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ORIGINAL SCIENTIFIC PAPER

Use of video surveillance systems for detecting seat belt usage, mobile device usage, or vehicle registration - penalty or prevention

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Abstract: The concept of smart traffic or smart cities involves the use of a large amount of data collected in real-time and processed using available tools. Data is collected from various sources. One common source for traffic control is video or imagery. In many countries, camera systems are installed to monitor traffic, track speed, or oversee intersections. Data is collected and processed in operational centers, allowing for insights into vehicle registration, vehicle speed, and passengers. At the same time, significant risks in traffic arise from the use of mobile phones or smart devices while driving. Furthermore, research indicates that wearing seat belts significantly reduces the risks of traffic accidents. A common occurrence in traffic is that vehicles are unregistered and uninsured. At the same time, the use of video surveillance systems is associated with the protection of privacy and personal data, necessitating the need to find an optimal balance between the right to privacy and the right to a secure environment, including safe participation in public traffic. The aim of this study is to explore the possibility and analyze the use of video surveillance to analyze the use of video surveillance in detecting mobile phone usage and seat belt compliance while driving. The systems for detecting mobile phone usage or seat belt usage during driving can instantly provide information on a prominently displayed screen near the roadside for preventive action. The paper analyzes the use of such systems for prevention purposes, along with an analysis of the potential application of penalties to reduce identified risks in traffic.

Keywords: Artificial Intelligence, Deep Learning, Machine learning, Smart Systems, Violations, Preventive Action

INTRODUCTION

The use of traffic video surveillance systems has significantly increased in recent years with the development of digital and video technologies. In the Republic of Srpska, systems have been installed to monitor traffic, particularly since this possibility has been legally defined for speed measurement.[1] Vehicle speed measurement systems are developed and widely used. As stated, the law in Bosnia and Herzegovina has defined the possibility of speed measurement, and a complete system for deploying radar or video systems that measure speed has been developed. Furthermore, enforcement systems have been developed to enable the identification, processing, and issuance of traffic violation notices, as well as monitoring of fine payments. An integrated system for issuing traffic violation notices and enforcing violations has been implemented, linking with vehicle registration systems and other citizen rights.

However, the development of high-resolution cameras equipped with integrated machine learning systems, along with the advancement of telecommunications systems for data transmission and data processing centers, has enabled the collection of large amounts of data about vehicles in traffic. It is now possible to read and automatically process vehicle registration data, as well as driver behavior data within the vehicle itself. Furthermore, systems for monitoring vehicles' compliance with traffic signals have been established.

The surveillance system for seat belt and mobile phone usage during driving, upon detection of an incident, instantly sends a notification to the display near the roadside for preventive action. The vehicle registration detection system identifies violations and sends a traffic violation notice to the vehicle owner. The paper describes these systems and analyzes their impact on law-

[1] Article 45, Law on Basics of Traffic Safety on the Roads in BiH (Official Gazette of BiH,6/06, 75/06, 44/07, 84/09, 48/10, 18/13, 8/17, 89/17, 9/18, 46/23, 88/23)

ful driver participation in traffic.

The paper presents in the chapter II "Artificial intelligence and machine learning in traffic surveillance systems" the possibilities of using artificial intelligence and machine learning in traffic surveillance systems. Furthermore, in chapter III "Detecting seat belt usage, mobile device usage and ANPR" a specific case in the Republic of Srpska is presented where a traffic surveillance system is used for detecting seat belt usage and mobile phone usage. The legal framework is discussed, particularly focusing on privacy protection aspects. Finally, in chapter IV "Data analisys", statistical indicators collected from internal records of the Ministry of Interior of the Republic of Srpska are presented.

ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING IN TRAFFIC SURVEILLANCE SYSTEMS

Artificial Intelligence, AI refers to the branch of science and engineering that produces intelligent machines, especially intelligent computer programs. In the security industry as well as in traffic systems, AI used is to create environmental analysis equipment. Deep learning technology, or improving intelligence by analyzing and learning from large datasets, has brought about a significant change in the field of AI [10]. The utilization of traffic surveillance systems gathers vast amounts of data, including information about the vehicles themselves, vehicle license plates, vehicle behavior in traffic, as well as the behavior of passengers inside the vehicle.

Systems of collecting and storing large amounts of data enable the development of machine learning systems. Machine learning is a subfield of AI that focuses on the development of algorithms and statistical models that enable computers to learn from and make predictions or decisions based on data, without being explicitly programmed to do so.

Subset of machine learning is deep learning. Deep learning, also known as deep neural learning, is a subset of machine learning that focuses on learning data representations using complex models inspired by the human brain, known as deep neural networks. These models are termed "deep" due to their ability to learn to represent data in hierarchical layers of abstraction. Deep learning often requires large amounts of data and computational resources to train complex models. It has become extremely popular due to impressive results in various fields, including image recognition, natural language processing, medical diagnostics, and many others.

In the surveillance industry, primary target objects of deep learning algorithms are people and vehicles. Key applications of deep learning, which are important for traffic surveillance systems, are metadata and ANPR (Automatic Number Plate Recognition) systems. [10]

Metadata is feature attribute information extracted from a target object which can be used for data retrieval. Currently, there are three main kinds of metadata in the traffic surveillance system industry: human face, human body, and vehicle metadata. Facial information includes sex, age, glasses, masks, expressions, beards. Human body information includes tops, pants, clothing color, hair, backpacks, seat belt or mobile device. Vehicle information includes license plate, color, brand, model, etc. [10]

ANPR (Automatic Number Plate Recognition) is a technology that uses optical character recognition on images to read license plates with high recognition accuracy. ANPR applications include toll collection, traffic monitoring and security, speed and journey time measurement, parking and access control. [10]

An important part of deep learning systems is false alarm detection. This is particularly important in traffic surveillance systems to accurately determine passenger behavior in vehicles.

All in all, traffic surveillance systems have enabled the collection of vast amounts of data about vehicles, drivers, and the behavior of drivers or vehicles in traffic. This data, through the use of metadata and ANPR systems, facilitates the identification of unlawful activities aimed at increasing traffic safety.

The following text will present traffic surveillance systems that identify seatbelt and mobile device usage in vehicles, as well as a system to check if the vehicle is lawfully registered. Further analysis will be conducted on the results regarding the prevention and punishment of detected occurrences.

DETECTING SEAT BELT USAGE, MOBILE DEVICE USAGE AND ANPR

By using smart cameras to recognize the use of mobile phones, not wearing a seat belt, and to review the average speed of the vehicle and display information to traffic participants on the LED display, the driver and other traffic participants are immediately warned on non-compliance with traffic rules that can greatly endanger the lives of all traffic participants. It is also possible to introduce certain meters that can indicate the number of minor offences that person committed up to that time for the recognized license plate.

Legal Framework

For public use of traffic surveillance systems, a legal basis is extremely important. In Republic of Srpska, the Ministry of Interior (MoI) is responsible for traffic control and has the authority to record[2] public areas including public transportation and roadways. In addition, the

[2] Law on Police and Internal Affairs (published in Official Gazzete no. 57/16,110/16,58/19, 82/19 and 55/23),video survilence including road traffic safety and traffic control and safety in other areas of traffic, Article 5, point 12).

Ministry of Interior is responsible for maintaining registries of citizens, vehicles, fines and driver's licenses, meaning it possesses data within its jurisdiction[3]. MoI has the capability to collect data from traffic surveillance video footage. Additionally, it possesses data about vehicles, drivers, and penalties.

Personal data protection

In Bosnia and Herzegovina, the Law on Personal Data Protection[4] is applied. This law guarantees privacy. The use of video surveillance systems, especially in the segment related to processing facial images, is strictly regulated and must be prescribed by law.

