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Using TRIZ Theory to Design and Analyze the Forest Environmental Factors Monitoring Platform

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Abstract

The study has proposed it can use the theory of TRIZ to improve Forest environmental factors monitoring platform (FEFMP) by solving the problem of organization, monitoring, control of power supply and so on during the networking of the forest IoT. The study first analyzes the evolution laws of the technology system, the best final solution, the substance-field models and technical contradiction in the application foundation of the TRIZ theory. Then, the best final solution of FEFMP based on mixed models has been raised by solving the technical contradiction using contradiction matrix tools and by solving the physical contradiction of the accuracy and power consumption using separation principle. It has raised and built mixed networking basing on 3G and ZigBee and established the FEFMP by using WebGIS and mobile GIS. Experiments show that the system runs well, which can provide reference for the following related researches.

***Keywords**: FSFMP, IoT, TRIZ, ZigBee, 3G, GIS*

1. Introduction

Real-time and accurate monitoring of forest environmental factors has great significance to the management of forestry resources, but the domestic forest monitoring tools are still at a relatively primitive stage. It is obvious that the forest environmental factors have not been effectively and intelligently monitored yet.

TRIZ theory provides people with a technological innovation system, which turn into a weapon of developing new products for high technological companies. The theory of conflict solving principles and substance-filed analysis principles have a strong advantage in terms of innovation, which provides us with methods to solve the problems of intelligent monitoring of forest environmental factors.

Through the thinking of layering, the construction of forest environmental factors monitoring platform(FEFMP) has been proposed by using the conflict solving principle and substance-filed analysis principles of TRIZ.

Nowadays there are various of methods of invention, famous of which, TRIZ raised by Archie Surratt is widely used. The application of TRIZ thinking tools in diverse industries has successfully replaced the unsystematic trial-and-error method in the search for solutions in the daily life of engineers and developers [20], look at the references [2-5]. Surely, the course of TRIZ system is gradually improved, there are always some new theories proposed to enrich the TRIZ theory. For example in the article An integration of TRIZ and the systematic approach of Pahl and Beitz for innovative conceptual design process, an integration of TRIZ and conceptual design process was proposed to overcome important deficiencies of conceptual design [6]. There are also some new ideas proposed

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in Using TRIZ with Other Tools [7] and [15-16].TRIZ theory is used in some other research field, look at the references [1], [8-9] and [11].

Obviously, TRIZ fits very elegantly into the "Ideate and Create" element of Suh's design process map[19], which helps in concept generation for solving design problems related to manufacturing[18]. Let's introduce some things about TRIZ at first.

2.Triz Inroduction

TRIZ(The Theory of Inventive Problem Solving) is an epoch-making theory of invention problem solving, which provides people with a new set of innovation principles and open up a new era of inventions and innovations . TRIZ aims to create an algorithmic approach by applying inventive knowledge abstracted from patent bases all over the world to solve inventive problems [17]. Genrich Altshuller, the inventor from Soviet, led a group of scholars established a set of systematic theory to solve the invention problem after collecting, researching and processing on tens of thousands of patents in the world.

The key points of the modern TRIZ theory are manifested in three aspects. Firstly, the development of the core technology is to follow the objective law. Secondly, all kinds of technical problems, conflicts and contradictions of resolving is the power of driving the system evolutionary process. The last one is that there is an ideal state of development in technology system in which little resources are used and more functions are realized.

2.1.TRIZ Architecture

As is known to us all that modern TRIZ theory system mainly includes the following aspects.

2.1.1.Innovative Thinking Method and Problem Analysis Method: TRIZ theory provides a scientific method on how to analyze the problem systematically, such as multiple screen method and so on. When it comes to complicated problems, the scientific method of physical field analysis model can help in identifying the core problems and found the fundamental contradictions quickly.

2.1.2.The Law of Technical System Evolution: In view of technology system evolution laws, TRIZ theory summarizes the eight basic laws of evolution by analyzing a large number of patents. The current technical state can be analyzed and confirmed by using these laws of evolution, as well as predicting the trend and developing competitive new products.

