INNOVATIVE APPROACH FOR INTEGRATED HIGHWAY TOLL GATE SYSTEM WITH AUTONOMOUS CAR USING RFID

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ABSTRACT

In this work we describe the integrated highway management system using RF technology and CAN based car automation system. Radio Frequency Identification (RFID) system is looked upon as one of the top ten important technologies in the 20th century. Industrial automation application is one of the key issues in developing RFID. Therefore, this paper designs and implements a RFID-based autonomous mobile car for more extensively application of RFID systems. Controller Area Network (CAN) technology is adopted by most automation industries, especially in automotive industry nowadays. This paper introduces a built network for data CAN transmission after the data acquisition (DAQ) from the required temperature sensors mounted on a car engine. The network should be able to be applied in various transportation industries due to its flexibility, extensibility and feasibility. In country like India the highways plays a vital role in social and economic development. Recent years with the rapid development of our economy, the growth of highway becoming faster. To overcome the highway management issues we propose the integrated highway management system based on the radio frequency identification (RFID) technology in which we will be tracking vehicles and Electronic toll collection system will be implemented. The electronic toll collection system offer the possibility of charging road vehicles in more flexible way and allow infrastructure charging policies to be implemented.

Keywords: technology; integrated management; highway; traffic supervision; no parking fee system; path recognition; CAN controller

1. INTRODUCTION

Road fatalities are a major concern in the developed world. Recent studies [1] show that a third of the number of fatal or serious accidents are associated with excessive or inappropriate speed, as well as changes in the roadway (like the presence of road-work or unexpected obstacles). Reduction of the number of accidents and mitigation of their consequences are a big concern for traffic authorities, the automotive industry and transport research groups. One important line of action consists in the use of advanced driver assistance systems (ADAS), which are acoustic, haptic or visual signals produced by the vehicle itself to communicate to the driver the possibility of a collision. These systems are somewhat available in commercial vehicles today, and future trends indicate that higher safety will be achieved by automatic driving controls and a growing number of sensors both on the road infrastructure and the vehicle itself [2].

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A prime example of driver assistance systems is cruise control (CC), which has the capability of maintaining a constant user-preset speed [3], and its evolution, the adaptive cruise control (ACC), which adds to CC the capability of keeping a safe distance from the preceding vehicle [4]. A drawback of these systems is that they are not independently capable of distinguishing between straight and curved parts of the road, where the speed has to be lowered to avoid accidents. However, curve warning systems (CWS) have been recently developed that use a combination of global positioning systems (GPS) and digital maps obtained from a Geographical Information System (GIS), to assess threat levels for a driver approaching a curve too quickly [5]; likewise, intelligent speed assistance (ISA) systems warn the driver when the vehicle’s velocity is inappropriate, using GPS in combination with a digital road map containing information about the speed limits [6]. However useful, these systems are inoperative in case of unexpected road circumstances (like roadwork, road diversions, accidents, etc.), which would need the use of dynamically-generated digital maps. The key idea offered by this paper is to use Radio Frequency Identification (RFID) technology to tag the warning signals placed in the dangerous portions of the road.

In the last years, RFID technology has been gradually incorporated to commercial transportation systems. A well known example is the RFID-based highway toll collection systems which are now routinely employed in many countries, like the Telepass system in Italy or the Autopass system in Norway. Other uses include monitoring systems to avoid vehicle theft [7], access control to car parking or private areas [8], and embedding of RFID tags in license plates with specially coded IDs for automatic vehicle detection and identification [9]. Placement of RFID tags on the road lanes has been proposed in order to provide accurate vehicle localization in tunnels or downtown areas where GPS positioning might be unreliable [10]. In the work by Seo et al. [11], RFID tagging of cars is offered as an alternative to traffic data collection by inductive loops placed under the road surface. The information about the traffic collected by a network of RF readers is then used to regulate traffic at intersection or critical points in the city. The work by Sato et al. [12] describes an ADAS, where passive RFID tags are arranged in the road close to the position of real traffic signals. An antenna placed in the rear part of the car and close to the floor (since the maximum transmitting range of the tags is about 40 cm) permits reading of the information stored in the tag memory and conveys a visual or auditive message to the driver. Initial tests at low driving speeds (20 km/h) show good results.

