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Item Type	Presentation
Authors	Sibanda, Vennan;Mpofu, Khumbulani;Trimble, John;Zengeni, Noreen
DOI	<a href="https://doi.org/10.1016/j.procir.2019.04.175">https://doi.org/10.1016/j.procir.2019.04.175</a>
Publisher	Elsevier
Rights	Attribution-NonCommercial-ShareAlike 4.0 International
Download date	2026-06-11 01:30:30
Item License	<a href="http://creativecommons.org/licenses/by-nc-sa/4.0/">http://creativecommons.org/licenses/by-nc-sa/4.0/</a>
Link to Item	<a href="https://hdl.handle.net/20.500.14519/1421">https://hdl.handle.net/20.500.14519/1421</a>

29th CIRP Design 2019 (CIRP Design 2019)

# Design of an Animal Detection System for Motor Vehicle Drivers

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## Abstract

Wildlife-vehicle accidents result in substantial personal, environmental and economic losses, including human injuries, fatalities, loss of wildlife, and vehicle damage. When driving on the highway wild and domestic animals pose dangers to road users. In most cases when the drivers notice an animal on their path, it will be too late to stop the vehicle in time to avoid an accident. This has prompted research into possible ways of developing an animal detection system that gives warning to the drivers and thus enabling them to take precautionary measures. This research is therefore aimed at developing an animal detection system that warns drivers of a possible collision with an animal. Research was carried out using various methods including looking at Literature on ultrasound hooting frequency, and other available warning systems. Questionnaires were also used to gather information from drivers on their experiences and needs to develop the safety measures. Experiments were carried out using Arduino UNO R3 to illustrate the image visibility on an infrared camera and the effect of infrared illumination on the camera system. Calculations were done to achieve the desired number of Infrared LEDs to be used on the camera. An ultrasound circuit and entire system circuitry was developed and simulated using proteus 8 professional to achieve the preferred response mechanism for the system. The system therefore can capture an image of the animal and retrieve its similarity from the animal system database. The results provide a developed animal detection and warning system that can be used by motorist any time of the day while driving.

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Peer-review under responsibility of the scientific committee of the CIRP Design Conference 2019.

*Keywords:* Animal detection system; Infrared; Ultrasound; Thermal detection

## 1. Introduction

When driving along country roads or intercity highways chances are, one animal or another will be met on the road. This could either be domestic or wild animals, depending on the country and region. In some instances, farms along highways have been responsible for the increase in accidents involving livestock and wild animals due to vandalism of fencing material resulting in livestock filtering onto the roads. In Zimbabwe, for instance, there is a total road network of 88 000 km which is made up of 18 460 km of State highways, 8 194 km of urban roads, which fall under the jurisdiction of urban councils, and rural roads which make up 61 000 km of the total road network [1]. The entire road fencing that covered around 18 460 km of State highways is gone, seriously affecting the safety of road users, with accidents involving livestock now a common feature on the country's major roads [2]. A good memory of dangerous spots along the highway due to animals, in the absence of signage that

indicates dangerous spots, has been the only source of good driving on the roads so far [3]. As the number of vehicles increases, particularly in developing countries, experts say road crashes will become one of the top 5 causes of death [4]. As of 2012, the report said road crashes is the 13th leading cause of death in Zimbabwe [5]. The aim of this research is to design an animal detecting device for motor vehicles that warns drivers of the impending danger ahead. Some systems have been developed in detecting obstructions on the roads such as the vehicle guidance system (VGS) which includes providing a system to facilitate the interaction between human operated vehicles (HOV) and autonomous driverless vehicles (ADV). The VGS detects the condition on the roadway, allowing safe interface with each other and with other elements, for example, weather conditions, traffic control systems, road conditions, obstructions that enter the roadway (people, rocks, animals, debris falling onto roadway from other vehicles), among others [6]. The animal detecting device will help in saving lives, preserving livestock and

avoiding fatal accidents. Thermography is a growing evaluation technique and has become a widely used non-destructive evaluation (NDE) technique or damage detection in metallic structural elements. The generally used form of active thermography employs heat pulses emitted to the surfaces and is called Pulsed thermography (PT) [7]. The introduction of focal plane arrays has resulted in superior thermal imaging system with better spatial and temperature resolution [8]. In infrared thermography, the infrared radiation (wavelength lies between 0.75  $\mu\text{m}$  and 1000  $\mu\text{m}$ ) emitted by a body is detected using an infrared detector and the information about temperature is obtained from the acquired data using Stefan–Boltzmann’s law, which is expressed as follows [9].

