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The System Design and Implementation of Vehicle Management

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***Abstract*—This paper describes the system design and implementation of a vehicle management system and covers the following five sections: (1) GPS signal. (2) Microcontroller functions. (3) SD card storage technology with FAT32 file system. Most MCU use FAT16 file system to manage files, but it wastes a lot of memory space when small files are stored to each cluster. Using the FAT32 file system will ensure an efficient use of the memory space. (4) GPRS transmission. (5) Real-time monitoring Server, which is used to monitor vehicles accurately in real-time. The system adopts a web-based solution aimed at gathering the information of vehicle's status and location in real-time. The location information is exposed with geographic coordinates, computed by a GPS processor in vehicle. The processor is embedded in the proposed device, a driving recorder, installed on a vehicle and responsible for transmitting location information to monitoring server. The recorder is a portable, highly accurate, and low powered vehicle tracking device, implemented with TI MSP430F5438 microcontroller.**

***Index Terms*—MSP430F5438, Vehicle Management System, FAT32**

I. Introduction

In recent years, with the continuous development of the economy, automobiles have gradually entered our lives. Although the vehicle is the most common transport, it is also one of the modes of transportation most frequently involved in traffic accidents.

In order to record and manage enough vehicle driving information to provide the necessary evidence in a traffic dispute, the intelligent driving recorder becomes more widely used.

The driving recorder can be generally divided into the traditional mechanical driving recorder and digital driving recorder. The traditional mechanical driving recorder has low accuracy, requires a long processing time, and is prone to error. In comparison, the digital driving recorder is convenient in data transmission and management, and has fewer errors, advantages of expandability, the possibility of integration, and the capability to record different data combinations according to requests.

This paper implemented a Vehicle Management System based on MSP430F5438 which carries out a solution with low cost, low power consumption, real-time processing, and high stability.

II. System Design

Fig. 1 shows the structure of the system. First of all, the system receives data from the GPS receiver. Through GPS and digital transmission, we can then collect the related vehicle's moving data, including longitude, latitude, driving speed, time, and date. All of that GPS data is sent to MSP430F5438 by the Universal Asynchronous Receiver/Transmitter (UART). GPRS also uses UART to transmit. There are two ways to process the data from the MSP430F5438 microcontroller shown in Fig. 1. The primary way is using a GPRS module to transmit vehicle information to management server for instantaneous monitoring. The second way is using Serial Peripheral Interface Bus (SPI) to access SD card. Stored trajectory data on SD card can be retrieved afterward if vehicle instantaneous information received by management server not successfully.

In accordance with FAT32 file system, specification based on SD card file system is implemented. An underlying SD card process was developed and integrated with the FAT file system, which enables rapid file storage when developing an embedded system. The data of real-time collection can be stored on the SD card in the form of text by the file system in a short time. If GPRS has no signal, the trajectory of the vehicle can be obtained from the SD card. The back-end server works via GPRS wireless communication and the Internet. The real-time monitoring server processes the spatial coordinates, real-time location, driving speed, time, date, and vehicle trajectory for producing the relative maps to achieve the purpose of real-time monitoring. At the same time, GPS data is still written to a file on the SD card continuously.

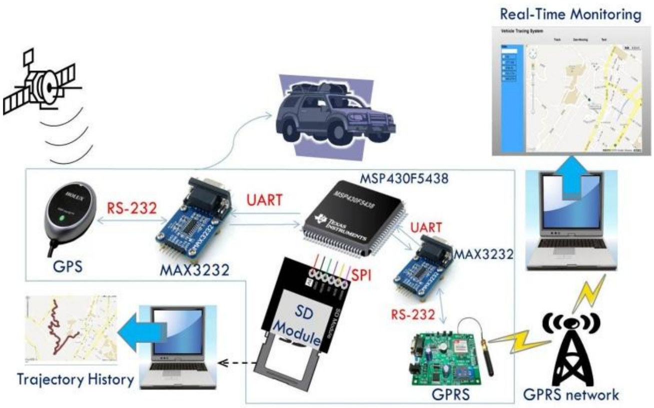


Fig. 1. The structure of system

A. Data Collection

This system receives the digital data from GPS. The GPS data includes longitude, latitude, speed, UTC time, date, and message produced from the mobile vehicles. The user can operate the real-time system to control the vehicle position status.

