Comparison of Response Time for Target-Following Mobile Robot between ON/OFF and PID Control Algorithms

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***Abstract*—Target-following with mobile robots is a challenging problem and is needed in several applications such as in the industry, transportation system, home scenarios, stores and environments. Mobile robot will keep on the target in a certain distance irrespective of its intended final destination. In this paper, the target following mobile robots is constructed with both ON/OFF and PID control algorithms. The main focus of this research is to compare the response time for mobile robots using both these algorithms. Response time is described by using the received serial data from control circuit and plotted in MATLAB software.**

***Keywords*—Mobile, target-following, ON/OFF, PID, Response time.**

I. INTRODUCTION

Mobile robots are developed rapidly with the strong support from the constitutional technologies. As a result, intelligent mobile robots, which are receiving attention instead of industrial robots, perform repetitive labor. Intelligent and autonomous mobile robots which recognize changes of environment and decide their reactions automatically appeared in daily lives.The necessity and utilization of autonomous mobile robots are gradually increasing according to the trends in industry automation. Many researchers have become more interested in autonomous mobile robot applications. This gives advantages to the robot creator to create a more user-friendly robot that is able to coexist with human and to support human. In order for a mobile robot to operate intelligently in an uncertain environment, the functions of the position estimation, motion planning, and motion control should be achieved in real time.In the target-following robot system, the unstable and non-smooth path was sometimes generated when sudden changes in the follower-robot movements. In this research, a comparison was made response time between ON/OFF and PID controller for the follower robot.

II. RESEARCH OBJECTIVE

In this research, the mobile robot should be capable to detect the direction and distance from the target object. The problem of tracking was examined the desired position and this type of related works are widely used in the industrial robots.The most difficult problem is stabilization about a desired posture. In particular, a method for a mobile robot is proposed to follow the target-object effectively.In this research, the tracking path made by the proposed control algorithm is more stable and smooth compared to those two methods. This system is defined as the target following robot system, which is a system that allows a mobile robot to follow a moving target in an indoor space.The control goal is to minimize the difference between the actual distance P and desired distance$P_d$in a safe way. The block diagram of control algorithm is shown in Fig.1.

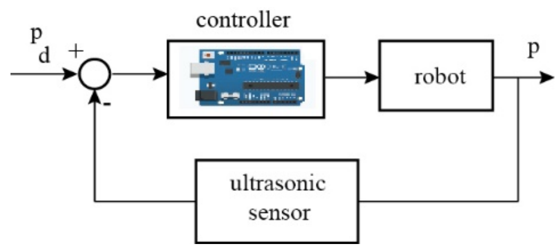

Fig.1Block diagram of control algorithm

III. PROPOSED CONTROL CIRCUIT DESIGN

Target-following robot is equipped with the needed sensor, software and hardware for it to be functional.

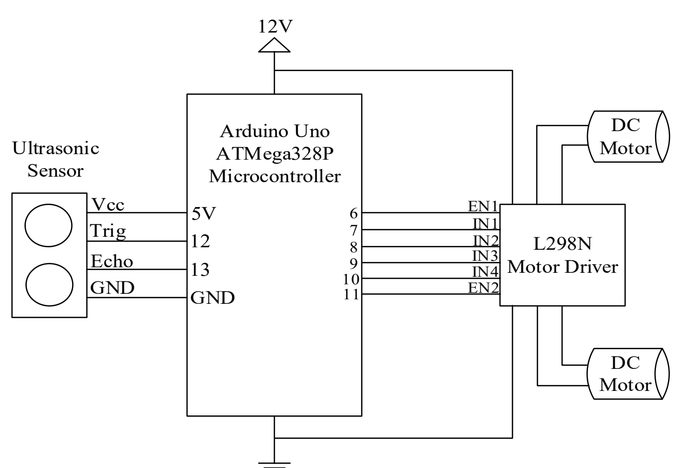

Fig.2Circuit diagram for target-following mobile robot

The two motors with deferential wheeled drive are used.The robot can be move forward and backward direction by using two motors with deferential wheeled drive. This deferential wheeled drive is based on PWM for speed of motor and direction of motor for forward and backward motion. This motor is controlled by microcontroller Arduino Uno using C programming language. The data received and processed by Arduino Uno will determine which direction of the motor will move.

The proposed control circuit designed is shown in Fig. 2In this circuit, ultrasonic sensor is used to measure the distance between object and robot. The ultrasonic distance sensor provides precise distance measurements. It is very easy to connect ATMega328 microcontroller requiring only on input output (I/O) pin. It has 4-header pin used to supply ground, power, trigger and echo which are connected to the Arduino board. The motor driver board plugs directly onto the Arduino connectors. Connect power for the motors were “6-12”V and “GND”.The control algorithm was programmed in Arduino using embedded C language.

