A TELEGEOMATICS-BASED ENVIRONMENTAL SURVEY AND INFORMATION SERVICE SYSTEM

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ABSTRACT:
In the last three decades, GIS, in terms of both its theory and methodology, has been going rapidly towards its maturity from its very infancy. Nowadays, the most fundamental task of GIS is extending its application in different fields. In retrospection, we can find that the most attention has been paid to development planning forecast, and subsequent evaluation and reflection. But few researches have been done on real-time or near real-time monitoring and decision-making, which is a very important field deserving more attention. To perform real-time monitoring and decision-making, support from telecommunication technology is needed. In fact, only through the integration of GIS and telecommunication technology, could real-time monitoring be enabled. In this paper, we argue that a promising direction in GIS applications is the integration of GIS and telecommunication. Then the concept of Telegeomatics is presented, and its basic structural characteristics analyzed.

The core of Telegeomatics is the integration of GIS and telecommunication, which will availably resolve the problem of obtainment and policy-making support for the real-time and near real-time spatial information.

1) In the case study, a real-time multi-factor environmental monitoring and information service system of Beijing is constructed. Through this research, we found that: 1) it is an effective way to integrate GIS, telecommunication and EO for real-time environment monitoring; 2) GIS is fundamental to the development of the proposed system; 3) The bottleneck of the proposed system is the development of Internet infrastructure, especially the development of IPV6. This indicates that it is urgent to develop IP infrastructure in order to further promote the development of the proposed system.

1. INTRODUCTION

With the deterioration of the environment, people are now no longer solely focus their attention on development. For a nation, a country, or a region, they tend to pay more attentions to the environmental capacity of the earth, of a city, or of a region in macro-scale when they make an economic develop-ment plan for the corresponding area. While for individuals, they tend to concern more about the environment issue in micro-scale, such as the air quality in their com-munity, the water pollution index in a river nearby, the noise level in the area where they are live, the level of ultra-violet radiation where they are traveling, and so on and so forth.

In the light of these concerns, there is clearly a need for improved information service about environment quality and pollution index for environmental monitoring. This informa-tion is required for a wide range of purposes, to name but a few, to help investigate the relationship involved as inputs to health risk assessment, to assist in establishing and monitoring air quality standards, to help evaluate and compare transport policies and plans, to provide ancillary information for industry location, to assist individuals with daily decision-making. For all these purposes information is required not only at macro-scale (such as at city, region level), but should also be bound to each specific location. To achieve the above goals, geo-spatial technologies (such as GIS) and communication technologies need to be integrated.

In retrospection of its development history, GIS has gradually extended its application in various fields and played an important role in setting the direction of strategic development in those fields. However, traditional GIS applications were limited by computer technology to a great extent. Those applications usually stayed in macro-scale. Today, great progress has been made in the development of computer technology, both in terms of software and hardware. Hence, it is possible to integrate GIS and technologies in other domains, such as communication. It is also possible to extend the application of GIS in related fields in micro-scale, such as environmental monitoring at each specific location.

This paper presents a model developing a GIS and communication based system – "Telegeomatics", and integrates it with environmental survey techniques for environmental monitoring and information service at micro-scale. The case study area is Beijing. Beijing government is the sponsor for 2008 Olympics. It now faces a very tough task in reducing pollution and improving its environment quality. The purpose of this research is to design a dynamic environmental monitoring system, which will provide service to any mobile users at any location. Through integrating environmental issue with people's daily life, and make the environmental issue open to the public, it is hoped that it will not only provide ancillary information for decision-making and environment manage-ment, but also help generate pressures for improving the environment.

