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On-water video surveillance: data management for a ship identification system

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Abstract

Video surveillance on both marine and inland waters still only plays a mainly auxiliary role in vessel traffic observation and management. The newest technical achievements in visual systems allow camera images to be used in more sophisticated tasks, such as automatic vessel recognition and identification in observed areas. With the use of deep learning algorithms and other artificial intelligence methods, such as rough sets and fuzzy sets, new functions can be designed and implemented in monitoring systems. In this paper the challenges that were encountered and the technology that has been developed in managing video streams are presented as well as the images needed for tests and proper operation of the designed Ship Recognition and Identification System (SHREC). The current technologies, typical setups and capabilities of cameras, with regard to existing on-water video monitoring systems, are also presented. The aspects of collecting the test data in the Szczecin Water Junction area are also described. The main part of the article focuses on presenting the video data pre-processing, storing and managing procedures that have been developed for the purposes of the SHREC system.

Introduction

The current achievements in the available image resolution and computing capabilities now allow the use of both machine learning (Lubczonek & Wlodarczyk-Sielicka, 2018) and deep learning methods to process many types of image data (Połap et al., 2018). Surveillance systems are already using some of these methods to recognize cars, people (Połap, 2018) and phenomena in the world that surrounds us today. Theoretically there is no reason to not use it in video monitoring systems for ship traffic management (Wawrzyniak & Stateczny, 2018). Although several practical obstacles can be easily predicted: uncertain environmental conditions, changeable lighting, the very large number of possible objects to be classified and identified (Bloisi et al., 2016); some issues still cannot be foreseen before the actual development of such solution. SHREC is a system that is being developed in order to ensure fully automatic recognition and identification of ships using the existing video monitoring that is part of the operating traffic information systems. Its focus is mainly on smaller nonconventional craft – that do not fall under the SOLAS International Convention for the Safety of Life at Sea (IMO, 1974) and cannot be identified by other existing identification systems. In the assemblies the SHREC system will use video streams from fixed cameras of one such system and process them separately to detect and classify ships that may appear in the recorded scene. Simultaneously the text detection and recognition module will extract the hull's inscriptions from a ship's image. Identification will be possible if the ship's class and extracted hull data match the data in the data base of the overarching traffic system. Integration of the image and non-image information topic has been presented previously (Bodus-Olkowska & Uriasz, 2017). A more detailed description of the identification process in SHREC can also be found in the literature (Wawrzyniak & Hyla, 2019).

SHREC is thought of as a subsystem that will work primarily with either marine Vessel Traffic Services or inland River Information Services (Stateczny, 2017). Cameras are commonly used by these systems, especially in restricted areas (Stateczny, Gronska & Motyl, 2018), and the video streams can be easily redirected and exploited by the SHREC subsystem for detection, classification and recognition of ships. Due to the existence of databases on ships in both systems (such as the Hull Data Base in RIS) the identification process can be automated using information from the DB as a reference that can then be compared with the results of the implemented method of identification. Then, the architecture of these systems allows a push notification of the identified vessel to be sent to different nodes or users of the VTS/RIS system. This will provide partial or full automation of the process of identifying ships, based on the visual information from the cameras.

In order to be able to develop such a system, a proper technology for managing the test and training data for the SHREC system had to be developed. For machine learning methods, a massive amount of source data is a crucial element that needs to be reasonably managed so that all parts of the system can learn and be tested in real conditions. Moreover the data must cover a large number of vessels types from different perspectives to allow good adjustment to the real working conditions of the RIS/VTS systems.

In this paper the challenges that have been encountered and the technology that has been developed when managing video streams and the images needed for tests and proper operation of the designed Ship Recognition and Identification System (SHREC) are discussed. The scheme for managing the video stream data in the SHREC system, from setting the objectives to producing the final data sets that are ready for use in each system module, is presented.

