Intelligent Anti-Theft and Tracking System for Automobiles

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***Abstract*—An efficient automotive security system is implemented for anti-theft using an embedded system occupied with a Global Positioning System (GPS) and a Global System of Mobile (GSM). The client interacts through this system with vehicles and determines their current locations and status using Google Earth. The user can track the position of targeted vehicles on Google Earth. Using GPS locator, the target current location is determined and sent, along with various parameters received by vehicle's data port, via Short Message Service (SMS) through GSM networks to a GSM modem that is connected to PC or laptop. The GPS coordinates are corrected using a discrete Kalman filter. To secure the vehicle, the user of a group of users can turn off any vehicle of the fleet if any intruders try to run it by blocking the gas feeding line. This system is very safe and efficient to report emergency situations as crash reporting or engine failure.**

***Index Terms*—Vehicle tracker, embedded system, GSM, GPS, Google earth, kalman filter.**

I. Introduction

Despite the various technologies that have been introduced in recent years to deter car thefts and tracking it, It was reported that as many as cars were stolen yearly in the world. According to National Crime Information Center (NCIC), in 2006, 1,192,809 motor vehicles were reported stolen, the losses were 7.9$ billion.

Several security and tracking systems are designed to assist corporations with large number of vehicles and several usage purposes. A fleet management system can minimize the cost and effort of employees to finish road assignments within a minimal time. Besides, assignments can be scheduled in advanced based on current vehicles location. Therefore, central fleet management is essential to large enterprises to meet the varying requirements of customers and to improve the productivity [1].

However, there are still some security gaps where these technologies don't prevent a vehicle from theft, don't assist to recover it and don't allow the users to know the status of their vehicles. They can't permit the owner to communicate with the vehicle online, even if the owner is certain that his vehicle was stolen.

The proposed security system in this paper is designed to track and monitor vehicles that are used by certain party for particular purposes, also to stop the vehicle if stolen and to track it online for retrieval, this system is an integration of several modern embedded and communication technologies [2]-[3]. To provide location and time information anywhere on Earth, the Global Positioning System (GPS) is commonly used as a space-based global navigation satellite system. The location information provided by GPS systems can be visualized using Google Earth.

In wireless data transporting, GSM and SMS technology is a common feature with all mobile network service providers [4]-[5]. Utilization of SMS technology has become popular because it is an inexpensive, convenient and accessible way of transferring and receiving data with high reliability [6].

Fig. 1 shows the proposed system which consists of: GPS receiver, GSM modem, and embedded controller [7]. The users of this application can monitor the location graphically on Google Earth, can stop any vehicle of the fleet if it was stolen; they also can view other relevant information of each vehicle in the fleet [8]-[9].

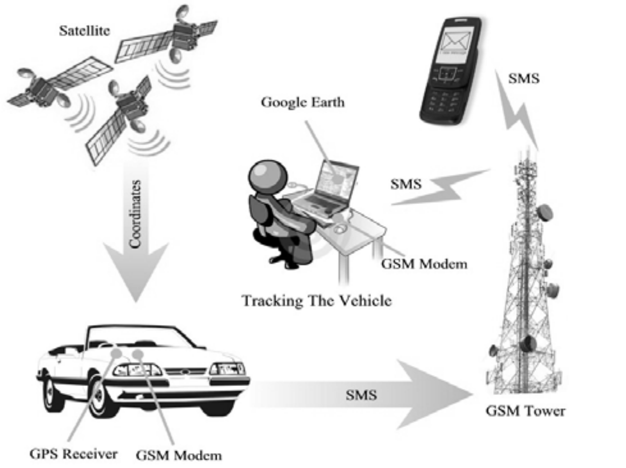

Fig. 1. The block diagram of Security system

As shown in Fig. 1, when the car starts running, the client receives a confirmation SMS that it is running now. If this is illegal operation or any intruders try to run the car, the owner can send SMS to switch off the car. Afterwards, the system will check the mobile number for received message, to confirm that the phone number could access the security system; if the phone number is legal the system will turn off the car. If the owner needs to track the vehicle, he/she have to send SMS contains special code, after that he/she will receive a SMS containing the GPS coordinates of the car, the SMS updating its content every predetermined period. Also the car owner can connect another GSM modem with laptop to track the vehicle immediately using Google Earth.

