Software Impacts 19 (2024) 100601

Contents lists available at ScienceDirect

Software Impacts

journal homepage: www.journals.elsevier.com/software-impacts

Original software publication

Smartphone-based extendable telematic data collection app

Thompson Iniakpokeikiye Peter [a,*], Ehud Reiter [b], Dewei Yi [b]

[a] Department of Computing Science, University of Aberdeen King's College, Aberdeen, United Kingdom
[b] Department of Computing Science, University of Aberdeen King's College, Aberdeen AB24 3FX, United Kingdom

ARTICLE INFO

Keywords:
Smart phone applications
Road safety
Driving data
Driving behaviour

ABSTRACT

There are three research objectives we set out to achieve in this work: to conceive and execute a dedicated smartphone-based driving data collection application that is carefully tailored for the acquisition of driving data from Nigerian drivers, add a layer that enables drivers to report external influences that affected each trip of their driving period, and to enhance its versatility by openly sharing the associated source code to facilitate adaptation for diverse driving data collection endeavours by researchers. This is very pertinent in the rapidly evolving landscape of transportation and road safety, where the need for comprehensive and accurate data on driving behaviours have become increasingly evident. Understanding how drivers behave on the road is essential for improving road safety, optimizing traffic management, and devising effective transportation policies. However, collecting real-world driving Behaviour data, especially in developing countries such as Nigeria, presents numerous challenges. Our innovative system not only efficiently collects invaluable driving data but also sets a new precedent for adaptability and collaboration within the research community.

Code metadata

Current code version	*v1*
Permanent link to code/repository used for this code version	https://github.com/SoftwareImpacts/SIMPAC-2023-456
Permanent link to Reproducible Capsule	
Legal Code License	*MIT License*
Code versioning system used	*git*
Software code languages, tools, and services used	*Room Database, Kotlin and Android Studio*
Compilation requirements, operating environments & dependencies	*Room Database, Kotlin Coroutine, Hilt Dependency Injection, Android lifecycle-livedata, Google Play Services, EventBus, GSON, CSV Writer*
If available Link to developer documentation/manual	
Support email for questions	iniakpothompson@gmail.com

1. Introduction

Real time driving behaviour analysis of drivers requires only real live driving data, this is even more necessary where technology and innovation are considered as identified by the Federal Road Safety Corps (FRSC) [1] . Some of these technologies are machine learning and AI [2], and these require a great amount of data. More so, in Nigeria, several research has gone into understanding the driving behaviour of drivers, but most of these studies have applied methods such as interviews, surveys through questionnaires and or road side observations [3–6]. These cannot engender solutions that would deal with real time interventions by both researchers and relevant intervention agencies. This is evident in our inability to obtain already existing and required real time driving data from Nigeria. This made us to develop this application to enable us collect such real live driving data from Nigerian drivers that are suitable for the training of Machine learning models that are capable of identifying driving behaviours of drivers in Nigeria.

2. High level functionality of the App

- At the commencement of a trip, the driver initiates the "Register Device" button to generate a unique token to identify the driver's device (see Fig. 1).

* Corresponding author.
E-mail addresses: i.thompson.21@abdn.ac.uk (T.I. Peter), e.reiter@abdn.ac.uk (E. Reiter), dewei.yi@abdn.ac.uk (D. Yi).

https://doi.org/10.1016/j.simpa.2023.100601
Received 27 October 2023; Received in revised form 18 November 2023; Accepted 22 November 2023

Fig. 1. Register device screen.

- Grant permissions for storage and physical activity (See Figs. 2 and 3).
- The data collection process is started by tapping the 'START TRIP' button. This action activates the application, enabling the collection of data as the vehicle moves (See Fig. 4).
- Upon completing a trip, the driver is expected to tap the 'STOP TRIP' button, concluding phase one of the data collection process (See Fig. 5).
- It is important to note that at the beginning of a trip, the screen called after the "Register Device" will have the button labelled "Start Trip". But when this button is tapped, the button text changes to "Stop Trip". (See Figs. 4 and 5).
- Phase two involves a post-trip survey form that appears immediately after tapping the 'End Trip' button. This form allows drivers to voluntarily report factors that influenced their driving during the just-concluded trip (See Figs. 6 and 7).
  - Two predefined actions that might influence driver behaviour, namely, alcohol consumption and overloading, are hard-coded into the app. Drivers can select 'Yes' or 'No' based on occurrences during the trip.

