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DriveGuard: enhancing vehicle breakdown assistance through mobile geolocation technology

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ABSTRACT

The DriveGuard mobile application addresses the growing demand for efficient vehicle breakdown assistance by connecting users to nearby workshops using advanced geolocation technologies. With the rise in private vehicle ownership, sudden breakdowns are increasingly common, necessitating quick access to assistance. DriveGuard utilizes GPS, GSM/CDMA Cell IDs, and Wi-Fi positioning for precise location tracking, enabling users to locate assistance rapidly and accurately. Developed through the waterfall model, the application offers a user-friendly interface built with the Flutter framework. Test results indicate high functionality and user satisfaction, achieving usability ratings between 88% and 90%. DriveGuard's design improves road safety by reducing waiting times for emergency services, alleviating the stress often associated with breakdown situations. Future work will focus on expanding service options, enhancing security, and refining user interactions to provide a more comprehensive roadside assistance tool. DriveGuard demonstrates the potential of mobile technology in promoting safe and efficient transportation.

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1. INTRODUCTION

The advent of technology has significantly transformed how individuals interact with their surroundings, especially in the realm of transportation. Increased reliance on cars as a primary mode of transportation has inevitably led to more vehicle-related challenges, particularly sudden breakdowns. These incidents not only cause inconvenience but also pose safety risks to drivers and passengers. In Malaysia, the number of registered vehicles surged to 17.7 million by December 2021, reflecting a substantial increase of 64.3% over a decade [1]. This growth underscores the need for efficient systems to assist drivers during vehicle breakdowns [2]. Traditional methods of locating workshops through signboards or word of mouth are time-consuming and often ineffective, particularly in unfamiliar areas. The integration of geolocation technology in mobile applications presents a promising solution to this problem [3]. This paper introduces DriveGuard, a mobile application designed to provide real-time assistance to drivers by connecting them with nearby workshops using GPS technology.

2. LITERATURE REVIEW

Transportation is a critical component of modern society, facilitating the movement of goods, services, and people [4]. Public and private transportation systems have evolved to meet the growing demands of urbanization and globalization. Private transportation, particularly the use of personal vehicles, has seen a dramatic rise, leading to an increased need for maintenance and repair services [5]. Vehicle breakdowns, whether due to mechanical failure or lack of regular maintenance, are a common occurrence. Literature indicates that while regular maintenance can reduce the likelihood of breakdowns, it cannot entirely prevent them [6]. In cases of sudden breakdowns, the availability of nearby assistance becomes crucial. Several vehicle assistance technologies are highlighted in the literature: i) geolocation technology roadside assistance [7], [8], ii) telematics-based breakdown assistance [9], iii) connected vehicle breakdown detection [10] and iv) AI-driven predictive maintenance systems [11], [12]. Based on this vehicle assistance technological assistance, this paper delves into geolocation technology, a technology that enables precise vehicle tracking, ensuring rapid and accurate service response times during breakdowns. Further, geolocation technology helps roadside assistance teams locate vehicles faster, reducing wait times and enhancing the overall customer experience [7].

Geolocation technology, which allows for the precise determination of a device's location, has been extensively explored in various fields. GPS, a satellite-based navigation system, is one of the most widely used geolocation technologies [13], [14]. It provides accurate positioning by triangulating signals from multiple satellites. GSM/CDMA Cell IDs and Wi-Fi positioning are alternative geolocation methods, each with its strengths and limitations. For instance, while GPS is highly effective in outdoor environments, its accuracy diminishes indoors, where Wi-Fi positioning can be more reliable [15], [16]. Existing applications such as Google Maps, Waze, and Grab utilize GPS and other geolocation technologies for navigation and location-based services [17]. However, these applications are primarily focused on navigation and do not specifically address the need for emergency vehicle assistance. This gap highlights the potential for a dedicated application like DriveGuard. Base on the previous studies, it was noted location-based services (LBS) are applications services that leverage geolocation technology to provide users with geographically relevant information and assistance [18]–[20]. Typically implemented through GPS, Wi-Fi, and cellular networks, LBS spans multiple sectors, from emergency response to commercial applications. LBS offerings generally include person-oriented services, which adapt information to the user's specific location, and device-oriented services, which track the device itself [21]. These services are delivered in two main formats: "push" services, which automatically send users information based on location, and "pull" services, which require users to retrieve information actively [22]. Thus, to further enhance the functionality, the development of DriveGuard application, aims to connect users with nearby repair services during breakdowns, extending LBS capabilities from conventional navigation to specialized emergency assistance, thereby filling a critical niche within the LBS landscape.

