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Implementation of a Can-Based Digital Driving System for a Vehicle

T.V.U. Kiran Kumar, B. Karthik and E. Bharath Kumaran

Department of ECE, Bharath University, Chennai-73, India

Abstract: With rapidly changing computer and information technology and much of the technology finding way into vehicles, vehicles are undergoing dramatic changes in their capabilities and how they interact with the drivers. Although some vehicles have provisions for deciding to either generate warnings for the human driver or controlling the vehicle autonomously, they usually must make these decisions in real-time with only incomplete information. So, it is important that human drivers still have some control over the vehicle. Advanced in-vehicle information systems provide vehicles with different types and levels of intelligence to assist the driver. Their introduction into the vehicle design has allowed an almost symbiotic relationship between the driver and vehicle by providing a sophisticated and intelligent driver-vehicle interface. Within this interface, vehicle control depends completely on the cooperation between the driver and the in-vehicle information systems by interactive communication through an intelligent information network. This paper discusses the development of such a control framework for the vehicle which is called the digital-driving behavior, which consists of a joint mechanism between the driver and vehicle for perception, decision making and control.

Key words: CAN (Controller Area Network) · Digital driving system · Driver-vehicle interface · IVISs (in-vehicle information systems) · LIN (Line Information network)

INTRODUCTION

In case of analog driver-vehicle interface, it is tough to build an automated driving system because most of the processing for decision-making regarding vehicle control uses digital electronic devices (like microprocessors etc) and requires data to be handled in digital format [1]. To avoid this drawback, we go for a digital driving system that uses digital data through out the processing thereby making the decision-making process more transparent as well as easy for design.

This paper discusses the development and implementation of one such intelligent control framework. A digital driving system for a semi-autonomous vehicle and CAN communication protocol are chosen to realize this objective.

The main issues to be considered for the control of a vehicle are speed control, fuel monitoring, temperature monitoring inside the vehicle, pressure monitoring of the vehicle tyres and engine pressure and most important of all, the driver-vehicle interface. A typical vehicle was generally [2] built with an analog driver-vehicle interface for indicating various parameters of vehicle status like temperature, pressure and speed etc. To improve the driver-vehicle interface, we go for an interactive system that is completely digital, hence the name-digital driving system.

Firstly, we use the microcontroller based data acquisition system that uses its resources like ADCs etc to bring all control data from analog to digital format and then, we can continue easily with the actual design of the decision making algorithms as required for effective operation the vehicle [4]. Since the in-vehicle information systems are spread out all over the body of a practical vehicle, we go for a communication module that supports to implement a one-stop control of the vehicle through the master controller of the digital driving system. In this case, the communication module used is embedded networking by CAN (Controller Area Network) and LIN (Line Information network). An easier driver-vehicle interface is realized by using a touch screen-LCD combination that provides for a better interaction between the vehicle and the driver.

Corresponding Author: T.V.U. Kiran Kumar, Department of ECE, Bharath University, Chennai-73, India.

The section II gives a brief idea of the driving systems in old generation vehicles which were based on the analog driver-vehicle interface. Section III presents the idea of the proposed digital driving system [5, 12]. The implementation model and the application for testing the proposed digital driving system are presented in sections IV and V respectively. Section VI gives the details of hardware used to implement the hardware model as well as for the analysis of the digital driving system. Section VII gives the result obtained after implementing the digital driving system for a typical vehicle and section VIII concludes the paper.

Existing System: Except for some high-end expensive vehicles that provide a very good vehicle-driver interface (most of these have the interface implemented using digital electronic systems), the existing driving systems are mostly analog in nature, designed for drivers who don't really have the knowledge of handling electronic systems. Though consumer electronic components like music players, television systems have crept into the vehicle arena, not many manufacturers still provide complete digital control of a vehicle as a feature in the vehicle [6, 11]. The main reasons behind this drawback in manufacturing a vehicle are the increase in the design time and cost as well as the overall price of the vehicle. Also, too much of technology may not go down well with the common man, who on average is not accustomed to the details of technology used and may feel alien to it and fail to accept, when exposed to a sophisticated driving system. Some vehicles are built with better control mechanisms but without proper coordination between them. This too is a drawback because the driver cannot have a one-stop control of the vehicle from the dashboard or the master controller itself [7, 10].

Though analog control has been used widely ever since vehicles were developed first, the way vehicles are developed is changing with digital technology getting into the design of vehicles to provide the best vehicle-user interface that eases the handling of a vehicle by a driver.

Proposed System: This paper gives the design issues and implementation details of a digital driving system for a typical vehicle. The block diagram of the proposed system for implementation is shown in Fig. 1. It shows the various components of a typical vehicle and how they can be connected to accommodate a digital driving supported by an intelligent road traffic information network environment. Reference [1] gives a brief idea about the issues regarding a digital driving system design.

