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Detecting and Counting People In Dense Crowd

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Abstract. Crowd counting is counting the objects for specific purpose. It is basically used for real-life applications for automated public monitoring or public counting and can be used for surveillance and traffic control. However, it is not exactly object detection only but Crowd Counting is aimed at detecting arbitrarily sized objects in various situations. When Countries started to remove Covid-19 lockdown restrictions during spring 2020, large crowds of people flocked to beaches and parks to enjoy spring temperatures, risking their lives. According to the guidelines of the World Healthcare Organization (WHO), people need to maintain a minimal social distance of 1 meter, and in many countries, it was maintaining 1.5 meters. However, enforcing and maintaining these rules is a challenging task and organizations have to pay fine if the rules are not followed. It is human nature to get close and interact with each other. In this COVID era, only limited people are allowed to enter malls and shops. It becomes very difficult to maintain the count of people. A system is needed which is secure and count the number of people entering and exiting the shop with highest accuracy.

Introduction

Crowd counting solutions based on video analytics can help alert authorities to when these places get too crowded and social distance is at jeopardy. These alerts will be received in real-time, and historical statistics will also be available. In today's world, crowd counting with a Convolutional Neural Network is an efficient way to keep track of the number of people who visit a mall on a regular basis. Mall crowd counting is the method of counting people in a mall using various scenarios such as goal detection, density dependent, CNN based, and so on. Our crowd counting system would be able to quickly and accurately locate and detect humans. For this form of counting method, there are a variety of techniques available, but we chose machine learning with Python OpenCV, which also allows us to

convert video frames into images [1]. This allows users to see how many customers are in the mall at any given time. Crowd counting is a critical and difficult problem in crowd visual analysis. For the crowd calculation as of a particular picture, the majority of current approaches make use of regression on density map. These techniques, on the other hand, are unable to locate individual pedestrians and thus cannot be used to approximation the actual giving out of pedestrians in the surroundings At different side, detection-based method become aware of as well as localize pedestrians in the picture, except the presentation of these methods degrades when applied in high-density situations. Each time, gatherings of thousands to millions take place intended for festivals, pilgrimages, protests, concerts, and sports events. There are a lot of reasons to wish for identify how many citizens are presence every of these activities. Both real-time management and future event preparation are depended on how numerous people are there, anywhere they are positioned, and where they are around for those hosting the event [2]. The size of the crowds determines how rapidly evacuations be capable of security reasons. Mass sizes are commonly preferred in newspaper journalism to measure the agreed out and where crowd can preteens a hazard to individuals for import of an occasion, and systems that can reliably information on the occasion amount are critical used for estimate.

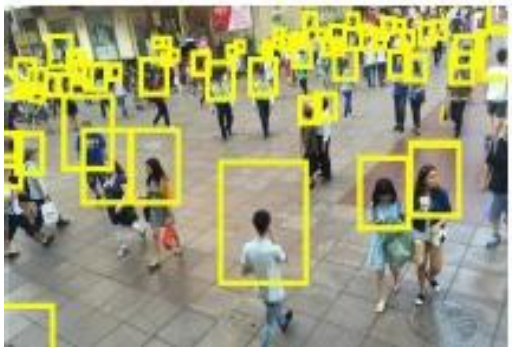

Fig. 1 . Counting of People at Public Place [4]

Related Works

Discovery and regression-based estimation are two methods used in crowd counting systems. The detection-based approach entails segmenting and recognizing each individual crowd scene, then counting them using classifiers. Convolutional Neural Networks were recently used in a regression-based approach (CNN) [5],[6],[7]. There are a lot of efforts in mass study, more confusion; contrast differences, non-uniform people allocation, and lighting and inter scene variations are only a few examples. When compared to other methods, CNN-based techniques have significantly reduced error rates. Each single day, meetings of thousands to millions take place for objections, holidays, visits, marathons, shows, and game actions. Aimed at slightly of these actions, nearby are uncountable explanations to wish to recognize in what way several persons are existing. Aimed at folks presenting the occurrence, together instantaneous managing and upcoming incident development is needy on in what way many individuals are existent, somewhere they are placed, and when they are existent [8].

