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A Machine Learning Approach to Enhance Real-Time Harbor Management

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Abstract—Fisheries industry is a vital sector of Sri Lanka's economy and each departing and arriving fishing vessel should have gone through ample security check by the harbor authorities. But with the COVID 19 pandemic and social distancing procedure, harbor authorities are facing difficulties detecting and recognizing fishing vessels by getting on the boats as usual. Also, currently harbors are using a paper-based system for recording the information on boat departures and arrivals. This leads to the inefficiency of harbor management process, delays in rescue missions and failures of security missions. To solve these problems, this paper introduces a Boat Recognition and Automated Harbor Management System (BRAHMS) which is based on YOLO v5 algorithm. In this research, a novel de-skewing method is discovered for the slanted license plate recognition process. The de-skewing process aims for three main approaches: auto de-skewing, manual de-skewing and a hybrid de-skewing which uses both auto and manual processes together.

Keywords— Boat Recognition, License Plate De-skewing, License Plate Recognition, YOLOv5

I. Introduction

BEING a nation in an island, fisheries sector plays an significant part in Sri Lanka's economy. The fishery industry contains of three sub sectors as coastal, offshore/deep-sea and inland. This fisheries sector provides over 250000 employments to fishermen and over 100000 supporting facilities [1]. And it funds 1.2% to the country's Gross Domestic Production (GDP).

Over thousands of fishing vessels are lounged to the ocean within a day for fishing purpose. These fishing vessels are range in size from small Dinghies to large Multiday Fishing Vessels. Those are lounging to the sea through a harbor where the departure and arrival of fishing vessels are going through an ample security check by the harbor authorities one by one.

But with the COVID 19 pandemic, harbor authorities are facing difficulties detecting and recognizing fishing vessels arriving and departing the harbor due to social distancing and virus spreading issue. So, authorities are unable to get on the boat and perform the recognition process as they have been done before the pandemic situation. Therefore, a solution must be given to detect and recognize the boats with maintaining the social distancing.

The boat detection and classification system, specially designed for Sri Lanka Navy, solves the above problem. With this system, fishing boats detect from far away and recognize their identities. Detecting and classification is done through image processing.

Recognizing the boat by the shape is done using YOLO which the name implies "You Only Look Once". Handling images with YOLO is simple and direct. The input image splits into a lattice of cells, and cells are accountable for calculating bounding boxes that enclose an object. Instead of choosing specific parts of an image, YOLO algorithm predicts classes and bounding boxes in one go.

II. Literature Review

Shipping industry is developing rapidly with the technology. Much research is lounged related to automated port management.

A. Intelligent ship image/video detection and classification with RDCNN

One application of this area is intelligent ship image/video detection and classification with improved Regressive Deep Convolutional Neural Network [2]. They are presenting a RDCNN network to attain the ship image/ video detection and classification task. They have experimented on seven types of ships with the detection and classification task with a self-build

dataset. This method is able to detect ships in real time approach and could solve the problem of low recognition rate. Although they are able to develop an accurate and efficient method, this can be executed on small datasets.

B. Ship Classification using Image Dataset

Another research related to this area is Ship Classification using Image Dataset [3]. In this research they have developed an algorithm to classify ships based on RGB color scheme of the image. This algorithm consists of three sets of classification approaches: bag offeatures, convolutional neural networks (CNNs), and SVM along with some preprocessing. The input is a ship image in RGB color format, and the output is the category of the given ship belongs. Although this algorithm provides better performance with CNN, other two methods are underperforming due to lack of datasets.

C. N-YOLO Approach

N-YOLO approach is another research done for ship detection [3]. N-YOLO is a method that uses a noise level classifier, a synthetic aperture radar target potential area extraction module, and a detection module based on YOLOv5. The image of the possible target area is combined with the original photograph in this method. Then it produces an image with a bright target and less noise. Then the image is sent to YOLOv5 for recognition purpose. Although this method provides a better detection performance, it partially damages the information of ship edge.

D. A Robust Real-Time Automatic License Plate Recognition Based on the YOLO Detector

This research has presented a real-time license plate recognition using Convolutional Neural Networks (CNN) using YOLO object detection technology [4]. They have trained a network for automatic license plate recognition for each stage of the recognition process but for the character recognition stage have used two separate CNNs for letter recognition and number recognition. A public dataset has been used for the training purpose, including approximately 4500 annotated images from 150 vehicles. The positive side of this research is that it can achieve 93.53% accuracy. But for the downside, the output delays due to the bottleneck occur in character segmentation and recognition stages.

III. Novel Approach on Boat Detection and Harbor Management

A. Input

For this research, I have captured images and video footage of fishing vessels under around 75 percent of training data and around 25 percent of validating data. Then the trained images are used for the license plate recognition process.

