# AIR POLLUTION MONITORING SYSTEM BASED ON GEOSENSOR NETWORK[1]

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## ABSTRACT

Environment Observation and Forecasting System(EOFS) is a application for monitoring and providing a forecasting about environmental phenomena. We design an air pollution monitoring system which involves a context model and a flexible data acquisition policy. The context model is used for understanding the status of air pollution on the remote place. It can provide an alarm and safety guideline depending on the condition of the context model.

It also supports the flexible sampling interval change for effective the tradeoff between sampling rates and battery lifetimes. This interval is changed depending on the pollution conditions derived from the context model. It can save the limited batteries of geosensors, because it reduces the number of data transmission.

***Index Terms—*** Pollution monitoring, Context model, Sensor network, EOFS, Geosensor

## 1. INTRODUCTION

Wireless sensor networks have been deployed for environmental monitoring, which includes collecting the observed data over time across a volume of space large enough to exhibit significant internal variation[1]. Geosensor network is a kind of sensor networks which is designed to measure data related to geospatial information [2]. It could be useful to detect the conditions of remote place as a new instrument for environmental monitoring in the physical world[3]. For example, there are various kinds of applications such as seabird habitat monitoring, microclimate chaparral transects, building comfort, and intrusion detection.

We design and implement an air pollution monitoring system based on geosensor network. It employs the context model for understanding the status of air pollution on the current and near future pollution area. It is essential to provide an alarm and safety guideline for a near future dangerous situation, because prevention is better than cure. It can reduce severe damage and recovery cost. It also supports the flexible sampling interval change depending on the pollution conditions of the context model. This interval change is useful for keeping the geosensor network, because of the limited batteries. The power efficiency is increased depending on the flexibility of the tradeoff between sampling rates and battery lifetimes[4].

## 2. RELATED WORK

Environment Observation and Forecasting System(EOFS) is a one of the large scale sensor network for monitoring and forecasting [5]. The environmental applications involving sensor network require the understanding of earth science, combined with sensor, communications and computer technologies [6, 7]. The characteristics of EOFS are a centralized processing, a huge data volume, and an autonomous operation, etc. The sensor network can be utilized for environmental monitoring applications [7]. For example, there are microclimate monitoring [1], habitat monitoring[4], GlacsWeb project [8], PODS project [9], etc. GLACSWEB project monitors the behavior of ice caps and glaciers for understanding the Earth's climate [8]. The PODS project monitors the rare and endangered species of plants in a volcano neighboring with high-resolution cameras, temperature, and solar radiation sensors [9]. The seabird habitat monitoring project discussed the requirements for monitoring, the system architecture, the sensor's property [4]. The microclimate monitoring application checks the climate data such as radiant light, relative humidity, barometric pressure, and temperature throughout the volume of giant trees [1]. Sensor network is also utilized in the flood monitoring to provide warnings and the monitoring of coastal erosion around small islands (EnviSense-SECOAS) [10]. The Automated Local Evaluation in Real-Time(ALERT) was developed for

[1] Published at IGARRS 2008, Boston.

providing important real-time rainfall and water level information to evaluate the possibility of potential flooding [11]. There are lots of challenges in the EOFS which include as wireless communication, a data acquisition, data processing, an automatic reaction by the context model. We focus on the data acquisition policy and the context model for understanding the air pollution status.

### 3. AIR POLLUTION MONITORING SYSTEM

Sensor data monitoring system receives the measured data from sensor network and provide the useful information for users by understanding the condition of the remote place. The proposed monitoring system structure is based on the framework for context awareness [12]. In order to control the geosensor network and to monitor air pollution, we use two system; sensor network control system and air pollution monitoring system. The control system supports the operators which control sensor network such as sampling interval change and network status check. The operators are useful for keeping the good status of data transmission in geosensor network. The air pollution monitoring system supports sensor data abstraction and air pollution prevention models for understanding the pollution level and area. The models are used for providing alarm message and safety guideline for people in pollution area.