The wheeled mobile robot has ultrasonic sensor on the top of robot body which is measured the distance between human and robot. It also has two infrared IR receivers on the bottom of robot body which is to detect the position of the target. Experimental setup of target-following robot is shown in Fig.3.

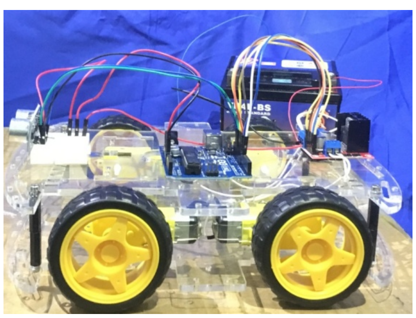

Fig.3 Hardware configuration of target-following robot

Optimizing the performance of the system require to capture the performance of data for analysis. To capture the motor-drive performance information, output data over serial communication via the USB port using the “Serial.print” instruction. The serial output data can be captured using the built-in serial terminal facility of the Arduino development environment. Selecting a baud rate of 9600 will give a quick data transfers. After the data is saved, plot with MATLAB software for graphing and comparison.

IV. PROPOSED CONTROL ALGORITHMS

The control algorithms are applied to mobile robot system for obtaining smooth following of two-wheeled differential which drive the mobile robot. In this proposed control system, ON/OFF and PID control algorithms are used to compare the response time.

There are two processes, the detecting process and the tracking process to follow the target-object for the target following robot. The desired point is determined by using ultrasonic sensor based on the relative position of the follower-robot and target-object. The ultrasonic sensor computes the distance between follower-robot and target-object in every direction.The overall flow of the target-following system is representing in Fig.4.

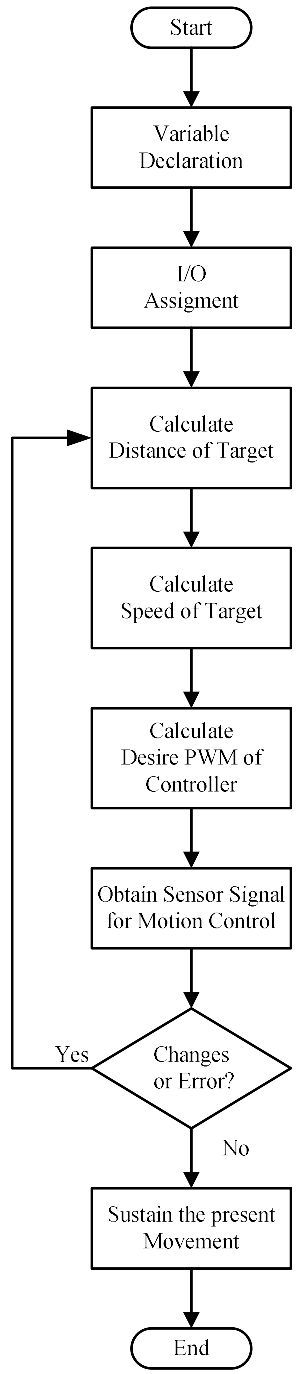

Fig.4 System flow chart for mobile robot

A. ON/OFF Control Algorithm

The simplest form of the control algorithm is ON/OFF control. An ON/OFF controller simply drives the manipulated variable from fully closed to fully open depending on the position of the controlled variable relative to the set-point.The output from the device is either on or off, with no middle state. An ON/OFF control device will switch the output only cross to the set-point. Disadvantage of ON/OFF algorithm is continuously and rapidly switch from open to close.

In this research,the wheeled mobile robot reaches the desired distance, the controller will be off. If the wheeled mobile robot is not achieving the desired distance, the controller will be on.

The distance between human and robot was measured by the ultrasonic sensor. The output of the ON/OFF controller was controlled the wheeled mobile robot.

B. PID Control Algorithms

PID controllers are widely used controllers for mobile robots. The PID term refers to the first letter of the names of the individual terms that make up the standard three term controller. These are P for the proportional term, I for the integral term and D for the derivative term in the controller. A PID controller is a control loop feedback mechanism (controller) widely used in industrial control systems. Even for complex industrial control system, the industries use the PID control module to build the main controller. The merit of using PID controllers lie in its simplicity of design and good performance including low percentage overshoot and small settling time for normal industrial process. A PID controller attempts to correct the error between a measured process variable and a desired set point by calculating and then outputting a corrective action that can adjust the process accordingly.The PID has K_P (proportional gain), K_I (integral gain) and K_D (derivative gain) and the transfer function of this controller is:

$$G(s) = K_P + \frac{K_I}{s} + K_D s$$

And the equation for the control output in time domain is:

$$u(t) = K_P e(t) + K_I \int_0^t e(t) + K_D \frac{de(t)}{dt}$$

Where, K_P is proportional gain, K_I is integral gain and K_D is the derivative gain, is error signal. Using the PID controllers will improve the performance of the plant, reduce the overshoot, eliminate steady state error and increase stability of the system.

