Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Social distance monitoring system using deep learning and entry control system for commercial application

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ABSTRACT

For the last few months, the world has been under an astringent lockdown due to COVID-19. The number of COVID-19 cases is incrementing steadily. Even though scientists have found a vaccine for the obviation of the virus, the threat of being affected is high when we head out. Thus, one of the most efficacious modes of aversion is social distancing and home quarantine. As this was a sudden outbreak, people have not stocked up supplies and most of their personal work has been halted. Therefore, when people start to go outside, with or without a vaccine, it will be arduous to follow social distancing in countries, which are densely populated. With this in mind, this paper proposes a system that can be used in commercial spaces such as shops, banks, malls, offices, restaurants, and other similar places, where the system continuously checks whether customers are adhering to social distancing norms and only allows a certain number of people into the commercial space. This system is made up of two parts: an Entry Control System and a Six feet Apart analysis. This paper's work has been compared to previously completed projects and discussed. People who are concerned about social distancing and overcrowding will benefit greatly from the installation of this gadget in the private and/or public sectors.

Selection and peer-review under responsibility of the scientific committee of the International Conference on Innovative Technology for Sustainable Development.

1. Introduction

Covid-19 is an extremely contagious virus that can quickly spread through the air. To protect oneself against the virus, use disposable masks and hand sanitizers as often as possible, and avoid contact with others, no matter how well you know each other. As a result, everyone was compelled to stay at home to prevent the disease from spreading. This resulted in a lack of time to stock up on the essential resources required by the public, and all services were either shut down or operated at less than 50% capacity, resulting in a decrease in supply and an increase in demand, resulting in overcrowding in public places such as banks, ATMs, grocery stores, and other commercial establishments. People were confused, frightened, and doubtful in the early phases of the pandemic due to the mass hysteria caused by the viral outbreak. Some individuals were downright dismissive of the virus's hazards. Because of these factors, governments imposed lockdowns and protocols that the public was required to follow in order to try to stop the spread, but no one properly enforced them. Furthermore, the majority of people were unconcerned with their own well-being, and as a result, the number of instances climbed significantly in every country. According to WHO Reports, the COVID Virus has mutated five times, with 'Omicron' being the most recent. Because of the virus's nature, preventing and controlling its transmission, as well as developing a vaccine for all COVID variants, is challenging.

The economic and societal effects of the pandemic are severe. Hundreds of millions of people are on the verge of sliding into extreme poverty, requiring governments to open their economies in order to avert catastrophic economic damage. According to a study released by the World Health Organization on February 1, 2022, the number of new COVID cases has been steady for several months, while the fatality rate has increased by 9%. Over 22 million new cases and 59,000 new fatalities have been recorded globally across all six WHO regions (Europe, Americas, South-East Asia, Eastern Mediterranean, Western Pacific, and Africa). Approximately 385 million confirmed cases and 5.7 million deaths have been reported as of January 30, 2022.

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2. Literature survey

As verbally expressed by Mersha A. *et al* [1] in their paper, the main arduousness faced by the health care workers is the lack of misconception of the virus and the incognizance of the community to congruously utilize a face mask and other PPE kits. Moreover, since there is minuscule to no fortification from the community and the lack of efficacious countermeasures by the regime, the healthcare workers have to surmount huge barriers to treat the patients.

Basu S. *et al* [2] in their paper, discussed that people who are over the age of 60 are at high risk of contracting the virus and they are recommended to stay at home and not to imperil by going out and doing other activities which places them in further risk. The next most vulnerably susceptible people are in their mid-40′s to 50′s with pre-subsisting medical conditions such as diabetes, chronic kidney disease, stroke, asthma, and dementia. Unfortunately, the people who hold the majority of the higher-level posts in companies/businesses fall in these categories of people who are most vulnerable susceptible. So, it is essential to take preventive measures in case there arises an ineluctable situation where the senior personnel have to be present in person to do their work. Multi-pronged strategies can enhance the safety of the workspaces. Zhang Q. *et al* [3] has found that some of the effective countermeasures against covid-19 are to utilize a single point for entry and exit (“one entry, one exit”) and to keep different entry/exit points for different classes of people within the company (customers, workers, managers, etc.). Also, frequent sanitization of commonly accessed areas averted the spread of the virus, along with the cessation in the utilization of centralized air conditioners and elevators will result in a considerably vigorous measure against the virus.

By the suggestions of Cirrincione L. *et al* [4], an organization can take measures such as minimization of the number of people inside the same room, considering a density of 1 person every 10 square meters, and keep a distance of 2 m between 2 or more people, splitting the workforce into 2 and making each group come to the office on alternative periods, cleaning at the terminus of the shift of inanimate materials which come in frequent contact. The support staff must also be given training on preventive measures to take and to give reasoning behind them so that they can amend their facility to avert & control the pandemic, and respond expeditiously if any emergency arises. By the study done by Jin S. *et al* [5], the organizations should additionally endeavour to maximize the ventilation in each and every closed space which ascertains fresh air is circulated and can thus minimize the risk of breathing air that is potentially infected.

