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Detection of illegal airstrips in digital images using artificial intelligence techniques

Abstract

Ecuador is considered a transit country for drug trafficking and smuggling activities. Being a current problem in the northern and coastal border of the national territory, unauthorized airstrips are used for these illegal activities where controlled substances, money, weapons, ammunition, and explosives are transported.

The research will be based on the design and development of a methodology using artificial intelligence techniques for the analysis and processing of images that will be obtained from reconnaissance missions carried out by Ecuadorian Air Force airplanes. For the recognition of clandestine airstrips, the YOLO deep learning-based object detection method and segmentation techniques will be used.

Keywords: deep learning, object detection, artificial intelligence, runways

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Introduction

For many years, Ecuador was considered a transit country for illegal activities related to drug trafficking. However, laws enacted by the governments in power and a lack of resource allocation for drug control over the past decade have turned this territory into a new hub for the production, storage, and transportation of controlled substances in the region. This has created high expectations for criminal mafias, and being a dollarized country, it has become a desirable haven for all criminal gangs operating in Central American countries.

As a result of an escalation of these criminal organizations and their illicit operations in the region, extreme acts of violence have been registered in the country's major cities during 2021. Consequently, the Social Rehabilitation Centers, where individuals involved in drug trafficking and organized crime are incarcerated, have become overcrowded. Thus, the events that took place at the Penitentiary of Guayaquil's Litoral during September were considered the most significant emergency due to the prison crisis, with a death toll of 116 inmates.[1]

One of the main causes of this problem lies in the territorial struggle for control of drug and arms trafficking, with the use of clandestine airstrips dedicated to narcotic activities in the coastal area of the national territory. For this reason, the importance of the research work is established, which will allow the timely identification of illegal landing strips using digital images provided by surveillance and reconnaissance aircraft of the Ecuadorian Air Force (FAE). The results of this work have enabled the identification, through images and videos, of areas designated for the development of narcotic activities.

Theoretical foundations of knowledge

"Computer vision is a branch of artificial intelligence which purpose is to design systems capable of understanding elements and characteristics of an image or scene in the real world".[2] It is closely related to pattern recognition and image processing techniques to detect areas of interest, identify, and classify objects found based on their characteristics.

Image classification or recognition consists of assigning a label to an image based on the characteristics of a defined set of categories. The "images for these algorithms are three-dimensional matrices whose dimensions are width, height and depth".[3]

It is important to note that machine learning is an area of artificial intelligence that encompasses a set of techniques that enable automatic learning through training with large volumes of data,[4] and in order to improve efficiency in object recognition with images and video, there are modern algorithms based on deep learning techniques.[5]

Deep learning is one of the most powerful and rapidly growing techniques in artificial intelligence. It processes data through convolution neural networks (CNN), a technique used in the object detection algorithm in this research (Figure 1).

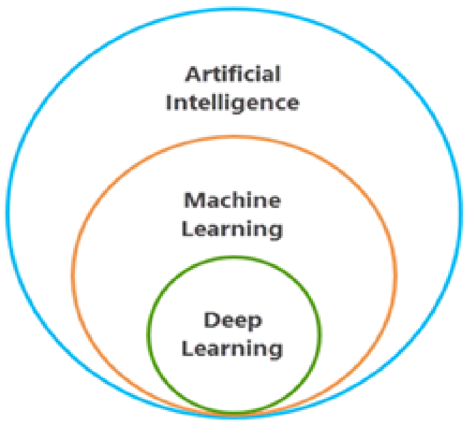

Figure 1 AI, artificial intelligence; ML, machine learning; DL, deep learning

Source: Berchane. M2 IESCI.[6]

CNN is a type of artificial neural network with supervised learning that processes layers by mimicking the visual cortex of the human eye, which uses feature identification in different inputs. To perform this procedure, it has multiple specialized hidden layers arranged hierarchically so that it reaches the deepest layers that recognize complex shapes such as faces or silhouettes of an object.[7]

For the detection of objects like illegal airstrips, YOLOv4 was employed, an open-source algorithm based on a CNN inspired by the Google Net system used for image classification. It consists of twenty-four convolution layers and two fully connected layers, with 1x1 dimensions to reduce the depth of previous layers,[8] as shown in Figure 2.

