Low Cost Blind spot warning system using a combination of Ultrasonic and Infrared Sensors

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ABSTRACT-In a country like India where there are a total of 1.25 million accidents recorded every year within a total population of 1.3 billion. It is important to consider the injuries and fatalities that are taking place due to automobiles. So, many of the accidents are caused due to blind spots in an automobile that is failure of 360° sensing of objects around the vehicle by the driver. The sensors that are available today are not covering the entire surface of the body of a vehicle. There are some regions which are not covered by the sensors and these are blind spots. To overcome the negligence of driver, Advanced Driver Assistance Systems (ADAS) were introduced. This ADAS might be as simple as warning the driver about his surroundings or can be further enhanced to take control of the vehicle. Few such cases include sudden lane change by driver, not noticing vehicles in blind spot, non uniform driving and so on. Here we have executed a low cost after market model which uses infrared and ultrasonic sensors together makes ADAS more efficient to detect the objects in the vicinity of the vehicle and warn the driver so as to avoid collisions. This could also guide the driver in cases of sudden lane changes and turning. We have identified an algorithm through which measurement rate of sensors was increases and also implemented neural fuzzy logic algorithm for accurate calculations.

KEYWORDS:- *Blind spots, Bi-sensor module, Arduino Uno, Ultrasonic sensor, Infrared sensor, Fuzzy algorithm, Chaotic Pulse Position Modulation*

INTRODUCTION

As the number of vehicles is increasing, the accident rate is also increasing proportionately. Accidents occur mainly due to the improper information the driver takes from the surroundings or by the delayed responses from the sensors. The improper information taken from the surroundings by the driver are due to various reasons. Blind spot negligence is one of the most severe causes for the accidents. The blind spot is the area not covered by the driver's line of sight and mirrors, alongside and off-set to the rear of the moving car on both sides. The rear view mirrors which act as passive blind spot detectors eliminate the risk of accidents but there are still few blind spots that are overseen by the drivers and about 30% accidents occur due to this. Additional to the mirrors, there are few sensors that are added to the car which dedicate themselves for monitoring the objects around the car. Trucks have larger blind spot region when compared to light motor vehicles, so it is important to have sensors which monitor the areas that the driver can't properly assess the surroundings. So, the trucks are to be added with more number of sensors than an average vehicle on the road so as to avoid accidents.

In this paper we have implemented a novel approach which helps the vehicle identify presence of obstacles like cars or motorcycles in the host vehicle's blind spot region. This system there by warns the driver of host vehicle whether it is a light vehicle like a car or even heavy vehicles like trucks or buses. Generally, ultrasonic sensors, radar systems, camera models, infrared are used for blind spot detection. Ultrasonic sensors use the sound waves, IR sensors use the infrared rays, radar systems use radio waves, camera uses imaging for the detection of vehicles and blind spots. These sensors are only used individually. So, using only one type of sensor was not effective enough to warn the driver in all conditions. These sensors when used individually are affected by the environmental conditions which can be avoided by using as a combination. So, we have come up with the solution using the combination of ultrasonic and infrared sensors to cover entire blind spot region which further reduced errors in detection. This system can also detect the fast moving vehicles which can be easily missed and can cause accidents while changing lanes. Our model is proposed using principle of neural fuzzy logic where we further improved the efficiency of ultrasonic sensors. Thus, we successfully obtained a low cost model by using combination of ultrasonic and infrared sensors interfaced via Arduino.

The remaining of this article is arranged as follows; here we firstly studied past work done under literature review section. This is followed by system architecture and functionality.

