Tracking Stray Camels Crossing the Roads to Prevent Vehicle Accidents in Oman

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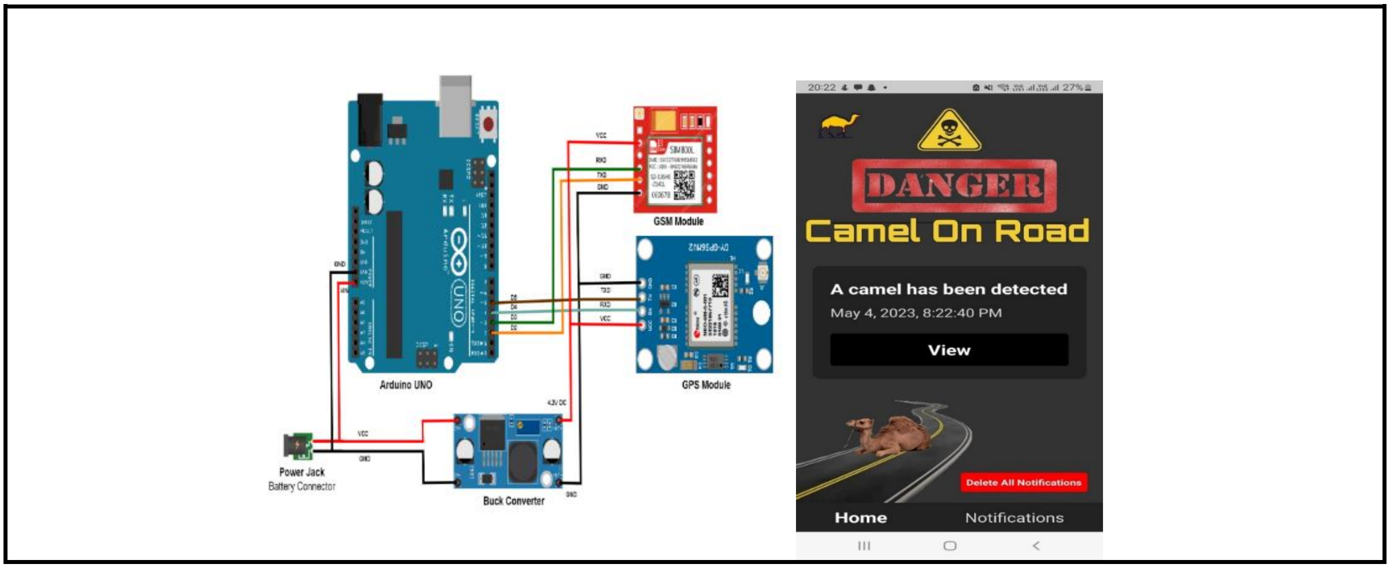

Keywords: Bracelet; Mobile application; Stray camels; Vehicle accidents; Oman

ABSTRACT: The work presented in this paper addresses the problem of vehicle accidents due to stray camels crossing the roads by notifying the drivers about camels' existence and location. Subsequently, the drivers can take precautionary measures to prevent collisions with camels. This is achieved by developing a system consisting of two parts. The first part is a bracelet tied to the camel's neck, and the second is the mobile application installed on the driver's mobile device. Hence, this proposed work aims to prevent road accidents in Oman due to stray camels moving freely on the roads and achieving safer travel during the day and night.

تتبُّع الجِمال السائبة العابرة للطرق لمنع حوادث المركبات في عُمان

مرشد عبدالله العلوي، شيخ مزهر حسين*

الملخص: يتناول العمل المقدم في هذا البحث مشكلة حوادث المركبات بسبب عبور الإبل الضالة للطرق من خلال إشعار السائقين بوجود الإبل وموقعها. وبعد ذلك، يمكن للسائقين اتخاذ الإجراءات الاحترازية لمنع الاصطدام بالجمال. ويتم تحقيق ذلك من خلال تطوير نظام يتكون من جزأين. الجزء الأول عبارة عن سوار مربوط في رقبة البعير، والثاني عبارة عن تطبيق الهاتف المحمول المثبت على الجهاز المحمول للسائق. ومن ثم، يهدف هذا العمل المقترح إلى منع حوادث الطرق في عمان بسبب حركة الإبل الضالة بحرية على الطرق وتحقيق سفر أكثر أمانًا أثناء النهار والليل.

الكلمات المفتاحية: سوار؛ تطبيق الهاتف المحمول؛ الإبل الضالة؛ حوادث المركبات؛ عمان

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DOI:10.53540/tjer.vol.21iss2pp114-125

1. INTRODUCTION

The number of car accidents involving straying camels has increased significantly in Oman. Several people were killed due to camel accidents on roadways in the Sultanate of Oman (Abdullah Al Shimemeri et al.(2012). People's lives are valuable; working on the initiative was motivated by the obligation to save people's lives. The biggest issue is that a free-roaming camel can cause several accidents on the road and may attack anyone living in the Sultanate of Oman. According to the traffic system report published by the National Center for Statistics and Information in Oman, camel/vehicle collision accidents rose by 17% (Ali S. Al-Ghamdi et al. (2004). Camel owners frequently leave their animals to roam freely, increasing the likelihood that the camel will approach the roads or highways that vehicle drivers use; the motorist will be surprised by the camel on the road and will not be able to stop or prevent the collision (S. Ansari et al. (1998) . To avoid such problems, the present research suggests an intelligent system that detects the camel as it approaches the road using IoT and other communication technologies such as GPS, and GSM (Shaik Mazhar Hussain et al. (2017). It instantly alerts the driver, indicating the camel's location on Google Maps, using the built-in GSM module (Shaik Mazhar Hussain et al. (2016).

It has been found that cars travelling at higher speeds have a greater risk of colliding with animals (Lao Yunteng et al. (2011) (Shaik Mazhar Hussain et al. (2018). Also, the author noted that the placement of the camel on the road, whether urban or rural, affects the availability of the animal on the road. However, this study lacks the transfer of information to the driver and is extremely difficult to implement; on the other hand, errors can occur easily.

