A New Trust Architecture for Smart Vehicular Systems

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Abstract: Modern vehicles are often equipped with event recording capabilities through blackbox systems. These allow the collection of different types of traces that can be used for multiple applications including self driving, post-accident processing and drive monitoring. In this paper, we develop a new trust architecture to enrich the existing blackbox models by adding timestamped optical flows. Our approach provides a tool to collect authentic traces regarding the mobile objects that interfere with the environment of the car, which is complementary to the events considered by the systems available in the litterature.

1 INTRODUCTION

An intelligent vehicle is a vehicle enhanced with perception, reasoning, and actuating devices that enable monitoring and automation of driving tasks. The motivation of building intelligent vehicles is making driving experience safer, more economic and efficient. Intelligent vehicles are equipped with sensors, radars, lasers and Global Positioning System (GPS) that allow to the vehicle road scene understanding. Smart vehicles assist the driver in driving monitoring by doing actions like safe lane following, obstacle avoidance, overtaking control and avoiding dangerous situations. There are many other functionnalities implemented in smart vehicles rendering them fully automated vehicles that use detailed maps to safely drive and navigate itself with no human interaction, the vehicle can not only drive itself but it can be parked on its own. Smart vehicles are also equipped with automatic traffic accident detection systems that detect accident and in some cases send notifications to concerned authorities (Broggi et al., 2008).

To realize the above describted functions, different types of traces are collected by vehicle's sensors from the surrounding environment. Collected data must be authentic to permit to the vehicle taking the correct decision. This paper addresses the security of collected traces during driving. We focus on information related to moving objects detection. Moving objects can influence the driving behaviour either through distraction or by causing a danger that may require an active response. Mobile objects are detected by cameras installed on board vehicles. Depending on the movement of the camera relative to the objects, three cases can be distinguished:

- Static camera and moving objects: In this case, images have a fixed background, which can help in moving objects detection.
- Moving camera and static objects: reference points for movement can be chosen since objects are known as static.
- Moving camera and moving objects: This is the case discussed in our paper, their is no static background or objects that can be taken as references. The camera is installed on board a vehicle and has the same view as the driver. The maximum value of vehicle's velocity is equal to 90 km/h.

Information about objects motion can be known by optical flow calculation (Agarwal et al., 2016). Optical flow is calculated from the recorded scene to have an estimate of the apparent motion. The optical flow describes the direction and time rate of pixels in a time slot of two consequent images. A two dimensional velocity vector, carrying on the direction and the velocity of motion is assigned to each pixel of the picture. Optical flow values are saved in the vehicle blackbox. The objective of optical flow calculation is having a feedback of events that happen during driving experience because these events can be used as authentic traces for self driving, post-accident processing and drive monitoring applications.

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To be used as an authentic trace, optical flow values must be protected against modification since their creation and must be verified with time values to have a trace when events have occured. To do this, we propose to timestamp optical flow matrix saved in the blackbox.

This paper is organized as follow: In section 2, we present a litterature review of mobile objects detection techniques. In section 3, we present optical flow basics and timestamping in vehicular networks. In section 4, we expose our approach for optical flow timestamping, we illustrate our proposal with a practical use case in section 5 and we conclude our paper in section 6.

2 LITERATURE REVIEW

There are three methods for mobile objects tracking which are frame difference, background subtraction and optical flow. Frame difference method is based on the difference between pixels to find the moving object. There is a frame which is taken as a reference. The difference between the reference frame and the current frame is calculated. The moving object is detected from the found difference. In (Singla, 2014), the video is captured by a static camera, the difference between the two consecutive frames is calculated, and then it is transformed to Gray image and filtered using Gauss low pass filter and binarized at the end. Experimental results show motion in the binary image found by calculating the difference between the two frames. In (Joshi, 2014), an algorithm is developed to calculate the speed of moving vehicles and detect those which violate the speed limits. Video is captured by a static camera, tracking of the moving object and calculation of the velocity of the object is done using segmentation in a first step, which separates regions of the image. Segmentation is done using frame difference algorithm.

The inconvenient of the temporal differencing method is that it cannot detect slow changes, for this reason, background subtraction method is used. This method is based on extracting background which is the region of the image without motion. The absolute difference between the background model and each instantaneous frame is used to detect the moving object.

