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An Intelligent Reconnaissance Framework for Homeland Security

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ABSTRACT

The cross border terrorism and internal terrorist attacks are critical issues for any country to deal with. In India, such types of incidents that breach homeland security are increasing now a day. Tracking and combating such incidents depends only on the radio communications and manual operations of security agencies. These security agencies face various challenges to get the real-time location of the targeted vehicles, their direction of fleeing, etc. This paper proposes a novel application for automatic tracking of suspicious vehicles in real-time. The proposed application tracks the vehicle based on their registration number, type, colour and RFID tag. The proposed approach for vehicle recognition based on image processing achieves 92.45 per cent accuracy. The RFID-based vehicle identification technique achieves 100 per cent accuracy. This paper also proposes an approach for vehicle classification. The average classification accuracy obtained by the proposed approach is 93.3 per cent. An integrated framework for tracking of any vehicle at the request of security agencies is also proposed. Security agencies can track any vehicles in a specific time period by using the user interface of the application.

Keywords: Vehicle detection; Vehicle tracking; Automatic number plate detection; Radio frequency identification; Reconnaissance

1. INTRODUCTION

India is facing internal and external security threats from major terrorist activities specifically in Jammu and Kashmir. The terrorist outfits are not only targeting military bases and their residences but also the common man. The external security concerns are not difficult as there is a deployment of security forces to handle the intruders. In the case of internal security, the situation becomes tedious. Terrorists use civil / fake army vehicles for targeting the armed forces thereby inflicting heavy causalities. After any such incidence, the suspicious vehicles are tracked manually. This manual surveillance process requires proper coordination between various security agencies and quick response time. Unfortunately, due to the lack of infrastructure and integration of the required technologies, the task becomes more challenging. Hence RFID and image processing based techniques are need of the time.

To overcome existing challenges, one can adopt intelligent traffic surveillance (ITS) system[3]. An ITS system processes video streams obtained from roadside CCTV cameras to monitor the traffic. ITS system has capabilities to automatically detect and track any moving vehicles. The developed countries use ITS system for traffic surveillance i.e. vehicle tracking[2] speed violation detection, traffic management[3], tracking of the vehicle.

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2. RELATED WORK

Many researchers are paying attention to involve the different state-of-the-art technologies to deal with homeland security issues. Tian[4], *et al.* proposed a surveillance system that automatically monitors the surveillance scenes and also has capabilities to perform event-based data retrieval. The Department of Homeland Security (DHS)[5] of the USA started a project called Border Safe in 2002. Dudek[6], *et al.* use wireless sensor networks for the border surveillance. The passive infrared sensors (PIR) with JN2139 microcontroller are deployed on various border points. Singh and Kushwaha[7] proposed a smart border surveillance system that is capable of detecting any intruder on border. The approach utilises image processing techniques to detect intruders.

Luvizon[8], *et al.* use feature extraction from license plate and optical motion flow in detection and tracking of the vehicles in urban roadways. Local features are used for tracking of vehicle from aerial images[1]. Elkerdawi[9], *et al.* and Singh and Kushwaha[7] use Haar-like features to detect the object of interest from the images. The automatic number plate recognition (ANPR) is the way of vehicle recognition. There exist various approaches for ANPR. To detect the license plate in the image of vehicles, features such as texture, intensity variation, aspect ratio etc. are used in various techniques[10-11]. Character segmentation approaches based on histogram intensity projection, connected component analysis, and blob region analysis is proposed in[12-14]. The segmented characters are used in the recognition process. Template matching, optical character recognition, and neural network-based approaches are proposed by several researchers[15-18]. Another technique to recognise the vehicles is based on RFID readers. RFID based approaches show 100 per cent accuracy in detection and recognition[20]. The GPS based techniques require that each vehicle must have a GPS receiver device connected to the internet[19].

