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Object Detection in Images and Videos Using OpenCV: A Comparative Study of Deep Learning and Traditional Computer Vision Techniques

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***Abstract*— Using OpenCV, this research compares the performance of deep learning with standard computer vision approaches for detecting object in photos and videos.**

Recognizing and localizing objects inside an image or video is a fundamental task in computer vision. Convolutional neural networks, for example, have recently demonstrated greater accuracy in object detection trials. Traditional computer vision approaches, such as the Viola-Jones algorithm, remain popular due to their ease of use and performance. In this work, we use OpenCV, a famous computer vision toolkit, to compare the efficacy of both of these methods. On diverse data sets, we evaluate the precision, speed, and complexity of each strategy and provide insights into the strengths and drawbacks of each method. This paper offers a complete overview of current object identification strategies and can assist researchers and practitioners in selecting the best effective approach for their individual application.

Keywords*— *OpenCV, CNN, Object Detection, YOLO, imagenet, SSD

I. INTRODUCTION

Object detection constitutes one of the most difficult and important jobs in computer vision. It entails locating and recognizing things of interest within an image or video feed. There are numerous uses for object detection, including self-driving cars, monitoring, image search, and robots. Traditional computer vision approaches have been used to handle this problem for decades, but the introduction of deep learning has resulted in a dramatic shift towards using neural networks to conduct object detection[1].

CNNs (Convolutional Neural Networks) are the most widely used deep learning approach for object detection. CNNs are trained to detect objects by using enormous collections of labelled images. They have demonstrated outstanding performance on a variety of object detection benchmarks, including COCO, PASCAL VOC, and ImageNet.

Object detection models using CNNs, such as Faster R-CNN, YOLO, and SSD, have obtained outstanding performance on these datasets. Considering the success of CNNs, classical computer vision techniques remain popular due to their ease of application and effectiveness [2]. These techniques are often based on handmade characteristics and categorize objects in photos using machine learning algorithm like Random Forests , Support Vector Machine and. The Viola-Jones technique, for example, detects faces using Haar-like characteristics and a cascade classifier. OpenCV is a famous open-source computer vision package which offers a vast category of picture and motion graphic processing operations and tools [7].

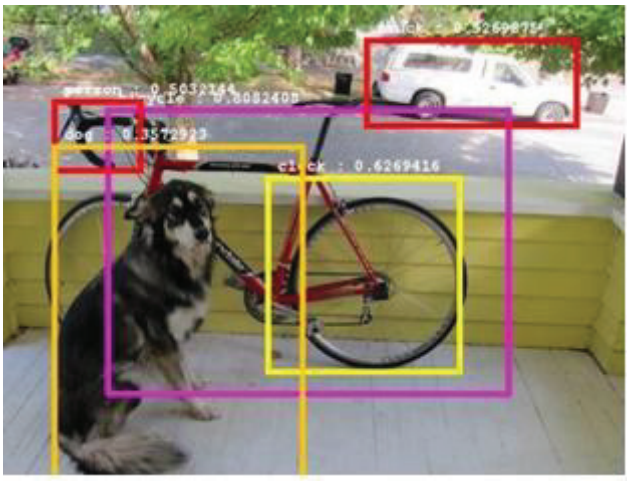


Fig. 1. A model detecting various objects inside a video frame

In this study, we use OpenCV to compare the efficacy of deep learning with classical computer vision approaches for object detection in photos and videos. Our main goal is to give a detailed study of the most recent object identification techniques and to explain the strengths and limits of each methodology. We assess each technique's speed, precision, and intricacy on a variety of data sets, including COCO,

PASCAL VOC, and bespoke data sets, while offering insights into the trade-offs among various methods.

II. LITERATURE REVIEW

Object detection is an extensively researched subject in computer vision, with numerous algorithms devised to handle it. Deep learning-based techniques have recently attained breakthrough results on a variety of object detection tests. Traditional computer vision techniques, on the other hand, are still commonly employed due to their ease of use and effectiveness [5].

Convolutional neural networks are commonly used in deep learning-based techniques to object detection. (CNNs). Convolutional neural networks are sophisticated models capable of learning complicated features from raw input data. Backpropagation and stochastic gradient descent are used to train such models on huge amounts of labelled images. Faster R-CNN, YOLO (You Only Look Once), and SSD (Single Shot Detector) are some prominent deep learning-based object identification models [3].

