VEHICLE TRACKING SYSTEM USING
MICROCONTROLLER
(MSP430)

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Name of Student: KAMUNYA JOHN MARWA
Registration Number: F17/39252/2011

College of Architecture and Engineering
Faculty/School/Institute: ENGINEERING
Department: Electrical and Information Engineering
Title of the work: VEHICLE TRACKING SYSTEM USING MSP430

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ABSTRACT

Vehicle tracking system is a system that allows the owners of the vehicle to be able to know the precise location of their vehicle.

This project will focus on implementing a user-friendly web based vehicle tracking system. It will enable the user to view accurate position of their vehicle by using GPS device installed in the specific vehicle. The location co-ordinates from the GPS device are sent via a GSM module to a web-based database.
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CHAPTER 1: INTRODUCTION

1.1 BACKGROUND THEORY

Vehicle tracking system is a system that allows the owner of the vehicle to be able to know the precise location of his/her vehicle.

In addition, it may be referred as a system used to determine the location of a vehicle using different ways/methods including radio navigation system and GPS, which uses satellites and ground based stations.

From the recent years, the number of vehicles has been increasing rapidly, thus making the need of installing tracking system in one’s vehicle due to various reasons including:

- Vehicle tracking system can help to determine whether the vehicle is being used to do unrelated work activities.
- In big companies vehicle tracking system can be used as a fleet management system. Thus, it might be essential in settling any false claims or complaints against a company.
- Due to increase in number of vehicles, there has been an increase in vehicle insecurity cases. Vehicle tracking system makes it easier for one to know where to start in case the owner was carjacked.
- In the country, most of the car theft cases are unresolved by the police. Having a tracking system increases the chances of one finding the lost vehicle.
- With Vehicle Tracking System, there will be no need to keep on calling the employees to know their location. Hence reducing the company’s expenses in terms of phone bills.
- By installing a tracking system, one reduces the amount of paper work done by drivers. This also reduces the discrepancies in the records.
- Since the employees will know that their movements are being tracked, they will tend to follow the work related activities and this would lead to increase in productivity.
The above examples are just a tip of an iceberg of how fruitful installing a vehicle tracking system can be, especially for those who own fleet based business.
1.2 GPS

GPS stands for global positioning systems. The U.S government department of defense forces in the early 1970’s initialized it, but later in the early 1990’s it was made free for the civilian to use. Although up to date, the U.S government still does the repairing and maintenance of GPS satellites. Honda designed the first GPS (navigation system) in 1983. Pioneer claims to be the first with a GPS-based auto navigation system, in 1990. Magellan claims to have created the first GPS-based vehicle navigation system in the U.S in 1995. Each GPS (satellite) transmits data that indicates the current time and its location. It transmits signals to a GPS receiver. These receivers require an unobstructed view of the sky hence they can only be of effective use outdoors. The systematic operation of the GPS is as seen in the figure 1 below [6].

![Figure 1: various steps of GPS operation [6].](image-url)
The system provides essential information to military, civil and commercial users around the world, which is freely accessible to anyone with a GPS receiver. GPS works in any weather conditions at any given place in the world. Normally, there are no subscription fees or system charges to utilize GPS [7]. Ordinarily three satellites are enough to triangulate the 2-D position (latitude and longitude) but four or more satellites are preferred. This makes it possible to compensate for timing errors. This is because a single microsecond offset in a satellite atomic clock can result in wildly inaccurate positioning information. With four or more satellites in sight, the receiver can also determine the user's 3D position (latitude, longitude and altitude).

All GPS satellite constantly transmits information about time and current location above the earth. They use CDMA (code division multiple access), which is used by various cellular carriers allowing multiple satellites to communicate over the same channel simultaneously.

Once the vehicle position has been determined, the GPS unit can determine other information like speed, distance, time and other relevant information. GPS receiver used for this research work detects the vehicle location and provides information to responsible person through GSM technology.

1.3 NMEA Data

The full description of NMEA is National Marine Electronics Association. This association has developed a specification that is used to define the interface between various pieces of marine electronic equipment, which includes the GPS receiver communication.

Each type of devices has their own standard sentences and each of these sentences has two-letter prefix. For example, the prefix for GPS receiver is GP. There are another three letters followed by prefix that are used to define the contents of the sentences. The standard sentence is begins with $ sign, followed with “talker ID” (2 characters), “message ID” (3 characters), various data fields (each information is separated by commas), optional checksum (begins with * sign), and ends with carriage return or line feed [8]. The figure below shows the list of GPxxx sentences.
Figure 2: Sample data of NMEA Data

The GPGGA is a basic GPS NMEA message. There are alternative and companion NMEA messages that provide similar or additional information as shown above.

