

An Autonomous and Car-Following System via DSRC Communication

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ABSTRACT

Inertia navigation system is capable to backup GPS unavailability. An autonomous system integrated different sensors to offer robots or remotely operated systems a reliable navigation means. This paper addresses an autonomous design method to accomplish continuously position positioning based on GPS positioning, gear-box speed, odometry, IMU and DSRC in deck reckoning. Besides, the availability of autonomous function is verified and applied using vehicles in car following or cooperative driving. This paper also presents an inter-vehicle geocasting format to accomplish multihop and car-following in cooperative driving and data exchanged based on GPS/IMU positioning and DSRC. The car following provides warning or situation awareness to drivers based on broadcast messaging the motions of neighboring vehicles obtained by one-way communication from other vehicles. The proposed system has the advantage of omnidirectional transmitting/receiving functions of DSRC module that provides 360-degree coverage in own surveillance region. The proposed system is carried out with theoretical application and hardware integration, and furthermore the result shows navigation ability and intelligent approach applicability.

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INTRODUCTION

Every year in Taiwan, about two thousand deaths within 24 hours in traffic accidents, there are about 2539 deaths per hundred thousand people and the statistical number is very serious in the world [1]. While many different factors contribute to vehicle incidents or accidents, such as rainy day or blind spot area, driver behavior is considered as the main cause of more than 95 percent. Traffic safety, in terms of infrastructure or injuries, has been discussed and improved by government's policy. However, the numbers of deaths or injuries have remained relatively flat due to the increasing number of vehicles or fatigued driving with low attention. In the recent years, more and more people like to have a team travel in the weekend. People like to take a portable navigation device with them. It provides high accuracy position, any weather condition and has the advantage in faster positioning. Although it is easier to know own location mapped onto GIS, groups of team trip cannot be aware of others position.

The inertial navigation system (INS) can overcome this shortcoming by inertia sensors. The acceleration and spatial information can be obtained from accelerometers and gyroscopes of any moving platform. An INS is an all-weather autonomous navigation system that can provide continuous

position, velocity and attitude information in real-time operation [2]. The main defect of the INS is that its mean-square navigation error increases with time and needs frequent calibration with reference signals. INS error accumulates due to inertial sensor's performance with time that long period performance of INS becomes less accurate. A vehicular unit (VU) could sense vehicle speed and heading by calculating odometry. Although lower accuracy inertial sensors might cause the integration error with time in speed and vehicle spatial motion, a VU could provide continuous speed and heading with movement through controller area network (CAN). As a result, an idea of GPS/INS and VU integrated system tries to adopt commercial GPS and inertial sensors to construct a higher reliable and better accurate navigation in lower cost platform. In order to limit INS navigation errors, the INS position information could be updated in accordance with GPS, and vehicular data information is updated and enforced by VU data acquisition and computation.

In the context of ITS, wireless communication plays a fundamental role in the recent two decades. In system concept, a vehicle can broadcast its driving parameters to others over Wi-Fi technologies, like dedicated short range communication (DSRC) [3]. The choice of ad hoc network,

contrary to cellular network, is more rigorous and justified by the fact that the network is organized without an infrastructure which avoids data blocking or unavailability of the network as in 2.0 to 3.5G mobile communication. To meet a higher vehicle safety, DSRC which has a wireless communication protocol in the 5.9 GHz frequency band plays an important role in vehicular system. Indeed, by communicating information in remote surveillance on possible emergencies, dangerous events can be avoided. Thus, exchanged data can be used to improve the safety and become aware of neighboring vehicles location, including speed, location and heading. In addition, IEEE has taken up the standardization of DSRC by creating IEEE 802.11p [4]. In the proposed system, 802.11p protocol had been porting into embedded system for DSRC data link layer.

This paper adopted an embedded system to construct an independent navigation platform using data fusion integration for driving navigation. Combining with the GPS/IMU integration, the vehicular signals may play a potential auxiliary support to derive another package of position and moving information to enhance the autonomous capability. The hardware has been implemented on microcontrollers and carried out verification tests. The DSRC application and collision design has been presented in ARTC. Besides, the packet and data geocasting method are also designed in the proposed system. The following content will be focused on autonomous design, car-following and its verification.