The implemented tracking and security system can be used to monitor various parameters related to safety; antitheft, emergency services and engine stall. The paper

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shows an implementation of several modern technologies to achieve a desirable goal of fleet monitoring and management.

II. Structure Of Anti-Theft Tracking System

The system has two main units; the first is security unit which is embedded in the vehicle. This unit consists of: a GSM modem, GPS receiver, control relay, current sensor and Microcontroller as shown in Fig. 2 [10]-[12]. The current sensor will send an analog signal to the microcontroller when the car is running. The microcontroller will send SMS directly to the owner to confirm that. NC control relay contacts are connected with the hot line that powers the fuel pump and ECM. The microcontroller can send a signal to the relay to cut off the power, when received SMS contains code from owner mobile to stop it. The GPS Receiver retrieves the location information from satellites in the form of latitude and longitude readings in real-time.

The Microcontroller processes the GPS information and transmits it to the user using GSM modem by SMS every 10 minutes when the user asked that from the system by sending SMS contains code. The Microcontroller also reads engine parameters from vehicle data port (OBD-II) and sends them to the second module in the same SMS. The second module is a recipient GSM modem that is connected to a PC or a laptop. The modem receives the SMS that includes GPS coordinates and engine parameters.

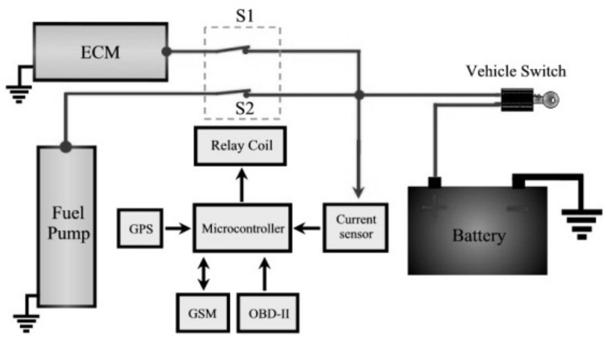


Fig. 2. The structure of main unit of anti-theft system

The modem receives SMS text that includes GPS coordinates, engine parameters, and vehicle engine status. This text is processed using a Visual Basic program to obtain the numeric parameters, which are saved as a Microsoft Office Excel file. To transfer this information to Google Earth, the Excel file is converted to KML (Keyhole Markup Language) format. Google Earth interprets KML file and shows vehicle's location on the map. The system's efficiency is dependable on the sufficiency of the used communication network.

III. Vehicles Retrieval

When the car starts running, the client receives a confirmation SMS that is running now. If this is illegal or any intruders try to run the car, the owner can send SMS to switch off the car, Fig. 3. After words, the system will check the mobile number of the massage sender, to confirm that the phone number is legal or illegal to access the system; if the phone number is legal the system will turn off the car.

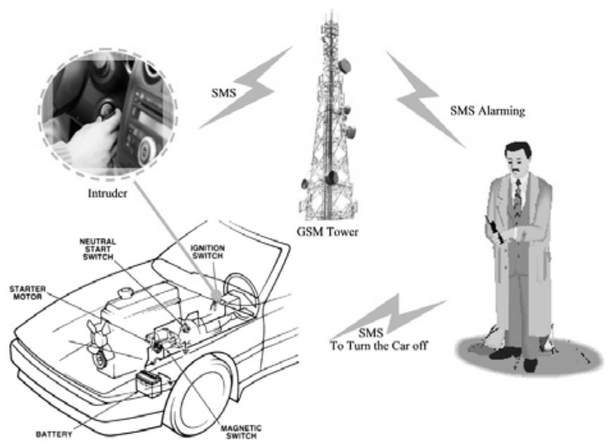


Fig. 3. System assurance of remote access.

IV. Kalman Filtering of GPS Coordinates

A Kalman filter is used to correct factors influencing the accuracy of position determination include: satellite geometry, shifts in the satellite orbits, clock errors of the satellites' clocks, tropospheric and ionospheric effects and calculation errors [13]-[16].