Considerable research on driving behavior has recently focused on compensating for human limitations by introducing advanced in-vehicle information systems. For example, driver information systems like GPS expand the driver's knowledge of routes and locations, collision-avoidance systems enhance the driver's ability to sense what is happening in the surrounding environment and driver assistance and automation systems simulate a driver's thinking and physical actions to operate a vehicle temporarily during emergencies. These in-vehicle information systems have helped increase driving safety significantly; however, they have led to a great expansion of both overlapping functions and the information potentially available to drivers. Investigating how to integrate these systems and coordinate them to work cooperatively with drivers is extremely difficult.

The integration of vision-based lane trackers with vehicle control systems has let vehicles drive on clear highways under controlled circumstances. Simultaneously, studies of automatic headway control (cruise control i.e., the control of vehicle spacing) and convoying have led to vehicles that can autonomously follow another vehicle. We can even use an intelligent parking guidance system based on SONAR acting in coordination with a camera which helps the automatic parking of a vehicle provided it gets information about the gap or space available in the parking lot. All these developments try to make driving a better job and surely, a safer job too. Some of the features that can be included in a digital driving system and the latest developments in vehicle driving systems are discussed in [2-4].

Joint perception, decision making and control are the three basic issues to be considered for building the digital driving system behavior. The in-vehicle information systems are chosen such that they serve the purpose of the perception of the vehicle status in real-time. The decision making process is developed according to the digital driving behavior required as well as the intelligent road traffic information network environment if any thing like that exists in the surroundings. The control of the vehicle in most of the cases needs mechanical links and rests with the manufacturers of the vehicle. However, the control inputs are implemented to originate from the driver-vehicle interface. With in this setup, the digital driving system framework must be framed to accommodate joint perception, decision making and control and a vehicle safety control system along with the coordination and support of an intelligent road traffic information environment.

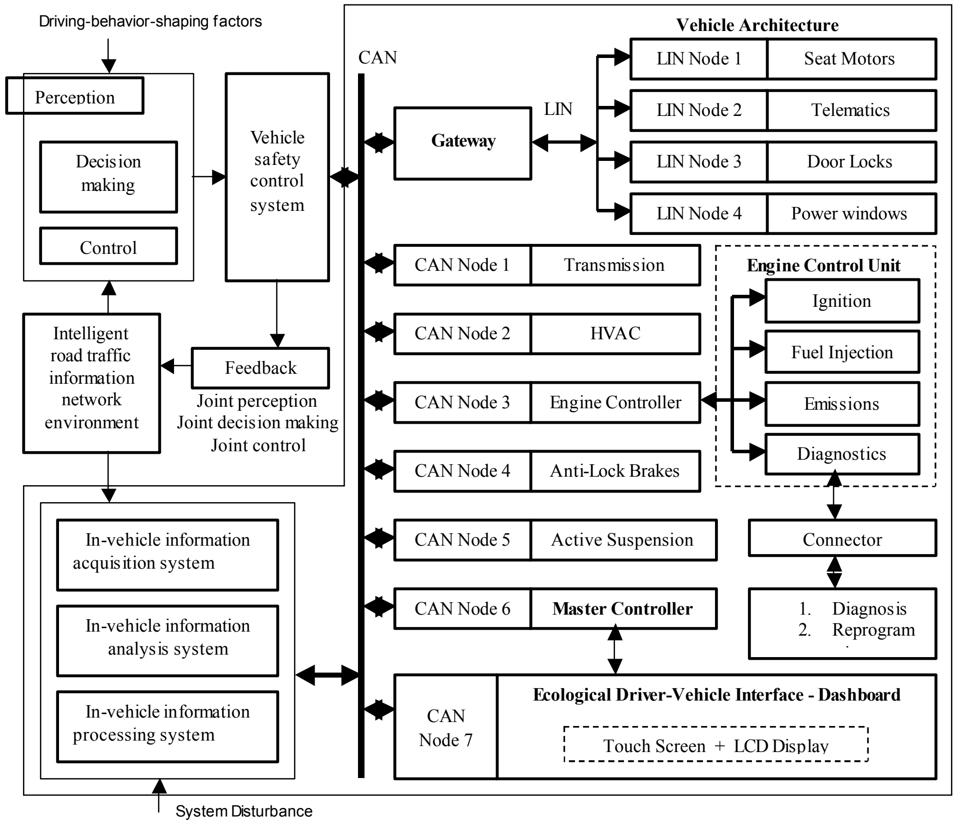

Fig. 1: Block diagram of the proposed system

Fig. 2: Block diagram of the implemented hardware model

The intelligent road traffic information network environment can be based on GPS, RFID or any other wireless protocol the serves the purpose of communicating with a vehicle while in motion. The rules for the vehicle running under such an environment are framed to help and suit good and safe driving. The parameters for framing the rules can be like speed limits, time of travel, special low-speed zones etc.