LITERATURE REVIEW

There were many vision, radar and sonar based obstacle detection systems proposed for blind spot detection and warning in the past. Our Blind spot detection and warning system is quite unique compared to the previously suggested models by various authors. Many models were not cost effective which was our main criterion while designing our model, few were not efficient, were not always reliable and used very complex and bulky materials in the designing of the systems. They even had complex algorithms which took lot of computing time which was a major downfall. Our model of making bi-sensor model came from three sensor model given by Takeshi et al. [1] using three sensors that is, ultrasonic, infrared and magnetic sensors for avoiding rear end collisions which we implemented for blind spot detection. Further the data transfer can also be made wireless by using Zigbee module and a neural fuzzy algorithm [2] were stated by Shweta Raj et al. and also by using Wireless Sensor Network (WSN) systems as proposed by Youngtae Jo et al [3], increased the feasibility but the cost of production was increased and so neural fuzzy logic was further improved. As given by Seungin Shin et al. efficiency of the ultrasonic sensors [4] can be increased by using Pulse position modulation (PPM) which was done in our model to increase rate of measurement.

Further on various developments were made which could not solve all the cases for light vehicles [5] and heavy vehicles [6]. Few of other developments were as follows. As given by Bruce E. Stuckman et al. [7] only infrared sensors can also be used for the vehicle detection but this has various limitations and cannot work properly in all environmental conditions. Further the usage of ultrasonic sensors in trucks for lateral collision avoidance as given by Kai-Tai song et al. [8] for detecting light motor vehicles moving at low speeds, was not be accountable for every scenario. To detect a vehicle moving in the wide range of velocities we need to develop a model which fulfills this requirement. The theory as given by Florian Miru et al. [9] uses the ultrasonic sensors to detect vehicles moving with high velocities, which becomes a problem in detection of vehicles in slow moving traffic. Radar technology was also used in the blind spot detection systems as given by M. Ruder et al. [9] which has high initial cost and is also difficult to install this technology in older cars. Labayrade et al. [10] integrated 3D cameras and laser scanner to detect multi-obstacles in front of the vehicle. The width, height, and depth of the obstacle were estimated by stereo vision and the precise obstacle position can be provided by laser scanner. The system proposed by us replaces the cameras and scanners with the low cost ultrasonic and infrared sensors. Wong et al. [11] installed six ultrasonic sensors and three image sensors in the car. They applied fuzzy inference in algorithm to forewarn the driver and reduce the car accident possibility.

SYSTEM ARCHITECTURE

The main idea presented in our model was to monitor for obstacles which are in the vicinity of the host vehicle. The host vehicle can either be a light motor vehicle or even a heavy vehicle as a truck or a bus. The simple working principle of our model is it keeps a track of the distance of the nearest vehicle from itself which is in the host vehicles vicinity and warn the driver if approaching vehicle is in the blind spot region. Now a blind spot in a vehicle is region as stated by ISO is defined as the region on either side of vehicle extending up to 3 meters and also rear ward 3 meters. This can be seen in figure 1 for a car and truck (this implies for bus also). As shown in the figure 1 for the first car orange region is not visible to the driver so termed as blind spot region and the green region is visible to the driver and even the white region behind the car is visible via inner central mounted rear view mirror. As in for a truck yellow region is region not visible to the driver of the truck and the greyed out region is only visible.

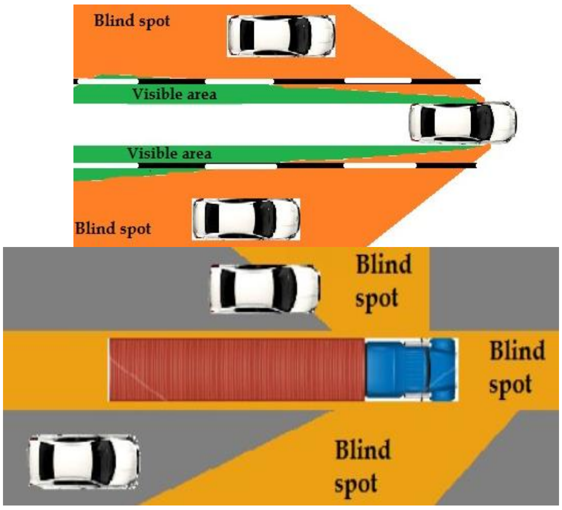

Figure 1: Blind spot region for Car and Truck

So to completely cover these blind spot regions depicted in figure 1 for a vehicle with sensors so as to warn the driver flawlessly we have implemented with the following components:

1. Arduino Uno Rev 3
2. Ultrasonic Sensor: HC - SR04
3. Infrared distance Sensor: Sharp 2Y0A710 – F
4. Warning unit

As in figure 2 which describes all the above mentioned components of our model photographically. Further the number of these bi-sensor modules which are being used depends on the size of the vehicle to which they are being installed.