$$\frac{P}{a} = \gamma \alpha T^4 \quad (1)$$

where  $P$  is the rate of energy emission ( $W$ ), ‘ $a$ ’ is the area of emitting surface ( $m^2$ ),  $T$  is the absolute temperature ( $K$ ) and  $\alpha$  is the Stefan–Boltzmann’s constant ( $\alpha = 5.676 \times 10^{-8} W/m^2K^4$ ) and  $\gamma$  is the emissivity of the material.

There are several animal detection techniques that can be used for this application. Discussed below are some of the techniques available. These are long range communication methods to detect animals and typical examples are the Global Position System (GPS), Ultrasonic, Radio Frequency Identification (RFID), radio wave, thermographic camera and infrared camera [10].

### 1.1 Global Positioning System

The Global Position System (GPS) is used to detect the activities of animals in the jungle like Orangutans [11]. The device is placed near the Orangutan’s ears. It is able to identify the coordinates of the object’s location as the transmitter will send the data every 3 seconds to the satellite and the GPS system will show the input such as area maps to detect the object in a certain area [11].

### 1.2 Radio Frequency Identification

Radio frequency identification (RFID) technology is a simple method of exchanging data between two entities namely a reader/writer and a tag. This communication allows information about the tag or the element carrying the tag to be determined and, in this way, it enables processes to be managed easily [11]. Low-frequency RFID systems (30 KHz to 500 KHz) have short transmission ranges (generally less than 180 cm). High-frequency RFID systems (850 MHz to 950 MHz and 2.4 GHz to 2.5 GHz) offer longer transmission ranges (more than 3 meters). In general, the higher the frequency becomes, the more expensive the system [10].

### 1.3 Ultrasound

The other method to detect the animal is ultra-sonic. It is used with reflection techniques. When the transmitter transmits a signal, the signal will be reflected by the object that obstructs it, then the reflected signal will be detected by the detector. It is used for short distances since it needs reflection. Usually it is used by deep sea fisherman to detect the fish [12].

### 1.4 Infrared

Infrared (IR) is an electromagnetic energy in which the wavelength is longer than the visible light [13]. The infrared

heat energy of an object does not appear visible to the human eye. However, this infrared energy can be transferred in basically three forms of energy, which are the reflected, transmitted and emitted. Infrared wireless is a device or system that transmits data through infrared radiation [14]. Passive infrared (PIR) sensors have been used to detect humans and animals. Infrared radiation exists in the electromagnetic spectrum at a wavelength which is longer than visible light. Objects that generate heat also generate infrared radiation and those objects include animals and the human body whose radiation is strongest at a wavelength of 9.4  $\mu\text{m}$  [14]. Wein’s Law highlights that objects of different temperature emit spectra that peak at different wavelengths [15]. The relationship between the true temperature of a body and its peak spectral existence or dominant wavelength is described by equation 2 below:

$$\gamma = \frac{k}{T} \pi r^2 \quad (2)$$

Where:  $\gamma$  = peak wavelength (m);  $k = 2.898 \times 10^{-3} mK$  (Wein’s constant);  $T =$  temperature (K)

