A Novel vision based embedded framework system to detect and track dynamic vehicles

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Abstract

A vehicle tracking system is a smart device installed in vehicles to detect and track the moving vehicle. In the emerging world the number of vehicles on road has been increasing globally. Intelligent transport system has been explored better to make an efficient transport system and also for traffic arrangements. Hence there is a need for a system that tracks the vehicle and provide assistance to the driver. The study aims at developing a novel embedded driver assistance framework that could analyze the dynamics of vehicle in the front and rear surround views. In the proposed study, to detect and track the moving vehicles Gaussian Mixture Model (GMM) and Kalman filter is implemented thereby critical safety to the vehicles is enabled by calculating the distance along with the directions. The developed prototype contains 4 cameras each equipped with an embedded processor. In order for the system to run at a near real time pace, optimized vision-based techniques are used that detect vehicles that are near-by. The only modality used for sensing are the camera sensors which analyze the surroundings of the ego or the host vehicle. Object detection by GMM technique proves to be more accurate and reliable in light traffic conditions and during day time whereas during night time the detection technique is not that accurate. Hence the developed prototype includes ultrasonic sensors that calculates the distance between the objects by sound wave. Further the developed detection system is validated by analyzing Receiver Operating Characteristics. Thus vision based embedded computing framework proves to be more efficient method for tracking objects.

Keywords: Vehicle tracking system, GMM, Kalman filter, Ultrasonic sensor, ROC

1. Introduction:

ITS have a great mark in road transport systems and it has been exploring in many developing countries. Driver assistance systems like automatic braking, vehicle detections using CCTV, using blob analysis and so on. These systems use many detection and tracking ways and have been evolved with many algorithms such as Viola jones, HOG and so on. The Voila jones undergoes with positive and negative databases. However these turned out to detect by the frames of an image. And also their detections encountered lack
of accuracy in traffic conditions. According to the study by Kichun Jo [1], the author developed a system for a self-driving vehicle that is autonomous and is capable of sensing its environment. In order to achieve autonomous driving capabilities, a mixture of complex algorithms such as perception, localization, planning and control along with a variety of different sensors, computing devices and actuators are required. To handle the complex nature of the algorithms and the heterogeneous components, the aforementioned paper utilizes distributed system architecture to the system and suggests a system platform and developmental plan for achieving it in an autonomous car. Guidelines for the design and development is provided by the developmental process. The proposed system platform allows minimized reliance between the hardware and the software. The used protocol is time triggered and is referred too as Flex Ray. This improves the overall system efficiency, makes the system more tolerant to fault and betters the network bandwidth. An evaluation of the system process and developmental process will be done in this paper using an autonomous car capable of being driven in urban areas. The system is about to dwell out an automatic assistance for driver in a heavy controllable surroundings. Many driver based algorithms are used for more sensible driving. But the system fails in the rear conditions since denying layout for rear side makes so complicated and also it has been put down by many automotive.

Guoliang Liu et al. [2] estimated lane shape by utilizing a particle filter driven measurement model. The measurement model, defines how accurate the generated hypothesis of current visual cues is. Previously used methods used a combination of many visual cues in a likelihood function without taking into account the probability relationship between lane model and visual cues and the uncertainties of the visual cues. While this paper creates an entirely different measurement model by using various kernel densities to mathematically estimate the relationship of the probabilities. Gaussian Kernels are utilized to model and consider the uncertainties of local visual cues. The shape of the lane boundaries is determined by using a linear-parabolic particle filter (PPF) and portioned particle filter integrated with the measurement model to estimate consecutive lane shapes in the frames. In the end, the proof of the robustness of the proposed algorithm is shown on DRIVSCO data sets. The model is about the detection of a particular lane by using kernels and PPF algorithms. This system only detects the lane and the vehicle are been monitored for the safety. The manual driver assistance is less and also the parabolic methods of detection leads to be economically high. Akhan Almagambetov et al. [3] Vehicle taillight tracking and sensing alter signals such as turns and brakes needs to be carefully considered when implementing collision avoidance. The author has developed a strong algorithm that stimulates real time vision to sense and track taillights and has implemented it, thereby inducing an alert signal irrespective of lighting conditions. The author tested the developed system in traffic scenario and were able to show better results. Indrabayu et al [4] in their study developed an intelligent transport system to track and detect moving objects. In this study Gaussian Mixture Model method was applied to detect moving vehicles and Kalman filtering technique was used to track the moving objects. The study was focused on two main conditions namely light and heavy traffic conditions. In the proposed study modification on the Gaussian mixture model and Kalman filtering technique was applied to both detect and track moving objects for both light and heavy traffic conditions and moreover for light and dark light conditions. Hence the aim of the study is to develop a modified Gaussian Mixture model and kalman filtering technique to detect and track the moving object with better accuracy and in a more efficient manner. In the proposed study distance calculation is carried out using Euclidean distance method and also central point of the moving objects is evaluated by calculating centroid value. Moreover by using ultrasonic sensor night time scenario of detecting moving object problem is resolved in the proposed study.

