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Object-Oriented Field Information Management Program Developed for Precision Agriculture

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Abstract: This study was conducted to develop software which provides automatic site-specific field data acquisition, data processing, data mapping and management for precision agriculture. The developed software supports acquisition and processing of both digital and analog data streams. The architecture was object-oriented and each component in the architecture was developed as a separate class. In precision agriculture research, the laborious task of manual ground-truth data collection will be avoided using the developed software. In addition, gathering high-density data eliminates the need for interpolation of values for un-sampled areas. This software shows good potential for expansion and compatibility for variable-rate-application (VRA). The FIM (Field Information Management) computer program provides the user with an easy-to-follow process for field information management for precision agriculture.

Keywords: Data Acquisition, Data Collection, Data Stream

Introduction

Precision agriculture is an important technological development for managing the spatial variability that naturally occurs in crop production. Precision agriculture is becoming an increasingly accepted method of crop production and it can help to achieve sustainable, environmentally friendly agriculture. The objectives of site specific farming are to increase yields while decreasing environmental impacts. Furthermore, the growing interest in automatic data acquisition and information processing is a step towards improved farm management and overall traceability in agricultural food production. The benefit and effectiveness of using precision agricultural techniques is highly dependent on the capabilities of the utilized technology (Ehrl et al., 2002).

Improved farm management, optimized decision support systems, and the traceability of farm products require automated acquisition of geo-referenced process data. Precision agriculture not only means site-specific crop production, but also improves farm management together with decision support systems, optimized fleet management, and field robotics with autonomous vehicles. Therefore, detailed data and reports are becoming more and more necessary. Collecting, aggregation, and analysis of these base data and additional process data, together with site information like position and time, will create the base for improved farm management and the traceability of farm products (Demmel et al., 2002).

Since precision agriculture deals with in-field variations, collection of high-density information is essential. A dependence on traditional means of manual data collection has hampered the success of precision agriculture (Tang et al., 2001). The National Research Council (1997) refers to precision agriculture as a management strategy that uses information technologies to bring data from multiple sources to bear on decisions associated with crop production. The key idea behind precision agriculture is to measure and manage in-field variability to optimize the crop production system. Li et al. (1998) categorized variability into six categories – yield variability, field variability, soil variability, crop variability, variability in anomalous factors, and management variability.

The successful use of precision agriculture technology for automated data acquisition, site specific farming, fleet management and field robots requires a detailed knowledge of the quality of all utilized equipment (Ehrl et al., 2002). A 'real-time' software tool was developed for data recording and synchronizing the different systems. Real-time stands in this case for a resolution of 1 msec, which was considered to be appropriate by Ehrl et al. (2002).

Tang et al. (2001) developed and tested a mobile, real-time, multi-functional, in-field variability mapping system. The

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system greatly improved the efficiency of field data collection compared with laborious manual field scouting methods (Tang et al., 2001). Demmel et al. (2002) developed automated process data acquisition with GPS and standardized communication as a basic for agricultural production traceability.

The objective of this research was to develop software architecture for site-specific field data acquisition, mapping, processing, and a management system for precision agriculture applications. The goal was to develop software for accurate and efficient field data acquisition and mapping. System integration strategies, data processing, and information extraction algorithms are introduced in this paper.

Materials and Methods

1. System architecture

(1) Software language

The Field Information Management (FIM) system was programmed using Microsoft Visual C++ version 6 and is designed to run on Microsoft Windows 98/NT compatible and newer operating systems where a programmable time resolution of 100 msec and processing time of 1 msec are guaranteed.

An object-oriented programming (OOP) approach was followed because of its many advantages over structured programming. In general, OOP uses software objects that resemble real world objects which are easier to understand and conceptualize. The OOP also enables the reuse of an object and easy modification through class inheritance and is less prone to error because of its capability for data encapsulation (Shrestha et al., 2003).

