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# The design and implementation of an integrated optimal fertilization decision support system

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ABSTRACT

This paper designs fertilization decision support algorithms from the perspective of decision support system with the model of agricultural fertilization principles. These integrated and optimal algorithms can provide accurate scheme of fertilization for users. The fertilization decision support system was designed and implemented in accordance with the B/S structure by using ASP.NET platform and SQL2000 database, which has wide applicability, flexibility and high accuracy. It is practical and interactive to meet the needs of most of the users.



## 1. Introduction

Decision support system (DSS) [1] is a computer-based and human–computer interactive system, which adopts the theory of decision making. And it is mostly used to solve the problems of segmental structured and non-structured decision in organizational management, and not only provides users flexibility to access data and to construct models, but also supports users to make right decisions. Generally speaking, DSS consists of data subsystem, model subsystem, dialogue subsystems and other components. Traditional decision support systems came to a conclusion by means of the data models and the conventional numerical calculations in the decision-making process. A great deal of knowledge and knowledge reasoning which is difficult to express by mathematical models and calculation methods exist in the traditional decision support system. Therefore, it is hard to simulate the conditions of the real world with traditional DSS. The best way to build a real-time or online intelligent decision support system (IDSS) of such a complicated fertilization decision-making process is combining multi-expert knowledge and the data from scenes. Combined with mathematical and knowledge models, decision support systems have the capability of numerical calculation and knowledge processing [2].

In recent years, computer technology and geographic information systems technology have been widely used in fertilization research, and a lot of fertilization decision support systems have been developed. The decision support system is based on agriculture models which are tested by a large number of fertilization experiments, and the modes of fertilization mainly include effect function method, nutrient balance method, and fertility combined method. By means of the "3414" experiment and discussion, soil fertilizer effect function method can be widely applied, soil nutrient balance method is one which includes the calculation of biomass crops, and dissimilar subtraction method of soil fertility computes optimal fertilization by using the soil value test. The algorithms of the existing fertilization decision support systems are generally based on those models. For example, some fertilization expert systems, which are using a single principle of the model according to the local agricultural test data have some decision support capabilities. But data processing is not accurate because of the defect of the model. Lacking of the design of the users real-time communication platform, incompletely accessing to the conditions such as real-time weather and soil data, the decision support data of which is not comprehensive [3–7].

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In this paper, based on agricultural fertilization models, using numerical calculation and integrating of knowledge management as a tool for thinking, we design some fertilization decision support algorithms using the "3414" test [8] data and GIS spatial analysis technology. According to the experimental data of different plants in different environments, the algorithm can measure the optimal fertilization. Based on B/S structure, a Fertilization System has been designed and implemented, which overcomes the shortcomings of existing fertilization system, such as poor system integration and scalability. Meanwhile, the system integrates the following functions. (1) Fertilization decision-making process management data acquisition, including the records of fertilization decision making, fertilization decision support operations, planting environmental data including weather, soil and planting scene. (2) Fertilization decision-making information bulletins, and searching functions; (3) Fertilization Knowledge Base search function; (4) Interaction management functions for experts, farmers and administrator. This provides a system design idea.

## 2. Materials and methods

### *2.1. Data acquisition*

The fertilizer experiments and other tests are carried out in jujube orchard which locates in the city of Aksu in Xinjiang province China (41°09′ N, 80°19′ W) and takes up area of 4 ha.

Fertilization decision-making systems are largely based on the "3414" test. "3414" test refers to the fertilizer experiments including 3 factors (nitrogen, phosphorus and potassium), 4 levels and 14 treatments of fertilizers. The scheme is designed to absorb the advantages of optimal regression design of less treatments and high efficiency. Four levels means: 0 is level of no fertilizer. 2 is the best fertilizer level for the local approximation. Standard level = 2 level, 1 level = 2 level × 0.5, 3 level = 2 level × 1.5 (this level is over-fertilization). Test field is divided to 14 treatments place, and each level in these treatments has different NPK fertilization amount.

