International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 10 Issue: 02 | Feb 2023 www.irjet.net p-ISSN: 2395-0072

CREATING CCTV CAMERA SYSTEM USING ARTIFICIAL INTELLIGENCE, IMAGE PROCESSING, AND CYBERSECURITY TOOL

Md Arham Siddiqui[1], Kunal Agarwal[2]

[1]BTech student, Dept. of Computer Science and Engineering, Vellore Institute of Technology, Vellore, India
[2]BTech student, Dept. of Computer Science and Engineering, Vellore Institute of Technology, Vellore, India

---

ABSTRACT - *The first CCTV camera was known to be installed in Germany in 1942. Since then, we have made a lot of progress, added a lot of features and now there are an estimated more than 750 million CCTV cameras installed all around the globe. But even with all the features already existing in current CCTV technologies, most CCTV cameras all around the world have too many loopholes, which makes them easy to exploit and ultimately leads hackers to attack and gain control of the cameras. In our project, we will be aiming to reduce these loopholes to a minimum by implementing various innovative and new features like specific human gestures detection such as the suspicious hand gestures that humans make while committing different crimes like holding a knife, hand movements while fighting with someone, etc. using deep learning including Artificial Intelligence. As there are a lot of thefts regarding vehicles like cars and bikes. So our next module will be focused on License Plate realization or recognition. Our module will be connected to the database which will be regularly updated with all the vehicles which are complained as missing or theft so that our camera can automatically detect using techniques like Image Processing and recognize the number plates for all the vehicles that pass from its vision. Our next module will be focused on Face mask detection using IP methods as per our government rules that a mask is mandatory for all the citizens due to the Covid-19 times. This will help reduce the load on all the officers working hard so the next variant after Omicron can't spread like the previous Covid waves, as warned by scientists. Our final module will solely be focused on securing the CCTV using various cybersecurity methods which aren't supported and implemented in real- time. But even when a CCTV camera is equipped with all these features, its purpose will be defeated if even for once it's under attack by a hacker. So we'll be further implementing cybersecurity protection by preventing DDoS, SQL, and other attacks. Image Processing and Cyber Security that are available in our framework will be easier to use by the public and a worthy step forward in the security sector. Therefore, an assistive app can be used that allows the users to traverse freely without worrying about their surveillance security and it also becomes a crucial requirement in their daily life. Therefore, our all-in-one application is implemented to make the life of the local businesses, small scale and large-scale businesses at check by proper surveillance of the same.*

***Key Words*: Artificial Intelligence, Image Processing, Cybersecurity, Deep Learning, Security Sector.**

1. INTRODUCTION

With the CCTV cameras numbers rapidly increasing, it's predicted to cross the 1 billion marks within the next few years. With the basic mindset, [7] the main benefits of the usage of CCTV cameras are security, safety, surveillance, and prevention of crime. As our technology is advancing many upgrades are being implemented in CCTV cameras, such as human detection using AI, real-time surveillance using IoT, these include detecting the human presence in front of the camera or a particular marked area that the camera covers in its view and alerting the [8] same to the live monitoring device, smartphone integration, using voice control to turn on and manage the controls of cameras, using solar-powered cameras with energy storage so they can work 24×7 in any environment, and features like night vision have been in use at present.

We plan to put up with the efficiency of the CCTV system, to include new [6] features, like detecting criminals within vehicles, facemask, during violent activities, along with securing the threats that most of the CCTV systems possess and prevent confidentiality, integrity and availability of the data stored within the same [9].

Objectives of the proposed work: Firstly, we'll be reducing loopholes to a minimum by implementing various innovative and new features like specific human gestures detection such as the suspicious hand gestures that humans make while committing different crimes like holding a knife, hand movements while [5] fighting with someone, etc. using deep learning including Artificial Intelligence. As there are a lot of thefts regarding vehicles like cars and bikes. So our next module will be focused on License Plate realization or recognition. Our module will be connected to the database which will be regularly updated with all the vehicles which are complained as missing or theft so that our camera can automatically detect using Image Processing and recognize the number plates for all the vehicles that [10] pass from its vision. Our next module will be focused on Face mask detection using image processing methods as per our government rules that a mask is mandatory for all the citizens due to the Covid-19 times. This will help reduce the load on all the officers working hard so the next variant after Omicron can't spread like the previous Covid waves, as warned by scientists. [11] Our final module will solely be focused on securing the CCTV using various cybersecurity

methods which aren't supported and implemented in real-time. But even when a CCTV camera is equipped with all these features, its purpose will be defeated if even for once it's under attack by a hacker. So, we'll be further implementing cybersecurity protection by preventing DDoS, SQL, and other attacks. Image Processing and Cyber Security that are available in our framework will be [12] easier to use by the public and a worthy step forward in the security sector.

2. LITERATURE SURVEY

Various models have been come across while we were conducting the literature survey.

First paper proposes a framework for Criminal Detection and Recognition of CCTV Data Using Cloud and Machine Learning. It is finished involving Microsoft Azure Cognitive Services and Cloud framework with the end goal of execution of the proposed framework. [13] The framework can likewise be utilized to find missing youngsters and individuals from the CCTV film that is accessible from the site. Using various methodologies, the authors have described the accuracy and costing of each method along with the sensors used and ultimate result that can be obtained by using these technologies with integration to the CCTV system.

