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# CONTRIBUTION TO THE DETECTION OF CYCLONES BY COUPLING THE CONVOLUTIONAL NEURAL NETWORK WITH THE BARYCENTRIC CALCULATION OF AN IMAGE

Pascal Mparany Fenoarisoa Rakotomandrindra
Department of Telecommunication, Automatism, Signal, Image/ Polytechnic University Antananarivo
fenopascarakotomandrindra@gmail.com

Hajasoa Malalatiana Ramafiarisona
Department of Telecommunication, Automatism, Signal, Image, Polytechnic University Antananarivo y mhramafiariso@yahoo.fr

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## Abstract
The material and human losses caused by the passage of a cyclone are becoming increasingly significant for countries located in tropical areas. Under the effect of climate change, we see from the analysis of data published each year that the power of these tropical cyclones multiplies over time. The direct impacts left by the passage of a strong storm, such as flooding, destruction of infrastructure and especially human loss, increase each year. Thus, obtaining prior information on the formation, detection, and prediction of the trajectory of these tropical cyclones plays a crucial role in minimizing the risks of disasters for the population affected. So, to meet this need for information, we will discuss in the context of this study a method of analyzing satellite images using the convolutional neural network algorithm combined with the calculation of the barycenter of an image and that is applied to the detection of a tropical cyclone and its center. This study aims to detect the presence of a cyclone and its center from a meteorological satellite image. The algorithm generally includes five steps: the preprocessing phase, object detection, classification by the convolutional neural network for predicting a cyclone, searching for the eye of the cyclone, and displaying the result.

**Keyword:** Convolutional neural network, Image segmentation, Image classification

## Introduction
Today, tropical cyclones are part of the most destructive natural system on the planet. The human and material losses caused by the passage of a high-intensity cyclone are almost always significant in all cases [1]. Indeed, prior knowledge of information about a tropical cyclone is very practical for alerting the regions that will be affected. Most of these cyclones often form around continents, so remote sensing plays an important role in detecting the formation and predicting the movement path of a cyclone [2]. The convolutional neural networks (CNN) method has successfully analyzed, classified and recognized objects in an image. Thanks to this success, this technique, combined with the method of calculating the barycenter of the image, is used in this study to detect the presence of a cyclone and its eye on a satellite image [3].

### Objectives of the Study

The objectives of this study are based on detecting the presence of a cyclone in a satellite image, locating its eye in relation to the entire image, and being able to trace its trajectory throughout its movement. To achieve these objectives, we will use the convolutional neural network detection technique coupled with the barycentric calculation of the satellite image.

### Formation of cyclones

A tropical cyclone is a natural disaster with enormous destructive force. Generally, cyclones are formed in the tropical zones of the earth because of the temperature of this zone, which is slightly higher compared to the polar zones, and which leads to warm marine currents [4]. Under the effect of climate change, the power of these tropical cyclones is increasingly significant in terms of destruction because the temperature in the tropical zone is experiencing a significant increase, leading to strong depressions. Because of the Coriolis force, the direction of rotation of a cyclone forming in the northern hemisphere follows the counterclockwise direction, while it is in the opposite direction for cyclones that form in the Southern Hemisphere [5].

### Characteristics of the data used

Images taken by meteorological satellites are currently considered the most appropriate first data for detecting a tropical cyclone and analyzing and forecasting its trajectory [6]. As part of this study, we limit ourselves to detecting the existence of a cyclone on a satellite image and finding its eye. To achieve this objective, we then use the object recognition algorithm on an image based on the use of artificial neural networks. Thus, we need a database of images that we call a data set in English, and which are real images of tropical cyclones taken by different types of meteorological satellites in the case of this study. The images which form this data set are then in "jpg" format and have an average size of 350×350 pixels. These are true colour images composed of three RGB bands (Red, Green, Blue) encoded at 24 bits. On average, an image in the data set occupies 50 KB of memory. We used 140 images to form the data set, which we divided in two according to an unequal proportion and which we could adjust to have better classification accuracy.
Figure 4.1 below shows an example of a tropical cyclone image from the dataset used in this study.

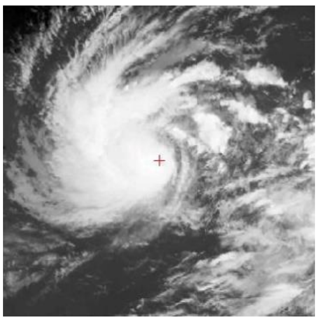


Figure 1: Example of satellite image used in the dataset

For the images to be classified, EUMETSAT satellite images were used for the images to be classified. These are "jpg" format images, true color and composed of three RGB bands. These images are cut out during processing to save time during program execution.

