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A multiple sensor automated warning system for roadkill prevention

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ABSTRACT

The rapid infrastructure development has shown complex negative impact on wildlife through increased animal mortality due to vehicular traffic, disruption of ecological processes, habitat degradation, isolation of wildlife habitat, and fragmentation of the landscape etc. Among those, the animal mortality due to vehicular traffic, generally known as 'Roadkill', has been reported as a serious bio-diversity conservation problem in various regions in India and across the world. The cause, effects and reduction of such fatal incidents, are a rapidly expanding areas of research across the world among the conservationists, scientists and technologists. On the other hand, presently Wireless Sensor Network based warning systems are widely used in different hazard scenarios. Such low cost multiple sensors based WSN systems can be used to generate an early warning about the presence of wild animals on forest roads and thus can prevent potential accidents so presently such system design and implementation is high on demand. Under present work, a WSN based indigenously designed, low cost, accurate multiple sensors based 'Automated System for Roadkill Prevention' has been proposed and studied with technical details. Proposed ASRP system will be having multiple types of sensor nodes, gate-way node and a local processing unit (server) with a warning unit for successful prediction and warning generation. Under present study, the algorithm of the proposed system has been developed and software implemented with MATLAB Simulink. Simulated outcomes show that such system will be very much effective to generate valuable early warnings against the wild animal presence at the conflict zone and will be helpful in preventing potential collateral damage.

KEYWORDS

Roadkill;
Sensors network;
Algorithm;
System design;
Simulation.

INTRODUCTION

Around the globe the phenomenal economic growth over the decades has been accompanied by a rapid expansion and improvement in transport and other infrastructure networks. The transport and infrastructure have affected nature in various ways[1]. The roads and railroads have caused habitat fragmentation, changed hydrological dynamics and disrupts natural biological processes. Not only that the road maintenance and traffic have contaminated the surrounding environment with a variety of chemical pollutants and noise and has imposed dispersal barriers to most non-flying terrestrial animals[1]. Along with those the most fatal consequence of those development activities, animal mortality due to vehicular traffic (Roadkill), has increased enormously and has caused a significant negative impact on bio-diversity conservation[2]. Like the other part of the world, animal mortality due to vehicular traffic in India is neither new, nor rare[3]. According to the report by Wildlife Protection Society of India (WPSI), almost eighty one species of large and small animals have been killed by traffic and train accidents in the country during last decade[4]. Under such scenario, the cause and solution of this Roadkill problem is a rapidly expanding area of research across the world where conservationists are working hard to understand the wild animal behavior and scientists are trying to find a way to avoid such fatal incidents.

According to the experts, an early detection of animals on or near forest roadways and railways track especially at night time and generation of a consequent alarm is the best solution to this problem[5]. Till now, to deal with this problem, plenty of ideas have been suggested and implemented by the experts but those are either very costly or heard to implement e.g.; implementation of doppler radar sensors with high sensibility to detect animal, video camera to film the surrounding animal activity, Radio Frequency identification technique, building animal overpasses and tunnels, electromagnetic field generation to track animal movement etc[6-7]. In many developed countries like U.S.A, Australia, Canada etc. have already implemented such costly systems to avoid Roadkill but under developed courtiers like India it's hardly feasible to implement because of the cost of such systems. Under such context, those sensor networks based warning systems can be redefined with low cost multiple sensors based system to provide valid solution to the Roadkill problem in India.

Under present study an 'Automated System for Roadkill Prevention' (ASRP) has been proposed which will be a type of wireless sensor network (WSN) system. Proposed ASRP system will be a kind of its own which will automatically sense wild animal activities on or nearby road through infrared sensors, seismic sensors, acoustic sensors etc. and will generate alerts for the passing vehicles. Proposed ASRP system will acquire sensed data from various multiple low cost sensors which will not only make it chipper; it will also make it versatile and reliable. The system will be a type of wireless sensor network (WSN) having a sensor node or primary nodes (infrared, geophone, acoustic sensors etc.) placed on the both sides of the forest road or railway track etc. which will detect nearby animal presence. The primary nodes will be connected to secondary nodes or gate-way nodes which will be having a bi-directional transmitter and receiver unit and signal from such multiple secondary nodes will be received by a local processing unit (server). Present work has been dedicated to develop an effective architecture and algorithm for such ASRP system. Along with the algorithm, the technical specifications and functionality of the different units of the proposed system has been discussed elaborately. The core algorithm of ASRP system has been designed and simulated with MATLAB Simulink and simulation outcome has been analyzed.