3. PROPOSED SYSTEM

To configure the proposed application, IP cameras and RFID readers are proposed to be installed in such a manner that the processing of information can take place in a distributed manner. To fulfill this requirement, various zonal control rooms are needed to be setup and placed at secure places where physical access to these is restricted such as police stations, army base camps, CRPF base camps etc.

Each zonal control room is connected to the IP cameras and RFID readers that fall in the respective zones. Figure 1 illustrates the proposed set up for the proposed surveillance system. All the zones are connected to a centralised server. The centralised server may be deployed at army headquarters. The RFID readers are secured by deploying at busy places such as hospitals, police stations, toll booths, check posts etc. It is suggested that all the army and other authorised vehicles be equipped with RFID tags. These tags cost only a few pennies. Even RFID readers are very cheap in price. The overall configuration of the zonal control room, centralised server, IP cameras, and RFID readers is as shown in Fig. 2.

The proposed system has three independent core modules. The first module is the vehicle detection and tracking module based on image processing techniques. The second module tracks the vehicles based on the RFID. The algorithms for target acquisition, request processing and response generation are implemented in the third module.

3.1 Module I - Vehicle Tracking based on Image Processing

This module proposes an approach for vehicle tracking based on image processing. The proposed techniques comprise two different sub-modules namely vehicle detection and tracking module and ANPR and vehicle classification module.

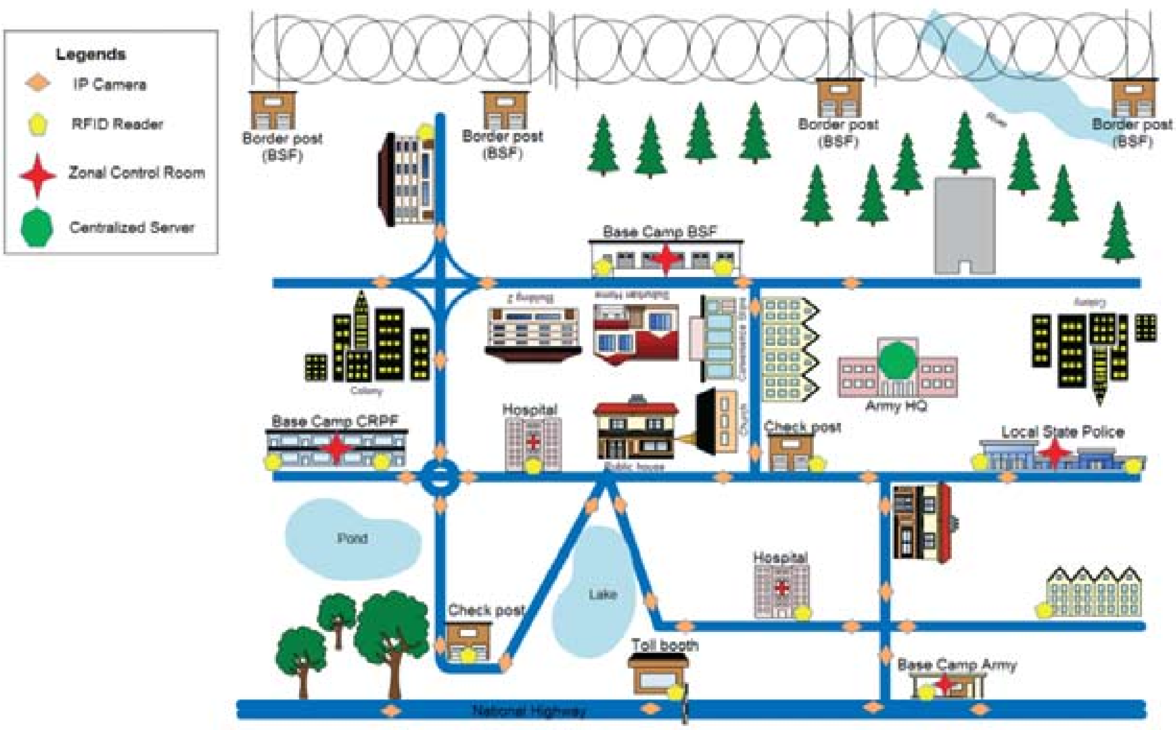

Figure 1. Proposed surveillance system across the city.

