Real-time passenger social distance monitoring with video analytics using deep learning in railway station

Iqbal Ahmad Dahlan[1,3], Muhammad Bryan Gutomo Putra[2,3], Suhono Harso Supangkat[2,3], Fadhil Hidayat[2,3], Fetty Fitriyanti Lubis[2,3], Faqih Hamami[4]
[1]Faculty of Military Engineering, Universitas Pertahanan Republik Indonesia, Bogor, Indonesia
[2]School of Electrical Engineering and Informatics, Institut Teknologi Bandung, Bandung, Indonesia
[3]Smart City and Community Center, Institut Teknologi Bandung, Bandung, Indonesia
[4]School of Industrial and System Engineering, Telkom University, Bandung, Indonesia

Article Info

Article history:

Received Jul 29, 2021
Revised Mar 8, 2022
Accepted Mar 22, 2022

Keywords:

CCTV surveillance
COVID-19
DeepSORT algorithm
People detection
People tracking
Social distancing

ABSTRACT

Recently, at the end of December, the world faced a severe problem which is a pandemic that is caused by coronavirus disease. It also must be considered by the railway station's authorities that it must have the capability of reducing the covid transmission risk in the pandemic condition. Like a railway station, public transport plays a vital role in managing the COVID-19 spread because it is a center of public mass transportation that can be associated with the acquisition of infectious diseases. This paper implements social distance monitoring with a YOLOv4 object detection model for crowd monitoring using standard CCTV cameras to track visitors using the deep learning with simple online and real-time (DeepSORT) algorithm. This paper used CCTV surveillance with the actual implementation in Bandung railway station with the accuracy at 96.5% result on people tracking with tested in real-time processing by using minicomputer Intel(R) Xeon(R) CPU E3-1231 v3 3.40GHz RAM 6 GB around at 18 FPS.

Corresponding Author:

Iqbal Ahmad Dahlan
Faculty of Military Engineering, Universitas Pertahanan Republik Indonesia
1680 Kawasan IPSC Sentul, Sukahati, Citeureup, Bogor, Indonesia
Email: iqbal.dahlan@idu.ac.id

1. INTRODUCTION

In 2020 the world was hit by the COVID-19 pandemic, which crippled the entire world situation. The total number of people affected by the virus was 185 million cases, while in Indonesia, there were more than 2.4 million cases with more than 35,000 new cases per day on Jul 10, 2021. The pandemic causes people to keep their distance and avoid crowds based on World Health Organization (WHO) recommendations. Some people who have COVID who has been infected would experience symptoms such as respiratory disease if they did not get the medical treatment, which can be fatal. In general, the condition is spread through saliva secreted from individuals who have been infected. The cleanliness of everyone must be maintained, and they must keep their health by following COVID-19 protocol such as using a face mask and cleaning their hands, and social distancing [1]-[6]. Social distancing is a preventive measure to control the spread of COVID-19. This system is developed to minimize the number of close contacts we have with other people who have symptoms or only a carrier without symptoms; this system can reduce the chance of transmission of covid to catch the virus and spread it to the community. In support of this issue, the government of Indonesia, through the task force for the acceleration of handling COVID-19 Indonesia, has issued an addendum to circular letter number 8 of 2021 concerning international travel health protocols during the COVID-19 pandemic, which was conducted on July 4, 2021.

As a result, PT. Indonesia railway corporation (KAI), as a regulator of the state-owned enterprises engaged in Indonesian railway transportation, has issued several rules which refer to the regulations of the covid protocol. This system is considered that need to be adhered to related to the COVID-19 pandemic if you want to use their services, such as train passengers who travel by train must provide evidence that passengers have a negative rapid antigen result on a polymerase chain reaction (PCR) test that has been carried out at least 72 hours before departure, in addition passengers must use face coverings such as 3-ply cotton face masks or surgical masks to reduce the level of possibility of spreading COVID-19 disease [2]-[8], but all of these rules will be less effective if passengers cannot keep their distance from one another which can be one of the most significant causes of the spread of the disease, the security officers guarding the facility are only limited in number and are not available at all time to regulate all passengers who do not follow social distancing regulations, therefore one of the efforts that can be made to provide security for passengers regarding close distances is to use closed-circuit television (CCTV) as a medium to detect the length of passengers [9] from one another so that it can be adjusted to the needs of social distancing and public safety can be maintained [1], [2], [9], [10]. According to the protocol standards by the WHO and COVID-19 Indonesia task force that has been published, the minimum distance that needed to be followed between passengers must be at least 6 feet (1.8 m) or more to mitigate a social spread among the people crowds [1], [2], [9], [10]. This proposed paper is necessary because the train station must be controlled to manage COVID-19 transmission risk. Public transport is a priority to maintain several measures which can also play an essential role in reducing and preventing crowding of visitors into ideal conditions. There are ways to reduce or eliminate the COVID-19 risk. In addition, this paper is created with a CCTV analytical system designed using artificial intelligence (AI) and internet of things (IoT) with the ability to meet needs with priority points: i) This solution can count the number of crowds and classify the types of people crowds into low-risk, medium-risk, and high-risk [1], [2], [9], [11], [12]. ii) This project can send data to the server and warn if this system captured an abnormal event [10]-[12]. iii) This system produces a social distancing monitoring system for monitoring the crowd of people in the station environment using public CCTV security cameras to capture people crowd and social distancing situations [1], [2], [9], [11], [12]. vi) This paper can provide an informative dashboard that can provide descriptive analytics, predictive analytics, and prescriptive analytics to the stakeholders [13]-[15]. A real-time dashboard is presented for high-level executives to prevent violations.

This research proposed a system to solve the social distancing aspect in public using CCTV analytics and deep learning algorithms, especially convolutional neural networks (CNN), which is also supported by the data integration using MongoDB to collect and store the data that has been processed [13], [14], [16]. The following research can be improved by big data technology such as Hadoop, Kafka, Cassandra, and another data engine to enhance the data transmission. The CCTV captures this system and then identifies the pattern needed for video analytics. The analytics that have been done can help comprehend the station's situation and be used as information that benefits the people who manage the station to ensure all safety protocols have been followed. The proposed method was evaluated in a single CCTV that is implemented in Bandung railway station with a secure local connection. The system was able to perform in various challenges, including occlusion, lighting variations, any conditions. The proposed prototype can detect persons with the ability to monitor social distancing using the YOLOv4 deep learning algorithm and COCO datasets. This system also can achieve real-time visitor counts with violations detection at roughly 18 frames per second (FPS) and accuracy 96.5% on a Mini PC to release high-risk, low-risk, safe-risk and to track the moving trajectories of the people, infection risk assessment and analysis to the benefit of the health authorities and governments by only viewing into the dashboard visualization.

