An Approach to Exonerate Innocent Suspects in Hit-And-Run Accidents via Route Reconstruction

Marian Waltereit
Supervised by Torben Weis
University of Duisburg-Essen

***Abstract*—We propose an approach to exonerate innocent suspects in hit-and-run accidents. This helps wrongly suspected drivers to support their innocence and eases the investigation of hit-and-run accidents by enabling law enforcement authorities to effectively reduce the number of suspects. We are developing an algorithm that automatically reconstructs the routes traveled by suspect drivers using vehicle data recorded while driving. In contrast, existing approaches only offer manual or semi-automated route reconstruction. If our algorithm cannot reconstruct a route that includes the accident location, the suspect driver is most likely innocent.**

I. Introduction

The rise of connected vehicles creates new opportunities for pervasive applications such as road condition monitoring [1]. Another application is vehicle forensics, where vehicle data is used to provide digital evidence in the investigation of accidents. In crash investigations, this data is often acquired from an event data recorder (EDR) installed in the vehicle [2]. In the event of an accident, the EDR stores vehicle data for investigation purposes. Another approach is the use of forensic data loggers that continuously store vehicle data such as speed or accelerometer readings [3], [4]. In all forensic investigations, the integrity and authenticity of the stored vehicle data must be guaranteed. Otherwise, the data cannot provide reliable evidence. Additionally, the privacy of the driver should be ensured [4], [5]. This means that the driver knows and decides which data will be stored.

In this research, we focus on the investigation of hit-and-run accidents in the area of vehicle forensics. Inspired by the scenario outlined by Hoppe et al. [3], we assume the following scenario: *A law enforcement agency is investigating a hit-and-run accident. Some of the suspects have no alibi, but claim their innocence. To support these claims, the suspects allow the law enforcement agency to use the data logged by forensic data loggers for analysis. The law enforcement agency uses this data to automatically reconstruct the routes traveled by the suspects. If a suspect's reconstructed route does not include the accident location, the suspect is most likely innocent.*

The aim of this research is to propose an approach to exonerate innocent suspects accused of hit and run. To achieve this, we develop an algorithm that automatically reconstructs the traveled routes of suspects using vehicle data captured by forensic data loggers while driving. If a forensic data logger has the permission to collect GPS data, route reconstruction is trivial. We believe that drivers may be concerned about their privacy and therefore disable the collection of GPS data. Nevertheless, a driver could still get into a situation where he wants to support his innocence. For this reason, we focus on the case where GPS data is not available. For reconstructing a route traveled by a suspect driver, we rely on the sequence of distances and turns that the route caused when traveled. This sequence is, for example, used in turn-by-turn navigation to guide a driver to the destination and can be measured while driving using wheel speeds [6] or gyroscope and accelerometer readings [7], [8]. Thus it can be measured using forensic data loggers. Our approach has two major benefits: (1) it helps innocent drivers to support their innocence, and (2) it enables law enforcement authorities to effectively reduce the number of suspects and thus eases solving hit-and-run accidents.

II. Related Work

Mansor et al. [4] proposed a system that enables collecting vehicle data from the CAN bus for forensic purposes. The data is stored in a cloud in a privacy-preserving and trustworthy manner. Cebe et al. [5] proposed a similar blockchain-based system. These systems are suitable to capture vehicle data in our approach while ensuring integrity and authenticity of the data. In addition, these systems respect the privacy of the driver, as the driver knows and decides what data is captured. This allows a driver who is concerned about privacy to disable, for example, the collection of GPS data. Algorithms as presented by Marchetti et al. [9] and Verma et al. [10] can be used to identify specific data in the captured CAN bus data.

Route reconstructing using sensor readings was intensively studied [6]–[8], [11]–[13]. These works have in common that the possibility of reconstructing the traveled route is considered a threat to the driver's location privacy. We want to use this possibility for a meaningful purpose. The existing approaches differ in the requirements necessary for the reconstruction and in the sensors used. Several approaches require the start and/or the end positions of the journey [7], [11], [12]. Other approaches need knowledge of the area in which the journey took place [6], [8], [13]. The data used for the reconstruction is typically based on accelerometer, gyroscope and/or magnetometer readings [7], [13]. Another option is to use the vehicle speed [6], [11], [12].

Hoppe et al. [3] presented an approach to the forensic reconstruction of routes using CAN bus data captured by a forensic data logger to investigate hit-and-run accidents and provide digital evidence. In contrast to our approach, this approach allows only a manual or semi-automated and not a

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fully-automated route reconstruction. The manual reconstruction is done by manually mapping the captured speed data to the street network and thus find the traveled route. For the semi-automated approach, they utilize a navigation system to simulate a journey based on the captured data and generate possible routes. However, this requires manual configuration and interaction steps and is hence not fully automated.

III. Research Challenges

In this section, we present the three main research challenges we have identified in the context of exonerating innocent suspects in hit-and-run accidents. In addition, we briefly discuss our progress in addressing these challenges.

a) Reconstruct Routes: The first research challenge is to reconstruct the traveled route using the accident location and the sequence of distances and turns. In prior work, we developed an algorithm that determines the traveled route in an area of about $400\,\mathrm{km}^2$ using the sequence of distances and turns [6]. However, the algorithm cannot handle measurement errors, e.g. wrong turn information due to undetected turn maneuvers. To overcome this, we developed another algorithm that can handle measurement errors and determines the route in an area of about $1200\,\mathrm{km}^2$ [8]. In the case of a hit-and-run accident, the accident location is known. This limits the area in which the route must be traveled if the driver is not innocent. We are currently developing an algorithm that leverages this knowledge and is also robust against measurement errors.

b) Identify Accident Position in Input Data: The second research challenge is to identify where the accident happened within the sequence of distances and turns. This is necessary to leverage the knowledge of the accident location when reconstructing the route. The sequence of distances and turns can be obtained from time series data such as wheel speeds [6], where the time information should correspond to the exact time of day as the data is used to provide digital evidence. This allows us to approximately identify where the accident happened within the sequence using the accident time. The accident location can be used to analyze the area around the accident in order to determine the distances to the next crossroads as well as the possible turn directions. We will use this knowledge to more accurately identify where the accident happened within the sequence of distances and turns by searching for similar patterns in the sequence.

c) Establish Confidence in Results: The third research challenge is to establish confidence in the results of our algorithm in order to enable law enforcement agencies to use the results as digital evidence. The confidence in the result increases with the total distance and the number of turns of the route as well as the size of the considered area, as it is less likely that a large route was reconstructed by chance in a large area. However, the smaller these values, the faster the route can be reconstructed. So there is a trade-off between computation time and confidence that we are investigating in our research. In prior work, we could reconstruct 95.50% of the routes when considering top 5 ranked candidates in an area of about $1200\,\mathrm{km}^2$, which is sufficient to reconstruct routes in the largest German cities [8]. The total distance of the routes was between $1278\,\mathrm{m}$ and $7702\,\mathrm{m}$. The routes included 6 to 21 turns. We consider this area size and these route characteristics to be large enough to be confident in the algorithm's results. To quantify and substantiate this confidence, we will conduct a comprehensive evaluation of our approach.

IV. Conclusion

This research aims to propose an approach to exonerate innocent suspects in hit-and-run accidents. We are currently developing an algorithm that addresses the discussed research challenges. Our approach eases solving hit-and-run accidents by law enforcement authorities and helps innocent drivers to support their innocence.

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