2.1.3.The Principle of Technical Conflict Resolution: Different inventions tend to follow the common law. TRIZ theory concludes all these into 40 kinds of innovation principles in which specific solutions can be found based on the innovation principles and engineering practice for specific technical contradiction.

2.1.4.Standard Solutions of Innovative Problems: For different characteristics of the physical field analysis model of specific issues, the processing method of standard models are listed, including trimming, converting and adding substance and field to model.

2.1.5. As Shown in Figure is the TRIZ Theory Architecture:

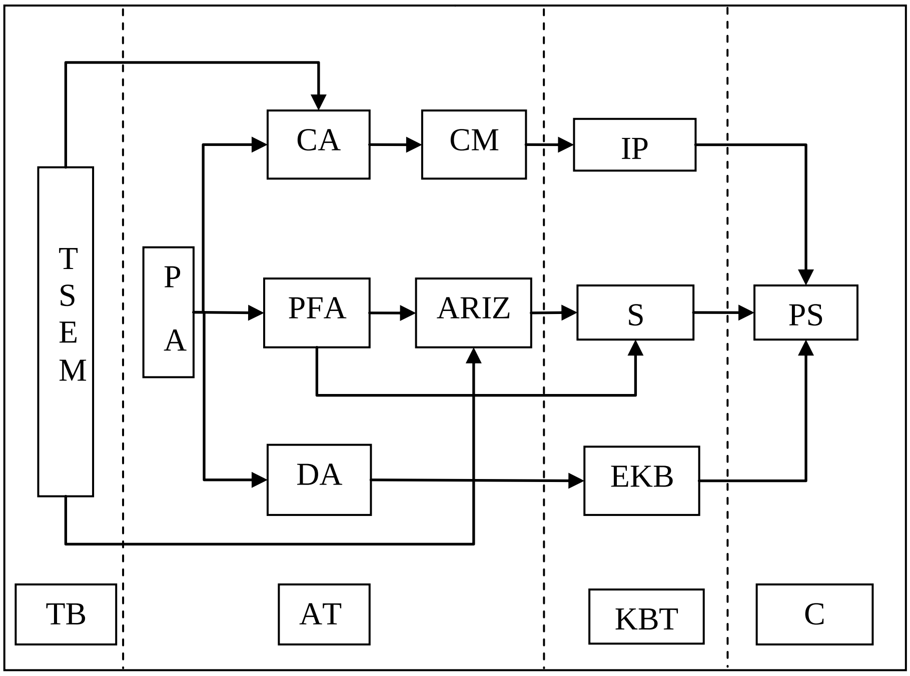

Figure 1. **The Architecture of TRIZ**

Where TSEM: Technology system evolution mode. PA: Problem analysis.TB: theory basis. CA: Conflict analysis. PFA: Physical field analysis. DA: Demand analysis.AT: Analysis tools.CM: Conflict matrix.IP: 40 kinds of innovation principles.S: 76 pieces of standards. EKB: Effect knowledge base.KBT: Knowledge-based tool.PS: Projects suggested.C: Conclusion

2.2.Technical System Evolution Theory

Genrich Altshuller founded TRIZ theory in 1946, one important principle of which is evolution principle of technology system. The theory has eight major evolution laws, which can be used to solve problems, forecast technology systems as well as generate and strengthen creative problems. The eight laws include stages of evolutions, uneven development of subsystems, increasing ideality, increasing dynamism and controllability, increasing complexity followed by simplicity, matching and mismatching of parts, transition toward micro-level and increasing use of fields, decreasing human involvement and so on. This article mainly uses the stages of evolutions and increasing ideality to forecast the product evaluation.

2.3.Problem-Solving Tools in TRIZ

Genrich Altshuller and his TRIZ research institutions proposed TRIZ, which contains a series of multiple tools in the past more than 50 years, such as conflict matrix, 76 pieces of standard answers, eight kinds of the evolutionary types, 40 kinds of innovative principles and so on. The ones commonly used are that conflict matrix method and physical field transformation method which are based on the microscopic. In fact TRIZ has complete theory in view of the relationship between input and output (effect), conflicts and technology evolution. These tools provide the foundation for the innovation theory of the software, which provide the conditions for the applications of TRIZ.

