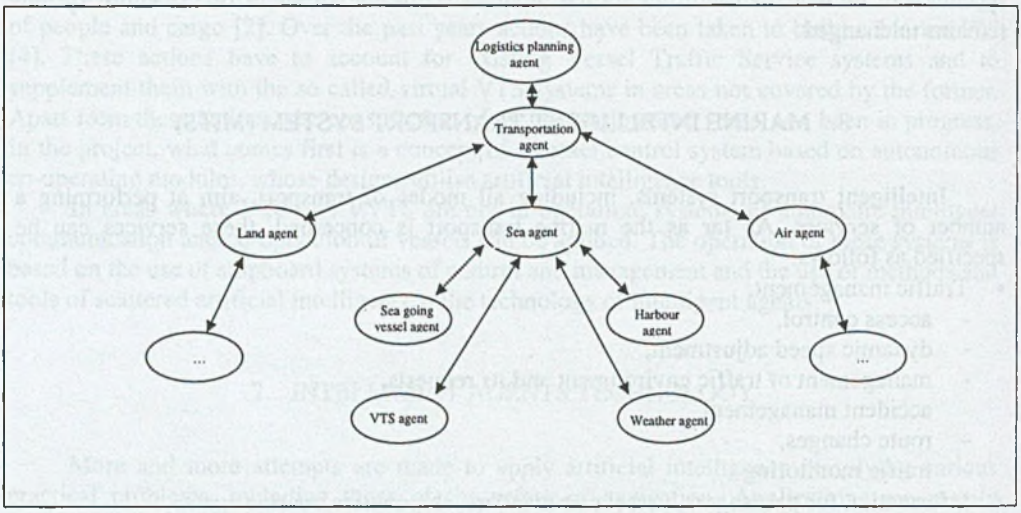

Fig.1. Configuration of Marine Intelligent Transport System based on intelligent agents technology

4. VESSEL TRAFFIC SERVICES (VTS)

At present numerous systems of vessel traffic control are in operation throughout the world. They cover heavy traffic areas and/or areas difficult to navigate in. As a rule, these systems are supposed to monitor vessel traffic. To enhance the effectiveness of their performance they are supplemented by additional modules for information management and supporting the operator's decisions. Recently, action has been taken to combine individual VTS systems so that their co-ordinated operation might cover lager areas of navigation. On the other hand, the introduction of AIS (Automatic Identification System) systems and fast development of communications and information technologies enable encompassing considerably larger areas including those not yet covered by virtual VTS systems. This stimulates search for new solutions of the organisation and functioning of those systems to improve their performance and widen their capabilities.

A Vessel Traffic Service system is considered to be a system put in operation by a coastal state administration in order to ensure safe navigation, effective traffic and marine environment protection [3]. Currently introduced VTMS systems are information systems based on specialised computer systems. Their characteristic feature is the use of special navigational equipment supporting the processes of data collection, processing and presentation.

Four basic structures distinguished in a VTMS system are: functional, information, technical and physical[10]. The functional and information structures are critical for an extension of a VTS system.

The functional structure identifies the goals and functions of the system. The primary objective is to ensure safe navigation and the safety of the environment within the system coverage. The principal functions of the system are as follows:

- traffic organisation in the fairway,

- traffic surveillance and control,
- navigational assistance (information function),
- co-ordination of rescue operations in the case of accidents and disasters,
- securing and supervision of navigational systems operation,
- provision of data for ports and region-covering services,
- collection of data for administration, research and planning.

The information structure encompasses:

- acquisition and recording of data on vessels (before arrivals and departures),
- vessel movement monitoring (vessel movement parameters),
- monitoring of other parameters important for traffic safety, (hydro-meteorological conditions, planned ship service in ports),
- mode of presenting the output data,
- area charts,
- definitions of dangerous situations,
- information on situations endangering safe navigation (alarms),
- prediction of traffic movements,
- communications: centre - vessel, between the centres, centre - other administrative units, resulting e.g. from the organisation and traffic control functions.

