Design An Omni-directional Mobile Platform with A Cannon

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Abstract— **In this thesis, we implement a remote-control cannon vehicle. There are three parts of system architecture within the cannon vehicle described. The first part is mechanical structure design. The second part is the remote controller design. The last part is the motor controller design. For the mechanical structure design, we use 3D CAD software to draw the sketch stress analysis, and to ensure the materials don't change shape. In the remote controller, a Nintendo Wii joystick is used to control the directions of the cannon vehicle. Finally, we separate the motor controllers into two parts. One part is the controller for the vehicle, and the other part is the motor controller for the cannon.**

***Keywords*— mechanism design; remote control; motor control**

I. INTRODUCTION

The 21st century is a century full of science and technology. New materials and new techniques continue to emerge in large numbers and are applied on military affairs generally. Modern wars will be the competition of precision guided munitions and high technology products. Only depending on one kind of technique, a weapon or the advantage of special field that won't be the reason why you won the war. Therefore, the main weapon of future battlefield will be unmanned reconnaissance vehicles and micro-robots to receive the messages during the war. The tank driven by the robot or controlled by the computer, cannon vehicle and control can lead to go on the offensive. Therefore, according to the statements this article will discuss of the cannon vehicle wireless remote control. Use unlimited Wii joystick to control the movement of the mobile platform, the launching of the transmitter and the angle of the movement. To simulate the remote control the movement of the mobile platform, the launching of the transmitter and the angle of the movement that can accurately hit the target

II. MECHANISM DESIGN

This thesis to bring up the cannon vehicle of the substance is according to Acrylonitrile butadiene styrene plus laser cutting. The procedures of the mechanism design showed in Fig1. First, set mechanism size of cannon vehicle and choose material, because material cost and stiffness need to consider in mechanism design. Size and material after setting are completed, calculations the required torque and choose appropriate motor, draw 3D CAD to confirm mechanism whether interference, use analysis software to confirm the material is a match.

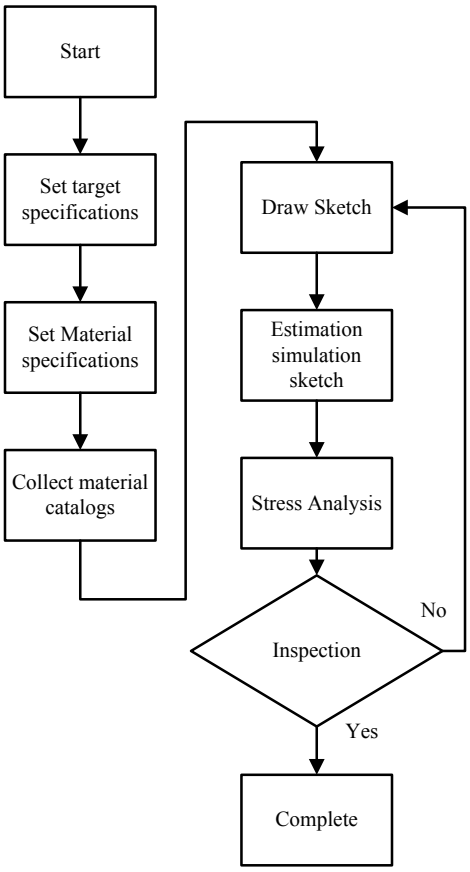

Fig. 1 procedures of the mechanism design

This thesis mechanism design sets the mechanism size of the cannon vehicle, sets cannon vehicle wheel diameter size, max speed and max load. Use formula choose appropriate motor. First, set cannon vehicle wheel diameter size into(1).

$$Motor_{max}(RPM) > \left(\frac{V}{R} \times \pi\right) \times 60 \quad (1)$$

Formulate the second speed.

$$V = V_0 + a \times t \quad (2)$$

After setting the load into.

$$F = m \times a \quad (3)$$

formula(3)into formula(4).

$$T = F \times r \quad (4)$$

V:Speed
R:Wheel Diameter
a:Acceleration
m:Load
F:Force
R:Whell radius
T:Torque

According to the above formulae, set whether the motor load showed in Table 1.

TABLE I
BASIC VALUES

Wheel Diameter	50mm
Max Speed	1m/s
Load Weight	1kg

$$Motor_{max}(RPM) > \left(\frac{V}{0.5} \times \pi\right) \times 60 = 38(\text{rpm})$$

$$V = 0 + a \times 1$$

$$a = 1(\text{m/s}^2)$$

$$F = 1 \times 1 = 1(\text{N})$$

$$T = 1 \times 25 = 25(\text{mNm})$$

Choose motor is LEGO NXT Servo motor, weight of LEGO Mindstorms NXT motor is 0.08(kg), rated torque 50(kg-cm), test to obtain 1.7(kg-cm), actual motor data showed in tabel2, LEGO Mindstorms NXT motor reduction ratio is 1:48, decelerator structure showed in Fig2, this thesis use LEGO Mindstorms NXT motor drive cannon vehicle mobile and transmitter angel.

