Research on the Framework System and Technical Platform of Digital Agriculture

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SUMMARY

By studying domestic and overseas' digital agricultural development status-quo, this paper firstly discusses the concept, characteristic, meaning and key technology of digital agriculture. Then, according to the theory and technology of "Digital Earth", combining with national and international present research status in quo, the article proposes the definition of digital agriculture and its science and technical framework. Finally, on the basis of the definition and framework, the authors construct the framework system of digital agriculture and present the main contents of its technical platform.

The digital agriculture framework mainly includes following aspects: the database creation; the data processing system; the decision support system and the user service system; different kinds of user groups. The digital agriculture technical system mainly includes: the remote sensing technology (RS); geographic information system (GIS); global positioning system (GPS); high resolution satellite image; computer network; database technology; the decision support system (DSS); man-machine interactive technology.

Based on the study of essential technology and analysis of successful experience, the article makes several suggestions: improving the agricultural fundamental and meta database construction; perfecting agricultural application system and fundamental information platform implementation plan; implementing multiple development strategy and establishing innovation mechanism of production, study and research. By establishing corresponding organizing leader and technical coordinating organization, a highly effective international digital agricultural development pattern will be boosted.

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1. INTRODUCTION

The digital agricultural technology is the expression, design, control and management of the modernized agricultural high-tech which deal with the digitization and visualization of objects and whole process related to agriculture. Supported by the computer and network communication technology□NCT□ as well as other high-techs, the digital agriculture is getting more achievements in following aspects: The timeliness and standardization of agricultural information obtaining, the intellectualization of agricultural design and managerial decision making, the automation of implementation process, and finally the realization of agricultural informationization and agricultural industrialization.

Digital Agriculture is also called informational agriculture or intelligent agriculture, which refers to the utilization of Digital Earth technology, including multi-resolution remote sensing, telemetering, GPS and GIS, computer etc. It also involves many high-new-techs of agriculture, such as farmland information fast collecting, farmland cultivation, land management, agricultural chemicals utilization, contamination control, agricultural engineering equipments and their industralization technology, as well as all the high-new-tech systems which are unified with the agricultural production activity and the production management. Namely, it's a comprehensive agricultural production management technical system which integrates Digital Earth technology and the modern agricultural technology. It has the following characteristics:

- Digital agriculture requires the digitization of each kind of process (biology, environment, economy) in every aspect of agriculture (including crop production, animal husbandry, aquatic products industry, forestry). In other words, each agricultural process must be expressed by the binary numeral (0, 1) and digital model.
- The data stored in digital agriculture database has the characteristics of multi-scale, multi-resolution, multi-source, multi-temporal, multi-media, multi-dimensional and large amount of quantity.
- A new temporal database management system should be studied to manage and organize those multi-dimensional, large amount of data, especially multi-temporal data, thus a temporal spatial information system is formed. This may not only effectively storage spatial data, but at the same time can vividly display multi-dimensional data and results analyzed spatially and temporally.
- The digital agriculture will make simulation and virtual reality of agricultural natural phenomenon or production and economic process on the basis of massive spatial and temporal data. For example, the virtual reality of agricultural chemicals in soil residual, the crop growth, the agricultural natural disaster and agricultural product market distribution.

2. THE APPLICATION PROGRESS OF DIGITAL AGRICULTURE TECHNOLOGY RESEARCH

At present the digital agriculture technology research and product development have made large progress, and have down research and exploration from each level and each aspect of agriculture and have made multitudinous technology advancement and achievement mainly in following several aspects.

2.1 The Model Technology of Agricultural Production Process

The model technology is the core technology of decision support system and virtual agriculture. By model technology, computer system can simulate agricultural bio-system object with all kinds of attribute, level or scale. At present, many countries have developed various models, from regional macroscopic agricultural economy development model to microscopic molecular level model, involving nearly all aspects of agricultural production. And the research scope is from whole world to various nations, locals, agricultural area, farm, biological community, individual structure and function and its growth rule.

2.1.1 The Model of Crops' Growth Simulation

US, Holland, Israel are at the front rank in the world in this domain's research and development (R&D) (Xuebiao Pan,1998). For example, the CERES model which can simulate crops production of the corn, wheat, paddy rice is one of the world's most representative systems.

2.1.2 The Model of Soil Moisture and Nutrient Process Simulation

The research and establishment of this kind of model has the vital effect on the improvement of present crops growth mechanism model and the regulation-controlling of farmland moisture and fertilizer, specially on the soil moisture and nutrient regulation-controlling and the research of soil spatial changeability mechanism.

