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Three-position gearshifts remote control for agricultural tractors

Thewin Sakunbunyong[1], Tossapol Jangnoi[2], Tanawat Chalardsakul[1], Viroch Sukontanakarn[1]
[1]Department of Mechatronic Engineering, Rajamangala University of Technology Isan, Khon Kaen Campus, Khon Kaen, Thailand
[2]Department of Mechanical Engineering, Rajamangala University of Technology Isan, Khon Kaen Campus, Khon Kaen, Thailand

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ABSTRACT

This research presents the development and evaluation of a three-position gearshifts remote control system for agricultural tractors, designed to improve operational efficiency and reduce operator fatigue. The system utilizes a programmable logic controller to remotely control a linear actuator, enabling seamless gear shifting between three predetermined positions. The primary objective is to provide operators with a convenient, ergonomic alternative to traditional manual gear shifting, particularly in challenging or confined working environments. The system was tested under two conditions: first, with a programmable logic controller controlling the linear actuator via a remote transmitter; second, with the system installed on an actual tractor and tested in a road scenario. Results from both tests demonstrate the system's effectiveness in enhancing ease of operation, reducing physical strain, and maintaining gearshifts precision. The findings suggest that the remote control system offers significant potential for improving tractor operation, particularly for tasks requiring frequent gear changes or when working in difficult terrain. This research contributes to the ongoing development of automation in agricultural machinery, offering insights into remote control applications and the integration of electromechanical systems in agricultural vehicles.

Corresponding Author:

Tossapol Jangnoi
Department of Mechanical Engineering, Rajamangala University of Technology Isan, Khon Kaen Campus
Khon Kaen, Thailand
Email: tossapol.ja@rmuti.ac.th

1. INTRODUCTION

In the future, tractors are likely to become one of the most widely used vehicles in agriculture. These tractors can operate both day and night and can be remotely controlled. Engineers are designing control systems for driverless tractors [1] with new components, which fall into two categories: one using an engine as the power source and the other using electric motors. The control mechanism involves designing a program, platform, and GPS navigation system to automatically guide the vehicle along a predetermined path. Autonomous tractors tend to be expensive due to their complex mechanical systems. The autonomous tractors [2]–[4] can be categorized into two types based on their control systems: the manually controlled type, known as remote-controlled tractors [5], and those that use navigation systems [6], commonly referred to as GPS-based systems [7].

Currently, the agricultural industry uses tractors in various forms, operating year-round for tasks such as soil preparation, planting, and harvesting. In the future, the industry may introduce autonomous robotic tractors [8] to address labor shortages, potentially replacing human labor. Many countries are already designing and developing new agricultural platforms, focusing on robotic systems and remote-controlled platforms. Notably, countries like Japan, China, the United Kingdom, Spain, France, Germany, and the United States are leading this development due to labor shortages and rising production costs.

Many studies have explored the use of wireless remote control for managing various agricultural machinery functions, including gear shifting. The wireless control systems for tractors, which allow the operator to change gear positions, steer, or control implements from a distance. The system used Bluetooth or radio frequency communication and aimed to increase the flexibility and usability of tractors in fields with limited space or complex layouts [9]. The automatic gear-shifting strategy for fuel savings by tractors based on real-time identification of draught force characteristics. While this is not strictly a remote-control system, it involves automation that helps tractors operate more efficiently without manual intervention [10]. The application of computer simulation technology in the development of tractor transmission systems, as the transmission system of tractors differs significantly from that of road vehicles [11].

The mechanical control system for tractors typically includes a two-position or two-directional control system for functions such as steering, braking, clutch, throttle, rear lift lever, and gear shifting. Human operators control the tractor's hydraulic systems for power and direction using their hands and feet. The team operated the tractor at three different speeds gear 1 at 10 km/h, gear 2 at 15 km/h, and gear 3 at 20 km/h, across various terrain conditions, such as dry, compacted soil, tilled soil, and asphalt road. Designing a three-position control system is more complex, as it requires sequential control, such as selecting positions 1-2-3, 3-2-1, 1-3, 2-3, 3-2, and 3-1. For tractors commonly used in Thailand, engineers implement the three-position control system through a shuttle gear lever that switches between forward and reverse gears and selects gears to adjust the tractor's speed.

This research presents the design of a three-position gearshift selector controlled by a programmable logic controller, with a position detection system for the gear lever, operated via remote radio control. Since an autonomous driving system requires navigation to control the tractor's direction and a system to stop the vehicle, humans still need to manually select the initial gear when starting. Engineers can implement the gear control system using a lever or pedal to replace human hands or feet in two ways: by using pneumatic or hydraulic cylinders [12], [13] or by selecting linear actuators. In this research, the team uses a linear actuator to control the gear lever, as shown in Figure 1, which illustrates the three-position control system.

