

# Dynamic Steering Control of Battery Operated Car for Lane Keeping using Image Sensor

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**Abstract—** This project presents simple prototype for driving automation of battery operated cars. The system consists of Decision Making Unit (DMU) & Control System Unit (CSU) to implement decision given by DMU. DMU performs the task of image acquisition, enhancing, thresholding, noise reduction, calculation of the position of car with respect to lanes and estimation of the desired position. DMU communicate with CSU using UART serial protocol, thereby informing CSU to take necessary control action regarding - speed control & position control of steering wheel. Speed control is an open loop system which controls the two DC motors powering the front wheels of car. Mechanical hardware for position control of steering wheel contains a high torque DC motor which is coupled to steering wheel using gears in mesh configuration. The control algorithm used here is digital PID algorithm. The PID is digitized using trapezoidal approximation, Newton's backward difference method to approximate integration & differentiation. Feedback signal is generated by 47k $\Omega$  potentiometer which gives a output of 0-5 volt. The algorithm based on these methods has been programmed in the Atmega16 which drives the dc motor coupled with steering wheel using L293d motor driver.

**Keywords-component:** Digitized PID, Lane keeping, Position Control.

## I. INTRODUCTION

Around the world many researches are going on to develop an intelligent automated car which can navigate through roads without a human driver to its desired destination. Such a car will perform the tasks like lane identification, elevation mapping of roads etc. However 3 dimensional imaging of roads require stereoscopic vision developed by two cameras. In this paper a small prototype of battery operated car is developed which utilizes single camera for the task of lane keeping (Fig.1). This prototype is capable of positioning itself in between the lanes identified on the road. The camera mounted over the car acquires the image at the rate of 25 frames per second. Each frame, logged in the data memory with time marking, is processed in the MATLAB to extract features like lane detection, lateral deviation and heading angle [1]. These parameters are converted into serial strings and are given to MAX232 for the TTL-Digital logic conversion. The output of the MAX232 is connected to the UART of the ATMEGA16 microcontroller in which the parameters obtained are established as the set-point variables. The 47k $\Omega$  potentiometer coupled with steering wheel measures the process variable. The Atmega-16 implements the digitized PID algorithm on the error generated by set-point and process variable and controls the dc motor using L293d driver to position the steering wheel.

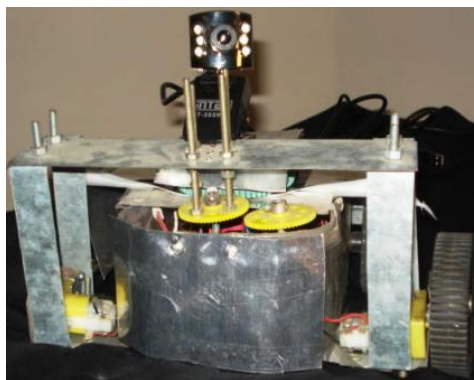


Fig.1 Prototype of Car

## II. DECISION MAKING UNIT

### A. Camera

A 1.3 mega pixel web camera is utilized for the image acquisition operation to detect the lanes on the road [3]. The specifications of camera are as follows:

- Frame Rate: CIF (352\*288) format, up to 30fps; with VGA (640\*480)format, frame rate being 15fps
- Focus range: 5.0cm-∞
- Image Resolution: 640\*480(Max)
- Color: RGB24 (true color: 24bit)

Here a compromise has to be made between image quality and frame rate. High frame rate enhances the functioning of control system because data will be available at high speed but high frame rate leads to poor image quality which causes problems for decision making unit to measure required features from image. In this project more emphasis is given on image quality, so a frame rate of 15 is set with 640\*480 pixels in image.

### B. Installation:

The camera is installed considering two parameters: height and incline angle with respect to ground. By adjusting these two parameters we can get desired camera cover range of road and keystone distortion.

