Development of a Data Acquisition and Processing System for Precision Agriculture

H. Chen[1], Y. Lan[2], W. Wu[1], W. C. Hoffmann[2], S. Zhang[1, 3]

[1]Jilin University, 5988 Renmin Street, Chang Chun, China, 130022
[2]USDA-ARS-APMRU, College Station, TX 77845
[3]Texas A&M University, College Station, TX 77843
*Correspondence Author: Email:yubin.lan@ars.usda.gov, Tel: 979-260-3759

ABSTRACT

A data acquisition and processing system for precision agriculture was developed by using MapX5.0 and Visual C6.0. This system can be used easily and quickly for drawing grid maps in-field, making out parameters for grid-reorganization, guiding for in-field data collection, converting data between different formats, managing databases, and drawing thematic maps for VRT(variable rate technology) application in-field. Experiment results have shown that the system works well for data acquisition of variable rate fertilizer application for precision agriculture and for generating output field maps. This paper describes the design and implementation of the software programs using MapX5.0 and Visual C 6.0 for data acquisition and processing for precision agriculture.

Keywords: Precision agriculture, data acquisition and processing, VC6.0, MapX5.0, China

1. INTRODUCTION

In recent years, the research and application of precision agriculture has been developing rapidly. Geospatial Information System, GIS, is one of the key technologies in precision agriculture technology systems. GIS uses a software platform for analyzing, processing, and displaying spatial geographical information. There are hundreds of kinds of commercial GIS software programs currently being used widely in the world. However, these programs can not fit the requests of particular users directly as commercial GIS products for all kinds of users. When using commercial GIS software on a particular agricultural field, many users usually need to make further developments and adaptations of the software. Some scholars and researchers have been developing and studying the special GIS requirements needed for precision agriculture. A wireless in-field sensing and control (WISC) software of an automated irrigation system, based on in-field wireless sensor network, has been developed by the Northern Plains Agriculture Research Laboratory of America (Kim et al., 2006). WISC is Windows-based GUI software which monitors the status of irrigation on plots via Bluetooth wireless communication. The WISC software was coded by using Microsoft Visual C++.Net (ver.7.1) as a console application type of Win32 project. Furthermore, an agriculture anti-flood information management system was developed by using Visual Basic 6.0 and MapX (Hailiang et al., 2006). There is a real-time monitor and data management system for sprayers designed by using Microsoft Visual Basic 6.0 and MapInfo MapX5.0 (Jun and Chundu, 2006). Shidong and Kuikui (2006) created a special geographical information system based on MapX4.5+ Visual Basic 6.0 models (Ruimin, 2000). Qing et al. (2004) developed a monitoring system for the field vehicle positions based on GPS and GIS by using MapX4.5 of MapInfo Company and Visual Basic 6.

The objective of this project was to design a data acquisition and processing system for variable rate technology (VRT) applications. The work described in this paper followed the rules of COM (Component Object Model) using MapX5.0 and Visual C 6.0. This system was based on electronic prescription maps provided by the ES (Expert System), including grid-divide, parameter output for grid-reorganizing, data management and processing, analysis of thematic maps, and guidance in sampling, etc.

2. MATERIALS AND METHODS

2.1 Hardware

The minimum computer powered required for this system was a CPU operating at 800MHz or higher. The computer also needs to have 64 megabytes of memory available.

2.2 Software

Operation system was Win2000/NT/XP (Microsoft Inc., Redding, WA). The geographical information system used was MapInfo Professional 7.0 with MapInfo MapX5.0 (MapInfo, Troy, NY). The developing tool used was Microsoft Visual C 6.0 (Microsoft Inc., Redding, WA).

2.2.1 Main functions and implementation

The data acquisition and processing system for VRT application in precision agriculture was developed using Microsoft Visual C6.0 and integrating MapX5.0. MapX5.0 from MapInfo Company is an ActiveX component, which enables developers to add mapping functionality to any application quickly and easily. In this project, ActiveX components were the programmable and reusable COM-base objects, and they communicated with other applications through interfaces of property pages, events, and methods. COM is a group of protocols for interface between modules. Applying COM can build a link between two modules and make them communicate with each other by using an "interface" as soon as the link is constructed.

