International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161

Available at http://inpressco.com/category/ijcet

Research Article

Controller Area Network based Cruise Control in Traffic Situations

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Accepted 15 July 2015, Available online 16 July 2015, **Vol.5, No.4 (Aug 2015)**

Abstract

Intelligent vehicle cooperation based on reliable communication systems contributes not only to reducing traffic accidents but also to improving traffic flow. Adaptive cruise control (ACC) systems can gain enhanced performance by adding vehicle–vehicle communication to provide additional information to augment range sensor data, leading to cooperative ACC (CACC). This paper presents the design, development, implementation, and testing of a CACC system. It consists of two controllers, one to manage the approaching maneuver to the leading vehicle and the other to regulate car speed. In the prototype, we are going to design the ACC using an ARM 11 processor as the Main controller and ARM Cortex M3 as the Low level controller. Using Controller area network (CAN) protocol the slave module will transmit the data i.e. GPS location, Speed using speed sensor and distance based on ultrasonic sensor interface. The data will be transmitted to the Master Controller for analyzing , based on the cruise control algorithm will plot the speed graph and if any values are crossed over the threshold level, then will control the motor (i.e Engine) .

Keywords: *Raspberry Pi, CAN Module, Arm Cortex M3*

1. Introduction

Significant developments in advanced driver assistance systems (ADAS) have been achieved during the last decade. Intelligent systems based on on-board perception/ detection devices have contributed to improving road safety [Q. Wang,2012]. The next step in the development of ADAS points toward vehicle-to-vehicle (V2V) communications to obtain more extensive and reliable information about vehicles in the surrounding area, representing cooperative intelligent transportation systems (ITS).Using wireless communication, potential risk situations can be detected earlier to help avoid crashes, and more extensive information about other vehicles' motions can help improve vehicle control performance. Research projects have been conducted throughout the world to define the requirements for an appropriate vehicular communication system and its possible applications [C. Han, 2012]. Although most of the V2V cooperative ITS applications have been focused on improving collision avoidance and safety [V. Milanés, 2012], the extension of the commercially available adaptive cruise control (ACC) system toward the cooperative ACC (CACC) system has a high potential to improve traffic flow capacity and smoothness, reducing congestion on highways. By introducing V2V communications, the vehicle gets information not only from its preceding vehicle—as occurs in ACC—but also from the vehicles in front of the preceding one. Due to this preview information, oscillations due to speed changes by preceding vehicles can be drastically reduced. Benefits from including communications in ACC systems have been widely studied in recent years [V. Milanés, 2012][L. Xiao ,2011][S. Moona,2009]. Prior experimental results using vehicle–vehicle cooperation to improve vehicle-following performance were achieved by the California Partners for Advanced Transit and Highways (PATH) in 1997 [J. Ploeg2011], [S. C. Calvert,2011] when a platooning maneuver involving eight fully automated cars was carried out using wireless communication among vehicles, mainly for longitudinal control, and magnetic markers in the infrastructure, mainly for lateral control. Based on the idea of a leading vehicle guiding several followers, the Safe Road Trains for the Environment (SARTRE) European Union project has developed virtual trains of vehicles in which a leading vehicle with a professional driver takes responsibility for each platoon [S. Oncu, 2011]. That concept of the professional driver in the first vehicle was originally developed in the European project called CHAUFFEUR [C. Desjardins, 2011]. Specifically related to CACC implementations in production cars, two important projects were recently conducted in the Netherlands. The Connect & Drive project, funded by the Dutch Ministry of Economic Affairs, carried out a CACC demo using six passenger

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vehicles [E. van Nunen,2012] adopting a constant time gap spacing policy. For the Grand Cooperative Driving Challenge competition in 2011, nine heterogeneous vehicles from different European research institutions tried to perform a two-lane CACC platoon [G. Naus, 2010]. This competition revealed some of the most important problems to be solved before bringing this technology into production, including communication systems reliability. From the control point of view, most of the implementations were based on proportional proportional-derivative feedback/feed forward controllers [G. Naus, 2010] or model predictive control techniques. When it comes to designing a CACC system, string stability plays a key role.