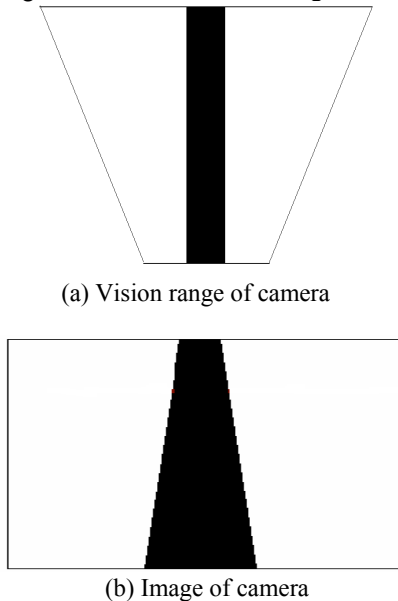


Fig.2 Sketch of keystone distortion

### C. Image Data Acquisition

The output of the camera is a composite video signal with VGA video format that one image are composed of 640\*480 resolution [4]. The video displays 15 frames per second.

IPT (Image processing tool box) in MATLAB is used to execute image acquisition by the use of following commands:

```
Vidobj = videoinput('dt', 1, 'RS170')
```

Acquisition Source(s):VID0, VID1, and VD2 are available. Acquisition Parameters: 1). 'VID0' is the current selected source. 2). 15 frames per trigger using the selected source. 3). 'RS170' video data to be logged upon START. 4). Grabbing first of every 1 frame(s). 5). Log data to 'memory' on trigger.

### D. Lane Identification

Fig.3 shows the flow diagram of lane identification from image logged into memory. To demonstrate the functioning of decision making unit a random image from MATLAB is taken Fig.4. Once a camera is set to a fixed height & inclination angle then only useful part of image is cropped because this improves the reliability of thresholding & noise reduction. The thresholding of image is done using Otsu's algorithm (Fig.5). After thresholding small connected objects are removed from image using noise reduction. The command used for noise reduction in Matlab is `f=bwareaopen(j, 105)`.

This command removes all the connected objects having less than 105 pixels from the image (Fig.6). Here j is Matlab handle of thresholded image. Now the boundaries of all the objects present in the image are identified

and green boundaries are drawn around them so as to distinguish between different objects (Fig.7). To identify lanes from the various objects present on image a function called lanes is constructed which calculates length of major axis & minor axis of all the objects. Then according to ratio of major axis & minor axis lanes are identified (Fig.8).

