

Vehicular Lifelogging: Issues, Challenges, and Research Opportunities

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ABSTRACT

Lifelogging provides us an opportunity to capture and track every moment of our lives in digital form and store them for augmenting human memory. Various technologies have been used to assist the people in capturing life events such as wearable devices, biometric devices, fitness devices, non-visual wearable and unwearable devices. These devices played a vital role in capturing life events of individuals. However, little attention has been given to capture and record events related to life on the road. Beside other lifelogging devices, the vehicle can be used as lifelogging devices (i.e. vehicular-lifelogging). Due to a bundle of sensors and other auxiliary devices, a vehicle or car can be an intelligent enough to capture personal as well as car related data. This captured data could be used for various purposes. For example, car owners may use this data for maintenance; law enforcement agencies may use this data for crime detection. Other possible uses may include human memory augmentation, safety, and recommendations. Despite numerous advantages of vehicular-lifelogging, interest in this area is still broader and need proper attention to build such system, as there is a number of issues and challenges. In this paper, we have investigated and reported the current trends, issues, challenges, and research opportunities in developing reliable and fine-tuned vehicular-lifelogging systems. In addition, the study contributes by providing research guidelines in the field of vehicular-lifelogging that may possibly introduce new research avenues.

Keywords: Vehicular Lifelogging; Issues; Challenges; Wearable Devices; Onboard Diagnostic; Infotainment System

Author's Contribution

¹ Data analysis, interpretation and manuscript writing, Active participation in data collection

^{2,3} Conception, synthesis, planning of research and manuscript writing

⁴ Interpretation and discussion

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INTRODUCTION

Every moment of our life is very important to us and sometimes we do not want to miss capturing any event of our life. Lifelogging is the process of tracking someone's personal data with the help of gadgets and devices. It is a prominent area as the people are taking keen interest to gather all the events that happens in their life and review them later on ¹. Various devices are available that can be used for lifelogging, i.e. wearable devices, biometrics devices, fitness devices, non-visual wearable devices, unwearable devices and smartphones. These

technologies can be used to record the entire life events of individuals including email, documents, photographs, videos, diaries, geodata, music, listening habits, blog entries, navigation history and web browser bookmarks ². Besides the storing of personal information, the purposes of lifelogging technologies can vary and may be used to store information about commerce, government, marketing, social networking, security and travel ³.

By the integration of sensors and latest technology in cars and due to the contextual rich interfaces and

interaction, cars become mobile sensing and computing devices and could be used for vehicular-lifelogging to log data about themselves, environments, drivers and passengers⁴. Nowadays people are spending most of their substantial part of the time in a vehicle, so that their journeys, trips, vehicles' information, and personal experiences can also be logged. The logged data could further be used for various purposes including car owners, law enforcement agencies, memory augmentation, and recommendation. The logged data could be annotated and will be used to assist the car buyers to find out the status of the car including the age of the car, usage pattern of the car, accident information. The law enforcement agencies will get benefit from the logged data by investigating the accident causes, car theft recovery, car attack or any other catastrophic situation. In addition, this data could also be used in the recommender system to recommend the best road, best filling station, refreshment spot on the road, and music etc. The generic model of vehicular lifelogging system is depicted in Fig. 1.



Fig. 1: Vehicular lifelogging generic model

Despite numerous advantages of vehicular lifelogging, interest in this area is still broader and need proper attention to build such system, as there are various issues and challenges. It is, therefore, necessary to build high-quality vehicular lifelogging system to store the car as well as personal and environmental experiences for the lifetime. This paper may help researchers and practitioners to work on some of the prominent issues and challenges in the area of vehicular lifelogging. The summarized objectives of this paper are three-fold: 1) to present state-of-the-art supporting technologies for

vehicular lifelogging so that researchers can get an idea of how these technologies approaching towards the successful building of vehicular lifelogging systems. 2) to identify and present the common issues and challenges in the design and development of vehicular lifelogging systems. 3) to present future trends and research guidelines that might help in coping with these issues for the designing of a reliable fine-tuned Vehicular lifelogging system.

