Simulating Camel-Vehicle Accidents Avoidance System

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Abstract

Animal-vehicle collisions (AVC) affect human safety, property and wildlife. The number of collisions with large animals worldwide and especially in the Saudi Arabia Kingdom has increased substantially over the last decades. This paper provides a survey of the existing systems that mitigate the AVC. Moreover, this paper presents the high-level design of a deployable and intelligent Camel-Vehicle Accident Avoidance System (CVAAS) using global positioning system (GPS) technology. The use of the GPS technology in this kind of application is a novel idea. To evaluate the CVAAS system a simulator has been implemented.

Keywords: *GPS, Animal vehicle-collision avoidance technologies*

1. Introduction

Reducing animal-vehicle accidents across roadways are significant issues to consider in highway construction for human safety, economical, and ecological reasons. In the *Saudi Arabia Kingdom* (*KSA*), hundreds of camel-vehicle accidents are reported every year causing numerous deaths and loss of property running into billions of Saudi Riyals. Summaries of traffic accident data show that more than 600 camel-vehicle accidents occur each year [1]. Similarly, the total number of reported animal-vehicle accidents in *United States* (*US*) is about 300,000 per-years [20]. In Europe and Canada moose and deer have been shown to be a considerable problem on the road [15]. *AVC* is not only a traffic problem in *KSA* but also considered a major safety problem in the *US*, *Japan*, and *Europe* [4], [40]. In *KSA*, usually camels that are found near highways are domestic camels because the owners like to live close to highway for transportation facility. These camels move across highways looking for water and food, and during mating season. Camels are very hard to detect by vehicle drivers especially in the night time and results in severe accidents if a collision occurred. According to *Al-Ghamdi* and *AlGadhi* [1] study, the most frequently involved animal in *AVC*'s is camel; it is estimated that 97% of all reported *AVC*'s were camel related. More than 90% of these accidents occur at night, between dusk and dawn [22]. These accidents cause a lot of damage to the environment, economy and social life such as significant economic loss, human injuries and/or fatalities, loss of valuable wildlife, and damage to properties as seen in figure 1. Langley [25] examined risk factors involved with fatal *AVC*'s in the *US* from 1995 to 2004 and found that 89.5% occurred on rural roads, 64.8% in darkness, 85.4% on straight sections of road, 91.1% occurred in dry weather conditions, and 28% of the victims were motorcyclists. More efforts need to be done to reduce the number of *AVC*'s. Most researches have attempted to cope the *AVC*, but neither unique solutions nor efficient results have been found.

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Figure 1. Camel-Vehicle Accident.

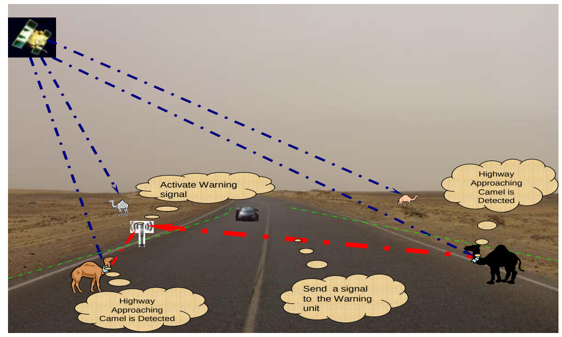

Figure 2. The Warning System being Activated as Camels approach the Highway.

Many kinds of animal detection and warning systems are used around the world to indicate presence of animals on highways to avoid accidents. Animal detection systems are divided into three main categories namely Road-based, Vehicle-based, and Animal-based. Detailed discussion will be undertaken in the literature review. This paper proposes a design of a Camel-Vehicle Accident Avoidance System (*CVAAS*) using global positioning system (*GPS*) technology. The use of *GPS* technology in this kind of application is a novel idea. Use of *GPS* receivers has increased tremendously for navigation purpose, in tracking animals [33], [35], in sensors networks, and many other applications. *GPS* receiver can be obtained for a reasonable price of around 20-50$. Thus, the use of programmable *GPS* devices in *CVAAS* is a novel and feasible solution. *CVAAS* system is an animal-based system that identifies the presence of a camel on or near the highway and then sends out its position to the Dedicated Short-Range Communication (*DSRC*) transmitter. Consequently, the *DSRC* transmitter forwards the camel position to a *DSRC* receiver mounted on a warning system. The signal will activate the warning system to warn the vehicle drivers to slow down in order to avoid collision with the camel. Figure 2 illustrates such a scenario.

