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The low-cost remote steering control using the DC motor with feedback position

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ABSTRACT

The research proposed the design and installation of the DC motor with a feedback position used to control the steering direction of a rice-planting machine here will be converted into driverless robots. The MATLAB/Simulink software is used to simulate and measure signal drive from the servo controller board to obtain results that can be used to drive BTS 7960 motor driver module for the DC motor with feedback position. The SkyDroid T10 is used to remote control of steering direction of rice-planting machines and the mechanism to drive all robots. The results of test results of the robot spraying chemicals in rice fields were excellent. The operator can remotely control the robot through the camera from the mobile phone. The chemicals can be sprayed quickly, and the chemicals are distributed evenly and evenly into the ground.

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1. INTRODUCTION

Thailand, especially the central and northeastern regions, has a large area of rice cultivation. Farmers in the Northeast prefer to grow rice by embroidering the seedlings. In the central region, immigration farming is done, after which farmers are sprayed with herbicides that can be harmful to the body if inhaled and in contact with the skin. Carrying a chemical sprayer for a long time will cause extreme fatigue and high labor costs. The researchers saw this problem, so they designed a robot to spray chemicals [1], [2] that can be controlled by humans at a distance, using old rice-planting machines to make a low-cost modification to serve as a model for further development. In this research, the rice-planting machine was used to modify additional equipment to control work in place of human labor to spray chemicals in rice fields remotely that can be controlled. The remote control by using a radio transceiver. In a low-cost steering wheel to control robots or radio-controlled cars. It is the application of technology and innovation in agriculture [3]–[5] while labor shortage. or in areas at risk of exposure to chemicals in rice fields or agricultural plantations.

The control steering of the tractor with a remote control or navigation system when operating in the agricultural autonomous tractor driving mode [6], [7]. This is done by using the DC motor with a feedback position to drive the steering axis and control the DC motor [8] to rotate in the direction it commands by turning the steering wheel to make the tractor turn left, turn right, or keep running straight.

The desired steering angle is tracked under the control of the steering controller [9], [10]. An effective steering mechanism and excellent control method can improve the steering accuracy. At present, there are two kinds of steering control modes. The first one is that an additional hydraulic valve body is added based on the original hydraulic circuit, which is easy to control but inconvenient to install and maintain.

The second one is that a steering motor is added to realize the steering control, which is low–cost but complicated to control. The design of the steering control system directly affects the operation quality of the tractor. No matter which control mode is adopted, high control accuracy, good reliability, and fast response are necessary for a qualified automatic steering system. There are different approaches to designing steering control systems.

The objective of the research is to develop a steering control based on the control of the steering column using the DC motor. It is a more precise and cheaper and practical control method that is proposed for the steering system based on motor control. For clear illustration, the paper is organized as section 2 introduces the methods and materials of the steering control system structure and the mathematical model of the DC motor. The results and discussion are detailed in section 3. Finally, conclusions are drawn in section 4.

2. METHOD AND METERIALS

2.1. The mathematical model of DC motor

This experiment research uses the permanent magnet DC motor, which is often used for velocity and position control. This proposed DC motor control is using the armature input voltage control method. The equivalent circuit diagram of the DC motor is the electromechanical system with electrical and mechanical components as shown in Figure 1.

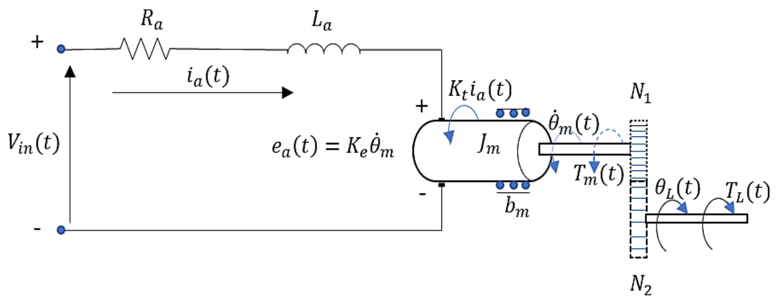

Figure 1. The equivalent circuit diagram of the DC motor

2.2. Electrical characteristics of the DC motor

As illustrated in Figure 1, the voltage is applied to the armature winding, a magnetic field is generated, reacting with the permanent magnet stator magnetic field to induce a torque [11] in the armature as shown in (1).

$$T_m = K_t i_a \tag{1}$$

Where T_m is the developed torque in the motor, K_t is the torque constant, and i_a is the armature current. The armature winding intersects the resultant magnetic field, a reverse emf is applied to the armature winding as shown in (2).