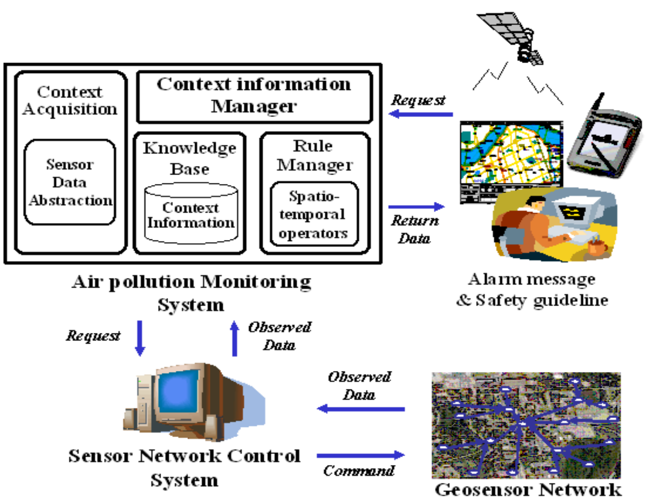



Figure 1. Air pollution monitoring system architecture

The observed data which is transmitted from the geosensor network is processed and abstracted by user defined rules with the abstraction model. The abstracted data is used for defining the pollution and the potential pollution area with the air pollution prevention model. It provides alarm message depending on the detected pollution area. In order to extract the status of the air pollution from row sensor data, we also design the context model; sensor data abstraction model and air pollution prevention model as shown in figure 2. Context model defines facts, events and their relationship for understanding the context of the remote place. It is utilized in mobile and small sensor network applications such as SOCAM(Service-oriented Context-Aware Middleware)[13], CASS(Context-awareness sub-structure), CoBrA(Context Broker Architecture).

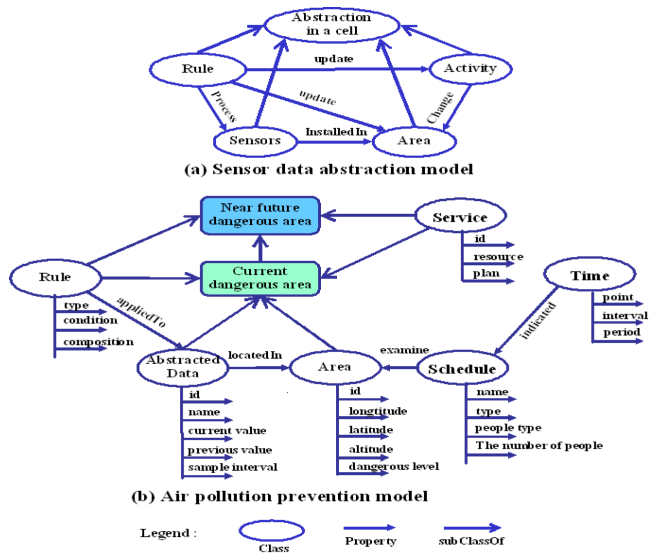



Figure 2. Context model for Air pollution prevention

The sensed data in each cell is presented by min(), max(), mean() for each data type with the abstraction model. It is used to represent the brief condition for each cell. The air pollution prevention model extracts the polluted area from this abstracted data depending on user defined rule. It also checks the dangerous rate for the polluted area with each area type and schedule. Finally we can get the two types of air pollution areas such as the current dangerous area and the near future dangerous area.

The current dangerous area is defined by combining the current dangerous types and levels in the local areas with some rules for pollution. It is a summarized map for the already polluted area. This information is used for providing the alarm message and safety guideline to the pollution areas. We also consider the pollution area in near future, because prevention is better than cure. To define the near future dangerous area is useful for reducing the pollution damage and the recovery cost by preventing the predicted pollution. First, it extracted the detected data, the gradient, and the dangerous level from current dangerous area. This data is processed by the user defined rule with other factors such as the priority of space, the constant for danger probability, and the reaching probability to critical point, etc. To define this predicted area, the domain knowledge is required depending on the pollution type.