(S Divya Meena et al. (2020) suggested an animal detection system for different types of animals using the technology known as a Sparse Network of Winnows by taking images of the animals detected and identifying animals on highways. The size of the camel, the vehicle's speed, the use, or non-use of seat belts by the passengers, and the protective reflex actions made to avoid contact are all directly related to injuries. The most often reported injuries are head, chest, and dorsal spinal injuries, particularly disc fractures.

(Tomas Bartonička et al. (2018) published a study on the conditions that may lead to a collision between a car and an animal and one of their conclusions was that if the animal was on the road, the sun's height relative to the horizon has a significant impact on the number of accidents.

The aim of this proposed work is to design a system to alert drivers about the existence of stray camels on the roads and consequently, prevent road accidents in Oman. Hence, to meet this goal, this article discusses the complete process involved in developing and framing the following research objectives.

i. The goal is to build a camel tracker bracelet with a built-in GPS tracking system to locate the camel once it is on or near a road and a built-in GSM module to transmit alerts to the driver's mobile application. The bracelet will be worn around the camel's neck and run on a lithium polymer battery.

ii. To build a smartphone application that can detect the camel on the road and receive notifications sent by the camel's tracking bracelet.

iii. Evaluate the system's performance and characteristics, such as latency, accuracy, and reliability.

The remainder of the paper is organized as follows:

Section 2 discusses the literature review providing insights into the existing techniques and identifying the possible gaps, inconsistencies, and limitations of the existing works. Section 3 focuses on the system design and analysis where the proposed block diagram and flowchart will be discussed in detail. Section 4 emphasizes the results obtained by briefly discussing the findings of the research work. Finally, the paper will conclude briefing about the research outcomes and recommendations for future work.

2. LITERATURE REVIEW

When comparing the various technologies such as Radio Frequency Identification (RFID), GPS tracking, Infrared and Thermal Imaging, and ultrasound and radar utilized in earlier studies (Shaik Mazhar Hussain et al. (2017), (Ali S. Al-Ghamdi et al. (2004) has discovered that the Internet of Things needed to be used to address the issue of camel/vehicle collision accidents. While some studies used radars to identify animals like camels, these solutions are more expensive and do not guarantee a safe driving environment. Most of the research relied on non-technological alternatives like fencing and reflecting signage. Consequently, IoT will be employed to create the proposed system. Hundreds of camel-drawn vehicle accidents are reported yearly, costing the Saudi economy countless lives and billions of Saudi dirhams. Gadhi's analytical summary of traffic accident statistics indicates well over 600 camel-vehicle collisions each year. The problem is that internal camel owners frequently set up camps near busy highways. They congregate here until they become thirsty, hungry, or in the breeding season. Drivers should avoid sharing the road with herds, especially at night. Most desert camels are not restrained; as a result, they frequently walk freely and occasionally cross roadways without turning, which can be deadly, especially at night as shown in Figure 1. Camels on the carriageway are a driver's greatest fear because there is nowhere to turn and no way to prevent a collision. Researchers evaluated 140 patients with low-neck spinal cord injuries at the Saudi Armed Forces Hospital. Forty-nine per cent of the clients have been in car accidents with camels. 97% of all Animal and Vehicle Collisions (AVC) that have been documented involve camels, and 90% occur at night (S. Ansari et al. (1998). These disasters result in the loss of millions of dollars, countless lives and limbs, the extinction of rare and precious species, and substantial property damage, but they also have very major negative effects on the economy and society. Global attempts have been made to lower fatal AVCs utilizing various technologies. Hence, this article categorizes the several strategies that have been used to reduce the incidence of AVC as follows. Methods that rely on motorized vehicles, animals, and public roads.

Figure. 1. Figure caption is here. Distraction to traffic flow by camels (Abdullah Al Shimemeri et al. (2012)

Figure. 2 Animal and Vehicle Collisions (S. Ansari et al. (1998)

Fencing has been put in place to keep animals from wandering into the street (Anthony P. Clevenger et al. (2001). One well-known traditional method of lowering AVC is to fence off specific stretches of a road. A big game fence that is only two meters tall can considerably reduce the number of deer-vehicle incidents. Since they have been linked with established infrastructure for wildlife crossings, these underpasses and overpasses are especially beneficial for wildlife. Compared to animal detection technologies, vehicle detection technologies operate on a slightly different premise. There are sounds like trains and planes, but no animals have been sighted. A car or train can be detected by large animals thanks to a variety of noises and 366 visual indications (Marcel P. Huijser et al. (2003). Lead cows were attempted to be radio-collared, although this wasn't always successful. The roadside receivers constantly scan for the signals from the various radio collars. The receivers that pick up the signal trigger the flashing lights connected to that receiver when the microphone users are less than 400 meters from the road. There are numerous receiver options available. Most of the time, only one receiver can pick up the signals at once, but if the man wearing the electromagnetic collar is situated anywhere between the two receivers, the signal may be picked up by both. The single flashing beacon is connected to just two receivers. Large animals that stray into the road can be avoided by vehicles using animal detecting systems. Drivers are warned by signs that have been activated indicating a huge animal has been seen on or close to the road. When a considerable animal is within a specific distance of an automobile, technology put in the car —often in the form of infrared detectors—can alert the driver. To prevent being hit by animals, drivers need to have enough stopping room. The method could detect and recognize giant creatures wherever they are found and wouldn't need any additional hardware by the side of the road. However, whether these onboard devices are still being produced is unknown (Dodd Norris L et al. (2003).

Various studies on communication have used multiple devices for information sharing between individuals, such as between users or between people and animals (Khaled Ragab et al. (2004). The autonomous community information system offers a decentralized information distribution infrastructure to fulfil the growing need for fast content delivery (Yiqun Liu et al. (2020). ACIS was created to improve two-way communication between the product's end users. The system explicitly achieves this goal by utilizing an application-level multicast method that may expand dynamically to handle enormous user groups. Another characteristic of the ACIS system is a scalable community development and maintenance architecture that makes it easier to administer an online discussion network. Below is the summary of existing works reviewed on camel/vehicle accident-avoidance systems.