SYSTEM ARCHITECTURE AND OPERATION

Proposed ASRP system will be a WSN system where IR sensors, acoustic sensors, and geophone sensors will be acting as primary nodes and those primary nodes will be placed in some indentified remote location near the edge of the forest road or railway track etc. Those primary sensor nodes will pick the various signals created by on road or roadside animal activities. A group of sensor nodes or primary units will be wirelessly connected to a secondary units or gate-way node which will be having a bi-directional transmitter and receiver[8]. Signal from such multiple secondary nodes will be received by a central processing unit (Server). This processing unit will compare the incoming signals with different reference threshold signal levels[9]. Based on that comparative analysis it will generate different types of local warnings to the passing vehicles with blinking of lights, massage display or low volume

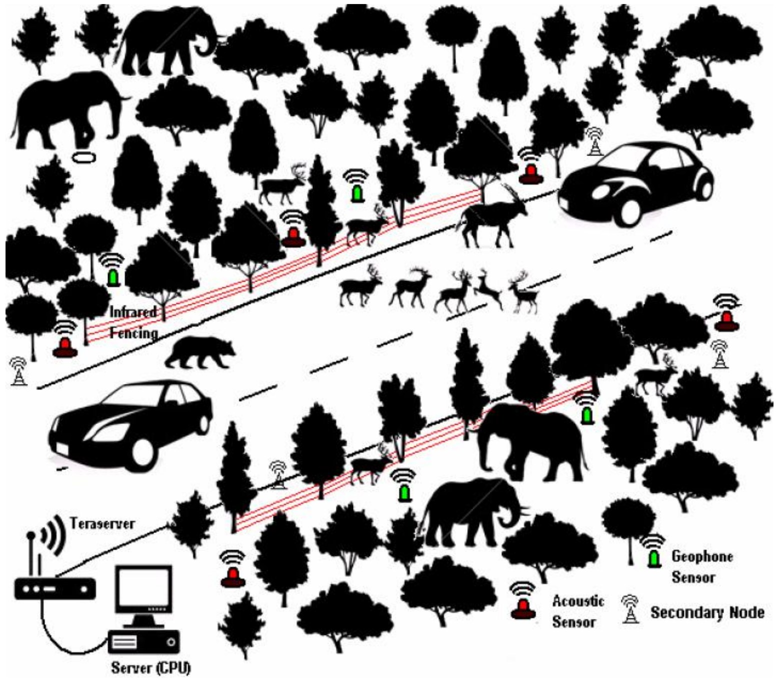

Figure 1 : A picture showing the functioning of an ASRP system

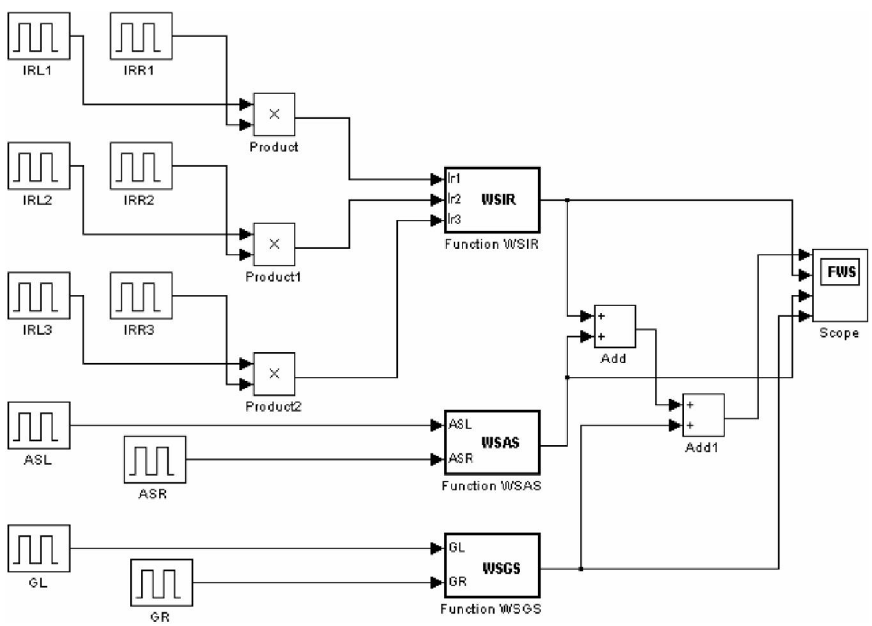

Figure 2 : Matlab Simulink model of proposed ASRP algorithm. Where; IRL 1 & IRR 1=Bottom IR sensor line left and right, IRL 2 & IRR 2=Middle IR sensor line left and right and IRL 3 & IRR 3=Top IR sensor line left and right, respectively; ASL and ASR are acoustic sensors left and right, respectively. GL and GR are geophone sensor left and right, respectively. Where as WSIR is over all Warning Signal from IR Sensors, WSAS is over all Warning Signal from Acoustic Sensors and WSGS is the over all Warning Signal from Geophone Sensors

sounds etc. It will also send the information to the nearby forest office or check post with specific location codes so that necessary safety measures can be adopted. Functioning of the proposed ASRP system has been shown in Figure 1.

