International Journal of Research in Circuits, Devices and Systems

E-ISSN: 2708-454X
P-ISSN: 2708-4531
IJRCDS 2022; 3(1): 85-91

www.circuitsjournal.com
Received: 05-11-2021
Accepted: 10-12-2021

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A survey on object detection for monitoring social distancing

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Abstract
The current epidemic due the Corona Virus, there has been had really severe impact. The crisis has put lives of many in jeopardy. The impact of the global pandemic could still last for long time as either an impact on economy of countries or the health scar on the people. It has been estimated about 4.5 million deaths and 220 millions of people have been infected. Apart from them lives of countless others have been impacted indirectly, including various ways stretching from mental issues to economic problems. Apart from the vaccines, there are very few ways to proactively protect oneself from COVID-19. One of those ways are to prevent exposure of oneself by maintain social distancing. It has been shown that social distancing helps in reducing ones exposure to COVID. It is also one of the easier things for one to do. Therefore, the purpose of the study is to explore various object detection frameworks as an implementation to monitor social distancing. The frameworks will detect presence of humans in a given frame, and monitor social distancing by calculating distance between two humans, and checking whether the distance more than acceptable distance. The further studies would include implementation of the models in surveillance and traffic cameras in public areas, and extend from just detecting human presence to identify whether individual has mask on.

Keywords: Object detection, social distancing, COVID-19, survey paper, machine learning

1. Introduction
The COVID-19 is disease caused due to infection due to Corona Virus, which was first noticed at late December 2019 at Wuhan, China. The global pandemic due to Corona Virus has been one of the most devastating outbreaks in the history of the mankind. It was declared by the WHO (World Health Organization) on 11 March 2020. As of October 2021, there has been estimated 4.5 million deaths and 220 million people who have been infected. The dangerous part of the virus stems from it being easily transmittable, according to WHO a person could get infected when he/she comes in contact with another person infected with the virus.

The social distancing is a safety measure that involves people to separate themselves to prevent exposure to one another. It is a proactive measure that prevents the spread of the disease. According to WHO, the person needs to be at least 2 meters without mask and 1 meter with mask. As there as been vaccination at steady pace, the next most sensible thing to do would include social distancing. Considering the large population, the time taken to completely vaccinate people would be very long, and that would be dangerous opportunity for mutation of virus. Hence, social distancing is a key to prevent escalating the scenario.

Social distancing does have a good impact in prevention of the virus, but it takes a toll on people considering many wouldn’t be to go to their jobs, and there would also be economic impact due to it. Still, the purpose of the study glances over explaining various studies on monitoring and maintaining social distancing and extending a proper survey on the latter.

For the recent years there has been exponential development in the field of object detection. This has caused it to be used in wide variety of applications stretching from academic purposes to research purpose. The point of object detection is to understand, classify and extract features from images. The concept of understanding images has potential in multiple industries, some of the notable ones are for surveillance at fields like military and security, medical fields etc. The study will give a detailed understanding to how object detection helps in monitoring social distancing, it will glance over working of various pre trained models and explain the effectiveness of each model.

The paper is composed of 7 sections. The literature review section would explain a brief about various others studies that have been made. Background section would explain key terms present throughout the paper.

The next parts of paper will start by giving further explanation to background of working, the third part will give introduction of few generic deep learning object detection models. The fifth section will give a brief on common data sets widely used and developed for object detection. The sixth part analyses the models and compares them. The seventh section would ponder over the issues that can be foreseen due to implementation of object detection for social distancing. The eight section would deal with the challenges faced in implementation of the study.