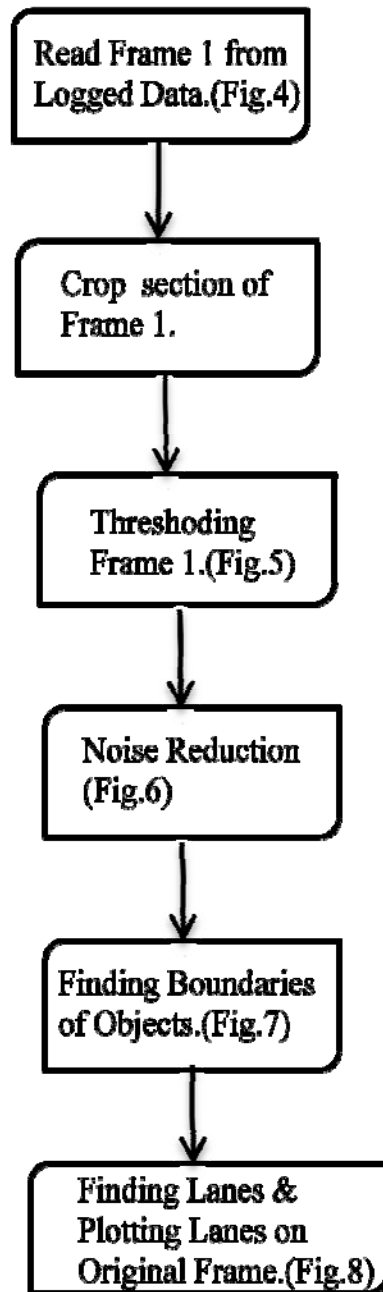


Fig. 3 Flow diagram of Lane Identification

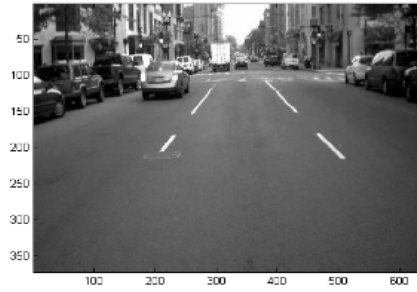


Fig.4 Image of road

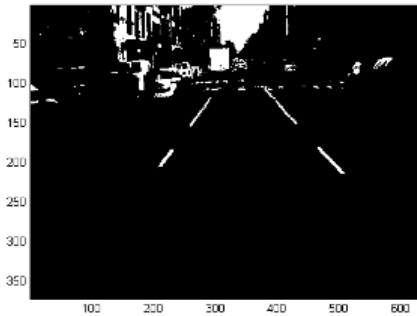


Fig.5 Thresholding of image

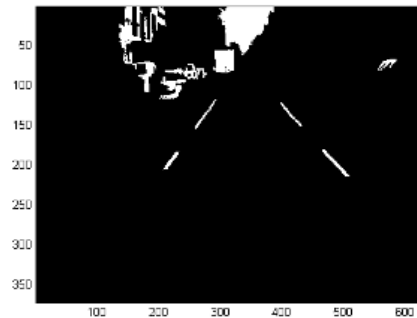


Fig.6 Noise reduction of image

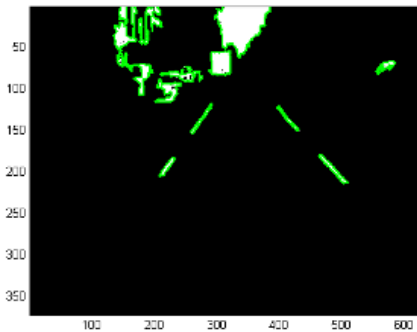


Fig.7 Boundaries of objects

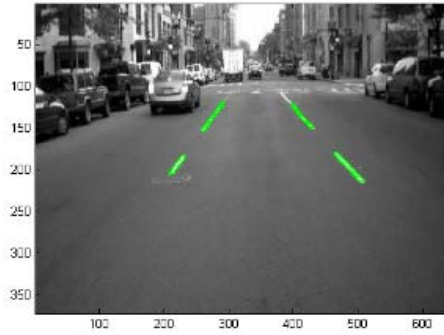


Fig.8 Plotting lanes on original image

*E. Measurement of Heading Angle*

To measure heading angle on a straight road, the geometric relationship of a car mounted with a camera with respect to the lane is shown in Fig.9 (a). As shown in figure the nearest distance that the camera can capture is located at baseline  $l_1$  with distance  $d$  ahead of the center of gravity of the vehicle. The two boundaries and the center line of lane all converge to a vanishing point Q at vanishing line in the image plane as illustrated in Fig.9 (b) according to the analysis mentioned above. Therefore, the heading angle  $\phi_h$ , can be obtained from the location of vanishing point which can be written as

$$\frac{\tan \phi_h}{\tan \theta} = \frac{\vec{OQ}}{\vec{OQ}_2} \cong \frac{\phi_h}{\theta} \quad \phi_h = \tan^{-1} \left( \frac{\vec{OQ}}{\vec{OQ}_2} \times \tan \theta \right) \quad (1)$$

The above formula is also valid for roads with small radius of curvature.