(N.Arun Prasath, 2015) uses the background subtraction as a first step to estimate vehicle speed. After conversion of the video into frames, the background is extracted to detect moving vehicles. After that, feature extraction and vehicle tracking are done to determine the speed. An algorithm that detects moving objects in high secured environments is proposed in (Singh et al., 2014). Detection is done online and offline. In Offline detection, the video is divided into frames. Moving object is detected by separating the foreground from a static background. When the moving object is known, it is marked by a rectangular box. When the object moves, the alarm is activated. The position of the centroid of the object is calculated, and the distance and the velocity of the object are determined. A system for monitoring traffic rules violation is presented in (Gupta, 2015) to monitor the velocity limits violation and detect the registered license plate number. To monitor velocity limits violation, velocity is calculated. The first step of velocity calculation is vehicle tracking which is done by background subtraction. Each frame is subtracted from the background model. The blobs that are found as result of subtraction correspond to moving objects.

Background subtraction is a widely used approach for detecting moving objects from static cameras.

Optical flow technique is used for moving objects tracking. It provides an apparent change of moving object location between two frames. It insulates the moving objects from the static background objects. Optical flow estimation is represented by a two-dimensional vector assigned to each pixen of the image and represents velocities of each point of an image sequence.

Optical flow was used in many works for mobile onjects tracking; (Garcia-Dopico et al., 2014) presents a system for the search and detection of moving objects in a sequence of images captured by a camera installed in a vehicle. The proposed system is based on optical flow analysis to detect and identify moving objects as perceived by a driver. The proposed method consists of three stages. In the first stage, the optical flow is calculated for each image of the sequence, as a first estimate of the apparent motion. In the second stage, two segmentation processes are addressed: the optical flow itself and the images of the sequence. In the last stage, the results of these two segmentation processes are combined to obtain the movement of the objects present in the sequence, identifying their direction and magnitude.

(Indu et al., 2011) proposes a method to estimate vehicle speed from video sequences acquired with a fixed mounted camera. The vehicle motion is detected and tracked along the frames using optical flow algorithm. The distance traveled by the vehicle is calculated using the movement of the centroid over the frames and the speed of the vehicle is estimated.

In many works, optical flow was combined with other techniques. In (Guo-Wu Yuan, 2014), Optical flow was combined with frame difference method. In this work, optical flow for Harris corners is calculated, and to localize the complete moving area, the method of frame difference is used. Optical flow was used in (DharaTrambadia,) with background subtraction. In this work, tracking of moving objects or persons is done using Adaptive Gaussian Mixture Modeling and optical flow. Adaptive Gaussian Mixture Modeling is used for complex environment but it is not a complete object tracking method, it is used with optical flow which is used for simple background. The foreground is extracted using Gaussian Mixture Modelling techniques.

3 OPTICAL FLOW AND TIMESTAMPING

This section deals with optical flow method description, and the need for timestamping optical flow in vehicular context.

3.1 Optical Flow and Smart Cars

Optical flow gives the displacement of each pixel of an image compared to the previous image. The displacement vector is called optical flow vector. It is used for motion segmentation for tracking moving objects. It is possible to find the moving objects in video frames by calculating the value of optical flow. If the value is significant, this means that the object is moving. If the value is very small, the object is static. In 1981, two differential-based optical flow algorithms were proposed by Horn and Schunck and by Lucas and Kanade. Horn's algorithm assumes that the motion field is the 2D projection of the 3D motion of surfaces. The optical flow is the apparent motion of the brightness patterns in the image. The flow is formulated as a global energy functional which is then sought to be minimized.

$$E = \int\int \left[(Ixu + Iyv + It)^2 + \alpha^2 \left(\|\nabla u\|^2 + \|\nabla v\|^2\right)\right] dxdy$$

where I_x, I_y and I_t are the derivatives of the image intensity values along the x, y and time dimensions respectively.

$$\overrightarrow{V} = [u(x,y), v(x,y)]^T$$

is the optical flow vector, and the parameter α is a regularization constant. Larger values of α lead to a smoother flow. Figure 1 represents motion vectors calculated using Horn and Schunck method for video frames recorded with a static camera installed on board a moving vehicle. Red lines represent optical flow vectors.