This paper was proposed under the motivation for minimizing the risks of contracting COVID-19 in high traffic areas by minimizing contact between any 2 persons or more. So, the paper aims at doing the following 2 functions. The Entry Control System, is to abbreviate the contact on the door, given the virus can reside for a fatal and minimal duration on the said door and to control the crowd inside the commercial building or retail space. Six feet Apart analysis is a Deep Learning concept-driven to truncate the distance between any 2 people if they don’t maintain social distance.

Observing the current and pre-existing works on social distancing, Nguyen C., *et al* [6] and his team has conducted a comprehensive survey on Wireless Technologies such as utilizing Wi-Fi, ZigBee, Bluetooth, Ultra-wideband, Cellular, RFID, and Global Navigation Satellite Systems for Authentic-time Monitoring of Crowds, both Stationary and Dynamic Crowds, Distance Detection and Passing the Infected Movement Data and the Contact Tracing along with it. About a Prototypical Model, C. T. Nguyen *et al.* [7] has given a more extensive and detailed survey on (a) Machine Learning with Artificial Intelligence and Computer Vision, (b) Sensing Intelligence with Thermal, Ultrasound, Inertial Sensors, and Visible Light, and even with block chain along with it has discussed open issues such as security and privacy-preserving in social distance, real-time scheduling, and optimization of the given prototype, and incentive mechanism to encourage social distancing where they want people to share any new methods to promote social distancing and enable new methods as well. C. T. Nguyen *et al.* have [6] and [7] as a 2-part paper and has covered the Software and Hardware applications with a comprehensive survey and has provided an overview, examined the state-of-the-art, and discussed how it can be utilized in different social distancing scenarios.

Raghav S. et al. [8] have devised an innovative method for encouraging social separation, which involves the use of Suraksha, a smart wearable device that may be worn when travelling outside and helps to maintain social distance. The system integration has PIR Sensors affixed to the user’s Cap and has a Buzzer that gives a sound notification to the utilizer along with a LED which is charged with normal AA Batteries and carried out on NodeMCU microcontroller. Similarly, Bian S *et al.* [9] have proposed a wearable proximity sensing system predicated on an Oscillating Magnetic Field that surmounts many of the weaknesses of the current state-of-the-art Bluetooth-predicated proximity detection. Their transmitter works with current smartphone-based exposure tracing protocols, and their system architecture is based on the ZigBee Module. Object identification and facial recognition for pedestrian video footage have been proposed by Shete, I. [10]. The YOLOv3, ResNet Classifier, and DSFD are examples of trained models. Faces without facemasks were spotted as well as people who violated the minimum distance.

All the cognate work, technical and non-technical has been discussed in the above section and this paper concentrates on the commercial space of various industries and sectors to promote social distancing with an Entry Control System in the said commercial space to mitigate the number of people inside and to sticking to the norms of Lockdown and Covid-19 policies that suggested by the government.

3. Problem statement

To reduce the amount of persons engaging in a commercial establishment that is confined. This factor has a significant impact on how many individuals are affected. To keep individuals at a safe distance from one another. If a virus-carrying individual enters the commercial space, we can prevent the virus from spreading if that individual maintains a social distance from everyone with whom he or she interacts. Because determining whom the carrier is takes time, we must guarantee that everyone maintains a social distance from one another.

4. Proposed work

The paper comprises two components, the first being the Entry Control System and the other is the Six feet Apart analysis. From the conceptual block diagram (Fig. 1 and Fig. 2), we can comprehend the working of the two independent systems and how they work when the system is implemented by the end user.

Fig. 3 shows all the hardware components with their respective connections. The number of people entering and exiting the commercial space will be tracked by the microcontroller (Arduino Nano). If the maximum number of customers allowed in the store is reached, the business’s entry gate (which is controlled by a servo motor) will be closed until a customer leaves. Only then, the store’s gate will be opened to allow new customers to enter. An LCD screen outside the establishment, near the gates, will display the current number of customers entering, exiting, and inside the