2. Literature Review

This section will give a brief in other works done on the related field of COVID-19. Since the disease started to spread, there has been various researches conducted on the field. There have been different studies that posses as an effective alternative. In the view of the study, Matrajt *et al.* [1] conducted a study effectiveness of social distancing on flattening the epidemic curve. They used age-structured susceptible-exposed-infectious-removed model to project the transmission of the virus and adjusted it for respective age distributions. The study divided the results obtained by running various simulations into 4 scenarios with each focusing on enforcement of social distancing on certain age groups. The study then concluded with rein station of importance of social distancing to flatten the epidemic curve. Another study was conducted to evaluate the impact of COVID-19 on economic well-being on social distancing. Tran *et al.* [2] conducted the study in Vietnam to describe the quality of life of people under curfew of social distancing. The study used ordered logistics regression and multi variable Tobit regression model to project the correlation of income of people and household income, health status, health-related quality of life. The study showed that 66.9% of Vietnamese citizens lost household income during national wide social distancing. Many studies [3-7] were conducted on application of Object detection to regulate social distancing. The studies uses deploys trained object detection models for human detection. The challenges faced will be discussed in further sections. Ahmed *et al.* [3] used YOLOv3 framework to maintain social distancing among humans through a video feed. They trained the model through a custom dataset, and propose usage of bounding box in calculation of distance between people. Rahim *et al.* [4] used YOLOv4 framework to perform real-time object detection. They proposed the model to work with motionless time of flight camera. Sergio *et al.* [5] used YOLOv2 framework to classify people using thermal images. The study involves application of Artificial Intelligence system in detecting and monitoring social distancing among people. The study further implemented the the model in a low-cost embedded device named Jetson nano, a NVIDIA system.

There have been many other technological related applications in maintaining social distancing among people. There have been many publications on them by many countries as well. Some of them are based on tracking people using their phones through mobile application, and further notifying others around them. India has developed an app namely Arogya Setu, which focuses on notifying people on infected people. As explained by Seetharaman *et al.* [6] there are more applications like C9 Corona symptom tracker by Germany and Corona100m by South Korea.

3. Background

Computer vision is the scientific field that deals with derivation of meaningful information from various visual inputs. Object detection is itself a subsection of Computer vision related task. The objective of object detection is identifying required objects in an image. The process of object detection involves identification of annotations and then predicting the ones consisting of required object using classification probabilities. The collection of the files involved in identification of any object is called as an object detection model.

Due to immense development in the field of computer vision, there are various pre trained models, IE models that are created to identify certain object. The object detection models can be classified based on its relevance in today's world as traditional and modern techniques.

The traditional technique or image processing technique do not take any annotated images during the training period as they are unsupervised in nature. There are very few studies that are still relevant today. Research papers [7, 8] have further elaborated on working of the unsupervised models.

The modern technique or deep learning methods fall under supervised learning category. Here a large amount of data is fed into it during training period. This significantly improves the overall robustness but also requires huge computation power. The modern deep learning models can further be classified into two types based on number of steps the model takes to achieve the required task,

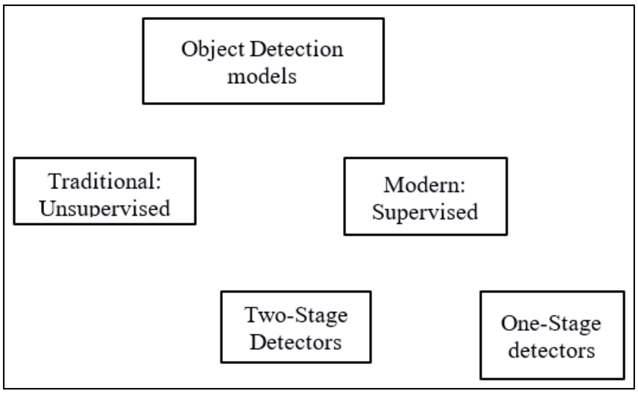

Fig 1: Classification of object detection model

Two-stage detectors are deep learning models that take two steps in identifying objects. The steps are proposing region of interests and classifying the regions based on bounding-box regression. Due to multiple steps, there is higher accuracy compared to One-stage detectors, but the same contributes to lower speed compared to the same.

One-stage detectors are other part of deep learning models that specifically achieve identification of object using single step. This models skip over the first step, proposal of regions of interest thereby reducing the time consumed. Due to it, there is decrease in accuracy and especially in detecting smaller objects.