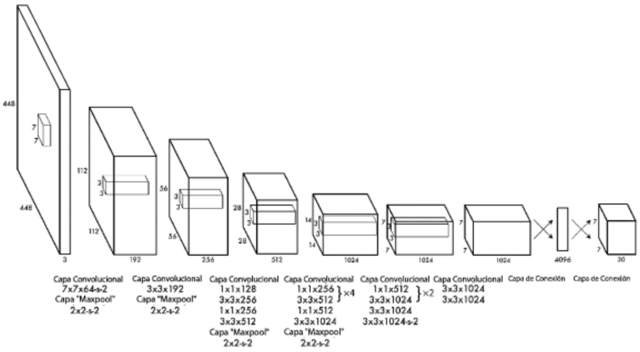

Figure 2 YOLO structure.

Source: Miranda-Pérez et al.[9]

Unlike other detection systems, the YOLO algorithm establishes object detection as a single regression problem,[10] directly from the image pixels to the bounding box coordinates. The trained model only observes the image once to predict which objects are present and where they are located,[5] thus optimizing the detection time with efficiency in the image and video processing in real time.

State of the art

There have been other studies conducted on the detection of clandestine airstrips. In 2017, the research titled "Autonomous Drone for Clandestine Airstrip Identification"[11] was developed, in which drones were employed to detect clandestine airstrips in captured images. Prior to that, the geographical coordinates were inputted into the unmanned aerial vehicle (UAV) system. The obtained images were analyzed using Global Mapper software, and once processed by an analysis group, it was determined whether the area could be used as an illegal airstrip for short takeoffs and landings.

This research paved the way for future work by developing the detection algorithm with artificial intelligence techniques for the identification of illegal airstrips using CNN techniques. To counterbalance the obtained results, tests were conducted on previously identified airstrips to determine, with the assistance of the analysis team, whether the area met the requirements for an improvised or clandestine airstrip. Meanwhile, for the validation tests in this research, artificial intelligence techniques were employed through a detection algorithm. In addition to this, it should be considered the obtained images were from rural and coastal areas in 2021, using aerial means where the identification of illegal airstrips poses a greater challenge.

The obtained results were the product of increased computing power, GPU processing capability, and the availability of large sets of properly labelled data, which drives the development of deep learning.[12] Another proposed improvement was the customization of the detection algorithm based on YOLOv4, considering the rapid advancements achieved in object detection with CNN and the predicted probabilities exceeding 80% for the detection of illegal airstrips.

Finally, "data augmentation" was employed in the algorithm customization, which is an extensive and helpful technique to improve the results of object detection systems.[13] It consists of creating new data through small transformations or distortions on the original data, which contributed to the training of the model with a final accuracy rate of 85.76%.

Objectives and methodology

General objective

Develop a deep learning model with artificial intelligence techniques for the identification and detection of clandestine airstrips using reconnaissance images of FAE aircraft.

Specific objectives

1. Obtain digital images of clandestine airstrips from FAE aircrafts.
2. Classify and label available images of airstrips within the obtained pictures.
3. Generate the dataset to be used with the obtained images through data augmentation techniques.
4. Determine the training and machine learning algorithm for the detection of clandestine airstrips.
5. Establish a deep learning-based object detection model using YOLO for the analysis and processing of images.

Work methodology

The methodology to be followed is based on CRISP-DM (Cross Industry Standard Process for Data Mining), which is used to standardize the data analysis process and knowledge discovery through deep learning. The purpose is to evaluate the training processes until a desired and validated algorithm is obtained, continuously assessing the model, and receiving feedback on the results achieved. Ultimately, a customized clandestine airstrip detector will be obtained. It is important to note that this proposed methodology is primarily based on the six stages described in Figure 3.

