CHAPTER 7

CONCLUSION AND SCOPE FOR FUTURE WORK

Transportation systems are an indispensable part of human activities. Estimation shows that an average of 40% of the population spends at least one hour on the road each day. People have become much more dependent on transportation systems in recent years, transportation systems themselves face not only several opportunities but several challenges as well. The competitiveness of a country, its economic strength and productivity heavily depend on the performance of its transportation systems. Intelligent Transportation Systems (ITS) have attracted increasing attention in recent years due to their great potential in meeting this above mentioned challenges. Advanced Vehicle Control System (AVCS) is a part of an ITS. The central theme of AVCS is to improve the throughput and safety of highway traffic by using automatic control with its precision and fast reaction to replace human drivers. Ultimately, in a more futuristic goal, AVCS might enable auto-piloted vehicles to take passengers to their destinations without human driver intervention. For many ITS research problems, a scale down platform is very useful for preliminary study and feasibility tests. However there is a very limited previous work in developing such a multipurpose ITS research platform. The course of the entire research work investigates the real time implementation of AVCS in prototype vehicles. Therefore this work proposes an approach that strikes a balance between real-size vehicles and pure computer simulations. The primary requirement for the real time implementations like track sensing algorithms, lateral control algorithms, longitudinal control algorithms with vehicle communication and vehicle
platooning algorithms are developed. These algorithms are simulated and the consolidated performance of all the proposed algorithms are tested in the proposed prototype vehicles and the results are plotted. Test result shows that the proposed algorithms are best fit for the proposed vehicles which was explained the respective chapters.

To summarize, the history of autonomous vehicles, need for current study, Intelligent Transportation Systems and Advanced Vehicle Control Systems (AVCS), AVCS Evaluation, AVCS benefits, AVCS space utilization and AVCS safety advantages are discussed in chapter 1.

The proposed work uses small scale electric vehicle to test the performance of the proposed algorithms in real time. Vehicle prototype modules such as vision system modules, vehicle steer module, vehicle drive module, microcontroller module and battery module which are being discussed. Two test bed tracks are used for real time performance analysis of the prototype vehicles. The nature of the track and its specifications are discussed. The circuit schematics of IR sensor array based sensing mechanism and linear sensor array based sensing mechanism are discussed. Obstacle sensor and wireless sensor module and its interfacing with prototype vehicles are discussed. The overall vehicle system model is discussed at the end of chapter 2.

Multiple sensors and multiple algorithms are proposed to identify the position and orientation of the vehicle in the track. The lane sensing strategies include road modeling, road marking extraction, pre-processing, vehicle modeling, position tracking and common assumptions. Two types of sensing strategies are used in the proposed work. One kind of sensing uses IR sensor array and the other kind of sensing uses linear sensor array. For IR sensor array based sensing, five different sensing algorithms are used. The complexity, limitations and sensitivity of those algorithms are discussed. For
128 x 1 linear sensor array, the sensor outputs at different lighting conditions are plotted and the problem due to light intensity variations during sensing is analyzed. The adaptive sensor calibration algorithm is proposed to make the sensing independent of light intensity variations. The sensor values at different light intensity before and after calibration are plotted and the plotted results prove that the proposed sensor calibration algorithm is independent of light intensity variations between 10 lux to 1000 lux. Sensor calibration is followed by threshold setting. Threshold setting technique is being discussed for three different position of the vehicle. The position and orientation of the vehicle in the track is identified by the error values. Finally the abnormalities due to the slanting rays and its impact are being discussed. Thus by combining sensor calibration algorithm, threshold setting techniques and slanting ray removal techniques, makes the line scanning camera to sense the proposed track independent of light intensity variations.

The survey of the lateral control algorithms followed by the proposed lateral control algorithms and its simulation results are discussed in chapter 4. IR sensor array uses five different sensing algorithms for line tracking. Error values are calculated from the sensor values in all these algorithms. These error values depict the deviation of the vehicle from the track. This error value is fed to the proposed PID controller for error correction. The PID controller output gives the corrected steer PWM value which is given to the servomotor based steering mechanism. The linear response of the PID controller for error values justifies the linear performance of the PID controller for prototype vehicle-1. This linear response improves the tracking accuracy of the prototype vehicle.