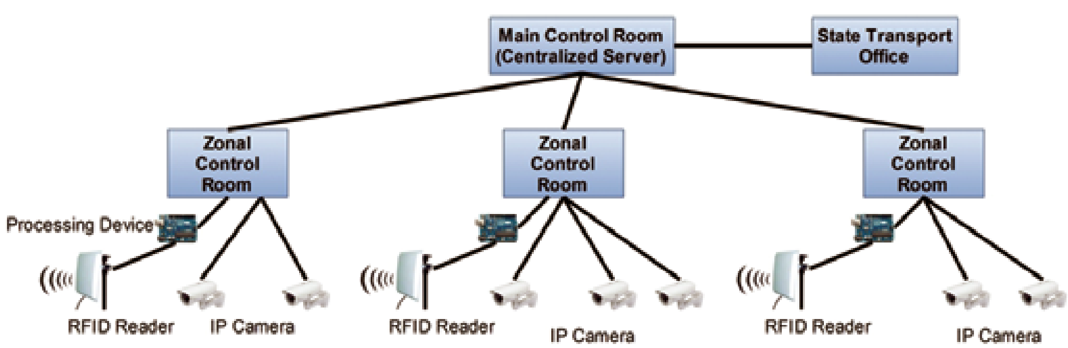

Figure 2. Configuration of data acquisition units in proposed system.

3.1.1 Integration of Image Processing Servers in Zonal Control Room

The zonal control room has four different servers for vehicle tracking based on image processing that are connected in a pipelined manner. The frame extraction server reads the video streams from the camera and extracts the frames from the video stream. The vehicle detection server processes the extracted frames and detects and tracks the vehicles and pass to the ANPR and vehicle classification server. ANPR server recognises the license plates of the vehicles and vehicle classification server classifies the type of the vehicles. The zonal database stores all the record of the vehicles detected in each video stream and sends the vehicle's information to the centralised server. Figure 3 shows the collaboration diagram of all servers in a zonal control room.

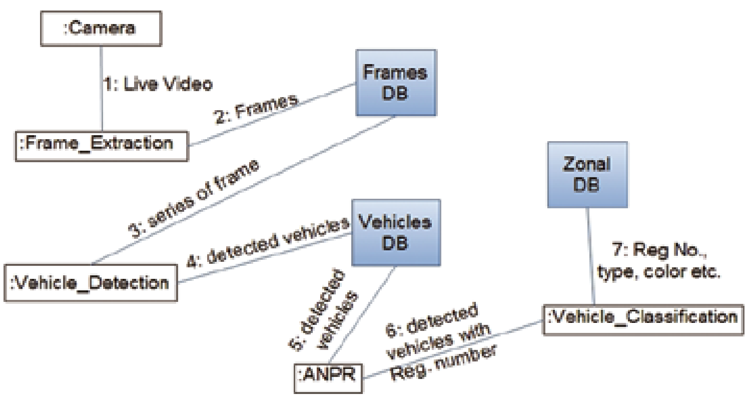

Figure 3. Collaboration diagram of image processing servers in zonal control room.

3.1.2 Vehicle Detection and Tracking

The process of vehicle detection and tracking involves four phases namely:

- Frame extraction
- Preprocessing
- Background subtraction
- Vehicle tracking

The process of frame extraction is carried out in the frame extraction server of the zonal control room. This involves the extraction of a series of the frames and labelling the frames with their timestamp. All the extracted frames are then utilised by the preprocessing phase. There exists one distinct database for each camera that contains the timestamp of the frame and image in a binary format. In the preprocessing phase, a filtering process and red invert operation are applied to the series of the frames retrieved from the database. To detect the moving vehicles, Region of interest (ROI) for the proposed approach is the dark shaded region formed under the vehicles road clearance area. Each pixel of the scalar image has value (255, 0, 0) in RGB colour mode. Background subtraction technique is used to detect the vehicles from the series of red inverted frames. It requires a background image of the site of interest. Location of each camera is distinct, so the system maintains the background image of each location. In the vehicle detection module, the vehicle is tracked to estimate their speed. It tracks the position of the detected vehicles in a series of frames. The position of the vehicle is monitored until the vehicles pass through the site of interest.

