International Journal of Soft Computing and Engineering (IJSCE)
ISSN: 2231-2307, Volume-4, Issue-ICCIN-2K14, March 2014

Traffic Light Solution for U.G.V. Using Digital Image Processing

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Abstract*: This paper presents an application of Digital Image Processing (DIP) techniques for traffic light detection. The application involves automated traffic light detection and response system for a UGV (Unmanned Ground Vehicle). The images provided by the CCTV camera installed on the vehicle are processed for several levels of detection like color detection (Red/Green/Yellow), shape detection (circle), co-ordinate analysis etc. The vehicle density estimation is also done. On the basis of results obtained by Image Processing command signals are generated for the vehicle. Thus the problem of congestion due to traffic lights can be solved quite effectively.

Keywords: Digital Image Processing (DIP), Traffic Light, Unmanned Ground Vehicle(UGV), CCTV camera.

I. INTRODUCTION

UGV (Unmanned Ground Vehicle) has been continuously intriguing and inquisitive field of research. An autonomous vehicle is expected to drive itself safely without any aid of driver or social infrastructure. For this autonomous operation various sensors are used to get the information about the surroundings and thus take the appropriate action. Traffic light detection and recognition is also an important aspect for UGV operation. Here a special system like IR (Infrared) or RF (Radio Frequency) can be used at the traffic crossroads and intersections. But for using these systems transmitters have to be installed at crossroads and receivers have to be installed at the vehicle. Thus, changes in the environment are required which is costly and hence undesirable. Therefore, Image Processing is used for traffic light detection & recognition.

Traffic light detection via Image Processing provides accurate information to the intelligence system of UGV about the traffic light scenario. Thus, traffic light problem for a UGV can be solved.

A traffic light has three main lights: red, green, and yellow. Each light represents a traffic signal; red means “stop”, green means “go”, and yellow means “slow down” or “prepare to stop”. Similar signals are produced for the UGV at the detection of any of these three traffic lights.

In this paper we present a new vision based algorithm for traffic light detection and recognition. Various real time scenarios like tail light of cars, traffic light system breakdowns etc. are also considered in this algorithm.

Manuscript received March 2014

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II. RELATED WORK

There has been a lot of research work on unmanned vehicles and signal light detection. In 1998, real-time stereo vision system for generic obstacle and lane detection was developed by Massimo Bertozzi and Alberto Broggi[1]. But this system detect only lane on the road and obstacle. This system is for cruising in normal road.

There are many researches for traffic light detection. First, there is study based on color tracking by Mahipa. R. Yelal *et al*[2]. This research is about real-time tracking of signal light. But, limitation is only simulation by using ‘Matlab’, and, condition of sample image is excellent. Backgound of signal lights is clean sky and, no experiment in real urban road.

Another study for traffic light detection is using ‘Fuzzy AI’ by Yun-Chung Chung et al[3]. They use position of light, and processes with ‘Fuzzy Map’. Using position, it can detect red, yellow and green signal. But time for processing is 0.5~1 sec per frame. Therefore, it does not support real-time processing.

Another research built in real car by Lampros Tsinas and Volker Graefe[4]. In this case, they use HSI color map for traffic light detection. That takes 20ms. That is fast, and experiment in real road, but limitation is that algorithm can not divide light from cars and another from signal lights. It makes a lot of errors in detection. Therefore, other light sources which are not traffic lights can also be detected. It is a serious error.

Another research work done by Jin-Hyung Park, and Chang-sung Jeong[5] in Traffic Light detection for UGV. They use frame check technique to distinguish between traffic lights and other similar lights like tail light of cars etc. This technique does not have good accuracy. This is a serious limitation as other light sources which are not traffic lights can be detected. Also system failure conditions are not considered.

III. THEORITICAL FRAMEWORK

A. Color Detection

Color Detection is the first step. In this step the pixels of the desired color are extracted from the image.