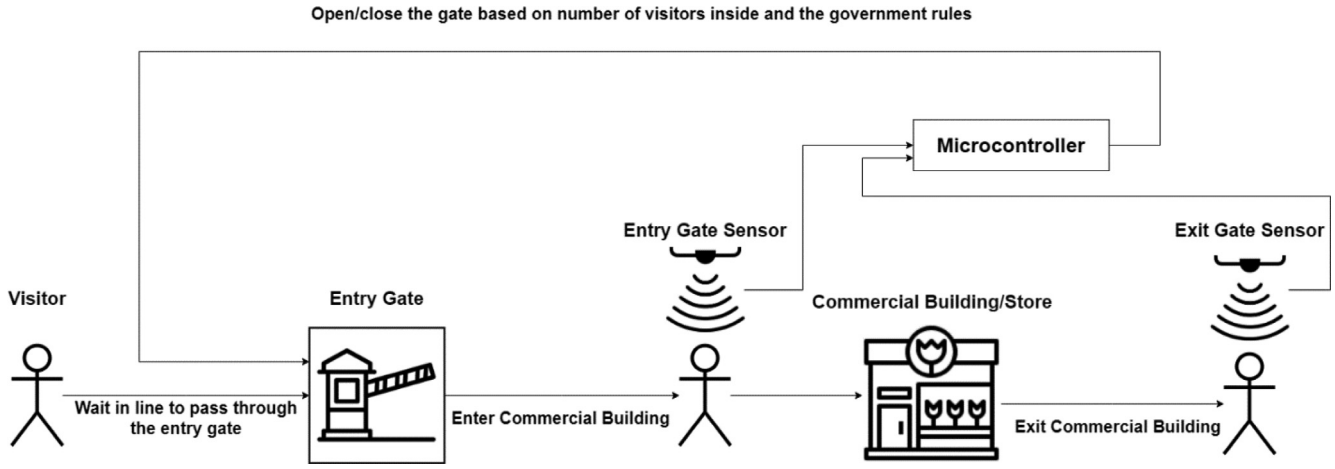

Fig. 1. Conceptual block Diagram Entry Control System.

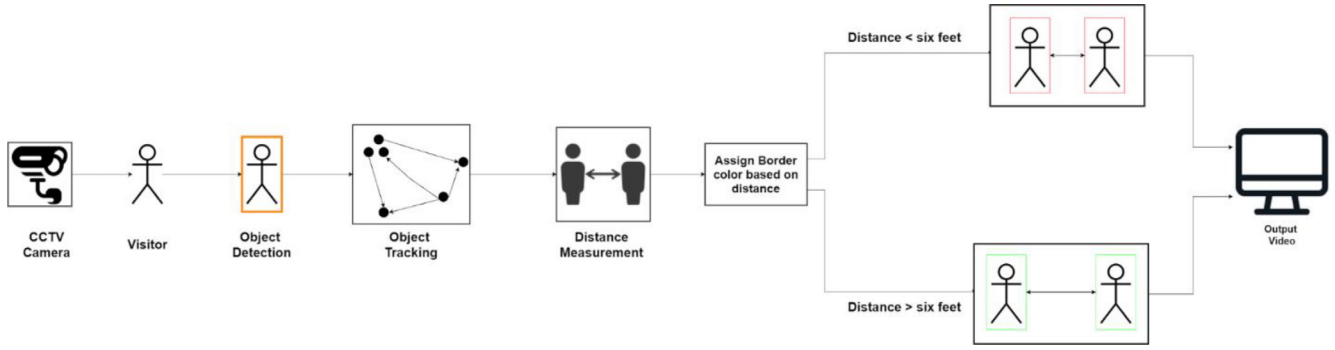

Fig. 2. Conceptual block Diagram of Six feet Apart analysis.

establishment, so that customers are well informed. This system keeps track of the total number of members present inside the shop from afar, ensuring the customer's safety. The entry control system restricts the number of customers who can enter the establishment and keeps it from becoming overcrowded.

The Six feet Apart analysis uses Object Detection, Object Tracking, and Distance Measurement using Euclidean distance, which are key concepts in Deep Learning. The proposed model has used python to create the Deep Learning Model for detecting all people in the given video frame and calculating the distance between them. To keep track of the distances between each customer present inside the shop and if desired, even outside the shop, the building/space administrator can install a camera or use existing CCTV cameras in the establishment and employ the proposed Deep Learning-based social distance monitoring system (six feet) to keep track of the distances between each customer as desired. It is a user-friendly system that continuously feeds live video recorded on a television display, displaying the number of violations committed by the customer as well as whether or not a single customer is at a safe distance from other customers.

Overall, the system is well designed to monitor and track whether social distancing is observed in the establishment, as the number of people infected by the virus continues to rise as the virus continues to evolve and produces multiple variants, despite having a viable vaccination against some of the variants. Fig. 4 depicts the flow chart of the deep learning system from conception to object detection, object tracking, and distance measurement, which leads to the final video output comprising all social distance violations.

5. Experimental setup and results

For Entry Control System (Fig. 5a and 5b), the user stands in front of the gate denoting the IR sensor that a person is present, and once the number of people reaches the maximum count set by the ascendancy in charge of the commercial space, the gate locks itself until the count commences decrementing from the store when the people start exiting the said commercial space. The results obtained were, locking and unlocking of the gate depending upon the count of people.