The vehicle safety control system is responsible to act in cases of any emergency during driving. It can do things as easy as slowing down the vehicle speed automatically when it enters the special low-speed zones and things as tough as maintaining the distance-in-between-vehicles during cruise control operation of a vehicle. While the earlier task needs very less intervention of the digital driving system, the other task during cruise control needs continuous intervention of the digital driving system because the operation is critical and any mal-function can result in a disaster. So, the design of the vehicle safety control system is of prime importance. Also, with every improvement in the vehicle safety control system, feedback should be given to the intelligent road traffic information network environment so that it too is improved to accommodate the improvement in the vehicle safety control system.

The architecture of a typical vehicle is shown in as part of the block diagram in Fig. 1. The basic components in a vehicle that compose the vehicle architecture are indicated in the diagram along with a communication model that connects those components. The mechanical components are connected by mechanical links where as the electronic or the control parts of the components are connected by a digital communication framework. Serial communication methods-CAN (Control Area Network) and LIN (Line Information Network) form the digital communication framework in the proposed system. CAN is faster and reliable than LIN, also widely accepted and has many vendors manufacturing CAN based products. So CAN is preferred to LIN for connecting critical components and LIN is used for less critical components. The gateway acts as the inter-connector for the CAN network and the LIN network.

The driver-vehicle interface is made up of a combination of touch screen and LCD at the dashboard. This provides a simpler method of interface because the LCD can display user-friendly digital values and the touch screen takes touch-based inputs from the user for controlling the vehicle. A voice processor can be included in the vehicle to raise sound alarms in case of an emergency.

The heart of the digital driving system is composed of a master controller operating in coordination with three vehicle units namely in-vehicle information acquisition system, in-vehicle information analysis system and in-vehicle information processing system. The master controller is responsible for securing all the information related to the vehicle from the slave nodes connected to each of the components of the vehicle, process it and take necessary decision related to the operation of the vehicle. These three units form the framework for sensing information related to operation of the vehicle as well as its status, analyzing the collected information in raw form and format it to suit the digital driving system and then, process it with the database information related to correct operation of the vehicle to take any corrective action (if required).

Implementation: A digital driving system for a semi-autonomous vehicle and CAN communication protocol are chosen to realize this objective. The CAN network implementation is used in realizing the hardware model for controlling the vehicle because it facilitates control of various parts of the vehicle from a central master CAN controller.

In the design of the vehicle system for the hardware model, a CAN network is implemented between two slave controller nodes and a master controller node where the slave controller nodes are responsible for interacting with various in-vehicle information systems and performing various control functions that are encountered in the operation of a normal vehicle as well as updating the master controller about the information from the in-vehicle information systems. The master controller node is responsible for processing the information obtained from the in-vehicle information systems through the slave nodes along with overall control of the vehicle.

The whole design can be divided into three parts. The first part is the development of the slave nodes with necessary hardware interface and software to implement the various tasks performed by the slave nodes. The second part is the development of the master node to interact with the remote control circuit, the touch screen, LCD display and raise alarms for violation of various user specified constraints. The third part is to implement CAN network between the master node and the slave nodes and develop additional software to achieve CAN based communication between the various nodes.

Node 1: Node 1 is the master node of the system and is implemented using a PIC 18F4685 microcontroller. The hardware modules in Node 1 circuit include the LCD display unit, the touch screen interface, the IR receiver for remote control access through the IR remote control, LED alarms for each of the parameters monitored in the system for violation of user specified constraints and a serial port module to update the current status of the vehicle including vehicle path to a PC connected to the vehicle. The software part includes microcontroller sub-routines for updating and displaying the current status of the vehicle in the LCD display as well as send the same data to the serially connected PC, sensing IR signal from the remote control circuit through the IR receiver, monitoring the current status of the vehicle by processing various control information received from the slave nodes in the system.

Node 2: Node 2 is a slave node in the system and is implemented with the same PIC 18F4685 microcontroller used for master node implementation. The hardware modules in Node 2 circuit include the speed control unit and the obstacle detection unit. The software part includes microcontroller sub-routines for setting the current speed of the vehicle, sensing any obstacle by using an IR transmitter-receiver combination and sending the current status signal of the slave node to the master node continuously.

Node 3: Node 3 is a slave node in the system and is also implemented with the PIC 18F4685 microcontroller. The hardware modules in Node 3 circuit include the pressure monitor, fuel-level monitor and temperature monitor. The software part includes microcontroller sub-routines for ADC conversion of the analog values of temperature and pressure measured by the respective sensors as well as fuel-level measurement and sending the current status signal of the slave node to the master node continuously.

