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FACULTAD DE INGENIERÍA PRODUCCIÓN Y SERVICIOS

ESCUELA PROFESIONAL DE INGENIERÍA DE SISTEMAS

NEW APPROACHES AND TOOLS FOR SHIP DETECTION IN OPTICAL SATELLITE IMAGERY

Tesis Formato Artículo presentado por:
AARON WALTER AVILA CORDOVA

Para optar el Título Profesional de:
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Asesor:
Mg. Eveling Gloria Castro Gutierrez.

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DEDICATORIA

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Mgter. Eveling Gloria Castro Gutierrez

RESUMEN

La detección de barcos usando imágenes satelitales ópticas es una tarea muy importante para el campo de la seguridad marítima, ya sea en la búsqueda de embarcaciones perdidas o en el control marítimo de tipo comercial o militar. A esto se suman los avances en el campo de visión por computador, especialmente en el uso de modelos basados en inteligencia artificial, los cuales, permiten construir sistemas de detección robustos y más precisos. Sin embargo, los escenarios geográficos, propios de una imagen satelital, limitan el desarrollo de este tipo de sistemas ya que requieren de la disponibilidad de un gran número de imágenes en diferentes escenarios. En el presente trabajo se propone un nuevo enfoque para la Detección de Barcos utilizando dos nuevos conjuntos de datos etiquetados con cuadros delimitadores horizontales. Así mismo, se presenta una nueva herramienta de etiquetado (DATATOOL) que permite una mejor organización y distribución de los datos. Los nuevos conjuntos de datos, Peruvian Ship Dataset (PSDS) y Mini Ship Dataset (MSDS), han sido generados a partir de imágenes satelitales ópticas obtenidas de diferentes fuentes. El PSDS se crea a partir de 22 imágenes satelitales del PERUSAT-1 cuya resolución espacial es de 0.7m. Mientras que el MSDS ha sido generado utilizando imágenes satelitales provenientes de Google Earth dando un total de 1006 imágenes de 900x900 pixels. Las embarcaciones se encuentran tanto en el mar como en la costa. Finalmente se presentan los resultados de las pruebas utilizando algoritmos de aprendizaje profundo como YOLOv4 y YOLT, siguiendo el enfoque y las herramientas propuestas.

Keywords: Annotation tool, Dataset, Deep learning, Remote sensing, Ship detection

ABSTRACT

Ship detection using optical satellite images is a very important task for the field of maritime security, either in search of lost ships or in maritime control of a commercial or military type. Added to this are the advances in the field of Computer Vision, especially in the use of models based on Artificial Intelligence, which allow the construction of robust and more precise detection systems. However, geographic scenarios, typical of a satellite image, limit the development of this type of system since they require the availability of a large number of images in different scenarios. In this paper, a new approach to Ship Detection is proposed using two new data sets labeled with horizontal bounding boxes (HBB). Likewise, a new labeling tool (DATATOOL) is presented that allows better organization and distribution of data. The new data sets, Peruvian Ship Dataset (PSDS) and Mini Ship Dataset (MSDS), have been generated from optical satellite images obtained from different sources. PSDS is created from 22 satellite images of PERUSAT-1 with 0.7m spatial resolution. MSDS has been generated using satellite images from Google Earth giving a total of 1006 images of 900x900 pixels. Ships are found both at sea or inshore. Finally, results of the tests using Deep Learning Algorithms such as YOLT and YOLOv4 are presented, following the approach and the proposed tools.

Keywords: Annotation tool, Dataset, Deep learning, Remote sensing, Ship detection

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Walter Avila Cordova, A., Condori Quispe, W., Jorge Cuba Inca, R., Nina Choquehuayta, W., Castro Gutierrez, E.