For 6 feet Analysis *(*Fig. 6*a* - Fig. 6*d)*, The Deep Learning algorithm avails in finding the people who are not situated 6 feet apart from other people. The video input notifies the utilizer visually perceiving the video with red boxes around the people who didn't maintain social distancing and green boxes around the ones who do. For live feed, the code has provisions for amendment and can be carried out successfully. The results obtained were, designation of Social Distancing Violations on each frame of the video and the people accountable for the contravention. As we can see the real-time implementation of the hardware design of the Entry Control System and along with it, the outputs from the Six feet Apart Analysis, where, people who contravene Six feet are boxed in red and people who are safe and maintaining Six feet are boxed in green.

6. Comparison with other works

The approach Suganeswaran K. *et al.* [11] taken is virtually homogeneous to what this paper has proposed, but they have utilized IR Proximity and IR Temperature Sensor at all entrances but

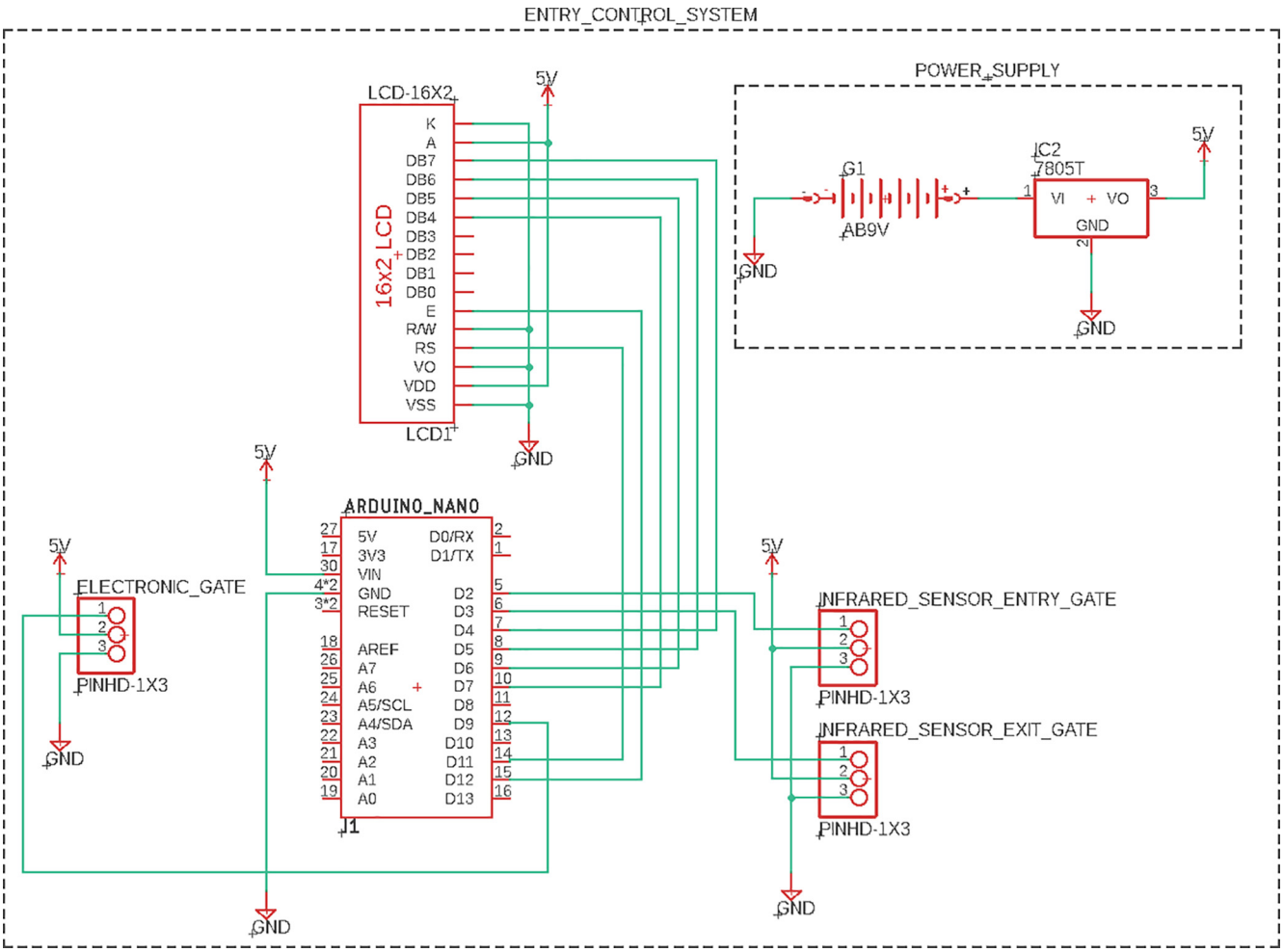

Fig. 3. Circuit Schematic of Entry Control System.

