POLISH MARITIME RESEARCH Special Issue 2018 S1 (97) 2018 Vol. 25; pp. 5-13
10.2478/pomr-2018-0016

AUTOMATIC WATERCRAFT RECOGNITION AND IDENTIFICATION ON WATER AREAS COVERED BY VIDEO MONITORING AS EXTENSION FOR SEA AND RIVER TRAFFIC SUPERVISION SYSTEMS

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ABSTRACT

The article presents the watercraft recognition and identification system as an extension for the presently used visual water area monitoring systems, such as VTS (Vessel Traffic Service) or RIS (River Information Service). The watercraft identification systems (AIS - Automatic Identification Systems) which are presently used in both sea and inland navigation require purchase and installation of relatively expensive transceivers on ships, the presence of which is not formally required as equipment of unconventional watercrafts, such as yachts, motor boats, and other pleasure crafts. These watercrafts may pose navigation or even terrorist threat, can be the object of interest of the customs, or simply cause traffic problems on restricted water areas. The article proposes extending the traffic supervision system by a module which will identify unconventional crafts based on video monitoring. Recognition and identification will be possible through the use of image identification and processing methods based on artificial intelligence algorithms, among other tools. The system will be implemented as independent service making use of the potential of SOA (Service Oriented Architecture) and XML/SOAP (Extensible Markup Language/Simple Object Access Protocol) technology.

Keywords: ship identification, unconventional crafts, video monitoring, SOA systems

INTRODUCTION

Ship traffic monitoring is a key issue for safety of navigation on restricted water areas. It becomes even more important in sea ports situated deep at the river mouth, such as ports of Hamburg or Szczecin for instance, in which sea/river navigation is well developed. On sea waters, the systems which are responsible for traffic supervision and management are so-called VTSs (Vessel Traffic Services) [1], while on inland waters, the navigation assistance system is the RIS (River Information Service) [2]. Although functional assumptions of these two systems are slightly different, their common aim is to deliver widely understood traffic information. On the areas covered by these systems, various technologies are used for this purpose, including AIS (Automatic Identification System) [3], radars, and video monitoring cameras. Among other activities, the monitoring centres of these systems share the nautical information with watercraft users, store the information about ships, and/or observe the watercraft traffic. Throughout the day, or even round-the-clock, the systems are operated by human operators, but there is a tendency to automate system operation using the XML/SOAP (Extensible Markup Language/Simple Object Access Protocol) technology [4] and SOA (Service Oriented Architecture) [4] for independent operation of individual service centres and transmission of the information stored by one system to other systems and end users, such as customs, police, port operators, ship owners, etc.

Nowadays there is no automated system nor method to identify small crafts navigating on water areas supervised by VTS/RIS systems. The only way to identify these objects is their visual observation and recognition based on craft side marks. The RIS or VTS information systems are equipped with video monitoring subsystems, which collect the information from cameras mainly mounted on river bridges and in ports, thus providing good opportunities for ship observation from different directions and distances. Here, monitoring is mainly used by the operator to observe current situation on the water area, or to make an assessment of archival situations in cases of events requiring a more detailed analysis. The information on ships and/or events is not processed in any way, nor passed to other receivers in the system. Moreover, there is no unambiguous marking system for small crafts, including standardisation of their side marks which would possibly facilitate remote craft identification.

To make identification of such a small craft possible, it should be firstly recognised in the video image and then compared with the existing database of similar crafts. The river information systems have databases of ships, and these data can be interchanged between systems. Automatic ship recognition implies the possibility of its identification in the European Hull Data Base.

However, a problem is what to do with the information on the recognised object when it is not in the database. One of possible solutions is its assignment to one of already defined categories based on the database of patterns. Developing such an automatic classification procedure would allow the system to take further action based on the category to which it has been assigned.

The article proposes the automatic watercraft identification system which provides opportunities for automatic video data-based traffic monitoring, thus eliminating the work presently done by VTS/RIS operators.

BACKGROUND

DEVELOPMENT PLANS FOR INLAND WATERWAYS IN POLAND

The assumptions adopted by the Council of Ministers on the development plan of inland waterways in Poland in years 2016-2020, with perspective to year 2030, say that until 2030, the river Odra, on its whole length, and the river Vistula, from Warsaw to Gdansk, will become international shipping lanes on which the River Information System (RIS) will be implemented. To create stable conditions for functioning and development of inland navigation in Poland, actions are planned to improve the condition of the river transport, which is very poor now. That is why the Ministry of Maritime Economy and Inland Navigation had recommended signing the European Agreement on Main Inland Waterways of International Importance (AGN), which was ratified this year.

