An Integrated Framework in Geographic Information System using Wireless Sensor Network

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ABSTRACT
Environmental Studies and Monitoring involves a repetitive process of sampling of the environment during certain period of time. It determines natural variability; and assesses changes and trends due to human activities. This paper presents an integrated environment monitoring framework using Wireless Sensor Networks (WSN) and Geographical Information System (GIS). The framework helps to visualize different types of micro weather data, like, temperature, light, humidity, pressure sensed by sensor motes throughout the day in specific region. It uses colour coding display to visualize monitored data in the specific geographic regions.

General Terms
Wireless Sensor Networks (WSN) and Geographical Information System (GIS).

Keywords
Environment monitoring framework, WSN, GRASS, PostgreSQL

1. INTRODUCTION
Environment monitoring process comprises the phases for collection of classified data in regular intervals and analysing those data with respect to certain threshold value. Monitoring data is used to ensure compliance with environmental standards and generate alerts for some necessary action plans. Weather monitoring or environment monitoring is very much essential for environmental impact assessment (EIA) [1].

This paper proposes an environment monitoring system for specific region through a wireless sensor network (WSN) which is integrated with a geographic information system (GIS). WSN is composed of sensor nodes communicating through wireless network. These small sensor nodes are GPS enabled and deployed within a previously chosen area, inside and outside the building premises. Environment monitoring data, usually temperature, light, humidity, etc. are sensed by these sensors at regular interval. These sensed data are sent to the base station for compilation. Because of the use of wireless sensor networks, the proposed system is capable of collecting micro- environment or weather data from a chosen area even inside a specific building. A colour-coding display may be used to visualize monitored data in the geographical locations displayed using the geographic information system.

Organization of this paper is as follows. Related work is discussed in Section 2. The integration of GIS and WSN along with the required technologies is briefed in Section 3. Proposed environment monitoring framework is presented in Section 4. The framework is demonstrated in Section 5. Section 6 concludes with a direction of the future work.

2. RELATED WORK
Wireless Sensor Networks have attracted the attention of many researchers. WSNs are used for various applications such as habitat monitoring, automation, agriculture, security, etc. Environment monitoring is one such important application of WSN. Existing research works related to environment monitoring are studied and presented in this section. In [5], Barrenetxea et al proposed the use of sensors in environmental monitoring using wireless sensor networks. This research work is a collaborative effort of computer science researchers to build a measurement system, with the ability of immediate transmission of gathered data to a distant server. As a result, it allows real-time as well as long-term monitoring of natural events in potentially large areas. In [3], Atish et al also proposed a methodology of environmental monitoring using sensor networks. A network of sensor nodes spread across a field has the capacity to provide temporal and spatial data regarding the properties of the environment. This research work aims at incorporating data compression and aggregation techniques to a sensor network which can be deployed to monitor vital properties like temperature, relative humidity and soil moisture and then report them through a routing tree to a base station for further analysis.

An agricultural environment monitoring server system has been proposed in [12]. This system integrates environmental and soil sensors, GPS module, CCTV etc. This system collects information such as luminance, temperature, humidity, wind direction, wind speed, EC, pH, CO_2 etc. through sensors and image information through CCTV. This information is used for monitoring the environment at crop plantations, and provides real-time environmental monitoring and various application services. Resch et al presented Live Geography approach with embedded sensing for standardized urban environmental monitoring in [18]. It combines live measurement data with historic data sources within its framework. This flexible framework aims at automating GIS analysis processes with manual input and replaces monolithic measurement systems.

The major goal of this system is to measure potential impact on urban policy and decision-making.

Development of indoor environmental monitoring system using wireless sensor networks has been presented in [19]. Objective of this paper is to monitor environmental condition inside a building for creating optimized energy usage. This system measures the environmental parameters like, temperature, relative humidity, and ambient light through Crossbow wireless sensor motes and displays the data using LabVIEW GUI. In [7], a web-based surveillance subsystem is presented for remote control and monitoring. Events occurring in remote places are observed, monitored and recorded using WSN.

Previous researchers mostly concentrate on developing environment monitoring system using wireless sensor networks. Our work is focused on the integration of environment monitoring data with an open-source GIS. Next two sections provide a brief overview of our proposed framework.

3. INTEGRATION OF GIS AND WSN

This section brief discusses the technologies, which have been used for the work presented in this paper. The integration of wireless sensor networks and geographic information system has been carried out using the technologies, namely, MoteView, GRASS GIS, and PostgreSQL database. The interface of the environment-monitoring framework is developed using Java programming language [13].

