Journal of Cleaner Production 113 (2016) 204–215

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Intelligent low cost telecontrol system for agricultural vehicles in harmful environments

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ARTICLE INFO

Article history:
Received 10 June 2015
Received in revised form
7 November 2015
Accepted 8 November 2015
Available online 22 November 2015

Keywords:
Agricultural vehicle
Harmful environment
Communications systems security
Low cost

ABSTRACT

The use of vehicles to control pests and crop diseases is needed to maintain agricultural production. This paper describes how to design and implement a low cost intelligent telecontrol system applied for agricultural machinery that are designed for use in places where human presence is not adequate, such as pesticide spraying tasks in farming environments as greenhouses. The intelligent system designed basically consists of these parts: States Encoding, Console Automaton, Vehicle Automaton, Communication System and Security of Communications. This system has been developed with a special-purpose UHF narrow band modem that interchanges digital operative commands/states from the console to the vehicle. The intelligent telecontrol system acts as a security system to protect against outsiders, and loss of communications due to fading or others interference. The originality of this system is based on the fact that it is 10 times cheaper than autonomous systems; those systems need electronic systems, GPS, a complex sensorial system, and a beforehand mapping performed on the new work environment. Related to classic remote control, our system protects from potential oversights of the operator. In addition, in the proposed system, the vehicle state is shown in the console, due the bidirectional communications. The system was successfully applied in prototype vehicle used for spraying tasks, and the result shows that the system operated stably and has confirmed the effectiveness of this intelligent telecontrol system. The proposed technology will help providing solutions for humans and robots working together in agricultural environments considered to be harmful to humans.

1. Introduction

Increasing yields on existing farmland is essential for 'saving land for nature' and for agricultural production systems, including systems with two or three crops per year. These crops may become progressively susceptible to disease and insect pests because of the insufficient diversity in crop rotation (Tilman et al., 2002; Stoate et al., 2009). Agriculture production has evolved into a complex process requiring the accumulation and integration of knowledge and information from many diverse sources, including marketing, horticulture, insect management, disease management, weed management, accounting and tax laws (Shaalan et al., 2012). Often, agronomic practices alone are insufficient for obtaining economically successful production, especially in the high value per acre production of vegetables and fruit (Felsot and Rack, 2007; Hilton and Mills, 2012). The rapid expansion of global demands for agricultural products, together with climate change, has caused a greater development of agricultural techniques, appropriate machines and equipment (Miodragović et al., 2012; Bennett et al., 2012). The use of machinery to control pests and crop diseases is needed to maintain agricultural production. Consequently, pesticides are applied in the presence of the people, and most of the pesticides are toxic to human beings (Jepson et al., 2014). Advances in mechanical design capabilities, sensing technologies, electronics, and algorithms for planning and control have led to a possibility of realising field operations based on intelligent agricultural vehicles (Kester et al., 2013). Furthermore the reduction of labour costs (Van Henten et al., 2006), problems with the availability of skilled labour and the improvement of the production process both quantitatively as well as qualitatively were and still are main driving forces of agricultural systems (Mueller et al., 2012). The navigation of field

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http://dx.doi.org/10.1016/j.jclepro.2015.11.015

robots in an agricultural environment is a difficult task due to the inherent uncertainty in the environment (Hiremath et al., 2014a, 2014b).

The harmful environments, derived from intensive agriculture are unfortunately frequent, e.g. in greenhouse farming the workers can suffer thermal stress (Callejón-Ferre et al., 2011; Pérez-Alonso et al., 2011), and this can affect more men than women (Manzano-Agugliaro et al., 2013). On the other hand, the use of low cost systems is extending for monitoring the environment (Cama et al., 2013) and in agricultural applications such as the stiffness analysis of wood with knots in bending (Guindos and Ortiz, 2013), for monitoring intensive agriculture (Montoya et al., 2013; Cama-Pinto et al., 2014), for fruit grading systems (Clement et al., 2012), and for agricultural land vehicles (Zhang et al., 2012).

Several control systems exist for vehicles for different uses. The deployment of autonomous robots is an opportunity for enhancing tasks such as weeding, spraying, harvesting and mowing (Emmi et al., 2014; Auat Cheein and Carelli, 2013; Suprem et al., 2013). These are characterised by their ability to navigate and perform certain tasks on their own (Montalvo et al., 2012). The main problem of Autonomous Vehicles is that they are very expensive (Pedersen et al., 2005). This means they can not be used on small farms, such as greenhouses farms, where the average farm size is about 2 ha (Manzano-Agugliaro and Cañero-Leon, 2010; Márquez et al., 2011).