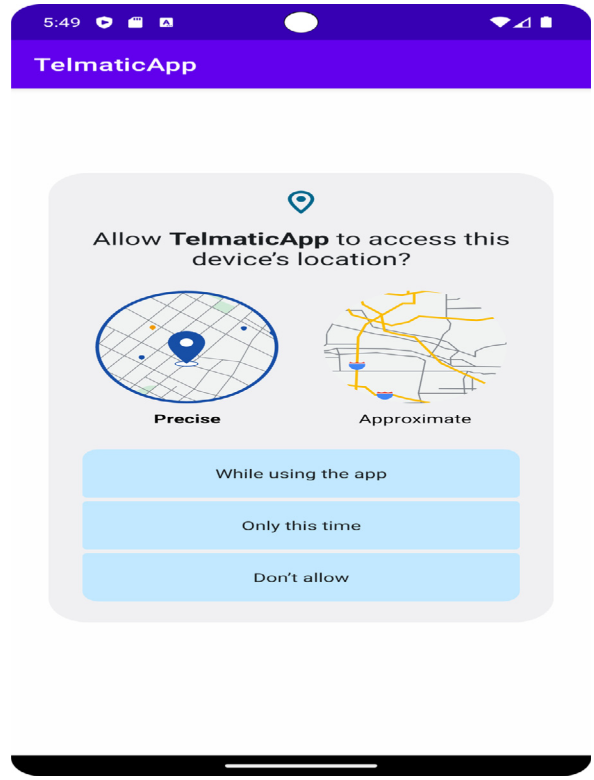

Fig. 2. Grant location permission.

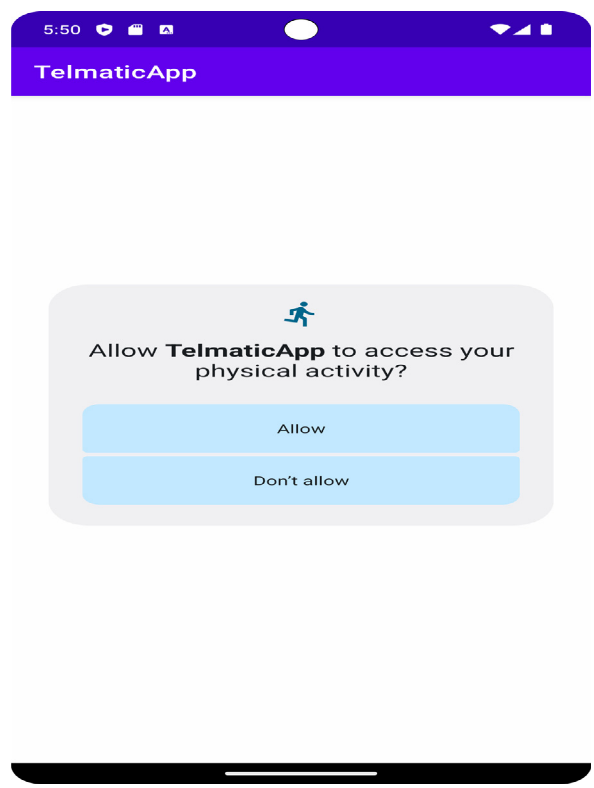

Fig. 3. Grant motion activity permission.