Due to the planned considerable river traffic intensification, extending the length of navigable waterways to the entire river Odra and the river Vistula between Warsaw and the Baltic sea will require installation of monitoring systems on the modernised river segments.

The modernisation programme for inland waterways in Poland includes implementation of the harmonised river information system (RIS) on all waterways of international importance, i.e. of class IV and higher. The main observation sensors within the area of RIS activity are video cameras. For instance, in the second stage of RIS development in the lower and border part of the river Odra, 16 new cameras are to be installed along the river fragment from Ognica to the A2 highway bridge at Świecko.

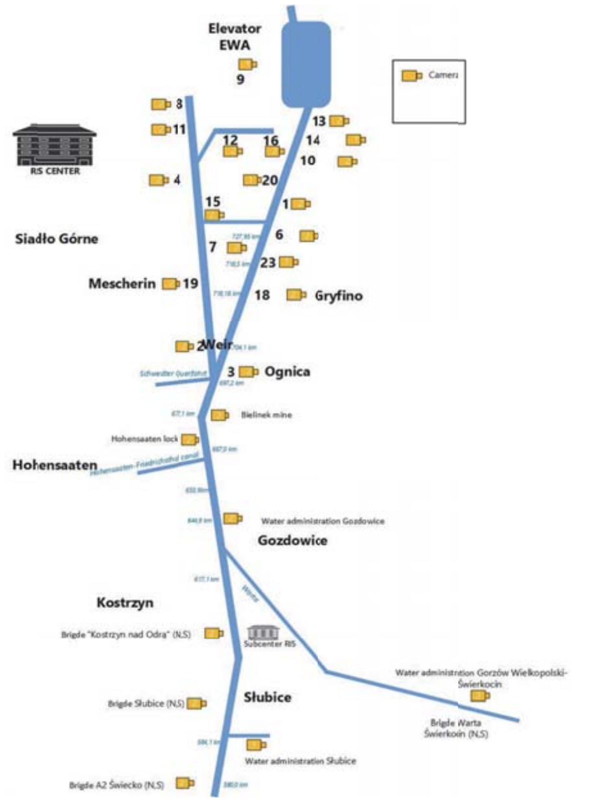

Fig.1. Schema of existing and planned cameras on Odra RIS area. [own elaboration based on 5]

Indeed, the observation of such a vast area of inland waterways cannot be done by human operators working in RIS Centres, therefore introducing assistance systems which will substitute their work is an absolute imperative. Introducing the RIS systems on the entire length of the river Odra and long fragments of the river Vistula is even more challenging [6].

ANALYSIS OF EXISTING WATERCRAFT MONITORING/ IDENTIFICATION SYSTEMS

The main and commonly used ship identification system is AIS. It makes use of the information on ship position and additional data introduced by the navigator, provided that the ship is equipped with a proper transmitter. The information on all ships situated within the monitored area is collected by the network of base stations and passed to all other crafts and monitoring centres equipped with AIS receivers. There is also an inland version of the AIS system (Inland AIS), which is consistent with the basic system and used on rivers and other inland water areas [7]. The SOLAS Convention [8] worked out by IMO (International Maritime Organization) says that AIS transmitters are to be installed on:

- all ships with gross tonnage of 300 and more, engaged in international navigation,
- all ships with gross tonnage of 500 and more, not engaged in international navigation,
- all passenger ships, irrespective of size.

All other watercrafts which navigate on water areas, including non-commercial and recreation crafts, yachts, and other small crafts, cannot be unmistakably identified by the system, which means that they are not seen by it, or seen as unidentified objects. That is why, among other reasons, a system of cameras is added to the AIS and radar systems. In older solutions, these were the CCTV (Closed Circuit TeleVision) systems making use of industrial cameras [9] and a closed dedicated network for signal transmission to the central unit, where the images recorded by the cameras were observed on-line. However, with the development of digital technologies and popularisation of broadband Internet, the more and more frequent solutions are those based on networks and IP cameras [10], from which the digital image is transmitted to the system via internet.

