Computers and Electronics in Agriculture 148 (2018) 8–18

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

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

Original papers

Near ground platform development to simulate UAV aerial spraying and its spraying test under different conditions

Yanchao Zhang, Yijian Li, Yong He *, Fei Liu, Haiyan Cen, Hui Fang

College of Biosystem Engineering and Food Science, Zhejiang University, Hangzhou, Zhejiang, China

ARTICLE INFO

Article history:
Received 27 March 2017
Received in revised form 31 July 2017
Accepted 4 August 2017

Keywords:
UAV
Spraying simulation
Platform development
PWM
Droplet analysis

ABSTRACT

Aerial spraying using UAV has gained great interest worldwide. UAV spraying can overcome crop height limits and is unlikely to crust soil or damage crop plants. More experiments concerning spraying are needed, such as spraying method tests, spraying droplet analysis, variable rating spraying tests, etc. These experiments either take a long time for real flights or have an unrecognized danger to UAV in real flights. To address this problem, an indoor spraying platform, which consists of X-Y direction movement and wind field generation was developed to simulate UAV aerial spraying. The maximum moving speed in the horizontal direction was 3.5 m/s and 0.25 m/s in the vertical direction. The horizontal moving distance was 11 m and the vertical moving distance was 0.5 m. The platform consists of 4 parts: upper machine software, central controller, X-Y moving part and far end spraying structure. CAN bus was used for communication between the central control board and far end controller. An experiment was carried out to test how the platform performs with different moving speeds and different wind strength. The wind strength test shows that wind forces the deposit down to the ground when droplets were equally affected by 2 wind forces. The result shows that the platform can meet the requirement of UAV aerial spraying.

© 2017 Elsevier B.V. All rights reserved.

1. Instructions

Aerial spraying using UAV has gained extensive attention around the world because it has obvious advantages over manual spraying and infield machinery spraying. It is a new kind of agricultural machinery that improves the plant protection mechanical level. It is hard to do in-season farm work because farmers and agriculture machinery in field work have to pay attention to crop plants. UAV has natural advantages in this since it flies in the air without touching the ground. It is much more labor saving and efficient.

Aerial spraying technology is advancing rapidly. Zhu et al. (2010) developed a variable rating precision spraying controller for UAV using a TL494 fixed-frequency pulse width modulator together with a data acquisition board and software developed. Labview was used to validate the controller. Xue (Zhu et al., 2010) used fluorescent dye Rhodamine-B in an unmanned aerial vehicle (UAV) trial in a paddy field. The deposition on the upper layer and under layer is more reasonable than traditional spraying because of the downdraft from the helicopter. Zhang et al. (2016)) extracted and analyzed droplet deposition parameters using digital image processing after scanning the cards. The results show that UAV performed better when working on open center shaped plants compared to round shaped trees at a 1.0 m working height compared to other heights. Malnersic (Zhang et al., 2016) discusses the aerodynamics and spray coverage analysis in air-assisted spraying. Nozzles specially designed with an electric fan were used for the experiment.

As the concept of aerial spraying UAV for plant protection is being accepted by farmers, and new UAV aerial spraying technology increasingly appears, experiments are needed to verify whether they are practical, appropriate, and effective. Spraying parameters such as sprinkling width, pesticide blending ratio, pesticide liquid flow rate, flying height and speed should be optimized. The influence of wind speed, nozzle type, ground bounce air, etc. should be identified. All of the above require extensive experiments. Real flight experiments require lot of time to prepare and are vulnerable to bad weather, such as windy, rainy, or extreme weather To the authors' knowledge, in some experiments, such as droplet analysis, variable rate spraying, and nozzle spraying effect, real flight is not necessary. Efficiency will increase if they are performed on a simulation system. Some spraying theory such as droplet evaporation (Teske et al., 2016), air assisted spraying

* Corresponding author at: Yuhangtang Rd 866, Hangzhou, Zhejiang, China.
E-mail addresses: yczhang@zju.edu.cn (Y. Zhang), yhe@zju.edu.cn (Y. He).

https://doi.org/10.1016/j.compag.2017.08.004
0168-1699/© 2017 Elsevier B.V. All rights reserved.

CFD calculation (Tsay et al., 2004) is better done in a controlled environment.

This paper describes the design and development of an indoor spraying simulation system that can simulate UAV farmland spraying. It is composed of 4 parts: upper machine software, central controller, X-Y moving part and far end spraying unit. The system can perform high precision UAV simulation spraying. Object and highlights

1. Development of a UAV spraying simulation platform, includes machinery, electrical hardware and user interface software. The machinery includes 2 servo motors for horizontal movement and vertical movement and a far end spraying unit. The hardware includes 2 control boards, sensors, and other speed controllers. Software was developed for the user on a PC.
2. CAN bus was used to communicate between the central board and the far end controller. CAN bus is highly resistant to interferences such as voltage and is discussed in detail.
3. The experiment was carried out to examine the performance of the platform. Water sensitive paper (WSP) was used for droplet analysis. After spraying at different conditions, WSP (water sensitive paper) were collected and scanned for droplet analysis. The results show that the deposit per cm2 has linear relationship with the moving speed and the wind speed has clear linear relationship with deposits DV1.