We combine three fertilization models, including soil fertilizer effect function method, dissimilar subtraction method of soil fertility, and soil nutrient balance method to design decision support algorithm based on the data of "3414" fertilizer experiment in this paper. Using spatial interpolation algorithm and fertilization models, we can get the land distribution map of fertility by means of set expansion; also can we deduce the optimal crop target yields and corresponding fertilizer scheme of N, P and K.

The system designs a wireless sensing LAN which supports the secure transmission of data messages and can transmit the real-time data which is obtained by transducer. In the data storage, data collection terminal includes a data cache device, to ensure the integrity of the data under special conditions. The system also designs a GIS data analysis server, the data from small experimental plots can be expanded to data sets of large blocks by using interpolation algorithms and GIS analysis techniques.

The system's software includes a fertilization decision-making platform and a SMS platform. The two platforms can receive, process and store the data from wireless sensing LAN and GIS server which is convenient for users to make fertilization decision and interact with each other.

### *2.2. System frame design*

According to DSS design idea, combining with the algorithms, we realize the key technologies. The structure of total system frame is designed as follow.

#### *2.2.1. Network layer design*

The system overall architecture design is based on software and hardware structure analysis. We design a wireless sensing LAN. Sensors measure real-time environmental data, such as soil moisture, conductivity, temperature, PH value, the air temperature, humidity, $CO_2$ concentration, illumination and so on. Wireless LAN send these data to the long range server, and the server post the real-time information on the platform of this system. Through this platform, users can immediately get access to the information of the farmland and orchards, making a reasonable decision making of fertilization.

The system uses the B/S (browser/server) structure mode. The design is to meet the requirements of highly interactive. Combined B/S structure software virtues, normal users can remotely control this system through browser. Rarely parts of the transaction are foregrounding processing. The main business logic is implemented on the server side. The system structure diagram is shown in Fig. 1 [9].

#### *2.2.2. System level design of facilities*

The system designs a Wireless sensing LAN whose WIFI routing is based on IEEE 802.11 protocol, supporting the secure transmission of data Messages. In the data storage, data collection terminal includes a data cache device, to ensure the integrity of the data under special conditions. Server receive the real-time data and regular backup it, so as to guarantee non-destructive and reliable data. The system also includes a GIS data analysis server, the data from small experimental plots can be fitted to large block by using interpolation algorithms and GIS analysis techniques [10]. Such a structure is used to reduce the cost of data measurement.

