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Implementation of Global Localization of Intelligent Vehicle in Lane Level via Lane Marking Detection and Shape Registration

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ABSTRACT: The lane detection and tracking is one of the challenging problems in computer vision. It is one of the key features of advanced driver assistance system. Lane detection is finding the white markings on a dark road. Lane tracking uses the previously detected lane markers and corrects/adjusts itself according to the motion model. In this paper, we implement a real-time positioning method for robotic cars in urban environments. The method uses a robust lane marking detection algorithm, as well as an efficient shape registration algorithm between the detected lane markings and a GPS-based road shape. Here, we exploit both the state-of-the-art technologies of visual localization based on lane marking detection and the wide availability of Global Positioning System (GPS) based localization. We have evaluated this method with a single forward looking camera mounted on an autonomous vehicle.

KEYWORDS: Advanced Driver Assistance System, Lane detection, Lane Tracking, Vehicle Detection, Vehicle Tracking.

I. INTRODUCTION

Autonomous vehicle is a type of vehicle that performs the required tasks without human guidance. Researchers are done to create such vehicle that can cope with the several of environment, typically, on land, underwater, air borne, underground, or in space. From there, the vehicle would take over and drive to destination without human input. The autonomous vehicle is one in which a computer executes all the tasks that the human driver normally would. Finally, this would mean getting a vehicle, entering the objective into a computer, and enabling the system. From there, the vehicle would take over and drive to destination with no human input. The vehicle would be able to sense its environment and make steering and speed changes as necessary. So to develop an autonomous vehicle it will involve automated driving, navigating and monitoring systems.

In the last couple of years, almost all vehicle manufacturers are busy developing some sort of self-driving vehicle that can maneuver in real world traffic [9]. Many projects on autonomous driving are in development in industry. In 1980, Mercedes-Benz was the first one to develop the autonomous road vehicle. Recently there are many researches until now about the autonomous driving systems used a lane-keeping vision system to detect the road lane and compute road information such as heading angle and offset displacement, which are then sent to the controller operating the forward steering wheel to ensure that the vehicles driving in the inside lane. The process of estimating the vehicle position and its heading direction inside the lane is essential for many autonomous vehicle applications. The developments of techniques of the navigation and control of the autonomous vehicles have become an active research topic. The autonomous navigation vehicle is the capability of moving on the required path without any intervention from human.

Many automobile manufacturers provide optional lane keeping systems including Nissan, Toyota, Honda, General Motors, Ford, Tesla, and many more. However, these systems require human monitoring and acceleration/deceleration inputs are not completely automatic. Ford's system uses a single camera mounted behind the windshield's rear-view mirror to monitor the road lane markings. The system can only be used when driving above 40 mph and is detecting at

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least one lane marking. When the system is active, it will alert the driver if they are drifting out of lane or provide some steering torque towards the lane center. If the system detects no steering activity for a short period, the system will alert the driver to put their hands on the steering wheel. The lane keeping system can also be temporarily suppressed by certain actions such as quick braking, fast acceleration, use of the turn signal indicator, or an evasive steering maneuver. Ford's system also allows the choice between alerting, assisting, or both when active. All these systems use similar strategies in aiding a human driver to stay in lane. GM, in particular, warns that their lane keeping system should not be used while towing a trailer or on slippery roads, as it could cause loss of control of the vehicle and a crash [13].

II. RELATED WORK

A large amount of research has effectively addressed the lane detection and vehicle tracking problem for highway driving. Suburban roads, however, present a very different situation. Highways typically consist of straight roads with multiple lanes and clearly identifiable surfaces, whereas on suburban streets these are uncommon (Wang et al. 2002; Kluge 1994; Aly 2008). Major state-of-art methods are discussed in this section.

Shehan Fernando, Lanka Udawatta, Ben Horan and Pubudu Pathirana [1] in their paper "Real-time Lane Detection on Suburban Streets using Visual Cue Integration" discussed a novel lane boundary detection algorithm by the integration of two visual cues. The first visual cue is based on stripe-like features found on lane lines extracted using a two-dimensional symmetric Gabor filter. The second visual cue is based on a texture characteristic determined using the entropy measure of the predefined neighbourhood around a lane boundary line. In this work, the image cues from both the Gabor filter and entropy image analysis were thresholded and morphological operations applied in order to emphasize the candidate lane markings and to remove unwanted objects. Both image cues to be integrated take the form of binary images. The two visual cues were integrated using a modified rule-based classifier, resulting in a lane image emphasizing lane markings and eliminating most of the unwanted areas within the region of interest. The authors have demonstrated that this algorithm is capable of extracting lane boundaries from a 640×480 image in less than 90 ms.

Xiaozhi Qu [2], proposed to use one or more cameras on a vehicle as a georeferencing system. To limit the drift of the trajectory due to the accumulation of errors, he proposed a registration on a set of visual landmarks that are precisely georeferenced. These landmarks were reconstructed using the reference data generated by precise and expensive mapping systems. Natural road features such as road markings and traffic signs were chosen as visual landmarks operation.