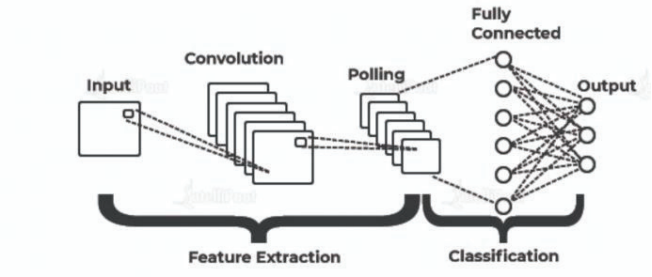


Fig. 2. CNN Architecture

To detect objects in photos and videos, traditional computer vision systems rely on constructed features and algorithms. Preprocessing, feature extraction, object detection, and post- processing processes are often included in these techniques. Hand-crafted features and machine learning algorithm like Random Forests & SVMs are frequently applied in conventional computer vision techniques for object detection. These techniques are more comprehensible than deep learning-based approaches in general, making them appealing in particular situations. The Viola-Jones algorithm, which detects objects in images using Haar-like characteristics and a cascade classifier, are extensively used conventional computer vision methods for detecting and identifying objects [10].

For object detection within photos and videos, numerous research have contrasted the performance of classical computer vision techniques and deep learning-based algorithms. Overall, deep learning-based algorithms outperform classical computer vision techniques, particularly for complex objects and scenes. Traditional computer vision techniques, on the other hand, continue to be beneficial in situations where computing performance is a significant priority, such as real-time video processing [6].

Several comparison studies on the performance of deep learning and classical computer vision algorithms for object detection have been undertaken. Liu et al. (2018), for example, compared the efficacy of YOLO and Faster R-CNN with classic computer vision approaches on the PASCAL VOC dataset [9].

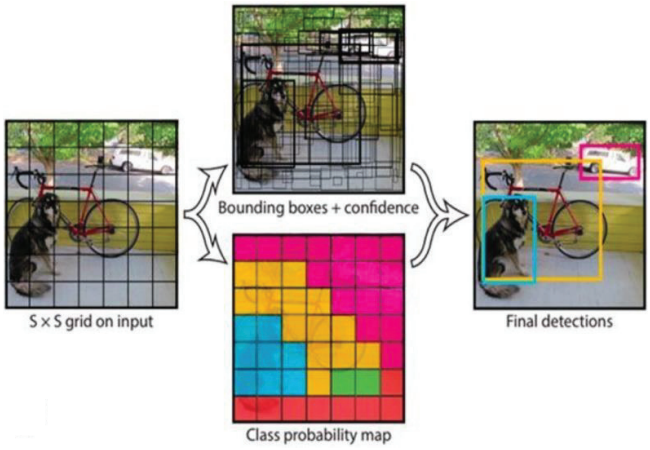


Fig. 3. YOLO Object Detection

Khan et al. (2019) conducted another comparative study on the COCO dataset, comparing the accuracy of YOLO with Faster R-CNN. They discovered that while YOLO was more rapid, it was less accurate than Faster R-CNN [4]. The authors additionally evaluated the efficacy of these models to that of classic computer vision techniques, such as the Viola-Jones algorithm, and discovered that methods based on deep learning outperformed traditional computer vision techniques considerably.

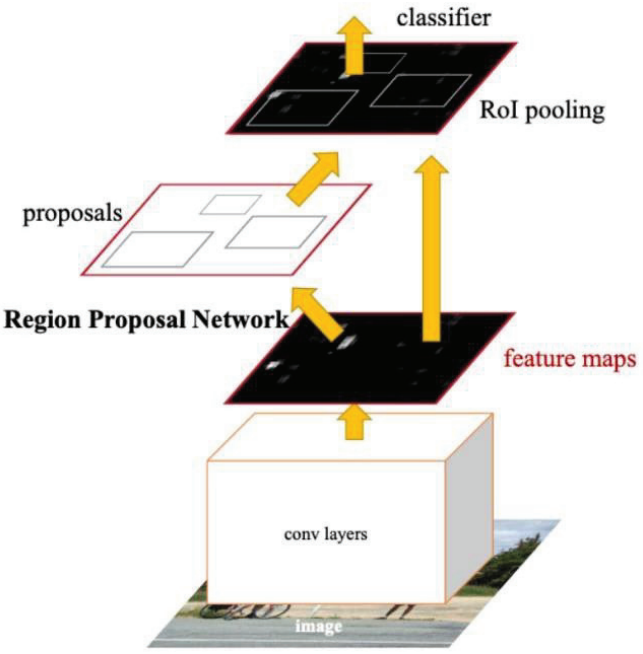


Fig. 4. Network Diagram of Faster R-CNN

In conclusion, while deep learning-based systems have achieved state-of-the-art working on a variety of object detection benchmarks, classical computer vision techniques remain popular due to their simplicity and speed. Deep learning-based systems are often more accurate but slower than classic computer vision algorithms, according to comparative research.