### 4. FLEXIBLE SAMPLING INTERVAL UPDATE

In the environmental monitoring system, it is essential to support the frequent update for reacting promptly against disaster. It is hard to constantly keep the air pollution description, because the frequent data transmission makes the batteries of the geosensors have gone out rapidly. The effective acquisition is required for tradeoff between battery lifetimes and sampling rates [5]. The measured data of heterogeneous geosensors is sent according to the sampling interval defined in the rule information database. To define the sampling interval is very important because their battery is limited. If the interval is short, the system can recognize the conditions of the remote place promptly, however the batteries of sensors could have gone out in a short time. If the interval is long, it can keep the electronic power in a long time. However the system can not promptly react for the detected events. So, we decide to change the sampling interval depending on the situation which is derived from the context model for the sensors.

It is to control the sampling interval for keeping a sleep mode as long as it can. The "power-saving" mode must require less power than a mode for active vigilance [14]. Of course, the interval can not be escaped beyond the user defined interval boundary for the environmental monitoring. When the sensors in the network receive the order for changing the interval, all of sensors will be in the sleep mode until the ordered time. Only timer is alive in the sensors. When it is time for wake up, all of sensors wake up and send their measured values to the sensor network control system in the same breath. After data transmission, the sensors are sleep again and wait the next awake time.

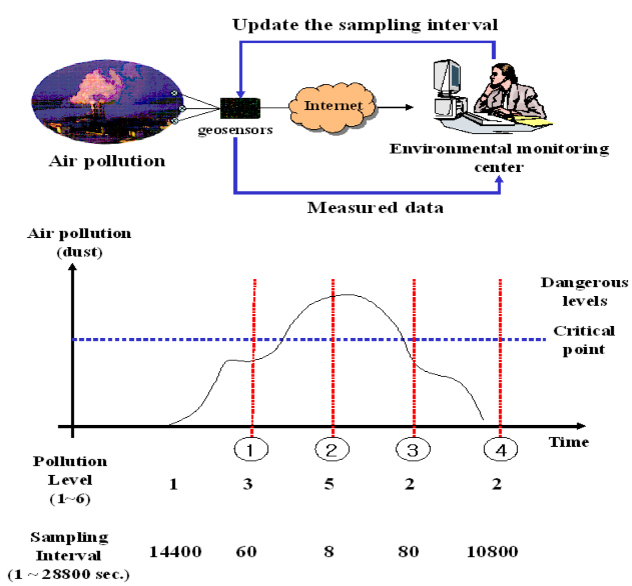



Figure 3. Flexible sampling interval change

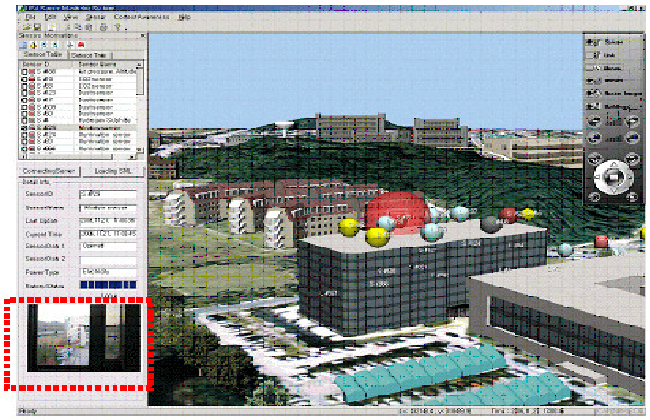
Figure 3 shows the example of sampling interval change depending on the air pollution level. The initial sampling interval is 14400 sec. under the assumption that there is no air pollution. At □, the system recognizes that it is an indication of air pollution after checking the observed condition. It changes the interval to 60 sec. If the system considers the only current pollution level, the interval could be longer than 60 sec. such as 480, or 600 sec. However the interval should be at most 60, or shorter because the pollution level is continuously increased from the initial time to □. It makes the interval shorter, because the probability for air pollution can be high. When the pollution level is so high and dangerous like □, the system should analyze and cope with the pollution as soon as possible. It makes the interval shorter (8 sec.). When the pollution level is lower and the gradient of measured values is also lower continuously at □, the system decides the current situation could be normal in near future. The interval is changed to 80 sec. It is longer than the previous interval (60 sec.), because the current gradient is opposite to the gradient at the beginning of pollution. It indicates that the probability of air pollution is also reduced. The system stops providing the alarm. When it is no indication of air pollution at □, the system changes the interval to 10800 sec. If there is also no pollution in near future, it could be longer for saving the batteries of geosensors.