Yue Wang, Eam Khwang Teoh, Dinggang Shen, proposed a B-Snake based lane detection and tracking algorithm without any camera parameters [3]. Since B-Spline can form any arbitrary shape by a set of control points, the B-Snake based lane model was able to describe a wider range of lane structures. A Canny/Hough Estimation of Vanishing Points, was used for providing an initial position for the B-Snake. Also, a minimum error method by Minimum Mean Square Error (MMSE)was proposed to determine the control points of the B-Snake model by the overall image forces on two sides of lane. This method was also applicable to marked and the unmarked roads, as well as the dash and the solid paint line roads. However, this work mainly focused on 2D lane model.

I. El hajjouji, A. El mourabit, Z. Asrih, S. Mars and B. Bernoussi, presented a system for robust lane detection and tracking [4]. Their proposed algorithm can be divided in two parts. The first one is for lane detection using Sobel operator with an adaptive threshold and the Hough transform, and the second part deals with lane tracking using Kalman filter. To meet real time requirements, they used gradient directions of edge stage to simplify CORDIC algorithm and to improve the performance and thus the detection efficiency.

Chanho Lee, Senior Member, IEEE, and Ji-Hyun Moon, developed a real-time vision-based lane detection algorithm with an efficient region of interest to reduce the high noise level and the calculation time [5]. This proposed algorithm processes a gradient cue and a color cue together and a line clustering with scan-line tests to verify the characteristics of the lane markings. It also removes any false lane markings and tracks the real lane markings using the accumulated statistical data. This algorithm was verified using 48 video clips, which represent 12 road and weather conditions. The authors claimed that the computation time satisfies the real-time operation with embedded processors running at 800 MHz.

Byambaa Dorj and Deok Jin Lee, in their work introduced a detection method based on top view image transformation that converts an image from a front view to a top view space [6]. After the image transformation is complete, a Hough

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transformation technique is integrated using a parabolic model of a curved lane in order to estimate a parametric model of the lane in the top view space. The parameters of the parabolic model were estimated by utilizing a least-square approach.

Huang Guan, Wang Xingang, Wu Wenqi, Zhou Han, Wu Yuanyuan, presented a novel and effective lane-vehicle detection and tracking system to achieve real-time and robust leading vehicle localization [7]. The system was composed of the following: (i)Lane detection and tracking, (ii)Sky and road region recognition and (iii)Vehicle detection and tracking. First, lane detection and sky and road recognition are performed to reduce the possible region of leading vehicle. Then vehicle detection is applied to get all vehicles in per image. Combined with ROI information, leading vehicle is localized. Finally, vehicle tracking is used to make the whole system fast and robust. The method is based on convolutional neural networks to achieve high-quality and real-time vehicle detection. However, this work did not focus on the integration of ROI reduction and vehicle detection.

Deok-Kwon Lee, Ju-Seok Shin, Je-Han Jung, Sang-Jun Park, et al [8], proposed a real-time lane detection and tracking algorithm using a simple filter and Kalman filter to develop a Lane Departure Warning System that can be implemented in an embedded system. This system was realized on I.MX6Q board, mounted on a test vehicle, and traveled about 1,000km to generate the experimental results. The authors claimed that this system operates at 97% detection rate in the day time and 95% in the night time. The average processing time of this system was 15 frame per seconds.

Oliver Pink, Frank Moosmann and Alexander Bachmann, in their work introduced a novel method for vehicle pose estimation and motion tracking using visual features [10]. This method combines ideas from research on visual odometry with a feature map that is automatically generated from aerial images into a Visual Navigation System. Given an initial pose estimate, e.g. from a GPS receiver, the system is capable of robustly tracking the vehicle pose in geographical coordinates over time, using image data as the only input. Authors claimed that the resulting pose estimates are accurate within several centimeters with respect to the feature map even when a large number of false detections are present. However, in this work, globally optimal methods for map matching were not used since they are not suitable for real-time applications.

Jian-ru XUE, Di WANG, Shao-yi DU, Di-xiao CUI, Yong HUANG, Nan-ning ZHENG, proposed a vision-centered multi-sensor fusing framework for the robotic cars perception problem, which fuses camera, LIDAR, and GIS information consistently via geometrical constraints and driving knowledge [11]. This framework consists of self-localization and processing of obstacles surrounding the robotic car. The machine vision algorithms were integrated with the framework and the work address multiple levels of machine vision techniques, from collecting training data, efficiently processing sensor data, and extracting low-level features, to higher-level object and environment mapping. They demonstrated the performance of the vision centered multi-sensor fusing approach from two aspects. The first aspect is vision-centered multisensory fusing for self-localization. They constructed the hybrid map by a vision-centered mapping method. The hybrid map improves the accuracy of self-localization from the meter level to the centimeter level in a real urban traffic environment. It also shows that using the constructed hybrid map can improve the perception of lane markings, road shapes, traffic lights, and obstacles. The second aspect is vision-centered multisensory fusing for processing of obstacles surrounding the robotic car.

