Unmanned Vehicle System Configuration using All Terrain Vehicle

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Abstract This paper deals with an unmanned vehicle system configuration using all terrain vehicle. Many research institutes and university study and develop unmanned vehicle system and control algorithm. Now a day, they try to apply unmanned vehicle to use military device and explore space and deep sea. These unmanned vehicles can help us to work is difficult task and approach. In the previous research of unmanned vehicle in our lab, we used 1/10 scale radio control vehicle and composed the unmanned vehicle system using ultrasonic sensors, CCD camera and kinds of sensor for vehicle's motion control. We designed lane detecting algorithm using vision system and obstacle detecting and avoidance algorithm using ultrasonic sensor and infrared ray sensor. As the system is increased, it is hard to compose the system on the 1/10 scale RC car. So we have to choose a new vehicle is bigger than 1/10 scale RC car but it is smaller than real size vehicle. ATV(all terrain vehicle) and real size vehicle have similar structure and its size is smaller. In this research, we make unmanned vehicle using ATV and explain control theory of each component

Keywords: unmanned vehicle, stereo vision, lane detecting, obstacle avoidance, wireless communication

1. INTRODUCTION

This paper deals with an unmanned vehicle system configuration using all terrain vehicle. Many research institutes and university study and develop unmanned vehicle system and control algorithm. Now a day, they try to apply unmanned vehicle to use military device and explore space and deep sea. These unmanned vehicles can help us to work is difficult task and approach. In the previous research of unmanned vehicle in our lab, we used 1/10 scale radio control vehicle and composed the unmanned vehicle system using ultrasonic sensors, CCD camera and kinds of sensor for vehicle's motion control. Fig. 1 is a concept of previous unmanned vehicle system. We designed lane detecting algorithm using vision system and obstacle detecting and avoidance algorithm using ultrasonic sensor and infrared ray sensor. As the system is increased, it is hard to compose the system on the 1/10 scale RC car. So we have to choose a new vehicle is bigger than 1/10 scale RC car but it is smaller than real size vehicle. ATV(all terrain vehicle) and real size vehicle have similar structure and its size is smaller. In this research, we make unmanned vehicle using ATV and explain control theory of each component

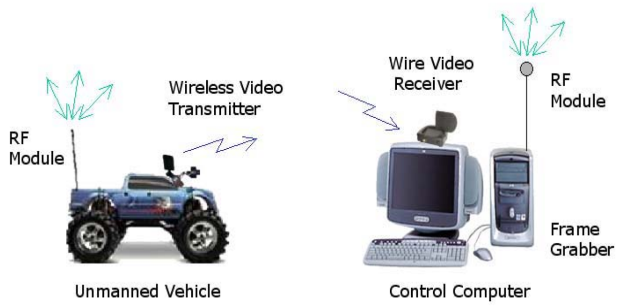

Fig. 1 Previous unmanned vehicle system concept

2. SYSTEM CONFIGRATION

In general, unmanned vehicle system need many systems and connect with each system organically. For example unmanned vehicle system is consists of vehicle control system, sensor system, vision system and communication system. Vehicle control system is composed with personal computer, micro controller and several actuators. This system can control vehicle movement. And sensor system is used to know vehicle condition. Vision system is used to detect lane on the road and obstacles. The user in the distance can control the unmanned vehicle and know vehicle conditions using communication systems. As you know, it is important to design control system of the unmanned vehicle and connect each system. In this research, we introduce our previous unmanned vehicle system and new unmanned vehicle system using all terrain vehicle.

