Social Distancing Monitoring for COVID 19 with Persondetection and Tracking

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Abstract: *Social distancing (SD) also called as Physical distancing is the process of maintaining a minimum of 6 foot or 2 meters distance between the individuals in public areas. It also involves avoiding or minimizing the contact between individuals. As per WHO (World Health Organization), SD is the current best known solution to slowdown the spread of Corona Virus. Most of the governments, national and international health specialists have prescribed a minimum distance of separation must be at least 2 meters in order to ensure safety in schools, shopping centres and other covered zones. SD is an applicable non pharmaceutical step against this new COVID-19 (Corona VIrus Disease 2019) pandemic. Conversely, it is not so easy for the common people to keep an imaginary safety space around them. Thus a system that can check and warn the individuals will help them to achieve the purpose of managing SD easily. In this effort, we are making use of a generic deep neural network based standard for detecting the people automatically, tracking, and estimating distance between the people in the crowd. The implementation can be much easier and economical by using the already fixed private or public CCTV cameras. The intended scheme utilizes inverse perspective mapping and YOLOv3 based algorithm for detection of people accurately and to implement social distancing.*

Keywords – Social Distancing, Physical distancing, COVID-19, People Detection and Tracking.

I. INTRODUCTION

The COVID 19 disease was first detected at Wuhan, a city in China during the month of late Dec 2019. Just after a few months, the virus has been spread to almost all countries of the world and it saw a global outbreak in 2020. The WHO has declared this new disease as pandemic on April 9th, 2020. The statistics by WHO on 1st June 2021 confirms that a total of **170,426,245**people are infected in more than 200 countries. The disease has caused deaths of **3,548,628**people.

With the growing trend of patients, scientists from all over the world, medical organisations and researchers of pharmacy industry are continuously occupied and striving hard to produce suitable medicines or vaccines for the deadly virus. As a result, many countries have produced vaccines within a very short period of time. As the time required for vaccinating the whole population of the country may take few months and up to a year and also, the newly invented vaccines are not yet proved to be secure and effective for children and pregnant women. The clinical tests are under process and results awaited. As a result, necessary precautions are to be taken by all countries of the whole world to prevent the spread of this infectious disease [1][2].

A. How virus spreads?

There are emerging evidences that prove COVID-19 is a contagious disease so that it can be carried by the air through minute particles of saliva which may enter the air once infected people cough or sneeze without any respiratory etiquettes or speak without wearing face mask. The chances are more in poorly ventilated settings, crowded or closed areas." This is the main purpose of maintaining this minimum distance to avoid spread of virus from reaching the other person through air or wind [3].

B. Controlling the spread of virus

With the COVID virus detected in December 2019, later it spread to almost all countries of the world by start of Jan 2020. In spite of severe actions such as border closure, partial / complete lockdowns in their countries and simultaneously isolation and treatment of infected individuals is carried down to prevent the spread of disease. Adopting these measures for prolonged periods affects the economic condition of the country and its people. At the same time the people will also find it difficult to lead their lives during complete or partial lockdowns of the countries or cities as a lot of people have lost their jobs and other earning sources. The disease was under control till end of 2020 with stringent SD rules being imposed on citizens. Later, as the daily number of cases started decreasing, the government started easing the SD measures. Slowly, the restrictions on movement across the borders, re-opening of shopping complexes, public transport, restaurants, are eased down to boost the economy.

As a result many countries today are facing severe second wave of the disease and few are in third wave. These tough conditions have forced the entire world's population to search for other substitute means to reduce the spread of the virus. Hence, during this process of removing restrictions, the government and citizens should not forget to maintain SD measures. The only current feasible solution to lift the imposed lockdown in order to manage the economy is strictly following Physical distancing and minimizing human contacts. Thus SD plays a pivotal role in prohibiting the spread of corona virus and thus helps in postponing or reducing the peak number of infected individuals.

C. Social distancing scenario

With reference to the fig. 1.1 which shows a general SD scenario where a minimum of 2 meters or 6 foot distance has to be maintained between the individuals.