The remainder of this paper is organized as follows. Section two illustrates and classifies the current animal-vehicle collision avoidance technologies. Section three briefly discusses and presents the design of *CVAAS*, the proposed novel system. Different camels movements scenarios have been simulated and tested in section 4. Finally, section five draws a conclusion of this paper.

2. Current *AVC* Technologies

2.1 Roadway-based Technologies

2.1.1. Roadway-based Conventional Techniques: This section briefly introduces three different roadway-based conventional techniques as follows.

Fences. They have been installed to keep animals away from the road [7], [6]. Roadway fencing is one the famous conventional techniques used to reduce *AVC*. It is the only method used to stop camels from coming on the *KSA*'s highways. Ward [36] signified that a 2m high big-game fence is effective in reducing vehicle collisions involving deer. Fencing is extremely expensive because they have been combined with wildlife crossing structures such as underpasses and overpasses that enable animals to move freely along both sides of the highways. Fencing must be inspected frequently and repaired to original condition to be successful at reducing collisions because animals quickly exploit breaks in the fence [10]. Apparently, deer continually test fencing, making a good maintenance program necessary [36].

Warning Signs. They warn drivers of high large animals crossing locations are the most common approach to reducing *AVC* [28]. Romin and Bissonette [31] suggested that deer crossing signs may be effective if drivers would reduce their vehicle speed. Lighted, animated deer-crossing warning signs were evaluated in Colorado. *Pojar* 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 [27].

Highway Lighting. Most of the *AVC* occurred from sunset to sunrise. It was expected that highway lightings enhance drivers' night vision and reduce *AVC*. Highway lighting did not affect drivers' behavior or animal crossings-per-accident ratios [30]. Thus, increased highway lighting was not effective at reducing *AVC*.

2.1.2. Roadway-based Detection Systems: Animals detect technologies detect large animals as they approach the road. When an animal is detected, signs are activated that warn drivers that large animals may be on or near the road at that time. Vehicle detect technologies operate on a slightly different principle as they detect vehicles, not the animals. They detect vehicles or trains, not the animals. Once a vehicle or train is detected large animals are alerted through a range of audio and visual signals from stations placed in the right-of-way [18]. Briefly, this section clarifies different technologies that have been used to develop animal-detect and vehicle detect techniques.

Infrared Sensors. They were designed and installed in seven sites in Switzerland to detect deer within 30-100m radius on both sides of the road. Once a deer was detected *LED* signs with a deer symbol were activated and stayed on for 45 seconds to alert the drivers [23]. This technique produced false detections because of strong winds and warm engines of passing vehicles. Moreover, the broken sensors, loss of power due to snow covered solar panels and broken lamps in the warning signs caused additional problems. Similarly, the Flashing Light Animal Sensing Host (*FLASH*) was designed to detect mule deer in Wyoming, *USA*. It also used a series of infrared sensors [14]. More than 50% of the detections through *FLASH* system were false. This was due to frost on the sensors, birds feeding on carrion in the crossing area, and snow has thrown by passing snowplows.

Microwave Radar Sensors. In Finland, they were designed and installed to detect large animal movements up to 50 m in distance within a 60° horizontal angle. When an animal was detected, LED message signs with an animal symbol were turned on and remained on for two-three minutes. To verify the presence of animals a video camera is installed. In addition, to distinguish animal from other moving objects such as rain or rain spray, the system was programmed to only detect objects moving towards the sensors at a speed greater than 0.8m/s. This technique produced false detection in spring when the snow melted and the water warmed on the pavement, spray from passing vehicles triggered the system.