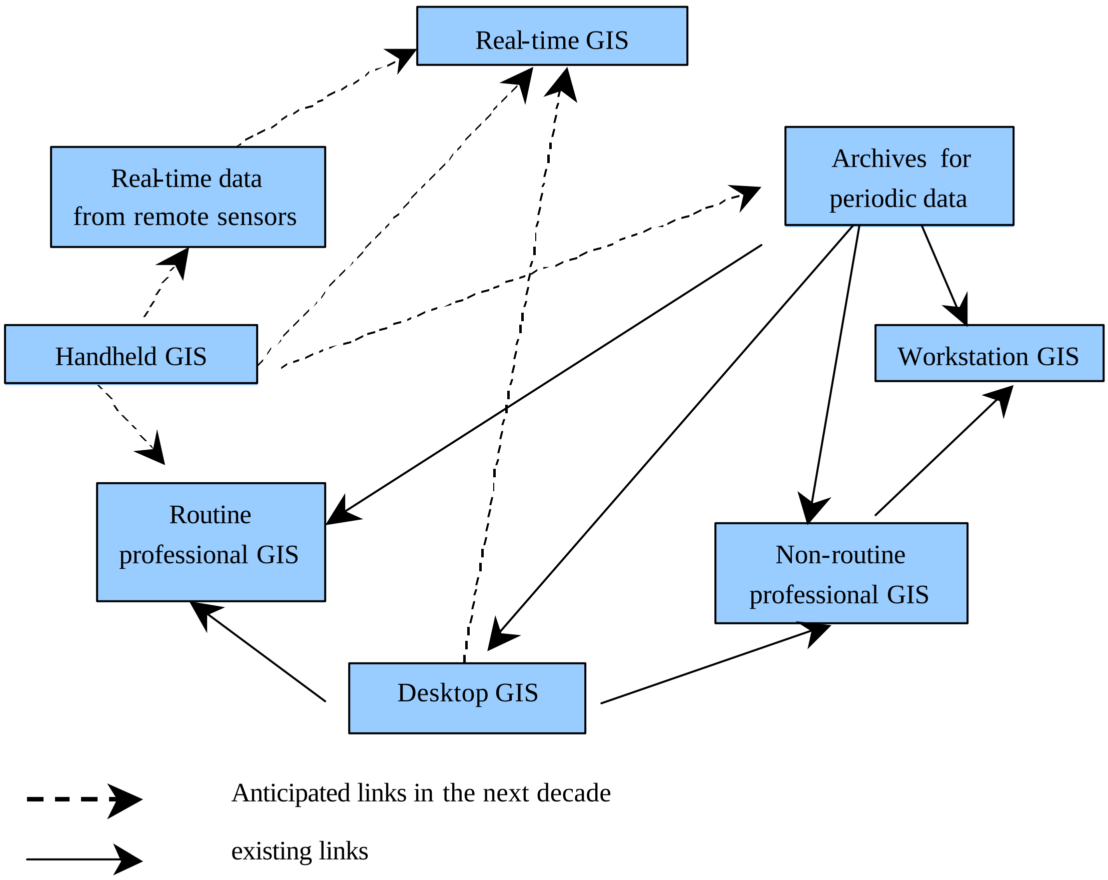

Fig.1 The evolution of GIS technologies (M Batty, 1999) to the Internet and the wireless communication technology, and integrate real-time application, shortest-distance routing, and remote control. The connection of hardware, such as cable, TV, telephone, and computer, will integrate GIS and other software technologies through input and output (Graham and Marvin,1996).

2. THE CONCEPT OF TELE-GEOMATICS AND ITS APPLICATION MODEL

The concept of Geomatics has been discussed by numerous scholars (Maguire, D. J., Goodchild, M. F., & Rhind, D., 1991). In many fields, applications require real-time or near real-time data, hence wireless communication technologies are integrated with Geomatics technologies, which gives birth to the concept of "Tele-geomatics". The applications of Tele-geomantics cover various fields which require real-time or near real-time spatial data. An example is field data collection, such as environmental survey (e.g., temperature, humidity, radiation, ultraviolet radiation, noise level, and other health related indices). If real-time data transmission can be realized by using additional facilities when collecting environment data, then we can not only acquire teledata, but also perform real-time decision-making. At the same time, it will be helpful to improve the measurement accuracy (M. Zingler, P. Fischer, J.Lichtenegger, 1999). In the mean time, this is consistent with Laurini's argument that "GIS without connecting will disappear" (laurini,2000).

2.1 The evolvement of GIS technology and the formation of the concept "Geomatics"

The 30-year development history of GIS was driven by technology development, including hardware, software, data collection, and structure design. At the same time it was guided by the market demand, including demands from individual user, organizations, and millions of Internet users. The development of technologies has remodeled the characteristics of GIS, and affected every corner of daily life. As Batty argued, GIS technologies have not only greatly impacted the development of other software technologies, but also been integrated with the data infrastructure in a society (Batty, 1999). Internet has been the focus of this process, which has aroused great attention on the real-time input and output of GIS.

