Traffic Sign Recognition Using Multi-Sensor Framework For An Autonomous Vehicle

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Abstract: In this paper, we describe a navigation and control system for autonomous vehicles by using a traffic sign recognition module based on data received from a multi-sensor module disposed in the autonomous vehicle. A computing system of the autonomous vehicle can detect an event based on the traffic signs by retrieving data from the multi-sensor module. The multi-sensor module can recognize the traffic signs and process this information and provide it to the computing unit of the autonomous vehicle. The multi-sensor module may include image sensing unit, global positioning system, traffic detection and/or other sensing units. The traffic signs provide very valuable data about the road to make driving easy and safer. The traffic sign board specifically can be easily recognized by the multi-sensory module as well as humans because of their color and shape that are particularly different from natural environment. Further, it will be useful for the autonomous vehicle to use the traffic sign recognition system along with other sensing units to provide safe control and navigation of the autonomous vehicle. The proposed system first detects the traffic signs using color and shape sign boards and second allows the classification using a neural framework disposed in the computing unit of the autonomous vehicle. Further, the system also focuses on minimizing the rejection rate of the traffic sign boards that are not recognized because of non-standardized traffic sign in different jurisdictions. The system allows standardizing images of the sign boards and advantageously reduces the need for additional unit for standardizing the sign boards. Further, this system allows notifying, the user of the autonomous vehicle, for the traffic sign recognized by the computing system on the user interface of the autonomous vehicle.

***IndexTerms* - Autonomous vehicle, Traffic sign recognition, Object standardization/normalization.**

I. INTRODUCTION

An autonomous vehicle can be manned or unmanned and capable of sensing its environment and can navigate without human involvement. The autonomous vehicle can sense surroundings with the help of multi-sensor module. The sensors disposed within the vehicle can be radar, laser, GPS, camera/computer vision etc. Among them, utilization of camera with computer vision technique is most adopted method for constructing such a system because camera provides a low-cost and rich information capture such as video, image and sound with a single unit. Unlike other sensors, they focus on providing a single function. Autonomous systems have several potential applications such as use in predictable and unpredictable natural disasters or terrorist attacks, automated large intelligent highway systems surveillance and rescue, and collaborative and interactive unmanned mobile robots/sensors motion navigation and control or driverless cars. The most important and crucial component of a successful autonomous system is the ability to reliably detect and recognize objects in their environment in real-time, under different and varying environment constraints. There have many studies and research on "road detection" and "road follower" to allow an autonomous vehicle to operate in safe and easy condition. Different approaches have been used over the year to simplify the working of an autonomous vehicle by using color segmentation, control theory, neural network [10], [11], and [12]. On the other hand, recent studies show development in traffic sign recognition by understanding traffic signs and sign boards by vehicle control system. However, these technologies use a server-based system or Global Positioning Systems (GPS) based control systems that have fixed speed limit information in their databases. Further, static sign boards do not provide any information related to roads that are under repair or where temporary sign boards are set. One may note that GPS provide street/road names only, but do not provide road signs, or other objects in the environment that are set on temporary basis. Further, a typical driver does not usually rely only on a GPS system to locate a street/road, but often he/she still needs to use local human visual sensory to identify/read the street/road name plate and to confirm the street/road name given by the GPS systems. Additionally, in many instances, the topology of the roads and streets might have changed or been destroyed in case of disasters/natural disasters, where assessment of the damage is hard to predict beforehand, and where GPS systems become obsolete.

Thus, the proposed system provides the use of traffic sign recognition system along with other units to correctly identify traffic sign and perform control and navigation of the autonomous vehicle. Further, standardization of traffic signs occurs by the computing unit once it captures the information through the multi-sensor module. The computing unit in autonomous vehicles can capture traffic sign information with the use of multi-sensor module. These signs provide traffic warning, regulations, routing and management that intend to affect the behavior of the driver. Specifically, they carry a lot of useful information that are required for navigating, such as to drive the vehicle in the correct lane and at the right speed; to avoid obstacles and potential risks; and to notice roadway access, position, and trajectory of other vehicles, pedestrian's movement, road lanes etc. Hence, traffic sign recognition system plays an important role for autonomous systems. In the past two decades, many approaches for traffic sign recognition have been proposed.