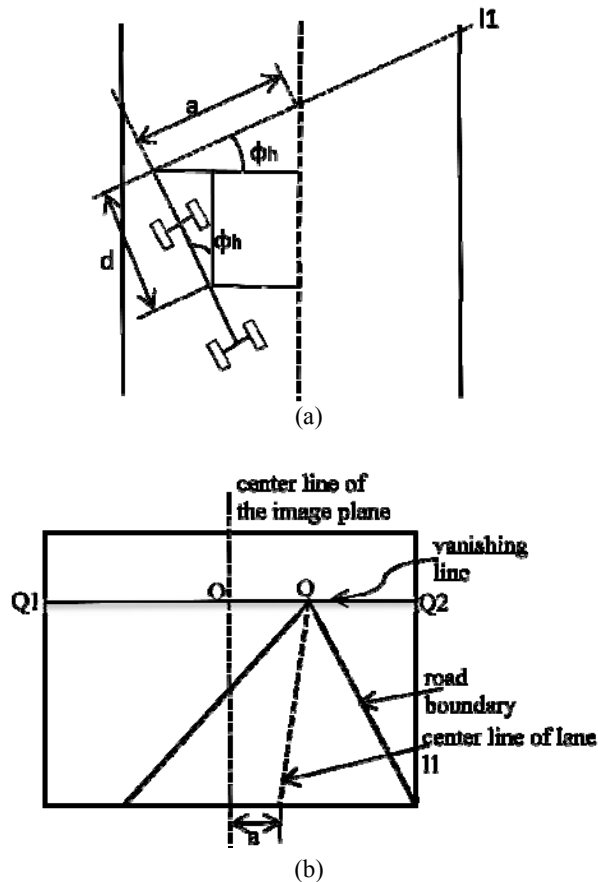


Fig.9 (a) Vehicle relative to lane (b) View in image plane

### III. CONTROL SYSTEM UNIT

Here we have adopted different kind of steering mechanism as shown in Fig.10. This kind of mechanism was used for the purpose of simplicity to validate the system proposed in this paper.

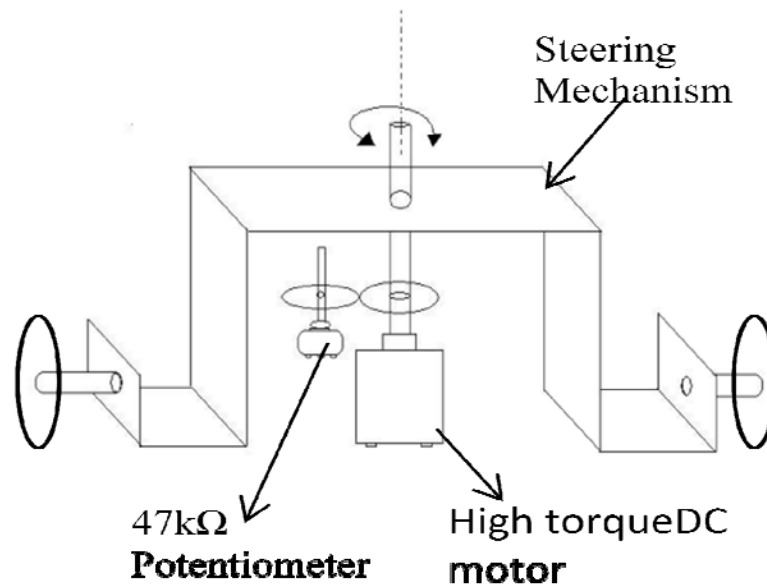


Fig.10 Mechanism of steering

The major part in control system unit is digitizing PID algorithm so that it can be implemented using Atmega-16 microcontroller.

A 47k potentiometer has 270 deg of rotational freedom. It encodes the angle of 0 to 180 deg into a voltage range of 0-3.5V. This voltage is read at the 10-bit ADC of Atmega16 and scaled to a range of 0 to 1024.

$$s_d = \text{set point}$$

$$s = \text{process variable}$$

So process variable is directly measured using 47kΩ potentiometer by 10 bit accurate ADC converter of atmega-16.

$$e_i(nT) = s_d(nT) - s(nT) \quad (2)$$

$e_i(nT)$  represents the error value calculated by the microcontroller. This value will vary from 0-1023 because ADC is 10 bit accuracy.

