TRACTOR GUIDANCE SYSTEM FOR FIELD WORK USING GPS AND GYRO

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Abstract: *A tractor guidance system using a differential GPS(DGPS) is developed to support the driving of a tractor to track the target lines in the field for plowing ,sowing, fertilizing, pesticide spraying , harvesting, manuring, grass teddering etc. The system, graphically designed, generate parallel paths automatically according to the work width and displayed more accurate and stable real-time position and direction through a developed filtering method based on Extended Kalman Filter using 3 axis gyroscope with the DGPS, and predicting position and direction after few seconds later considering the delay of the driving operation. The system enables high precise straight and parallel work in the wide field even for a beginner without setting marks. After practiced, the deviations from the target lines were less than ±20cm.*

Key words: *GPS, Guidance, Navigation, Tractor, Kalman filter*

INTRODUCTION

The numbers of farmers is decreasing year by year in Japan, as a result, the problems such as an aging of farmers and a growing shortage of experts are aggravated. The case is especially serious in regions with large-scale farming such as Hokkaido, where the shortage of experts is acute. The speedup of the work is highly required with the extension of the size of operational holdings per one farmer. However, the need for accurately controlling the implement is inevitable. So, Information technology (IT) is expected to provide a solution by enabling unskilled farmers to work with both reliable accuracy and performance (RAP). Field preparation requires straight, uniformly spaced crop rows to ensure well germination, growing of plants, efficient herbicide and harvesting work.

The guidance system we developed ensure that even undisciplined farmers can achieve fast and accurate round trip parallel work which is a base of field work, by equipping a tractor with this operation assist system using IT such as global positioning systems (GPS) and geographic information systems (GIS). Drivers follow a target line indicated in a display mounted on a front panel of a tractor.

Commercially available agricultural navigation systems using GPS, such as the Bio-oriented Technology Research Advancement Institution's farm navigator (Matsuo et al., 2003), Nikon-Trimble Co., Ltd's EZ-Guide, Hemisphere GPS Co., Ltd's Outback Guidance, and TeeJet-LH Agro Co.,Ltd.'s Centerline are well known. Some systems, however, are not sufficient for accurate positioning owning to the bias error of differential GPS(DGPS) caused by the change of satellite arrangement and electric noise etc., and for the meandering driving due to the time delay of driving operation.

The system we developed uses an integrating DGPS with an inertial navigation system (INS) of a three-axis gyroscope by the method of extended Kalman filter(EKF)(Kalman, R, E. (1960)) algorism to eliminate GPS pseudo-range error and estimate the position and direction of tractor after few seconds by a kinetic movement model of tractor.

OVERVIEW

1. System Configuration

The system we developed consists of a DGPS (Magellan Systems Corporation, DG14), a submeter-accuracy GPS antenna receiving corrected information from the MTSAT Satellite-Based Augmentation System for Multifunctional Transport Satellites (MSAS), a laptop personal computer (PC) enabling touch-panel input, a posture sensor (Tokyo Keiki Inc., Vsas-2GM), and an external liquid crystal display (LCD) panel (Quixant Ltd., 801B-AV (8.4inch)), as shown in Fig.1.The Vsas-2GM's geomagnetic direction sensor and accelerator determine the direction of gravitational acceleration, detect vehicle posture, and calibrate gyroscopic offset drift. The Vsas-2GM can adjust the output update rate between 1 and 100Hz, mounts GPS inside which is used for posture calibration. Three-axis positioning angle accuracy is nearly 2 degrees. GPS's VTG GGA positioning and velocity format information and information on positioning sensor directional angle, positioning angle, and angular velocity are received by the PC at 10Hz through an RS-232C communication interface. Power is supplied by a 12V tractor battery through a dedicated stabilizing power source. A GPS antenna with magnet rigid support is mounted on an iron board which is attached on the roof of a tractor with an adhesive vibration absorption rubber, and a GPS receiver, a laptop PC, an external LCD panel, and a power source are placed in the cabinet. The external LCD panel is located on the tractor's dashboard, so that it does not interrupt the driver's vision. The system is movable to another tractor.

Fig.1. Standard guidance system hardware construction

2. Software Configuration

Fig.2. diagrams the software configuration. The software consists of data recording and prediction equipment and a graphic user interface (GUI). The center position of the tractor reflected on the ground is calculated after slant correction using posture data of the gyroscope. GPS and gyroscopic raw data, filtering data of position, direction, velocity and estimated position and direction after several seconds (0.5 to 3 seconds) which are calculated using a kinetic movement model, are simultaneously recorded automatically.