However, based on our survey, mainly, most of them [1], [2], [3], [4] and [5] consist of three main stages: Region segmentation for extracting the specific region of signs. In this stage, color feature is usually worked and analyzed as the signs have specific color to be analyzed, Shape analysis for classifying signs into circle, rectangle and triangle shape, and the last recognition for identifying the sign for certain class and meaning. Specifically, the recognizing step can be done by several classification techniques. Artificial neural network (ANN), k-nearest neighbor (KNN), support vector machine (SVM), and random forest (RF) are among the most commonly used. Reference [2] reported that, KNN is the best classifier among these classification techniques.

There is a fair amount of research that is been conducted to build driver assistance navigation systems. Due to the visual component that is required, most of the research done uses computer vision and image processing techniques combined with AI (Artificial Intelligence) to detect and classify the road signs. Further, these systems does work on minimizing the rejection rate of captured traffic signs where it would be helpful if all the traffic signs were normalized, as different countries have different traffic sign designs. Thus, a system is required that would reduce the rejection rate of detecting the traffic signs and also normalize the traffic sign into one single design.

In this work, a system to recognize traffic sign, removing noise, standardizing traffic signs and providing instructions on a Multi Informative Display (MID) screen is presented. In a real environment, the traffic signs may have different form and color. The form of a traffic sign can be triangle, rectangle, circle, diamond, etc. Commonly, a traffic sign may have blue background or white background with red border. Traffic signs with yellow background also exist in some countries. To do such task, we considered some challenges that are color and shape of traffic sign. The process for the proposed work includes

(a) Segmentation: The color from the traffic sign boards are extracted and processed
(b) Shape Analysis: The shape is then classified based on the shape i.e. either square, circle, rectangle, triangle etc. Each shape denotes some meaning such as possible hazards ahead, warning signs, regulatory notices etc.
(c) Recognition: The computing unit recognizes the meaning and class to which the traffic sign belongs and then processes it to the MID screen of the autonomous vehicle. The recognition step involves further two main categories: (a) Classification, (b) Noise Removal and (c) Standardization.

The broadly illustration of our system can be seen at Fig.1. Below

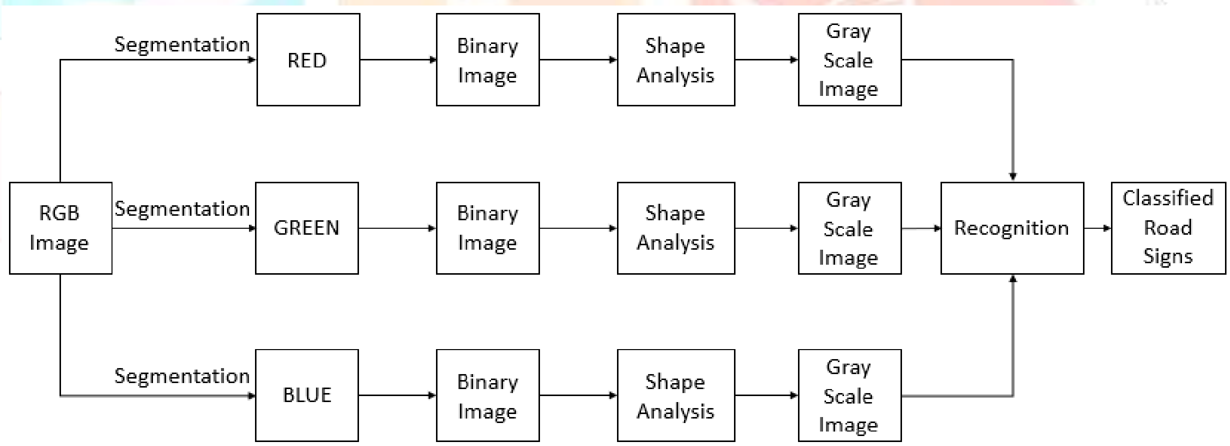

Fig.1: Whole System Illistration

The block diagram in Fig. 1 shows a machine-based traffic sign recognition system that operates according to our proposed method. The image data from the multi-sensor module are captured and processed in the computing unit. The image data is analyzed and classified by the computing unit and based on the image details, a particular class of traffic signs is determined by the classifier.