$$e_a(t) = K_b \frac{d\theta_m(t)}{d_t} = K_b \omega_m \tag{2}$$

Where e_a is the back electromotive force (EMF), K_b is the EMF constant, ω_m is shaft angular velocity, R_a is the armature resistance, L_a is the armature inductance, θ_m is the motor shaft output angle and V_{in} is the input voltage. The electrical equivalent circuit in Figure 1 can be applied Kirchoff's law of voltage as following:

$$V_{in} - V_R - V_L - e_b = 0 \tag{3}$$

$$V_{in}(t) = R_a i_a(t) + L_a \frac{di_a(t)}{dt} + K_b \frac{d\theta_m(t)}{d_t} \tag{4}$$

Rearrangement and taking Laplace transform, given as (5).

$$V_{in}(s) = R_a I_a(s) + L_a s I_a(s) + K_b s \theta_m(s) \tag{5}$$

The transfer function of DC motor electric component related armature current, and voltage is as:

$$\frac{I_s(s)}{[V_{in}(s)-K_b\omega(s)]}=\frac{1}{(L_a s+R_a)} \tag{6}$$

$$I_a(s)=\frac{[V_{in}(s)-K_b\omega(s)]}{(L_a s+R_a)} \tag{7}$$

2.3. Mechanical characteristics of DC motor

As illustrated in Figure 1, the mathematical model can be derived in the sum of the torques must equal to zero, we have,

$$K_{t.}i_a(t)-T_L(t)-J_m\left(\frac{d^2\theta_m}{dt^2}\right)-b_m\left(\frac{d\theta_m}{dt}\right)=0 \tag{8}$$

taking the Laplace transform, we have

$$K_t I_a(s)=(J_m s+b_m)s\theta_m(s)+T_L(s) \tag{9}$$

Where T_L is the load torque, b_m is the damping friction, and J_m is the inertia of motor.

The mechanical component transfer function in term of output torque and input rotor speed is given by (10).

$$\frac{\omega_m(s)}{K_t I_a(s)-T_L(s)}=\frac{1}{J_m s+b_m} \tag{10}$$

If no load attached, $T_L=0$, we have

$$\frac{\omega_m(s)}{K_t I_a(s)}=\frac{1}{J_m s+b_m} \tag{11}$$

then,

$$K_t I_a(s)=(J_m s+b_m)s\theta_m(s) \tag{12}$$

substituting (8) in (13), gives.

$$K_t\left[\frac{1}{L_a(s)+R_a)}\right][V_{in}(s)-K_b\omega(s)]=[J_m s^2\theta_m(s)+b_m s\theta_m(s) \tag{13}$$

The open-loop transfer function of the DC motor without load attracted relating the input voltage to the motor shaft output angle is given by (14).

$$\frac{\theta_m(s)}{V_{in}(s)}=\frac{K_t}{s[(L_a s+R_a)(J_m s+b_m)+K_t K_b]} \tag{14}$$

The open-loop transfer function of the dc motor without load attracted relating the input voltage to the motor shaft output angular velocity is given by (15).

$$\frac{\omega_m(s)}{V_{in}(s)}=\frac{K_t}{[(L_a s+R_a)(J_m s+b_m)+K_t K_b]} \tag{15}$$

The simplification of the open-loop of the DC motor response is dominated by the slow mechanical time constant and the electric time constant is faster. Thus, assume that the armature inductance is equal to zero. The simplification of the open-loop transfer function of the DC motor without load attracted relating the input voltage to the motor shaft output angular velocity is given by (16).

$$\frac{\omega_m(s)}{V_{in}(s)}=\frac{K_t}{[(R_a J_m)s+(R_a b_m)+K_t K_b]} \tag{16}$$

The simplification of the open-loop transfer function of the DC motor without load attracted relating the input voltage to the motor shaft output angle is given by (17).

$$\frac{\theta_m(s)}{V_{in}(s)} = \frac{K_t}{s[(R_a J_m)s+(R_a b_m)+K_t K_b]} \tag{17}$$

2.4. The block diagram of DC motor with gearbox

As illustrated in Figure 1, the transfer function of equations mentioned above, we can draw a block diagram showing the operation of a DC motor as follows in Figure 2. The open-loop block diagram of the DC motor with the gearbox is shown in Figure 3. Figure 3 shows the block diagram of the transfer function of the DC motor with the gearbox which it is used input voltage, V_{in} to control the shaft output of steering position, θ_L.