## 5. IMPLEMENTATION

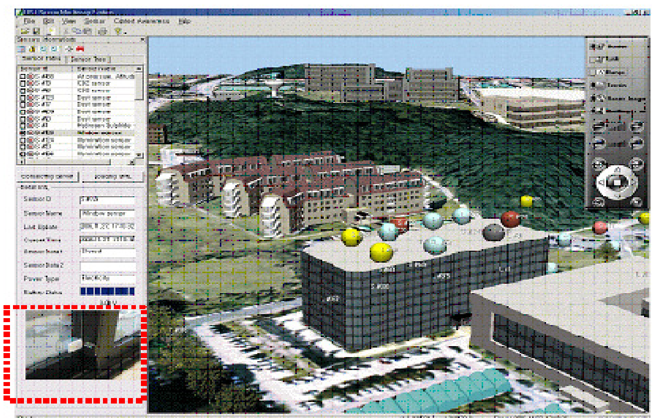
We installed 10 routers and 24 sensors with various 12 types on a field such as temperature, humidity, illumination, dust, carbon dioxide, ultra violet, wind direction, wind speed, air pressure, and altitude, etc. After installing various kinds of sensors on the field, the system can recognize the locations, types, and accuracies of the installed sensors by importing the sensorML [15] which describes the properties of geosensors. It also connects the sensor network control system which operates the sampling interval change, network status check, and the communication control. The observed data is transmitted from sensors to the air pollution monitoring system through the control system.

When the observed data of a dust sensor is higher than the dangerous level of the air pollution, the context model checks the current pollution area the cells around the sensor. It also checks the area types such as a school, a factory, and an apartment, because the dangerous rate is changed depending on the area types. After defining the current pollution area, it also checks the potential pollution area in near future with the related factors such as the pollution level gradient, the area type, wind direction and speed. When it finds a factor to make a dangerous condition in near future, it shows an alarm message about that until the factor is gone. The alarm message is include the pollution level and type, and safety guideline.

To have a test about the recognition of the proposed context aware model, we use the simulated sensor data for dust, because there is no real pollution. After updating the dust level, the system recognizes the pollution area and indicates a factor for the potential dangerous factor like the (a) of figure 4. It shows an opened window of a building in a potential pollution area, because it is a primary factor for air pollution inside the building. The status of the window is also observed by a window condition detection sensor.



(a) Warning alarm



(b) Terminating Alarm

Figure 4. Alarm message for air pollution

The system shows an alarm for air pollution by a dust in figure 4. This alarm message continued until the window is closed. The people in the building can recognize what the problem is and its dangerous effect. After closing the window, the system understands that the dangerous factor is gone and the building will be not polluted. So, it terminates the alarm message. The system also shows the condition of sensors such as the current value, last update time, and the status of battery. This information is used for users to understand the current condition of the sensors.

## 6. CONCULSION

We implemented the air pollution monitoring system utilizes the context model for understanding current and near future pollution area. It provided the alarm and safety guideline according to the condition of remote place which is derived from the proposed context model in the test. It also employed the flexible sampling interval change depending on the status of the recognized situation. It is useful for tradeoff between battery lifetimes and pollution description in context model. Currently we are focusing on the heterogeneous geosensor data abstraction and combination for a higher context.

## 7. ACKNOWLEDGEMENT

This work was supported by the Korea Research Foundation Grant funded by the Korean Government(MOEHRD). No. KRF-2007-357-D00206

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