Figure 1: Optical flow vectors calculated with Horn and Schunck Method.

The Lucas-Kanade approach assumes that the flow remains constant in a local neighborhood of the pixel under consideration, and solves the basic optical flow equations for all the pixels in that neighborhood by the least squares method. The Lucas-Kanade algorithm computes the optical flow by calculating the spatio-temporal derivatives of intensity of the images. This algorithm assumes that intensity of the image remains constant between the frames of the sequence.

Using Taylor Series, the expression can be written as:

$$I(x,y,t) = I(x+dx, y+dy, t+dt)$$
$$I(x,y,t) = I(x,y,t) + (\frac{\partial I}{dx})dx + (\frac{\partial I}{dy})dy + (\frac{\partial I}{dt})dt$$
$$Ix \times u + Iy \times v + ft = 0 \qquad \text{Optical flow equation}$$

The optical flow equation can be assumed to be true for all the pixels in a window centered at the point p(x,y). Considering a window of $[n \times n]$ pixels:

$$\begin{pmatrix} Ix(p1)u + Iy(p1)v = -It(p1) \\ Ix(p2)u + Iy(p2)v = -It(p2) \\ . \\ . \\ . \\ Ix(pn)u + Iy(pn)v = -It(pn) \end{pmatrix}$$

where $p1, p2, ..., pn$ are pixels within the window, and $Ix(p1), Ix(p2), ..., Ix(pn)$ are the partial derivatives of the image I according to the space variables x,y and time t, measured at the point pi and the current time.

Figure 2 represents motion vectors calculated using Lucas Kanade method for video frames recorded with a static camera installed on board a moving vehicle. Red lines represent optical flow vectors.

Figure 2: Optical flow vectors calculated with Lucas Kanade Method.

3.2 Timestamping Architecture

VANETs are a key technology for enabling safety and infotainment applications in the context of smart vehicles. To connect smart vehicles, several issues must be addressed. There are important issues related to security. Various techniques are used to ensure security in VANETs, bellow we cite few cryptography techniques:

- Public Key infrastructure (PKI): it is used for user authentication. It is based on the use of a public key, known by other users in the network and it is used for message encryption, and a private key, which is known only by the owner and is used for message decryption. PKI is based on the use of a Certification Authority (CA) that is charged of issuing certificates, signing the messages digitally and providing public and private keys to ensure users authentication.
- Digital signature: Vehicle sends messages after encrypting it using the receiver public key (to ensure data protection) then digitally signs it (to ensure data authentication)
- Timestamp series: This technique is used to prevent Sybil attack in VANET. It is not possible that two vehicles go through different RSUs at the same time with the same timestamp. If a vehicle sends a timestamp message that issued by passed RSUs and this message has the same timestamps series with other messages, Sybil attack will be detected.

Generally, Timestamp is used in VANET to ensure the message freshness. According to (Galaviz-Mosqueda et al., 2017), packets sent in VANETs are commonly composed by:
PACKET= (M, ($sign_n$(M, T), $Cert_n$)
$sign_n$: Digital signature of node n over the concatenation of a message M and a timestamp T to ensure message freshness to prevent replay attack.

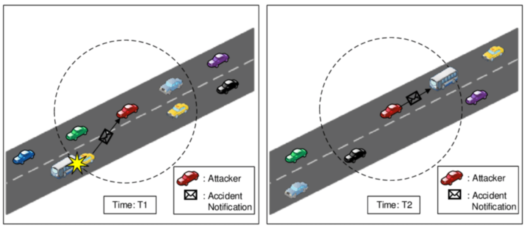

Figure 3: Replay attack scenario.

$Cert_n$: certification of node n.
Receiving node can verify packet authenticity by verifying the signature sig.
Figure 3 (Sakiz and Sen, 2017) illustrates a replay attack, in which accident notification message generated and sent in T1 was sent a second time in T2.