This proposed research is structured as shown in; Section 1 is about the introduction. Section 2 is about the proposed method and also includes related work of previous research. The method of this research is defined in section 3 related to discuss about image acquisition, object detection, object tracking, social distance analyzer and data visualization. Test results and interpretations for part 4 are announced. Section 5 provides a concluding statement and the acknowledgement of this research.

2. PROPOSED METHOD

This section presents state-of-the-art research that reviews object detection and social distancing [1], [2], [9]. Social distancing is one of the activities that can be done to prevent the spread of COVID-19 from increasing rapidly. In 2020 several researchers from Malaysia conducted research on the detection of social distancing using wearable devices [12]. This study uses hardware consisting of ultrasonic sensors, microcontrollers, buzzers, and liquid crystal display (LCD) modules, which can become a tool capable of detecting objects around the user so that the distance between users and other humans can be determined. This study will inform the stakeholders when the distance between users and other people is less than 1 meter. The device will emit a sound indicating that social distancing is necessary. These previous works [13], [14], [16] have identified how to present improving technologies such as CCTV surveillance with AI in the railway area case. The previous research discusses algorithms, architecture, concepts, and deployments for social distancing monitoring guidelines. They proposed CCTV surveillance using the YOLO framework with big data technologies such as Hadoop, Apache Kafka, Apache Spark, or NoSQL database. Each image from CCTV is extracted to semi-structured data and presented in real-time to count the objects, track them, and find unusual events.

Intelligent surveillance systems for social distancing monitoring are implemented [1], [2], [9], [12], [17]; Those papers proposed DeepSOCIAL built on deep neural network architecture with a large dataset to detect and track people with social distancing metrics and performs well in various environments. DeepSOCIAL was implemented CSPDarkNet53 as a backbone. In the neck module, they proposed spatial attention module and spatial attention module for parameter optimization, while in the head model, they configured as YOLOv3 to detect multiple objects. Yang *et al*. [2] also used deep learning to identify objects and Euclidian distance to measure object distances. The object identification area is square, and things that pass through it will be detected. This research was conducted with a railway dataset and built using the faster region based convolutional neural networks (R-CNN) and YOLOv4 methods but has not yet been deployed in the original station area. The system implemented YOLO or scaled YOLO also uses the tracking algorithm deep learning with simple online and real-time (DeepSORT) to monitor people's movement that has been detected and also tracks the number of social distancing violations from the previously seen people [9], [12]. Punn *et al*. [9] implemented the DeepSORT approach to track objects using YOLOv3. The experimental result was compared with faster RCNN and single-shot detector (SSD) model. It was gained that YOLOv3 is better with the higher FPS with this work [12] also implemented YOLOv4 with COCO dataset with several network sizes to detect objects. It also implements DeepSORT to track people with a distance threshold of 2 meters. Several researchers have also discussed preventive measures with technology-based solutions such as [18], [19] and AI-related studies such as [11], [12], [20], [21] have tried to intervene to help the health and medical community overcome the challenges of social COVID-19 successfully distance practice. This a previous work [22] vary from GPS-based patient localization and tracking to crowd segmentation and estimation. This research method has a weakness because it depends on the strength of the GPS network and satellites.

Ahmad *et al*. [23] has addressed a deep learning-based social distancing monitoring framework for COVID-19 using the YOLOv3 detection model by comparing YOLOv3 with transfer learning and without transfer learning. This method achieves 92% and 98%, and the tracking accuracy is 96%. This paper describes a people tracking scheme with a bounding box review clearly by using Euclidean distance, the distance of the bounding box centroid pair detected from the movement of people. To estimate social distancing violations between passengers, the authors use a physical space-to-pixel approach, set a threshold, and submit the number of violations. The system uses 5G infrastructure to transmit high-speed bandwidth recorded video streams to enhance deep learning, which requires intensive processing to provide near-real-time solutions for top-view multiple-person tracking. This system requires high costs and a very complex and reliable infrastructure. The limitation of previous research is only implementing how social distancing monitoring can operate without an end-to-end solution. In our paper, we implement social distancing monitoring as a platform by implementing technology data integration from image acquisition to dashboards with also recommendations for stakeholders. This system is carried out using the YOLOv4 object detection model and DeepSORT as tracking methods based on the Kalman filter approach [1], [2], [9]. This SORT algorithm is more accurate than the Euclidean distance and the Hungarian algorithm. This system is also implemented at the Bandung train station by implementing a 24-hour real-time system with a dashboard that helps stakeholders monitor this social distancing condition. The social distancing scheme will be illustrated in Figure 1.

This work is proposed and evaluated on CCTV as an image sensor to study people's behavior in a railway station. Firstly, we introduce the sensor functionality and its hardware. Then, we describe and motivate the choice of the communication with internet protocols and software components combining a detection algorithm with a counting algorithm and how to integrate into an end-to-end solution with the ability to collect, store and analyze the data with a platform architecture, in Figure 1 we can see that there is a platform architecture that will be developed to assist in this research, the use of IP cameras contained in the train station helps in the initial implementation of video data retrieval regarding the environment around the facility, then the data will be sent into network video recorder (NVR) for storage via power over ethernet using real-time streaming protocol (RTSP), data from NVR will then be carried out to start the process of detecting passengers using combination of multiple deep learning algorithm, calculating the number of passengers in the environment, sending processed data to databases and related components, and displaying processed data through the dashboard system. This proposed method is designed from sensing until acting or visualization.