The data acquisition and processing system, developed based on Microsoft Visual C 6.0 and MapX5.0 was specially applied in precision agriculture production. It consists of functions of the MapInfo platform. Here, the key points of the system's design are not only in designing and programming its basic functions, but in solving practical problems in variable rate technology application in order to meet the needs of automatic variable rate applicators. The functions of the system are as follows.

2.3 Design for User Interface

In general, the style and features of a user interface (UI) are sorted into three classes in software development, namely UI of menu, table, and command lines. These three classes of UI have their own styles and features respectively. In the system, a complex interface style was made of a menu, a table, and command lines according to needs of the users and applications. The UI was composed of five parts: main menu, toolbar, operating map window, parameter input window for grid-divide, and parameter output window for grid-reorganize. Figure 1 shows the main UI of the system working. The basic functions of the operating map were achieved with menu and command lines on the screen. The key maps and functions of grid-divide used a table style to display. Thus, this kind of complex interface style is concise and easy to operate.

2.4 Functions and Implementation

According to the requirements of the map-based VRT (Variable Rate Technology) application, the system functions were sorted into five objects to be operated: map, menu command, dialog box, toolbar, and serial communication interface by means of the OOP (Object-Oriented Method of Programming). After building models for every object and link between the objects, the objects are available through their property pages, methods, and events. The main functions are as follows.

3. RESULTS AND DISCUSSION

3.1 Map

This system has the general functions of operating a map in GIS, such as zoom out, zoom in, navigation, and map editor (Fig. 2). All these functions were implemented by operating a set of objects of m_ctrlMapX by citing property pagers and methods of objects integrated in MapX5.0.

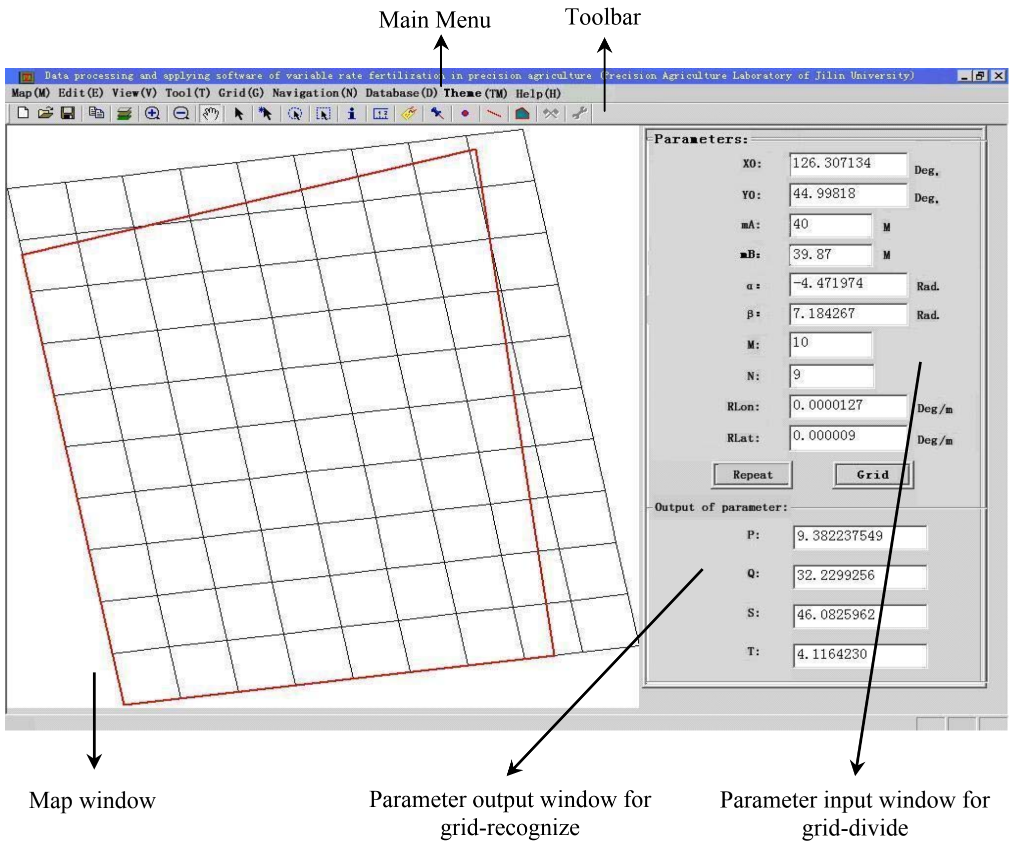

Figure1. User interface for variable rate applications.

