DATA ACQUISITION SYSTEM BASED ON MOBILE SENSOR NETWORKS

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Key words: Data acquisition, Microcontroller, GIS, GPRS, Sensor, Network.

The present paper presents a Data Acquisition System (DAS) set up and implemented in our laboratory. Its main purpose is to collect distance data offered by a set of mobile sensors with different geographical locations. By using the GPS and GPRS techniques, DAS gathers and processes both the data from sensors and the GPS coordinates of the locations. DAS is composed of a central data base (CDB), resident on a PC connected to the Internet and a number of distributed mobile data bases (MDBs), resident in the data acquisition mobile equipment (DAME), which communicates with CDB via GPRS. Accessing CDB, through a “client-server” application, enables presentation on a GIS map of the coordinates of mobile locations and presentation, in a tabular form, of the data collected from the sensors corresponding to each location.

1. INTRODUCTION

The main purpose of the system is to collect remote data by a set of mobile sensors located at different geographical positions. Using GPS (Global Positioning System) and GPRS (General Packet Radio Service) techniques, the DAS collects and processes both data from sensors and the GPS coordinates of the locations. DAS consists of a central data base (CDB), resident on a PC connected to Internet, and multiple distributed data bases, in the mobile locations, that communicate with CDB through GPRS. The access to CDB, through a “client-server” application, enables display on a GIS (Geographical Information System) map of the coordinates of the mobile locations and presentation, in a tabular form, of data collected from sensors [1, 2].

According to its design, the system’s application is not punctual, the user being able to select the type and number of sensors he desires, provided that he observes a few requirements.

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2. STRUCTURAL AND FUNCTIONAL CONCEPTS REGARDING THE DATA ACQUISITION SYSTEM FOR MOBILE SENSORS NETWORKS

Conceptually and functionally DAS is structured on three levels: two levels meant for data acquisition, subordinated one to the other and an information-communication level disseminated throughout the first two, that ensures the good cooperation of the first two levels and the functionality of the entire system (Fig. 1).

Thus, the first functional level, assisted by the third, is represented by a set of data acquisition mobile equipment (DAMEs). Each DAME consists of a platform with a microcontroller, placed on a vehicle (mobile location), around which is structured a so called mobile data base (MDB) linked both to the sensors set, for collecting the necessary data, and to the GPS receiver for estimating the position and the exact time. The communication between DAME and CDB is provided by a GPRS modem.

Fig. 1 – DAS structure.
The second functional level, also assisted by the information-communication level, is represented by the CDB, which is split into two parts: the physical database and the command point, the latter being an application developed in Visual C++ that provides: communication with DAME, processing of the received data and their storage in the database [3, 4]. The interface between the operator and CDB, a “client-server” application developed in Visual Basic, enables the positioning data to be extracted from CDB and displayed on a GIS map as “footprints” left by each mobile location; these footprints are represented by the data collected from each mobile location and printed out in a table.

A series of problems has been solved at the information-communication level. The first one regards the data transfer mode between DAME and CDB. The solution was the transfer of data to CDB through GPRS and Internet, because, when connecting to GPRS, the IP address is dynamically allocated by the telecommunications operator. The selected solution enables IP address of CDB to be known by DAME that is meant to initiate the connection. A communication protocol, specific to the application, was developed in the context of data transfer.

A second problem solved is connected to dealing with image maps. Generally, GIS operates with vectorial maps, consisting of lines and points linked to a proper data base, wherein each point can be inserted by help of its geographical coordinates. This facility is not available in the image maps, so a mixed solution was adopted by creating an empty GIS form, that is overlaid on the image map, wherein the points can be inserted after a conversion of the geographical coordinates.

3. DATA ACQUISITION MOBILE EQUIPMENT

MDBs, belonging to mobile locations which host the sensors, are simple data bases that acquire messages sent by sensors, save these messages in the RAM of each Central Unit, process and send them to CDB. Once confirmed, the messages are deleted enabling other messages to be acquired. Each DAME involved both a hardware and software conceptual approach.

3.1. THE HARDWARE STRUCTURE

In the DAME block diagram (Fig. 2), the GPS receiver, the sensor (sensors) and the mobile communication equipment are peripheral equipment connected to the serial ports of a microcontroller board (80C552), which incorporates two interfaces: an interface for data acquisition and another for the GPRS communication equipment. It is possible to use one mobile equipment only, that contains both the communication terminal and the GPS receiver, this enabling to obtain a compact data acquisition unit.
The nature of sensors is not clearly specified, as they can be of any type, offering versatility to the system and possible to be specific to different applications. The positioning coordinates and the exact time are established by help of the GPS receiver and these, together with the data from the sensors form a message that will be processed and temporarily stored in MDB for transition towards CDB through the GPRS mobile communication equipment. The message destination is the control point, that, for each message received replies with a confirmation message that along with the so called confirmation also includes a command that specifies the time interval for data acquisition. This is the reason why the connection with the communication equipment is bidirectional [5].