have not taken into account the Six feet Apart analysis that is essential for social distancing, but their Face recognition system is carried out by OpenCV and TensorFlow. Razavi M. et al. [12] developed a computer vision system to automatically detect the infringement of face mask-wearing and physical distancing among construction workers to ensure their safety on infrastructure projects, where they developed an automatic system that monitors the physical distance and face mask recognition takes place in a construction site for the workers, where they developed a computer vision system to automatically detect the infringement of face mask-wearing and physical distancing among construction workers to ensure their safety on infrastructure projects. The researchers gathered and analysed 1,000 pictures, including variations of facemask wear, and combined them with a previously published facemask dataset to create 1,853 images. They then used the facemask dataset to train and evaluate several TensorFlow state-of-the-art object identification models, eventually settling on the faster R-CNN Inception ResNet V2 network, which had a 99.8% accuracy.

Shrestha, S et al. [13] made a great contribution and took an interesting approach by designing a system for the visually impaired to learn social distancing since their low eyesight prevents them from keeping a safe physical distance from other individuals. The suggested technique is a smartphone-based computationally efficient deep neural network that detects crowds and relays the hazards to the Blind or Visually Impaired (BVI) user via directional audio alarms. From the smartphone's monocular camera feed, the algorithm initially identifies persons and evaluates their distances. The algorithm then groups people into crowds in order to provide density and distance maps from the crowd centres. Finally, the system uses motion maps created from prior frames to forecast crowd movements and provide an appropriate auditory warning. The work done by Ahamad A. et al. [14] is kindred to the proposed Six feet Apart analysis. The cited paper has utilized the MobileNet Single Shot Multibox Detector (SSD) object tracking model and OpenCV library for image processing whereas this paper has utilized the YOLO (You Only Look Once) object tracking model, which produces relatively better object detection and tracking. By their extensive tribulations utilizing various datasets, we observe that their system's accuracy is significantly better when alimenting indoor video streams over outdoor video. Utilizing a microcontroller in lieu of a microprocessor is better, so that it can handle both the Entry Control System and the Six feet Apart analysis instead of having it as two separate systems would greatly increase the responsiveness of the overall system and offer better performance. If the commercial space has outward-facing cameras, we could also utilize that to count the visitors instead of utilizing infrared sensors on the microprocessor so it is more reliable and easier to deploy and more cost efficient. The Six feet Apart Analysis has been tested for various video feeds where the only change is the perspective of the camera. Thus, we have found that the analysis provides better results when the camera's perspective is similar to a bird's eye view of the desired space. This can be amended upon, by constraining the analysis to only certain