In the software designing procedure, the first step is to build a group of tools and menus through programming in VC 6.0, then, commands are carried out in response to the functions of the tools and menu commands. The functions of the operating maps, such as zoom out, zoom in, pan, layer etc., are implemented by using the map controls to cite predefined tools in MapX5.0.

.

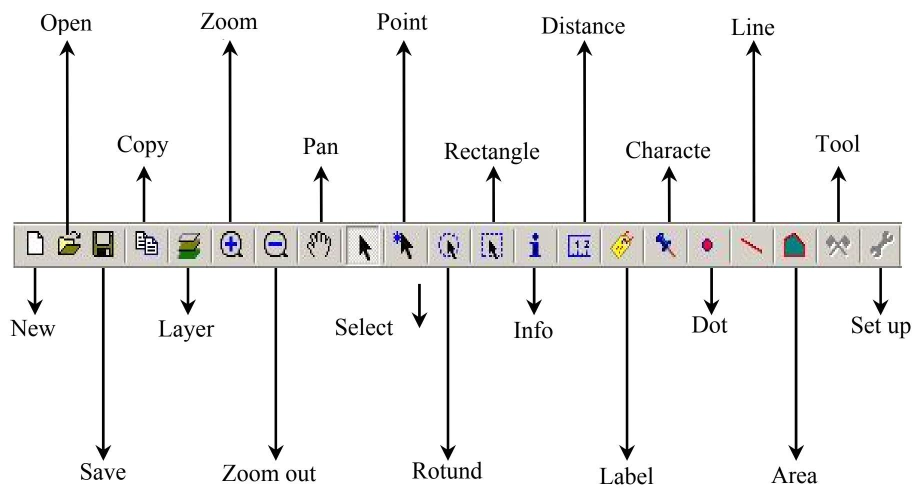

Figure 2. Toolbar designed for MAP functions in the user interface.

3.2 Data Management and Processing

This system can manage three kinds of format data: * .tab of MapInfo, * .gst of MapX and * .txt of Windows. It is able to construct and process the electronic maps in vector format, add and save map data easily, record and save the data coming from the GPS receiver to meet the needs of VRT applications, which are map-based.

In the system, the data management module was divided into three sub-modules, which were used for building, saving the data files with *.gst format and *.tab formats, and recording data received by the GPS receiver respectively.

> The first was called a map sub-module for data with *.gst format. The *.gst format file can be directly loaded-on when clicking the drop-down menu [Map]||[Open GST] in the working window of the system. At the same time, a *.tab format file can also be opened and saved as a *.gst format file by the clicking drop-down menu [Map]||[Save GST].
>
> The second was a data sub-module for files with *.tab format. A *.tab format file can be built and loaded directly when clicking the drop-down menu [Map]| [Building TAB layer]. If the users want to add spatial data to a map, they can easily input attribute data when building data tables without using MapInfo platform. A *.tab layer is added to the GST layer directly by clicking the drop-down menu [Map]||[Add TAB layer] in loading a *.tab function.

The third is a sub-module for GPS data acquisition, which saves the navigation data received by the GPS receiver as a *.txt format file used for checking and saving data.

3.3 Navigation and Positioning

GPS positioning data can be received in real-time and displayed in the map window so that the system implemented real-time navigation and positioning for in-field sampling and application. The function of navigation and positioning by using GPS receivers was composed of two sub-modules, which are used for the port configuration and navigation respectively.