3.1.3 ANPR and Vehicle Classification

This module recognises the license plates of the vehicles and also detects the type of the vehicle. To perform the operation, zonal control rooms have ANPR and vehicle classification server. The module has two independent sub-modules called ANPR and vehicle classification.

3.1.3.1 ANPR

The objective of this sub-module is to recognise the license plates of the vehicles detected in vehicle detection and tracking module. The module itself comprises of three phases. The first phase is license plate detection followed by character segmentation and character recognition. The detection of the license plate is based on the texture structure of the license plate. To detect the texture features the connected component labelling[12] is used. Gabor filter with morphological dilation operation is used to remove any kind of noise and improve texture structure. The above process isolates the license plate of the vehicle that is processed by the character segmentation algorithm. The histogram intensity projection is used to segment the characters. The horizontal intensity projection and vertical intensity projection isolates each character of the license plate. These isolated images of the characters are processed by the character recognition module. To recognise the license plate characters, a hybrid approach based on template matching and optical character recognition is proposed in this paper. The optical character recognition is used to recognise the characters that are not recognised by the template matching. The OCR is also used to verify similar characters such as '0' and 'O', '8' and 'B' etc.

3.1.3.2 Vehicle Classification

It classifies the detected vehicle into their type i.e. car/bus/van etc. and colour. A feed-forward neural network is used to classify the vehicles based on the edge map. The Sobel edge detection is used in the approach for edge map generation. To detect all the edges in the images, two Sobel filters are used. The first filter detects the horizontal edges and the other vertical edges. A feature vector maintains the edge map of each image.

3.2 Module II - Vehicle Tracking based on RFID

This module is developed for detecting and tracking of the vehicle based on the RFID tags. At present, few of the vehicles have RFID tags. Security agencies may force these RFID tags in their vehicles and track their vehicles in the city by installing the RFID readers at various places. Each RFID reader must be connected with a processing device i.e. Arduino, Raspberry-pi, etc. These processing devices are connected to the zonal control room and centralised server as shown in Fig. 2. The centralised server obtains the tag information from various RFID readers and maintains the complete details of the vehicle.

3.3 Module III - Integrated Application Framework for Information Retrieval

In the proposed system, the above two modules detect the vehicles, their location and stores into the database. These two module act as data acquisition and information extraction module from the input video stream or tags. The objective of this module is to provide an application framework for various security agencies. This will be used for retrieval of the targeted information from the database. This consists of two sub-module namely target acquisition and information retrieval. These two sub-module are as explained in Appendix A.

4. RESULT AND ANALYSIS

The performance analysis of each module is carried out to establish the efficacy of the proposed reconnaissance Framework.

4.1 Performance Analysis based on Image Processing

The next subsection carries out the performance analysis of vehicle detection and tracking on some of the video clips.

4.1.1. Vehicle Detection and Tracking & ANPR

The proposed technique for vehicle detection and tracking is tested on three pre-recorded videos[20]. Each clip consists of multiple vehicles recorded at the different time of the day. The module is implemented in OpenCV and Java, and Mysql is used to store the result. Frame extraction module extracts the frames and labelled them with the timestamp. The system is able to detect the vehicles and their speed in all the weather conditions. Table 1 shows the detected speed of the vehicles in all videos. The standard deviation and confidence interval is computed by using Eqns. (1) and (2). The value of confidence level at 95 per cent is considered 1.96[21].