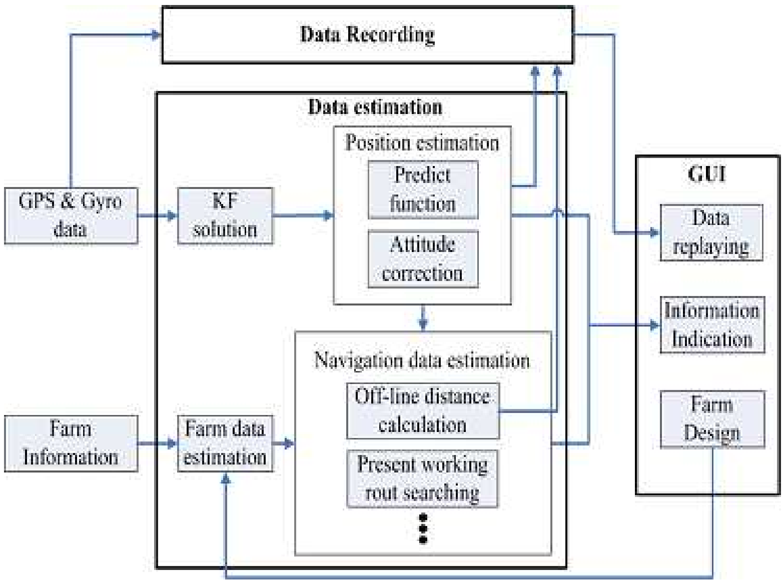


Fig.2. Flow-chat of the software of guidance system

3. GUI

The graphic user interface (GUI) of the system is a window of assisting driving operation as shown in Fig.3.(Yun et al. 2007).The system registers and updates operating conditions, field geometric information, machine and tractor conditions, operating method in the field and displays target line, operated track, attitude of tractor, guideline for turning around at the end of the field according to the operation width, positioning angle, and has functions such as automatic screen sliding, switching of orientation viewpoint, display of multiple windows, easy input from touch panel, real-time GPS information ,automatic recording and replaying of operation, and output of ledger sheet for operation report. After registration, a driver can initiate operation simply by selecting the registered name of operation in the field. The driver can alter the route to any given routes on the way of operation in the field. The driver is supposed to overlap the center of a tractor and direction of the body onto a target line displayed in green color and control steering so that an upper bar showing traveling direction becomes the center.

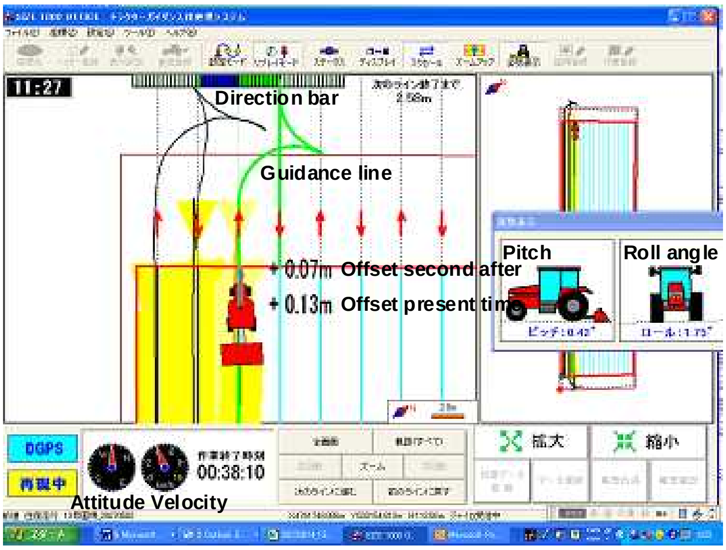


Fig.3. GUI of software of guidance system

4. Operation Setup

Software is used as follows::

(1) Select Japanese (Tokyo97Bessel, ellipsoid) or world (ITRF94 , ellipsoid) geodetic coordinates. Select public or universal transverse mercator(UTM) plane rectangular coordinates.

(2) Input a center position of a tractor and a set position of GPS antenna, an altitude of the GPS antenna from the ground, a longitudinal distance between the centers of the tractor and of implement, and a transversal offset distance between the centers of the tractor and of implement (implement) with every used tractor and implement in setup menu. Set a time for predicting tractor travel between 0.5 and 3 seconds. Select filtering on or off and set measuring time for initializing. These setting data are recorded and next time only alter the necessary corresponding items.

(3) Input the coordinates of the four corners of the field and register it with a name. When setting operation area, turning around space, operation width, operation method (round trip, transfer, intermediate division, surrounding) and operation direction, starting point, the driving rout in the field is created automatically and displayed as shown in Fig.4. Since this setting contents are registered as few operational files to every field, the system is immediately initiated only by selecting the registered operational file of the field.

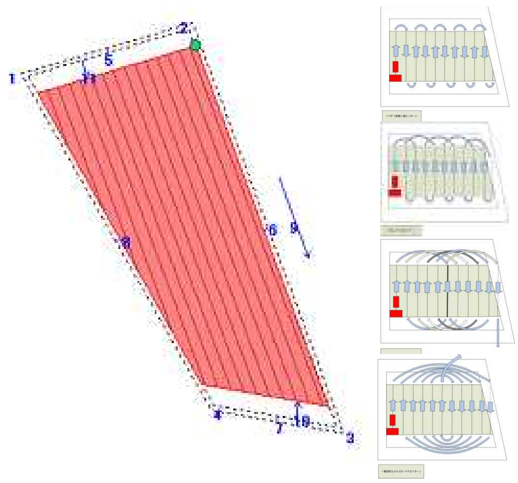


Fig.4. Method of pass planning

(4) Click on “Start Operation”, select a field name and an operation file, press the start button, then the field block map and the driving rout in the block is displayed. Move to the real starting point, where the system is initialized- calculate initial offset error of GPS and covariance matrix of error of GPS and gyroscope for filtering.

