Design and Implementation of Visible Human-machine Interface for Trajectory Tracking in Agriculture Vehicle Navigation

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Abstract. This paper designs a visible human-machine interface for field computer in an agriculture vehicle navigation control system. Field computer, with the function of system configuration, vehicle configuration, steering configuration, job management, path planning and map views, is the human-machine interface in agriculture vehicle navigation control system. This paper introduces the design of map views including field view and machine view for field computer system based on coordinate conversion. Field View gives a bird’s eye view of the map. The agriculture vehicle moves while the map keeps stationary. Machine view keeps agriculture vehicle in center of screen, while the map moves along the reverse direction of the agriculture vehicle.

Introduction

Precision agriculture is the latest trend in contemporary agriculture in the future. Many countries such as US, Canada, and Argentina have launched relational research and wide range of applications on precision agriculture. The practice show that application of precision agriculture can reduce production costs up to 20% by saving 50% irrigation water, 30% fertilizer and agricultural chemical\cite{1}. Agriculture vehicle navigation control system is the core of precision agriculture. The human-machine interface of field computer system which is the important part of agriculture vehicle navigation control system provides different map views that directly reflect the result of agriculture vehicle navigation control system and provide a reliable basis for operators to display the operation status and route\cite{2}.

Currently, there are many mature products in developed countries. GreenStar2 of John Deere can display the operation and the controlling process of agriculture vehicle in perspective and overhead views; AGCO also has similar products of Field Star that primarily comprises on-board data processing, an in-cab terminal interface, implement monitoring and control technologies, automated sensors, satellite GPS equipment, and easy-to-use desktop computer software; In addition, Outback S3 of Hemisphere has the function of tractor guidance, automated control and mapping for various precision agriculture operations.

Now many researchers still study the agriculture vehicle navigation control system. Linker, Raphael proposes a relatively simple approach for determining optimal paths for car-like vehicles operating in orchards\cite{3}. Wei Yang develops a field computer based on embedded PC104. The field computer has the functions of GPS data receiving and processing, field mapping, grid sampling, and features logging\cite{4}. Pecka A designs a new Human-Machine Interface system. The system is based on statically positioned indicators for data output and a touch screen above them for data input. With the advantage of economy and robustness the system can be used in industrial facilities and agriculture\cite{5}.

The present research of precision agriculture is still at the initial stage in China. Many institutes and universities have done many researches in precision agriculture. Gang Chen designs an agriculture intelligence machinery vehicle terminal based on MSP430. The device has the function of drawing and displaying\cite{6}. Hui Liu of China Agricultural University introduces the function of AgGPS 170 and proposes some ideas including drawing the path of agriculture vehicle online and AB-line navigation on development of field computer with own property right \cite{7}. Weidong Zhuang
develops software for agriculture machinery straight line operation. The software has the functions of calculating distance and area of operation region[8]. Weidong Zhuang also studies the moveable operation review of agriculture vehicle operation[9].

This paper aims to develop a visible human-machine interface for field computer system in agriculture vehicle navigation control system. The interface contains two map views: the field view and the machine view. The structure of paper is organized as following: section II introduces the navigation control system; section III introduces coordinate Frames; section IV and section V describe the design of field view and machine view in detail; the last part summarizes this paper.

**Introduction of Navigation Control System**

**A. Structure of Navigation Control System**

This paper designs a visible human-machine interface for navigation control system. The navigation system consists of three parts: which are the navigation controller for running control algorithm of navigation and sending signal to field computer, the autosteerer for executing the command from navigation controller to control the heading and speed of agriculture vehicle and the field computer for providing a human-machine interface. Each part of the navigation control system connects with CAN bus (See Fig. 1).

**B. Software Structure of Field Computer**

Field computer, with the function of system configuration, vehicle configuration, steering configuration, job management, path planning and map views, is the human-machine interface in the navigation control system (See Fig. 2). For keeping a view in the field computer to display the status of agriculture vehicle, the map views including field view and machine view are designed.

![Fig. 1 Agriculture Vehicle Navigation Control System](image1)

![Fig. 2 Software Structure of Field Computer](image2)

**Coordinate Frames**

For displaying the path of Agro-machine in the field computer, the map views convert the latitude and longitude coordinates of the agriculture vehicle’s position received from the navigation controller into the screen coordinate of field computer. The following are the coordinates used in the converting process.