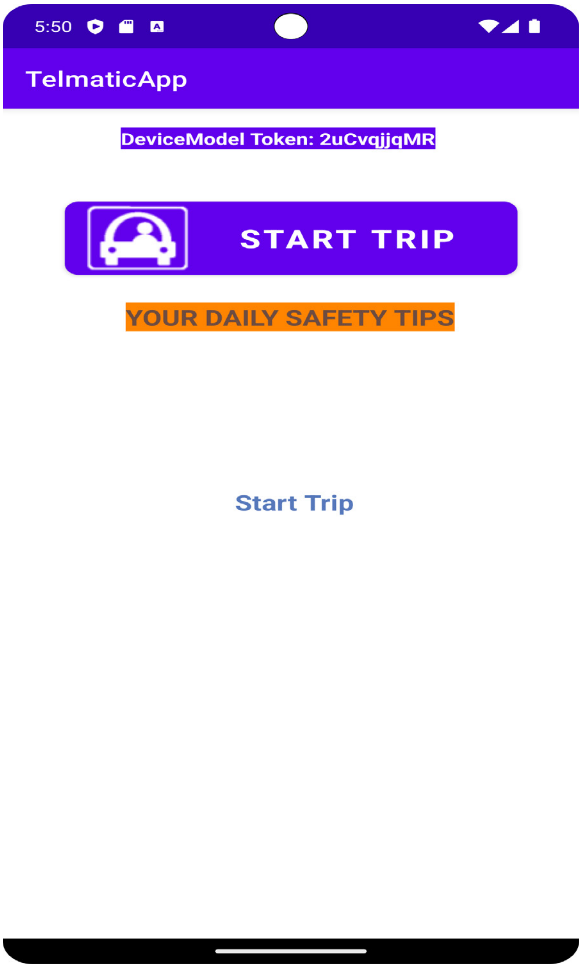

Fig. 4. Start Trip.

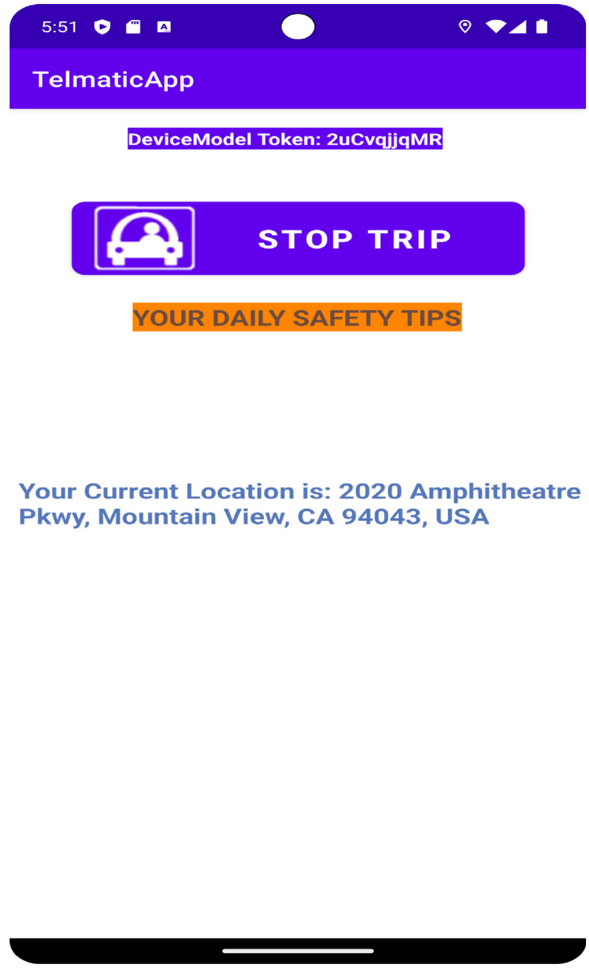

Fig. 5. Stop Trip.

  – Additionally, an open-ended question encourages drivers to specify any other factors that may have affected their driving.

- All generated data are stored to a room database on the phone.
- To extract this data, the phone is connected to android studio, either through a USB cable or Wi-Fi connection.
- While the app is running on the phone in that connected mode, the database is explored and exported from the app to the local computer using the App Inspection tool at the bottom of the android studio (See Fig. 9).
- Subsequently, the extracted data is transferred to the researchers' desired destination for use.

2.1. Problem statement and research objectives

The central problem addressed by this research is the scarcity of reliable and comprehensive real-world driving Behaviour data in Nigeria. Existing data sources are often fragmented, outdated, or insufficient for a country of Nigeria's size and complexity. To bridge this gap, our research aims to achieve the following objectives:

1. Develop a cost-effective and scalable methodology for collecting real-world driving Behaviour data.
2. Utilize smartphone technology as a data collection tool to capture diverse driving conditions.
3. Make the code open source and adaptable with a layer to collect external factors affecting driving behaviour.

The system is developed using the Model View View-Model (MVVM) design pattern. The architecture is as shown in Fig. 8.

