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Study on implementation of shape video recognition on an USV platform

Cristea Ovidiu, Trif Camelia*, Popa Nicolae-Silviu

ovidiu.cristea@anmb.ro, trifcamelia05@gmail.com, nicolaesilviu13@gmail.com

Corresponding author: trifcamelia05@gmail.com

Naval Academy "Mircea cel Bătrân", Fulgerului street, no.1, Constanta, Romania

Abstract: This project is based on a video recognition prototype intended for use in Naval Forces missions. The study involves multiple tests on different methods of recognition. It starts with objects and face recognition and goes to something that is more complex than the incipient stage, more exactly military ships recognition and classification. All these concepts work through the Raspberry Pi module. The recognition of objects at sea is a very important step for the evolution and efficiency of military operations. Also, it has a significant role in the integration of modern systems that use equipment based on algorithms much more technically advanced than the current ones.

Keywords: object recognition, Raspberry Pi, OpenCV, USV platforms

1. Introduction

1.1 Pattern recognition

Pattern recognition is a type of data analysis that involves sorting, grouping, classifying and/or reorganizing available data into a form that is easy to process and/or analyse. [1]

Automatic image classification is a problem of strategic importance in many domains of high interest. Solving is based on pattern or content recognition methods for images. Recognizing and classifying images is a process that unfolds in four essential and inevitable steps. Highlighting these four steps then allows for a guaranteed systematization of all existing methods.[2]

The four steps mentioned above are as follows:

- Image preprocessing – applying specialized DIP algorithms to improve image quality. [2]
- Image feature extraction (feature extraction) – the key stage which gives the measure of the performance and professionalism of the recognition application.[2]
- Feature or descriptor measurement (feature/pattern measurement) – there is a mathematical apparatus – Measure Theory – with the help of which one can introduce different matrices or efficient discriminative methods. The result of this step is a uni-dimensional or multi-dimensional numerical value, regarded as the "distance" of the attributive vector forms the region boundaries or classification "bounds". [2]
- Image classification (pattern classification) – the results of previous multiple measurements are collaborated. It determines the memberships of the shape, object

or image to an image class based on mathematical criteria for membership functions. The result is the C-number of the membership class or directly its name. [1]

In the military, pattern recognition is a very important skill for effective combat. Commanders must be able to interpret visual stimuli in the form of maps and overlays. [5]

Form classification can be done from two points of view:

- Controlled classification which assumes that there is a set of shapes whose class membership is known. The training set can be used to develop a classifier that best recognizes the membership of the shapes in the set to the corresponding classes or it can be the prediction set on which the trained classifier is evaluated. [3]
- Uncontrolled classification where there is no prior knowledge of whether a shape belongs to a class. The method develops algorithms that allow during their execution the construction of classes as the analyzed shapes are considered. [3]

Object identification and recognition is an area of artificial intelligence that focuses on building robots capable of recognizing different classes of objects. As machines, based on artificial intelligence algorithms, are increasingly integrated into people's everyday lives, the field of Machine Learning (ML) is bringing improvements in object detection and recognition abilities. [6]

Image recognition aims to assign a label containing the identified objects within an image while object detection aims to place a frame around each identified object and attach a label with a representation of the class it belongs to. [6]

Examples of pattern recognition used in different domains:

- Voice recognition.
- Voice-based person identification.
- Automatic medical diagnosis.
- Multimedia document recognition. [4]

Pattern recognition requires the following features:

- The recognition system must identify familiar shapes quickly and accurately.
- Recognition and identification of unfamiliar shapes.
- Accuracy in recognizing shapes and objects from different angles.
- Identifying shapes even if some of them are hidden.
- Recognizing shapes quickly, easily and automatically. [4]

Pattern recognition in the military is a very important skill for effective combat. Commanders must be able to interpret visual stimuli in the form of maps and overlays. Combatant reasoning involves understanding pattern recognition, such as enemy deployment patterns, enemy activity patterns, and terrain features. Therefore, situation assessment is likely to involve recognizing tactical patterns.[15]