1. The WGS-84 latitude and longitude coordinate in the form of latitude and longitude is received from GPS position system by navigation control system.
2. The Universal Transverse Mercator (UTM) coordinate is plane rectangular coordinate having its origin near the equator, one axis point at north and the other point at east.
3. The object region coordinate is plane rectangular coordinate having its origin near the object region, and axes along with UTM coordinate.
4. The screen coordinate is plane rectangular coordinate having its origin at the top left corner of screen, X axis point at right of screen and Y axis point at bottom of screen.
Design of Field View

Field View gives a bird’s eye view of the map. In this view, the agriculture vehicle appears to move in the screen with the real agriculture vehicle in practice while the map keeps stationary on the screen (as show in Figure 3).

Since the output coordinates of navigation controller show in the form of latitude and longitude, it is necessary for tracking the path of agriculture vehicle to convert the output coordinates into the screen coordinates of field computer. Figure 4 shows the transformation between coordinates.

UTM coordinate system is a grid-based 2-dimensional Cartesian coordinate system[10]. UTM projection converts latitude and longitude coordinate to plane rectangular coordinate. Since the agriculture vehicle takes the form of WGS-84 latitude and longitude coordinate[11], We convert the latitude and longitude coordinate into UTM coordinate by UTM projection. The main formula[12] is as follows:

\[ E = FE + K_f[A + (1 - T + C)A'] / 6 + (5 - 18T + T^2 + 72C - 58C^2)A' / 120 \]

\[ N = FN + K_f[M + V + M(2A' + 5C + 4C^2) + 2A'] / 24 + (5 - 80T + 8C^2 + 360C^2 - 480C^3) / 45 \]

Where

- \(T = \tan^{-1} \phi\)
- \(C = e^2 \cos^2 \phi / (1 - e^2)\)
- \(A = (\lambda - \lambda_0) \cos \phi, \text{with } \lambda \text{ and } \lambda_0 \text{ in radians}\)
- \(V = a / (1 - e^2 \sin^2 \phi)^{1/2}\)
- \(M = a(1 - \frac{e^2}{4} - \frac{3e^4}{64} - \frac{5e^6}{256} - \frac{15e^8}{1024})\sin 2\phi - \frac{3e^2}{8} + \frac{15e^4}{32} + 45e^6 / 1024 \sin 2\phi\)
- \(e' = \sqrt{(a / b)^2 - 1}\)
- \(e = \sqrt{1 - (b / a)^2}\)

The UTM coordinate value is quite big at high latitudes, because the origin of UTM coordinates closer to the equator. For easily calculating we convert the UTM coordinate into object region coordinate. Then, for easier drawing the path using GDI+ and showing the path in the screen, the object region coordinate is converted into screen coordinate by using the mathematical method. The mathematical equations are given as follows:

\[ \begin{align*}
E' &= k \cdot (E - E') \\
N' &= -k \cdot (N - N')
\end{align*} \]

Where
- \(A (E, N)\): One point in UTM coordinates; \(K\): Scale factor;
- \(O' (E0', N0')\): The selected origin of object region coordinates;
- \(A' (E', N')\): A point’s coordinate values in screen coordinate;
After finishing the convention from the latitude and longitude coordinate to screen coordinate, we develop a software to draw the field view. Fig. 3 shows the result of the software.

**Design of Machine View**

In this view, the agriculture vehicle appears still, while the map keeps moving along the reverse direction of the real machine. It makes us feel as sitting in the agriculture vehicle (as shown in Fig. 5).

Fig. 5  The Result of Machine View

The machine view also needs the coordinates conversion following the same procedure as in the field view. For the direction of travel is always at the top of the screen in the view, the screen coordinates have to be rotated according to the angle between the heading and the up direction of screen.

**A Translation and Rotation of Screen Coordinate**

As shown in Fig. 6, A is the center of rotation; \( \theta \) is the angle from B to B'; \( \phi \) is the angle AB line with X axis.

Fig. 6  Screen Coordinate Rotation

The formulas derive from Fig. 7 as follows:

Rotates in clockwise direction:
\[
\begin{align*}
    x' &= x0 + d \cos(\phi + \theta) \\
    y' &= y0 + d \sin(\phi + \theta)
\end{align*}
\]

Rotates in counterclockwise direction:
\[
\begin{align*}
    x' &= x0 + d \cos(\phi - \theta) \\
    y' &= y0 + d \sin(\phi - \theta)
\end{align*}
\]

Where
\[
d = \sqrt{(x-x0)^2 + (y-y0)^2}
\]

**B Drawing Machine View**

After finishing the rotation of screen coordinates, the software of drawing machine view is developed following the same procedure as in the field view.

**Conclusions**

This paper designs a visible human-machine interface for field computer in an agriculture vehicle navigation control system. The main work focuses on the design of map views that include field view and machine view. And it has realized the goal of tracking the agriculture vehicle’s trajectory. This is just a start of developing field computer system. There are many problems that need to further study such as designing of 3D view map, path planning and managing of job.
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