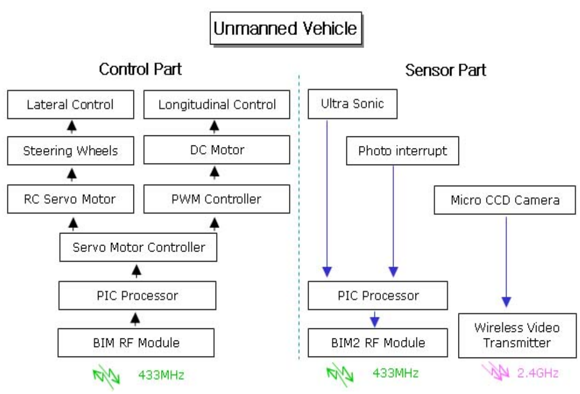

Fig. 2 Previous unmanned vehicle system component

2.1 Previous system

Our previous unmanned vehicle system was composed on 1/10 scale RC car. Fig. 2 shows the previous unmanned vehicle system components and fig. 3 shows its control system components. This system can drive itself for detecting lane and obstacle on the road. It has four subsystems as control, sensor, vision and communication systems. Control system and sensor system have own microprocessor, and operate itself. The microprocessor of sensor system can transmit sensor value to control system on the vehicle. And main processor of control system can communicate with control computer and transmit and receive driving condition of vehicle and vehicle control value. Vision system is used to road lane detection, and communication system is used to receive and send from road and vehicle data.

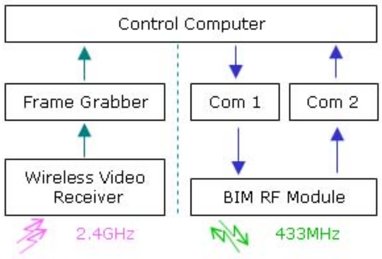

Fig. 3 Previous control station

2.2 New System

Our new unmanned vehicle system is composed on the ATV(all terrain vehicle). This ATV is made by E-ton. Fig. 4 shows ATV for unmanned vehicle system. This outward appearance of ATV is different from a passenger car but it has analogous structure with general vehicle.

Fig. 4 All terrain vehicle made by E-TON

Table 1 Specification of ATV

Length		1730 mm
Width		980 mm
Height		760 mm
Wheel base		1150 mm
Weight		172 kg
Maximum load		150 kg
Engine		150cc Oil-cooled 4 stroke engine
Transmission		CVT
Tire	front	20*7-10
	rear	22*10-10
Break	front	Drum
	rear	Disk

Table 1 is a specification of ATV. This ATV has a 150cc 4 stroke engine, CVT transmission and drum type brake for front wheel and hydraulic disk type brake for rear wheel.

2.3 Control system

Control system of unmanned vehicle system using ATV is consists of longitudinal control system and lateral control system. We can see the control system components on fig. 5. We made vehicle control system using personal computer and DAQ system made by national instrument company for sensor system. For control and drive of several actuators, we used PIC micro controller.

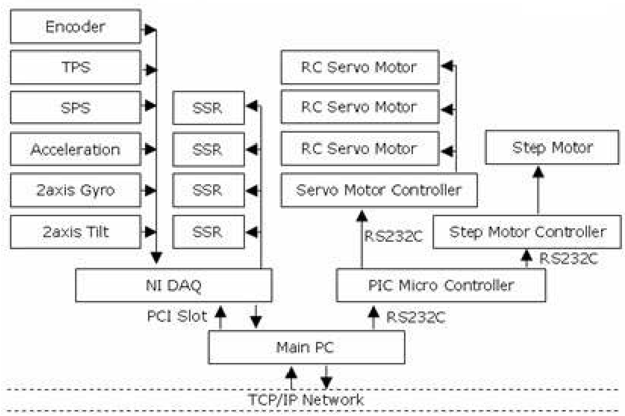

Fig. 5 ATV control system

2.3.1 Longitudinal control

ATV used this research has 150cc gasoline 4 stroke engine and CVT transmission. This engine and transmission are made a single body. Fig. 6 shows an engine and transmission of ATV. This CVT transmission is possible to drive backward. So it has shift lever for changing forward gear, neutral and reverse gear. For longitudinal control of unmanned vehicle, we should control throttle valve angles and shift lever on transmission.