An analysis of the officer training process shows that officers are not directly trained for pattern recognition on the battlefield. They are presented with effective rules and methods of command, but this does not include direct training in the interpretation and use of pattern recognition. If these skills were to be developed, they are likely to be a by-product of experience and individual study, which may take a long time.[15]

1.2 USVs overview

USVs (Unmanned Surface Vessels) are used for various purposes: maritime surveying, climate monitoring, naval operations, submarine hunting, commercial applications, oceanographic applications and search missions. USVs are robotic boats that can operate without a human crew. Surface vehicle technologies were originally developed for military applications and complex missions.[16]

These vehicles can be as small as a bait boat (used in sport fishing) or as large as a rad tug. Most USVs are developed with GPS tracking, ISR systems, robotics, sonar and other sensors that allow them to navigate autonomously. USVs can be remotely controlled by an operator or can be programmed to perform specific missions. They offer a number of advantages over traditional manned vessels, including cost efficiency, greater flexibility and reduced risk to human life.[16]

The primary military use of USVs is to serve as a mobile target at sea for military training and defense system testing. These ships are powerful, stable, fast and agile. They are also used by mining teams, protection forces, anti-piracy forces, anti-terrorist forces and observation and reconnaissance teams.[16]

USVs offer a versatile and efficient solution for various marine applications. They can be equipped with a wide range of sensors and payloads to suit specific application needs and can operate independently for long periods of time. This makes them ideal for missions such as surveying large areas of water, monitoring environmental conditions with environmental sensors or collecting and transmitting data from hard-to-reach locations. USVs are also becoming increasingly popular for naval applications such as anti-submarine warfare, imaging systems and mine detection. [16]

Another important use of USVs is the possibility to monitor maritime and river traffic, to monitor fishing activities (to prevent illegal fishing) and also the possibility to monitor the extraction of fossil fuels from maritime districts, thus (to prevent pollution). These actions/missions of USVs can be supported by aerial drones (AUWs).[16]

Among other applications of a USV, hydrographic surveying is the most popular and well-developed application. Normally, it requires extensive navigation time and frequent changes of course and back, jeopardizing the health and safety of mariners. However, the autonomous control system technology of small USVs for hydrographic survey can significantly reduce the survey-related costs and at the same time, possible incidents specific to hydrographic survey activities can be significantly reduced.[16],[17],[18]

2. Components of pattern recognition systems and software used for the concept

Computer Vision – one of the most important sciences within information systems, recognizes and analyses a wide range of images. The key component of computer vision used by Computer Vision is object detection. Object detection involves performing a range of activities within artificial intelligence, such as facial recognition, human emotion detection, vehicle detection and automated driving. [7]

Machine Learning (ML) – the objective of Machine Learning is to transform data into information by extracting rules or patterns from that data. For example, one can take a database of 10,000 face images, run an edge detector on the faces and then collect features such as edge direction, edge strength and distance from the centre of the face for each face. The principle of Machine Learning is to separate the dataset into a large training set and a smaller test set. The classifier is running on the training dataset to learn the model and the feature vectors are given. Finally, the classifier can be tested on the remaining images from the test set. [8]

The Viola-Jones Classifier – this classifier utilizes AdaBoost at each node in the cascade to learn a high classifier detection rate with multiple voltages at each node of the cascade. This algorithm includes innovative features:

- It uses input features like those used by the Haar classifier used in object recognition. It uses a threshold applied to the sums and differential differences of rectangular image regions.
- Computing with increased speed the value of rectangular regions by rotating at 45 degrees. This method is used for speeding up the calculation of Haar input features.
- It uses statistical amplification to create binary classification nodes that are characterized by high detection and poor rejection.
- Nodes that have a low classification rate lead to a rejection cascade. The whole process proceeds in the following way: the first group of classifiers is selected which are intended to detect image regions containing an object. At the same time, this first group of classifiers also allows test detections, which may be wrong. The second group of

classifiers follows the principle of weak rejection detection. After this step, the test is entered: the object is detected only after it has gone through the whole process cascade.[8]