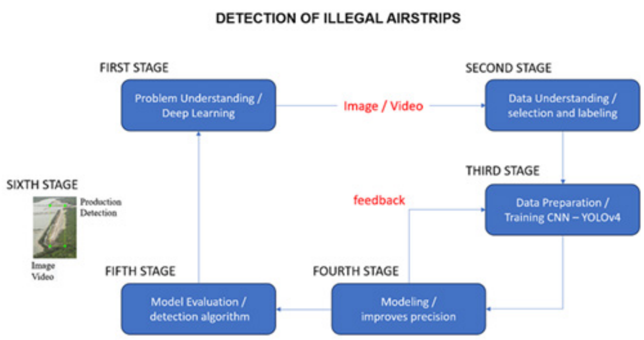

Figure 3 CRISP-DM methodology.

Source: Own elaboration.

First Stage (Problem Understanding): This initial stage is crucial as the application of the project will be useless if the objectives are not understood. In this stage, the problem was understood, the necessary requirements were identified, and the benefits of the development were established. Subsequently, the objectives were determined, setting the goals to achieve, aiming to obtain a trained model with accuracy higher than 80% to establish the detection of illegal airstrips in Ecuador.

Second Stage (Data Understanding): In this phase, the collection of available images of illegal airstrips from the Air Operations and Defense Command will be conducted, as well as the Operational

Command No. 2 "Occidental". Furthermore, the image type and format for our training will be defined, with *.jpg format being established.

Third Stage (Data Preparation): In this phase, the images to be considered in our training dataset will be selected, with two thousand images to be trained. In this stage, the identification of the images to be used will be carried out, separating the dataset for training (80%), validation (15%), and testing (5%), as well as the customization of the YOLOv4 detector. The labeling of the available images will be done using the LabelImg tool, as shown in Figure 4.

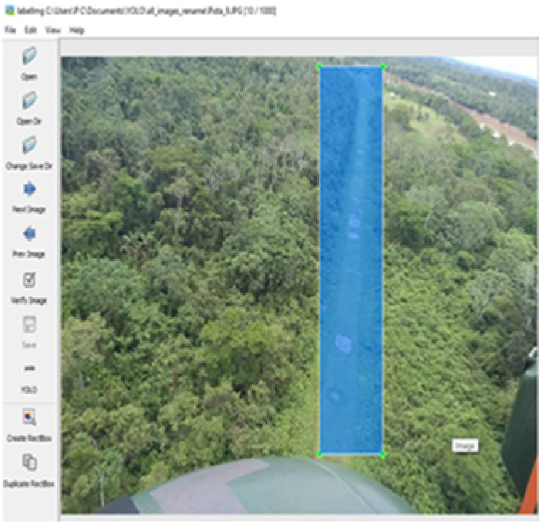

Figure 4 Labeling of airstrip with labelImg

Source: LabelImg software 15/NOV/2021.

Fourth Stage (Modeling): In this stage, the neural network training with YOLOv4 takes place, along with the observation of obtained weights and detection accuracy. Throughout the execution of this stage, trials with continuous improvement are conducted to return to the data preparation stage and correct the over fitting, the code, neural network parameters, and image labeling. Feedback from the training process is applied by employing data augmentation techniques, such as image rotations, translations, darkness variations, and segmentation, in order to obtain a larger number of images in the training and addressing over fitting issues of illegal airstrip images. This will be repeated until the desired outcome is attained, evaluating model accuracy and loss to acquire a dataset of 96,000 images for the training algorithm.

Fifth Stage (Model Evaluation): In this stage, the effectiveness of the trained model will be assessed based on the analysis of statistical metrics and comparison of results with intelligence reports regarding clandestine airstrip detection. Verification is conducted using test images to ensure that the algorithm performs the detection of illegal airstrips accurately, while also evaluating its effectiveness with new images not included in the dataset.

Sixth Stage (Production): Once the model for illegal airstrip detection has been created, the understanding of the acquired data has increased significantly. The production of this model will be based on the analysis of the data and the results obtained in the evaluation.

Evaluation and results

The evaluation of an illegal airstrip constructed with asphalt pavement material, including the use of signage and windsocks, will be conducted. These type airstrips are being used without authorization from the competent authorities for the landing and takeoff of large-scale aircraft. The detection of the illegal airstrip will be verified using the trained model, as shown in Figure 5.

Figure 5 Inference of illegal airstrip.