Many GPS receivers provide navigational output data so that the device can be connected, for example, to a PC to collect and analyze this data. This output data is usually in serial format and the communication protocol conforms to the RS232 serial standards.

Using the MAX3232 generates the required negative voltage for a RS232 line and translates the TTL level signals from the MSP430F5438 levels to RS232 levels [1]. The MAX3232 board is used for establishing RS232 communication with devices powered from 3V ~ 5V. It contains RS-232 Transceiver and DB9 connector used for connecting PC and MCU.

The default serial communication parameters of most GPS receivers are set as follows [2]:

1) 4800 Baud rate.
2) 8 data bits
3) No parity bit
4) 1 stop bit

The data output from a GPS receiver is in ASCII text format and is known as the NMEA-0183, or simply the NMEA format [3]. According to this format, navigational information is sent in the form of “sentences”, where each NMEA sentence starts with a “$” sign, each navigational parameter is separated by commas, and each sentence is terminated by two hexadecimal checksum characters.

The NMEA sentence used in this system is the $GPRMC, which has the following parameters: $GPRMC: Although there are some variations in its format, this sentence basically defines the basic navigational parameters, speed, course, date of fix, and magnetic variation. An example is:

$GPRMC,132031.000,A,2502.5585,N,12125.4856,E,12.81,354.81,100512,,,A*51

GPRMC format is described in Table I.

TABLE I: GPRMC FORMAT

Field	Format	Example	Description
1	$GPRMC	$GPRMC	Start of Sentence
2	hhmmss.ss	132031.000	UTC time
3	a	A	Position validity (A: valid, V: invalid)
4	ddmm.mmmm	2502.5585	Latitude
5	a	N	Latitude direction (N: North, S: South)
6	dddmm.mmmm	12125.4856	Longitude
7	a	E	Longitude direction (W: West, E: East)
8	x.x	12.81	Speed (knots)
9	x.x	354.81	Heading (degrees)
10	ddmmyy	100512	Date
11	x.x		Magnetic variation (degrees)
12	a		Magnetic variation direction (W/E)
13	a	A	Mode (A: Autonomous mode, D: Differential mode, E: Estimated (dead reckoning) mode, M: Manual input mode, S: Simulator mode, N: Data not valid)
14	*aa	*51	Checksum
15	<CR><LF>		End of message termination

B. Data Processing

TI’s MSP430F5438 is used as the processor of this Vehicle Management System. The processor was chosen because of its good features and integrated peripherals. Its portability and low-power consumption design can satisfy the prolonged outdoor work.

MSP430F5438 Microcontrollers (MCU) from Texas Instruments (TI) is a 16-bit, RISC-based, mixed-signal processor designed specifically for ultra-low-power [4]. It is combined with a flexible clock system by using a Von-Neumann common memory address bus (MAB) and a memory data bus (MDB). Fig. 2 shows the architecture of this microcontroller. MSP430F5438 has the right mix of intelligent peripherals, ease-of-usage, low cost, and the lowest power consumption for thousands of applications. Its flexible clocking system, multiple low-power modes, instant wakeup, and intelligent autonomous peripherals enable true ultra-low-power optimization, dramatically extending battery life [5]. Its power modes are shown in Table II. The system is running in Active Mode. If the process is finished, the system will be in Standby Mode.

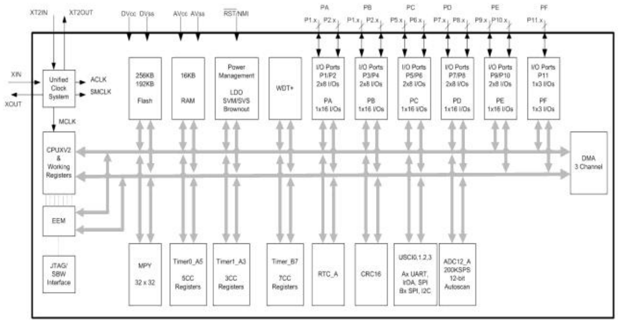


Fig. 2. MSP430F5438 architecture

TABLE II: MSP430F5438 POWER MODES

Ultra low Power Consumption	
Mode	Current
Active Mode(AM)	165µA/MHz
Standby Mode(LPM3 RTC Mode)	1.5µA/MHz
Off Mode(LPM4 RAM Retention)	1µA/MHz
Shutdown Mode(LPM5)	0.1µA/MHz