ZHANG Wei-wei, SONG Xiao-lin, ZHANG Gui-xiang, proposed a technology for unintended lane departure warning [12]. Lane boundaries were detected based on principal component analysis of grayscale distribution in search bars of given number and then each search bar was tracked using Kalman filter between frames. The lane detection performance was evaluated and demonstrated in ways of receiver operating characteristic, dice similarity coefficient and real-time performance. For lane departure detection, a lane departure risk evaluation model based on lasting time and frequency was executed on the ARM-based platform. The authors have claimed to have obtained the average processing speed of 25 frame/s on embedded platform with S3C6410 processor.

Robert Spangenberg, in his thesis report entitled “Landmark-based Localization for Autonomous Vehicles”, dealt with the design and development of a system for landmark-based localization in urban scenarios suitable for autonomous driving [16]. The sensor input was limited to a stereo camera pair, vehicle odometry and an off-the-shelf GPS. Prior knowledge in the form of a landmark map was also available. Pole-like structures are identified as robust, long-term stable and common three dimensional landmarks in urban scenarios. These are easily detectable by a stereo camera and are used as primary landmarks. In comparison to lane markers they have a lower occlusion probability and lower change rate. As pole-like structures can be rather small, a high quality depth reconstruction is crucial for robust detection. A new matching cost was presented and Semi-Global Matching was modified to become more reliable

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scalable. A robust extraction method for pole-like landmarks was introduced. The localization method proposed in this work uses particle filters and the complete processing chain from feature extraction to processing a latency corrected vehicle pose output is covered.

Guangqian Lu, in his thesis proposed a real-time lane assisting framework for intelligent vehicles, which consists of a comprehensive module and simplified module [18]. This was the first parallel architecture that considers not only lane detection and tracking, but also lane marking recognition and departure warning. A lightweight version of the Hough transform, PPHT was used for both modules to detect lines. After detection stage, for the comprehensive module, a novel refinement scheme consisting of angle threshold and segment linking (ATSL) and trapezoidal refinement method (TRM) takes shape and texture information into account, which significantly improves the LDT performance. Also based on TRM, colour and edge informations are used to recognize lane marking colors (white and yellow) and shapes (solid and dashed). In the simplified module, refined MSER blobs dramatically simplifies the preprocessing and refinement stage, and enables the simplified module performs well on lane detection and tracking. The report claims, the detection rate of LDT system in comprehensive module average 95.9% and exceed 89.3% in poor conditions, while the recognition rate depends on the quality of lane paint and achieved an average accuracy of 93.1%. The simplified module had an average detection rate of 92.7% and exceeds 84.9% in poor conditions.

Zongzhi Tang, in his thesis report, proposed a real-time lane marking detection framework for ADAS, which included 4-extreme points set descriptor and a rule-based cascade classifier. By analyzing the behavior of lane markings on the road surface, a characteristic of markings was discovered, i.e., standard markings can sustain their shape in the perpendicular plane of the driving direction. By employing this feature, a 4-extreme points set descriptor was applied to describe the shape of each marking first. Specifically, after processing Maximally Stable Extremal Region (MSER) and Hough transforms on a 2-D image, several contours of interest were obtained. A bounding box, with borders parallel to the image coordinate, intersected with each contour at 4 points in the edge, which was named 4-extreme points set. Afterward, to verify consistency of each contour and standard marking, some rules abstracted from construction manual were employed such as Area Filter, Colour Filter, Relative Location Filter, Convex Filter, etc. [19]

To reduce the errors caused by changes in driving direction, an enhanced module was then introduced. By tracking the vanishing point as well as other key points of the road net, a method for 3-D reconstruction, with respect to the optical axis between vanishing point and camera center, was possible. The principle of such algorithm was exhibited, and a description about how to obtain the depth information from this model was also provided. Among all of these processes, a key-point based classification method is the main contribution of this work because of its function in eliminating the deformation of the object caused by inverse perspective mapping. The report claims the detection rate of the markings by this proposed algorithm reached an average accuracy rate of 96.77% while F1 Score (harmonic mean of precision and recall) also attained a rate of 90.57%.

Young-Woo Seo, in his thesis investigates computer vision algorithms to automatically build lane-level detailed maps of highways and parking lots by analyzing publicly available cartographic resources, such as orthoimagery [20]. The map-building methods recognize image patterns and objects that are tightly coupled with the structure of the underlying road network by: 1) identifying, without human intervention, locally consistent image cues and 2) linking them based on the obtained local evidence and prior information about roadways.