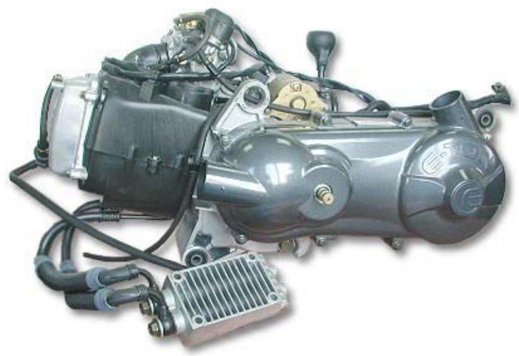

Fig. 6 150cc 4 stroke engine for ATV

For control throttle valve, we used RC servo motor. This servo motor is small but it has enough torque to control throttle valve. Fig. 6 shows throttle valve on engine and servo motor. And we used big size RC servo motor for shift lever on transmission and 4 link system. For moving the shift lever, it needs motor that has large torque. General servo motor is difficult to use and is bigger than RC servo motor. This RC servo motor is made by Hitec RCD. Its maximum torque is 24.5kgcm. It is satisfied to control the shift lever and drive four linkage system. Fig. 7 shows four linkage system and big scale RC servo motor mounted on the bottom of transmission.

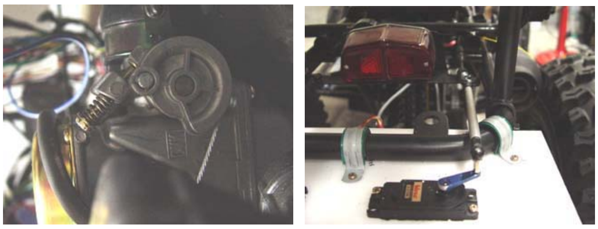

Fig. 7 Throttle body and actuator

Fig. 8 Gear shift lever and actuator

2.3.2 Lateral control

We used big size step motor for lateral control of unmanned vehicle system using ATV. This step motor has 1:10 reduction gear so it has enough torque for control steering angle. This step motor is connected with steering shaft directly. For driving the step motor, we made step motor driver using PIC micro controller. It is controlled by ATV main computer using RS232C communication. And we used rotary potentiometer for measuring steering angles. It is mounted on the bottom of steering shaft. Fig.9 shows step motor and steering shaft for lateral control.

Fig. 9 Step motor for steering control

2.3.3 Break control

The brake system of ATV has two kinds of brake system. One is a drum type brake at front wheels. And the other is hydraulic disk type brake at rear wheel. In this research, we used rear hydraulic disk brake. Because the drum brake needs copious force for operating brake system but hydraulic disk brake system that use oil pressure doesn't have large torque. We can get enough brake torque using tiny power. We used RC servo motor for brake actuator. It is connected with rear brake lever through linkage. Fig. 10 shows rear hydraulic disk brake system and RC servo motor for brake actuator.

Fig. 10 Rear hydraulic disk brake and break actuator

2.4 Vision system

The vision system used the unmanned vehicle is divide into two parts. The one is the system which can simply observe process courses and environments. The other is lane recognition using stereo vision and driving lane measurement system. Fig. 11 shows the flowchart of vision system.

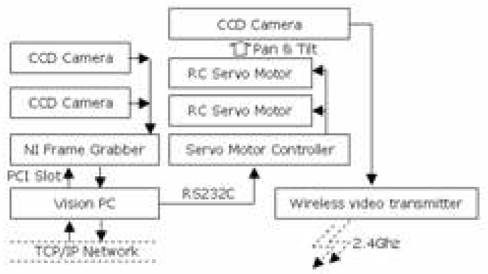

Fig. 11Vision system configuration on ATV

2.4.1 Observation vision

The observation vision system is composed micro CCD camera, pan & tilt system, and wireless video receiver modules. Images of micro CCD camera are transmitted control station using wireless video receiver module. And then a user far away can see circumference of vehicle.

2.4.2 Stereo vision

The Stereo vision system sets up in front of vehicle and is used lane detection. We used the IMAQ frame grabber made National Instrument Co. for the image processing and we are programming visual C++ using measurement studio for the fast image processing.

