The Development of Motion Control for Unmanned Ground Vehicle Navigation

Anantachai Suwannakom, Buntoon Wiengmoon, and Thanaban Tathawee

Abstract—**This paper presents design an Unmanned Ground Vehicle (UGV) Navigation, which has the ability to drive by itself. The control system uses GPS, digital compass and laser range finder for effective navigation. The system consists of an adaptive steering control, throttle and brake system to assist the smooth motion control of UGV. The discrete PID algorithm with anti-windup was applied for DC motor position control tuning. Experimental results show that the proposed method can successfully navigate the UGV by way points as well.**

Index Terms— **Unmanned Ground Vehicle, motion control, DC motor position control**

I. Introduction

Unmanned ground vehicle (UGV) is applied in various condition such as agricultural, reconnaissance, patrol guard and targeted searches [1, 2]. Moreover, the UGV can access in the harmful area which were used instead a human. However, the obstacles of UGV development are the efficient perception algorithm and understanding of environment. Moreover, the developments of effective remote control on this vehicle are difficult. Communications were sent through radio waves [3] and the sending protocol. Sometime, the unstable of the communication system can lead instantaneous lost control of vehicle and lead to harm situation for life and property.

Losing remote control can arise every second and lead to a difficult situation. Although, the efficient perception system decreases during losing the control. The range sensor such as laser scanner and ultrasonic sensor [4, 5] can avoid the harmful situation during control lose [6, 7]. In addition, the losing control lead to be incomplete doing a mission that was given to UGV or this vehicle cannot visit to the destination. Thus, the autonomous driving of UGV can prevent the problem of losing a control and maintain the mission will proceed until done. The principle of autonomous control of UGV proceeds automatically by using combine sensor of GPS and digital compass. The GPS navigates the UGV move from the current position to the next position or goal. The digital compass detects the direction of UGV movement. The traveling of the UGV almost control by autonomous but the high-level of mission or permeate with the obstacle, the manually were applied.

According to the problem of remote controlling of UGV, we applied GPS and digital compass on developed UGV from All-Terrain Vehicle (ATV) for tracking the way point. The developed UGV includes with laser scanner and camera for obstacle perception and remote control on manual mode. Moreover, the controlling handle based on discrete PID algorithm with anti-windup for improve performance of handling as well as automation driving. Which can be applied to be several of application that mentioned on first of this content.

In this paper, we propose a technique for the vehicle tracking by vehicle heading control. The steering wheel position is the function of the desired heading on based “toward, turn left and turn right” behaviors by using discrete PID algorithm with anti-windup method. Moreover, the GPS and digital compass were applied for autonomous GPS tracking.

II. Hardware Design

A. Controlling system

Main autonomous control or brain of UGV proceeds on computer. The peripheral system, including the steering, throttle, brake, GPS and digital compass system has the separate processing unit by using a microcontroller.

Headlamp of All-Terrain vehicle were replaced by DC motor with gearbox for controlling the handlebar. The sprocket were installed on the handlebar with the chain to connect sprocket on DC motor. In addition, the position movements of DC motor were detected by an encoder (Fig. 1).

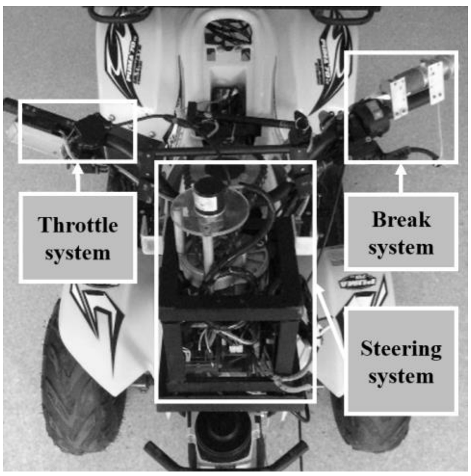

Fig. 1 the steering, throttle and brake system.

Manuscript received January 8, 2016;
Anantachai Suwannakom is with Department of Physics and Research Center for Academic Excellence in Applied Physics, Faculty of Science, Naresuan University, Phitsanulok, 65000, Thailand. (Corresponding author E-mail: anantachain@nu.ac.th).
Buntoon Wiengmoon is with Department of Physics, Faculty of Science, Naresuan University, Phitsanulok, 65000, Thailand.
Thanaban Tathawee is with Biology Department, Faculty of Science, Naresuan University, Phitsanulok, 65000, Thailand.

The controlling of mechanic throttle and brake were handled by servo motor and DC motor respectively (Fig. 1). The direction movements of these are set on the same plane of throttle and brake lever for smooth controlling.

DC motor steering position data from an encoder were sent to feedback PID controller, which showed on Fig. 2. PID parameter is obtained from DC motor position control in tuning of PID controller method. The design of the position controller has stability and simple structure. The PID will carry the handlebar on center position until the steering system receives turn left or right command. Moreover, the degree of steering is adaptive, which relate to direction of movement.