Figure-1 demonstrates how GIS has integrated various current technologies and become parts of data infrastructure. Real-time data transmission in GIS has made it the key to related applications, such as traffic management, emergency service, and even real-time mapping. By updating data from handhold facility through wireless communication, it also supports basic daily applications such as urban navigation and information query. In fact, in the future, the new generation GIS will resort to the Internet and the wireless communication technology, and integrate real-time application, shortest-distance routing, and remote control. The connection of hardware, such as cable, TV, telephone, and computer, will integrate GIS and other software technologies through input and output (Graham and Marvin,1996.

Nowadays, more and more attention has been paid to Geo-Spatial Information Science (it will be called Geomatics in the following sessions). Geomatics mainly includes Global Positional System (GPS), Geographic Information System (GIS), Remote Sensing (RS), and its technical supports include computer technology and communication technology. It is a comprehensive and integrated information science that is used to collect, measure, analyze, store, manage, display, and distribute geo-spatial data. Geomatics is a preceding field in earth science and it is a significant element in geographic information science. It is still in its infant period regarding to the development of its theory and its methodology. An integrated theoretical structure of Geomatics is yet to be built. The technology for geo-spatial data collection, storage, management, representation, and distribution is yet to be developed.

In the integrated application of 3S, different parts have different functionalities. GPS is mainly used for real-time target searching, including global positioning of various sensors and carriers (automobile, boats, airplanes, satellites, et al); RS is mainly used to supply real-time data about the targets, and its semantic or non-semantic information, detect all kinds of changes in the surface of the earth, and update GIS data; GIS is used for comprehensively processing, integrated management, and dynamic storage of temporal-spatial data from various inputs, it also acts as basic platform of new integrated system, and provides spatial knowledge for data collection using AI. In Geomatics, on the one hand it is urgent to solve the theoretical and technical problems related to the integrated process; on the other, it is necessary to solve problems related to the application of the integrated system.

2.2 The concept of TeleGeomatics and its characteristics

In the modern application of geography, it is common to integrate field survey data and EO data with some other data (such as data from aerial photos) using data collector. The further application is to bind positioning facilities and related communication technologies. For example, a field survey center (immobile) can be built by connecting a handhold computer such as a PDA (Personal Digital Assistant) with a wireless communication system within a certain distance. Further more, a data linkage can be built if several mobile platforms are connected to the field survey center. More applications can be achieved if additional plug-in sensors are used, such as digital camcorder sensor for temperature and humidity measurement, radiation sensor for radiation measurement.

The rapid data collection system without using any paper will save lots of time and money in field survey. In some applications, PDA is used to avoid signal attenuation when the data to be communicated is very important. Sometimes cellular phones are integrated with GPS and connected to mini hand-hold computers to perform computation and display. In modern geographic applications, the demand for real-time communi-cation and the demand for spatial information are usually twins. TeleGeomatics is the integration of spatial information and real-time management. It is not an application focusing on traditional map-making, but an integration of real-time management with spatial information. The characteristics of its application include: 1)the demand for GIS; 2) the demand for modern positional technique (e.g. GPS); 3) exchanging positioning information among various locations; 4) real-time Decision Support System (RTDSS); 5) remote control.

TeleGeomatics uses GIS and various communication techniques to effectively transmit information and perform spatial analysis. All these spatial analysis are real-time and its ultimate goal is to provide real-time decision support. Here, "real-time", or "near real-time" is the time within the scope of human reaction, and usually lasts from several seconds to several minutes.

A TeleGeomatics system is a real-time geographic information system that strengthens decision support. It has a mechanism to support decision-making, for which purpose it has to have a complete system to transmit commands and information, and to execute commands. It also needs a remote activating mechanism, such as the typical automatic control facility (Boulmakoul, Laurini, 1999-2000). It has an important application in dynamic environmental monitoring and remote control.

2.3 The techniques for TeleGeomatics and its application model

The way to connect field surveyors with the GIS platform is similar to the way central computing facilities are connected with outside users (M. Zingler, P. Fischer, J.Lichtenegger, 1999). By connecting them together, it is possible to transmit data timely to the users, and at the same time, the field surveyors can return collected data.