A class-specific feature in the image detail is identified and a modified image is generated with detail of the class-specific feature in the image center. A modified image region is created by shifting the class-specific feature to the center that is padded with suitable pixels and this modified image details, with centered class-specific feature, is processed to a classificator (Fig. 2). The Fig. 2 below shows the internal units of the recognition module that provides classification, noise removal and standardization of the traffic sign recognition system.

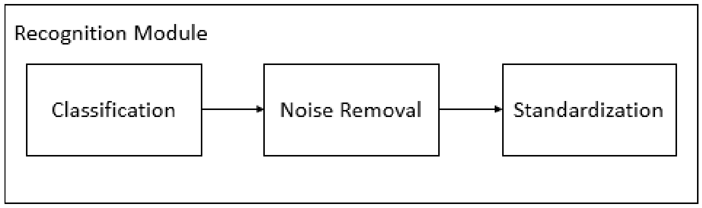

Fig. 2 : Internal Units of the Recognition Module

The class-specific feature here represents an arrow sign for routes or speed limit sign. The system performs correction and provides standardization of the traffic signs, for example, if the speed limit signs deviates from the uniform standard i.e. the numerical block is not centered, the image is modified in such a way that class-specific feature, here for example, the numerical block, is shifted to center wherein the modification occurs before processing the image details to the classificator. Further, a classification is performed by the classificator based on the modified image of the traffic sign. Thus, the processing and training of the classificator can be reduced by standardizing the traffic signs universally by generating a traffic sign that may have a numeral block in center. Also, learning of the classificator can be greatly reduced by this method and help reduce the overall cost of the system.

II. THEORETICAL FRAMEWORK AND RESEARCH METHODOLOGY

Fig. 3 shows the proposed overall system architecture for road sign object detection, representation, classification and recognition system. The proposed architecture of the system is comprised of 3 fully independent subsystems. The output from one subsystem will be the input to another subsystem.

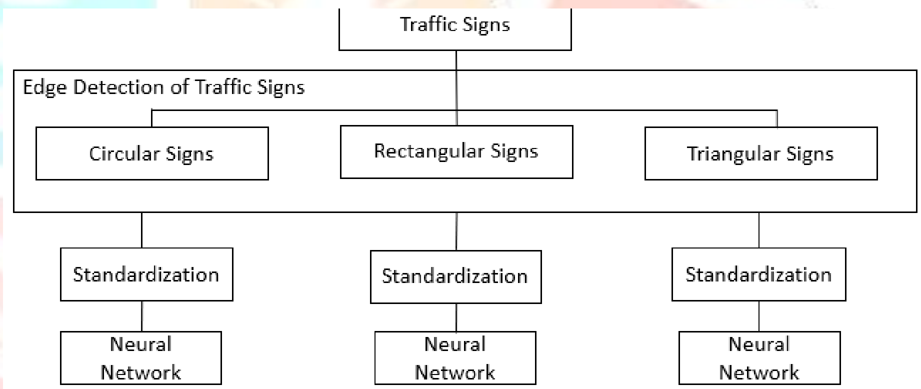

Fig. 3 : Proposed Overall System Architecture

The developed algorithm is divided in two basic features each one composed of a certain number of steps. In the first feature, the detection of the location of the sign center of gravity (which is used as a location reference point) in the image coordinate system is carried out, based on its geometric characteristics. The second feature is the sign recognition with the matching between the search image and the template images, already stored in a database. The below images fig. 4, 5 and 6 shows the test results of the recognized traffic signs. The test was performed on the square sign boards that shows left turn, turn back and turn right. The algorithm was able to detect the traffic signs and provided instructions on the interface as well. Further, this method can be implemented in autonomous vehicle, where the user can be notified for the event detected such as taking a left, right or u-turn on the interface of the autonomous vehicle.

