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Simulating Camel-Vehicle Accidents Avoidance System

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Abstract: Animal-Vehicle Collisions (AVC) affect human safety, property and wildlife. Furthermore, the number of collisions with large animals worldwide and especially in the Saudi Arabia Kingdom has increased substantially over the last decades. This study provides a survey of the existing systems that mitigates the AVC. Moreover this study 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.

Key words: GPS, animal vehicle-collision avoidance technologies, human safety, wildlife, decades, deaths

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 >600 camel-vehicle accidents occur each year (Al-Ghamdi and Al-Gadhi, 2004). Similarly, the total number of reported animal-vehicle accidents in United States (US) is approximately 300,000 years^{-1} (Huijser *et al*., 2008). In Europe and Canada moose and deer have been shown to be a considerable problem on the road (Haikonen and Summala, 2001).

AVC is not only a traffic problem in KSA but also considered a major safety problem in the US, Japan and Europe (Bruinderink and Hazebroek, 1996). In KSA, usually camels that are found near highway 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 Al-Gadhi (2004) study, the most frequently involved animal in AVC's is camel; it is estimated that 97% of all reported AVC's were camel related. About >90% of these accidents occur at night between dusk and dawn (Sullivan, 2009). 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 shown in Fig. 1. Langley *et al*. (2006) examined risk factors involved with fatal AVC's in the US from 1995-2004 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.

Fig. 1: Camel-vehicle accident

More efforts need to be done to reduce the number of AVC's. Most researches have attempted to deal with the AVC but neither unique solutions nor efficient results have been found. 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 study 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

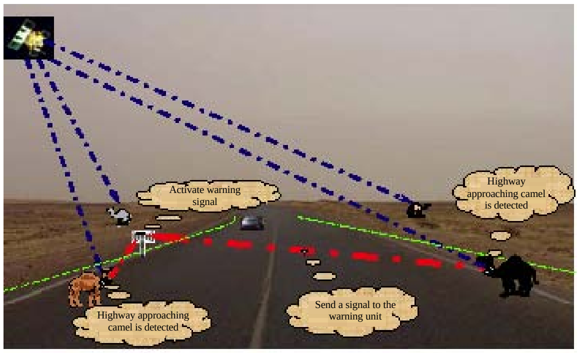

Fig. 2: The warning system being activated as camels approach the highway

tremendously for navigation purpose in tracking animals (Rutter, 2007; Turner *et al*., 2001) 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 shows such a scenario.

CURRENT AVC TECHNOLOGIES

Roadway-based technologies (Roadway-based Conventional techniques)

Fences: They have been installed to keep animals away from the road (Clevenger *et al*., 2001). 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 (1982) signified that a 2 m 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 (Foster and Humphrey, 1995). Apparently, deer continually test fencing, making a good maintenance program necessary (Ward, 1982).

Warning signs: They warn drivers of high large animals crossing locations are the most common approach to reducing AVC (Putman, 1997). Romin and Bissonette (1996) 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 (Pojar *et al*., 1975).

Highway lighting: Most of the AVC occurred from sunset to sunrise. It was expected that highway lighting enhance drivers' night vision and reduce AVC. Highway lighting did not affect drivers' behavior or animal crossings-per-accident ratios (Reed, 1981). Thus increased highway lighting was not effective at reducing AVC.

Roadway-based detection systems: Animal 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 (Huijser and McGowen, 2003). Briefly this section will list 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 30-100 m 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 sec to alert the drivers. 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 (Gordon, 2001). About >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 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 2-3 min. 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 >0.8 m sec^{-1}. 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 a 1 week lifespan while the red strobes were solar powered.

The sighting of the lasers proved difficult, partly because of the distance between 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 1 min, the warning signals were turned off and drivers are no longer warned of its presence Bertrand (2010). 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 a uniquely coded, continuous microwave RF signal to its intended receiver (STS, 2002).

The transmitters and receivers were mounted about 120 cm above the ground. The system produced a large number of false detections for several causes such as snow spray.

