Sensei No Kuruma : Car Advising System with Digital Forensic Evidence

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Abstract— Drivers need to be well-aware of the conditions of their cars. Most drivers, especially women, are not well-versed in automotive systems and functionalities. On the other hand, there are now many available mobile applications to assist drivers in terms of navigation as well as car maintenance. However, most of these applications on car maintenance provide very technical information that are not user-friendly for laymen. Our newly developed application aims to solve this problem by providing the list of trouble codes, with their respective descriptions, and suggestions to fix the problems. Hence, it is called Sensei No Kuruma ("Car Teacher" - in Japanese word) to give advice to the drivers regarding their cars. The application will connect to the On-Board Diagnostic (OBD) port of the car using ELM327 via Bluetooth. Additionally, the application also records all the diagnostic sessions for further assessments, and has an extra feature for parents to be alert on the presence of their children in the car. These features are possible through real-time extraction of digital forensic evidence. This app could be useful for car owners and drivers to know the condition of their cars. Additionally, the logging of the data can be useful for forensic purposes.

Keywords— car forensic, On-Board Diagnostic, mobile application.

I. INTRODUCTION

Driving a car without the technical know-how of the engine is common among drivers. The main purpose of having a car is for transportation– to take us wherever we want to go. However, most car owners and drivers are not well-versed about the in-vehicle systems and functionalities. An average car owner would take care of the car by maintaining routine services performed by workshops. If there is any abrupt or sudden technical issue with the car, the car owner would either bring the car to the workshop to be fixed or just simply ignore the error as long as the car can still provide its basic functions. A car advising system would be useful, whereby the owner is always updated on the condition of the car, whether it is related to safety, main functions, or supplementary functions such as for comfort purposes or driving assistance functions.

During forensic investigations, a complete and available record of data/information regarding the car would be useful. This would help the digital forensic investigator to conclude the investigation more accurately. For example, to determine whether an accident is caused by a faulty part, or driver's negligence, or simply an accident. Additionally, for the purpose of car maintenance, these well-kept records can help to increase the car value. This would make a clear evidence to the potential buyers especially during car resale.

II. RELATED WORKS

In-vehicle network security has been an important research area in the current era. Cars were originally designed for physical access and with physical in-vehicle communication only. Therefore, security was not considered for the in-vehicle network design. However, with the technology development, this has changed. The in-vehicle networks can be accessed from external without any physical connection, i.e. wirelessly and remotely.

There are a number of works discussed the issues and challenges of vehicle network security [1] [2] [3]. There are also works that introduced secure protocols to eliminate the security issues [4] [5]. Secure protocols are introduced for the different car applications for example for ECU firmware update [6] [7], digital forensics [8] [9] [10][[11] [12] and maintenance services [13].

In car digital forensics, data stored in the Event Data Recorder (EDR) of the vehicle is used as the digital evidence [14]. With the newer versions of cars, data from the telematics units that are used as the infotainment system, may also be useful for digital forensics [15]. However, this digital evidence is not accessible by the car owners. They can only be extracted by service providers or car manufacturers.

For car resale, a car might be of higher value if the maintenance services record is available. However, the record and the logging of the maintenance services may not be available as the current process is very hassle. The records of the maintenance services are either recorded in a log book of the car owner, or just a handful of receipts showing the services performed.

Currently, there are many available mobile applications that provide data extraction from the in-vehicle networks. We analysed three existing On-Board Diagnostic (OBD)

mobile applications that provide this service. These mobile applications which are Car Scanner [16], Torque Lite [17] and EOBD-Facile [18] are all using the same interface. The mobile application is connected to the car through ELM327 device. The ELM327 is the most widely used, practical, and supports all OBD protocols such as Keyword Protocol (KWP), Pulse-Width Modulation (PWM), Virtual Private Network (VPN), and Controller Area Network (CAN). Accessing to Electronic Control Units (ECUs) of vehicle is performed via OBD, where the data communicated within the in-vehicle network can be monitored. Then, combination of OBD with wireless technology can enhance the feature through mobile device applications. We analysed existing systems to gather useful information by evaluating and testing the application requirements and functionalities to help us to introduce improved features. All three applications (Car Scanner, Torque Lite and EOBD Facile) have the same functionalities. They can read diagnostic trouble codes (DTCs), can display real-time operating data in graphs for better visualization, and can monitor the performance of the electrical/electronic components through its diagnostic feature.

III. THREAT MODELLING AND SECURITY REQUIREMENTS

A. *Threat Modelling*

A threat modelling of the car maintenance system is analysed to identify potential threats. Among the common threats to car maintenance services are:

- **Unavailability of the maintenance record.** Car owners may not be particular to take a good care of their cars. Some would just ignore the routine services, and some may have financial difficulties to keep up with the car maintenance. This would affect the car performance and its life. Additionally, the records of maintenance services are either available on hard copy receipts or sometimes logged in a maintenance logbook, which could be hard to keep track. This may cause availability issue of the maintenance record.
- **Inaccurate data.** Some workshops may be practicing unethically, whereby the technicians may perform unwanted activities such as stealing parts, replacing parts with unauthentic parts, or not performing the actual required services but claiming to do so.
- **Unauthentic parts.** Using unauthentic parts in the car may cause performance issue as some parts are specially designed for the specific model of a car.

