Leveraging Surveillance Cameras with Machine Learning Algorithms for Real-Time Detection of Criminal Activities

Arsh Virk

Northwood University

MGT-665: Solving Business Problems using Machine Learning

Prof. Mohammad Nasim

May 9, 2024

Abstract

This paper presents a comprehensive framework for using surveillance cameras to detect motion related to different forms of criminal activities such as robbery, burglary, theft etc., an advance proactive approach to prevent such crimes. Even with technological advancements, traditional ways of detecting and preventing crimes often depend on responsive approaches, which might not be effective in tackling ever changing criminal activities. Thus, this paper suggests a framework combined with a few different machine learning algorithms, including Convolutional Neural Networks (CNN), object detection algorithms, feature engineering, anomaly detection techniques, geospatial analysis, ensemble learning, and data fusion can provide law enforcement agencies with proactive and holistic approach to prevent various types of crimes. The suggested method or system can analyse real-time video streams from surveillance cameras, extract the relevant features, detect suspicious motion patterns, and then alert authorities of possible criminal activities or life threating situations. By utilizing the versality, scalability and flexibility of machine learning algorithms, this framework has the notable potential to enhance public safety and security.

Keywords: Surveillance cameras, proactive approach, machine learning algorithm, Convolution Neural Network (CNN), real-time video streams, public safety

1. Introduction:

From **Table.1** and **Graph 1**, we can observe that there is a significant drop in the number of incidents of larceny theft and burglary but rest of the crimes remained less or more the same in terms of number of cases. And from **Graph 2**, if we analyze the difference between violent crime and property crime then there is notable decrement in property crime, however, the violent crime stayed almost same with a little drop in the crime. So, there is no doubt that the

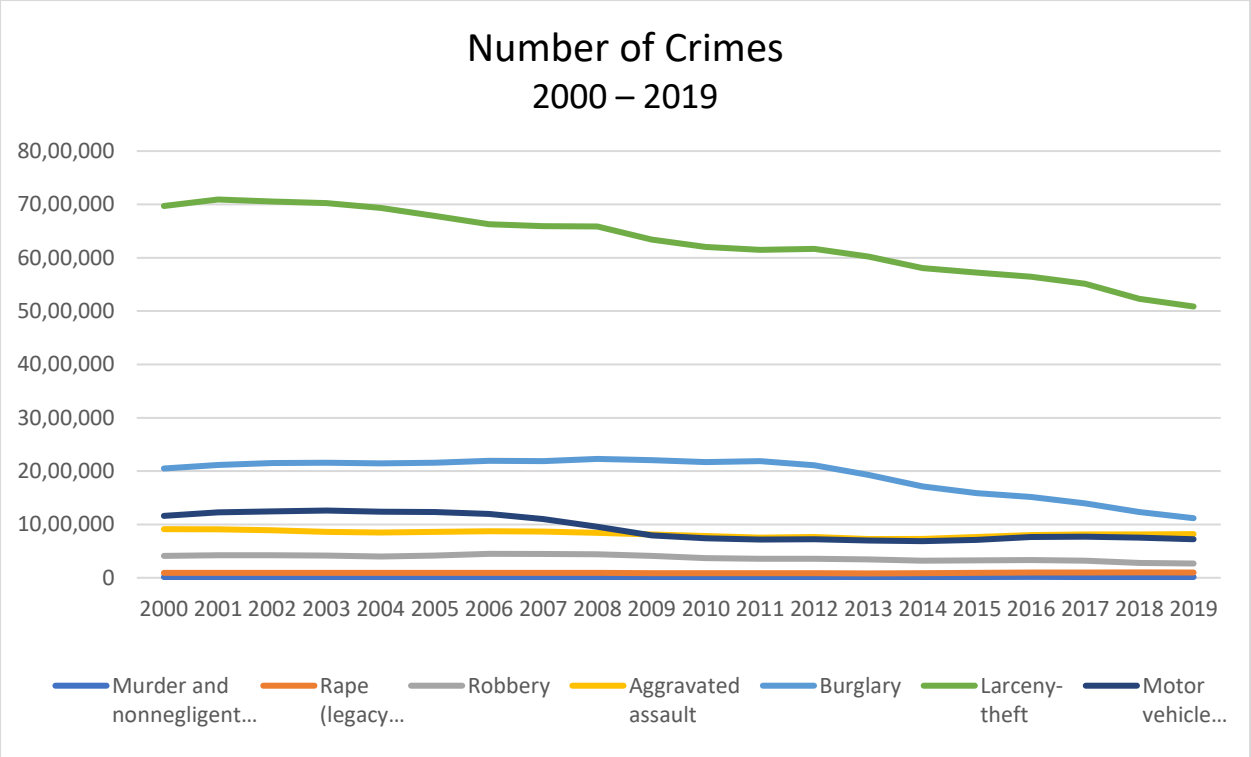
crime has decline in whole in last few years remarkably but there are still many criminal activities take place every year that poses significant challenges to public safety and security around the country and it cannot be neglected even it is in small numbers since it is not a rightful thing to do and can cause so much harm to societies and any nation. Tradition methods of crime detection and prevention are not alone sufficient to prevent or address the dynamic nature of criminal actions or behaviours. Surveillance cameras present a valuable tool for the law enforcement agencies in monitoring public spaces to stop criminal activities. Although, the substantial amount of video data produced by these cameras poses a significant challenge in terms of analysis and interpretation (Simon, 2004). Thus, this paper introduces an innovative framework for leveraging surveillance cameras to promptly detect motion associated with various types of crimes, providing proactive measures to prevent these crimes.

