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Pedestrian Detection using Data Fusion of Leddar Sensor and Visual Camera with the help of Machine Learning

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***Abstract*— In the concept of autonomous cars, pedestrian safety is one of the important factors. So there is a need for the improvement of the safety of pedestrians with growing number of automobiles and automobile technologies. There have been many research and development works going on in the area of pedestrian detection and distance estimation. And Data fusion has become one of the most talked about topics in the area of Advanced Driver Assistance System (ADAS) in the recent years. This paper attempts to use a data fusion technique to detect pedestrian as well as to estimate the distance of the pedestrian using Light Emitting Diode Detection and Ranging (Leddar) and Images sensor.**

The main problem in this data fusion is combining the output of the Leddar sensor with that of the image sensor. A unique method of correlating the Leddar output with image sensor output is identified and an algorithm is developed using this method which can identify Region of Interests (ROIs) in the image sensor output with respect to the Leddar sensor output. The ROIs will then be processed using machine learning algorithms to detect pedestrians. It is found that this data fusion is able to identify whether there is a pedestrian along with the distance of the pedestrian.

Keywords:Pedestrian detection, Data Fusion, Leddar sensor

I. Introduction

According to a World Health Organization (WHO) article titled Make Walking Safe, more than 270,000 pedestrians lose their lives on the worlds roads each year accounting for 22 percentage of the total 1.24 million road traffic deaths [9]. The number of pedestrian deaths in road accidents in India alone was 7,088 in the year 2015, according to a The Indian Express article [10]. The above statements indicate the concerns over pedestrian safety. With the growing number of automobiles and automobile technologies, there is a need for the improvement of pedestrian safety as well.

Fernando Garca et al. (2013) suggested a data fusion technique with Lidar Scanner and Computer Vision sensor for Advanced Driver Assistance System (ADAS). It uses Joint Probabilistic Data Association (JPDA) with Kalman Filter for image processing [1]. Danut et al. proposed incremental cross-modality training for pedestrian detection where the learning of one Convolutional Neural Networks (CNN) is transferred to another CNN up to 3 stages, which provided better results over the conventional CNNs [2]. A. Bartsch et al. developed a pedestrian detection system using automotive radar sensors which was based on a classification algorithm using weighing function, which in turn could be used to back track the results [3]. Bo Wu et al. proposed a technique for pedestrian detection using laser and image data fusion, which was claimed to detect pedestrians at a higher speed than the vision based method [4]. A research led by Navneet Dalal and Bill Triggs has shown that locally normalized Histogram of Oriented Gradients (HOG) Descriptors provide good performance in human detection [5]. A. K. Sandeep et al. published a model where pedestrian is detected from real time video through Blob analysis and braking action is performed as a control measure [11].

Based on the learnings from above papers, we have decided to use Leddar sensor and Image sensor for data fusion to find out the results. Leddar sensor in a sensing technology based on Time-of-flight and Infra-Red Light Emitting Diode(LED) illumination. The LED emitters illuminate the area of interest (pulsed typically at 100 kHz) and the multichannel sensor receiver collects the backscatter of the emitted light and measures the time taken for the emitted light to return back to the sensor. A 16-channel photodetector array is used and provides multiple detection and ranging segments. Full-waveform analysis enables detection and distance measurement of multiple objects in each segment. The Leddar sensor output consists of Affected Leddar Segment, Distance, Amplitude and Flag status. An illustration of the working of Leddar sensor is shown in Fig.1. Leddar sensor has less signal degradation, providing high robustness to inclement weather and changing light conditions [6]. Raspberry pi v2 camera module is used for image capturing.