The rest of this paper is organized as follows: Section II describes the current technology used in the video monitoring implemented in VTS/RIS systems. Section III presents three kinds of video stream acquisition for the purposes of the SHREC system. Section IV describes the processing and management of the acquired data. The conclusion and future works conclude the article.

Video surveillance of marine and inland areas

At present, a wide range of hardware and software solutions, constituting an integral system that is able to integrate and fuse the acquired data, is used to monitor marine and inland navigation (Möller et al., 2018). The regulations regarding the video surveillance equipment found in VTS specifications say that the scope of the VTS area should be taken into account with the necessary supervisory equipment. In principle, the equipment should be able to cover an area much larger than the designated VTS region, to allow observation even in bad weather conditions (IALA, 2016). Monitoring devices that are used for surveillance are mainly radar, automatic identification system (AIS) and CCTV systems. Although these complex systems also use other sensors such as sonar (Kazimierski & Zaniewicz, 2018), these systems are also intended to support the safety of navigation between vessels, but also to support supervision by the operators of the RIS or maritime VTS.

Companies producing monitoring systems have in their offering a number of solutions dedicated to

	DS-2CD4A26FWD-IZS/P **ANPR Camera**		DS_2CD6986F-H **Panoramic Network Camera**
Technical details:	– DarkFighter ultra-low light technology – 1/1.8” progressive scan CMOS sensor – Full HD 1080p – up to 60 fps – 120 dB WDR – Full smart feature-set – up to 50 IR range – up to 128 GB on-board storage – motorized lens with Smart Focus		– 4 × 1/1.9” CMOS sensors, 1-ch – 4096 × 1800 real time video output – 180 horizontal panoramic view – DarkFighter ultra-low light technology

Figure 1. CCTV cameras dedicated to maritime monitoring systems (Hikvision, 2017)

observing objects from the water side; one system is presented in Figure 1.

The strategic parameters when choosing a camera are: sensor type, matrix size, maximum resolution, sensitivity, viewing angle with the possibility of optical zoom and operation in night conditions. The minimum specification for cameras is their resolution standard, i.e. the number of pixels vertically and horizontally for digital cameras are 1920 × 1080, a standard called 1080p or Full HD. The type of sensor used in cameras is CMOS (Complimentary Metal-Oxide Semiconductor) characterized by lower energy consumption and good image parameters, but it is produces more noise in low light conditions. The size of the matrix affects the image quality – the larger the matrix the better the image quality, but also the smaller the depth of field. Sensitivity expressed in lux is the smallest amount of light that allows a picture to be registered – the smaller the value, the higher the sensitivity; the angle of view also affects the quality of the data received. The larger the angle of view, the smaller that objects in the center will seem and the more stretched the image will seem on the edges. For observing detail, a camera should be placed further away, with a smaller viewing angle, but with a larger focal length.

An example of a video monitoring system for inland areas is the RIS Center located in Szczecin. This unit is a part of the Inland Shipping Office in Szczecin and its main task is to provide navigation information to users of the inland waterway route and to ensure the safety of moving ships. In 2013, as a part of a pilot implementation of a RIS system for the Lower Oder area, a CCTV system was installed, consisting of 34 cameras deployed throughout the entire area of operation of the RIS Center. The cameras were located in places critical for shipping; mainly on bridges and in the places where the navigation route is delimited.

Video stream acquisition

In order to ensure proper and diverse sets of test and training data for the development of a ship classification and identification method, and later for implementation of the SHREC system, it was decided to obtain video streams from existing monitoring systems as well as to acquire our own recordings.

Thanks to the courtesy of the Inland Waterways Authority in Szczecin, image data was made available from the RIS monitoring system as part of an agreement on data exchange for the SHREC project. The video resources included data from 10 cameras operating in the Lower Oder Area. A simplified data exchange diagram for CCTV monitoring is presented in Figure 2. Cameras, mainly installed on bridges and masts, are connected to the platform with a switch device, and then the signal is transmitted via a radio network to the individual nodes of the system, which are concentrated on the EWA granary building. Direct transmission to the RIS Center server, which collects data, is done with the use of a fiber optic cable.