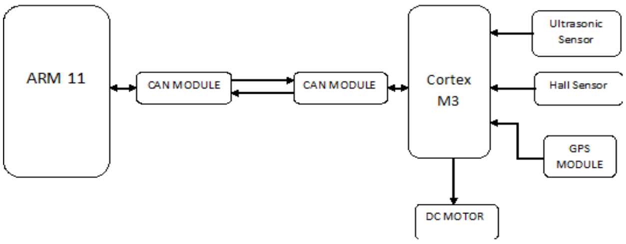

Fig 1 Control architecture Block Diagram

The goal is designing a system able to reduce disturbances propagated from the leading vehicle to the rest of the vehicles in the platoon. There are two different approaches to car-following gap regulation, i.e., one based on constant spacing or one based on constant time gap. A comparative study between them, where CACC stability was discussed, was presented in. Several papers have dealt with string stability analysis and simulations [Q. Wang, 2012]–[L. Xiao, 2011], based on simplified theoretical models of ACC vehicle-following behavior, and have shown encouraging results.

2. Hardware Description

Architecture of LPC1768

The LPC1768 is a 32-bit mixed signal processor from NXP semiconductor, is most widely used in a number of embedded systems such as mobiles, automobiles, industrial control etc. LPC1768 Xplorer board was purchased from NGX Technologies, Bangalore, which cost about 35$. It consists of ARM Cortex M3 as its core with 512kB flash memory and 64kB data memory, which offers high level of integration and low power consumption. Other important features include:

- Operates at a frequency up to 100MHz
- It incorporates a 3 stage Pipeline architecture of 0.91MIPS/MHz (fetching, decoding and running)- Harvard architecture with separate instructions, local data buses and a third bus for Peripheral communication. The on-chip peripheral components of the LPC1768include: Ethernet MAC, a USB interface that can be configured as either Host, Device, or OTG, 8 channel general purpose DMA controller, 4 UARTs, 2 CAN channels,2 SSP controllers, SPI interface, 3 I2C interfaces, 2-inputplus 2-output I2S interface, 8 channel 12-bit ADC, 10-bit DAC, motor control PWM, Quadrature Encoder interface, 4general purpose timers, 6-output general purpose PWM, ultra-low power RTC with separate battery supply, and up to70 general purpose I/O pins .It supports the operating systems such as WINDOWS CE,LINUX, Palm OS and so on. The block diagram of ARMcortex M3 is shown in fig. 1(a), fig. 1(b) shows the internal architecture and fig. 1(c) shows the LPC1768 Xplorer board.

Raspberry Pi

The original Raspberry Pi is based on the Broadcom BCM2835 system on a chip (SoC), which includes n ARM1176JZF-S 700 MHz processor, VideoCore IV GPU, and was originally shipped with 256 megabytes of RAM, later upgraded (models B and B+) to 512 MB. The system has Secure Digital (SD) (models A and B) or MicroSD (models A+ and B+) sockets for boot media and persistent storage In the figure 1, Raspberry Pi is connected to the USB port. In the PC, Raspbian operating system is installed. Raspberry-pi works only on Raspbian operating system, Linux., Raspbian is a free operating system based on Debian optimized for the Raspberry Pi hardware. An operating system is the set of basic programs and utilities that make your Raspberry Pirun. However, Raspbian provides more than a pure OS: it comes with over 35,000 packages, pre-compiled software bundled in a nice format for easy installation on your RaspberryPi. Putty configuration and VNC viewer are needed to install Raspbian OS. Putty configuration is SSH and Telnetclient. It is an open source software that is available with source code. Virtual network computing is a Graphical desktop sharing system that allows us to remotely control the desktop interface of one computer from another. The Raspberry Pi primarily uses Linux kernel-based operating systems (it is not possible to run Windows on the Raspberry Pi). The ARM11 is based on version 6 of the ARM on which several popular versions of Linux no longerrun (in current releases), including Ubuntu. The install manager for Raspberry Pi is NOOBS.