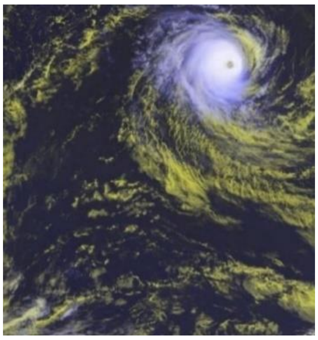


Figure 2: Example of satellite image to be classified

**Methodology**

The methodology used in this study is based on the recognition of objects through the convolutional neural network or CNN (Convolutional Neural Network) algorithm, and then the calculation of the barycenter of the image is applied to detect the eye of the storm. The CNN algorithm just makes it possible to predict the existence of a cyclone in the satellite image to be analyzed. But before going into this algorithm, we must segment the image into several objects, and each detected object is classified with the CNN to predict whether it is a cyclone or not. If an object is classified as a cyclone, the method of calculating the barycenter of the image allows us to locate the eye of the cyclone. This methodology can be divided into four steps:

- Pretreatment
- Image segmentation
- Classification
- Location of the eye

**Pretreatment**

Preprocessing consists of converting the true RGB color image to grayscale. Remember that for an RGB image, each pixel of the image is defined by three values and each value itself is between 0 and 255. While for a gray level image, each pixel has only one value between 0 and 255 [7]. To convert an RGB image to a gray-level image, we apply the following relationship to each pixel of the image:

$$P = 0.299 * R + 0.587 * G + 0.114 * B \qquad (1)$$

P: pixel value of the image in grey level
R: value of the image pixel associated with the red band
G: value of the image pixel associated with the green band
B: value of the image pixel associated with the blue band

The coefficients in front of R, G and B are coefficients coming from the difference in luminance between the red, green and blue bands.

**Image segmentation**

During this segmentation, we detect the contours of the objects present in the image. These contours are determined from the predefined filters present in the contour detection algorithms, and in this study, we used the “Canny” filter to detect the contours. Then, we segment the image from the contours detected when using the filters, which leads us to obtain objects we save separately in image files.

**Classification**

During this phase, the objects recorded in image format during the segmentation step will pass one by one into the convolutional neural network algorithm to be classified as a cyclone or not. In the case of this experimental study, we only have two classes for classification: the object is either a cyclone or not a cyclone. To do this, the algorithm will learn on 70% of the images in the database (we set the learning parameter to 0.3). The remaining 30% of the image is used for the test, which means that the learning thus obtained will be tested on the 30% of the image of the data set. We can vary the value of the learning parameter, but it should be noted that the precision of the classification result obtained depends mainly on the value assigned to this learning parameter. The convolutional neural network platform used in this study is ResNet50. It is a neural network platform composed of 50 layers.

**Localization of the eye**

This step makes it possible to identify the cyclones on the image to be classified. If the object is classified as a cyclone after passing through the neural network, it is framed with a red rectangle. Otherwise, it is framed with a green rectangle. However, to correctly position the rectangle on the image, we must first determine the eye of the cyclone and trace the rectangle from the eye, which is considered the center of the rectangle. To detect the eye of the storm, we calculate the barycenter of the image for each object by considering that each pixel is identified by its coordinates (x, y) and is weighted by a weighting coefficient equal to its value. The mathematical model of this calculation is given by relations (2) and (3).

$$B_C = \sum_{j=1}^{N} \sum_{i=1}^{L} \frac{\alpha_{ij} * j}{\alpha_{ij}} \quad (2)$$

$$B_L = \sum_{j=1}^{N} \sum_{i=1}^{L} \frac{\alpha_{ij} * i}{\alpha_{ij}} \quad (3)$$

$B_C$: coordinate of the barycenter following column j
$B_L$: coordinate of the barycenter along line i
L: number of lines in the image
N: number of image columns
$\alpha_{ij}$: value of the pixel located in row i and column j

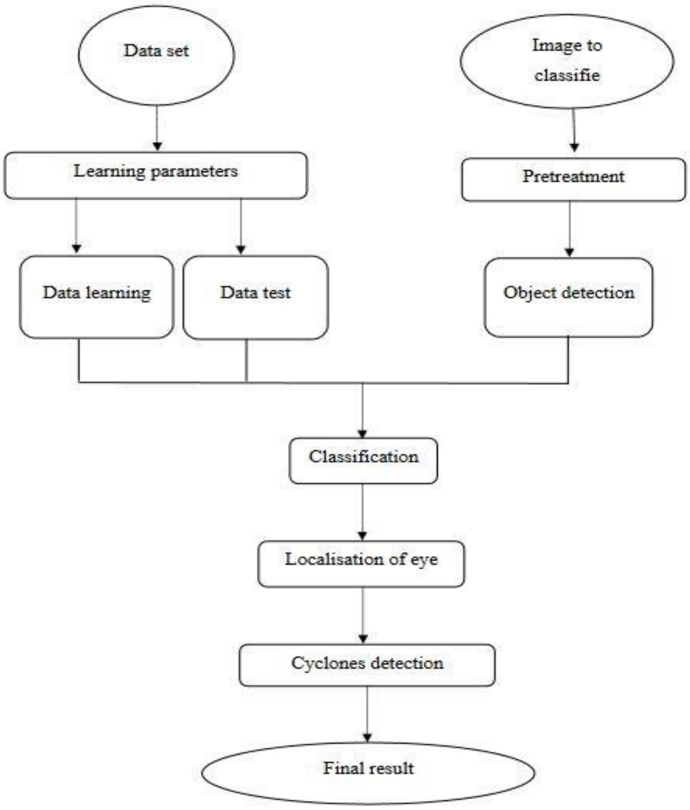
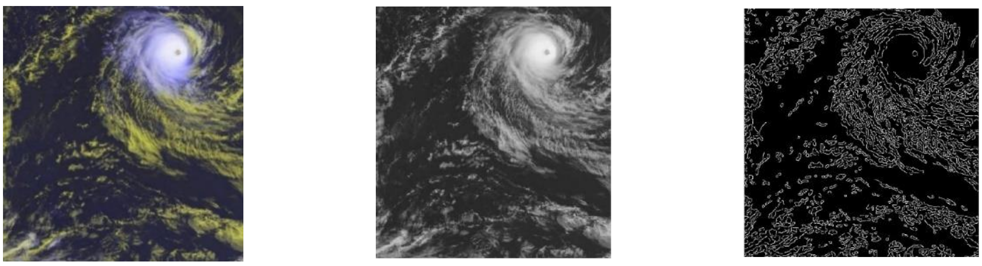