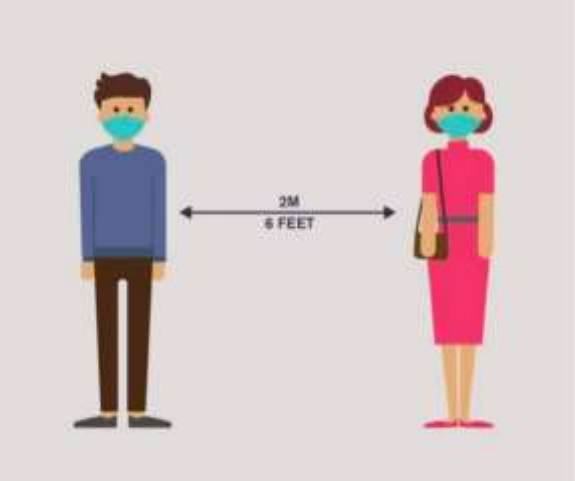

Fig 1.1 Social Distancing scenario

Also, Social distancing helps prevention of multiplying of the contagious infection, by reducing the vicinity of personal interactions in enclosed or congested shared spaces such as offices or workplaces, gyms, cinema halls, schools or universities, party halls, temples, hotels etc., to slowdown the infection risk. WHO has confirmed that the COVID 19 infected people may show symptoms such as cold, cough and fever with increase in the body temperature. There are chances of taste and smell loss in addition. The researches have also established that, individuals with minor or no symptoms (asymptomatic) might too be the transporters of COVID virus, who are known as passive carriers. Therefore, it is very essential that every individual adopt disciplined behaviours and follow SD [4].

Fig. 1.2.Social distancing monitoring

Fig 1.2 shows people at a public place. The people with Green bubble around them are following SD while those with red bubble around them indicate violation of SD. Similarly, Fig 1.3 shows the accrued infection risk indicated with red coloured areas due to many violations of the SD[1].

Fig 1.3. Infection risk (shown in red coloured spots) due to several SD violations

D. Effect of Social Distancing

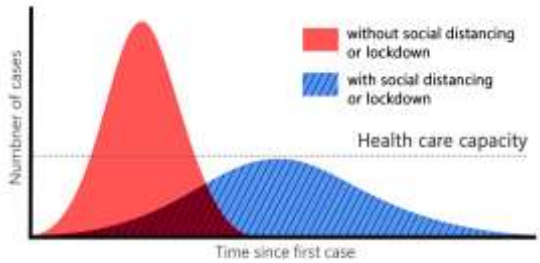

Fig. 1.4 Total number of infections without and with SD implementation [4]

With reference to above fig. 1.4.which shows the total number of COVID-19 cases without and with SD measures implemented. From the graph it can be observed that, if there are no restrictions on the movement of people and no SD measures, then the total number of daily corona cases will be in a very large number which is indicated in the curve filled with red colour. If the total number of cases is very high then,

the existing medical facilities and capacities cannot fulfil the needs of raising cases. That is there will be a clear shortfall in the medical equipment, general beds, ventilator beds, ICUs and even there are chances of acute shortage of medicines if the state or country is not prepared for pandemic since its first case[4].

But, with strict SD measures and control over the movement of people, the daily total number of cases is reduced and the peak of the cases is postponed. The health care system will get a considerable amount of buffer time to increase its capacity. During this time, the government may try to setup new hospitals or increasing the beds by setting up of temporary care centres where COVID patients can be treated effectively.

In summary, without SD the daily total number of cases will be large and exceed the present available healthcare capacities. And with SD measure, the peak of the pandemic is postponed and the total number of cases does not exceed the present healthcare capabilities.

E. Automatic system to monitor SD

During the outburst of corona virus disease, with restrictions on people's movement, it is necessary that people will have to go out for procuring the essential goods which are basic for their daily living such as food, medicines, fuel, healthcare and other necessary works.