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New Approaches and Tools for Ship Detection in Optical Satellite Imagery

Aaron Walter Avila Cordova, William Condori Quispe, Remy Jorge Cuba Inca, Wilder Nina Choquehuayta and Eveling Castro Gutierrez

Universidad Nacional de San Agustín de Arequipa, PE Perú

E-mail: aavilac@unsa.edu.pe, wcondoriqu@unsa.edu.pe, rcubai@unsa.edu.pe, wnina@unsa.edu.pe, ecastro@unsa.edu.pe

Abstract. Ship detection using optical satellite images is a very important task for the field of maritime security, either in search of lost ships or in maritime control of a commercial or military type. Added to this are the advances in the field of Computer Vision, especially in the use of models based on Artificial Intelligence, which allow the construction of robust and more precise detection systems. However, geographic scenarios, typical of a satellite image, limit the development of this type of system since they require the availability of a large number of images in different scenarios. In this paper, a new approach to Ship Detection is proposed using two new data sets labeled with horizontal bounding boxes (HBB). Likewise, a new labeling tool (DATATOOL) is presented that allows better organization and distribution of data. The new data sets, Peruvian Ship Dataset (PSDS) and Mini Ship Dataset (MSDS), have been generated from optical satellite images obtained from different sources. PSDS is created from 22 satellite images of PERUSAT-1 with 0.7m spatial resolution, giving a total of 1310 images. MSDS has been generated using Google Earth satellite images, generating 2993 images of 900x900 pixels. Ships are found both at sea or inshore. Finally, results of the tests using Deep Learning Algorithms such as YOLT and YOLOv4 are presented, following the approach and the proposed tools. Resource and source code available at https://gitlab.com/williamccondori/datatool

Keywords: Annotation tool, Dataset, Deep learning, Remote sensing, Ship detection

1. Introduction

Ship detection is an important task for maritime security, its applications include searching for lost ships up to commercial and military control This task is usually performed by Automated Identification Systems (AIS) that use VHF radio frequencies to wirelessly transmit their location, identity and destination to nearby receiving devices on other ships and terrestrial systems [1]. However, such systems can be manually disabled so that the boat cannot be detected. This is where the use of satellite images becomes very important, as observation satellites constantly collect information from the Earth's surface. In recent years, studies related to object detection in satellite images have been increasing thanks to advances in the field of artificial intelligence, remote sensing and large-scale data processing. [2]. However, there are some limitations on the availability of data to perform this type of task. There are also some factors that can affect the detection results, such as the presence of complex textures formed by elements outside the object, the high presence of clouds and the quality of the images. Works based on machine learning and deep learning seek to solve these types of problems.

However, a large amount of data is required for these algorithms to function properly. It is for this reason that in this article we present two new approaches and tools for the detection of ships in satellite images. First, we perform an analysis of the most widely used data sets, differentiating those composed of natural scene images and those composed of satellite or aerial images. We also did a comparative analysis of the different image labeling tools, highlighting the features and benefits they offer. Secondly, we present two new data sets: Peruvian Ship Dataset (PSDS), Mini Ship Dataset (MSDS), which were built in order to contribute to research in the detection of ships. In addition, a new labeling tool is presented, which was called the Dataset Annotation Tool (DATATOOL), which was used for the labeling of ships present in MSDS. Finally, the detection tests are performed using YOLT [3] and YOLOv4 [4] deep learning algorithms. The training of these algorithms was performed using the datasets proposed in this work. Conclusions and future work are described in the final section of the document.

2. Related work

2.1. Natural Scene Image Dataset

Currently there are different deep learning models designed to work with classification, detection and segmentation tasks, which require large data sets, created specifically for each type of task. Data sets [5] have played a key role throughout the history of object recognition research, not just as common ground to measure and compare the performance of competing algorithms, but also to push the field toward increasingly complex and challenging problems. Recently, deep learning techniques have brought enormous success to many visual recognition problems, and it is the large amounts of annotating data that play a key role in their success. Access to a large number of images on the Internet allows the construction of complete data sets to capture a great richness and diversity of objects, allowing unprecedented performance in object recognition. Four of the most famous datasets focused on generic object detection are PASCAL VOC [6, 7], ImageNet [8], MS COCO [9] and Open Images [10].