In urban environment monitoring, real-time data can be transmitted by using Internet or Modem. Considering the limited computing capacity of hand-hold facilities, we can compare the characteristics of C/S connection with the Internet: most data processing tasks are performed in the server side, and only some simple data processing tasks are done in the client side. They communicate through protocols.

Only in those areas not covered by the Internet or telephone services wireless communication system will be used. Some standard commercial communication companies (such as GSM) or some other companies such as CORDAN will provide specialized wireless transmitters to transmit collected data. As we know, communication through GSM is usually limited by geographic conditions, which usually results in failure or communication blind spot. Only satellite communi-cation system can provide error-proof and permanent connec-tion without suffering from blind spots.

An applicable environmental monitoring system should be able to support information service. It is an effective as well as ideal method to increment information by integrating different data sources.

In a word, an important method to fulfil TeleGeomatics is to develop a complete data service system. TeleGeomatics system will guarantee the provision of objective, detailed, and updated data, as well as affiliated data sets. It provides not only standard data, but also detailed data for specific domain, which contain classified data or synthesized data. It not only uses common geographic matching system, but also resorts to topological relationships to build linkages between different data. What's more, it integrates field survey data transmitted from NRT. The fact that all the data (including GPS data and spatial data) can be effectively matched or joined together implies that we only need to concern about different types of data and their reference systems. We need to perform some transformation before transmitting the field survey data to our database if they are of different reference systems.