TRAVEL DATA FILTERING

1. Procedure

Since there is an initial bias error in a direction of vehicle measured by a gyroscope and temperature and time drift of gyroscope due to the accumulation error of rotational rate, the bias error is automatically corrected by GPS position data during the traveling. To improve the accuracy of position, direction and velocity data together the position (xk, yk) (k is step time) and velocity vk of the center of vehicle measured by GPS and the directional data θ k (Fig.5.) from the gyroscope are filtered using Extended Kalman Filter algorithm (Toru, 2005) as shown in Fig.6. The reason why acceleration data from the gyroscope is used in this algorithm is that since GPS data sometimes largely varies due to the change of satellites arrangement or noise, and that error in determination of forward or backward travel and travel direction are reduced by incorporating acceleration factor into quantity of state. The positioning data is measured at 10Hz cycle, so the travel direction of the vehicle is calculated using the direction of the vehicle body and velocity.

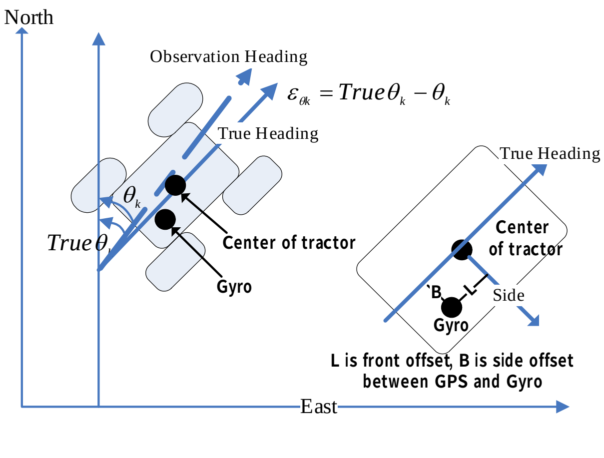


Fig.5. 4-wheel tractor moving model

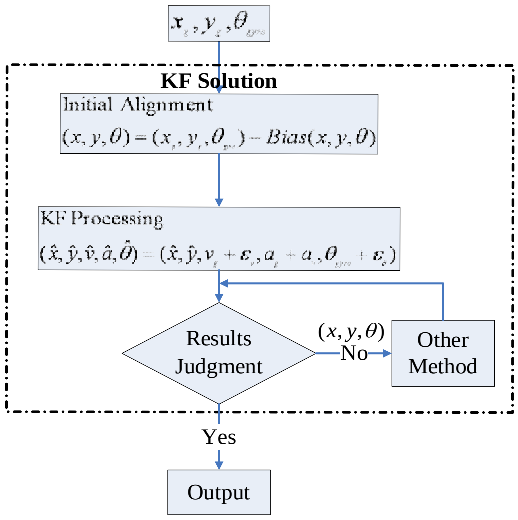


Fig.6. Flow-chat of KF solution

When erroneous components (εv,εa,εθ) of (xk,yk), true direction True θk, true velocity True vk, and true acceleration True ak are state vectors:

$$
\begin{aligned}
True\theta_k &= \theta_k + \varepsilon_{\theta k}, \\
Truev_k &= v_k + \varepsilon_{vk}, \qquad (1) \\
Truea_k &= a_k + \varepsilon_{ak}
\end{aligned}
$$

we take into account equation $\{Truev_k\, sin(True\,\theta_k)\}^2 - \{Truev_{k-1} sin(True\,\theta_k)\}^2 = 2Truea_k$

$\boldsymbol{sin}(True\,\theta_k)\,(x_k - x_{k-1})$, $\quad Truev_k = Truev_{k-1} + Truea_k\ dt$,

System equations (xk, yk) of state transition incorporated with an acceleration term are as follows:

$$
\begin{aligned}
x_k &= x_{k-1} + Truev_k \sin(True\ \theta_k)dt \\
&\quad + Truea_k \sin(True\ \theta_k)dt^2 / 2.0
\end{aligned}
\tag{2}
$$

$$
\begin{aligned}
y_k &= y_{k-1} + Truev_k \cos(True\ \theta_k)dt \\
&\quad + Truea_k \cos(True\ \theta_k)dt^2 / 2.0
\end{aligned}
\tag{3}
$$

When we substitute equation (1) into the above equations,

$$
\begin{aligned}
x_k &= x_{k-1} + v_k \sin\theta_k dt + \varepsilon_{vk} \sin\theta_k dt \\
&\quad + \varepsilon_{\theta k} v_k \cos\theta_k dt + a_k \sin\theta_k dt^2 / 2.0 \\
&\quad + \varepsilon_{ak} \sin\theta_k dt^2 / 2.0 + \varepsilon_{\theta k} a_k \cos\theta_k dt^2 / 2.0
\end{aligned}
\tag{4}
$$

$$
\begin{aligned}
y_k &= y_{k-1} + v_k \cos\theta_k dt + \varepsilon_{vk} \cos\theta_k dt \\
&\quad - \varepsilon_{\theta k} v_k \sin\theta_k dt + a_k \cos\theta_k dt^2 / 2.0 \\
&\quad + \varepsilon_{ak} \cos\theta_k dt^2 / 2.0 - \varepsilon_{\theta k} a_k \sin\theta_k dt^2 / 2.0
\end{aligned}
\tag{5}
$$

and express it as a matrix,

$$
X_k = A_k X_{k-1} + b_k + u_k \tag{6}
$$

where $X_k = [x_k, y_k, \varepsilon_{vk}, \varepsilon_{ak}, \varepsilon_{\theta k}]^T$, $u_k = [0, 0, \xi_{vk}, \xi_{ak}, \xi_{\theta k}]^T$, ξ is white noise,

$$
b_k = \begin{bmatrix} v_k \sin\theta_k dt + a_k \sin\theta_k dt^2 / 2.0 \\ v_k \cos\theta_k dt + a_k \cos\theta_k dt^2 / 2.0 \\ 0 \\ 0 \\ 0 \end{bmatrix} \tag{7}
$$

$$
A_k = \begin{bmatrix} 1 & 0 & \sin\theta_k dt & \sin\theta_k dt^2 / 2.0 & \alpha \\ 0 & 1 & \cos\theta_k dt & \cos\theta_k dt^2 / 2.0 & \beta \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} \tag{8}
$$

$$
\begin{pmatrix} \alpha = v_k \cos\theta_k dt + a_k \cos\theta_k dt^2 / 2.0 \\ \beta = -(v_k \sin\theta_k dt + a_k \sin\theta_k dt^2 / 2.0) \end{pmatrix}
$$