Laser Sensors. In 2000 an animal detection system was installed in Washington, *USA*. It consisted of two lasers, one placed on each side of the road, two standard deer warning signs, two smaller rectangular signs that read "When Flashing," and two solar-powered red flashing beacons. When the laser beam was broken the lights were switched on. The lasers operated on batteries with one-week lifespan while the red strobes were solar powered. The sighting of the lasers proved difficult, partially because of the distance among the sensors. Sunlight heating up of the plastic boxes holding the laser equipment may have caused problems with the sighting of the laser. False detections caused the batteries to drain quicker than anticipated. Similarly, in October 2002, an animal detection system was installed along US 97A, near Wenatchee, Washington. It used laser beams to detect deer. If deer stays there longer than one minute, the warning signals were turned off, and drivers are no longer warned of its presence [37]. The laser beams could only be used for short distances on straight sections of roadway. Anything that broke the beam triggered the warning, including birds, dogs, mail trucks and snow plow curls. Perfect alignment was critical (high maintenance costs). Even the sun could trigger the beacons depending on the time of year as sunrise and sunset angles changed.

Microwave Technology. An animal detection system consisted of series of transmitters and receivers. It was installed in 2002 along the highway in Montana. Each transmitter sent an uniquely coded, continuous microwave RF signal to its intended receiver [34]. The transmitters and receivers were mounted about 120cm above the ground. The system produced a large number of false detections for several causes such as snow spray.

A vehicle detection system has been installed in April, 2002 in *Canada*. It consists of a small cabinet with electronics, sensors for vehicle detection, and an animal warning device. The units are powered by solar panels and batteries. When no vehicles are present the system is not active. Once vehicles are detected, units in the roadside are activated that alert deer through a variety of noise and light signals [21]. Many kinds of animal have been shown to adapt to disturbance if this is not accompanied by an immediate and real threat. Therefore, the audio and visual signals produced by the stations in the right-of-way may not scare the animals away from the road once they have been exposed to it for a certain time. Additionally, such system is not well suited for high traffic flows since the animal warnings would be running continuously in such locations.

2.2. Animal-based Technologies

The animal based technologies to mitigate *AVC* used different types of collars fasten with the animal to trigger a warning system such as blinking signals. They are classified as reflective collars and radio collars.

Reflective Collars. In British Columbia, Canada, the ministry of environment conducted a method to reduce *AVC*. In 2006, they put collars with reflective tape on a number of animals to increase their visibility to drivers. In addition, a major company *Aramco* in *KSA* distributed around 3000 reflective collars to the camels' owners in Al-Ahsa. These collars are not efficient to reduce the *AVC* because vehicles must be close enough to ensure that the collars are visible which defeats the whole purpose of avoiding accidents. Moreover, the reflective materials of the collars will disappear over time.

Radio Collars. Multiple of projects employed radio collars since 1999 up to now. A system was installed along a 4,827m long section of Hwy 101, near Sequim, on the Olympic Peninsula, Washington. In 1999 about 10 percent of the elk herd was radio collared [5]. An effort was made to radio collar lead cows, but this was not always possible. Receivers placed along the road scan for the frequencies of the individual radio collars 24 hours per day. When the radio-collared individuals come within about 400m of the road, the receivers that pick up the signal activate the flashing beacons. As a consequence, the animals without a radio collar are only detected if radio-collared animals accompany them. Therefore, the system only works well for highly gregarious species. The radio-collar system requires re-collaring effort. The batteries of the radio collars usually run out after several years, and then they must be replaced.

***GPS* Collars.** It is a valuable tool for documenting the movements of large, wide-ranging animal kinds. Recently, *GPS* collar has been instrumental in monitoring large mammal use of highways and wildlife underpasses in Arizona [26]. Using data gathered from *GPS* collar, [26] were able to identify spatial patterns in bighorn sheep movement relative to a key section of *US* 93. Based on *GPS* collar data, the authors were able to make informed recommendations regarding placement of wildlife-engineered crossing structures on *US* 93. *Dodd et al*. [8] used *GPS* collars to assess permeability of SR 260 to elk through successive phases of reconstruction, which included widening the highway, integrating wildlife crossing structures, and implementing ungulate-proof fencing. *Gagnon et al*. [11, 12] were able to determine how patterns in traffic flow affected elk crossing and distribution in the vicinity of SR 260; the authors found that although high traffic volumes greatly affected elk crossings, seasonality and proximity to quality habitat also strongly affected elk behavior. To the best of our knowledge, most of the systems that used *GPS* collars only to monitor large animal movements for the sake of recommending the placements of wildlife-engineered crossing structures on highways.