2.1.3 The Model of Animals' Production Process Simulation

The research of animals' production process model is less than the research of plants'. Australia once developed a program to simulate the amount of energy and protein used by a newborn pig. Recently it has developed a new program to simulate the amount of energy and amino acid used by the newborn pig from the birth to the growth, which is used in animals' quota raising and behavior forecast in order to carry on the experimental application. England and Japan also have the similar research..

2.2 The Virtual Agriculture and Visualization of Animal and Plant Data

France is at the international leading position in the virtual plant and landscape design, and has already produced a series of virtual crops and landscape design software (AMAP). But

the virtual plant model is not ideal in the simulation of reciprocity of plant and environmental condition. To solve this problem, the ideal method is to surmount the boundary between the virtual crops model and the crops physiological process model and construct new virtual model which considers both plant's shape and its function. Then the model can have the feedback ability of structure and function, and conforms to the plant growth mechanism.

2.3 The Control System of Digital Greenhouse

The greenhouse facility and automatic monitoring technology have been developed rapidly and have been applied widely (Guilan Peng,2002), such as the Complex system designed by Austrian Professor Ruttuner and the vegetable factory created by Japanese central electric power research institute.

2.4 The Intellectualized Agricultural Expert System

At the end of 1970's in the 20th century, the expert system (ES) starts to be applied in agricultural domain. After nearly 30 years' development, its application domain has spread into the crops cultivation management, installation horticulture management, poultry raising, aquaculture activity, plant protection, breeding as well as economical decision-making (Shimin Sun,1998).

2.5 3S and Precision Agricultural Technology

At the beginning of 1980's in the 20th century, some developed countries started the research and practice of precision agriculture. After carrying on the applied research and practice on crops cultivation simulation, crops management and plant protection expert system, the agronomists who are engaged in the plant cultivation, the soil fertilizer and crops plant disease management promulgated the obvious spatial and temporal difference in the habitat condition and small farmland's crops output which takes the square meter as unit. Thus they proposed the production method, also called the prescription agriculture, which means the located and needed variable invested plant cultivation management should be adopted.

2.6 The Real-Time Collecting Technology and Equipment of Field Information

It is extremely important to instruct the agricultural production by knowing the related information of soil moisture, fertility (nitrogen, phosphorus, potassium), weed, plant disease, the status of crops seedling growth. The information is greatly affected by the natural condition, and its spatial and temporal variability is strong, and its real-time collecting is very difficult. So it's money-time-consuming to directly carry on massive field information collecting and processing. How to realize real-time information collecting promptly and effectively has become an important research direction in this domain (Shimin Sun,1998). At present the moisture content survey technology of TDR has been basically mature, and has had commercialized product (Yangyui Wang, 2000). There are many research results dealing with the spectrum technology of weed and seedling growth recognition, the vision image

processing technology, the soil nutrient ion selective field and water jet measurement technology, but the further practical application still needs a period of time.

2.7 Agricultural Biological Informatics

The biological informatics technology is mainly used in the mining and analysis of biological information (nucleic acid and protein sequence data) (Guoqing Zheng,2002). At present, the biological informatics have been already penetrated into the various domains of life science of post-genome era, such as the functional genomics, proteome, phamarcogenomics, environmental genomics etc. Bio-computing and macromolecular structure dynamic simulation, computation and digitized design are key technologies of agricultural chemicals innovation and development based on the genome.

3. THE MAIN CONTENT OF DIGITAL AGRICULTURE

On the basis of analyzing the world digital agricultural development status in quo, we can reduce the digital agricultural content into following three aspects:

3.1 Digital Informationization of Agricultural Factors

Any agricultural system has four factors: biological, environmental, technical and social economic. Each factor contains many sub-factors. For example, in the crops of biological factor, there are wheat, paddy rice, corn, cotton and other factors. And the same crop's growth also includes sub-factors of photosynthesis, breath, transpiration and nutrition. According to the request of digital agriculture, all these factors need to be expressed by the binary numeral 0,1.

3.2 Digital Informationization of Agricultural Process

The inherent laws and external relations of each agricultural process may be revealed by agricultural mathematical model (or agricultural model). It is an important achievement on the international 20th century's agricultural scientific development to express the agricultural model. It is also a key technology of digital agriculture. It digitizes the agricultural process and makes the agricultural science to be enhanced from the experience cognition to the theory summary. With agricultural model, many research works can be done which is unable to carry on by traditional agricultural experiments. The funds and time used by agricultural research can be saved greatly. And it also causes the agricultural research achievement to be applied at a bigger geographic scope and in a longer time.