To understand the NMEA message structure, we examine the popular GPGGA message. This particular message was output from Ublox GPS receiver:

$GPGGA,181908.00,3404.7041778,S,07044.3966270,W,4,13,1.00,495.144,M,29.20
M,0.10,0000*40

All NMEA messages start with the $ character, and each data field is separated by a comma.

- GP represents that it is a GPS position (GL would denote GLONASS).
- 181908.00 is the time stamp: UTC time in hours, minutes and seconds.
- 3404.7041778 is the latitude in the DDMM.MMMMM format. Decimal places are variable.
- S denotes south latitude.
- 07044.3966270 is the longitude in the DDDMM.MMMMM format. Decimal places are variable.
- E denotes East longitude.
- 4 denotes the Quality Indicator
- 13 denote number of satellites used in the coordinate.
- 1.0 denotes the HDOP (horizontal dilution of precision).
- 495.144 denote altitude of the antenna.
- M denotes units of altitude (e.g. Meters or Feet).
29.200 denotes the Geoidal separation (subtract this from the altitude of the antenna to arrive at the Height above Ellipsoid (HAE).

M denotes the units used by the Geoidal separation.

1.0 denotes the age of the correction (if any).

0000 denotes the correction station ID (if any).

*40 denote the checksum.

1.4 GSM

GSM is the short for global system for mobile communication [8]. It is a communication system, which originated in Finland Europe and developed by using digital technology. GSM is a 2G technology that is implemented globally and used to transmit voice and low volume digital data service. Examples of low volume digital data are SMS (short message service) and MMS (Multimedia Message Service). Besides that, GSM has four frequency ranges, which are 850MHz, 900MHz, 1800MHz and 1900MHz.

1.4.1 GSM modem

GSM modem is similar to mobile phone. It is a specialized wireless modem which needs a SIM card and works with a GSM wireless network. GSM modem utilizes the radio wave for sending and receiving the messages. Utilization of SMS technology has become popular because it is an inexpensive, convenient and accessible ways of transferring and receiving data with high reliability [8]. Besides that, GSM modem can be used for automating business process, sending SMS from a computer and vehicle tracking with integrated GPS. There are three different types of GSM modem [8], which are:

- A GSM modem with SIM card can be an external modem device, which is connected to a computer through USB port, serial port, Bluetooth or infrared.
- A GSM modem can be a PC card or PCMCIA card, which is installed in a notebook computer.
- A GSM modem can also be a standard GSM mobile phone.
A GSM modem is controlled by using the AT commands. If the user would like to do the operation such as reading, writing, deleting and sending messages, an extended set of AT commands that are defined in the GSM standard are needed.

1.4.2 GSM Network

GSM network [8] is a public land mobile network (PLMN). Mobile station which is made up of a SIM (Subscriber Identity Module) card, is the user terminal in GSM network, while the mobile terminal refers to the user device such as mobile phones. A system that uses a cellular network based around broadcast stations or satellite technology that is connected to signal from orbit are part of the GSM network. The main purpose of the GSM network is to facilitate easier access to cellular and satellite platforms across international lines.

A GSM network comprises of three major systems, which are:

I. **Switching system (SS):** The main functions of this system are performing call processing and subscriber related task. The functional units under the switching system are home location register (HLR), mobile services switching center (MSC), visitor location register (VLR), authentication center (AUC) and equipment identity register (EIR).

II. **Base station system (BSS):** Base station system is responsible for radio related functions, which consists of the base station controller (BSCs) and base transceiver station (BTSs). The base station controller is used to manage the resource distribution while the base transceiver station is radio equipment, which responsible for handling the radio interfaces to the mobile station.

III. **Operation and support system (OSS):** The OSS will be connected to the equipment in the switching system and base station system. Operation and support system is used to provide a network overview, customer support for operation and maintenance activity, which required for a GSM network.

1.5 GPRS

GPRS is the acronym for General Packet Radio Services. It is available with almost every cellular network. GPRS is considered as an upgrade over the basic features of GSM. GSM and GPRS systems provide inter-working and share the resources between the users. For the mobile phone that has GPRS, it can be used to track the
subscriber’s location when connected to the cellular network. However, the standard GSM network is unable to transmit the data in packet-switched mode, so it has to be altered to support the GPRS. There are several advantages of using this technology, it allows the user to connect to internet all the time and communicate on a worldwide scale.