Primary node

This will consist of a sensor, a transducer, a transmitter with antenna and a power source[8]. Under the proposed system, the sensors are very vital components and they need to be small, reliable, highly sensitive, cost effective and easily installable. Among the sensors Infra Red (IR) sensors will play an important role in animal detection. On the both sides of the road the IR sensors will from three level fencing and will generate signals whenever there will be a breakage of IR lines due to animal road crossing. Such multiple levels IR fencing will not only enhance the robustness of the proposed system it will also help to categorize animals based on their sizes. Along with the IR sensor the second type of sensor will be implemented under the proposed system is Acoustic sensors, which will detect calls of various animals on both side of the road. Since the large animals like elephant are known to generate seismic signals, Geophone sensors will be also deployed on road side to detect such seismic signals and thus to enhance the system reliable[10]. Under the proposed project, the transducer part will be as simple as possible which will generate a signal to be transmitted to the secondary node and for less complexity it will be a unidirectional unit.

Secondary node

It will be having a transmitter and receiver with bi-directional communication ability and will filters to eliminate noise from the incoming signal of

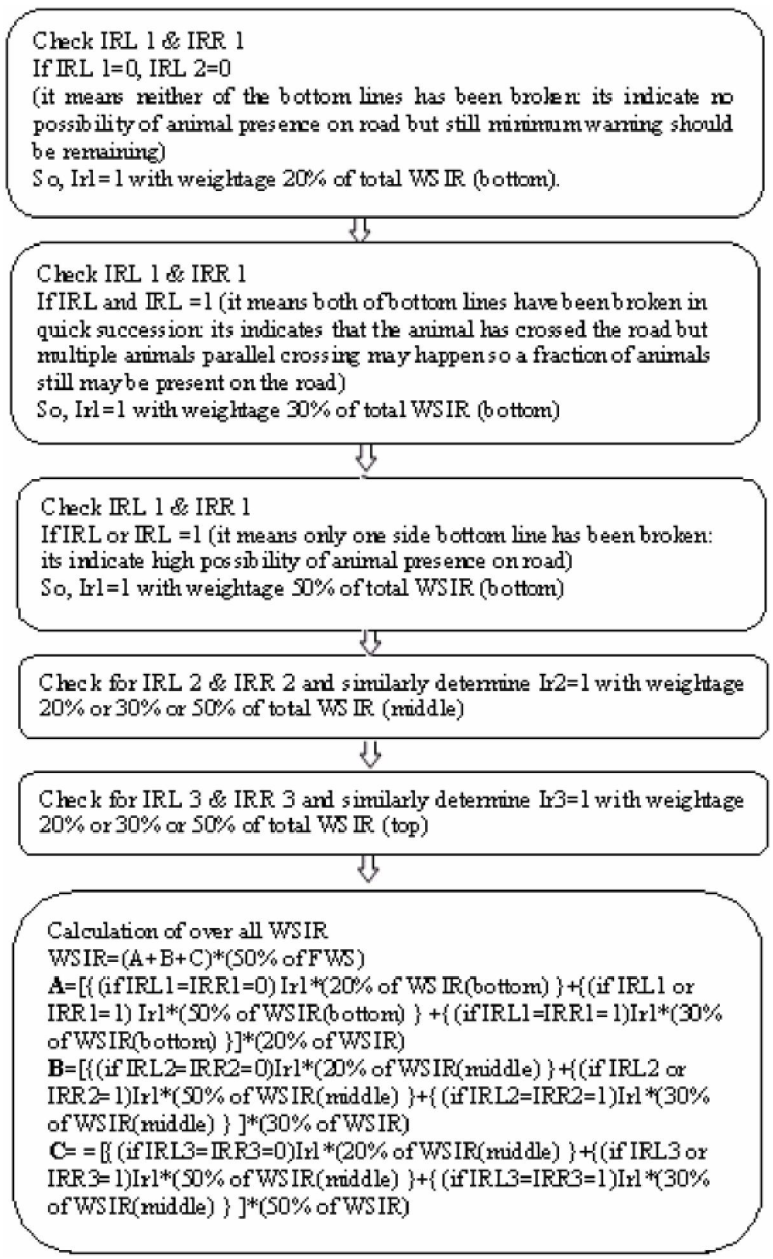

Figure 3 : Flowchart for calculating WSIR

specific frequency and amplitude[8-9].

Central processing unit (server)

This will be a microcontroller based unit which will be mounted in some secure place and having a GPS transmitter and receiver, a local warning system and communication link with the secondary nodes[8-9].