3. Using the Theory of Triz to Design FEFMP

3.1.The Design of Existing FEFMP

Current FEFMP are limited to artificial data, which show great malpractice in collecting real-time and accurate factors data or in terrible environment(such as the virgin forest, *etc*.). There are some new monitoring ways [10-12], which are still in the experimental stage.

3.2.Research of the FEFMP Based on TRIZ

3.2.1.Limit conditions of the FEFMP Design: As has been mentioned above, existing FEFMP has a lot of limitations. To solve these problems, there is a need to design a new-style FEFMP. However, there will be many limit conditions during the design:

(1)Sampling tools shouldn't cost too much, or it will be unable to meet the market demand.

(2)Communication should be reliable enough to ensure the correctness of the collected environmental information.

(3)The speed of data transmission can't be too slow to meet the needs of real-time.
The FEFMP we designed should meet the above three conditions.

3.2.2.The System Analysis of the FEFMP: (1) System completeness principle**:** By using the system completeness principle analysis, it is obvious that the FEFMP system includes the above several parts, as shown in the Figure 2. Completeness principle is helpful to determine the method of realizing the required technical function and saving resources, in which way, the inefficient

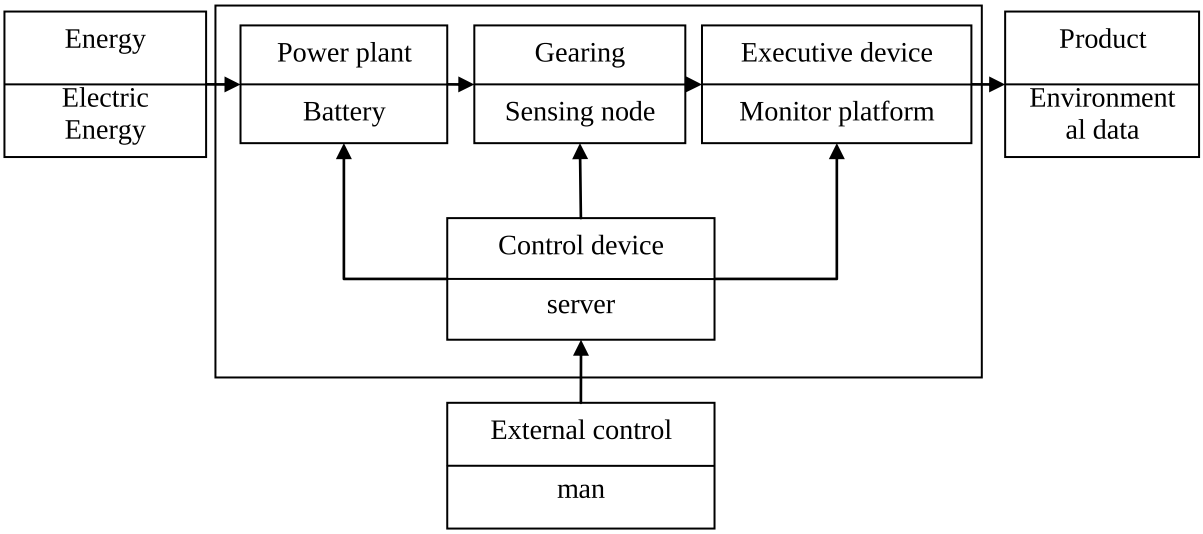

Figure 2. System Completeness Principle

technology system can be simplified.