In order to meet such demands, there is a requirement to develop an automatic system that is capable of simplifying social distancing. But, the development and deployment of such an activemonitoring system entails clever design of the system and few of the considerations. The foremost requirement is the protection of individuals' privacy. i.e. there are chances of intentional or unintentional violations of privacy of individuals when data is recorded and stored. Another important aspect is being non-intrusive i.e. no direct warnings are to be issued to the individuals. A non alarming audio visual signal may be posted to the locality of the public place showing the SD breaches. Hence, the system must be real time i.e. system should not store any information.

Second, the system should not differentiate. This can be achieved securely by designing an Artificial Intelligence based system. There must not be any interference from human supervisors. A connectionist machine learning system or parallel distributed processing model, such as a pre trained DNN can be used.

In India, the government is making use of the contact tracing application known as Arogyasetufor tracing and tracking of infected persons with the help of Internet, Bluetooth and GPS technologies[5].

With this motivation in this work, the authors are making an effort to provide a general meaning of social distancing in the present context to COVID 19 situation. The paper is organised as follows. The system block diagram is presented in section II. Later, in Section III we have discussed on Preliminaries, Problem formulation, Methodology along with the solution. Section IV gives the Flow diagram and Algorithm for the system. Implementation is considered in section V. Results of the scheme are discussed in section VI. Applications of the system are dealt in section VII. Limitations and Future scope are discussed in Section VIII and Section IX. At the end the paper is concluded in section X.

II. SYSTEM BLOCK DIAGRAM

We suggest a scheme with 3 phases for SD monitoring, namely

- Identification of people or pedestrians
- Tracing of people and
- Calculation of distance between people

With reference to fig. 2.1 which shows the proposed system's overview. Against this framework, we are proposing a non intrusive, artificial intelligence based active observation scheme for directing audio visual cues whenever a violation of SD is detected. As a solution to the problem of monitoring SD, a 3 stage model is proposed. The system performs function of pedestriansidentification, their tracking and finally the distance between them is estimated.

The images or videos are captured with the help of pre-existing CCTV cameras. The videos or stream of images is then fed as input to our deep neural network model. Then the people are detected in the image with their localising bounding boxes. The proposed scheme has to identify the pedestrians with different postures, varying sizes, different cloth colours and with varying weather conditions such as poor light. With this planned system, the persons are identified in the given image with bounding boxes utilising a pre trained deep CNN. Then, these findings in the image domain are converted into real-world bird's eye view (BEV) coordinates. Whenever a distance less than the prescribed SDis observed, the model initiates a warning signal. Concurrently, if the number of people in a particular area is over a predetermined value called critical threshold, the system gives an optional control signal to the admin and avoid congestion of people by controlling the number of people that are entering into premises.

The real time monitoring and detection of people (real time processing of videos and images from the cameras) with this technique requires high computation capable computer with a large amount of Graphics card and RAM. In order to make the system more economical and for easy implementation of the system, the system is made simple and easy.This work makes use of a general personal computer or a laptop with Python IDE. Here the videos are captured from the public places and are compressed. Then the code takes the video and further required processing is performed. This proposed work can be made use to accommodate SD in public areas like Railway stations, public transport systems, Offices or workplaces, Schools and colleges etc.

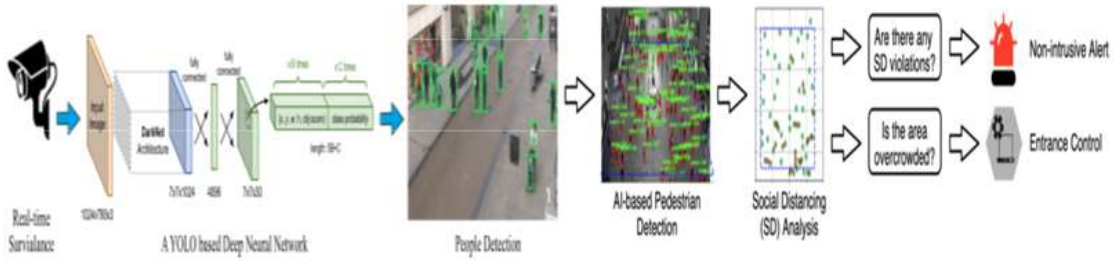

Fig. 2.1 proposed system's overview

The steps involved in a SD detector involves the following:

1. The people in a video stream are detected using an object detection technique. Here we are making use of YOLO object detector to detect people in our video stream.