3. SYSTEM DESIGN AND ANALYSIS

3.1 System Analysis

The first component of the system will be a developed necklace that will be worn around the camel's neck to allocate its location and communicate real-time data once the camel reaches or is near the road. While the second component of the system is the application that will be installed on the driver's mobile device, the prominent role of the application is to receive alerts sent by the camel's neck bracelet and to activate an alerting buzzer while showing the exact location of the camel on Google Maps.

Table 1. Summary of existing works reviewed on camel/vehicle accident-avoidance system.

Reference	Paper concept	Findings	Improvements
(Han-Shue Tan et al. (2006)	Reduces errors in animal detection utilizing AI-based techniques by using machine learning and data sets.	The majority of ADSs now in use are insufficient for medium-sized animals. The system cannot detect smaller animals, highlighting the urgent need for strategies to lower WVCs in all living forms.	Create an algorithm for a system that uses real-time data to detect animals.
(Batool Zahara et al. (2012)	The state's problems with highway safety were analyzed qualitatively.	Didn't offer any recommendations for how to stop animal-vehicle collisions on the road.	It is advised to develop more novel, improved, and practical solutions.
(Falko Brieger et al. 2016)	Studies on installing fencing to stop animals from wandering into traffic have been conducted.	There is no use of technology to address the issue.	Useful technological tools include smart fencing and other devices.
(A. Allan Degen et al. 2019)	A car or train can be detected by large animals thanks to various noises and 366 visual indications. Signals from stations along the corrido's right-of-way should be visible.	The driver is not warned about the animal, and the animal is the only one who gets warned.	It is necessary to use warning signals for both drivers and animals.

3.2 System Block Diagram

The suggested system's block diagram is divided into two sections because the system will send data via the camel neck bracelet and receive data via the drivers' mobile application. Block 1 is an intelligent camel necklace, which will be worn around the camel's neck and contains all the hardware components. The rechargeable lithium polymer batteries will power the Block 1 system to collect real-time location data via the GPS (Global Positioning System) module. The Arduino Uno will receive data from the camel's real-time location, which will be processed and filtered. Once the data indicates that the camel is on or near the road (with a range of 5m), the Arduino will use the GSM module (SIM800L) to automatically send notification over the internet using the General Packet Radio Service (GPRS) built into the Sim800L. In the second block, the user's mobile application will receive the sent data. The application will be built and installed on the driver's mobile device to receive all alerts sent by the camel necklace system (block 1). As a result, the program serves three key functions: receiving the alerting notification, activating a sound warning to notify the driver of the risk, and showing the driver, the actual location of the camel using Google Maps. The detailed block diagram is shown in Figure 3.

This work shall only use 2g/3g signals because they are the only approaches supported by the SIM800L's built-in GPRS. The GPRS (General Packet Radio Service) core network is a system that allows mobile networks such as 2G, 3G, and WCDMA to send Internet Protocol (IP) packets to external networks such as the Internet. It is part of the network switching component of the GSM (Global System for Mobile Communications). On the other side, the following steps will be performed to identify and decide that the camel is crossing the road:

A. Using GPS information, the proposed work will create a virtual perimeter around the route. This can be accomplished by defining a set of GPS coordinates that form a polygon around the area where animal crossings are to be detected.

B. The Arduino software will compare the animal's GPS coordinates to the virtual perimeter. The spatial coordinates are encoded and stored in a database.

C. When an animal is observed crossing, the Arduino software can do an action, such as sending a notification.

3.3 System Block Diagram

The system flow chart describes the primary tasks the system will perform and specifies the logical order in which the studies will be served. The system will include input data provided by the GPS module, a condition that can be true or false, a processing unit, the Arduino UNO, which will be programmed to process the data received from the GPS module, and finally, outputs represented by audio alerts that notify the driver about the presence of the camel on the road, and visual outputs that show the driver the camel's exact location on the road using Google Map.

3.4 Circuit diagram

The diagrams below show the system circuit schematic design and connections for all the essential components, including the Microcontroller, GSM module, GPS module, buck converter, and battery. Figure 5 illustrates the circuit diagram. The Arduino Uno is the central component of the system that processes the commands received from the interfaced components. It processes the camel location received from the GPS module and sends messages to the driver's mobile through the GSM module. The geographic location (latitudes and longitudes) of the environment that the camel is traversing, the device must connect to a remote server via the internet to retrieve these values.