(2) System activities

The chronological activity of the entire system is shown in Fig. 1 a flow chart-like diagram. For field data acquisition, the system must first read the six categories (yield variability, field variability, soil variability, crop variability, variability in anomalous factors, and management variability) of field data. For flexibility and compatibility, it should be able to accept different types of data from different ports. The data could be one-dimensional numeric data like soil pH, or it could be a string of characters like the GPGGA string associated with the GPS signal. For these two different types of data, the software being developed will accept, parse, map, and correlate data from different channels.

Once the six categories of data are read from the data acquisition system with the position data via GPS receiver, all of these data are temporarily stored in computer RAM. The external devices have to be paused during data processing. After completion of processing, the computer RAM is freed and another block of data is logged. The acquired data is analyzed, mapped, interpolated and all of these data are stored. The crop modeling, database, decision making and VRA sections of the overall system (Fig. 1) remain for future study.

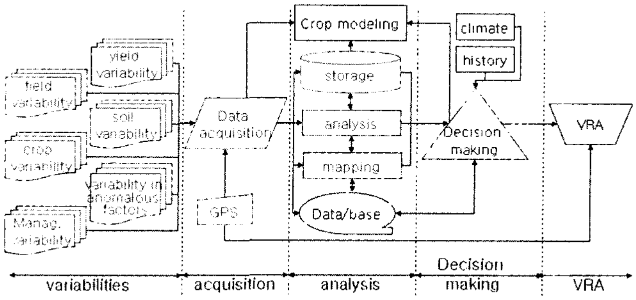


Fig. 1 A diagram of the FIM designed for field data acquisition, processing, coordinate mapping and information extraction. The software architecture developed acquires data, analyzes, coordinate mapping, produces site-specific information, and stores information on the hard drive (grayed boxes).

(3) User case scenario

A user case model (Fig. 2) attempts to graphically depict the system users (researcher, consultant, modeler, farmer, agricultural machine designer). In a typical field application scenario, the researcher, consultant and modeler could access the system to read data. Additionally, the researcher, consultant, modeler and farmer could analyze data and mapping information using these data. The database can be accessed

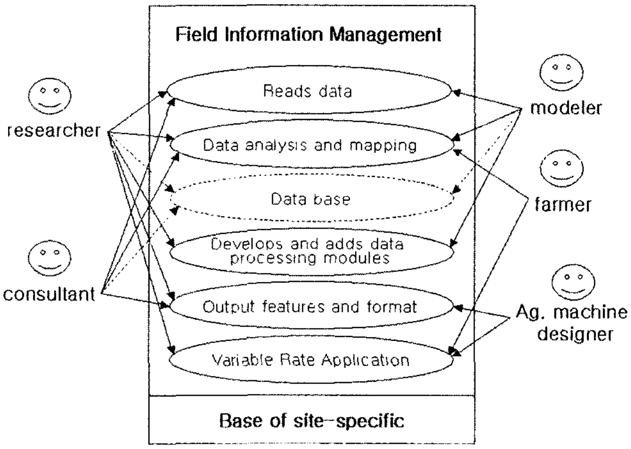


Fig. 2 Use-case diagram. The field information management system interacts primarily with these users. The dashed lined circle (data base) is under construction.

by the researcher, consultant and modeler.

Researchers and farm managers may also add new processing modules into the system to extract more information. The management can make a future in-field management decision based on the extracted information. An agricultural machinery designer can access output for use in agricultural machinery design. All of these tasks can be performed on a site-specific basis.

2. Class Design

(1) System architecture and flow chart

The architecture was object-oriented and each component in the architecture was developed as a separate class. The relationship between the classes is shown in Fig. 3. The FIM consists of 11 types of class which were synchronized and instructed to perform in harmony. Class diagrams are used to show the relationship between the system objects. The flow chart to realize the OOP approach of the FIM is shown in Fig. 4.

(2) Data acquisition class

To acquire data Personal Daq USB Data Acquisition Modules (DAQ-55/56, Model : 55/56, IOTech, USA) were used. This module can be attached to a PC using USB hubs, for a total capacity of 8,000 channels. It is designed for high resolution (22-bit), and can directly measure multiple channels of voltage, thermocouple, pulse, frequency, and digital I/O. The flow chart to realize the OOP approach for the data acquisition class is shown in Fig. 5.