Open Computer Vision (OpenCV) – this is an open-source library written in the C and C++ programming language and can be run under the following operating systems: Linux, Windows and Mac OS X. The library is under ongoing development for interfaces such as Python and Matlab. The primary purpose for which OpenCV was designed is low computational performance which places a strong emphasis on real-time applications. Moreover, OpenCV provides a machine vision software platform which goes into the process of creating systems used in areas such as visual inspection in factories, security, medical imaging, stereo vision and robotics. In addition to all these elements that go into the composition of OpenCV, it also contains a general-purpose machine learning library (MLL) since computer vision is not in an automated link with ML. Thus, by merging all the libraries included in OpenCV, the result focuses on pattern recognition and statistical clustering. [8]

Background Substraction – this is a particular case of image sub structuring for which the difference is realized between the pixels of the current frame and the pixels of a reference image (called background).

Applications:

- Security/video surveillance.
- Traffic monitoring/analysis.
- Tracking systems.

General organization:

- Foreground Object Mask – binary image in which one level represents foreground objects and the other level represents background pixels.
- Frame difference method – a non-recursive method that stores several frames in a buffer and uses them to estimate the background.[9]

Hough Transform – in Hough Transform space, a line appears as a point. That point provides information about the orientation of the line and its distance from a reference point. The mathematical features of shapes are computed in the image space, but also in the spaces of transforms on the image.[10]

The transform is the representation of an image in spatial frequency space. The Fourier transform of a geometric shape is invariant to the translation of the shape in basis space but is not invariant to the rotation of the shape. Mathematically, the Fourier transform is an operation that is applied to a complex function and produces another complex function that contains the same information as the original function but rearranged by the component frequencies.[10]

Python – a high-level scripting language, interpreted and developed in the late 1980s by Guido van Rossum at the National Research Institute for Mathematics and Computer Science in the Netherlands. Python has grown in popularity in recent years, in 2018 it was ranked the 7^{th} most popular and the number one most searched technology of the year.[11]

Raspberry Pi is a Single-Board-Computer (SBC) which was developed in the United Kingdom by the Raspberry Pi Foundation together with Broadcom. The original aim was to provide an inexpensive tool for teaching basic computer science in schools and developing countries. The first model was launched in 2012. The difference between a Raspberry Pi and a regular computer is that a computer is made up of a main system board called a motherboard or logic board and a few other components, as they are enclosed in a case.[12]

Raspberry Pi High Quality 12.3 MP Camera is the last Raspberry Pi accessory. It offers higher resolution, 12.3 MP compared to 8 MP, and sensitivity about 50% more area per pixel for improved low-light performance. [13]

3. Steps of the video recognition concept and its validation

The whole process is divided into several steps as follows:

- Video recognition of common objects.

- Facial recognition.
- Personalized object recognition.
- Identification of military vessels and maritime buoys.

The first step is video recognition of common objects. This is a general concept that identifies, in real time, the surrounding objects and calculates a percentage of similarity by comparing them with the input database from which their images are extracted. The program operates with a high degree of accuracy, being able to distinguish objects that are part of the same sphere. For example, in Fig. 1, you can see two objects detected and the percentage of similarity displayed.

