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DEVELOPMENT OF A PWM PRECISION SPRAYING SYSTEM FOR UNMANNED HELICOPTER

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Abstract. *Application of protection materials is a crucial component in the high productivity of agriculture. Motivated by the needs of aerial precision application, in this paper we present a pulse width modulation (PWM) based precision spraying system for unmanned helicopter. The system is composed of the tank, pipelines, pump, nozzles and the automatic control unit. The system can spray with a constant rate automatically when the speed of the UAV fluctuates between 1 m/s to 8 m/s. The application rate can also be controlled by remote control terminal the automatic control unit is the core of the system which is composed of double-channel PWM controller, wireless communication module, GPS module and MCU. MCU obtains the helicopter flying speed real time and changes the output rate by moderating the flow of the pump and On-off time of the nozzle. PWM controller designed basing on the embedded PWM generator of ATmega128A and dual full-bridge driver chip L298. By the theory analysis and experiments in laboratory, the relationship model of output rate with helicopter flying speed and pump output rate with on-off time ratio of the nozzle were built. The optimal operating parameters of the system were obtained. If the pipeline pressure keeps constant, the output rate could be adjusted from 0.19L/min to 0.78L/min. If the PWM control method cooperates with regulation of pump work voltage, the output rate could adjusted from 0.10L/min to 1.28L/min. Tests for system performance are carried out and the results show that the controller has promise as a higher precision technique for spray applications, which will improve efficiency of pesticide application. The development of the UAV spraying controller has a great potential to enhance pest management over small crop plots or spots within a large crop field to realize highly accurate site - specific application. It is also very promising for vector control in the areas that are not easily accessible by personnel or equipment.*

Keywords. *Aerial spraying, PWM, UAVs*

Backgrounds

Protection of crop from insects and diseases is a crucial factor of crop management in agriculture. UAV, especially the unmanned helicopter, is more and more applied in pesticide and fungicide spraying in China. So far, most of UAVs used for spraying is manual controlled and fully autonomous UAVs in agricultural or vector control spray applications were seldom found. The flying speed of the UAV fluctuates strongly, and which leads to much difference of deposition quantity. The objective of this research was to develop an output rate controller for a manual remotely controlled helicopter which can precisely apply sprays for agricultural protection products. The emphasis with this present work is hardware design and control model of the controller.

Materials and Methods

UAV

The UAV used in our research were Vertical Take-off and landing helicopters which equipped with an autonomous stabilization control system. It is manufactured by Quanfeng corporation, a local crop protection UAV manufacture of China. The type of this helicopter is Q80,which is a gas one with a main rotor diameter of 2 m and a maximum payload of 15 kg.

Fig 2. The UAV used in our research

Design of PWM controller

The controller is developed based on the Atmega128L microcontroller chip (Atmel Corporation) and L298, an integrated monolithic circuit (ST microelectronics).

The ATmega128 is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega128 achieves throughputs approaching 1 MIPS per MHz allowing the system designed to optimize power consumption versus processing speed.

The L298 is an integrated monolithic circuit in a 15-lead Multiwatt and PowerSO20 packages. It is a high voltage, high current dual full-bridge driver de-signed to accept standard TTL logic levels and drive inductive loads such as relays, solenoids, DC and stepping motors. Two enable inputs are provided to enable or disable the device independently of the input signals. The emitters of the lower transistors of each bridge are connected together and the corresponding external terminal can used for the connection of an external sensing resistor. An additional supply input is provided so that the logic works at a lower voltage. Figure 2 is the block diagram of L298 and Figure 3 is the driver module based on L298 designed by us.

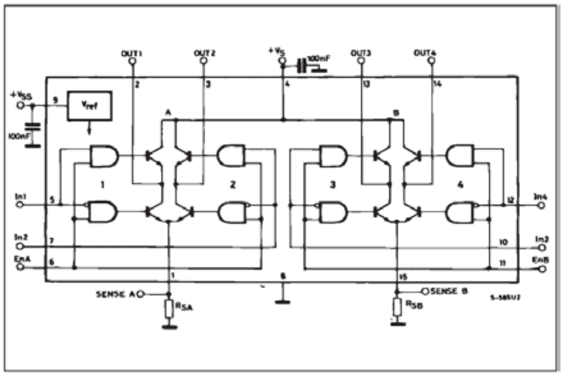

Fig 2. Block diagram of L298

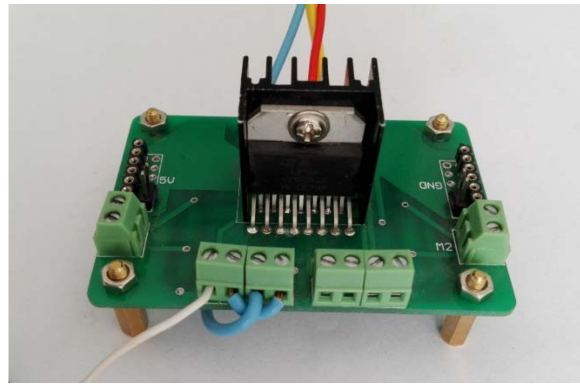

Fig 3. Driver module based on L298

The flying speed was acquire from a GNSS module, named u-blox PAM-7Q (U-box holding AG). It Highlights is embed GPS antenna, excellent antenna performance, low power consumption, form-factor compatible with UP501 and easy integration into design. We know that the application rate could be calculated as follows using average values of output rate, ground speed and effective swath width:

$$\mathrm{R} = \frac{QK_3}{VS}$$

Where

R = application rate, L/ha or kg/ha

Q = output rate, L/min or kg/min

K3 = constant, 600

V = ground speed, km/h

S = effective swath with, m

If the controller could adjust the output rate as the change of the helicopter flying speed to keep the ratio between Q and V constantly, then the application rate R shall keep constant. PWM moderate method was used to control the output rate, by which the output rate would has ration ship with on time percentage in one on-off cycle of the switch valve.