3. METHOD

The development of DriveGuard followed the waterfall model approach. This approach was chosen due to its linear and sequential nature, which is well-suited for projects with clearly defined requirements [23]. The project began with the planning phase, where the problem statement, objectives, and scope were established. This is then followed by the analysis phase, which involved a thorough review of existing literature and technologies related to geolocation and vehicle breakdown assistance. Based on the findings, the GPS and GSM/CDMA Cell ID geolocation techniques were selected for integration into the application. In the design phase, the application's system architecture was outlined, focusing on the user interface and the backend database [15]. The user interface was designed using Flutter, a cross-platform framework that enables the creation of visually appealing and responsive interfaces. Firebase was chosen as the backend database due to its real-time data synchronization capabilities, which are essential for the application's functionality. Implementation included coding in Dart, integrating the Google Maps API for geolocation, and developing key features such as user registration, login, and request submission. The final phase, testing, was crucial to ensure the application's functionality and usability. Functional testing was conducted to verify that all features operated as intended, while usability testing involved user feedback to assess the application's ease of use and overall user satisfaction. The results from these tests were analyzed to identify any issues and make necessary improvements.

3.1. System architecture

The system architecture of the DriveGuard project is illustrated in Figure 1. It comprises several key modules: a) the location module, b) the nearby workshop module, c) the request module, and d) the service type module. These modules work cohesively, storing interactions and service requests in a central database, ensuring seamless data flow from location identification to service request fulfillment and enhancing the user experience within the DriveGuard application. First, the location module is responsible for retrieving user location data, including coordinates and addresses, using Flutter packages. This module plays a critical role by supplying data to subsequent modules. Next, the nearby workshop module utilizes the user's location to identify and display registered workshops within proximity, calculated based on distance from the user. Then, the request module facilitates user interaction with the identified workshops, enabling service requests. Integrated with the Google Maps SDK, this module displays a map and allows users to select a nearby workshop based on their service needs. Finally, the service type module enables users to specify the service required from the chosen workshop. These modules function collaboratively, with all interactions and service requests stored centrally in the database, ensuring efficient data management and a smooth, user-friendly experience.

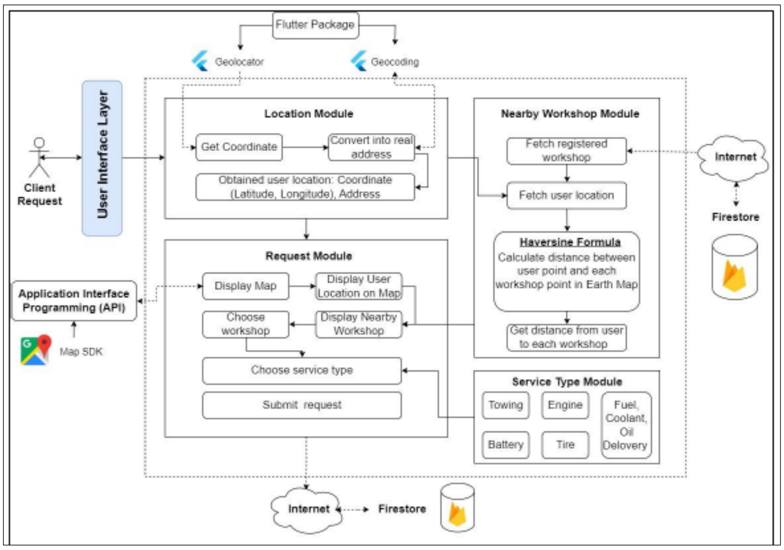
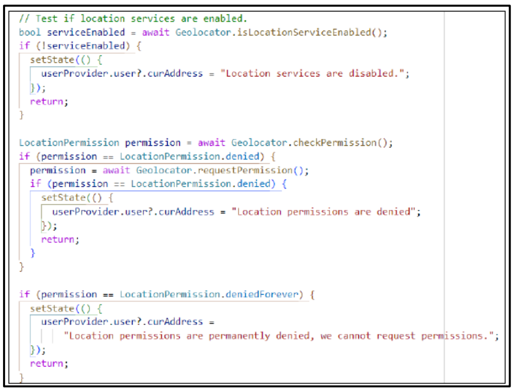


Figure 1. DriveGuard system architecture

3.2 Geolocation implementation

DriveGuard's geolocation technique in Figures 2 and 3 implemented in this project is through a hybrid approach, combining GPS for precise outdoor location tracking and GSM/CDMA Cell ID for continuous coverage, especially in areas where GPS signals may be obstructed. This combination supports the application's LBS by providing an accurate, real-time location data, enabling users to find nearby vehicle assistance efficiently. The Haversine Formula further enhances this functionality by calculating the distance between the user and workshops based on GPS or Cell ID coordinates, prioritizing closer workshops for faster assistance and a smoother user experience [24], [25].