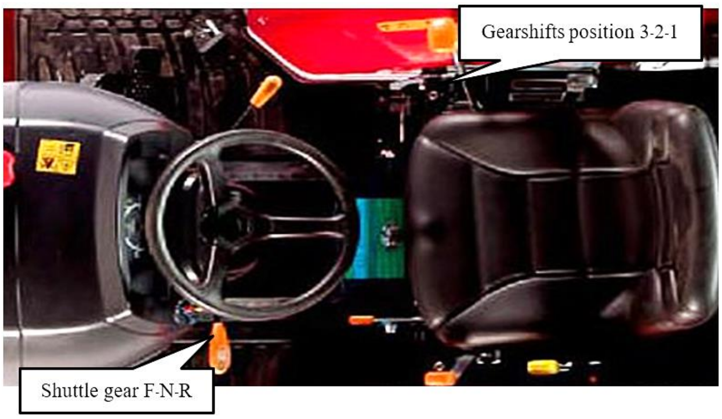


Figure 1. The three-position gear selector lever stalk of the prototype tractor

An electric linear actuator [14] in this research is used to drive a screw or belt mechanism, converting rotational motion into linear motion. These actuators are often used in applications where precise control and moderate force are required, such as in robotics and automation systems. The programmable logic controller can be used to control linear actuators in robotics applications or to drive components in vehicles.

The objective of this research is to develop a remote control system for selecting gearshifts positions based on a programmable logic controller and utilizing an electric linear actuator. This proposed method is more precise, cost-effective, and practical compared to existing methods. For clarity, the paper is organized as follows: section 2 describes the research method, including the structure of the linear actuator control system and the mathematical modeling. The results and discussion are presented in section 3, and conclusions are drawn in section 4.

2. RESEARCH METHOD
2.1. Overview of the proposed system
The overall architecture of the system is shown in Figure 2. The control system can be divided into two parts: the tractor side and the user side. The programmable logic controller is responsible for controlling the clutch pedal and selecting the 1-2-3 gear positions. Instead of using human muscles, arms, and legs, a low-cost electric linear actuator is employed to control the agricultural tractor. On the user side, control modes are selected using the Flysky FS-i6A and FS-iA6B radio transmitters [15]. The CH-3 channel controls the tractor's braking, the CH-5 channel is used to select the gearshift positions for the 1st and 2nd gears, and the CH-6 channel is used to select the 3rd gear position.

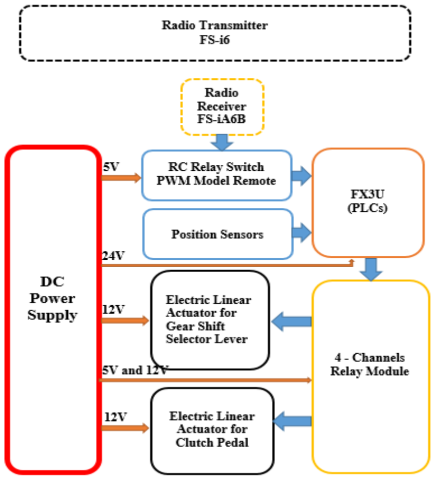


Figure 2. The block diagram of system architecture control

2.2. Electrical and mechanical model
An electric linear actuator typically consists of a direct current (DC) motor, a lead screw or ball screw, a nut or carriage, and a housing. Figure 3 show the equivalent mechanical circuit and its equation variables.

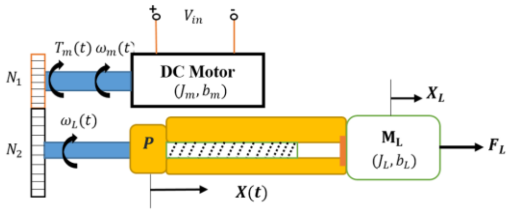


Figure 3. Representative of electric linear actuator with load

The open-loop transfer function of the DC motor [16] with a load, which relates the input voltage to the motor shaft's output angle, is given in (1)-(3).

$$\frac{\theta_L(s)}{V_{in}(s)} = \frac{K_t\left[\frac{N1}{N2}\right]}{L_a J_T s^3 + (R_a J_T + b_T L_a)s^2 + (K_t K_b + R_a b_T)s} \tag{1}$$

$$J_T = J_m + J_L \left(\frac{N_1}{N_2}\right)^2 \tag{2}$$

$$b_T = b_m + b_L \left(\frac{N_1}{N_2}\right)^2 \tag{3}$$

The translation of angular motion to linear motion is represented in (4)-(6).

$$\theta_L(t) = \frac{2\pi}{l} \tag{4}$$

Define $P = 2\pi/l$ and replaced in (4). We have:

$$\theta_L(t) = Px(t) \tag{5}$$

Replace (5) in (1), we have:

$$\frac{X(s)}{V_{in}(s)} = \frac{K_t\left[\frac{N1}{N2}\right]}{P(L_aJ_Ts^3+(R_aJ_T+b_TL_a)s^2+(K_tK_b+R_ab_T)s)} \tag{6}$$

where $V_{in}(s)$ is the input voltage command, T_m is output torque of the motor, K_t is the torque constant, R_a is the armature resistance, L_a is the armature inductance, K_b is the electromotive force constant, J_T is the total rotation inertia, b_T is the total viscous friction, J_L is the load rotation inertia, b_L is the load viscous friction, J_m is the motor rotation inertia, b_m is the motor viscous friction, P is the conversion ratio of linear to rotational motion, X is the displacement of linear actuator, F_L is the load disturbance, M_L is the mass of load, N_1 and N_2 are the numbers of teeth of gear 1 and gear 2 respectively, and l is the ball screw lead. Figure 4 shows a block diagram of the motor when a DC electric voltage is applied.