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(\chi_i - \mu)^2} \quad (1)$$

here, σ is the standard deviation of the difference in actual and estimated speeds of the vehicles, N is the total number of vehicles in a video, is the estimate of the i^{th} vehicle in the video and μ is the mean difference in actual and estimated speeds of the vehicles in a video.

$$C.I. = \mu + = \alpha\frac{\sigma}{\sqrt{n}} \quad (2)$$

where μ is the sample mean, σ is the standard deviation and α is confidence level value.

The proposed technique measures the average difference between actual and estimated speed which is +2.58 km/h. For verification, a confidence interval on 95 per cent confidence level is computed for all three session. The approach achieves 1.84-6.56 confidence intervals in the morning session, 0.05-0.85 confidence in the afternoon session and 2.22 to 4 in the evening session as shown in Table 2.

The approach for ANPR is implemented on the MATLAB. For the verification of the approach, the experiments are performed on the images of the vehicle detected by the vehicle detection module. The Accuracy of the vehicle recognition is obtained for the detected license plates as shown in Table 2.

Table 1. Actual and estimated speed (in KM/h) of the vehicles detected in all three videos

Vehicle Id	Video 1 (Total 11 vehicle)		Video 2 (Total 7 vehicle)		Video 3 (Total 14 vehicle)	
	Actual speed	Estimated speed	Actual speed	Estimated speed	Actual speed	Estimated speed
1	23.6	24.19	27.4	33.58	40.1	43.26
2	28.1	29.60	25.2	27.10	30.8	32.14
3	39.4	41.66	29.2	31.6	45.9	51.13
4	34.0	34.09	29.6	31.25	39.4	39.47
5	32.6	33.08	24.1	27.77	26.1	28.48
6	28.8	29.22	26.1	28.48	23.9	25.56
7	24.1	24.19	42.4	53.57	29.6	31.69
8	26.7	26.78	-	-	23.4	25.56
9	33.0	33.08	-	-	28.8	31.25
10	25.5	25.56	-	-	33.5	37.50
11	25.2	25.28	-	-	32.6	38.13
12	-	-	-	-	30.0	32.60
13	-	-	-	-	42.4	47.87
14	-	-	-	-	40.1	45.91

Table 2. Analysis of the difference of actual and estimated speed of vehicles

Video	Mean diff. between actual and detected speed (Km/h) (*μ*)	Standard deviation (σ)	Confidence interval (alpha=95)	Recognition Accuracy (%)
Video 1 (Afternoon)	0.45	0.69	0.05-0.85	93.33
Video 2 (Morning)	4.2	3.18	1.84-6.56	92.25
Video 3 (evening)	3.11	1.7	2.22-4	91.81

4.1.2 Vehicle Classification

This module classifies the detected vehicle into their type i.e. car/ bus/van etc. and colour. It processes the image of the vehicle retrieved from the database of the vehicle detection module. The approach is based on the observation that there exist large variation in terms of their shapes based on edges of car, van and bus. In the proposed approach, a feed-forward neural network is used to classify the vehicles based on the edge map. To train the neural network, 200 sample are used for each category and the size of each sample image is 80x160 pixels. A gradient back-propagation algorithm is used to train the neural network. Table 3 shows the classification accuracy of the approach for each category. Results in Table 3 are obtained during the testing of the trained neural network with (12800 input neurons, 25 hidden layers and 3 output layers).

The average classification accuracy of the approach is 93.3 per cent as shown in Table 3. This module classifies each vehicle into the three categories. The vehicles other than the defined categories are labelled as the default category.

Table 3. Accuracy of the vehicle classification approach

Category	No. of sample images	Correct classification	Misclassification	Accuracy (%)
CAR	200	180	20	90
VAN	200	190	10	95
BUS	200	190	10	95

4.2 Performance Analysis of Vehicle Detection and Tracking based on RFID

The performance and feasibility of the proposed surveillance system are tested on the NS-2 with the integration of the Simulation of Urban Mobility (SUMO). A model road map that is part of any city described in Fig. 4 is developed in SUMO. Parameters such as response time of RFID readers, the accuracy of tag detection and tracking of the route of the vehicles are recorded in this simulation. In Fig. 4, there are 15 RFID readers installed at the various junction points across the city. The readers from R0 to R14 represent the RFID readers. The identity of RFID reader is set from 2001 to 2015.