Application: A semi-autonomous vehicle has been chosen to realize the digital-driving system and analyze its performance. Since it is not feasible in terms of resources to implement all the mechanical components of a typical vehicle, the hardware implementation model as well as the application is restricted to accommodate the digital driving system within the best possible electro-mechanical model of a vehicle which is run by electrical motors for testing purposes alone. Implementing the practical vehicle with all-mechanical components and testing the digital driving system is beyond the scope of this paper.

So, the basic tasks like movement of the car, obstacle detection, cruise control, fuel-level measurement etc only are implemented among the two slave nodes of the digital driving system. The monitoring and control of system status is through the single master node of the system. The primary vehicle-driver interface for this system is the remote control of the vehicle. A Philips television remote is used for this purpose.

As an alternative to the IR based remote control for implementing the vehicle-driver interface for this application, a touch screen is also used to provide additional control input to the vehicle. The two control methods are independent and can act simultaneously too. A touch screen-LCD combination, if used along with GPS and a digital camera can provide a high-end digital driving system with sophisticated features like wireless tracking of the vehicle's position, better obstacle detection, better user interface between the driver and the digital driving system. Due to financial and resource constraints, in the hardware implementation, the usage of the touch screen is restricted to just to provide control inputs to the vehicle.

Since the idea is to implement and analyze the digital driving system mechanism, the implementation has been cut short to operate on a semi-autonomous vehicle where the digital driving system indicates the error in the vehicle operation to the driver and may take partial corrective decisions in some cases. Though the same system can be used with a completely autonomous vehicle (artificially intelligent i.e. completely free of driver intervention for decision making), the implementation is restricted to semi-autonomous vehicle which provided easy strategy for testing the digital driving system while developing the hardware model. The same digital driving system can be extended to any practical vehicle with the optimal driver-vehicle interface considering the requirements of the vehicle operation and the automation tradeoffs i.e. on which parts of the control should rest with the driver for decision making and on which parts the master controller of the digital driving system takes decisions.

Hardware: The CAN nodes are implemented using PIC 18F4685 microcontroller from Microchip. It is Enhanced CAN enabled and supports 29-bit CAN identifiers. The remote control circuit uses a Philips television remote control operating at 36 kHz frequency. The other source of control inputs is the touch screen. A 5-wire analog touch screen is used along with a touch screen controller that takes the touch inputs and converts them to control signals that are understood by the master controller of the vehicle. PIC 16F76 microcontroller form Microchip is used to implement the touch screen controller. Reference [5] gives a good introduction about programming the touch screen interface. The basics of PIC microcontroller programming are discussed in [6]. Both the microcontrollers are programmed in C language using MPLAB IDE from Microchip.

The movement of the vehicle can be visualized in a PC using a serial port connection between the PC and the master node of the digital driving system. In the PC, A front-end graphical user interface is created to show the current status as well as path of the vehicle from the moment the vehicle operation is started. The master node keeps updating the current status of the vehicle to the LCD display as well as the PC connected to its serial port.

A LM35 temperature sensor is used for temperature measurement and a MPX5100 series pressure sensor is used for pressure measurement. A 16x2 LCD display is used to display the current status of the vehicle. Two TSOP 1736 IR receivers are used-first IR receiver in the obstacle sensor circuit and the second IR receiver in the master node circuit for remote control sensing. The alarms for violation of user constraints are implemented using LEDs. The IR transmitter circuit in the obstacle sensing module is implemented using a 555timer based circuit operating in astable mode, driving an IR LED. The motor drive for moving the vehicle is implemented using a combination of DC motors, driven by a pair of relays-one DPDT relay and one SPDT relay. The relays are connected to the microcontroller through a pair of transistor switches that are driven according to the required movement of the vehicle.

Remote control inputs for the vehicle implemented in the hardware model include start, stop, speed increment, speed decrement, move right, move left and cruise control (at an average base speed).

RESULTS

The implementation was done for a semi-autonomous vehicle and the hardware model of the digital driving system has been tested for satisfactory operation with respect to control inputs from the IR remote control as well as the touch screen.

CONCLUSION

This digital driving system architecture can be extended to a high-end vehicle with provisions for sophisticated features like wireless tracking of the vehicle's position using GPS or WiMAX, a digital camera for better obstacle detection, a touch screen-LCD combination for better user interface between the driver and the digital driving system. A voice based digital driving system will reduce the driver's effort in handling the vehicle. Also, better cruise control can be achieved by using advanced sensors in the vehicle. Advanced automatic vehicle parking systems can also be realized by using additional mechanisms like SONAR.

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