Wireless sensor network (WSN) is the primary component in our framework. It consists of many spatially distributed and autonomous sensor nodes [9], [21]. The sensor nodes are known as motes, which cooperatively monitor physical or environmental conditions. Each sensor node comprises sensing, processing, transmission, and power units. These sensors are able to communicate with each other or directly to a base-station (BS). As the sensor nodes are small in size they have limited power and memory. But because of their smaller size they can be effectively deployed in difficult-to-access locations. The design of a WSN depends significantly on the application with deploying environment factors and system constraints. Battery is the main power source in sensor nodes. Secondary power supply can be arranged from the deployed environment if possible. A WSN deployed for environment monitoring should be able to collect data from different areas and to analyze and evaluate them as rapidly as possible [4].

In this work, Mica2 motes are used to sense temperature, humidity, pressure, and light data from the environment for constant monitoring. These motes consist of small intelligent sensing devices with wireless communication facilities. Each mote has l 8 MHz processing unit, 4 KB Random Access Memory (RAM), 128 KB memory, 512 KB storage, 433/915 MHz frequency, more than 20 meter of sensing range and battery set as power source. The dimension of each mote is 15 mm height, 60 mm width, and 35 mm length [2].

For visualizing the data generated by the sensor nodes, we use the *MoteView* [20], [8] graphical user interface. However, MoteView is supported by Windows operating system and therefore cannot be directly integrated within an open-source framework. MoteView is designed to simplify, the task from the perspective of the end user, and the administration of the sensor networks. It introduces a method that performs calibrated unit conversion of all sensor readings and forms a set of abstraction layers in order to allow extensibility. In this work, MoteView version 2.0 is used.

Geographic Information System (GIS) [10], [16] is a computer-based tool or system for mapping and analyzing spatial data. GIS is an organized collection of hardware, software and geographic data designed to efficiently capture, store, update, and manipulate all forms of geographically referenced information. GIS technology is used to make decisions and visualize categorized data in many aspects of the society. The most important components in a GIS is data and data is organized and managed with the help of a database management system (DBMS). Data in the GIS database provides a simplified, digital representation of earth features for a given region.

In this work we have used GRASS [15], [11], [6] as the open-source GIS. GRASS is a geographic information system released under the GNU general public license. GRASS is being developed for the GNU/Linux, Mac OS/X, and Windows operating systems. GRASS is capable of doing data management, image processing, graphics production, spatial modeling, and visualization of many types of data.

The database used in this work is *PostgreSQL* [17], [14], which is an open source relational database system. It is included in both GRASS-6.4 and MoteView-2.0. PostgreSQL database is supported by Windows as well as Linux operating systems. PostgreSQL supports procedural languages which are used to create user-defined functions (also known as stored procedures) to be executed by the database server. PostgreSQL allows orderly data storage, rapid data retrieval, and complex data analysis.

Proposed integrated environment monitoring framework is presented in the next section.

4. PROPOSED ENVIRONMENT MONITORING FRAMEWORK

The environment data is gathered through wireless sensor networks and is visualized with a geographic information system (GIS). The WSN within the framework monitors micro-environment data of any specific region throughout a time period using sensor nodes and the data is saved in a PostgreSQL database. The same database is used in GRASS for further analysis and display. The proposed framework for environment monitoring is a two-tier framework, it has a *data access layer* and a *graphical interface*. Communication between geographic information system and wireless sensor network is implemented through the *data access layer*. The sensed data from all the deployed sensor nodes are then displayed in the map of the region, which is being monitored.

The GPS enabled sensor motes are placed in a region and these locations are plotted in the map of that region. Sensed data are continuously monitored through Crossbow MoteView. Base station for gathering data from the sensors motes is located at a remote place. Sensed data are then collected at regular intervals and stored in the PostgreSQL database. Visualization of environment monitoring data can be done through graph or colour coding. Finally, locations of the sensor motes along with the sensed information are displayed into the map of the specified region in GRASS. An interface for integrating the data from PostgreSQL database with the GRASS software is developed to enable the authenticated users accessing and viewing this data. The overall framework of the framework is shown in Figure 1.

