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Research on Development of Corn Production Decision Support System

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Abstract

This research was about the application of decision support system in agriculture. The subject of study was the corn cultivated in Jilin province, northeast of China. The research synthesized expertise and experience on corn cultivation, plant protection, soil and fertilizer, and synthesized agriculture ecology from experts, integrating computer technology, principle of decision support system with corn production knowledge. The research also concerned decision support system for corn fertilization and diagnosis of insect disease and weed harming, which included system concept design, database design, knowledge base design , model base design and preliminary inference engine design according to the characteristics of corn diseases and pests of weeds.

Keywords*: database, knowledge base, model base*

1. Introduction

After the advent of information agriculture, agricultural production is no longer empirically extensive production activity. It is the agriculture industry combined with high-tech ordering, quantitative and scientific. The rapid development of computer and information technology provides new ways and means for the modernization and informatization of crop production control. The analysis and guiding function of the decision support system, which concentrate on many agricultural experts knowledge and experience, is a very good instructor for scientific farming [1].

2. Decision Support System

A decision support system (DSS) is a computer-based information system that supports business or organizational decision-making activities. DSSs serve the management, operations, and planning levels of an organization and help to make decisions, which may be rapidly changing and not easily specified in advance.

A properly designed DSS is an interactive software-based system intended to help decision makers compile useful information from a combination of raw data, documents, personal knowledge, or business models to identify and solve problems and make decisions.

Technique construction of DSS:

(1) User interface: input and output, human-computer interaction window.
(2) Database (DB): manage and store the data related to decision making problem area.
(3) Model base (MB) management: According to the user's requirements, model management system selects the basic model. Storage and dynamic modeling function shall be included in the model management system. Model management is realized by the model base system.
(4) Knowledge base (KB) management: manage the knowledge (rules and facts) of the decision making problem area, including knowledge acquisition, expression and management functions.
(5) Reasoning: identify and answer the user questions, including certain inference and uncertain inference.

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(6) Analysis and comparative: analyze and compare the strategy, model and operating result, find out the best solution.
(7) Problem solving: according to the issues raised by the interactive session, construct model and strategy, including matching algorithm, variables and data, running and finding the system.
(8) Controlling: connect and coordinate various part of the system, specify and control the program, maintain and protect the system. In addition, the technical construction also includes consultation, simulation and optimization [2].

3.Design of DSS

3.1. System Design

3.1.1. UML Use Case Diagram

Use case diagram can describe the software system function and requirement in a simple and intuitive way [3]. The use case diagram of corn production decision system in Figure 1 can describe the user's requirement of the system.