Table.1: Report of Crimes in USA of last 20 years by the FBI

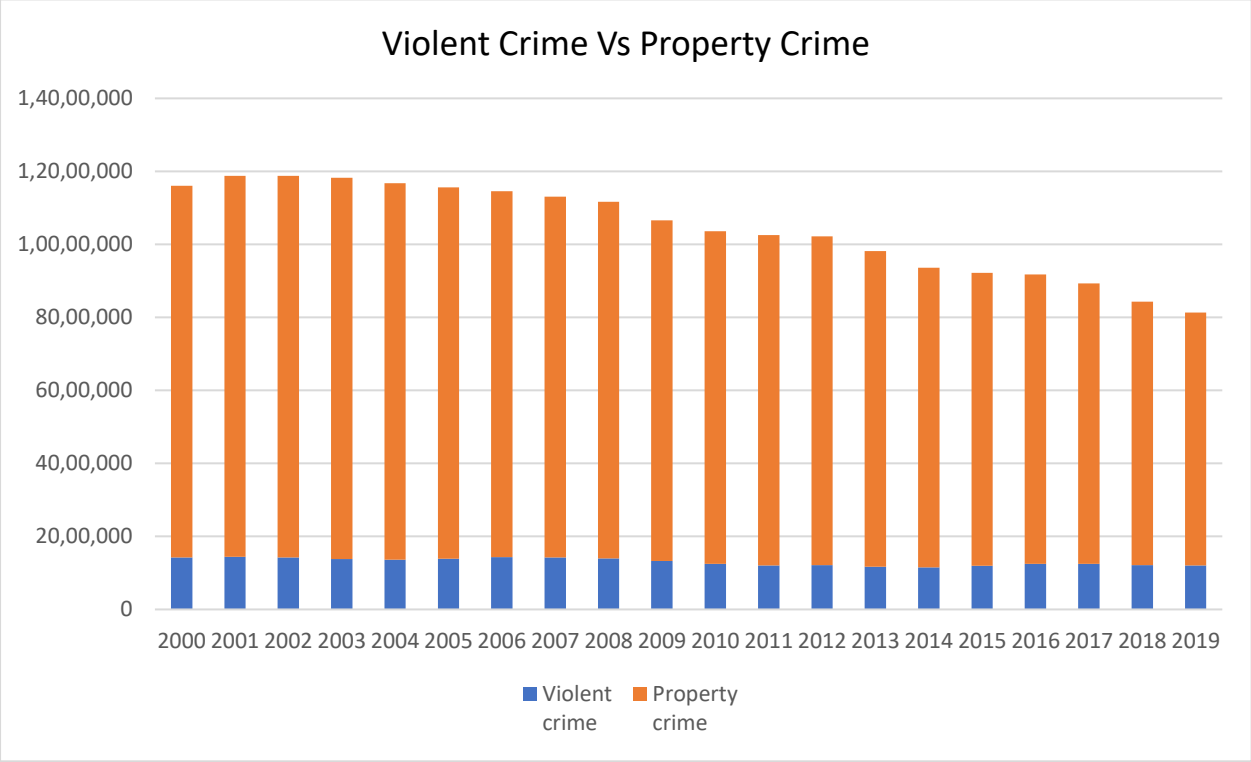
Year	Population	**Violent crime**	Murder and nonnegligent manslaughter	Rape	Robbery	Aggravated assault	**Property crime**	Burglary	Larceny-theft	Motor vehicle theft
2000	28,14,21,906	14,25,486	15,586	90,178	4,08,016	9,11,706	1,01,82,584	20,50,992	69,71,590	11,60,002
2001	28,53,17,559	14,39,480	16,037	90,863	4,23,557	9,09,023	1,04,37,189	21,16,531	70,92,267	12,28,391
2002	28,79,73,924	14,23,677	16,229	95,235	4,20,806	8,91,407	1,04,55,277	21,51,252	70,57,379	12,46,646
2003	29,07,88,976	13,83,676	16,528	93,883	4,14,235	8,59,030	1,04,42,862	21,54,834	70,26,802	12,61,226
2004	29,36,56,842	13,60,088	16,148	95,089	4,01,470	8,47,381	1,03,19,386	21,44,446	69,37,089	12,37,851
2005	29,65,07,061	13,90,745	16,740	94,347	4,17,438	8,62,220	1,01,74,754	21,55,448	67,83,447	12,35,859
2006	29,93,98,484	14,35,123	17,309	94,472	4,49,246	8,74,096	1,00,19,601	21,94,993	66,26,363	11,98,245
2007	30,16,21,157	14,22,970	17,128	92,160	4,47,324	8,66,358	98,82,212	21,90,198	65,91,542	11,00,472
2008	30,40,59,724	13,94,461	16,465	90,750	4,43,563	8,43,683	97,74,152	22,28,887	65,86,206	9,59,059
2009	30,70,06,550	13,25,896	15,399	89,241	4,08,742	8,12,514	93,37,060	22,03,313	63,38,095	7,95,652
2010	30,93,30,219	12,51,248	14,722	85,593	3,69,089	7,81,844	91,12,625	21,68,459	62,04,601	7,39,565
2011	31,15,87,816	12,06,005	14,661	84,175	3,54,746	7,52,423	90,52,743	21,85,140	61,51,095	7,16,508
2012	31,38,73,685	12,17,057	14,856	85,141	3,55,051	7,62,009	90,01,992	21,09,932	61,68,874	7,23,186
2013	31,64,97,531	11,68,298	14,319	82,109	3,45,093	7,26,777	86,51,892	19,32,139	60,19,465	7,00,288