Fig. 3 shows hardware connection, and the work flow of the MSP430F5438 is shown in Fig. 4. After turning on the device, it automatically initializes the hardware, file system and SD card. Then it gets the GPS data in NMEA 0183 format of GPRMC. This GPS data will be placed in RX_buffer. It creates files by date, so, if the device turns on for the first time, FAT32 will create a new file on the SD card and write data from RX_buffer. It then tries to connect to GPRS. If it fails due to GPRS unavailability, then the data is still stored on SD card, and it tries to connect to the GPRS again. After establishing the GPRS connection, it tries to connect to the service provider’s server using the HTTP protocol. If the connection is successful, the GPS data will be sent to the server as a string. In this way, the device communicates with the server and sends the current location.

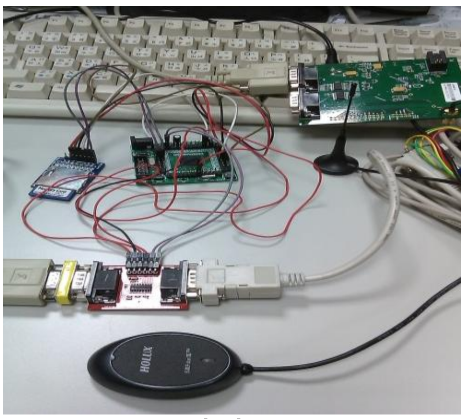


Fig. 3. System hardware connection

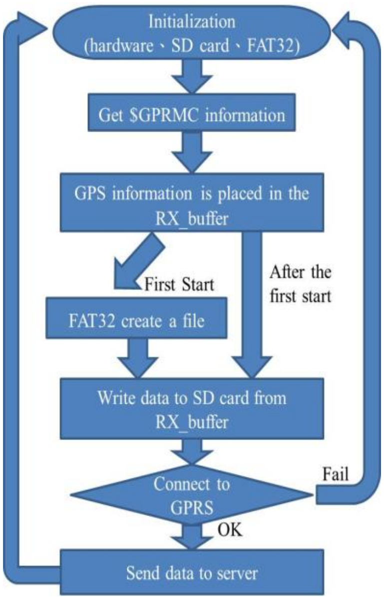


Fig. 4. Processing flowchart of the system

C. Data Storage and File Management

The system is equipped with a removable sending SD (Secure Digital) card, which is used for GPS data storage. Saving the acquired data by this type of storage media is appropriate not only because of its large capacity, but also because of the subsequent processing of stored data, which is performed in the service application on a PC of Windows. If GPRS service fails, the past trajectory information of the vehicle can still be obtained from the SD card.

In order for the system to read and write from the SD card, the SPI (Serial Peripheral Interface) from MSP430F5438, shown in Fig. 5, is used. The number of signals of SPI (three or four wires) is larger than IIC's two wires, but the transfer rate can rise up to 20 Mbps or higher depending on the device's ability (5~50 times faster than IIC). The SPI interface permits communication with only four physical connections. The basic configuration consists of a clock signal, a Slave In Master Out (SIMO), a Slave Out Master In (SOMI) and a Slave Select (CS), besides 3.3V and GND [6].

When interfacing multiple slaves to a single master, the slave ICs can be attached in parallel, and separate CS signals from the master IC are connected to each slave ICs. The data output of the slave IC is selected by which CS signal is enabled, and deselected devices are disconnected from the MISO line.

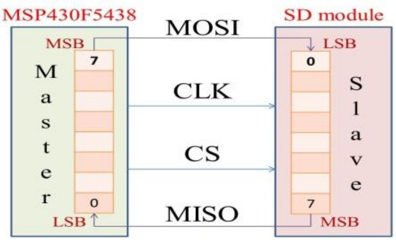


Fig. 5. SPI single Master / Slave application

For the SD Memory Card protocol, the SPI messages consist of command, response and data-block tokens [7]. All communication between the host and the cards is controlled by the host (master). The host starts every bus transaction by asserting the CS signal low.