B. Output

The main output of this research is the information of the detected fishing vessels. This output is used by the harbor authorities for their daily functionalities and security purposes.

C. Process

The process of this system consists of four major modules as registration, boat recognition, search and report module. All the fishing vessels and fishing vessel owners should be registered with the system with reference to the related port location. Respective information is stored in the database. Fishing vessel detection and recognition is executed using special methods and tools. The detected license plate numbers of the fishing vessels are matched with the stored license plate numbers in the database and retrieve requested information with reference to the given fishing vessel. In the search module, any information can be retrieved as boat name wise, boat owner wise, port wise, etc. In the boat information report module, the retrieved information is displayed as a report and circulates among authorized parties.

D. Users

The users of the implemented system are Sri Lanka Navy, harbor authorities, defense authorities and researchers interested in this research area.

E. Features

The most important module of this research is the boat detection process. Unlike regular license plates of the other vehicles, fishing vessels' license plates are placed as skewed and cannot be detected by ordinary license plate recognition algorithms. Therefore, I have researched and developed a method for detecting the slanted license plates of the fishing vessels. In this method, first the cropped license plate should go through a de-skewing process and there it will deskew the image. Then the detecting algorithm can read the fishing vessel's license plate. The findings of this research will be beneficial for all the future researchers in their research studies.

IV. Rsearch design

The harbor authorities are using a paper based, manual system for the fishing vessel management purpose. That leads to lots of inconsistencies, redundancies and so many delays on certain tasks. Therefore, an automated harbor management system will be a worthy solution.

The system consists of four main modules as follows.

1) Boat Registration Module
2) Boat Recognition Module
3) Boat Information Search Module
4) Boat Information Report Module

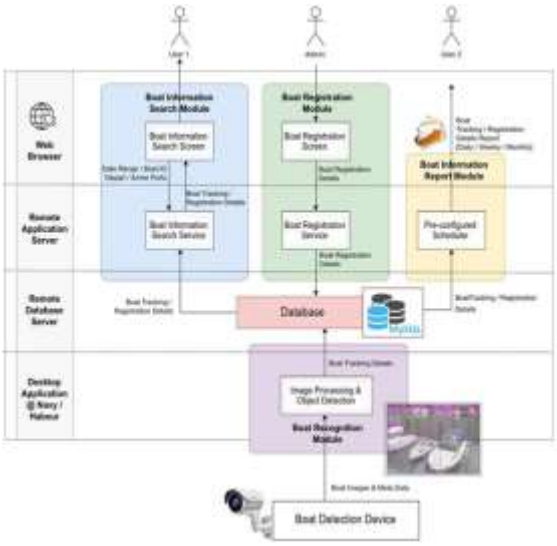

Figure 1: Module Diagram

A. Boat Registration Module

In this module, initial information relevant to the boat and the boat owner should be entered.

B. Boat Recognition Module

Recognizing the boat is done using the YOLO algorithm which the name implies "You Only Look Once". All the fishing vessels have a unique vessel registration number which is placed two sides of the boat, back and the top of the cabin. Using the YOLO algorithm, this license plate will be detected and cropped then read it using character recognition.

C. Boat Information Search Module

In this module, users can search boat tracking details and boat registration details by entering data such as Date/Time range, arrival port information, arrival time, departure time etc.

D. Boat Information Report Module

In this module, boat tracking information report is emailed to predefined set of e-mail addresses. This is done using a preconfigured scheduler. The report can be generated for a specific time interval such as daily, monthly, weekly or annually.

E. Database Structure

A centralized remote database is used to share the data with all four modules. Data updated to the remote database from Boat Registration Module and Boat Recognition Module together. Data consumed from remote database by Boat Information Search Module and Boat Information Report Module.

V. Implementation

A. Dataset Creation

For this research, I generated my own fishing vessel dataset by manually capturing over hundred images and video frames from the Negombo boatyard. It is recommended that users train with over 1500 images per class and over 10,000 instances per class to achieve a robust YOLOv5 model. It is also advised to include up to 10% background images to reduce false-positive errors.

Figure V-1: Captured Fishing Vessel Images

B. Labeling Dataset

To train models, first need to label and annotate the image dataset. Inside the training data, need to separate images and labels. Before training the dataset need to classify them with specific labels. First should insert the label name, then draw bounding boxes around the sequence and select the relevant label. After finishing labeling the images, then should export those labeled images in YOLO format inside the labels folder. Validation dataset should also have gone through the same labeling procedure. For the training purpose, Google Colab has been used. Labeled dataset then uploaded to this platform and specify the class name. Trained the dataset with three epoch times. Epoch time is the number of iterations the training dataset passed through [5]. Labeled images are directly saved in YOLO format. One of the advantages in this YOLO format is we don't need to resize any image in the dataset, and we can annotate images of any size. YOLO takes care of image size when training.