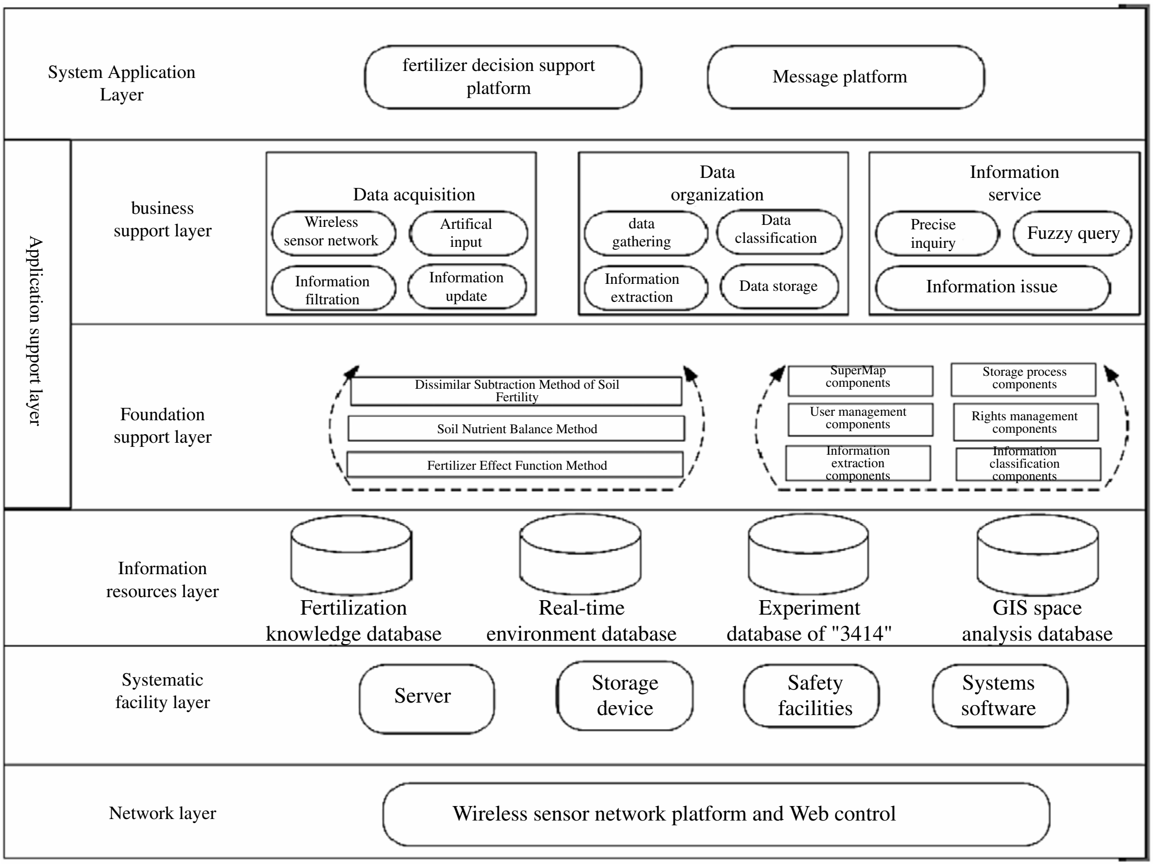


**Fig. 1.** The total system frame.

#### 2.2.3. *Information layer design*

Layer of information resources include fertilization knowledge database, real-time environment database, "3414" experiment database, GIS spatial analysis database. The association of the data is reasonable. This structure is convenient for data storage, aggregation and classification.

#### 2.2.4. *Application support layer design*

Application support layer includes basic support levels and business support layer, basic support layer contains algorithm design and component design, business support layer is mainly about data design, as shown in Fig. 1.

The difficulty of the Application support layer design is user-oriented class that we should design different function for different kinds of users. The application management system mainly for the three types of users: farmers, experts and system administrators. This paper provides a general user-oriented class design patterns, the underlying architecture is relatively stable, which can be applied to different types of development, providing a system architecture design model for similar systems.

The problem for normal farmers is that they are lack of network applications knowledge. The fertilizer knowledge query module is designed and integrated in the system which supports fuzzy and accurate searching. Users can find the fertilizer theoretical knowledge and common sense by demand. According to farmers' requirements on fertilizer advice, the system also designed the SMS (Short Message Service) platform. Using this platform, farmers can consult experts by sending text messages through mobile telephone or computer; experts can also answer those questions by sending or replying messages through this platform. Meanwhile, farmers can also visit the above module to find a solution when they have difficulties.

To meet experts' demands, the SMS platform in the system has a fertilizer expert recommendation module, providing fertilizer recommendations which are sent by Web and SMS, so experts can solve farmers' questions online.

According to the administrator's task, the system is designed and administrated in the fertilization decision-making and messaging platforms to realize the functions of going over and putting out articles, entering, modifying and updating data of fertilizer knowledge databases.