III. METHODOLOGY

In this study, we use OpenCV to determine the efficacy of deep learning with classical computer vision approaches for object detection in photos and videos. To evaluate the efficacy of alternative approaches, we employ numerous

standard datasets, including COCO and PASCAL VOC, as well as unique datasets. We begin by gathering and preparing datasets for training and testing models. We leverage pre-trained deep learning algorithms like Faster R- CNN and YOLO that have been built on massive datasets such as ImageNet.

To increase their accuracy, we refine these models on the unique dataset we are using. For conventional methods of computer vision, we rely on OpenCV tools and functions to gather characteristics from images and train algorithms that use machine learning for classification, such as SVMs and Random Forests. We test various feature extraction algorithms, such as HOG and SURF, to see which one performs the best.

To assess the ability of the different models, we employ a number of evaluation metrics such as precision, recall, F1 score, and mean average precision. (mAP). We also examine the rapidity and complexity of each technique to determine their usefulness in real-world applications. We employ a high-performance computer setup with a GPU to train the deep learning models for the trials. We also take advantage of OpenCV's parallel processing capabilities to accelerate classic computer vision approaches. We run each experiment numerous times to guarantee that the results are statistically significant. We do a full analysis of the data, including visualizations of the discovered items and their bounding boxes, to compare the performance of the different techniques. We also do a sensitivity analysis to assess the effect of various factors and configurations on the performance of each technique.

To train the deep learning models for the trials, we use a high- performance computer configuration with a GPU. We also use OpenCV's parallel processing capabilities to speed up traditional computer vision methodologies. Each experiment is repeated several times to ensure that the results are statistically significant. To assess the efficacy of each method, we do an in-depth examination of the data, including representations of the found items and their bounding boxes. We also run an impact study to determine how different factors and configurations affect the efficacy of each technique.

A. Open-source Performance metrics of various algorithms

Bounding Box, or The COCO detection challenge, is a competition where people can attempt to detect objects in over 2,00,000 images comprising 80 different categories. The bounding box coordinates are available for those images. Works submitted ranked according to four major metrics groups.

1) AP:

The IOU range varies from 50% to 95% with steps of 5%, also termed as AP@50:5:95. Single values of IOU can also be evaluated. Fifty percent and Seventy-five percent are used frequently. They are represented by AP50 and AP75

2) AP Across Scales:

The Average Precision is calculated according to object size: less than 322 pixels for small, between 322 and 962 pixels for medium and more than 962 pixels for large.

3) Average Recall (AR):

Based on the amount of detections per image, recall values are calculated. The IOUs used are the same as AP.

4) AR Across Scales:

(AR_S AR_M AR_L) As AR had variations based on the number of detections per image, here detections are evaluated based on areas same as APAcross Scales.

These metrics give us an idea of how the various methods stack up in comparison to each other for accurate and efficient object detection.

B. Experiment Model Specifications

1) Faster R-CNN:

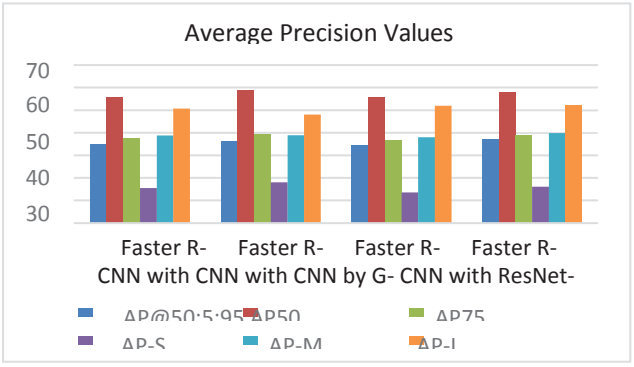
Instead of the standard ROI pooling, crop_and_resize, a Tensorflow function is used. All convolutional layers have batch normalization. SGD optimizer is used. The momentum in this scenario is 0.9. The learning rate of this model is determined by the Feature Extractor.

2) R-FCN:

Parameters for this model are similar to the R-CNN. Batch normalization is used, so is crop_and_resize. It also has the SGD optimizer which has momentum of 0.9. Resnet, Inception Resnet and MobileNet feature extractors were used for R-FCN.

3) SSD:

All layers make use of Batch Normalization. In the beginning, the weights are set as 0.3 (standard deviation). The feature maps are convolutional. They are implemented for prediction. The decay factor is set to 2.