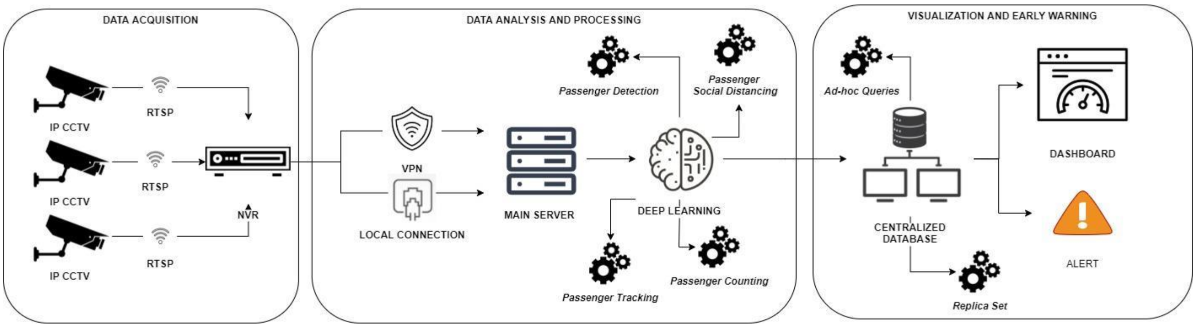


Figure 1. Social distance analyzer platform architecture

3. METHOD

This section presents state-of-the-art research that reviews image acquisition, object detection, object tracking, social distance analyzer and data visualization. The previous method consists of the following steps. Image acquisition with RTSP protocol, object detection with YOLOv4 detector model, object tracking with simple online and real-time (DeepSORT) as tracking methods based on the Kalman filter approach, social distance analyzer with euclidean distance, and data visualization with NodeJS and MongoDB.

3.1. Image acquistion

Image acquisition serves as the initial stage in the social distancing analysis system. At this stage, the environment that needs to be analyzed will be recorded using CCTV so that the data from the recording can be processed further. In this study, the environment that is the focus of research is the Bandung train station. This station is the primary public transportation that provides various services for travel destinations. This station has two main entrances, namely the north and south entrances. Train’s passenger entrance will access the entrance counter and continue into the station. One of the locations within the station that passengers often pass is on the platform. This area is the part that connects the main building with the train and is the place where passengers get on or off the train. CCTV has been installed so that the movement of passengers on the platform can be detected. CCTV will be used as the primary source in the implementation of image acquisition rather than other devices. Besides, CCTV can operate for 24 hours so that data collection needed for the detection process can be analyzed more readily. In this schema, CCTV from NVR will be transformed into the dashboard through video stream protocol using real time streaming protocol (RTSP), real-time messaging protocol (RTMP), or hypertext transfer protocol (HTTP). In this paper, we implemented RTSP as a video stream protocol because it doesn't need a media server, is supported by most CCTV products and is suitable for local LAN or WAN video access. This schema will illustrate in Figure 2.

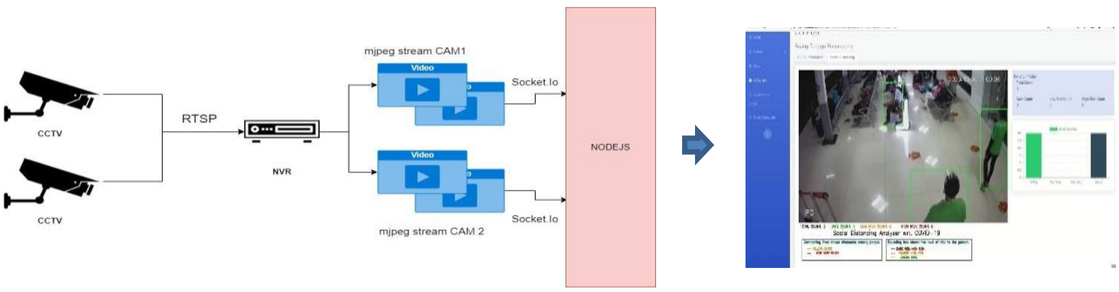


Figure 2. Image acquisition schema flow

3.2. Object detection

Object detection is developed to detect objects in the environment that have been captured by CCTV. In this study, the main thing is to train passengers because these passengers have a high priority in implementing social distancing in train facilities. Deep learning can be used at this stage to be able to carry out object detection. One of the current state-of-the-art detection objects is YOLOv4 [24]. YOLOv4 is an object detection method that can be used in real-time and is able to detect several objects in one image. The technique identifies objects in the image using bounding boxes and classifies objects that have been identified so that objects in the image can be detected according to need, in Figure 3. It is the basic architecture of an object detection model.

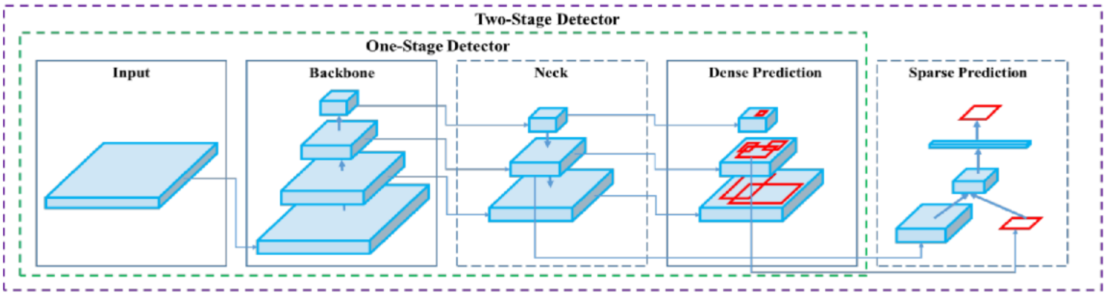


Figure 3. Object detector model [15]

This object detector model uses CSP Darknet 53 as the backbone; cross stage partial network (CSPNet) is a model that can improve CNN performance and significantly reduce the need for calculations on the system. CSPNet was created to mitigate the problems found in the previous backbone model wherein the previous model heavy computing was needed so that it could affect system performance [24], [25]. CSPNet overcomes this problem by integrating the feature map at the beginning of the network stage and at the end of the network stage, which in turn is able to reduce computing requirements by 20% [CSPnet]. Spatial pyramid pooling (SPP) and path aggregation network (PAN) are used as the Neck. In general, CNN requires input (image) with a predetermined size. This need can reduce the efficiency of the model to be used, therefore SPP is used in YOLOv4 [24], [25]. SPP has a function to eliminate input images with a specific size; this method generates a fixed-length representation in the training implementation. It is not tied to image size. This method increases the accuracy of classification activities and can speed up the detection process. Then PANet was used because, in the previous CNN, the data flow contained in the network was that input would enter the initial layer, which would then be transferred to the next layer until the input was successfully processed, but the more layers used, the possibility of the information needed in deep learning could not be used. Therefore, PAN is used in deep learning [24], [25]. PAN aims to increase information flow on the network so that relevant features at the layer n be utilized to the maximum. This method works by way of information in the previous layer, with the layer at this time will be integrated to produce a new vector that can be used on the network. In a network, the head section is used to perform dense predictions, namely is predictions. At the end of the layer consisting of vectors containing coordinates for bounding box sizes such as length and width, as well as confidence scores for the prediction results that have been made and the last but not the least is a label that corresponds to the object that has been detected, for the head used in this architecture is YOLOv3 [9], [24], [25] because the model can produce good accuracy values for detection results. The time required for inference is lower when compared to other detection models [25]. These components play an essential role in retrieving the features in the image and identifying objects in the environment.

