Automatic Ship Identification Approach for Video Surveillance Systems

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***Abstract*—Existing methods and systems for ships identification are mostly tailored for large, commercial vessels. Nowadays, a need to automatically identify smaller craft emerged, especially in coastal, port or busy river waters. This paper presents a proposal of automatic vessel identification method using video streams from existing marine and inland surveillance systems that are part of vessel traffic services. The identification uses image processing methods to detect and classify ships, as well as recognize vessel plates. The results of these processes are then matched with vessels hull data from internal and external data bases. Fuzzy logic and historical analysis are used to assess identification certainty. The proposed preliminary solution is described and visualized with the use of systems logic schema.**

Keywords-ship identification; marine systems; image processing; video surveillance.

I. Introduction

Identification of vessels taking part in marine and inland ships traffic is a complex and difficult task. Especially now, in turbulent times, when the risk of pirates or terror attacks is rising, fast and reliable identification of ships in coastal, port, and busy river areas has become a crucial task for traffic information services systems. Existing solutions differ in assumptions, used sensors and scale of operation depending on reasons why such identification must be undertaken. Nevertheless, in each situation, identification means comparing results of object detection and recognition with some reliable sort of source information on existing vessels.

Identification of vessels not covered by International Convention for the Safety of Life at Sea (SOLAS) [1] convention is the biggest challenge, because such vessels are not required to own and use Automatic Identification System (AIS) or Long-Range Identification and Tracking (LRIT) transponders, which allow to identify ships automatically and at least passively. These non-conventional ships are small, but they are the most numerous group of units present on inland waterways. The group includes leisure crafts, motorboats, yachts, authorities' vessels, specialized port units, etc. Due to this fact, video surveillance plays a very important role in restricted areas both marine and inland (inland waterways class 4b, ports, and others) [2]. The surveillance is usually a part of traffic information systems - Vessel Traffic Services (VTS) on marine waters and River Information Services (RIS) on inland waters [3]. However, video monitoring and ship identification is done manually by an operator, which is time consuming, resource intensive and insufficient at the same time. Usually, all other information in such systems (built mostly using Service Oriented Architecture (SOA)) is pushed via Simple Object Access Protocol (SOAP) to different traffic participants and to other systems (e.g., authorities). Hence, the need for automation of identification in such systems is urgent.

In this paper, we propose an initial solution for conducting automatic ship identification using video streams from existing surveillance systems on areas covered by vessels traffic information systems, such as RIS or VTS. We propose the scheme for ships identification and discuss its evaluation method. The research is done as a part of Automatic Recognition and Identification System for Ships in Video Surveillance Areas (SHREC) project [4]. SHREC is a system that is going to use multiple existing video streams to identify passing ships. The system does not require specialized cameras and has modular and scalable architecture that allow connecting many surveillance cameras.

The rest of this paper is organized as follows. Section II describes the problem of identification and current state of the art. Section III presents the identification approach used in SHREC system. Section IV describes our approach to system evaluation. The conclusion closes the article.

II. Background

There are four main approaches to track and monitor ships traffic: AIS, LRIT, Vessel Monitoring System (VMS), and via already mentioned VTS and RIS traffic services. The first two are imposed by the SOLAS convention, and therefore, work for large international voyaging ships, passenger crafts, offshore drilling units, etc. Moreover, AIS [5] is a passive way of identification, because ships for a variety of reasons can turn off their transponders or send false messages. VMS is used in commercial fishing for environmental and regulatory purposes and uses a variety of sensors. Nowadays, more and more of such systems use airborne and satellite-borne imaging sensors. In the detection and tracking domain, the main research is going in two ways: (i) using optical sensors [6][7] and (ii) Synthetic Aperture Radar (SAR) [8]. Still some additional information must be used to identify units. Usually, the identification is based on data provided by AIS [9] or some other referenced data, e.g., Ship Arrival Notification System [10].

The problem of detection and identification of small, noncommercial crafts remains a challenge. VTS and RIS systems, besides AIS (when possible) and radars (for detection and tracking), use video monitoring [11] as a way to visually identify units. Surveillance is used by a system operator to observe current traffic or to make an assessment of archival situations. Detection, recognition and identification of units based only on surveillance in coastal and inland areas are very complicated due to many factors including scene characteristics: illumination changes, reflections, existence of high frequency background objects [12], etc., as well as the lack of unification of ships markings [4].