Fig. 2 – DAME block diagram.

3.2. DAME’S SOFTWARE

The role of the central unit is mainly to create a connection to the GPRS network and to send to server the data acquired from the sensors and GPS. For programming the data acquisition equipment, the assembler language of the Philips 80C552 microcontroller was used, which is the “brain” of this equipment. Mention should be made of the fact that programming could also be made by using the C language of this microcontroller, but the assembler language was preferred because it generates a smaller source code (which consequently occupies less memory), and the operations performance speed is higher. The C language is used in case of intensive mathematical operations and complex programs, but it was not needed here.

The first function of the data acquisition system is to create a GPRS connection with the server, connection that is made with the help of the GPRS modem.
The connection with the server once established, the data communication between DAME and CDB can start (Fig. 3). For this the microcontroller has to command the data acquisition from the sensor and GPS receptor. Communication with both these equipments is established through asynchronous serial lines, and the data are ASCII coded octets. These data are subsequently processed by the microcontroller (useful information is only stored) and saved in the RAM.

The communication with the GPRS modem is made through the AT commands. The AT commands are transmitted to the modem through a serial link, in asynchronous mode at baud rates which can be selected between 300 and 115 200 bps. The number of data bits and stop bits, as well as the flux parity and control, can also be selected. These settings are made also through AT commands and, if necessary, can be stored in the device, otherwise, after stopping or resetting, reversion to the initial mode occurs. The AT commands as well as modem responses consist of ASCII coded octets. The commands always begin with AT characters (41h, 54h in ASCII code) and are ended with the <CR> character.
(„Carriage Return”, 0Dh in ASCII code). The replies provided by the modem begin and end with <CR> <LF> characters („Carriage Return” „Line Feed”, 0Dh 0Ah in ASCII code), excepting the replies to 2 more special commands, namely ATVO DCE end ATQ1. Observation: the commands may contain capital or small letters, but the replies are always written in capital letters.

4. THE CENTRAL DATA BASE

CDB consists of two parts: the physical data base [3, 4], set up in MySql, and the command point – the application responsible for the communication with MDB, data processing and data writing in the data base. When accessing this application, two execution threads are started: one executing thread of interface type that is the management window and an execution thread, named “ListenUDP”, with the role of “listening” in the management window for the arrival of messages from DAME. Apart of these threads, each monitored DAME has its own execution thread (Fig. 4).

5. COMMUNICATION TECHNIQUES

Because the peripheral equipment (sensors, GPS receiver and GPRS modem) communicates in a serial manner and the microcontroller has parallel ports for the
communication between sensors and DAME, the need of interconnecting these circuits arises. For this purpose the Z80-SIO circuit was used. It enables independent interconnection of two channels allowing the implementation of synchronous and asynchronous communication protocols, either bit- or character-oriented.

For a better understanding, the “DAME-CDB” communication will be described at each corresponding functional level from the OSI (Open System Information) reference stack (Fig. 5).

**Level 1** – This level is provided by the telecommunications operator, is transparent for the user and consists in the allocation of a radio communication channel between the mobile equipment (the GPRS modem) and BTS (Base Transceiver Station).

**Level 2** – The PPP (Point to Point Protocol) was used for this level because it offers a standard method for the transport of multi-protocol datagrams through point to point links.

**Level 3** – The IPv4 (Internet Protocol version 4) was used for the network level.

**Levels 4, 5, 6 and 7** – The UDP (User Datagram Protocol) was used for the bidirectional data transfer between DAME and CDB, as a starting point for the transfer protocol developed for DAS. In view of a safe and efficient transfer this newly created protocol must offer certain facilities such as: data transfer, communication security and connection management. The initialization of the connection is made by DAME and consists of a simple initialization confirmation mechanism. When the packet that confirms the reset is received, the connection is established. In table 1 is presented the structure of the protocol packets (reset, reset confirmation, data packet and data confirmation packet).

![Fig. 5 – The “DAME-CDB” communication protocol.](image-url)
Table 1
Format of packets used by DAS protocol

<table>
<thead>
<tr>
<th></th>
<th>Vehicle number (1 octet)</th>
<th>Packet type (1 octet)</th>
<th>Nr of sent packet (1 octet)</th>
<th>Unused field (2 octets)</th>
<th>0D terminator (1 octet)</th>
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<tbody>
<tr>
<td>Reset Packet</td>
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<td>Reset Confirmation Packet</td>
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<td>Data Packet</td>
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The role of the “DAME-CDB” protocol is to provide a safe and efficient transfer of data from MDB to CDB and of the commands in the opposite direction. With this aim in view it was developed in the following directions:

- transfer of basic data,
- communication reliability,
- connections management.