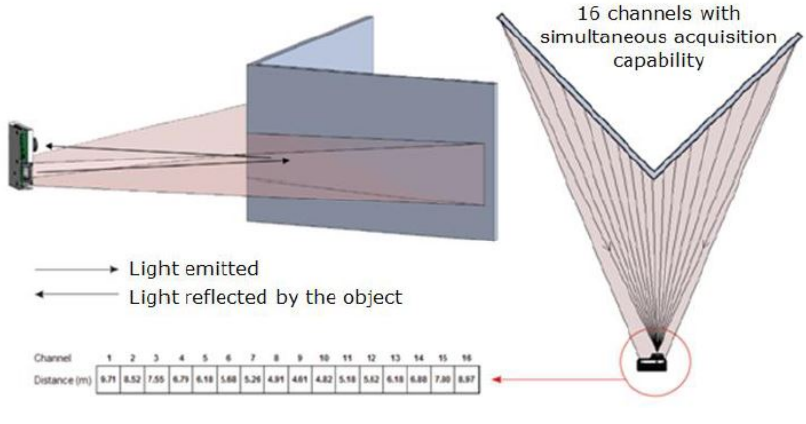

Fig. 1. Respresentation of Ledddar sensor working

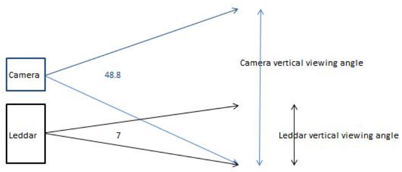

Fig. 2. Representation of Leddar and Image sensor arrangement side view

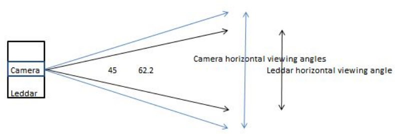

Fig. 3. Representation of Leddar and Image sensor arrangement Top view

II. Fusion Methodology

There is a need to find out multiple ways to relate the Leddar sensor and Image sensor data in order to successfully implement data fusion. Below are the relations, which have been considered to be included in this data fusion algorithm.

A. Obtaining relation between sensor outputs

Leddar sensor produces output in the form of affected segments and distance in each segment, when an object is detected whereas the images sensor provides an image file. In order to relate these two outputs, we considered the field of view of the sensors which are producing the outputs. Both the sensors have horizontal and vertical viewing angles, so if they were placed one above the other making their vertical axes to coincide, then their origin of point of view for the horizontal viewing angle would be same. Fig.2 and Fig.3

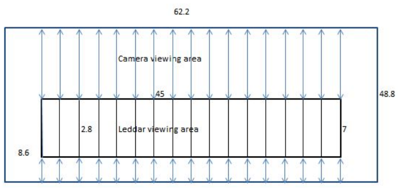

Fig. 4. Representation of Projection of Leddar Data over Camera Image

provide representational images of the placement of sensors. The horizontal and vertical viewing angles of camera sensor used in the testing are 62.2 degrees and 48.8 degrees and of Leddar sensor are 45 degrees and 7 degrees [7],[8]. And so the same are represented in the Fig.2 and Fig.3. A relationship between the segments of the Leddar sensor and pixels of the camera image has been worked out for this type arrangement. Considering the 16 segment output of the Leddar sensor as 16 horizontal frames in space with the viewing angles of the Leddar as the frame size and comparing it with the camera image with their respective viewing angles, the resultant will be similar to the representation as in Fig.4.

B. Horizontal Mapping

In Fig.4, the horizontal frames do not fully cover the horizontal coverage area of image sensor and as such will be the case with most Leddar sensors and image sensors. We have followed a two way approach for mapping the horizontal frames to the image horizontal pixels. The horizontal frames are mapped directly to their respective area of horizontal pixels by using equation(1).

$$\alpha = (\frac{x}{\theta})(\frac{\phi}{n}) \qquad (1)$$

Where,
α- Number of image horizontal pixels corresponding to each segment in Leddar

x- Number of horizontal pixels in the image
θ- Horizontal Viewing angle of the Image sensor in degrees
ϕ- Horizontal viewing angle of Leddar sensor in degrees
n- Number of segments in Leddar sensor
When an object is detected by Leddar on any segment i, the horizontal pixels belonging to segments i-1, i and i+1 will be chosen on the Image for Image processing. For the horizontal pixels which are not covered on both left and right ends of the image, if an object is detected at the 1st and 2nd segment of Leddar sensor, then the uncovered pixels area on the left end and the pixel area for the first segment will be chosen for image processing, if an object is identified at the 16th segment of Leddar sensor, then the uncovered pixels area on the right end and the pixel area for the 16th and 15th segment will be chosen for image processing.