Amir Mukhtar et al [5] have discussed that the detection technique for vision based vehicles in the aspect of road safety has improved and gained attention. But the effectiveness of these techniques has reduced because of robustness in content to big variability and driving nature. So they have approached an ample survey on the detection of vision based vehicles and the system used for tracking for CASs. The techniques used to reach this conclusion has been discusses in the paper. Tongtong Chen et al [6] have discussed the crucial necessity of dynamic vehicle detection and the process of tracking in an urban surrounding. In their
study, they have developed a dynamic detection system and an algorithm for tracking which can be used to solve the issues of ALV (autonomous land vehicle). For the detection process, an improved 2D virtual scan was presented in order to detect any dynamic vehicle with potentially differing scan operations. Both quantitative and qualitative test results have been validated on the basis of their algorithm used on the datasets they collected. Farid Bounini, Denis Gingras et al [7] have emphasized that advanced driving assistant systems, autonomous and intelligent vehicles are beneficial solutions to improve road and passenger safety issues. Such an application needs advanced vision computer algorithms with powerful computers having high speed ability to process. This paper aims in putting forward an efficient and accurate road boundary and detection of painted lines algorithm for an intelligent and an autonomous vehicle. It is a combination of Hough Transform and Canny edge detector, least square method and the kalman filter. Michalis Mavrovouniotis et al [8] have stated that many of the real time world problems are related to the dynamics of environment and need an optimization algorithm to note the optimal during the changes. Algorithms like Ant colony optimization (ACO) were found to be a powerful tool to address the combinational dynamic optimization problems. In the paper, the scheme used was immigrants schemes which were solely designed as a solution for the problem of dynamic vehicle routing. The experiments conducted were based on a set of systematically designed DVRP cases and compared and benchmarked the ACO algorithms proposed. An analysis on the sensitivity was conducted regarding the key parameters based on the algorithm that was proposed.

R. Omar Chavez-Garcia et al [9] have discussed the importance of accurate classification and detection of moving objects in an Advanced Driver assistance system (ADAS). They have defined an object description for including period information. Then a complete architecture on perception fusion was proposed based on the framework evident to solve the issue of Detection and tracking of moving objects (DATMO). This was done by combining the composite representation and the ambiguity management. Finally they integrated the fusion and it was tested using various data based on different driving scenarios. Alberto Hata et al [10] have stated that an important feature of automobile vehicle is localization. It enables completion of tasks like navigation and path planning. The paper focuses on proposing a method for curb and road marketing detection and is being applied to vehicles localization. For detecting curbs in an occluding scene, a method was developed focusing on ring compression analysis and the least trimmed square. A modified version was developed for road marking detection process. The feature detection techniques were combined with Monte Carlo Localization technique for estimating the position of the vehicle. Xinyu Zhang et al [11] have discussed about the important topics in the field of traffic management and transportation. This paper revolves on the contribution to a new segmentation algorithm in the images pre-processing state. It also talks about a symmetric based computation on a traditional histogram of gradient (HOG) feature added in the detection phase in a vehicle. A motion based model was designed based on the adaptive Kalman filter.