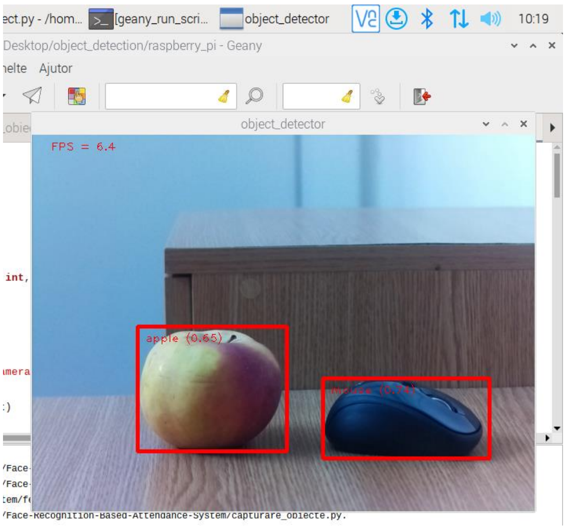

Fig.1 – Recognition of common objects

The second step is facial recognition. To accomplish this task, I created a database automatically by taking screenshots and entering the person's name.

In Fig. 2, you can see how the camera shoots in real time, frames the face of the person in the image. On the right side you can see the field for entering the name and save button in the database. For higher performance and better accuracy, it is preferable that the database contains multiple images capturing the face from multiple angles.

The facial recognition algorithm is a forerunner of the personalized object recognition algorithm, namely ships and buoys from the IALA Maritime Buoyage System. Both use the same principle, facial recognition using a database of only the people who are entered there, and ship and buoys identification is performed in the same way, the difference being the libraries used as in the former case there are libraries specifically trained for facial expressions and emotions, while in the latter case more technical libraries are used, emphasizing dimensions, geometric shapes and other technical features.

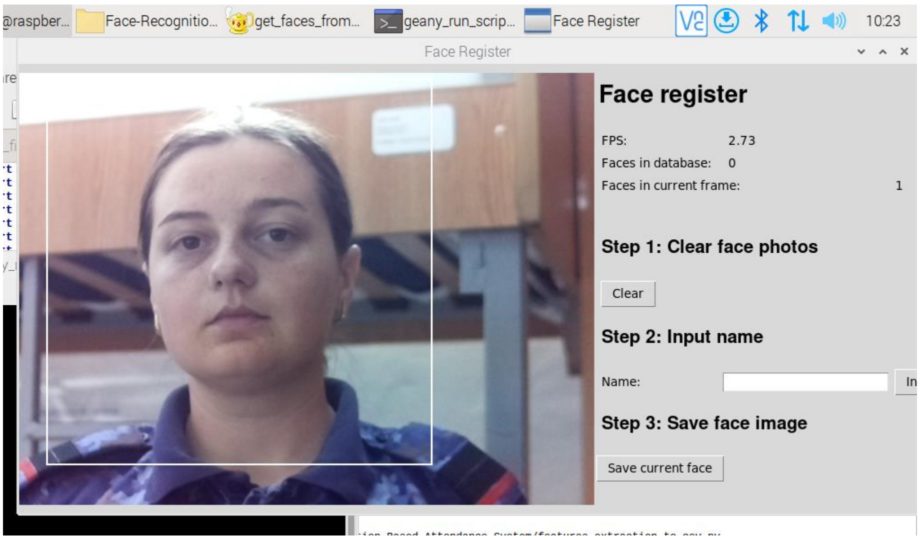

Fig. 2 – Face capture for the database

Once the database is created, the camera is started in the live movie, the detected faces are framed and if they are found in the customized database with the images of the faces of the desired persons, their names will be displayed (Fig. 3), otherwise the word “unknown” will be displayed (Fig. 4).

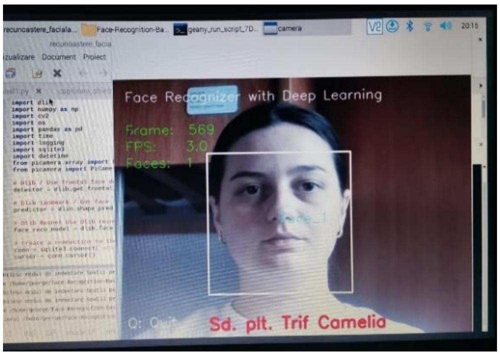

Fig. 3 – Facial recognition – 1

Fig. 4 – Facial recognition – 2

The third step is personalized object recognition. Specifically, this paragraph is about using a database in which images of particular objects are entered. In this case, the database includes images of two different cups. Their shape and structure are analysed and using the line detection method the type of the cup is displayed.