3.3 Digital Informationization of Agricultural Managements

The agricultural management includes agricultural administration, agricultural production management, agricultural science and technology management and agricultural enterprise management. According to the request of digital informationization, each kind of agricultural management system supported by agriculture informational technology has been formed at

present. For example, the agricultural database system, which includes agricultural biology database, agricultural environment database and agricultural economy database, manages all levels of each kind of agricultural data scientifically and centrally. The agricultural planning system applies each mathematical programming method to carry on the auxiliary decision-making to the agricultural question. The agricultural expert system fully uses expert experience to provide the support agricultural decisions-making. The agricultural simulation optimization decision-making system unifies agricultural process simulation and agricultural optimized principle to provide support to agricultural decision-making.

4 THE BASIC FRAMEWORK OF DIGITAL AGRICULTURE

The construction of digital agriculture is a huge and complex system engineering, involving widespread domains and specialties. From the content and goal of digital agriculture, the basic framework of digital agriculture is composed of four layers: fundamental, technical, data and application (see figure 1).

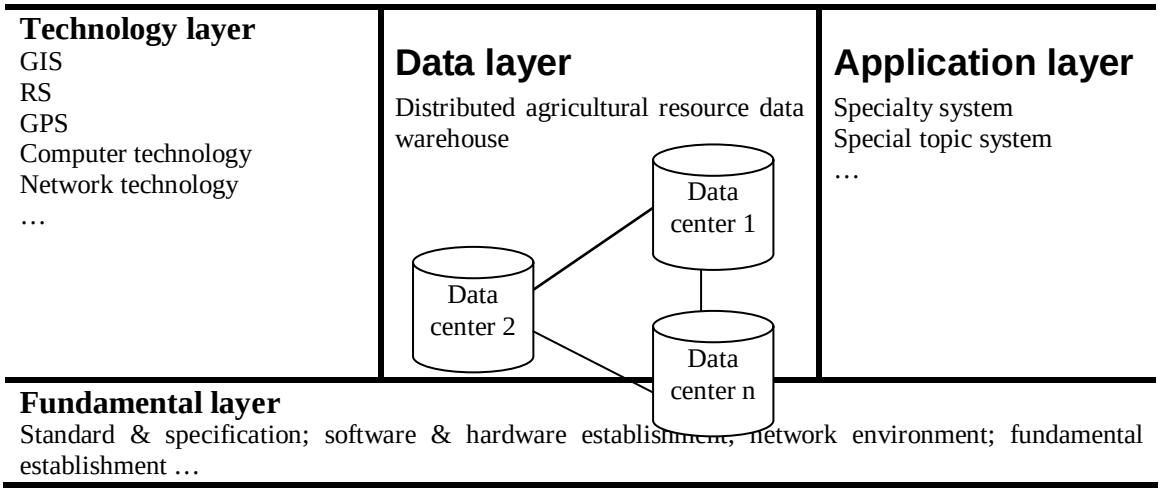

Figure 1: The fundamental framework of digital agriculture(Zengyuan Li,2003)

4.1 The Fundamental Layer

The fundamental layer is the foundation and prerequisite of digital agricultural framework. It include all kinds of standards and specifications related to digital agriculture construction, software and hardware condition, network environment, infrastructure and so on. It is the most important content of digital agriculture construction, which will directly affect and restrict the development and the efficiency of other three layers.

4.2 The Technical Layer

The technical layer is the support of digital agricultural framework. Its goal is to build the public technical platform with advanced technical method for digital agriculture. It includs 3S technology, computer technology, network technology, intelligent technology, visualized

technology and so on. And the integration of 3S technology is the core technology of digital agriculture.

4.3 The Data Layer

The data layer is the core content of digital agricultural framework. Located in the center of digital agricultural system, its goal is to provide the multi-source data sharing platform for the digital agricultural framework. It includes the construction of each level's digital agriculture data center, the establishment of agricultural resource distributed network database and multi-dimensional spatial data warehouse, as well as the seamless connection of spatial data.

4.4 The Application Layer

The application layer is the realization of digital agricultural framework system. Its goal is to establish corresponding specialized system according to the aim and service object of digital agriculture. Be faced with different kind of user's demand and different specialized domain, the application layer serves for the user and the specialized service.

5. THE DIGITAL AGRICULTURAL TECHNICAL SYSTEM

As mentioned above the digital agricultural technical system is more complex than the tradition agricultural technical system. It's a long-term process to establish this technical system. It has become more enrichment and more perfect along with the digital agricultural development. At present, the research of digital agriculture technical system mainly concentrates on following domains.