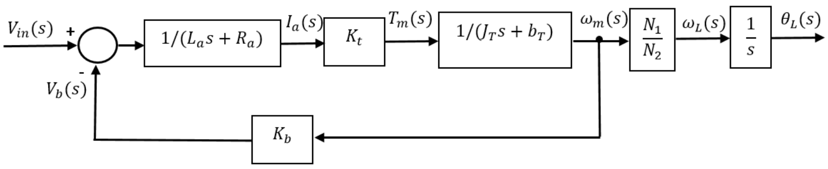


Figure 4. Block diagram of motor position with speed changer

2.3. Hardware setup and experiment in laboratory

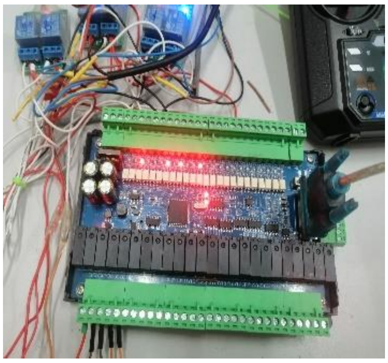
The operational test of the three-position remote gearshift control system is shown in Figure 5. The operational circuit includes a programmable logic controller [17] model FX3U, which is connected to the hardware and operated using the GX Works2 software [18] installed on a personal computer. The system is controlled via an FS-i6 radio transmitter, with the FS-iA6B receiver [19], [20] sending control signals to the remote control (RC) module shown in Figure 6. These signals are input to the programable logic controller (PLC) to execute the programmed instructions as depicted in Figure 6(a) show a transmitter FS-i6. Figure 6(b) is run program GX Works2 write ladder program of the system, and Figure 6(c) FX3U programmable logic control board.

The circuit connection from the FS-iA6B radio receiver to the RC relay module [21], [22] for each signal channel, sending the input signal to the input section of the FX3U programmable logic controller. Figure 7(a) shows CH-3 controlling the X7 and X10 inputs of the FX3U PLC. Figure 7(b) shows CH-5 controlling the X0 and X1 inputs of the FX3U PLC, and Figure 7(c) shows CH-6 controlling the X7 and X10 inputs of the FX3U PLC.

Figure 5. Overall setup of the practical program test in the laboratory

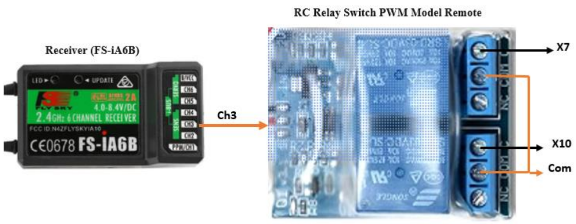
(a)

(b)

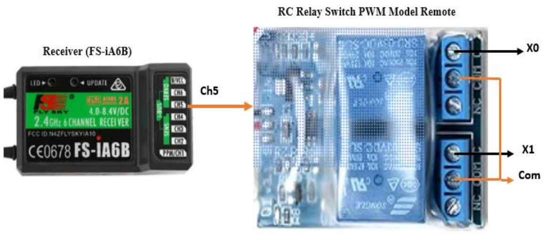


(c)

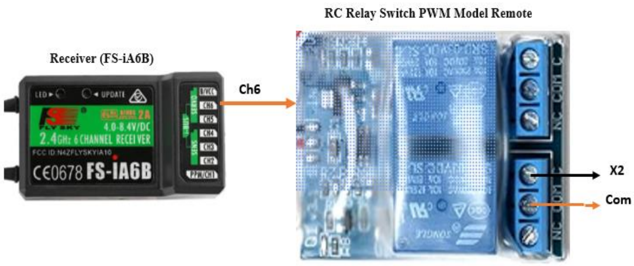
Figure 6. Device showing implementation of the proposed system; (a) transmitter FS-i6, (b) GX Works 2 write ladder program of the system, and (c) FX3U programmable logic control board



(a)



(b)



(c)

Figure 7. Radio receiver connected to the RC module on each channel; (a) Ch3 connected, (b) Ch5 connected, and (c) Ch6 connected

The four-channel relay module receives commands from the PLC and drives the DC linear actuator of the clutch and gear position selection system to move forward or backward, a process referred to as shuttle shifting gear [23], [24] in accordance with the commands, as depicted in Figure 8. The connection of the photoelectric sensor [25], [26] sends signals to the input section of the PLC, as shown in Figure 9. Figure 9(a) shows a photoelectric sensor that detects the gear position and sends a signal to the X4 input address of the PLC. Figure 9(b) shows another photoelectric sensor that detects the gear position and sends a signal to the X5 input address of the PLC, while Figure 9(c) shows a photoelectric sensor that detects the gear position and sends a signal to the X6 input address of the PLC.