2014	31,89,07,401	11,53,022	14,164	84,864	3,22,905	7,31,089	82,09,010	17,13,153	58,09,054	6,86,803
2015	32,08,96,618	11,99,310	15,883	91,261	3,28,109	7,64,057	80,24,115	15,87,564	57,23,488	7,13,063
2016	32,34,05,935	12,50,162	17,413	96,970	3,32,797	8,02,982	79,28,530	15,16,405	56,44,835	7,67,290
2017	32,51,47,121	12,47,917	17,294	99,708	3,20,596	8,10,319	76,82,988	13,97,045	55,13,000	7,72,943
2018	32,66,87,501	12,09,997	16,374	1,01,363	2,81,278	8,10,982	72,19,084	12,35,013	52,32,167	7,51,904
2019	32,82,39,523	12,03,808	16,425	98,213	2,67,988	8,21,182	69,25,677	11,17,696	50,86,096	7,21,885

Resource Linke: https://ucr.fbi.gov/crime-in-the-u.s/2019/crime-in-the-u.s.-2019/topic-pages/tables/table-1

Graph.1: Number of crimes from 2000 - 2009



Graph.2:



2. **Problem Statement:**

Typically, the conventional methods of crime detection are reactive, depending on incident reports or emergency calls to law enforcement agencies. These methods or approaches may lead to delays in response time and limited effectiveness in stopping criminal activities. Moreover, the large amount of video data generated by the surveillance cameras make it challenging or difficult for the law enforcement agencies to analyze and interpret this data effectively due to its size and the time taken to analyze it. Hence, there is an urgency of proactive and comprehensive framework or system that can utilize surveillance cameras to identify suspicious motion patterns signaling criminal activities in real-time, thereby advance proactive efforts to prevent crime and to make safe and secure place for everyone.