The report demonstrates the accuracy of bootstrapping approach in building lane-level detailed roadway maps through experiments. This thesis report also addresses the problem of updating the resulting maps with temporary changes by analyzing perspective imagery acquired from a vision sensor installed on a vehicle.

He Zhao, in his thesis presents a semi-automated method for extracting meaningful road features from mobile laser scanning (MLS) point clouds and creating 3D high-definition road maps for autonomous vehicles [21]. After pre-processing steps including coordinate system transformation and non-ground point removal, a road edge detection algorithm is performed to distinguish road curbs and extract road surfaces followed by extraction of two categories of road markings. On the one hand, textual and directional road markings including arrows, symbols, and words are detected by intensity thresholding and conditional Euclidean clustering. On the other hand, lane markings (lines) are extracted by local intensity analysis and distance thresholding according to road design standards. Afterwards, centerline points in every single lane are estimated based on the position of the extracted lane markings. Ultimately, 3D road maps with precise road boundaries, road markings, and the estimated lane centerlines were created.

Dixiao Cui, Jianru Xue, and Nanning Zheng [23], proposed an accurate and real-time positioning method for robotic cars in urban environments. This method used lane marking detection algorithm, as well as an efficient shape registration algorithm between the detected lane markings and a GPS-based road shape prior, to improve the robustness

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and accuracy of the global localization of a robotic car. By formulating the positioning problem in a relative sense, they estimated global localization of a car in real time and bound its absolute error in the centimeter level by a cross-validation. The cross-validation scheme integrates the vision-based lane marking detection with the shape registration, and it improves the accuracy and robustness of the overall localization system. The authors opinioned that the GPS localization can be refined by using lane marking detection when the GPS suffers from frequent satellite signal masking or blockage, whereas lane marking detection is validated and completed by GPS-based road shape prior when it does not work well in adverse weather conditions or with poor lane signatures. Further, the authors claim to have evaluated this method with a single forward-looking camera mounted on an autonomous vehicle that travels at 60 km/h through several urban street scenes.

In the recent past several advancements occurred in the lane detection and tracking field. In this review, we intend to give a detailed view of various lane detection and tracking algorithms in urban environment. The state-of-art methodologies developed by various researchers for lane detection and tracking in the recent past are investigated and presented here. Lane departure warning is an inevitable module in the advanced driver assistance systems. Vision based approach is a very simple modality for detecting lanes. Even though lot of progress has been attained in the lane detection and tracking area, there is still scope for enhancement due to the wide range of variability in the lane environments

III. METHOD FOR IMPLEMENTATION

The block diagram of prototype developed is shown in figure.1. A power supply of 5V, 2A is given to power up Raspberry Pi 3 board. Input video is recorded using Pi camera for lane detection. The video recorded is displayed on the screen/monitor. The real time location of the vehicle is tracked using GPS modem. The algorithm detects lane and outputs the value of latitude and longitude of vehicle location. The display screen shows value of latitude and longitude of vehicle location when prompted to do so. After this, the location of vehicle is displayed on the screen using google maps satellite images along with nearby landmarks.

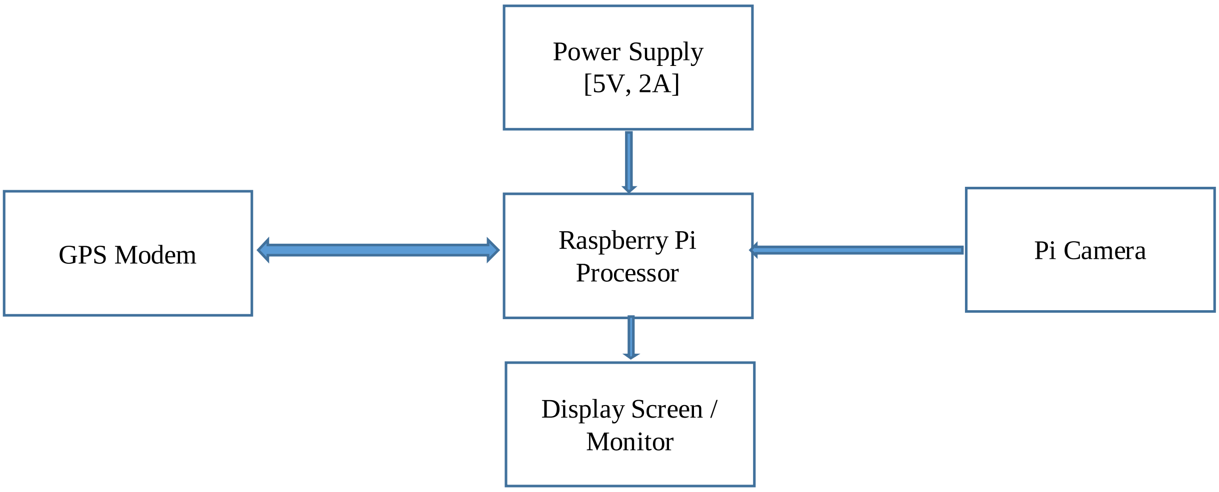

Fig.1: Block diagram of proposed system.