The architecture of the proposed system will be more or less same as described above but precise requirements of technology and instrumentation part can be properly figure out through some practical field survey and related analysis.

SYSTEM ALGORITHM DESIGN

To establish the algorithm of the proposed system, a scalable mathematical relationship has to be formed between input signals and Final Output Warning Signal (FWS). Based on the review study sensors selected for the present study are Infrared sensors, Acoustic sensors and Geophone Sensors[3-6]. The signal generated from each sensor will be assigned a weight in percentage based on its estimated importance in predicting on-road and off-road animal activities and subsequently, it's weightage will determine its impact on overall FWS generation as shown in "Figure 2".

The six infrared sensor pairs from left and right side of the road have been represented as IRL (1,2 & 3) and IRR (1,2 & 3), respectively. Such three levels IR fencing will play the most significant role in animal activity detection and will carry highest weight percentage (50%) in overall FWS determination. The over all warning signal generated from six pairs of IR sensors will be noted as WSIR and it will be subdivided as WSIR (bottom), WRIS (middle) and WSIR (top), assigned to each left right pair. The WSIR (bottom) will be determined by IRL 1 and IRR 1 whereas WSIR (middle) will be determined by IRL 2 and IRR 2 and WSIR (top) will be determined by IRL 3 and IRR 3. Fractional weightage assigned with WSIR (bottom), WRIS (middle) and WSIR (top) will be 20%, 30% and 50% respectively in overall WSIR determination. Such weight factor has been assigned on the basis of fallowing concept; signal from WSIR (bottom) indicates the presence of smaller animals (rabbit, wild pig, wild ground birds etc.) so risk is minimum, signal from WSIR (middle) indicates the presence of medium size animals (dear, fox etc.) so risk is moderate and the signal from WSIR (top) indicates the presence of larger animals (bison, elephant etc.) so risk factor is considered maximum.

The calculation of the WSIR is given in form of a flow chart in the "Figure 3". For acoustic and geophone sensors the design constrains are kept minimum to maintain simplicity in the algorithm. Under present analysis WSAS and WSGS have been assigned percentage weightage of 30 and 20 of overall FWS, respectively. The contributions in overall WSAS, from left and right side sensors are assumed to be 50% each and those are also same for WSGS determination. The over all warning signal from the acoustic sensors WSAC will be calculated as;

WSAC=(D+E)*(30% of FWS) **(1)**

where D=ASL*(50% of WSAC) & E=ASR*(50% of WSAC). Similarly the over all warning signals from the geophone sensors WSGS will be calculated as;

WSGS=(G+H)*(20% of FWS) **(2)**

where G=GL*(50% of WSGS) & E=GR*(50% of WSGS). All though, the number of sensors and their actual impact on overall output warning signal generation is a subject of practical field study but those adjustments can be incorporated effectively with little or moderate modification of proposed simulation model.

RESULTS AND DISCUSSION

Under the present study, the algorithm for the proposed ASRP system has been developed and software implemented with MATLAB Simulink. In simulation model, input signals for various sensors are randomly generated squire pluses with variable pulse width and period but with equal amplitudes. The combinations of various warning signals WSIR, WSAS and WSGS will generate subsequent FWS which has been shown with time scale in Figure 4. In the presented analysis, all the weight percentage of input signals and output have been converted into

Figure 4 : FWS with time has plotted with a scale of maximum 0 to 5

a scale of 0 to 5.

At any point of time (positive edge) the FWS will be the over all added contributions from WSIR, WSAS and WSGS and FWS will be having three levels. When FWS value is less or equal to 1 (marked with line 'a' in Figure 4), it will be considered as low warning (e.g., time range 3.5 to 4 in Figure 4). When FWS is between the range of 1 to 3 (marked between lines 'a' to 'b' in Figure 4), it will be considered as medium warning (e.g., time range 1.2 to 2 in Figure 4). When FWS is more or equal to 3 (marked with line 'b' in Figure 4), it will be considered as high warning (e.g., the time range 6 to 6.5 in Figure 4).

CONCLUSION

Under present analysis, algorithm and architecture of a multiple sensor based automated warning system has been developed which will be useful for Roadkill prevention. The proposed ASRP system has been divided into different functional units and sub units and their functionality have been presented with technical details. The algorithm for the proposed system has been successfully designed and implemented with MATLAB Simulink and some important results have been simulated to understand the operation and performance of such system. The architecture and algorithm, designed under present study is a generalized platform which can be modified further to enhance the versatility and efficiency of the system. Practical implementation of ASRP will provide valuable early warning to passing vehicles about the on road and off road animal activities even in dense forest locations. Such valuable warning through proposed ASRP system will not only prevent tragic Roadkill event it will also help to maintain biodiversity.

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