Figure.4 shows the controller and Figure 5 is the drive signal for switch magnetic valve output by the controller.

Fig 3. The PWM controller

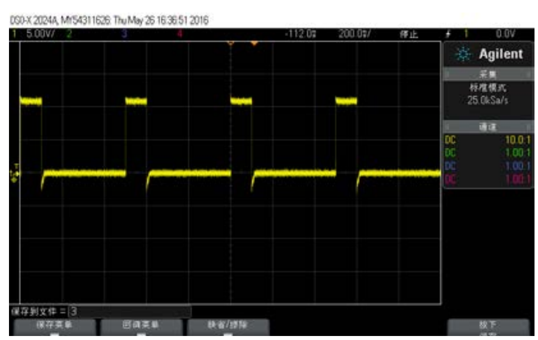

Fig 4. the drive signal for switch magnetic valve output by the controller.

Result and discussion

After design of the PWM controller, a platform was built to test the performance and to find the relationship between the output rate and the on-off time in one duty cycle. In the test, a high speed switch magnetic valve, a membrane pump and a surge tank were used. The magnetic valve could works at a pipeline pressure of 10 bar and with an on-off delay time 5ms. The pump could supply output rate as high as 4 literatures per minute. The surge tank could sustain pressure as high as 5 bars. After many test, 300ms was selected as the optimal cycle. Under this cycle, the relationship between output rate and the on time percentage in one duty cycle of valve is shown as table 1. If take duty cycle data as x-axis and output rate as y-axis, a relation curve has been got as figure 5.

Table 1. Experimental data between output rate and the on time percentage in one duty cycle of PWM controller

Duty cycle.	Pipeline pressure(bar)		
(%)	2	3	4
5	190	100	170
10	330	380	390
15	380	660	630
20	490	800	810
25	500	880	990
30	510	900	1100
35	570	940	1180
40	610	990	1230
45	650	1000	1270
50	710	1020	1280
55	730	1050	1280
60	750	1070	1280
70	780	1070	1280
80	780	1070	1280

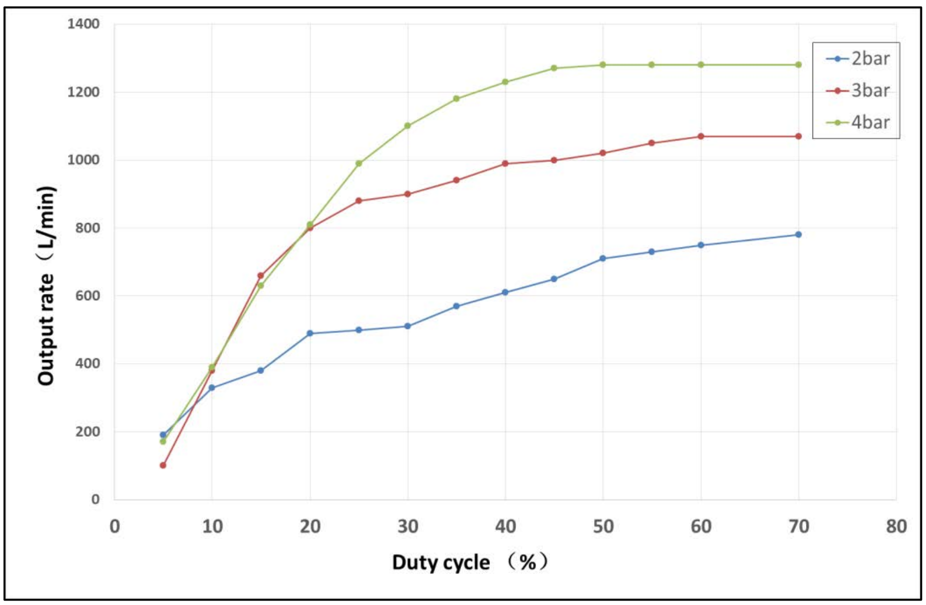

Fig 5. Relationship between duty cycle and output rate

Conclusions

The research has shown that a PWM controller was successfully developed for UAV precision spraying control. The optimal operating parameters of the system were obtained. If the pipeline pressure keeps constant, the output rate could be adjusted from 0.19L/min to 0.78L/min. If the PWM control method cooperates with regulation of pump work voltage, the output rate could adjusted from 0.10L/min to 1.28L/min. Tests for system performance are carried out and the results show that the controller has promise as a higher precision technique for spray applications, which will improve efficiency of pesticide application. The development of the UAV spraying controller has a great potential to enhance pest management over small crop plots or spots within a large crop field to realize highly accurate site‐specific application. It is also very promising for vector control in the areas that are not easily accessible by personnel or equipment.

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