Integral term in case of PID is

$$\int_0^t e_i(t) dt = [s + e_i(nT)]t \quad (3)$$

The integral equation may be written as:

$$Y(t) = \int_{t_0}^t \{s_d - s(t)\} dt + Y(t_0) \quad (4)$$

Where  $Y(t_0)$  is the initial value of  $Y(t)$ . The trapezoidal integration rule is used to approximate the definite integral. Let  $t = nT$  and  $t_0 = (n-1)T$ .

$$\int_{(n-1)T}^{nT} \{s_d - s(t)\} dt = \{s_d T\} - \left\{ \frac{T}{2} [s(nT) + s(n-1)T] \right\} \quad (5)$$

For the simplicity of calculation it is assumed that the computation time delay (the time required to execute the PID algorithm) is equal to one sampling period  $T$ .

This means that the integral computational result will be at  $t = (n-1)T$  and Equation-(5) is digitized by the following state equation.

$$Y(n+1)T = (s_d T) - \left\{ \frac{T}{2} [s(nT) + s(n-1)T] + Y(nT) \right\} \quad (6)$$

Where  $Y(nT)$  is the initial state of  $Y(n+1)T$ .

The derivative part of equation is approximated using the Newton backward difference equation.

$$\frac{d[e_i(t)]}{dt} = \frac{e_i(nT) - e_i(n-1)T}{T} \tag{7}$$

The PID control algorithm in discrete time form thus becomes

$$e_i(n+1)T = k_p e_i(nT) + k_i Y(n+1)T + \frac{k_d[e_i(nT) - e_i(n-1)T]}{T} \tag{8}$$

This algorithm is implemented assuming that the time required performing the computation and output the result is small compared to the sampling time, T.

IV. EXPERIMENTAL RESULTS

The gains of the PID controller were initially estimated based on a simplified model of the drive motor. Thereafter, the gains were fine tuned manually to yield the best possible performance. Now the results of all PID values within the test range are plotted with respect to time. The values which yield the best curve will be used for the PID controller.

