Camel Monitoring and Tracking System Across Fenced Highways

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***Abstract*— Available information indicates that fatality rate of traffic accidents resulting from the collision of motor vehicles with camels is very high. Consequently, several countries, including the Gulf countries, have fenced off their highways to prevent camels from straying onto them. Although, the use of fencing is an effective method in reducing collision of motor vehicles with camels, fences can block camels' movements, and their access to forage and water. An inexpensive and durable crossing technique that is friendlier to vehicles and camels is developed in this research. The system has been designed using the global positioning system (GPS), and a global system for mobile communication (GSM) technology. Lab experiments indicate that the system has a unique capability of being able to monitor and track camels and thus could mitigate the number of accidents involving vehicles and camels.**

Keywords— Radio Collar, Global Positioning System (GPS), Global System for Mobile Communication (GSM).

I. INTRODUCTION

Animal-Vehicle Collisions (AVC) occur frequently in many countries including countries in the Middle East and Europe and in the United States, Australia and Canada. The animals involved in most of these collisions are: moose in the United States/ Europe/ Canada, kangaroos in Australia, and deer in the United States.

In the Middle East camel is the main animal involved in AVC. Camels are always found in rural areas moving from one place to another. In the UAE, it was reported that there are more than 300,000 camel registered in Dubai [1] and 394, 224 in Abu Dhabi [2]. In Oman, there are more than 243, 323 [3] while in Saudi Arabia there are more than half a million camels moving freely [4]. They are usually domesticated and supervised during their movement. However, sometimes they are unsupervised and approach the highways without warning. Most of the highways in the rural areas (deserts in Middle East) are high speed roads. The camel-vehicle collisions almost always occur at dawn in the early morning, and the end of the day at twilight [5]. It has been reported that the fatality rate of AVC with camel is four times higher than for other causes of traffic accidents due to the size of the camel [6].

Many Methods have been used experimentally, investigating their effectiveness in reducing the AVC. The scope of these investigations fall into two main areas; traditional and technology based methods.

The traditional method involves fencing, animal crossing overpasses/underpasses, and warning signs. Fences and overpasses/underpasses can obviously reduce the AVC, however it has been reported that the fences are expensive to install, difficult to maintain, and they limit the camels' movements [7].

The effectiveness of the warning signs were studied using different sign configurations. The study concluded that even though there is a significant speed reduction of the vehicles due to the installation of warning signs, the reduction was found to be either small than that hoped for or inconsistent [8]. Based on the above it was concluded that most of these methods are ineffective.

Different techniques were reported in the literature for technology based AVC. Many studies reported the use of camera-based systems to detect the moving animal which detect the animal and either notify the drivers through flashing signs installed at the side of the road or via an inside car systems that warns drivers when animals are detected [9-12].

In [9], the authors used an infrared thermal camera with a tracking system to detect the presence of deer for avoiding AVCs. The system is comprised of an infrared thermal temperature image grabbing and processing system and a motion tracking system. The system was able to detect the presence of an animal in night or day time. Other research conducted by [10] reported the use of vehicle mounted night vision animal detection systems. The system is used by the Audi, BMW and Daimler companies to detect animals up to 200 meters away from the car with very few false warnings. The study declares that the system was able to detect almost all animals including occluded ones regardless their viewing angles. However, the study reported that there is a need for a large test data set to assess the rate of false detections with statistical significance.

Even though the camera based system can be very efficient in capturing animals, it has some disadvantages, including the fact that the system detects animals on the road and not the surrounding area and false alarms can be triggered as a result of air movements and some other external factors [11].

Another technology used for reducing AVC is attaching collar to the animal to activate a warning when the animal is crossing the road. Animal Radio collar are used in USA to activate crossing signs when the collared animal is within a quarter of a mile of the signs [13]. The study reported that the system helped to reduce the number of AVC.

An Intelligent Camel-Vehicle-Accident Avoidance System (CVAAS) using global positioning system (GPS) technology was developed in [14]. The system was comprised of three subsystems: the Animal-Based Unit (ABU), the Animal detection system (ADC), and the Warning System (WS). The ABU is attached to the camel and includes a GPS system which aims to transfer camel location and movement to the ADC system. The ADC is the web based servers that process the received data and compare it with its database to identify the camel and determine if the camel is in the dangerous zone or not. If the location is identified as dangerous zone, an SMS will be send to activate the WS which is a flashing light installed in the road for alerting drivers to slow down to avoid any collision with the camels. However, the study reported that in the testing for some instants the system is not able to detect the camel while it is in the danger zone and this could be due to the width of the danger zone.

