Development of vehicular farmland information processing system based on Beidou Positioning

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Abstract—A set of vehicular farmland information processing system is developed in this paper. System uses the EPCS-8980 ARM industrial control computer and embedded GIS system as the information processing center, take Beidou navigation receivers as positioning tool, and Hall approach switch sensor as unit speed detecting device, in order to realize farmland information distribution map generating, variable pesticide spraying prescription map interpretation and unit speed detecting, the prescription map is completed by off-line computer. The on-board computer receives Beidou positioning information through RS-232 interface, and interconnected with other devices of system by CAN bus. The embedded GIS system is developed with eSupermap 6.0, and working on Windows CE 5.0 operating system. A series of experiment are taken to test system function, the test results show that the prescription map interpretation time is less than 1 s, the grid discriminant error is less than 0.75 m, and the unit speed detecting error is about ±0.1 km/h. Results show that the Beidou receiver can be used in this system, system can interpret pesticide prescription map correctly.

Keywords—Beidou positioning; precision agriculture; vehicle; information processing system; prescription map

I. Introduction

Traditional agricultural management is centralized management for a piece of land, while ignoring the spatial difference and time difference exist in majority of land[1,2]. Precision Agriculture, contrapose this difference exist in the field, carry out fertilizer, pesticide and other soil management measures, and develop planting, harvesting and other crop management practices Accurately; In the condition of lower inputs to obtain better output, improve crop yield and quality; At the same time, protecting the ecological environment and promoting agricultural sustainable development[3~6]. In 1995,the United States began to applied the GPS technology in the agriculture field, it made the GPS technology got application and popularization in the practice of Precision Agriculture. On October 25, 2012, China launched the last satellite of second generation of Beidou successfully, and Beidou navigation engineering area network was completed[7]. The application range of the Beidou system is the same as GPS roughly, the functions GPS has, so does Beidou[8,9], it means that Beidou system can applied in Precision Agriculture field instead of GPS completely. Additionally, Beidou navigation positioning technology applied in Precision Agriculture is benefit for the development and expanding market of navigation system which is domestic independent research and development, and to get rid of the situation that America's GPS monopolized market.

So far, China's Beidou system mostly applied in forestry management system and emergency rescue system or transportation[10~12]. In agriculture field, Beidou system is mainly used for the local links such as soil moisture detecting and farmland information acquisition, but less for the research about intelligent prescription farming information integration and processing. In 2013, the first domestic application

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demonstration project of Precision Agriculture based on beidou system was passed the acceptance in Shunyi[15]; In July 2014, "the eight division Shihezi Beidou system of Precision Agriculture application demonstration project" replied in Beijing[16]. The projects above, can complete farmland information acquisition and monitoring and management, and established the field differential reference station and a series of work. System fully detailed, but is relatively complex, high cost, and it is not suitable for a wide range of promotion.

The purpose of this paper is to research a set of simple vehicular farmland information processing system based on Beidou navigation and positioning technology. The system is focuses on pests, disease and weeds information processing and quantification, then fuses with coordinates of system. System could generate the farmland information distribution map and interpret the variable pesticide spraying prescription map. The system is researched through the experiments, to explored the feasibility of the farmland information processing system in Precision Agriculture application.

II. Composition structure of vehicular farmland information processing system

Vehicular information processing system is mainly composed of on-board computer which installed embedded GIS system, Beidou receiver and the unit of speed detecting device. The system is mainly used to complete farmland information distribution map generation and pesticide prescription map interpretation and speed detecting, its structure is shown in Fig .1.

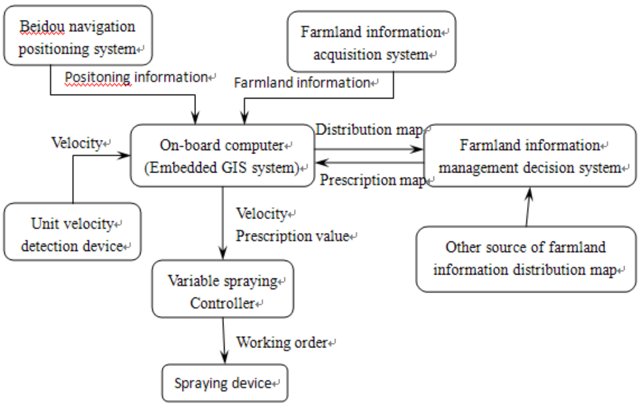

Figure 1. Structure composition of vehicular farmland information processing system system

In Fig .1,the Beidou receiver provides real-time positioning information, and transfered it to on-board computer through RS232 interface. The on-board computer is responsible for farmland information distribution map generating and pesticide prescription map interpretation. Off-line computer installed the farmland information management and decision system which can generate variable pesticide spraying prescription map. The speed detecting device is used to detect the instantaneous speed for spraying unit. On-board computer sends speed and pesticide prescription value information to the variable spraying controller through the CAN bus, then the controller to control the spraying device for spraying.