1.6 WEB BASED VEHICLE TRACKING SYSTEM

This system is designed using combination of various modern information and communication technologies. The system mainly consists of a vehicle-mounted device, a central server system and a web based application. Using this system, the users have the facility of monitoring the location graphically and other relevant information about their vehicles. The users are able to browse location track on a map through a developed web application embedding GOOGLE MAP and interact with database server for vehicle track details with the ease of internet access [2].

1.7 WEB INTERFACE DESIGN

To display information about vehicle tracking system to the end user, front-end software is required. This software should display all information about this system and send it to the end user. In this case, the end user is the person who has installed the tracking system or the administrator who is managing the system [4]. There may be a number of vehicles installed with the tracking system therefore the server must ensure all the vehicles information is stored in a database. The web interface should support this functionality [4]. In addition, since the web interface is all over the internet access, the interface must be restricted to authorized users only [4].
According to [2], the overall design goals of the web interface are summarized as follows:

- Define and manage all clients account information by the system Administrator.
- Define, manage and browse all agents account information and tracking data by clients.
- Receive and identify tracking information from each device unit.
- Store tracking information received from the tracking device to the related agent in the database.
- Display the track location on electronic map by using several browsing types.

The web pages are formatted using HTML elements, appearances and text layout. HTML embeds scripts such as JavaScript and PHP, which performs functions and effects on behavior of HTML pages. JavaScript performs all the background operations and functions such as login checking, data validation and paging function. In addition, JavaScript embeds Google Map API on the website using key and Google maps class provided by the Google where locations’ co-ordinates are illustrated [2].

PHP functions can be used to achieve the administration of accounts. In addition, PHP commands can be inserted directly into HTML source documents rather than using external file to process data. The administrator functions include adding, editing, erasing, perusing clients and administrators accounts and designing those accounts into tables. PHP is used at the server side to store the GPS information into forms that are less demanding to examine and check relevant parts of the received data. Finally, yet importantly, PHP functions can also be used to generate detailed reports of the agent track where the relevant information is presented as a table containing agent’s basic information and detailed tracking system information with the exact time and location.
1.8 DATABASE DESIGN

According to Dictionary.com, a database is a collection of data arranged for ease and speed of retrieval.

A database system consists of the software, hardware, users and most importantly the data. It allows users to store, protect, update, organize and retrieve their data with ease.

For this project, the database will be responsible for enforcing data integrity by ensuring that the data is collected and presented using a consistent format [2].

For the system to be usable, it must retrieve data efficiently. The need for efficiency has led to use of complex data structure to represent data in the database. The database architecture consists of the following layers:

- **Presentation layer**: This is the topmost level of application, which displays information related services. The presentation layer communicates with other tiers by outputting results to the browser/client tier and all other tiers in the network.

- **Business Logical Layer**: (Data Access Layer or Middle Layer): The logical layer is pulled out from the presentation layer and, as its own layer; it controls an application’s functionality by performing detailed processing. Another in-between layer added to make benefit of the reusable set of functions performing database operations is the DB Worker Layer.

- **Data layer**: This layer consists of database servers. The information is stored and retrieved here. This keeps data neutral and independent from application servers or business logic. Giving data its own tier also improves scalability.
CHAPTER 2: SYSTEM ANALYSIS

2.1 PROPOSED SYSTEM DESCRIPTION

GPS is one of the technologies that is regularly used in a huge number of applications today. One of the applications is tracking your vehicle and regularly monitoring them. This tracking system can inform you the exact location and route travelled by vehicle, and in addition, this information can be viewed from any remote location. It also includes the web application that provides you with the exact location of target. This system enables us to track target in any weather conditions. This system uses GPS and GSM technologies. This project includes the hardware part which comprises of GPS, GSM, MSP430G2553 microcontroller and software part which is used for interfacing all the required modules, A web application is also developed at the client side. Main objective was to design a system that provides a platform for further enhancement and installed easily.

In this project, GPS tracker with integrated Google maps is build. The GPS chip outputs the position information (latitude and longitude) of the car which is transferred over GPRS link to a mobile operator’s GGSN and then to a remote server over HTTP connection. The HTTP server stores the incoming positional data in a MySQL database when a client logs in to the tracking webpage, a PHP web application embedded with JavaScript code. The JavaScript runs in the browser and integrates this information into Google Maps through Google Maps API, which displays the position on a map. Since the positional information is retrieved almost every second and the maps are updated at the same frequency, a real time GPS tracking effect is then achieved.