V. EXPERIMENTAL TEST RESULTS

In order to evaluate control performance, a number of experiments were performed with the two described controllers: ON/OFF controller and PID controller. Control algorithms are written in pseudo code.

A. Test Result of Mobile Robot forON/OFF Control Algorithm

The first experiment was tracked the desired position with ON/OFF control algorithm. The follower-robot followed the target-person while maintaining a desired position P_d. The performance of ON/OFF control algorithm was shown in Fig.5. The desired distance (position) $P_d$is 10 cm.The performance of ON/OFF control algorithm is takes almost 4.2 seconds to reach the predefined distance.

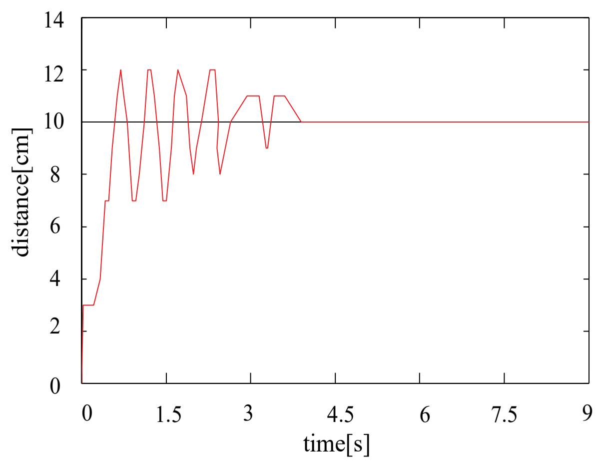

Fig.5Performance response of ON/OFF control algorithm

In Fig 5, the black line represents the desired distance and the red line represents the actual tuning distance.Pulse width modulation PWM duty cycle parameter which is controller output of the ON/OFF control algorithm is shown in Fig.6.

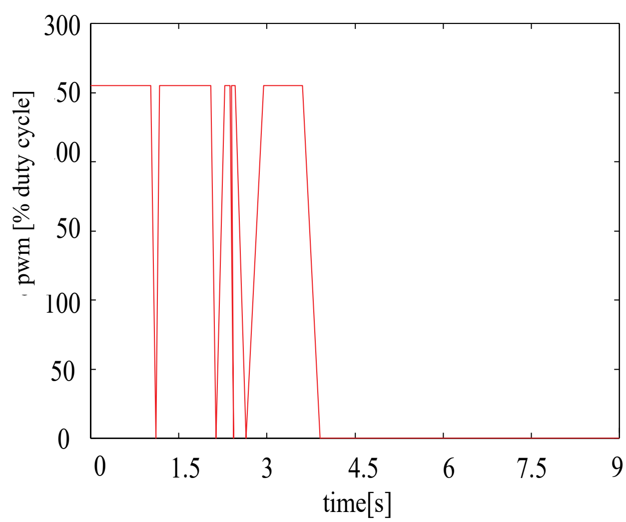

Fig.6Controller output of ON/OFFcontrol algorithm

B.Test Result of Mobile RobotforPID Control Algorithms

In a second experiment, PID control algorithm is used to reachthe desired distance. The parameters setting used for PID controlleris shown in Table I.After the several experiments have been achieved, the more accurate two parameter settings are expressed in this journal.The PID controller is used to minimize the difference between the actual distance P and desired distance P_d.

TABLE I

PID PARAMETER SETTING A AND B

Parameter	A	B
K_P	30	30
K_I	20	10
K_D	0.003	0.003

In results figures, the black line represents the desired distance and the blue line represents the actual distance which is controller PWM duty cycle parameter output of the PID control algorithm. The output of the control logic was applied to the actuator. The serial communication data of controller responses are plotted in the following Figures.