Fig. 1

The authors try to efficiently manage the traffic accidents and the deaths that take place due to it in the second paper, considering lack of helmet usage being one of the biggest reasons for it. To perfectly manage the traffic, and its rule breakers, an intelligent [4] automated system is proposed, wherein maximum number of two-wheelers will be detected via the video and those disregarding the traffic, their number plate will be noted and corresponding fine or charges are imposed via the electronic fine management system.

In the third one, which is chapter, we observed that cyber-attacks like the DDoS and other attacks which lowers the CCTV security are something that needs to be detected automatically rather than putting manual efforts into detection which can too much time consuming. Creators attempt to investigate the conceivable outcomes to give better security to video reconnaissance frameworks and correspondence organizations. After appropriately checking on arrangements that relate to relocating AI-based derivation towards the edge and [14] brilliant client gadgets, as well as different strategies for DDoS (Distributed Denial of Service) canny identification, where DDoS assault is perceived as one of the essential worries in network safety, strategies to prevent such attacks are developed within the same.

The next research article is regarding the newly considered evaluations on the crime prevention effects on CCTV. It shows that, that CCTV is associated with a significant decrease in crime. The largest and the most consistent effects of CCTV were observed in car parks. The results of this analysis can also demonstrate evidence of significant crime reductions within other settings, [15] particularly residential areas. CCTV schemes incorporating active monitoring that are generated by larger effect sizes than did passive systems. Schemes deploying multiple interventions alongside CCTV generated larger effect sizes that did schemes deploying single or no other interventions besides CCTV. As CCTV surveillance increases day-by-day, high end and high-quality evaluations of outcomes and implementations is of utmost importance, only then the crime rate can be kept relatively low.

Particularly, in the next paper authors have really emphasized on how the detection of crime in CCTV videos can be done using deep learning. In their proposed model, they represent what things are important for this whole methodology to work. Firstly, a crime dataset needs to be analyzed and studied, followed by the neural network training, which filters several layers to figure out what exactly the activity is about. If the respective activity detected is matched with the [16] one in the dataset, then it needs to send some sort of alarming system that can make the owner protect his or her property or maybe call for help and local police. With good amount of accuracy, the details of the technical findings can be distinguished by reading through the paper.

The reasoning of paper number six portrays a study using a quasi-experimental design to determine the actual impact of an integrated CCTV program on all of crime in Detroit, USA. The methodology used by the authors was also unmatched, the data on the first 87 businesses in the Project named Green Light Detroit was collected, along with a matched comparison group of 201 other businesses. A Bayesian [17] hierarchical linear growth curved model was deployed to determine the overall effect of CCTV camera surveillance at Green Light businesses over the span of 2 years. On proper finding, it indicated that Green Light businesses experienced an immediate, but transient increase in property crime reports, as well as more consistent proactive police activity post-intervene. The outcome, that can be concluded [18] through is that integrated CCTV programs may increase the reporting of minor crimes which may have not been reported before. However, these programs may not likely impact violent crimes. In addition, tying all the proactive response and to

patrol the patrol the participating businesses places higher manpower costs on departments.

The authors take up Named data networking (NDN) as an essential information transmission recreation technique. It focuses on proficient substance conveyance and diminishing the overt repetitiveness of information transmission. In NDN, one of the significant issues is how to use them is generally reserved items to decrease the client's reaction to delay and work on the usage of the genuine [1] store assets. In this paper, a clever substance disclosure framework is utilized to completely use the store assets, called DENA, is proposed, which envelops the profound outstanding reserve declaration and reserve energy-based reserve substitution calculations. DENA gives the easiest routeways to intrigue parcels to get to designated information bundles under directions of a declared table built by a shift accuracy-based reserved content declaration calculation with low correspondence upward. Meanwhile, a store substitution calculation to help the reserve declaration is likewise proposed. The technique utilizes a [19] purported reserve energy list to teach the substitution of stored content. The recreation results show that the framework works on the usage of store assets and the organization limit while keeping the organization's control traffic at a generally low level.

Eighth paper again depicts the philosophy for weapon discovery in observation recordings utilizing profound brain organizations. Creators attempt to work on the normal accuracy of firearm [2] discovery at various scales, lastly, they figure out how to increase to however much 18% more accuracy than the past and existing arms recognition draws near.

Like most of the papers we came across, authors of this paper too are talking about weapon detection and how to control and minimize crime rate in crowded as well as suspicious lonely areas. So, authors try to implement an automatic weapon detection, particularly guns, using CNN (Convolutional Neural Network) based SSD (single shot detection), along with faster RCNN (region CNN). After using 2 types of datasets pre- labelled image and manually labelled accuracy of application is tabulated. Further, SSD and Faster RCNN algorithms are simulated for pre labelled and self-created image dataset for gun detection. Both the algorithms are efficient and give good results, but their application progressively depends on the [3] trade between speed and precision. As far as speed, SSD calculation gives better speed with 0.736 seconds per outline. Though Faster RCNN gives a speed of 1.606 seconds per outline, which is poorly contrasted with SSD. As for precision, Faster RCNN gives better exactness of 84.6%. Though SSD gives an exactness of 73.8%, which is poorly contrasted with quicker RCNN.SSD gave constant location because of quicker speed yet Faster RCNN gave unrivaled precision. In terms of future works, the authors relate that high-end GPUs and DSPs (digital signal processors) large datasets can be used to train for more accurate algorithm.