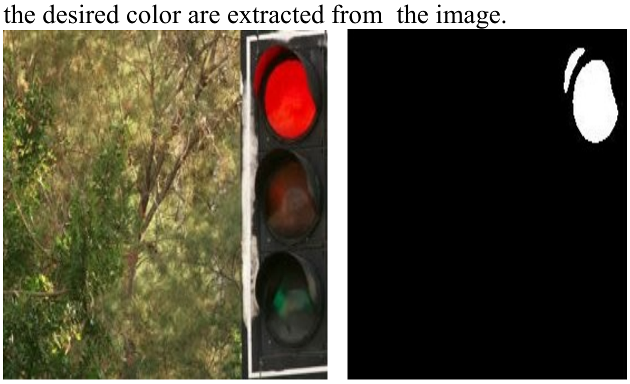

Fig.1 Red Color Detection

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B. Circle Detection

Circle Detection is done in this step. There might be various light signals on the roads like advertising boards, tail light of cars etc. But traffic light signals are circular in size. Thus circular detection technique is used to filter out light sources which are not circular in size and hence increasing the accuracy. The algorithm used for circle detection is quite simple. It involves perimeter and area calculation and then estimates the extent of circularity using this relation:

$$C = \frac{4*pi*area}{(perimeter)^2}$$

Closer the value of the factor ‘C’ to 1, closer is the shape of the detected object to the circle

C. Camera Orientation

Camera mounted on the vehicle is oriented in such a way that the images it gets have a high probability of traffic light signals as compared to other light signals such as tail light of other cars and other light signals sources on the road.

D. Co-ordinate Analysis

Although with the camera orientation technique most of the undesired light signals can be ignored. But still some light signals may be misinterpreted as traffic signals. To overcome this problem co-ordinate analysis technique is used. In this method we set the co-ordinates in the image where the possibility of detecting only the traffic light signal is maximum.

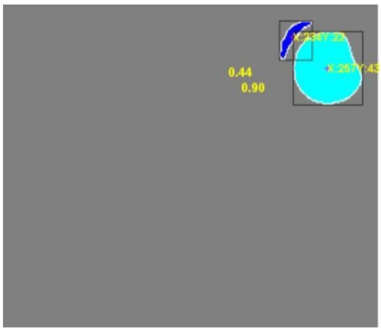

Fig.2 Co-ordinate Detection

E. Vehicle Density

Vehicle Density is consiered in a situation where our system keeps on detecting red signal indefinitely or traffic light system failure.

In this situation vehicle density at the crossroad is calculated, if it is less than a threshold value then vehicle is allowed to move otherwise not.

Fig. 3 Vehicle Density

IV. METHODOLOGY

The flowchart shown in fig. 3 gives the complete working of the system. First of all the system is initialized. Then traffic light condition is checked, if there is no traffic light detected, the vehicle keeps on moving.

If there is a traffic light present than its color is recognized first by color detection technique. At this step there are three possibilities:

(a) Red- If red color is detected then circle detection and co-ordinate analysis techniques are applied to ensure that the light signals are from traffic lights only. If these condition are satisfied then a stop command is generated for the vehicle otherwise it keeps on moving. After the stop command, a timer is initialized. When the timer exceeds the limit, vehicle density is checked. If it is less than a threshold value then move command is generated otherwise traffic light is again checked.

(b) Yellow- If yellow color is detected then circle detection and co-ordinate analysis techniques are applied to ensure that the light signals are from traffic lights only. If these condition are satisfied then a slow down command is generated for the vehicle otherwise it keeps on moving.

(c) Green- If green color is detected the the vehicle keeps on moving.

