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Attitude Calibration Study on Agricultural Machinery Navigation

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Abstract:- The subject of this study is on the basis of improved pure tracing model navigation algorithm upload attitude correction algorithm of the introduction of pavement under the environment of ups and downs of linear planning and path tracking control, the first study of navigation and positioning system composition and working principle as well as the absolute positioning receiver and differential positioning principle, etc. Secondly on the basis of the navigation and positioning and analyzes the attitude measuring principle and pose measurement principle of electronic compass, and then the research and design of attitude calibration algorithm and the hardware and software design of agricultural machinery automatic navigation control, analyze the basic structure of the carriage, provide hardware platform for the research on the experiment; Analyze the mathematical model of the four-wheel electric vehicle research, provide a basis for the research of automatic navigation algorithms. An improved path tracking algorithm is proposed, and conducted on MTALAB simulation.With electric cars, modified by finally open field experiments on the grass, on campus on the PC controller will travel route set, automatic navigation experiments.
Keywords:- Precision agriculture, intelligent agricultural machinery, automatic navigation, calibration, path tracking.

I. INTRODUCTION

The use of GNSS technology is not independent, when in the ground flat on the road of agricultural machinery, agricultural machinery navigation through the RTK technology can easily implement positioners and attitude, which is a good way to design vehicle navigation control method, through the hydraulic steering system to control the lateral error of agricultural machinery operation in the process of car body or speed, realize automatic navigation of pure tracking path. [1]

But after the work to the field of agricultural machinery, because the land surface is in a state of ups and downs, so in this case, even the RTK - GNSS[2] positioning, orientation technology to control the automatic navigation of agricultural machinery operation will not like on the flat surface and high precision automatic navigation, in the process of agricultural machinery in the field work, and as a direct result of car body centre of gravity will fluctuate within a certain scope, it represents the tilt of the body. Often the homework Angle can reach 30 degrees. The tilt of automatic path following the stability and effectiveness of a serious impact.

Theoretical analysis found that the longer the GNSS antenna phase center distance from the ground, then the pitch Angle and roll Angle in the direction of car body coordinate system to produce, the greater the final formation of the gps-rtk positioning directional error will be beyond the cm-level positioning precision of RTK, for high precision requirement of agricultural machinery navigation is fatal, must design effective posture correction algorithm to focus frequent fluctuations in a certain space.[3]

Through the research on agricultural machinery navigation tilt correction, can be the agricultural machinery in the field of our country better automatic navigation operations, better improve the efficiency of agricultural production, reduce the production cost, accelerating the development of agricultural mechanization to agricultural automation and intelligent

II. BODY POSTURE CORRECTION METHORDS

2.1 The definition of coordinate system transformation

2.2.1GNSS attitude Angle measurement of three kinds of coordinate system

GNSS measure, is usually in a motion vector space coordinate system respectively corresponding to the position of the GNSS signal receiving antenna, then through GNSS carrier phase measurement theory guidance to solve the process of the three-dimensional attitude parameter of the motion vector. For plane requirements of GNSS pose measurement platform, must be two Angle of the vector to determine formation, therefore, if you want all the attitude Angle measurement in the experiment that must need to install on the movement of carrier three GNSS signal receiving antenna, exactly on car body coordinate system and the corresponding position, through this design to form two independent baseline, so as to complete the GNSS attitude measurement.