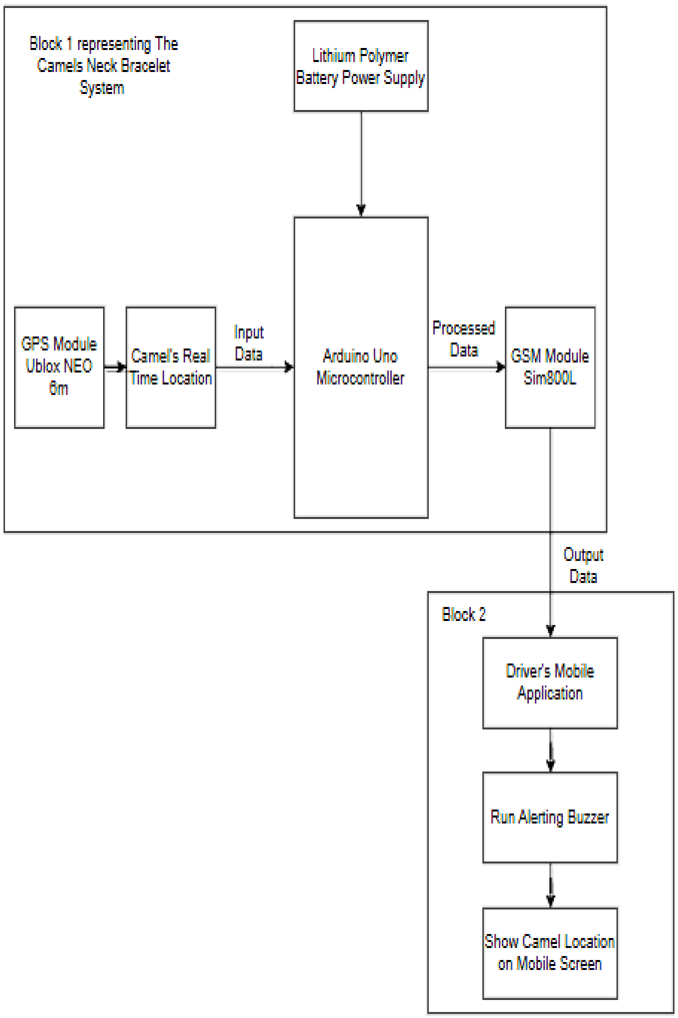

Figure. 3 Proposed blockdiagram.

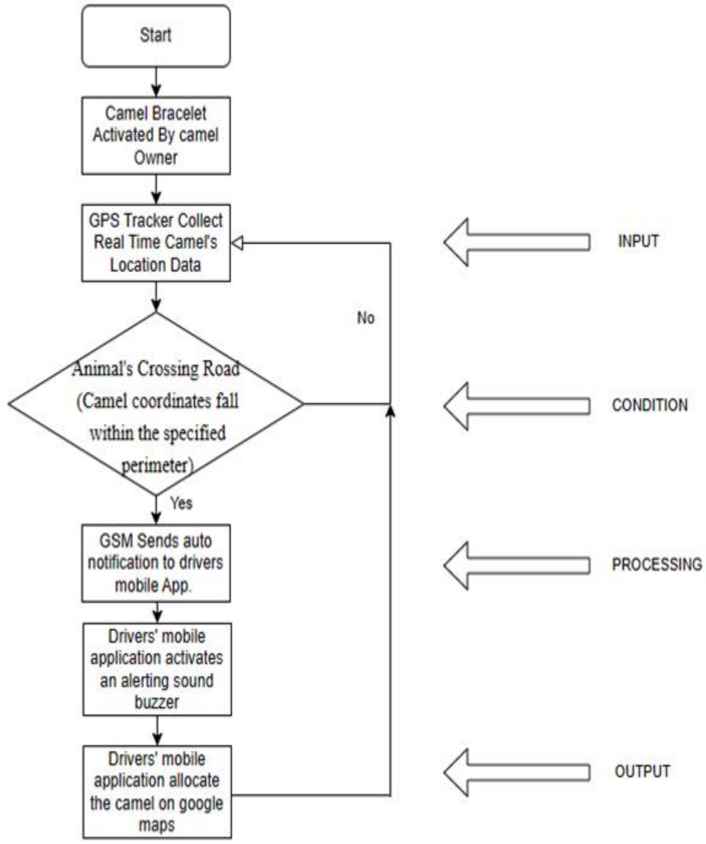

Figure. 4 Proposed flowcharts

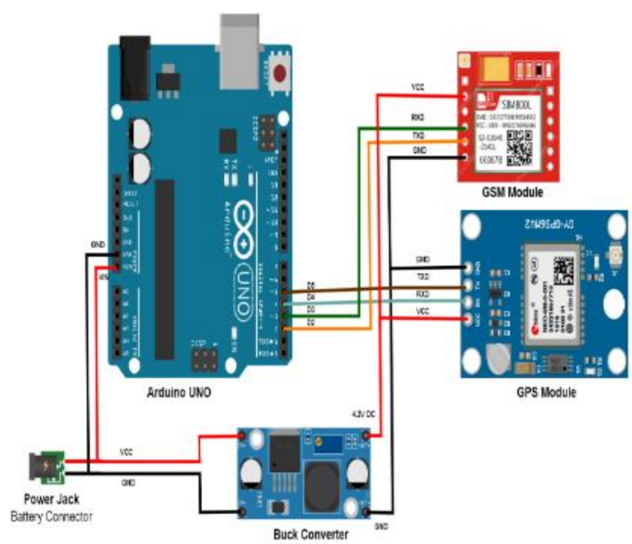

Figure. 5 Circuit diagram.

4. SIMULATION AND HARDWARE PROTOTYPE IMPLEMENTATION

This section focuses on system simulation and implementation. This section will go over the many stages of testing that were performed to ensure the system's dependability and correctness. Simulation is an important phase in the development process since it helps to discover and prevent potential issues prior to deployment. The testing process ensures the system meets the design criteria and needs. Testing points were defined, and test strategies were devised to guarantee that the system satisfies the desired performance standards. This section also compares the system's implemented values to the design and simulation values. The final section goes over the system's actual implementation. The difficulties encountered during the implementation process are identified, and the solutions put in place to overcome them are discussed. The section finishes with an overview of the simulation, testing, and implementation phases, noting the process's triumphs and obstacles.

Figure 6 shows the circuit simulation using proteus which combines mixed-mode SPICE circuit simulation. Proteus was used to simulate the behaviour of the system under various scenarios and settings in the context of a camel/car accident-avoidance study. The team was able to verify the system's performance and discover any potential faults by simulating it before deploying it in the field. Proteus enables a complete investigation of the system's behaviour under various conditions, such as voltage and temperature variations, noise interference, and a variety of other factors that may affect the system's performance. The behaviour of the camel tracking system was properly simulated with Proteus, allowing it to refine the system's design and ensure its dependability and accuracy in the field. Proteus can supply all of the test resources, directly evaluate the accuracy of the hardware circuit design, directly debug the software with the hardware schematic diagram, validate the operation of the entire design, and test controllable, easy-to-evaluate, and easy to implement. Figure 6 shows the GPS module, and GSM module are interfaced to Arduino uno. The messages were displayed on a virtual terminal.