Overall, the relationship between video surveillance in traffic systems and personal data protection underscores the importance of striking a balance between security needs and privacy rights, ensuring that data is collected and processed lawfully, transparently, and responsibly.

Installation of the system

The installation of intelligent cameras should be carried out above the road at the minimum allowed height, in the middle of the monitored traffic lanes, for greater accuracy. Cameras should have built-in analytics described in the introductory chapter. They should perform license plate recognition, detection of seat belt non-usage, and mobile phone usage.

An industrial computer is mounted on the pole in an appropriate space and serves to display warnings on the screen. A communication link enables data transmission to the MoI server. The camera should have a built-in SD card. In case of a link failure, it stores data in internal memory and sends it later to the server.

FIGURE 1: Recording of vehicles, detection, and notification[5]

Smart System for Detection and Notification Usage Safety Belt and Mobile Phone (AI-SS4DNUSBMP) improve traffic safety and traffic monitoring, where citizens receive information about the following events during the drive via LED displays:

1. Phone usage detection and warning on usage
2. Seat belt non-use detections and warning on non-use

The following image depicts the installation method of the system.

The camera contains a chip with embedded machine learning elements. Based on the specified functionality, the vehicle fulfilling the given parameters is identified, and an image of such a vehicle, along with certain metadata, is stored on an industrial computer. In real-time, the license plate data is read using ANPR functionality. Subsequently, the license plate data and information about the committed violation are projected onto the LED display.

FIGURE 2: Phone detection, example of picture[6]

In this way, it becomes visible to the driver and serves as a warning. Vehicles on which no violation is observed are not recorded. The following images provide an overview of real data that the machine learning system has detected as committing various types of violations.

[3] Law on Police and Internal Affairs (published in Official Gazzete no. 57/16,110/16,58/19, 82/19 and 55/23), Article 141 a

[4] Law on Protection of Personal Data („Official Gazette of Bosnia and Herzegovina" 49/06, 76/11 and 89/11)

[5] Source: Internal Project Documentation of the Ministry of the Interior of the Republic of Srpska

[6] Source: Real data from the traffic surveillance system of the Ministry of the Interior of the Republic of Srpska

FIGURE 3: Seat belt detection, example[7]

The previous image clearly shows the use of a mobile phone. Nighttime conditions are present, but the violation has been identified.

The installed system has the capability of detecting and reading license plates. As stated, these systems send data in real-time via web services to the database of registered vehicles. If an unregistered vehicle is detected in traffic, then a violation ticket is processed.

DATA ANALISYS

The traffic surveillance system was installed in the Republic of Srpska during the period of 2021 and 2022. During this time, traffic data was collected. Certain cameras detected seatbelt and mobile phone usage, providing information for preventive action. All ANPR cameras detected registered vehicles. Upon detection of driving an unregistered vehicle, violation processing was conducted.

Violations related to seatbelt usage and mobile phone use are identified by police stopping vehicles. There is no explicit legal provision that addresses the use of video surveillance systems for seatbelt and mobile device usage violations while driving.

Further in the text, data is presented alongside a description of the sample.

Detecting seat belt usage

Data on seatbelt usage and smart phone usage was collected from April 2021 to April 2024 on a camera in Banja Luka. The system collected data and informed drivers via a display without imposing penalties. The following table provides monthly data.

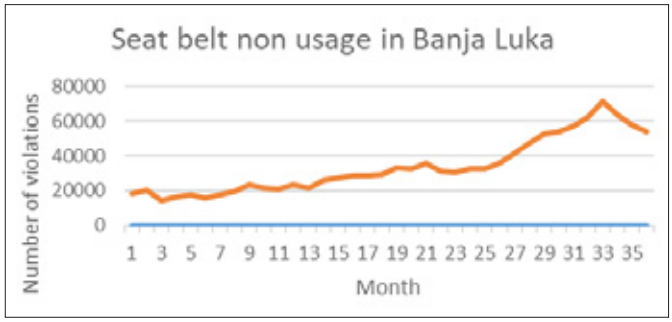


FIGURE 4: Number of detection seat belt usage in Banja Luka in one location per month

