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Future Challenges for Object Detection and Image Recognition Techniques

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Abstract:
Object detection and object recognition are the two main techniques that enable the identification of objects in images and videos. These techniques utilize Deep Learning and Machine Learning by simulating human-like image recognition. There are various methods developed recently, which have made significant progress in object detection or image recognition, and therefore, through this work, we present the latest advances in this field and their operation through Machine Learning and Deep Learning. We discuss the challenges that appear in object detection and the necessary improvements that must be made in order to increase the efficiency of this technology. Furthermore, the future challenges for object recognition has been addressed as well, by providing an analysis on the possibilities of continuous development and facilitation of these techniques in various domains.

Keywords:
Object Detection, Image Recognition, Deep Learning, Machine Learning, Convolutional Neural Networks

1. Introduction

Object detection and image recognition techniques have recently had substantial development in a fair proportion to the advancement of technology in the world. Many Machine Learning and Computer Graphics researchers have intensified their work in improving and advancing these techniques. Object detection has found high application in video games, in automotive industry, in medical devices, in traffic safety etc. On the other hand, face recognition is increasingly becoming an authentication paradigm, finding application in a large number of mobile applications that require face recognition, as well as in biometric applications. These vast application possibilities present an urgent requirement to increase security, due to the rapid development of digitalization. In addition to these two techniques, we will also focus on some other paradigms, to analyze their implementation progress, as well as to see the shortcomings and sensitive points where we estimate that there is still a need for improvements in the future.

The rest of this paper is organized as follows. In section 2we first make a review of the literature to give a right orientation to our analysis. We emphasize the importance of this technology and its development so far. Next, in section 3 and section 4 we provide separate analyzes for both technologies, i.e. object detection techniques and image recognition techniques and the challenges and issues in their further development. Finally, in Section 5, we give a recommendation about what issues developers should deal with more specifically, in order to make greater advancement of this field.

2. State-of-the-art

Object detection and image recognition techniques are the two highly used object recognition techniques. In order to achieve a complete understanding of the image, it must be made clear that we have several other tasks to deal with in addition to classifying the different images, i.e. to accurately

assess the concepts and locations of the objects contained in each image. This task is referred to as object detection [1]. After the realization of this first phase, the next phase consists of several other subtasks such as face detection [2], pedestrian detection [3] and skeleton detection [4]. In order to be able to recognize objects better and have have stronger semantics, we need to extract representative features, which is achieved through Scale-Invariant Feature Transform (SIFT) [5], Histogram of Oriented Gradients (HOG) [6] and Haar-Like that considers adjacent rectangular regions at a specific location in a detection window of the image then sums up the pixel intensities in each region and finaly calculates the difference between these sums [7]. HOG is a feature descriptor that is used in computer vision and processing of images for object detection and recognition. FiSIFT as a technique for image matching can identify and match features in images that are invariant to scaling, rotation, and affine distortion and it is widely used in computer vision, image matching, object recognition, and also, 3D reconstruction. We can say that Deep Neural Networks (DNNs), or the more representative Convolutional Neural Networks (CNNs), operate in a completely different manner compared to traditional approaches. CNNs have deeper architectures with the ability to learn more complex features than shallow ones. Also, expressiveness and powerful training algorithms enable us to obtain features of objects without having to draw them by hand [8].

3. Object Detection

When we talk about object detection, we mean the computer's ability to detect objects within a given frame, similar to how humans are able to detect objects within a given image. Object recognition [9] is widely used in machine vision industry for inspection, registration and manipulation tasks. We will cover some of the object detection tasks, for example, objects under different angles, lighting and variations within the classroom and challenges in object detection [10]. We estimate that object detection is divided into two periods. Object detection Based on traditional methods until 2014, and after 2014 we have object detection based on deep learning. We will address the biggest developments, applications of these technologies as well as the challenges these technologies are facing.

A. Object Detection in Computer Vision

Computer vision is extremely important in improving object detection. These algorithms have found high application in medicine, such as in detection of tumors, in detection of potential anomalies of children yet to be born etc. Other implementations of object detection include security systems with face detection, traffic management with car license plates recognition and implementation in automotive industry where high precision detectors have been developed to detect objects that may have a direct or indirect impact on the moving vehicle. Of course, object detection is used in a very large number of everyday-life fields as well, such as ensuring that people on the "No Fly" list do not pass through security gates at airports, animal monitoring in agricultural farms and zoos, detection of roads, pedestrians and traffic lights in autonomous vehicles, scanning and verification of faces against passports at airports, detection of health abnormalities etc.