2.2 SIM800L MODULE

The sim800L module has different parts that make it suitable to be of use in car tracking system for this project, these are:

- GSM baseband
- GSM RF
- Antenna interface
- Other interface

The block diagram below shows the main function parts of the GSM module above.

Figure 3: sim800L function diagram
2.3 MICROCONTROLLER (MSP430)

The Texas Instruments MSP430 family of ultra-low-power microcontrollers consists of several devices featuring different sets of peripherals targeted for various applications. The architecture, combined with five low-power modes, is optimized to achieve extended battery life in portable measurement applications. The device features a powerful 16-bit RISC CPU, 16-bit registers, and constant generators that contribute to maximum code efficiency. The digitally controlled oscillator (DCO) allows wake-up from low-power modes to active mode in less than 1 µs.

The MSP430G2x13 and MSP430G2x53 series are ultra-low-power mixed signal microcontrollers with built-in 16-bit timers, up to 24 I/O capacitive-touch enabled pins, a versatile analog comparator, and built-in communication capability using the Universal Serial Communication Interface (USCI). In addition, the MSP430G2x53 family members have a 10-bit analog-to-digital (A/D) converter. (For this project, MSP430G2553 is used).

2.3.1 Device features

The device has a low supply-voltage that ranges from 1.8V – 3.6V. In addition, the device has an ultra-low power consumption that is categorized as:

- **Active Mode**: 230 µA at 1MHz, 2.2V
- **Standby Mode**: 0.5µA
- **Off Mode (RAM Retention)**: 0.1µA

These devices consist of Universal Serial Communication Interface (USCI); which supports Enhanced UART supporting Auto Baud rate Detection (LIN), IrDA encoder and decoder, synchronous SPI and I²C™.

In addition, the device has an on-chip comparator for analog signal, compare function or slope analog to digital (A/D) conversion.

Another feature provided by the device includes serial onboard programming, thus no external programming voltage needed. This feature also provides Programmable Code Protection by security fuse.

Below is a function diagram of the MSP430G2553 that is in use for this project.
2.4 UBLOX NEO-6M GPS MODULE

The NEO-6 module series is a family of stand-alone GPS receivers featuring the high performance u-blox 6 positioning engine. These flexible and cost effective receivers offer numerous connectivity options in a miniature 16 x 12.2 x 2.4 mm package.
Their compact architecture and power and memory options make NEO-6 modules ideal for battery operated mobile devices with very strict cost and space constraints. The 50-channel u-blox 6 positioning engine boasts a Time-To-First-Fix (TTFF) of less than 1 second. The dedicated acquisition engine, with 2 million correlators, is capable of massive parallel time/frequency space searches, enabling it to find satellites instantly. Innovative design and technology suppresses jamming sources and mitigates multipath effects, giving NEO-6 GPS receivers excellent navigation performance even in the most challenging environments.

For more of the U-Blox GPS module features kindly see the attached datasheet. Its functional diagram is as shown by the block diagram below.

Figure 5: function block diagram of Ublox Neo-6m GPS
2.5 ENERGIA IDE

Energia is an open-source electronics prototyping platform started by Robert Wessels in January of 2012 with the goal to bring the Arduino and wiring framework to the Texas Instruments MSP430 based LaunchPad. Energia is based on Arduino and the Wiring framework. It includes an integrated development environment (IDE) that is based on Processing. The foundation of Energia and Arduino is the Wiring framework that is developed by Hernando Barragan. The framework is thoughtfully created with designers and artists in mind to encourage a community where beginners through experts from around the world share ideas, knowledge and their collective experience. The Energia team adopts the philosophy of learning by doing and strives to make it user friendly to work directly with the hardware [7]. Together with Energia, LaunchPad (MSP430 board) can be used to develop interactive objects, taking inputs from a variety of switches or sensors, and controlling a variety of lights, motors, and other physical outputs. LaunchPad projects can be stand-alone (only run on the Target Board, i.e. your LaunchPad), or they can be communicate with software running on your computer (Host PC). In addition, Energia is a cross-platform application written in Java that is self-installable. The Energia programs are written in C/C++. This IDE provides a powerful yet user-friendly programming environment. It allows compilation and uploading the programs to the board through USB connection.