(2)Life curve

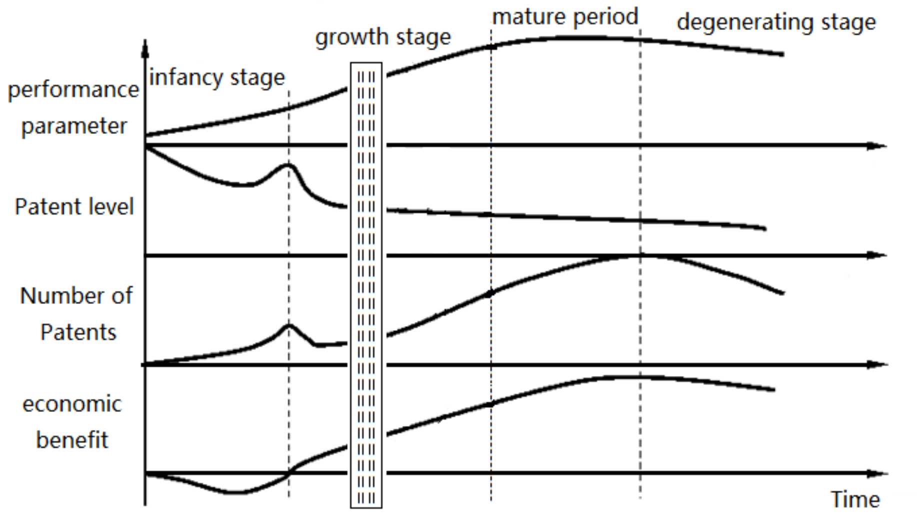

Figure 3. Life Curve of the FEFMP

As is shown above, the FEFMP system is in the booming growth. All kinds of problems of the system is gradually resolved and the degree of products' reliability is improved, which is a good opportunity for our work.

(3)Increasing ideality principle

Increasing ideality principle is the core of technology system evolution principle, ideality refers to the ratio of the beneficial effects and the sum of harmful effect and cost, it is defined as follows

$$I = \frac{\sum B}{\sum C + \sum H}$$

Where I—Ideality of a solution

B—Benefit or a useful function of the solution

C—Cost of the solution

H—Harmful effect of the solution

It is easy to understand that the general method of improving system is to maximize the ideality. For this system, we discuss as below.

In the condition of ignoring secondary factors and analyzing main factors, we define m for each sampling point's cost and energy consumption, n for the number of sampling points, p for the cost of the human resources used to spread each sampling point under the traditional way and t for the total consumption of accurate monitoring system(such as the cost of spreading sampling equipment by aircraft and the cost of the maintaining the FEFMP and so on. The association between this kind of cost and the number of sampling points is very small, as a account of which we can consider this kind of cost as a constant).

At the same time it can be roughly thought that the useful and harmful function(respectively defined as f1 and f2) of each sampling node is same. Then it is defined that β is the ideality of the traditional FEFMP and α is the ideality of the FEFMP we designed. Then we get

$$\beta = \frac{\sum f_1}{\sum f_2 + \sum m + \sum p} = \frac{n \times f_1}{n \times (f_2 + m + p)} = \frac{f_1}{f_2 + m + p}$$

Obviously, p has the positive correlation with n, so we might define that p(n) is a polynomial of n

$$p(n) = k \times e^{q \times n}$$

The parameter k meet

$$k > \frac{p(n-1)}{e^{q \times n}}$$

When the number of n is very large(In real life when the test object is forest, the number n will obviously be very large), the value of p(n) will be impossible to estimate. For example, when the monitoring sites are large, using artificial method will take a lot of manpower, which make it impossible to complete the test process, so the value of p(n) will be very large.

However when it comes to using the FEFMP we designed, the ideality will be

$$\alpha = \frac{\sum f_1}{\sum f_2 + \sum m + t} = \frac{f_1}{f_2 + m + t/n}$$

When n is large, t/n will approach zero and α will tend to

$$\lim_{n \to +\infty} \alpha = \lim_{n \to +\infty} \frac{\sum f_1}{\sum f_2 + \sum m + t} = \lim_{n \to +\infty} \frac{f_1}{f_2 + m + t/n} = \frac{f_1}{f_2 + m + \lim_{n \to +\infty}(t/n)} = \frac{f_1}{f_2 + m}$$

So that

$$\lim_{n \to +\infty} \alpha = \frac{f_1}{f_2 + m} > \frac{f_1}{f_2 + m + p} = \lim_{n \to \infty} \beta$$

So we can control the number of sampling points to control the ideality of α. That is to say when n>N (N is a constant), we can control the α to be greater than a constant, which can not be measured by the traditional way.