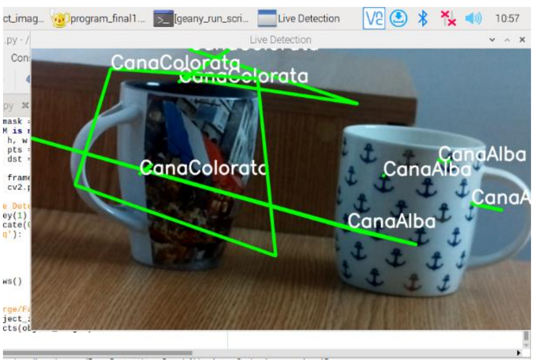

Fig. 5 – Cups detection – 1

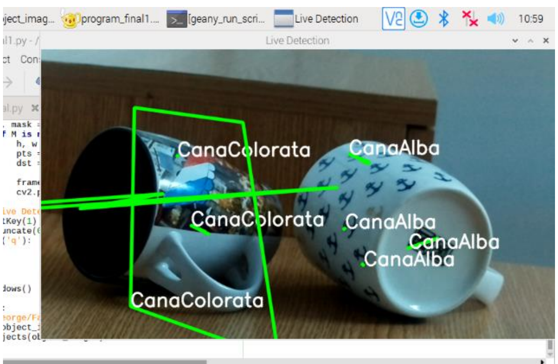

Fig.6 – Cups detection – 2

In Fig. 5 and Fig. 6, the detection of the two cups can be seen. Several images of these objects taken from different angles have been inserted in the database to facilitate their recognition. One can also observe the detection lines joining the essential points of the objects in order to compare them with those in the database and if the similarity is greater than a safe threshold, the object's name is displayed.

The fourth step is the last part of the video reconnaissance project, namely the identification of military vessels and maritime buoys. In this part, the principle used in the previous parts was followed. A database was created with the images of military vessels of the Romanian Naval Forces (Fig. 7). One ship from each class of ships was chosen. Pictures of the buoys of the IALA Buoyage System have also been introduced (port buoy, starboard buoy, cardinal buoys) (Fig. 8).

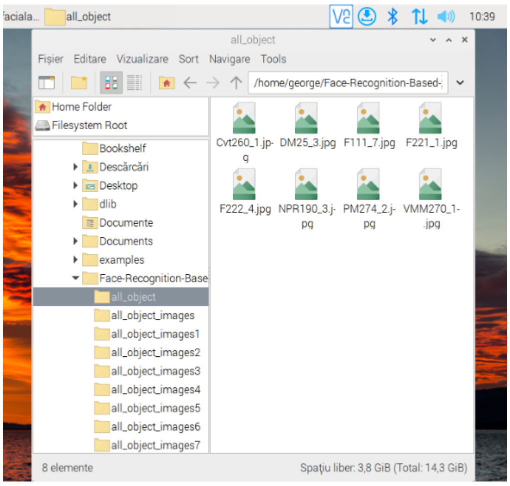

Fig. 7 – Database of ships

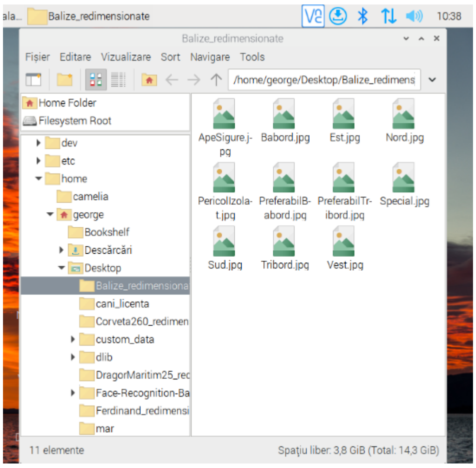

Fig. 8 – Database of buoys

Validation of system operation is the most important part of the paper. In the following, suggestive images for the correct execution of the program will be presented, illustrating the results of the program in the process of identifying military ships. Each of the ships mentioned in the previous chapter will be tested and identified, illustrating the results.