The SD commands are shown in Table III.

TABLE III: SD COMMANDS OF SPI MODE

Command	Argument	Response Type	Description
CMD0	None	R1	Reset the SD Memory Card.
CMD1	None	R1	Activates the card initialization process.
CMD9	None	R1	Asks the selected card to send its CSD.
CMD16	block length	R1	Set the block length.
CMD17	data address	R1	read a block data address.
CMD24	data address	R1	write a block data address.

To make managing the data easier, the FAT32 file system support was implemented in the processor. FAT32 uses space more efficiently than FAT16 [8]. Table IV shows the cluster size, comparing FAT32 with FAT16. FAT32 uses smaller clusters (4 KB for drives up to 8 GB), resulting in 11 to 15 percent more efficient use of disk space compared to large FAT16 drives [9]. FAT32 also reduces the resources necessary for the MCU to operate. The boot record on FAT32 drives has been expanded to include a backup of critical data structures [10]. This means that FAT32 volumes are less susceptible to a single point of failure than FAT16 volumes.

TABLE IV: FAT32 VS. FAT16

Drive Size	Default FAT16 Cluster Size	Default FAT32 Cluster Size
16MB~32MB	2KB	Not support
32MB~127MB	2KB	512Bytes
128MB~255MB	4KB	512Bytes
256MB~259MB	8KB	512Bytes
260MB~511MB	8KB	4KB
512MB~1023MB	16KB	4KB
1024MB~2047MB	32KB	4KB
2048MB~8GB	Not support	4KB
8GB~16GB	Not support	8KB
16GB~32GB	Not support	16KB
>32GB	Not support	32KB

D. Wireless Communication

On this system, the user can send out wireless communications by GPRS, text, and status messages. Thus, a powerful communications tool is created, enhancing the organization's performance and efficiency to achieve the purpose of real-time monitoring.

The GPRS of system is integrated with the TCP/IP protocol; extended TCP/IP AT commands are developed so the user can utilize the TCP/IP protocol easily, which is very useful for those data transfer applications.

AT command is shown in Table V.

TABLE V: AT COMMAND

AT COMMAND	FUNCTION
AT+CIPCSGP=1,"f3prepaid"	Defines GPRS Connection, APN
AT+CIPSTART="TCP","XXX.XXXX.XXX","XXXX"	Set Domain name or IP address and port, wait for "connect ok"
AT+CIPSEND	Data to be sent, use CTRL-Z to send data
AT+CIPSHUT	Disconnects the GPRS connection

E. Real-Time Monitoring Server

The GPS data is sent via GPRS service from the GSM network to a web server using the HTTP protocol [11].

Real-time Monitoring is the major part of this system. This enables the user to view the live position of a vehicle on the map. Google Map Satellite version is used to locate the position.

The server is a web-based application developed by Java Programming, and it uses PostgreSQL as the database server. The data from the data collector is stored in the PostgreSQL database. The data includes vehicles' information, coordinates, and position. PostgreSQL is chosen to be the database because it is light-weighted, scalable and able to support many platforms. Java framework, such as Hibernate, is chosen to be used in this system to make it standardized and easy to develop. JSP is used for web presentation. Google Map is used for showing vehicle information, and AJAX technology is enhanced to enable more real-time web interface. The server diagram is shown in Fig. 6. Fig. 7 shows the architecture of the server.