4 PROPOSED APPROACH

(Wolfgang and Delp, 1998) presents an overview of image security techniques with applications in multimedia systems. Images can be protected againt illegal uses using encryption, authentication and timestamps. In this paper, we present a scheme for timestamping optical flow matrix. Let OP be the data to be timestamped, and Y = H(OP) be the hash of OP. A request named R, is sent to a third party timestamping service (TSS) to ask for a timestamp. The syntax of the request is as follows:
$(R_n)= (Y_n, t_n)$
The TSS then produces a certificate, C_n :
C_n= (n, t_n, I_n, Y_n; L_n)
$L_n = (t_{n-1}, I_{n-1}, Y_{n-1}, \mathrm{H}(L_{n-1}))$

- n: The request number
- I_n: The owner's identification string
- t_n: the time of the request
- L_n: The linking string, it is the concatenation of the previous request time, the identity string, the document hash and the linking string hash.

The TSS waits for the next request I_{n+1}, then concatenates it to C_n, the timestamp returned to the user is: S= F((C_n, I_{n+1}), K_P)

- F: The encryption function
- K_P: The private key of the TSS

A requester for a timestamp authenticates in a first step the TSS signature on the stamp. The requester can then ask for I_{n-1} (embedded in L_n) to show her timestamp. The quantities in L_n must match those in

C_{n-1}. The hash of L_{n-1} must also match the value of H(L_{n-1}) present in L_n. If any value does not match, one of the two timestamps is false. In practice, the linking string contains information from the last N requests. This distributes the authentication responsibility, since any one of the N requesters may verify the timestamp. The proposed process is illustrated by Figure 4.

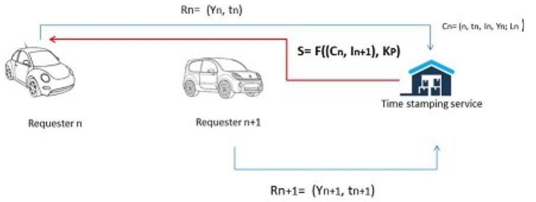

Figure 4: Proposed process of timestamping optical flow.

5 CASE STUDY

Traffic accidents are confusing events. How they occur, who or what caused them, and why they occurred are facts that police must determine. The accident investigator plays an important role in the process of investigation and reporting on the contributing factors to an accident. His report is important to the police services, traffic enforcement, vehicle owners and insurance companies. The accident investigator uses a wide variety of tools at the accident scene. There are also vehicle technology that assist the investigator in establishing the causes of the accident. Vehicle blackbox can tell a lot of information concerning the accident: Amount of travel prior to the accident, driving style prior to the accident, speeds achieved and maintained, unauthorised stops, speed, detail prior to the accident, significant braking, ... It tells also date, time, location, speed, distance and engine Rpm. We take the example of an accident that occurs and investigators use data saved in the blackbox for investigation. The image with optical flow vectors is used for marking the detected object in the image/video frame. The ability to verify the integrity of files is important for investigators. Especially if files are to be used as evidence in court, the ability to prove that a file existed in a certain state at a specific time and was not altered since is crucial. We propose the accident scenario illustrated by Figure 5. The motorcycle tries to overtake the green vehicle that changes direction and turn on the left. (positions a and b). The result was a crash with the red vehicle (position c) which captured the motorcycle since it was trying to do the overtake operation.

Red vehicles uses blackbox system for recording events that happen during the driving experience. Mobile objects are tracked using the optical flow technique. Optical flow matrix are stored in the blackbox. Requests for timestamping are sent according to the steps described in Section 4. Green vehicle and red vehicle send the following requests for timestamping:

(R_{Gn})= (Y_{Gn}, t_n)
(R_{Rn+1})= (Y_{Rn+1}, t_{n+1})
Certificates are produced by Timestamping Service:
C_{Gn}= (n, t_n, I_{Gn}, Y_{Gn}; L_n)
C_{Rn+1}= (n+1, t_{n+1}, I_{Rn+1}, Y_{Rn+1}; L_{n+1})
The timestamps returned to vehicles are:
SR= F((C_{Gn}, I_{Gn+1}), K_P)
SG= F((C_{Rn+1}, I_{Rn+2}), K_P)