2. Methodology:

The proposed study aims at developing a novel embedded driver assistance framework that analyzes the dynamics of the vehicle in the front and rear surround views of the host vehicle. The developed prototype contains 4 cameras each equipped with an embedded processor. In order for the system to run at a near real time pace, optimized vision-based techniques are used that detect vehicles that are near-by. The only modality used for sensing are the camera sensors which analyze the surroundings of the ego or the host vehicle. The system has been tested and is found to be highly robust in real life stimulating conditions. Additional cameras can be added to scale the system. Detailed evaluation of the set up showed maximum accuracy and operation at nearly 15 frame per second.
Corresponding to the centralized system architecture, most of the components of the system with important functions are merged into a single computational unit. The unit contains all the sensors and actuators. As a result, the system structure is simplified, minimizing delay and information loss due to the absence of an additional network. In the proposed prototype, Universal Asynchronous Receiver Transmitter (UART) is used for asynchronous serial communication where the speed of transmission and format of data can be controlled. The electric signaling level and methods are taken care of by an external driver circuit. Atmega328p microcontroller is used that has read and write capabilities and a 32kb ISP ash memory. The other features include 1kB EEPROM, 2kB SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible timer/counters with compare modes, internal and external interrupts, serial programmable USART, byte-oriented 2-wire serial interface, SPI serial port, 6-channel 10-bit A/D converter (8-channels in TQFP and QFN/MLF packages), programmable watchdog timer with internal oscillator. The device can be operated between 1.8 to 5.5 volts and achieves a throughput up to 1MBPS per MHz.

Video processing is the key part of the proposed system. Input video used in the proposed study for further processing is .mov format captured from the camera of 25 fps and has a resolution of about 640*480 pixels and each path is processed separately. Figure 2 shows the software process of the proposed study. The first step in the process is to feed the video from the webcam of a particular resolution. As the duration of the video increases, the number of frames also increases. On the other hand, a large number of frames may lead to delay. Extract frame is the process to extract a frame from the input video and assign the total number of frames. This process is done to fetch the frames separately to detect and track the moving objects.

Gaussian mixture model (GMM) is used for object detection. GMM is the fastest algorithm with maximum accuracy in real-time detection. GMM utilizes maximum likelihood function to recognize the clusters thereby reducing the bias in cluster formation. Gaussian Mixture Model is the process of separating the foreground and background separately. Since it is a density model, it consists of several functions with Gaussian components. Fitting the parameters of the clusters is performed with Expectation maximization (EM)
algorithm. EM algorithm is done in two steps namely estimation step and maximization step by initial assumption of random Gaussian parameters like mean, covariance matrix and standard deviation. Estimation step analyzes the data and estimates the missing variables. Maximization step updates the Gaussian parameter for cluster formation from the estimated parameters. The next step in the processing is to separate the area in the frame using ROI segmentation. Here the object to be detected is considered a foreground and the ignored area is considered as the background. First step of ROI segmentation is to create a polygon pixel for the observation point of view. In the created polygon the non-region of interest area are covered and those objects that comes under that area are ignored. This region is considered as background and the region of interest is considered as the foreground.

Figure 3 shows the exact pixel boundary with in the region the objects are ignored. Once the clusters are identified, each cluster undergoes the ROI segmentation process. Each and every pixel used for detection is assigned with Gaussian distribution properties such as standard deviation and weight factor. Each pixel from the video frame are compared with the GMM model. The pixels with similar values of standard deviation and highest value of weight factor are considered as the back ground and those pixels with highest value of standard deviation and pixels with lowest weight factor is considered to be foreground. Pixel which are characterized as background are said to have black color or the value zero and those pixels categorized as foreground are said to have white color or one. After extraction of binary image, image processing will be carried out. Moving object or the dynamic one are said to be foreground and the static object are considered as background.

Once the foreground object is detected the object is marked with a blob. Hence considering the foreground object with the blob bounding box is given. The bounding box is dependent on the area of the detected foreground object. The objects without the blob are ignored. This method is proven to be better than the repeated detection technique and it is conversely reliable only to the light conditions. Once the object is detected, tracking the trajectory of the object is essential as the project aims in detecting the dynamic
objects. Kalman filtering is an efficient method used for object tracking in real time. It is a recursive method used to track the vehicles at each frame. Kalman filter follows the centroid point of an object in each and every frame in order to track and locate the object. The information from the detected object in the previous frame is used for future estimation. Prediction and correction are the two steps involved in kalman filtering. Prediction process is used to predict the current and the future object position and the correction step is a combination of actual measurement. The Euclidean distance is stated as the distance between two points in a space known as the Euclidean space. The two points P and Q are in 2D Euclidean spaces with P having coordinates (p1, p2), and Q with (q1, q2). A line Segment drawn with the end points of P and Q will form a right angled triangles hypotenuse. The distance between P and Q is defined as the square root of the sum of the squares of the differences between the coordinates of the points. The Euclidean distance between two points \(a=(ax, ay)\) and \(b=(bx, by)\) is given by

\[
d(a, b) = \sqrt{(bx - ax)^2 + (by - ay)^2}
\]