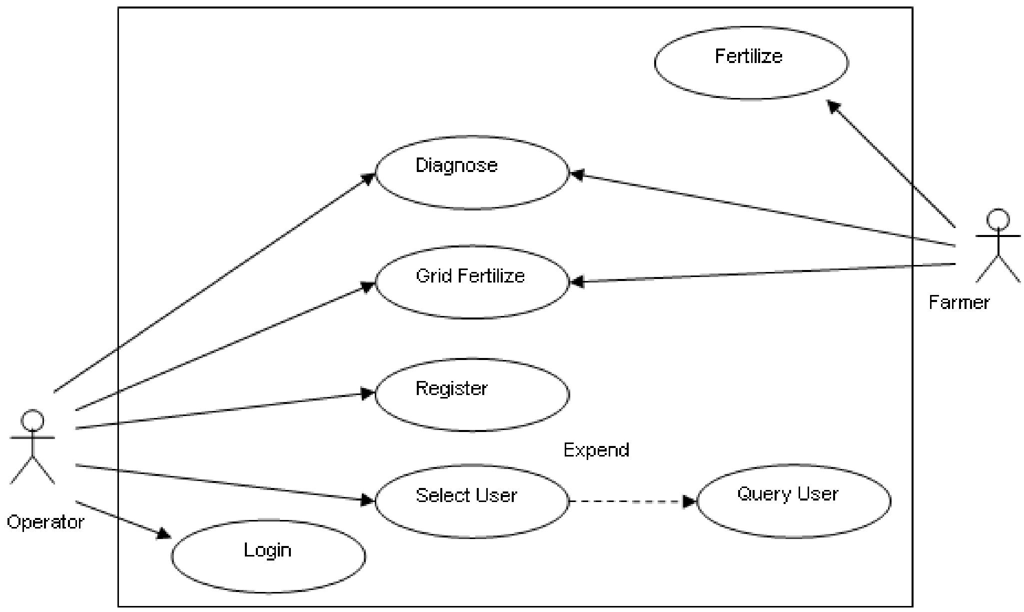

Figure 1. Use case view

3.1.2. UML Activity Diagram

Activity diagram of corn production decision system is used to describe the use case or events flow for operate this system. It shows the relation of each activity and describe the jobs during system running[4]. Entering the system home page is the starting point of use case, and the description of each activity is a specific affair as shown in Figure 2.

3.2. DB Design

3.2.1. Preparation of DB Design

DB (database) technology allows the separation of data and programs. It, that data and program present independently, is very meaningful for the constantly data updating and the program maintenance. For general understanding, besides the domain expert professional knowledge and experience, the knowledge of agriculture DSS also includes the data related to the domain problem solving and system operation. That means KB includes DB in contents. But if the information storage in the computer system is considered, knowledge is ultimately data [5]. From this point of view, DB includes KB in form. During the development of the decision-making system with development tools, data in the database can be added, deleted and modified by development tools or other programs. Data can also be handled by the database management system.