3. Related work

3.1. Significance of data collection for driving behaviour analysis

Real-world driving Behaviour data are essential for several reasons. First, they provide insights into the factors influencing driver Behaviour, including road conditions, traffic congestion, and weather. Second, such data are instrumental in identifying risky Behaviours and patterns that contribute to accidents and traffic violations. Third, real-world data serve as a foundation for evidence-based policy development and transportation system optimization. The importance of real-world data in enhancing road safety, particularly in car safety development is highlighted in [7]. They explored various data collection methods, including mail surveys, document case studies, and video-recordings, to study driver Behaviour in incidents and accidents.

The importance of the collection and analysis of driving data, is said to play a crucial role in enhancing vehicle safety and mitigating road traffic accidents caused by various driving Behaviours [8], particularly through the use of on-board sensors and technology like the CAN bus. This is even as it underscores the significance of leveraging data to identify, predict, and address driving Behaviours effectively [8].

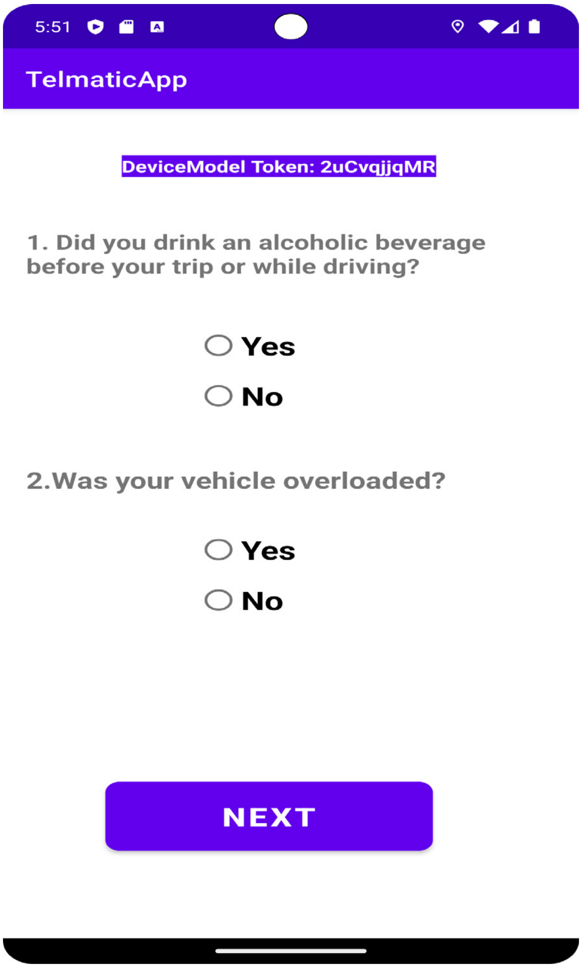

Fig. 6. Trip influence report form 1.

3.2. Smartphone-based data collection Apps

In recent years, the proliferation of smartphones have opened new avenues for collecting driving Behaviour data. These devices are equipped with a range of sensors, including accelerometers, GPS, and cameras, making them ideal tools for capturing real-world driving experiences. Several studies have explored the potential of smartphone-based data collection methods, including the use of dedicated mobile applications, to collect driving Behaviour data efficiently and at a lower cost compared to traditional methods. A novel system called MIROAD uses Dynamic Time Warping (DTW) and smartphone-based sensor-fusion to detect, recognize, and record potentially aggressive driving Behaviour [9]. This system is mobile, effective, and inexpensive, detecting and recording events that characterize a driver's style. The system uses inter-axial data from multiple sensors into a single classifier and uses Euler representation of device attitude.

[10] presents SenseFleet, a new mobile device and vehicle-independent driver profiling and scoring application that detects acceleration, braking, steering, and over-speeding events by fusing motion sensors and GPS data. The platform uses a calibration phase to adapt fuzzy set limits for event detection for multiple devices and vehicles. It also proposes a scoring algorithm that considers context information like weather conditions and time of day.

A portable device using an Android-based smartphone's three-axis accelerometer to analyse driver Behaviours and external road conditions is proposed in [11]. The device can evaluate vehicle conditions, including gear shifts and road conditions like bumps, potholes, rough roads, and smooth roads.