The rest of the paper is organized into six sections. Section II presents the supporting technologies for the development of vehicular lifelogging systems; Section III is related to issues and challenges that vehicular lifelogging systems are currently facing. Methods and Materials are discussed in Section IV while results are discussed in Section V. Section VI presents solutions and guidelines and finally, Section VII concludes the discussion. References are enlisted at the end.

SUPPORTING TECHNOLOGIES FOR VEHICULAR LIFELOGGING

Today's cars are fully equipped with latest technologies, which provide a safe and comfortable journey to both drivers and passengers⁵. Some companies are introducing an intelligent system based on sensors to learn driver's driving behavior and alert them to pull over and take rest in the case when they start swaying or being inattentive⁶. A night vision system has been introduced in car dashboard to allow the drivers to see wildlife or any other thing in the complete dark⁷.

A. Onboard Diagnostic-II (OBD-II)

OBD-II adapters are available which could be used to track down engine problems through cars Engine Control Computer and then send the results to smartphone using Bluetooth technology. OBD-II ports are available in all vehicles since 1996 that extract information from the car including car RPM, throttle position, pedal position, fuel level, fuel ratio, oil temperature, catalyst temperature, km/liter, and speed. Hwa-seon Kim et al.⁸ designed and applied a protocol consisting of message structure to request data transmission from smartphone to Engine Control Unit (ECU) and response message from ECU to smartphone. Zaldivar, Jorge, et al.⁹ proposed an Android-based application that uses OBD-II that monitors vehicles and provides help for accident detection. Khanapuri,

Akhila V., et al.¹⁰ proposed an android application to track and monitor car engine RPM, fuel status etc. through OBD-II. Araújo, Rui, et al.¹¹, also presented a new smartphone application based on OBD-II that will assist drivers to reduce fuel consumption of their vehicles. Lee, SeokJu et al.¹², designed and implemented a vehicle tracking system to track vehicle from any location at any time.

B. Vehicular GPS-based Navigation System

Nowadays various cars are delivered from the car manufacturing company with built-in GPS navigation system¹³. GPS combined the signal received from the satellites with interactive onboard maps to plot and show vehicle routes and its current position¹⁴. Most of the navigation systems are connected with sources like traffic information system to automatically alert the drivers for any inconvenience and best route recommendation. GPS car navigation system also provides a facility for the drivers to interact the car through voice and visual instruction¹⁵. Moreover, many vehicles i.e. taxi, buses, police cars, fire brigade, and ambulances are equipped with navigation systems that cannot be only providing the current location but also constantly communicate to monitoring cell¹⁶.

C. In-Vehicle Infotainment System (IVI)

Modern in-car infotainment systems provide a variety of functionalities including audio/visual features and navigation system. These features are normally accessed using central command unit located within the center console or using hard key buttons¹⁷. Nowadays android-based in-Vehicle Infotainment Systems (IVI) are available which can be used as a replacement for the traditional vehicle stereo system. This system provides more informative materials that will assist the drivers by providing features from the mobile-based operating system¹⁸. In-Vehicle Infotainment System combines hardware and software to provide features including GPS navigation, music players, video players, SMS texting, USB and Bluetooth connectivity, Hands-free calling, in-car internet and Wi-Fi.

D. Car Cameras

The camera is the most widely used capturing device used in lifelogging systems for capturing still images and videos¹⁹. Many researchers have recognized that images and videos can play a vital role in remembering the past

memories²⁰. One of the researchers²¹ presented a technique to detect daytime fog using a camera mounted on a moving vehicle. Furthermore, vehicular surveillance can be achieved using camera²². These cameras can be used for Vehicular lifelogging i.e. to have evidence in case of the unforeseen situation (such as an accident or assault, or break-in), to monitor and identify safety-related critical situations, to provide a facility for assistance like healthcare, or to simply record memorable events such as trips or birthdays²³.