5.1 The Research of Digital Agricultural Technology Standardization System

The main contents include:

- Making the standard of digital agriculture implementation, development, interface, information gathering, metadata and information sharing .
- Studying and forming digital agriculture implementation specification to conduct digital agriculture's standardization implementation and development and to form the digital agriculture development system.
- Tracking the new tendency of digital agricultural development to study and establish digital agricultural development strategy and carry on the dynamic track and appraisal to digital agricultural development (ChunJIang Zhao. 2004).

5.2 The R&D of Digital Agricultural Technology Software Platform

It mainly includes the platform of: Agricultural remote diagnosis software system development; Agricultural expert system development (Wenyun Wang, 2004); Portable agricultural information system development; Crops virtual reality; Facility cultivation environment monitoring software; Spatial information acquisition and process, remote sensing platform; Spatial information analysis (geographic information system); Countryside

development intelligence dynamic programming decision-making support system; Agricultural enterprise synthesizes information management; Electronic commerce; Remote multimedia education etc.

5.3 The R&D of Agricultural Information Resource Database

Under the unified standard, the information databases related to technical, production, management, market, policy laws and regulations (Shijian Mei, 2004) are constructed, which mainly includes meteorological, soil, agricultural crop production, fish breeding and poultry raising, forestry, processing industry and so on. The concept of these information resources and database is quite broad. Therefore, the research not only lies in the concrete database structure, more important lies in the digitized analysis research of agricultural macroscopic and microscopic process, which is the infra-structure of digital agricultural technology system.

5.4 The R&D of Remote Diagnosis and Agricultural Expert System

On the basis of the research of intelligence agricultural expert system's development platform based on the remote diagnosis technology and agricultural information database, the agricultural knowledge-base and model-base are established and the specific domain-oriented agricultural management intelligence application system as well as the macroscopic decision support system (Wenlong Zhang,2004.) by system integration are studied. The specific domains include:

- The main grain, cotton and oil crops, such as paddy rice, rape, wheat, big wheat, corn, cotton, soybean and so on;
- The main vegetables, such as cucumber, tomato, watermelon, cabbage, mushroom, shiitake mushroom and so on;
- The installation horticulture crops and edible fungus,
- The main fruit tree and forest special product, such as citrus fruits, peach, pear, grape, waxberry, tea, bamboo shoots and so on;
- The main poultry and aquatic product, such as pig, chicken, duck, cow, aquatic product and so on.

5.5 Multimedia Information System Development of Agricultural Remote Education

Under the standards of database technology, the multimedia courseware base of technology, production, management, market, policy laws and regulations are studied and developed, which is based on meteorological, soil, agricultural crop production, fish breeding and poultry raising, forestry, processing industry and so on. The related courseware management and edit-broadcast hardware-software system (Junfeng Zhang,2002) are developed. The Internet-based agricultural science and technology remote education system is developed, which can realize bi-directional synchronization interoperation and asynchronous non-interoperation compatibility.

5.6 The R&D of Hand-hold Agricultural Technical Consultation Product

This refers to the R&D of a series of low-cost, convenient, hand-hold agricultural information consultant and decision-making aided equipments which faced to the domain of poultry cultivation and economical crops (vegetables, flowers and plants, fruit tree). These equipments can perform following tasks:

- To promulgate each kind of practical agricultural production technical knowledge;
- To provide famous, special, superior, new variety and technology;
- To input observed data immediately in the field;
- By reason-machine, to carry on plant disease diagnosis and prevention decision-making, lacking element and crops nutrition condition diagnosis and fertilizer decision-making, soil and crops moisture content condition diagnosis and irrigation decision-making, cultivation pattern decision-making and agricultural product quality examination and so on (Jianquan Ouyang,2002).

5.7 The R&D of Digital Intelligent Greenhouse Environment Control System

This mainly refers to the following functions:

- The automatic monitoring of greenhouse environmental information and moisture content information as well as information model analysis processing technology;
- The construction of warm, light, water, gas management model used in main greenhouse crops under the condition of cultivating substance and related knowledge base and database;
- The R&D of greenhouse intelligent management system based on the crops growth model, synthesis environment forecast and analysis model, and cultivation expert system;
- The R&D of greenhouse group intelligent control interface, wireless network communication technology and computer distributed control system (Haiye Yu, 2003);
- The R&D of software and hardware used in the highly effective production intelligent control system of greenhouse, including the greenhouse special-purpose sensor, highly effective water, fertilizer, medicine integrated irrigation equipment and control software etc.
- Through system integration, a series of technology and product used in greenhouse intelligent control and management is constructed, and the data collecting, intelligent control system and supplemental project facility are integrated (Jiang Chu, 2004).