Contrary to data in other VTS/RIS subsystems, information on ships identification is not processed in any way, nor passed to other receivers in the system. RIS and VTS systems were developed to primarily exchange information between its centers and other external systems (e.g., authorities or shipowners). On the other hand, there is no standardized marking system for vessels side marks, which could possibly facilitate remote craft identification.

In image or video stream analysis, the identification process is usually the third step after objects detection and recognition (or classification). The identification itself is to compare results of classification/recognition and match it with actual knowledge from systems own information on vessels or some external data source (e.g., Hull Data Base in RIS). In order to identify objects, a number of image processing algorithms must be executed to analyze video streams. There is vast ongoing research on this matter. Detection can be done using multiple approaches [13][14]. Many times, classification, besides traditional image processing approach (Feature-based template Matching, pattern matching, etc.), uses artificial intelligence methods like neural networks or other deep learning algorithms [8][15]. Moreover, from systems' performance perspective, it is much more difficult to execute these methods in close to real-time mode. They use more resources, take more time to execute and training database must be large and well-structured. Interestingly, recognition of vessel plates (side marks) can be very helpful [16].

III. Identification in SHREC system

SHREC is being developed as a system that can be easily integrated with existing RIS or VTS systems. The core of SHREC system is the ships recognition and identification method. It will need an access to any number of video streams in order to run image analysis and to systems vessel database to be able to perform identification. The simplified schema of SHREC identification process is shown in Figure 1.

The system can be divided into four layers. The video capture layer is responsible for receiving and decoding of video streams into series of bitmap. Each stream is decoded separately and forwarded to corresponding frame analysis module in detection and recognition layer. This module consists of three different submodules responsible for ship detection, ships classification and text (vessels plate) recognition. After a ship is being detected, a cropped frame and detection mask is forwarded for classification purposes. The classification is being processed on cropped image, but in original resolution. Detailed classification method is being part of ongoing separate research in SHREC project. Simultaneously to classification, a text analysis is being processed on vessels' labels, when they extracted from cropped frame. Information of classification and text recognition results are passed into identification layer with corresponding quality measures.

Here, the main identification process takes place. First, the collected information for a single frame is checked if it is sufficient for fast identification (a classification ratio and percentage of recognized text allows comparing it with referenced information in the traffic systems database). When it is positively identified, the information about ship and the quality of the identification with the original data frame is passed into Vessel Identification Log and later Identification History Database. If not, the recognition results are passed into AI-Based Identification module, which uses additional information to identify a vessel. Primarily, it uses a buffered, short term history of frames that were analyzed before the current candidate frame. A built-in voting system, using fuzzy logic [17], allows classifying a ship based on earlier results from *n* video stream frames. The output of the ship type classification algorithm for each frame is fuzzified, which means that there is a quality indicator for each class telling how good the adjustment is to each ship type. When the indicator value is firm, it outputs one ship type of high positive quality. However, sometimes the classification shows good or average matching to few types based on one frame. The fuzzy processing is used to calculate the final ship type and the voting is based on the output of this process and on a series of *n* previous results.

Secondly, the system can perform analysis with the use of rough sets theory [18] using systems Identification History, that stores the information on identified vessel, and the corresponding identification quality measure. When the spatial configuration of cameras in the monitoring system is known (e.g., two cameras point at the same area), then a Multi-View Analysis can be performed using recognition results from frames of two video streams from Short Term History. Rough sets are used to build decision rules needed to perform final identification. Multiple input arguments from the modules mentioned above are mapped into conditional attributes. Decisional attributes are different types of identification output: no ship, moving unknow ship, ship with known type, locally identified ship (e.g, the ship was previously seen by the system), or externally identified ship (e.g., the ship's registration number was matched with an external ships' registry). That approach helps to manage ambiguous cases that occur due to properties of coastal and inland video monitoring. The biggest influence on the proposed approach has an existence of a large amount of poor quality data.