(3) GPS signal class

To acquire position data, the Coast Guard Beacon receiver (Model : T-100, Micro-Trak® Systems, Inc, USA) was used. The accuracy of this dual-baud, 12-channel receiver is 1 m to 3 m, acquiring the data at 1 PPS (position per second), and providing a GPGGA string. This receiver comes with a single magnetically mounted antenna. The

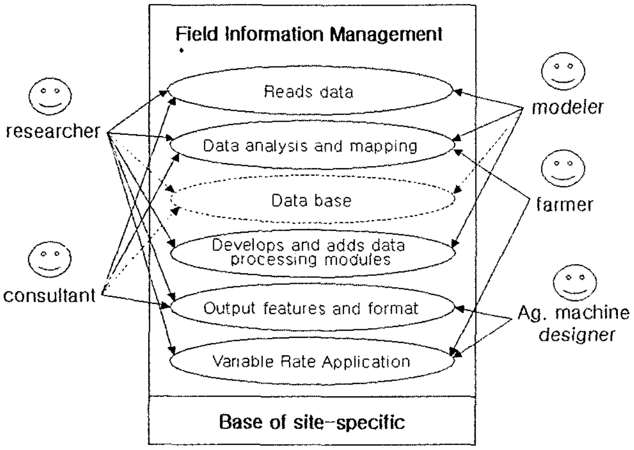


Fig. 3 System architecture of FIM. The grayed boxes are under construction for future study.

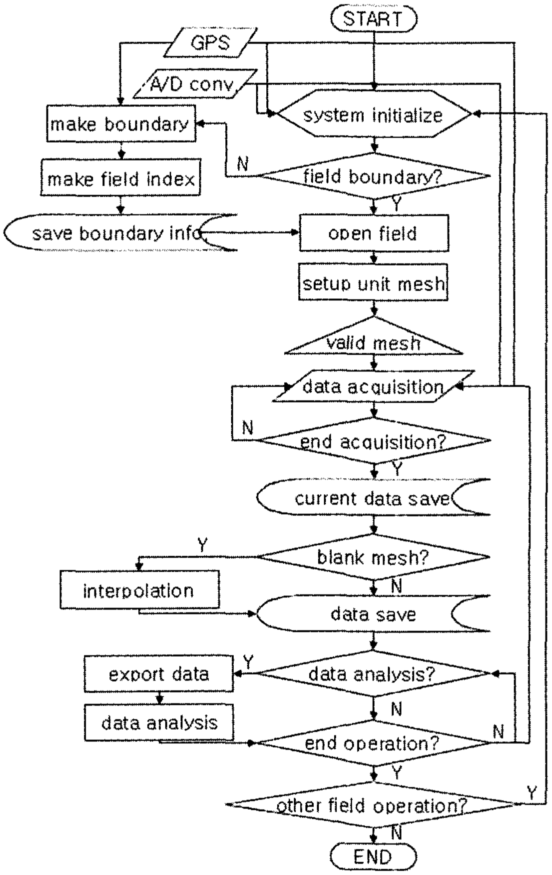


Fig. 4 The flow chart to realize the OOP approach of the FIM.

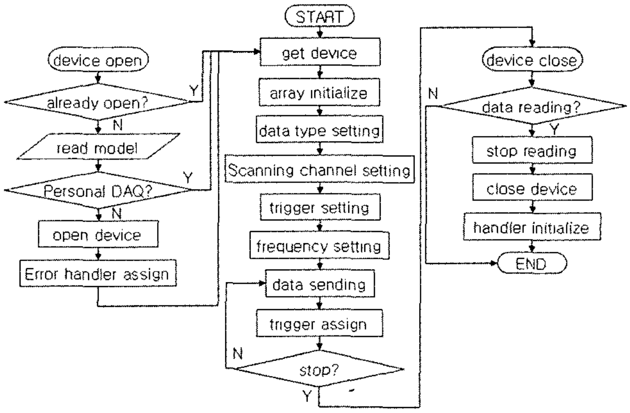


Fig. 5 The flow chart to realize the OOP approach of the data acquisition class.