3.3. Object tracking

Object tracking is an activity that consists of several stages, including detecting objects in the scenario, assigning an identity to each object that has been seen, then tracking objects in the system that have been given a previous identity so that each object can be tracked. In research using simple online and realtime tracking (SORT) [1], [2], [9], [11], [12], [17], this method was published several years ago and is able to produce suitable object tracking performance, ranging from accuracy in conducting object tracking to inference speed which can be done quickly compared to other object tracking methods. This method uses frame-to-frame prediction and association of this process. Next, it was applied by the latest object detection method so it can produce the best performance in object tracking on speed and accuracy. The purpose of implementing object tracking in this system is to track objects in the environment. In this case, the object that is focused on is train passengers so that every passenger passing through CCTV monitoring will be detected and then tracked their movement for further analysis [1].

DeepSORT is using YOLOv4 as an object detection model with a CNN, and for tracking methods we integrate to the system are the Kalman filter and Hungarian algorithm. Ahmed *et al*. [23], the Hungarian algorithm is a method for solving the assignment problem; for example, the 2-D matching of assigning some people to specific tasks. That method is then generalized to an n-D Hungarian and becomes a 3-D Hungarian algorithm for solving the tracking problem in video processing. A researcher sometimes uses the Kalman filter to track and predict object location. According to Rezaei and Azarmi [1] and Li *et al*. [26], the definition of Kalman filter is a set of mathematical equations that provide an efficient (recursive) computation of the means for estimating the state of a process. This filter used three main steps to achieve their task: prediction, estimation, and update. The Kalman filter can track an object from the data by estimating a state vector that contains parameters of the object, such as velocity and position [23], [26]. This algorithm objective is to track the people's movement from frame to frame so that we can calculate the passenger's count becomes accurate. This is in accordance with what is illustrated in Figure 4.

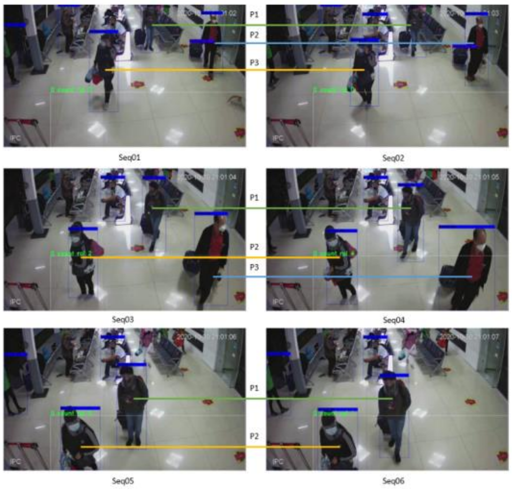


Figure 4. People tracking illustration

3.4. Social distance analyzer

Social distancing is one of the main aspects that will be examined in this study, with the aim of ensuring that the distance between each passenger can be adjusted to the needs of social distancing distances to prevent the spread of disease so that if there are train passengers who do not comply with social distancing rules, station employees can find out the incident through the CCTV system that has been integrated with a social distancing analyzer. For each passenger who CCTV has detected, the system will detect and track each passenger; after the process steps have been successfully carried out, each passenger who has been tracked will be given a distance in the area around the passengers which has a certain radius, the purpose of this stage is to be able to obtain the empty distance that exists for each passenger, when a passenger approaches a certain distance to another passenger who has passed the predetermined threshold for each space between passengers, the system will indicate that the relevant passengers have an unsafe distance from the surrounding passengers [9]. This social distance method measures the distance between objects, the coordinates of the individual objects are necessary to obtain the coordinates of each object, the bounding box of the object detected in the video frame is used. Figure 5 is the bounding box area of the detected object. The O_{center}, which is the center point of the lower bounding box of the object, can be determined in (1).

$$O_{center} = \left(\frac{x'-x^0}{2} + x^0, y'\right) \quad (1)$$

The object's actual x and y coordinates are derived, and the distance between each object can be calculated. To measure the distance between objects, we use the Euclidean distance formula. By applying the two-dimensional Euclidean distance formula for measuring the distance between objects through (2), which is the distance formula between $person_d$ and $person_e$, is obtained as (2).

$$d_{d,e} = \sqrt{(x_d - x_e)^2 + (y_d - y_e)^2} \quad (2)$$

As it can be seen in Figure 5, we can see the distance ($d_{d,e}$) if the $d_{d,e}$ is higher than threshold (1.8 m) is a safe condition. As a result, if the distance ($d_{d,e}$) is lower than threshold, the system will show the high-risk indicator with red bounding box like $person_d$ and $person_e$ in Figure 4.

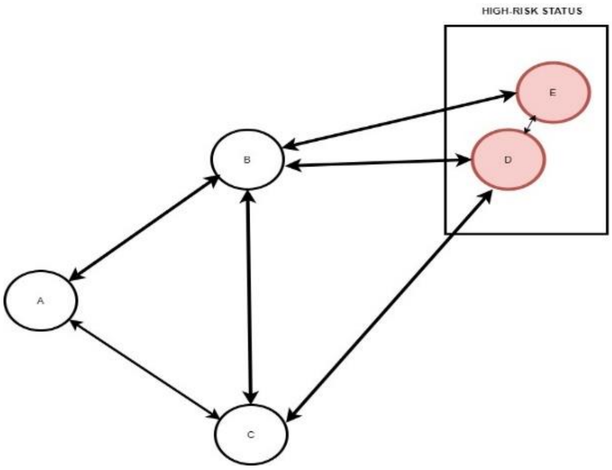


Figure 5. Social distance analyzer schema

3.5. Data visualization

The results of the analysis that each previous stage has carried out will produce results in the form of images or videos on each object of interest, namely, train passengers passing through the field of view from CCTV will be processed using object detection and social distance analyzer so that each detected passengers will be given bounding box on each frame so that each passenger can be tracked, as well as another output is that each passenger detected by the system will be given a heatmap, with the aim of representing the safe distance contained in every distance between passengers, with if the heatmap is red then the distance shown is red being in between passengers is too close or is said to be a violation of social distancing rules. First, the data that has been captured from the CCTV will be transferred using the RTSP protocol, and then the data will be analyzed for further processing in the database. The extracted standard formats such as JavaScript object notation (JSON) and extensible markup language (XML) can be displayed in real-time with map visualization, pie charts, and bar graphs with the function that authorities can get the information that CCTV has captured. The example can be seen in Figure 6 [13].