## 2 Thermal detection

Thermal imaging allows accurate temperature measurements for objects in motion at a distance. It tends to be very hot and dangerous to touch [16]. It also provides fast and accurate measurements of objects that are difficult to reach, altered, or impossible to shutoff [16]. In fact, Thermal Imaging, or Infrared Thermography, is a noncontact technology that measures or detects infrared wavelengths emitted from objects, and then converts the resultant temperature information into visual images [17]. The image displays a colour shade that represents a temperature range of the image displayed. Thermal infrared imaging and photogrammetry have the capacity to capture detailed information of geothermal surface features and surrounding vegetation in a chosen area [18]. Infrared (IR) thermal imaging is an evolving field of science that has seen applications in IR detection, electronics and computer science among others. It is currently used in research and development and other fields such as non-destructive testing, condition monitoring etc. A special lens focuses the infrared light emitted by all of the objects in view. The focused light is scanned by a phased array of infrared-detector elements. The detector elements create a very detailed temperature pattern called a thermo gram [19]. It only takes about one-thirtieth of a second for the detector array to obtain the temperature information to make the thermo gram [20]. Fig. 1 shows how the thermal imaging system works.

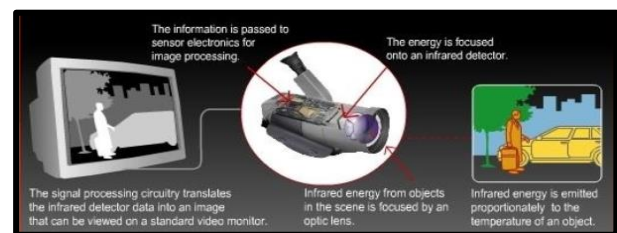


Fig. 1. Thermal Imaging System [20]

The concept of thermal radiation is related to the ideas of energy and temperature. The key principles were discovered

in 1898 by the German physicist Wilhelm Wien [21]. Wien discovered that all bodies constantly emit thermal radiation and that thermal radiation does not depend on what the body is made of [22]. Table 1 shows a list of common animals and their temperatures.

Table 1. Animal Temperature Ranges [19]

Animal	Average Temperature °C	Average Temperature K
Dairy Cow	38.7	311.7
Beef Cow	37.9	310.9
Donkey	37	310
Goat	39.1	312.1
Dog	38.9	311.9
Horse	37.8	310.8
Human	37	310
Rabbit	39.4	312.4

Objects emit radiation whose intensity is a function of their temperature, the higher the temperature the greater the intensity of the emitted infrared energy [16]. The architecture of thermal energy accumulation can be demonstrated as shown in Fig. 2. Arrows indicate the direction of net energy transfer for the temperatures shown. If the surroundings, however, became warmer than the animal, then the arrows between the animal its immediate environment would be reserved [23].

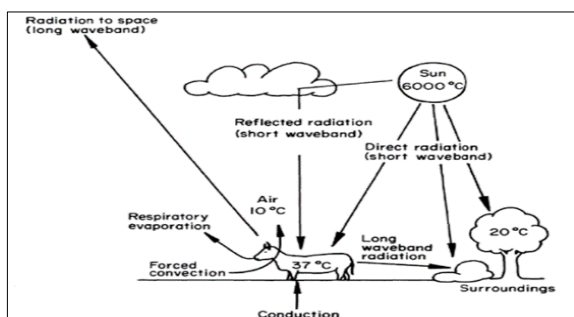


Fig. 2. The exchange of heat between an animal and its environment [23]

### 2.1 Camera Detection Setup

A camera is an optical instrument for recording or capturing images, which may be stored locally, transmitted to another location, or both [24]. The camera as a remote sensing device, senses objects without physical contact [25]. The mechanics of the camera is made up of the image capture, lens and the focus. Traditional cameras capture light onto photographic plate or photographic film. Video and digital cameras use an electronic image sensor, usually a charge coupled device (CCD) or a (CMOS) sensor [24]. These are used to capture images which can be transferred or stored in a memory card or other storage inside the camera for later playback or processing [25]. Fig. 3 shows how the image is identified and detected by the camera was used in the model.

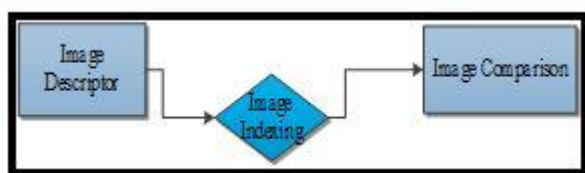


Fig. 3. Camera model detection system

## 3. Detection System Concepts

Four concepts were chosen for the detection system, namely, the Passive Infrared System, Active Infrared System, Thermographic Image Sensor and the Active Thermographic Image Sensor.