The work described in this paper is a collaboration between AUTOPIA (Autonomous Vehicles Group) and LOPSI (Localization and Exploration for Intelligent Systems), both belonging to the Center for Automation and Robotics (CAR, UPM-CISC). The aim of the research is to build a sensor system for infrastructure to vehicle (I2V) communication, which can transmit the information provided by active signals placed on the road to adapt the vehicle’s speed and prevent collisions. By active signals we mean ordinary traffic signals that incorporate long-range active RFID tags with information stored into them. This information is collected in real time by RFID sensors placed onboard of the vehicle (an electric Citroën Berlingo), which we have modified to automatically change its speed to adapt to the circumstances of the road. In
particular, we have implemented a fuzzy logic control algorithm acting on the longitudinal speed of the vehicle, with actuators which control the vehicle’s throttle and brake to reach and maintain a given target speed.

2. THE OVERVIEW OF RFID TECHNOLOGY AND CAN

An RFID system consists in a set of emitters or tags which, periodically or upon interrogation, transmit a short digital radiofrequency message containing an identification code (unique to each tag) as well as some data stored in the tag’s memory. These data can be obtained remotely by a computer equipped with an RFID reader. Besides the tag ID, which confirms the presence of the tag within the detecting range of the reader, the RFID reader measures the received signal strength (RSSI) of the RF signal, which is an indicator of the range from tag to reader.

The main advantage of RFID systems— with respect to other RF technologies, which could be used for infrastructure-to-vehicle (I2V) communications—is its low cost and minimum infrastructure maintenance, which results in a high scalability and easy deployment of the infrastructure. The kind of active RFID tags used in this research are cheap (10–20 euros each), can be easily attached to the traffic signals and last for at least five years. For this application we have chosen RFID equipment provided by Wavetrend Inc. Two model RX-201 RFID readers are placed on the right side of the computer controlled vehicle, and are polled by a PC through the serial port (two independent readers are used for redundancy, since occasionally tag detections might be missed by one reader). RFID data are transmitted upon detection through an Ethernet connection. It is convenient that the RF signals from the tags placed in the traffic signals are detected from a distance large enough that timely control actions might be taken over the car.

Physically, the transmitting range of an RF system is limited by the interference of the wave transmitted directly from emitter to reader, and the one reflected by the ground plane [Rappaport 1996]. For ranges larger than a critical distance, these two waves cancel each other out, and the received signal strength decreases sharply.

Radio Frequency Identification, is a technology used for the automatic identification and tracking of goods, animals and people. A typical system consists of a three parts — a transponder, a reader, and a controlling application. Transponders hold data on whatever person or object they are attached to, usually containing a unique code used for identification, such as a serial number. When within an appropriate range of a reader, the transponders transmit this data to the reader using radio waves[5]. The reader decodes this radio signal into digital information, which is then relayed to a computer application that makes use of it. RFID technology is extremely widespread, used in many different applications such as security systems, public transport payment systems, the tracking of commercial goods, and livestock identification.

3. THE INTEGRATED MANAGEMENT SYSTEM OF HIGHWAY

Integrated management system of highway based on RFID technology consists of a series of subsystems, including the monitoring and controlling subsystem of freeway, the freeway...
subsystem of multi-path identification and tolling split account management, the highway toll collection subsystem of RFID and the comprehensive information management platform of resource sharing. Moreover, various systems carry on the exchange and transmission of data information using the computer networking technology and they are all monitored and managed by the total management centre system of highway. Besides, they can provide powerful data support for the movement of their respective system and achieve the sharing of information resources.