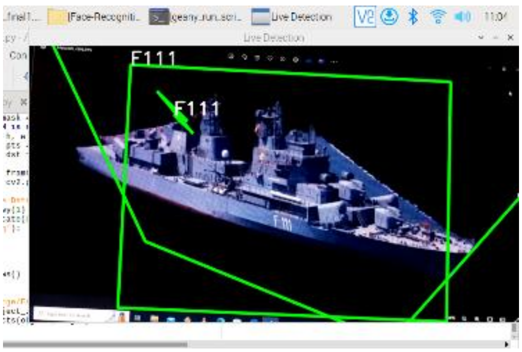

Fig. 9 – Ship detection – 1

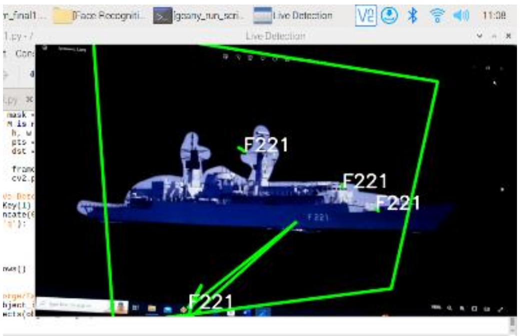

Fig. 10 – Ship detection – 2

Fig. 11 – Ship detection – 3

Fig. 12 - Ship detection – 4

Fig. 13 – Ship detection – 5

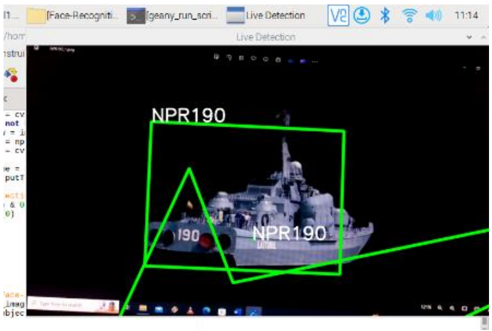

Fig. 14 - Ship detection – 6

Fig. 15 – Buoy detection

The communication of the USV platform with the ship from which it is launched can be done in different ways. The most efficient method is chosen according to the conditions of use and the systems available both on board the ship and on the platform. In the general case, the connection can be made in the following ways:

- **Radio Frequency (RF)**. Line-of-Sight (LoS) communication is the most common way of linking the ship to the platform. High frequency radio waves are used to transmit data. Control commands, telemetry data and real-time response are included. The communication distance is limited to the skyline but can be extended with the use of high antennas or communication relays.
- **Satellites** are used for longer distances. In this case it is possible to control and monitor the USV platform from a very long distance, including from the shore. It is a more expensive method but can provide global coverage.
- **Wi-Fi and Bluetooth**. For short distance (port) operations, Wi=Fi can be used for fast communications. Bluetooth is used for very short communications, more specifically for initial setup or diagnosing possible problems.
- **Communications protocols and security**. Standardized communication protocols are used to ensure compatible and efficient communications. These include TCP/IP, UDP or other protocols specific to autonomous vehicles. In terms of security, communication must be encrypted and secured to prevent unauthorized access. High-level encryption and two-way authentication are therefore used.[14]

4. Conclusions

As a conclusion, the development of a video reconnaissance concept, implemented on a USV platform contributes considerably to the optimal conduct of military operations of the Romanian Naval Forces ships. Currently, the development of weapon systems and the evolution of combat methods, both passive and active, also involve the military field in a continuous development which puts a significant emphasis on artificial intelligence and the implementation of systems based on these modern concepts. In this sense, it can be appreciated that change in the field of technology is a common term which has behind designed, tested and implemented with the aim of facilitating military operations, in this case.

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