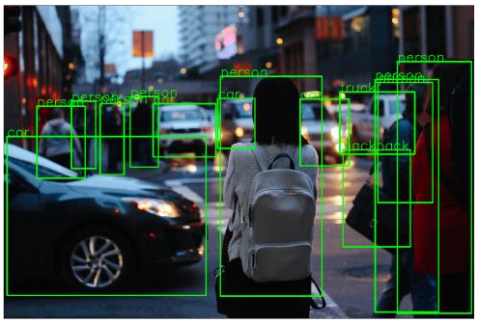

Figure 1: R-CNN Object Detection

In recent years, object detection algorithms have been further enhanced by deep learning, increasing processing speed, as well as providing more accurate results. Some of the most popular deep learning

architectures in object detection are known as: Fast R-CNN, Yolo, SSD, R-CNN. The Fast Region-based Convolutional Neural Network method (Fast R-CNN) works as a CNN (usually pre-trained on the ImageNet classification task) with its final pooling layer replaced by a region-of-interest pooling (ROI pooling) layer and its final fully connected layer (FC) (that operates on a flattened input where each input is connected to all neurons) is replaced by two branches: a (K + 1) category softmax layer branch and a category-specific bounding box regression branch. YOLO (You Only Look Once) deep learning architecture as a popular object detection algorithm has made a revolution in the field of computer vision with its characteristics as fast, efficient and easily applicable in real-time object detection tasks. Single Shot Detectors architecture (SSD) is also a popular and efficient in object detection. SSD uses a single CNN in order to predict bounding boxes and class labels for objects in an image, and that makes it faster and more efficient than other methods. For the last architecture, regions with convolutional neural networks (R-CNN) it is a technique where objects are detected in an image by combining rectangular region proposals with convolutional neural network features.

B. Object Detection Algorithms and Detectors

Below is a list of some of the most important developments in object detection technology:

a) The detectors of Viola and Jones [11], where in 2001 they achieved for the first time in real time the detection of human faces without any limitations. This VJ detector was hundreds of times faster than the algorithms of that time.
b) HOG detector, N. Dalal and B. Triggs developed this detector during 2005 where a significant improvement of scale invariant feature transformation was achieved [12] and shaping contexts of his time [13].

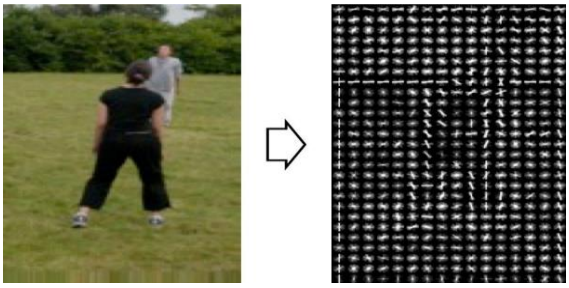

Figure 2: Input Image & Visualization of the HOG features

c) R-CNN, makes the extraction of a set of proposed objects through a selective search. Then all of these propositions are converted into still images and fed into a CNN model, so that features can be extracted from them [14].
d) SPPNet model is an improvement over CNN models, as they require input of fixed size, while SPPNet does not depend on fixed dimensions of input images. It also has an object detection speed about 20 times faster than R-CNN.
e) Fast R-CNN, is a new model developed in 2015. Which is an improvement over R-CNN and SPPNet models, where it has an object detection speed of about 200 times greater than R-CNN. This model allows to simultaneously handle a detector and a regressor within the same link.
f) FPN algorithm, developed during 2017 and proposed by T.-Y.Lin [15], has increased accuracy in locating objects in contrast to the above models.

C. Object Detection Challenges

Throughout all these developments, Object detection has also had challenges, some of which have been improved while others still need to be worked on in the future. Below we list some of the key challenges for which we believe more can be done.

a) Disadvantages of RCNN are excessive feature calculations on a large number of overlapping propositions (over 2000 boxes from one image) lead to an extremely slow detection speed (14 seconds per image with GPU)
b) SPPNet still has some shortcomings, such as the training is still performed in multi-stage and it only adjusts its fully connected layers, while simply ignoring all previous layers.
c) Deformation. In many cases object detection detectors are trained for solid objects and have difficulty detecting fluid or very flexible objects.
d) Occlusion. Object detection detectors also encounter difficulties when asked to find an object, where part of it is covered by another object. For humans this is not a problem.
e) Illumination conditions. In different illuminations the detectors assign different features to the same object and as a result several different objects are detected.

4. Image Recognition Techniques

Image recognition is a machine vision, which has the ability to recognize objects, images, people, etc., knowing how to distinguish and compare the same features in different images. Image recognition requires many processes, which require high processing speed, then accuracy in recognition, as well as small tolerance in the obtained results. Below we have made an analysis about image recognition through deep learning and machine learning. We have also shown the most frequent applications of this technology and finally the challenges that this technology faces.

It is known that image recognition has found a very large application in practice, where today it is used by a large part of the industry, security systems, smart phones, etc. Some of the applications of this technology include:

a) Medical diagnosis, i.e. in health, image recognition is used quite a lot, especially in software that is integrated into devices through which many recordings are made, such as X-Ray devices, etc., where through advanced algorithms it is possible to recognize abnormalities in patients.