Source: Pista_123 Colab Pro 04/FEB/2022 (dataset).

An image of a rural farming area will be utilized, showcasing the presence of an illegal airstrip with a marked runway threshold, as well as the area where the aircraft can turn around for takeoff in a vegetated rural region. The detection algorithm is applied, and the results can be observed in Figure 6.

Figure 6 Inference in rural areas.

Source: Pista_146 Colab Pro 04/FEB/2022 (dataset).

Furthermore, it can be observed that the proposed model achieves a detection rate of 98%, which was performed in 20.81 milliseconds. It is considered that this image was not found in the dataset and was sourced from open resources to verify the trained model. The functionality is successfully demonstrated through algorithm evaluation, establishing that it can be used for detecting new illegal airstrips (Figure 7). It is considered that the best accuracy of the model was 85.76 %, which is deemed acceptable for the conducted study and validation of the applied methodology in the training model for the detection of illegal airstrips in Ecuador. For video detection in *.mp4 format, darknet was compiled with CUDA and OpenCV, and then <darknet detector demo> command was executed. As can be seen, the video detection was performed at a rate of 50.6 FPS (frames per second), representing the frequency at which images are captured in motion. Consequently, a new video with the detection of illegal airstrips is obtained, as depicted in Figure 8.

Figure 7 Inference with additional image to the dataset.

Source: Pista_nueva2 Colab Pro 04/FEB/2022 (prensalibre.com).

Figure 8 Inference of illegal airstrip in video.

Source: Video Noticiero Ecuavisa, 2021.

Conclusion

Finally, after the evaluation and verification of the proposed methodology for the detection of illegal airstrips, it is determined that the deep learning-based method for the generation of the detection algorithm, through the customization of the YOLOv4 detector and continuous feedback to improve precision, accuracy, and mitigate over fitting in training, has achieved a model with 85.76% precision for both image and video detection. Hence, it fulfills the objective of this research and establishes its applicability in contributing to the control and surveillance of illegal airstrips in Ecuador.

For this research, the data augmentation technique was used on YOLOv4, which allowed the expansion of available images by horizontally, vertically, and slantwise flipping them. With the use of this technique, Gaussian filters and image segmentation with Sobel and Canny techniques were applied in order to detect lines and edges of clandestine airstrips and eradicate noise in areas with more vegetation or in desert-like locations. Thus, it was possible to improve the amount of images in the dataset, enabling the model to detect illegal airstrips with established characteristics in rural areas and with large zones of vegetation. Improving the illegal airstrip detection model can be considered by incorporating a larger number of images in the training process. At least two thousand labelled and classified images could be employed, leading to increased detection accuracy and improved precision in the images. It is necessary to apply newer versions of the YOLO detection tool because the one used in this research was YOLOv4, released in April 2020. Since then, YOLOv5 has been developed and released, offering excellent object detection and is more efficient in speed reasoning, qualified as a new generation of YOLO.

Conclusions and future work

The Air Operations and Defense Command "COAD", through the Air Force Research and Development Center "CIDFAE", as well as the 2nd Operations Command "Occidental," contributed to obtaining digital images of illegal airstrips. This strategy becomes more recurrent with the escalation of illicit activities in Ecuador and the need to identify illegal airstrips in the region. The image classification was successfully performed since not all the provided images could be used for the generation of a training model, thus achieving the labelling of illegal airstrip images using the LabelImg software.

The training dataset was constructed with two thousand labelled images, separating the data set for training with 80%, validation with 15%, and testing with 5% of the image set. The CRISP-DM methodology was established for the detection of illegal airstrips, enabling the determination of the training and machine learning algorithm. The training dataset was optimized using data augmentation techniques to increase the quantity of processed images. The detection model based on deep learning with YOLOv4 was established, in which continuous improvements were made in the code, accuracy, and over fitting, resulting in a trained model accuracy of 85.76% for the detection of illegal airstrips.

The future implementation of this algorithm will be established in the Air Force's Command and Control Centers to have real-time information and enable decision-making in national security and defense. Thus, illicit activities derived from the use of clandestine airstrips will be reduced.

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Conflicts of interest

The author declares that there is no conflict of interest.

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