TABLE 1: Number of detection Seat Belt and Smart Phone Usage in Banja Luka in one Location per Month[8]

YEAR	MONTH	NUMBER OF SEAT BELT	NUMBER OF PHONE USAGE	YEAR	MONTH	NUMBER OF SEAT BELT	NUMBER OF PHONE USAGE
2021	4	18.651	3.009	2022	10	33.129	3.870
2021	5	20.563	2.880	2022	11	32.535	3.331
2021	6	14.545	2.019	2022	12	36.088	3.592
2021	7	16.341	2.192	2023	1	31.579	2.930
2021	8	17.485	2.338	2023	2	30.336	3.147
2021	9	15.484	2.117	2023	3	32.585	3.955
2021	10	17.799	2.183	2023	4	32.571	4.091
2021	11	19.539	2.054	2023	5	35.598	4.644
2021	12	23.459	2.355	2023	6	41.445	5.184
2022	1	21.746	1.920	2023	7	47.346	5.488
2022	2	20.878	2.137	2023	8	52.794	5.882
2022	3	23.218	2.876	2023	9	54.007	5.951
2022	4	21.664	2.972	2023	10	57.281	6.055
2022	5	25.956	3.473	2023	11	62.455	6.512
2022	6	27.139	3.474	2023	12	71.550	6.902
2022	7	28.860	3.514	2024	1	63.684	5.887
2022	8	28.627	3.738	2024	2	58.023	6.054
2022	9	29.215	3.874	2024	3	53.683	6.396

[7] Source: Real data from the traffic surveillance system of the Ministry of the Interior of the Republic of Srpska

[8] Source: Data from the records of the Ministry of the Interior of the Republic of Srpska

Before the system was put into operation, a campaign was conducted, and drivers were informed about the implementation of such a system through public communication channels.

Before the system was put into operation, a public awareness campaign about the system's functioning was organized. From the diagram, it is evident that there is a lower number of violations in the initial months. This is clearly a result of the campaign. Violation data is only displayed as notifications on the LED display. Violation tickets are not issued, nor is there any punishment. Data shows that the number of violations is increasing from month to month.

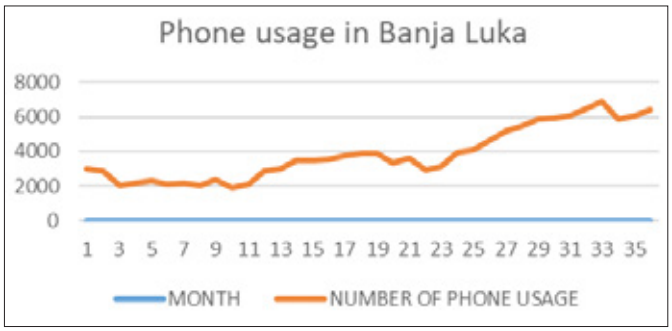


FIGURE 5: Number of detection phone usage in Banja Luka in one location per month

In Doboj, a system with cameras detecting seatbelt and phone usage was installed. The following table provides an overview of 12 months starting from November 2022.