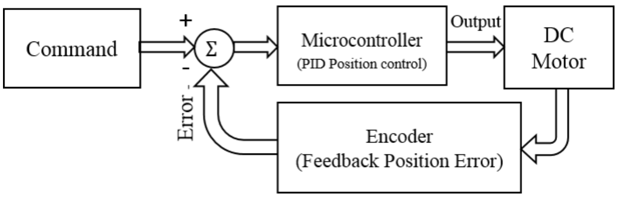

Fig. 2 feedback PID controller

The proportional term implemented simple by replacing the continuous variable with their sampled version (1).

$$P(t_k) = K_p e(t_k) \tag{1}$$

The integral term is achieved from approximated the integral with the summation show on equation (2).

$$I(t_{k+1}) = I(t_K) + K_i Te(t_k) + K_T T(u(t_k) - v(t_k)) \tag{2}$$

Where $K_T T$ represented the anti-windup term. The derivative term D can be writing as (3)

$$D(t_k) = \left(\frac{T_f}{T_f + T}\right) D(t_{k-1}) - \left(\frac{K_d}{T_f + T}\right)(y(t_k) - y(t_{k-1})) \tag{3}$$

When

$$v(t_k) = P(t_k) + I(t_k) + D(t_k) \tag{4}$$

And

$$u(t_k) = sat(v, ulow, uhigh) \tag{5}$$

B. Direction and movement

The current position of the UGV received from the GPS module which data were compared with the database position of movement for automation driving. After automation driving running, the current position is calculated with goal position as in (6) and (7) to define the direction of UGV movement.

$$direction = \tan^{-1}\theta \tag{6}$$

$$\theta = \frac{(x' - x)}{(y' - y)} \tag{7}$$

When x', y' are longitude and latitude of goal respectively. Otherwise, x and y are longitude and latitude of current. In addition, longitude and latitude current are the coordinate position at the current time of the UGV, and longitude and latitude goal are the coordinate position of next assign position that UGV will arrive. This relation was shown on Fig. 3. The UGV was controlled on the way point to the goal by compare the calculated direction and heading UGV direction from digital compass.

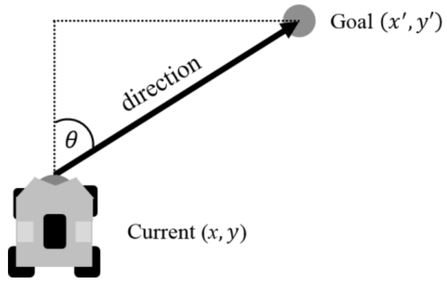

Fig. 3 illustration of direction calculation

After getting the direction, if the difference of the direction is more than 5 degrees, the steering will turn left or right, which depends on the turning radius of the UGV will move forward. The process follows by flowchart on Fig. 4.

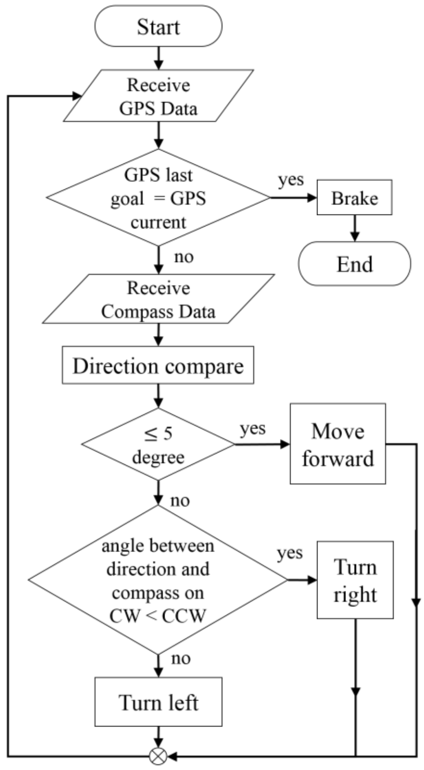

Fig. 4 autonomous flowchart control

ISBN: 978-988-14047-6-3
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

C. GPS tracking with PID

GPS position database is collected from GPS module on the UGV totally six positions on straight testing route and 17 positions on rectangle testing route. The position between points on the straight route is 10 meters, and total is 60 meters. Each position of rectangle route is far 5 meter and total distance 85 meters. The experimentation proceeded during a clear sky for highest performance of GPS device. We choose the parking on straight path and the testing mission on the rectangle path on an outdoor basketball court at Naresuan University. The GPS position data of the straight and rectangle route are shown on table 1 and 2 respectively. During the experiment, the current GPS position and direction driving command were collected every 1 second by the developed program which shown on Fig 5.

