Development of a Path Generation and Tracking Algorithm for a Korean Auto-guidance Tillage Tractor

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Abstract

Purpose: Path planning and tracking algorithms applicable to various agricultural operations, such as tillage, planting, and spraying, are needed to generate steering angles for auto-guidance tractors to track a point ahead on the path. An optimal coverage path algorithm can enable a vehicle to effectively travel across a field by following a sequence of parallel paths with fixed spacing. This study proposes a path generation and tracking algorithm for an auto-guided Korean tractor with a tillage implement that generates a path with C-type turns and follows the generated path in a paddy field. A mathematical model was developed to generate a waypoint path for a tractor in a field. This waypoint path generation model was based on minimum tractor turning radius, waypoint intervals and LBOs (Limit of Boundary Offsets). At each location, the steering angle was calculated by comparing the waypoint angle and heading angle of the tractor. A path following program was developed with Labview-CVI to automatically read the waypoints and generate steering angles for the tractor to proceed to the next waypoint. A feasibility test of the developed program for real-time path tracking was performed with a mobile platform traveling on flat ground. The test results showed that the developed algorithm generated the desired path and steering angles with acceptable accuracy.

Keywords: Auto-guided steering, Minimum turning radius, Paddy field, Path planning, Path tracking, Turning pattern

Introduction

Agricultural productivity has significantly increased in recent years through mechanization and automation. The application of automation to agriculture has lowered production costs, reduced reliance on manual labor, and raised the quality of products (Edan et al., 2009). These advances have been achieved with sensors and controllers. Sensors and mechanical actuators are used in many agricultural machines such as automated navigators in agricultural vehicles. Automatic guidance has been an active area of study in agricultural machinery automation.

Automated guidance of agricultural vehicles (e.g., tractors, combines, sprayers, and spreaders) has been motivated by a number of factors—the most important factor is to reduce the need for operators to continuously adjust vehicle steering while operating various implements for agricultural operations (Groover and Grisso, 2009).

A typical auto-guidance system consists of hardware and software. A position sensor, such as an RTK-GPS (Real Time Kinematic - Global Positioning System), a steering angle sensor, and a steering actuator comprise the hardware components, while a path planning and steering algorithm and an operation program for controlling the system constitute the software components.

Much research on automatic navigation of agricultural vehicles has been reported in recent years. Stoll and
Kutzbach (2000) tested a self-propelled forage harvester equipped with an automatic steering system and a path planning algorithm that generated paths based on position information from an RTK-GPS system. Noguchi et al. (2001) used an RTK-GPS, a FOG (Fiber Optic Gyroscope), and an IMU (Inertial Measurement Unit) as guidance sensors and a sensor fusion algorithm to identify FOG bias and compensate for location errors in real time. Zhang and Qiu (2004) developed a dynamic path search algorithm to guide an agricultural tractor on a desired path and make effective turns at the ends of a field. Massey (2006) developed a waypoint following algorithm that drove a truck on a course defined by GPS waypoints at speeds as high as 80 km/hr. A simulator was also developed, based on a three-degree-of-freedom model of vehicle dynamics. Recently, Gomel-Gil et al. (2011) proposed a simple method to improve tractor positioning by applying a low-cost GPS receiver and kinematic laws of tractor movement.

Path planning algorithms compute target points for a vehicle based on the coverage area in a field, the vehicle’s minimum turning radius, and other constraints. In principle, the path planner provides the position of the desired vehicle, and the desired position is then compared with the position measured with a position sensor such as RTK-GPS. The steering angle is calculated from the difference between the desired and the measured waypoints, and a command signal is then sent to a controller to activate the steering actuator.

The objectives of this research were: 1) to generate a waypoint path model with C-type turning for a tractor traveling in a paddy field, 2) to develop a waypoint driving program that generates steering angles by measuring and comparing the waypoint and tractor heading angles at each location, and 3) to evaluate the developed algorithm through a feasibility test using a moving platform traveling on flat ground for real-time path tracking.

**Materials and Methods**

**Research platform**

In this study, a Novatel ProPak RTK-GPS was used to measure the absolute position of the vehicle. The RTK-GPS transmitted data at 10 Hz with a baud rate of 115,200 bps and received "$GPGGA" frames, extracted latitudes and longitudes, and then sent data to the navigator. The path generation and tracking navigator was a Samsung laptop computer running a waypoint driving program, designed with Labview (ver.2011, National Instruments, USA) software, that calculated steering angles based on data from the RTK-GPS.

**Turning patterns for tillage operation**

Based on previous results reported by Seo (2010), there are mainly three types of turning patterns used in Korean tillage operations: C-type, X-type, and R-type, as shown in Figure 1. The C-type turning pattern is defined by the turning radius, R, and a turning angle of 90°. This C-type pattern features continuous forward motion and avoids reverse movement. When the tractor reaches a location where it will make a 90° turn, the PTO power is shut off, the tillage implement is raised, and the tractor turns. The tractor then moves forward to another point and makes another 90° turn, forming a C-shaped curve. The X-type turning pattern consists of a combination of a