III. The hardware composition of farmland information processing system

The hardware integration structure of vehicular farmland information processing system is shown in Fig .2. On-board computer is the core component of information processing system, selecting the EPCS-8980 ARM industrial control machine and liquid crystal display matched to compose on-board computer for the system. Its board resource is rich, the interface is complete, power consumption is low, and reliability is high, these characteristics can completely meet the requirement of the system.

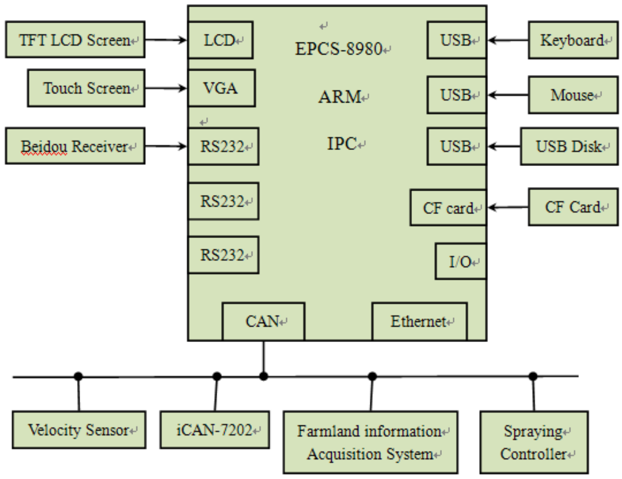

Figure 2. The hardware integration of vehicular farmland information processing system

Selecting P207 Beidou single frequency multi star DGPS board of Unistrong and auxiliary antenna as the positioning receiving device. Its positioning accuracy can achieve submeter, data update rate can up to 20Hz, working temperature is between -40℃ and + 85℃, and it can operate in variable farmland environment. Positioning data can be transmitted to on-board computer through RS232 interface.

Selecting Hall proximity switch as the speed detecting sensor. Because the EPCS-8980 motherboard without pulse signal input channel, so using iCAN-7202 frequency measurement module to test the signal frequency that output by the Hall approach switch, then obtained the forward speed of spraying unit indirectly.

IV. Function Realization of farmland information processing system

A. Software platform of information processing system

The On-board computer pre-installed genuine Windows CE 5.0 operating system; Embedded GIS system is developed in the form of library by eSupermap of Beijing hypergraph. The application is developed by Embedded visual C++. The farmland information management and decision system on off-line computer is developed by Mapinfo 9.5 software.

Because the format of files that respectively from farmland information management and decision system and GIS system are different, it always be necessary for file format conversion before farmland information distribution map transmitted to farmland information management and decision system and spraying prescription map sent to embedded GIS system. Using Fieldmapper Tools and eSmTranslator Tools on the offline computer to converses file format.

B. Beidou Positioning Information Acquisition and transmission

Beidou receiver can obtain submeter positioning data when it works. And the data can be sent to embedded GIS system by RS232 interface.

Beidou positioning data following NEMA-0183 serial port communication protocol. And 5 statement format often used with the communication protocol. RMC statement format will be used in this paper.

C. Principle of speed detecting

Beidou receiver itself can provide speed information, but due to speed of the spraying unit is low and limited by the field conditions, instantaneous velocity information that Beidou receiver provided is not accurate enough, so other speed detecting device will be needed. When host computer stop working, speed detecting device can be used with lower computer, so that the spraying unit can working normally.

Selecting a wheel of the machine, and fixed several magnetic steel in the hub bolt by fine arc length. When the wheel is rotating, every magnet near the Hall switch, there is a pulse signal outputted. Frequency measurement module can obtain the pulse signal frequency f, the wheel velocity can be expressed as

$$V=(2\pi R/n)\cdot f\cdot(1-\delta) \qquad (1)$$

Where R is the distance from center of the wheel to the ground, n is the number of magnetic steel that installed, and δ is the slip rate of the wheel.