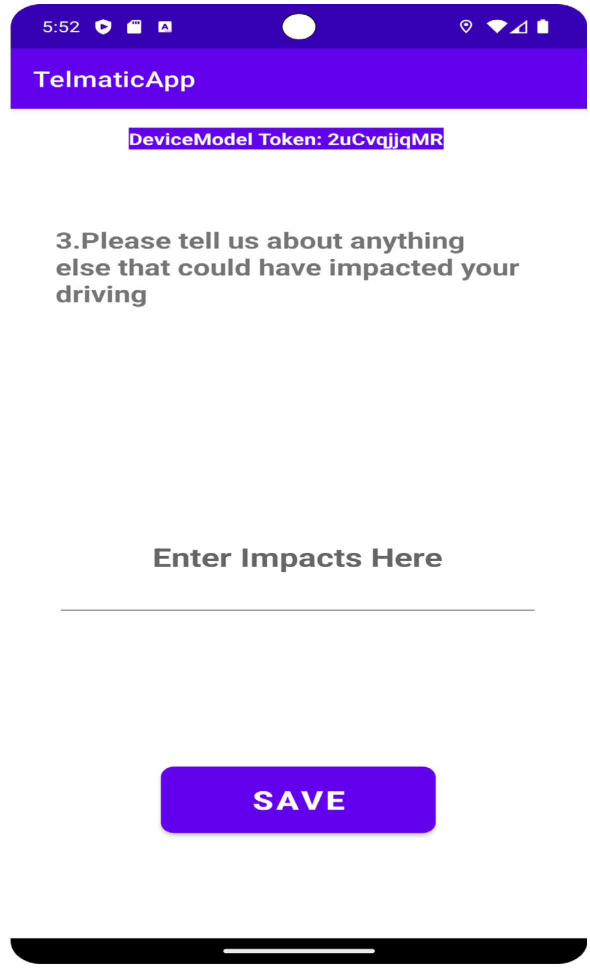

Fig. 7. Trip influence report form 2.

The study by [12] proposes a fine-grained system, D3, to improve driving safety by detecting and identifying specific types of abnormal driving Behaviours. The system uses smartphone sensors to detect acceleration and orientation, and uses machine learning methods like Support Vector Machine (SVM) and Neuron Networks (NN) to train features and output a classifier model.

In [13] an adaptive driving manoeuvre detection mechanism that builds a statistical model of the driver, vehicle, and smartphone combination using a multivariate normal model is being proposed. The system adapts to different driving conditions and device types, avoiding dependency on a priori training data.

A highly efficient system for early detection and alerting of dangerous vehicle manoeuvres related to drunk driving is presented in [14]. The system uses a mobile phone with an accelerometer and orientation sensor to compute accelerations and compare them with typical drunk driving patterns. If any evidence of drunk driving is present, the phone will alert the driver or call the police. The system achieves high accuracy and energy efficiency, with plans to integrate all available sensing data on the mobile phone.

Damoov's [15] mobile telematic app is able to collect raw telematic data as well as other driving behaviour data for the purpose of safe driving. Application Programming Interfaces (APIs) are provided by [15] for developers for the purpose data retrieval, sensors activation and deactivation and user on-boarding.