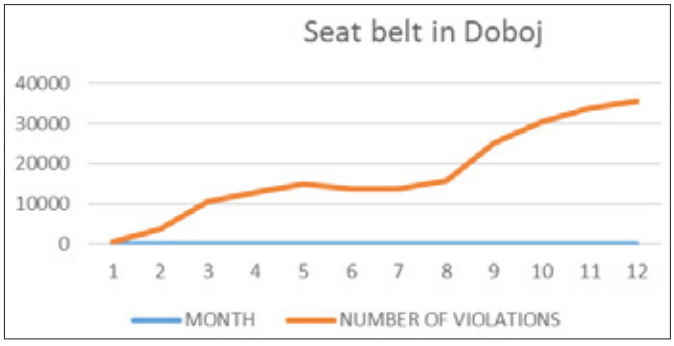


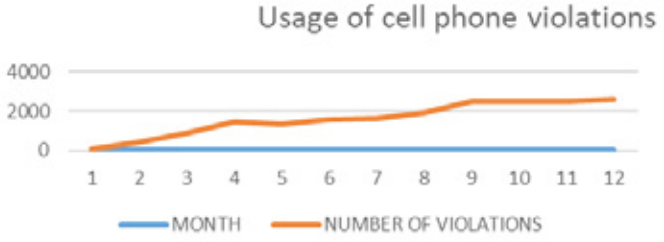
FIGURE 6: Number of detection seat belt usage in Doboj on one location per month

TABLE 2: Number of detection seat belt usage and phone usage in Doboj in one location per month[9]

YEAR	MONTH	NUMBER OF SEAT BELT	NUMBER OF PHONE USAGE
2022	9	458	56
2022	10	3.745	435
2022	11	10.558	862
2022	12	12.955	1.459
2023	1	14.895	1.365
2023	2	13.745	1.580
2023	3	13.632	1.633
2023	4	15.846	1.889
2023	5	25.287	2.513
2023	6	30.300	2.510
2023	7	34.006	2.518
2023	8	35.620	2.597

In Doboj, situation is same like in Banja Luka. In the initial months of using the system, there are fewer violations. Since there are no penalties, the number of violations increases over time.

FIGURE 7: Number of detection phone usage in Doboj in one location per month



Detection of unregistered vehicles

In Republic of Srpska, a system of ANPR cameras has been installed. The purpose of ANPR cameras is described in earlier chapters. Regulations in Bosnia and Herzegovina stipulate that drivers and vehicle owners who enable the participation of unregistered vehicles in traffic will be penalized. [10]

As stated, the MoI of Republic of Srpska is responsible for maintaining records of registered vehicles and records of monetary fines. Accordingly, a system has been developed that detects the vehicle's license plate. The license plate number data is then transmitted via a web service to the vehicle registration system, where a check is performed to determine if the vehicle is registered.

If it is determined that the vehicle is not registered, the violation is processed. The owner of the vehicle is identified, and a violation notice is sent.

In the mentioned case, sanctions are imposed on the offender because there is a legal basis for it.

In cases of seatbelt and mobile phone usage, violations were not issued. Drivers were only informed about the violation through the display. Additionally, information about the operation of such cameras was disseminated through public communication channels. However, in the case of registered vehicles, violation notices were sent to the drivers.

[9] Source: Data from the records of the Ministry of the Interior of the Republic of Srpska

[10] Article 234 and 234a, Law on Basics of Traffic Safety on the Roads in BiH (Official Gazette of BiH,6/06, 75/06, 44/07, 84/09, 48/10, 18/13, 8/17, 89/17, 9/18, 46/23, 88/23)

TABLE 3: Uregistered vehicles in Banja Luka and Bijeljina[11]

Year	Month	Banja Luka	Bijeljina	Year	Month	Banja Luka	Bijeljina
2020	10	3.638	1.163	2022	06	1.165	271
2020	11	1.653	1.077	2022	07	1.130	272
2020	12	1.370	488	2022	08	1.129	365
2021	01	912	214	2022	09	1.302	367
2021	02	795	291	2022	10	1.188	357
2021	03	961	346	2022	11	797	297
2021	04	866	268	2022	12	821	248
2021	05	1.132	372	2023	01	559	198
2021	06	1.515	412	2023	02	665	203
2021	07	1.311	428	2023	03	720	221
2021	08	1.284	452	2023	04	842	232
2021	09	1.264	396	2023	05	1.037	248
2021	10	1.321	431	2023	06	1.093	346
2021	11	1.082	282	2023	07	1.004	401
2021	12	980	296	2023	08	989	292
2022	01	680	214	2023	09	961	377
2022	02	859	221	2023	10	1.020	377
2022	03	1.036	263	2023	11	952	260
2022	04	1.146	205	2023	12	944	263
2022	05	1.248	333				

The previous table provides an overview by months, starting from October 2020 until the end of 2023.