Using locations determined by GPS as observed vectors, we obtained the following observation equations from equation of the set GPS location:

$$
X_{gk} = H_k X_k + d_k + v_k \tag{9}
$$

where

$$X_{gk} = \begin{bmatrix} x_{gk} \\ y_{gk} \end{bmatrix} \quad , \; d_k = \begin{bmatrix} L\sin\theta_k \\ L\cos\theta_k \end{bmatrix}, \; v_k = \begin{bmatrix} \xi_{gxk} \\ \xi_{gyk} \end{bmatrix} \tag{10}$$

$$H_K = \begin{bmatrix} 1 & 0 & 0 & 0 & L\cos\theta_k + B\sin\theta_k \\ 0 & 1 & 0 & 0 & -L\sin\theta_k + B\cos\theta_k \end{bmatrix} \tag{11}$$

Kalman gain is expressed as follows:

$$K_k = A_k P_k H_k{}^T \left[H_k P_k H_k{}^T + R_k \right]^{-1} \tag{12}$$

The estimated state vector $\hat{X}_{k|k}$ is:

$$\hat{X}_{k|k} = A_k \hat{X}_{k|k-1} + b_k + K_k (X_{gk} - H_k \hat{X}_{k|k-1} - d_k) \tag{13}$$

The estimated error covariance matrix is:

$$P_{k+1} = A_k \left[P_k - P_k H_k{}^T \left[H_k P_k H_k{}^T + E(v_k) \right]^{-1} H_k P_k \right] A_k{}^T + Q_k \tag{14}$$

Based on the above equations, we calculated an error covariance matrix in format processing before operation starts and achieved stable and highly accurate position, velocity, and direction by filtering during travel. In rapid direction change during turning at the end of the field, the estimated value is dispersed, so we calculate swept path from raw data of GPS and gyroscope. To prevent the impact of transition data close to abnormal value of GPS, we determine the abnormal value from the direction and velocity of the vehicle and calculate the position through dead reckoning. For the center position of the vehicle (xk, yk), we perform slant correction in which projected position onto the ground from the center of the vehicle in a vertical direction of the vehicle is calculated using the posture sensor.

2. Display Location Accuracy through Filtering

To confirm the accuracy of the system display location, we placed the system on a tractor (Kubota M90-PC, FQ1BMAL,engine power 66kw) as shown in Fig.7.and examined filtering accuracy using a highly accurate GPS (Leica Geosystems Inc., SR530 RTK-GPS) that accuracy was 2cm for evaluation. The test is performed in a flat 12x160m field at the Hokkaido Agriculture Research Center in Sapporo. We drive the tractor in meander moving on purpose in twice round trip travel. The data of swept paths are compared with the data of SR530 after the treatment of initial position correction (subtracting difference between a 10 second-average position at initial operation position and an average point of RTK from subsequent position data of DG14).

Fig.7 Field experiment using the guidance system

3. Results of Test of Display Location Accuracy

Fig.8. compares displayed tracks of filtering data in combination with gyroscope and GPS with the swept path of RTK traveling in the direction as Y axis at 13km/h speed. The numbers of caught GPS satellites are 7 to 8. Right figure is an expansion of locations (surrounded by red circle) in which measured position of GPS has varied. Display locations of filtering data were almost same with the GPS data, however, more smoothed. Position error of filtering data slightly exceeded GPS data immediately after turning around on third line or in traveling in a large S-shape. In the travel of fourth line, accuracy of GPS data is improved, so both GPS and filtering data close to the RTK's. In the right figure, GPS data at sometimes varied in a step shape within a range of 25cm (in some locations, reverse travel), however, filtering data tended to slowly

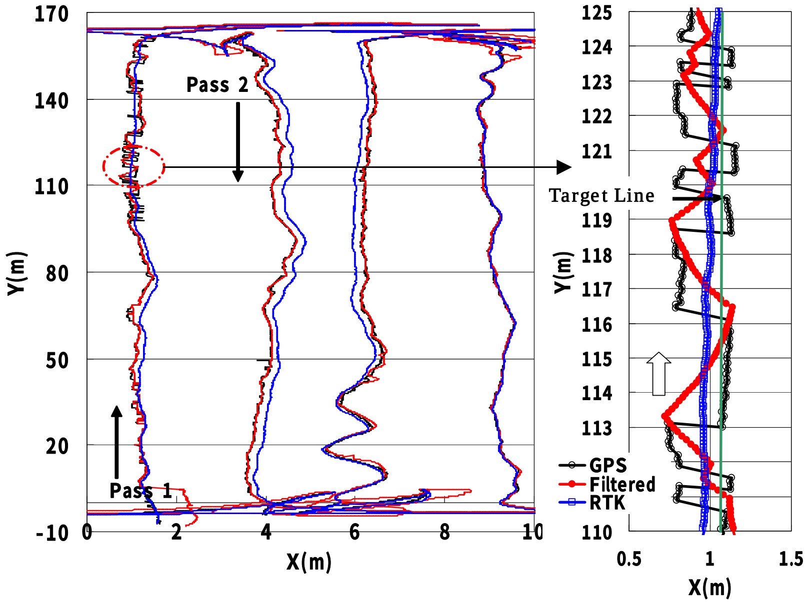


Fig.8. Tracks comparison between position data of DGPS ,filtering processing and RTK-GPS on experimental round trip working in the field.