Figure 10 illustrates the input and output assignment address for ladder programming, along with the external circuit connections for the programmable logic controller. Figure 11 show the gearshifts selection diagram for the prototype tractor, illustrating both sequential and skip-shifting methods. This includes shifting from position 1 to position 2, from position 2 to position 3, skipping from position 1 directly to position 3, and from position 3 to position 2, as well as shifting from position 2 to position 3, and skipping from position 3 directly to position 1. In Figure 12, the ladder diagram for the gearshifts position circuit is presented, created using the GX Works2 program for the FX3U programmable logic controller.

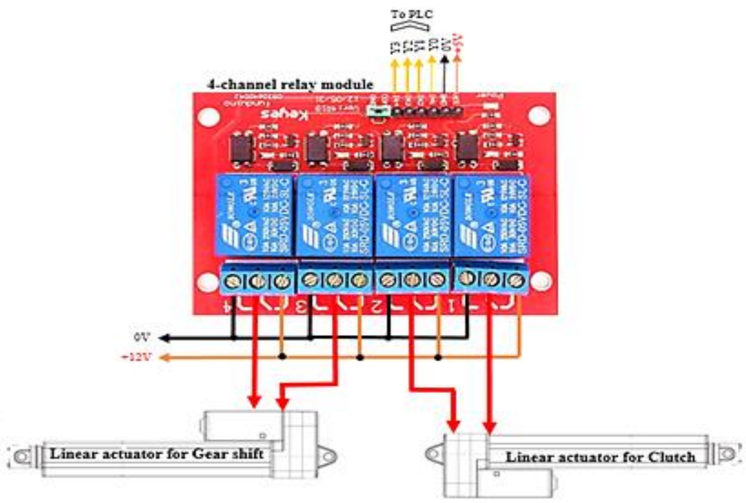
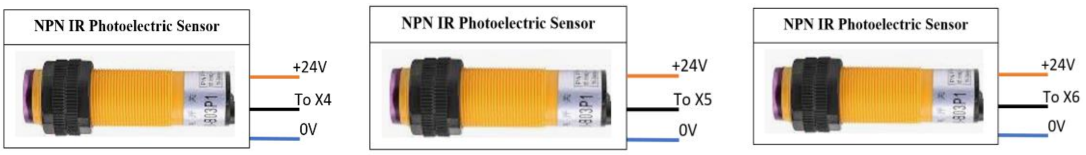
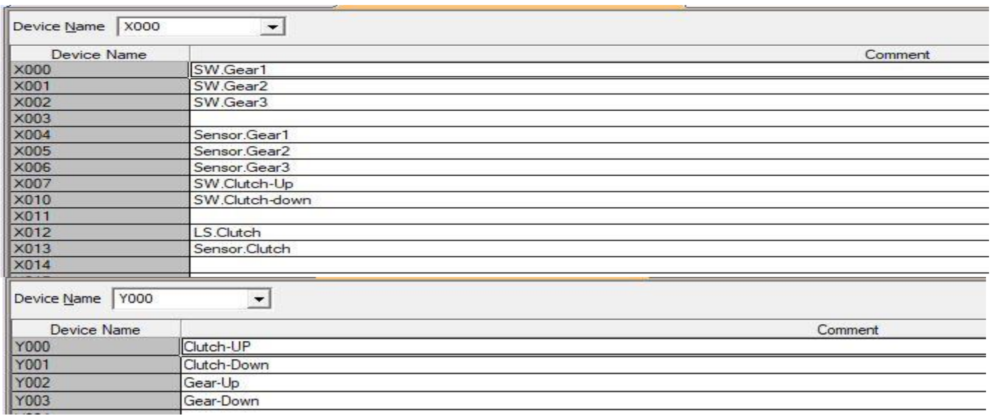


Figure 8. The 4-channels relay module dtives the DC linear actuator and its connection to a PLC



(a) (b) (c)

Figure 9. NPN IR photoelectric sensor for a gearshift selector lever and its connection to a PLC; (a) connect to X4, (b) connect to X5, and (c) connect to X6



Device Name X000

Device Name	Comment
X000	SW.Gear1
X001	SW.Gear2
X002	SW.Gear3
X003	
X004	Sensor.Gear1
X005	Sensor.Gear2
X006	Sensor.Gear3
X007	SW.Clutch-Up
X010	SW.Clutch-down
X011	
X012	LS.Clutch
X013	Sensor.Clutch
X014	