IV. Evaluation

The proper verification of the ship identification method is a complex task and requires preparing a database with video samples that can be used in automated benchmarks. In SHREC, the database consists of video samples and corresponding files with structured description. The video samples are divided into two data sets. The first one contains around 500 samples taken from publicly available video streams from different ports in Europe. The second one consists of around 2000 video samples that were gathered on waterways around Szczecin by our team during the summer of 2018. The next step is to describe these samples using expert opinion, i.e., an expert must identify exact points in time (frames in a video sample) where she or he thinks the ship should be detected, its type recognized and identified. That later allows to compare answer given by the system with actual data that was visually confirmed by a witness/expert. The description for each sample is written to a structured file (a spreadsheet), so an automatic test can be easily executed.

The quality of the identification algorithm will be measured using two parameters. The first parameter is a False Negative Identification Ratio (FNIR). It will measure the ratio of ships that have not been identified to all ships identification events. It is worth mentioning that it does not matter if a ship that passes through camera is identified based on one frame or more frames. The positive identification event is a situation when the occurrence of a ship is properly identified in a video sample regardless of the number of frames that contain that ship. The second parameter is a False Positive Identification Ratio (FPIR). It measures the ratio of incorrect ship identification events to all ships identification events.

Before we will start testing the identification algorithm, the detection algorithm, as well as the ship type classification And the text recognition algorithms will be tested using a similar approach. Based on our video samples database and structured description, the FNIR and FPIR will be measured. Regarding the identification algorithm, we assume that positive result is when a ship is properly detected or recognized through its occurrence in front of a camera one or more times. Additionally, the algorithms will be tested on the frame basis using a parameter that will show a ratio of frames in which the ship was detected to the number of frames provided by an expert.