approaching GPS values and are closer to swept path measured by RTK. Filtering is effective to reduce error of rapid change of GPS position data. When positioning data of GPS transitions and transverse position remains for a certain time, this Kalman filter algorithm cannot estimate its offset and estimated position tends to approach GPS data moderately.

Fig.9. compares the error of GPS data and filtering data in a round trip traveling in Fig.8. In the rout from 110 to 160m distance from the edge of outward route of Pass1, filtering data was fluctuated by a large variation of GPS data and took long time to converge, consequently was less accurate than GPS data. However, filtering data is more smoothed as a whole and accuracy of position is slightly improved than GPS data. Comparing RMS, on Pass1, GPS data is 14.0cm and filtering 12.3cm, and on Pass2, GPS data is 22.6cm and filtering 22.3cm. In the filtering process, error covariance matrix of Kalman gain, which is multiplied by a difference between observed value and estimated value, is updated with time passing. So the accuracy of filtering data tends to be improved as time passing. Direction data measured by VSAS which has time drift is also improved by filtering with the position and velocity data of GPS. Filtering position data tend to be deviate from the true data after turning.

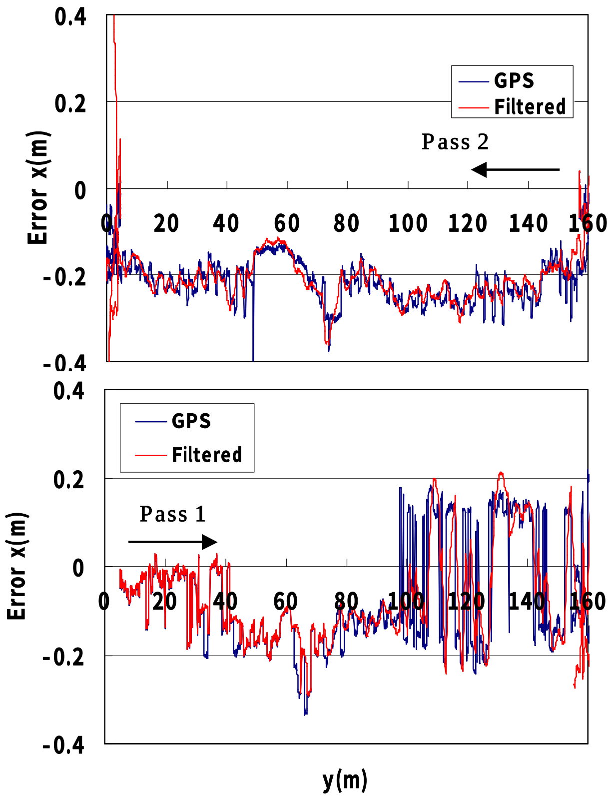


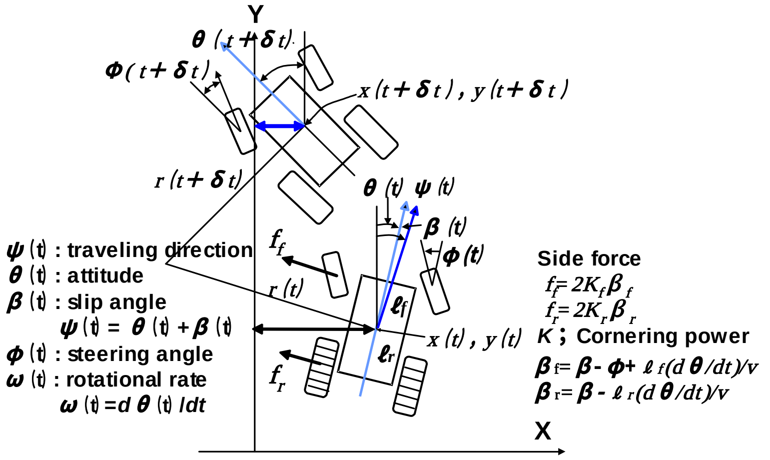
Fig.9. Comparison between offset error of DGPS data and filtering processing

Position error of GPS, which is different from white noise, drifts like a step shape and continue for a certain time. Some improvement of filtering method is necessary, such as adjustment of error covariance matrix of GPS, an integration method with bias error compensation using INS distinguishing actual skidding motion.