Device Name Y000

Device Name	Comment
Y000	Clutch-UP
Y001	Clutch-Down
Y002	Gear-Up
Y003	Gear-Down

Figure 10. I/O assignment of the PLC

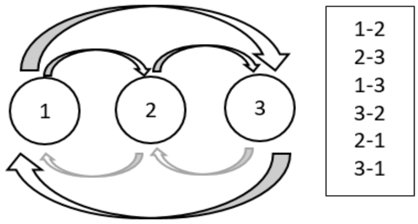


Figure 11. The gearshifts diagram of three position for a tractor

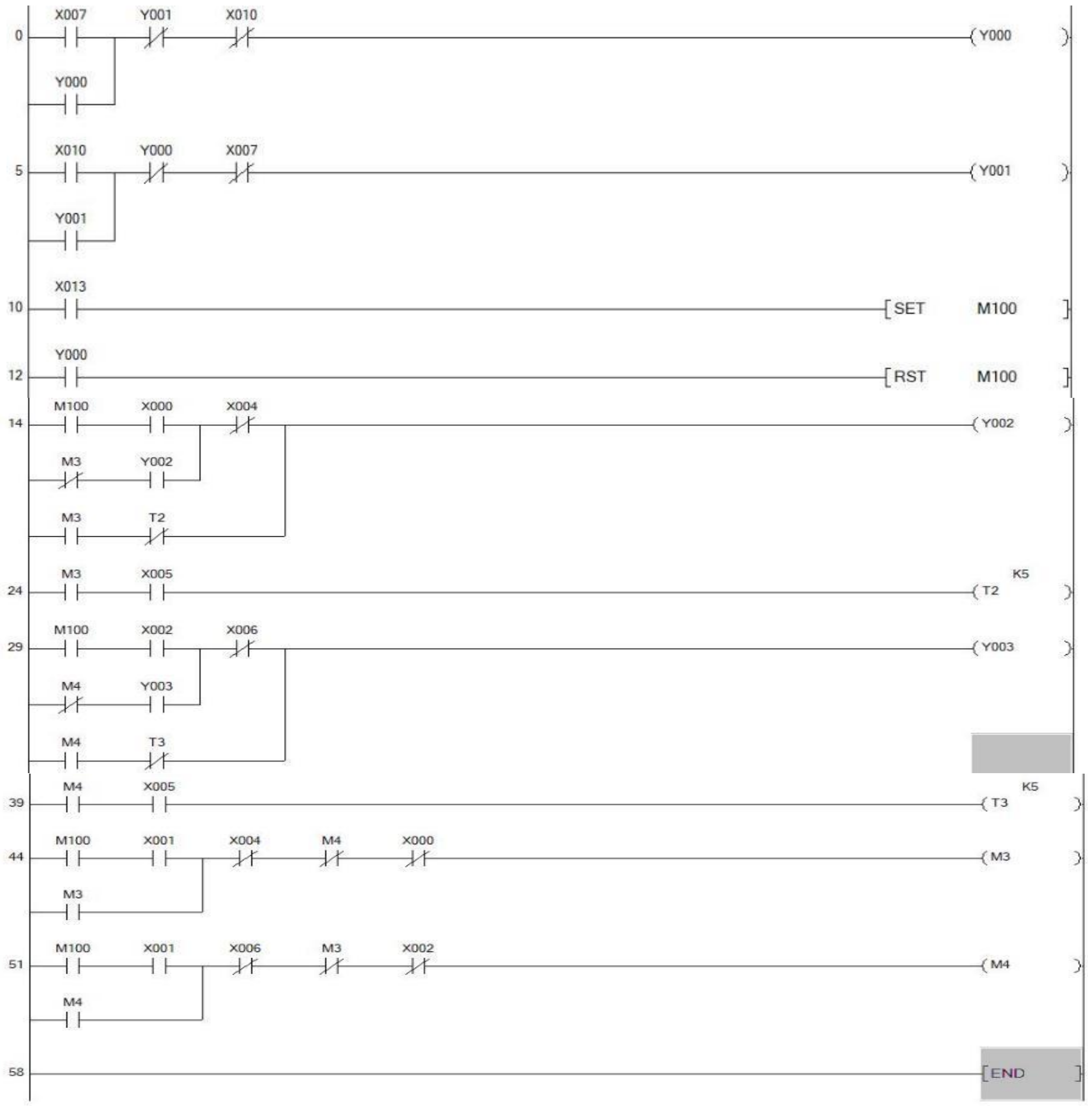


Figure 12. Ladder diagram of the proposed control system method, created using GX Works2

3. RESULTS AND DISCUSSION

This article presents only the control of gearshifts position selection, excluding other remote control systems. From the test of the remote gearshifts selection system to change the speed of the tractor, the test results can be divided into two cases. The first case involves testing a programmable logic controller to control a linear actuator to move to the desired position based on commands from a remote control transmitter. The second case involves installing the equipment on the tractor and conducting a test. The results of the tests are shown as follows.

3.1. Results of experiment in the laboratoty

The laboratory test results are shown in Figure 13. The testing of the sequence gearshifts with three-position selection is conducted using a control switch from the remote radio transmitter. It features two linear actuators: the first actuator presses the clutch pedal, while the second actuator pushes the gear lever to the desired position as specified by the user. Additionally, sensors detect the positions of the gear and clutch, providing feedback to the programmable logic controller. Figure 13(a) shows the result of selecting the gear in the 3th position, Figure 13(b) shows the result of selecting the gear in the 2nd position, and Figure 13(c) shows the result of selecting the gear in the 1st position.