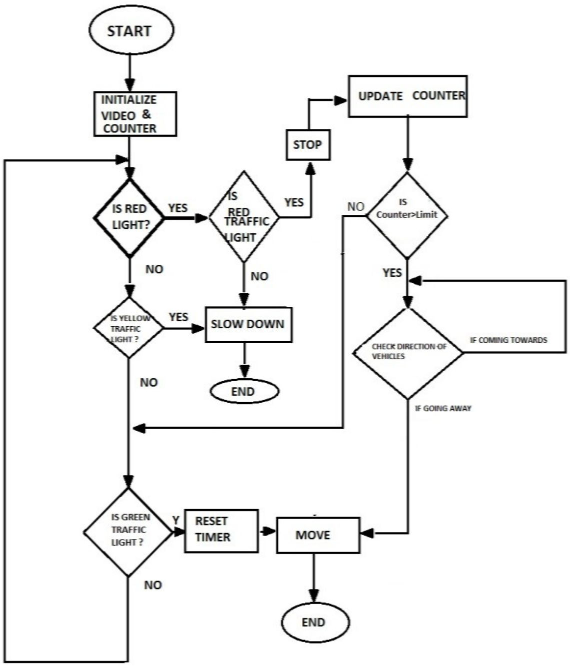

Fig. 4 Flow Diagram of System

V. RESULT & EXPERIMENTAL SIMULATION

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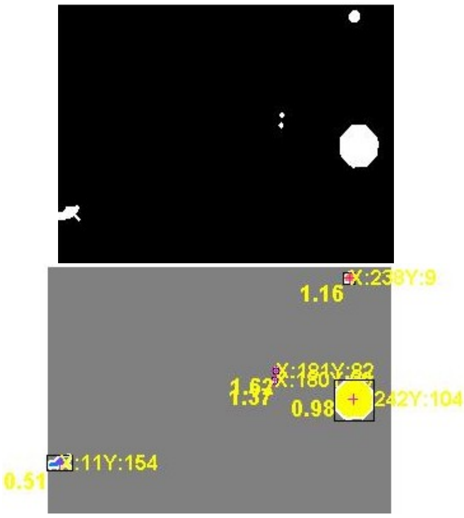

Fig. 5 Red Light Detection

Fig. 6 Green Light Detection

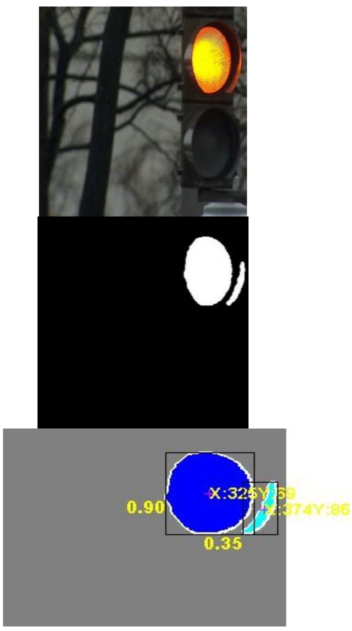

Fig. 7 Yellow Light Detection

Fig. 5, 6 & 7 show the real life images of the traffic lights. Color extracted images and co-ordinates are also shown. These real life images shows the high accuracy and detection rate of the algorithm used. The below table shows the execution time per frame as compared to other algorithm used.

Table 1. Time Complexity.

Method (Year)	Time	Detection
This algorithm	15~20 ms	Traffic Light and Vehicle Density
-Hyung Park, and Chang-sung Jeong(2009)	7 ms	Traffic Light
Yelal's (2006) [4]	105~120 ms	Traffic Light
Chung's (2002) [5]	500-1000 ms	Traffic Light

VI. CONCLUSION

There has been a lot of research work in the field of UGV as it has been a topic of keen interest for the researchers. If the UGV is to be used in an urban environment then it must be able to detect the traffic lights at crossroads. This study showed that image processing is a better technique to detect the traffic lights at crossroads, than any other proposed technique earlier.

The algorithm showed in this paper uses color detection, shape detection, co-ordinate analysis etc. to detect and recognize the traffic light. Also a special exception is also added to avoid longer unnecessary wait at the crossroads using vehicle density estimation. This algorithm has a good detection rate and accuracy. The execution time of the algorithm is also optimum.

Overall, the system is good but it still needs improvement to achieve 100% percent accuracy.

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