2.3. Vehicle-based Technologies

The vehicle based technologies to avoid *AVC* can be broadly classified into two major groups: warning whistles (e.g. deer whistles) and infrared detection systems. They would not depend on the installation of any roadside equipments. Deer whistle was introduced as early as late 1970s, [24]. Air activated deer whistles, mounted on the fronts of vehicles, allegedly produce ultrasonic frequencies and/or audible sounds from the wind rushing through them. These sounds are supposed to scare away animals. It has been observed that given the masking effect of road and vehicle noise, however, it is unlikely deer would be able to hear the whistles *Romin* and *Dalton* 1992 [32]. In addition, there is no evidence that audio signals affect animal behavior [2] and habituation to sounds has been observed [32], [29]. However, the infrared detectors inform drivers when a large animal is detected within a certain range from the sensors attached to the vehicle (e.g., [3], [16], and [17]). The range should be sufficient to allow for the driver to stop the vehicle before impacting the detected animal. As an option on the *Cadillac DeVille* an infrared sensor, mounted in the front grille, picks up heat energy from a person or an animal. The image is projected onto a monochromatic display on the lower part of the driver's side of the windshield.

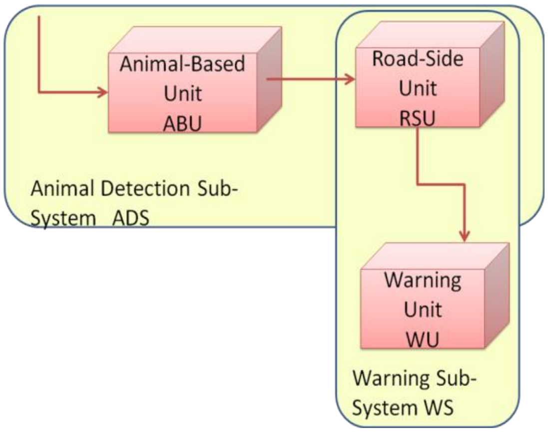

Figure 3-a. CVAAS: Block Diagram

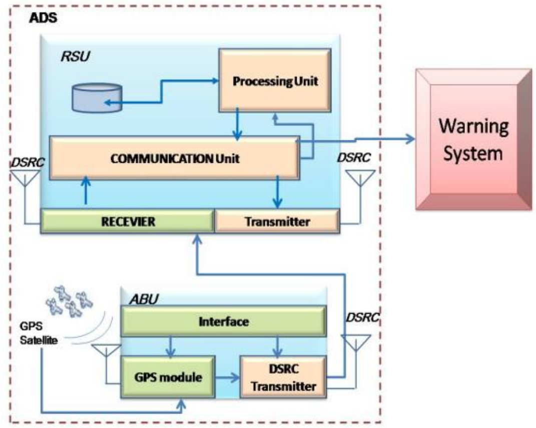

Figure 3-b. CVAAS Components.

Hot objects appear white and cool objects appear black in that image. Some drivers have noted that objects are difficult to see and appear fuzzy due to the field of view that is too limited to be useful. Others have complained of headaches after only one hour of use. These systems are used to reduce *AVC* encountered some technical problems and maintenance issues. More significantly they experienced false positives and false negatives. The false positive occurs when the warning system is activated even if there is no animal. Whereas, false negative occurs when there is animal but the warning system is not activated. The *AVC* systems with break-the-beam sensors may experience false positive detections due to falling branches in forest, especially in strong winds or snow spray from snowplows, etc. Broken sensors, loss of power due to snow-covered solar panels, and broken lamps in the warning signs may caused false positive. False negative may occur due to curves, slopes not covered by sensors and insufficient warning time [19]. False positives may cause drivers eventually to ignore activated signs [13] and false negatives present drivers with a hazardous situation. It is of immense importance that any system designed to reduce or avoid *AVC* should ensure minimal number of false positives and false negative. *CVAAS* aims to address these false detection problems through employing the novel idea of using a programmable *GPS* device which gives accurate positioning of an animal. In the following section, this paper discusses the high level design of *CVAAS*.