A vehicle detect 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 (IRD, 2002). 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.

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 utilized radio collars since 1999 up to now. A system was installed along a 4,827 m long section of Hwy 101, near Sequim, on the Olympic Peninsula, Washington. In 1999 about 10% of the elk herd was radio collared (Carey, 2001). 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 h day^{-1}. When the radio-collared individuals come within about 400 m 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 mammals use of highways and wildlife underpasses in Arizona (McKinney and Smith, 2007). Using data gathered from GPS collar were able to identify spatial patterns in bighorn sheep movement relative to a key section of US 93. Based on GPS collar data, the researchers were able to make informed recommendations regarding placement of wildlife-engineered crossing structures on US 93. Dodd *et al*. (2007) 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*. (2007, 2009) were able to determine how patterns in traffic flow affected elk crossing and distribution in the vicinity of SR 260; the researchers 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 the 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.

Vehicle-based technologies: The vehicle based technologies to avoid AVC can be broadly classified into two major groups: warning whistles (deer whistles) and infrared detection systems. They would not depend on the installation of any roadside equipment. Deer whistle were introduced as early as late 1970s (Knapp *et al*., 2004). 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 in 1992 (Scheifele *et al*., 2003). In addition, there is no evidence that audio signals affect animal behavior (Bender, 2001) and habituation to sounds has been observed (Scheifele *et al*., 2003; Ujvari *et al*., 2004). However, the infrared detectors inform drivers when a large animal is detected within a certain range from the sensors attached to the vehicle (Bendix Commercial Vehicle Systems, 2002; Hirota *et al*., 2004; Honda Motor Co. Ltd., 2004).

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. 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 1 h of use.

The systems to reduce AVC encountered some technical problems and maintenance issues. More importantly 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 (Huijser *et al*., 2006).

False positives may cause drivers to eventually ignore activated signs (Gordon and Anderson, 2002) 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.

CVAAS: DESIGN

The design of the CVAAS consists of two sub-systems: Animal Detection sub-Systems (ADS) and Warning Sub-System (WS) as shown in Fig. 3a. ADS includes two units: Animal-Based Unit (ABU) and Road-Side Unit (RSU). ABU is attached to the animal and consists of GPS receiver, DSRC transmitter and interface as shown in Fig. 3b.

The European Telecommunications Standard Institute (ETSI) decided to allocate frequency band from 5875-5905 MHz for ITS. Similarly, we decide to utilize DSRC transmitter and receivers that operate with 10 MHz band 5885-5895 MHz in CVAAS. They operate with 33dBm2@ 10 MHz transmit power that enable transmitters and receivers to reach communication distance range from 500-1000 m. 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 (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 100-300 m around the RSU and the description of the dangerous zones around it as shown in Fig. 4a. 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 (Fig. 4b). As soon as, the RSU_activate() procedure receives the key data that matches 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 Fig. 4b. When

(a)