In the tenth paper authors try to prove and describe the development and implementation of an early warning system that recognizes people automatically in a surveillance camera environment and then use data from various sources to identify these people and build their profile and network the authors extracted feature vectors of all face images from camera feed and gallery images. We utilized OpenFace model and our prepared model to gather two separate element vectors for each picture to look at which highlight extraction model works better in an observation climate. After which they compared the accuracy of recognition in two different settings, one with only one face of a person in the gallery (neutral face) compared to when having two faces in the gallery for every person (neutral and smiling face). After setting up the database gallery, one of the authors ran tests on each portal and sequence with the three different cameras available and then finally showing accuracy results of using the different recognition models to classify people passing, using three tables. Further, they aim to improve accuracy and reduce runtime by experimenting different techniques other than those already used in.

The work thus this paper is centered around giving a safe spot involving a CCTV film as the principal source to distinguish hurtful weapons by applying open-source profound learning algorithms. They have carried out paired order expecting gun as the reference class and pertinent disarray objects incorporation idea is acquainted with lessen misleading up-sides and bogus negatives. With the help of a series of experiments, we concluded that object detection algorithms with ROI (Region of Interest) perform better than algorithms without ROI. The authors have tested many models but among all of them, the state-of-the-art Yolov4, trained new database, gave very few false positive and negative values, hence it achieved the most successful results. It gave 91.73% mean average precision (mAP) and a F1-score of 91% with almost 99% confidence score on all types of images and videos, hence developing an automatic real time weapon detector. Reduction of false positives can be seen as in future works to make it more accurate according to authors in this eleventh paper.

While analyzing the cost and accuracy of using cloud and machine learning for detection of violence, both factors don't go hand-in-hand along with proper CCTV system management. The accuracy we deal with here is way less than 90%.

Also, there is no domain within any one of the papers which is improving accuracy and integrating Image processing, Artificial Intelligence and Cybersecurity, under one CCTV website system [20], which can be used as a number one domain to login and use the most high-tech system for surveillance in the country.

As we came across more and more papers within the span of past 3 years, we always ended up negotiating the security or data of the CCTV system of a particular organization or

government. Which turns out to be easily hackable, especially in Indian states. Thereby, a core module of cybersecurity is ardently needed, securing majority of attacks, and triggering warning if system is about to get compromised. Most of the top technology and algorithms among the CCTV system business revolves within different governments trying to secure their individual bag of surveillance. In simple words, private sector companies and other small business owners are excluded from reaping benefits of such technologies. Therefore, all the above modules under one website providing CCTV security services is something that can be found almost nowhere, and needs to be taken charge of creating developing as soon as possible.

3 OVERVIEW OF PROPOSED SYSTEM

Summarizing the complete project, inculcating all the modules under one name, 'EyeSpy'.

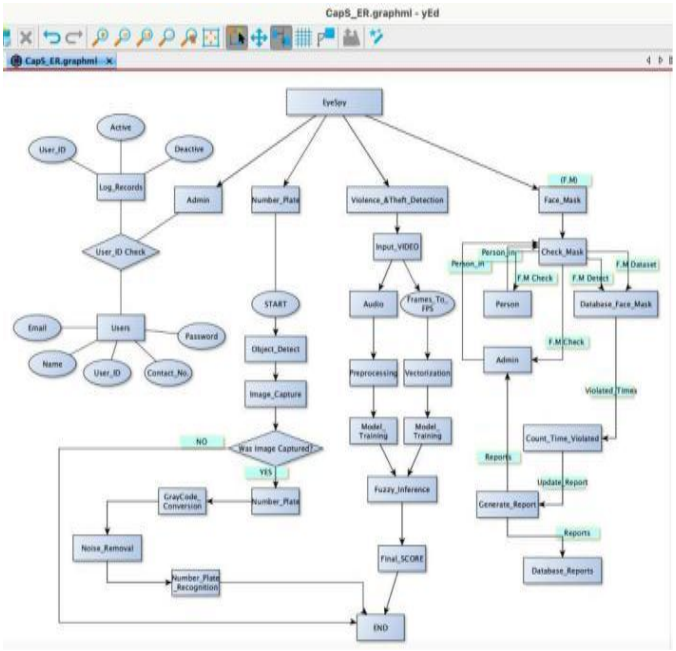

Fig. 2 ER Diagram

3.1 METHODOLOGY

Worldwide pandemic COVID-19 conditions arose in a scourge of hazardous infection from one side of the planet to the other. Wearing a facial covering will help with thwarting the spread of defilement and hold the individual back from getting any airborne overpowering organisms. Using our module of Face Mask Detection System, one can screen assuming that people are wearing covers or the other hand not. Another ordinary issue is Traffic control and vehicle owner ID has become major in every country.

Occasionally it becomes testing to perceive a vehicle owner who for the most part mishandles traffic rules and drives unreasonably rapidly.

Thusly, it is ridiculous to try and expect and repel that sort of kind of individual in light of the fact that the traffic individual might not have the choice to recuperate the vehicle number from the moving vehicle before the camera because of the speed of the vehicle.

Furthermore, although Violence rates have been brought down around 57% during the range of recent many years yet it doesn't impact the way that the exhibition of brutality occurs, concealed by the law. Brutality can be mass controlled in some cases by higher specialists, anyway, to keep everything in line one must "Microgovern" over every development happening in each street of each square. So, modules and calculations like HAAR CASCADE are utilized for picture recognition. Additionally, [22] to address the butterfly impacts sway in our setting, we made an exceptional model and a hypothesized framework to deal with the issue using profound learning. The model takes the contribution of the CCTV video takes care and later draws surmising perceives assuming [21] a vicious development is going on. Likewise, we created the Automatic Number Plate Recognition (ANPR) framework as one of the answers to these issues.