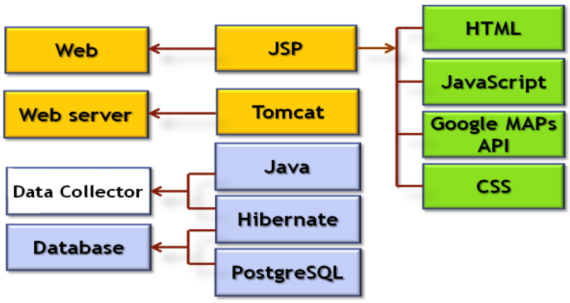


Fig. 6. Server diagram

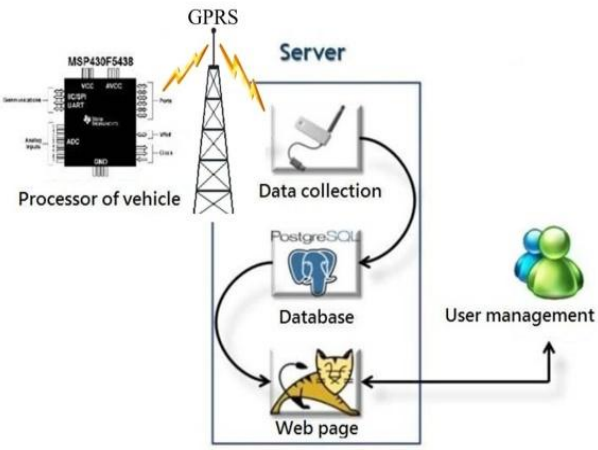


Fig. 7. Data collection server

III. EXPERIMENT RESULTS

To view the current position of the vehicle, a web-based application has been developed. Using this web application, an end user will be able to view the live position of the vehicles and also see the past trajectory stored on the SD card.

A. Real-Time Tracking

After program coding and function testing, the information system was carried out for vehicle management. It can monitor several vehicles. The server snapshot is shown in Fig. 8.

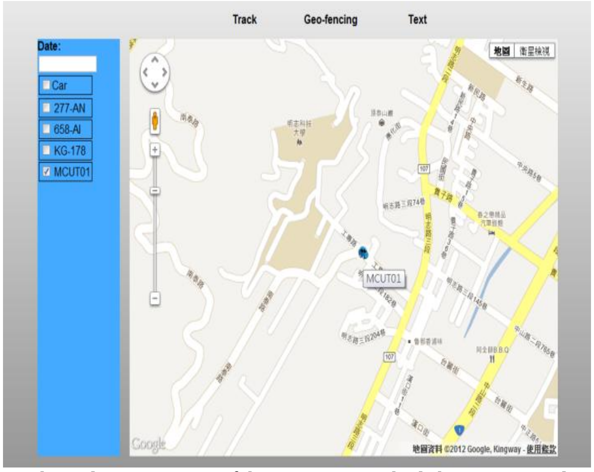


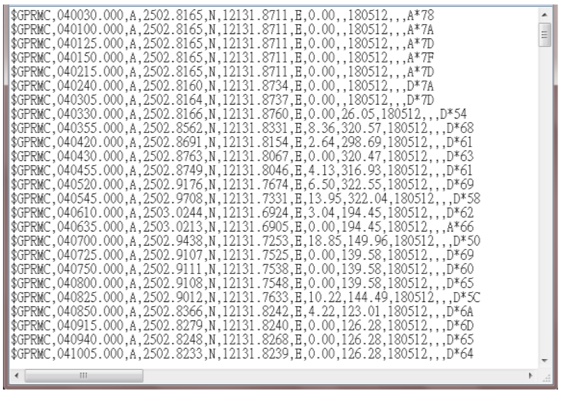
Fig. 8. The real-time position of the monitoring vehicle by using Google map

B. Trajectory History from the System

To ensure that the system's functions work, a data set collected on-site with the designed scenarios was operated on by the system to test its effectiveness in an off-line basis.

Fig. 9 shows the vehicle's trajectory. It also contains GPS data that we need.