Fig. 4

Fig. 5

Fig. 6

Fig. 4, 5 and 6 : Test results of the recognized traffic signs.

The traffic sign recognition system comprises the apparatus for acquiring image information preferably a camera and a traffic sign recognition unit and the output unit .

The traffic sign recognition unit comprises a device for detecting the traffic sign boards and an identification unit for detecting the sign board and the database. Once the traffic sign board is detected and identified, it is then matched with the available templates stored in the database where it will suggest for the appropriate match for the traffic sign and will provide the information of autonomous vehicle. The following fig. 7, shows the above concept of capturing the image and providing it to the interface of the autonomous vehicle.

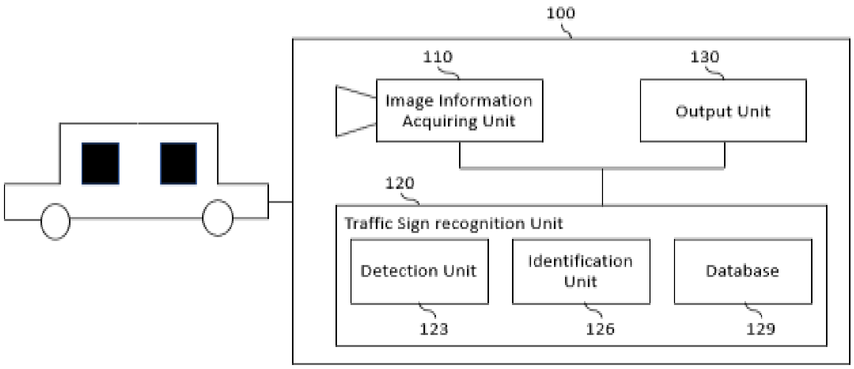

Fig . 7 : Concept Of Capturing The Image

The structure of the block diagram according to fig. 8 shows a detailed functioning of the machine-based traffic sign recognition system and standardizing/normalizing the traffic signs. Now, an image capturing unit such as a camera (201) captures images of the surrounding environment from the autonomous vehicle. The corresponding captured image data is stored in a storage unit (203) of the processing unit (202). Further, the processing unit comprises of a detection unit (204), classification unit (205) and output storage (206). Based on the stored images, traffic signs are identified and processed to the detection unit. The detection unit (204) identifies those image regions that shows the shape of the traffic signs and to which it is further processed to the classification unit (205). The output storage (206) stores the recognized traffic signs and later available to the output unit (207). The output unit can be a notification provided to the MID screen of the autonomous vehicle or central display. Also, we have shown the recognition of traffic signs and providing on-screen the instructions on the display. Further, a centering unit (208) may be integrated with a size normalization unit (209). The image detail from the detection unit block (204) can be supplied to the size normalization unit (209) to modify the size and shape of the numerical block recognized in the image detail into a normalized size. The image detail modified is supplied to the centering unit to generate a further modified image detail according to fig. 9 with a centered numerical block from the image detail modified by the size normalization unit and the centering unit.