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The below figure. 2 shows the flowchart of system and figure .3 shows the actual prototype of system respectively.

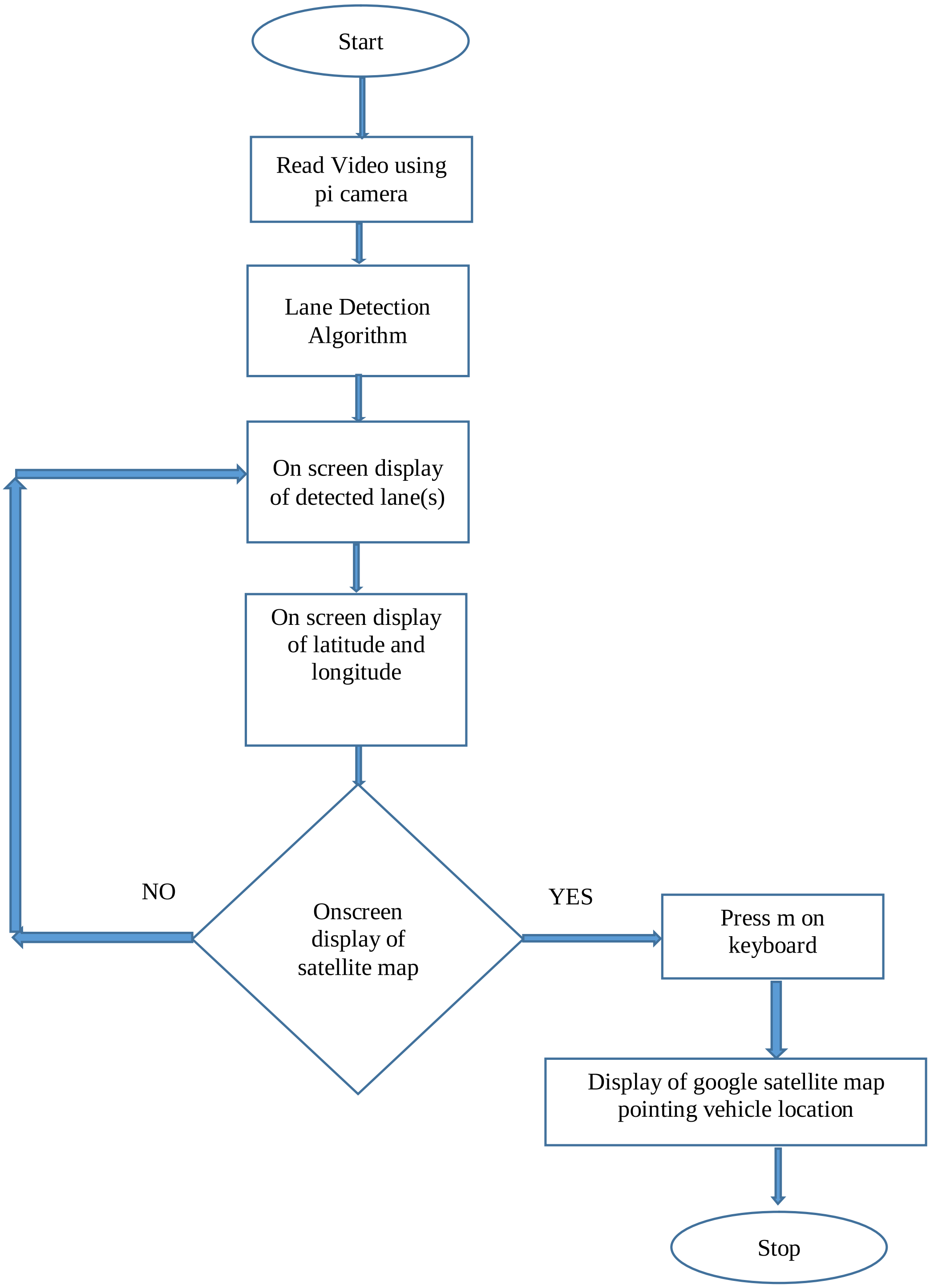

Figure.2

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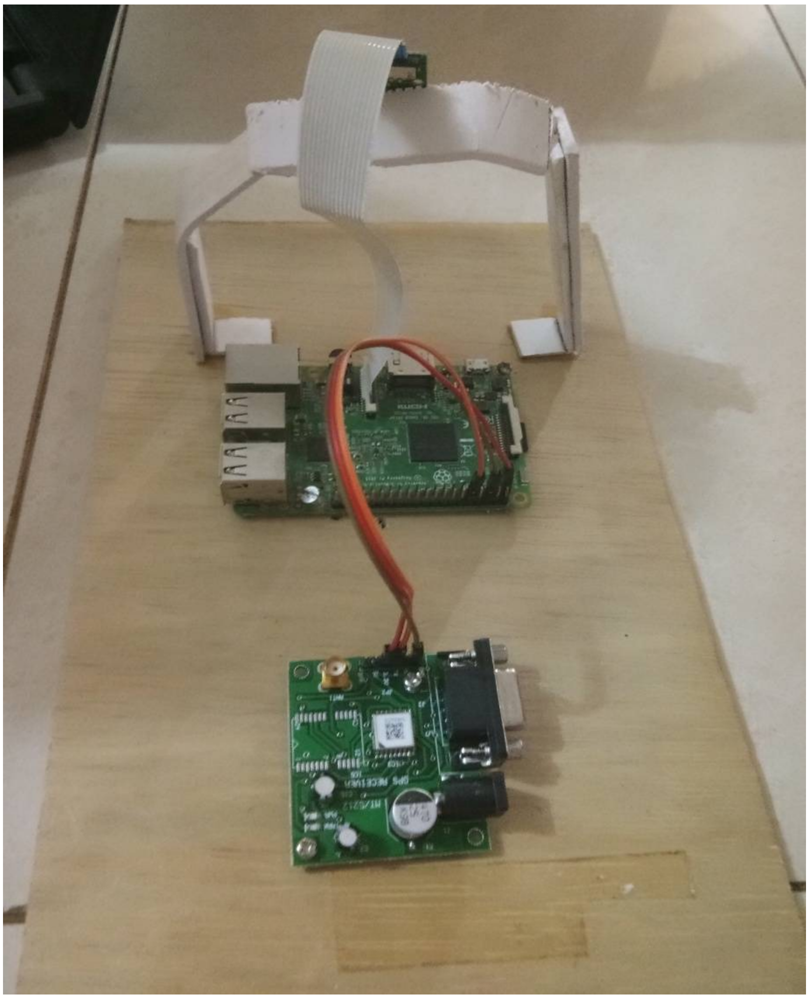

Figure.3. System Prototype

IV. RESULTS

Once we run the python script, the lane detection video prompts up displaying radius of curvature and location of vehicle from center. It also simultaneously displays the latitude and longitude of the vehicle under consideration in real time. If