3. Designing *CVAAS*

The *CVAAS* consists of two sub-systems: Animal Detection sub-Systems (*ADS*) and Warning sub-System (*WS*) as shown in figure 3-a. *ADS* includes two units: Animal-Based Unit (*ABU*) and Road-Side Unit (*RSU*). *ABU* is mounted to the animal and consists of *GPS* receiver, *DSRC* transmitter, and interface as shown in figure 3-b. The European Telecommunications Standard Institute (ETSI) decided to allocate frequency band from 5875 to 5905 MHz for Intelligent Transport Systems (*ITS*) [9]. Similarly, we decide to utilize *DSRC* transmitter and receivers that operate with 10MHz band 5885 to 5895 MHz in *CVAAS*. They operate with 33 dBm[2]@10MHz transmit power that enables transmitters and receivers to reach communication distance range from 500m to 1000m.

[2] *dBm* is the measured power referenced to one milliwat.

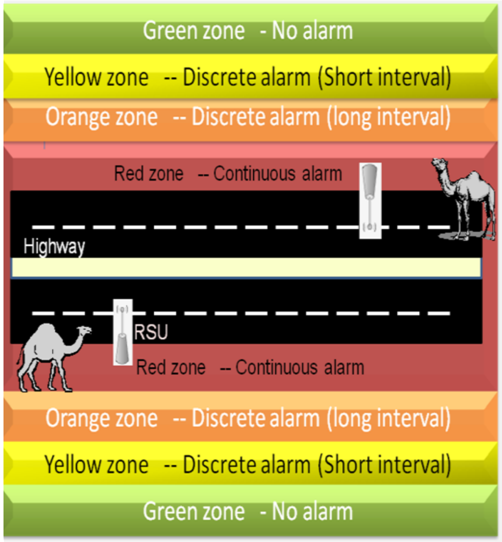

Figure 4-a. Description of Dangerous Zones.

```
RSU_activate(){
 while(1){
 receive(key-data);
 activate_message->zone=match (key-data);
if (activate_message->zone != green)
    send(activate_message);
} }

Warning_setup(){
zone= green; // default value
Alarm = silent;
while(1) {  receive(activate_message)
 switch (activate_message->zone){
 case red: Alarm= continuous; break;
 case orange: Alarm = long_discrete;
 break;
 Case yellow: Alarm=short_discrete;
 break;
 default: Alarm = silent; break;
} } }
```

Figure 4-b. RSU_activate() and Warning_setup() Modules.

GPS receiver operates to capture key-data such as animal's position, velocity, acceleration, heading, etc. The transmitter forwards that key-data to the *RSU* The *ABU*'s interface grants the ability to update the system parameters of both *GPS* receivers and *DSRC* transmitter such as the frequency of key-data transmission, positioning times based on animal behavior (e.g. more frequent during activity, less frequent when relaxing), packet payload size and message life time. Road-Side units are organized along the highway. Each *RSU* consists of DSRC transmitter and receiver, communication unit, processing unit (Application processor) and storage area. It stores the highway map for a distance of 100-300m around the *RSU*, and the description of the dangerous zones around it as shown in figure 4-a. Table 1 outlines the *CVAAS*'s components and their functions. The *RSU*'s receiver gets the key-data from *ABU*'s transmitter. The communication unit forwards the received key-data to the *RSU*'s processing unit. The processing unit executes a thread that runs the *RSU_activate()* procedure, see figure 4-b. As soon as, the *RSU_activate()* procedure receives the key-data that match with the description of the dangerous zones it takes the decision to send activate message to the *WS*. The activate message includes the classification of dangerous zones. The *WS* executes a thread that runs the *Warning_setup()* procedure as shown in figure 4-b. When the *Warning_setup()* procedure receives the activate message, it identifies the degree of hazardous and setups the alarming period. For example, red-zone is the most dangerous zone that includes bi-direction lanes and stripes around it with range10-20 meters. As shown in figure 5, if any camel belongs to the camels' group *B* in the red-zone sends its key-data to the *RSU* then the *RSU* activates the *WS* to produce continuous alarm with a red *LED* sign with a camel symbol until it receives different key-data from the *ABU* (i.e. head off the red-zone). Otherwise, the *WS* will not be activated while it is not receiving any key-data or it is receiving a key-data from a camel resides in the green-zone that is belonging to the group *A* as shown in figure 5. A green LED sign with a camel symbol is continuously activated whenever there is no camel nearby.