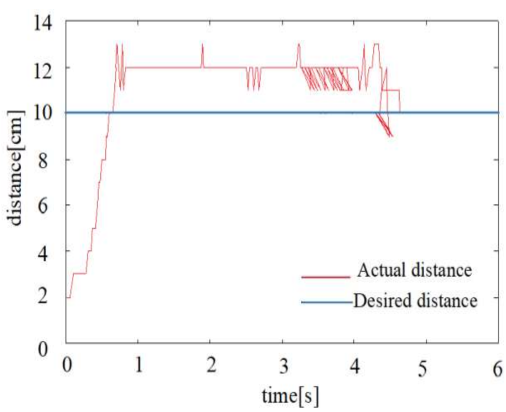

Fig.7PID response for parameter A

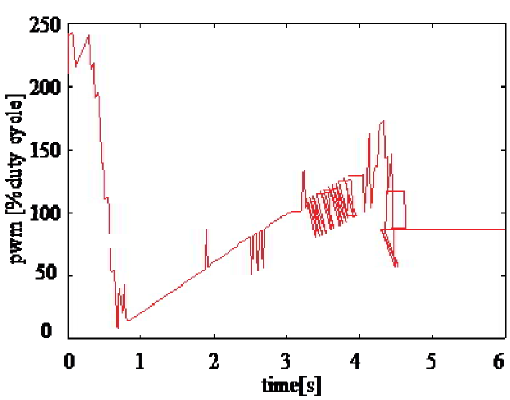

Fig.8 PWM output for parameter A

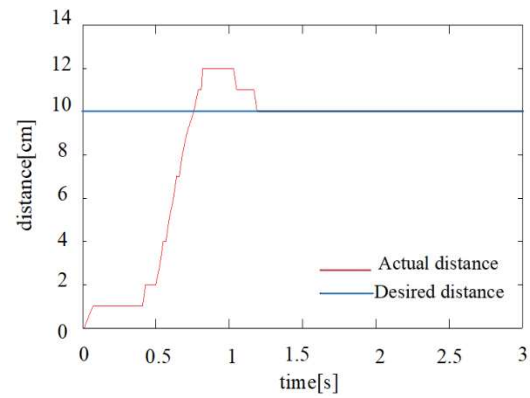

Fig.9 PID response for parameter B

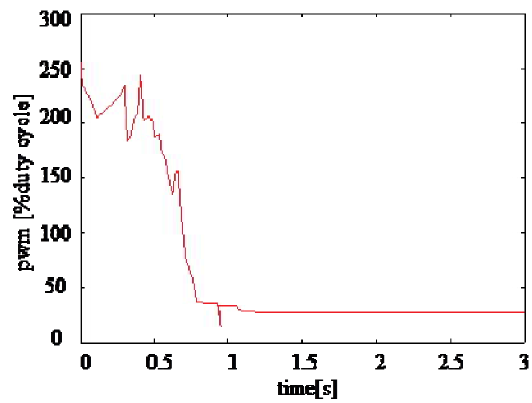

Fig.10 PWM output for parameter B

This setting A isdesired to increase the integral term. The integral term sums the error history over time. If a system starts far from the final desired set point, the initial errors will be large and the integral term will quickly grow very large. This accumulated integral usually produces a dominating effect which prevents the system from quickly achieving the set point. Fig.8 shows the result of the controller output performance when K_I=20. As shown in the Fig.7, the system was overshoot when t=0.7 sec and oscillation when t=4 sec. Thus, wheeled mobile robot was not stable when tracking the desired distance.

The result of setting B improved the performance of PID. The rise time t=0.6 sec is faster than above settings. However there is a little overshoot at t=0.7 sec, the oscillation is stable in the desired distance 10cm after t=1.2 sec as shown in Fig.9 and Fig.10. So, the setting B is the best performance for the dynamic stabilization of target following robot.

C.Comparison of Response Timefor Control Algorithms

The data in Table II shows that the error values are obtained from two different controllers. It can be seen that ON/OFF control applied to wheeled mobile robot has a maximum error and a significant time of oscillation to reach the desired distance at t=4.2 sec.

TABLEII

OUTPUT RESPONSE OF VARIOUS CONTROLLERS

Controller	Desired distance(cm)	Maximum distance(cm)	Error	Settling Time(s)
On/Off	10	12	2	4.2
PID: parameter setting B	10	12	2	1.2

The parameters of the PID controller K_p=30, K_I=10, K_D=0.003 were designed. This optimal PID controller was applied to the control system. The start response time is 0.01sec. It can be seen from Fig 9that the response of reach time is faster than ON/OFF control. The maximum percentage of overshoot is 2. The wheeled mobile robot achieves both accurate tracking and safe recovery motion at a period of 0.7 sec.

VI. CONCLUSION

This research focused on a main comparison of ON/OFF andPID control algorithms to generate a stable and smooth tracking path for the follower-robot.Since it is difficult to obtain significantly better tracking results by more parameter tuning, the results obtained with the PID controller were used as a reference to compare the behavior of ON/OFF controller.The ON/OFF controller was tuned towards tracking performanceand which was found to be unsafe. PID is capable of producing over damped resuming motion from large positional errors during normal operation.PID is suited for situations where large positional errors that accompany actuator-force saturation due to unexpected environment contact and non-smooth position commands.

ACKNOWLEDGMENT

This work has been periodically performed hardware performance testing and data collection in the framework of target-following system. The authors would like to give her special thanks to Thet Naing Soe, Htet Paing Lin, Aung Myat Phyo and Min Hone Swan for their helps while doing this research.

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