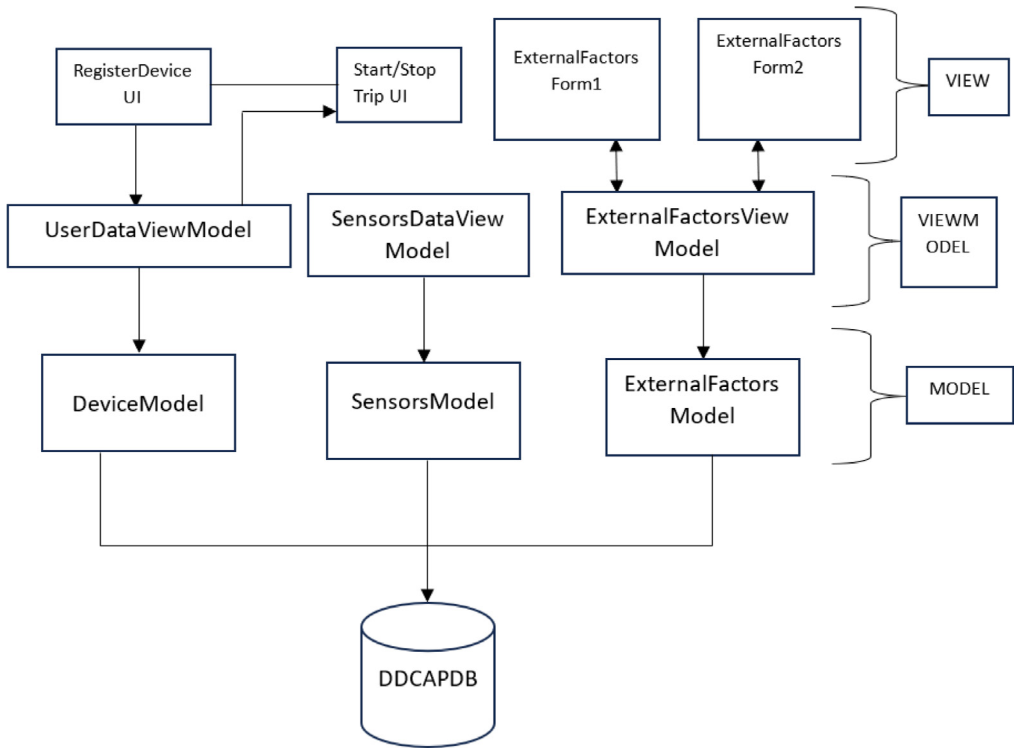

Fig. 8. Smart phone driving data collection App architecture.

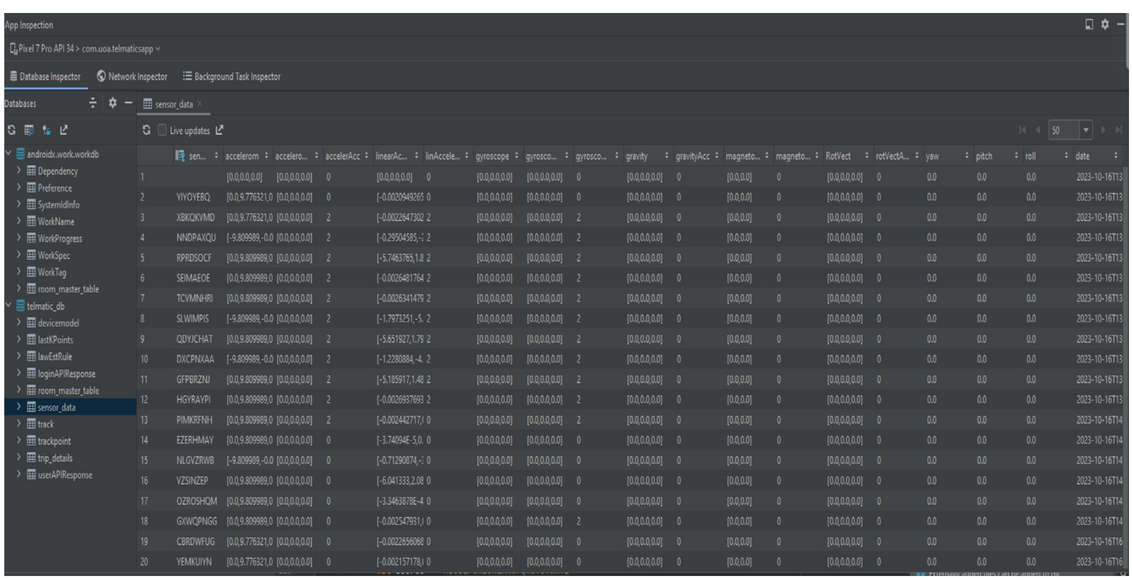

Fig. 9. Exploring database for export.

3.3. Research gap

While smartphone-based data collection methods hold significant promise, there remains a gap in the literature regarding their application in data-scarce regions, particularly in developing countries such as Nigeria. Also, none of the proposed smartphone data collection solutions in the literature primarily focus on the core aspects of raw driving data collection, rendering them less suitable for future research purposes aimed solely at raw driving data collection for driving behaviour analysis. More so, data relating to external factors are not mostly considered in the design of the proposed apps in the literature. More so, retrieval of the collected data poses a challenge to researchers, because they rely on the developers of these apps to access the data collected and stored in the developers servers.