Table 1. Components of the *CVAAS*'s Block Diagram.

Unit	Configuration Data	Input	Output	Functions (Tasks)
ABU	- *GPS* fixing time - Transmitting interval	*GPS* signals	Camel's key-data (position, velocity, heading)	- Determine camel's key-data. - Transmit camel's key data
RSU	Zones definition	Camel's key-data	Warning (activate) message.	- Receive camel's key-data - Forward appropriate warn message to *WU*.
WU	Alarm's frequency Coverage area to send SMS message.	Activate message	Flashing light and alarming, or SMS message to drivers.	Activate warning to drivers.

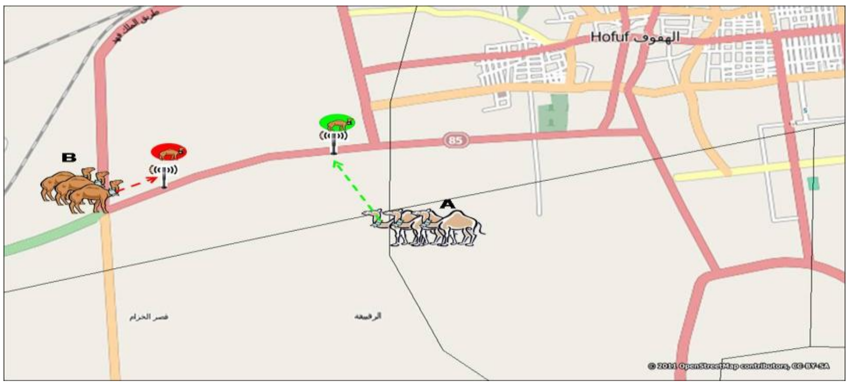

Figure 5. Hofuf–Riyadh highway: Two groups of Camels Groups A in green-zones and Group B in red-zone

4. Simulating *CVAAS*

To study the effectiveness of the proposed *CVAAS* in terms of minimizing or eliminating false positives and false negatives simulation was carried out. The author implemented a simulator that emulates the existence of the camel unit (*ABU*) and the road side unit (*RSU*). This section illustrates the steps to program the *GPS* device to determine the current position at the camel unit (*ABU*). Moreover, it explains the used method to calculate the distance between the camel and the roadside unit (*RSU*). This simulation implements two programs: *ABU* emulator and *RSU* emulator. The *ABU* emulator captures the camel's key-data and transmits such data to the *RSU* emulator. Accordingly, the *RSU* emulator calculates the distance between the *RSU* and the camel to determine the degree of hazardous to trigger the warning system.

The *ABU* simulator was run on a Fujitsu U820 mini-notebook tablet with 1.6 GHz Intel z530 processor, 1GB RAM and built-in *GPS*. It is running Microsoft Windows VISTA operating system. While, the *RSU* emulator ran at Dell PC with 2.2.GH Intel processor and 2GB RAM. It is running Microsoft Windows XP Professional operating systems. Each machine has an IEEE 802.11a/b/g wireless device and they communicate through a wireless router. Both *ABU* and *RSU* emulators communicated in software level through Windows Socket (Winsock). It enables them to set up a communication session based on TCP/IP protocol. As soon as this communication session has been established, the *ABU*'s Winsock could send the camel's key-data to the *RSU*'s Winsock. A free LCC-Win32 C compiler system for windows operating system

(LCCwin32) has been used to compile and link the *ABU* and *RSU* emulators. The *GPS* receiver captures key- data based on a special standard so called NMEA. NMEA standard has been discussed in details in the second report.