Figure 2: Labeled dataset

After training the labeled images, it generates a predicted dataset as follows with the confidence level. Predicted bounding boxes as appeared here.

Figure 3: Predicted Dataset

C. Capturing License Plate

In the boat recognition phase, the recognition is mainly processed through identifying the license plate of the fishing vessel. The code for capturing license plate area is as follows.

python3 detect.py --weights last.pt --img 640 --conf 0.25 --source data/videos/20220512_115353.mp4 --save-crop

Here, "detect.py" is a file which comes along with YOLOv5. It is the runnable file to access the input data. The input data can be from a real-time video stream or from a live CCTV footage. "--weights last.pt" is an argument which acts as the intelligence in the detecting process. "--img 640" is the default image size in pixels. "--conf 0.25" is the confidence level which is used to detect the labels. "--save-crop" argument used to save the cropped images of the license plates in the device. But this was done only for demonstration purposes. This argument has to be removed when deploying the system in a real environment since these saved images can consume a lot of space inside the device.

D. License Plate recognition

The most important component of the system is to identify the fishing vessel by its license plate. Recognition of the license plate is done using PyTesseract library.

E. Image to Text Reader

Input file is the fishing vessel image which was given previously for this class. Wait time is allocated 10ms for the demonstration purpose. But in the actual system wait time is not given for the sake of the efficiency of the system.

Here the retrieved text will be filtered further to remove new lines, un-recognized symbols which may lead to system malfunctions. "filterText" parameter should always keep true to ignore symbols which are not letters and numbers. [^A-Za-z0-9]. So it will remove all the unwanted characters which are not playing an important role in the recognition process.

Text will be detected by the "img2char" command. It converts the image into a string value.

img2char = pytesseract.image_to_string(image)

To display the retrieved text on the image, "putTextOnImage" method is utilized. The text will appear on top of the image. But this is utilized only for the demonstration purpose. When the system is processing in real time in order to reduce the execution time and increase the efficiency, this code segment can be omitted.

This method of converting an image to a text only works for perfectly aligned standard license plates. But if the image is slanted, skewed, blurred or handwritten, the above method cannot be successful in the license plate recognition process.

F. De-skewing the License Plate

The registration number or the license plate of the fishing vessel is not aligned horizontally when we look at the fishing vessel from the front. It is skewed a little.

Figure 4: Skewed License Plate of the Fishing Vessel

In order to read the license plate, first need to deskew the image horizontally. Because when the text is in the angle shape, the text cannot be detected. This is the most challenging component of the research.

De-skewing of the license plate comes with three approaches for different scenarios.

1) Auto De-skewing
2) Manual De-skewing
3) Auto and Manual De-skewing

G. Auto De-skewing

This is the first approach I have tried for the de-skewing process of the license plate. This approach first draws a minimum area of the rectangle around the region of interest. The bounding rectangle is drawn around the minimum area. In my research the minimum area rectangle is drawn around the skewed license plate. Then the skewed rectangle should bring on to the normal bounding rectangle as follows.

Figure 5: Minimum Area Rectangle and Normal Bounding Rectangle

This process is executed using OpenCV. Minimum area rotated rectangle can be detected using the following function

of OpenCV.

cv2.minAreaRect()

It will return the following information of the minimum area rotated rectangle.

(center(x, y), (width, height), angle of rotation)

To find the four points of the rectangle it uses cv2.boxPoints() function and return the four corner points. Based on that, it will easily draw the rectangle around the skewed license plate as displayed above. The four points are numbered clockwise from 0 to 3. The rotating angle is derived from cv2.minAreaRect() function and it results the angle between the horizontal line and the skewed line which joins the starting and end point of the rotated rectangle.

Figure 6: Angle of Rotation

By this function it finds out the angle of rotation and deskew the slanted license plate into the horizontal line. Now the PyTessarcat is able to convert the image into a text.

The downside of the auto deskew method is that, if the cropped license plate is not clear enough or cropped license plate area is consistent with other background images such as part of the boat name, the function confuses which object is to be rotated. Therefore, it will not result the accurate angle to be rotated horizontally. To use the auto deskew, the area of the cropped license plate should be clear. But that is not always practical with Sri Lankan fishing vessels. Therefore, in this research I have used another advanced method for the deskew process called manual deskew.

H. Manual De-skewing

The license plate's cropped image should be deskewed to accurately detect the text. As mentioned above, in some cases for the system, it is difficult to find out the angle of rotation of the skewed license plate if the cropped area is consistent with other details like part of the boat body, extra paintings etc. So, in this method, the image will be rotated in both directions one degree by degree up to 20 degrees until the system is capable of correctly spot the text of the registration plate. In each of the rotation it will go through the text detection procedure. Once the text is detected, it will be checked for successful match against the registered license plates that is retrieved from the database (boat_meta_data). These registered boat license plates were added to the data base at the boat registration module.