Finally, we integrate all the combined modules and figure out the criminals by verifying those detected on CCTV with that of the database.

3.2 MODELING AND ANALYSIS

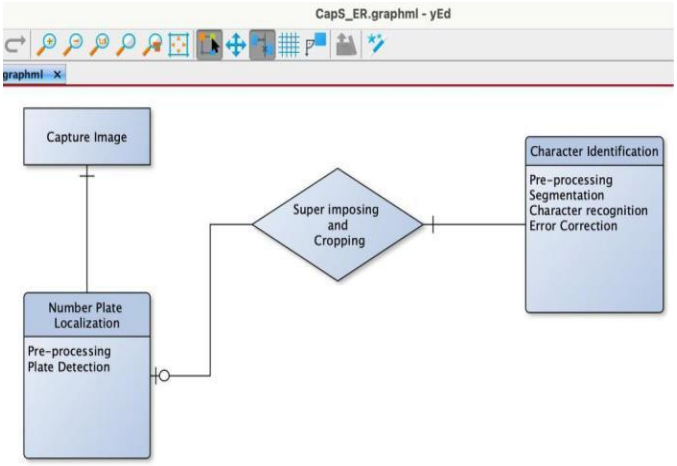

Fig. 3 Number Plate Detection

This application is implemented using ReactJs for the front-end and PHP, sql, MongoDB for the back-end. In ReactJS application an image is accepted as input from the user which will be saved in our local directory. That image is read in the back-end application using the OpenCV module.

The image read is pre-processed and first the diameter of the circular shaped objects present in our image is determined.

After logging in, the user selects the 'Number Plate' option on the menu bar to check if the image of the number plate of the vehicle that he or she took or has is a stolen vehicle or not. So, a Haar Cascade classifier is being used here to detect the numbers on the number plate. This classifier gives an element-based object discovery procedure, which matches very nearly 18000 highlights in a picture to recognize an objective item. Utilizing 'object identification' we distinguish an article situated inside the picture. In the beginning advance, it needs bunches of positive pictures for example number plate pictures, and negative pictures for example pictures that don't contain a number plate, to prepare the calculation.

All things considered, we have utilized a pre-prepared number plate recognizer utilizing Haar Cascade to distinguish a number plate in a given picture.

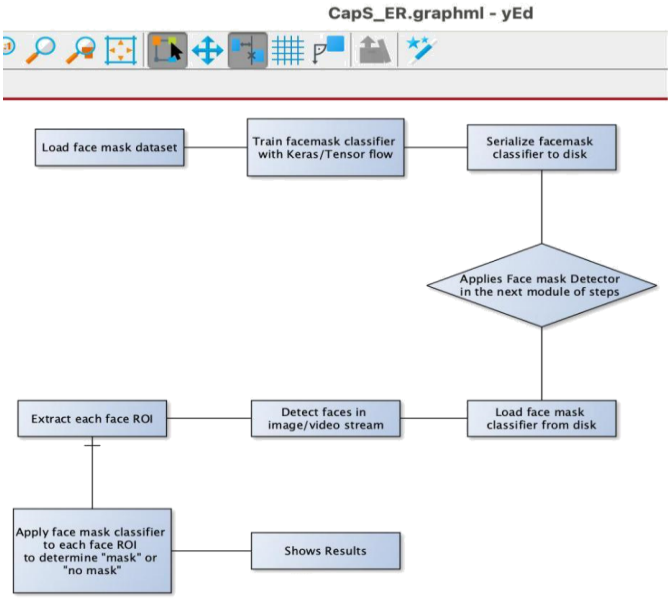

Fig.4 Face Mask Detection

This application is implemented using ReactJs for the front-end and PHP, sql, MongoDB for the back-end. In ReactJS application an image is accepted as input from the user which will be saved in our local directory. That image is read in the back-end application using the OpenCV module.

The image read is pre-processed and first the diameter of the circular shaped objects present in our image is determined.

After logging in, the user selects the 'Number Plate' option on the menu bar to check if the image of the number plate of the vehicle that he or she took or has is a stolen vehicle or not. So, a Haar Cascade classifier is being used here to detect the numbers on the number plate. This classifier gives an element-based object discovery procedure, which matches very nearly 18000 highlights in a picture to recognize an objective item. Utilizing 'object identification' we distinguish an article [23] situated inside the picture. In the beginning advance, it needs bunches of positive pictures for example number plate pictures, and negative pictures for example pictures that don't contain a number plate, to prepare the calculation.

All things considered, we have utilized a pre-prepared number plate recognizer utilizing Haar Cascade to distinguish a number plate in a given picture.

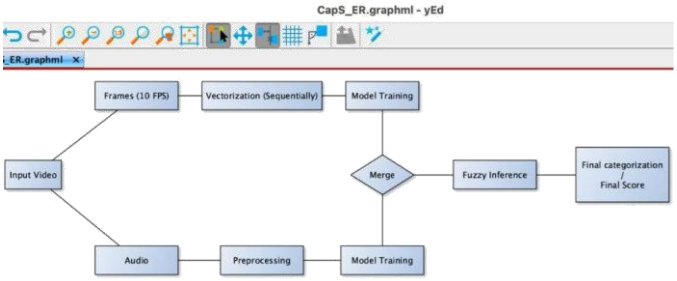

Fig.5 Detection of violence, crime detection by AI human actions of crime from (dataset)

Further, the third option within the menu bar can be seen is 'Theft and Violence', using this option, clicking the user can check if the live video of the CCTV camera the user is one involving violence, theft, or not. The following architecture can be seen below.