δ can be test as following. The output terminal of Hall sensor is connected to the input terminal of iCAN-7202 frequency measurement module, driving spraying unit straight on a road, and frequency measurement module counts the number of corresponding pulse, the number is N. Beidou navigation module records the start and the end coordinates, and the distance that spraying unit driven can be calculated according to the coordinate values. Because of the positioning error problem of Beidou module, in order to reduce the distance error that Beidou brings, the S should be more than 20 m, there are

$$S'=(2\pi R/n)\cdot N \qquad (2)$$

$$\delta = 1-S/S' \qquad (3)$$

D. Generation of farmland information distribution map

The field contour can be determined by Beidou positioning, then a polygon which is overlapped with contour is determined according to contour and tendency of crop row in the field, and choose a vertex of polygon as the origin to set up a geodetic coordinate system.

Using the grid maker of GIS to divide the polygon into grid and named grid, insert farmland information into each grid with linear interpolation method, recording and storing it, then to generate the farmland information distribution map.

E. Generation and interpretion of spraying prescription map

Farmland information management and decision system receives the farmland information distribution map that after format conversion, reference to other agriculture expert system, the spraying value of pesticide should be determined, thus generating a specific spraying space map.

The spraying space map is transmitted to embedded GIS system after format conversion. When the spraying unit is working in the field, the GIS system obtains real-time location information and fused with prescription coordinate according to spraying space map, then judge which grid the spraying unit is on, so that read the pesticide value in grid successfully.

V. System function test

A. Generation of farmland information distribution map and pesticide spraying prescription map

A random number program is used in the experiment, pressing the Enter key once the program produces a random integer in range of 0 to 10, and upload the integer to GIS system as the weed density grade value.

Information processing system is installed on the Shanghai-50 type tractor, take it as the experiment unit, the spraying range of unit is 4 m. Take a rectangular block where is on the school playground as the test site, the area of block is 40×60 m^2. The test site is divided into 10 work band and each band is 4 m wide, then marked 10 random test points in each band. Opening system, driving spraying unit around the site, so that the site contour can be obtained by Beidou positioning data. When the vertical projection of Beidou antenna falls on the test point transverse line, press the Enter key to get the weed density of the test point and record it artificially. After all these work, information processing system divide the contour into grid and the size of grid is 4×4 m^2, thus generating a farmland information distribution map.

Farmland information distribution map introduced into farmland information management and decision system after its format conversed. According to the relationship between the amount of pesticide and weed density, set the pesticide spraying value into 11 grade from 0 to 15 mL/m^2 in average, so as to generate the variable spraying prescription map, prescription map is shown in Fig .3.

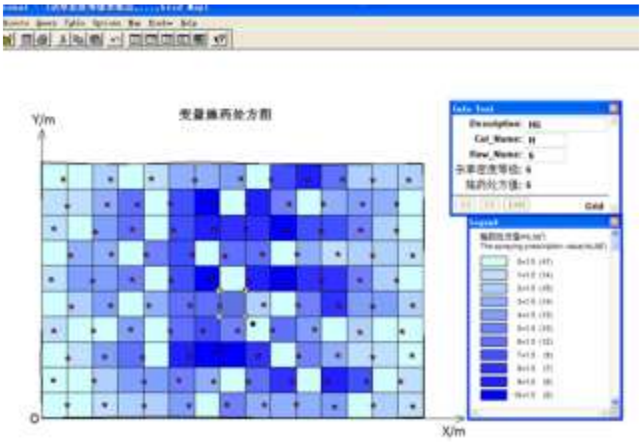

Figure 3. Prescription map for variable spraying

Compare the data in spraying prescription map with data that recorded artificially, the most prescription value in grid of map is completely consistent with the weed density grade that recorded.

B. Simulation test of pesticide spraying prescription map interpretation

The experiment adopts PMW intermittent and variable spraying controller[17], controller will send confirmation message to the information processing system once received pesticide spraying value.

The application program of information processing system enable software timing function, timing and display interpretation time of spraying prescription map. The interpretation time is from receiving Beidou positioning information to confirmation message which is sent by controller. Driving unit on the test site at speed about 3.5 km/h along the working band, on-board computer display the latest spraying value of prescription map and interpretation time, record spraying value and interpretation time of each grid in prescription map artificially; When the vertical projection of Beidou antenna falls in the detection point transverse line on working band, recording the prescription value displayed on the screen. Statistical results of interpretation time show that the maximum value is 0.95s, the minimum value is 0.69s, and the average value is 0.876s; According to results, it shows that the system can interpret prescription map in real-time.