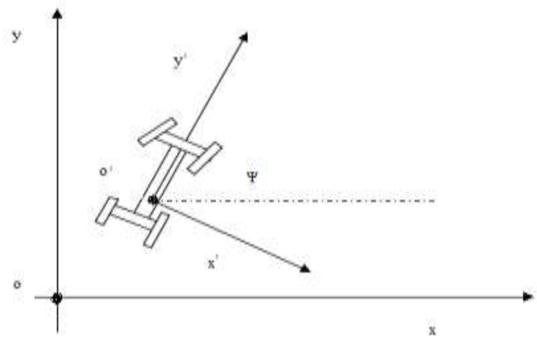

Figure-1: The vehicle coordinate system and the local level

2.2, The coordinate transformation of GNSS measurements attitude

2.2.1 ,The first step is to coordinate with local level transformation of coordinates

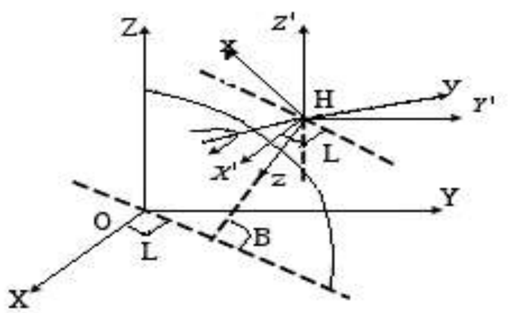

Figure-2: transformation between the two coordinate diagram

In space any point of the position, level through the local coordinate system origin of coordinates with the earth coordinates of latitude and longitude coordinates conversion to the level of local coordinate system, according to the corresponding coordinate transformation model, can get the following formula:

$$X^{LLS} = R_X(180^\circ)R_Y(270^\circ + B)R_Z(180^\circ + L) * (X^{WGS} - X_0^{WGS}) \qquad (1)$$

$$R_X(180^\circ) = \begin{pmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & -1 \end{pmatrix}$$

(2) $$R_Y(270^\circ + B) = \begin{pmatrix} \cos(270^\circ + B) & 0 & -\sin(270^\circ + B) \\ 0 & 1 & 0 \\ \sin(270^\circ + B) & 0 & \cos(270^\circ + B) \end{pmatrix} \quad (3)$$

$$R_Z(180^\circ + L) = \begin{pmatrix} \cos(180^\circ + L) & \sin(180^\circ + L) & 0 \\ -\sin(180^\circ + L) & \cos(180^\circ + L) & 0 \\ 0 & 0 & 1 \end{pmatrix} \quad (4)$$

The WGS - 84 coordinates, and the relationship between the level of local coordinates as follows:

$$\begin{bmatrix} X_M \\ Y_M \\ Z_M \end{bmatrix} = \begin{pmatrix} -\sin B\cos L & -\sin L & -\cos B\cos L \\ -\sin B\sin L & \cos L & -\cos B\sin L \\ -\cos B & 0 & -\sin B \end{pmatrix} \left[\begin{bmatrix} X_M \\ Y_M \\ Z_M \end{bmatrix}_{WGS} - \begin{bmatrix} X_H \\ Y_H \\ Z_H \end{bmatrix}_{WGS} \right] \quad (5)$$

2.2.2,The second step in the local horizontal coordinates, and vector coordinate transformation

$$X^{BFS} = R_X(\varphi)R_Y(\theta)R_Z(\psi)X^{LLS} \quad (6)$$

$$R_{ypr} = R_Z^T(\psi)R_Y^T(\theta)R_X^T(\varphi)X^{BFS} = \begin{pmatrix} R_{11} & R_{12} & R_{13} \\ R_{21} & R_{22} & R_{23} \\ R_{31} & R_{32} & R_{33} \end{pmatrix} \quad (7)$$

Comprehensive theoretical analysis shows that in front of said more straightforward GNSS actually pose measurement is the process of solving the three attitude Angle. But different to the requirement of actual life production application, in the process of obtain the attitude Angle, using the step of decoding algorithm also has the very big difference, special is the way in high accuracy RTK - GNSS navigation and positioning measurement profile cases, the general calculating process goes through a single point positioning, differential decomposition, floating point solution, fixed solution these four steps. By antenna baseline coordinates in the carrier system components, and accurately measure the baseline length, so as long as the real time measurement baseline at the other end at the local level the RTK space coordinates of coordinate system, we can get the three attitude angles according to the formulas 8 to 10.