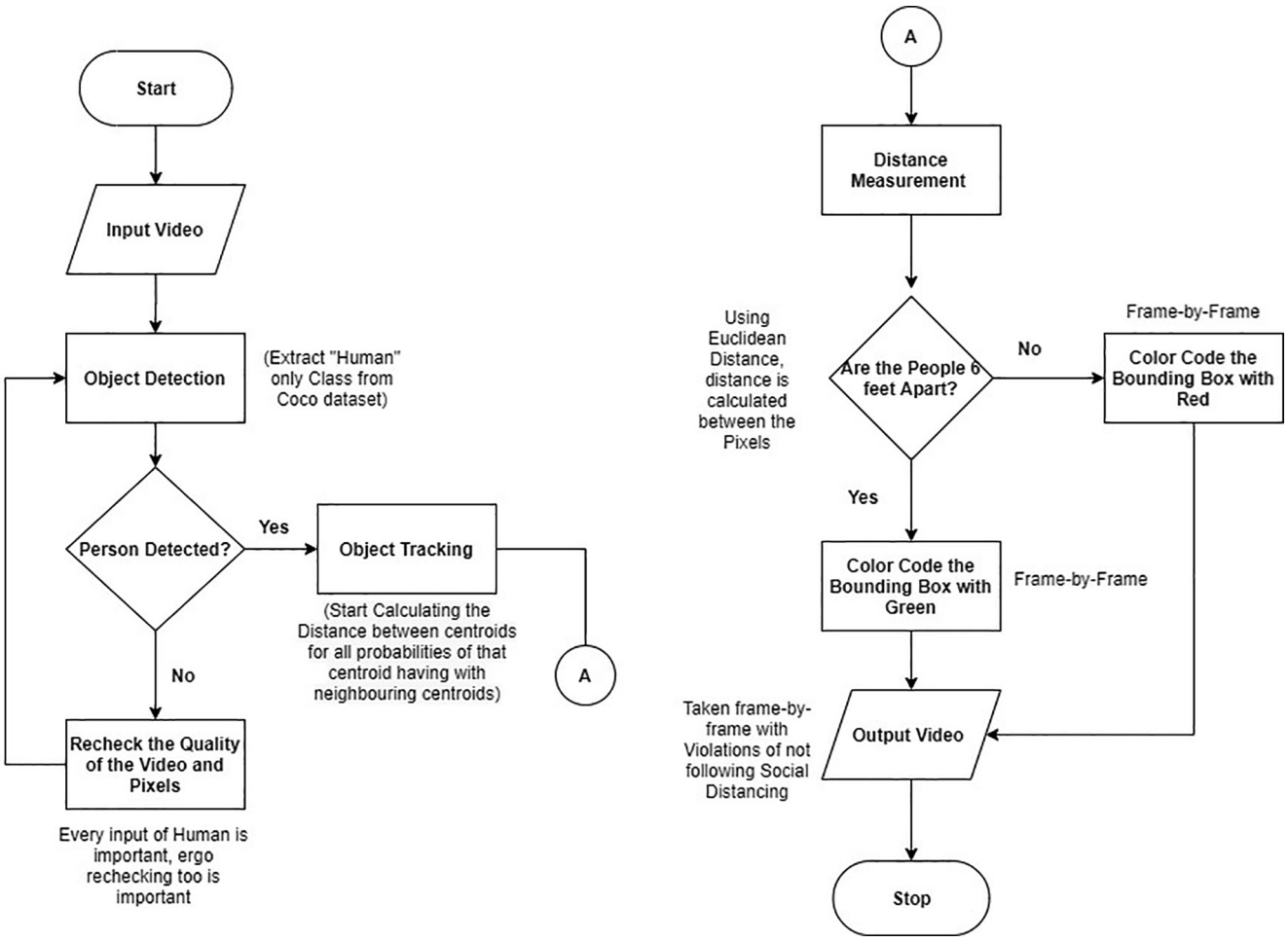

Fig. 4. Flow Chart of Six feet Apart analysis.

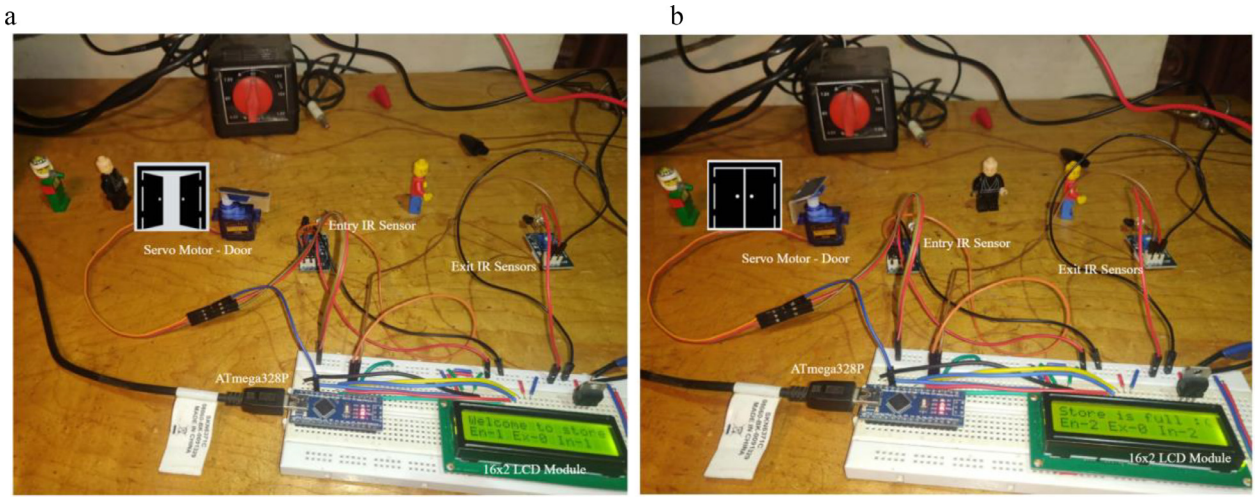

Fig. 5. Entry Control System Hardware: We can visualize a 16x2 LCD Screen Module, Arduino Nano – ATmega328P, IR Sensors, Servo Motor, DC input voltage and jumper wires all connected using the Breadboard. (a) Door open (Servo Motor) when threshold is not met (Threshold of people to be contained in the establishment = 2) (b) Door closed (Servo Motor) when threshold is met.

components of the video feed, rather than the entire frame, which would lead to more precise and informative results. As an extension to the proposed system, implementation of an autonomous bot to sanitise the place, in case the support staff are overwhelmed with other work as done by Shenoy G. et al. [15]. The bot can also be used to sanitise in regular intervals when the support staff is preoccupied with other supplementary tasks.