The dimension of the masses controls how speedily emigrations can be passed out and somewhere crowding can attitude a risk to people for safety causes. Mass dimensions are usually used in reporting to evaluate the prominence of an occurrence, and organisms that can consistently information on the affair dimension are grave for an exhaustive valuation. For crowd regulator and municipal protection, precisely guesstimating the total or concentration of packs is fetching gradually essential. In congestion conditions, folks as well as make presented serious evidence that can be charity to avoid coincidences and accomplish circulation jamming.

"Crowd Counting" contributions in the robotic footage of habitually stayed entities by recognizing individuals moderately than physically calculating or forecasting. It countenances the supervisor to contact and conversion archives at whatever time. Through this organization's technique, fewer stage will be finished calculating and fewer broadsheet will be jumble-sale [9]. It can also calculation publics if the entrance and exit are in isolated situations. Table I describes the applications of Crowd Counting.

These days, crowd calculating and analysis is the most attentive investigation and public question in computer visualization and arrangement acknowledgement. The multitude singularity has been increasing in bike with development, generating notice in an extensive choice of requests such as crowd administration, civic planetary plan, simulated atmospheres, visual investigation, and intellectual surroundings type styles are built-in; examples of the type styles are provided throughout this document and are identified in italic type, within parentheses, following the example. Some components, such as multi-leveled equations, graphics, and tables are not prescribed, although the various table text styles are provided. The formatter will need to create these components, incorporating the applicable criteria that follow.

Objective

The aim of a crowded counting is to determine how many people are present in a given area. (1) Security Organization videocassette security cameras preferred for security reasons in locations like game stadiums, shopping centers, and airports contain validated mass tracking for performance study, obstruction study, and irregularity discovery. (2) Disaster organization - Large crowds, such as those at song festivals and political protests, are vulnerable to disasters like stampedes. Usage for early identification of overcrowding. (3) Open Locations - There are a variety of public places where mass levels can be large, such as shopping centers, train, and airport terminals, all of which can have an effect on human health. (4) Visual Surveillance - Since public places like playgrounds and large arenas are so crowded, this form of device cannot be able to identify a person in the crowd. By detecting and alarming anomalies, the optical observation structure helps to decrease the malfunction fraction [3].

Approaches to Crowd Discovery System

Key in information, Approaches, characteristics, and termination make up the Crowd Detection System, as shown in the diagram. The difficulty has been approached in a diversity of ways, with discovery base solutions, regression base solutions, and density base solution being mainly common.

Discovery Base Solutions

The detection model attempts to figure out how many people there are by detecting a single person and their locations all at once. Spatiotemporal information is used to identify pedestrians in a scanning window. Total difference, Haar-like filters. Three types of filters are used to capture moving objects: the Haar filter, the shifted difference filter, and the shifted difference filter. Eight separate pedestrian detectors were conditioned for eight different movements using the Adaboost learning algorithm. Furthermore, this algorithm is used to create and attempt to organize the moving person by using both movement and appearance data. In possible top-down segmentation, a structure for pedestrian discovering in mass picture uses a structure that combines limited and worldwide characteristics. To take out the characteristics pattern of head form, the Haar Wavelet Transform (HWT) was used. A Support Vector Machine (SVM) was used to categories a highlighted region into the presence and absence of a head. This approach had limitations in dynamic circumstances where the head wasn't simple, and it posed a significant computational burden in real-time applications.

Table 1: Applications ff Crowd Counting

Applications	***Description***
Crowd managing	Contain of emerging crowd organization approaches mainly for gradually extra repeated and common actions corresponding game matches, performance occasions, community demos and etc. in direction to escape gathering mischances and guarantee the municipal protection. Crowd managing frequently calculated through the sociologist, psychologist as well as civil engineers.
Virtual atmospheres	Contain of calculated prototypes of mass can be working in effective atmosphere so that improve the imitations of crowd occurrences, to supplement the social lifetime understanding. Simulated atmosphere is normally calculated by the computer graphic scientists.
Visual investigation	This one is used to notice irregularities and distresses mechanically. Simulated observation is generally calculated by computer visualization.
Intelligent atmosphere	Include a pre mandatory for supporting the mass or a single in the mass. On behalf of case in what way to distract a mass constructed on the shape of mass in an outside atmosphere similar to space lot.
Public Space Plan	Comprise of strategies for the enterprise of civic planetary for instance to enhance the planetary practice of a workplace

Density Bases Solutions

The linear mapping among restricted way characteristics and equivalent entity density maps is attempted using a density-based approach. However, it should be noted that learning linear mapping is difficult. To vote for densities of multiple target choices, Random Forest Regression commencing numerous picture patches is used.