$$\theta = \arcsin R_{32} \quad (8)$$

$$\varphi = \arccos(\frac{R_{33}}{\cos\theta}) \quad (9)$$

$$\psi = \arccos(\frac{R_{22}}{\cos\theta}) \quad (10)$$

III. POST CALIBRATION PROCESS

3.1 Double Antenna Measurement Appearance

GNSS antenna measurement appearance, for any two of the euler Angle of attitude Angle measurement. In a motor vehicle body coordinate system of two different vertical or horizontal position respectively installed M600 receiving antenna, because in theory a baseline can only determine two attitude Angle, through GNSS carrier phase measurement theory of two-dimensional profile parameters of motion vector is given.

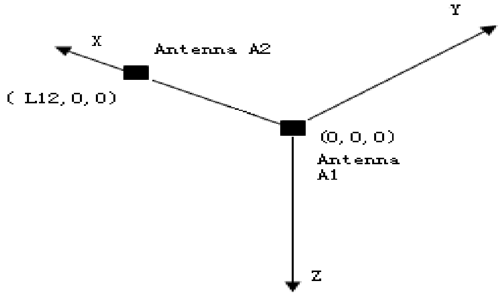

Figure-3: The vehicle coordinate system and the antenna configuration

In figure 3, sets the antenna A1 to carrier origin coordinate system and the local level can directly calculate the yaw Angle and pitching Angle:

$$\psi = \text{-}\tan^{-1}\left(\frac{y_2^{LLS}}{x_2^{LLS}}\right) \tag{11}$$

$$\theta = -\tan^{-1}\left(\frac{z_2^{LLS}}{\sqrt{(x_2^{LLS})^2 + (y_2^{LLS})^2}}\right) \tag{12}$$

Through to the carrier phase observations of A1 A2 antenna can be very precise relative antenna in the WGS - 84[4-5] to measure the three-dimensional position of geocentric coordinate system, which is the baseline in the projection of geocentric coordinate system, according to the relationship between the WGS - 84 coordinate system and the local level formula to transform it into antenna A1 as local horizontal coordinates of the origin of coordinates, and then by the above formula (11) and (12) will be able to calculate the yaw Angle and pitching Angle.

3.2, The principle and application of the adaptive filter

3.2.1, Adaptive signal processing

Adaptive filter is a nonlinear system, so when analyzing system characteristics than for linear time invariant filter usually consider the parameters and the relationship between the impact on the system more, at the same time, due to the design of the adaptive filter is more dependent on the actual output signal and the desired signal and the relationship between the pattern is controlled by the designers, not just like fixed filter, only according to the system output decision, so the design of the adaptive filter is more simple.

3.2.2, The application of adaptive filter

The main purpose of this section is to illustrate how the general adaptive filtering algorithm, and the study of specific adaptive filtering algorithm is used to solve practical problems. Once those signals to determine, in the selection of the objective function of minimization, can use their any known features to understand the expectations of adaptive filter.

Assuming that the unknown system impulse response h (k), k = 0,1,2,3,... And, when k < 0 to zero, then the error signal is zero

$$e(k) = d(k) - y(k)$$

$$= \sum_{l=0}^{\infty} \mathrm{h}(l)x(k-l) - \sum_{i=0}^{\mathrm{N}} w_i(k)x(k-l) \qquad (13)$$

$$\xi = \mathrm{E}\left\{\left[h^{\mathrm{T}} x_{\infty}(k) - w^{\mathrm{T}} x_{\mathrm{N+1}}(k)\right]^2\right\}$$

$$= \mathrm{E}\left[h^{\mathrm{T}} x_{\infty}(k) x_{\infty}^{\mathrm{T}}(k) h - 2h^{\mathrm{T}} x_{\infty}(k) x_{\mathrm{N+1}}^{\mathrm{T}}(k) w + w^{\mathrm{T}} x_{\mathrm{N+1}}(k) x_{\mathrm{N+1}}^{\mathrm{T}}(k) w\right]$$