The data will be provided via SMS and a 2G signal, and the GPS will be used to determine the location. Once the camel is on the road, the system will filter the notification messages so that they are received only by drivers on the relevant road and within proximity of the camel, to avoid distracted driving and hence, ensure safety. This approach is utilized to give the driver an idea of where the camels are most likely to cross the road and to alert any friends or family members who may be travelling that route. There are primarily two methods for data communication from the camel's system to the driver.

4.1 Message Transmission to Driver Mobile

A. The first method is via SMS: after downloading the program, the driver will register and his mobile number will be requested; after providing the mobile number, the data is sent to a server backend that can accept data from the mobile application and store the mobile numbers in a database. Then, connect the Arduino device to the server backend using a GSM module. Then, in the Arduino code, a necessary logic will be built to retrieve the mobile numbers from the server and deliver messages to them. To transmit SMS messages, an SMS gateway service and a GSM module are used. Finally, while the camel is on the move, the Message Sending feature is activated, and the message is transmitted to all registered mobile phone numbers continuously.

B. The second method is to deliver the data over the internet over a 2G network. When delivering data over the internet over the GPRS-2G network, a link must be established between the Arduino and the backend server. The data can be delivered in various formats, but this work will use JSON. The defined backend server serves as a go-between for the Arduino and the mobile application. Arduino sends the data to the server, which processes and distributes it to the appropriate mobile applications. The backend server oversees sending notifications to all applicable devices. Finally, each device's mobile application must be created and programmed to accept and handle notifications delivered by the backend server.

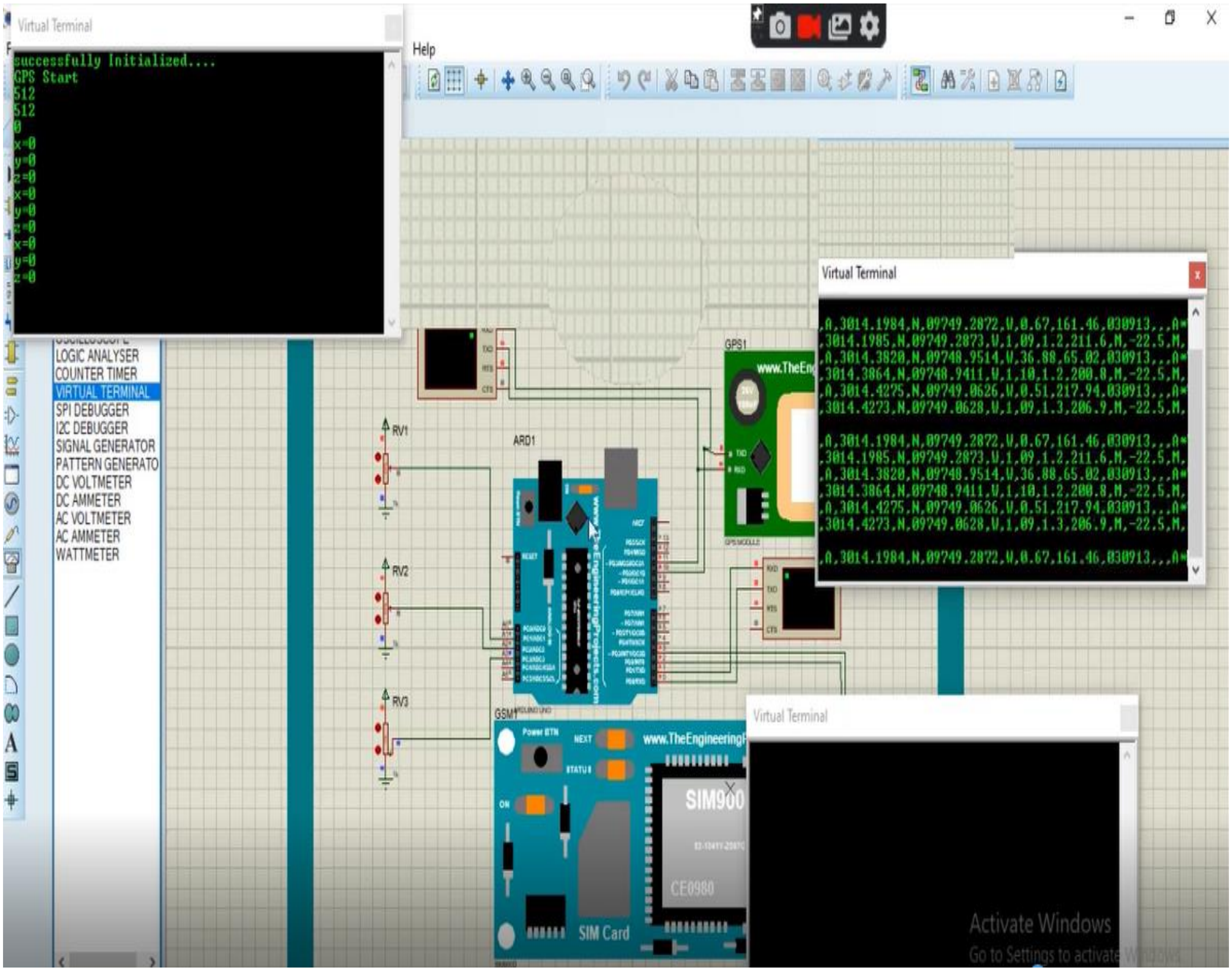

Figure. 6 System simulation.

4.2 Message Transmission to Driver Mobile

Equip each camel with a GPS tracker that constantly sends its location to the server. The server then analyzes this data to determine if the camel is within a predefined proximity to a road. The server constantly analyzes the GPS data against the map of roads. If a camel's position falls within the designated proximity to the road, it's flagged. An alert is sent if a camel is within 100 meters of a road and moving towards it. Upon triggering an alert, the system then executes the notification process as follows:

- The server retrieves the mobile numbers of registered users from the database.
- Using the Arduino device connected via a GSM module, an SMS message is composed.
- The message is sent through an SMS gateway service to all registered mobile numbers, notifying them of the camel's proximity to the road.