Further, enhancing cybersecurity of the CCTV system by automating the vulnerability scan and alerting the host system when a threat is detected.

This particular module involves a lot of brainstorming and formulation of architecture before putting it out online, the development of this module is done by using 'Hacker Target' vulnerability scanner, which is an open-source vulnerability scanner which runs frequent scans against our website. Wherein, we will be interacting with the Hacker Target API through our website.

4. RESULTS AND DISCUSSION

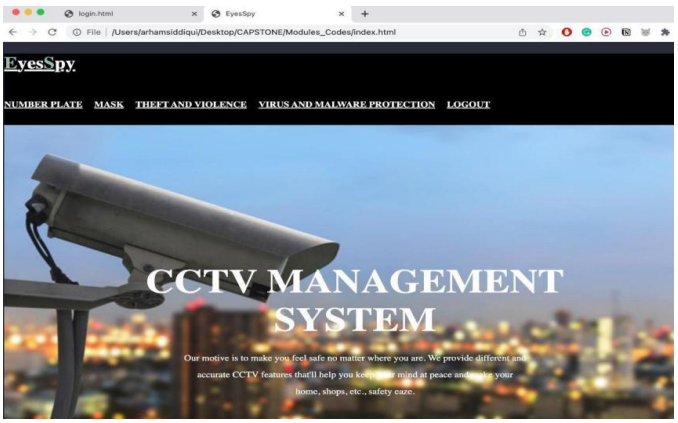

Fig.6 Main Page

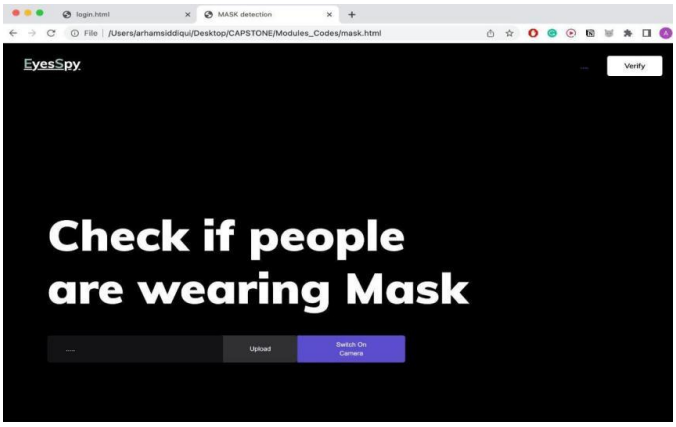

Fig.7 Face Mask Page

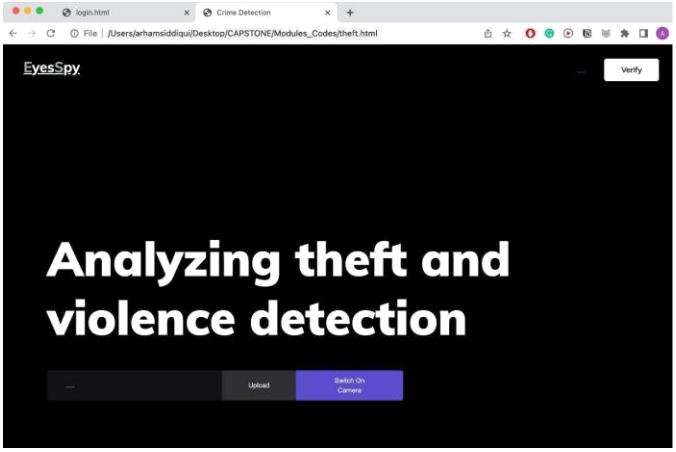

Fig.8 Theft and Violence Page

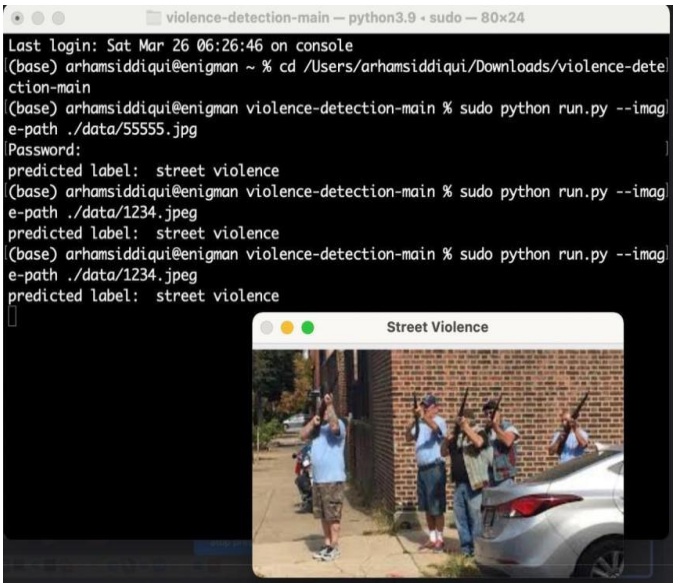

Fig.9 Output of Image Theft

Test Case Type	Description	Test Step	Expected Result	Status
Login	Logging into system	Inputting password and username	Logged into the system	PASS
FMM-1	Normal people with face mask.	Uploading an image of a couple posing at the camera with masks.	Green box with mask detected and percentage.	PASS
FMM-2	People without mask	Uploading an image of people posing at the camera without masks	Red box with no mask detected and percentage.	PASS
FMM-3	A crowd of people.	Uploading an image of people walking down the street with and without mask.	Red and green boxes with people without and with masks respectively.	PASS
NPDM-1	License plate and face of a person	Uploading an image of a car with a person sitting inside.	The vehicle number and image of the person extracted and matched.	PASS
NPDM-2	In extreme conditions	Inputting an image of a car with extreme unclesr image.	Matching the person and the car.	PASS
TVDM-1	Violent Video	Uploading a violent video	It is a violent video with percentage confidence.	PASS
TVDM-2	Non-violent video	Uploading a violent video	It is a non-violent video with percentage confidence.	PASS