$$= \sigma_x^2 \sum_{i=0}^{\infty} h^2(i) - 2\sigma_x^2 h^{\mathrm{T}} \begin{bmatrix} \mathrm{I}_{\mathrm{N+1}} \\ 0_{\infty\times(\mathrm{N+1})} \end{bmatrix} w + w^{\mathrm{T}} R_{\mathrm{N+1}} w \qquad (14)$$

$$h_{\mathrm{N+1}}^{\mathrm{T}} = h^{\mathrm{T}} \begin{bmatrix} \mathrm{I}_{\mathrm{N+1}} \\ 0_{\infty\times(\mathrm{N+1})} \end{bmatrix} \qquad (15)$$

3.3 Kalman waveform after processing[6]

Figure in the black curve for pure sine wave signal, the substantial gaussian noise superimposed on the sine wave signal, as shown in the red curve, after kalman filtering of the output waveform as shown in the blue curve. Analysis of waveform characteristics, can be observed clearly to the filtering effect is obvious, in addition to the waveform is slightly delayed, denoising effect is good, and can be very good to start and end the continuation of the EMD[7] have good inhibitory effect, at the same time, the signal denoising effect is very obvious.

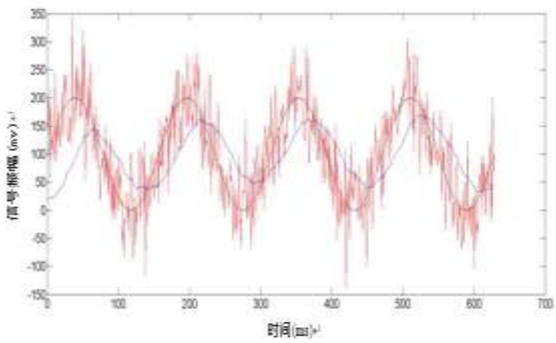

Figure-4: Kalman filtering effect

3.4 SEC345 pose measurement sensors

This task at present is mainly used in sensor Angle sensor and electronic compass SEC345 pose measurement sensors, they collected the original Angle data are real-time to PC to carry on the corresponding processing, combined with directional data receiver of the original location and then eventually transmitted to the hydraulic steering control system of the expected corner [8].

3.5 Posture calibration process

Model car navigation operation caused by the uneven road GNSS positioning error in the first place in the body coordinate system generated transverse direction and the vertical axis direction:

$$e_x^{'} = \mathrm{H}\sin(\varphi) \qquad (16)$$

$$e_y^{'} = \mathrm{H}\sin(-\theta) \qquad (17)$$

Type of H for GNSS receiver antenna phase center is apart from the ground level

From body coordinate system and the horizontal coordinate system, the relationship between the antenna position at a local level coordinates positioning errors caused by transverse direction and the positioning error in the vertical direction:

$$e_x = e_x^{'} \sin\psi + e_y^{'} \cos\psi \qquad (18)$$

$$e_y = -e_x^{'} \cos\psi + e_y^{'} \sin\psi \qquad (19)$$

Then use the positioning error can tilt correction on GNSS original location data.

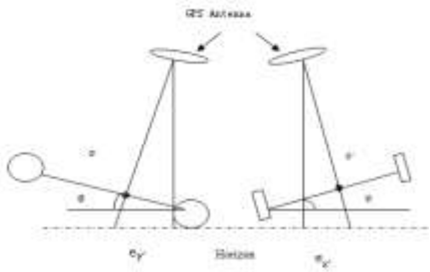

Figure-5: Model car is influenced by the road of attitude Angle change

3.6 Course Angle measurement and Kalman filtering

SEC345 electronic compass magnetic induction sensor is used to measure the 3 d pose parameters of motion carrier, mainly analyze the heading Angle measurements, because motion model car hard iron parts and installed on the hydraulic steering system consists of motor, the current signal of the receiver must produce a similar to heading Angle measurement of gaussian white noise interference magnetic field, this topic in order to improve the precision of navigation and positioning and design a digital band-pass filter, complete the heading Angle measurement in the navigation operation process to produce a graded real-time estimation bias error.