It can confirm the feasibility of our research through the system analysis above.

3.2.3.Solving the Contradictions in the System using TRIZ Tools: (1)Technical contradiction.Technical contradiction is caused by two factors in the system, who promote each other and restrict each other as well. To solve the technical contradictions we can use the contradiction matrix tools of TRIZ.

①When real-time and precision of the measurement improved, then the cost of the whole system(such as energy consumption, *etc.*) will be increased, which means it will need some more extra cost to maintain the intelligent system. The improve parameter(IP) is the precision of the test while the worsen parameter(WP) is the power consumption. To analyze by the contradiction matrix table, as shown in Figure 4.

WP / IP	Power consumption
Test precision	3、6、32

Figure 4. Contradiction Matrix Table 1

3—Locality principle: To make different parts of the object have different functions

6—Increasing asymmetry principle: To change the symmetric form to asymmetric one.

32—The color principle: To improve the system value or solve problem by changing color of the system.

Using the invention principle 3(Locality principle), the whole system can be divided into server subsystems with different functions. Then we can get the system's optimal solution by solving the problems of every subsystem so that we can achieve the aim of minimize the energy consumption.

②To reduce the energy consumption of the whole system, we'll use the corresponding sampling modes to control the operation of the system. However these modes will produce certain effect on the real-time information. Now the improving parameter is energy consumption while the worsen parameter is the loss of time. To analyze by the contradiction matrix table, as shown in Figure 5.

WP / IP	Time loss
Energy consumption	6、10、20、35

Figure 5. Contradiction Matrix Table 2

6—Increasing asymmetry principle: To change the symmetric form to asymmetric one.

10—Action in advance principle: To facilitate the process of the work by performing some action before incident.

20—Effective continuous principle: To improve the system efficiency due to the continuity of the happening of the action

35—Performance conversion principle: There is already a useful innovation to change the property system.

Using effective continuous principle(invention principle 20) to solve the contradiction of time loss and energy consumption. The changes of environmental factors is continuous in time and space, account of which we can collect data at a particular frequency rather than a continuous acquisition if there is no special requirement in order to achieve the purpose of energy saving.

③It is obvious that the FEFMP we designed will use the modern intelligent monitoring system, which will produce some problems as well. The main point is the safe and reliable transmission of information. When the intelligent sensors were distributed in the corresponding sampling point, the safety of the data transmission will be affected to a large extent when the complexity of the forestry environment is unknown to us. The improving parameter is the intelligent degree while the deteriorate parameter is reliability. To analyze by the contradiction matrix table, as shown in Figure 6.

WP / IP	Reliability
Intelligent degree	11、27、32

Figure 6. Contradiction Matrix Table 3

11—Preset precaution principle: To improve the reliability of the system by preparing in advance.

27—Substitution principle: Using a set of cheap object instead of an expensive one.

32—The color principle: To improve the system value or solve problem by changing color of the system.

Analyzing by the matrix table above, we can use the transmission protocol, such as the relatively mature ZigBee transmission protocol, to ensure the safety and reliability of the transmission.

(2)Physical contradiction

The physical contradiction produced when a opposite request for a parameter in the system is proposed.

Not only do we need to design the system to be real-time and accurate, but hope to finish the system with low energy consumption. By using the separation principle of TRIZ, we can divide the whole system into several subsystems. That is, the whole system is divided into information acquisition layer, transport layer and application layer. Then the design of the whole system will has better reliability because we can realize every layer by using the technology adapting to this layer.

Under the separation principle, the FEFMP is designed by using separation and combination method of TRIZ. Firstly, the whole system is divided into sensor layer, transport layer and reference layer and each part will achieve different functions. Secondly, each layer will be connected by some reliable protocol(such as ZigBee protocol, 3G network, *etc.*), as shown in Figure 7. This makes the physical contradictions of the whole system solved to a great extent.