4. Generic Deep Learning Object Detection Models

As explained in previous section, there are various pre trained object detection models that are capable to be used in various dedicated tasks. To understand them further we will discuss some of them in this section. Pre trained common models that follows two-stage object detection are,

a. R-CNN

Region with CNN features(R-CNN) is a common deep learning model for object detection and is a region proposal based framework. It was developed by Ross Girshick in 2014 [13]. The working of R-CNN involves in using of "selective search" to identify a number of object regions knows as "region of interest" and then extract features out of them independently. Even though it is a common model, it ends up with large number of regions(around 2000 regions per image). Also it takes long time while training, considering large amount of images in larger data sets. But since the model is bit old, the concept of selective search itself is an algorithm which implies that the model is not changing.

b. Fast R-CNN

Fast R-CNN was developed in 2015 to solve disadvantages of R-CNN [14], one of them was speed hence the name of fast R-CNN. The improvement made in the algorithm was at "selective search". Instead of the concept of RoI (Region of interest), Fast R-CNN works by using a convolutional feature map. Since for each image, convolutional operation is done only once, Fast R-CNN is much faster than R-CNN.

c. Faster R-CNN

Faster R-CNN [15] model was first published in the year 2015. As the name suggests, the model was developed as next iteration to previous two models. The improvement in the performance arises from not using the selective search approach. The model instead of working on selective search algorithm, which learns the region proposals.

Unlike the Fast R-CNN, where on the convolutional map selective search method is applied to find out the region proposals, the faster R-CNN relies on using a separate network to predict the region proposals. This change highly increases the speed of model from even the Fast R-CNN.

e. YOLO

You only look once (YOLO) is a One-stage Detector [16]. YOLO works on Unified Pipeline, here the complete process works on a single stage. In YOLO, the image is split into multiple smaller parts in grid. For each box in grid, it uses probability to map the object to the image. Since it splits the image and finds, the model's advantage is that it can detect larger object easily but same makes it harder in situations with smaller objects in image. The model is known for its speed and lower accuracy, this is also commonly used for real time processing.

Due to architectural differences in the pre trained models, there can be various performance difference during implementation. Sanchez *et al*. [17], has ilustrated the performance metrics on the models. The datasets used in them to conduct the study are elaborated in the next section. The performance can hence be summarized to,

Table 1: Comparison between performance of the pre trained deep learning models

Models	Accuracy ***** indicates high and * indicates low	Speed ******* indicates highest and * indicates lowest
R-CNN	**	*
Fast R-CNN	***	**
Faster R-CNN	_****	*****
YOLO	**	*******

Datasets and Benchmarks

Detecting required objects from the given images is the requirement of object detection itself, to train such a model, we would need large set of images and information. Datasets are other part of object detection that helps in training, testing and bench marking the models. The working of the model depends on a good benchmark. This allows us to compare various object detection models and test them. Any datasets depends on good data for model to learn from. In this study we will be focusing on relevant data sets involving pedestrian and face detection.

A. Benchmarks available

i. MS-COCO: Microsoft Common Objects in Context [9] is large-scale object detection, segmentation, and captioning dataset. It covers 91 object categories and massive 2.5 million object instances in 330K images. The dataset consists about 800K for object category "person". The images in the dataset are in 640x840 pixels of resolution.

ii. PASCAL VOC: The PASCAL VOC [10] was developed from the year 2005 to 2012. It is a common object detection dataset that consists of over 20 categories and about 11,000 images. The images in them can be split into 5.7K images for training set, 5.8K images for validation set and 10K for testing set. Each image under the dataset is in 469x387 pixels of image resolution, and for each image on average there are 2.711 object instances per image.

iii. ILSVRC: ILSVRC or ImageNet Large Scale Visual Recognition Challenge [11] is a large scale visual dataset. The dataset consists of 200 object categories. It has 456K images in training set, 20K images in validation set and 40K images in training set. Each image in the dataset is in 482x415 pixels of image resolution, and the image consist of 2.758 object instances on average per image.

iv. DOTA: DOTA is a large scale dataset of aerial images [12]. There are various versions for the dataset. The latest one is version 2.0. It has 18 categories, 11K images consisting of 1.8 million images in it. The split for dataset consists of 1,830 images for training set, 593 images for validation set and 2,792 images for testing set. The dataset consists of images varying from 800x800 pixels to 20,000x20,000 pixels resolution.

b. Evaluation Metrics for datasets

As one of the purpose of the datasets is to test the algorithmic object detection models, there are few ways in objectification of the differences in the models. The need for various different types of measures is to elaborate the ways in which the models could be utilized. Some of the metrics are as follows

- **Accuracy**

The accuracy of a model can be explained by the percentage of correct samples.