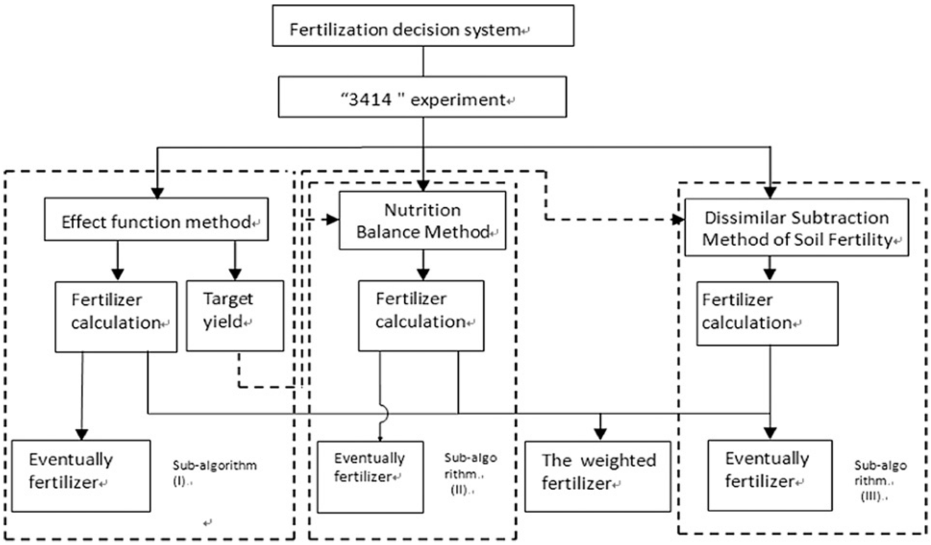


**Fig. 2.** Fertilization decision-making algorithm chart.

*2.2.5. System application layer design*

The system is designed Fertilization server platforms and SMS platform. Fertilization decision-making platform is mainly used for farmers' fertilizer and information inquiry, SMS platform is mainly used for interaction in farmers, experts and farm administrators. The structure is shown in Figs. 5 and 6.

*2.3. Fertilization decision-making algorithms*

This Fertilization decision support system design focuses on that decision-making algorithm combines several kinds of fertilization decision theory models in a single system to approach one optimal result through mathematical logic methods. The system is designed multi-modules, multi-selection, multi-output, and its modules are joined to one system and the structure of the global system is optimized. This algorithm structure is shown in Fig. 2.

We first design a data entry section. We could have different selection in the algorithm.

(1) Use of the 12 kinds of fertilizer effect function method models and "3414" experimental data, fit for each model and calculate the variances. Weighing according to variances to get the optimal solution and the optimal fitting function, we can get optimal fertilization scheme and target yield. This is sub-algorithm (I).
(2) Take the result of sub-algorithm (I) as the target yield of sub-algorithm (II) which based on Soil Nutrient Balance Method theory model, to calculate the optimal fertilization scheme. In this way, not only the data we get is more precise, but also the times of test are reduced.
(3) Take the target yield output from sub-algorithm (I) to Dissimilar Subtraction Method of Soil Fertility to calculate and get the optimal fertilization scheme as sub-algorithm (III).
(4) The decision-making module we proposed allows you to select the results of the three sub-algorithms above mentioned and weight the final fertilizer.

This algorithm contains the mathematical model of decision-making fertilizer, crop biomass and soil test values, provide a more scientific fertilization by weight method [11].

The overall algorithm is designed on idea of Multi-module, multi-choice, multiple-output, Inter-connection and optimization. Any one of the three sub-algorithms can be used to calculate the scheme of fertilization, or we can weigh the optimal fertilization amounts from the results of the three methods. The plant's biomass were not taken into account in Soil Fertilizer Effect Function Method, so we combine the last two of methods to get the result. The Modules have high cohesion and low coupling property, they achieve the optimal fertilization purposes. The system can fit out optimal fertilization amount for a variety of crops and fruit trees, and has well targeted and wide application range. It provides a guideline for the design of similar systems. Fertilization decision-making flow sheet as shown below (see Fig. 3):

*2.4. Data flow-sheet design*

The data of this system, which submitted to the server to calculate and store, is got from real-time equipment and process such as sensors, "3414" experiment, and GIS spatial analysis. Fertilization decision-making platform is responsible for processing and calculation as a reference for fertilization decision-making module and production management module,