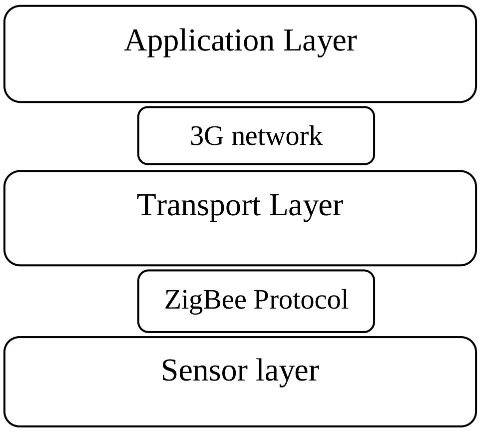

Figure 7. The Layering Structure

3.2.4. The Function Realized by TRIZ:(1)Realizing the multivariate of sampling parameters.Using the resources analysis of TRIZ theory, we found that the utilization of forest resources is not too full in the traditional FEFMP.

The sampling type of the traditional FEFMP tend to be single, but the actual forest environmental factors are various, such as air temperature and humidity, soil temperature and humidity, the concentration of CO_2, light intensity and so on.

So the problem of insufficient using of resources can be solved by the diversity of sampling parameters. On the one hand, the forest factors collected are varied. On the other hand, the meaning of each kind of environment factor is varied. Such as soil temperature and humidity, we'll collected soil layer temperature and humidity from the soil 10cm, 20cm and 30cm below the surface in order to realize the multiple monitoring of environmental factors.

(2) Realizing the multivariate transmission modes

By using the material field analysis of the TRIZ, we introduce the electromagnetic field on the basis of the traditional FSFMP's mechanical field in order to achieve the real-time and accurate monitoring of forestry environmental factors. That is, it has realized the two kinds of transmission way (3G and ZigBee based transmission) namely the multivariate transmission modes.

(3) Realizing the multivariate of the system integration

By using the contradiction analysis of TRIZ theory, it can be found that in order to be able to monitor the environmental factors everywhere, with only static WEB side monitoring could not be achieved, which is the contradiction between movement and stillness. Through the adoption of the separation principle of TREZ, we divided the monitoring platform into WEB end and mobile end two parts.

3.2.5. Ideal Final Result(IFR): Through the analysis of the above parts, it comes to the ultimate ideal solution of the problem.

A real time and accurate FEFMP should include the following three layers:

①A sensor layer which can collect the forest environment accurately and timely.

②A network translate layer which can transmit the data stably and reliably.

③A application layer which can response rapidly and display effectively.

What's more, it also realizes the diversities mentioned above.

4.The Specific Implementation Process

4.1.Sensor Layer

Figure 8. Temperature and Humidity Sensor and the Holding Collector

By using the air temperature and humidity sensors, soil temperature and humidity, light intensity sensors and CO2 sensors, we can collect a variety of forest environmental factors accurately.

4.2.Transport Layer

Figure 9. The Gateway Based on ZigBee Protocol and 3G Network

The date collected by the sensors will be transmitted to the application layer through the gateway stably, accurately and timely, as shown in Figure 9.

4.3.Application Layer

4.3.1.WEB Monitoring Platform: ①By using the WEB technology, we can show the forest environmental factors timely on the browser, which was established on the B/S architecture, as shown in Figure 10.