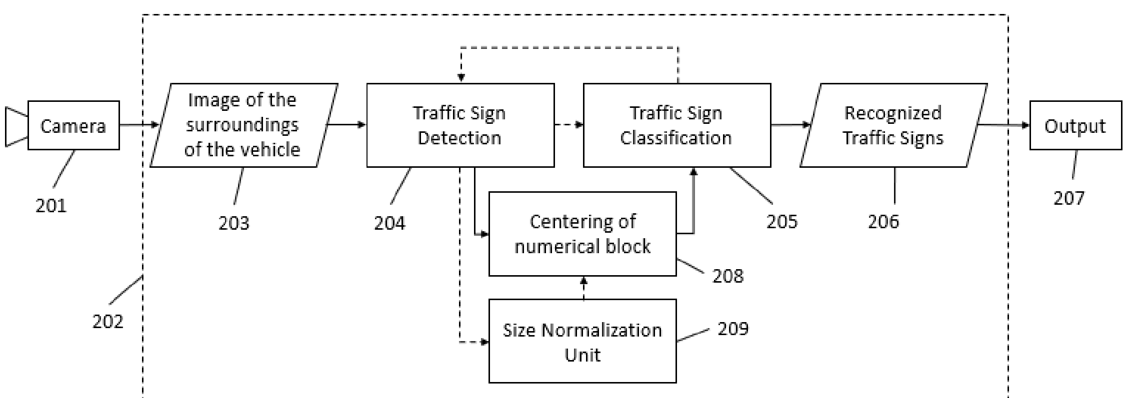

Fig. 8 : Detailed Functioning of the Machine-Based Traffic Sign Recognition

Figs. 9a and 9b shows the functioning of the normalization and standardization of the traffic signs that are not unified. The image detail (301) contains a speed limit circular sign with the numerical block (302). Here, the numerical block (302) represent a class-specific feature and indicates a speed limit of "60". The traffic sign clearly illustrates a non-standard traffic sign board where the image of the numerical block (302) is not centered and requires modification as per our system.

Figs. 9a and 9b : Functioning of the normalization and standardization of the traffic signs that are not unified.

In order to normalize and standardize the numerical block (302) of the image detail (301), the image details is supplied and processed to the centering unit. The centering unit generates a modified image detail (303) wherein the numerical block is centered which is represented in fig. 9b. This modification is generated by shifting the numerical block (302) to the center of the image detail (303). An image region (304) of original position of numerical block (302) is generated where the image region is replaced with best pixels as provided in (304). This replacement of the pixels involves clone stamping of the image regions that will be in accordance with the predetermined and standardized traffic signs that can be stored in the databases. This replacement is performed by replacing the pixels of the surroundings of the numerical block (304) or with pixel with specific color or with corresponding to a mean value of pixels according to a standardized template. Similar method can be employed for the generating a centered image of the fig. 9b where speed limit includes a alpha-numeric text and can also replace and provide with the standardized image with the numerical block is centered. Thus, the image generated in figs 9a and 9b shows modified image detail (303) and (403) that corresponds to the standardized traffic sign.

The modified image detail is further processed the classification unit that determines the traffic sign with class-specific feature, such as speed limit of “60”, from the image details. This information is stored temporarily in the output storage from where the driver of the autonomous vehicle can be notified with captured traffic sign that might have been missed by the driver or the autonomous system. This information can be presented to the driver or system in the form of an alert or warning or on the MID screen of vehicle.

III. ALGORITHM

The basic steps of the correcting traffic signs algorithm are:

1. An image capturing unit captures a first image of a traffic sign that includes a traffic sign background and numerical block that is at a un-centered position geometrically relative to overall boundary of the traffic sign board;
2. A processing unit analyzes the captured first image to detect the entire traffic sign and numerical block;
3. A generating unit creates a second image (modified image) of the entire traffic sign that includes traffic sign background, outer border and a corrected and standardized position of numerical block, wherein the numerical block is centered relative to the outer border;
4. An evaluating unit evaluates the modified second image to recognize the entire modified traffic sign;
5. An output unit configured to provide notification onto screen or the autonomous system of the traffic sign by providing notification on the vehicle interface or MID screen.

IV. CONCLUSION

The proposed system allows standardizing images of the traffic sign boards and advantageously reduces the need for additional unit for standardizing the sign boards. Further, this system allows notifying, the user of the autonomous vehicle, for the traffic sign recognized by the computing system on the user interface of the autonomous vehicle.

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