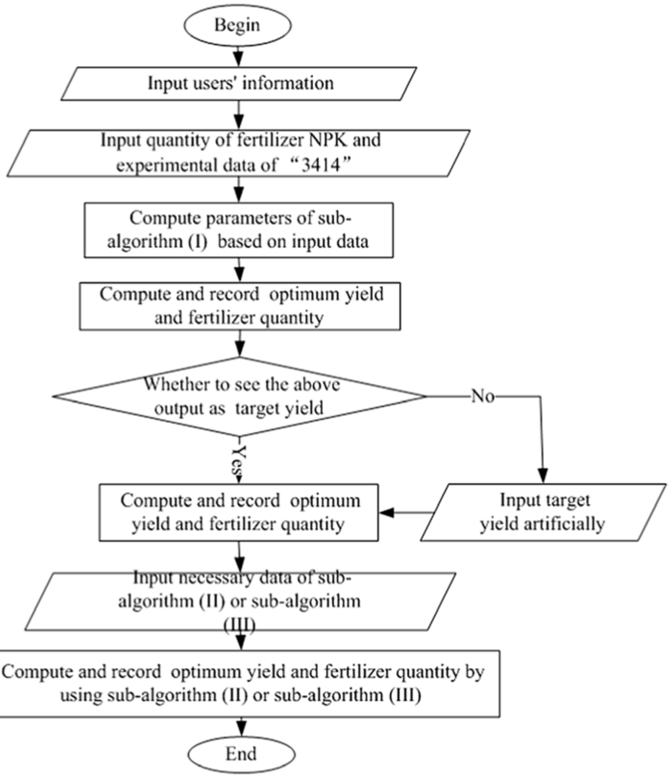


**Fig. 3.** Fertilization decision-making flow sheet.

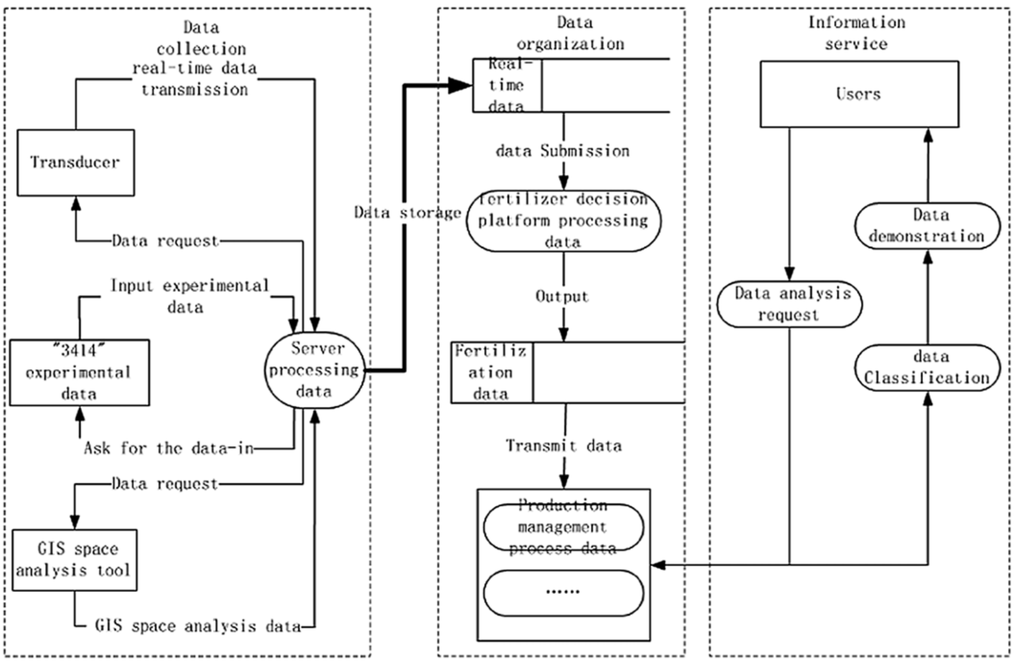


**Fig. 4.** System data flow diagram.

etc. Data is maintained and backup by the administrator. After censored, it can be published on the Web. The system data flow diagram in Fig. 4.