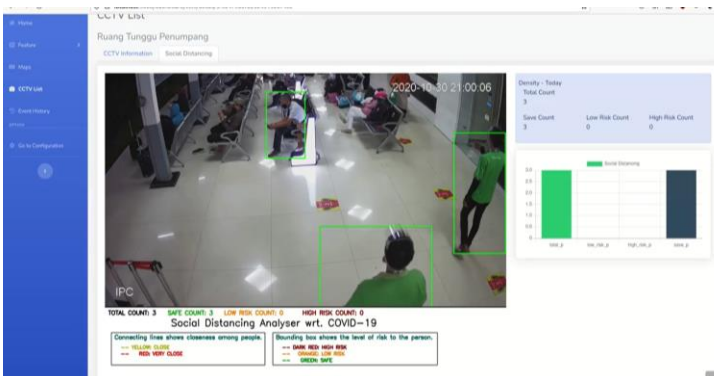


Figure 6. Social distancing dashboard

4. RESULTS AND DISCUSSION

This implementation uses the python language, with YOLOv4 darknet as a module to carry out object detection and SORT tracking as a module used to track objects that have been detected. The libraries used in this study include OpenCV, Numpy, Matplotlib, and Pillow. At the implementation time, the hardware system used to perform image processing starts from input to output social distancing; we are using a mini-computer with a specification Intel(R) Xeon(R) CPU E3-1231 v3 @ 3.40GHz with Ubuntu 18.04. The hardware setup configuration can be seen in Figure 7 and this hadware specification also illustrated in Table 1.

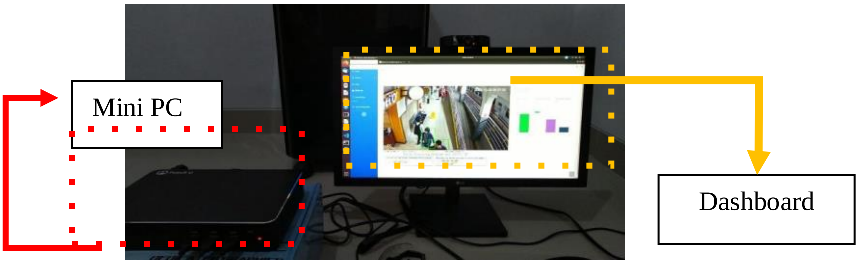


Figure 7. Hardware setup configuration

Table 1. Hardware specification

Hardware	Specification
Processor	Intel(R) Xeon(R) CPU E3-1231 v3
RAM	DDR3 8B
VGA	GP107 GeForce GTX 1050 Ti
Clock	100 MHz

4.1. Evaluation for passengers tracking

This evaluation of passenger tracking result is illustrated in Figure 8. Figure 8 devides into Figure 8(a) shows the actual video footage without further analysis. Figure 8(b) illustrates the result of object tracking after analysis. In Figure 8(a) it can be seen that there is video data retrieval without further analysis. This captured video only shows video streams and other tasks only record which will then be stored on the hard disk so that if there are abnormal events such as social distancing violations or the accumulation of the number of passengers captured by the camera. This previous video streaming cannot provide notifications automatically. The Figure 8(b) illustrates the result of object tracking that has been carried out using CCTV at the Bandung station, which is located on the platform. This result is the final product of our system which will then be sent to the dashboard to be input to stakeholders in determining policies or even changing the layout of the area to optimize the people's tracking. Besides that, in addition to people's movement and people tracking data, the system also analyzes the location and the density of people in the area that do not adore the social distancing rules where it can be seen as a violation. This tracking method will send the level of crisis value into the dashboard.

(a)

(b)

Figure 8. Display the difference of using tracking algorithm in (a) actual video footage without further analysis and (b) shows the passenger tracking results of the video

4.2. Evaluation for passengers heatmap

This paper also releases a heatmap from the level of crisis that has been generated based on this research product related to people tracking, people detection and social distancing monitoring. This result is described in Figure 9 that represents a frame analysis with heatmap visualization, in that figure, these zones include crowded zones where there are groups of people walking hand in hand and violating social distancing rules. However, in other parts of the station, a minimal level of risk is identified if crowds of people in the zone are less than 1.8 m apart and also more than 3 persons.

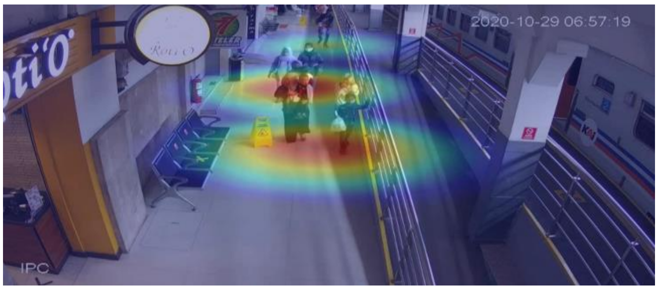
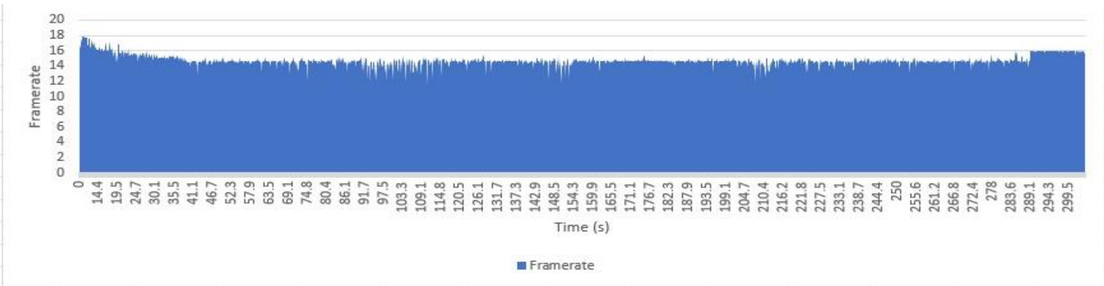