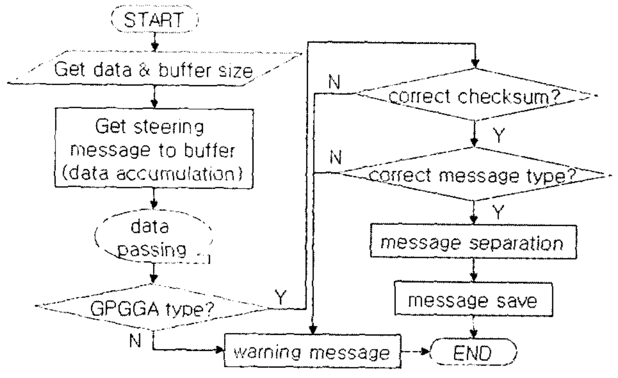


Fig. 6 The flow chart to realize the OOP approach of the GPS signal class.

GPS signal class serves as a container to store GPS data. The GPS signal class provides functionalities to step through the acquired GPS data in RAM. The flow chart to realize the OOP approach of the GPS signal class is shown in Fig. 6.

(4) Coordinate class

Degrees, minutes, and seconds in the WGS84 coordinate system were used to describe latitude, longitude and altitude. In this software all of these coordinate values were converted to meters.

In addition, this metric system is converted through three transformation pipelines (Viewing Transformation, Scaling and Viewpoint Transformation) into eye coordinates for easy recognize by users. The translated equations, Viewing Transformation, Scaling, and Viewpoint Transformation are shown in equation 1 to 6 respectively. Eq. (1), (3) and (5) are equations which transform metric to eye coordinates, and 2, 4 and 6 are inverse equations which transform eye coordinates to metric.

$$x' = \cos(\theta)\times(x-COPx) - \sin(\theta)\times(y-COPy),$$
$$y' = \sin(\theta)\times(x-COPx) + \cos(\theta)\times(y-COPy) \tag{1}$$
$$x' = \cos(\theta)\times x + \sin(\theta)\times y + COPx$$
$$y' = -\sin(\theta)\times x + \cos(\theta)\times y + COPy \tag{2}$$

where,

COP is center off projection,

θ is radian degree of counterclockwise

x, y are coordinates of the metric system.

x', y' are coordinates of the eye coordinate

$$x' = 2\times x/(f\times w), \quad y' = 2\times y/(f\times h) \tag{3}$$
$$x' = (f\times w)\times x/2, \quad y' = (f\times h)\times y/2 \tag{4}$$

where,

f is scaling factor,

w, h is screen width and height, respectively

$$x' = w\times(x+1)/2, \quad y' = h\times(y+1)/2 \tag{5}$$
$$x' = 2\times(x-1)/w, \quad y' = 2\times(y-1)/h \tag{6}$$

(5) Valid mesh segmentation

During the practice of field data acquisition, the program checked if the mesh was valid or not. Valid mesh refers to those completely or partially inside the boundary map. During data acquisition or when the user enters data in the data entry screens, the program checks data validity first. If the data entered is outside the validation data area the program will not accept the data entry.

(6) Legend class

To describe the legend, the upper and lower limit as well as the number of divisions are needed. In addition, the color can be selected for the upper and lower sections. The intermediate colors are determined automatically.