2.2. Satellite and Aerial Imagery Dataset

Within the Remote Sensing field, different data sets are also used for classification, detection and segmentation tasks, but unlike natural scene image data sets, satellite and aerial image data sets are used.

Over the past few decades, several satellite and aerial image datasets for object detection have released [11], including TAS [12], SZTAKI-INRIA [13], NWPU VHR-10 [14] [15], VEDAI [16], UCAS-OD [17], DLR 3K Vehicle [18], HRSC2016 [19], RSOD [20], DOTA [21] and xView [22]. Table 1 shows a summary of the mentioned datasets and their main characteristics.

Table 1. Aerial and satellite image data sets. Adapted table[11].

Name	# Categories	# Images	# Objects	Image width	Annotation type	Year
TAS	1	30	1319	792	Horizontal BB	2008
SZTAKI-INRIA	1	9	665	~ 800	Oriented BB	2012
NWPU VHR-10	10	800	3775	~ 1000	Horizontal BB	2014
VEDAI	9	1210	3640	1024	Oriented BB	2015
UCAS-AOD	2	910	6029	1280	Horizontal BB	2015
DLR 3K Vehicle	2	20	14235	5616	Oriented BB	2015
HRSC2016	1	1070	2976	~ 1000	Oriented BB	2016
RSOD	4	976	6950	~ 1000	Oriented BB	2017
DOTA	15	2806	188282	800 - 4000	Oriented BB	2017
DIOR	20	23463	192472	800	Horizontal BB	2018
xVIEW	60	-	100000	-	Horizontal BB	2018

Table 2 shows only datasets focused on ship detection, as these are included in whole or in part.

Table 2. Data sets for ship detection. Own table.

Name	Only ship?	Annotation type	Classes	# Objects	# Images	Average image size
DOTA [21]	No	Oriented BB	No ship: small vehicle, large vehicle, plane, swimming pool, storage tank, harbor, tennis court, bridge, roundabout, helicopter, baseball diamond, soccer ball field, ground track field, basketball court (14) Ship (1)	144546 43736	2806	4000 x 4000
AIRBUS [23]	Yes	Horizontal BB	Ship	81723	192556	768 x 768
HRSC2016 [19]	Yes	Oriented BB	Ship	2976	1070	1048 x 770
Kaggle San Francisco [24]	Yes	Horizontal BB	Ship	3000	4000	80 x 80
Masati [25]	No	Horizontal BB	No ship: sea, land, coast (3) Ship: Ship, Multi, Coast and ship (3)	3099 3113	5386	512 x 512

Like the datasets shown in Table 2, the proposed datasets are focused on ship detection, but with images taken mainly from the Peruvian coast. In addition to showing various scenarios of the Peruvian sea and coast, the images are unique in size, making them easy to use for various research cases.

2.3. Tools

There are many tools developed for image annotation in recent years, one of them is LabelMe [26], this web-based tool is designed for object class recognition instead of instance recognition, in addition to run on many platforms and allow instant sharing of collected data. Another tool designed for image annotation is VIA [27], this software allows defining and describing spatial regions in images or video frames, also allowing collaborative annotation. ImageTagger [28] is a tool focused on creating and exchanging large image data sets online. V-RSIR [29] is another web-based tool that allows volunteers to participate in the generation of new data sets, providing tools for editing, labeling and trimming remote sensing images. In [30] introduces GTCreator, which in addition to offering fast and accurate annotations, also offers editing and collaboration capabilities among annotators, to speed up annotation processes on large data sets. Other existing image annotation tools are LabelImg [31], Annotation Tool [19], Lionbridge AI.

Table 3 shows a comparison between other more common labeling tools and the one proposed.