TVDM-3	With animals as a reference	Uploading the video	It is a violent or non-violent video with percentage confidence.	PASS

5. PERFORMANCE METRICS

Considering the overall efficiency we have been successful in achieving more than 95% accuracy on our trial datasets.

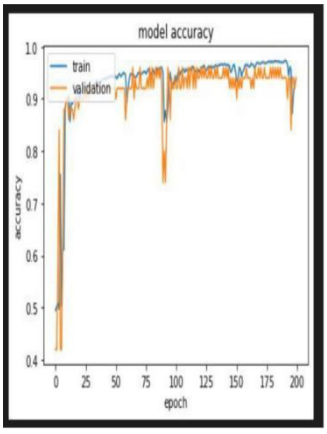

Fig. 10

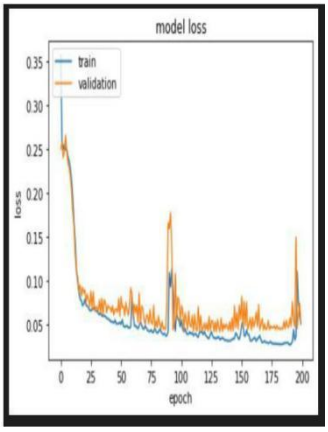

Fig. 11

The process called hyper-tuning has been used solely on the 'hockey dataset'. The hyperparameter tuning is applied for each dataset within, using only 20 epochs and early stopping of 5 instead of 15 as we apply in the final optimal network training, we also use a classic 80-20 split for train-test data. The dropout of 50% improved the model performance and resulted in 98.5% accuracy.

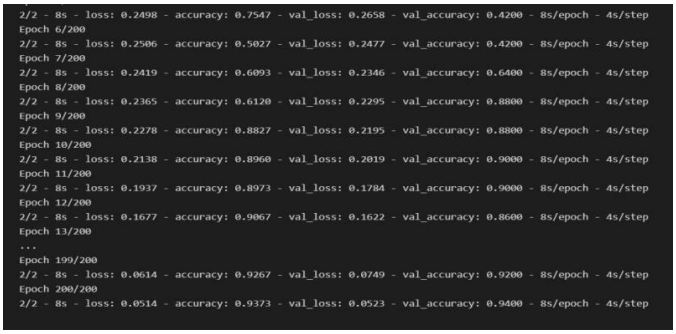

Fig. 12 Epochs

With the Epochs, we were able to have an accuracy of 93% which can be grown till 98% Considering the 'mask detection module', we used OpenCV, tensor flow, Keras, Pytorch, and CNN to detect whether people were wearing the face masks or not. We have used 'With mask' and 'Without mask' datasets.

Our accuracy almost touched the asymptote from the beginning. The total loss came out as 1.4 and the efficiency was 98%.

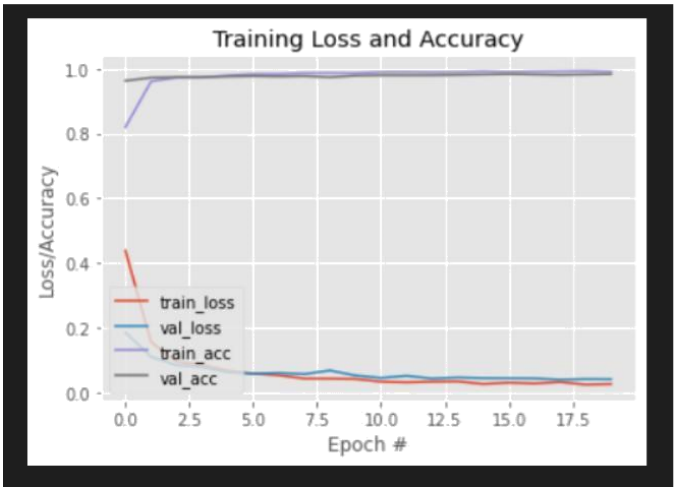

Fig. 13 Graph of TEST vs TRAIN

Each of the models was tried with various dataset pictures, recordings, and continuous video transfers. The exactness of this model is fundamentally accomplished and the streamlining of this model is essentially a persistent cycle we are intending to fabricate an exceptionally precise arrangement by tuning the hyperparameters. This specific model [24] can likewise be utilized as a utilization best case for edge examination. Besides, the proposed strategy accomplishes the best outcomes on a public facial covering dataset. With the improvement of facial covering location, we can recognize on the off chance that the individual is wearing a facial covering, and permitting their entrance would be of incredible assistance to society.