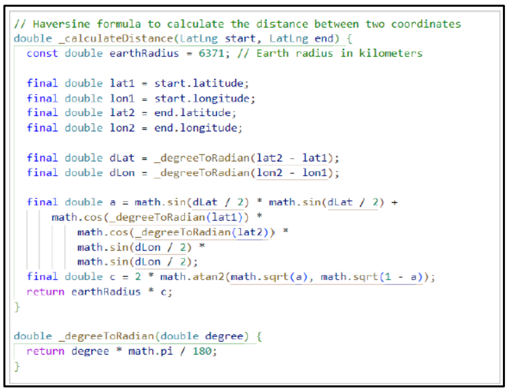


```
// Test if location services are enabled.
bool serviceEnabled = await Geolocator.isLocationServiceEnabled();
if (!serviceEnabled) {
  setState(() {
    userProvider.user?.curAddress = "Location services are disabled.";
  });
  return;
}

LocationPermission permission = await Geolocator.checkPermission();
if (permission == LocationPermission.denied) {
  permission = await Geolocator.requestPermission();
  if (permission == LocationPermission.denied) {
    setState(() {
      userProvider.user?.curAddress = "Location permissions are denied";
    });
    return;
  }
}

if (permission == LocationPermission.deniedForever) {
  setState(() {
    userProvider.user?.curAddress =
        "Location permissions are permanently denied, we cannot request permissions.";
  });
  return;
}
```

Figure 2. Location services permission



```
// Haversine formula to calculate the distance between two coordinates
double _calculateDistance(LatLng start, LatLng end) {
  const double earthRadius = 6371; // Earth radius in kilometers

  final double lat1 = start.latitude;
  final double lon1 = start.longitude;
  final double lat2 = end.latitude;
  final double lon2 = end.longitude;

  final double dLat = _degreeToRadian(lat2 - lat1);
  final double dLon = _degreeToRadian(lon2 - lon1);

  final double a = math.sin(dLat / 2) * math.sin(dLat / 2) +
      math.cos(_degreeToRadian(lat1)) *
          math.cos(_degreeToRadian(lat2)) *
          math.sin(dLon / 2) *
          math.sin(dLon / 2);
  final double c = 2 * math.atan2(math.sqrt(a), math.sqrt(1 - a));
  return earthRadius * c;
}

double _degreeToRadian(double degree) {
  return degree * math.pi / 180;
}
```

Figure 3. Haversine formula

3.3. User interface

The user interface (UI) design of the DriveGuard application aims to create an intuitive, user-friendly experience, essential for a LBS application with geolocation functionality. Developed using the Flutter framework, the UI components are visually appealing and enable smooth navigation across pages. Among the main UI elements include: a) home page, b) request page, and c) history page. Each of these UI is shown in Figures 4 to 6.