### 3.1 Concept 1 – Passive Infrared System

Above absolute zero temperature living organisms emit infrared rays which cannot be detected by a naked eye [26]. A passive infrared motion detection detects heat energy radiated or emitted by the animal moving across a field of view of a heat sensor of the motion detection system [27]. This system does not emit any light for detection assistance, it only relies on the infrared being emitted by the object to be detected. The response mechanism for the Passive Infrared System is shown below in Fig. 4. It includes automatic hazard indicators switching on LED lighting for 5 seconds and vibrating the steering all at once. This design is relatively cheap and uses sensors that require low power and does not wear out easily. It, however, has problems in measuring the range and velocity of targets. It cannot function well in the dark and can be falsely triggered. Also, it cannot penetrate easily through cloud, smoke or rain and has short wavelengths and thus making it difficult to use. The application of passive thermography is prevalent for temperature control in food manufacturing and for monitoring heat processes [27].

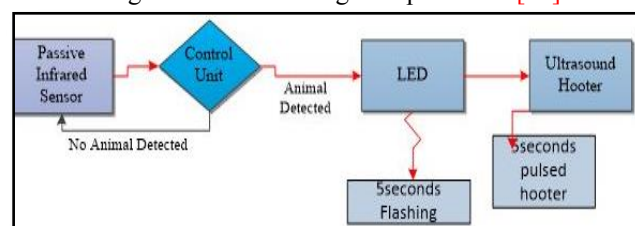


Fig. 4. Response mechanism for the passive infrared system

The active infrared system uses an Infrared light source built onto the car to illuminate the road ahead with light that is invisible to humans. The imaging system has a transmission source that provides pulses and sensors for receiving pulse reflections from objects located beyond a minimal range. There are two kinds of active systems known as gated and non-gated. The gated system uses a pulsed light source and a synchronized camera that enables longer ranges [28]. The pulse and gate are timed and controlled for creating a sensitivity as a function of range, and thus the amount of the energy received increases progressively with the range [29]. The sensor emits radiation which is directed towards the target to be investigated. The radiation reflected from that target is detected and measured by the sensor. It incorporates an imaging system, including a transmission source providing pulse(s), and a gated sensor for receiving. The response mechanism for the active infrared system is shown in Fig. 5. It includes LED lighting that flashes for 5 seconds and an ultrasound hooter turning on for 5 seconds as well. The active infrared system can function effectively during the day and night. It employs a sensor that can directly measure the range and velocity of targets. It has a higher resolution image that penetrates through cloud, smoke or rain better than the passive sensor. Its disadvantage is the short wavelengths and a larger amount of energy supply required.

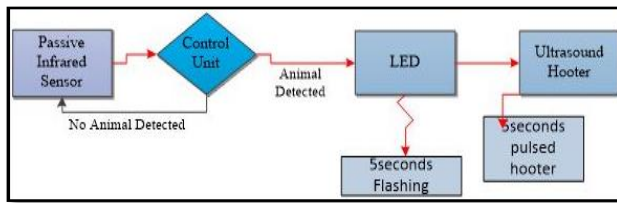


Fig. 5. Response mechanism for the active infrared system

### 3.3. Concept 3 - Thermographic Imaging System

In this system, the thermographic cameras usually detect radiation in the long-infrared range of the electromagnetic spectrum (roughly 9,000–14,000 nanometers) and produce images of that radiation, called thermo grams [30]. Since infrared radiation is emitted by all objects with a temperature above absolute zero according to the black body radiation law, thermography makes it possible to see one's environment with or without visible illumination. The value of modern infrared thermography is its ability to produce a digitized image or high-speed video rendering a thermal map of the scene in false colour [6]. The sensor requires low power and does not wear out easily, although it is expensive. Images can be difficult to interpret accurately when based upon certain objects and the sensor has problems in measuring range and velocity of targets. It is not reliable due to giving false alarms. The response mechanism, Fig. 6., includes a thermographic display placed on the driver's dashboard and an ultrasound hooter sounding when an animal is detected