The consideration of a VTS system structure, mentioned before, in the computer system framework, allows to specify tasks for intelligent agents in order to provide for the safety of navigation, effective vessel traffic and environment protection. These are as follows:

- vessel traffic optimisation,
- regulations compliance control,
- analysis and evaluation of a navigational situation,
- identification of a dangerous situation,
- situation prediction,
- collision avoidance,
- procedures in emergency situations,
- distribution of information in the system,
- communication and information exchange with other objects within the VTS – harbour area,
- communication and information exchange with other objects outside a harbour area, e.g vessels with a known ETA proceeding to an area covered by a VTS and their port of departure, etc.

5. VIRTUAL VESSEL TRAFFIC SERVICES (VVTS)

In areas not covered by VTS systems the so-called VVTS systems are proposed (Fig.2). In [4] the system is considered to be a data base in a network. A vessel sends its data to a VVTS and receives information on other vessels. It is, however, possible to supplement the system with functions and tasks typical of a VTS system.

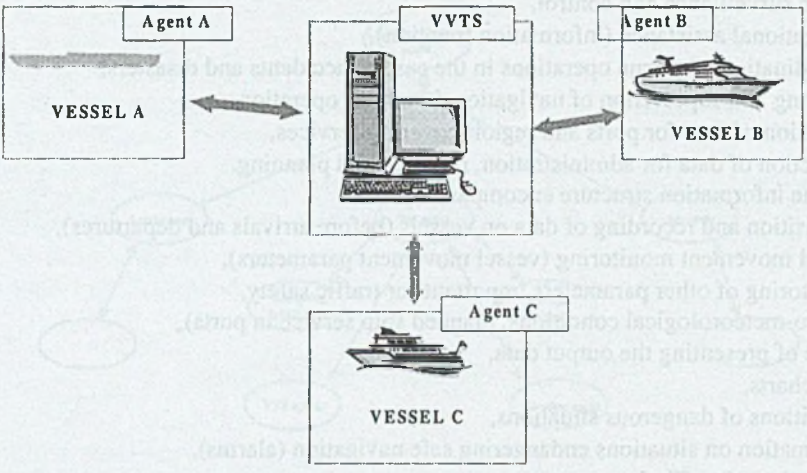

Fig.2. Concept of Virtual Vessel Traffic Services

The Automatic Identification System (AIS) can be one of the basic elements of such a system. The AIS mainly aims at supporting navigational safety. The system is a tool for the ship-ship and ship-land-ship information exchange. Other available systems and equipment are also recommended to be used, such as an Electronic Chart Display and Information System (ECDIS).

The system tasks can be summarised as follows:

- detection and tracking of vessels (AIS),
- analysis and evaluation of a navigational situation,
- collision and grounding avoidance (AIS, ECDIS),
- situation prediction,
- regulation compliance control,
- vessel traffic optimisation, including weather routing,
- distribution of information in the system,
- communication and exchange of information with other objects/systems, e.g. VTS or other VVTS systems.

6. VESSEL COMMUNNICATION AND CO-OPERATION SYSTEM

In the case of areas not covered by VTS or VVTS system operation or where only an AIS system or a VVTS operating as a virtual data base only, the communication and co-operation rests on those who steer vessels, i.e. navigators. Each of the vessels constitutes an autonomous object executing its own goals and tasks. The improvement of communication and co-operation between them may substantially enhance the safety and effectiveness of transport.

The acquisition of precise information on a vessel and its parameters requires that a direct communication is established, which causes a time delay. The same refers to arrangements that have to be negotiated before vessels proceed with any manoeuvres. These tasks can be undertaken by intelligent agents representing particular vessels (Fig.3).