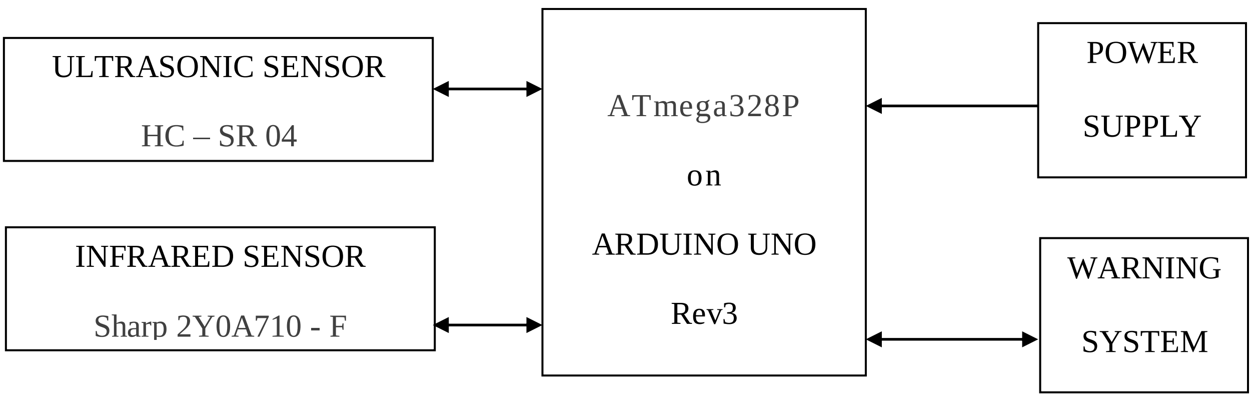

Figure 2: Implementation Block Diagram

Here on we would like to describe in detail about the architecture or implementation block diagram. Although they exist much better wireless networks for the system all the components were only connected through wires as that would be a costly fair. As in block diagram we see ATmega328P mounted over Arduino Uno board, this was chosen as our central processing unit as it consists of 6 Analog pins to which up to 6 Infrared distance sensors can be connected. Then the board also houses 14 digital input output pins which enable us to connect up to 7 Ultrasonic sensors as each requires 2 digitals pins for trigger and echo to be activated simultaneously. Then for heavy vehicles which require more number of bi-sensor modules these can be interfaced to the same central unit consisting of two Arduino Unos which are mutually synced.

The Ultrasonic sensor used here is HC – SR 04 which is simple 4 pin sensor where pins have the following nomenclature: GND for ground, VCC for power supply which works on supply up to 5V which is directly available on the Arduino Uno Board. Then it consists of digital pins Trig for trigging the sensor to start ultrasonic wave and echo which notes the duration of receiving the echo. We have chosen this as it’s the cheapest available sensor in the market and as per various studies and tests performed by Navya Amin Singh et al this sensor is found to be least affected by external factors [12]. This sensor was found to be highly accurate up to a distance of about 3 meters which was our ideal case. It had the following practical specification that is Field of View of 30° horizontally and up to 20° vertically as stated by [13]. It was also stated that it had accuracy error of about 5%. So to overcome these faults of ultrasonic an infrared distance sensor was coupled in our model which makes ours novel.

The Infrared sensor used in our model was Sharp 2Y0A710 – F this transmits infrared light rays and then it notes the angle at which these rays were received by its receiver after its reflection from an obstacle. Through this angle distance was calculated. This sensor is a 3 pin device where each pins are GND for ground and VCC where input voltage of up to 7V so 5V input from Arduino Uno would do the job. This sensor has an accuracy range up to 5m. So combining this and ultrasonic brought this bi-sensor module.