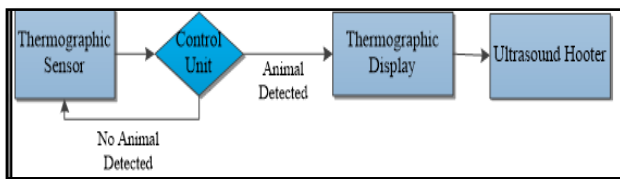


Fig. 6. Response Mechanism for Thermographic Imaging

### 3.4 Concept 4. Active Thermographic Image Sensor (REFF)

In this approach, an energy source is required to produce a thermal contrast between the feature of interest and the background. The active thermography approach is necessary in many cases given that the inspected parts are usually in equilibrium with the surroundings. Active illumination couples imaging intensification technology with an active source of illumination in the near infrared (NIR) or shortwave infrared (SWIR) band [31]. The response mechanism for the active thermographic image sensor unit is displayed on the vehicle dashboard. The schematic representation is shown in Fig. 7

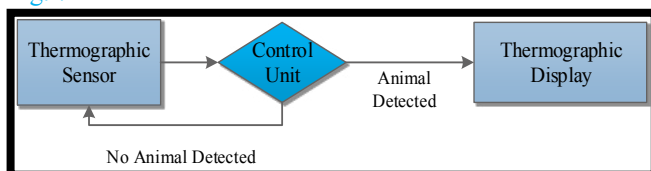


Fig. 7. Response Mechanism for Active Thermographic Imaging

The final detection system was developed, through a combination of Concepts 1 and 2 (Passive and active infrared systems). The choice was determined after a comprehensive process selection using Pugh Matrix and taking note of their

advantages. Fig. 8 demonstrates its decomposition. The detection system, control system and reaction system are all broken down into their units to demonstrate their operating disposition.

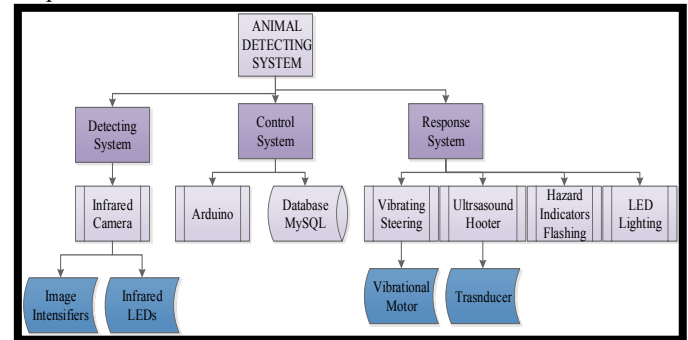


Fig. 8. Product Decomposition

This development is based on Active infrared systems that use an Infrared light source built onto the camera to illuminate the road ahead with light that is invisible to humans. The system has a database of the animals found on the road and can compare the image of the captured animal with what is available in the database. The detection system sensor can penetrate through cloud, smoke or rain. An active infrared detection system has high a resolution image. The system response mechanism includes automatic hazard indicators that switch on for 5 seconds, to alert other drivers. LED flashes for 5 seconds with vibrational steering all at once. ultrasound hooter warns the animal about the car approaching Fig. 9 below demonstrates the arrangement of the systems architecture

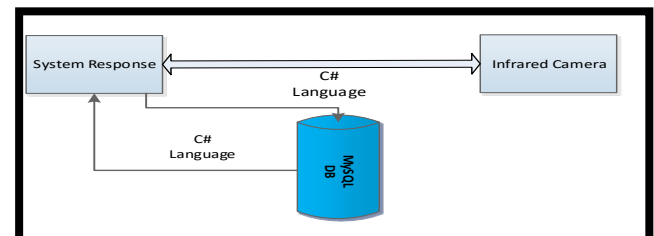


Fig. 9. System architecture

## 4. Experimental Setup

The Arduino was used due to ease of use by both beginners and advanced users to accommodate a beginner. It has the advantage of running a simple C programming language and interfacing with the developed programme. An experiment was carried out using an infrared camera and a normal camera as the control, to study the effect of infrared image in the dark, in normal lighting and in infrared lighting. Each image was taken at 0.6m from the camera due to clear images obtained at this distance.