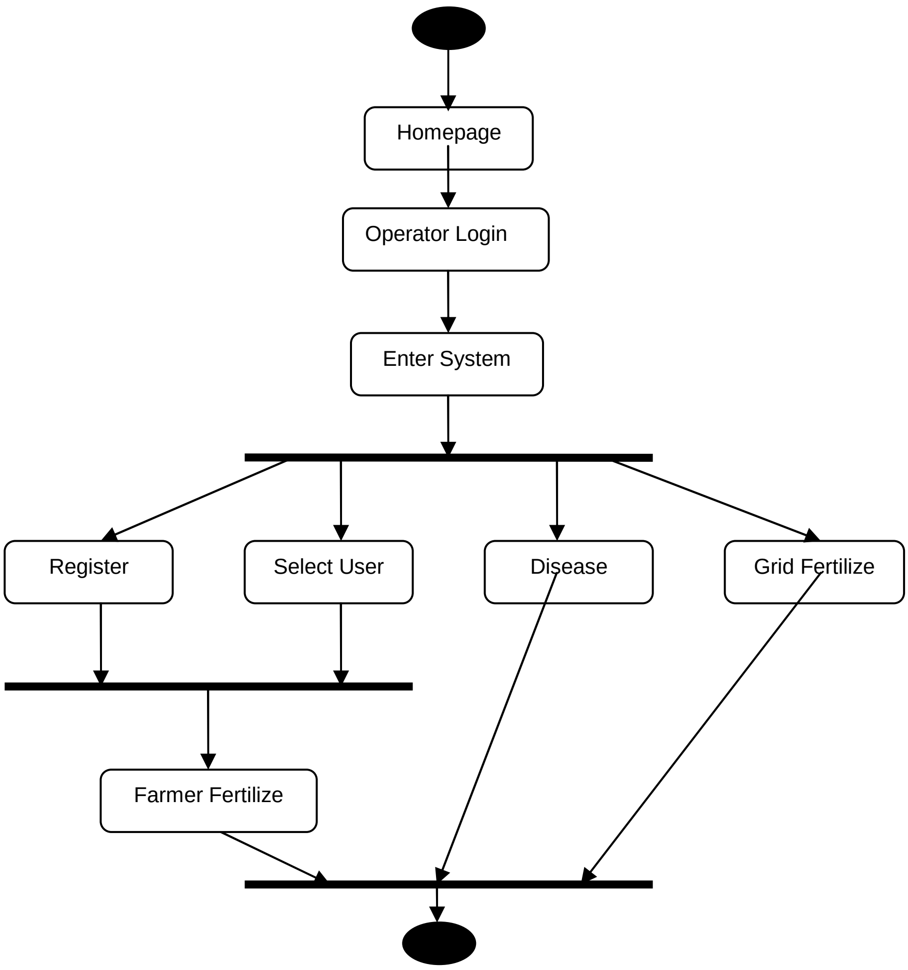

Figure 2. Active view

3.2.1.1. Sources of Data in Database

(1) Survey: including survey in the field and peasant household. Get the data of yield, fertilizing amount over the years and so on by on-site survey, meeting, questionnaire and so on.
(2) Collection with instrument: including on-site collection and laboratory analysis. Soil sampling and nutrient analysis data can be acquired in this way.
(3) Literature consult: including published books and papers. Some frequently used fertilization parameters can be acquired in this way.
(4) Expert consulting: fertilization model, time and method can be acquired in this way [6].

3.2.1.2. Functionality Provided by Database

(1) Maintenance: data insert, modify, delete and browse
(2) Query: including two major categories: peasant household-based query and grid-based query. In more detail: querying the fertilization amount of field or grid, querying the soil nutrient content of field or grid.
(3) Statistics: number of samples, minimum, maximum, mean, standard deviation, skewness, kurtosis and coefficient of variation.
(4) Report: display or print the query results in table or graphics.

3.2.2. Concept Design
3.2.2.1. Object Definition Language Design

According to various domain experts' knowledge and experience on corn cultivation, plant protection, soil and fertilizer, agriculture ecology, conceptual design is described with object definition language (ODL) as follows:

```
interface Corn (key name){
 attribute string name ;
 attribute string unit；
 attribute string growth_p；
 attribute float ac_temperature;
 attribute string maturity;
 attribute string tightness;
 attribute float ap_temperature;
 attribute string fertilizer;
 attribute string S_cultivation;
 relationship set<user> beplant
 inverse::user plant;
 relationship set<Disaster> having
 inverse::Disaster had;
}
interface User (key number){
 attribute string number;
 attribute string type；
 attribute string name；
 attribute string telephone;
 attribute string address;
 attribute string zipcode;
 attribute string password;
relationship set<corn> plant
inverse::coin beplant;
relationship set<fertilizer> use
inverse::fertilizer beuse;
relationship Demonstration belong
inverse::Demonstration have;
}
interface Demonstration{
 attribute string province ;
 attribute string city；
 attribute string county；
 attribute string township；
relationship set<user> have
inverse::user belong;
relationship set<grig> has
inverse::grig belongs;
}
interface Grid (key number){
 attribute string number ;
 attribute string location；
 attribute float longitude;
 attribute float latitude;
 attribute float altitude;
 attribute string texture；
 attribute string topography；
relationship set<Demonstration> belongs
inverse::Demonstration has;
relationship set<nutrient> including
inverse::nutrient included;
}
interface Fertilizer (key name){
 attribute string name ;
 attribute string unit；
 attribute float price;
 attribute float Ncontent;
 attribute float Pcontent;
 attribute float Kcontent;
 attribute string others；
relationship set<user> beuse
inverse::user use;
}
interface Nutrient{
 attribute float AHN;
 attribute float AP;
 attribute float OM;
 attribute float QAP;
relationship set<Grid> included
inverse::Grid including;
}
interface Disaster (key name){
 attribute string name ;
 attribute string controlmethod；
 relationship set<corn> had
 inverse::corn having;
}
```

3.2.2.2. E-R Model

Another conceptual design method is using the E-R model. Comparing with the ODL design, the description of relationship between objects is more vivid. In order to clearly describe the relationship between the individual object, E-R model design is used, shown in Figure 3. Attribute of entity set design is omitted as it is more or less the same as the ODL attribute design.