So, once the correct match found it will stop rotating further. The recognized license plate text will be saved in the boat_tracking_info with the time and port details. Then it will continue to next frame of the input source to detect further license plates and recognize its contents.

Image is rotated by rotateImageAndIdentifyPlate() method and the maximum angle for rotation is given as 20 degrees at maxAngle parameter. Once the license plate is identified the rotation stops.

Although this process produces high detection ratio and high accurate results, it consumes more time because the image needs to be examined in each and every degree value until it aligns horizontally.

I. Auto and Manual De-skewing

This method is a hybrid version of both auto de-skewing and manual de-skewing. Here, If the license plate is not recognized by Auto Deskew, then proceed with Manual Deskew. This is a balanced method when compared to previous execution modes since it provides accurate results and speedy results.

J. Preprocessing

At the preprocessing stage of the input images first the brightness and contrast levels are controlled. It removes the background. Here everything will be changed to white where pixel is not black. Then the cropped license plate is converted to grayscale. Then the grayscale image is inverted. So, it converts into a negative image using bitwise not. I have implemented this preprocessing step because generally detection is successful if the background is black and the text is white. At this point it will detect the angle of the cropped license plate and then rotate the image horizontally as discussed above.

K. Boat Registration Module

Boat details and boat owner details are inserted to the database using a User Interface. License plate number, Boat name, Boat type, NIC number of the boat owner and the Port ID should insert from this UI. When trying to enter the NIC number of the boat owner, it will automatically display all the owners already registered with the system. If the respective boat owner is a not in the existing list, then with the New Owner function, we can add a new owner.

New owners should submit following details.

1) NIC Number
2) Owner Name
3) Owner Address
4) Owner Contact Number
5) Registered Port ID

When trying to add the Port ID details, it will automatically display all the registered ports and the user must select the relevant port from the appeared list. If the necessary port is unavailable with the given list, then the user must add the port details from the New Port function.

L. Boat Information Search Module

The information regarding the departed fishing vessels can be retrieved using this module. Information can be retrieved using following labels.

1) Boat name

2) Boat type
3) License plate number
4) Port name
5) Port city
6) Owner name
7) Date period

Search results will be displayed under the information search table when the user start inserting the relevant label.

M. Boat Information Report Module

In this module, boat tracking information report is e-mailed to predefined set of e-mail addresses. This is done using a preconfigured scheduler. The report can be generated for a specific time interval such as daily, monthly, weekly or annually.

Better if you can include the results

VI. Evaluation

With better effectiveness, better performance may be automatically generated. To measure the performance of the system, a Confusion matrix can be used. The confusion matrix is a simple methodology to represent how many expected categories or classes were productively anticipated vs how many were incorrectly guessed [6]. It is used to determine the number of classes that were precisely forecasted as their real class using the outputs of a predictive model with a class outcome.

Figure 7: Resulted Confusion Matrix

After implementing the system, I was able to achieve approximately 90% of confident level.

Figure 8: Confident Level

VII. Conclusion and Future Work

Harbor authorities are currently using a manual, paper-based system for recording the information on fishing vessel management like boat departures, arrivals and other tasks. That leads to lots of inconsistencies, redundancies and so many delays on certain tasks. Therefore, an automated harbor management system will be a worthy solution. Boat Recognition and Harbor Management System (BRAHMS) is consisting of four main modules as Boat Registration Module, Boat Recognition Module, Boat Information Search Module and Boat Information Report Module.

Boat recognition process executed by license plate recognition techniques. To recognize the regions of interest of license plate within an image, YOLO v5 is used. Then OpenCV and Tesseract to go in pre-process the image and extract the license plate number from the image itself.

In this system, I have implemented a novel de-skewing method for the slanted license plate recognition process.

A. Limitations

The quality of the input images is directly dependent on the quality of the capturing device. For the current system I have used a 4K resolution camera. But for high accuracy, a capturing device with high FPS could be used for the research. Also, satisfactory data set was not found therefore must manually capture the input images and implement the system.

With reference to the lack of GPU and the hardware limitation of the device, there can be limitations of thread pool execution.

B. Future Work

In this system distorted license plates are not able to recognize. There can be damaged license plates and plates with un-formalized hand writings. So, in the future, I'm planning to enhance the system to read those types of license plates using deep learning algorithms too.

Since I could not get fishing vessel images which are in far way in the open sea, I could not demonstrate the license plate recognition for such boats. I'm planning to generate that recognition procedure with two approaches. Since the boat is in far, direct license plate recognition is difficult. So first need to detect the boat by its shape, then zoom it and crop the license plate. Then can proceed with the normal recognition

process.

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