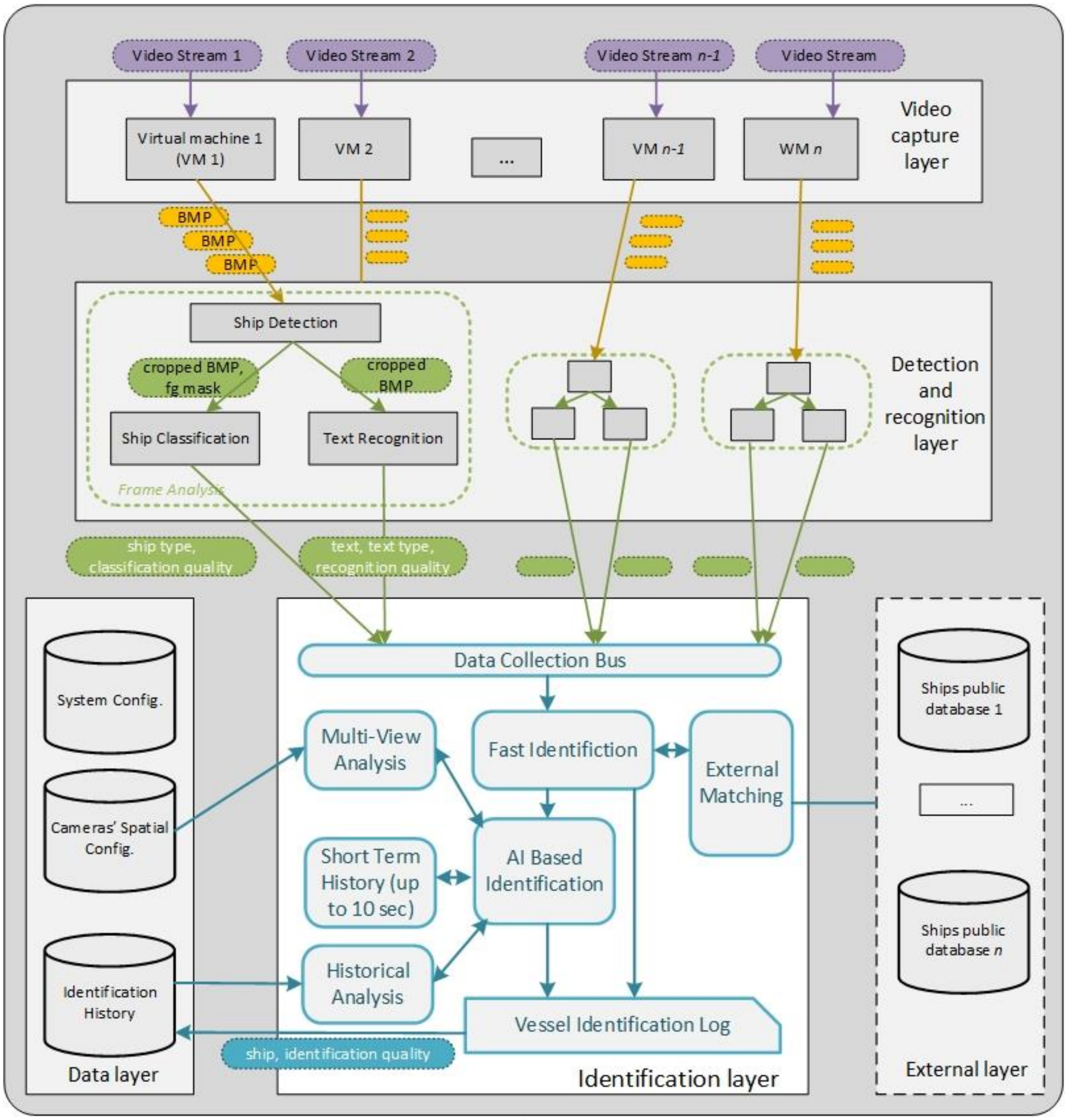

Figure 1. Ship Identification schema in SHREC system.

V. CONCLUSION AND FUTURE WORK

We have presented a vessel identification method using video surveillance that is a part of traffic information services and is an ongoing research in SHREC project. The architecture of VTS/RIS systems allows using these systems' databases as a reference crucial for the identification process. Also, the databases can also be used when VTS/RIS has access to external systems (authorities, shipowners).

The main purpose of the research is to develop a flexible solution that identifies voyaging vessels regardless of their size and other passive identification systems. In the SHREC system, a single camera stream is analyzed separately using image processing methods for detection, classification and text recognition to properly recognize a ship. When the recognition quality is sufficient, matching with data from a traffic system database provides identification. When the quality of recognition is unsatisfactory then identification using historical data and AI methods, namely, fuzzy logic and rough sets theory, are used. Multi-view analysis is also possible, when monitoring system' configuration allows recognizing that two cameras point at the same area.

Some limitations were discovered in initial tests of each part of the proposed system. They are concerning the visual layer, such as quality of camera image, the maximum distance between ship and camera that allows for a detection/recognition, visibility of vessels plate, etc.. They were expected and will be precisely specified in further development of the system. However, the biggest challenge to overcome seems to be the performance limitations that appear due to massive computational effort, which needs to be conceived especially for better classification results. This issue can be reduced by introducing some manual interference into the systems operation, e.g., limiting the area where ships can appear in the cameras' scene.

Nevertheless, the proposed solution will automate the process of visual tracking of a camera image by the operator of the surveillance system. The system can work as an independent service and use SOAP protocol to push information of identified ships to other subsystems of vessels traffic information services.

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REFERENCES

[1] International Maritime Organisation, "SOLAS International Convention for the Safety of Life at Sea", 1974.

[2] A. Stateczny, D. Gronska, and W. Motyl, "Hydrodron – new step for profesional hydrography for restricted waters", Proceedings of Baltic Geodesy Congress BGC, IEEE, June 2018, pp. 226-230, DOI: 10.1109/BGC-Geomatics.2018.00049

[3] A. Stateczny, "Sensors in River Information Services of the Odra River in Poland: Current State and Planned Extension". Proc. Baltic Geodesy Congress (BGC), IEEE, June 2017, pp.301-306, DOI: 10.1109/BGC.Geomatics.2017.77

[4] N. Wawrzyniak and A. Stateczny, "Automatic watercraft recognition and identification on water areas covered by video monitoring as extension for sea and river traffic supervision systems," Polish Maritime Research, vol. 25, no. s1, June 2018, pp. 5-13, DOI:10.2478/pomr-2018-0016..