A different function is played by professional commercial monitoring systems, especially in port areas. These systems are based on military systems and are mainly implemented in strategic or extremely sensitive areas, such as ports, offshore military bases, or offshore electric power plants [11]. They are dedicated hardware-software solutions of systems making use of different remote observation technologies, such as radars, surface and underwater cameras, sonars, and motion detectors. They deliver the information on moving crafts and help to detect and track their motion, or even counteract in emergency situations. A huge number of information sources requires their fusion into one integral piece of information concerning the motion of one individual object [12]. However, professional systems store sufficiently large amounts of data about crafts (especially military watercrafts) to make their identification possible [13]. Such a possibility does not exist in information systems, although they have their own databases on ships navigating in their areas and can interchange the data with other systems of the same type.

IMAGE PROCESSING FOR WATERCRAFT RECOGNITION

Recognising objects from streams of video images is a widely used methodology in different fields. Dynamic development of computer techniques affects the range of use of traditional image processing methods, which are still intensively developed, as well as artificial intelligence methods in video signal analyses performed using most recent technological solutions and a variety of digital devices. A good example here are commonly used smartphones which can recognise faces in the recorded photos, and more advanced extended reality systems making use of such tools as interactive glasses and helmets which can superimpose the on-line generated 3D graphics onto real images.

Each time, the object recognition problem starts with formulating a goal: what object is to be recognised in the given scene. Then, the process comprises two main stages: (1) processing, segmentation, extraction and description of features, and (2) final recognition and identification/interpretation. To extract and describe features, the system filters the analysed object using an edge filter and then analyses the created geometric shapes, circles for instance, with the aid of the EDCircles algorithm working online [12] or making use of properties of isosceles triangles [13]. Another approach to feature extraction is analysing image colours and texture. A good example here is skin cancer diagnosis described in [14]. The approach making use of these two relations is frequently applied for recognising distinguished objects [15]. Sometimes, for better object recognition, all three elements are taken into account: shape, colour, and texture [16-17]. There is also a possibility to use methods which base on certain pieces of information a priori introduced to the system and not coming directly from the image analysis. These data may refer to the object alone or the entire scene, the data transmission method, the optical system, or the used processing method. This approach replicates human way of image data analysis, which bases on earlier experience gained by the person interpreting the observed scene [18]. At each stage of the object recognition process, a method or algorithm is to be selected or developed which will lead to the final effect. On utmost importance is selecting a classifier from a relatively long list of available options. Depending on problem complexity, such methods can be used here as: decision trees, naive Bayes classifiers, kNN, neural networks, and machine learning.

Due to high availability of Computer Vision (CV) in free libraries, attention should be paid to the Viola–Jones algorithm [19]. Indeed, the first implementation of the algorithm took place as early as in 2001 when it was used for face image detection, but its assumptions and principles have been developed and used until now. This is particularly true for the use of the Haar-like feature for street traffic monitoring, to identify vehicles and their registration plates [20-21]. An example of applicability of image recognition systems can be the Polish registration plate identification system GV-LPR, produced by GeoVision.

The problem of watercraft recognition and identification in images recorded by the monitoring system is solved in the existing, individually dedicated and comprehensive, military systems created to protect most sensitive strategic objects, such as nuclear power plants, military bases, weapon test centres, etc., from the sea. Advanced research work in this field is mainly performed by commercial companies, such as General Dynamics, for instance. These systems make use of local features and geometric relations between them, which do not depend on changes in the remaining content of the image, nor in its illumination, sharpness, scale, and orientation [22]. The most recent achievement in detecting small crafts has been made by ViNotion, a company which delivers comprehensive monitoring systems for different transportation fields.

When analysing images for watercraft detection purposes, it is worth pointing out that nowadays, it is common practice to use satellite images [23-24]. Unfortunately, they do not provide opportunities for precise identification of small watercrafts, and the time resolution of satellite systems limits the access to most recent data.

POTENTIAL OF SEA AND RIVER TRAFFIC SUPERVISION SYSTEMS

Both sea and inland traffic supervision systems provide their various users with, first of all, the access to nautical information. On the area of their activity, the systems frequently make use of video monitoring as the source of complementary information to that obtained from the AIS system and/or the radar sensor system, or even as the basic source of information on ship traffic. These systems are more or less open and their architecture can vary. Nevertheless, there are technologies and standards which make it possible to use the information collected and processed by them. Depending on the monitored region, these systems deliver services strictly related with the performed tasks. Aspects of sensor planning in RIS systems are discussed in [25-26]. To provide opportunities for system extension by incorporating a subsystem of automatic identification of unconventional watercrafts based on the image information collected from the monitoring, it is essential to know system architecture, applied technologies, and formats of data transfer between individual modules A key element here is the access to the module which collects and/or stores the data about watercraft motion on the monitored area, as these data will make the basis for final watercraft comparison and identification.