The following components are essential to effectively implement this triggering mechanism,

- GPS trackers for camels
- Processing GPS data in real-time and performing geospatial analyses.
- Arduino with GSM module

4.3 Driver Mobile Application

A mobile application was developed using JavaScript, specifically React Native with Expo, and was designed for installation on driver's smartphones. The rationale behind choosing React Native with Expo for developing the mobile application comes with several advantages that directly contribute to the application's efficiency, usability, and overall development experience. Benefits include cross-platform development, employing a component-based architecture, live reloading and hot reloading, expo integration, community, and ecosystem.

The primary objective of this application was to receive messages from the Arduino system, alerting the driver whenever a camel was detected on the road. Upon receiving a notification, the application would emit a beep to capture the driver's attention. Moreover, the program displayed the precise location of the camel on a map, enabling the driver to easily pinpoint the camel's position. Additionally, the mobile application was engineered to archive all past notifications for future analysis. This feature would facilitate a thorough investigation of the most frequent locations where camels were found on the roads. The data collected could then be leveraged to enhance the overall performance of the system, such as improving alert mechanisms and identifying the areas where occurrences are most common. Overall, the mobile application played a pivotal role in the effective functioning of the camel tracking system. Figure 7 illustrates the application screen when a camel is detected. Figure 8 depicts the application page where messages are stored. Figure 9 displays the hardware connection.

In designing a mobile application for drivers to alert them of nearby camels on the road, several key considerations must be considered to ensure effectiveness, user-friendliness, and efficiency. These considerations include user interface design, notification delivery, and data storage for past notifications.

User Interface Design:

For simplicity and clarity, the application user interface should be straightforward and intuitive, allowing drivers to understand and react to alerts quickly without causing distractions.

Notification delivery:

Notifications must be delivered promptly to give drivers enough time to react.

Data storage for past notifications:

Storing past notifications can be valuable for drivers and system administrators. Drivers can review past encounters, and administrators can analyze data to identify patterns or high-risk areas.

The camel tracking system integrates various technological components to accurately track camels and communicate their location to drivers, thereby enhancing road safety. The primary components include a GPS module, a GSM module, and an Arduino Uno board. Each plays a critical role in the system's overall functionality:

Global Positioning System (GPS) Module: The GPS module is essential for determining the precise location of the camel. It receives signals from GPS satellites orbiting the Earth to calculate the device's current latitude and longitude.

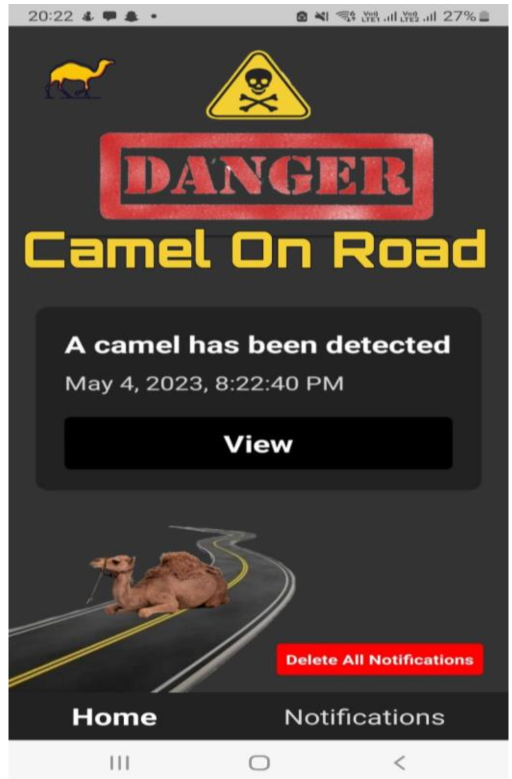

Figure. 7 Mobile App illustrating notification "A camel is detected."

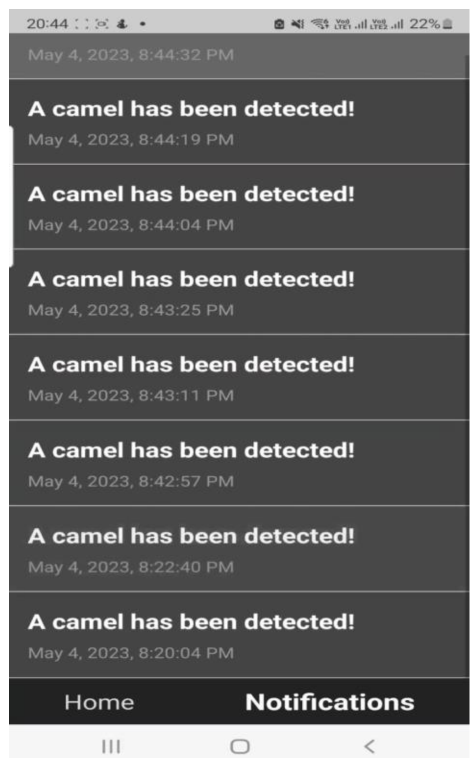

Figure. 8 Application Page showing the saved history of camel detection.

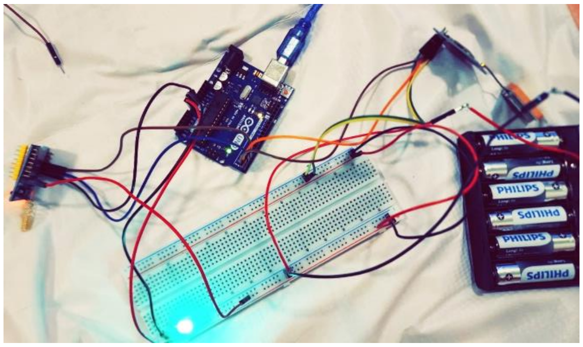

Figure. 9 Hardware connection

Upon calculating the location, the GPS module sends these coordinates to the Arduino Uno board. This information can be processed and used to determine if a camel is near or attempting to cross a road, which is critical for the next steps in alert generation.