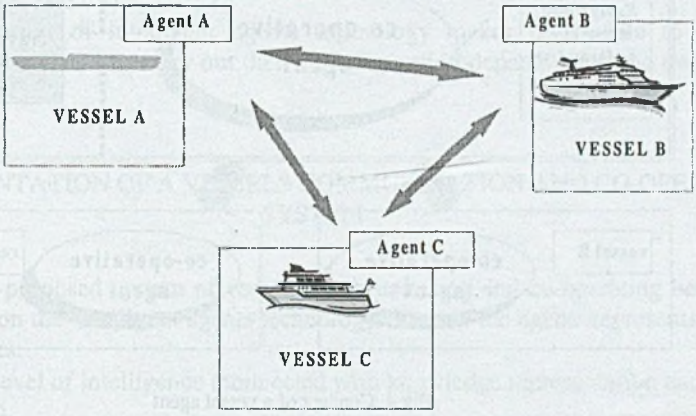

Fig.3. Vessel communication and cooperation system based on intelligent agents technology

Each of the agents executes three basic functions:

- acquisition and distribution of navigational information,
- analysis of a navigational situation and collision situation solution,
- communication, co-operation and co-ordination of actions with agents representing other vessels and interaction with a supervising navigator.

Practically the implementation of each of the functions can be based on a specialised agent: informative, navigational and co-operative (Fig.4) [12].

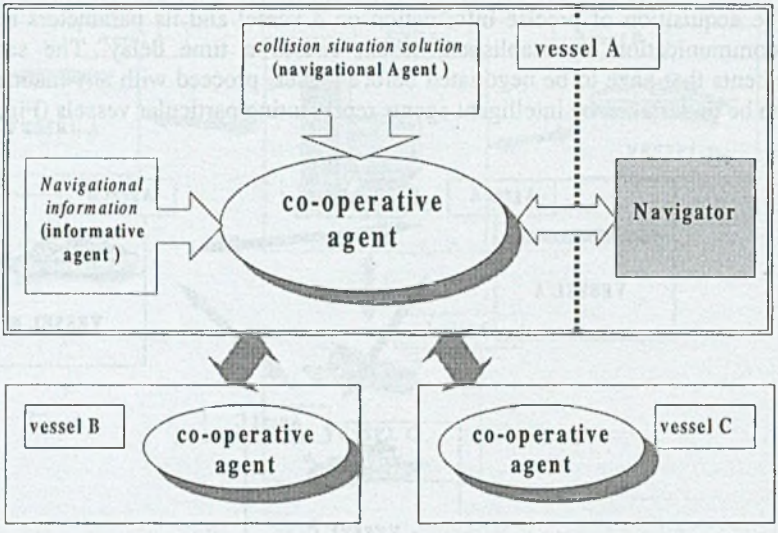

Fig.4. Concept of a vessel agent

7. INTELLIGENT SEA-GOING VESSEL

The notion of an intelligent vessel is understood as a vessel equipped with advanced control systems. As a rule, these systems include the navigational bridge, the engineroom, special deck equipment for the carriage of certain cargoes. They can also take into account problems of vessel management. One example of such a vessel is a Japanese-designed ultra-automated ship which features:

- automatic collision and grounding avoidance system,
- marine traffic control in heavy traffic fairways,
- system of assisting vessel arrival / departure, including automatic berthing.

Advanced control systems are created, among others, for the navy; their concepts are presented in [9] and other works. The systems, implemented as part of the Smart Ship Program, include:

- machinery control system,
- damage control system,
- integrated bridge system,
- integrated condition assessment system.

The advanced control systems that are now being developed are based on the concept of autonomous systems using the so-called component level intelligence techniques. These feature the following subsystems:

- ship control,
- command, control and communication,
- combat systems,
- administrative systems.

The architecture of these systems utilizes methods of scattered artificial intelligence, forming smaller autonomously acting subsystems controlling particular vessel systems with the use of intelligent agents technology.