2. The distances between the detected people is computed

3. Check for any SD violations. If yes, then people are bounded by red box else bounded by a green box.

A. YOLO: The Object detection algorithm

YOLO stands for You Only Look Once. It is the recent and real time object detection technology. In the field of computer vision, object identification is thought to be one of the most challenging tasks. In YOLO with a single evaluation, the bounding boxes and class probabilities are anticipated using only one neural network from the images directly. In the meantime, frame detection is treated as a regression problem, a simple pipeline is enough. It will have an optimised performance i.e. YOLO is extremely fast with pipeline in detection and in one second, it can process 45 frames. Using YOLO it is possible to estimate which objects are present and where they are. Since we assume detection here as a regression problem, a complex pipelining is not necessary.

YOLO is pleasingly straightforward: With reference to figure several bounding boxes and their bounding boxes class probabilities are guessed simultaneously using a single convolutional network. YOLO's identification performance is enhanced by pre training it on full images.

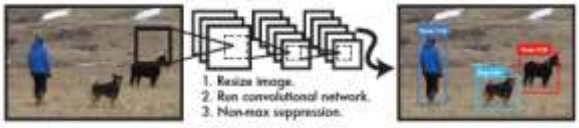

Fig.2.2: The YOLO Detection System.The input image is resized to 448X448, then object detection along with their confidences are resulted using a single convolutional network

An image is divided into an SXS grid. Then an object is detected, if it's center stays in that bounding box. For the bounding boxes detected, the confidences are calculated. The confidence is a measure of how confident or accurate the system is about its prediction of the object that it detects. The bounding box confidence will be equal to zero whenever there is no object inside that bounding box. The confidence of the bounding box along with 4 coordinates x,y,w&h are predicted. The center point of the bounding box is denoted by (x,y). The width and height of bounding box is denoted with x and y respectively [6][7].

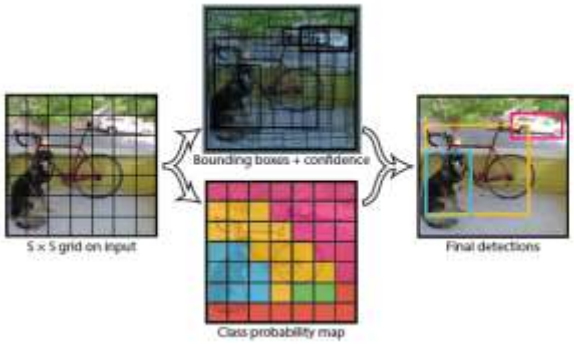

Fig. 2.3. YOLO object detection procedure

B. Advantages of YOLO

1. In comparison with Fast R-CNN, YOLO sees a very less number of background errors

2. On training with natural images and YOLO can detect random images very accurately.

C. Limitations of YOLO

1. Not capable of detecting small objects in groups as it can only predict two boxes and only one class in each grid cell.

2. Incorrect localizations is another source of error

III. PRELIMINARIES

Object detection with deep learning: The fundamental computer vision problem is the object detection in the image domain. The objective here is to identify cases of objects belonging to particular classes like buildings, cars, humans etc. CNNs are utilized for object detection. Data augmentation techniques can be used to train these models by supervised learning to increase diversity of data.

Model generalization: The accuracy of the recent technology is decent and sufficient for employing pre trained models to new environments. The pre trained models have shown a better performance in 2 dimensional object detection under various conditions such as a number of camera models, illumination levels and angles of capture.

Thus a deep learning centred pedestrian detector could be used for implementing of the chore like SD.

A. Methodology

A fixed camera captures videos from the area or region of interest (ROI). Then the individual distances between persons is to be calculated. Whenever there is a violation and breach of SD, a non-intrusive audio visual cue is displayed. Also instructions can be given to control inflow and outflow to have a check on density of people [8].