The system obtains the GPS data from the SD card, and it then inserts the SD card into a PC to view the trajectory history of a vehicle. This part is shown in Fig. 10.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$GPRMC,040030.000,A,2502.8165,N,12131.8711,E,0.00,,180512,,,A*78
$GPRMC,040100.000,A,2502.8165,N,12131.8711,E,0.00,,180512,,,A*7A
$GPRMC,040125.000,A,2502.8165,N,12131.8711,E,0.00,,180512,,,A*7D
$GPRMC,040150.000,A,2502.8165,N,12131.8711,E,0.00,,180512,,,A*7F
$GPRMC,040215.000,A,2502.8165,N,12131.8711,E,0.00,,180512,,,A*7D
$GPRMC,040240.000,A,2502.8160,N,12131.8734,E,0.00,,180512,,,D*7A
$GPRMC,040305.000,A,2502.8164,N,12131.8737,E,0.00,,180512,,,D*7D
$GPRMC,040330.000,A,2502.8166,N,12131.8760,E,0.00,26.05,180512,,,D*54
$GPRMC,040355.000,A,2502.8562,N,12131.8331,E,8.36,320.57,180512,,,D*68
$GPRMC,040420.000,A,2502.8691,N,12131.8154,E,2.64,298.69,180512,,,D*61
$GPRMC,040430.000,A,2502.8763,N,12131.8067,E,0.00,320.47,180512,,,D*63
$GPRMC,040455.000,A,2502.8749,N,12131.8046,E,4.13,316.93,180512,,,D*61
$GPRMC,040520.000,A,2502.9176,N,12131.7674,E,6.50,322.55,180512,,,D*69
$GPRMC,040545.000,A,2502.9708,N,12131.7331,E,13.95,322.04,180512,,,D*58
$GPRMC,040610.000,A,2503.0244,N,12131.6924,E,3.04,194.45,180512,,,D*62
$GPRMC,040635.000,A,2503.0213,N,12131.6905,E,0.00,194.45,180512,,,A*66
$GPRMC,040700.000,A,2502.9438,N,12131.7253,E,18.85,149.96,180512,,,D*50
$GPRMC,040725.000,A,2502.9107,N,12131.7525,E,0.00,139.58,180512,,,D*69
$GPRMC,040750.000,A,2502.9111,N,12131.7538,E,0.00,139.58,180512,,,D*60
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$GPRMC,040825.000,A,2502.9012,N,12131.7633,E,10.22,144.49,180512,,,D*5C
$GPRMC,040850.000,A,2502.8366,N,12131.8242,E,4.22,123.01,180512,,,D*6A
$GPRMC,040915.000,A,2502.8279,N,12131.8240,E,0.00,126.28,180512,,,D*6D
$GPRMC,040940.000,A,2502.8248,N,12131.8268,E,0.00,126.28,180512,,,D*65
$GPRMC,041005.000,A,2502.8233,N,12131.8239,E,0.00,126.28,180512,,,D*64
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Fig. 9. GPS data on the SD card

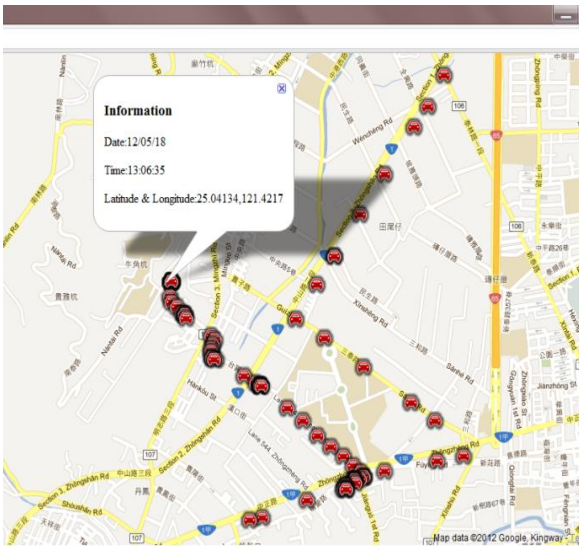

Fig. 10. Trajectory history of vehicle

IV. Conclusion

This paper presents a low power and low cost Vehicle Management System using MSP430F5438, SD card, FAT32 File system, GPS, and GPRS of GSM network that is suitable for a wide range of applications all over the world.

The combination of the GPS and GPRS provides continuous and Real-time Tracking. Data is integrated and transmitted to a web server using Apache's Tomcat extensions to provide Internet access via a vehicle tracking website. The FAT32 file system was developed to replace the older FAT16 technology. It allows for larger disk partitions and a smaller cluster size, resulting in less wasted disk space. It is more efficient for storing the GPS information of a vehicle.

This system focused on using the FAT32 file system for management, GPS information, and a web-based server has been developed.

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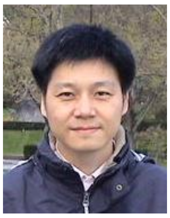

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