Figure 4. Home page

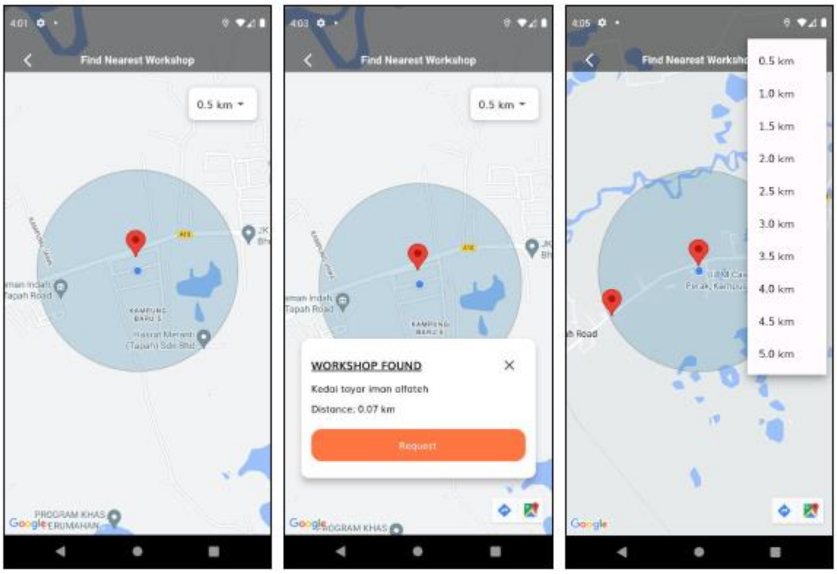


Figure 5. Request page – finding nearest workshop

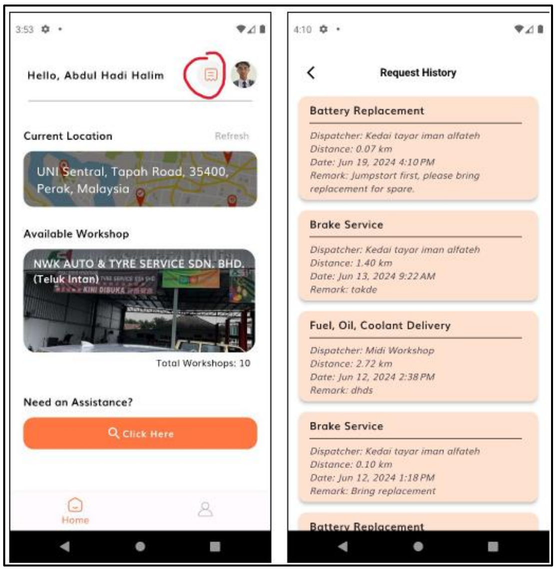


Figure 6. History page

4. RESULTS AND DISCUSSION

The DriveGuard application was successfully developed and tested. The functional testing in Table 1 confirmed that the application's features, including user registration, login, and request submission, worked seamlessly. The geolocation functionality, powered by the Google Maps API, accurately detected user locations and displayed nearby workshops. The integration of Firebase ensured that user data was stored securely and synchronized in real-time across devices.

Usability testing in Table 2 involved 15 participants who evaluated the application based on criteria such as understandability, learnability, operability, and attractiveness. The results were overwhelmingly positive, with usability scores ranging from 88% to 90%. Participants particularly appreciated the intuitive interface and the application's efficiency in locating nearby workshops. However, some suggestions were made to enhance the user experience further, such as adding a feature to filter workshops based on specific services offered.

Table 1. Functional test result

No.	Test case	Test scenario	Test result
1	Start-Up	User run the application in smartphone.	√
2	Login	User input their registered email and password and click login button.	√
3	Register	User input the detail in the registration form and click register button.	√
4	Forgot/reset password	User input the registered email and click the send button.	√
5	Fetch user location	User clicks the refresh button or tap on the address to update the latest address.	√
6	Displaying map	User clicks the “Click here” button on the homepage and navigated to the request page.	√
7	Find nearby workshop	User check whether there is any workshop found within the searching radius.	√
8	Change preferred distance	User changes the preferred searching distance by using the filter button.	√
9	Request found workshop	User clicks the detected workshop and submit the request details.	√
10	History	User navigates to history page.	√
11	Change profile picture	User navigates to profile page and click the icon attached to the profile picture.	√
12	Edit personal detail	User clicks the edit detail option on the profile page and update the personal detail.	√
13	Account deletion	User clicks the account deletion option.	√
14	Display user guide	User clicks the user guide option.	√
15	Log out	User clicks the log out option.	√

Table 2. Usability testing result

Respondent	Understandability	Learnability	Operability	Attractiveness
1	15	15	13	11
2	13	13	14	14
3	12	15	13	15
4	12	11	13	14
5	14	14	14	15
6	13	12	15	13
7	11	14	12	14
8	14	13	14	12
9	15	15	13	14
10	13	12	15	14
11	12	13	15	14
12	14	11	12	15
13	13	15	13	12
14	15	14	12	13
15	14	13	14	15
Actual score	200	200	201	204
Ideal score	225	225	225	225
Percentage	88.89%	88.89%	89.33%	90.67%

In summary, both functionality and usability testing confirm that DriveGuard is a robust and user-centric application, aligning well with its intended purpose. The functionality testing ensured that all essential operations, from user login to locating nearby workshops, performed as expected in real-time scenarios. This validation of DriveGuard's core features reassures that the application can reliably support users in vehicle breakdown situations, facilitating smooth and efficient assistance requests. The usability testing further emphasized DriveGuard’s focus on user experience. By achieving high scores in understandability, learnability, operability, and attractiveness, DriveGuard demonstrates that users find the application intuitive and easy to navigate. The high usability ratings reflect its ease of learning, operational functionality, and visual appeal, which are critical for engaging users during potentially stressful breakdown situations. Overall, the combined results of these tests underscore DriveGuard’s readiness for deployment, highlighting its capability to effectively meet user needs and provide a positive, efficient experience in emergency roadside assistance.

5. CONCLUSION

In conclusion, DriveGuard represents a significant advancement in the field of vehicle breakdown assistance. By leveraging geolocation technology, the application provides a practical solution to the common problem of locating nearby workshops during a vehicle breakdown. The use of GPS and GSM/CDMA Cell IDs ensures accurate location tracking, while the integration of Firebase facilitates real-time data synchronization and secure data storage. The application's user-friendly interface and high usability scores further demonstrate its potential to improve transportation safety and efficiency. Future work will focus on expanding features to include additional services, such as real-time traffic updates and integration with insurance providers. Moreover, efforts will be made to enhance security measures within the application to protect users from fraudulent activities. By addressing these areas, DriveGuard can continue to evolve and offer even greater value to its users, ultimately contributing to a safer and more efficient transportation system.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

No conflict of interest.

DATA AVAILABILITY

The data that supports the findings of this study are available from the corresponding author [Mohamed Imran Mohamed Ariff], upon reasonable request.

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