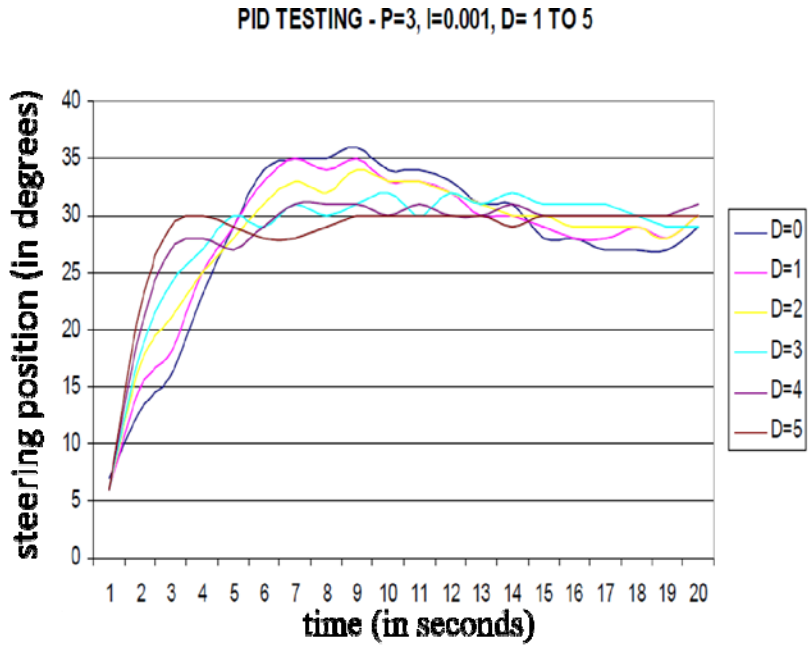


Fig. 11 PID response curve

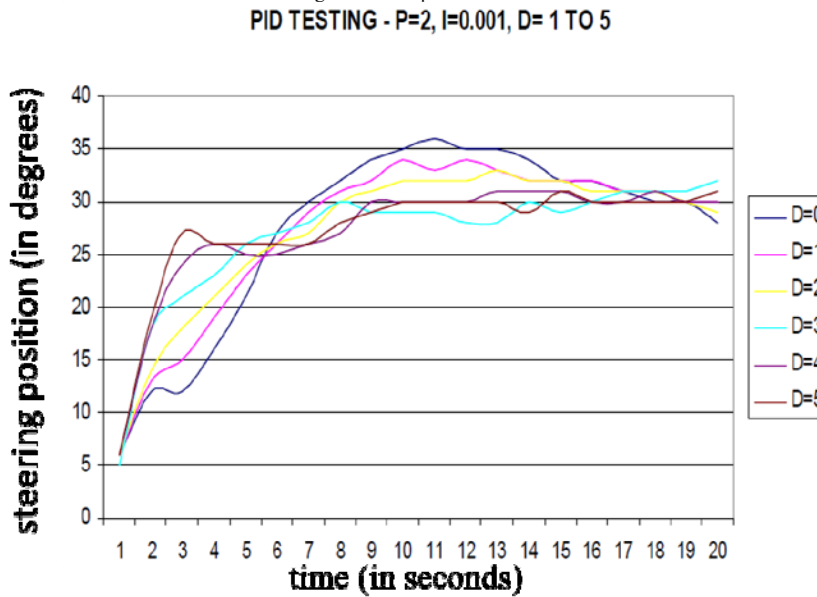


Fig. 12 PID response curve

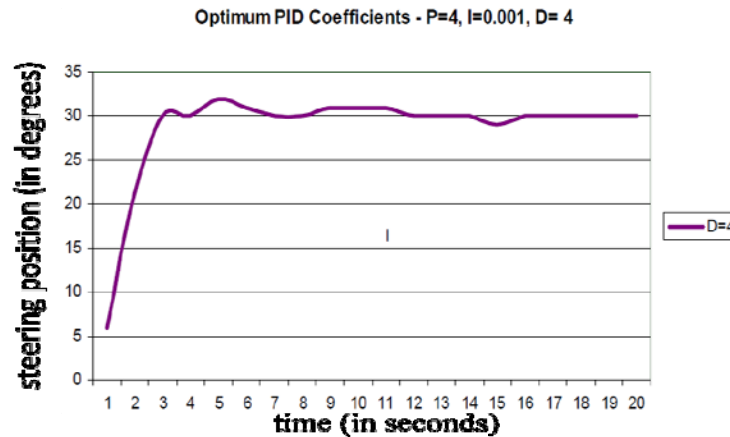


Fig.13 Optimized PID response curve

Hence the optimized value of the tuning parameters suitable for the efficient steering control were experimentally found to be  $K_p=4$ ;  $K_i=0.001$ ;  $K_d=4$ . The steering control method introduced in this section is equivalent to a nonlinear P control. By repeated tuning and testing, the model car can run stably on a given testing track at a maximum speed of 120 cm/s.

#### V. CONCLUSION

This paper validates the design of Decision making unit (DMU) & Control system unit (CSU). In DMU image acquisition, enhancement, thresholding, noise reduction have been successfully implemented. These parameters were inculcated to identify lane markings over desired image & spatial parameters were calculated to take the desired control action. The limitation of this system is that it doesn't work on rainy days & in dark night when there is no illumination source and may also fail due to extra luminance.

In CSU steering control system was successfully implemented. Steering control also produces some oscillation in the desired angle due to improper tuning of PID controller by trial & error method so we have compromised with the resolution of the system to damp the oscillation.

This system can be further improved by utilizing arm processor for image processing & adding one more camera to the present system will help in 3 dimensional analysis of the surroundings

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Ankit Sharma completed his B.tech in Electronics & Instrumentation from VIT university in may 2010. Presently he is working with Ballarpur Industries as instrumentation engineer. He was the part of the first indian student group to design & fabricate payload for sounding rocket RH-200 of Indian Space Research Organizatio (ISRO). This payload was launched from TERLS trivandrum on 7/07/2010.

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