SERVICES AND SYSTEM ARCHITECTURE ASSUMPTIONS

On the restricted sea areas and, more rarely, on inland areas monitored by VTS systems, three types of services are provided: (1) Navigational Assistance Service (NAS) which provides ships with instructions and navigational assistance, (2) Traffic Organisation Service (TOS) which is responsible for operational traffic management and ship route planning to avoid dangerous traffic situations, etc., and (3) Information Service (INS) which provides the users with relevant information on request, or when a certain event has occurred, or at a pre-determined time (or after certain period of time). The data are transmitted in the IVEF format developed by IALA [27], which in the standardised form (XML scheme) makes it possible to share the data between different VTS receivers, and to transmit them to other e-Navigation systems, or even completely external systems which need the information on ship traffic.

The operating scheme of IVEF service is given in Fig. 2.

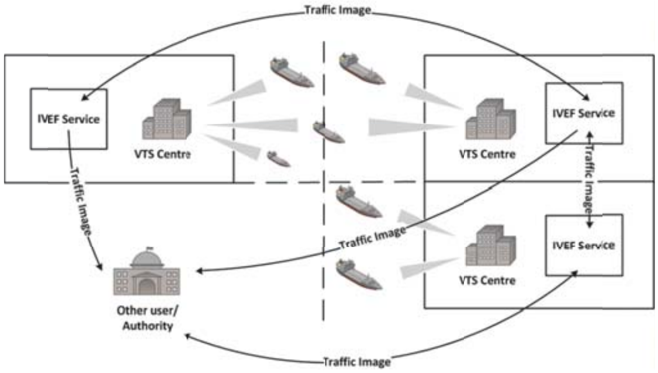

Fig. 2. Operating scheme of IVEF service [own elaboration based on 27]

This service refers to the Vessel Traffic Image Data, which contain statistical data about watercrafts, their positions and voyages. These data come both from the AIS system and the Global Integrated Shipping Information Systems (GISIS), while the dynamic data come from fusion of AIS and radar data. Aspects of AIS and radar data fusion are discussed in [28]. In this case the camera system is neglected. Data exchange with IVEF is done using the TCP/IP protocol for data transfer and TLS/SSL for encoding. It is based on client-server architecture, which means that it is not predefined, but negotiated between sides after the connection is established [29].

On inland areas covered by RIS, ship traffic supervision and monitoring of navigational situations takes a slightly different course. This results from the fact that the main method to reach the same goal as VTS (safety and performance of navigation) is, first of all, delivering the largest possible amount of information to the navigating objects connected with the system. Navigational aspects of inland watercraft traffic are discussed in [30].

The burden of proper use of the received data is borne by their users. With this approach, greater emphasis is placed on information distribution, and not on navigational traffic management, which is reflected in system architecture. The system provides 8 main services related with, among other actions, delivering information on traffic, waterways and transportation, and calamity abatement assistance. The data belonging to 5 different categories can be passed both between individual users within the RIS operation area, and between other interested users in Poland and Europe that use XML/SOAP technology and benefits of SOA architecture, being the basis for the RIS system architecture.

The system architecture for RIS data exchange is shown in Fig. 3 [31].

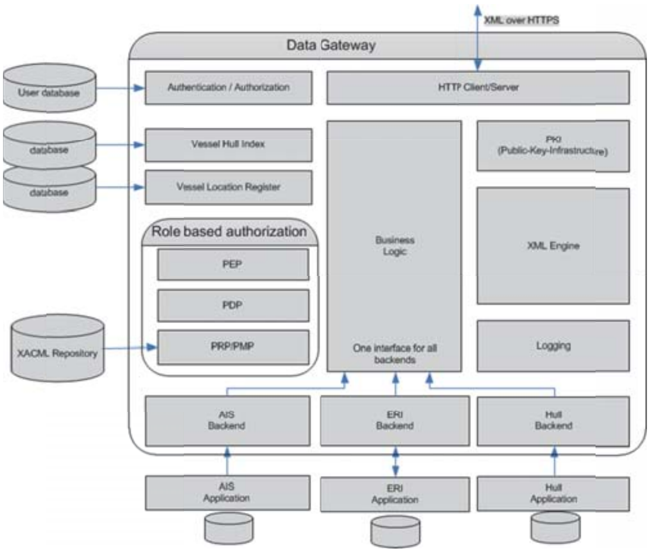

Fig. 3. Architecture of National and International Data Exchange module for RIS systems [31].