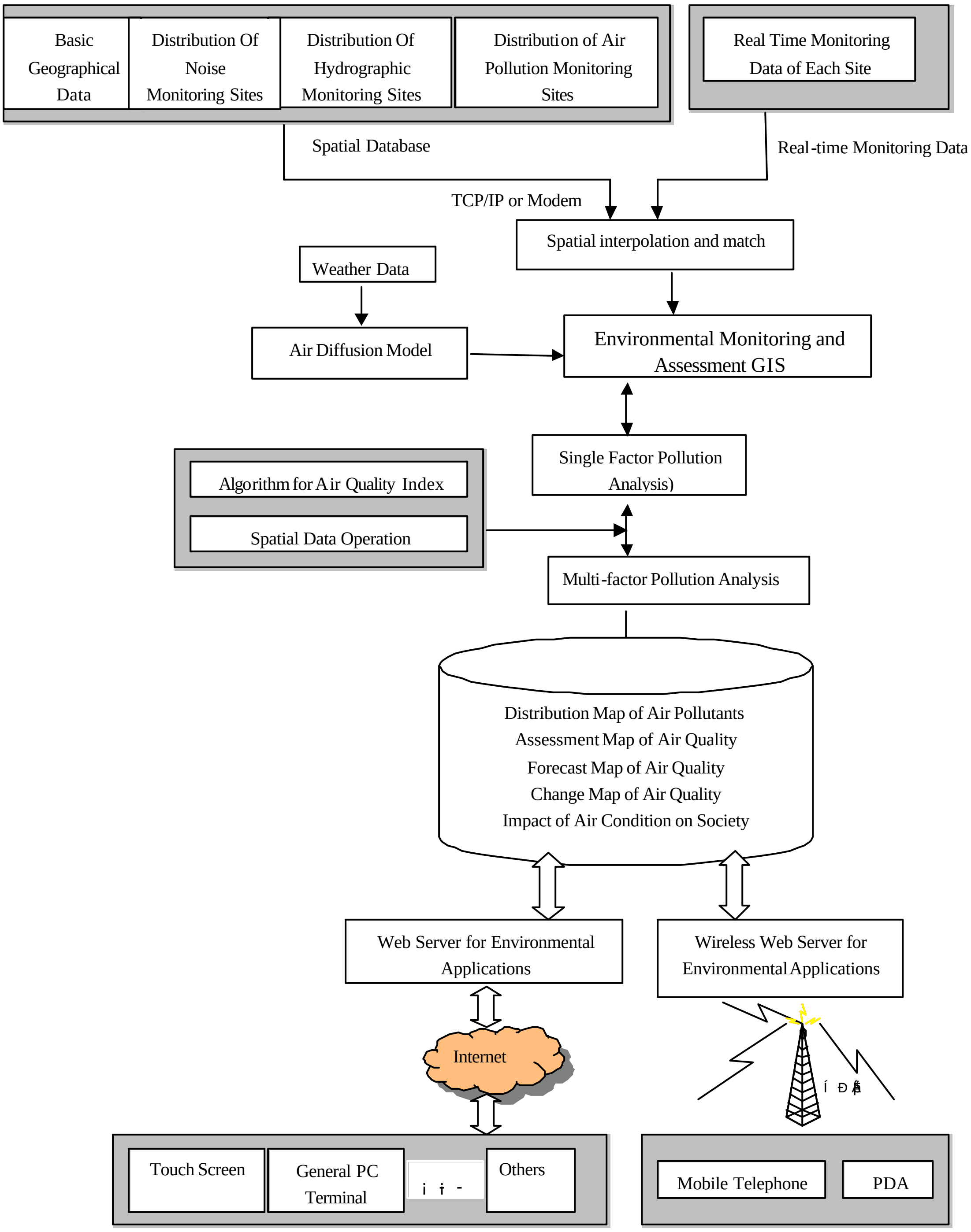

Fig. 2 The Framework of Environmental Information Service System

3. THE DESIGN OF A DYNAMIC SERVICE SYSTEM FOR ENVIRONMENTAL INFORMATION

3.1 Environmental information service is part of Digital City

The rapid development of cities brings about great challenges to urban management. Traditional management techniques using statistical information can no longer meet the require-ment of modernization. It is necessary to build a data management system based on computer technology, which is able to store and manage huge volume of data related to urban development.

Digital City is a description of urban development. It indicates that digital technology, information technology, and Internet technology will penetrate every corner of urban life. The key issue in constructing a Digital City is information sharing. At the same time, it is important to construct a dynamic database that is linked to the Internet. With the extensive application of such technologies as GIS, CAD, OA and AM/FM, the information service based on urban database is developed rapidly. Usually urban is the cradle where new technology is tested and the place where new technology is most intensively used. Recently, most of the GIS or GIS related systems, which are being built or have already been built, are in the urban areas. Urban GIS or GIS related systems have switched their development stage from "technology-driven" to "application-driven". Environmental monitoring and service has been a key component in the construction of Digital City (Wang Dan,2000).

3.2 The Framework of Environmental Information Service System

The major purpose of this system is to take the advantage of modern information technology and realize real-time monitoring and evaluation of the urban environment in Beijing city. It will provide environmental decision support for the development of Beijing city as well as real-time environmental information service. Considering the current condition of Beijing city, the major objects of environmental information monitoring and service are air pollution; water pollution and noise pollution.

At the client side of the measurement system, air quality, noise, radiation, and other environmental sensors are integrated. Real-time data are transmitted to the server side through wire or wireless network system. Then the server of the system will perform such tasks as data interpolation, data storage, and data management. The server of environmental information application will send the environmental indices to the users (e.g., the Internet users, mobile device users) corresponding to their current location based on their requests.

3.3 Major Research Contents

1. Build a digital, web-based, and information-based Geographic Information System for environmental monitoring so that real-time information about environmental condition can be conveniently collected, digitized, and transmitted through the Internet; realize information-sharing based on distributed database management system; provide decision support for urban planning based on the information extracted from the survey data (including historical data and current data).

2. Improve the fundamentality, integration level, and publicity of the Geographic Information System for environmental monitoring.

3. Build a geographic information center for environmental monitoring; build Internet connections between the information center and monitoring stations and among those monitoring stations.

4. Build environmental monitoring data warehouse in the information center to management historical as well as current environmental monitoring data.

5. Build mobile IP infrastructure IPV6 to provide real-time environmental information service for mobile users at any specific locations. Provide open environmental information service for the public to improve people's quality and efficiency of life.

3.4 Implementation Steps

1. Build environmental information database for Beijing city, including:
   - Fundamental geo-spatial information, such as water system, land cover, topography, temperature, road system, residential distribution, industry location, et al. The above geographical elements directly impact the environment condition of Beijing. The scale of the spatial database should be between 1:2000 to 1:1000 in the built-up area, and could be 1:5000 in the suburban area.