So, semi-autonomous control could be used in small farms like greenhouses, and some low-level tasks could be performed by a robot, in order for the operator to focus his/her attention on more high-level control tasks including the supervision. The base contains recorded knowledge about the environment, possible obstacles and possible trajectories for the vehicle. Collision avoidance methods and navigational systems are used to estimate the position of the vehicle (Kruse et al., 2013).

Additionally, well-known classical telecontrolled vehicles in which the operator remotely handles servomechanisms with a radio system can be considered an extension of the controls. These systems require intensive training by the operator, and information regarding what the vehicle is doing. The state of the vehicle is obtained by direct vision. Events such as a loss of communication may cause serious consequences in these systems or in the environment.

Collision avoidance methods can be divided into global and local approaches. Global methods assume that a complete model of the environment surrounds the vehicle, including routes, obstacles, alternative routes, allowed movements, etc. (Gasparetto et al., 2012). The main problem with these methods is that they are not appropriate for obstacles requiring fast avoidance. Local approaches consider only a small subset of obstacles surrounding the vehicle (Ogren and Leonard, 2005), which introduces limitations in the autonomous functioning of the vehicle. An interesting example of an autonomous vehicle that uses a combination of both techniques is given by Hentschel et al. (2007).

The position of the vehicle may be estimated using the Global Positioning System (GPS) (Gomez-Gil et al., 2011; Corpe et al., 2013) or Dead Reckoning (DR) (Ryan and Bevly, 2014). However, the use of these two methods or even a combination of these two methods does not provide a perfect solution to the problem of autonomous navigation.

Road scene analysis is a challenging problem that has applications in autonomous navigation of vehicles. Intelligent vehicles exist that navigate in complex, off-road terrain using embedded learning algorithms (Gopalan et al., 2012). Therefore, the main problem with autonomous systems is the necessity of a priori information regarding the workspace and possible changes in the environment for making decisions in unexpected situations. These vehicles have a complex sensorial system, including a local computer with a high capacity for calculus and information storing. In addition to a complete knowledge of the workspace, these vehicles require careful maintenance.

Intermediate solutions between autonomous and classical telecontrolled systems have already been considered by different authors. Schmidt and Boutalis (2012) proposed the substitution of a human controller with fuzzy automaton, which carried out decisions for the control of the vehicle in real time. This solution is quite similar to autonomous vehicles. Courbon et al. (2013) proposed a mixture of the two concepts. For the first stage of learning, the vehicle recorded marks, paths, etc., provided by a human controller. Later, in the second stage, the vehicle functioned as an autonomous vehicle. Rajamani and Zhu (2002) using simulation, they offered a similar solution to the one proposed in this paper. However, it is designated for road vehicles, where the semi-autonomous systems would be immediately deployable on today's highways.

However the semi-autonomous vehicle presents lower materials costs with same efficiency giving it better advantages over other systems. The developed system is mainly aimed for agriculture in greenhouses since horticultural areas necessitating use of pesticides are dangerous for human interaction at close distances. Some other authors determined that feedback information is used to control the vehicle automatically. Sharbafi et al. (2010) introduced a system in which the operator provides a final position instruction, the robot reaches that position in an autonomous way and the robot learn from the events that take place along the trajectory.

The system that is introduced in this work is a hybrid between autonomous and classical telecontrolled vehicles. It gives these vehicles some microprogrammed intelligence against unforeseen and requires the operator moderate supervision over the robot. An operation console interprets commands, and the vehicle performs the corresponding actions. A dialogue of operative commands and state responses is established, and the vehicle automatically solves serious problems, such as a loss of communication. Bandwidth use in the communication channel is reduced. Moreover, preprogrammed decisions can be selected for unexpected events, such as an automatic stop due to a loss of communication or the proximity of an obstacle in the vehicle's trajectory. The system is adequate for controlling vehicles that can be directly observed by the operator or monitored by video cameras in the vehicle in a control room in the area providing direct assistance through live video camera. The security of communications may also be an important issue depending on the purpose of the vehicle. Therefore, a novel encryption key selection method is used, which fits real time communications and is based on a Linear Feedback Shift Register (LFSR) that allows key selection from a list in a pseudorandom order (Novas et al., 2008). This remote control system has been tested for motor vehicle spraying and is manufactured at the University of Almeria.

Table 1 presents the three telecontrol types described here, and where advantages and disadvantages are highlighted. Intelligent telecontrol can be described as an intermediate approach that selects the best features of classical telecontrol and autonomous vehicles.

The gap which the proposed system tries to solve is to find a cheaper solution than autonomous systems to protect the vehicle and work space from the mistakes generated by the operator using classic remote controls. The final solution must neither be a complex system nor a too much expensive one. This aims to solve the problem of the operator who cannot pays permanent attention for driving a vehicle in a harmful environment for himself.