C. Vertical Mapping

The vertical images pixels, which are to be processed, are chosen based on the distance of the object. Considering the Leddar sensor and image sensor arrangement will be mounted with their viewing axis parallel to the road on the vehicle at a height h and the height of coverage for processing is m meters. The vertical area of pixels is chosen using equation(2) and (3),

$$\beta = (\frac{y}{2}) - (\frac{(m-h)y}{2d\tan\theta}) = (\frac{y}{2})(1 + (\frac{h-m}{d\tan\theta})) \quad (2)$$

Adding a buffer of 0.2*m meters to the height h (h=h+0.2*m) to include additional pixels in the bottom area for error rectification.

$$\gamma = (\frac{y}{2}) - (h(\frac{y}{2d\tan\theta})) = (\frac{y}{2})(1 + (\frac{h}{d\tan\theta})) \quad (3)$$

Where,
β- Vertical pixel from which the image will be considered for processing
γ- Vertical pixel up to which the image will be considered for processing
y- Number of vertical pixels in the image
h- Height of the placement of sensor from ground (buffer added only for equation(3))
m- Desired length of vertical area to be covered in meters
d- Distance of the object from the sensor in meters
θ- Horizontal Viewing angle of the Image sensor in degrees

D. Distance Mapping

Leddar sensor data is further used to concentrate only on the objects, which are closer to the road and remove the unwanted area from the image file such as the sky and objects, which are further away from the road. This is achieved by the equations(4) and (5), assuming that the Leddar sensor is placed at the front center of the vehicle and the required width to be covered is w. Below check is done on the detected objects based on their distance and the required width, they are taken for consideration only if they satisfy the conditions in equations(4) and (5).

$$For segments 0 to 7 : ((7-s)\psi l) < (w/2) \quad (4)$$

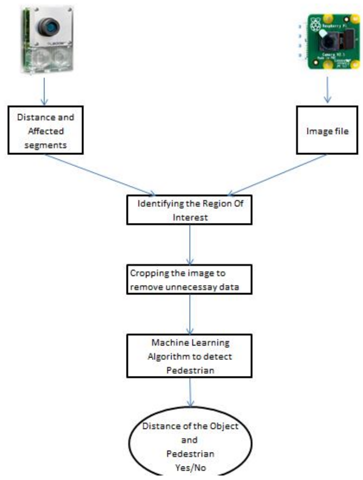

Fig. 5. Data fusion process flow representation

$$For segments 8 to 15 : ((s-8)\psi l) < (w/2) \quad (5)$$

Where,
s- Affected Leddar segment number (0-15)
ψ- Horizontal angle carried by each Leddar segment ($\psi = \frac{\phi}{n}$)
l- Distance detected in the affected Leddar segment

III. Process Flow

Affected segments along with the distance in each segment are received from Leddar sensor. An image file is received from the Image sensor. This model is designed to detect and identify the closest object to the vehicle. Next step is identifying Region Of Interest (ROI) along with the distance of object in that region. So, as soon as the data is received from the Leddar sensor, the data is reordered in ascending order of the distance. Width check equations are used to check if the object needs to be taken into account. If no, it moves on to the next segment in the ascending list. If yes, then its related horizontal and vertical pixel areas are identified. This pixel information is our ROI. The image file is then cropped according to the ROI and the cropped image is sent for Histogram of Oriented Gradients (HOG) generation. HOGDescripter() from cv2 was used in this processing. Support Vector Machines (SVM) then classifies that whether or not the image contains pedestrian based on the gradients. SVMDetector of getDefaultPeopleDetector() from HOGDescripter() was utilized in this step. The processed image along with the distance and pedestrian info is displayed as the final result. A program was written using python which takes Leddar sensor reading and image file name as input and run the processing methodology described above. Fig.5 shows a schematic representation of the process followed.