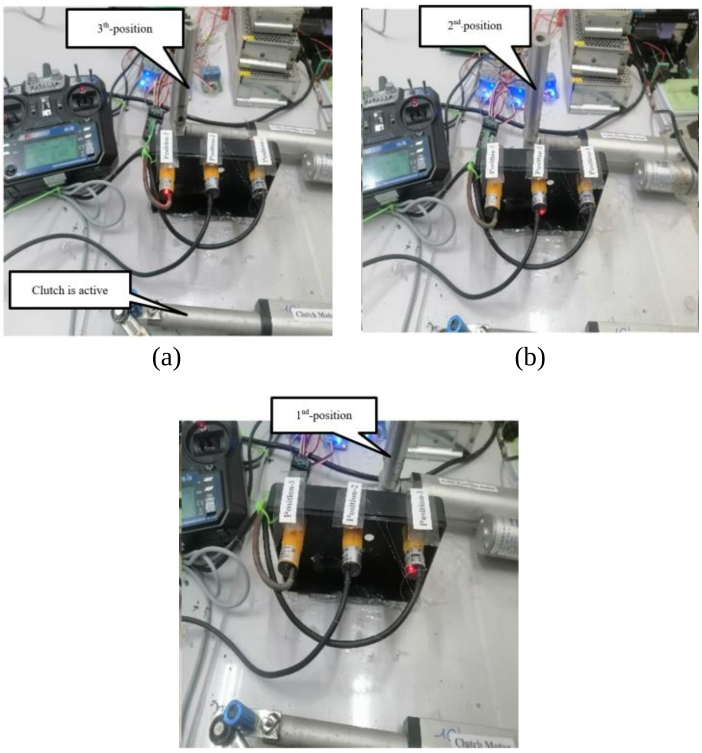


Figure 13. Laboratory test of gearshifts position selection using the control switch from the remote radio transmitter; (a) results of selecting gear 3th position, (b) results of selecting gear 2nd position, and (c) results of selecting gear 1st position

3.2. Results of hardware installation on agricultural tractor and operational testing

All equipment has been installed on the tractor. This section will focus on the control used to select the three gear positions. The same control method as in the shuttle gear system is employed, which features a lever for selecting positions: forward, neutral, and reverse, thereby enabling control over the three gear positions. In Figure 14, it can be seen that when the switch on the radio transmitter is pressed, the clutch pedal is engaged, after which the gear is selected according to the operator's desired position. Once the clutch is released, the tractor will begin to move forward or backward based on the selected shuttle gear position.

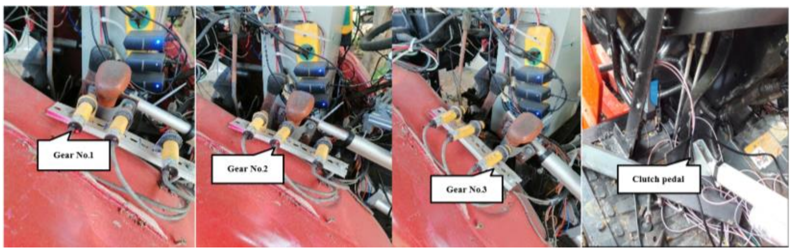


Figure 14. Installation and test operation of the gearshift position sensor on a real tractor

The testing of the remote-controlled tractor drive system is a comprehensive evaluation; however, this article focuses on the method for controlling the three-position gear sequence using the FS-i6 FLYSKY radio receiver for remote control. The test begins by pressing the switch to engage the clutch, followed by selecting the desired gear for operation. After that, the clutch, controlled by the DC actuator, is released, allowing the tractor to move in the desired direction, as shown in Figure 15.

The three-position gearshifts remote control system allows for remote shifting between three gear positions on a tractor, typically controlled via a linear actuator or a motorized system. This remote control enhances the operator's flexibility and convenience by enabling them to change gears without manually operating the gearstick. Which is particularly useful for tractors working in tight spaces or on road with varying terrain.

Figure 15. Testing drive of an agricultural tractor using radio remote control on the road

4. CONCLUSION

The three-position gearshift remote control system is a significant step forward in making tractor operation more efficient and less physically demanding. However, compared to other research, it is relatively simple in terms of automation, with most advancements focusing on more comprehensive, multi-functional, or automated systems that enhance precision, fuel efficiency, and user comfort. Further research may lead to the development of more integrated systems that combine remote gearshifts control with other automated agricultural tasks, such as steering or operational monitoring. The test results for the three-position gearshift functioned as designed. The linear actuator used in this system must be installed with a gear lever that is aligned in a straight line to control the gearshift selection and allow the tractor to move at the desired speed. Therefore, future research could potentially expand into navigation systems using GPS for autonomous movement, long-range vision with video cameras, communication via the internet, artificial intelligence for controlling direction, obstacle avoidance, and command control for various system components. The advancement of robotic tractors for the global agricultural sector presents a significant challenge due to these specific domains.