The server used to collect, view and manage the data was based on QNAP software, and in the following months it was exchanged for a NOVUS system. The data obtained for further analysis were mostly recorded with Funkwerk cameras, which were configured to transmit images in HD resolution (1280 × 720 or 1280 × 960), and the number of frames transmitted per second varied between 15 and 25. These values were still not achievable during live video playback, because the radio transmission network degraded the signal, which ultimately significantly reduced the number of frames recorded on the server. The best data set was obtained from a rotating camera located on the roof of the Office of Inland Navigation's headquarters. This camera with newer technology, when directly connected to the

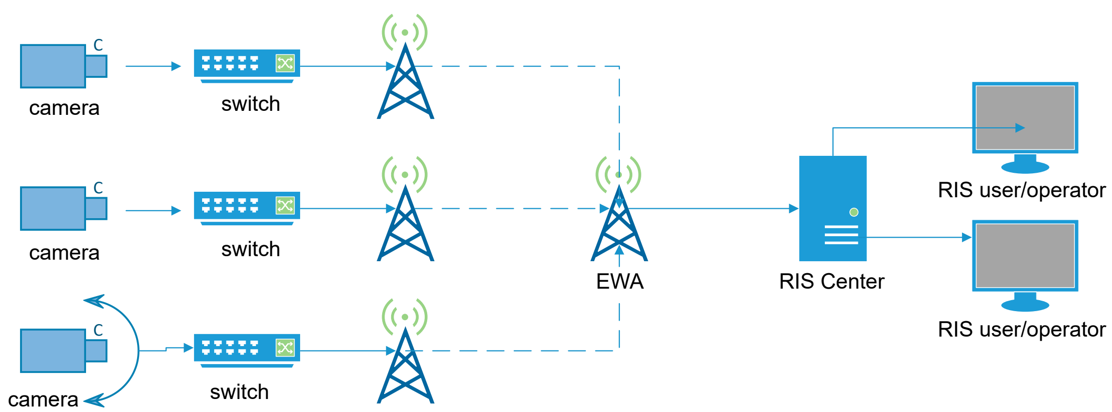

Figure 2. Simplified diagram of the CCTV data transmission in the RIS Center

Ethernet network, provided video streams in Full HD resolution with a guarantee of recording 25 fps. The quality of data obtained with a newer camera, with better parameters, gives better material for analysis, interpretation and processing. Still, assuming the planned replacement of other cameras in RIS with newer ones, the use of radio transmission technology will not increase the number of frames transmitted.

The second source of test data were publicly accessible data streams from webcams in maritime ports such as Rotterdam, Hoek van Holland, Dordrecht, Maassluis, and Vlaardingen; examples can be seen in Figure 3. These video streams made it possible to supplement the data collection with units less frequently occurring in the area of our own acquisitions on inland waters. The main interest was in large commercial seagoing vessels, cargo ships and other conventional vessels. Additionally, in situational terms, these cameras also represent different scenes and observation cases that provided valuable material for testing detection and recognition algorithms – busy waterway situations, port roadstead traffic, multiple ships passing in waterway nodes etc. (Figure 4). The obtained data was a total of 604 recordings reduced to 168 videos containing actual images of units.

The final and the biggest set of video data came from our own recordings. The cameras used in the SHREC project are GoPRO HERO6 Black with the possibility of configuring the recording resolution. For comparison purposes, there were two qualities of 4K and 1080p video recording at 30 fps that were used. Before the actual recordings, reconnaissance was carried out for the area of Międzyodrze and the Szczecin Water Junction. More than a dozen locations with a good view of the area and the vessels moving across it were found.