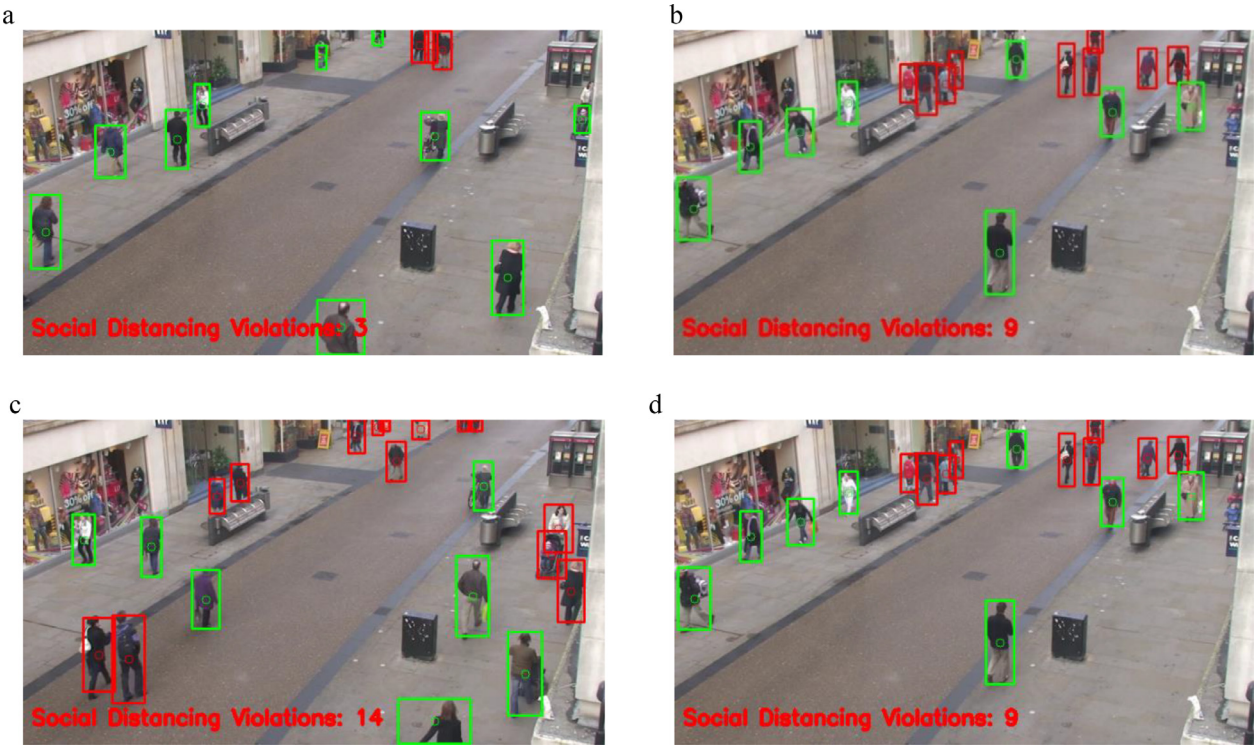

Fig. 6. (a) - (d) shows the output of the Deep Learning Six feet Apart analysis at different instances of the processed video where the text on the left-hand side indicates the number of violations that have happened at each second of the video at that particular instance.

7. Conclusion and Future work

The proposed low-cost system is intended to improve the standard of social distancing in the commercial spaces. This technology keeps track of the total number of people present inside the establishment in order to ensure the safety of the customer by the use of cameras. The building/space administrator can install a suitable camera or use the existing CCTV cameras in the establishment and employ the proposed Deep Learning-based social distance monitoring system (six feet) to keep track of the distances between each customer as desired. It is a user-friendly system that continuously feeds live video recorded on a television display, displaying the number of violations committed by the customer as well as whether or not a single customer is at a safe distance from other customers. The Entry Control system regulates the number of consumers who enter the establishment and keeps it from becoming overcrowded.

Overall, this is a well-designed method to verify and track whether social distancing is observed in the shop, as the number of people infected by the virus continues to rise as the virus continues to evolve and produces multiple variants, despite having a viable vaccination against some of the variants. As a result, this approach will be useful in implementing the social separation preventive measure, which has proved to be the best approach to avoid getting infected with the virus. We are confident that our approach, either alone or in combination with other solutions, can be utilized to stop the virus from spreading while maintaining social functionality, allowing us to go about our daily lives in some semblance of normalcy and contributing to the betterment of the world.

In the Future, the proposed system can be modified easily to be used with multiple entry/exit gates, which are present in large spaces like large shopping complexes, offices, theatres, educational institutions, public transportation systems and other such places where there are many visitors making crowd management a top priority. Another major improvement is to connect this system to the internet so that we can monitor the commercial space from anywhere and maintain detailed records of all events.