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REFERENCES

[1] A. Ghobadpour, L. Boulon, H. Mousazadeh, A. S. Malvajerdi, and S. Rafiee, "State of the art of autonomous agricultural off-road vehicles driven by renewable energy systems," *Energy Procedia*, vol. 162, pp. 4–13, Apr. 2019, doi: 10.1016/j.egypro.2019.04.002.
[2] C. Cheng, J. Fu, H. Su, and L. Ren, "Recent Advancements in Agriculture Robots: Benefits and Challenges," *Machines*, vol. 11, no. 1, p. 48, Jan. 2023, doi: 10.3390/machines11010048.
[3] J. Backman, R. Linkolehto, M. Lemsalu, and J. Kaivosoja, "Building a Robot Tractor Using Commercial Components and Widely

Used Standards," *IFAC-PapersOnLine*, vol. 55, no. 32, pp. 6–11, 2022, doi: 10.1016/j.ifacol.2022.11.106.

[4] M. O. Yerebakan and B. Hu, "Human–Robot Collaboration in Modern Agriculture: A Review of the Current Research Landscape," *Advanced Intelligent Systems*, vol. 6, no. 7, Jul. 2024, doi: 10.1002/aisy.202300823.

[5] J. Chourasia, S. Gautam, A. S. Rajpoot, and D. Bhangre, "Remote Operated Tractor for Agriculture work," *International Research Journal of Modernization in Engineering Technology and Science*, vol. 5, no. 9, pp. 1071–1076, Sep. 2023, doi: 10.56726/IRJMETS44696.

[6] R. Galati, G. Mantriota, and G. Reina, "RoboNav: An Affordable Yet Highly Accurate Navigation System for Autonomous Agricultural Robots," *Robotics*, vol. 11, no. 5, p. 99, Sep. 2022, doi: 10.3390/robotics11050099.

[7] J. Qu, Z. Zhang, Z. Qin, K. Guo, and D. Li, "Applications of Autonomous Navigation Technologies for Unmanned Agricultural Tractors: A Review," *Machines*, vol. 12, no. 4, p. 218, Mar. 2024, doi: 10.3390/machines12040218.

[8] F. Mocera, A. Somà, S. Martelli, and V. Martini, "Trends and Future Perspective of Electrification in Agricultural Tractor-Implement Applications," *Energies*, vol. 16, no. 18, p. 6601, Sep. 2023, doi: 10.3390/en16186601.

[9] Y.-S. Kim *et al.*, "Analysis of Tillage Depth and Gear Selection for Mechanical Load and Fuel Efficiency of an Agricultural Tractor Using an Agricultural Field Measuring System," *Sensors*, vol. 20, no. 9, p. 2450, Apr. 2020, doi: 10.3390/s20092450.

[10] B. Li *et al.*, "Automatic gear-shifting strategy for fuel saving by tractors based on real-time identification of draught force characteristics," *Biosystems Engineering*, vol. 193, pp. 46–61, May 2020, doi: 10.1016/j.biosystemseng.2020.02.008.

[11] Y. Li *et al.*, "Application of Computer Simulation Technology in the Development of Tractor Transmission Systems," *Agriculture*, vol. 14, no. 9, p. 1547, Sep. 2024, doi: 10.3390/agriculture14091547.

[12] K. Choi *et al.*, "Experimental Study on the Dynamic Characteristics of Hydro-Pneumatic Semi-Active Suspensions for Agricultural Tractor Cabins," *Applied Sciences*, vol. 10, no. 24, p. 8992, Dec. 2020, doi: 10.3390/app10248992.

[13] C. Yin, Q. Sun, J. Wu, C. Liu, and J. Gao, "Development of Electrohydraulic Steering Control System for Tractor Automatic Navigation," *Journal of Electrical and Computer Engineering*, vol. 2018, pp. 1–7, 2018, doi: 10.1155/2018/5617253.

[14] K. A. Daniel, P. Kowol, and G. Lo Sciuto, "Linear Actuators in a Haptic Feedback Joystick System for Electric Vehicles," *Computers*, vol. 13, no. 2, p. 48, Feb. 2024, doi: 10.3390/computers13020048.

[15] C. Leonard, E. E. Prasetiyo, and I. R. Putra, "Design and implementation of electrical system morphing wing flight control on prototype light aircraf, " *International Journal of Power Electronics and Drive Systems (IJPEDS)*, vol. 14, no. 2, pp. 781-788, Jun. 2023, doi: 10.11591/ijpeds.v14.i2.pp781-788.

[16] V. Sukontanakarn, T. Chalardsakul, and B. Saengchandr, "Design and implementation of DC linear actuator and stepper motor for remote control of the driverless tractor robot," *International Journal of Power Electronics and Drive Systems (IJPEDS)*, vol. 13, no. 3, pp. 1285–1294, Sep. 2022, doi: 10.11591/ijpeds.v13.i3.pp1285-1294.

[17] K. Selvakumar, R. Palanisamy, P. Nikhil, D. Karthikeyan, and D. Selvabharathi, "Control system of automatic garage using programmable logic controller," *TELKOMNIKA (Telecommunication Computing Electronics and Control)*, vol. 18, no. 5, pp. 2654–2664, Oct. 2020, doi: 10.12928/telkomnika.v18i5.14398.