SYSTEM ARCHITECTURE

The system technology is designed with an integration of INS module and data transmitting through DSRC module. The INS module could provide a good positioning solution, and then the positioning information may display on the screen to monitor other neighboring vehicles in remote operation. The vehicular data of vehicle will be routed by CAN module and broadcast to neighboring vehicles by UDP protocol onto the internet via DSRC communication. The concept of proposed system architecture is shown in [Figure 1](#). The test information is debugged and showed in the screen of laptop using well defined format, and the total lengths which follow CAN 2.0A are about 8 bytes with its id in different devices.

A general vehicular communication which depends on its coverage area can be classified into four categories: inter-vehicle, outer-vehicle, vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V). A common solution, Bluetooth, its coverage is too low to do vehicular communication as a precaution. In outer-communication, mobile communication has presented its wide coverage, high reliability of data transmission in surveillance applications. However, mobile communication has a drawback in time delay about 1.0 sec in TCP mode or 0.8 sec in UDP mode [5]. To meet a high converge, data rate and low time latency, DSRC is a good choice, and it theoretically provides up to a 1 km range and allows communications between vehicles moving up to 160

km/h [6]. It also has low latency about 50 millisecond and 8 priority levels. In DSRC software, the network protocol is based on IEEE 802.11p standard under open system interconnection (OSI) model. This layer is ported from revising 802.11a, and other layers are followed UDP/IP mode.

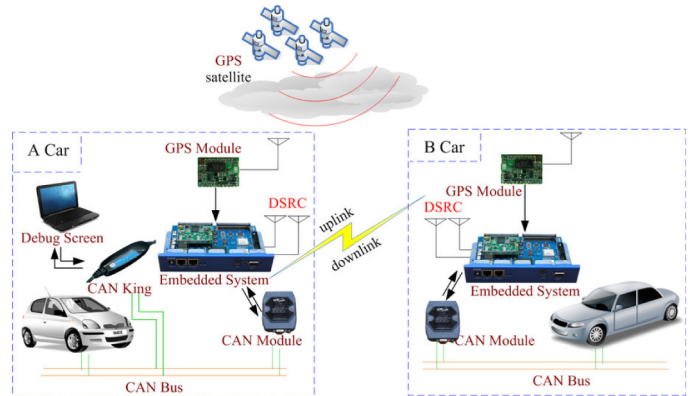


Figure 1. System architecture.

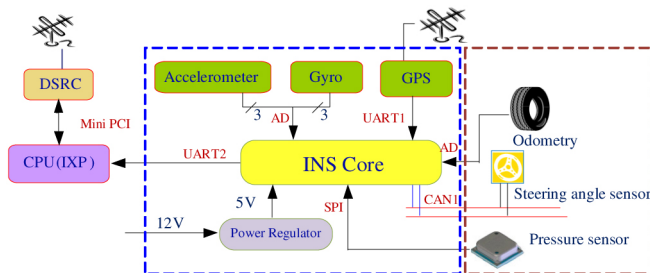
A. THE PROPOSED SYSTEM ARCHITECTURE

A data fusion of car-following system platform is built of the basic three parts, including INS module, DSRC communication unit and vehicle unit. A X86 processor is the mainly adopted controller, where the embedded kernel to access data input and output is programmed. To fulfill the proposed anti-collision application, INS data as well as vehicular data are processed in specific logic, digital formats and sent through DSRC module in controlled intervals. The data packet is formed up in X86 processor from the peripheral sensors as well as INS. Each data packet is collected and sent to DSRC module within each cycle of data surveillance. Meanwhile, the processor is activated by embedded Linux system. The USB of embedded system interface is simulated as a serial port that is used as COM1 port for INS module to capture positioning data, and two mini-PCI slots for DSRC modules to transmit data or receive data from other vehicles.

An INS module, autonomous function, is built of the basic four parts of processing core; Inertial Measurement Unit (IMU) sensors with accelerometer and gyroscope; GPS Receiver and vehicular information unit [7]. The system architecture of INS core is shown in [Figure 2](#). The dsPIC30F6014 [dsPIC30F6014 Datasheet, Microchip Products Inc., web: <http://www.microchip.com/>] is chosen as the core controller to handle real time message. Time slots are used to process and measure the inertial sensors data and GPS data through Universal Asynchronous Receiver and Transmitter (UART) port.