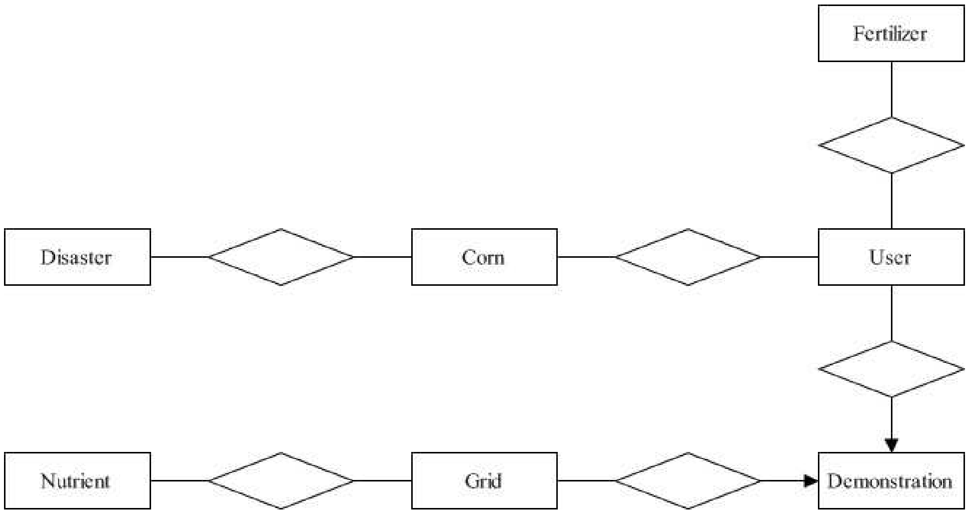

Figure 3. E-R model.

3.2.3. Logical Design

ODL design is converted to a relational model, which means converting class, class attribute and the relation between classes to relation schema. According to the converting principle, conceptual design can be converted to the following 7 relations:

(1) Corn (name, unit, growth_p, ac_temperature, maturity, tightness, ap_temperature, fertilizer, S_cultivation, user number).
(2) User (number, type, name, telephone, addr, zipcode, password, demonstration_number).
(3) Fertilizer (user_number, fertilizer_name, price, Ncontent, Pcontent, Kcontent, others).
(4) Demonstration (grid_number, number, province, city, county, township).
(5) Grid (number, location, longitude, latitude, altitude, texture, topography).
(6) Nutrient (grid_number, AHN, AP, OM, QAP).
(7) Disaster (corn_name, disaster_name, controlmethod).

3.2.4. Physical Design

According to conceptual design and physical design, suitable data types are set for various objects in database. SQL-Server is used as the development tool for the physical design of database. Some of the table structures are as Figure 4, Figure 5, Figure 6, Figure 7, Figure 8 and Figure 9.

Column Name	Data Type	Length	Allow Nulls
name	char	10	
unit	char	10	✓
growth_p	char	20	✓
ac_temperature	float	8	✓
maturity	char	10	✓
tightness	char	10	✓
ap_temperature	float	8	✓
fertilizer	char	20	✓
S_cultivation	varchar	50	✓

Figure 4. Corn table.

Column Name	Data Type	Length	Allow Nulls
name	char	10	
price	float	8	✓
Ncontent	decimal	9	✓
Pcontent	decimal	9	✓
Kcontent	decimal	9	✓
others	varchar	50	✓

Figure 5. Chemical fertilizer table.

3.3. KB Design

KB (knowledge base) is used to store and manage the knowledge of the expert system. Knowledge in KB is the important object or advanced data used by inference engine and interpreter. The expression of knowledge has a direct impact on the efficiency of the system.

Column Name	Data Type	Length	Allow Nulls
number	char	8	
type	char	10	✓
name	char	10	✓
telephone	char	13	✓
address	varchar	50	✓
zipcode	char	6	✓
password	char	6	

Figure 6. User table.

Column Name	Data Type	Length	Allow Nulls
number	char	10	
location	char	20	✓
longitude	float	8	✓
latitude	float	8	✓
altitude	float	8	✓
texture	char	20	✓
topography	char	20	✓

Figure 7. Grid table.

Column Name	Data Type	Length	Allow Nulls
province	char	10	
city	char	10	
county	char	10	✓
township	char	10	✓

Figure 8. Demonstration table.

Column Name	Data Type	Length	Allow Nulls
AHN	float	8	✓
AP	float	8	✓
OM	float	8	✓
QAP	float	8	✓

Figure 9. Soil nutrient table.

Production system, frame structure, semantic net and object oriented knowledge are the common knowledge formats. Rule-based knowledge is used in precision fertilization, while frame structure based knowledge is used in pest and disease diagnosis according to the attribute and complexity of pest and disease.