Global System for Mobile Communication (GSM) Module: The GSM module facilitates communication between the tracking device and the server, and ultimately, to the drivers. It allows the system to send SMS alerts and transmit data over mobile networks. After the Arduino uno processes the location data and identifies a potential risk (e.g., a camel close to a road), the GSM module sends an alert or data to a central server, which can then relay warnings to registered drivers via SMS or through a mobile application. This module ensures that even in remote areas if there is mobile network coverage, the system can communicate the necessary information.

Arduino Uno: The Arduino Uno serves as the central processing unit of the tracking system. It is a microcontroller board that is both powerful and easy to program, making it ideal for prototyping. The Arduino Uno receives location data from the GPS module, interprets this data to determine if an alert should be triggered, and then commands the GSM module to send the alerts out. It can be programmed to consider various factors such as the proximity of the camel to known roads or paths, before deciding to send an alert. The Arduino Uno can also manage power consumption, ensuring that the device operates efficiently to prolong battery life. These components work together seamlessly to create a functional tracking system. The GPS module continuously updates the camel's location, which the Arduino Uno processes. If the system determines a potential risk based on the camel's location, the Arduino Uno uses the GSM module to send alerts. The overall objective is to inform drivers in real time about the presence of camels near or on the roads to prevent accidents. This system not only enhances road safety but also contributes to the welfare of the camels by reducing the likelihood of collisions.

When designing a camel tracking system intended to ensure accurate detection and timely alerts to drivers, several specific factors must be considered to make the system effective and reliable. These factors are critical in developing a solution that can prevent potential accidents involving camels on or near roadways. Here's a summary of these key considerations:

GPS Accuracy and Reliability: The system relies on GPS technology to track the location of camels in real time. High accuracy and reliability in the GPS tracking device are essential to ensure precise tracking of the camel's position. This involves selecting GPS modules that can provide location updates with minimal error margins, even in areas with potentially weak GPS signals.

Real-Time Data Transmission: The capability to transmit data in real-time is crucial for timely alerts. This requires a robust communication system, typically utilizing GSM or other wireless communication technologies, to ensure that location data from the camel's tracking device can be sent to a central server and then relayed to drivers without significant delays.

Energy Efficiency and Battery Life: Given the potential for camels to roam freely and the difficulty of regularly accessing these animals for maintenance, the tracking device must be energy-efficient and equipped with a long-lasting battery. This might involve using low-power GPS modules, optimizing the device's software to reduce energy consumption, and possibly incorporating solar charging to extend battery life.

Durability and Weather Resistance: The tracking device must be durable and capable of withstanding harsh environmental conditions, including extreme temperatures, dust, and moisture, which are common in regions where camels are found.

Alert Mechanism Efficiency: The system must include an efficient mechanism for alerting drivers, which could involve SMS messages, mobile app notifications, or other real-time alert systems. The alert mechanism should ensure that drivers receive a warning with enough lead time to take precautionary measures.

User Interface and Accessibility: For drivers, the system should include an easy-to-use interface, possibly through a mobile application, that can provide not only alerts but also visual information (e.g., maps showing the location of nearby camels).

These are the specific factors that were considered in the design of the camel tracking system to ensure accurate detection and timely alerts to drivers.

Various system attributes and performance were tested and tabulated in the camel tracking system to guarantee the system meets the necessary standards. Table 2 shows the performance metrics to evaluate the system performance.

These performance metrics are used to evaluate the performance of the camel tracking system in terms of its ability to detect camels, transmit alerts, and display accurate locations to drivers.

Table 2. System performance metrics

Performance metrics	Measurement value	Description
Resolution	0.1 m	The minimum detectable change in the location of the camel
Efficiency	98%	The percentage of time the system was operational and transmitting data
Errors	< 1%	The percentage of data transmissions that resulted in errors or were not successfully received by the mobile app
Accuracy	98%	The percentage of GPS location data that was accurate and within 2 meters of the actual location of the camel
Linearity	99%	The percentage of measured location data that was linear and in agreement with the expected location data
Latency	< 2 secs	The time taken for data transmission and processing from the microcontroller to the mobile app.

Furthermore, reliability, latency, and scalability are the factors that are crucial for ensuring that drivers receive timely and accurate alerts about camels on or near the road. Hence, these three parameters are used to assess the effectiveness of two communication methods, SMS, and internet-based data transmission, for a camel tracking system.

- Reliability: SMS is generally considered highly reliable, as it does not require an internet connection and can work on basic mobile network infrastructure. It ensures that alerts can be received even in areas with poor or no internet connectivity. However, SMS delivery can sometimes be delayed due to network congestion or other issues. In contrast, internet-based data transmission offers faster and more versatile communications, its reliability heavily depends on the availability and stability of an internet connection. In remote or poorly connected areas, this method might be less reliable than SMS. The evaluation for both methods is done by conducting field tests in various locations, including areas with varying levels of network coverage, to measure and compare the success rate and consistency of message delivery for both methods.
- Latency: The messages are often delivered within seconds; network congestion can lead to delays. In critical situations, even short delays could potentially compromise safety.
  In contrast, Internet-Based Data Transmission offers lower latency under optimal conditions. However, it also offers some limitations like any other internet-based communication. To evaluate both methods, real-time tests are performed to measure the average time taken for a message to be delivered from the tracking system to the end-user's device via both SMS and internet-based methods.
- Scalability: Scalability is challenging especially from a cost perspective, as each SMS sent incurs a charge. The financial implications of scaling up SMS notifications for many users and camels can be significant. In contrast, internet-based data communication offers excellent scalability, especially when cloud-based services are used. The evaluation of both methods can be done by assessing the infrastructure needed to support increased loads and the financial costs associated with sending a large volume of messages.