Now the warning system would be a flashing LED which can either be placed on the dash board or a point where driver could notice easily. Now all this would be powered by the same battery which is used for ignition and all other electronics in the vehicle. Now these bi-sensor modules are placed on either side of the vehicle as in figure 4 as per the design architecture which varies from 4 to 7 depending on type and size of vehicle. From our various experiments and testing to get the maximum coverage of the blind spot region in the rear end it is appropriate to place sensor modules either at an angle of 30° from the surface of C – pillar or in the rear wheel wells which even give protection to the bi-sensor module. In the front end we could get maximum coverage of blind spot region by placing sensor unit under the side view mirrors projecting out ward. In figure 3 we have shown a car which is placed with 4 bi-sensor modules. In case of a truck as in figure 1 which has a larger blind spot region it is suggested to place these bi-sensor modules at a separation of 1.5 meter as the ultrasonic is having an horizontal range of 30° and infrared sensor having much wider range.

FUNCTIONALITY

As proposed in the system architecture which consists of a sensor module which hosts an ultrasonic and an infrared sensor packed as single unit. These are connected to main central processing unit which in our case is a Arduino Uno. They can be either wired or connected wirelessly [2] [3] as in models proposed by Shweta Raj et al and Youngtae Jo et al. But in our case we have used wired connection only as powering them individually would amount to twice the same wiring required by a normal model which isn’t practical for a low cost model. Further on working of the model is explained.

As described the bi-sensor modules consists of ultrasonic and infrared distance sensors. The ultrasonic sensor works by calculating the ToF (Time of Flight) that is the total duration of time for ultrasonic wave to be transmitted and received. Then it calculated the distance is

Distance = Speed * Time

Since we know speed of sound in air is 331.3 m/s we can and wave travel twice that is forward and reflected back we divide by 2. Now distance can be deduced as

Distance = 331.3 * Time of Flight /2

Figure 3: Car with bi-sensor modules placed at 4 points

Now taking decision by setting up a threshold for just one reading would cause a lot of faulty error so further Neural Fuzzy Logic Algorithm [5] was implemented where decision is not made on just one reading but the average of previously noted readings is to be considered where we have considered previously noted 3 reading and based on the final distance calculated trigger is sent to warn the driver. The formula of Neural Fuzzy Logic Algorithm can be given as:

$$D = (D_n + D_{n-1} + D_{n-2}) / 3$$

Here D is distance based on which decision is made, D_n is the distance first previously noted distance which was preceded by D_{n-1} & D_{n-2}. So by this efficiency of the model is improved and with the above algorithm we have also implemented algorithm where the capture rate of the system also much faster. This is achieved by using Chaotic Pulse Position Modulation (CPPM) [4]. This algorithm would enable transmission of second signal without the first transmitted signal received. It works by emitting ultrasonic sound from transmitter at a fixed intervals and this fixed interval is saved by the system, so that it enables calculation of Time of Flight. This would help achieve much faster calculation of distance. Therefore combining CPPM and Neural Fuzzy Algorithms a novel and fastest way of calculation of distance through ultrasonic is achieved. But as every sensor has its own disadvantages any ultrasonic sensor cannot measure the accurate distance when it is passed through severe vibrations or as this is placed externally water and other dust lead to absurd values. So to avoid this, infrared sensor is combined. An infrared distance sensor works on principle of calculating distance by noting the angle at which the transmitted light is being received by the receiver unit. The detector is similar receiving unit present in the image sensor of the camera. Thus the entire working of our system can be described as follows:

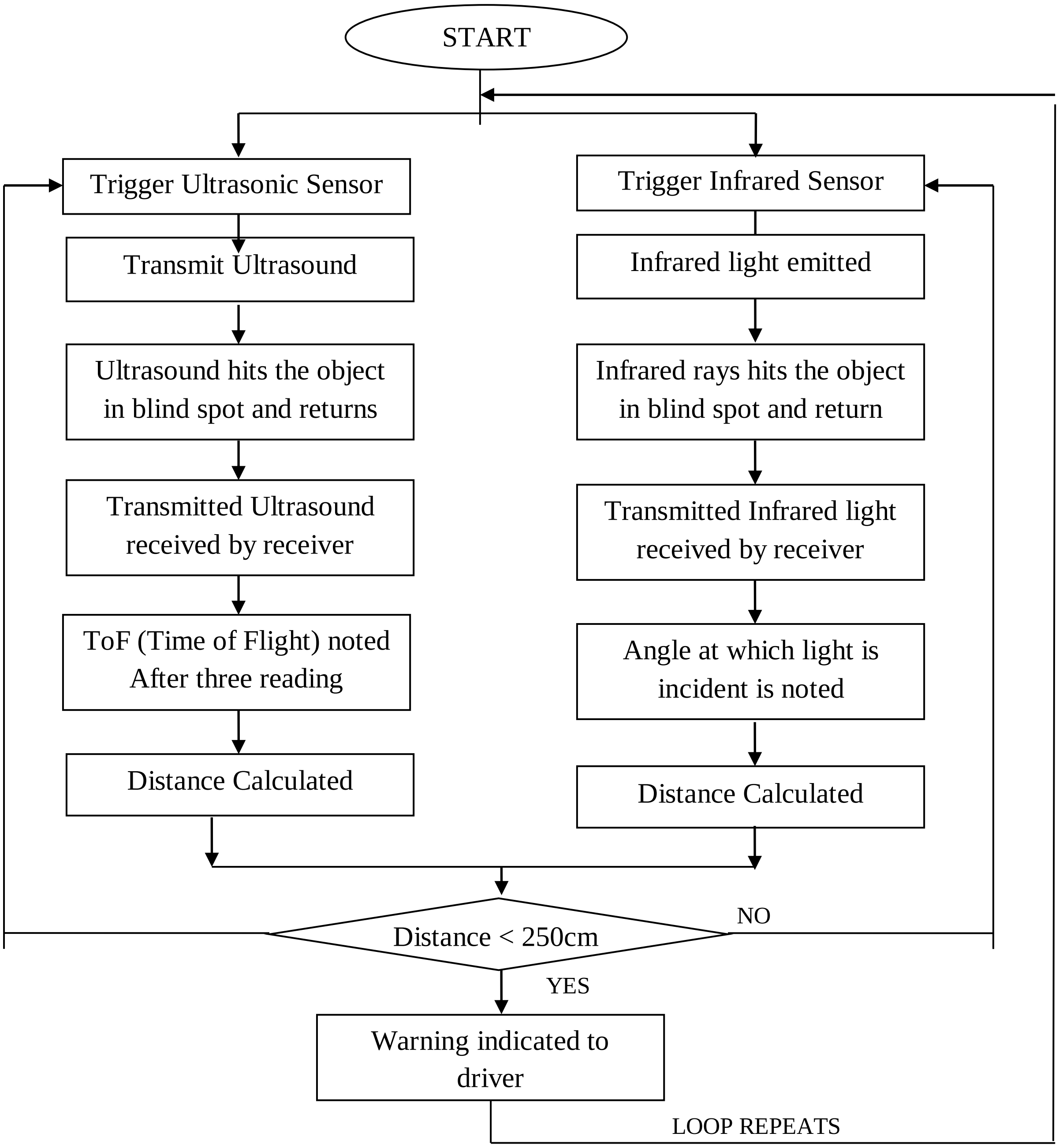

Figure 4: Flow Chart Algorithm

RESULTS AND CONCLUSION

In this paper, we have achieved successfully in creating a model which avoids blind spot collisions by detecting with a combination of ultrasonic and infrared sensor. A combination was used so that the system over comes the defect of one sensor over other, that is an ultrasonic might not work in a few cases such as during thick foggy conditions, rain et cetera but in these cases infrared works as backup and helps in detection of vehicles in blind spot region. In case of infrared which cannot function in cases where there is intense sunlight or rear headlight beam directly being incident on the sensor et cetera which does not affect ultrasonic and there by both work as a single flawless unit. We could test and succeed in all the seven cases as listed in [5], which were major causes for blind spot related accidents. Thus to conclude our model is simple reliable, low cost, and most efficient in detection and warning thereby avoiding accidents due to blind spot negligence.

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