SIMULATION OF TRACTOR MOVEMENT AND STATE PREDICTION

1. Method

To clarify the effect of steering operation referring to state prediction display, movement of a vehicle changing a predictive time and steering operation was examined using a field traveling simulation model based on Equivalent Two-Wheel Model, as shown in Fig.10. Vehicle movement equations on the horizontal ground are as follows:



$$\theta(t+\delta t) = \theta(t) + \omega(t)\cdot\delta t$$
$$x(t+\delta t) = x(t) + v(t)\cdot\delta t\cdot\sin(\psi(t) + \omega(t)/2\cdot\delta t)$$
$$y(t+\delta t) = y(t) + v(t)\cdot\delta t\cdot\cos(\psi(t) + \omega(t)/2\cdot\delta t)$$

Fig.10. Schematic diagram of tractor movement

$$mv\,(d\beta/dt) + 2(K_f+K_r)\beta + \{mv + 2(K_f\ell_f - K_r\ell_r)/v\}\omega = 2K_f\phi \qquad (15)$$
$$I_z(d\omega/dt) + 2(K_f\ell_f - K_r\ell_r)\beta + 2(K_f\ell_f^2 + K_r\ell_r^2)\,\omega/v = 2K_f\ell_f\phi \qquad (16)$$

When there is no rapid change, then dβ/dt=0, dω/dt=0,

$$\beta = \left[1 - \frac{m\ell_f}{2K_r\ell_w\ell_r}v^2\right]\left[\frac{\ell_r}{\ell_w}\right]\phi/C \qquad (17)$$
$$\omega = \left[\frac{v}{\ell_w}\right]\phi/C \qquad C = 1 - \frac{m(K_f\ell_f - K_r\ell_r)}{2\ell_w^2 K_r K_f} \qquad (18)$$

where β slip angle, ω angular yaw velocity, K cornering power (suffix f is the front wheel and r the rear wheel), ℓ the distance between the center of gravity and wheel ($\ell w = \ell f + \ell r$), m tractor mass, and V velocity.

Direction of a vehicle body θk+1, deviation of X-direction xk+1 and Y-direction yk+1 after calculation step δt time are calculated as follows using θk and βk in equations (17) , (18).

$$\theta_{k+1}=\theta_k+\omega_k \cdot \delta t \tag{19}$$

$$x_{k+1}= x_k+ v_k \cdot \delta t \cdot sin(\psi_k+\omega_k/2 \cdot \delta t) \tag{20}$$

$$y_{k+1}= y_k+ v_k \cdot \delta t \cdot cos(\psi_k+\omega_k/2 \cdot \delta t) \tag{21}$$

where, ψk is the traveling direction of the vehicle, ψk= θk+βk.
when a steering angle is given, state of vehicle (θk , xk , yk) is calculated using βk and ωk. In actual operation in the field, steering is controlled so as to fit the vehicle location and direction to the target line in the display. In this simulation, a exponential curve revealed as follows equations(22) shown in Fig.11. is assumed as a converge curve to the target line Y axis from the current position (xk, yk).

$$x= x_k \cdot \exp[-(y-y_k)] \tag{22}$$

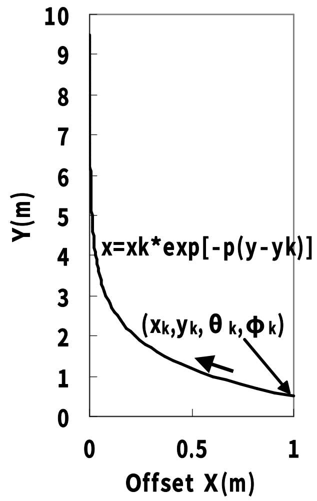


Fig.11. Objective convergence curve of a vehicle to Y axis for steering control (p=1)

As there is a relation dy/dx= 1/tanθ, steering angle is controlled so as to follow equation (22) (Inoue, 2003):

$$tan\theta=-x \tag{23}$$

In the predictive steering control, the steering angle is controlled with the same (23) equation replaced δt as predictive time ν.

$$\theta'=-arctan(x') \tag{24}$$

Due to the power steering hydraulic control delay, time delay λ generally occurs as follows until target steering angle φik is reached.

$$\lambda= \tau+ | \phi_{ik}- \phi_k | / \kappa \tag{25}$$

where τ is a idling time of hydraulic valve, κ is rotation rate of steering angle. During continuous changing of steering angle, τ=0 .Then, steering angle ϕk+1 is expressed as follows:

$$\phi_{k+1} =\{(\lambda-\delta t)\phi_k+\phi_{ik}\delta t\}/\lambda \qquad (0<\delta t< / \phi_{ik}-\phi_k / /\kappa)$$

$= \phi_{ik} \qquad\qquad (\delta t > | \phi_{ik} - \phi_k | / \kappa)$ (26)

κ is measured by changing steering angle 0 to 10 degree controlled by computer with the hydraulic valve. As a result, after idling time 0.2 seconds, the steering angle changes linearly to 10 degrees after 0.7 second, as shown in Fig.12. The relationship between passing time t and steering angle φ is expressed as follows:

$$\phi = 14.3(t - 0.2) \qquad (27)$$

κ is determined as 14.3deg/s

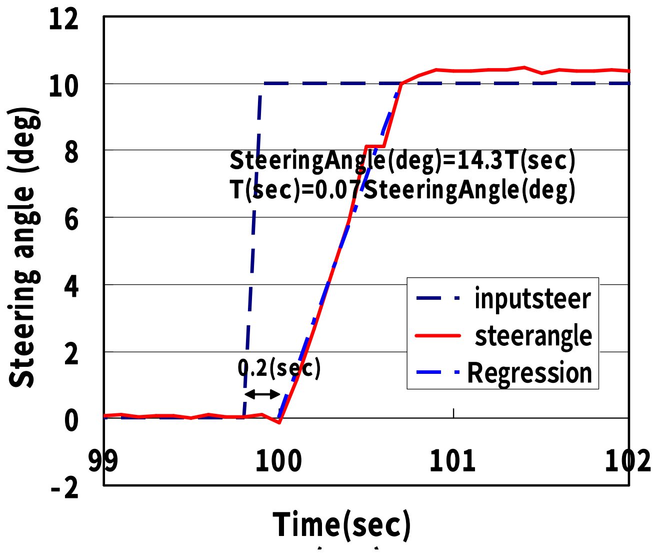
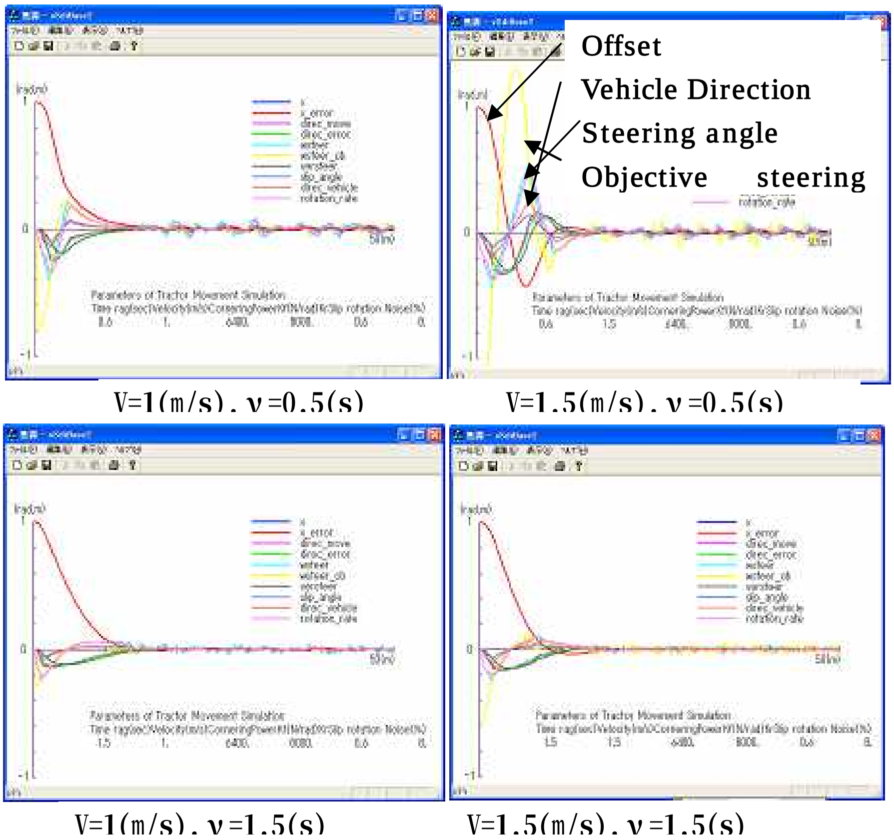


Fig.12. Response of electro-hydraulic power steering angle

Movement of a vehicle is estimated by giving numerical values as shown in Figure 13. Cornering power Kf , Kr were estimated in the experiment of measuring turning characteristic of a tractor (Kubota Co., M90, 66kW) in the field. we calculated ??travel view?? through a simulation model we created. In the simulation, the noise of a pseudo random number of 8% to $\delta\theta / \theta$ and $\delta\phi / \phi$.

2. Results of Prediction and Travel Simulation

Comparing simulation results of setting predictive display time ν as 0.5s and 1.5s, the convergence movement of the vehicle at 0.5s is quick, however slightly meandering, while at 15s, is smooth and no meandering as in Fig.13. on the condition of initial deviation 1m. At travel velocity of 1.0 m/s, there is no meandering at both ν. At travel velocity of 1.5 m/s, however, there is meandering at 0.5s. This is considered to occur when steering control is delayed due to the large difference between current and target steering angles. There is the large impact of variation by external disturbance at 0.5s after convergence to x=0, while, small impact at 1.5s. This is considered that the steering is controlled slowly when ν is long. At predictive display time more than 2.0s, the convergence is smooth (abbreviated), however, the response is too slow and unable to follow the target line. ν must be set appropriately according to the extent of steering velocity.



m(kg)	Lf(m)	Lr(m)	Kf(N/rad)	Kr(N/rad)	δ t(sec)	V(m/sec)	x_0(m)	ϕ_0(rad)
4100	1.5	0.8	6400	8000	0.167	1.0-1.5	1	0

Fig.13. Results of simulation of movements of vehicle

The above results are of automatic steering control under the regulation of (21). The movement of actual manual driving is considered to be similar. Meander moving may be occurred on short predictive display time. Adequate predictive time must be set for support driving within 1 to 2 seconds. In this system, steering angle is not sensed, movement of a vehicle is approximately calculated by equation (2) using the vehicle body direction. The location and direction of a vehicle after 0.5 to 3 seconds (variable in setting) are calculated using an approximation curve of swept truck. By setting properly a predictive display time depending on operational velocity, the vehicle is controlled accurately without meandering.

DRIVING TEST IN THE FIELD

1. Driving Accuracy Test using the Guidance System

Driving tests were excused in the 160m long flat field at speed from 2.5 to 4.3 km/h, operating width to 2.54m and a transverse offset between the center of an implement and the center of a tractor as 0.1m. A RTK-GPS (SR530) was used for measuring accuracy of the location display of the system. A test driver, who has a 10-year experience of tractor driving, traveled in the field for 20 minutes before test.