- **Precision**

The precision of a model is the percentage of True positives among total positive results.

$$Precision = \frac{TP}{TP+FP}$$

For the above equations,
TP is True Positives
FP is False Positives

- **Recall**

The recall of a model is the percentage of True Positives among total true results.

$$Recall = \frac{TP}{TP+FN}$$

For the above equations,
TP is True Positives
FN is False Negatives

- **Intersection over Union (IOU)**

IOU of a model is defined by ratio of area of the overlap and its union between the prediction and the bounding truth.

$$IOU = \frac{areaofoverlap}{areaofunion}$$

- **Average Precision (AP)**

Average Precision for a model is defined as the area under curve of precision and recall of the model. The average precision is often associated with IoU as well. For example AP50 implies Average Precision at IoU = 0.50.

- **Mean Average Precision(mAP)**

Unlike others, this factor is commonly used as metric for evaluation of an object detection model. It is calculated by taking the average of AP for each class.

6. Results and Discussion

This first part of the section would deal with performance of the object detection models and compare them to understand the implementation for social distance monitoring. The results of each model is for pre trained/ models. The performance of the individual models were explained in references [5-9]. The datasets for comparison would be the already mentioned ones. The second part of the section consists of discussion of various cases in which each model faces its own challenge, also to compare them with traditional method to check whether implementing a object detection model is feasible and makes considerable difference in overall social distance monitoring.

a. Results of object detection model

Table 1: Results for performance of R-CNN

Dataset	AP[0.5] on person category	mAP[0.5]	Time per image
VOC 2010	53.6	50.2	47 sec
VOC 2007	45.8	47.3	
MS-COCO	-	24.6	

Table 2: Results for performance of Fast R-CNN

Dataset	AP[0.5] on person category	mAP[0.5]	Time per image
VOC 2007	69	66.9	2 sec
ILSVRC 2013	70.4	24.9	
MS-COCO	-	35.9	

Table 3: Results for performance of Faster R-CNN

Dataset	AP[0.5] on person category	mAP[0.5]	Time per image
VOC 2007	69	75.1	0.2 sec
ILSVRC 2013	70.4	46.9	
MS-COCO	41.5	42.5	

Table 4: Results for performance of YOLO

Dataset	FPS	mAP[0.5]	Time per image
VOC 2007	45	63.4	0..02 sec
VOC 2012	45	57.9	
MS-COCO	45	51.5	

Table 5: Comparison of performance of the models

Models	Accuracy ***** indicates high and * indicates low	Speed ******* indicates highest and * indicates lowest
R-CNN	**	*
Fast R-CNN	***	**
Faster R-CNN	_****	*****
YOLO	**	*******

b. Observation

The above results explains that each and every model available are to used for separate use case, and hence not all models fulfill the requirement required. For our study since we would need to monitor social distance in real time, the proper model must be fast and light weight. Hence to accommodate the current requirements the chosen model is required to be fast and can be compromised on accuracy.
Also for further improving the implementation in CCTV cameras, the model might be challenged with its accuracy since a standard CCTV cameras record larger view at relatively smaller resolution, the accuracy is still required in the model.
The results from above shows a picture about the effectiveness of the models. From the tables above it is clear that Faster R-CNN is much faster and accurate compared to Fast R-CNN and that is much faster and accurate than R-CNN. But there is another part as well, the data shown for YOLO model might not show the full capabilities and its weakness itself. The comparison between mAP for Fast R-CNN and YOLO might say that Fast R-CNN is slightly better than YOLO, but as explained in previous section the differences in architecture for two algorithms are completely different. Hence, that causes an incomplete explanation. The capabilities of YOLO is hinted from the time take from the image. For almost 100 times the speed of Faster R-CNN,YOLO is one of the most capable model to be chosen for required scenario.

7. Issues and Challenges

This section would illustrate on various issues presented in application of technology in monitoring social distancing.