3.3.1. Production Rule Notation

Knowledge of production rule is generally expressed as: if A Then B, simplified as A→B. It means: if A is tenable, then B is tenable. A is the collection of the condition factors, B is the conclusion factors. In the collection of condition factors, the relationship between them can be "and", represented by "∧", or can be "or", represented by "∨", or can be the combination of them [7]. This representation has the modularity, naturality, and it's easy to express heuristic knowledge and use the domain knowledge to guide the deductive procedure. However, production is pure correlation, sensitive interpretation cannot be provided, procedure and heuristic knowledge can't be expressed easily.

The rule of forecast production is stored in KB as follow:

Rule: if annual precipitation is greater than 400mm for plot 5 – 9, there are no soil constraints for the plot.

Production: IF JYL = 2 THEN DIZH = 0

JYL means annual precipitation for plot 5 – 9. 0 means less than 350mm, 1 means less than 400mm and equal or greater than 350, 2 means greater than 400mm. DIZH means soil constraint, 0 means there is no soil constraint, 1 means there is soil constraint. Others will not be discussed because of space limitation.

3.3.2. Framework Representation

Knowledge is not able to decompose causality. Narrative and descriptive knowledge could use framework representation. Framework is a data structure which is used to describe certain state. It can be composed by any finite number of grooves; each groove may have any finite number of values. The disadvantage is that it is difficult to embody universal knowledge association intuitively and efficiently. The real status opens inconsistent with the prototype because of the fixity of the framework.

Due to the corn pests attack symptoms and law is affected by natural conditions and other factors, it is difficult to express the situation with a single knowledge representation. We select the framework based knowledge representation method in corn insect pest diagnosis and treatment module in Figure 10.

The framework knowledge representation has the following characteristics:

(1) The corn pests could be divided into several interdependent sub-problems by using framework. The sub-problems constitute the knowledge hierarchy.

(2) Child knowledge is described in one framework in this kind of knowledge representation. Knowledge is modular and compacted in this way.

(3) This kind of knowledge representation has practical applicability in processing determines exemplary.

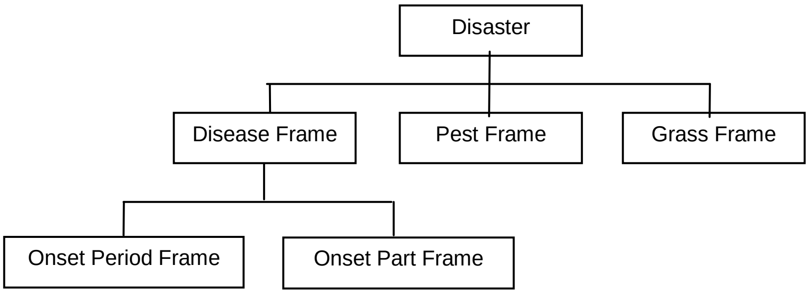

Figure 10. Frame chart of disaster

This system consists of three main framework, disease framework, pests framework, grass framework. The specific structure of the grass framework is shown in Table 1, Table 2 and Table 3. An example of black spot disease is described as Table 4.

Table 1. Frame of Grass

Framework Name	Disease
Onset period	x
Toxicant parts	y
x, y are variable	

Table 2. Subframe of Morbidity Time

Framework Name	Grass status
Seeding	A
Growth	B
Maturity stage	C
A, B and C are variable	

Table 3. Subframe of Grass

Framework Name	Hazards
Root status	I
Leave status	J
Stems status	K
Flowers status	L
Inflorescence status	M
Fruit status	N
I, J, K, L, M and N are variable	