FIGURE 8: Number of detected unregistered vehicles per month in Banja Luka

In the case of Banja Luka, it is evident that the number of unregistered vehicles participating in traffic has been decreasing since the installation of cameras and the commencement of issuing violation notices.

Similar like in the Banja Luka is in the Bijeljina. Number of unregistered vehicles participating in traffic has been decreasing since the installation of cameras and the commencement of issuing violation notices.

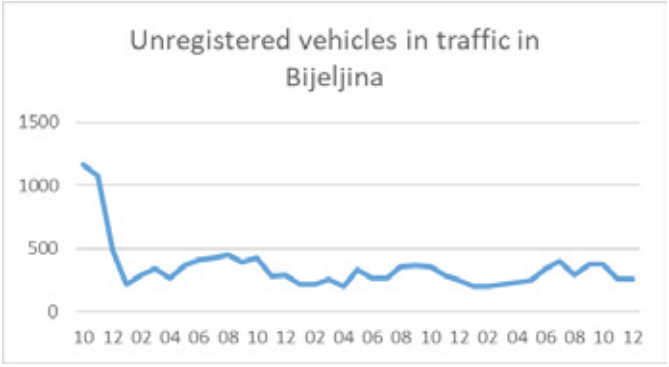


FIGURE 9: Number of detected unregistered vehicles per month in Bijeljina

In Bosnia and Herzegovina, the Law on Personal Data Protection[12] is applied. This law guarantees privacy. The use of video surveillance systems, especially in the segment related to processing facial images, is strictly regulated and must be prescribed by law.

Overall, the relationship between video surveillance in traffic systems and personal data protection underscores the importance of striking a balance between security needs and privacy rights, ensuring that data is collected and processed lawfully, transparently, and responsibly.

[11] Source: Data from the records of the Ministry of the Interior of the Republic of Srpska

12 Law on Protection of Personal Data („Official Gazette of Bosnia and Herzegovina" 49/06, 76/11 and 89/11)

CONCLUSION

The use of traffic surveillance systems opens up possibilities for implementing mechanisms that can significantly increase traffic safety. However, the video surveillance system must be designed to ensure lawful and transparent use of data, especially from a privacy protection perspective. The study has shown that it is possible to establish mechanisms based on artificial intelligence methods, including machine learning and deep learning, that can detect various types of illegal behavior in traffic. The technical mechanisms for the use of such systems must be prescribed by law. It is also necessary to define the optimal relationship between penalty policy and preventive action in traffic.

The analysis shows that it is possible to detect violations related to mobile phone usage or failure to wear a seatbelt in the car. This information is immediately available to the driver at the moment the violation occurs in the form of a warning, aimed at prevention. However, the number of violations of this type is constantly increasing. This is indicated by the results of the analysis from two cities in Republic of Srpska over different time periods.

At the same time, the ANPR system enables reading the vehicle's license plate. Based on that data, it is determined whether the vehicle is registered. If it is found that the vehicle is not registered, a violation notice is issued. In this case, the number of violations for driving unregistered vehicles is trending downward.

The conclusion is that preventive activities alone are not sufficient in traffic management and that they need to be combined with penalty enforcement. However, even though violations for driving unregistered vehicles have been issued for years, it is evident that there is consistently a certain number of unregistered vehicles in traffic. Therefore, even penalty enforcement alone is not sufficient. It is necessary to seek an optimal balance between preventive measures and penalty enforcement, utilizing modern technologies including traffic surveillance combined with intelligent systems.

Finally, it is crucial that there is a legal basis and clear procedures for the use of surveillance systems, as well as for enforcement.

Further research should continue towards examining the impact of legislative changes and the introduction of penalties on the number of offenses. Additionally, research should continue in the domain of expanding the possibilities of using AI in traffic surveillance systems.

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