3.1. The monitoring and controlling subsystem of freeway

In order to enhance the effectiveness of highway management, this paper proposes a traffic monitoring and management system of highway based on RFID technology. The specific operations of the system are as follows: It consists of two parts. In the control point, it is composed of the RF tags which are attached to the vehicle and contain the information of ID card, vehicle brands, driver’s name and others, the readers that are installed in the various control points and antennas. It can achieve automatic identification of vehicle identity and the supervision of vehicle, and simultaneously transmits the monitoring data to the total control centre server through the network. In the highway’s total control center, we carry out the binding of radio frequency cards and driver’s identity to realize the information management of vehicle, which includes checking the payment records of vehicles, the legitimacy of the vehicle, etc. Moreover, according to the ID number of RF card attached on the vehicle and the IP address of the receiver, and combining with GIS and GPS technology, managers can timely and intuitively understand the traffic condition and determine the position of vehicle to realize the tracking of traveling vehicles, the real-time control and scheduling of vehicle, the optimization of traffic routes and the alleviation of traffic congestion. With this advanced traffic monitoring tool, it makes the level of scheduling, command and management in highway get greatly enhanced. The monitoring identification system of highway based on RFID technology is shown as figure 1.
3.2. The radio frequency identification toll subsystem

In here, we put forward highway radio frequency identification toll system based on RFID technology. It can achieve the collection of charges without stopping in the condition of vehicle running in high speed. The concrete operations are as follows: It is need to install equipment required by the system in each expressway toll station, namely, installing reader, intelligent controller, the data transmission unit, intelligent remote non-contact charging machines and other facilities in the engine room of toll station, installing antenna and installing the electric fence, lights, alarms and other devices in the side of road to realize automatically the release or block of vehicle after the payment[8]. When a high-speed vehicle drives into the work area of antenna in toll station through the traffic lane, the reader automatically identifies information (such as the code of electronic tag, the code of vehicle type, the information of ownership, the code of toll station in entry ways, the date and time of getting through toll station in entry ways and so on.) that is carried by the vehicles electronic tag, and simultaneously carries on the confirmation of the vehicle identity, then the data information will be transmitted to toll collectors in the toll station using the data transmission unit after that confirmation isn’t wrong. By now, the toll collector in toll station will carry on automatic collection according to the amount of collection that is confirmed by the centre toll collection system in the total management centre. After the success of collection, it opens the signal--green light and directs the vehicle to pass normally. If no signal is received or the information of vehicle type is not legal, then the warning will be given out and the toll station will execute the manual handling. Simultaneously, charging information is automatically uploaded to the total management centre system to store, preparing for others use. The highway radio frequency identification toll system is shown as figure 3.

![Figure 3: The radio frequency identification toll system of highway](image)

3.3. Efficiency analysis of the integrated management system

The highway integrated management system based on RFID technology is the final reflect form to realize the informatization of highway. Firstly, its application solves the problems which exist...
in the management of highway well and greatly improves the level of supervision of the vehicles on the highway[9]. Moreover, carrying out the no parking fee on the highway, it improves the efficiency of toll collection greatly, eliminates the disadvantages of the traffic congestion in expressway and makes the efficacy of highway play to the best. At the same time, because there is no person engaging in the process of charge, so it eliminates the artificial errors and the illegal thing about corruption and so on[12]. Furthermore, it also avoids the loss of toll and makes the toll collection become more reasonable and transparent. Finally, it makes the management of highway become more modern, informationalized and intelligent.

3.4. Description of the Cruise Control Architecture

The proposed architecture for cruise control is shown in Figure 4, and comprises two parts: placement of RFID sensors (tags) in the road’s traffic signals, and the on-board systems in the vehicle, which we will describe in this section.

The autonomous longitudinal control of the vehicle takes place in three stages: environment perception (sensor data acquisition), decision, and control action. The perception stage corresponds to the acquisition of information from the environment and the car itself, and passing it to the control computer. There are three sensorial inputs: RFID detections from active traffic signals detected on the road (this is performed by a secondary PC in the car and transmitted to the main computer by an Ethernet connection); an on-board GPS receiver for acquiring driving information; and, finally, readings from the Hall effect sensor located in one of vehicle’s forward wheels, with an accurate estimation of the vehicle’s velocity. The decision stage is responsible for interpreting the data obtained in the perception phase, and is divided in two phases. The first is the co-pilot, whose mission is to select among all the different controllers. These controllers—all of them based on fuzzy logic—have been designed to take

**Figure 4. Control scheme onboard the vehicle and its interaction with the infrastructure.**
into account any possible traffic condition in the longitudinal control—straight-road tracking, bend tracking, intersections or adaptive cruise control [4,14]. The second phase is the pilot, made up by the low level controllers that decide which is the best controller for each traffic situation and generate the output for the actuators. This phase is divided in the lateral and longitudinal control, to evaluate the behavior of the proposed system, only the fuzzy longitudinal controller is needed.