2. Results of Driving Test

Fig.14. compares the results of the accuracy of driving on the 1st and 2nd pass and 3rd to 5th pass. On the 1st and 2nd pass, the driver failed to follow the target line on the display due to driving operation delay and excess steering operation. Maximum misalignment was 47cm in the test. In the travel on the third to fifth pass, the operator, got used to the characteristic of the system, drove the tractor correctly to the target line by adjusting the direction of the tractor early at appropriate steering angle referring to a bar of predicted direction shown at the top of the display screen. Consequently, he could eliminate meandering move and keep misalignment from the target line within ±20cm(driving accuracy). Driving accuracy can be improved by matching direction and location on the screen with the actual and quickly adjusting the direction. The LCD panel of the system on the dashboard is effective for accurate and safe driving because the driver can view ahead without missing the eyes.

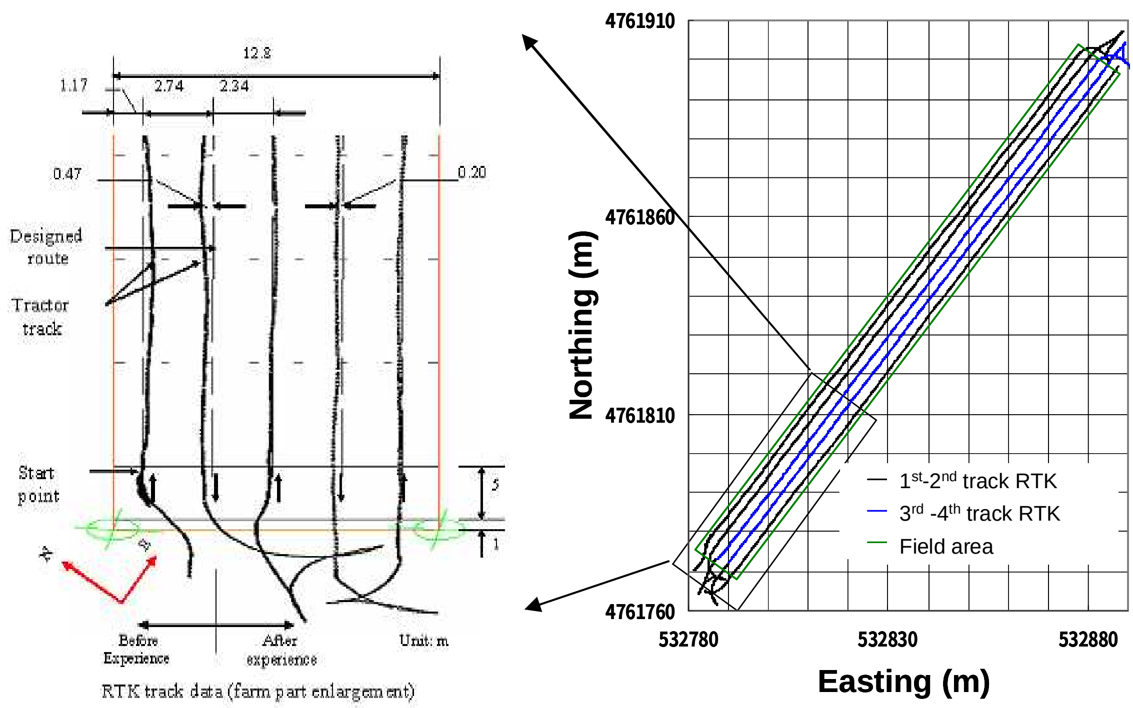


Fig.14. Vehicular swept path on round trip working by using guidance system

METHOD OF MAKING FARM MAP USIG GOOGLE EARTH

Coordinate points of farm are got by matching a local satellite photo of Google

Earth and a vector map of same area using GIS(AutoDesk,Civil3D or Tokyo Cart Graphic, Chizutaro) as shown Fig.15. More than 2 correspondence points measured locally which are easy to find on a satellite photo are inserted into the map to confirm the accuracy of the map. By using this cording map, field, road, building etc are marked as layer on GIS and output as a shp file shown Fig.16. Coordinate points of field are input into an Exel file and each farm division is registered as filed points in the guidance system.

Fig.15 Coordinate points of farm and field area got by matching local satellite photo of Google Earth and a vector map on GIS(GIS ;Chizutaro)

Fig.16 GIS filed map of a farm(GIS; AutoCad Civil3D)

CONCLUSIONS

A tractor guidance system, which displays graphically effective route in the field, current position, direction, and velocity of a vehicle and predictive position and direction after a certain time ,was developed for supporting the driving in the field work such as tillage, seeding, fertilizer and pesticide spraying, grass tedding, etc. We stabilized and improved the accuracy of DGPS by using an integration method combining DGPS and three-axis gyroscope applying Extended Kalman Filter. Following results were confirmed through the field operation tests.

1. The accuracy of location, direction, and velocity was stabilized and slightly improved by the integration method. The accuracy of location displayed on the screen was within ±40cm.
2. The integration method was effective for smoothing the variation of DGPS data, however could not estimate the bias error of GPS owning to the lack of algorithm for estimating the bias error.
3. The graphic display of the system was easy understanding and effective for driving and after used to the system, misalignment can be reduced to within ±20cm.
4. A method of making a field map is shown.

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