In UAE, fences were installed in many areas for avoiding AVC. Even though it is an expensive solution, it ensures safety for human and camel lives. On the other hand, these measures limited camel movement from one side to the road to other side. This, in turn, limits their food resources and causes them to change their habits. In order to overcome this problem, the core objective of the current project is to present a novel approach that automates fenced gate to allow the camel crossing the highway as well as ensuring nonoccurrence of camel vehicle collisions.

The remainder of this paper is organized as follows: Section II presents an overview of the proposed approach. The proposed system is described in section III. Simulation and experimental results are presented in section IV and V respectively. Finally, conclusions are drawn in section VI.

II. Overview of the Proposed Approach

The proposed approach was derived through inference from the idea that fences were already installed to mitigate AVC. Although, the use of fencing is an effective method in reducing the number of collisions of motor vehicles with camels, fences block camel movement, and access to forage and water. In this contribution, the problems are tackled following five steps:

A. Fencing the highways

Several countries, particularly the countries of the Gulf Cooperation Council (GCC), are moving ahead with new techniques and technologies to reduce the number of Animal-Vehicle Collisions (AVC) [15] [16]. The conventional roadway fencing method still the most effective and practical technique that can be used to prevent camels from crossing the long highways and traffic roads. Nevertheless, this method needs many accessories to make it more useful, in particular underpasses (tunnels) and overpasses (wild-bridges) that enable animals to move freely along both sides of the highways. Unfortunately, these accessories are very expensive and impractical because of the very long highways in the GCC countries.

B. Adding automated gates

In this work, we aim to design smart gates that manage the movement of camels between the two sides of highways. Moreover, we need the process of camel-crossing to be performed without blocking traffics while helping to prevent fatal collisions. To do so, these gates should automatically open for camels-crossing and close again in a precise timing where the closest car will not reach the gate before the camel-crossing has finished.

C. Installing light strips on the highways

Even though we have automated gates, we still need to warn drivers about camel-crossing locations. Lighted, animated deer-crossing warning signs were evaluated in Colorado. Pojar et. el. concluded that drivers' speeds were initially slightly reduced, but after the drivers got used to the animated sign, it lost its effect in reducing the drivers' speeds [17]. To overcome this human behavior, we need to make the light signs change their color and gradually increase their blinking speed as the camel approaches the gates. This adjustment will make the awareness of drivers increase continuously until they pass the camel-crossing gates.

D. Using radio collar

Researchers have extensively used Radio collars in several projects since 1999 up to the present. Solar cell units permanently power our Radio Tracking Collars where these Radio collars are designed to aid in frequently tracking camels over extended distances. Receivers placed on the automated gates scan for the frequencies of the individual radio collars 24 hours per day. When the radio-collared camels come within a specific distance from the gate, the receivers that accept the signal activates the automated gate system. As a consequence, the animals without a radio collar are only detected if radio-collared animals accompany them. Therefore, the system works well for a highly gregarious species.

E. Using GSM to send SMS to all driver before and after gates

GSM (global system for mobile communications) is an open, digital cellular technology used for transmitting voice and data services. When a radio-collared animal comes close to the automated gate the system can automatically detect the presence of the animal and one of the main warning methods of our system is the sending of SMS to drivers and the owners, instantaneously.

III. System Description

Nowadays, wireless technologies present a wide range of possible solutions for automating livestock farming. Technologies such as Internet of Things (IoT) are being utilized to target specific needs of farmers like monitoring animal behavior, and searching for lost animals. Our contribution is the development of an intelligent system for tracking and monitoring camel behavior across fenced highways. The system consists of three parts: Fences and automated gates, a highway-based detection system, and finally, a Radio collar. Fences well be used to keep camels away from the highway, while automated gates are essential for controlling the movements of the camels. A highway-based detection system will be used to regulate the opening and closing of the gates, flashing the light, receiving camels' location and transmitting them to their owners. Radio collar will be equipped with a small RF transceiver and given to each camel in the herd. The following is the description of each component.

A. Radio Collar

As shown in figure 1, the radio collar dedicated for this project incorporates a power source, an RF transceiver, Arduino Nano, and GPS. The collar's power system consists of a 7.2V 750mAh rechargeable lithium polymer battery, charger, and a printed organic solar cell. Organic solar cell is a type of photovoltaic cell that uses organic molecules. Unlike silicon-based solar cells, organic solar cells (carbon-based cells) are lightweight, and offer huge potential when incorporated into the design of such a collar.

