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EXPERIMENT STUDY OF AUTONOMOUS SYSTEM FOR INTRA-ROW WEED CONTROL

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ABSTRACT

The study is used to propose and test by experiment a procedure for autonomous hoeing system for intra-row weed control. The proposed system utilizes the RTK-GPS navigation system. The system consists of autonomous vehicle equipped with side-shifting frame and cycloid hoe. The navigation of the system is controlled using a pre-specified plan and implemented in the system internal computer. The internal computer is also attached to a field station using the wireless local area network (WLAN). The performance of the system was measured through an experiment consisted of making rows having small plants and soil conditions similar to the actual field. The results based on chi-square shows that transverse deviation had normal distribution indicating the performance of the side-shift control. The results related to the longitudinal deviation distance between plants and the nearest line trajectories showed good chi-square fit which is an indication of performance of the cycloid hoe control. The result shows that the system is promising and can be used at larger level with suitable adjustments.
Keywords: WLAN, Autonomous, Vehicles, Agriculture.

INTRODUCTION

Robots are the norm of the 21st century modern urban world. In many industrial settings, the robots are taking part of the human labor such as automobile and security organizations. Robots are also used for providing technology education and raising children attention towards the technology. By use of robots, children can easily be made interested in fields like mathematics, information technology, and other science related subjects. The application of robots in various fields is undeniable and cover fields like welding ship walls inside double hulled structures 9, forest fire monitoring, agriculture, construction, mining, and medical. Mostly, robots are used in variety of settings where use of human labor can be risky and pose health and safety risk. The research areas in the robotic field include logistic, safety, data sensing and fusion, and navigation and control. The mechanism for robot functioning can be different based on their function and application. For example, in guidance systems for autonomous vehicles consist of sensor for monitoring the position of a vehicle, controller for controlling the car position, and actuator which combines the forward movement and steering system of the vehicle (Gonzalez-de-Soto, Emmi, Perez-ruiz, Aguera, & Gonzalez-de-Santos, 2016). Modern automatic guidance and auto-steering systems function on the basis of global positioning system or GPS 12. A GPS device measure a car's actual position and a path planner calculates the path need to be covered by a vehicle; while, autosteering system consists of comparator for calculating the position error and a controller for generating correct signal based on calculated path. The system also includes an actuator which is used for applying the control signals for making necessary adjustment in car target position (Griepentrog, Norremark, Nielsen, & Ibarra, 2007).

In this study, the objective is to develop and optimize a side-shift and cycloid hoe system for intra-row hoeing and quantify and evaluate the performance of the system under field conditions.

MATERIALS AND METHODS

An autonomous tractor programmed with a predefined route parallel to crop rows and make turns at the end of rows was used in the study. The autonomous tractor had electrical and hydraulic power attached to its linkage, and had ability to lower, lift, and pull at predefined waypoints. The tractor had programmed for bringing variation in its engine speed, steering and rear three-point linkage, and transmission through onboard computer. The onboard computer of the tractor was connected with an RTK-GPS system.

The tractor was attached with a cycloid hoe through its rear three-point linkage based on hydraulic side-shifting frame. The cycloid hoe transverse position is managed by side-shifting frame according to the crop row. Telescopic stabilizer unlocked is used for pulling the implementation consist of side-shift frame, electro-hydraulic drive, and the cycloid hoe. Due to the transverse float of implement, the RTK-GPS was implemented. Two trajectory modes were possible for the cycloid hoe rotating tines.

For autonomous intra-row weed control system, global positions of individual plants can be used as navigation waypoints. Therefore, there is required a system for geo-referencing of individual plant for the system to operate in the field. Geo-spatial seed map can be used for estimating the global position of plants.

Positioning System

For tractor side-shift and cycloid hoe control positioning, the RTKGPS was used. The positioning system consisted of two mobile receiver and a reference station receiver and reference signals were sent using the radio-linked modems.