(7) Equation class

In this software the Free Expression Equation was developed (FEE). The FEE allows calculation of the channel outputs using four fundamental rules of arithmetic and squares. It allows elementary and bracket operations on channel outputs. When the FEE class receives channel data, [n] of the equation is replaced by the n'th channel value and calculated in real time. The result of this computation is stored with the channel outputs. Eq. 7 shows an example of FEE. This equation means the output of channel 1 ([1]) is multiplied by 2.1, then added to the output of channel 2 ([2]) multiplied by 1.5 plus the output of channel 3 ([3]) and then 3 was subtracted.

$$2.1*[1]+(1.5+[3])*[2]-3 \tag{7}$$

where, [n] of the equation is replaced by the n' th channel value

(8) Interpolation class

A blank mesh, where data was not acquired, an estimated value can be obtained using an interpolation process. Fig. 7 shows a 25 segment mask for interpolation. The blank mesh can be interpolated using this mask. The flow chart to realize the OOP approach of the interpolation class is shown in Fig. 8.

2	2	2	2	2
2	1	1	1	2
2	1		1	2
2	1	1	1	2
2	2	2	2	2

Fig. 7 The weight factors of a 25 segment mask for interpolation.

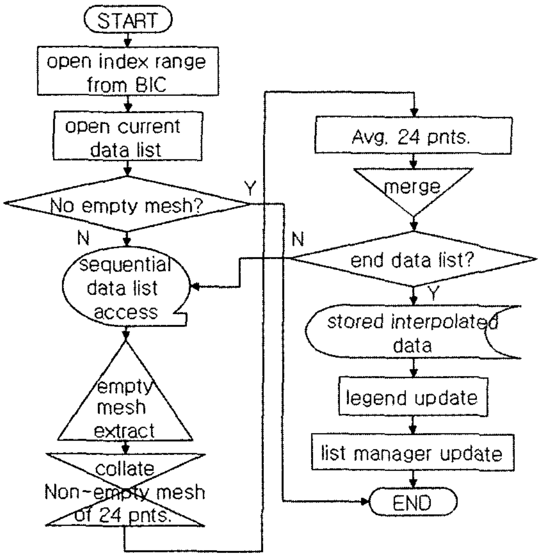


Fig. 8 The flow chart, to realize the OOP approach, of interpolation.

Results and Discussion

1. System architecture

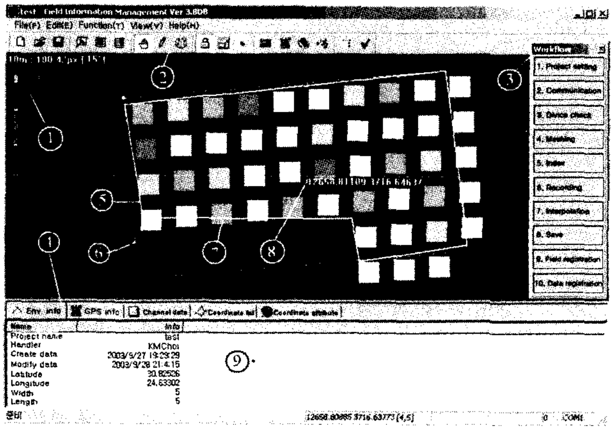
The 31 menu items of the FIM are shown in Fig. 9.

① is map scale and rotating information, ② is toolbar, ③ is workflow, to allow user easy access, ④ is five types of tab, allowing the user easy access to program information, ⑤ is the boundary line of field, ⑥ is a fitting line, it allows mesh segmentation, ⑦ is the legend mark, containing the properties of field, ⑧ is the center mark of screen map with latitude and longitude coordinates and ⑨ is the project information (Fig. 10).

The toolbar shown in Fig. 11 is displayed in the FIM computer program to indicate the sequence, from left to right, of data entry screens that the user accesses to complete the design process. Each of these tools has a balloon menu, allowing the user to easily access icons.

File	Edit	Function	View	Help
New	Cut	Project info.	Center mark	About FIM
Open	Copy	File manager	Legend	
Save	Paste	Legend edit	Scale/Azimuth	
Save as	Delete	A/D converter	Value display	
Export		GPS setting	Map grid fill	
Import		Control steering	GPS receiver	
Print		Equation	Practices guide	
Print preview		Interpolation		
Exit		Data base		
		SQL server setup		

Fig. 9 Menu structure of FIM.