Figure 3: Processing organization

## Results

To highlight the results obtained during this study, we will take a satellite image in "jpg" format of size 582×618, which is part of the scene of a satellite image taken by the EUMETSAT meteorological satellite. We made this division to improve time savings when executing the program. The results of the preprocessing of this satellite image are presented in Figure 4.



(a) (b) (c)

Figure 4: Result of preprocessing

(a): satellite image of a cyclone, true RGB color
(b): image converted to gray level
(c): contour detected after using the canny filter

**Object detection**

To detect objects on the image, we start from the contour data obtained during preprocessing. Then, we define the minimum number of pixels that will make up an object. In the case of this study, we will set this value to 10000.

Figure 4: Object detected in the image

In the case of this image, two objects were found. The next step is to separate these objects and save them under another image to be able to feed it into the convolutional neural network. Thus, we obtain the two images below:

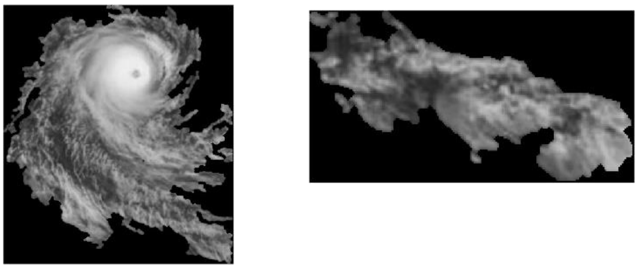


Figure 5: Conversion of object to image

**Classification and display of the final result**

The red dot on the image in Figure 6 represents the barycenter of the image of each object. If the object is classified as a cyclone, the barycenter coincides with the eye of the cyclone, and otherwise, it remains just the barycenter of the image. After passing through the convolutional neural network, object 1 in the image is classified as a cyclone, while detected object 2 is classified as a non-cyclone. So, Figure 7 shows the final result of cyclone detection in this example satellite image.

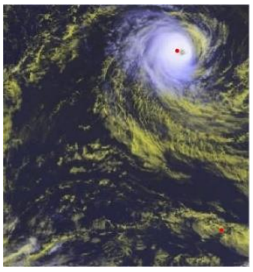


Figure 6: Barycenter of each object

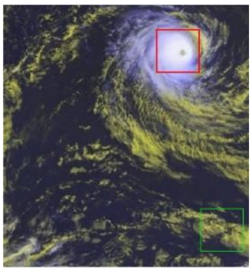


Figure 7: Cyclone detect

**Measuring the accuracy of the methodology**

To measure the precision of the methodology used in this experimental study, 60 tropical cyclone images and 40 non-cyclone images were tested. The value of the learning parameter is set to 0.3; among the 60 cyclone images that were tested, 56 images are classified positively and 4 as non-cyclone. After checking 40 non-cyclone images, 35 are classified positively and 5 are classified as cyclone. The precision of the methodology is given by the relation (4)

$$\text{Prec} = \frac{\text{CP}}{\text{TOT}} \qquad (4)$$

Prec: Precision of the methodology
CP: Number of cyclones detected correctly
TOT: total number of images tested
According to this relationship (4.4), the precision of this methodology is therefore

$$\text{ACC}(\%) = \frac{56}{60} \times 100 = 93{,}3\% \qquad (5)$$

## Conclusion

The analysis of satellite images for prediction, detection, and forecasting of the trajectory of a cyclone is a crucial method to alert and assist populations who reside in areas where a tropical cyclone passes each year during the storm season. rains. Prior knowledge of this information can be a tool that controls the actions to be taken before, during and even after the natural disaster to minimize material damage, especially human losses. As part of this study, we used a new classification methodology which combines the convolutional neural network method and the calculation of the barycenter of the image to predict the presence of a cyclone and locate its eye on a satellite image. According to the results mentioned in this study, we can say that the precision achieved is satisfactory. Even though the results of this study are satisfactory, the search for new methods for improving the precision of the results remains an important option in the field of scientific research.

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