   - Information related to the environment, such as the condition of stations for environmental monitoring (location, type of those stations and their monitoring facilities, et al), the distribution of those pollution hot spots (their location, total amount of pollution, type of contamination, et al), the condition of pollution prevention (such as the distribution and capacity of those sewage farm and garbage farm), and relevant information about environment quality and pollution prevention.

2. Build well-distributed environmental monitoring network including monitoring stations for air pollution, water system (including surface water, precipitation, ground water, et al). The monitoring stations should be evenly distributed across the whole area to effectively reflect the environment condition in Beijing. In the seriously polluted area, the number of stations could be reasonably bigger. In different areas, the types of environmental monitoring facilities and the items to be monitored could be different according to their different situations.

3. Set up advanced data acquisition and digitizing facilities so that the environmental monitoring data can be directly digitized from the raw data and be transmitted to the computer system through specific transmission ports. In this way, the efficiency and accuracy of environmental monitoring can be increased.

4. Develop GIS software for environmental condition evaluation and prediction based on the environmental monitoring data warehouse. A qualitative description on the environment condition in Beijing can be obtained through analyzing various environmental data. Furthermore we can simulate the dynamic evolution of the environment condition in Beijing and its spatial distribution rules; analyze the quantitative relationship between pollution sources and the environment quality. All these information will be helpful for decision-making in directing future urban construction and urban management.

5. Build a public environmental information distribution and query system in Beijing. Every citizen will be able to access to the environment evaluation information and environment prediction information, which will bring about great convenience to their daily life and daily travel.

4. DISCUSSIONS

1. The technology of Telegeomatics has great potential, especially in its applications in various fields. In the future development, it is promising to integrate Telegeomatics with the break-through of sensor techniques and technologies in other fields, such as electronic technology, automation technology. To certain extent, its applications in various fields has bring about great convenience to daily life, improve the quality of life, and even change the life style of human being.
2. GIS, as a macro-framework, is fundamental in the implementation of the proposed system. The theory and methodology in designing a Geographic Information System, as well as its quality, will directly impact the performance of each component of the proposed system, and hence the performance of the whole system.

3. The bottleneck of the proposed system is the development of Internet infrastructure, especially the development of IPV6. This indicates that it is urgent to develop IP infrastructure in order to further promote the development of the proposed system.

4. The proposed system is characterized by its strong expandability. It is possible to add components based on user's needs with great flexibility. For example, we can add a component for radioactive elements monitoring if we use the proposed system for environmental survey. Beijing is now speeding up its pace in developing physical infrastructure in order to prepare for the 2008 Olympics. In the planning, several big nuclear power stations will be built in the eastern coastal area close to Beijing. This will meet the demand for electronic power; however, it will also bring about potential danger such as nuclear leakage, nuclear storm, and nuclear smoke. Therefore it is necessary to have such a prevention and monitoring system.

5. When a comprehensive TeleGeomatics system is designed with all necessary monitoring components, then in the next step, we need to put our efforts in designing an open decision-making system. Using such an open decision-making system, we can not only provide real-time

information for positioning and environmental monitoring at specific location, but also provide optional specialized solutions for specific problems. Any mobile user will be able to request information service about the environment index that are monitored by the TeleGeomatics system, and will be provided possible solutions. When the environment index at any location is above the alarming level, the mobile users at that specific location will receive a warning message from the system. For example, when you are nearby a factory that is venting air contamination, the system will provide the environment index in that area. If the air pollution or noise pollution is beyond the alarming level, then you can choose appropriate ways to protect yourself after you receive the warning message from your mobile service, you will also have the right to request emergency service to stop the pollution, or you can even sue the factory. This is very important for specialized decision-making related to air pollutions or radioactive pollutions that could do serious harm to the human body. In an environment that has potential danger of nuclear radiation, people may choose some emergency service such as: 1) withdrawing from the polluted environment temporary; 2) moving away if the nuclear radiation in that area is constantly above the warming level; 3) using something the cover the radiation; 4)taking some medicine containing Iodine; and 5) food supervision (Simplified Outdoor Emergency Service Expert System for Nuclear Radiation, Nuclear Research Insititution, Zeng, Y., He, B.J., 995889).

6. Since the system is still under development, there are still many foreseeable or unforeseeable problems to be explored.

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