When the model car running at a certain speed vertical velocity is v_k , ψ_k is K time be model car heading Angle,$\Delta\psi_k$ is k Time to get the course of the offset error, Model car k time of plane coordinates is （x_k， y_k）, Model plane coordinates of k + 1 time is（x_{k+1}， y_{k+1}）, There are：

$$x_{k+1} = x_k + Tv_k \cos\psi_k \cos\Delta\psi_k - Tv_k \sin\psi_k \sin\Delta\psi_k \qquad (20)$$

$$y_{k+1} = y_k + Tv_k \sin\psi_k \cos\Delta\psi_k + Tv_k \cos\psi_k \sin\Delta\psi_k \qquad (21)$$

Thus, set the kalman filter state variables is:

$$X_k = \lfloor x_k, y_k, v_{axk}, v_{ayk} \rfloor \qquad (22)$$

$$v_{axk} = v_k \cos\Delta\psi_k \qquad (23)$$

$$v_{ayk} = v_k \sin \Delta\psi_k \tag{24}$$

$$X_{k+1} = \varphi_k X_k + \omega_k \tag{25}$$

Get car body posture correction after GNSS positioning data as follows:

$$x_{ck} = x_{rk} + e_x{}' \sin(\psi_k + \Delta\psi_{k-1}) + e_y{}'\cos(\psi_k + \Delta\psi_{k-1}) \tag{26}$$

$$y_{ck} = y_{rk} - e_x{}'\cos(\psi_k + \Delta\psi_{k-1}) + e_y{}'\sin(\psi_k + \Delta\psi_{k-1}) \tag{27}$$

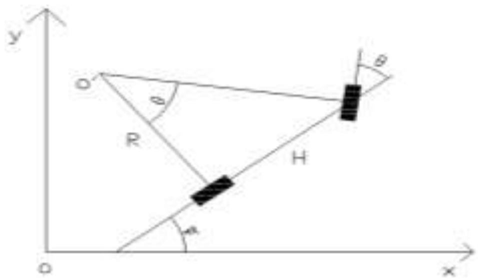

Figure-6: Simplified analysis of two-wheeled vehicle kinematic model

The pure tracking model shows that when the car body deviated from its path from a distance, start the navigation control algorithm, through the lateral deviation error, the current course Angle deviation and determine the next step the expectations of the steering Angle of front distance.

For pure tracking algorithm in path planning of course Angle deviation does not get effective control and steering Angle without changing conditions in a smooth transition, this topic proposed to trace a path on pure improved, through to the front wheel steering Angle of the positive and negative periodic direction control, make electric cars around the baseline AB space do changes as small as possible, the steady state tracking tracking path.

The calculating formula for pure tracking algorithm:

$$\theta = \arctan\left[\frac{2H(P_e \cos\psi_e - \sqrt{L^2 - P_e{}^2}\sin\psi_e)}{L^2}\right] \tag{28}$$

The calculation formula of pure tracking algorithm is:

$$\theta_1 = \arctan\left[\frac{2H(P_e \cos\psi_e - \sqrt{L^2 - P_e{}^2}\sin\psi_e)}{L^2}\right] \tag{29}$$

$$\theta_2 = \frac{H * \Delta\psi}{v * T} - \frac{\theta_0}{2} \tag{30}$$

$$\theta_3 = 0 \tag{31}$$

3.7 Pure tracking attitude correction model simulation analysis

Pure tracking algorithm under the environment of matlab simulation of straight line motion tracking simulation conditions of the original set is as follows: AB starting point and end point, car body with AB line starts at the same starting point, the positioning error is 0.3 m, course Angle measurement error is 0.5 °, steering Angle measurement error is 0.6 °, velocity error in 0.2 m/s. Maximum steering Angle of 20 °, control cycle, wheelbase. In speed, pure tracking no attitude correction algorithm and tracking the introduction of posture correction algorithm simulation tracking error as shown in figure 7, 8.