Regression Base Solutions

The regression base solution uses restricted picture patches to take out feature mapping for calculating purposes. Centre characteristics, edge characteristics, consistency and gradient characteristics are some of the features used to encode low-level details. Local Binary Pattern (LBP), Histogram of Oriented Gradients (HOG), and Gray Level Co-occurrence Matrices (GLCM) are examples of methods that capture local and global scene properties to get better performance. Once extracting restricted and worldwide attributes, various regression solutions are used to learn to map for crowd counting purposes, such as linear regression, ridge regression, and neural networks

Convolution Neural Networks

Deep knowledge methods for mass recognition and density study are focused on Convolution Neural Networks. CNN uses non-linear functions to learn counts from crowd videos. The following are some of the approaches that contain projected in the fiction. CNN uses two types of techniques: patch-based training, which uses patches of pictures of various sizes, as well as entire picture-based training, which uses the entire picture. Wang and Fu be along with the primary to apply CNNs to the mission of estimating mass density. For counting people from high-density crowded videos, Wang used deep

CNN regression model. For mass calculation, produced the AlexNet. His method is based on patch-based inference [10].

Instead of calculating density maps, Fu categorized the picture into following categories: very average, low down, average, high, and extremely near to the ground density. His method is based on patch-based inference. For cross-scene counting, C. Zhang suggests learning a map of pictures for crowd calculation and adapting this localizing to fresh object scenes. Initially, they trained their network with two goals: the approximate objectives of crowd density prediction and crowd density prediction. Proposed method is based on patch-based inference. For commodity market price prediction algorithm also referred to deep understanding of topics[20].

Crowd Counting can be divided into two techniques: supervised and unsupervised crowd counting. In supervised technique, the input data is known and labelled, the machine is only used to determine the objective function (hidden pattern). In latter technique, the used data and labels are not known, the machine learning algorithms is used to label the data and determine the

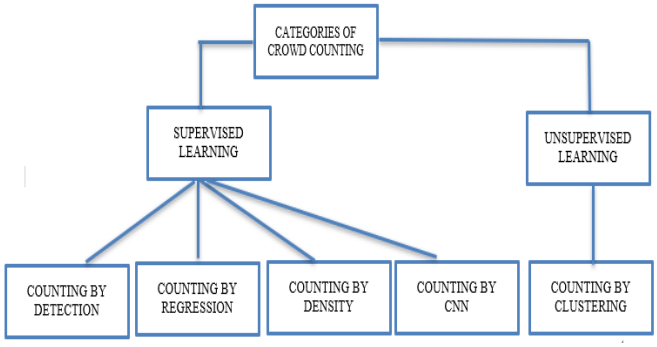

Fig. 2. Categories of Crowd Counting

hidden patterns. These techniques can be further categorized into different methods, as shown in Figure 2. The Multi-Column Convolutional Neural Network (MCCNN) architecture proposed by Y. Zhang allows for images of any size or resolution. Filters for each column of various sizes are used to replica the density maps equivalent to heads of a variety of balance.His method is used in the entire image-based inference process. Rather than the patch-based inference method used in the previous techniques. Shang suggested an end-to-end count estimation methodology based on CNN [11]. As an alternative of cropping picture keen on patches, their process keeps the complete picture as enter and exit the total number of people. Figure 3 shows the general structure of crowed detection system.