An emphasis has been put on an advanced human computer interface and the integration and assessment of information on ships state at the compartment level (reduced Ships Crew by Virtual Presence - RSVP).

The application of intelligent agents technology makes it possible to efficiently diagnose ship systems and to carry out their reconfiguration depending on the transport task being performed [1].

8. IMPLEMENTATION OF A VESSELS COMMUNICATION AND CO-OPERATION SYSTEM

The herein proposed system of vessels communicating and co-operating between one another is based on the intelligent agents technology. Each of the agents represents a specific vessel and features:

- a certain level of intelligence (connected with knowledge representation and inference processes),
- ability to communicate, co-operate and co-ordinate activities with other agents,
- capability of interacting with a supervising navigator.

One of the basic symptoms of intelligence represented by an agent is the representation of knowledge. In the system presented herein the agents have the knowledge needed for:

- formulating enquiries,
- analysis and assessment of a navigational situation,
- making a manoeuvre (connected with inference processes),
- negotiating solutions to collision situations with other agents.

The implementation of the system is based on PC class computer systems working in a LAN. Each of the agents representing an object, i.e. a vessel, in practice operates a separate computer system. The communication between agents is realised by means of the communication platform JatLite [5]. This is a collection of the libraries of the Java programming language. They contain ready-made methods and classes which make it possible to establish communication among at least several computer systems. The communication is carried out using the TCP/IP protocol as a data transmission protocol.

The agents communicate between one another using the KQML (Knowledge Query and Manipulation Language) [7]. KQML has a construction and qualities making intelligent communication possible, that is it facilitates co-operation, co-ordination of actions and negotiation processes.

One of the computers is used for establishing a communication session. When a session is established, the other computers are connected to it (logged in). It is possible to change the following simulation conditions:

- area parameters,
- navigational obstructions,
- hydro-meteorological conditions.

Figure 5 shows a diagram of operation of a vessel communication and co-operation system.

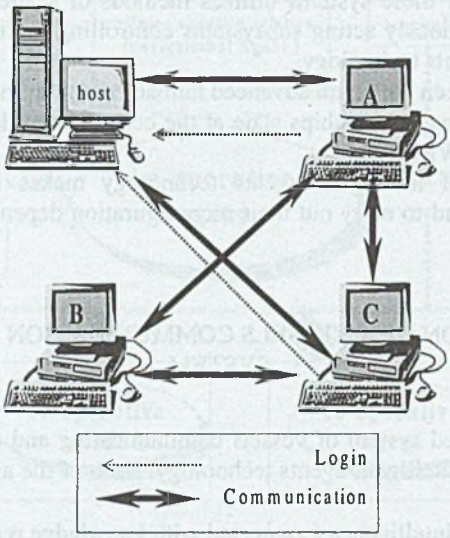

Fig.5. A diagram of a vessel communication and cooperation system

9. SUMMARY

In order to enhance the safety and effectiveness of transport services in maritime shipping it is necessary to introduce uptodate tools and systems supporting the vessel management process at various levels of making decisions.

Intelligent transport systems, or more specifically, marine intelligent transport systems, are used for the task. The VTS systems now in operation and planned VVTS systems make up one of the basic elements of marine intelligent transport systems.

It is proposed that intelligent systems of vessel communication and co-operation are used in areas not covered by VTS or VVTS systems.

All the mentioned systems can utilise methods of scattered artificial intelligence – intelligent agents technology. This also refers to a system of management and control of one vessel.

In the case of vessel communication and co-operation systems, an agent representing a given vessel faces the following tasks: acquisition and distribution of navigational information, analysis of a navigational situation and solution of collision situations, communication, co-operation and co-ordination of actions with agents representing other ships and the communication with the supervising navigator.

The preliminary implementation of such a system has been characterised and presented. The technology applied allows to extend the system or incorporate it into VVTS, VTS or MITS structures.

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Reviewer: Prof. Bernard Wiśniewski