Table 4. Framework of Black Spot Disease

Framework Name	Giant foxtail
Onset period	Seeding, Growth and maturity stage
Weeds Stats	Roots, leaves, stems, flowers, inflorescence, fruit
Control methods	(1). Agricultural control methods: (1-1). Cleaning seeds: clear weed seeds. (1-2). Clean the farmland environment: clear the grass inside and outside of the farmland. (1-3). Reasonable rotation：Rice field-upland field Rotation crop rotation. (1-4). Establish reasonable soil farming system: ploughing in spring and turn up the soil in autumn, harrow before preemergence and after postemergence. (1-5). Intertillage hill up: manually shovel, mechanical intertillage and grass. (2). Chemical control methods： Per acre with atrazine 75g plus 50% acetochlor 75g (or 48% Toure 75g or chemical% cable 75g) mixed with water 30 ~ 50kg , the spraying effect is up to 90%. Chlortoluron can also use the 25%, 25% nitrofen, 50% prometryn, linuron 50%, 25% diuron. (3). Biological control methods： Insects, pathogens, nematodes and animals could be used to control grass. (4). Physical control methods： Fire, electricity, laser and microwave (5). Other control methods： Use coverage, blackout, choking principle to control grass.

3.4. MB Design

MB (model base) is the aggregation of model, which correlate to each other, serve for certain purpose, store in specific structure. In order to combine qualitative analysis and quantitative analysis and combine symbolic processing and numerical treatment, agricultural expert system shall not only take full advantage of the expert's knowledge and experience, but also combine the mathematical model provided by the expert. KB, MB, and inference engine combined in this way [8].

Data needed by the model in the database may be retrieved, and after processing these data, the result may be put back into the database for further processing, or as the input of other models. So, it, that bases on the database, combines all the models are together, is an ideal structural form of the decision-making system.

Brief introduction for individual models in the design is as follow. The following model is based on many years' experimental analysis done by the domain expert, mainly including:

(1). Corn fertilization model:

(1-1). Weighted mean algorithm for soil nutrient content

$$Y = \sum_{i=1}^{n} \frac{A_i}{A} \times B_i$$

A is the total cultivated area for the user, A_i is the user's cultivated area in the number i grid, B_i is the soil nutrient in the number i grid.

(1-2). Nutrient balance method fertilization model

$$\text{Fertilizing\_amount} = \frac{\text{Cpt} \times \text{Ngc} / \text{100KG\_seeds} - \text{Msn} \times \text{Vsnr}}{\text{Fnv} \times \text{Furcs}}$$

For example, the mathematical model of calculating the phosphate fertilizer in Nongan County (Provided by the Agricultural Technology Promotion Center, the content of P2O5 in diammonium is 46%).

$$\text{(1-2-1). Phosphate\_fertilizer\_amount} = \frac{\text{Cpt} \times 0.07 - 0.3 \times \text{Snv} \times \text{Vsnr}}{0.46 \times \text{Fur}}$$

$$\text{(1-2-2). Vsnr} = \begin{cases} \dfrac{1578.8 \times \text{Snv}^{-0.98}}{100} \cdots\cdots\cdots \text{High\_fertilizer} \\ \dfrac{1068 \times \text{Snv}^{-0.832}}{100} \cdots\cdots\cdots \text{Medium\_fertilizer} \\ \dfrac{732 \times \text{Snv}^{-0.749}}{100} \cdots\cdots\cdots \text{Low\_fertilizer} \end{cases}$$

$$\text{(1-2-3). Bap} = \frac{0.3 \times \text{Snv} \times \text{Vsnr}}{0.022}$$

$$\text{(1-2-4). Fur} = \begin{cases} \dfrac{(43.4 - 0.024) \times \text{Bap}}{100} \cdots\cdots\cdots \text{High\_fertilizer} \\ \dfrac{(36.6 - 0.025) \times \text{Bap}}{100} \cdots\cdots\cdots \text{Medium\_fertilizer} \\ \dfrac{(40.6 - 0.035) \times \text{Bap}}{100} \cdots\cdots\cdots \text{Low\_fertilizer} \end{cases}$$

Cpt: Corn production target;
Ngc: Nutrient got by corn
Msn: Measured soil nutrient
Vsnr: Valid soil nutrient ratio
Fnv: Fertilizer nutrient value
Furcs: Fertilizer usage ratio in current season
Snv: Soil nutrient vale
Fur: Fertilizer usage ratio
Bap: Blank area production