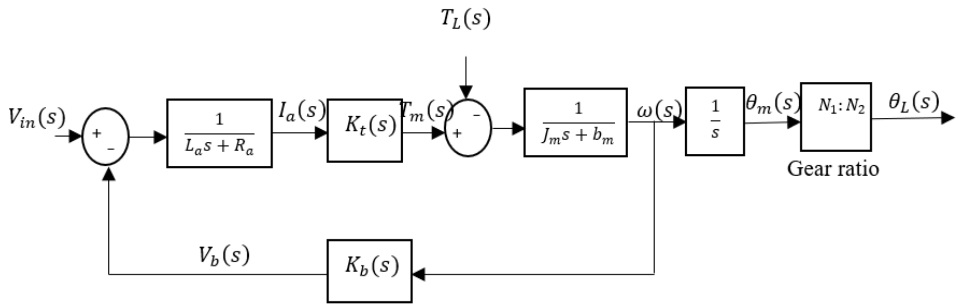

Figure 2. The open-loop block diagram of DC motor with the gearbox

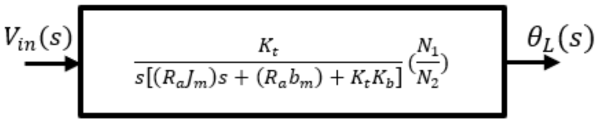

Figure 3. The block diagram of the DC motor with the gearbox

2.5. The overall of block diagram of control system

We used the servo controller board from a part of the servo drive, then wire connect to drive a BTS7960 to drive the DC motor as a servo motor [12], [13]. The potentiometer connected to the rod of the steering wheels and sent the feedback signal to the servo controller board. The RC receiver of the SkyDroid T10 set is used to command signal input to the servo controller board. The circuit diagram is shown in Figure 4. As illustrated, Figure 5 shows the overall block diagram of the position control system using a feedback potentiometer.

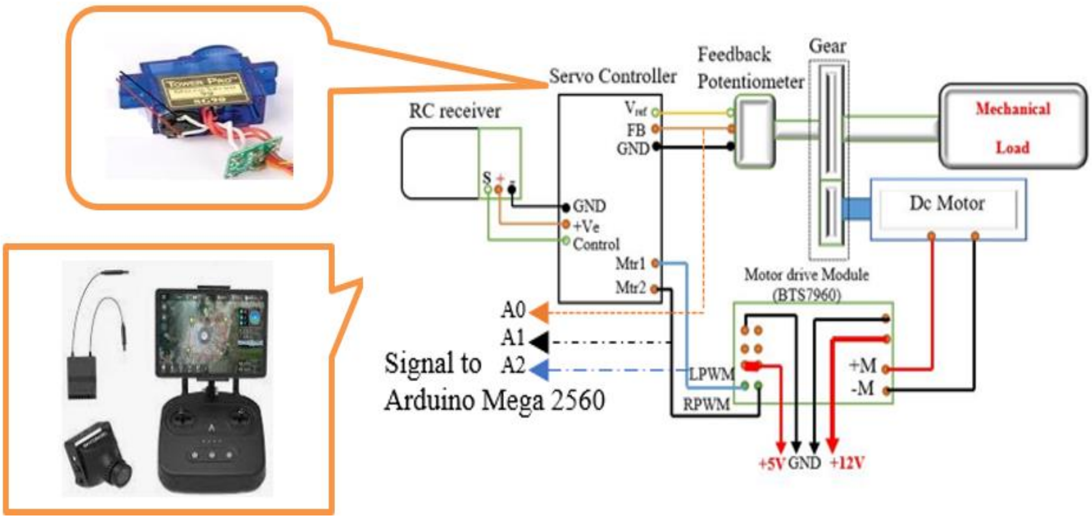

Figure 4. The overall architecture circuit diagram

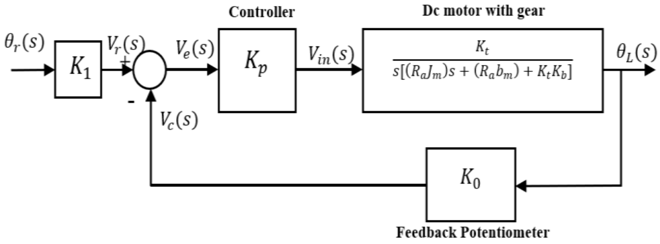

Figure 5. The overall block diagram of system

3. RESULTS AND DISCUSSION

The mathematical model equation of the DC motor is using MATLAB program for analysis. The block diagram of the transfer function is using MATLAB/Simulink [14], [15] to evaluate, test, and verify the correctness of DC motor characteristics. The equipment installation results, test simulation, and a real remote steering control system test can be described as the following topics.