- n: The request number sent by the green vehicle
- n+1: The request number sent by the red vehicle
- I_{Rn+1}: The Red vehicle's Identification string
- I_{Gn}: The Green vehicle's Identification string
- R_{Gn}: Request sent by the Green vehicle
- R_{Rn+1}: Request sent by the Red vehicle
- Y_{Rn+1}: Hash of optical flow matrix recorded by Red vehicle
- Y_{Gn}: Hash of optical flow matrix recorded by Green vehicle
- t_n: the Time of the request sent by the green vehicle
- t_{n+1}: the Time of the request sent by the red vehicle
- L_n , L_{n+1} : Linking strings
- C_{Gn}: Certificate of Green vehicle
- C_{Rn+1}: Certificate of Red vehicle
- SG: Timestamp returned to Green vehicle
- SR: Timestamp returned to Red vehicle

  Motorcycle tracking is timestamped by TG and TR described above. When analyzing saved data in the red's vehicle blackbox, investigator can make sure that the crash occured after the green vehicle tuns on the left and the motorcycle was trying to overtake it, according to saved optical flow in the red's vehicle blackbox system that indicates positions of the green vehicle and the motorcycle.

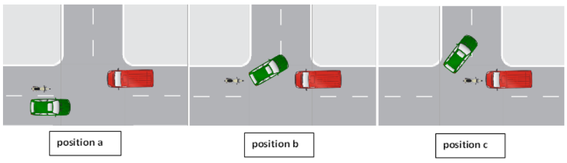

Figure 5: Accident scenario.

6 CONCLUSIONS

In this paper, we proposed to timestamp optical flow used for mobile object tracking to be used as an authentic trace for smart vehicle applications. We exposed a timestamping process and we illustrate it by a post-accident investigation use case.

REFERENCES

Agarwal, A., Gupta, S., and Singh, D. (2016). Review of optical flow technique for moving object detection. pages 409–413.

Broggi, A., Zelinsky, A., Parent, M., and E. Thorpe, C. (2008). *Intelligent Vehicles*, pages 1175–1198.

DharaTrambadia, ChintanVarnagar, P. Moving object detection and tracking using hybrid approach in real time to improve accuracy. *International Journal of Innovative Research in Computer and Communication Engineering*, pages ISSN(Online): 2320–9801, ISSN (Print): 2320–9798.

Galaviz-Mosqueda, A., Morales-Sandoval, M., Villarreal-Reyes, S., Galeana-Zapién, H., Rivera-Rodríguez, R., and Alonso-Arevalo, M. A. (2017). Multi-hop broadcast message dissemination in vehicular ad hoc networks: A security perspective review. *International Journal of Distributed Sensor Networks*, 13(11):1550147717741263.

Garcia-Dopico, A., Pedraza, J. L., Nieto, M., Pérez, A., Rodríguez, S., and Osendi, L. (2014). Locating moving objects in car-driving sequences. *EURASIP Journal on Image and Video Processing*, 2014(1):24.

Guo-Wu Yuan, Jian Gong, M.-N. D. H. Z. D. X. (2014). A moving objects detection algorithm based on three frame difference and sparse optical flow. *Information Technology Journal*, 13:1863–1867.

Gupta, T. P. (2015). Vehicle detention using high accuracy edge detection. *Int. J. Adv. Eng*, 1(1):28–32.

Indu, S., Gupta, M., and Bhattacharyya, A. (2011). Vehicle tracking and speed estimation using optical flow method. *Int. J. Engineering Science and Technology*, 3(1):429–434.

Joshi, S. (2014). Vehicle speed determination using image processing. In *International Workshop on Computational Intelligence (IWCI)*.

N.Arun Prasath, G.Sivakumar, N. (2015). Vehicle speed measurement and number plate detection using real time embedded system. In *Network and Complex Systems, ISSN 2224-610X (Paper) ISSN 2225-0603 (Online) Vol.5, No.3*.

Sakiz, F. and Sen, S. (2017). A survey of attacks and detection mechanisms on intelligent transportation systems: Vanets and iov. *Ad Hoc Networks*, 61:33–50.

Singh, T., Sanju, S., and Vijay, B. (2014). A new algorithm designing for detection of moving objects in video. *International Journal of Computer Applications*, 96(2).

Singla, N. (2014). Motion detection based on frame difference method. *International Journal of Information & Computation Technology*, 4(15):1559–1565.

Wolfgang, R. B. and Delp, E. J. (1998). Overview of image security techniques with applications in multimedia systems. In *Multimedia Networks: Security, Displays, Terminals, and Gateways. Vol. 3228. International Society for Optics and Photonics*.