5.8 The Introduction, Digestion, Absorption and Independent Innovation of Precision Agricultural Essential Technologies and Equipment

It mainly refers to the following aspects:

- The obtaining and analysis processing technology of remote sensing information. On the demand of precision agriculture, centering on the fertilizer and water monitoring, using advanced technical equipment, a technical system is established which can obtain and analyze the aviation remote sensing information of crops. The remote sensing platform and related application method are included in this system (Jiahua Zhang, 2000).
- The fast obtaining and diagnosis technology of farmland information. It includes the

R&D of the theory and method of farmland information sampling design; The fast gain and diagnosis technology of soil and crops moisture content, nutrient information, output and quality information and disease- insect pest-grass information (Rongrong Chen, 2004).

- The R&D of precision agriculture essential equipment. It refers to the R&D of farm machinery essential equipment suitable for the precision agricultural implementation.
- The platform development of precision agriculture software system are based on 3S technology

5.9 The R&D of Digital Macroscopic Monitoring Technology and Dynamic Decision-Making System

This refers to the construction of digital agricultural macroscopic environmental monitoring system with the characteristic of new information transfer structure, big scope, precision location and quasi real-time. This monitoring system uses agricultural disaster and economic environment occurred in a wide range as its main research object by means of model and simulation technology, computer network technology, 3S technology and modern digital communication technology. It uses several models as its research core, such as the harmful agricultural biologic occurrence and migration spatial model, the drought information extraction model, the regional crops output prediction and estimate model (Chunjiang Zhao,2004), international agricultural products macroscopic supply and demand relational model, the productive forces appraisal model, the agricultural industry comparison superiority model etc.

5.10 The Research of Farmland Information Gathering Technology and Product Development

This refers to the study of plant and soil information gathering technology and product development suitable for agricultural production management digitization with unified technical standard and information management mode. The main contents include:

- The technology and product of farmland plant growth and nutrition condition's survey without damage, including the plant growth information such as density, disease- insect pest-grass, crops nutrition, yield of sample point.
- The R&D of products such as crops nutrition diagnostic equipment, crop growth condition tester, crops plant disease monitors etc.
- The technology and product of soil information gathering which aims at farmland nutrient precision management, including several technology such as synthesis appraisal technology of large, medium and trace element content, sampling technology based on 3S, fast and accurate survey technology, laboratory data automatic gathering and management technology, managed object automatic generation technology and so on.

5.11 The Research of Crops Growths Model and Digital Design

The main contents are:

- Research on digital information gathering and processing technology based on the growth

condition of grain oil, vegetables, fruit tree and other crops. And development of crops growth rule extraction systems with these technology.
- Establishment of plant organ shape description model library and parameter library, development of 3D visual system to realize digital plant design.
- The establishment of growth condition virtual model which can precisely simulate crops change along with environmental condition.
- The development of crop's shape structure optimization system, and the ultra high-yield crop's digital shape structural design system prototype.
- The establishment of digital fruit tree prototype which can enhance the fruits output and quality, optimize the pruning measurement for typical fruit tree.
- The development of main crops' root system configuration model and the nutrient, moisture absorption optimization root system configuration digitized design system . Based on the content studied above, an integrated digital plants' research, development and design system is established from the aspects of experimental observation and parameter extraction, model and parameter base's construction, plant's digitized design, digital plant's practical application.

5.12 The Research and Product Development of Agricultural Bioinformatics

This refers to the molecular level study of agricultural animals' and plants' digital breeding based on the fundamental research of agricultural bioinformatics and biological model. At the same time, it refers to the molecular level theory and experimental research of biological idioplasm and medicine digital design based on the theory of bioinformatics.

6. CONCLUSIONS

Because it's a long-term process to construct the digital agricultural technology system, we should start from the basic study and develop gradually. Among the research domains discussed above, several core technologies of digital agriculture should be developed firstly, such as the research of digital agricultural technology standardization system, the R&D of remote diagnosis and agricultural expert system, the R&D of agricultural information sharing database, the R&D of multimedia information system for agricultural remote e-learning, the R&D of digital macroscopic monitor technology and dynamic decision system, and the R&D of digital agricultural technology software platform. Several aspects should be strengthened, such as the R&D of hand-hold agricultural technology consultation or examination product, the R&D of digital greenhouse environmental intelligent control system, the R&D of precision agriculture key technology and equipment, the research of farmland information gathering technology and product development. And we can then speed up the application step on the basis of realizing agricultural informationization gradually. For the fundamental research of digital agriculture such as crops growth model and digital design technology, biological informatics technology and product development, it's better to integrate them with other research and develop them gradually. At the same time, it's important to strengthen the demonstration application base construction, transform as soon as possible the research results into the realistic productive forces.

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BIOGRAPHICAL NOTES

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