Environment monitoring requires continuous sensing of the environmental parameters within the region to be monitored. This can be achieved through the following steps:

a) Insertion and display of the map of a specific region

Geographical map of the selected region is captured in the GRASS software

b) Selection of sensor deployment position through map

The sensor deployment positions are chosen in the map. The small sized sensor motes are placed / deployed in these positions. The placement of sensors is done according to their sensing and communication range.

c) Creation of table in PostgreSQL database

The coordinates of the sensor nodes and their corresponding ids are stored in GIS database. PostgreSQL is used as GIS database. An interface for creation of the table is shown in Figure 2.

d) Insertion of data into the table

Data is inserted in the above-mentioned table for each sensor mote with their specific node-id, x-coordinate and y-coordinate values of deployment positions (as shown in Figure 3)

e) Gathering of data and displaying through MoteView

Sensor nodes sense the environmental data (like temperature, humidity, light, pressure etc.) at regular intervals which is visible continuously through MoteView.

f) Exporting data into PostgreSQL database

The data extracted from the sensors are converted into a text file, which is imported in the PostgreSQL database of GRASS. The labels are created with corresponding data (temperature or humidity or light).

g) Displaying the data through GRASS

Finally, the vector map with all the sensor nodes along with their labels are displayed by overlapping these into separate layers of the base vector map.

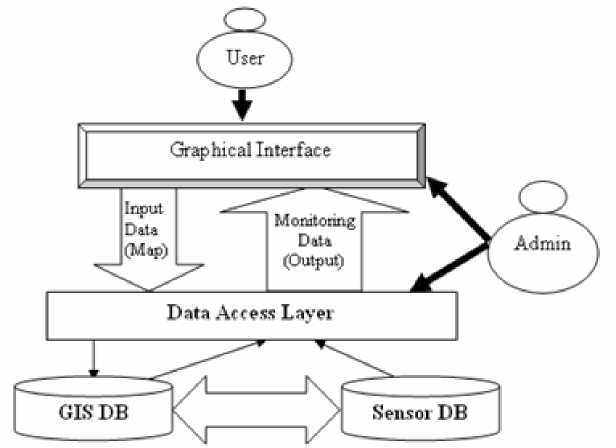

Figure 1: Proposed Environment Monitoring Framework

A Java-based graphical interface is created. The graphical interface takes the input from the database and displays the output in the form of a map or graph. Authenticated users can login and check the data from the sensor nodes sensed within a particular time interval. These users are not given access beyond the data access layer. Thus, the users cannot create or update the database of the geographic information system or that of the wireless sensor networks. Users can access only the existing database. On the other hand, the administrators are capable of doing further modifications to the interface and the database as well. The deployed sensor locations of all the sensor nodes along with temperature monitoring data obtained from each sensor node (averaged over a time interval) is displayed in Figure 4.

Next section presents a real-life scenario, which has been used to demonstrate our framework.

5. EXPERIMENTAL RESULTS

The proposed framework is actually implemented within the School of Mobile Computing and Communication (SMCC) building in the Salt Lake campus of Jadavpur University. The map of this building is inserted and displayed in GRASS, as shown in Figure 5. Sensor motes are deployed within the building premises to form a wireless sensor network. The locations of the deployed sensor nodes are marked in the provided map of SMCC building (as shown in Figure 5). Red node indicates maximum while blue node represents minimum temperature of that particular day. The data from the sensor nodes are gathered at a regular interval (every hour) from 11:00 am to 5:00 pm. and Figure 6 represents graphical representation of humidity and temperature monitoring data.

6. CONCLUSION

In this paper we have presented an environment monitoring framework based on WSN and GIS. The deployment locations of sensor nodes can be chosen within any region or city using the respective geographical map. Monitoring data collected from sensor nodes can be visualized through such map. A graphical interface is developed for enabling authenticated users to access this system. Messages, and alerts may be delivered and relevant data can be disseminated through this interface for public use. In future data aggregation protocols will be implemented to gather and present data from enormous number of sensors, which would be deployed in much larger region compared to the region selected in this work.