- **Cybersecurity and Privacy**

In general terms monitoring social distancing is just tracking people. Further the implementation of real time video surveillance, would require expansion of existing cameras around us. Basically, it increases the chances of cuber-vulnerabilities and data breach. Such are already a common around us already. But since the video monitoring now consists data on people as well, there is higher possibilities for someone to hack into the system for such data.

Apart from data breach, there is also possibility of misuse of data. There has been history of people in power misusing CCTV footage for unlawful activities, and application of such monitoring frameworks would further increase the chances of misuse of data.

- **Feasibility**

Another part of issues presented in implementation of monitoring algorithm in public places consists of viability of such system itself. Most of discussed methods requires a person to manually check with the monitoring framework, this might lead to inefficiency. Also, if system detects a interaction between two people, there might be no point in it if people do not abide by the rules, thereby further deterring the point of implementation of the system.

The application of system in workplaces like warehouses also faces certain issues. Since the interaction between the employees in a workplace are shorter and there are higher possibilities of transmission of disease through different medium (like handles in door, commonly used objects etc.), the effectiveness of the system decreases.

- **Cost of Implementation**

Since the monitoring algorithm relies deeply on quality on input images, there is further requirement of quality of cameras. This thereby limits the viability of the implementation.

The system also poses various more requirements, like more servers to store and process data collected through cameras. Also requires more people to maintain, which increases the cost of implementation further.

- **Awareness among people of social distancing**

The intention of monitoring people is mainly to make sure they follow social distancing. Since there aren't much ways to actually punish someone for violating social distancing especially in a public place, the people might not consider the importance of social distance seriously.

- Economic effects due to social distancing

There is intrinsic challenge of social distancing in first place, that is the economic effects due to social distancing. There has been immense impact on economic well-being of people all around the world. Many factors like average house-hold income, average spending among people, even mental health have indicated the immense pressure due to social distancing. Due to such factors, it is a challenge to consider an implementation for social distance monitoring.

8. Conclusion

Object detection is a field with immense possibilities and challenges. With the development in the technology, the chances of the possibilities also increase. The paper gives a comprehensive review for a methodology for maintaining social distancing using object detection model was studied. The paper explains working of various models and explained by their performance. The paper also gave an introduction to datasets, gave a glimpse to few common ones and explained how models are evaluated using them. As the development of the technology, the paper also intends to have future research.

9. Future Studies

The future studies that are intended to be a part of this paper are:

a. **Explanation of models using transfer learning:** The concept of transfer learning wasn't touched in the study. It is the concept of reusing a pre trained model to learn something specific. Such implementation would improve chances of specifically targeting "person" thereby improving the performance of the model.
b. Multiple model machine learning: The working of multiple model is also a relevant concept which is planned to be included in future studies. The concept of solving a drawback by partial implementation of another algorithm is an ingenious idea. This helps in cases like YOLO to improve its accuracy much more if implemented with faster R-CNN.
c. **Diverse object detection models:** Another area the study is further planned to study. There are plenty more object detection models with distinct architectural differences which might give better results. Some of them include models like Single Shot detector modes (SSD) [16] and Mask RCN [17]. Here, the SSD is another popular single stage model similar to YOLO which is commonly used for real time object detection. There is small difference in performance between them which stems from the way of handling convolutional network [18-23].

The mask *R-CNN* is a different type of model when compared to the mentioned ones. Unlike the other models, mask RCN has the capabilities of a feature known as instance segmentation. Instance segmentation is classifying each pixel and generating a much cleaner mask (bounding) when compared to bounding box generated by other models. This feature is useful as it gives more idea in the image.

Considering our requirement, the implementation of Mask R-CNN's instance segmentation would significantly help in analyzing accurate position of detected object, as such information is vital in understanding the distance between two objects. Also, machine or deep learning can helpful in emerging technologies like Blockchain, Cloud Computing, etc., which can be found in the research works of Tyagi et. al., [24-35].

D. Testing against custom datasets: Custom datasets consist of data collected by someone from scratch for a specific purpose. Training models based on custom datasets helps it condition to meet the specific requirement much better. As a model only learns based on its interaction in training model, the customization in training datasets influences the model in desired ways. Often times it is a way to tune the specification like its performance, speed, accuracy etc.

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