The system can be complemented with other services, which will deliver the information to system users indirectly (by improvement or extension of the existing information resource), or directly as an additional service. Therefore, the information on monitoring- based watercraft identifications can either supplement the existing traffic data obtained from other systems, Inland AIS for instance, or be an independent assistance service for monitoring centres, by presenting the information on the identified watercraft together with the camera image. An interesting approach to the problem of information presentation is described in [32].

MAIN ASPECTS OF EXTENDING VTS/RIS SERVICES BY AUTOMATIC IMAGE DATA ANALYSIS

The VTS system delivers information services, but first of all it ensures supervision and provides active navigational assistance to the watercrafts navigating on the monitored area. In this case, system extension should take into account implementation of the recognition module which will have access to the video data stream from the monitoring system and to the GISIS database. This module will pass the obtained information mainly to its operators in VTS coastal stations. Passing the verified/confirmed information to the module responsible for preparing static information about ships, which can be further exported to other internal VTS modules in the IVEF structure and to external systems, is a secondary concern.

In turn, for the RIS system with service-oriented architecture, its extension can have a form of separate service which can be used by other system components. The information can be structured and disseminated in the entire system in a fully automatic way. In this case, it is essential to ensure direct connection with the monitoring system to obtain the source data, and with the hull database connected with the RIS European Hull Data Base for final watercraft identification.

These two different approaches do not make it impossible to create an extension which would be sufficiently flexible to meet conditions of both the VTS and RIS system. This service should:

- have access to the watercraft database in the given system,
- ensure communication with a given video monitoring system to perform current image analysis,
- have an interface to other services and systems, to which it would pass the information on the identified watercrafts.

The data exchange concept in the RIS system is much wider than in the VTS system. However, a tendency is observed in recent years to develop the IVEF format, which is related with development of the entire e-Navigation concept. Among other things, this is indicated by creation of IVEF SDK, intended to facilitate implementation of IVEF model in different systems and services making use of ship traffic information. This mean at least partial opening of the VTS system for data delivery to other receivers than only the own VTS centres.

Taking into account properties of these two systems, it is possible to develop an extension which would satisfy both solutions.

SERVICE ARCHITECTURE OF THE EXTENSION MAKING USE OF SOAP/ XML TECHNOLOGY

By assumption, the watercraft recognition and identification system is designed as a separate module representing the service which can be united with the existing navigation supervision system, only in minimal way limiting further work related with implementation of the extension to a given VTS or RIS centre. This solution is possible due to service-oriented architecture of the extension. Its individual components are considered as separate units which share their interfaces and communicate with each other as black boxes. All messages are parsed and controlled by implemented schemes, and in this form they are passed between individual services. Here, use is made of XML technology with XSD schemes to control the transmitted information, due to the SOAP protocol over the HTTM/SMTP protocol for the transmission alone.

FUNCTIONAL CONCEPT

Simplified architecture is shown in Fig. 4.

When the existing ship database exchanges the information with other systems (for instance between different RIS systems in the European network of inland waterways), the system will ensure an opportunity to identify watercrafts stored in the network of databases. However, when after recognising the watercraft, its further identification is not possible, the system will enable its classification based on the own base of patterns.

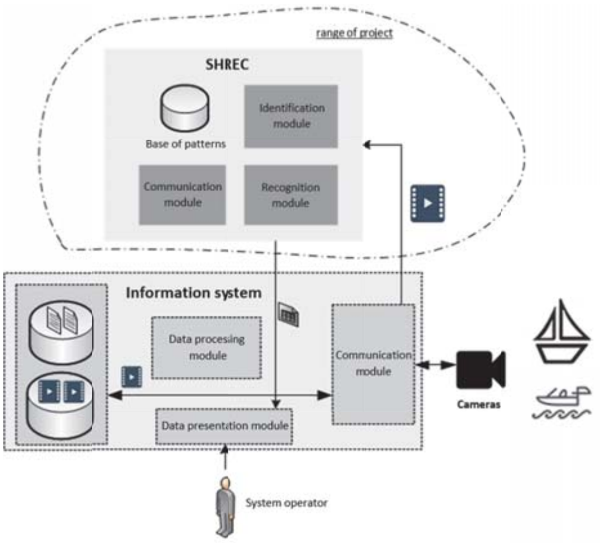

Fig.4 Simplified architecture scheme of traffic supervision system extension [own elaboration].