Converting prescription value that recorded into weed density grade value correspondingly, calculating the difference value of converted weed density grade value and the value of corresponding position in the prescription map, and dividing the difference value into 3 level; The results of statistical data that calculated respectively are shown as table 1. Gird center area in the table is region that based on grid geometry center area within a circle, radius of 1.5 m.

TABLE I. The results of interpreting error for variable spraying prescription map

Error range	Grid number	Test point number		
		Total	Grid center region	Grid edge region
0	115	76	50	26
1~3	12	7	2	5
3~10	23	17	2	15

Table 1 shows that the interpretation result of grid prescription values is satisfactory, the test points who's prescription value error is large most are on the grid edge. The main error sources are positioning error and dynamic error. Positioning information is not accurate enough may cause grid discriminate to the adjacent grid, especially the test point located in the edge of grid. If the difference value of adjacent grid is smaller, the error is small, whereas the error is large. The grid discrimination error can be expressed as

$$\delta_w = \delta_b + vT \qquad (4)$$

where the δ_w is grid discrimination error, δ_b is Beidou positioning error, and T is the update cycle of Beidou positioning information. In the system, $\delta_b=\pm 0.6$ m，T= 0.1 s，so the grid discrimination error is -0.51~0.70 m approximately. It can be concluded that Beidou receiver can provide the positioning information normally and steadily in the system, and can be well integrated with the system.

C. Test of spraying unit speed detecting

The outside diameter d of the test wheel is 1.3 m, the number of magnetic steel is 6, take the pulse counting N as 50. Counting channel counts every 50 pulse, calculating a slip rate to revised δt. Frequency detecting channel output a pulse frequency of f for a second, taking δt and f into the speed calculation formula can derive the instantaneous speed of spraying unit.

Driving spraying unit with uniform speed, enabling the test wheel turned 20 laps, measured the vehicle real driving distance S, then the initial slip rate δ_0=4.21% can be obtained.

Driving spraying unit for 100 m with different speed respectively, record a speed value displayed on screen every 3 s. Record the driving time of first 50 m and last 50m respectively to calculate the average speed, the first 50 m denote A and the last 50 m denote B. At the same time, record the real-time slip rate δt of the two distance. The test result is shown in Table 2, and error in table is the absolute value of average error.

Form the analysis of table 2, in the two distance with same speed, the wheel slip rate is modified in the last 50 m and the speed error is relatively small. And table 2 shows that the speed error is ±0.1km/h, the value of speed in the system is relatively stable.

TABLE II. Measuring results of running speed for driving unit

order	Velocity（km/h）				Slip rate /%	Error
	Max	Min	Average display	Average velocity		
A	3.56	3.47	3.52	3.58	4.21	0.06
B	3.67	3.61	3.64	3.61	4.16	0.03
A	4.75	4.68	4.71	4.79	4.18	0.08
B	4.76	4.65	4.71	4.74	4.19	0.03
A	6.27	6.18	6.25	6.21	4.17	0.04
B	6.30	6.21	6.22	6.24	4.18	0.02
A	7.57	7.45	7.49	7.54	4.16	0.05
B	7.56	7.47	7.52	7.54	4.19	0.02

VI. Discussion

1) The system can generate reasonable pesticide spraying prescription map correctly, but it is necessary to consult other agriculture expert system to determinate the amount of pesticide. We can take the relationship between amount of pesticide and weed density into a database in the future, to make the farmland information management and decision system more perfect.

2) A series of experiment is did to test the function of system, and the results show that the system can realize its functions normally. But the whole system test were not conducted in actual field, so it has certain limitations, it can be researched follow-up.

VII. Conclusion

1) The system is composed of Beidou navigation positioning system, on-board computer, embedded GIS system and speed detecting device. Experiments were took to test the system functions, the results show that the grid discrimination error is less than 0.75 m, and the average value of spraying prescription map interpretation time is 0.876 s. It shows that the system can effectively complete prescription map generating and interpretation.

2) The speed detecting device adopts Hall proximity switch sensor, and using Beidou receiver to assisted the wheel slip rate correction, the method is simple and easy. Test results show that the speed error is ±0.1km/h, and it shows that the accuracy of velocity detection device can meet system requirement.

3) Beidou receiver plays an important role in the farmland information distribution map generating, prescription map interpretation and speed detecting of spraying unit. The test result shows that it can work stably and reliably in each step, and it has important practical value for the application of Beidou navigation positioning technology in Precision Agriculture.

4) The system structure is relatively simple and lower cost, it has good popularization and application value.

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