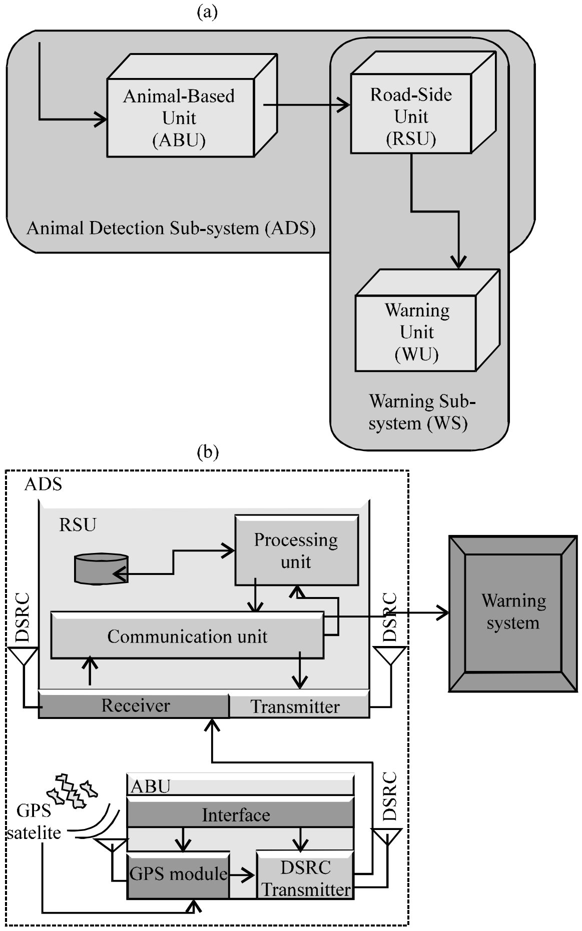

Fig. 3 a: CVAAS: Block diagram; b) CVAAS components

(a)

(b)

```
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;
} } }
```

Fig. 4a: Description of dangerous zones; b) RSU_activate() and Warning_setup() modules

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 and 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

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 m. If the key data received from the ABU matched with the definition of the red-zone then the RSU activates the WS to produce continuous alarm until receives different data key from the ABU. Otherwise, the WS will not be activated whereas the key data matched with the definition of the green-zone. Currently, we are developing a simulation of the CVAAS 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 RSUs/Km, etc. This simulation will provide 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.

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 researchers implemented a simulator that emulates the existence of the camel unit (ABU) and the Road Side Unit (RSU). This study 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 8 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 that 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 ABUSocket and then determines the distance between ABU and RSU using the distance function based on their latitude and longitude of those points as defined by James and Tsu. 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 (ABU Socket, 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;
}
```

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 1 h (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 5a and b demonstrates the camel's crossing model for three different crossing numbers per h 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 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:

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

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

Table 2 shows the simulation results. The average of the ρ and ϕ are 63.55 and 0.5%, respectively. The percentage of false positives and the average number of false positives per hour was relatively low (≤1%; ≤0.10/h). False positives do not appear to be a major concern with regard to the reliability of animal detection systems. Moreover, the percentage of intrusions (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 5b shows 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.

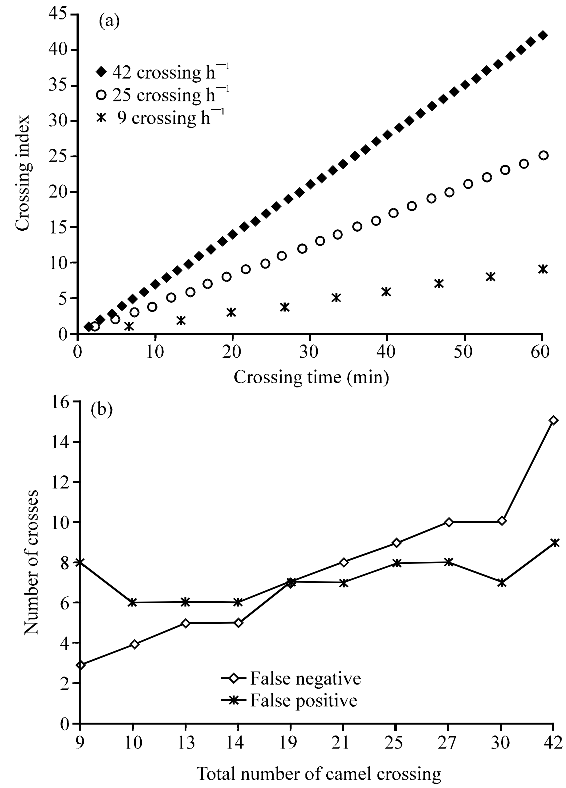

Fig. 5a: Camel's crossing model; b) Camel's crossing model

Table 2: Simulation results

Total no. of crossing/h	No. of false negative/h	No. of false positive/h
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 %

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 enables us to improve the systems before deploying on a large scale.

CONCLUSION

This study 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 study introduced the design of the camel-vehicle accident avoidance system CVAAS in KSA. The CVAAS took first comprehensive steps toward a system that will detect 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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