Name	Info
Project name	test
Handler	KMChoi
Create data	2003/9/27 19:29:29
Modify data	2003/9/28 21:4:15
Latitude	30.82526
Longitude	24.63302
Width	5
Length	5

Fig. 10 Projection screen of FIM.

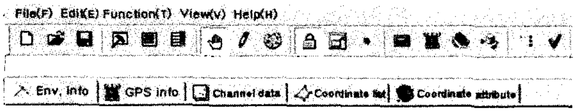


Fig. 11 The Toolbar (upper) and tab (below) of FIM.

(1) Extension format

The FIM has seven kinds of files with these extensions :

*.fim is the FIM project file,
*.bnd is the boundary file,
*.ltf is the valid mesh data file,
*.ntf is the invalid mesh data file,
*.dat is the channel data file,
*.idx is the data position base index file; and
*.ide is the relative distance of projection base index file format.

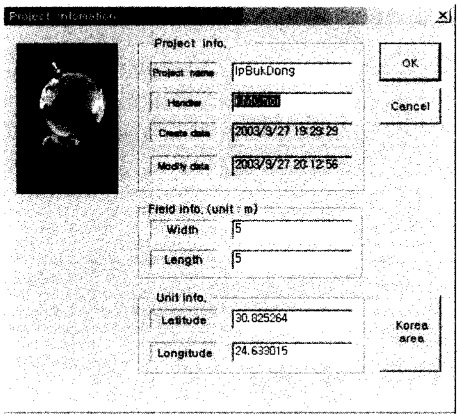
2. Classes

Classes included 'new': newproject; 'open': saved project open; and 'save': current project save. In project save, all the related data of the current project are saved. Other features of the classes are the export data, export to text, idx (Data position base index) and ide (Relative distance of projection base index) format. Import data, import from text format to idx or ide format. There are the Cut, Copy, Paste and Delete commands for cutting, copying, pasting and deletion of selected data and/or coordinate features, including the Project info. The menu shows project name, handler, generation date, date modified, mesh size and other important data fields.

The system includes a legend edit menu allowing editing of legend, and setting of upper and lower limit, color, the number of sections and other settings. The A/D converter menu is used to select A/D converter, (Personal Daq55/56) currently available and control to start and stop the converter. The GPS setting menu allows choice of communication port, data transfer rate, parity bit, data bit and stop bit setting. The equation menu allows access to FEE while the interpolation menu allows interpolation of blank mesh points. The center mark menu allows center tracking of the mapping. The legend and Scale/Azimuth menu allows control of the legend and scale information to a projection screen. The map grid fill menu allows filling of the mesh to the legend value of the map. The GPS receiver menu has a popup option to display the GPS signal status.

3. Discussion

This architecture is particularly beneficial for several various groups of people. One group is researchers trying to record crop growth parameters such as crop greenness, spectral reflectance, plant spacing, plant height, or top



Project info.

Project name: IpBukDong

Handler: [illegible]

Create data: 2003/9/27 19:29:29

Modify data: 2003/9/27 20:12:56

Field info. (unit : m)

Width: 5

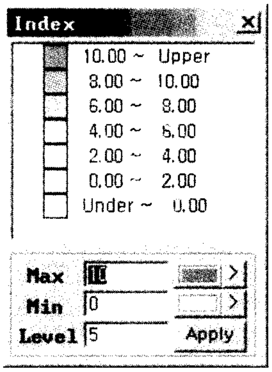
Length: 5

Unit info.

Latitude: 30.825264

Longitude: 24.633015

Fig. 12 Project information screen, showing the project name, handler, generation date, modify date, mesh size, and other data fields.