(1-3). Fertilization model of fertilizer effect function method

With regression analysis, in black soil in Changchun, middle of Jilin Province, the high-yield cultivation output model of normal corn is:

$$y = 12492003 + 378.562x_1 - 52.229x_2 + 81.854x_3 + 96.354x_4 + 251.521x_5 + 43.719x_1x_2 + 139.156x_1x_3 + 208.156x_1x_4 + 51.719x_1x_5 - 210.719x_2x_3 + 153.031x_2x_4 + 16.844x_2x_5 - 39.156x_3x_4 + 47.031x_3x_5 - 285.594x_4x_5 - 339.880x_1^2 - 126.693x_2^2 + 69.870x_3^2 - 240.380x_4^2 - 335.068x_5^2$$

The decision variables (x) of the formula and the linear-coded values are as Table 5.

Table 5. Experiment Decision Variable and Uniform Encoding

Variable (Xi)	Space (Xi)	Design r = -2	r = -1	r = 0	r = 1	r = 2
Density (X1)	1.25 (10^4/hm2)	3.50	4.75	6.00	7.25	8.50
N (X2)	90(Kg//hm2)	0	90	180	270	360
P2O5 (X3)	45(Kg//hm2)	0	45	90	135	180
K2O (X4)	30(Kg//hm2)	0	30	60	90	120
Harvest time (X5)	4(d)	15/9	19/9	23/9	27/9	1/10

(2). Special corn with high quality and high yield planting function model:

(2-1). High-protein varieties' high protein planting function model:

$$y = 12.697 + 0.040x_1 + 0.138x_2 + 0.039x_3 0.063x_4 - 0.056x_5 + 0.091x_1x_2 - 0.169x_1x_3 + 0.016x_1x_2 - 0.056x_1x_5 - 0.017x_2x_3 + 0.148x_2x_4 + 0.044x_2x_5 - 0.179x_3x_4 - 0.048x_3x_5 + 0.052x_4x_5 - 0.068x_1^2 - 0.085x_2^2 - 0.064x_3^2 - 0.050x_4^2 - 0.090x_5^2$$

(2-2). High-oil corn's high-oil cultivation function model:

$$y = 8.045 - 0.032x_1 + 0.189x_2 + 0.128x_3 + 0.065x_4 - 0.025x_5 + 0.094x_1x_2 - 0.167x_1x_3 + 0.021x_1x_4 + 0.026x_1x_5 - 0.032x_2x_3 + 0.131x_2x_4 + 0.051x_2x_5 - 0.160x_3x_4 - 0.022x_3x_5 + 0.056x_4x_5 - 0.180x_1^2 - 0.056x_2^2 - 0.101x_3^2 - 0.035x_4^2 - 0.070x_5^2$$

(2-3). High starch, normal corn high-yield function model:

$$y = 12492003 + 378.562x_1 - 52.229x_2 + 81.854x_3 + 96.354x_4 + 251.521x_5 + 43.719x_1x_2 + 139.156x_1x_3 + 208.156x_1x_4 + 51.719x_1x_5 - 210.719x_2x_3 + 153.031x_2x_4 + 16.844x_2x_5 - 39.156x_3x_4 + 47.031x_3x_5 - 285.594x_4x_5 - 339.880x_1^2 - 126.693x_2^2 + 69.870x_3^2 - 240.380x_4^2 - 335.068x_5^2$$

(2-4). The combination of best technical measures with high quality and high yield are shown in Table 6, Table 7 and Table 8.

Table 6. Corn High Starch and High Production Best Combination

Item	Variable: Density (10^4/hm^2)	Nitrogen Fertilizer (Kg/hm^2)	Phosphate Fertilizer (Kg/hm^2)	Potassic Fertilizer (Kg/hm^2)	Harvest Date
Protein (>9.8%)	6.21~6.48	212.4~231.3	84.6~95.4	62.4~69.0	21/9~22/9
Yield (>12000Kg/hm^2)	6.81~7.01	160.2~180.9	108.5~120.2	64.5~70.8	24/9~25/9