Transfer of basic data. Our protocol provides the data transfer from MDB to CDB by including the data in the message in clearly defined positions. The data are contained in packets numbered such as to avoid duplicates at reception. The value range of these sequence numbers is the multitude of decimal numbers, which enables to also solve the situations when the transmission delays through Internet are high enough to cause, in case of certain packages, a later arrival than of the ones subsequently sent. At the arrival of a packet in case of which the sequence field does not contain the number of awaited packet, the received packet is ignored. At the reception of one packet, in case of DAME, the packet is erased from MDB, and another message to be transmitted is introduced at the proper time. The lack of confirmation, at a certain time interval after transmission, conducts to the automatic transmission of the packet (Fig. 6), as the delayed confirmation does not disturb the protocol. The waiting time interval was set up keeping in mind the fact that the minimum interval between two transmissions is of ten seconds.
Communication reliability. In order to provide a reliable communication it is imperative for the protocol to cope with the loss of certain packets and to be able to recover the data flux (Fig. 7). This situation is solved through both confirmations and allocation of certain sequence numbers to the data packets. This avoids both accepting duplicate packets at reception and also loss of packets. If the reception of one packet is not confirmed after ten seconds, the packet is retransmitted. In case that the packet is neither confirmed after a period during which one of the three possible confirmations is awaited, there is considered that the problem is more serious, the connection is regarded as interrupted, and it is shifted to the procedure of establishing a new connection.
Connections management. In order to provide a reliable communication, such as previously presented, the protocol has to initiate and maintain certain connections. Each connection is identified by the number of DAME through which the communication proceeds, this number being assigned through the program of platform microcontroller, before the platform is put into operation.

Connection preset is made by DAME and consists of a mechanism of simple confirmation of presetting. At the receipt of the presetting/resetting confirmation packet, the connection is considered as stable.
The connections are made through the sockets provided by the UDP level. The 69 port is used with both microcontroller and server for establishing the connection and for the transfer this protocol is maintained with the microcontroller, while a static port from the 10 001–10 005 multitude is allocated to the server because the firewall of the telecommunications operator allows only the traffic through “known” ports, such as the 69 port. For this reason a TFTP server cannot be used with the computer on which the central unit operates.

6. SUPERVISION CLIENT-SERVER APPLICATION

The part that completes DAS is the operator interface, which, by calling on GIS shows, on a map, the locations wherefrom DAMEs have collected the data. Through these, the operator can visualize, under a tabular form, the information regarding a particular location. Among the functions of this application the following can be mentioned: utilization and management of data bases located on a MySql server; TCP communication; “Challenge Response” type authentication with MD5 encoding; display of points based on the GPS coordinates and locations data; display and manipulation of GIS maps; modification of a specially designed GIS form; saving the image from the monitor in Bitmap format and, last but not least, sending the image through E-mail.

Because the application is used in a LAN and it is presumed that not everyone is allowed to access the data, attention was also paid to the security on entering the program. For this an authentication function was adopted that combines the “Challenge Response” algorithm with MD5 encoding. This conducted to the necessity of a new data base, stored on the same MySql server as CDB, to keep the user-related data including the password in MD5 format (Fig. 8) [3, 4].

The main purpose of this application consists in: displaying of maps, insertion of points belonging to the location the data were collected from and, last but not least, basic functions of a map (zoom and shift of the enlarged map) [6]. This is where the first problem is generated: because of utilization of a raster map, which does not contain any positioning information, it is impossible to insert a point based on geographical information. The solution was to create a new GIS form, empty, i.e. containing no information, to be placed over the raster map. After a conversion of the GPS coordinates to the map’s X and Y coordinates, the point can be inserted, in the newly created form, based on the new coordinates. These “foot-prints” of the mobile locations, personalize the data collected from various mobile locations by simply clicking on the desired location. The flow chart for the server application is presented in the Fig. 9.
Fig. 8 – User administration function flowchart.

For satisfying as many needs the users may have, other two functions have also been implemented i.e.: the first function – for saving the image from the monitor in a bitmap file, by making a snap-shot of the visible part of the map, and the second – for sending the visible part of the map in an E-Mail message. The Windows API (Application Program Interface) functions were used for the second function, because they create and send the message in background, independently of a mail program installed on the computer, considering the fact that not all the computers which will run this application are provided with a mail program.
7. CONCLUSIONS

The aim of the paper was to show a new data acquisition system for collecting remote data, provided with a set of sensors placed in different geographical locations. As the sensors have been placed on vehicles, we can speak about mobile sensors. Application of techniques such as GPS, GPRS and Internet, optimization of the data bases structure and use of adequate software products enabled development of the presented DAS, which can be useful both in civil and military applications.

Received on 16 July, 2006
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