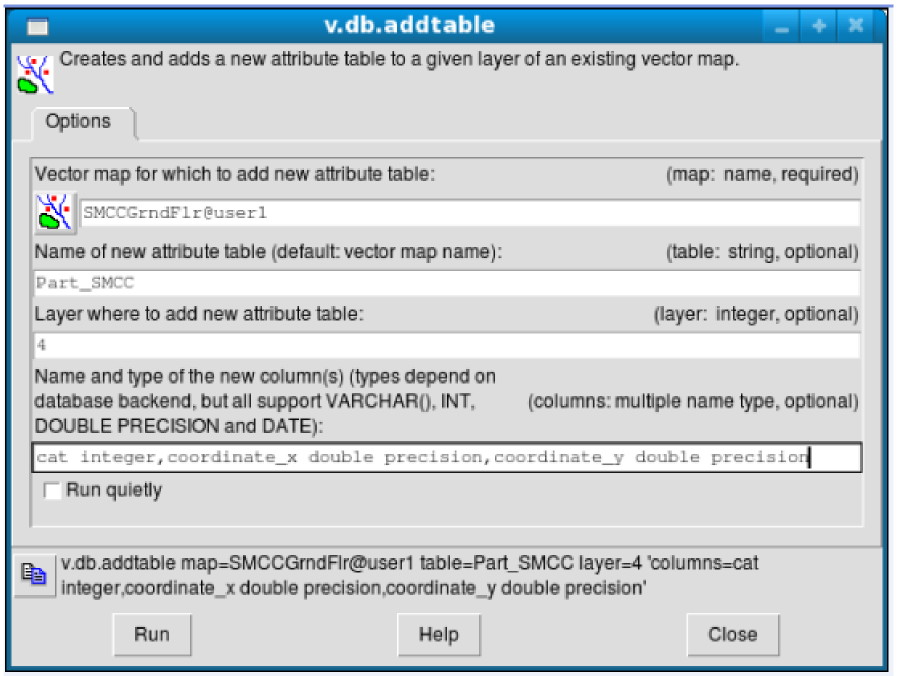

Figure 2: Creation of Table in PostgreSQL through GRASS

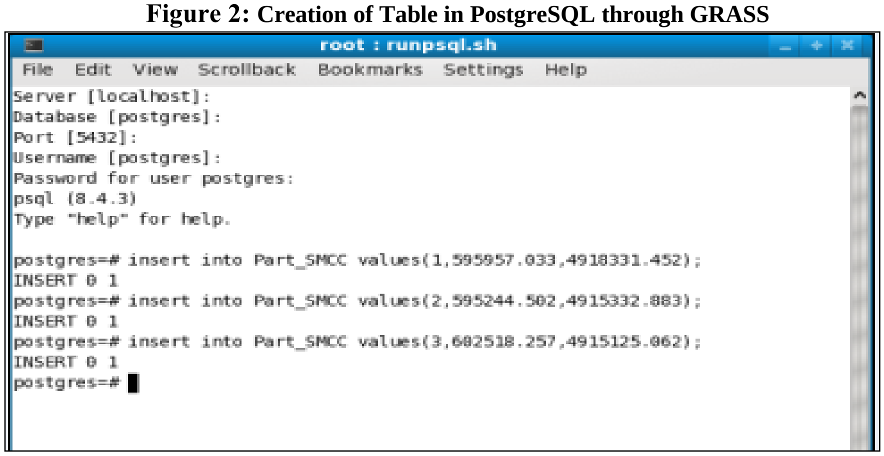

Figure 3: Insertion of data in PostgreSQL database

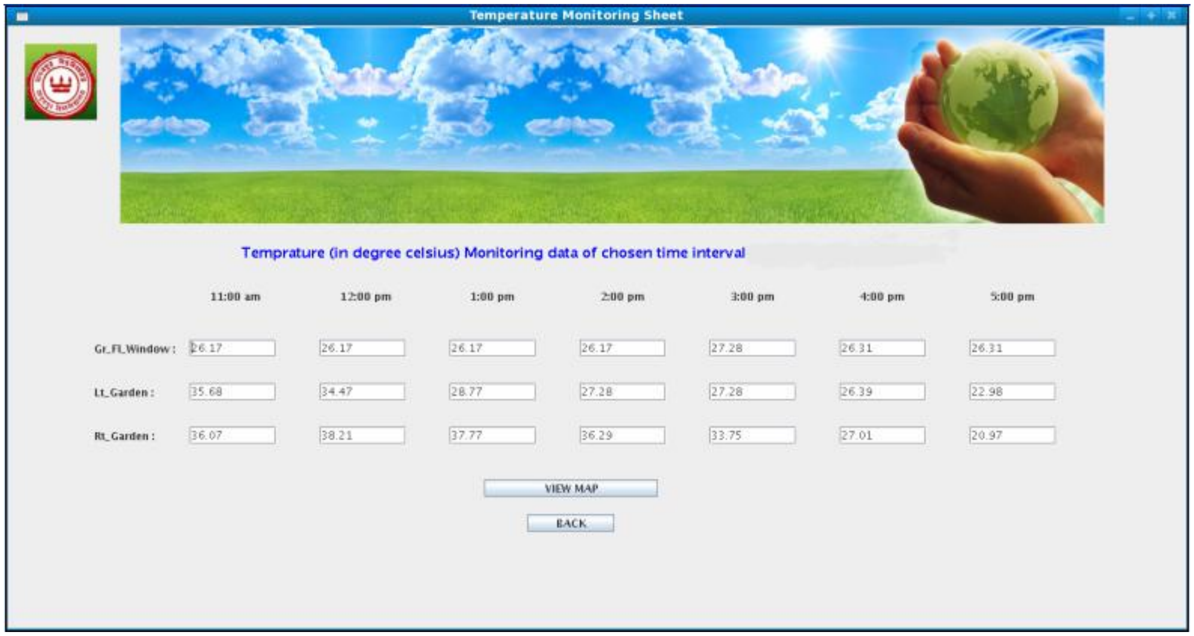

Figure 4: Average Temperature Monitoring Data Display in Interface