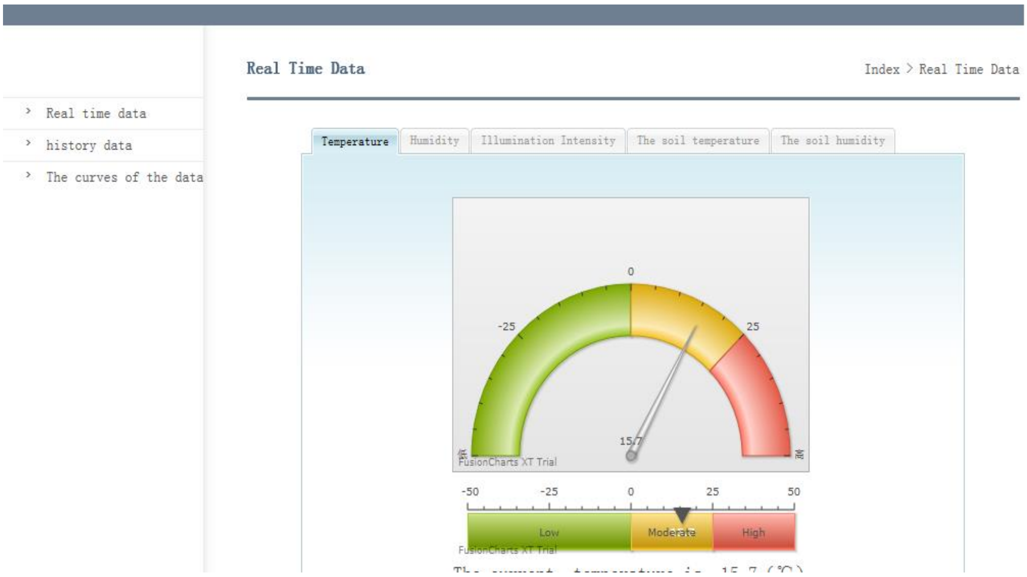

Figure 10. The Chart Shows of the Terminal Web

②The system uses ArcGIS server of the GIS secondary development environment and show the monitoring information through the Web GIS. Then it has been realized the GIS show of web end, as shown in Figure 11.

Figure 11. The GIS Show of the Terminal Web

4.3.2. Mobile Monitoring Platform: Firstly, convert the SHP file format to the format can be identified by the UCMAP by using the map configuration program provided by the UCMAP. Then we can read the map be using the UCMAP API and define the users' interface by using the layout of Android. After importing the map, we can changing the map parameters easily. Then the users can input the information of the geographic.

On the basis of the above function, we set up the mobile monitoring platform based on the UCMAP, which implements the multivariate of the system, as shown in Figure 12.

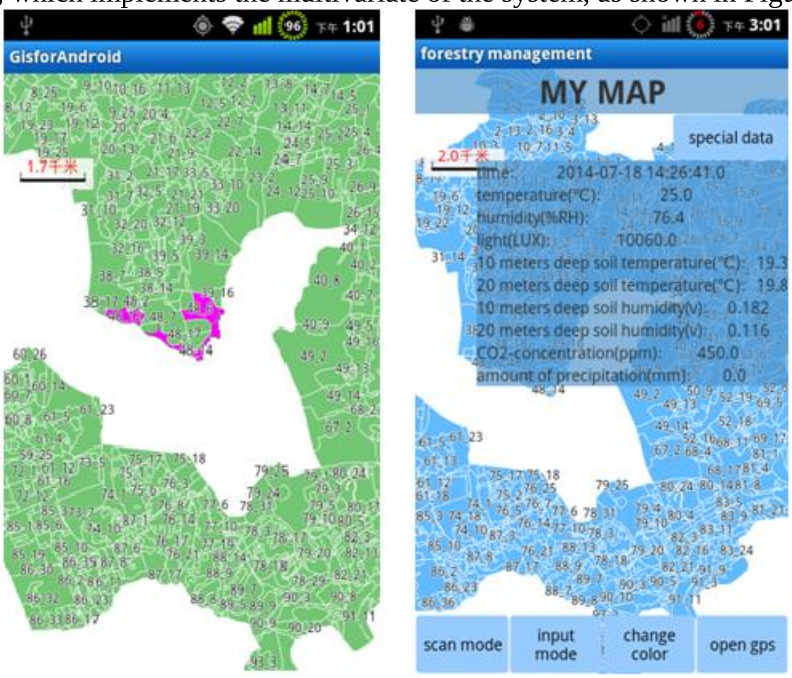

Figure 12. The Mobile Monitoring Platform

5. Conclusions

TRIZ theory is a landmark innovation theory. This article introduces the basic content of TRIZ theory, which also establishes a new kind of FEFMP by using the knowledge of TRIZ and IoT(Internet of Things). The FEFMP can be used to collect the forest environmental factors accurately and monitor them timely by using the diversified method. For example, we can use the web end as well as the mobile monitoring platform to monitor the forest environmental factors. Then this article also makes the market analysis and evaluation by using the knowledge of life curve and increasing ideality principle, which can prove the feasibility of the research.

Acknowledgments

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