3.1. Installing of hardware on rice planting machine

Installing a DC motor to turn the steering wheel is shown in Figure 6. The mechanism control drive is used a programmable logic controller (FX3U-48MR) [16]–[20]. There is an input signal from various sensors, from a radio transmitter. The signal from the radio receiver is connected to the RC relay unit that feeds the signal to the input of FX3U as shown in Figure 7. As for other mechanical systems such as the clutch pedal, gear knob, and accelerator pedal, the researcher uses the DC linear actuator [21]–[23] as a driver by receiving control commands from the programmable logic controller.

Figure 6. Install the DC motor to steering wheel

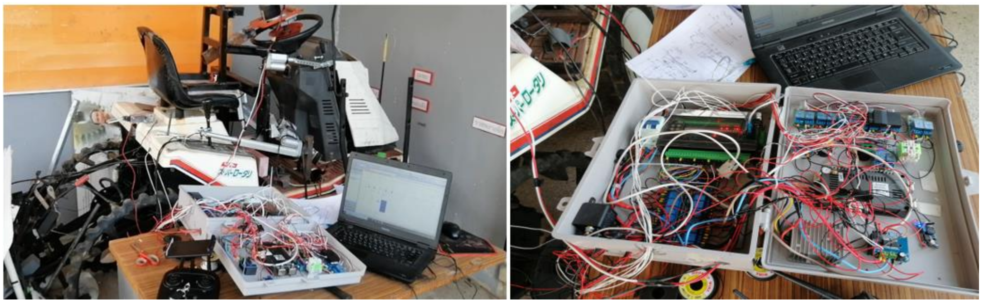

Figure 7. The PLC type FX3U, and Flysky type FS-i6x radio control and the RC module

3.2. Results of the open loop DC motor simulation with MATLAB/Simulink program

The parameters of the DC motor in this study are shown in Table 1. By using these equations above, the DC parameters, and the Simulink model of the DC motor without the controller compensate. We get the time response of the characteristics of the equation shown in Figure 8. Shows a simulated and uses the ‘plotscope’ function [24] to capture the scope plot and produce a figure plot.

Table 1. The DC motor parameters

Parameters	Notation	Value
Voltage input	u	12 V
Armature resistance	R_a	3 Ω
Viscous friction	b_m	$1x10^{-8}$ Nm/rad/s
Inertia at the armature	J_m	0.00025 kgm^2
Motor back emf constant	K_b	0.0637 V/rpm
Motor torque constant	K_t	0.066 Nm/A

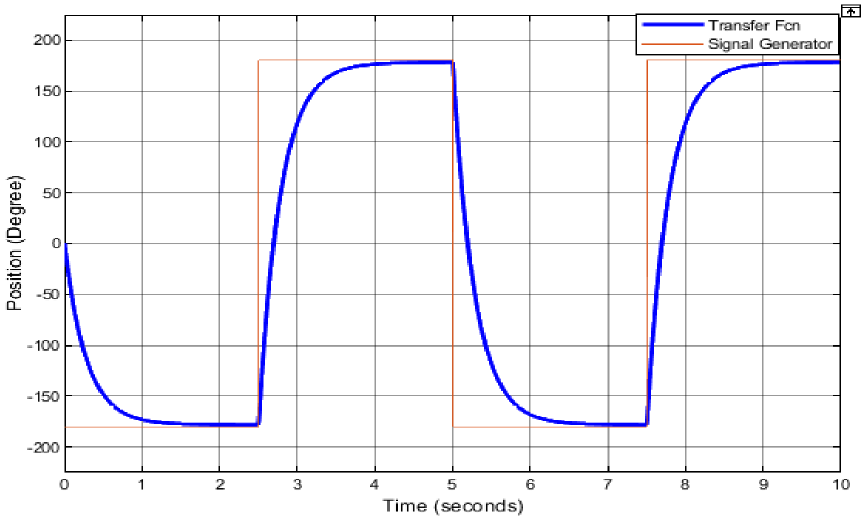

Figure 8. The overall architecture circuit diagram

3.3. Results of testing circuit for small DC motor

We have finished testing our model in Simulink. It has to be prepared for implementation on real-time hardware. This means the system model has to be replaced by the I/O components that form the interfaces to the real plant. The testing of speed and direction control circuit to small DC motor [25] before real installation to the robots is shown in Figure 9. The measure of the signal controller to drive the DC motor is shown in Figure 10.