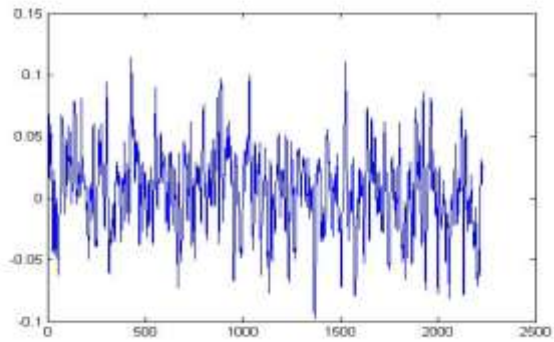

Figure-7: Tracking error chart of pure pursuit algorithm

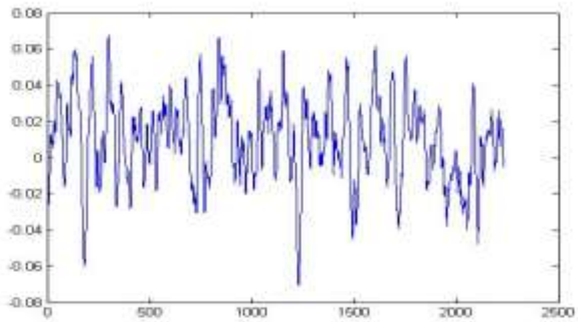

Figure-8: Tracking error chart of improved pure pursuit algorithm

Ⅳ. CONCLUSION

This paper is mainly on the basis of the previous research on pure track model navigation algorithm theoretical derivation of the algorithm, based on the mathematical model of two wheels and achieve steady state tracking baseline expectations corner design, to determine based on forward-looking distance under the premise of posture correction navigation decision control system. Through the simulation analysis was made on the navigation algorithm based on attitude correction, the simulation experimental results show that when through the lateral deviation error, course deviation, vehicle speed and control cycle as input parameters to determine the best front distance, the best control effect and the system has good stability and sensitivity.

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REFERENCES

[1]. Kitchen NR，Snyder CJ，Franzen DW，et al.Educational Needs of Precision Agriculture Precision Agriculture[J].2002，3(5):341-351.

[2]. Li Yongjian ZhaoZuoxi. Vehicle positioning navigation field calibration method based on Kalman filtering study [J]. Journal of agricultural equipment and vehicle engineering, 2011, 6 (9) : 3-9.

[3]. Lee fled chang, Hu Jingtao, gar. Pure tracking model of agricultural machinery based on fuzzy adaptive path tracing method [J]. Journal of agricultural machinery, 2013, 44 (1) : 205-210.

[4]. Hamner B， Singh S，Bergerman M， et al.Improving orchard efficiency with autonomous utility vehicles[A].In.2010 ASABE Annual International Meeting[C]. Pittsburgh: 2010:205-214.

[5]. Tosaki K， Miyahara S，Ichikawa T，et al. Development of a microcomputer controlled driverless air blastsprayer[J].Japanese Society of Agricultural Machinery，2005， 1(5):49-56.

[6]. Zheng-lin wang, Wang Shengkai etc. MATLAB/Simulink simulation and control system [M]. Beijing: electronic industry press, 2012.1.

[7]. Xiao-hong Yin, zhao han, Wu Yanming etc. Based on kalman filter automatic guided vehicle cascade trajectory tracking control [J]. Journal of agricultural machinery, 2010, 9 (2) : 180-184.

[8]. Lv Antao zheng-he song, en-rong MAO. Tractor automatic steering of the optimal control method research [J]. Journal of agricultural engineering, 2006, 3 (8) : 116-119.