Table 3. Labeling tools. Own table

Tool	Online	Open source	Label type (shapes)	Export format	I. Upload	I. Management	I. Distribution
LabelMe	X	X	polygon	XML	X	X	
VIA	X	X	multiple	JSON, CSV	X		
ImageTagger	X	X	multiple	User defined	X	X	
V-RSIR	X	X	multiple	User defined		X	
LabelImg		X	polygon	PASCAL, VOC			
GTCreator	X	X	polygon	Binary, CSV	X	X	
Lionbridge AI	X		multiple	Unknown	X	X	
DATATOOL		X	rectangle	PASCAL, YOLO, JSON	X	X	X

Despite not working online, the proposed tool, DATATOOL, offers various features that make it easy to manage and create a new data set, with tools such as cropping or editing the image to improve the quality of annotations and the administrator of classes and places. Other improvements over other tools are the ease and time of exporting the datasets for evaluation with various models such as YOLO or PASCAL.

3. Dataset Annotation Tool

Dataset Annotation Tool (DATATOOL) is a multiplatform image tagging tool, which has been developed in order to provide better organization and distribution of images during the process of creating a dataset. One of the most important features of DATATOOL is the possibility of creating workspaces for organized information management, from the creation of labels to the distribution of data. The correct process for creating a dataset is detailed in Figure 1.

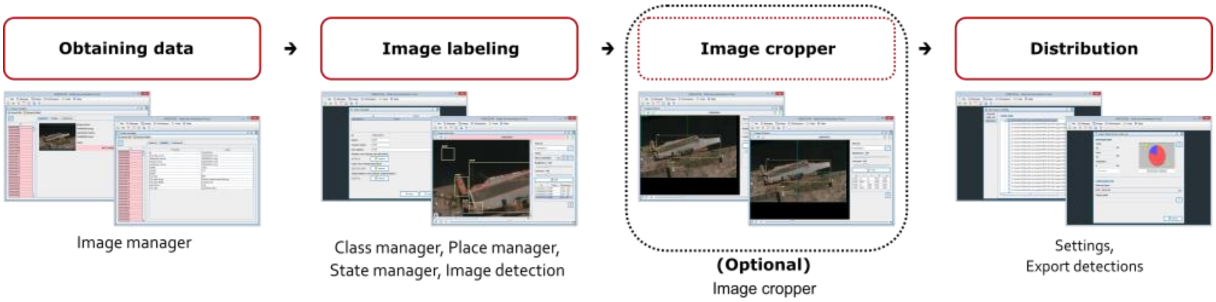

Figure 1. Process to create a new dataset using Dataset Annotation Tool.

The tool creates directories for each workspace and they store the information necessary for the construction of the data set. This information is divided into three components: the images, the labels and the configuration file, the latter being the most important, since it contains the configuration of each workspace and the disk location of each element.

DATATOOL is made up of a workspace manager, an image manager, a data manager (classes, places and states). In addition, it includes a window for tagging images and a cropper for already tagged images (See Figure 2). Added to this is the export capacity (PASCAL VOC, YOLO) and data distribution (training, evaluation and testing).

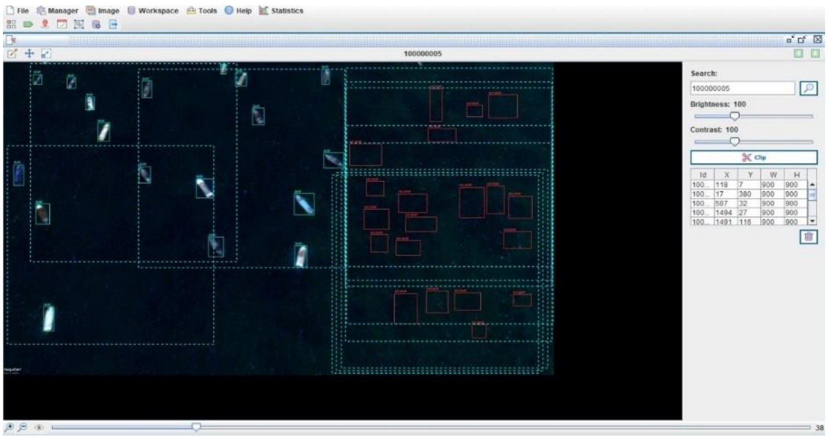

Figure 2. Image cropper (DATATOOL).