prompted, we also get a satellite map of location of vehicle displayed in red colour. Hence, this algorithm not only detects and tracks lane in real time but also gives the location of vehicle in terms of latitude and longitude with satellite map. This process is automatic and continuous in real time and the algorithm has to be exited to stop/cancel lane detection and tracking with location information. After executing the code from python shell the following results are displayed [fig.4, fig.5 and fig.6].

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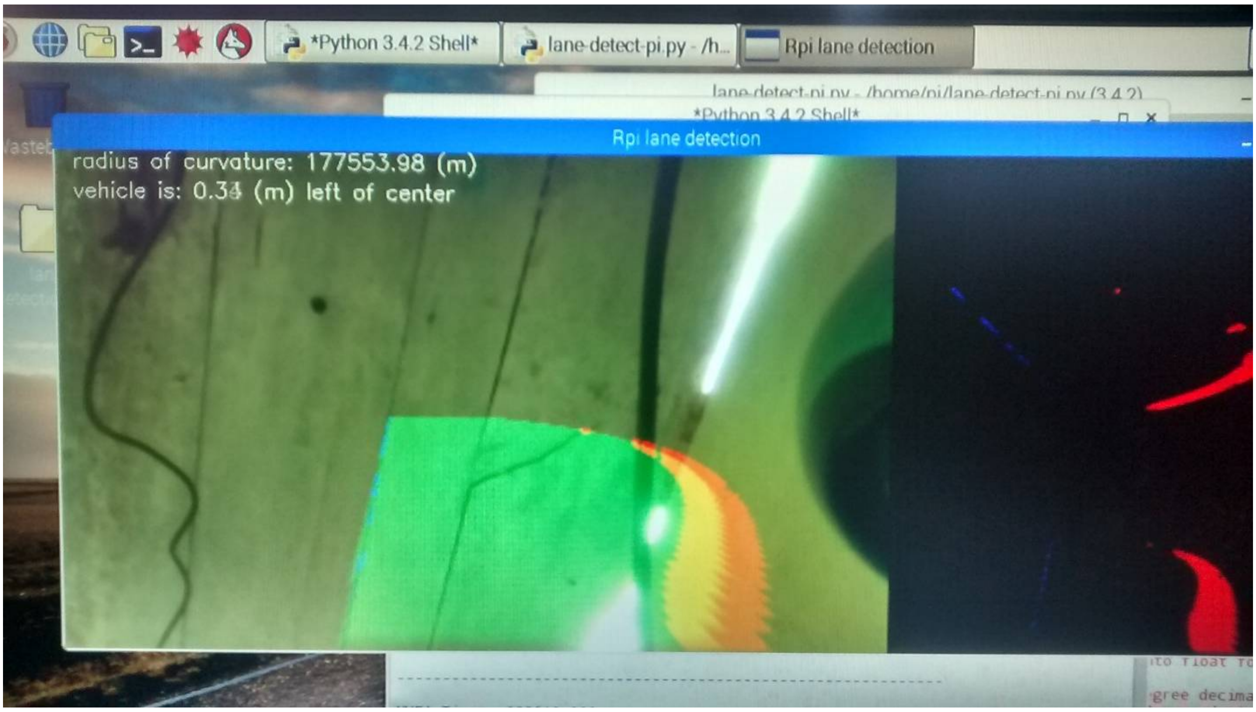