For single image crowd counting, Zeng anticipated a story Multiscale Convolutional Neural Network (MSCNN). It used a column network centered on the multi-scale blob to extract scale related features from crowd images. CNN pixel and FCNN-skip architectures were suggested by Kang. CNN-pixel is a pixel-by-pixel prediction method based on CNN [12]. FCNN skip stands for Completely Convolutional Neural Network with Skip Branching. For localization tasks, formed the utmost feature density map, through a minor deterioration for calculating tasks

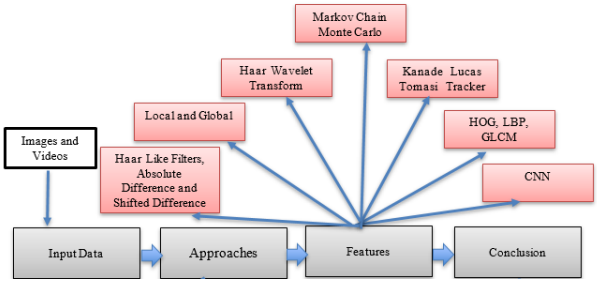

Fig. 3. Crowd Detection System

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A CNN is made up of many layers [Figure 4] Convolutional, Pooling, and Fully connected layers are the three major types of layers used to build architecture. Input - Convolution - ReLU - Pooling - Fully Connected make up the architecture.

Input Layer:

The unprocessed pixel estimations of picture of thickness 32, altitude 32, and three shade channels of Red, Green, and Blue will be stored in the 32 x 32 x3 format.

Convolution Layer:

This will work out the production of neurons related through the input limited region, all computing a dot multiplication of their heaviness and an enter volume. This could result in a volume of 32 * 32 * 2 for 12 filters, for example. It creates answer maps by combining input frames with linear sliding filters.

$$X_i = \sum_{i=0}^{i} w_i x_i + b \quad (1)$$

Xi denotes the input function map, wi = [Wi1, Wi2,....., Wik] denotes the filter, xi denotes the enter filter, and bi denotes the bias.

ReLU Layer:

Rectified Linear Units (ReLU) is an contraction for Rectified Linear Units. The non-saturating activation mechanism is used in this sheet. f(x) = max is the ReLU function (0; x). The volume's size remains 32 x 32 x 12 after this layer is applied.

Pooling Layer:

Pooling uses a down sampling process, as well as width and height, to produce a volume of 16 x 16 x 12. The outputs of neuron are clustered at one layer and are combined to a single neuron in the next layer of the pooling layer. For peak pooling the value from each cluster of neurons at the previous layer is used [13]. The average value from each cluster of neurons at the previous layer is used in average pooling.

Fully-Connected Layer:

The class scores will be computed by the completely connected sheet. Completely linked layers in the neural network perform high-level reasoning. To change answer maps as close up to the land fact as possible, Layer needs a fixed number of inputs and outputs.

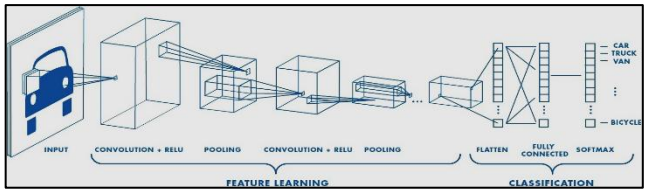

Fig. 4. CNN Architecture

Materials and Methods

Crowd densities can differ significantly between images and between different spatial positions within a single image. The approach is as follows: first of all, we are collecting feed from cameras. We'll have three key variables, such as individuals. The first is people entered, which represents the total number of people entering the mall through the entry gates, and the second is people exited, which represents the total number of people leaving through the exit gates [14]. The people present is determined by as differentiating people exited from people entered. The whole training process was done using Tesla T4 GPU VM on Google Colab.

In order to detect people, we used MobilenetSSD to detect people in each frame. On a regular basis, we will also have an excel sheet to store data for total visited customers in the mall. The aim of this project is to create a system that can be used to keep track of how many people visit a mall on a regular basis. Admins can quickly count the total number of people in a mall at any given time. Often receives notifications if the appropriate configurations have been completed. Since the creation of this initiative, security guards will no longer have to remember how many people are in or out (which will help in situations like COVID-19). Essentially, this system will assist administrators in effectively maintaining daily records, as data will be stored automatically when the system is closed [15]. This will aid in the calculation of advertising fees based on daily records. The UI was built with bootstrap, HTML, and other web development software, and the backend files were connected with flask.

Dataset Used

We have collected images from various open-source datasets including ShanghaiTech dataset and Open Images V6 dataset, COCO dataset and PASCAL VOC dataset. Our main goal was to collect crowded images of People and Mannequins. Thus, we have used images from the open-source datasets. A large-scale crowd counting dataset containing a huge number of images having objects of different classes. The images included in our dataset are major of the morning, afternoon, and evening hours.