4. Datasets

An adequate dataset to perform ship detection tasks using satellite images must be made up of a large number of samples and instances, in this case, ships. Likewise, the quality of the labels and annotations determine the reliability of the results obtained by the detection model. The coordinates must faithfully represent the correct location of the ship within the image.

The proposed datasets are Peruvian Ship Dataset (PSDS) and Mini Ship Dataset (MSDS), both generated with images of the Peruvian coast. Table 4 shows a summary of the main characteristics of both, and the generation processes of each one is detailed in more detail below.

Table 4. Characteristics of proposed data sets. Own table

Dataset	Annotation direction	Class	Number of instances	Number of images	Average image size (in pix.)
MSDS 900x900	BB Horizontal	Ship	4710	2993	100 %: 900x900
Full MSDS	BB Horizontal	Ship	4070	200	62 %: 2400 x 1422 38 %: 4800 x 2705
PSDS 900x900	BB Horizontal	Ship	9662	1310	100 %: 900x900

4.1. Peruvian Ship Dataset

In 2016, PERUSAT-1 was the first satellite of a Peruvian public institution to be launched into space, it is an observation satellite, whose temporal resolution is 26 days, with an optical observation of the earth and a sweep width of 14.5km; it is operated by the National Center for Operations of Satellite Images (CNOIS) - CONIDA [32]. The images it provides are of two types, a high-resolution panchromatic that can reach 0.7 meters per pixel, and a 4-band multispectral: red, green, blue, and near infrared, which can reach 2.8 meters per pixel.

One of the sectors most benefited by the images provided by the satellite is that of research, due to this and the lack of a dataset of ships from the Peruvian coast, the Peruvian Ship Dataset (PSDS) is presented. PSDS is a dataset made up of 1,310 elements that correspond to aerial shots of the Peruvian coast. The process by which this data set was constructed is shown in Figure 3.

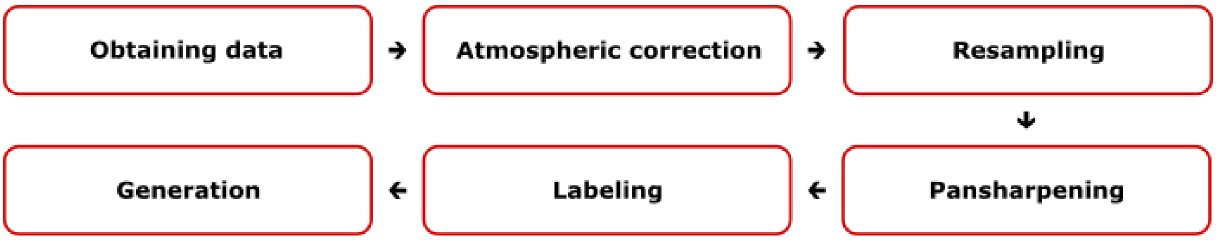

Figure 3. Process to create PSDS dataset.

The dataset creation process consists of 6 steps, the first is *Obtaining data*, in this step the satellite images are requested from CONIDA (PERU). These images are level 3 and consist of a 0.7m panchromatic image and a 2.3m multispectral image. The next step, Atmospheric Correction, is performed to eliminate atmospheric effects and recover the physical parameters of the Earth's surface, including surface reflectance, ground visibility, and temperature. The third step, Resampling consists of doing a process of upsampling on the multispectral image increasing the number of pixels by 4 to be able to generate a matrix that is the same size as pansharpening to perform matrix operations. Then in step 4, Pansharpening, the image quality is increased by combining the panchromatic band and the multispectral bands. Then, in step Labeling, manual labeling is performed with the QGIS tool, generating the bounding boxes necessary for the creation of the data set. The final step Generation of the final images consists of generating the final clippings of the dataset, this step is shown in the Algorithm 1: we consider a desired width and height, the list of bounding boxes generated in step Labeling and pre-processed image. The algorithm generates boxes that meet the following conditions:

(i)Do not split or cut any bounding box (function GetDataset lin. 7-12)

(ii)The box must contain at least one bounding box (function GenDataset lin. 14-21)

The algorithm ends once all bounding boxes have been covered at least once.

Each of the generated images has a size of 900*px. x* 900*px.*, the resulting dataset presents different scenarios, some of which are shown in Figure 4.

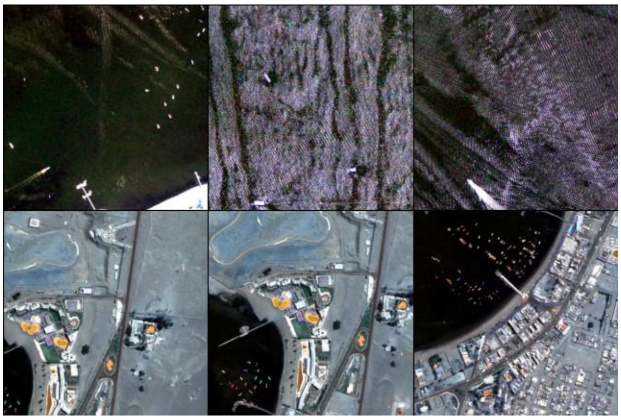

Figure 4. PSDS images

Algorithm 1 Generating dataset images

```
function GenDataset(BoundingBoxes, fileTif, HeightNewCut, WidthNewCut)
    copyBB ← copy(BoundingBoxes)
    cutsReturn ← []
    while copyBB.lenght ≠ 0 do
        newPoint ← GenNewPoint(fileTif,HeightNewCut,WidthNewCut)
        validation ← True
        for bb in BoundingBoxes do
            if not (bb ∉ newPoint or bb ∈ newPoint) then
                validation ← False
                break
            end if
        end for
        count ← 0
        if validation then
            for bb in copyBB do
                if bb ∈ newPoint then
                    copyBB.delete(bb)
                    count ← count + 1
                end if
            end for
        end if
        if count ≠ 0 then
            cutsReturn.add(newPoint)
        end if
    end while
    return cutsReturn
end function
```

4.2. Mini Ship Dataset

Mini Ship Data Set (MSDS) is a dataset created with a small number of images geared for quick testing on known architectures. The creation process was carried out in 3 stages (See Figure 5), the first is Obtaining data, where Google Earth images were extracted using a manual procedure, taking as a starting point the main fishing ports of Peru where the largest number of conglomerations of boats. The stage of Labeling consists of labeling each found ship object, for which first a class called *ship* was created to later perform the labeling of each ship, in this step the DATATOOL tool was used.

Finally in the Generation stage, which is comprised of a Cutting process that consists of defining a window width to obtain another subset of data called MSDS *900x900* as shown in Table 4, and then a process *distribution* that consists of establishing the output formats as the percentages of number of images for the training, validation and evaluation stage. Figure 6 shows example images showing boats near the shore and the sea, with noise and without noise. The Full MSDS dataset consists of 200 images with a resolution of 2400 *x* 1422px and 4800 *x* 2705, and MSDS *900x900* consisting of 2993 images.

Figure 5. Process to create MSDS dataset.

Figure 6. MSDS images

5. Results of object detection techniques

Initial experiments [33] were performed using YOLOv3 and YOLT on MSDS focused on the detection of small objects. Experiments with MSDS using YOLT and YOLOv4 were performed in this paper where a mAP of 69.80% and 93.57% respectively was obtained. Table 5 shows the results of mAP. The data distribution was 2095 (70%), 599 (20%) and 299 (10%) for the training, validation and testing sets respectively. Transfer learning was used to reduce time on different training sessions. Figure 7 shows the loss and accuracy curves of the training and validation set of MSDS and PSDS.