The filter is used to reduce GPS errors and thus increase the accuracy of the localization system [17]-[19]. In a GPS measurement system $[S_{xi}\ S_{yi}\ S_{zi}]$ refers to i^{th} satellite coordinates, $[G_x\ G_y\ G_z]$ indicates GPS receiver coordinates and R_i represents satellite range as $[S_x\text{-}G_x\ \ S_y\text{-}G_y\ \ S_z\text{-}G_z]$. Also, pseudorange PR_i is defined as [20]-[21]:

$$PR_i = \sqrt{(S_{xi}-G_x)^2+(S_{yi}-G_y)^2+(S_{zi}-G_z)^2}+b_u = |R_i| + b_u \qquad (1)$$

Where bu is receiver clock offset error.

The state vector $\boldsymbol{x}$ of the system at time $(k+1)$ are produced by:

$$\boldsymbol{x_{k+1}} = \emptyset_{\boldsymbol{k}} \boldsymbol{x_k} + \boldsymbol{w_k} \qquad (2)$$

where: $\boldsymbol{\phi_k}$ is the state transition matrix. The noise $\boldsymbol{w_k}$ is a white Gaussian noise with zero mean and covariance $\boldsymbol{Q_k}$. The state vector is defined as:

$$\boldsymbol{x} = [G_x\ \ G_y\ \ G_z\ \ b_u\ \ ]^T \qquad (3)$$

where: $[G_x\ G_y\ G_z]$ indicates GPS receiver coordinates, bu is receiver clock offset error. The state transition matrix $\boldsymbol{\phi_k}$ is an identity matrix of 4×4. The process measurement is defined as:

$$\boldsymbol{z_k} = \boldsymbol{H_k}\boldsymbol{x_k} + \boldsymbol{v_k} \qquad (4)$$

Where $\boldsymbol{H_k}$ is the measurement matrix and noise $\boldsymbol{v_k}$ is assumed to be Gaussian with covariance matrix $\boldsymbol{R_k}$. $\boldsymbol{v_k}$ has zero cross-correlation with $\boldsymbol{w_k}$.

The GPS receiver measurement vector for i^{th} satellite includes the pseudorange $PR_i=|R_i|+b_u$ as in (1). Linearization of the satellite range $|R_i|$ about estimated GPS receiver coordinates, we find:

$$|R_i| = \sqrt{(S_{xi}-G_x)^2 + (S_{yi}-G_y)^2 + (S_{zi}-G_z)^2} \approx \frac{-(S_{xi}-G_x)\hat{G}_x}{|R_i|} + \frac{-(S_{yi}-G_y)\hat{G}_y}{|R_i|} + \frac{-(S_{zi}-G_z)\hat{G}_z}{|R_i|} \quad (5)$$

Therefore, the measurement vector is:

$$\boldsymbol{H_k} = \left[\frac{-(S_{xi}-G_x)}{|R_i|} \quad \frac{-(S_{yi}-G_y)}{|R_i|} \quad \frac{-(S_{zi}-G_z)}{|R_i|} \quad 1\right] \quad (6)$$

The procedure is initiated by the assumption of x_0^- and P_0^- : initial estimate of states and its error covariance respectively. The optimal Kalman gain $\boldsymbol{K_k}$ is utilized to achieve the update estimate of the pseudorange measurements $\hat{\boldsymbol{x}}_{\boldsymbol{k}}$ and its error covariance $\boldsymbol{P_k}$ as:

$$\boldsymbol{K_k} = \boldsymbol{P_k^- H_k^T}[\boldsymbol{H_k P_k^- H_k^T} + \hat{\boldsymbol{R}}_{\boldsymbol{k}}]^{-1} \quad (7)$$

Then, the update estimate with measurement z_k:

$$\hat{\boldsymbol{x}}_{\boldsymbol{k}} = \hat{\boldsymbol{x}}_{\boldsymbol{k}}^- + \boldsymbol{K_k}\,(\boldsymbol{z_k} - \boldsymbol{H_k}\hat{\boldsymbol{x}}_{\boldsymbol{k}}^-) \quad (8)$$

The error covariance is computed as:

$$\boldsymbol{P_k} = (\boldsymbol{1} - \boldsymbol{K_k H_k})\boldsymbol{P_k^-} \quad (9)$$