2. System design and structure

This system was built in a 12-m long 3.5-m wide room on the rooftop of a 7-floor building at N30.2983, E120.0909. The system mainly consists of four parts: the moving part, central controller, upper machine software, spraying part. The moving part is the horizontal motor and vertical motor. In this system, the servo motors' parameters are listed below. The reason why servo motors are chosen is that servo motors move with constant torque and can precisely control every spinning step.

A linear guide was selected for horizontal movement and an integrated actuator was used for vertical movement. A linear guide is often used for moving parts support and guidance and is commonly seen in highly precise mechanical structures such as industrial automation equipment, PCB printing and precise measurement apparatus. It features exceptional accuracy and bearing capacity. An actuator is more precise because there is a ballscrew inside to transform rotational movement to rectilinear movement. The nearly 300 kg system was suspended below the ceiling. To make a 12-m long guide rail, 3 4-m long HGH30HA linear rail rolling bearings (Hiwin Technology Corp, China) were mounted on channel steel and butt jointed. A linear guide has uniform bearing against forces from different directions because of its unique structure inside (Zhang et al., 2016). A reference surface was lathed on the base steel channel for the rail to be mounted. To reduce inner stress and make the structure stable, 2 sliders were bolted on a steel channel and formed a triangle with the vertical actuator. This structure can also resist instantaneous acceleration at start and deceleration at stop.

A Dorna servo motor (Dorna Technology, China Jiashan) was used to drive the sliders. The working power was 1200 W. At both ends of the rail, 2 photoelectric proximity switches were used: one for calibration and the other for position limitation. An NPN normally closed proximity switch (Roko technology Ltd, China Leqing) was used to detect if the slider came close. A proximity switch is a kind of very reliable sensor, which features quick response, long lifespan and strong anti-interference. Its detect distance is 5 mm. The proximity switch is powered by the central controller board and sends a pulse signal to the main controller. The position of proximity switches was set to be the horizontal original point in the system coordinates.

The actuator is an integration of servo motor and ball screw which can transform rotation from a motor to pushrod rectilinear motion. The servo motor used was a Panasonic MSME022G1 AC servo motor 200 W (Panasonic Co. Ltd, Japan Osaka). An electromagnetic NPN normally closed proximity switch was fixed at the bottom end of the actuator. Its working theory was similar to the horizontal but it senses the magnetic ring inside the actuator around the guide screw (see Figs. 1 and Fig. 2).

The system accuracy has been discussed in (Zhang et al., 2016). With different moving speeds, the horizontal repeated error was less than 2 mm, and vertical repeated error was 1 mm. The high control accuracy is due to the adoption of robust machinery parts and servo motor. The linear rail has strong resistance to vibration and the ball screw inside the vertical actuator has high precision. The servo motors divide 1 rotation into 2^{17} by the motor driver, the horizontal pulse equivalent is 0.001 mm, and the vertical is 0.0005 mm. This makes a good foundation for high accuracy.

2.1. Upper Machine software

The upper machine software is written in C++ as the figure shows. Microsoft Foundation Class was used for the GUI. OpenGL was used to demonstrate how the system works. The PC is connected to a wireless router so that the upper machine software can communicate with a mobile tablet via a Wi-Fi connection. If a user wants to have a close look into the system far from the PC, the tablet can control the system nearby. The communication between software and central control board uses UART serial in ASCII as is illustrated in Table 1 (see Fig. 3).

2.2. Central controller

The central controller was developed to control the whole system according to control orders received from the upper machine software. STM32F4 series micro controller was used to control moving parts. In this system, all controllers are STM32F1 micro controllers because they are reliable and have plenty of interfaces. The STM32F4 series micro controller was released by ST company (STMicroelectronics, Geneva Switzerland). It features high computing performance, a rich peripheral set and small package size. The STM32F4 series is based on Cortex™-M4 core running at 168 MHz. ST's 90 nm process, ART Accelerator and the dynamic power scaling enables the current consumption of STM32F4 in run mode and executing from Flash memory to be as low as 238 μA/MHz at 168 MHz. It has rich connectivity including 2xUSB OTG, 6xUART, 3xSPI, 3xI^{2}C, 2xCAN. It has 2 12-bit DAC and 3 12-bit ADC, which can meet the demand of analog signal collection. The central board is designed in the following way (see Figs. 4 and Fig. 5).

μVision IDE which is developed by the ARM company for program compiling, debugging, and burning into flash was used for programming. The software components contain libraries, source modules, configuration files, source code templates, and documentation. Software components can be generic to support a wide range of devices and applications. The μVision Debugger provides a single environment where you may test, verify, and optimize your application code. The debugger includes traditional features such as simple and complex breakpoints, watches windows, and execution control and provides full visibility to device peripherals.

LM2576 was used for the central board power supply with maximum 3 An output. It can transform 7–40 V DC input power into 5 V in an on-off switching way. The DC input power comes from an AC-DC converter. An MCP1825 (Microchip Inc., USA) linear regulator was used for STM32F4 power management. It outputs up to

دریافت فوری ← متن کامل مقاله

ISIArticles
مرجع مقالات تخصصی ایران

- ✓ امکان دانلود نسخه تمام متن مقالات انگلیسی
- ✓ امکان دانلود نسخه ترجمه شده مقالات
- ✓ پذیرش سفارش ترجمه تخصصی
- ✓ امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
- ✓ امکان دانلود رایگان ۲ صفحه اول هر مقاله
- ✓ امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
- ✓ دانلود فوری مقاله پس از پرداخت آنلاین
- ✓ پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات