High Accuracy Path Tracking for Rice Drill Seeder in Uneven Paddy Fields

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Abstract.

High accuracy track tracing is a challenging task in paddy fields due to uneven grounds as well as wet soil conditions, thus restricting the development of autonomous rice drill seeder in China. For the purpose of overcoming the obstacles in application of autonomous rice drill seeder in paddy fields, a path tracking algorithm with high accuracy used for steering control during straight traveling in uneven mud paddy fields is introduced in this paper. Combining lateral deviation and heading angle deviation as feedback, a nonlinear steering control model is developed in the algorithm. Integrators are added to the nonlinear control model to eliminate the steady-state errors. Moreover, the velocity of vehicle is also taken into consideration in this model to improve the accuracy of path tracking. Attitude variation incurred by uneven fields and side slipping make it troublesome for the tractor to acquire the accurate position of the vehicle from Global Positioning System (GPS) whose antenna is located on the top of the tractor cabin, which as a consequence limits the accuracy of path tracking. In order to solve this problem, the influence caused by the roll angle and the pitch angle of the vehicle on position coordinates given by GPS are taken into account when the vehicle is on a slant. Afterwards, the algorithm for improving the position accuracy is illustrated in detail in this paper. The overall control scheme was implemented and experiments were carried out to verify the effectiveness of the algorithm in arable paddy fields. With the introduced algorithm, the autonomous rice drill seeder is able to follows the predefined path, makes a turn at the boundary line of the paddy filed, and moves to the next desired straight path.

Keywords.

Autonomous rice drill seeder, tracking algorithm, paddy fields, uneven ground, control model, inclinometer.

The High Accuracy Track Tracing

Precision agriculture has been significantly developed in recent years thanks to advances in mechanization and automation. As a result, lower production costs, less reliance on manual labor and more reliable quality of crops turn into reality with the use of automated agriculture machines (Edan 2009). One of the key features of automated agriculture machines is the automatic guidance. Auto-guidance system enables agricultural machines to work on the defined path automatically without drivers controlling the steering wheel anymore. In addition, drivers will feel tired after driving for several hours, resulting in the increment of lateral deviation of path tracking, while auto-guidance machines are capable of completing the task more accurately during long periods of work and will never get exhausted (Wilson 2000). Therefore, automatic guidance of agricultural machines has been a hot spot recently and gets motivated with the development of computer and sensor technology (Lenain 2006).

This study aims at presenting a high accuracy path tracking algorithm of rice drill seeder in uneven paddy fields. To that end, a reliable approach with incline taken into consideration to avoid effects on path tracking accuracy when the tractor is on a slant is illustrated in detail. Additionally, a steering control law was developed to achieve high accuracy. Experiments in uneven paddy fields verified the accuracy of the algorithm in this study.

Control Methods

Position Compensation Algorithm

Running on the ground that is uneven and rough is troublesome to get the accurate position of the tractor from Global Positioning System (GPS) whose sensor is installed on top of the vehicle because the absolute coordinates will be affected when the vehicle tips on the uneven ground and the projection point of GPS sensor on the ground is not coincident. The effects can be split into two groups. One is the roll effect, which results in lateral position error. Another is the pitch effect, which results in longitudinal position error.

Suppose that the mounting height of GPS sensor is *H*, roll angle of the vehicle body is φ, and the pitch angle is ψ. As shown in Fig. 1(a), the roll effect is given as e_{lat}:

$$e_{lat} = Hsin\varphi \tag{1}$$

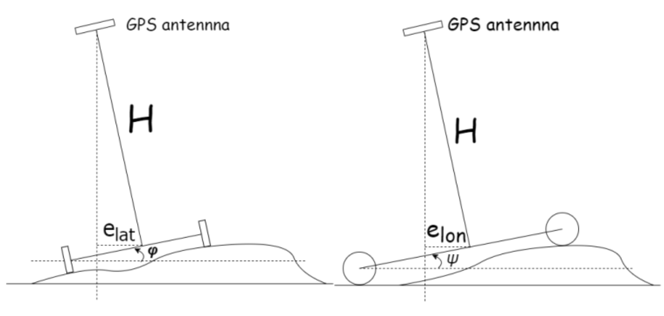
As shown in Fig. 1(b), the pitch effect is given as e_{lon}:

$$e_{lon} = Hsin\psi \tag{2}$$

Hence the coordinates can be corrected with the equations given below:

$$\begin{cases} x_m = x'_m + Hsin\varphi cos\theta - Hsin\psi sin\theta \\ y_m = y'_m + Hsin\varphi sin\theta + Hsin\psi cos\theta \end{cases} \tag{3}$$

In (3), (x_m, y_m) are the modified coordinates, while (x'_m, y'_m) is the coordinates given by the GPS sensor. θ is the heading angle.



(a) (b)

Fig. 1 Position errors caused by incline

Steering Control Algorithm

The steering control algorithm is given by (4) as follows:

$$\delta = \varphi + arctan\frac{k(d - Lsin\theta)}{v} + k_i I_{int} \tag{4}$$

where *d* is the lateral deviation, and *φ is* the heading angle deviation. I_{int}, which is employed to eliminate the steady-state errors, is the integral of *d*. *L* denotes the vehicle wheelbase, and *v* represents the realized vehicle linear velocity. The steering control parameters (k_i and *k*) were obtained experimentally. The value of *k* is set to 1.3 and k_i is set to 0.5 in this study.

Performance Evaluation

Table 1 shows the summary of the performance of the path tracking algorithm in the field experiments. The rms lateral deviation from the desired path was observed to be less than 0.05m, and the heading angle rms error was no more than 2.6 degrees. The mean absolute lateral deviation of each path was less than 0.04m. The mean absolute heading angle error was observed to be less than 0.04 degrees.

Table 1. Performance evaluation of the algorithm

Path No.	Lateral deviation (m)				
	Max	Min	Mean Absolute	rms	Std
1	0.101	-0.109	0.032	0.044	0.044
2	0.088	-0.112	0.043	0.051	0.051
3	0.082	-0.087	0.033	0.039	0.039
4	0.096	-0.078	0.026	0.032	0.032
5	0.088	-0.087	0.029	0.036	0.035
6	0.094	-0.142	0.025	0.039	0.039
7	0.112	-0.088	0.021	0.030	0.029
8	0.093	-0.092	0.018	0.026	0.025
overall	0.112	-0.142	0.028	0.038	0.038

Path No.	Heading angle error (degree)				
	Max	Min	Mean Absolute	rms	Std
1	6.32	-3.41	0.03	1.83	1.82
2	8.20	-5.94	0.04	2.62	2.75
3	5.04	-7.07	0.03	1.96	1.96
4	6.73	-2.89	0.03	1.83	1.84
5	4.68	-7.73	0.03	2.07	2.07
6	7.58	-5.08	0.02	2.10	2.07
7	4.32	-7.03	0.02	1.81	1.81
8	5.96	-1.81	0.02	1.49	1.46
overall	8.20	-7.73	0.03	2.02	2.02

Summary

A high accuracy path tracking algorithm for rice drill seeder in uneven paddy fields is presented in this paper. The effect on position measurement caused by the incline of the tractor cabin when the tractor is on a slant was investigated. The method for compensating the position errors of the tractor is developed in the proposed algorithm to improve the accuracy of path tracking. Moreover, a steering control model with feedback components and integrators is proposed to control the rice drill seeder to travel along the desired path with high accuracy.

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