The next state $\hat{\boldsymbol{x}}_{\boldsymbol{k+1}}^-$ and error covariance $\boldsymbol{P_{k+1}^-}$ is then calculated based on the current state estimate as in (10) and (11).

$$\hat{\boldsymbol{x}}_{\boldsymbol{k+1}}^- = \emptyset_{\boldsymbol{k}}\hat{\boldsymbol{x}}_{\boldsymbol{k}} \quad (10)$$

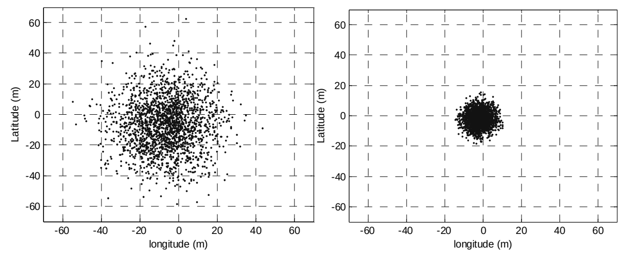
$$\boldsymbol{P_{k+1}^-} = \emptyset_{\boldsymbol{k}}\boldsymbol{P_k}\emptyset_{\boldsymbol{k}}^{\boldsymbol{T}} + \hat{\boldsymbol{Q}}_{\boldsymbol{k}} \quad (11)$$

The GPS accuracy is measured using ***2DRMS*** (Twice Distance Root Mean Squared). The computation of ***2DRMS*** is attained by:

$$\boldsymbol{2DRMS} = \boldsymbol{2}\left(\sqrt{\boldsymbol{\sigma_x^2} + \boldsymbol{\sigma_y^2}}\right) \quad (12)$$

where: $\boldsymbol{\sigma_x}$, $\boldsymbol{\sigma_y}$ are the standard deviations of latitude and longitude respectively of the estimated coordinates by Kalman filter.

The results showed ***2DRMS*** accuracy in the in-vehicle GPS latitude and longitude measurements, Fig. 4.



(a) (b)

Fig. 4. Latitude and longitude measurements for (a) in-vehicle GPS receiver and (b) corrected location based on Kalman filter.

V. HARDWARE SPECIFICATION

The security unit, as shown in Fig. 5, consists of three main inputs: The first received input is the GPS output, which has a sentence based on NMEA 0183 standard. The second input is obtained by the vehicle data port, typically called ON Board Diagnostics port, version II (OBD-II). The unit sends an SMS using Hayes command (AT Command). The third is analog signal from the current sensor when the vehicle is running.

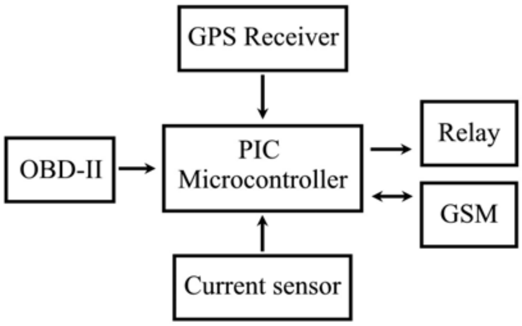


Fig. 5. Block Diagram of tracking unit.

On-Board Diagnostics port (OBD-II) is a universal automotive protocol supported by modern vehicles to retrieve diagnostic errors over a Controller Area Network (CAN) bus of the microcontroller (MCU) [22].The used GSM module is of type SIM900D, this module supports standard AT command and compatible with several GSM networks. Transmission parameters are set to: Baud rate is set at 19200 bps, the data is 8N1 format, and flow control is set to none.

The GPS receiver is a MediaTek MT3329. The GPS module supports up to a 10Hz update rate. The microcontroller is the main operational unit of the tracking device. The GPS receiver collects the latitude, longitude and speed information and forwards them to the microcontroller [23].

The GSM module communicates with the microcontroller to send the information package to another GSM Module at the recipient station, all information appears on Google Earth after processing [24]. Fig. 6 shows the external view of the tracking unit. The tracking unit is designed to be powered by the vehicle battery. However, a power source is built-in the device as an emergency backup.