Table 7. Corn High Protein and High Production Best Combination

Item	Variable: Density (10^4/hm^2)	Nitrogen Fertilizer (Kg/hm^2)	Phosphate Fertilizer (Kg/hm^2)	Potassic Fertilizer (Kg/hm^2)	Harvest Date
Protein (>12.5%)	4.57~4.76	216.9~232.2	86.4~95.9	65.7~72.0	22/9~23/9
Yield (>9600Kg/hm2)	4.98~5.15	207.0~221.4	63.5~72.9	71.7~78.3	25/9~26/9

Table 8. Corn High Oil and High Production Best Combination

Item	Density ($10^4/hm^2$)	Nitrogen Fertilizer (Kg/hm^2)	Phosphate Fertilizer (Kg/hm^2)	Potassic Fertilizer (Kg/hm^2)	Harvest Date
Protein (>10.6%)	4.88 ~ 5.03	232.2 ~ 250.2	100.4 ~ 108.9	58.8 ~ 64.5	22/9 ~ 23/9
Yield (>11100Kg/hm2)	5.95 ~ 6.10	235.8 ~ 252.0	91.8 ~ 102.6	55.2 ~ 61.5	23/9 ~ 24/9

(2-5). Benefit model:
R =Py*Y-∑Pi*Xi-P, in the formula,
R - net income per mu of land, units, RMB / mu;
Py - commodity corn price, units, RMB / kg;
Y - soybean yield, units, kg / mu;
Pi - the price of a variety of variable resources;
Xi - the input of a variety of variable resources;
P - the value of a fixed assets.

The content of model is stored in accordance with the relational data's type of organization. Classification, query and modification is easy in this way [9]. Each model consists two parts: basic attribute which stored in the model's basic information form, file group which stored in the model's file group information form. The relationship between the two table is one too many. Model basic information form can be used for querying the model library by the user or the system maintainer. Model file group is set up for editing and running the model.

3.5. Inference Engine
3.5.1. Inference Engine Introduction

The inference engine is based on the realization of the knowledge-based reasoning computer, which includes the reasoning and the amount of control. Control strategies have decided the method of knowledge acute. It has influence on reasoning effect and reasoning efficiency. There are three common control strategies: data-driven reasoning (reasoning), target drive control (also known as the repercussions reasoning) and mixed control (also known as bidirectional inference) [10]. The reasoning process of this system is under the control of certain reasoning strategy, and using the knowledge database rules for matching or operating to get the conclusions of the process.

3.5.2. Realization of Inference Engine

In the corn fertilization consulting module, location is confirmed through the man-machine dialogue, all the information of the location will be retrieved from climate, soil resource library. According to growth period, accumulated temperature, density tolerance, optimum temperature, fertilizer and other varieties, fertilization parameter will be reasoned.

In corn insect pest diagnosis and treatment module, according to specific pests, the most similar framework will be selected and "top-down" match will be implemented. If it is matched, the framework attribute of this pests knowledge would be provided to the user. If it is not matched, another matching process will be launched or modify the last framework until a satisfactory answer is provided.

In the process of pests reasoning, the attribute will be added sometimes. Attribute operation are included in each step of reasoning, the result of attribute operation is part of the whole reasoning result. The reasoning result may have ambiguity in reasoning result and attribute, sub-framework attribute, it is called matching conflict.

The backward reasoning matching conflict has the following situations:

(1) There are n>1 right part of production can match with a sub-goal.
(2) There are m>1 data can match the same sub-goal.
(3) There are L>1 sub-goals can find data or right part of production and they are matched.

According to matching conflict theory, we use the predefined order strategy, which means all the productions in a production system are arranged in a total order. Production will be selected when conflict occurs. For example, if the pre-shape of lesion sub-frame in black spot is matched with several attributes in pre-shape of sub-frame, we could digest the conflict according to the affected part attribute of black spot main frame.

4. Conclusion

In this research, UML is used for system concept design. Main parts of DSS are designed in detail: including concept design, logic design and physical design in DB design; corn fertilization model and special corn with high quality and high yield planting function model in MB design; In KB design, rule-based knowledge is used in precision fertilization, frame structure based knowledge is used in pest and disease diagnosis, and inference machine is preliminary designed. Based on the above design, development tool can be used to design the interface. A complete production DSS can be finally produced by the above designs.

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