E. Available Apps

There are varieties of Android applications available in app market which contains features related to vehicular environments²⁴. These applications are mostly getting data from OBD device connected with vehicles using Bluetooth technology. One of the most famous applications is Torque Pro, used to assist drivers to alert them about their cars²⁵. OBD eZWay application assists drivers to check fuel statistics, trip statistics, average speed, maximum speed, and driving time etc.²⁵. FuelLog an android application also provides information about fuel consumption, mileage, cost of the car, services etc.²⁶. Car Locator is an Android-based application, which provides information about car location that where you parked so that you can easily see²⁶. Speed View app uses smartphone built-in GPS sensors and displays information including car speed, direction, total traveled distance and remaining time to reach destination²⁶. Beat the Traffic application assists drivers and car owners by providing accurate traffic map available to date while navigating through busy cities²⁷.

ISSUES AND CHALLENGES IN VEHICULAR LIFELOGGING

Due to objects and human interactions, the world becomes an interconnected network²⁸. In this interconnected world, cars play an important role by giving a chance for vehicular lifelogging while driving on the road. However, a vehicular lifelogging system faces some issues and challenges, which need proper attention before the development of reliable and fine-tuned vehicular lifelogging systems. The main issues and challenges are discussed in the following sub-sections.

A. Privacy and Security Issue

Privacy and Security are assumed to be the key

elements for lifelogging systems ²⁸. By using the lifelogging technologies, risk of security and privacy may be raised when someone is intentionally sharing lots of personal information ²⁹. There may be possibility for an attacker or malicious user, to collect the personal information uploaded by individuals and then use for hacking purpose. The trend of vehicular lifelogging leads to a number of privacy and security issues, which need to be resolved on time in order to log the car as well as personal experiences. To highlight the significance and possible risks of vehicular lifelogging, we need to consider some real-life scenarios. When someone drives a car lonely or with family, he or she may visit different locations, he or she can stay somewhere for refreshment, he or she may use their mobile phones for making calls and messages. It means their life will be under surveillance which leads to some security and privacy risks, including location, memory threats which means that mistakes occur in life cannot be forgotten easily also in the long-term availability of personal information will remain even if his lifestyle and ideology has changed. In other words, you will not hide your driving style, your communications etc. from your children if your lifestyle is changed in the future.

B. Data Anonymization Issue

Regarding data anonymization, the important challenge in vehicular lifelogging is what to store and what not to store ³⁰. Every system that store personal information will always lead to privacy issues ³¹. Vehicular lifelogging systems need to automatically anonymize personal information before storing into the server so that the people whom the data describe remain anonymous. Solutions are needed to be developed to answer some common questions such as where to store data, who owns the stored data, what could be the lifetime of stored data, who will have to access the data etc. ³². To address this issue, vehicular lifelogging system needs to be designed so that a person might have a control to manually anonymize his/her own data before uploading ³³.

C. Storage Issue

The initial stage in generating lifelong is to gather the data in a non-intrusive manner ³⁴. Lifelogging systems are popular due to the availability of inexpensive data storage on the local devices as well as on the cloud. However, storage capacity available in the car is not much enough

as compared to personal computers. For the vehicular lifelogging systems, the huge amount of storage is required to store different type of data e.g. video data, vehicular data, image data, and sensory data ³⁵. Reading the data continuously from the sensors and other devices incurs overheads including increased memory size. For example, 16 hours HD video required about 90GB of storage capacity and for one year 32TB of storage capacity is required ³⁶. Therefore, vehicular lifelogging systems should be optimized to capture and store data intelligently by adjusting device readings and filtering the raw data.

D. Processing Issue

Bell pointed out in his paper that the future of lifelogging will probably bring us a massive storage in less amount of time with limited cost ³⁷. Due to the battery power improvements, capturing devices will never stop capturing data and will run all the time ³⁶. All these are possible with a dedicated infrastructure having a server for computation and complex algorithm for information retrieval. For the real-time assistant, vehicular lifelogging systems need to process a huge amount of data, which will be difficult for the state-of-the-art hardware of the car. In order to overcome the processing and storage issues, vehicular lifelogging system need to store the events rather than raw data.