The first sub-module was for a RS-232 serial port configuration. As soon as the port parameters for communication were set by directly clicking the drop-down menu [Navigation]||[Port set], the system established communication with the GPS receiver and carried out GPS navigation. The RS-232 serial communication between the system and the GPS receiver was bridged by using MSCOmm32.OCX, (Microsoft Inc., Redding, WA), which provided RS-232 data communication with all the protocols. At the same time, VC6.0 programmable language provided the controls with standard functions for dealing with events and processes and a port configuration for the serial communication through their property pagers and methods. The procedure of software design was realized through two steps: The first was to define a group of parameters, called m_ctrlCom with type of CMSComm, and then to apply this object to cite its property pagers and methods to complement the port configuration. The key sentences of the program are showed below:

```
void CDCASView::SetPortParameter()

{m_ctrlCom.SetCommPort(1);//set communication port COM1；
m_ctrlCom.SetInBufferSize(4096); //set buffer area
m_ctrlCom.SetSettings("9600,N,8,1");//set communication parameters
m_ctrlCom.SetRThreshold(122);//means one character initiate one event
m_ctrlCom.SetInputLen(0);//if character is valid, accept all character content
m_ctrlCom.SetInputMode(1);
if(!m_ctrlCom.GetPortOpen())

{AfxMessageBox ("serial initialization succeed!\nPort:COM1\nbaud rate: 9600\ndata bit: 8\nstop bit: 1\nparity bit: N\nserial close!");} //set-up state displays to users via dialog box
```

The second sub-module was for navigation and positioning. The applicator's position was displayed in the map window. The GPS receiver started to work when clicking drop-down menu [Navigation]||[Begin navigating] in the UI. This sub-module reads the positional data, including longitude, latitude and speed of the applicator, coming from the navigation system with NEMA0183 format from the GPS receiver.

3.4 Field Parameters and Grid-Divide

After getting the outline map of the working-field by using the GPS receiver, a grid-map was generated. The grid-map divided the working-field into many operational units for a map-based VRT applicator. This process is referred to as a grid-divide. Field parameters are defined when making a grid-map. Field parameters consist of a group of data which are used to describe shape, location of the working-field, length, and width of the grids involved in the working-field which the VRT applicator is. When a user inputs field parameters in the parameter input window for the grid-divide (see Figure 1), the system divides a working-field into many grids according to the field parameters, saves them as the grid-map with vector format, and outputs these parameters to the controller of the VRT applicator.

Users can freely set the length and width of the grid-map according to their needs and working direction of the applicator. A grid-map can be produced by clicking the drop-down menu [Grid]|[Divide grid] in the main window and saving as a *.tab format file automatically.

3.5 Grid-Recognize and Parameters Output

When an automatic map-based VRT applicator is working in the fields, it must know where the applicator is as it receives the signals of the GPS's positioning. This process of judgment is called grid-recognize. The goal of grid-recognize is to let the VRT applicator know which grid or operating unit it is in. It calculates the grid coding M and N of the operation unit automatically. The formula of coding (M, N) for grid-recognize was:

$$M = L\,\mathrm{int}\left[(Y - Y_0)\times P + (X - X_0)\times Q\right] + 1$$

$$N = L\,\mathrm{int}\left[(Y - Y_0)\times S - (X - X_0)\times T\right] + 1 \qquad (1)$$

Where (see Figure 3):

M – coding number in horizon

N – coding number in vertical

X_0、Y_0 —longitude and latitude coordinates of base point of the working-field (°);

X、Y—current longitude and latitude coordinates (°);

α —angle between y'-axis and one edge of the working-field (°),(y'-axis is vertical to x'-axis);

β —angle between x-axis and the other edge of the working-field (°);

mA —width of a grid (m);

mB —height of a grid (m);
RLon —coefficient in latitude (°/m);
RLat —coefficient in longitude (°/m);
Lint —integrated function, that is to convert a real number to an integer less than its.

Defined *P, Q, S* and *T* as parameters of grid-recognize gotten by following:

$$P = \frac{\sin\beta - \cos\beta \times \tan\alpha}{mA \times RLat}$$
$$Q = \frac{\cos\beta + \sin\beta \times \tan\alpha}{mA \times RLon} \qquad (2)$$
$$S = \frac{\cos\beta}{mB \times RLat}$$
$$T = \frac{\sin\beta}{mB \times RLon}$$

In formula (2), parameters for grid-recognize (P, Q, S, T) and longitude and latitude coordinates of base point of the working-field(X_0, Y_0) were considered as a group of constants in a given working-field. Parameters for grid-recognize (P, Q, S, T) were calculated and output to the controller on the VRT applicator are displayed in the working window. The function of the grid-recognize is an important part in the system. Users can get parameters for grid-recognize from the working window automatically when inputting field parameters and by clicking the button of the grid in the working window.