Fig 2: Raspberry Pi Board

GPS

The Global Positioning System (GPS) is a satellite based navigation system that sends and receives radio signals. A GPS receiver acquires these signals and provides the user with information. Using GPS technology, one can determine location, velocity and time, 24 hours a day, in any weather conditions anywhere in the world for free.

The Global Positioning System (GPS) includes 24 satellites, in circular orbits around Earth with orbital period of 12 hours, distributed in six orbital planes equally spaced in angle. Each satellite carries an operating atomic clock (along with several backup clocks) and emits timed signals that include a code telling its location. By analyzing signals from at least four of these satellites, a receiver on the surface of Earth with a built-in microprocessor can display the location of the receiver (latitude, longitude and altitude). Military versions decode the signal to provide position readings that are more accurate, the exact accuracy. Civilian receivers are the approximate size of a hand-held calculator, cost a few hundred dollars and provide a position accurate to 100 meters or so. GPS satellites are gradually revolutionizing driving, flying, hiking, exploring, rescuing and map making. The goal of the Global Positioning System (GPS) is to determine the position of a person or any object on Earth in three dimensions: east-west, north-south and vertical (longitude, latitude and altitude). Signals from three overhead satellites provide this information. Each satellite sends a signal that codes where the satellite is and the time of emission of the signal. The receiver clock times the reception of each signal, then subtracts the emission time to determine the time lapse and hence how far the signal has traveled (at the speed of light).This is the distance the satellite was from the object when it emitted the signal. In effect, three spheres are constructed from these distances, one sphere centered on each satellite. Thus, the object is located at the single point at which the three spheres intersect.

Ultrasonic Sensor

The sensor is primarily intended to be used in security systems for detection of moving objects, but can be effectively involved in intelligent children's toys, automatic door opening devices, and sports training and contact-less-speed measurement equipment. The ultrasound transmitter **TX** is emitting ultrasound waves into sensor ambient space continuously. These waves are reflecting from various objects and are reaching ultrasound receiver **RX**. There is a constant interference figure if no moving objects are in the placement.Any moving object changes the level and phase of the reflected signal, which modifies the summed received signal level. Most low cost sensors (car security systems, for instance) perform reflected signal amplitude analysis to detect moving objects. In spite of implementation simplicity, this detection method is characterized by a high sensitivity to noise signals. For example, heterogeneous airflows, sensor vibrations, room window and door deformations, and gusts can change the interference figure and generate false alarm signals. Better noise resistance may be obtained if the receive sensor is performing reflected signal frequency analysis instead of amplitude examination. The reflected signal spectrum emulates a Doppler Effect. Frequency components of the moving object speed vector have a component in the direction of ultrasound radiation propagation. Because ultrasound waves reflect from the windows, walls, furniture etc., the sensor can detect object movements in any direction. To implement this principle, the sensor must perform selection and processing of Doppler Effect frequency shift to detect moving objects. The air condition systems, heat generators, and refrigerators typically include movable parts, which can cause device vibrations that generate high-frequency Doppler components in the reflected ultrasound signal. The heterogeneous variable temperature airflows are characterized by different ultrasound propagation speed that can raise low-frequency Doppler components in the reflected signal. That is why the noise resistant motion detection sensor should limit the Doppler signals' frequency range from lower and upper bounds to satisfactory false-alarm free operation.