TABLE I
GPS STRAIGHT TESTING ROUTE

Position no.	latitude	longitude
1	16.73982483	100.2004947
2	16.73978883	100.200397
3	16.73975683	100.2003003
4	16.73970483	100.2002352
5	16.73966133	100.2001693
6	16.73960883	100.2000892

TABLE II
GPS RECTANGLE TESTING ROUTE

Position no.	latitude	longitude
1	16.74118671	100.1951293
2	16.74115705	100.1951663
3	16.74120533	100.1952223
4	16.74122633	100.1952826
5	16.74124833	100.1953313
6	16.74122783	100.1953593
7	16.74119871	100.1953872
8	16.74115983	100.1953853
9	16.74112567	100.1953903
10	16.74109967	100.1953517
11	16.74107917	100.1953078
12	16.74106317	100.1952633
13	16.74105233	100.1952237
14	16.74106217	100.1951852
15	16.74109983	100.1951545
16	16.74113833	100.1951385
17	16.74116842	100.1951135

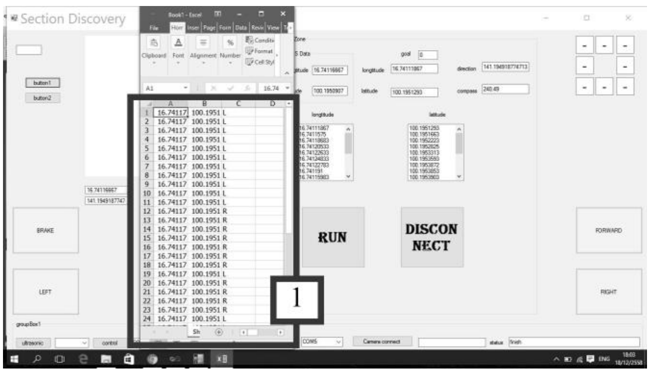

Fig. 5 GUI of data logger developed program for GPS position display and direction driving command.

III. EXPERIMENTAL RESULT

GPS tracking on autonomous control based on discrete and anti-windup PID control, with parameters obtained from demonstrate by $K_p = 0.01$, $K_i = 0.00363$, $K_d = 0.0019$, $T_f = 0$ and $K_t = 10$. The example results of GPS tracking on the straight testing route are shown on Fig. 6. The average highest of error on straight route is 2.91±0.29 meter and lower is 0.98±0.57 meter.

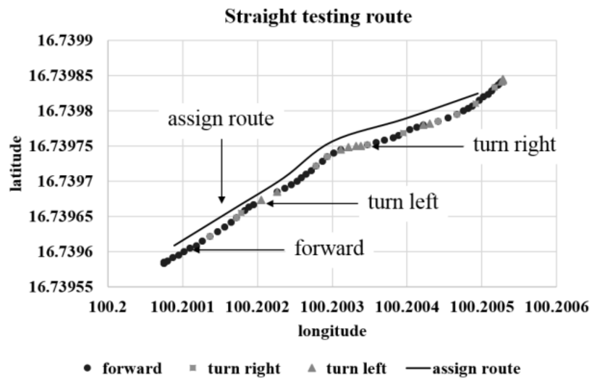

Fig. 6 GPS position and direction driving command driving of straight testing route. The x is longitude and y axis is latitude. The rectangle dot is the turn right. Triangle dot is the turn left and circle dot for forward. The assign straight route is the black line.

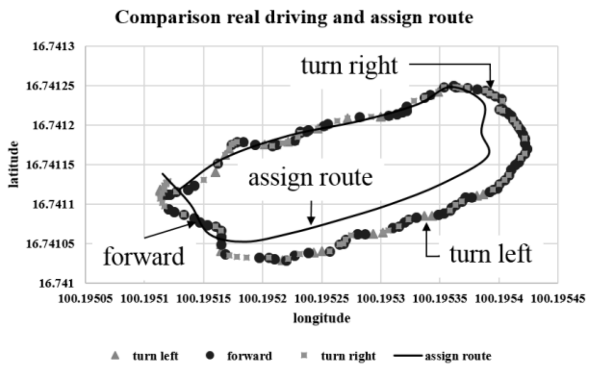

Fig. 7 the data of real driving show on the dot plot which rectangle is the turn right, triangle is the turn left and circle for forward. The assign route show on black line. The x and y axis represents longitude and latitude respectively.

According to Fig 7, developed UGV drive automatically near the assign rectangular route. The average highest error of comparison between the real drive and the assigned route is 4.67±0.78 meter and lowest at 0.06±0.06 meter. However, the example driving result showed the overlap of collecting GPS position during running the system (Fig. 8). Which can explain the error of real drive effect from GPS device error and the sensitivity of GPS module. For instant, the UGV arrived to destination before the GPS device responds to global position.