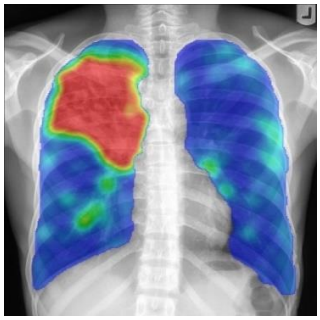

Figure 3: Detection anomalies in X-Ray with CNN

b) People identification. In these cases the security institutions use special equipment that enables people to be recognized through the collected photographs and videos.
c) Fingerprint recognition is one of the simplest implementations based on small features such as fingerprints-impressions.
d) Face recognition [16] is a technology that is mostly used in smart phones, in access control, and recently in cars.
e) Visual search is a search method that allows people to search for something via input image, as Google Lens tool makes searches.
f) Iris scan recognition. After DNA, iris is the second most unique organ in the human body and contains more information about the human than fingerprint impressions [17]. Therefore, recently we have technology developments where iris recognition is used as authentication

instead of fingerprint or face recognition. This technology has started to be used also in ATM devices.

Figure 4: ATM authentication with Iris recognition

A. Image Recognition with Machine Learning & Deep Learning

Deep learning [18] as a new field, comes from machine learning which aims to build a neural network, which is capable of analyzing data and learning similarly to humans, through advanced algorithms. Deep learning has boosted image recognition in a rapid manner. Mainly, traditional models have applied color for image recognition, as well as features of image shape and structure [19]. One of the main concepts in image recognition through deep learning is Convolutional Neural Networks (CNN). This concept consists of several smaller layers of neurons that all contain parts of the image, and after image processing, all parts are superimposed in one place. And so the layer below repeats this process, learning more about the composition of the image. CNN [20] brought a revolution in the field of computer vision by increasing the accuracy of image classification, but also many times improved scene classification, object detection, semantic segmentation of biological images and face detection, text recognition and human body recognition in natural images. The main practical success of CNN is the face recognition and autonomous driving of cars. Also, we have Multi-Layer Perceptron (MLP) with a feed forward learning algorithms. MLP is a frequent choice because of its simplicity and its capability in supervised pattern matching. It has been successfully applied to many pattern classification problems [21, 22]. Linear discriminant analysis (LDA) is a powerful method for face recognition. This model gives effective representation that linearly transforms the original data space into a low-dimensional feature space. A subspace analysis method for face recognition called kernel discrimination locality preserving projections (MMDLPP) was proposed in [21] based on LDA analysis.

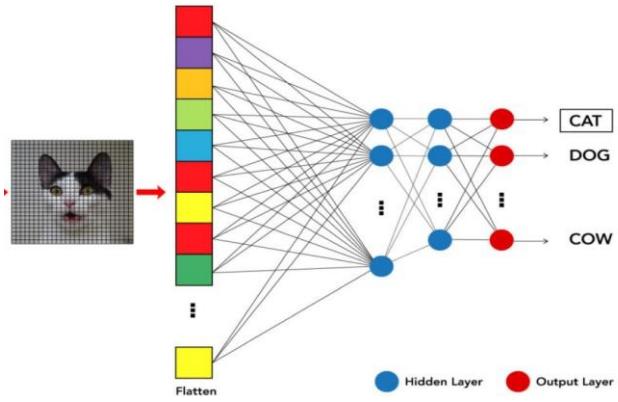

Figure 5: Image recognition using CNN

B. Image Recognition Challenges

After analyzing the techniques for image recognition, we estimate that we have found some shortcomings, which we have listed below.

a) CNN requires a large database which helps in image detection, comparison and recognition, but consequently comes with a higher cost.

b) False image recognition. This happens in many cases, for example, when the algorithm recognizes another person who has some features similar to the person who is really being searched for.
c) Racial bias. This is a strange issue, but it is worth noting that image recognition algorithms distinguish black people more easily than white people.
d) There are challenges in protecting personal data.

5. Conclusion

After evaluating the results obtained from the literature review, we estimate that a remarkable amount of work has been done in the last two decades. Both object detection and image recognition technologies have found a great application in practice, greatly facilitating some processes that were quite difficult until recently. There is a growing trend of organizations dealing with the development of complex algorithms, which will continue to facilitate this process. In general, the advantages of using these technologies are significantly greater than the shortcomings or drawbacks. Where, after the analysis of the results found, we recommend to work more with the image recognition technology, which has greater challenges due to the various factors that we mentioned above. We recommend that more work be done in the future in the field of health, where there is great potential for this very important sector for people to shine through the advanced use of these technologies. Also, one of the most sensitive sectors is undoubtedly privacy, the protection of personal data, since through the use of image recognition we have a high exposure of our personal images as well as our sensitive data. Therefore, more work is required in terms of protecting the data, code them, in order to be more confident in the use of various applications related to object detection and image recognition.

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