A webcam is used for capturing the video in a particular resolution and the video is followed by the software process where the objects in each frame gets detected and tracked to get out the distance value. The video processing unit may not produce accurate results when the light conditions are not satisfactory as the image quality from the webcam may not be clear. For effective functioning of the unit during all light scenarios, the proposed system is added with ultrasonic sensors. Ultrasonic sensors is a device that uses sound wave to find the distance at which an object is located. Distance are measured by transmitting a wave of specific frequency. By means of calculating elapsed time between the transmitted sound wave and sound wave returning back it is the distance between the object and the sensor can be calculated. Ultrasonic sensor used for the proposed study can measure up to a distance of 2cm to 4 m. Since it has established range guaranteeing accurate data, less data has the chance of being lost in the error zone.

The sensor is triggered externally by supplying a pulse to the signal. Supply voltage of 5v DC supply and a supply current of 20ma is used. Bidirectional TTL pulse interface on a single I/O pin can communicate with 5 v TTL or 3.3 V CMOS microcontroller. The ultrasonic sensor calculates the distance by sending out the sound out the sound waves at particular frequency and waits to hear, when it bounces back. It can operate upto 40 kHz. Though the detection and tracking is done by GMM and and kalman filtering they are reliable against light due to which the night time scenarios are not dealt properly. So to overcome this draw back ultrasonic sensors are used. This will simultaneously detects the object and it is programmed with micro controller to bring out the distance value and to display that on LCD.

The distance value by the ultrasonic is calculated using the following formula for.
The input video used should be minimum of 640*480 resolution and the frame rate used here is 20 fps. Microcontroller (At mega 328p) has a power supply in the range of 1.8-5 volts. Ultrasonic sensors use modulation at 40 KHz. 5V DC Supply voltage. Current <20 Ma. Echo pulse: positive TTL pulse, 87 μs minimum to 30 ms maximum (PWM). The LCD is maintained at 3.3 volts. IEEE 1394, this is the standard that stands for the serial communication for high speed communication and real time data transfers.

3. Algorithm

Step 1: Get the input video
Step 2: Determine the total number of frames
Step 3: Extract the first frame and apply Gaussian mixture model with mean, standard deviation and covariance matrix as the Gaussian parameters to form clusters.
Step 4: Perform ROI segmentation for identifying the dynamic objects. If object is detected move to next step. Else output the video stream.
Step 5: Apply Kalman filtering to track the object.
Step 6: Check whether all frames are processed. If completed, output the video stream. Else go to step 3.

4. Results and Discussion

The study aims at detecting and tracking the moving objects. Upon extraction of the frame object detection is done using GMM model. In the proposed study by using the blob of the detected foreground the process of bounding box has been done.

![Figure 5: Detection of object using GMM and bounded box](image)

Figure 5 depicts the objects detected using GMM model where the foreground objects are assigned using red colored blobs. Hence to illustrate the working of the proposed prototype red color objects are used here. The former results are used for tracking the object using kalman filtering technique where the object is tracked in each frame with its central point. The centroid of different axis is located using kalman filtering and thereby using Euclidean distance formula the distance between the object is calculated.
Figure 6 depicts the tracking of object carried out using kalman filter by evaluating the centroid points in different frames. Moreover the distance calculated using Euclidean distance formula is displayed in the LCD screen. An alternative distance calculation is also done to overcome the night conditions. This is been done using ultrasonic sensors that calculates the distance between the objects by the sound waves. Hence the developed prototype aim at developing a prototype to detect and track the moving objects using modified Gaussian Mixture model and Kalmann filtering technique. The prototype also detects the distance between the moving objects using Euclidean distance formula.

5. Conclusion:
The study focuses on to evaluate the distance between the moving objects inculcating both sensors and algorithm. Object detection using Gaussian Mixture Model proves to be more efficient during light condition or during day time but down performs during night time or during low light conditions. Hence in the proposed study modified version of GMM model is imposed so as to improve the performance during night time. In the proposed model ultrasonic sensors have put down the drawback of GMM model and effectively calculates the distance during night conditions. Tracking the moving object is done using kalman filter also aids in the better calculation of distance. Hence the proposed system proves to be one of the most efficient and accurate method in distance calculation between the moving objects. The system can even update the neighbor cars by Bluetooth tracking and also GPS indications can drive to better alerts. However these are the future scopes of the work.

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