E. Car Life Cycle and Transfer of Ownership Issue

All the vehicles are passed through distinct stages including manufacturing stage, operation stage and end-of-life stage ³⁸. According to a research carried out by Polk & Co, the average age of a vehicle is about 11.4 years on the road and the average time for changing new vehicle is about 71.4 months means almost 6 years whereas, for used vehicles, this interval is about 49.9 months ³⁶. This change of ownership will lead to some potential challenges in the development of vehicular lifelogging systems. Vehicular lifelogging systems are supposed to record every aspect of life on the road including car information, journeys, driver personal information, accidents, environmental information etc. However, it would be difficult for the car owners to switch such type of information from one car to another whenever they want to change their car.

F. Legal Issue

One potential issue that the user may face while

using vehicular lifelogging system is the empowerment of the individuals³. The personal lifelogs should be the property of person or person who creates them. Vehicular lifelogging system should be designed in a way that no one records the personal information of an individual without his/her proper permission. A customized system has to be designed in vehicular lifelogging systems in order to block lifelog surveillance when an individual is not agreed to allow others to log his/her personal information. Furthermore, to provide a full control over lifelog data, the owner of lifelogging should be able to delete or add the data. No one should be allowed to copy the lifelog or transfer the lifelog data without proper permission of the owner³⁹.

METHODS & MATERIAL

We conducted a study to learn about the user experiences of vehicular lifelogging systems and their possible issues. A random sample of 200 car owners has been interviewed in the university campus, which are depicted in Table 1. In the age group of 20-29, we have included 73% of BS & MS students and 27% of university employees. Above this age group, we have 70% of employees and 30% of students (enrolled in Ph.D.). Table 1, shows a complete picture of the selected sample. One reason for choosing this sample is the huge and diverse number of cars available on the university campus. In 200 selected sample, 11% are female car owners and the rest 89% were male car owners. The method of collection was semi-structured interviews.

Table 1: Demographics of sample

Age (Years)	Frequency	Percent
20-29	24	12%
30-39	66	33%
40-49	60	30%
50-59	36	18%
60-69	14	12%
Gender		
Male	178	89%
Female	22	11%
Camera in CAR		
No	192	96%
Yes	08	04%

RESULTS AND DISCUSSION

As shown in Table 1, most of the car owner (96%) do not have a camera in their cars. Only 4% of the total selected sample have a camera available in their cars as shown in the following Fig. 2. However, 98% car owners wish to have a camera in their car for different purposes including security and capturing different events as shown in Fig. 3.

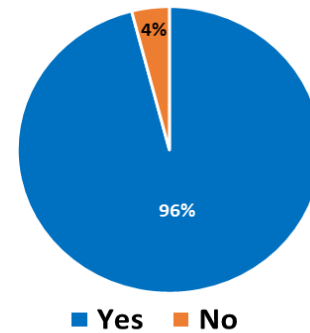


Fig 2: Camera Availability in CARs

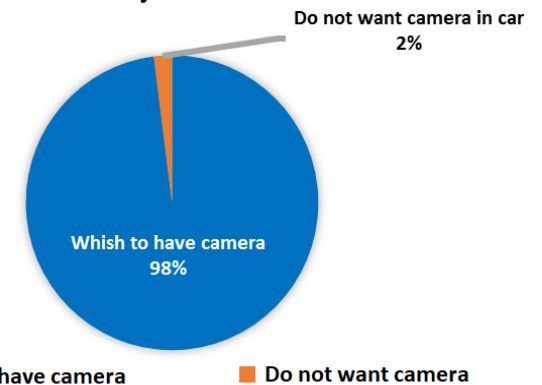


Fig.3: Number of car owners, wish to have a camera

When we asked about privacy leaks, 99% people were reluctant to have a camera that may expose their personal discussion or events. It means that privacy is a major hurdle in vehicular lifelogging. Asking for an email address and cloud storage package for storing digital data showed that almost 60% of people have an email address, while among this 60% (120) people majority of them 52.5 % (105) did not use cloud storage. This shows that we have to store most of the lifelogging data locally in cars. We have to manage proper storage devices in cars. Asking for existing facilities, sensor, dashboard design etc., 70% people were not satisfied. Advanced sensors were found only in 4% (i.e. 08 cars) latest model Japanese cars. However, they only inform a driver about low fuel, seatbelt, open door etc. They do not store this data for future use that may possibly generate some interesting and useful patterns about a car and its

maintenance.