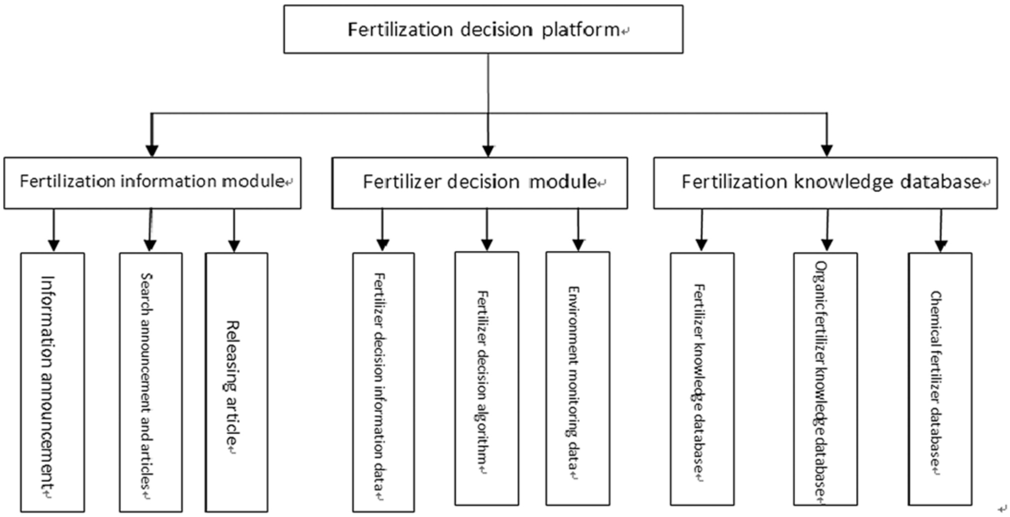


**Fig. 5.** Fertilization system function structure chart.

### *2.5. System implementation*

#### *2.5.1. The main function of the system*

The fertilization decision-making system is divided into two platforms, fertilization decision-making platform and SMS (Short Message Service) platform. Fertilization decision-making platform has three major modules: Fertilization of information modules, Fertilization decision-making module and Fertilization Knowledge Base Module. The main function of fertilization module is to get decision support data by using integrated decision support algorithm and real-time environmental monitoring data. Fertilizer Knowledge Base Module consists of professional fertilizer knowledge base, organic fertilizer and inorganic fertilizer knowledge base, users can obtain relevant professional information by searching. Fertilization information module has the functions that users can query the database to get the information posted on the platform. SMS (Short Message Service) platform provides real-time communication space for farm administrators, experts, and farmers. On this platform, farmers can get suggestions from experts, and experts provide new technologies and new products' information for the farmers. Administrators manage all the users and post messages on the platform. The system functions can meet the needs of this three types of users, enable users to obtain scientific and reasonable fertilization advice to solve their planting problems in time or to feedback circumstances to the fertilization expert or farm administrators for further research at the same time, and the system functions make it easy to manage and record.

The fertilization decision support system's overall function structure is as Fig. 5, the overall structure and function of SMS platform as Fig. 6.

#### *2.5.2. System user interface*

The interface design includes fertilizer information notice interface, fertilization knowledge query interface, fertilization decision-making interface, and SMS (Short Message Service) platform interface, it meet the needs of different objects and fertilization natural environments. And the administrator interface is designed for management facility. The layout of every interface is in accordance with the system's overall function structure.