Figure 9. Heatmap for passengers distance

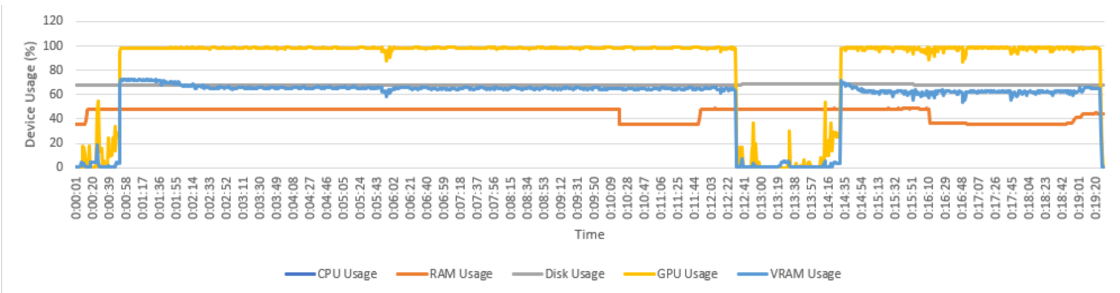
4.3. Evaluation for real implementation

The evaluation for this system achieved the accuracy and recall rate of 96.5% and approximately at 15-18 fps which are respectively, in Figure 10 divides into 2 illustrations in Figure 10(a) and (b), this social distance monitoring results in violations with clusters such as a high-risk number, low-risk number, safe-risk number, and total people. Figure 10(a) shows the results obtained after we carried out tests on system for 7 days to use continuously and get the results in the image below which shows it is stably between 18 FPS. Figure 10(b) shows the system utilization to know about central processing unit (CPU) usage, random access memory (RAM) usage, data usage, graphics processing unit (GPU) usage, and video random access memory (VRAM) usage when this platform is activated. This experiment is tested in a personal computer with specification Intel(R) Xeon(R) CPU E3-1231 v3 @ 3.40GHz with Ubuntu 18.04.

This system will send the notification when a violation occurs where the people that have been tracked violate the distancing rules. All the people detected as breaking the rules will be seen as a high-risk transmission. The algorithm has multiple use cases where the algorithm's results can be utilized differently by the policymaker or the authorities that monitor the area regarding the distancing rule safety protocol. These results of this social distancing violation will be depicted in Figure 11 and Figure 12. For example, Figure 11 shows data of counting visualization from social distancing for general and Figure 12 shows the visualization of high-risk individual from the real CCTV in Bandung railway shows the line graph about the total count of people in every frame, the status of people who do not follow social distancing rules, and the number of that exclude coupled group violations.



(a)



(b)

Figure 10. Display various performance results from the system such as (a) shows the FPS result and (b) shows the system utilization from the system