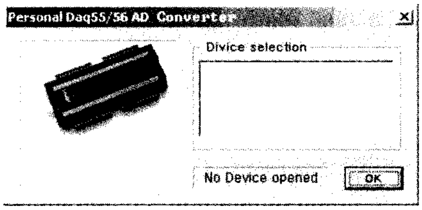
▨ 10.00 ~ Upper
▨ 8.00 ~ 10.00
☐ 6.00 ~ 8.00
☐ 4.00 ~ 6.00
☐ 2.00 ~ 4.00
☐ 0.00 ~ 2.00
☐ Under ~ 0.00

Max: 10

Min: 0

Level: 5

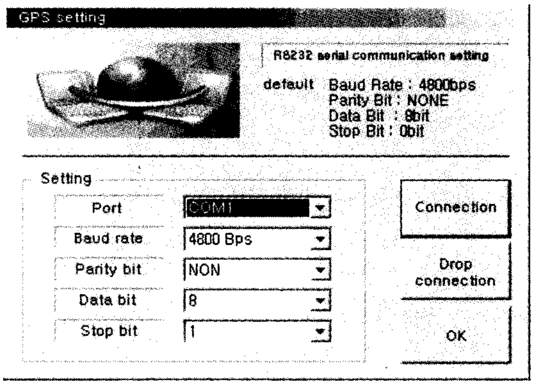
Fig. 13 Legend edit screen, showing the legend setting, upper and lower limit, color, the number of sections, etc.



Divice selection

No Device opened

Fig. 14 A/D converter screen, showing the selected A/D converter.



RS232 serial communication setting

default Baud Rate : 4800bps
Parity Bit : NONE
Data Bit : 8bit
Stop Bit : 0bit

Setting

Port: COM1

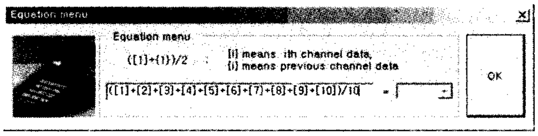
Baud rate: 4800 Bps

Parity bit: NON

Data bit: 8

Stop bit: 1

Fig. 15 GPS setting screen, showing the port, data transfer rate, parity bit, stop bit and data bit etc.



Equation menu

([1]+(1))/2 : [i] means ith channel data, (i) means previous channel data

([1]+[2]+[3]+[4]+[5]+[6]+[7]+[8]+[9]+[10])/10 =

Fig. 16 Equation menu screen, showing the calculation of channel outputs using four fundamental rules of arithmetic.

projected canopy area. This program can allow the researcher to easily obtain site-specific data. In addition, it allows an easier analysis and mapping of data that can also evaluate compatibility. Researchers are able to benefit from the use of this system since its utilization reduces the distractions typically encountered when introducing new information streams or processing algorithms into a system. The architecture helps develop such a system with minimal overload as it is designed to use a standard hardware interface which greatly reduces unnecessary distractions from a research point of view.

The consultant uses this system as it allows easy site-specific data acquisition and mapping. The system can also be a good bridge between consultant and farmer as well as with other project members. Once data acquisition is completed, the system extracts and analyzes the site-specific information. Crop consultants and agricultural producers will benefit from such a program as a component within a larger decision support system. The extracted information may be used in crop modeling to establish the relationship between yields and a set of indicator variables. The information may also be used to produce a GIS database, which can be used in farm management for field variability mapping. An ordinary farmer would be able to use this system as it allows easy mapping, data cross-checking and management recording. It also provides support for agricultural management decision making. In addition, agricultural machinery designers may utilize this system as it is suitable in design for VRA of precision agriculture.

In the future, the FIM program might incorporate a Data Access Objects (DAO) model for manipulating the Microsoft Access database used by the program. This would allow more reusability and extensibility. In addition, an agricultural management decision support system should also be incorporated for practical VRA.

Conclusion

This paper presents software which will automate site-specific field data acquisition, processing, mapping and management for precision agriculture. The architecture supports acquisition and processing of different data streams such as digital and analog. The architecture was object-oriented and each component in the architecture was developed as a separate class. The use of this program for precision agricultural research will eliminate the laborious task of manual ground-truth data collection. In addition, gathering high-density data will eliminate the need for interpolation of values in unsampled areas. This software shows good expandability and compatibility for VRA. The FIM computer program provides the user with an easy-to-follow process for field information management for precision agriculture. Some improvements are necessary to develop the system further.

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