B. *Security Requirements*

Based on the threat modelling, the security requirements are as follows:

- Availability of the updated information/data regarding the car condition. Car owners need to be aware of the conditions of the car. Any problem or issue should be alerted to the car owner, and the level of urgency to get the issue fixed also need to be informed to the car owner/driver. Workshops having the full information can alert the car owners for the required services.
- Integrity-protected data. Any information updated to the car owner must be integrity-protected. Only correct and authenticated messages are communicated through the in-vehicle networks, and updated to the car owner/driver.
- Authenticity of the parts. Parts used must be authentic to ensure full functionality and compatibility.

IV. PROJECT DESCRIPTION

Based on the security requirements, and our literature review, we propose a solution that considers all the limitations in other available applications.

A. *Proposed Solution*

We developed an Android-based mobile application, whereby the application is to assist car owners to know the conditions of their cars. The app is named as "Sensei No Kuruma", which means "Car Teacher" in Japanese.

B. *Tools used*

For this project, the hardware involved are the Xiaomi Mi A3 phone, and ELM327 with Bluetooth connection as shown in Fig. 1. The ELM 327 is connected to the OBD port of the car, and act as the interface between the mobile app and the in-vehicle networks.

Fig. 1: ELM 327 with Bluetooth interface

For software, we use Android 9.0, and Android Studio 3.5 for development.

C. *Features of the application*

Looking at the three existing apps, all the features are useful for maintenance purposes. However, they are not user-friendly for laymen, where technical terms are used in all the apps. Hence, our app may provide assistance in a form of advice and urgency level indication as a user-friendly feature for laymen to use. TABLE I shows the comparison of features among existing applications.

TABLE I

COMPARISON OF FEATURES AMONG EXISTING APPLICATIONS AND SENSEI NO KURUMA

Application/ Features	EOBD Facile (Free)	Torque (Free)	Car Scanner	Sensei No Kuruma
Connected using ELM 327 interface	√	√	√	√
Reading of DTCs	√	√	√	√
Recording of DTCs	√	X	√	√
Recording of customised report	x	X	X	√
Child alert system	x	X	X	√

Additionally, as this is an app to assist drivers, a child alert system is also considered. Every year, there are many cases of children dying from heat stroke and hyper-thermia due to being left unattended in parked cars. There are a few existing applications of car seat apps that could help lessen the risk of leaving children behind, which are Waze, Kars 4 Kids Safety App and The Backseat App. Some of them are connected to the car system, and will automatically give alert when the driver leaves the car, while some apps require manual user input to initiate the alert system. Fig. 2 shows the features in the app.

Sensei No Kuruma is developed to assist car owners to know the conditions of the car. Hence the features include the list of diagnostic trouble codes (DTCs) with the respective advice and actions to be taken, nearby workshops providing the maintenance and repair services, and an alert system for child's presence in the car.

a) DTCs and advice. Whenever the app is connected to the car, any error codes/DTC happening in the car will be sent to the app. The app will show the respective DTC with the level of urgency to fix the problem indicated by a color-coded box (Red, Yellow, Green). It will then advise the driver on how to fix the issue, or ask the driver to send the car to the nearest workshop providing the related services. The *advice is* easily comprehended by laymen as the words/terms used are non-technical by pointing out which component is giving the error, and what can be done to fix it. The color code indicates the level of urgency to get the error fixed (i.e. red box indicates - very urgent and important, yellow – urgent but not important, green – not urgent and important). If the issue requires technical expertise, then, it *advises* accordingly.

b) *Navigate to the nearest available workshop.* Based on the location of the car (through Global Positioning System (GPS) signal of the phone), the app will advise the driver to the nearest available workshop providing the related services.

c) *Child presence alert system.* This is the extra feature of the app that is useful for parents. This will alert parent on the presence of a child during a trip. When the car stops, the app will alert the driver so that he/she would not forget about the child in the backseat.

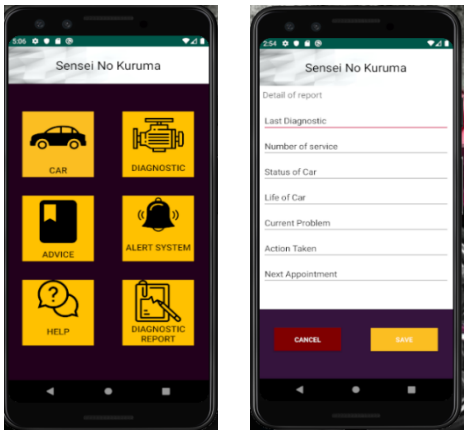

Fig. 2: Features of Sensei No Kuruma

V. CONCLUSIONS AND FUTURE WORK

This app would be useful for car owners and drivers to know the condition of their cars. Additionally, the logging of the data can be useful for forensic purposes. Other than the maintenance record, the operating data can also be recorded, hence can be used as the forensic evidence. For example, the location of the car and the speed of the car during an incident or at a particular time. The app is useful for laymen to know the well-being of their cars, and useful for parents with the child alert system.

Next phase is to include more features for security functions. For example, to include the integrity protection to ensure no data is changed/modified during the transmission, and during the storage. Integrity is an important requirement if this app is going to be used as an evidence in forensic investigations. Another important feature is to ensure the confidentiality of the transmitted data. Some of the data must be protected to ensure privacy of the car owners, for example the location of the car must not be accessible by unauthorized party.

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