RECOMMENDATIONS AND RESEARCH GUIDELINES

By investigating the issues and challenges discussed in Section III, we are presenting some guidelines that might be helpful for the designing of fine-tuned vehicular lifelogging systems. These guidelines will perform better in mitigating issues such as privacy and security, data anonymization, storage, processing, searching and retrieval, car life cycle and transfer of ownership and legal issues. These guidelines are:

1. Sustaining the privacy of individuals is the primary hurdle of lifelogging especially in those environments in which a variety of information has been exchanged between the users and devices. In order to ensure the privacy in vehicular lifelogging systems, the principles of privacy should be applied. These principles are openness, participation of individuals, limits of recorded data, data quality, limits of use, accountability and awareness²⁸. Openness needs to be established when the recorded information is transparent. Participation of Individuals should be ensured if recorded data need to be seen by individuals. Limit of Recorded Data should have to be imposed on specified application when required. Data Quality of stored data should be correlated and accurate to the application. Limits of Use should be imposed for the authorized user for an assessed purpose. Accountability of recorded data should be ensured and finally the awareness should be imposed based on user point of view.

2. Vehicular lifelogging systems may face the privacy issues as contain rich archive of personal life information. There is strong probability of damaging the logged data and could be misused. If the vehicular lifelogging systems also are left open for the individuals then someone can intentionally erase and change their data, which may also lead to further confusion.

3. To overcome the storage and processing issues, vehicular lifelogging systems need to filter out the information before storing into a storage device. Naturally, sensors and other data capturing devices are recording the data in raw form containing unnecessary readings, which need further preprocessing to filter out the meaningful events before storing into storage devices. For this purpose, it would be better to have a classifier that filter out meaningful events before storing into a storage device.

4. A Vehicular lifelog represents a collection of events, where each event would be represented and interpreted by textual annotation as a semantically meaningful metadata. Sematic annotation can be formed to extract contextual information by interpreting multiple source lifelog data for answering daily life common questions (i.e. who, what, when, where). Information retrieval techniques could be used in combination with semantic web indexing and querying technologies to extract and annotate fine-grained indexing and retrieval of information from large lifelog.

5. Switching the data during the car transfer of ownership is the key challenge to vehicular lifelogging systems. To sustain the integrity of logged data, it would be better to have a storage facility inside the car as well as on cloud. Data stored inside the car storage will be helpful for the real-time assistance and can be erased when car ownership is changed but data stored in the cloud will remain for the lifetime and only be accessible to the car manufacturing companies and law enforcement

CONCLUSION

With continuous economic growth, the number of vehicles are increasing rapidly. Currently, it is reported that about 1.2 billion vehicles are on the road and will be grown up to 2 billion by 2035. The primary goal of a vehicle is to carry someone or something from one location to another location. However, due to the latest technologies and sensors, modern vehicle can be used as vehicular lifelogging device. Since nowadays, people are spending a substantial part of their time in vehicles, so that their journeys, trips, vehicles information, and personal experiences can also be logged. The logged data could be used for various purposes including car owners, law enforcement agencies, memory augmentation, and recommendations. Despite numerous advantages of vehicular lifelogging, interest in this area is still broader and need proper attention to build such systems, as there are some issues and challenges. In this paper, we have articulated some prominent issues and challenges, which are discussed to mitigate that what has been done and what needs to be done in the form of different research opportunities and guidelines. These research opportunities and guidelines may be followed in coping with the latest problems, such as security and privacy, anonymization, storage, processing, searching

and retrieval, transfer of car ownership and legal issues.

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