The chosen sites differed in terms of the observation angle, in order to capture vessels from all possible perspectives, as well as all possible types of ships; images of which could be recorded. Some of the stations were located near the Trasa Zamkowa route and the bridge – Most Długi. This section of the Western Oder is characterized by the presence of bigger ships, passenger ships, small motor yachts and motorboats available for rent; this is due to the touristic character of the surroundings. Different locations near the passage to Dąbie Lake allowed data on small leisure craft to be acquired, due to the proximity of lake marinas (Figure 5).

The data were collected in the period of time from the end of July to the end of September 2018.

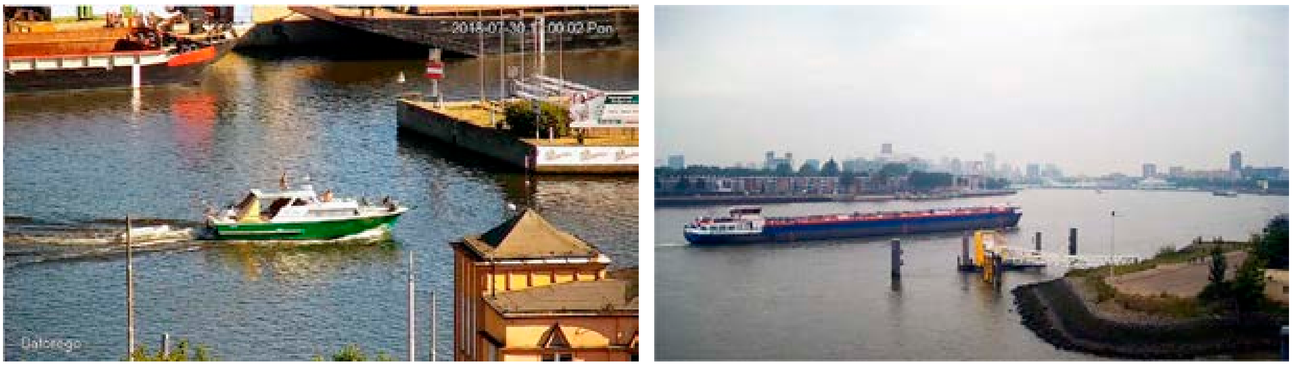

Figure 3. Representative camera images from external sources – the RIS of Lower Oder (left) and the Port of Rotterdam (right)

Figure 4. Map of locations near Castle Route in Szczecin (left) and an exemplary camera image from one of this locations (right)

Figure 5. Map of locations near the passage to Dąbie Lake (left) and exemplary camera image from one of this locations (right)

During the whole recording period, 381 videos were obtained from 659 units which were captured and described. The focus was mostly on small leisure craft, due to the fact that external sources covered other types of vessels such as conventional (under SOLAS), marine units (internet cameras in sea ports) and larger inland units (RIS cameras). When selecting the location, the distance from the passing vessels had to be taken into account. In the case of small vessels which are too far away from the camera, there is a problem with the verification of inscriptions and symbols marked on the ship's hull. The markings such as the registration number, vessel name, and home port or IMO number are essential for the identification process. Due to the technical possibilities, most of the unit's images are registered in profile, i.e. at the angles 90° or 270°. This was caused by observations on rivers with linear characteristics. However, frontal recordings are possible, for example, from bridges. Assigning a vessel to a particular type is not a clear situation. It is especially difficult in some cases, e.g. between a motor boat and a motor yacht, or a motor yacht and a large motor yacht.

The data acquisition stage was the first part of the second phase of the video and image data management process (Figure 6), which is described further on in this article. This phase had a great influence on the later performance of the designed, developed and tested methods for the detection, classification and identification of ships. The observed characteristics and the problems encountered allowed proper solutions to be designed during the process of determining the scope and operation of the algorithms.