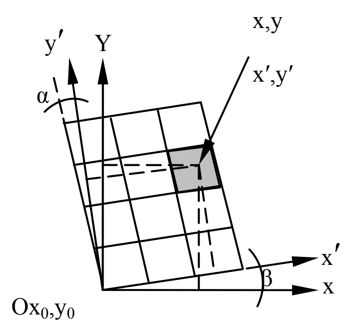

Figure 3. Parameters in reference coordinate

3.6 Data Query

Data query mainly functions as a query and attributes information about every grid. By data query function, users can gather ‘attribute data’ and utilize the toolbar to zoom out, zoom in, and revert or hide legends functions. While selecting the grids, user can pick up and display attribute data, such as soil nutrient contents and yield in every grid, output decision prescription about rate of fertilizer application, pest control and other parameters, in the table style. All of the attribute data saved in database can be shown to users in the form of a dialog box by clicking any position with Info tools in the opened map window.

The data query function was composed of two sub-modules. The first one was a module for database link. It linked the attribute database to the map layer and data display, analyses and query of attribute data in GIS. The other was a module for database query and display. The attribute information linked to the layer was displayed in the dialog box by user-defined Info tools.

3.7 Analysis of Thematic Maps

After attribute data were linked to the map layer, all of the attribute information was displayed in thematic map style, which complements the analysis of thematic maps. For instance, nutrient contents of N, P and K in the soil of a given working-field can be displayed in thematic maps respectively by clicking the drop-down menu [Thematic maps]||[Add thematic maps]. The main program sentences are as follows:

```
void CDCASView::OnThemeAdd ()
{ds = m_ctrlMapX.GetDatasets().Add(miDataSetLayer, layerVt);
    ds.GetThemes().Add(miThemeRanged, "N");//implement analysis of thematic map N
    ds = m_ctrlMapX.GetDatasets().Add(miDataSetLayer, layerVt);
    ds.GetThemes().Add(miThemeRanged, "P");// implement analysis of thematic map P
    ds = m_ctrlMapX.GetDatasets().Add(miDataSetLayer, layerVt);
    ds.GetThemes().Add(miThemeRanged, "K");// implement analysis of thematic map K}
```

4. CONCLUSIONS

In order to carry out the VRT application in precision agriculture, a special data acquisition and processing system was designed, which is one of the key technologies in precision agriculture production. The system was developed in user-friendly interface, using familiar windows and drop-down menu and was easy to use. The system was made with modular GIS technology. It not only has traditional GIS functions, but has also integrated GPS receiver. Its specialization and simplification made the system easy to popularize and apply for the precision agricultural production. Data of GIS was processed by the self-developed VRT applicator according to the specialties of precision agriculture production management and needs of automatic variable rate fertilizer application for precision agriculture. Grid-maps and parameters for grid-recognize in a given working-field were output to the auto/semi-auto variable rate fertilizer applicator. The system has been successfully employed in variable rate fertilizer applicator since 2004.

The system was programmed with MapX5.0 controls, which can be installed and run on any platform supported by ActiveX conveniently. Furthermore, there is good compatibility with the Windows operation system using the VC6.0 program language. Using modular design technology, one module fulfills one function, and thus, improves the stability and expandability of the system.

5. REFERENCES

Hailiang, Z., H. Dongjian, and W. Jianhua. 2006. Research of application of GIS integrated technique in agriculture anti-flood information management system. *Journal of Agricultural Machinery*. 37(1): 111-113.

Jun, W., and W Chundu. 2006. Position data collection and processing for variable rate sprayer. *Mechanization study*. 10: 161-163

Kim, Y., R.G. Evans, W.M. Iversen, F.J. Pierce, and J.L. Chavez. 2006. Software design for wireless in-field sensor-based irrigation management. ASABE Paper No. 063074. St. Joseph, MI: ASABE.

Qing, Y., Z. Zheng, and P. Shujie. 2004. Field vehicle position monitoring system based on GPS and GIS. *Transactions of the Chinese Society of Agricultural Engineering*. 20(4): 84-87.

Ruimin. 2000. *Mapinfo 5.X Operating Guide*. China: China Railway Publishing Company.

Shidong, W., and C. Kuikui. 2006. Development of geographic information system application based on MapX. *Computer Study*. 4: 1-3.