The NRF24L01 transceiver module is used in this project to make a wireless communication link between collars and a highway-based detection system. The current consumption of this module is just around 12mA, operating voltage is 3.3V, and the communication range is around 100 meters. The reasons for the selection of such a low range module are to enable battery lifetimes up to several years, and to compensate the difference in speed between camels and vehicles.

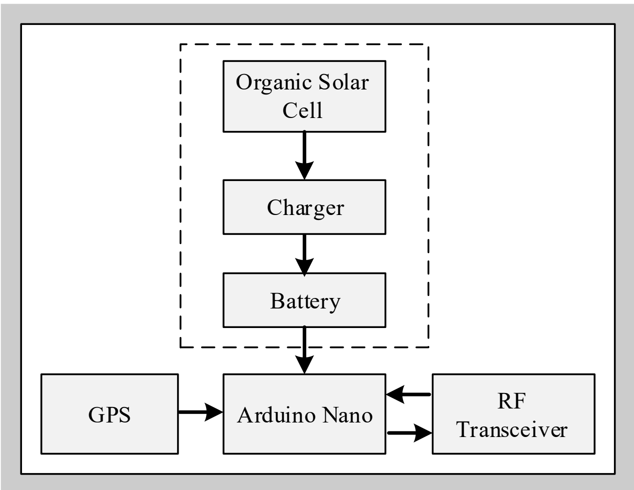


Fig. 1. Block diagram of the radio collar module.

The weight of this collar is less than 100 gm including the belt which makes it suitable to be fitted around the neck of the camel. Another module which is essential for any collar is the GPS module. Since the GPS module uses a lot of power, and the goal of this research is to present a wireless technology with enough battery power to last the lifespan of the camel, a GPS module was excluded from all collars except the one used by the leader of the herd.

B. Highway-based Detection System

As shown in figure 2, a highway-based detection system consists of the following parts: automated gates, RF transceiver, lightning system, Arduino Uno, global positioning system (GPS), and global system for mobile communication (GSM). Gates are equipped with a DC motor and controlled through the Arduino board. RF transceiver is similar to that one used in the radio collar. The device is used to receive the camels' IDs and communicate them to the Arduino board. In cases where there is heavy traffic on the highway, gates are locked regardless of the presence of any camel.

The lighting system is controlled by a mobile network operator based on the SMS that are broadcasted to all drivers. As camels get close to the highway, the gate is opened and an SMS is sent to the nearby tower. The message contains the camels' IDs and the location of the station. Consequently, mobile network operators will send another SMS to all drivers on the highway. This, in turn, will switch on lighting system. The distance between the lighting system and the gates are set based on the announced speed limit for the relevant highways.

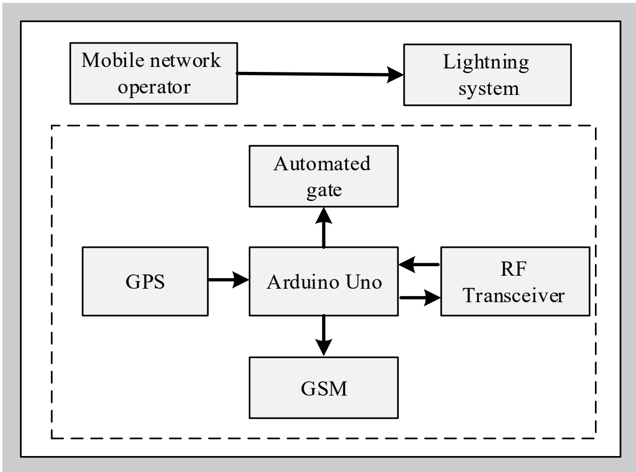


Fig. 2. Block diagram of the highway-based detection system.

IV. SIMULATION RESULTS

To study the performance of our automated system, we carried out several simulations for different road speed limits. In figure 1, a descriptive scenario of a radio-collared camel detected by our automated system. We show a descriptive providing scenario where a radio-collared camel is approaching our automated gate within the maximum range of the gate receiver (100 m in our installation). Our system measures the distance between the gate and the closest car, X. Similarly, it measures the distance between the gate and the detected radio-collared camel (camel-gate distance) Y_1. Considering the speed limit of the highway and the average speed of camels, our system calculates the time needed for the car to reach the gate and the time needed for the camel to cross the road. Based on these calculations, our automated gate will decide whether to open the way for the camel to cross through or it will be blocked. Assuming that the driver obeys the assigned speed limit of the street S_v and that the camel moves with an average speed $S_c = 3.5\ km/hr$, the car then needs a time $t_v = X/S_v$ to reach the gate while the camel needs a time

$t_c = (Y_1 + Y_2)/S_c$ to finish the camel-crossing process where Y_2 is the road width.