Problem formulation: At any instant of time t from an image, our aim is to find the pedestrians or people class in the scene. Then the next step is to find the distance 'd_i' between the people which is called as the interpedestrian distance is compared with the threshold SD value. If there is a violation of SD, then sends an audio visual cue bounding the people in red and green boxes accordingly. The red bounded box indicates SD violation whereas a green bounded box indicates no SD violation. Also total number of SD violations are to be displayed on the screen.

Let, define a 6 tuple, $T=\{C,R_i,d_{min},k_1,k_2,C_0\}$

Where, $C \in R^{HXWX3}$ denotes a colour image (RGB) taken with a camera which is at a height'H' and-width'W'.

The ROI on the ground plane in real world is-denoted as $R_i \in R$ and the required minimum physical distance is defined as $d_{min} \in R$.

Whenever, the inter pedestrians distance is less than d_{min}, a non intrusive audio visual signal needs to be sent depending on the binary control signal k_1.Overcrowding in ROI can be handled by another binary signal k_2 to impose control at the entrance. With the outline of critical SD (d_c) overcrowding is detected. d_c ensures SD violation occurrence likelihood stays lower than C_0.

Problem 1:- S is given and our interest is preparing a list of pedestrian vectors $I = \{i_1, i_2,\ldots, i_n\}$, $i \in R^2$, in real-world coordinates on the ground plane. Also find a corresponding list of inter-pedestrian distances $D = (d_{i1,2},...,d_{i1,n}, d_{i2,3},\ldots,d_{i2,n};\ldots, d_{in-1,n})$, d_i is always a positive real number. And n indicates the total count of pedestrians identified in the ROI. There is a need to ensure the total number of violations does not cross critical density value.

After solving the problem 1, the subsequent control algorithm can be used to notify/guide the people in the ROI.

Algorithm 1:- The parameter k_1, the control signal is set to '1' and a non intrusive audio visual signal is initiated, whenever distance between the two people 'd_i' is less or equal to the critical SD value d_{min}. Else the control signal k_1 is set equal to '0'. Whenever there are a large number SD violations, i.e. if total number of SD violations are in very large number compared to the SD followers, then the control signal k_2 is set to '1' indicating the admin that the people entering into the ROI has to be restricted thereby allowing to have check on the density of people.

Solution: At first, the pedestrians or people are identified in the image domain using a trained deep Convolutional Neural Network model. The identified people are bounded by bounding boxes with four corners. The middle point or centroid of the bounding box is calculated.

Detection of pedestrians in the image domain

A deep Convolutional Neural Network prototype which is trained on real world dataset detects the people in the image.

$\{Ti\}k = fcnn(I)$ ---- (a)

f_{cnn}: **I**→ $\{Ti\}_k$ maps an image into n tuples $Ti=(l_i,\beta_i,s_i),\forall_i \in \{1,2,3,4,5,...,n\}$, where n indicates total number of objects identified. The object class label $l_i \in$ L, where L indicates object label's set, is defined in f_{cnn}. The four corners of the associated bounding box is represented with $\beta_i = (\beta_{i,1}, \beta_{i,2}, \beta_{i,3}, \beta_{i,4})$. The pixel indices in the image domain are obtained as $\beta_{i,j} = (x_{i,j} , y_{i,j})$. The corners at top-left, top right, bottom-left, and bottom-right respectively are indicated by second sub index j. The detection score of corresponding item is s_i.

Here our interest is only limited to the person case i.e. l = 'person'. The bounding box's bottom edge middle point is calculated as :

$$p_{ibm}' = (\beta_{i,3} + \beta_{i,4})/2 \quad \text{---} \quad \text{(b)}$$

Mapping to real world from Image

The second mapping function h : p' → p is obtained in the next step. The mapping of p' into image coordinates to $p \in R^2$ in real-world coordinates is done by the inverse perspective transformation function 'h'. The co-ordinates of 2D BEV is p by imagining the ground plane z = 0. This task can be done by using the renowned inverse homography transformation:

$$p^{bev} = M^{-1}p^{im}, \quad \text{---} \quad \text{(c)}$$

The rotation and translation from world coordinates to image coordinates is described by the transformation matrix, $M \in R^{3x3}$.