As already mentioned, the extension has modular structure. The communication module is responsible for transmitting the images from the supervision system monitoring database and the data on watercrafts required for ship identification. Additionally, it transmits the recognition and/or identification results back to the system for information presentation or further processing by systems connected with the RIS or VTS system. The recognising module makes use of the pattern database extracted from test images of watercrafts, worked out and introduced for system operation purpose. The identification module, in turn, utilizes the results of operation of the recognition module, and after comparing with the information on ships stored in the databases, passes the results to the communication module.

To sum up, the proposed extension is an independent system which can be integrated with an arbitrary sea or river information system which:

a. uses or stores data from video monitoring installed in its jurisdiction area,
b. has the database on watercrafts navigating on its area.

RECOGNISING AND IDENTIFYING

The created recognition method was mainly based on: (1) the analysis of current regulations, norms and standards used in European solutions concerning conventional and unconventional watercraft identification, (2) the analysis of current regulations on vessel marks on sea and inland waters, and (3) the analysis of the existing algorithms of image recognition from the video stream, from the point of view of their use for ship identification. A number of inland watercrafts, selected as examples of different ways of identification number and name marking, are shown in Fig. 5.

Pusher tug	
RZGW craft	
Inland pleasure boat	
Push train	
Hydrographic boat	

Yacht	

Fig.5.Examples of unconventional watercrafts [own elaboration]

The recognition method can be based on a set of local properties of individual watercrafts or, for instance, on recognising craft side marks. A frequent problem here is that the regulations concerning craft marking are not precise, which makes fast craft identification extremely difficult. A test database should be created which will help to determine situational and technical requirements, and to select patterns for craft classification purposes. A preliminary approach assumes two possibilities: recognising the object and its further identification based on the existing external ship database (for instance, Hull Database in the RIS system), or classifying the object when its unmistakable identification is not possible. A number of variants of the method will be developed, with further comparison analysis of the results of the performed tests. The method will take into account achievements in machine vision and artificial intelligence methods, in particular the use of artificial neural networks [33] for recognising patterns, and other video image processing methods, for instance those used in short-range photogrammetry [34].

SUMMARY

A basic novelty being the direct result of the project is the possibility to identify unconventional watercrafts on the areas monitored by RIS or VTS systems, which has not been carried out so far by any existing navigation monitoring system. At present, the installation of neither the AIS system, which is currently used for ship identification, nor the Inland AIS system is required on small non-commercial watercrafts. The identification will be independent of craft equipment, which means that no additional devices will have to be bought nor operated by the craft's owner. Moreover, the system will ensure automaticity of the entire process, which means that the camera image does not need to be tracked by human operator. The system will be an independent service, able to integrate with an arbitrary nautical information system equipped with video monitoring and database on ships which can navigate on the monitored area. The system will make use of XML/SOAP technology and other most recent solutions for systems with Service Oriented Architecture (SOA), which are expected to be implemented in European RIS navigation system networks. In cases when unmistakable watercraft identification from its marking or side superscription is impossible, or there is no information about it in the ship database, the system will perform watercraft recognition based on classification principles and the possessed base of patterns. The entire system will be based on an innovative method of watercraft recognition from the video data stream, which will make use of most recent achievements in the fields of machine vision and artificial intelligence (in particular artificial neural networks and rough set algebra-based inference). The effect of action of the described system will be the appearance of automatic and structured information in RIS/VTS about the recognised/identified watercraft, which can be passed through the defined interfaces to other connected external systems (for instance, services responsible for taking steps on water areas, customs, ports, police, etc.).

Activities towards the modernisation of the rivers Odra and Vistula within the framework of the development programme for inland waterways in Poland have been already started on both rivers. Once the modernisation is completed, the implementation of RIS services, including video monitoring, will begin.

ACKNOWLEDGMENTS

This scientific research work was supported by National Center for Research and Development (NCBiR) of Poland (grant No. LIDER/17/0098/L-8/16/NCBR/2017).

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