Our model gave 98% accuracy with tensorflow gpu.

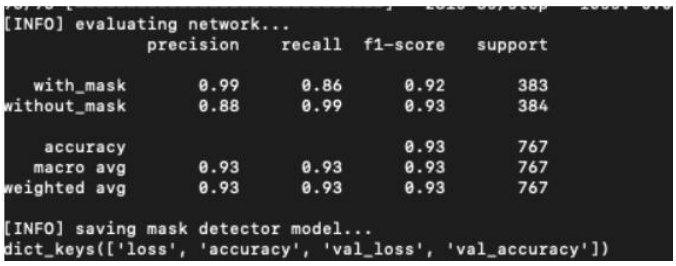

Fig. 14 Accuracy of Face Mask

Considering the 'number plate detection module', this project was successful in performing mainly four tasks. The venture was effectively planned with the goal that we can comprehend the innovation utilized in these days' programmed tag frameworks and OCR frameworks utilized in most evolved nations like Germany, France, Singapore, Japan, and so on. It is seen that security powers all around the world deal with issues finding or enrolling vehicle numbers to follow any guilty party. It is also seen that technology can greatly help us in this situation by solving it [25]. After manually testing it, the results and efficiency came about 94%.

6. CONCLUSIONS

Communication with user and account holder of the CCTV system they run, during the time of security breach and crime detected, is very important. Thus, providing IoT feature and alerts for a range of users of CCTV system is attained in this project. Failure to converse alerts and improve accuracy of detecting criminals through AI and image processing, can lead to major losses as an individual and as a particular company as well. For this general population can be an inconvenience to all-inclusive security of vital information and feelings of freedom for legitimate observation. In this paper, with the abilities and the inspiration, we created something for the small and medium sized businesses so that they keep track of their processes through a responsive surveillance, we made this application which will help individuals who are figuring out how to discuss better with their CCTV framework. Our visionary application vision is an application that leads a discussion through Image Processing. Even with all these features some features could not be implemented because of GPU issues. For example the live CCTV face mask detection could not be implemented as well as the live footage of car number detection. For future use we will be happy to work with better systems who has a better GPU so we can implement our live footage from CCTV face mask detection and number plate detection.

We also did our best to increase our accuracy by using different techniques as much as possible like they previous at best accuracy was about 91% and we took it to 95% which is the current accuracy for future we will be using different variations and different techniques like Convo LSTM + CNN so we can increase our accuracy even more and take it to 98% or even 99%.

REFERENCES

[1] S. Shirsat, A. Naik, D. Tamse, J. Yadav, P. Shetgaonkar and S. Aswale, "Proposed System for Criminal Detection and Recognition on CCTV Data Using Cloud and Machine Learning," 2019 International Conference on Vision Towards Emerging Trends in Communication and Networking (ViTECoN), 2019, pp. 1-6, doi: 10.1109/ViTECoN.2019.8899441.L. Eschenauer, V. D. Gligor and J. Bara, 'On Trust Establishment in Mobile Ad Hoc Networks', Security Protocols Springer, (2004), pp. 47-66.

[2] Roopa, Y. M., Popuri, S. H., Sankar, G. G. S., & Kuppili, T. C. (2020, July). Convolutional Neural Network-based Automatic Extraction and Fine Generation. In 2020 Second International Conference on Inventive Research in Computing Applications (ICIRCA) (pp. 230-234). IEEE. doi: 10.1109/ICIRCA48905.2020.9182844.

[3] Gavrovska, A. and Samčović, A., 2020. Intelligent Automation Using Machine and Deep Learning in Cybersecurity of Industrial IoT. Cyber Security of Industrial Control Systems in the Future Internet Environment, pp.156-174, doi: 10.4018/978-1-7998-2910-2.ch008.

[4] Piza, EL, Welsh, BC, Farrington, DP, Thomas, AL. CCTV Surveillance for crime prevention: A 40-year systematic review with meta-analysis. Criminology & Public Policy. 2019; 18: 135– 159. https://doi.org/10.1111/1745-9133.12419

[5] Morales G., Salazar-Reque I., Telles J., Díaz D. (2019) Detecting Violent Robberies in CCTV Videos Using Deep Learning. In: MacIntyre J., Maglogiannis I., Iliadis L., Pimenidis E. (eds) Artificial Intelligence Applications and Innovations. AIAI 2019. IFIP Advances in Information and Communication Technology, vol 559. Springer, Cham. https://doi.org/10.1007/978-3-030-19823-7_23

[6] Circo, G., McGarrell, E. Estimating the impact of an integrated CCTV program on crime. J Exp Criminol 17, 129–150 (2021). https://doi.org/10.1007/s11292-019-09404-y

[7] L. J. Halawa, A. Wibowo and F. Ernawan, "Face Recognition Using Faster R- CNN with Inception-V2 Architecture for CCTV Camera," 2019 3rd International Conference on Informatics and Computational Sciences (ICICoS), 2019, pp. 1-6, doi: 10.1109/ICICoS48119.2019.8982383.

[8] J. Lim, M. I. Al Jobayer, V. M. Baskaran, J. M. Lim, K. Wong and J. See, "Gun Detection in Surveillance Videos using Deep Neural Networks," 2019 Asia-Pacific Signal and Information Processing Association Annual Summit and Conference (APSIPA ASC), 2019, pp. 1998-2002, doi: 10.1109/APSIPAASC47483.2019.9023182.