Hydraulic Side-Shift

A horizontal parallelogram linkage is used to connect side-shift system based on two frames. On the autonomous tractor three point-linkage, the front frame was rear mounted; while, the rear frame was linked to the front frame using the two pivoting brackets.

Cycloid Hoe

For controlling soil tillage depth, the cycloid hoe based on tine-rotor and housing mounted onto a vertical parallelogram attachment with a ground wheel.

Side-Shift and Cycloid Hoe Control System Hardware

The system consisted of a computer with 600 MHZ power. The computer was connected with digital in/out board and combined counter/timer for digital and pulse-width modulation in/out channels. With the Quartz-MM-5 board, a signal amplifier was also connected. The amplifier board was used for controlling the power and voltage and operating the electro-hydraulic valves and rotary solenoids.

Mission Planning Method

For autonomous tractor side-shift and cycloid hoe, individual mission files were created related Wtractor, WSide-Shift, and WCycloid. The files consisted of waypoint vector containing easting and northing coordinates and relevant instructions. For vehicle route way points, the tractor mission files contained global coordinates. Additionally, the files contained additional instructions for lifting and lowering the rear three-point linkage, turning procedure, and velocity. A wireless local area network was used for connecting the onboard tractor computer to a station computer. This network is used for displaying the graphical user interface for navigation software. The navigation software controlled the tractor movements using the RTK-GPS.

Side-Shift and Cycloid Hoe Control System Software

MATLAB is used for developing the control system software for modelling and simulation function. Six interdependent modules were used for navigation of side shift and cycloid hoe control. These modules included longitudinal control for tine spindle control, transverse control for side shift, waypoint following, global position determination for cycloid hoe reference point, filtering and prediction by making use of Kalman filter, and global position of GPS antenna at ground level. Upon computer initiation, the control system software opened the two specified mission files for cycloid and side-shift hoe, their way points and additional instructions.

Experiment Details

For testing the performance of the autonomous control system, an experiment was conducted. Real field settings were created with the help of sandy loam soil. The soil was ploughed, harrowed, and rolled for creating similarity. The soil was kept as dry and hard to match with the warm field conditions. Small crops were implanted in the prepared field. The field consisted of 3 rows each having length of 32 me and consisted of 150 small crops. The position and altitude of plants were tracked using the RTK-GPS. Point A was noted as beginning of the row and point B for the end of the row. The autonomous tractor was driven from point A to B and from point B to A in all rows. The nominal velocity of the tractor was set at the range of 0.3 to 0.5 ms^{-1}. A standard video camera was used for monitoring the performance which was connected to a laptop. The video camera was mounted on the cycloid hoe housing. For performance monitoring, a steel ruler was mounted on the cycloid hoe just below the video camera so that the ruler and the actual plants are visible in the images.

EXPERIMENT RESULTS

The experiment was conducted to test the performance of control system in terms of its accuracy in avoiding collision with the crop plants. Images were collected to test the performance which shows that RTK-GPS showed good performance in terms of avoiding collision.

The test drives were conducted based on velocities ranging of 0.3 to 0.5 m s. This nominal velocity was set in the autonomous tractor mission plan and was kept constant during driving. The mean forward velocities of 0.31 ms^{-1}were achieved with SD range of 0.03 based on the logged position of the tractor GPS antenna.

For testing the performance of the side-shift control, we used the deviation from the row of the plants were used. The Chi-square result shows that the transverse deviations had normal distribution and had good fit level. The results states that for transverse deviations, the row was followed within a range of 15 mm with std of 0.31 range.

The longitudinal deviation distance between the plants and the nearest tine trajectories were used for measuring the performance of the cycloid hoe control. The distance was labelled as training distance and the leading distance which are distance before and after the plants respectively. The chi-square results obtained based on the field images shows that the leading and trailing distance were equally distributed and had good fit level.

The conclusion of the study is that by using the autonomous vehicle which equipped with side-shift and cycloid control can be effectively used for autonomous weed control system without having any collision with plants.

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