[18] Mitsubishi Electric Corporation, "GX Works2 Programming Software." 2019. [Online]. Available: www.mitsubishielectric.com/fa/, (Accessed: 23-Nov-2024).

[19] R. Nasimi *et al*., "Use of Remote Structural Tap Testing Devices Deployed via Ground Vehicle for Health Monitoring of Transportation Infrastructure," *Sensors*, vol.22, p.1458, 2022, doi: 10.3390/s22041458.

[20] R. Wahyudi and M. Ariandi, "Implementation of Hand Tractor Control Device Remotely Using Flysky Fs-I6 Remote Control-," *PROtek : Jurnal Ilmiah Teknik Elektro*, vol. 11, no. 1, pp. 69–73, Jan. 2024, doi: 10.33387/protk.v11i1.6741.

[21] J.-C. Liao, S.-H. Chen, Z.-Y. Zhuang, B.-W. Wu, and Y.-J. Chen, "Designing and Manufacturing of Automatic Robotic Lawn Mower," *Processes*, vol. 9, no. 2, p. 358, Feb. 2021, doi: 10.3390/pr9020358.

[22] T. Suganya, P. Mangaiyarkarasi, G. Thirugnanam, and T. M. Sathish Kumar, "A hybrid approach with MPPT controller for weed cutting based on solar powered lawnmower with minimal intervention of human involvement adopting IoT technology," *Analog Integrated Circuits and Signal Processing*, vol. 119, no. 2, pp. 249–267, May 2024, doi: 10.1007/s10470-024-02263-2.

[23] B. Li *et al.*, "Control Strategy of Shuttle Shifting Process of Agricultural Tractor During Headland Turn," *IEEE Access*, vol. 11, pp. 38436–38447, 2023, doi: 10.1109/ACCESS.2023.3267800.

[24] C. Jiang, C. Yin, J. Gao, and G. Yuan, "Position Control of Gear Shift based on Sliding Mode Active Disturbance Rejection Control for Small-Sized Tractors," *Science Progress*, vol. 105, no. 1, Jan. 2022, doi: 10.1177/00368504221081966.

[25] S. S. Khairullah and A.-N. Sharkawy, "Design and Implementation of a Reliable and Secure Controller for Smart Home Applications Based on PLC," *Journal of Robotics and Control (JRC)*, vol. 3, no. 5, pp. 614–621, Sep. 2022, doi: 10.18196/jrc.v3i5.15972.

[26] T. A. Alkaar, M. S. Daw, and A. F. Jamjom, "Automated Parking System Using PLC Technology," *International Journal of Electrical Engineeringand Sustainability (IJEES)*, vol. 2, no. 3, pp. 35–46, 2024, doi: 10.5281/zenodo.13854887.

BIOGRAPHIES OF AUTHORS

Thewin Sakunbunyong received the B.Eng. degree in Mechanical Engineering from Rajamangala University of Technology Thanyaburi, Phathumtany, Thailand, in 1996, and the M.Eng. degree in Mechanical Engineering from Srinakharinwirot University, Bangkok, Thailand, in 2009. He is currently a lecturer in the Department of Mechatronics Engineering at Rajamangala University of Technology Isan, Khon Kaen Campus, Thailand. His current research interests include programmable logic controllers, automation and robotics, pneumatic and hydraulic systems, and electric motor drives. He can be contacted at email: thewin.sa@rmuti.ac.th.

Tossapol Jangnoi received the B.Eng. degree in Mechanical Engineering from Rajamangala University of Technology Isan, Khon Kaen, Thailand, in 2006. The M.Eng. degree in Mechanical Engineering from King Mongkut's University of Technology Thonburi, Bangkok, Thailand, in 2009, and D.Eng. in Mechanical Engineering from King Mongkut's Institute of Technology Ladkrabang, in 2019. He is currently a lecturer in the Department of Mechanical Engineering at Rajamangala University of Technology Isan, Khon Kaen Campus, Thailand. His current research interests include automatic control, pneumatics and hydraulic system, automation system, robotics, IIOT, and computer aided design. He can be contacted at email: tossapol.ja@rmuti.ac.th.

Tanawat Chalardsakul is an Assistant Professor at the Field of Mechatronics Engineering at the Rajamangala University of Technology Isan Khon Kaen Campus, Thailand. He received M.Eng. in Electric Power System and Ph.D. in Buddhist studies from Mahachulalongkornrajavidyalaya University. His research interests are mechanical system, renewable energy, and robot design. He can be contacted at email: tanawat.ca@rmuti.ac.th.

Viroch Sukontanakarn is a lecture in Mechatronics Engineering at the Rajamangala University of Technology Isan Khon Kaen Campus, Khon Kaen, Thailand. He received M.Eng. in Electric Power System Management and D.Eng. in Mechatronics from Asian Institute of Technology, in 1998 and 2011, respectively. He has been an Assistant Professor at the Field of Mechatronics Engineering at the Rajamangala University of Technology Isan Khon Kaen Campus, Thailand since 2002. His current research interests are power electronics, electrical power systems, microcontrollers, robotics, programmable logic controller, and electric motor drive. He can be contacted at email: viroch.su@rmuti.ac.th.