3. Controller Area Network (CAN)

CAN is a multi-master serial bus that broadcast messages to all nodes in the network system. The CAN system offers a transmission speed of up to 1 Mbit/s with reliable and error detection method for effective transmission .CAN uses carrier sense multiple access protocol with collision detection (CSMA/CD) and arbitration on message priority as its communication protocol [C. Han,2012]. This communication protocol allows every node in CAN to monitor the bus network in advance before attempting to transmit a message. When no activity occurs in the network, each node has the same opportunity to transmit a message. Additionally, this communication protocol allows collision to be solved using bit-wise arbitration, based on a preprogrammed priority of each message in the identifier field of a message. This configuration allows messages to remain intact after arbitration is completed even if collisions are detected. In order for the arbitration process to be successful, the logic states need to be defined as dominant or recessive. CAN defines the logic bit '0' as the dominant bit whereas the logic bit '1' as the recessive bit. An example of CAN arbitration can be seen in "Figure 1" when three nodes are assumed to be transmitting simultaneously. This figure is illustrating CAN arbitration when three nodes start transmitting their start of frame (SOF) bits simultaneously. Nodes 1 and 2 stop transmitting as soon as they transmit bit „1" (recessive level), and Node 3 is transmitting bit „0" (dominant level). At these instances, Nodes 1 and 2 enter the receiver mode, indicated in grey. When the identifier has been transmitted, the bus belongs to Node 3 which thus continues transmitting The ISO standard defined CAN with a standard 11-bit identifier that provides for signaling rates from 125 kbps to 1 Mbps. This standard is later improved to allow for larger number of bit, where the "extended" version with 29-bit identifier. The standard 11-bit identifier field provides for 211, or 2048 different message identifiers, whereas the extended 29-bit identifier provides for 229, or 537 million identifiers. The data format of both standards can be seen in Figure 2. CAN protocol can be considered as a message-based protocol as messages are transmitted to all nodes in the network. Therefore, each node receives the messages and decides whether the message received is to be discarded or processed. Depending on the configuration of the network, a transmitted message can be destined to either one node or many nodes. This has several important consequences such as system flexibility, message routing and filtering, multicast, together with data consistency.

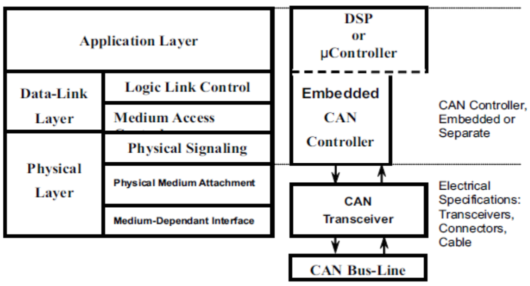

Fig 2: CAN Standard Architecture

The data link and physical signaling layers of Figure 2, which are normally transparent to a system operator, are included in any controller that implements the CAN protocol, at 3.3-V DSP with integrated CAN controller. Connection to the physical medium is then implemented through a line transceiver such as MCP3206 3.3-V CAN transceiver to form a system node. Signaling is differential which is where CAN derives its robust noise immunity and fault tolerance. Balanced differential signaling reduces noise coupling and allows for high signaling rates over twisted-pair cable. Balanced means that the current flowing in each signal line is equal but opposite in direction, resulting in a field-canceling effect that is a key to low noise emissions. The use of balanced differential receivers and twisted-pair cabling enhance the common-mode rejection and high noise immunity of a CANbus. The two signal lines of the bus, CANH and CANL, in the quiescent recessive state, are passively biased to» 2.5 V. The dominant state on the bus takes CANH » 1 V higher to » 3.5 V, and takes CANL » 1 V lowerto » 1.5 V, creating a typical 2-V differential signal.

The CAN standard defines a communication network that links all the nodes connected to a bus and enables them to talk with one another. There may or may not be a central control node, and nodes may be added at any time, even while the network is operating (hot-plugging). CAN is ideally suited in applications requiring a large number of short messages with high reliability in rugged operating environments. Because CAN is message based and not address based, it is especially well suited when data is needed by more than one location and system-wide data consistency is mandatory. Fault confinement is also a major benefit of CAN. Faulty nodes are automatically dropped from the bus, which prevents any single node from bringing a network down, and ensures that bandwidth is always available for critical message transmission. This error containment also allows nodes to be added to a bus while the system is in operation, otherwise known as hot-plugging. Many features of the TI CAN transceivers make them ideally suited for the many rugged applications to which the CAN protocol is being adapted. Among the applications finding solutions with CAN are automobiles, trucks, motorcycles, snowmobiles trains, buses, airplanes, agriculture, construction, mining, and marine vehicles.