The latter stage is the actuation stage, which is in charge of the execution of the goals coming from the previous stages. Its function is to adapt the output value generated by the pilot to values that can be applied to the actuators, i.e., throttle and brake pedals. The actuators have been modified to permit autonomous control of the longitudinal speed/position of the vehicle, but its lateral position is still controlled by the driver with the steering wheel.

4. EXPERIMENTAL RESULTS
We had developed an prototype of the can based car automation and RFID based toll gate collection system
PROGRAM
Main routine
void main()
{
  unsigned char i;
balance1 = 20;
balance2 = 20;
led=0;
greenled=0;
relay=0;
balance=0;
pauper1=0;
pauper2=5;
pauper3=0;
IE=0x84;
IT0=1;
IT1=1;
delay(8000);
initial();
delay(2000);

for (;;)
{
  loop:
    P3=0xFE;
    SBUF = ' ';  
    IE=0x8b;
    snap=1;
    initial();
    command_write(0xC0);
    for(i=0;i<20;i++)
    {
      data_write(array0[i]);  //lcd display--Toll collection
    }
    command_write(0x94);
    for(i=0;i<20;i++)
    {
      data_write(array1[i]);   //lcd display--Based on rfd
    }
    crook=0;

    receive1();
    IE=0x00;
    compare();
}
if (balance < 10)
{
    crook = 1;
}
if (crook == 1)
{
    command_write(0x94);
    for (i = 0; i < 20; i++)
    {
        data_write(array5[i]);    //lcd display--Not permitted
    }
    command_write(0xD4);
    for (i = 0; i < 20; i++)
    {
        data_write(array5[i]);    //lcd display--Not permitted
    }
    snap = 1;
    IE = 0x8k;
    delay1(10000);
}
else
{
    balance = balance - 10;  //balance 10 rs reduce
    command_write(0xD4);
    for (i = 0; i < 20; i++)
    {
        data_write(array6[i]);
    }
    deci2ascii4lcd(balance);
    command_write(0xE3);
    data_write(digit2);
    data_write(digit1);
    data_write(digit0);
    IE = 0x84;
    delay1(10000);
}
goto loop;

4. CONCLUSIONS

This paper presents an architecture for automatic adaptation of the longitudinal speed control of a vehicle to the circumstances of the road which can help to decrease one of the major causes of fatalities: the excessive or inadequate vehicle speed. Our approach is based on a combination of
different sensor technologies: RFID tagging of traffic signals to convey their information to the car, Hall Effect sensors located in the vehicle’s wheels for high accuracy measurement of the speed of the car, and DGPS for precise positioning of the vehicle and control loop time. Sensor fusion is applied to the information received by these subsystems, and used to adjust the longitudinal speed of the vehicle with a fuzzy controller. The proposed on-board architecture is portable and easily adaptable to any commercial car with minimal modifications.

The system shows promising results, since active RFID technology permits to detect the presence and identity of the traffic signals reliably and sufficiently in advance, so corrective actions on the vehicle’s behaviour can be taken. The integrated highway management system proposed in this paper has good guiding significance for management mode of highways and an intelligent traffic management expert system with RFID technology. The system provides both practically important traffic data collection and control information and can trace criminal or illegal vehicles such as stolen cars or vehicles that evade tickets, tolls or vehicle taxes. By doing so, increased efficiency will be guaranteed since RFID is known as a highly stable technology. With the elimination of human interaction in the entire toll collection process, we can create a better ETC system to be implemented in Malaysia.

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