Therefore, the unique challenges posed by Nigeria's road infrastructure, traffic and socio-cultural conditions necessitate a tailored approach to collecting real-world driving Behaviour data, especially at a time when there is a high rate of smartphone penetration.

This study seeks to bridge these identified gaps by developing a dedicated smartphone-based data collection system tailored specifically for gathering driving data from Nigerian drivers. Furthermore, we aim to enhance its adaptability for use in various driving data collection projects, with an emphasis on open-sourcing the associated code. By doing so, we hope to contribute to the growing body of knowledge on smartphone-based data collection methods for driving Behaviour analysis and their potential impact on road safety and transportation policy.

4. Impact overview

In their studies, [4,16] used interviews, questionnaires, and road-side observations to gather the data for their analysis. As an improvement on these data collection methods, our app provides researchers and any one concerned with road safety the capability to be able to collect real-time driving data directly from drivers as they drive, utilizing a mobile phone within the vehicle. This is accomplished by installing the app on the Android mobile phones of recruited real-life drivers. With this app, researchers in transportation and driving safety in Nigerian can easily collect real-live driving data.

The feature of the app that enables drivers to report the factors that influenced a trip at its end adds more utility to the app that engineers the real time labelling of trips such that the data is easily adaptable for machine learning purposes.

The app also has the potential to be used as a tool to start an independent data gathering of anonymous driving data from real live drivers who drive on the roads in Nigeria, because presently, real-live driving data-sets are very scarce and this app is also a contribution towards solving this problem which will help requisite transport safety research, especially as it affects drivers behaviour and safety. We deployed the app as part of our wider PhD research project to capture diverse drivers driving data in Nigeria. Areas the app was deployed include the roads from South–South to North-Central, South–South to South-East, and South–South to South-West geopolitical zones of Nigeria, including some rural villages and some notable cities such as Abuja, Lagos, Port-Harcourt, Yenagoa, and Oweri all in Nigeria. This first real world deployment of the app enabled the successful collection of over 400,000 data points which are currently been analysed as part of the research requirements a wider PhD research project.

Plans are also on the way to setup an independent real live driving data collection hub, using the app as the data collection tool.

5. Limitations

Our smartphone-based real-world driving data collection app represents a crucial step towards enhancing road safety and transportation planning.

To enhance the data collection process, it is imperative to further investigate and optimize sensor data rates. This includes exploring hardware and software solutions that may increase the sampling frequency of smartphone sensors. By doing so, we can collect more granular and detailed driving behaviour data, which can provide richer insights for analysis.

Future iterations of this application will also consider the inclusion of weather conditions through weather APIs as part of the collected data. Weather conditions can significantly influence driving behaviour, and capturing this information can provide valuable context for analysis. Incorporating weather data can enhance the comprehensiveness of driving behaviour analysis and contribute to a deeper understanding of how weather factors impact road safety.

The data collected does not include roads speed limits. This is partly due to the cost of accessing speed limit APIs from map providers as well as our discovery to the fact that major map providers speed limit APIs only covers either partially (a small number of roads) or no Nigerian roads in particular. Notwithstanding, future updates to the app will include speed limits, especially future versions that focuses specifically for collecting data from Nigerian roads.

More so, data is stored on the phone in a local database, which may impact performance, future iterations will use an API to store the data real time to an online database or data repository.

Illustrative example

https://youtu.be/91xMeTcY6IY.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Thompson Iniakpokeikiye Peter reports financial support was provided by Tertary education Trust Fund.

Acknowledgements

We extend our heartfelt gratitude to the individuals and organizations that made this research endeavour possible. First and foremost, we would like to acknowledge the voluntary efforts of the drivers at Deprize Motors and others at Etegwe Roundabout Motor Park, Yenagoa Bayelsa State Nigeria.

We also extend our sincere appreciation to Mr. Kabiru Momodu, a key collaborator in this research project. His tireless efforts in mobilizing and coordinating drivers, as well as his commitment to the project's success, played a pivotal role in data collection and use of the software in a real world scenario.

Furthermore, we would like to express our gratitude to the Tertiary Education Trust Fund (TetFund) for their generous sponsorship of this research. Their support made it possible to undertake the bigger PhD research project, focusing on the use of AI/NLG-enabled mobile apps for driving Behaviour change and the promotion of safe driving practices in Nigeria.

Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.simpa.2023.100601.

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