$p^{im} = [p_x', p_y', 1]$ is the homogeneous representation of $p' = [p_x', p_y']$ in image coordinates.

p^{bev} = is the homogeneous representation of the mapped pose $[p_x^{bev}, p_y^{bev}, 1]$vector.

The world pose vector p is derived from p^{bev} with $p = [p_x^{bev}, p_y^{bev}]$.

Social distancing detection

Obtaining the corresponding list of inter-pedestrian distances D, after getting $D = (d_1, d_2, \ldots, d_n)$ in real-world coordinates is straightforward. The Euclidean distance between pedestrians i and j is distance $d_{i,j}$which is obtained by taking the their pose vectors:

$$d_{i,j} = ||d_i - d_j|| \quad \text{---- (d)}$$

In a scene, the sum of SD violations 'v_t' can be estimated by:

$$vt = \sum_{i=1}^{n} \sum_{j=1 j \neq i}^{n} \mathbb{I}(di,j) \quad \text{--- (e)}$$

where$\mathbb{I}(di,j)$ is equal to 1 if $d_{i,j}$ is less thand_{min}, else 0.

In order to obtain the exact results, the camera is to be calibrated with intrinsic and extrinsic parameters to map the pixels into units that can be measured. A less accurate but an easy alternative method is applying triangle similarity calibration which is made use here. For easiness, our OpenCV social distancing detector realisation will trust on distances between pixels.

The second step is to gather the mapping function where the image coordinates are converted into real world coordinates. Once the real world co-ordinates are obtained, then the job is to get inter pedestrian distance between people which is achieved by taking Euclidian distance between the bounding box centroids.

Also the total number of SD violations arecalculated if there are any, else the total number of violations will be zero.

IV. FLOWCHART AND ALGORITHM

Below is the flowchart for scheme

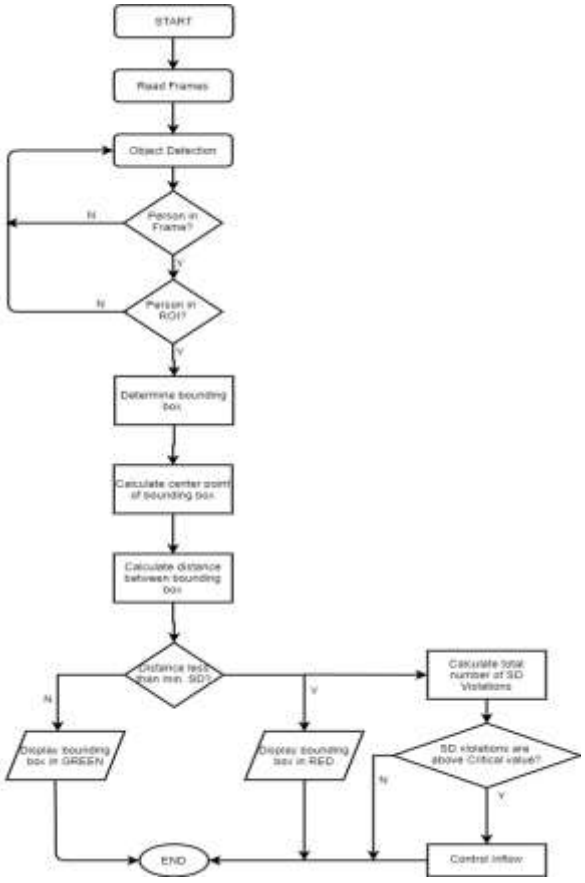

Fig.4.1. Flowchart

Algorithm steps are listed below:

Step1: Import all the necessary packages and configuration files required for processing

Step 2: Take the input video stream or directly from camera

Step 3: The people class is detected from the frames and it returns the prediction probability for a person, bounding box co-ordinates and also the object's centroid.