ISBN: 978-988-14047-6-3
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

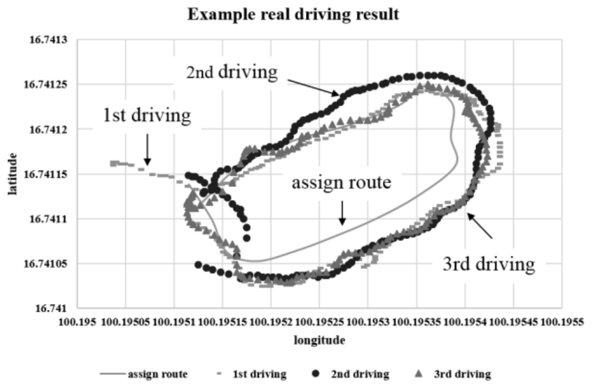

Fig. 8 example result of automation driving, assign route represent on line and test driving on dot.

The percentage of each command (turn right, turn left and forward) for autonomous driving from 3 replication (data in Fig. 8) has a similar trend (Table 3). The percentage of turn left, and right commands are similar but the forward quite different. However, this result indicated the stability of autonomous system on developed UGV. In addition, the series of scene shot of self-driving was shown on Fig. 9.

TABLE III
PERCENTAGE OF COMMAND

Running	Turn right (%)	Forward (%)	Turn left (%)
1	22.22	50.65	27.13
2	26.82	36.24	36.94
3	21.36	46.60	32.04

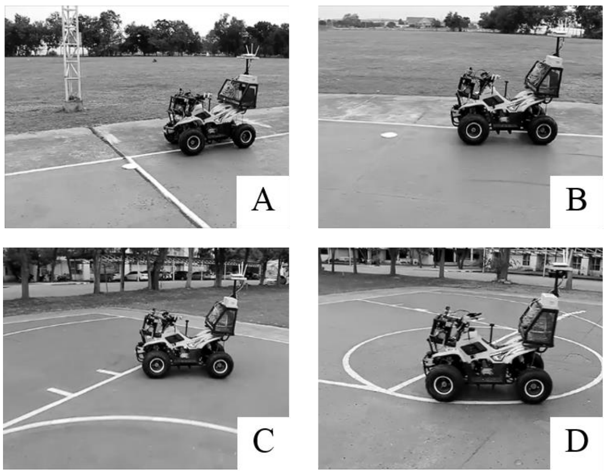

Fig. 9 Scene shot of automation driving. Picture A, B, C and D are way point no. 3, 6, 12 and 15 respectively.

IV. Conclusion

The application of GPS module, digital compass for GPS tracking is suitable for autonomous driving of the unmanned ground vehicles (UGV). The GPS tracking was control by discrete PID control with anti-windup method. The result shown the lowest and highest error at 0.06±0.06 meters and 4.67±0.78 meters respectively. In fact, the high sensitivity and respond of GPS module can enhance the performance of UGV to drive precisely.

Acknowledgment

This research project financially is supported by the Naresuan University research fund**.**

References

[1] A. M. Khaleghi, D. Xu, Z. Wang, M. Li, A. Lobos, J. liu and Y. Son, "A DDDAMS-based planning and control framework for surveillance and crowd control via UAVs and UGVs" *Expert Systems with Application,*"2013, pp. 7168-7183.

[2] A. Singh, B. Ganapathysubramanian, A. K. Singh and S. Sarkar."Machine learning for high-throughput stress phenotyping in plants", *Trends in Plant Science*, article in press.

[3] Meong-hun Lee, Yoon-ju Lee, Kwang-jae Lim, Dong-seung Kwon, Seong-hoon Kim, "Mobile WiMAX Performance Measurements and the selection of Path Loss Model for UGV", 2010 *IEEE int, International Conference on Information and Communication Technology Convergence (ICTC)*, pp. 183-184.

[4] J. Rejas, A. Sanchez, G. Glez-de-Rivera, M. Prieto and J. Garrido. " Environment mapping using a 3D laser scanner for unmanned ground vehicles", *Microprocessors and Microsystems*, vol. 39, 2015, pp 939-949.

[5] S. Budzan, J. kasprzyk. "Fusion of 3D laser scanner and depth images for obstacle recognition in mobile applications", *Optics and Lasers in Engineering*, vol. 77, 2016, pp. 230-240.

[6] F. Garcia, J. Garcia, A. Ponz, A. de la Escalera, J. M. Armingol, "Context aided pedestrian detection for danger estimation based on laser scanner and computer vision" *Expert Systems with Applications*, vol. 41, 2014, pp. 6646-6661.

[7] Hee-Chang Moon,Jae-Hwan Kim and Jung-Ha Kim, "Obstacle Detecting System for Unmanned Ground Vehicle using Laser Scanner and Vision", *International Conference on Control, Automation and Systems*,2007.