Experiments to determine the number of LEDs started with 2 and ended with 16 which gave the best result. In the experiment 0.8 m was used but to determine the number of LED lights required at 250 m the following equations were used:

$$P = IV \quad (2)$$

Where:  $P = \text{power (W)}$ ;  $I = \text{current(A)}$  and  $V = \text{voltsge (V)}$

$$K = 4d^2\pi \quad (3)$$

Where:  $K = \text{sphere surrounding the point}; d = \text{distance between light and point of interest}$

$$I_v = \frac{P}{K} \tag{4}$$

Where:  $I_v = \text{light intensity } (Wm^2); P = \text{Power } (W),$  and  $K$  is sphere surrounding point ( $m^2$ )

Fig. 10 shows the Arduino connected to the photo resistor to measure the light intensity reaching the animal picture. Due to best results being obtained at 0.80m, it was used throughout the experiment but a change in the number of infrared lighting was made. Below is the setup of the LDR against the picture to be taken by the infrared camera.

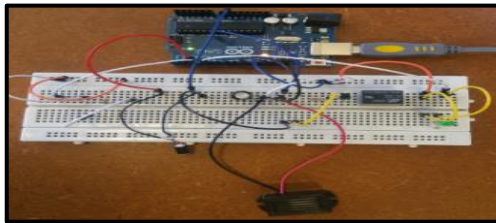


Fig.10. Arduino Setup with LDR

The code for the photo resistor to give values of the infrared intensity is illustrated in Fig 11.

Infrared light from LEDs provided lighting for the system. It was placed at 0.6m. Image intensifiers were not present in the imaging therefore becoming a cause of the blurry images.

```

Transistor_Reading_Value_code
1 void setup () {
2 // initialise serial communication at 9600 bits
3 Serial.begin (9600) ;
4 }
5
6 // the loop routine runs over and over again forever
7 void loop () {
8 // read the input on analog pin 0 :
9 int sensorValue = analogRead ( AO ) ;
10 // print out the value you read :
11 Serial.println ( sensorValue ) ;
12 delay ( 1 ) ; // delay in between reads for
13 }
    
```

Fig. 11. Snippet of LDR Code

4.1 Imaging Results

The infrared light from LEDs provided lighting for the system. It was placed at 0.6m. Image intensifiers were not present in the imaging therefore becoming a cause of the blurry images. The number of infrared LEDs also influences the image quality, therefore the more the LEDs the better the image. Fig. 12 shows system response mechanism.

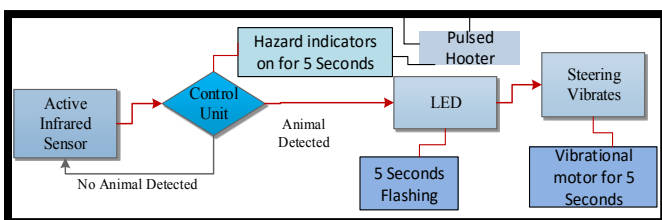


Fig 12. System response mechanism

With increasing number of LED's the image clarity changes, Fig 13.

No. of Infrared LEDs Used	Image Obtained	LDR Value	No. of Infrared LEDs Used	Image Obtained	LDR Value
2		23	4		113
6		144	8		137
10		162	12		192
14		204	16		234

Fig. 13. Images Obtained from the Number of Infrared LEDs used

The image descriptor used was the 3D RGB colour histogram. An image is captured from a camera and ranking the images in the database is based on how similar they are to captured image. The image with the smallest distance metric to the camera image is returned. The distance metric was termed the percentage difference. Positive and negative results were taken. Positive is when an animal is found to be like the one in the database and a pop up on the screen is shown which only pops up at a threshold of 6.5. Fig. 14(a) shows the positive result giving a percentage accuracy of 0.72.