To make the idea simpler, we will not add any time for extra safety and will assume that the camel will move to the other side of the road exactly with the time needed for the car to reach the gate. In such case, the gate will only open when the two times match: $\boldsymbol{t_v = t_c}$. Moreover, we give the priority to vehicle traffic, so we do not expect the driver to reduce vehicle speed. The calculation starts by calculating $\boldsymbol{t_c}$ and the minimum activation distance between the car and the gate, $\boldsymbol{X_{min} = t_c S_v}$. The gate will open for the camel-crossing if and only if the actual distance $\boldsymbol{X \geq X_{min}}$. This condition secures the camel-crossing process from start and finish before the car reaches our gate. In addition, to make our system more secure, the automated gates perform these calculations frequently and continuously even while they are open. This step is important to determine whether to change the decision of opening the gate in case of any emergencies.

In table 1, we document some simulation results for different speed limits on 30 m road wide and camel's average speed $S_c = 3.5\ km/hr$. Moreover, it is important to mention here that the automated gates should add extra time for more safety and should use some conventional techniques to make the camels cross the road as quick as possible.

TABLE I. Speed-distance calculations for road width, $\boldsymbol{Y_2 = 30\ m}$, and camel average speed, $\boldsymbol{S_c = 3.5\ km/hr}$. Here the unit of speed limit $\boldsymbol{S_v}$ is km/hr.

$\boldsymbol{Y_1}$ (m)	$\boldsymbol{t_c}$ (s)	$\boldsymbol{X_{min}}$ (km)				
		$\boldsymbol{S_v = 160}$	$\boldsymbol{S_v = 140}$	$\boldsymbol{S_v = 120}$	$\boldsymbol{S_v = 100}$	$\boldsymbol{S_v = 80}$
100	133.71	5.94	5.20	4.46	3.71	2.97
80	113.14	5.03	4.40	3.77	3.14	2.51
60	92.57	4.11	3.60	3.09	2.57	2.06
40	72.00	3.20	2.80	2.40	2.00	1.60
20	51.43	2.29	2.00	1.71	1.43	1.14
0	30.86	1.37	1.20	1.03	0.86	0.69

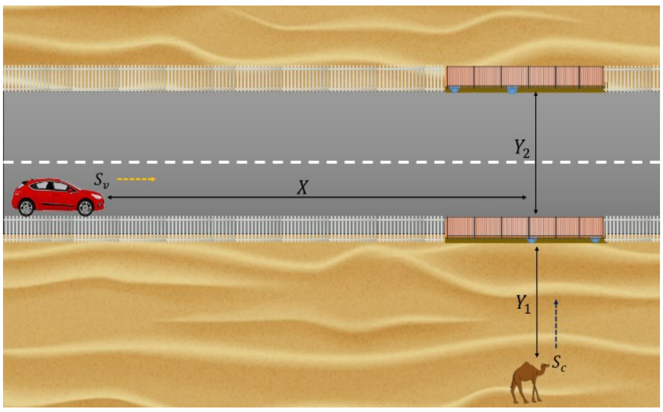


Fig. 3. A descriptive scenario of a radio-collared camel detected by our automated system.

In figure 4, we show the simulation results of the minimum distance required by the cars in order to activate the gate and also the camel-gate distance. The plot line shows that X_{min} is linearly proportional to the camel-gate distance Y_1. However, the slope of $X_{min}\ vs.\ Y_1$ decreases with decreasing road speed limit. This means that, as the speed limit goes higher, the camel-gate distance becomes more critical and effective. Based on the calculations in table 1, the first warning light sign should be fixed on the road side at X_{min} when $Y_1 = 100\ m$. For example, if the speed limit is $S_v = 160\ km/hr$, the first light sign should be 5.94 km before our automated gate while it should be 2.97 km for $S_v = 80\ km/hr$.