[9] H. Jain, A. Vikram, Mohana, A. Kashyap and A. Jain, "Weapon Detection using Artificial Intelligence and Deep Learning for Security Applications," 2020 International Conference on Electronics and Sustainable Communication Systems (ICESC), 2020, pp. 193-198, doi: 10.1109/ICESC48915.2020.9155832 .

[10] Salim Afra, Reda Alhajj, Early warning system: From face recognition by surveillance cameras to social media analysis to detecting suspicious people, Physica A: Statistical Mechanics and its Applications, Volume 540, 2020, 123151, ISSN 0378-4371, https://doi.org/10.1016/j.physa.2019.123151.

[11] M. T. Bhatti, M. G. Khan, M. Aslam and M. J. Fiaz, "Weapon Detection in Real-Time CCTV Videos Using Deep Learning," in IEEE Access, vol. 9, pp. 34366-34382, 2021, doi: 10.1109/ACCESS.2021.3059170.

[12] Donath P., Grega M., Guzik P., Król J., Matiolański A., Rusek K. (2020) Dangerous Tool Detection for CCTV Systems. In: Dziech A., Mees W., Czyżewski A. (eds) Multimedia Communications, Services and Security. MCSS 2020. Communications in Computer and Information Science, vol 1284. Springer, Cham. https://doi.org/10.1007/978-3-030-59000-0_18

[13] R. Kakadiya, R. Lemos, S. Mangalan, M. Pillai and S. Nikam, "AI Based Automatic Robbery/Theft Detection using Smart Surveillance in Banks," 2019 3rd International conference on Electronics, Communication and Aerospace Technology (ICECA), 2019, pp. 201-204, doi: 10.1109/ICECA.2019.8822186.

[14] Sung, CS., Park, J.Y. Design of an intelligent video surveillance system for crime prevention: applying deep learning technology. Multimed Tools Appl 80, 34297–34309 (2021). https://doi.org/10.1007/s11042-021-10809-z

[15] Minh T. Nguyen, Linh H. Truong, Trang T. Tran, Chen-Fu Chien, Artificial intelligence based data processing algorithm for video surveillance to empower industry 3.5,Computers & Industrial Engineering,Volume 148, 2020, 106671, ISSN 0360-8352, https://doi.org/10.1016/j.cie.2020.106671.

[16] Kim, J., Lee, D. & Park, N. CCTV-RFID enabled multifactor authentication model for secure differential level video access control. Multimed Tools Appl 79, 23461–23481 (2020). https://doi.org/10.1007/s11042-020-09016-z

[17] Sanjana, S., Sanjana, S., Shriya, V.R. et al. A review on various methodologies used for vehicle classification, helmet detection and number plate recognition. Evol. Intel. 14, 979–987 (2021). https://doi.org/10.1007/s12065-020-00493-7

[18] Che-Yen Wen, Shih-Hsuan Chiu, Jiun-Jian Liaw and Chuan-Pin Lu, "The safety helmet detection for ATM's surveillance system via the modified Hough transform," IEEE 37th Annual 2003 International Carnahan Conference onSecurity Technology, 2003. Proceedings., 2003, pp. 364-369, doi: 10.1109/CCST.2003.1297588.

[19] N. Boonsirisumpun, W. Puarungroj and P. Wairotchanaphuttha, "Automatic Detector for Bikers with no Helmet using Deep Learning," 2018 22nd International Computer Science and Engineering Conference (ICSEC), 2018, pp. 1-4, doi: 10.1109/ICSEC.2018.8712778.

[20] Gavrovska, A. and Samčović, A., 2020. Intelligent Automation Using Machine and Deep Learning in Cybersecurity of Industrial IoT. Cyber Security of Industrial Control Systems in the Future Internet Environment, pp.156-174, doi: https://doi.org/10.3390/su13031210

[21] Shakya, Subarna. "Analysis of artificial intelligence based image classification techniques." Journal of Innovative Image Processing (JIIP) 2.01 (2020): 44-54.

[22] C. T. Kong and S. M. Yiu, "Hacking CCTV by changing time," 2021 International Conference on Electrical, Communication, and Computer Engineering (ICECCE), 2021, pp. 1-8, doi: 10.1109/ICECCE52056.2021.9514241.

[23] Thirumagal E., Saruladha K. (2021) Design of LSTM–CNN with Feature Map Merge for Crime Scene Detection in CCTV Footage. In: Bhateja V., Satapathy S.C., Travieso-González C.M., Aradhya V.N.M. (eds) Data Engineering and Intelligent Computing. Advances in Intelligent Systems and Computing, vol 1407. Springer, Singapore. https://doi.org/10.1007/978-981-16-0171-2_2

[24] R. Ke, Y. Zhuang, Z. Pu and Y. Wang, "A Smart, Efficient, and Reliable Parking Surveillance System With Edge Artificial Intelligence on IoT Devices," in IEEE Transactions on Intelligent Transportation Systems, vol. 22, no. 8, pp. 4962-4974, Aug. 2021, doi: 10.1109/TITS.2020.2984197.

[25] Chavda, J. Dsouza, S. Badgujar and A. Damani, "Multi-Stage CNN Architecture for Face Mask Detection," 2021 6th International Conference for Convergence in Technology (I2CT), 2021, pp. 1-8, doi: 10.1109/I2CT51068.2021.9418207.