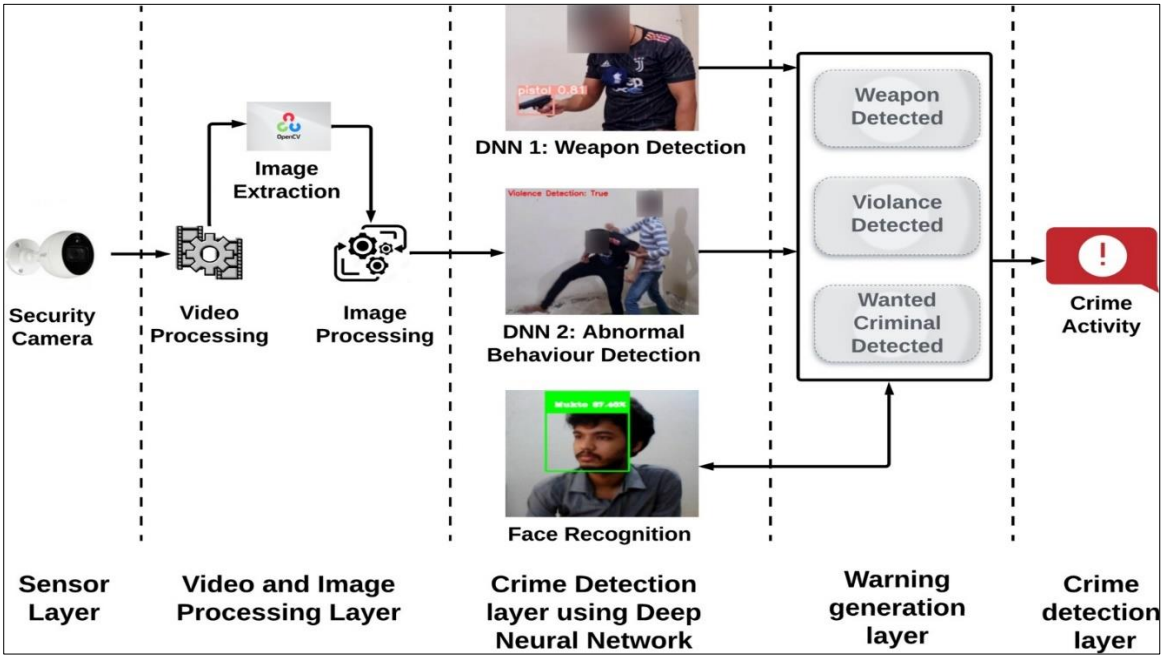
3. **Methodology:**

The proposed system architecture is a combination or collection of a few different machine learning algorithms such as CNNs, object detection algorithms, feature engineering, anomaly detection techniques, geospatial analysis, ensemble learning, and data fusion. The framework consists of multiple elements, including video processing modules, feature extraction modules, machine learning models, and alerting mechanisms. The system is designed to analyse real-time video streams from surveillance cameras that pull outs the relevant features or attributes such as motion patterns, object trajectories, spatial distributions and detect anomalies indicative of criminal activities. The system will use data of various kinds of criminal activities and environmental conditions or situation to train and evaluate upon.