IV. Experimental Setup and Result

Leddar M16 sensor with horizontal field of view of 45 from Leddar Evaluation Kit and RaspberryPi camera v2 were

Segment	Amplitude	Distance (m)	Flag
0	nil	nil	nil
1	nil	nil	nil
2	nil	nil	nil
3	nil	nil	nil
4	nil	nil	nil
5	nil	nil	nil
6	nil	nil	nil
7	nil	nil	nil
8	nil	nil	nil
9	0.55	24.47	1
10	2.14	17.59	1
11	2.87	13.68	1
12	4.62	11.65	1
13	2.97	9.68	1
14	3.77	8.47	1
15	4.22	7.77	1

Fig. 6. Leddar sensor output

chosen for sensors. Leddar Evaluation Kit consists of a Leddar M16 sensor, power cable, data cable to connect to computer, power cable adapter and connectors. Pi Camera and Leddar sensor were arranged in a box, which had clear cut openings in the front for placing the sensors keeping the vertical axis of the sensors aligned and in the back open so as to connect the Leddar sensor and Camera to their respective interfaces. Leddar GUI configurator software was installed in computer and Leddar sensor was connected to the computer with the help of provided data cable. Leddar configurator software acts as an interface between computer and Leddar sensor and also allows recording the Leddar sensor data for desired amount of time. Leddar sensor was powered by the power cable provided with the Leddar Evaluation Kit. Raspberry pi camera v2 was connected to Raspberry Pi 3 model B board, where python program for capturing images was installed.

Distances of 3 m, 5 m, 10 m, 15 m, 20 m and 25 m were marked on the ground from the sensors with the help of measuring tape. A person was made to stand at different marked places at different times. Each time, Images were captured by the Raspberry Pi camera and the Leddar sensor readings for the same time were recorded using the Leddar configurator software.

Image files were copied from Raspberry Pi board to computer. The Leddar sensor reading corresponding to an image and the image file name were given as the input to the Program. This program returned an image file which consisted of information about the distance of the object and whether or not the object is a pedestrian. Leddar sensor readings, image sensor output and the result of the fusion algorithm for 25m distance are show in Fig.6, Fig.7 and Fig.8 respectively for reference.

Fig. 7. Camera Output

Fig. 8. Final Result after completing data fusion and image processing

V. Conclusion and Future Work

The fusion algorithm was able to successfully integrate the outputs from Leddar sensor and Image sensor. The result consisted of both the distance of the object as well as whether or not the object is pedestrian. This approach also adds more integrity to the system by being able to provide the output of one sensor even if the other one fails. The algorithm has been designed as such that in case the Leddar sensor fails, complete image will be processed and the result will be displayed and in case the Image sensor fails, the distance info will still be displayed over the corrupt image. Fig.9 and Fig.10 show the result in case of failure of Leddar sensor and Image sensor respectively. This algorithm has taken the closest object into account for displaying distance, future work can be developed to include all affected objects within range.

Fig. 9. Final result when Leddar sensor fails

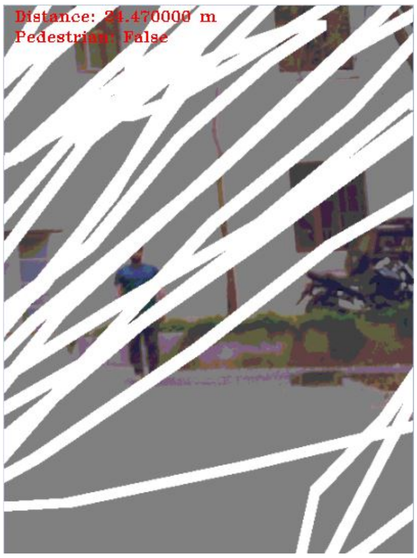

Fig. 10. Final result when image sensor fails

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