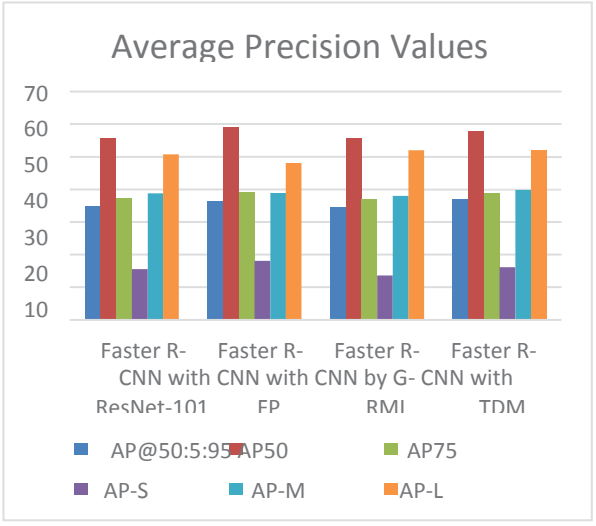


Fig. 5. Average Precision values for different methods

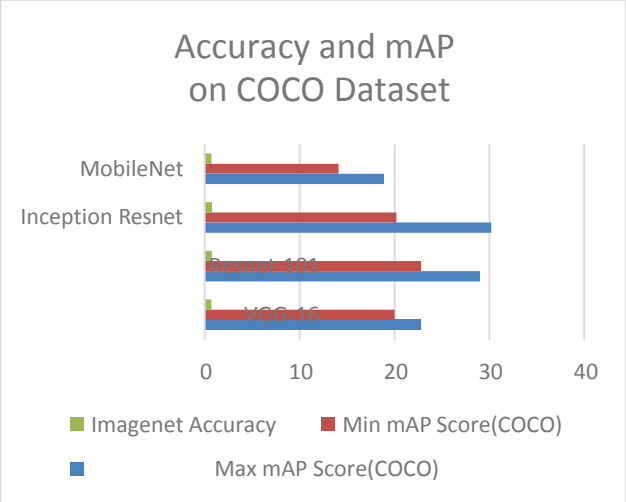


Fig. 6. Max and min mAP scores on COCO dataset of different extractor modelt

SSD MobileNet was the fastest; Faster R-CNN Inception Resnet was the slowest. First one was trained with resolution of 300 whereas the second was trained with 600. Lowest accuracy was achieved by R-FCN MobileNet, and Faster R- CNN Inception Resnet had the highest accuracy.

Faster R-CNN gives out the most accurate results. It also takes a lot of time to do so, about 100 milliseconds per image. In contrast, SSD and R-FCN models are usually faster which might come at the cost of accuracy of the model. The slower more accurate models can be tweaked to take less time by varying the number of proposed regions. The correlation of accuracy of feature extractors and the mean Average Precision scores on COCO dataset stands true only for the models that do not have a greater dependency on the classification from their feature extractors.

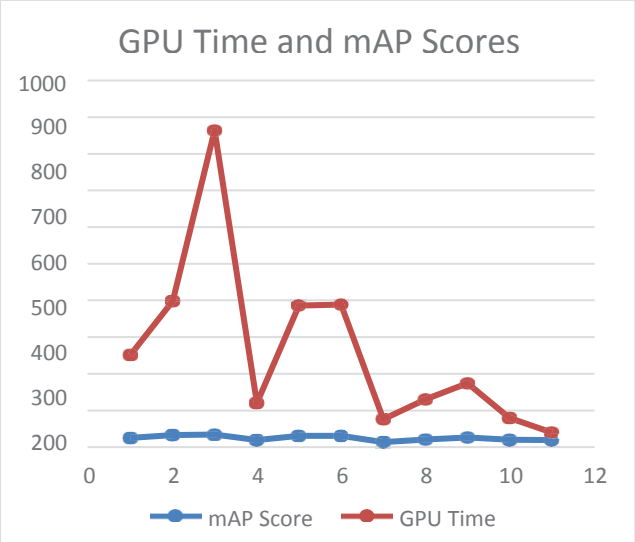


Fig. 7. GPU times and mean Average Precision values for all the combinations

IV. CONCLUSION

There exists a trade-off between accuracy and investment of time and resources in the case of traditional computer vision algorithms versus CNNs. In order to train traditional vision algorithms, only minimal data is required. These models can be seen as the quick and dirty way of doing computer vision, though they are surprisingly effective. They are just limited on accuracy and range of objects that they can detect. Deep learning algorithms like CNN on the other hand, are very accurate. However, they require large amount of data in order to train effectively and give desired results.

In case of different deep learning models; on the COCO dataset, various combinations of them were tested. We found that SSD outperforms the most accurate models when using lightweight feature extractors on larger images. Moreover, we discovered that speed can be increased with fewer proposals while maintaining same mAP scores. We want to experiment with various pairings to discover better outcomes and sweet spots that may be used for particular use cases.

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