4. System Architecture Development:

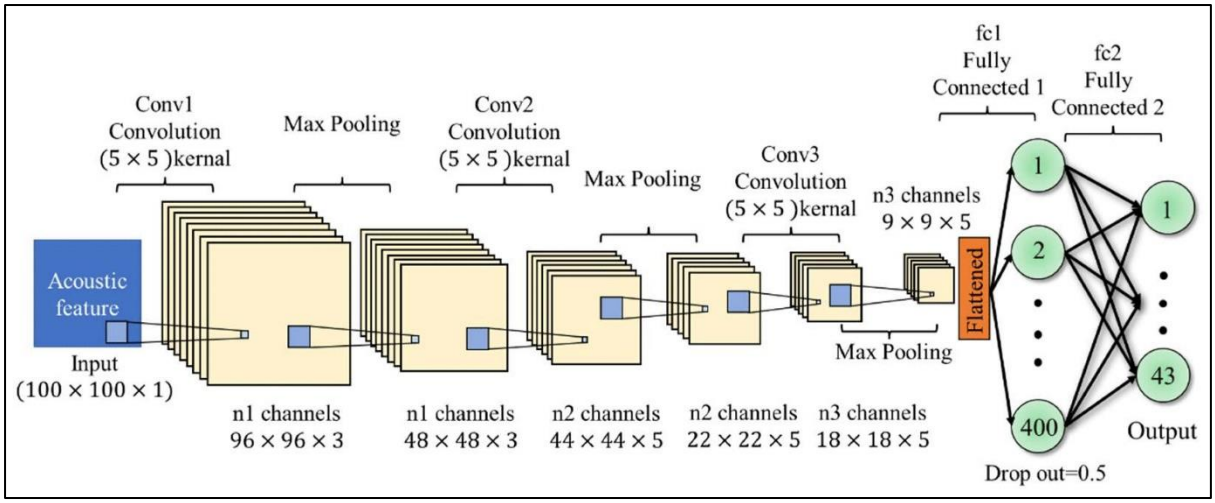
For the development of our surveillance system which aim to detect motion associated to criminal activity or life threating actions in real-time, there are several machine learning algorithms and techniques systematically implemented in the proposed framework.

Fig.1:



As you can see from the **Fig.1**, the proposed system architecture consists a few several layers where in first layer system will capture surveillance footages using security cameras by using sensor motion and then, theses videographic images will go to next layer where the model will extract features from these the images and videos captured from the surveillance cameras. Next, model detect suspicious object such gun, knife other any other kind of weapon and abnormal behaviour as well. And once it has identified the dubious objects then it will send warning alert to law enforcement agencies.

Fig. 3: *Convolutional Neural Network Framework*



For detection of suspicious objects such as weapons or any suspicious or abnormal behaviour, Convolutional Neural Network (CNNs) machine learning algorithm is used in the system framework. Convolutional Neural Network is a Deep Neural Network, consists of several layers such as input layer, convolutional layer, max pooling layer, fully connected layers. As you can see from Fig. 3 the first layer is input layer, in which CNN takes a picture and divide it into number of grids or small square regions, and every grid has certain number of pixels int it with a specific size. For instance, in the Fig.3, the input layer has pixel size 100 X 100 X 1, which means 100 width and 100 height and 1 means all the pixels with one colour. Once first layer divides the picture in certain number of grids then these small grids or regions go one by one to next layer which is called convolution layer. The convolutional layer is a set of filters that are also called karnel, these filters then extract the features such as corner, edges and texture of the objects in the image from these small regions and also reduce the size of pixels of these regions to make them lighter to process quickly and increases the colours to improve the quality of these grids of image. For example, in the Fig.3, the pixels size in convolutional layer is 96 X 96 X 3, where 96 X 96 is width and heigh of the pixel and 3 are colours Red, Green, and blue. After that, these small grids or regions go to next layer which is

Max pooling layer. Max pooling layer reduces the size of these small regions by keeping the necessary details and removes the other unimportant details. This process happens multiple times in the network, and once all the important features get extracted then these grids or regions get flattened in one dimension in flattened layer. At the end of Convolution Neural Network there are a few hidden layers which are also called fully connected layers, these layers then arrange all these small regions or grids into one complete image, which is our final output. With the help of library like OpenCV, I utilized YOLO (You Only Look Once) a pre-trained models to identify or detect objects of interest very efficiently with more accurate and faster approach (Yin, 2020). By implementing this Object Detection Algorithms, we can train models like YOLO to detect specific object related to criminal activities. This step requires extensive training to identify weapons, or any suspicious object or behaviour with more accuracy to provide appropriate outcome.