Table 1. Requirements and specifications of INS Core.

Criterion	Required	Desirable	dsPIC30F6014
On chip nonvolatile memory	Enough to eliminate need	for data storage and use to buffer the data	144kB Flash, 8kB RAM
ADC	6 channels, at least 12-bit resolution, with 100SPS	Simultaneous sampling, ADC buffer memory	16 channels, 12-bit resolution, simultaneous S/H, up to 500k SPS
I/O pins	Enough I/O pins to support transmission	I/O pins available for more buttons	Over 48 I/O pins
Timers	At least one 16-bit timer	More timers	5*16-bit timers available
Controller Area Network interface	Data Acquisition from CAN	Vehicular data available	2 channel CAN, up to 500 kbits

**Figure 2. Block diagram of INS.**

B. AUTONOMOUS CORE (INS)

The dsPIC30F6014 is Microchip product for signal processing. This chip is designed to perform as supervisor core, where GPS message and inertial analog signals are on-lined captured, sampled and processed, back to the DSRC application, while the vehicular data is determined as the calibrated information. This INS core has the communication interface to a personal computer/IXP to downlink messages and broadcast to adjacent vehicles in real time. As the needs for the system, the specification and requirement of dsPIC30F6014 are listed in the following Table 1.

An IMU is a closed system that is used to detect altitude, location, and motion. It normally uses a combination of accelerometers and gyroscopes to track the vehicle motion in attitude and location. The IMU is capable to transmit inertia data from core to IXP, where the interface is full duplex UART2. In order to output vehicle spatial states, it is accomplished by integrating an output set of sensors, such as gyros and accelerometers. Gyros measure angular rate with reference to inertial space, and accelerometers measure linear acceleration with respect to vehicle's frame. The IMU utilizes a tri-axis accelerometer and three one-axis gyroscopes as inertial measurement components. The accelerometer is measured for X-Y-Z axis, while the gyros are assigned to X-Y-Z axis correspondingly. The IMU plays a full inertial function for vehicle in real time.

The ADXRS614 operates on the principle of a resonator gyroscope. The output signal of ADXRS614 is a voltage proportional to angular rate about the axis normal to the top surface of the package. With the increase of the rotation rate,

the output voltage leaves the neutral point [ADXRS614 Datasheet, Analog Devices Products Inc., UK, web: <http://www.analog.com/>]. An external capacitor is used to set the bandwidth. Use external capacitors in combination with on-chip resistors to create two low-pass filters to limit the bandwidth of the ADXRS614's rate response. ADXL330 is made by the principle of resonant accelerometers. It can measure both dynamic acceleration (e.g., vibration) and static acceleration (e.g., gravity). The outputs are analog voltages proportional to acceleration [ADXL330 Datasheet, Analog Devices Products Inc., UK, Rev. A., 2003. Available on web: <http://www.analog.com/>]. This sensor is capable of measuring both positive and negative accelerations to at least ± 3 g. Because the signal measure from the accelerometer is analog, it may be disturbed by external noise. According to specifications, the external capacitor can be chosen to determine the bandwidth of the accelerometer, e.g., $0.47\mu\text{F}$ capacitor for 20 Hz is used in this paper.

C. VEHICLE UNIT FROM ON-BOARD DIAGNOSTIC CONNECTOR

The amount of electronic devices in vehicles is diagnosed by CAN bus in recent years [8]. In system platform, data is transmitted or received by CAN bus. CAN is a serial, asynchronous, multi-master communication protocol for connecting electronic control modules, sensors and actuators in automotive and industrial applications. The CAN-based system is based on the broadcast communication mechanism which is achieved by using a message oriented transmission protocol. The bit rate of CAN bus is up to 1 Mbps and is possibly operated at network lengths below 40 meter. In this study, the data rate is 500 kbps and its sampling point is held in 75%.

The CAN bus is designed and built in self-defined protocol, but the data acquisition from OBD should refer to motor standard [9]. To fulfill the proposed application, steering angle data as well as inertial data are processed in specific logic, digital formats and sent through CAN bus in controlled intervals. Each data packet is less than 8 bytes using standard ID (11 bit); moreover, the refresh time of packets is about 20ms. The CAN transceiver is the interface between the CAN protocol controller and the physical