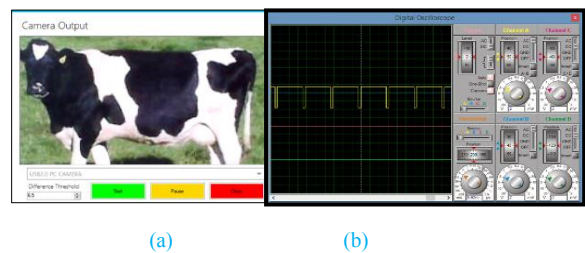


Fig. 14. (a) Positive detection result of a dairy cow and (b) Ultrasound oscilloscope circuitry simulation

The electrical circuit was simulated using proteus 8 professional using a digital oscilloscope and the actual frequency being produced by the circuit is 33864 Hz. Fig. 14(b) above shows the simulation of the ultrasound using the oscilloscope and proteus 8 professional as the switch is on and the timer is timing for 5 seconds.  $T_{high}$  is observed to be  $14 \cdot 10^{-6}$  seconds and  $T_{Low}$  is  $1.57 \cdot 10^{-6}$  seconds. The simulation showed the waveform of the integrated circuit as of the actual intended wave. A motor is used for vibrating the steering wheel. The developed circuit and components were tested through simulation to ensure proper function during operation. Fig. 15 shows a successful circuit simulation of the entire response system.

The animal detection system was thus developed having automatic hazard indicators switching on LED lighting for 5 seconds, vibrating the steering and a pictorial representation of the animal displayed in the vehicle. Fig 16 demonstrates the operation of the developed animal detection system.

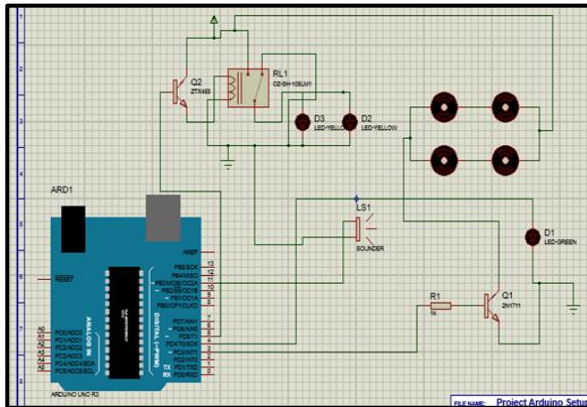


Fig. 15. Entire Circuitry Simulation using Arduino

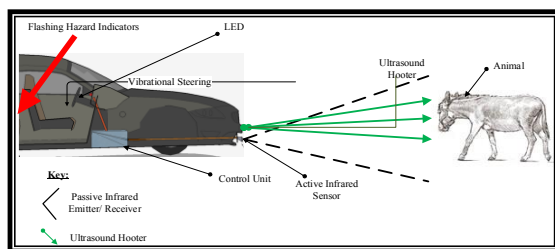


Fig. 16. Animal detection system

## 5. Discussion

Calculations for the design were used to determine the distance at which an animal can be detected. This also assisted in choosing the type of camera, MZ-CA-C249P with a CMOS sensor. This camera has an ability to detect an animal at 250 m. Once detected an image is captured and compared with images in the database using a predetermined code. The response system is activated, and a video image of the animal is displayed

## 6. Conclusion

An animal detection system was developed using a combination of passive and active infrared systems. The imaging system identifies the temperature differences between animals and the surrounding and that enables animal detection. A MySQL database was developed to retrieve images through a code and displayed in the car. The system could successfully change the safety and lives of road users tremendously and protect both domestic and wildlife on the roads. A comparison was made between the knowledge base extracted from the observed object and a value of 65 % positive process image was observed to be an animal detected.

## 7. Acknowledgements

The Tshwane University of Technology, particularly the Industrial Engineering Department. Opinions expressed, and conclusions arrived at, are those of the author and are not necessarily to be attributed to the institution

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