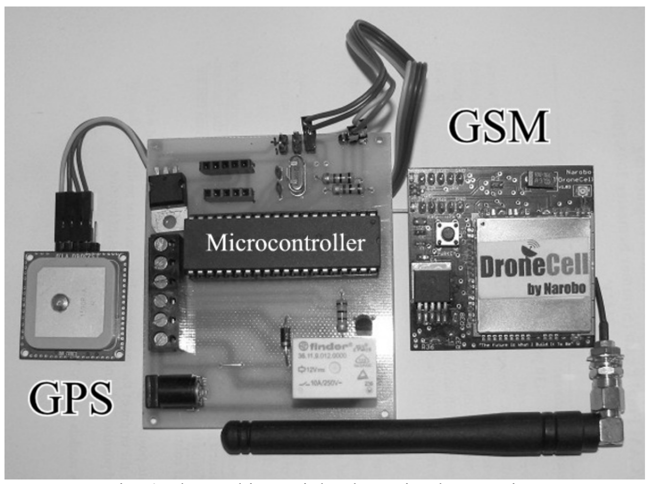


Fig. 6. The tracking unit hardware implementation.

VI. SOFTWARE SPECIFICATION

In our tracking system we used Google Earth software for tracking and viewing the status of the vehicle [25]. Google Earth currently supports most GPS devices. The engaged GPS Module has NMEA 0183 Protocol for transmitting GPS information to a PC. This protocol consists of several sentences, starting with the character $, with a maximum of 79 characters in length. The NMEA Message to read data with both position and time is: $GPRMC. Therefore, only the $GPRMC information is used to determine the location of the vehicle to reduce SMS text. The status of the vehicle along with $GPRMC information is sent by the GSM modem of type MediaTek MT3329.

Consequently, the recipient GSM, also has NMEA 0183 protocol, receives the transmitted SMS to obtain GPS coordinates and status information of the vehicle.

The received data is processed by a Visual Basic program to sort the data in an Excel sheet. The Excel file is exported to a KML file that is compatible with Google Earth program. Hence, Google Earth will view the location and status of the vehicle on the map by reading the KML file. Fig. 7 illustrates the block diagram of the recipient module in the system.

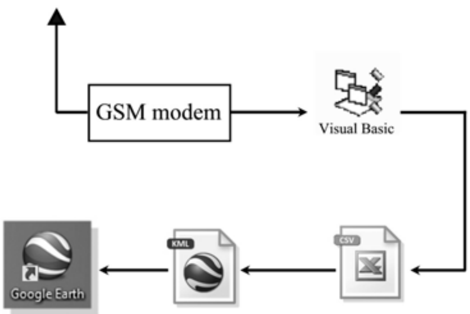


Fig. 7. The block diagram of the recipient module in the system.

The KML file, developed for Google Earth, is used to save geographic data that includes navigation maps and other driving instructions. Based on included information in the KML file, Google Earth provides the ability to track an object and view the related information at any position as shown in Fig. 8.

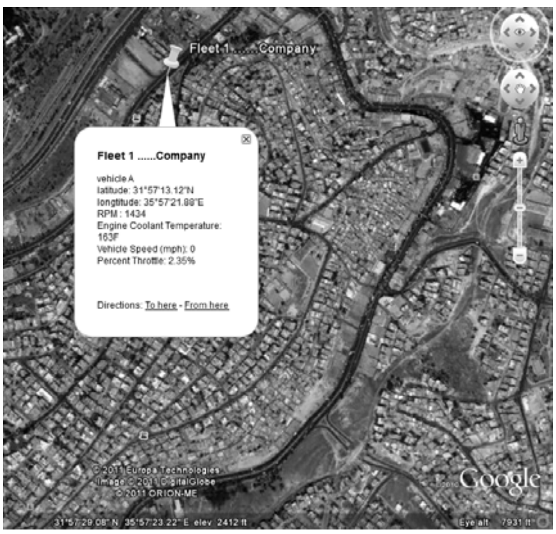


Fig. 8. Google Earth showing the location and engine parameters of the vehicle.

VII. CONCLUSION

In this paper, a low-cost vehicle tracking and monitoring system is presented. The application included a transmitting module which contains an embedded system to combine GPS and GSM devices to retrieve location and vehicle status information and send it to the other stationary module; the second part is the receiving module which collects the transmitted information by SMS and process it to a compatible format to Google Earth to view the location and vehicle status online.

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