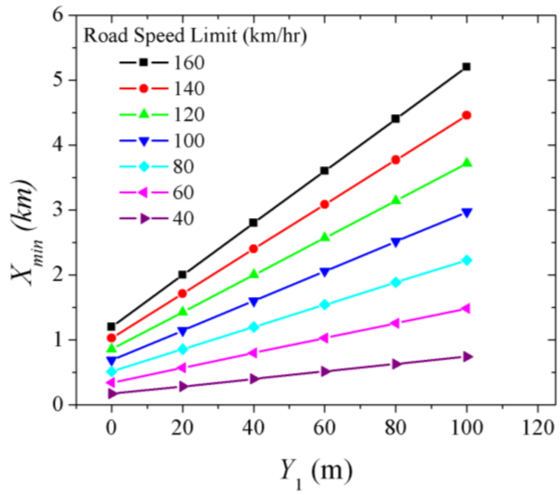
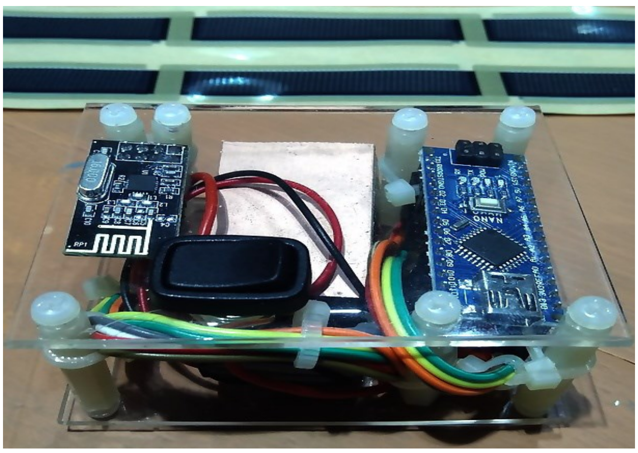


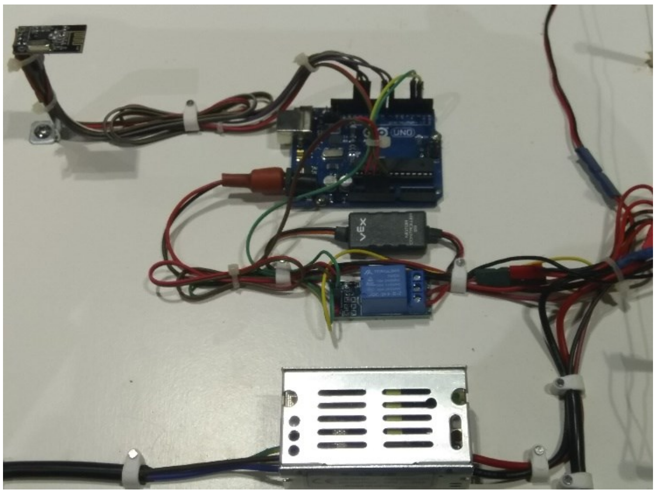
Fig. 4. Minimum activation distance vs. the camel-gate distance.

V. Experimental Results

Currently, a prototype has built in our labs to validate the proposed system. As stated before in section III, figure 3 shows our prototype which is comprised of off-the-shelf components. While this project is at its infancy stage, the components presented so far have been enough to conduct several experiments. In these experiments, we performed two sets of tests: The collar's power system was tested outdoors. The result was promising in terms of energy consumption. The communication link between the radio collar and the highway-based detection system was tested indoors and three observations were taken at d = 50m, 75m, and 100m. The results indicated that the received signal is recorded for just one observation; the 50m. In summary, the environment plays a major role on the transmitted signal's attenuation.



(a)



(b)

Fig. 3. Overview of the main components used in the system design. (a) Collar module. (b) Part of the highway-based detection system.

VI. Conclusion and Future Work

Fencing the highway is considered as one of the solutions that used today to mitigate accidents between camels and vehicles. Although, the use of fencing is an effective method in reducing collision of motor vehicles with camels, fences can block camels' movements, and access to forage and water. In this paper, we have presented a new intelligent system where gates are allocated along the fences and equipped with the proposed system. The system is triggered by the existence of the camels and as a result, drivers got warning messages. For a certain cases, where a heavy traffic phenomena occurred with the existence of camels; the system will give higher priority to the vehicles. To demonstrate the performance of the proposed system, we carried out several simulations for different road speed limits. The results show that as the speed limit on the highway goes higher the camel-gate distance becomes more critical and effective. In the current stage, a prototype was built at the labs to test the proposed approach. The results were promising and the system is ready to be implanted in the near future.

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