5. Scope of Improvement:

Having only object detection and abnormal behaviour is not enough to have effective surveillance system. Apart from this I also need other information to make it more effective and robust for preventing these suspicious and harmful activities. Thus, I suggest some other algorithm to make our system architecture more robust.

The most crucial component of the system development will be Feature Engineering since different features such as time of day, location, multiple activities presence and weather conditions may affect the quality of surveillance footage to detect suitable motion patterns (Karbalaie, 2022) . By using python libraries like Pandas, Geopy and Weather APIs like pyown (python OpenWeatherMap), these features will be processed and then will be incorporated into the machine learning models to improve the performance and predictive

accuracy of the model. Anomaly Detection techniques will also be employed into the system to identify unusual activities or outliers in the surveillance footage by leveraging algorithms such as Isolation Forest from libraries like TensorFlow Probability that will be able to flag suspicious actions or behaviours that are different from normal behaviours (Patrikar, 2022).

Geospatial Analysis will improve capability of the system by analysing the spatial patterns of crime incidence. For this, by using libraries like PySAL, we can implement spatial clustering algorithms such as K-means to identify areas with high concentrations of criminal activity (Xie, 2017), this will allow low enforcement agencies to focus on those areas which are more crime prone with more effectively and efficiently tactics. In addition to this, to improve prediction accuracy and generalization performance, Ensemble Learning methods will be employed to combine the strength of multiple models utilized in this framework. This can be achieved by using method Gradient Boosting Machines (GBMs) from libraries scikit-learn which can be used to ensemble various types of machine learning models (e.g., CNNs, RNNs, object detection algorithms) to enhance predictive accuracy and model performance.

Finally, Data Fusion algorithm will be pivotal in integrating diverse data sources to enhance situational awareness and decision-making processes for motion detection surveillance system or framework (Li, 2021). For this purpose, the Python libraries for data handling and integration like Pandas and NumPy are utilized to combine or link data from surveillance cameras, sensor data, social media feeds, etc., to facilitate law enforcement agencies with a more comprehensive understanding of criminal activities.

6. **Conclusion:**

The proposed framework postulates a proactive and holistic approach to detect real-time criminal activities by utilizing advance machine learning algorithms along with surveillance

cameras to mitigate such activities. The aim of proposed system to enrich situation awareness and decision-making for law enforcement agencies by systematically implementing several machine learning algorithms into the system.

The systematic combination of these algorithms and techniques allows the detection of motions associated with criminal activities that facilitates timely intervention and proactive efforts to prevent these activities. By analysing real-time video streams, extracting relevant features, and detecting suspicious motion patterns, the system provides a comprehensive understanding of criminal activities, this enhances public safety and security.

Throughout the system development process, considerations such as model accuracy, computational efficiency, and scalability have been addressed to ensure the effectiveness and practicality of the surveillance system. With its versatility, scalability and flexibility, the proposed framework has the potential to significantly enhance proactive crime prevention efforts, ultimately contributing to a safer and more secure society.

References

Simon, S. R. (2004). Quantification of human motion: gait analysis—benefits and limitations to its application to clinical problems. *Journal of biomechanics*, *37*(12), 1869-1880.

Yin, Y., Li, H., & Fu, W. (2020). Faster-YOLO: An accurate and faster object detection method. *Digital Signal Processing*, *102*, 102756.

Karbalaie, A., Abtahi, F., & Sjöström, M. (2022). Event detection in surveillance videos: a review. *Multimedia tools and applications*, *81*(24), 35463-35501.

Patrikar, D. R., & Parate, M. R. (2022). Anomaly detection using edge computing in video surveillance system. *International Journal of Multimedia Information Retrieval*, *11*(2), 85-110.

Xie, Y., Wang, M., Liu, X., & Wu, Y. (2017). Surveillance video synopsis in GIS. *ISPRS international journal of geo-information*, *6*(11), 333.

Li, X., Yu, Q., Alzahrani, B., Barnawi, A., Alhindi, A., Alghazzawi, D., & Miao, Y. (2021). Data fusion for intelligent crowd monitoring and management systems: A survey. *IEEE Access*, *9*, 47069-47083.