4.4 Feasibility of the Use of the Proposed System

This section will detail the analysis and findings regarding the cost estimates and potential adoption by camel owners.

Cost Estimates:

Initial Investment – The initial cost of developing and deploying the camel bracelet system includes the cost of the GPS devices, the development of the mobile and server applications, and any additional hardware such as the Arduino and GSM module for sending SMS alerts. Based on the preliminary market research and quotes from suppliers, the estimated cost per unit for a GPS tracker with the necessary durability and battery life for this application is approximately 50 USD.

Operational costs: These include server hosting fees, SMS gateway fees, and maintenance of the hardware and software components. The estimated monthly operational cost for a system supporting let's assume 1 camel includes,

Server hosting - 30 USD

SMS gateway – 2 USD

Hardware Maintenance – 5 USD

Software Maintenance – 50 USD

Therefore, the operational cost is approximately 88 USD per month for a system supporting a single camel.

Total Estimated Cost: Combining the initial investment and operational costs, it is estimated the total cost for deploying the camel bracelet system for 1 camel would be approximately 138 USD.

Legal and Ethical Considerations:

This designed system will benefit society by minimizing the frequency of incidents caused by vehicle and camel collisions on Oman highways, improving daily trips and making the roads safer for all drivers and passengers. However, it is vital to evaluate the system's potentially detrimental impact on the workplace and societal quality of life. For example, the installation and maintenance of the system may necessitate a significant number of workers who will be exposed to a variety of dangers and hazards. The system may also have an impact on the natural environment and the well-being of nearby populations.

Another factor to consider is the addictive nature of technology and how it can depersonalize people to the point where ethical concerns may no longer be relevant. For example, if the system encourages over-reliance on technology and reduces individual drivers' obligation to pay attention to the road, there is a risk of complacency and a false sense of security. This could raise ethical problems about individual drivers' responsibilities and duty of care to other road users.

To address these ethical challenges, electrical engineering professionals must set ethical standards and rules to ensure that the project is conceived and implemented responsibly and ethically. This may entail working closely with stakeholders, such as delivery drivers and transportation industry officials, as well as other interested parties such as camel owners, to ensure that the project does not have a negative influence on their livelihoods and working conditions.

Simulation and testing in real-world scenarios to validate the performance and reliability of the camel tracking system before deployment in field trails:

Simulating and testing real-world scenarios are crucial steps in validating the performance and reliability of a camel tracking system before its deployment in field trails. This process helps ensure that the system can effectively detect and alert drivers about nearby camels under various conditions, thus preventing potential accidents. Here’s an overview of how these simulations and tests might be conducted:

1. Simulation scenarios: Using software tools, these scenarios are simulated. For example, GPS simulators can mimic camel movements across different terrains and proximity to roads.

2. Hardware and Software testing: Initial tests are conducted in a lab setting to ensure the hardware can withstand various environmental conditions which are common inhabited areas. The software’s capability to accurately process data from the GPS and GSM modules and send timely alerts is tested under simulated conditions. This includes testing the system’s response to simulated GPS data of camels approaching or crossing roads.

3. Integration testing: Tests are conducted to ensure that the hardware and software components of the system work seamlessly together. This includes verifying the accuracy of data transmission from the GPS tracker to the server and the reliability of alert messages sent to drivers.

4. Field trails: Before full deployment, the system is tested in a controlled real-world environment. This might involve attaching GPS trackers to camels in a confined area and simulating road crossings under monitored conditions. Test drivers are equipped with the app to assess the effectiveness of alerts, the clarity of the information provided, and the overall user experience. Feedback from these users is crucial for further refinement.

5. Performance Metrics Evaluation: Data collected from simulations and field tests are analyzed to evaluate the system’s performance. Metrics such as detection accuracy, alert timeliness, system reliability under different conditions, and battery life of tracking devices are assessed.

6. Iterative testing: The testing process is iterative, with each round of tests leading to refinements in the system. This cycle continues until the system’s performance meets the predefined criteria for effectiveness and reliability.

5. CONCLUSION

This research work has designed a camel tracking system consisting of a camel wearable system integrated with GPS, GSM, and Arduino Uno and a mobile application for drivers to reduce vehicle collisions specifically with camels. The paper will have a tremendous positive impact on society by making roadways safer for both drivers and camels.

During the development and implementation of the camel tracking system, some of the potential challenges faced are limited budget, storage, and time constraints. However, to address these potential challenges, several measures were taken such as using open-source software, free tools, and libraries to avoid licensing fees and to reduce costs and reducing storage requirements. Furthermore, identifying and focusing on core functionalities that are crucial for the system’s operation allows for efficient time management.

To assess the willingness of camel owners to utilize the system, it is essential to conduct surveys and interviews across various regions known for camel-vehicle interaction. This will be considered as a future work. The primary concerns among owners were the safety of their animals and the potential financial losses due to accidents.

The study on the camel tracking system to prevent vehicle accidents presents a significant step forward in using technology for wildlife conservation and road safety. Enhancing system accuracy, scalability, and adaptability to different environments are crucial aspects that future research could focus on. Some of the suggested directions for future research based on these aspects are incorporating more sophisticated sensors, such as infrared sensors or motion detectors, which could improve the system's ability to detect camels accurately. Further, machine learning algorithms can enhance the system's accuracy by enabling it to learn from historical data and improve its prediction capabilities over time, such as predicting camel movements and potential road crossing areas. Leveraging cloud computing can improve the system's scalability allowing it to handle a growing amount of data and an increasing number of users without a drop in performance. Future versions of the system could include mechanisms for adapting to various environmental conditions, such as temperature changes, humidity, and terrain, ensuring reliable performance across diverse geographic locations.

CONFLICT OF INTEREST

The author(s) have no conflicts of interest to disclose.

FUNDING

The author(s) declare that no financial support or funding was received for this research.

ACKNOWLEDGMENT

The authors would like to acknowledge Middle East College (MEC), Muscat, Oman for providing all facilities and resources in successfully completing this research work.

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