2.6 DATABASE DESIGN

The database designed in this project is hosted on a cloud Azure server. This design is preferred to a local host because of factors such as:

- Reliability as it is accessible from anywhere as long as there is an ample internet connection.
- It provides for redundancy as the server is mirrored through other connection routes hence a contingency plan is available.

It is easy to integrate with an online web interface page, such as one used in this project. The database is hosted by a Microsoft SQL server on Microsoft Azure Cloud.
services to facilitate runtime streaming of NMEA data strings directly into the
database tables as displayed in the following diagrams below:
CHAPTER 3: SYSTEM DESIGN

3.1 Introduction
This chapter will discuss about the approach and process flows used to complete this project. Each of the hardware devices and programming that was involved in this project are also discussed.

3.2 System Overview
This project is divided into two parts, which are the tracking part and a displaying part. The tracking part is responsible for obtaining the user location while the control and displaying part is for displaying the detected location on the Google Map through a C# Windows Form application. The tracking part consists of the GPS, Micro-controller and the GSM while the displaying part was a web based application that shows location on the Google Map.

3.3 System Development
The figure below shows the design process of the Tracking system. The design process was started by writing the source code for the tracking part and displaying module. After that, the coding for tracking part was downloaded into the
microcontroller. Both of the coding for tracking and displaying parts was tested to make sure they meet the specifications. When both of the coding met the specifications, the whole system was re-tested to ensure it works properly.

Figure 6: Design flow of the Tracking System.
3.3.1 Development of Tracking Module

START

Turn on GPS and GSM on

Set the Baudrate for both GSM and GPS

Set the GSM into GPRS mode

Wait for the GPS to have a satellite fix

Does the GPS have a fix?

YES

Send the GPS strings to a database using GSM via GPRS

NO

Figure 7: Flow chart for development of the tracking module
The GSM when it is turned on, it is given a few seconds delay. This is to allow the Simcard inserted to register to a network. Similarly, for GPS it was given a few seconds delay for it to get a satellite fix.

The GPS module was connected to the MSP430 board as shown by the image below.

The four pins from Ublox GPS module were connected to the MSP430LaunchPad as follows:

<table>
<thead>
<tr>
<th>Ublox Pins</th>
<th>MSP430 Pins</th>
</tr>
</thead>
<tbody>
<tr>
<td>GND</td>
<td>GND</td>
</tr>
<tr>
<td>RX Pin</td>
<td>TX Pin (Pin3)</td>
</tr>
<tr>
<td>TX Pin</td>
<td>RX Pin (Pin 4)</td>
</tr>
<tr>
<td>VCC</td>
<td>VCC</td>
</tr>
</tbody>
</table>

**Table 1: pin connections between GPS and MSP430**
One thing to note was that the TX pin of the Ublox was connected to the RX pin of the MSP430. The main reason for this was, TX stands for Transmit where data is send out. Therefore, the UBLOX-TX sends data to the MSP430-RX and the UBLOX-RX receives data from the MSP430-TX.

In order to test if the GPS was getting the satellite fix, the following code was uploaded to the Microcontroller.

```java
String inputString = "";  // a string to hold incoming data
boolean stringComplete = false;  // whether the string is complete

void setup() {
    // initialize serial:
    Serial.begin(9600);
    // reserve 200 bytes for the inputString:
    inputString.reserve(200);
}

void loop() {
    // print the string when a newline arrives:
    if (stringComplete) {
        Serial.println(inputString);
        // clear the string:
        inputString = "";
        stringComplete = false;
    }
}

void serialEvent() {
    while (Serial.available()) {
        // get the new byte:
        char inChar = (char)Serial.read();
        // add it to the inputString:
        inputString += inChar;
    }
}
```

// if the incoming character is a newline, set a flag
// so the main loop can do something about it:
if (inChar == '\n') {
    stringComplete = true;
}
}

After the code was uploaded to the Micro-controller, following was observed on the serial Monitor of the computer.
CHAPTER 4: IMPLEMENTATION AND TESTING

4.1 SCHEDULING OF THE WHOLE PROJECT
The project had various tasks that were carried from commencement to completion. A Gantt chart was developed to keep track of project progress. Project tasks were listed against their estimated start and completion times to accurately complete the project within the estimated time. However, there were delays in the implementation of the project because SIM800L was not readily available in the local market and had to be imported which took a long time. The Gantt chart used was as below:

4.2 SOFTWARE IMPLEMENTATION
The software design was implemented first from the application layer. The design of the homepage was simple and could easily be understood and used by most users. It had few links to navigate through the website.

4.3 HARDWARE IMPLEMENTATION

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