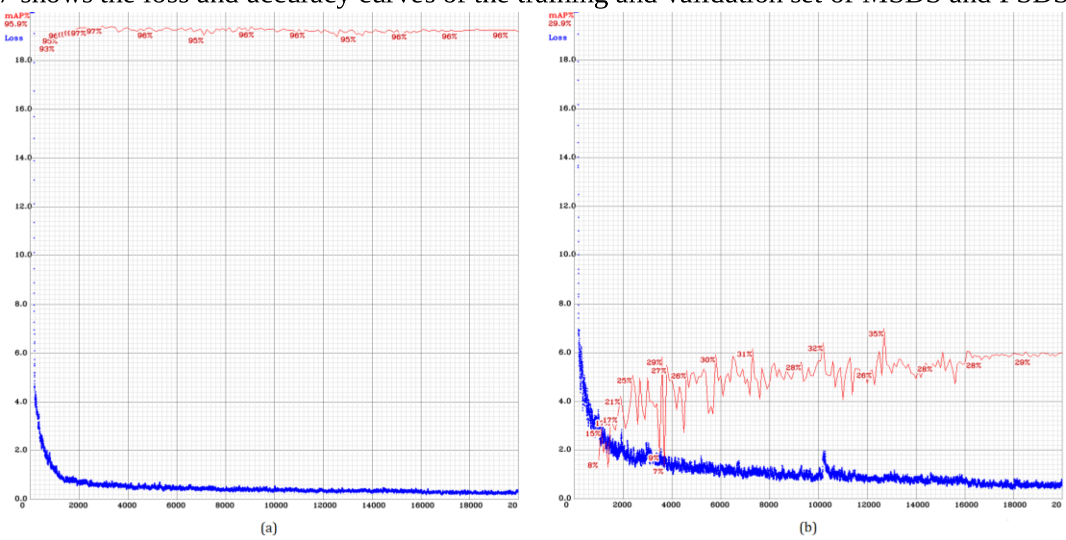

Figure 7. Loss and accuracy curves. (a) MSDS (b) PSDS.

Table 5. Results of mAP of YOLO and YOLT on MSDS.

	YOLT @0.65	YOLOv4 @0.50	YOLOv4@0.65
mAP	69,80%	95.94%	93.57%

We also run tests using the PSDS dataset. The data distribution was 917 (70%), 262 (20%) and 131 (10%) for the training, validation and testing sets respectively. The results obtained are shown in Table 6.

Table 6. Results of mAP of YOLOv4 on PSDS.

	YOLOv4 @0.50	YOLOv4 @0.65
mAP	29.86%	16.60%

Infrastructure for training and testing stage was used a NVIDIA QUADRO P5000 graphics card with 2560 CUDA cores and 16 GB of memory.

6. Conclusions and future work

In the present work, two new approaches were presented for the detection of ships in optical satellite images. Likewise, two new data sets (PSDS and MSDS) and a new labeling tool called DATATOOL for the creation, administration, labeling and distribution of a data set were presented. Detection tests were performed using deep learning models: YOLT and YOLO v4. For the training of these models he used the datasets proposed in this work. We determine, the effectiveness of both approaches that will help the development of research in the detection of ships using optical satellite images.

In the future, we will increase the number of images from the PSDS and MSDS. Orientation data will be added for the detection of oriented ships. In addition, work will be done on developing new functionalities for DATATOOL, adding collaborative work and tagging images in TIFF format.

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Aaron Walter Avila Cordova[1], William Condori Quispe[1], Remy Jorge Cuba Inca[1], Wilder Nina Choquehuayta[1] and Eveling Castro Gutierrez[1]

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