Step 4: Then the blobs are constructed to perform object detection with YOLO and Open CV

Step 5: Based on the confidences of detection, the people object class is detected with confidence more than the threshold

Step 6: The Euclidean distance between the centroid pairs are computed

Step 7: Step 6 is repeated until all the distance pairs are calculated

Step 8: With the calculated distance between centroids, check if it is violating SD rules (To check whether the centroids are N pixels apart)

Step 9: If the calculated distance < SD recommendation, then bound the object (people) with red bounding box

Step 10: If the calculated distance > SD recommendation, then bound the object (people) with green bounding box

Step 10: Determine the total number of SD violations at a time

Step 11: Display the audio visual cue with total number of violations at that time

Step 12: If the SD violations are in large number then send message to admin to control the inflow.

V. IMPLEMENTATION DETAILS

The size of the reference object is first approximated with an object in the image by matching it with the dimensions of identified people. Also the vital features of the test object are then utilized to perform the proportional transformation.

Few videos were recorded in our college campus at Sri Siddhartha Institute of Technology, Tumakuru campus with few of the pedestrians. The output video's screen shots are given below.

The program or algorithm approximately consumes around 7 to 9 minutes to give the output video file, which indicates SD violations and current total number of violations active at particular instant.

VI. RESULT DISCUSSION

With reference to fig. 5.1.which shows six pedestrians and all of them being violated SD rules and hence all of them are bounded with red bounding box.

Fig. 5.1 Input image

Fig. 5.2. Pedestrians with active 6 SD violations

With reference frame where there are two active SD violations red bounding to fig. 5.2. which shows four marked by pedestrians in the boxes and two people are following SD rules marked with green bounding boxes.

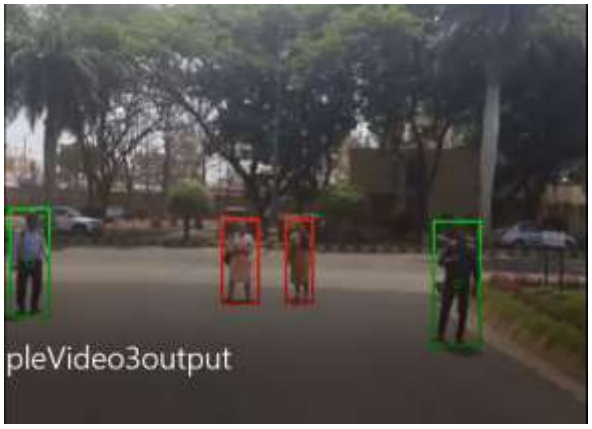

Fig. 5.3. Pedestrians with 2 active violations

With reference to fig. 5.3 where there are no SD violations. All pedestrians are bounded by green boxes as depicted in referred fig below.

Fig. 5.4. Pedestrians with no SD violations

VII. APPLICATIONS

1. To maintain SD norms in public areas like Shopping Malls, metro & Railway stations, Roads, Cinema halls

2. To monitor worker activity in a workplace like an office or a manufacturing plant

VIII. LIMITATIONS

1. Input data accuracy

2. Weather constraints and filter design

3. Speed and performance

4. The system needs processor with high computational capabilities

5. The distance here is approximated with the pixels in the image. Hence, the distance calculated will be 80% to 90% accurate.

IX. FUTURE IMPROVEMENTS

- The distances can be calculated based on top down view of the people which leads to better approximation of distance between pedestrians.
- Using a SSD (Single Shot Detector) will result in faster results, instead of YOLO (You Only Look Once) which is quite slow comparatively.
- A GPU (Graphics Processing Unit) can be employed in the system to improve the throughput.
- The system may find its applications in areas such as human detection at the controlled areas, analysing the crowd i.e. estimating total number of people and their behaviour related to SD, or in systems where people identification is the primary motive.

X. CONCLUSION

As per the recommendations from WHO, State and Central government's health authorities, for current situation Social Distancing is the only best and temporary preventive solution to curb spread of infectious disease like COVID-19. Even though many vaccines are being available now, yet their effectiveness is to be experimented and it is not 100% effective. Also, it may take few months to a year to vaccinate the whole population in a country like India.

The proposed SD detector can detect people and identify who are violating SD measures. An audio visual cue display shows the violations by bounding the people in red boxes. It is also capable of showing total number of violations at any instant helping the admin to control inflow and outflow.

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