[5] S. Chaturvedi, Ch. Yang, K. Ouchi and P. Shanmugam "Ship recognition by integration of SAR and AIS". Journal of Navigation. Vol. 65(02). 2012, pp. 323-337, DOI:10.1017/S0373463311000749

[6] Ch. Corbane, L. Najman and E. Pecoul, "A complete processing chain for ship detection using optical satellite imagery", Dec. 2010 INT J REMOTE SENS. 31(22). pp. 5837–5854 DOI:10.1080/01431161.2010.512310.

[7] F. Maquera and E. Gutierrez, "Wakes-ship removal on high-resolution optical images based on histograms in hsv color space", IJACSA , vol.9 (7), 2018, pp.223-227, DOI:10.14569/IJACSA.2018.090732

[8] G. Margarit and A. Tabasco, "Ship classification in single-pol SAR images based on fuzzy logic," IEEE Trans. Geosci. Remote Sens., vol. 49, no. 8, pp. 3129-3138, 2011

[9] G . Margarit , J. J. Mallorqui, J. M. Rius, and C. Lopez-Martinez, "On the usage of GRECOSAR , an orbital polarimetric SAR simulator of complex targets, to vessel classification studies," IEEE Trans. Geosci. Remote Sens., vol. 44, no. 12, pp. 3517-3525, 2006.

[10] M. D. Sullivan and M. Shah, "Visual surveillance in maritime port facilities", Mar. 2008, SPIE Proceedings, Visual Information Processing XVII, vol. 6978, pp.8 DOI:10.1117/12.777645

[11] D. Bloisi, F. Previtali, A. Pennisi, D. Nardi, and M. Fiorini, "Enhancing Automatic Maritime Surveillance Systems With Visual Information", Aug 2016, IEEE Transactions on Intelligent Transportation Systems, vol.8(4) pp.824-833, DOI:10.1109/TITS.2016.2591321

[12] D. Bloisi, L.Iocchi, M. Fiorini, and G. Graziano „Automatic maritime surveillance with visual target detection" Proceedings of the International Defense and Homeland Security Simulation Workshop DHSS, pp. 141-145, 2011

[13] K. Prasad, D. Rajan, L. Rachmawati, E. Rajabaly, and C. Quek, "Video processing from electro-optical sensors for object detection and tracking in maritime environment: A Survey,"Intelligent Transportation Systems, IEEE Transactions on Intelligent Transportation Systems , 2017, vol. 18(7), pp. 1993-2016, DOI: 10.1109/TITS.2016.2634580

[14] R. da Silva Moreira, N. F. F. Ebecken, A. S. Alves, F. Livernet, and A. Campillo-Navetti, "A survey on video detection and tracking of maritime vessels," International Journal of Research and Reviews in Applied Sciences, vol. 20, no. 1, July 2014, pp. 37–50.

[15] Q. Zhou, L. Ma, M. Celenk, and D. Chelberg, "Object Detection and Recognition via Deformable Illumination and Deformable Shape", Nov 2006, pp. 2737 – 2740, DOI:10.1109/ICIP.2006.313113

[16] J. C. Ferreira, J. Branquinho, P. C. Ferreira, and F. Piedade, "Computer vision algorithms fishing vessel monitoring—identification of vesselplate number," Ambient Intelligence–Software and Applications – 8th International Symposium on Ambient Intelligence (ISAmI 2017), J. F. De Paz, V. Juli´an, G. Villarrubia, G. Marreiros, and P. Novais, Eds. Cham: Springer International Publishing, 2017, pp. 9–17, 10.1007/978-3-319-61118-1_2.

[17] K. Valášková, T. Kliestik, and M. Mišanková, "The Role of Fuzzy Logic in Decision Making Process", Proc. of ICMIBI 2014, Jan 2014, Lecture Notes in Management Science, vol.44 DOI: 10.5729/lnms.vol44.143

[18] N. Wawrzyniak and T.Hyla, "Managing Depth Information Uncertainty in Inland Mobile Navigation Systems". In: Kryszkiewicz et al. (eds) 2014 Joint Rough Sets Symposium, Springer LNCS (LNAI), vol. 8536 pp. 343-350,

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