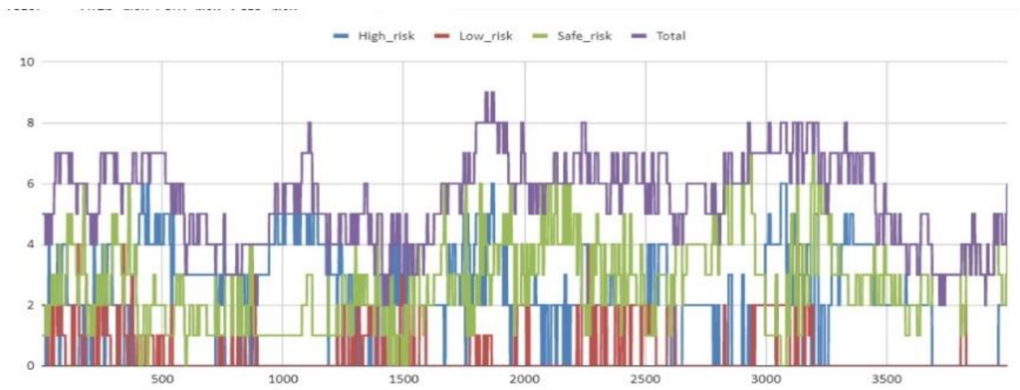


Figure 11. Social distancing of total distribution visualization

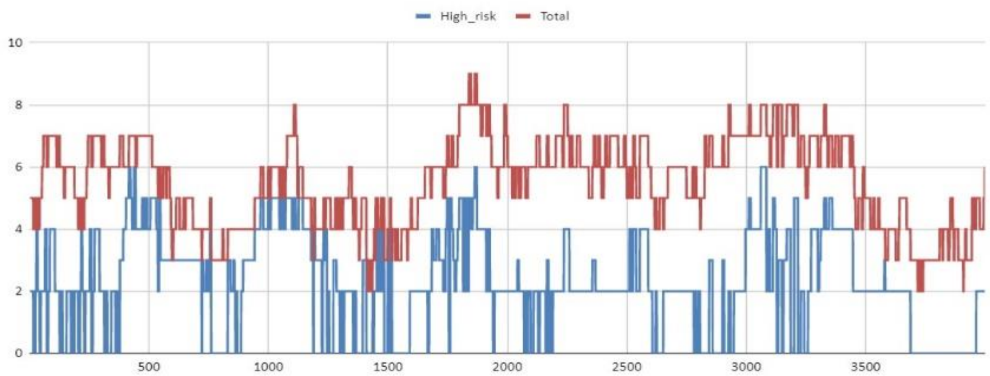


Figure 12. Social distancing high-risk individual visualization

5. CONCLUSION

Our research proposed a system to solve the social distancing aspect in public using CCTV analytics and deep learning algorithms, especially CNN, which is also supported by the data integration using MongoDB to collect and store the data that has been processed. The following research can be improved by big data technology such as Hadoop, Kafka, Cassandra, and another data engine to enhance the data transmission. The CCTV captures this system and then identifies the pattern needed for video analytics. The analytics that have been done can help comprehend the station's situation and be used as information that benefits the people who manage the station to ensure all safety protocols have been followed. The proposed method was evaluated in a single CCTV that is implemented in Bandung railway station with a secure local connection. The system was able to perform in various challenges, including occlusion, lighting variations, any conditions. The proposed prototype can detect persons with the ability to monitor social distancing using the YOLOv4 deep learning algorithm and COCO datasets. This system also can achieve real-time visitor counts with violations detection at roughly 18 FPS and accuracy 96.5% on a Mini PC to release high-risk, low-risk, safe-risk and to track the moving trajectories of the people, infection risk assessment and analysis to the benefit of the health authorities and governments by only viewing into the dashboard visualization. This solution was tested in Bandung railway station with a single camera on a mini PC. This solution can reduce violations significantly through real-time interventions to reduce or eliminate the COVID-19 risk associated with all situations. In the following research, this paper should be improved into multi cameras to better understand social distancing monitoring in some station areas. This research also needs to improve with better GPU by using Tesla, DGX 100 or more to improve the quality of detection, computation, and video frames processing. This algorithm or method can also use other object detection models like YOLOR, and Yolov5.

ACKNOWLEDGEMENTS

This research can be finished thanks to the partially funded support of the Ministry of Research, Technology and Higher Education under the WCU Program managed by the Bandung Institute of

Technology also supported by both Indonesia Endowment Fund/Lembaga Pengelola Dana Pendidikan (LPDP) Komersial and LPDP BRIN Konsorsium COVID-19 grant schema. This project schema is also funded by LP2M Republic of Indonesia Defense University (RIDU) with an Institutional Lecturer Schema. This research project is managed by Smart City Community Lab at the Bandung Institute of Technology (ITB), and Pusat Inovasi dan Komunitas Cerdas (PIKKC) ITB with also collaborated in Republic of Indonesia Defense University Laboratory in collaborating with Indonesia Railway Corporation (PT KAI) and PT LEN Industri Persero.

REFERENCES

[1] M. Rezaei and M. Azarmi, "DeepSOCIAL: Social distancing monitoring and infection risk assessment in COVID-19 pandemic," *Applied Sciences*, vol. 10, no. 21, p. 7514, Oct. 2020, doi: 10.3390/app10217514.

[2] D. Yang, E. Yurtsever, V. Renganathan, K. A. Redmill, and Ü. Özgüner, "A vision-based social distancing and critical density detection system for COVID-19," *arXiv*, no. July, Jul. 2020, [Online]. Available: http://arxiv.org/abs/2007.03578

[3] Q. Li *et al*., "Early transmission dynamics in wuhan, china, of novel coronavirus–infected pneumonia," *New England Journal of Medicine*, vol. 382, no. 13, pp. 1199–1207, Mar. 2020, doi: 10.1056/nejmoa2001316.

[4] C. Huang *et al*., "Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China," *The Lancet*, vol. 395, no. 10223, pp. 497–506, Feb. 2020, doi: 10.1016/S0140-6736(20)30183-5.

[5] Y. Bai *et al.*, "Presumed asymptomatic carrier transmission of COVID-19," *JAMA - Journal of the American Medical Association*, vol. 323, no. 14, pp. 1406–1407, Apr. 2020, doi: 10.1001/jama.2020.2565.

[6] T. P. B. Thu, P. N. H. Ngoc, N. M. Hai, and L. A. Tuan, "Effect of the social distancing measures on the spread of COVID-19 in 10 highly infected countries," *Science of The Total Environment*, vol. 742, p. 140430, Nov. 2020, doi: 10.1016/j.scitotenv.2020.140430.

[7] K. K. W. To *et al*., "Temporal profiles of viral load in posterior oropharyngeal saliva samples and serum antibody responses during infection by SARS-CoV-2: an observational cohort study," *The Lancet Infectious Diseases*, vol. 20, no. 5, pp. 565–574, May 2020, doi: 10.1016/S1473-3099(20)30196-1.

[8] M. Gandhi, D. S. Yokoe, and D. V. Havlir, "Asymptomatic transmission, the achilles' heel of current strategies to control COVID-19," in *The COVID-19 Reader*, New York, NY: Routledge, 2021: Routledge, 2020, pp. 36–39.

[9] N. S. Punn, S. K. Sonbhadra, S. Agarwal, and G. Rai, "Monitoring COVID-19 social distancing with person detection and tracking via fine-tuned YOLO v3 and Deepsort techniques," *arXiv:2005.01385*, May 2020, doi: 10.48550/arXiv.2005.01385.

[10] S. A. Velastin, R. Fernández, J. E. Espinosa, and A. Bay, "Detecting, tracking and counting people getting on/off a metropolitan train using a standard video camera," *Sensors (Switzerland)*, vol. 20, no. 21, pp. 1–20, Nov. 2020, doi: 10.3390/s20216251.

[11] P. Khandelwal, A. Khandelwal, S. Agarwal, D. Thomas, N. Xavier, and A. Raghuraman, "Using computer vision to enhance safety of workforce in manufacturing in a post COVID world," *arXiv:2005.05287*, May 2020, [Online]. Available: http://arxiv.org/abs/2005.05287

[12] P. D. I. Torino, "Monitoring COVID-19 prevention measures on CCTV cameras using deep learning," PhD Thesis, Politecnico di Torino, 2020.

[13] I. A. Dahlan, F. Hamami, S. H. Supangkat, and F. Hidayat, "Big data implementation of smart rapid transit using CCTV surveillance," in *Proceeding - 2019 International Conference on ICT for Smart Society: Innovation and Transformation Toward Smart Region, ICISS 2019*, Nov. 2019, pp. 1–5, doi: 10.1109/ICISS48059.2019.8969830.

[14] F. Hidayat, F. Hamami, I. A. Dahlan, S. H. Supangkat, A. Fadillah, and A. Hidayatuloh, "Real time video analytics based on deep learning and big data for smart station," *Journal of Physics: Conference Series*, vol. 1577, no. 1, Jul. 2020, p. 012019, doi: 10.1088/1742-6596/1577/1/012019.

[15] F. Hamami, I. A. Dahlan, S. W. Prakosa, and K. F. Somantri, "Big data analytics for processing real-time unstructured data from CCTV in traffic management," in *2020 International Conference on Data Science and Its Applications, ICoDSA 2020*, Aug. 2020, pp. 1–5, doi: 10.1109/ICoDSA50139.2020.9212858.