2.5 Control Station

We are composed the control station for the monitoring of unmanned vehicle and the remote control. This control station has steering wheel, brake, acceleration pedal, gearshift lever.

We used DAQ system to get values of control station. And the control station has small 6-axis motion platform which can express the present state and motion of unmanned vehicle and the control station has the observation monitor and wireless video transmitter module to observe the surroundings around the unmanned vehicle. Fig. 12 is the configuration of control station.

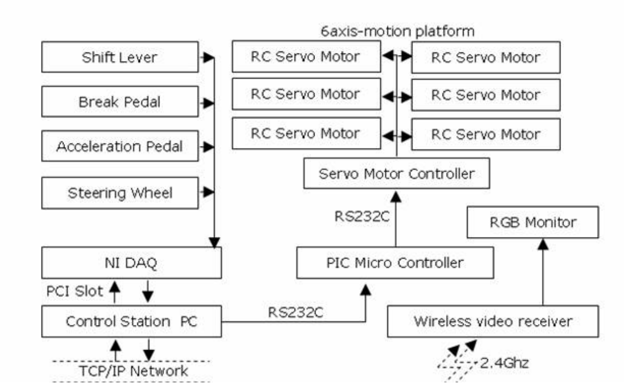

Fig. 12 Control station configuration

2.6 Communication system

We used TCP/IP communications to communicate with many computers and control station for remote control. The vision computer is connected around the vehicle control computer through the Network hub and networks are composed using wireless LAN solution for communication of control station.

And we constituted the entire communication system using RS232C communication which is each computer and its controllers. Fig. 13 is the communication method of block diagram.

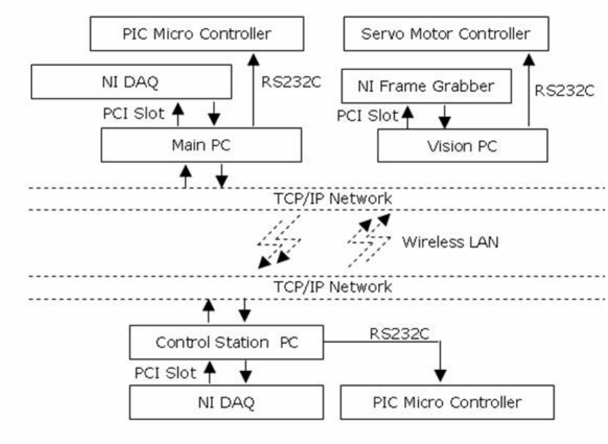

Fig. 13 Communication method of ATV and control station

3. CONTROL METHOD

3.1 Longitudinal control method

We used closed loop control for the longitudinal control of unmanned vehicle. The longitudinal control elements of vehicle consist; engine system, transmission system, brake system and power transmit system. Fig. 14 is flowchart of longitudinal control. The engine is 150cc gasoline 4 stroke cycle engine. The control elements are angle of throttle valve and angle of RC servo motor which controls the throttle valve.

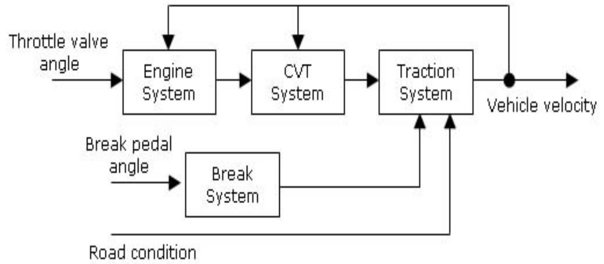

Fig. 14 Longitudinal control model

Let V_0 be the steady state vehicle speed for a throttle input θ_0. Define $\overline{V} = V - V_0$ as the deviation of the vehicle speed V form V_0 and $\overline{\theta} = \theta - \theta_0$ as the throttle deviation from θ_0. Using the validated nonlinear longitudinal vehicle model we find that, around a operating point (θ_0, V_0), the throttle to vehicle speed model can be approximated by

$$\frac{\overline{V}}{\overline{\theta}} = \frac{b}{s+a} \quad (1)$$

Where b, a vary with V_0. The effects of the fast mode terms and uncertainties neglected in the approximation may by modeled as disturbance term d, leading to the model equation (2) or (3).