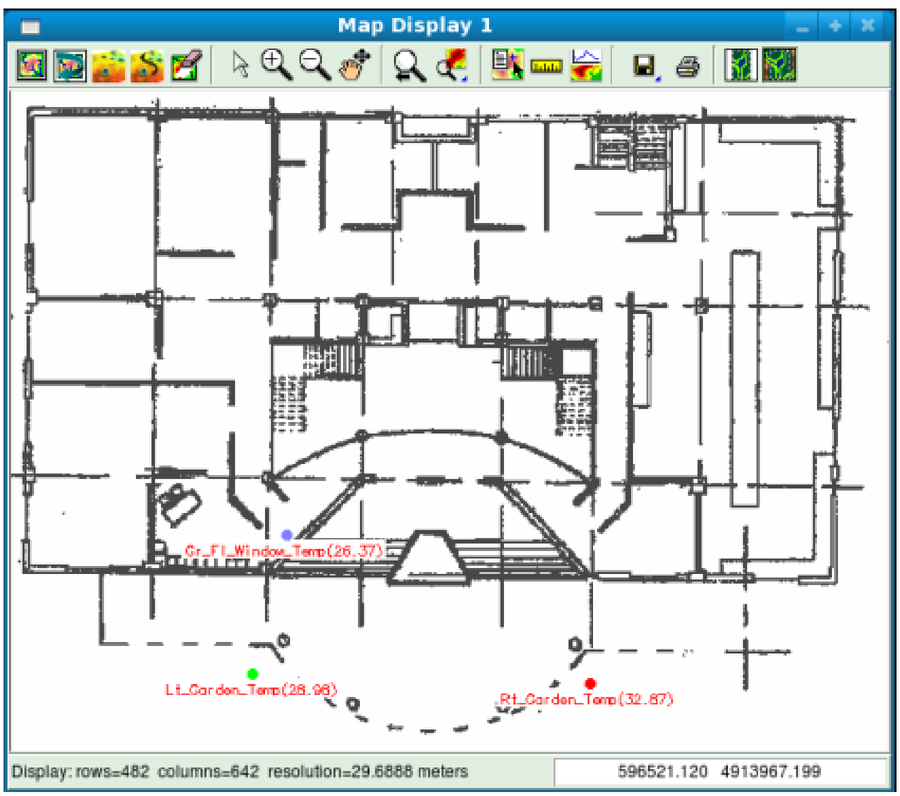

Figure 5: Colour Coded Display of Temperature Monitoring Data in SMCC map

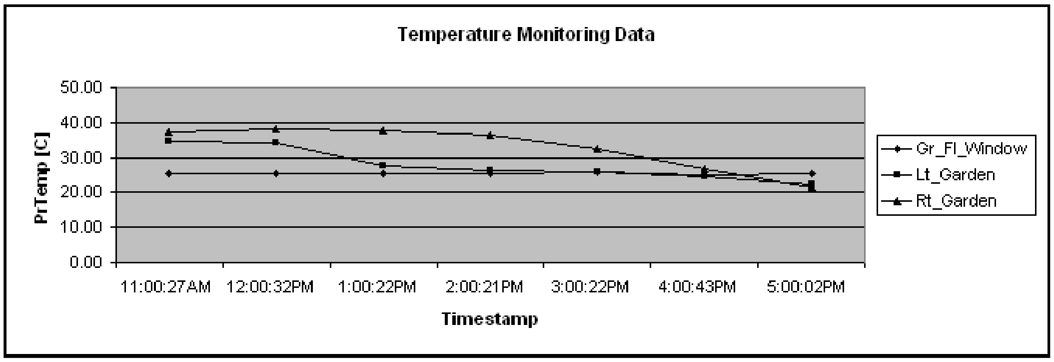

Figure 6: Temperature Monitoring Data

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