The hardware interface for *GPS* units is designed to meet the NMEA requirements. They are also compatible with most computer serial ports using RS232 protocols (RS232 1969). The interface speed can be adjusted on some models but the NMEA standard is 4800 b/s (bit per second rate) with eight bits of data, no parity, and one stop bit. All units that support NMEA should support this speed. Note that, at a b/s rate of 4800, you can easily send enough data to more than fill a full second of time. The following code is a part of the *ABU* emulator. It is used to open the port “COM3” for reading key-data from *GPS* device into a buffer so called “*mData*” with length “*readed*”. It interprets these data to identify the key-data and ignore non-interested sentences. Finally, it forwards that key-data to the *RSU* using the windows socket.

```
HANDLE hCom;
char *pcCommPort = "COM3";
BOOL RSUccess;
BYTE mData[NP_MAX_DATA_LEN]={0};
hCom = CreateFile( pcCommPort,
           ENERIC_READ |GENERIC_WRITE, // open for read or write
           0,  // must be opened with exclusive-access
           NULL, // no security attributes
           OPEN_EXISTING, // must use OPEN_EXISTING
           0,    // not overlapped I/O
           NULL // hTemplate must be NULL for comm devices
                );
 if (hCom == INVALID_HANDLE_VALUE) // Handle the error.
 {
     printf ("CreateFile failed with error %d.\n", GetLastError());
     return (1);
   }
do
 {
      // read Key-data from serial port COM3 with a
     //  length “readed”
    RSUccess=ReadFile(hCom, mData, sizeof(mData), &readed, NULL);
    if (RSUccess)
     {    //intepret the received buffer and ignore
         // non interested sentences
      Interpret_Buffer(mData, readed);
      Send(keyData); } // send key-data to the RSU
                      // using Winsock.
  } while (1);
```

The following code is a part of the *RSU* emulator. It receives the key-data from the *ABU* emulator through the *ABU*Socket and then determines the distance between *ABU* and *RSU* using the distance function based on their latitude and longitude of those points as defined in [38]. Consequently, the *WU* is activated based on the description of the dangerous zone.

```
double longa=49.35477; //Location of the RSU. It is fixed
double lat=25.20846;  // however it could be variable if
                      // the RSU has a GPS reciver.
double dis;
int iRecvResult;
iRecvResult = recv(ABUSocket, KeyData, recvbuflen, 0);
if (iRecvResult > 0) {
   dis=distance(lat, longa, KeyData->Latitude,
                                KeyData->Longitude)/1000;
   Activate_WU(dis);      // Activate the warning unit based
                       // on dangerous zone
   printf("distance is %lf Meters \n", dis);
   }
/*-------------------------------------------------------*/
// The routine calculates the distance between two points
//(given the latitude/longitude of those points).
// Definitions:
//  South latitudes are negative, east longitudes are
//  positive Passed to function:
//  lat1, lon1 = Latitude and Longitude of point 1
//  (in decimal degrees)
//  lat2, lon2 = Latitude and Longitude of point 2
//  (in decimal degrees)
/*--------------------------------------------------------*/
double distance(double lat1, double lon1, double lat2,
                                                 double lon2)
{
      double earthRadius = 3958.75;
      double dLat = deg2rad(lat2-lat1);
      double dLng = deg2rad(lon2-lon1);
      double a = sin(dLat/2) * sin(dLat/2) +
                 cos(deg2rad(lat1)) * cos(deg2rad(lat2))
                                    * sin(dLng/2) * sin(dLng/2);
      double c = 2 * atan2(sqrt(a), sqrt(1-a));
      double dist = earthRadius * c;
      double meterConversion = 1609.00;
   return dist * meterConversion;
   }
```

4.1. Simulation Results

The simulation focuses on the conditions that lead to activate the warning system such as when camel is approaching or when it's on the highway. The *CVAAS*'s team repeats testing this simulation. Each test is performed in one hour (test period). Consequently during each test period, the *ABU* unit detects its positions every 15 sec. Moreover, different scenarios have been tested with simulating different camel's movement patterns.

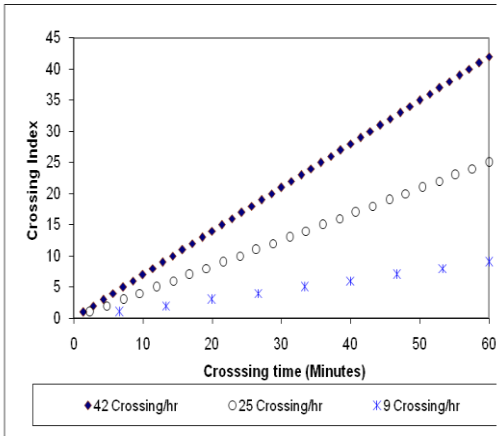

Figure 6-a. Camel's Crossing Model.