MobileNet SSD

MobileNet is a mobile and embedded vision object detector that was published in 2015 as a powerful CNN architecture [11]. To construct lightweight deep neural networks, this architecture employs established deepness wise separable convolutions. The MobileNet model is focused on depth wise separable convolutions. The deepness wise obscurity used by MobileNets applies a particular sort out to all enter outlet. The deepness wise obscurity's outputs are after that combined using 1×1 convolution by the aim wise convolution. In one step, a typical convolution filters and combine the inputs to generate outputs. The deepness wise discrete convolution divides this keen on 2 layers: one used for filtering plus the other for joining. Model size and computational time is reduced significantly by factorization.

SSD (Single Shot Detector)

SSD requires only one attempt to become aware of numerous substances inside a picture, at the same time as RPN based techniques such as the R-CNN sequence has need of 2 attempts, 1 used for generating region applications and 2 used for discovering the item of all application. As an outcome, SSD is greatly quicker than 2-attempt RPN based techniques. Figure 5 shows the original SSD architecture.

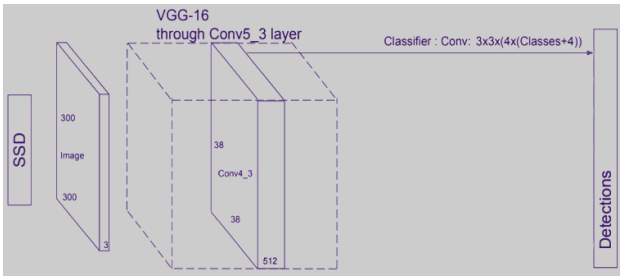

Fig. 5. An SSD Architecture

MobileNet was incorporated into the SSD [16] system to address the functional precincts of successively soaring source and successively power NN on low ending devices in actual period applications. As a result, while MobileNet was used as SSD's support system, it was dubbed MobileNet SSD. For classification, the last layers of the neural network look like Figure 6.

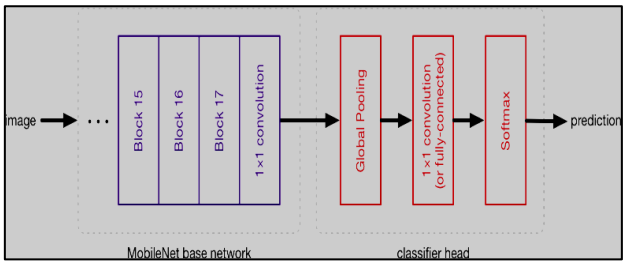

Fig. 6. Last layers of the Neural Network

When SSD is used with MobileNet, the last layers look like Figure 7. Along with output of last base network, output of several previous layers is taken and fed into SSD layers. Pixels of input image are converted into features by MobileNet that describes the contents of the image, and are passed to the other layers. Therefore, MobileNet acts as feature extractor for a second layer of neural network.

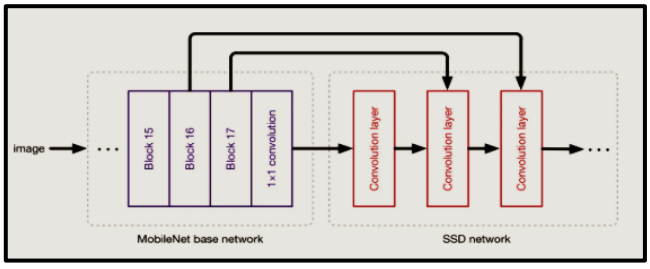

Fig. 7. Combination of SSD and MobileNet Base Network

YOLO Object Detector

Introduced by Redmon, et al. in 2015, YOLO [17],[18],[19] is a single-stage detector which is capable of running in real-time, obtaining 45 FPS on a GPU. A smaller variant called as “Fast YOLO” is known to achieve 155 FPS on a GPU. It is more than 1000 times faster than R-CNN and 100 times faster than Fast R-CNN. YOLO has gone through several different iterations which also includes YOLO9000, known as YOLOv2 which is able to detect more than 9,000 categories of object. To

achieve detection of such a large number of categories, the authors performed training on both datasets viz. ImageNet classification dataset as well as COCO detection dataset simultaneously. The resulting model could predict detections for such object classes which do not have labeled data. Performance of YOLOv2's was quite satisfying. In 2018, Redmon, et al. introduced YOLOv3, though significantly larger than previous models, was the best model among the YOLO family of object detectors. In 2020, YOLOv4 [16] out-performed YOLOv3 as well as other state-of-the-art object detection algorithms. It achieved 43.5% AP (65.7% AP50) on the MS COCO dataset running in real-time at a speed of ~65 FPS on a Tesla V100 GPU.