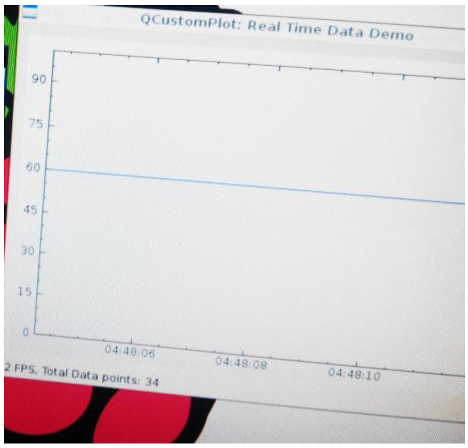

Fig 4: Graphical Analysis of Vehicle Idle State

4. Results

The above section describes the control system design using CAN standard.

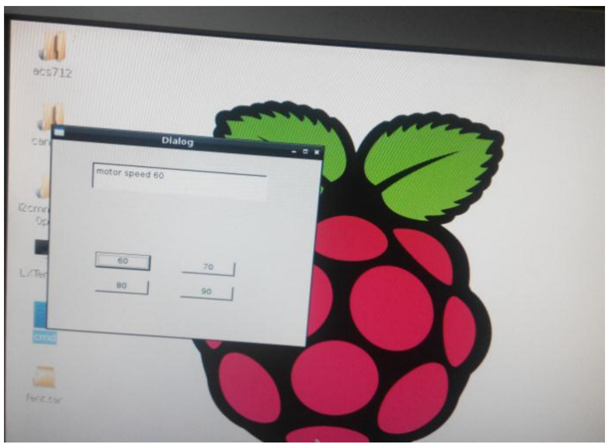

Fig 5: GUI Interface for turning on/off the device

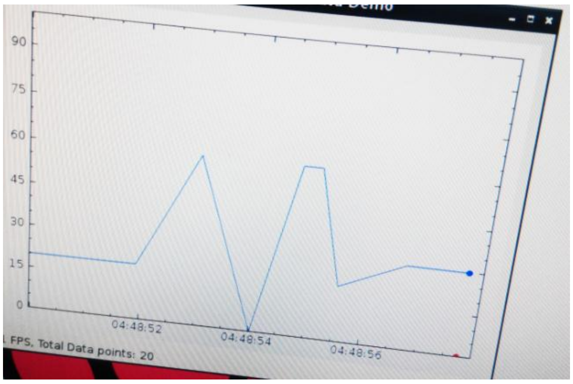

Fig 6: Graphical interface while vehicle running

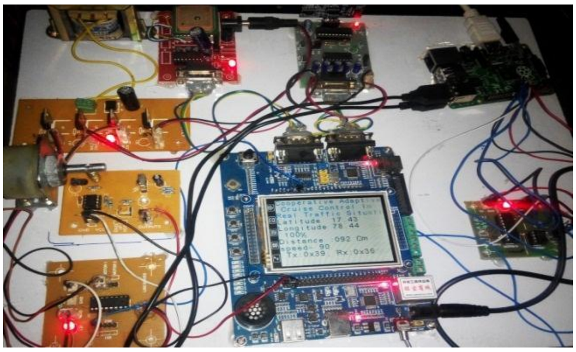

Fig 7: Hardware Assembly of the complete circuit

The system is then successfully simulated and this section describes the result obtained. The result is obtained in terms of graphs and data analysis. The graph of engine speed represents variation of engine speed and velocity in terms of (rpm/min) with respect to time. The ARM outputs from the CAN component are TX and RX. These outputs need to be level translated in order to obtain the CANH and CANL signals. MCP2551 is the CAN transceiver IC used CAN requires only two wires a CAN bus. A standard jumper wires may be used to connect two CAN nodes. Three components are used in the hardware design LCD, and CAN controller.

Conclusion & Future Scope

The data set of commuting trips gathered during this experiment was examined in terms of overall commuting time and opportunity for ACC or CACC use, as measured by the number of events when the motor was travelling at different speeds. Most of the baseline following events that were collected during this study were relatively short, with the mean speeds during the events ranging from just over 60-90 mph (the cutoff for this analysis) up to freeway cruising speeds. In future, the system can be improved and reduce the cost of the implementation.

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