## 3. System analysis

The major error source of this paper's fertilization decision-making algorithm is least-square method and "3414" experiment. Least-square method's principle is minimizing error's sum of square. And the least-square method is widely used in fields of statistics. The experiments obtain reasonable results by statistical calculations, therefore, the error caused by least-square method can be ignored. The error of "3414" experiment mainly depends on soil fertility, test material, operation in field and accidental factors [12]. Because the data we get is from the same orchard in Aksu, Xinjiang, the difference of soil fertility in tests is little. And while conducting the tests, we strictly control the experimental process, so there is almost no difference of the material and operation. As to the accidental factors, it is out of human control. Considering the conducting process of the test and the algorithm implementation, the algorithm elaborated in the paper is suitable for the calculation of the fertilization in agricultural production. Its error is little.

This algorithm is integrated in a fertilization decision-making web page, the average decision time is statistically 16.3 ms. The system designs two modes of the exact and fuzzy query. Exact query executes by searching keywords, while fuzzy query

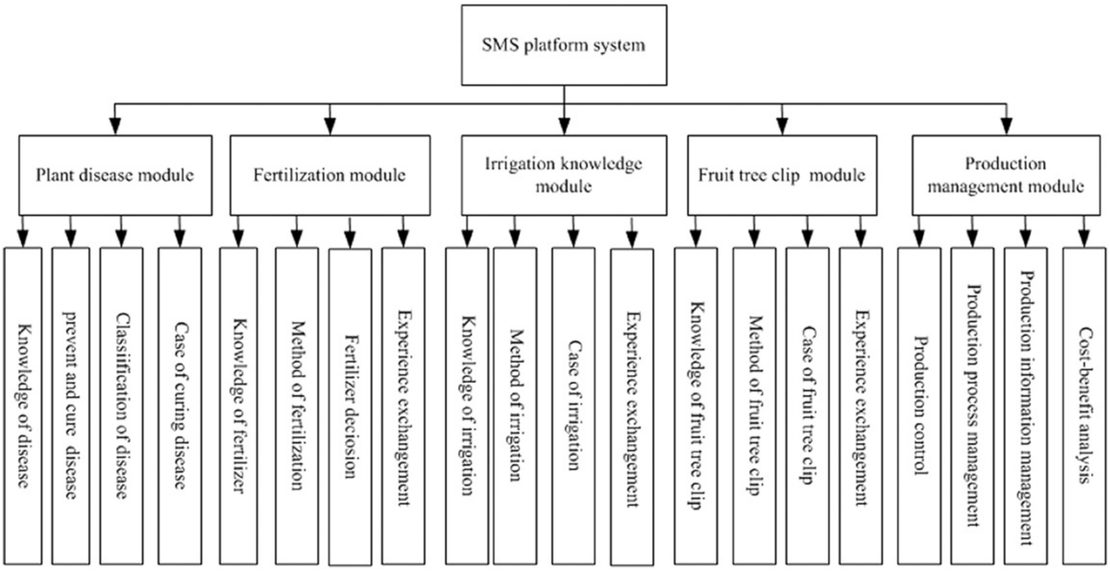


**Fig. 6.** SMS (Short Message Service) platform system function structure chart.

executes by searching similar words. The statistically average running time of two methods is 11.7 and 10.5 ms. Considering the decision and searching time, this system performs well and is suitable for the remote decision making and service.

## 4. Conclusions

The Fertilization decision support system described in this article considers various kinds of factors that influence fertilizer decision making. This fertilization decision support system has several advantages to overcome the weakness of the current Fertilization decision-making algorithm, and reduce the defects in hardware and software system architecture [13–15].

Firstly, fertilization decision-making algorithms integrate several relatively mature fertilization models into an algorithm system to get the optimal decision-making solution combining the advantages of various models.

Secondly, we design a practical platform for users. The real-time environmental monitoring data of farmlands and orchards, decision support information, technical Information bulletin, fertilizer recommendations of experts, professional fertilization repository, and professional fertilization repository are all integrated into this system.

Thirdly, various factors about fertilization decision making are taken into account, combined with wireless sensor network technology and GIS spatial analysis techniques, we have designed a stability, economic and practical hardware and software architecture.

## Acknowledgement

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