Figure.4. Detected lane displaying radius of curvature and location of vehicle from center

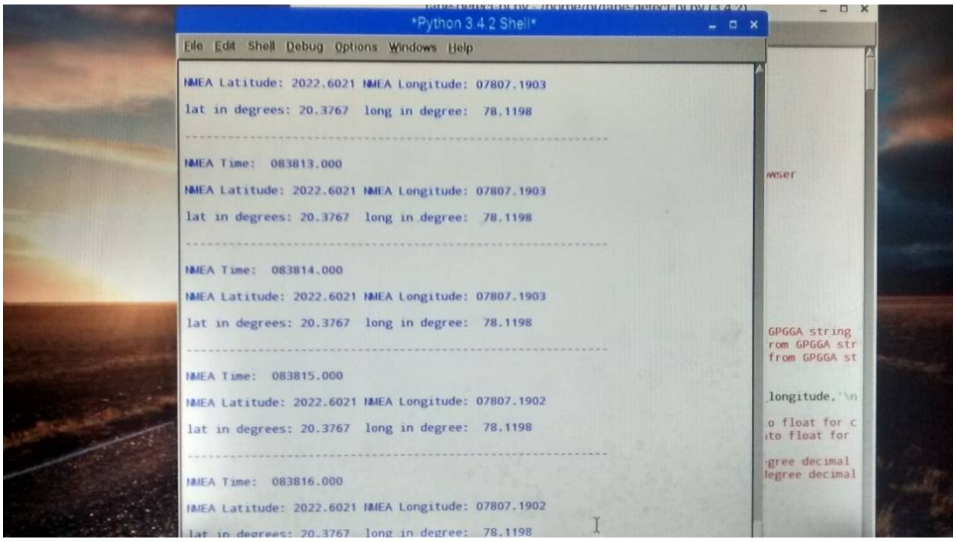

Figure.5. Snapshot displaying latitude and longitude.

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Figure.6. Satellite map showing vehicle location (in red)

V. CONCLUSION AND FUTURE WORK

It can be summarized that this module, although only a prototype, is completely functional device that performs its function safely, reliably and efficiently thus avoiding collision of vehicle. Possibility of application is not limited only to the vehicle tracking. The module is expandable in both ways: it is upgradeable for new tasks as well as compatible for integration into other existing systems. The system is implemented with simple devices for more compatibility in different environmental conditions.

The lane detection camera used in this thesis only detects vehicle's host lane. When the uncertainty in the cross-track direction increases, ambiguity on which lane the vehicle is in appears. So we rely on the type of the detected lane marking. This strategy works in this thesis because the test video is a two-lane road mainly with dashed lane marking in the center. For a multilane road, the lanes can be indistinguishable by the type of the lane marking. Multilane detection and ego-lane estimation algorithm will be helpful since it provides a direct observation on which lane the vehicle is in. Multilane detection is more challenging, but it can be improved by exploiting the prior knowledge defined in the lane marking map (e.g. lane number and each lane width). It relies on the localization system to extract the prior knowledge from the feature map. This will highly improve the robustness and availability of feature detection. The other way round, the map may be not up-to-date and the camera detection can be quite confident under ideal situations. In those situations, if the extracted features are inconsistent with the detected ones, the camera detections can be used to evaluate and update the map.
In addition to this, work could be on expanding the proposed system along with conceptual clues or the sensors to accurately detect the obstacles and make smart driving vehicles. The road sign detection can also be included as an enhancement.

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REFERENCES

1.Shehan Fernando, Lanka Udawatta, Ben Horan and Pubudu Pathirana "Real-time Lane Detection on Suburban Streets using Visual Cue Integration", International Journal of Advanced Robotic Systems, Int J Adv Robot Syst, 2014, 11:61.

2.Xiaozhi Qu, "Landmark based localization: Detection and update of landmarks with uncertainty analysis", thesis report, PARIS-EST University, October 2016.

3.Yue Wang, Eam Khwang Teoh, Dinggang Shen, "Lane detection and tracking using B-Snake", Image and Vision Computing 22 (2004) 269–280, ELSEVIER.

4.I. El hajjouji, A. El mourabit, Z. Asrih, S. Mars and B. Bernoussi, "FPGA Based Real-Time Lane Detection and Tracking Implementation", 2nd International Conference on Electrical and Information Technologies ICEIT'2016, 2016 IEEE.