Prototype vehicle-2 is used for testing the proposed cascaded Kalman with PID controller. The 128 x 1 linear sensor array is used in the prototype vehicle-2. The track sensing algorithms used for linear sensor array
and the sensor output at different lighting conditions are plotted and the problem due to light intensity variations during sensing are discussed. The performance of the proposed lateral control algorithm is tested by applying different error values. The analysis shows that for the entire range of the error values, the proposed algorithm takes maximum 101ms to settle, is an added advantage of the proposed algorithm. The linear sensor array is more sensitive to ambient light intensity variations which produce maximum noise in the sensor reading. Proposed Kalman filter suppresses the noise and other uncertainties in sensor reading. The anomaly detection feature of the proposed method helps to find the vehicle in out of track and vehicle is brought back to the track by trace back algorithm. Kalman filter based lateral control algorithm takes very minimum iteration to predict the change as well as takes very minimum iterations to settle. This improves the performance of the vehicle by fastening the position identification and orientation. Consolidated performance of the proposed two layer cascaded Kalman filter with PID control architecture for the lateral control of the vehicle is discussed. Kalman filter output is given as an input to the PID controller, to control the servo motor based steering mechanism. The proposed cascaded Kalman filter with PID controller approach provides better steering accuracy when compared with conventional steering algorithms.

The survey of the longitudinal control algorithms includes vehicle cruise control, vehicle acceleration control, obstacle detection and collision avoidance, vehicle communication and vehicle platooning. All these algorithms are implemented in the work and its simulation results are analyzed.

Prototype vehicles-1 and 2 are used to test the proposed longitudinal control algorithms which includes adaptive speed control algorithm, adaptive acceleration control algorithm, obstacle detection and
collision avoidance algorithm. In the proposed algorithm current speed of the vehicle is compared with the reference speed and based on the difference, the speed correction is achieved smoothly. This proposed algorithm makes the vehicle to travel the test bed track with optimum speed, independent of uncertainties.

Adaptive acceleration control algorithm uses steer error based speed control where the delta difference between the present and past deviation is used for acceleration/deceleration. The entire possible acceleration/deceleration values with respect to present deviation and past deviation are shown. This algorithm makes the vehicle to travel in the maximum speed in straight line as well as when the error is minimum, thus makes the vehicle to complete the desired lap is short duration of time. The torque required to propel a vehicle is directly proportional to the steering angle of the wheel and inversely proportional to the speed of the vehicle. This condition is achieved by providing steer error based speed control technique. The speed of the vehicle is varied according to the distance of the obstacle. Vehicle communication is established for implementing intersection collision avoidance between vehicles through vehicle cooperative systems and road side infrastructure controlled systems, in which the vehicles in the coverage zone are controlled by the roadside infrastructure unit for better traffic control.

Chapter 6 discusses about the simulation results and inference of various algorithms independently. The test results of the consolidated performances of all the algorithms in the prototype vehicles are analyzed. Overall system structure and the block diagram of the proposed model are shown. The performance analysis of the proposed lateral control algorithms in prototype vehicles-1 and 2 is analyzed and the comparisons of tracking
accuracy of various algorithms like PID and Kalman are plotted. Proposed lateral control algorithms is compared with Ismail’s method, Gengyun’s method, Oscar’s method, Normey’s method and Naranjo’s method and comparison test results are plotted and tabulated based on the corresponding comparison metric. Performance analysis of the proposed longitudinal control algorithms in prototype vehicles-1 is tabulated and comparisons of speed accuracy of various algorithms are plotted. The overall performances of the proposed algorithms are tested in multiple prototype vehicles and the results are plotted and their tracking accuracy and speed accuracy are tabulated. The combination of proposed sensor calibration algorithm, pre-processing algorithm, cascaded Kalman and PID steer control algorithm, adaptive speed and acceleration control algorithm together makes the test bed vehicle to complete the test bed track in a shortest time smoothly without oscillations at desired speed.

7.1  FUTURE SCOPE

The reliable intelligent driver assistance systems and safety warning systems is still a long way to go. However, as computing power, sensing capacity, and wireless connectivity for vehicles rapidly increase, the concept of assisted driving and proactive safety warning is speeding towards reality. As technology improves, a vehicle will become just a computer with tires. Driving on roads will be just like surfing the Web: there will be traffic congestion but no injuries or fatalities. Advanced driver assistant systems and new sensing technologies can be highly beneficial, along with large body of work on automated vehicles.

These findings suggest that the research into autonomous vehicles within the ITS field is a short term reality and a promising research area and these results constitute the starting point for future developments. Some of the
suggestions towards extension and/or future related works are identified and are summarized below:

- New sensory systems and sensory fusion is to be explored to plug additional information to the control system.

- This work can be extended to include different maneuvers to make the driving system capable of dealing with all driving environments.

- Future issues may also include an algorithm for autonomous formation of the cooperative driving.

Thus, with the current and growing awareness of the importance of security, trustworthy vehicle autonomous systems can be deployed in few years.