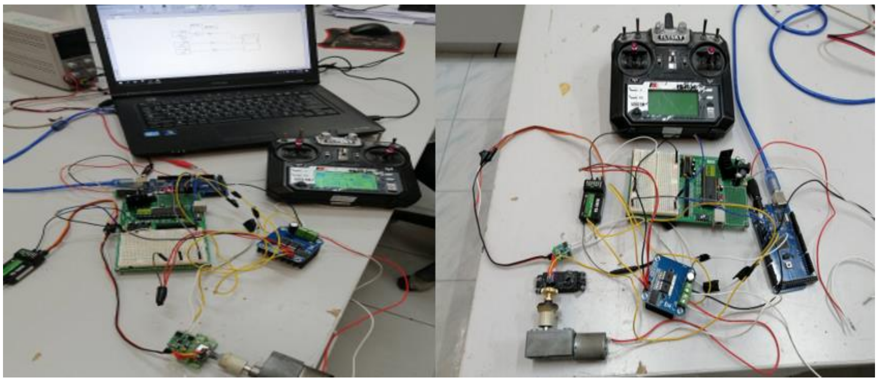

Figure 9. Measuring signal from the control circuit set

3.4. Testing results of remote steering control for rice planting machine on the road and rice filed

Before taking the robot to a real test to spray chemicals in the rice fields. The propulsion system and the steering wheel steering remote test were carried out on the road to test and improve the robotic propulsion test shown in Figure 11. The robot was tested in rice fields to spray chemicals at a long distance, as shown in Figure 12. Figure 13 shows how to use the SkyDroid T10 with an android mobile phone that is connected via USB with an application. Visualize to control the robot at a distance through mobile visualization.

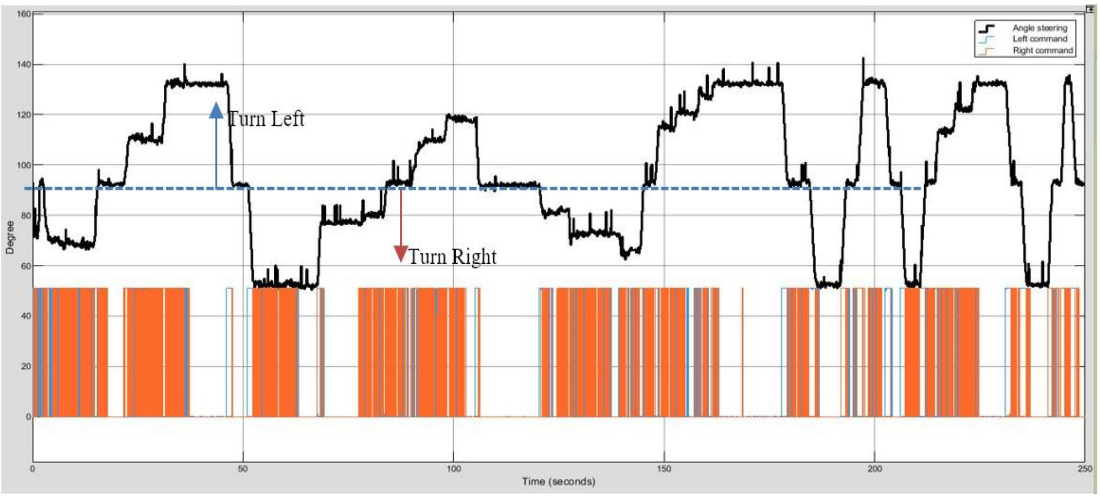

Figure 10. Measure signal from servo controller board by Arduino Mega 2560 with MATLAB

Figure 11. Test drive the robot steering on the road

Figure 12. Test drive a robot and spray chemicals in the rice fields

Figure 13. Control robots by the SkyDroid T10 with android phone

4. CONCLUSION

This research focuses on the design and installation of a DC electric motor with the potentiometer position feedback to control the steering of rice planting machines converted to a chemical spraying robot in rice fields. Humans can control a robot by using the SkyDroid T10 which has an application to transmit video to an android phone to see the direction of movement of the robot steering. The test results can quickly control the rotation of the steering wheel to control the robot as a quick response. The control distance is not more than 1 kilometer in rice fields. The result of using robots to replace human labor for spraying chemicals in rice fields reduces the risk of chemical exposure. The robot can spray chemicals quickly and consistently. It takes less time to spray chemicals per area than manual labor.

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