The mobility of the vehicles and the position of the RFID readers are imported into the NS-2. During simulation, we have tracked the path of vehicles having tag number 500 and 501. Vehicle 1 (Tag id 500) passes through reader R0 to node R6 and vehicle 2 (Tag id 501) from reader R9 to R3. The trace file stores the time of each vehicle detected at various RFID readers. Table 4 shows the vehicles detected at any junction and their next possible location. Vehicle having Tag Id 500 is detected at junction R0 and its next location could be junction R1.

To establish mean time to tag detection (MTTD), simulation is performed for increasing vehicle count i.e. 2, 5, 10, 20 and 30 vehicle. The average time to detect the RFID tag and accuracy of RFID readers are recorded during the 5 different iterations with an increasing number of RFID tag enabled vehicles. Table 5 shows the MTTD, Standard Deviation and the confidence intervals of the RFID reader in different simulations scenario.

The accuracy of all the RFID readers is 100 per cent and the average tag detection time of the RFID reader is below 0.5 s.

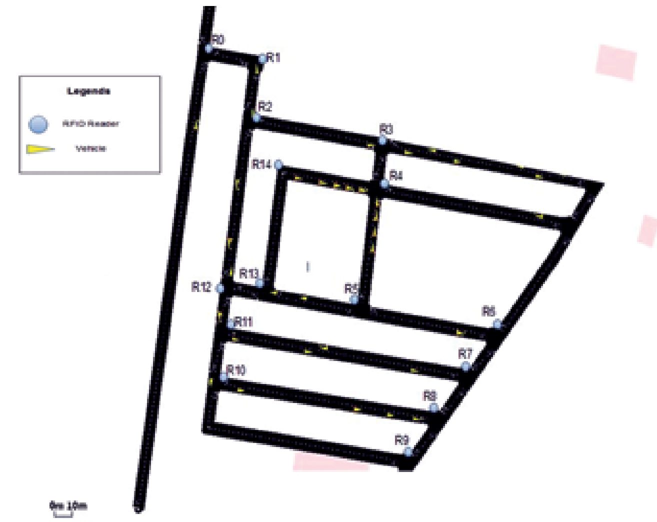

Figure 4. Simulation of RFID based vehicle detection and tracking in SUMO.

Table 4. Vehicle detection at various locations in the city

RFID reader ID	Vehicles tag ID	Time (s)	Duration (s)	Next possible location
2001(R0)	500	0	3	2002 (R1)
2010 (R9)	501	1	2	2009 (R8)
2009 (R8)	501	9.3	1	2008 (R7), 2010 (R9), 2011 (R10)
2008 (R7)	501	11.5	0.3	2007 (R6), 2009 (R8)
2002 (R1)	500	12.1	1.1	2001 (R0), 2003 (R2)
2007 (R6)	501	14.9	1.2	2006 (R5), 2008 (R7)
2006 (R5)	501	22.3	0.7	2005 (R4), 2007 (R6), 2014 (R13)
2003 (R2)	500	24.2	4.2	2002 (R1), 2004 (R3)
2005 (R4)	501	26.4	1.3	2015 (R14), 2006 (5)
2004 (R3)	501	30.1	16	2003 (R2), 2005 (R4)
2004 (R3)	500	31.9	1.3	2003 (R2), 2005 (R4)
2005 (R4)	500	33.2	1.8	2015 (R14), 2006 (R5)
2006 (R5)	500	39.7	2.4	2005 (R4), 2007 (R6),2014 (R13)
2007 (R6)	500	47.7	3	2006 (R5), 2008 (R7)

Table 5. Analysis of MTTD

Number of vehicles	MTTD (s)	S.D.	Confidence interval (α=1.96)
2	0.21	0.0141	0.209-0.211
5	0.23	0.0109	0.230-0.231
10	0.27	0.0194	0.267-0.273
20	0.24	0.0276	0.232-0.241
30	0.23	0.0257	0.229-0.233

Table 6. Comparison of proposed system with existing GPS/GSM based system

Parameters	Proposed RFID based tracking system		GPS/GSM based system	
	Passive RFID tag	RFID reader	GPS receiver	GSM module
Price (range)	$1.5-$4	$23-$600	$50-$100	$15-$50
Power consumption	Power not required	12 Volt	12 Volts	12 Volt
Installation location	On each vehicle	Only on junction points	On each vehicle	On each vehicle
Dependency on Google map services	Not depend on Google map services		Completely dependant on Google services	

5. COMPARISON WITH EXISTING APPROACHES

Most organisations use global positioning system (GPS) based devices to track vehicles. In GPS based approach, each vehicle must be equipped with a GPS receiver device with global system for mobile (GSM) or general packet radio service (GPRS) connection that require uninterrupted availability of mobile network which is yet not available in remote border areas. Table 6 shows the comparison of the proposed RFID based tracking approach with GPS based approach for various parameters. The application proposed in this paper has an objective to provide an economical way of vehicle tracking.

6. CONCLUSIONS

This paper proposes a novel application to detect and track any suspicious vehicle to achieve intrusion proof homeland security and surveillance system. It is based on the integration of the two different technologies namely image processing and RFID. It provides real-time vehicle location, their route for the specified period and prediction of the vehicle's direction of the fleeing. The approach for vehicle detection and tracking based on image processing achieves 92.45 per cent accuracy in vehicle recognition and 93.3 per cent accuracy in vehicle classification. The approach for vehicle tracking based on the RFID achieves 100 per cent accuracy in vehicle recognition. The centralised server maintains a database of all the vehicles detected at various places in the city. This paper also proposes an information retrieval algorithm to track the targeted vehicles. The application can retrieve the targeted vehicle information for any time period by using either registration number, make and colour of vehicle and RFID tag or all of these attributes. The application generates the response against the targetted vehicle for the security agencies such as the current location of the target vehicle, their route, their direction of fleeing and their details of the registration. This proposed application is an economical solution for the intra-city homeland surveillance of the vehicles.

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Contribution in the current study he detailed design of the proposed system, implementing ANPR algorithm and simulating results in SUMO and NS2.

Prof. Dharmender Singh Kushwaha received the BE in computer engineering from University of Pune, India in 1990. He received the MTech and PhD in computer science and engineering from Motilal Nehru National Institute of Technology Allahabad, Allahabad, India in 2007. He was recipient of Gold Medal for his Masters. Since 2018 he is working as Professor with Department of Computer Science and Engineering, Motilal Nehru National Institute of Technology Allahabad, India. His research interest includes: Distributed systems, service oriented architecture, software engineering, data structure and image processing.
Contribution in the current study, he stressed on the need for research that helps national security, outline of the proposed system along with its applicability, and mentor and supervision of the proposed work.

APPENDIX- A

1. TARGET ACQUISITION

In general, security agencies use barricading and checkpoints to monitor the situations. These checkpoints are monitored manually by the soldiers. These soldiers alert the control rooms in case any suspicious vehicle is identified. The control room obtains the vehicle information and feeds into the target acquisition interface of the system. The request tracking server start tracking of the targeted vehicle and alert all the base camps, control room, and checkpoints.

To achieve the above goal, this proposed module provides a graphical user interface to the security agencies. The interface is used for locking the target information into the surveillance system. This interface transfers the target information to the request tracking server. Target acquisition is the process of selection of the target and requesting the surveillance system to locate and track the target in the scene. The input information could be registration number, RFID tag number, vehicle make or colour of vehicle.

The request can be raised on the basis of registration number of the vehicle or may contain information about vehicle type, colour etc. The control room submits the target information to the centralised server in form of three set.

- In first set, the type of request need to be given such as track the vehicle based on registration number or its type and colour or both.
- The second sets contain the information about the nature of request i.e. track the location of vehicle one time or track the location of the vehicle continuously.
- The set third record the required response for the request such as alert the location of the vehicle to all security agencies or alert the control room only or alert the selected base camps only.

The request tracking module extracts the vehicle location based on set first, track the vehicle based on the set second and generate the response as defined in set third. Figure 5 shows the dataflow diagram for the target request in the system.

2. REQUEST TRACKING

The request tracking server processes the target information and extracts the details of the targeted vehicles from the database. After extraction of the required information, the server sends the response to the security agencies. The

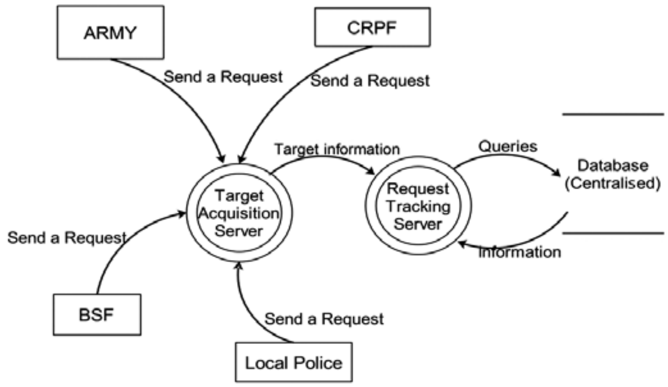

Figure 5. Target acquisition - dataflow diagram.

request tracking module, categorised the request on the basis of initial information obtained from target acquisition module. The module accesses the vehicle information extracted from ANPR module and vehicle classification module and matches the requested parameters. The paper proposed an algorithm to track the targeted vehicles based on the requirements.

In the proposed algorithm, target request is defined for the following three different kind of requests:

- Vehicle Parameters ***VP***={ Request by registration number R_N | Request by type ***T*** and Color ***C***| R_N, ***T and C***}
- Track Vehicle Location request type ***VL***={Track the target location only one Time O_T | Track the target location continuously C_T}
- Vehicle Alert ***VA***={Alert the ALL camps of all security agencies A_A | Alert the control rooms of the requesting agencies A_{CR} | Alert the selected base camps only A_{SB} ***(***B_i, B_j, B_k ***….)***}

Algorithm

Input Req. { *{*R_N*|T,C}, {*O_T*|*C_T*}, {*A_A*|*A_{CR}*|*A_{SB} *(*B_i*,*B_j*,*B_K*..)}*}

Output send vehicle_record (*id, registration number, type, color, time , location*) to *RR*

Procedure *tracking **(VP, VL, VA)***

{

If VP==R_N *then*

If VL == O_T *then*

Extract vehicle_record from database based on R_N

*response **(VA, vehicle_record)***

Else if VL == C_T *then*

While intrupted by control room

Extract vehicle_record from database based on R_N

*response **(VA, vehicle_record)***

End while

Else if VP == T, C then

If VL == O_T *then*

Extract vehicle_record from database based on T and C

*response **(VA, vehicle_record)***

Else if VL == C_T *then*

While intrupted by control room

Extract vehicle_record from database based on T and C

*response **(VA, vehicle_record)***

End while

End if

}

Procedure *response**(RR, vehicle_record)***

{

*If **VA** ==* A_A *then*

Broadcast ***vehicle_record*** *to all camps*

*Else if **VA**==* A_{CR} *then*

Broadcast ***vehicle_record*** *to* A_{CR} *only*

*Else if **VA**==*A_{SB} *then*

Broadcast ***vehicle_record*** *to all base in* A_{SB} *only*

}

In response to the target request, security agencies get route of the targeted vehicle and the direction of the movement of the specified vehicle.