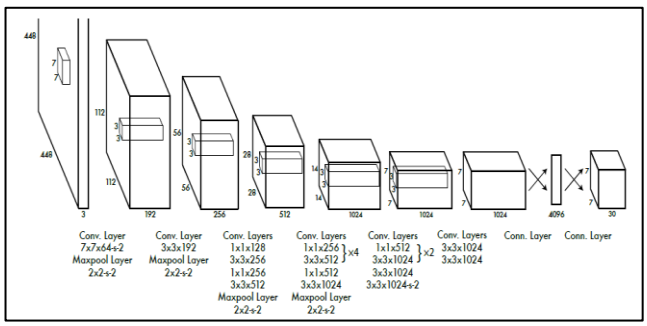

Fig. 8. The Yolo Architecture

Results and Discussions

Table 2: Mobilenet comparison to state-of-the-art models

Model	***Image Net Accuracy***	***Million Multi-Ads***	***Million Parameters***
1.0 MobileNet-224	70.6%	569	4.2
GoogleNet	69.8%	1550	6.8
VGG16	71.5%	15300	138
YOLOv4	92.6%	4400	25

Different model to count the number of people present in the given image, video, or live-feed surveillance camera were used in the paper. While running on a video or a surveillance camera, object detection algorithm on each frame becomes a computationally expensive task, giving a very less frame rate (FPS).

Therefore, it is not computationally feasible. Compared to object detection, object tracking is computationally less expensive. Thus, we run the object detection algorithm only for specific frames. And for the rest frames, an object tracking algorithm tracks the detected objects. For object tracking, centroid tracking algorithm is used which is based on the Euclidean distance between (1) the objects that centroid tracker has already seen before and (2) the new object centroids between subsequent frames in a video. The MobileNet SSD technique was earliest qualified on the COCO dataset before being fine-tuned on the PASCAL VOC dataset, achieving a mAP of 72.7% (mean average precision). We trained a object detection model using YOLOv4 [18] for 4400 iterations. It attained 92.6% mAP25

and an Average Loss of 0.9754. Since a loss value, less than 1 was attained just after 4400 iterations, the training was stopped. It can be evident from Table 2 that Yolov4 gives best accuracy. Number of parameters is less in GoogleNet and MobileNet but the resulting accuracy provided by YOLOv4 outperforms the other models.

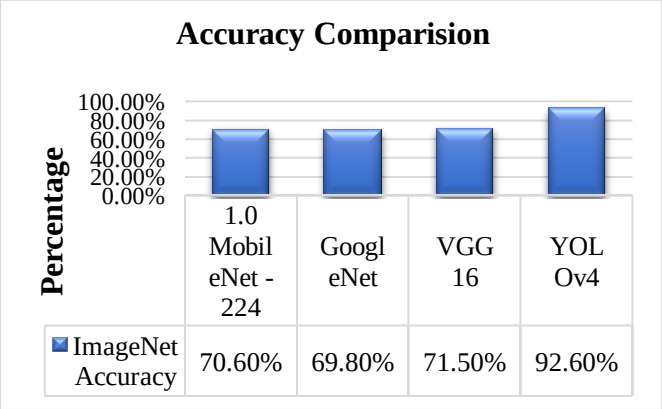

Fig. 9. Comparison of Accuracy

Conclusion

Comparison between 4 state of the art models is performed. YOLOv4 outperformed all the other competitive models with 92.60 % accuracy. The paper encourages and gives directions to researchers for further research work in the area of crowd counting. The work can be extended for real applications that can be used in real scenarios. Web or mobile based applications can be developed that can be installed at required locations.

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