CRediT authorship contribution statement

T.V. Vishnu Kumar: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Visualization, Funding acquisition. **Andrew John:** Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Visualization, Supervision, Funding acquisition. **M. Vighnesh:** Conceptualization, Validation, Formal analysis, Investigation, Writing – original draft, Funding acquisition. **M. Jagannath:** Writing – review & editing, Supervision, Project administration, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

[1] A. Mersha, S. Shibiru, M. Girma, G. Ayele, A. Bante, M. Kassa, S. Abebe, M. Shewangizaw, Perceived barriers to the practice of preventive measures for COVID-19 pandemic among health professionals in public health facilities of

the Gamo zone, southern Ethiopia: a phenomenological study, BMC Public Health 21 (1) (2021) 1–10.
[2] S. Basu, K. Baster, P. Giri, Getting back to work: risk assessing personal vulnerabilities to COVID-19, Public Health 185 (2020) 150.
[3] Zhang Q., Wu Y., Li M., and Li L., "Epidemic Prevention During Work Resumption: A Case Study of One Chinese Company's Experience." Frontiers in Public Health. Volume 8. ISSN=2296-2565. January 2021.
[4] Cirrincione L., Plescia F., Ledda C., Rapisarda V., Martorana M., Moldovan R., Theodoridou K., and Cannizzaro E., "COVID-19 Pandemic: Prevention and Protection Measures to Be Adopted at the Workplace. Sustainability". MDPI, Open Access Journal. Volume 12. April 2020. pp 1-18.
[5] J. Shen, H. Duan, B. Zhang, J. Wang, J.S. Ji, J. Wang, L. Pan, X. Wang, K. Zhao, B. Ying, S. Tang, Prevention and control of COVID-19 in public transportation: experience from China, Environmental pollution 266 (2020).
[6] C.T. Nguyen, Y.M. Saputra, N. Van Huynh, N.T. Nguyen, T.V. Khoa, B.M. Tuan, D. N. Nguyen, D.T. Hoang, T.X. Vu, E. Dutkiewicz, S. Chatzinotas, A comprehensive survey of enabling and emerging technologies for social distancing—Part I: fundamentals and enabling technologies, IEEE Access 8 (2020) 153479–153507.
[7] C.T. Nguyen, Y.M. Saputra, N. Van Huynh, N.T. Nguyen, T.V. Khoa, B.M. Tuan, D. N. Nguyen, D.T. Hoang, T.X. Vu, E. Dutkiewicz, S. Chatzinotas, A comprehensive survey of enabling and emerging technologies for social distancing—Part II: emerging technologies and open issues, IEEE Access 8 (2020) 154209–154236.
[8] Raghav S., Vijay G., Harika P., Rao V., Gopinath A., Shibu S., and Gayathri G., "Suraksha: Low Cost Device to Maintain Social Distancing during CoVID-19". 4th International Conference on Electronics, Communication and Aerospace Technology (ICECA), Coimbatore, India. December 2020. pp. 1476-1480.
[9] Bian S, Zhou B and Lukowicz P. "Social Distance Monitor with a Wearable Magnetic Field Proximity Sensor." Special Issue, Magnetic Sensors 2020. Volume 20, Issue 18. ISSN 1424-8220. September 2020.
[10] Shete, I. "Social Distancing and Face Mask Detection using Deep Learning and Computer Vision" NORMA eResearch, NCI Library, Master's thesis, Dublin, National College of Ireland. September 2021.
[11] Suganeswaran K., Dhileephan K., Nithyavathy N., Ganeshan P., Arun Kumar., and Antony A., "Machine Learning based Mechanism for Crowd Mobilization and Control," 6th International Conference on Inventive Computation Technologies (ICICT), Coimbatore, India, February 2021, pp. 1334-1339.
[12] Razavi M., Alikhani H., Janfaza V., and Sadeghi B., (2021). "An Automatic System to Monitor the Physical Distance and Face Mask Wearing of Construction Workers in COVID-19 Pandemic." January 2021. arXiv:2101.01373v2
[13] Shrestha, S., Daohan L. Hanlin T., Qiming C., Julie L., John-Ross R., and William H., "Active Crowd Analysis for Pandemic Risk Mitigation for Blind or Visually Impaired Persons". Computer Vision – ECCV 2020 Workshops, Lecture Notes in Computer Science, Springer International Publishing Springer, Cham. Volume 12538. January 2021. pp. 422–439.
[14] A. Ahamad, N. Zaini, A. Latip, Person Detection for Social Distancing and Safety Violation Alert based on Segmented ROI, in: 10th IEEE International Conference on Control System, Computing and Engineering (ICCSCE) , September 2020, pp. 113–118.
[15] Shenoy G., Chithu R., Shibi V., Vignesh M., Shanmugapriya M., Priya S., and Aparna G., "STERILOID: Room Sanitization Robot". International Research Journal on Advanced Science Hub. Volume 2, Issue 8. ISSN: 2582-4376. August 2020 pp 100-104.