$$\dot{\overline{V}} = -a\overline{V} + b\overline{\theta} + d \quad (2)$$

$$\dot{V} = -a(V - V_0) + b\overline{\theta} + d \quad (3)$$

The brake used unmanned vehicle is a hydraulic disk brake system of rear wheel. Control model to control this brake system can approximate following equations.

$$\dot{V} = \frac{1}{M}(-c_1 T_b - f_0 - c_2 V - c_3 V^2) \quad (4)$$

Where T_b is the braking torque, M is the vehicle mass, $c_1 T_b$ is the braking force, f_0 represents the static friction force, $c_2 V$ represents the rolling friction force, $c_3 V$ represents the air resistant force. The linearized brake actuator model is equation (5).

$$T_b = \alpha\theta_{actuator} \quad (5)$$

3.2 Lateral control method

We used bicycle model of basic models which is 2 degree of freedom for steering control model of unmanned vehicle. This model is not enough to correspond with real vehicle model but is useful to express basic characteristics of vehicle such as parameter changes. Fig. 15 is bicycle model which have 2 degree of freedom.

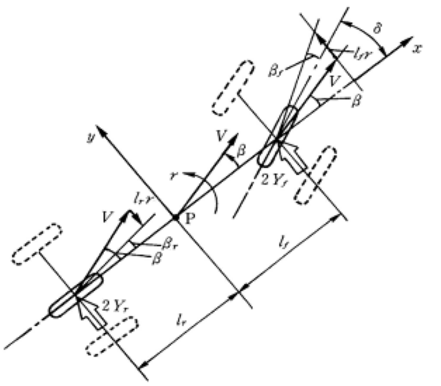

Fig. 15 Bicycle model

The dynamic equation of vehicle using this bicycle model is equation (6).

$$mV\frac{dt}{d\beta}+2(K_f+K_r)\beta+\left\{mV+\frac{2}{V}(l_fK_f-l_rK_r)\right\}r=2K_f\delta \quad (6)$$
$$2(l_fK_f-l_rK_r)\beta+I\frac{dr}{dt}+\frac{2(l_f{}^2K_f+l_r{}^2K_r)}{V}r=2l_fK_f\delta$$

Yaw rate of vehicle based on these equations is equation (7) to control lateral control.

$$\psi=\frac{A}{pol(S)}\left\{(1+T_f\cdot s)\delta_f-(1+T_r\cdot s)\delta_r\right\} \quad (7)$$

And side-slip angle of vehicle is equation (8).

$$\beta=\frac{1}{pol(s)}\left\{B_f(1+\tau_f\cdot s)\delta_f+B_r(1+\tau_r\cdot s)\delta_r\right\} \quad (8)$$

Lateral acceleration of the vehicle using equation (7) and equation (8) is equation (9).

$$\begin{aligned} a_y &= V(\dot\beta+\dot\psi) \\ &= \frac{V}{pol(s)}[\left\{A+(B_f+AT_f)\cdot s+B_f\tau_f\cdot s^2\right\}\delta_f \quad (9) \\ &\quad +\left\{-A+(B_r-AT_r)\cdot s+B_r\tau_r\cdot s^2\right\}\delta_r] \end{aligned}$$

4. CONCLUSION

In this paper, we told about unmanned vehicle system using ATV and each system configuration and its control method of each system such as steering angle, throttle angle and brake system. Although the vehicle system is incompletion, we learn the method of composing and operating unmanned vehicle system. As the vehicle size is bigger than previous system, we have to concentrate safety of experiment and stability of system. We should design more stability vehicle system through verify driving algorithm and regulate parameter during vehicle driving test.

ACKNOWLEDGMENTS

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