[16] H. Alawad, S. Kaewunruen, and M. An, "A deep learning approach towards railway safety risk assessment," *IEEE Access*, vol. 8, pp. 102811–102832, 2020, doi: 10.1109/ACCESS.2020.2997946.

[17] M. Shamim Hossain, G. Muhammad, and N. Guizani, "Explainable AI and mass surveillance system-based healthcare framework to combat COVID-I9 like pandemics," *IEEE Network*, vol. 34, no. 4, pp. 126–132, Jul. 2020, doi: 10.1109/MNET.011.2000458.

[18] N. S. Punn, S. K. Sonbhadra, and S. Agarwal, "COVID-19 epidemic analysis using machine learning and deep learning algorithms," *MedRxiv*, 2020, doi: 10.1101/2020.04.08.20057679.

[19] L. E. Emokpae, R. N. Emokpae, W. Lalouani, and M. Younis, "Smart multimodal telehealth-IoT system for COVID-19 patients," *IEEE Pervasive Computing*, vol. 20, no. 2, pp. 73–80, Apr. 2021, doi: 10.1109/MPRV.2021.3068183.

[20] S. H. Khan, M. H. Yousaf, F. Murtaza, and S. Velastin, "Passenger detection and counting for public transport system," *NED University Journal of Research*, vol. XVII, no. 2, pp. 35–46, Mar. 2020, doi: 10.35453/nedjr-ascn-2019-0016.

[21] F. Ganansia, C. Carincotte, A. Descamps, and C. Chaudy, "A promising approach to people flow assessment in railway stations using standard CCTV networks," in *Transport Research Arena (TRA)* 2014 Proceedings, 2014, pp. 1–10.

[22] A. Jhunjhunwala, "Role of telecom network to manage COVID-19 in India: Aarogya Setu," *Transactions of the Indian National Academy of Engineering*, vol. 5, no. 2, pp. 157–161, Jun. 2020, doi: 10.1007/s41403-020-00109-7.

[23] I. Ahmed, M. Ahmad, A. Ahmad, and G. Jeon, "Top view multiple people tracking by detection using deep SORT and YOLOv3 with transfer learning: within 5G infrastructure," *International Journal of Machine Learning and Cybernetics*, vol. 12, no. 11, pp. 3053–3067, Nov. 2020, doi: 10.1007/s13042-020-01220-5.

[24] C. Y. Wang, A. Bochkovskiy, and H. Y. M. Liao, "Scaled-yolov4: Scaling cross stage partial network," *Proceedings of the IEEE Computer Society Conference on Computer Vision and Pattern Recognition*, Nov. 2021, pp. 13024–13033, doi: 10.1109/CVPR46437.2021.01283.

[25] A. Bochkovskiy, C.-Y. Wang, and H.-Y. M. Liao, "YOLOv4: optimal speed and accuracy of object detection," *arXiv:2004.10934*, Apr. 2020, doi: 10.48550/arXiv.2004.10934.

[26] Q. Li, R. Li, K. Ji, and W. Dai, "Kalman filter and its application," in *Proceedings - 8th International Conference on Intelligent Networks and Intelligent Systems, ICINIS 2015*, Nov. 2016, pp. 74–77, doi: 10.1109/ICINIS.2015.35.

BIOGRAPHIES OF AUTHORS

Iqbal Ahmad Dahlan pursued a Master Engineering in School of Electrical Engineering and Informatics, Institut Teknologi Bandung. He has worked as teaching in the Department of Military Electrical Engineering at the Faculty of Military Engineering in the Republic of Indonesia Defense University, and he has two years of experience in the field of Smart City and their applications such as Deep Learning, Internet of Things, and Big Data. His research interests lie in the areas of Smart Safe and Secure to improve the quality of life in many areas. He can be contacted at email: iqbal.dahlan@idu.ac.id or dahlanelka@gmail.com.

Muhammad Bryan Gutomo Putra is currently pursuing MEng Degree in the School of Electrical Engineering and Informatics, Institute Teknologi Bandung. He obtained his bachelor's degree in Informatics Engineering from Universitas Komputer Indonesia in 2019. His area of interest in computer vision, image processing, and Artificial intelligence. He can be contacted at email: 23219312@std.stei.itb.ac.id.

Suhono Harso Supangkat is currently a Professor with the School of Electrical Engineering and Informatics, Bandung Institute of Technology (ITB), Indonesia. He formerly served as the Director of the Smart City and Community Innovation Center. His research interests include smart cities concepts, smart city governance, and the Internet of Things. He is also the information technology scientific group leader in Institut Teknologi Bandung. He can be contacted at email: suhono@stei.itb.ac.id.

Fadhil Hidayat pursued a Ph.D. degree in the School of Electrical Engineering and Informatics at the Bandung Institute of Technology, Indonesia. He received his M.S. degree in Information Technology from the Bandung Institute of Technology in 2011. Since December 2012, he has been with the Bandung Institute of Technology as a lecturer and researcher. His current research interests include distributed multi-robot systems, smart city, intelligent transportation, robot for smart city, and management of information security. He is also the LPDP Safe and Secure Project leader funded by Indonesia Endowment Fund for the smart railway. He can be contacted at email: fadhil@stei.itb.ac.id or fadhil.2persen@gmail.com.

Fetty Fitriyanti Lubis is researcher in Smart City and Community Innovation Center (SCCIC) at the Institut Teknologi Bandung, Indonesia. She is also a lecturer in Institut Teknologi Bandung with Information Technology Group. Her primary areas of interest include Information Technology, Natural Language Processing, Data Visualization, Data Science, and Learning Analytics. She can be contacted at email: fettyfitriyanti@staff.stei.itb.ac.id.

Faqih Hamami is a Lecturer in the Information Systems Study Program at the Telkom University, Bandung. He pursued undergraduate education majoring in Informatics Engineering at the Sepuluh November Institute of Technology, Surabaya, and continued his Master's education for the Department of Informatics at the Bandung Institute of Technology. He is a Lecturer in the Cybernetics and Data Engineering Expertise Group. His primary areas of interest include Information Technology, Big Data, Deep Learning, Data Engineer, and Data Analytics. He is also creating ngodingdata.com as a platform to study everything about data. He can be contacted at email: faqihhamami@telkomuniversity.ac.id.