Data processing and management

The whole process was divided into four main phases (Figure 6). The initiation phase consists of defining the process objectives, performing reconnaissance and defining the best possible methods and sources of data collection. The expert knowledge used in this phase was transformed in the second phase, called acquisition and storage, to define the schemes in which the data will be collected and later processed. The acquisition process was described in the previous section and the accumulated video data was verified and organized. The main aspect of the verification was the quality of the recordings and their suitability for further processing, but also editing the recordings in order to eliminate unusable parts. Each video stream was described in a separate file according to a pre-determined scheme; this scheme later allowed the acquired data to be tested.

The description of the scheme of the recordings included:

- sequential numbering – numbering of successively qualified units, after editing the verified test recordings;
- naming the recording – numbering of the recordings assigned by the observer;
- background frame – information about the occurrence of a background frame, i.e. a frame in which the described unit has not yet appeared;
- number of vessels in a recording – information on the number of vessels in a particular recording;
- passing time – time from when a given unit appears in the frame and when it disappears from this frame;
- vessel type – the vessel type as defined by the observer in the previous stage;
- visible inscriptions on the vessel – inscriptions that could be read on the recordings, such as: the ship's name, home port, registration number, IMO number, shipowner's mark, trademark, and ENI.

From the recorded, described and ordered recordings, the next stage was to cut the individual ships out of the recordings in the form of bmp images. This process was carried out for a few classes, which had the largest number of collected