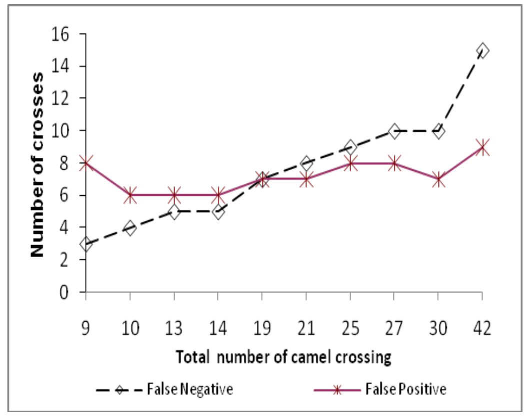

Figure 6-b. Camel's Crossing Model

Table 2. Simulation Results

Total Number of Crossing/hour	Number of False Negative/hour	Number of False Positive/hour
25	9	8
19	7	7
13	5	6
27	10	8
10	4	6
21	8	7
30	10	7
9	3	8
42	15	9
14	5	6
Average (ρ) =	**63.55%**	
Average (ϕ) =		**0.5 %**

Figure 6-a demonstrates the camel's crossing model for three different crossing numbers per hour selected from table 2. In order to study the effectiveness of the *CVAAS*, the author used a method that is often used to study incident detection algorithm [39] as follows.

Assumes τ is the total crossings of an animal to the highway, α is the number of false negative detections, β is the number of the false positive detections, ρ is the detection rate, ϕ is the false alarm rate, and δ is the total number of applications of detector (60 *60*60/15=1440).

Consider the following definitions:

$$Detetction\ Rate\,(\rho) = 100\% * \left(\frac{(\tau - \alpha)}{\tau}\right)$$

$$False\ Alarm\ Rate\ (\phi) = 100\% * \left(\frac{\beta}{\delta}\right)$$

Table 2 shows the simulation results. The average of the ρ and ϕ are 63.55%, 0.5% respectively. The percentage of false positives and the average number of false positives per hour was relatively low (≤1%; ≤0.10/hr). False positives do not appear to be a major concern with regard to the reliability of animal detection systems. Moreover, the percentage of intrusions (i.e., situations where at least one animal was present in the detection area) that were detected is around 64%. The average number of false negative per hour is around 24%. Figure 6-b. presents the total number of camel's crossing versus the number of crosses that leads to false negative and positive respectively. It shows that false negative is increasing larger than the false positive. The results suggest that false negatives are a major concern.

The simulation results show the proposed system *CVAAS* is working effectively. Moreover, it shows that the *CVAAS* experiences some drawbacks due to the low accuracy of the *GPS* device mounted to the (*ABU*). We recommend using more accurate and programmable *GPS* device for real implementation. The programmable *GPS* device enables us to set the position fixing time to reduce the number of false negative. The recommended performance requirements for the reliability of animal detection systems were compared to the results of the reliability tests. However, experiences with installation, operation, and maintenance will show the robustness of animal detection systems that enable us to improve the systems before deploying on a large scale. Currently, we are developing this simulation to identify the efficient values of the system's parameters of both *GPS* receivers and *DSRC* transmitter such as the frequency of key-data transmission, positioning times and number of *RSU*s/Km, etc. This simulation provides some recommendations for system deployment. It enables us to select efficient parameters that consider the system's power consumption and the system's deployment cost.

5. Conclusion

This paper introduced a survey of the developed animal detection and warning systems. It provided recent and numerous reviews of the worldwide technologies that have been used in attempts to reduce *AVC*. Moreover, this paper introduced the design of the camel-vehicle accident avoidance system *CVAAS* in *KSA*. The *CVAAS* took first comprehensive steps toward a system that detects camels on the highway and warn drivers as well. The innovation of the *CVAAS* is the careful and intelligent use of the programmable *GPS* device to detect the camel position, direction and movement. Moreover, *CVAAS* classifies the dangerous zones that enable the warning system to adapt the alarming period. Simulation concluded that false negative is the major concern for further study and analysis.

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