5.Chanho Lee, Senior Member, IEEE, and Ji-Hyun Moon, "Robust Lane Detection and Tracking for Real-Time Applications", IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS, 2018 IEEE.

6.Byambaa Dorj and Deok Jin Lee, a research article on "A Precise Lane Detection Algorithm Based on Top View Image Transformation and Least-Square Approaches", Journal of Sensors, Hindawi Publishing Corporation, Volume 2016, Article ID 4058093.

7.Huang Guan, Wang Xingang, Wu Wenqi, Zhou Han, Wu Yuanyuan, "Real-Time Lane-Vehicle Detection and Tracking System", 2016 28th Chinese Control and Decision Conference (CCDC), 2016 IEEE, pp-4438-4443.

8.Deok-Kwon Lee, Ju-Seok Shin, Je-Han Jung, Sang-Jun Park, Se-Jin Oh and In-Soo Lee, "Real-Time Lane Detection and Tracking System Using Simple Filter and Kalman Filter", 2017 IEEE.

9.C. Rouff and M. Hinchey, Experience from the DARPA urban challenge: Springer Science & Business Media, 2011.

10.Oliver Pink, Frank Moosmann and Alexander Bachmann, "Visual Features for Vehicle Localization and Ego-Motion Estimation", 2009 IEEE.

11.Jian-ru XUE, Di WANG, Shao-yi DU, Di-xiao CUI, Yong HUANG, Nan-ning ZHENG, "A vision-centered multi-sensor fusing approach to self-localization and obstacle perception for robotic cars", Xue et al. / Front Inform Technol Electron Eng 2017 18(1):122-138, Frontiers of Information Technology & Electronic Engineering, ISSN 2095-9184 (print); ISSN 2095-9230 (online).

12.ZHANG Wei-wei, SONG Xiao-lin, ZHANG Gui-xiang, "Real-time lane departure warning system based on principal component analysis of grayscale distribution and risk evaluation model", J. Cent. South Univ. (2014) 21: 1633−1642, DOI: 10.1007/s11771-014-2105-2, Springer.

13.Mr. Tony Fan,Wayne and Dr. Gene Yeau-Jian Liao,Wayne State University, "Lane Keeping System by Visual Technology", American Society for Engineering Education, 2017, Paper ID #18751.

14.A. Desoky, A. Bayoumy, G. Hassaanffi, "Implementation of Vision-Based Trajectory Control for Autonomous Vehicles", 17th International Conference on AEROSPACE SCIENCES & AVIATION TECHNOLOGY, ASAT - 17 – April 11 - 13, 2017, Military Technical College, Kobry Elkobbah, Cairo, Egypt.

15.S. Li, H. Yu, J. Zhang, K. Yang, R. Bin, Video-based traffic data collection system for multiple vehicle types, IET Intell.Transp. Syst. 8 (2) (March 2014) 164–174, http://dx.doi.org/10.1049/iet-its.2012.0099.

16.Robert Spangenberg, "Landmark-based Localization for Autonomous Vehicles", a doctoral thesis, University of Berlin 2015.

17.R. O'Malley, E. Jones, M. Glavin, Rear-lamp vehicle detection and tracking in low-exposure color video for night conditions, Intell. Transport. Syst. IEEE Trans. 11 (2) (June 2010) 453–462, http://dx.doi.org/10.1109/TITS.2010.2045375.

18.Guangqian Lu, "A Lane Detection, Tracking and Recognition System for Smart Vehicles", a thesis report, School of Electrical Engineering and Computer Science Faculty of Engineering University of Ottawa, Canada 2015.

19.Zongzhi Tang, a thesis report on "A Novel Road Marking Detection and Recognition Technique using a Camera-based Advanced Driver Assistance System", School of Electrical Engineering and Computer Science Faculty of Engineering University of Ottawa, Canada 2017.

20.Young-Woo Seo, a doctoral thesis report entitled, "Augmenting Cartographic Resources and Assessing Roadway State for Vehicle Navigation", The Robotics Institute Carnegie Mellon University Pittsburgh, PA, April 2012.

21.He Zhao, thesis entitled "Recognizing Features in Mobile Laser Scanning Point Clouds Towards 3D High-definition Road Maps for Autonomous Vehicles", University of Waterloo, Waterloo, Ontario, Canada, 2017.

22.Tony Fan,Wayne and Dr. Gene Yeau-Jian Liao,Wayne State University, "Lane Keeping System by Visual Technology", American Society for Engineering Education, 2017, Paper ID #18751.

23.Dixiao Cui, Jianru Xue, Member, IEEE, and Nanning Zheng, Fellow, IEEE, "Real-Time Global Localization of Robotic Cars in Lane Level via Lane Marking Detection and Shape Registration", IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS, October 12, 2015.