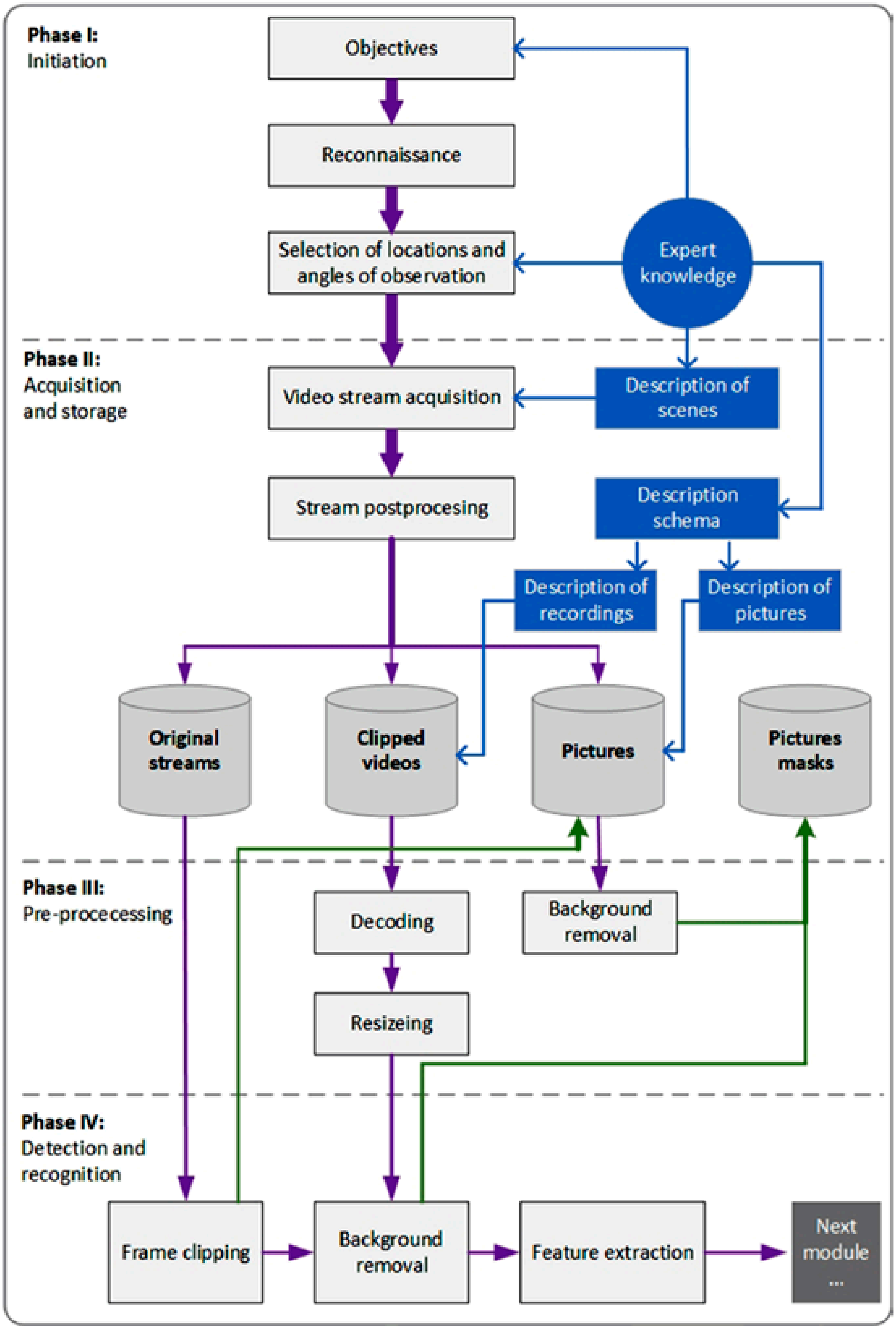

Figure 6. Scheme for the acquisition and management of the image data in the SHREC system

examples in their ranks. There was only one unit in the frame, captured at the best possible moment. The individual unit provided at least one picture, as it could appear from different perspectives while passing through the scene. The schema of the image description specified the:

- sequence number – numbering of a sequentially saved photo;
- name of the photo – numbering of recordings assigned by the observer;
- test number – this is the number which informs the system which unit from the recording is this

one; this number is adequate for ordinal numbers from the table of recordings;
- execution time – time on the described recording;
- observation angle – shows the perspective from which the unit is shown on a particular frame. Eight angle settings have been set, starting from 0°, which is the front of the ship in eight aspects – 45°, 90°, 135°, 180°, 225°, 270°, 315°.

In the pre-processing phase, the clipped videos are decoded and resized for the further detection algorithm that uses data in smaller resolution and, as an outcome of its performance, cuts the detected ship's images from the original streams and produces pictures masks; this defines what is actually a ship and what is only the background in each frame. A more detailed description of the detection process can be found in the literature (Hyla & Wawrzyniak, 2018). These picture masks are later used in the classification module. Some methods of feature extraction need such pre-processed information in order to facilitate the process (Bobkowska et al., 2017).

Throughout the whole process, the data is structured and transferred to the system server to create a test database. The server used in this project was a Dell Precision 36 30 MT. The disk space on the server was 8 TB, consisting of two 4 TB HDDs. The project used FTP protocol, which allows for two-way file transfer. Currently, the database contains about 600 GB of raw images and recordings that have been grouped and described according to the accepted guidelines. The amount of processed data is constantly growing with the development of the system's main methods.

Conclusions and future work

At this stage of the project's implementation it can be assumed that the data that has been referred to in this article are crucial for the further development of each partial submodule of the SHREC system. They allow the system's performance to be developed and later tested and verified with the use of the wide range of methods that use many pre-processed forms of the acquired data. Right now it seems that the most important parameter for interpretation is not the number of frames transmitted per second, but the quality – the resolution of the analyzed image. The settings of the camera itself and its aspect in relation to the moving vessel greatly influences the assumed identification or automatic reading of the vessels inscriptions. With ship detection and even tracking it seems reasonable to use images recorded by different cameras, as long as their spatial configurations are known. It is important to emphasize the diversity of data that has been collected in order to create a database of objects. The latest technologies have been used in data acquisition (Full HD, 4K), but sources from older solutions that still perform their function of water monitoring, but have reduced image quality, have also been used to help build the system's data base. The authors plan to further expand the data base with new recording in the summer of 2019 to supplement the current data sets with video streams and images of types of ship that have not been recorded in sufficient numbers so far.

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