TABLE II
MOTOR SPECIFICATION

NXT	Torque	Speed	Currents	Mechanical power	Electrical power	Efficacy
4.5 V	16.7 N.cm	33 rpm	0.6 A	0.58 W	2.7 W	21.4 %
7 V	16.7 N.cm	82 rpm	0.55 A	1.44 W	3.85 W	37.3 %
9 V	16.7 N.cm	117 rpm	0.55 A	2.03 W	4.95 W	41 %
12 V	16.7 N.cm	177 rpm	0.58 A	3.10 W	6.96 W	44.5 %

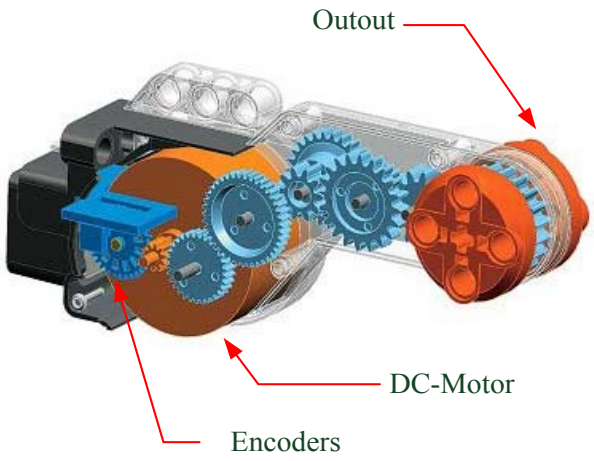

Fig.2 Gearbox

The creation in this thesis designed was made use of Solid Works. So robot mechanism design can be easier to achieve the goal of robot-assisted mechanism design and be more efficient to save time. SolidWorks is based on Windows to develop the 3D modelling system. The big and powerful function of modelling can let the designer easy to complete mapping exercise. The compatibility can cooperate with other CAD Software. SolidWorks also fully integrated third-party applications can direct to carry the material monogram out also simulation animation, engineering analysis, aided manufacturing and data management. In short, it's ideally suited for computer-aided design software of using on mechanical design. (Fig.3 and Fig.4)

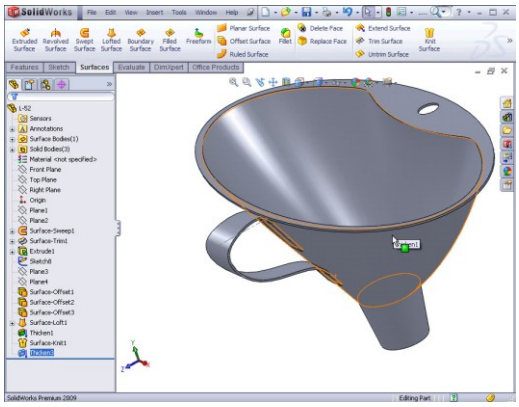

Fig.3 SolidWorks Screenshot

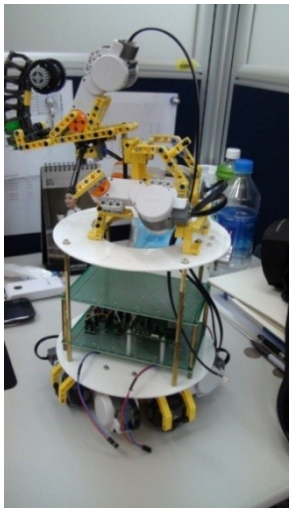

Fig.4 Mobile Platform

III. Hardware Devices

The hardware details are shown below:

A. Wiimote and Wii Nunchuk

Wii Remote also called Wiimote is the controller for Wii game console. The appearance of Wiimote is just like a remote controller, but it's a motion-sensing controller that is shown as Fig.5. Not like traditional gamepad controllers, Wiimote not only has buttons but also has some sensors. So Wiimote can detect motions of a user.

Fig. 5 Wii Remote

Using the infrared camera in front it with two LEDs, it can be a pointer. The use of accelerometer, we can know user's gesture.

Wiimote can communicate with any device that has Bluetooth protocol. So Wiimote can be used to control other devices, not only play games.

Cause of the integrity of Wiimote, it's easier to use than using sensors directly The specification of Wii Remote is shown in Table 1. And we also connect a Wii Nunchuk to Wiimote.

TABLE III
Wii Remote Specification

Manufacturer	Nintendo
Input	Accelerometer
	Gyroscope (Wii Remote Plus only)
	Infrared camera
	Digital buttons (A, B, -, +, HOME, 1, 2, POWER)
	D-pad
Connectivity	Bluetooth
	Accessory connector port (400 kHz I²C)

B. Raspberry Pi

Raspberry Pi is an ARM-based single-board computer, shown as Fig.6. That is developed for teaching computer science, but it's also useful for software development.

Fig.6 Raspberry Pi Model B

Raspberry Pi has many common interfaces, so we can develop with it easily. The operating system on Raspberry Pi is Linux that is a successful operating system for software development.

TABLE II
Raspberry Pi Model B Specification

Operating System	Linux (Raspbian)
Power	3.5 W
CPU	ARM1176JZF-S 700 MHz
Memory	512 MB SDRAM
Storage	SD Card Slot
Network	10/100 Mbit Ethernet
I/O	8 GPIOs
	UART
	I2C Bus
	SPI Bus

C. Bluetooth USB Adapter

Bluetooth is common wireless communication method these days. Bluetooth has many advantages like low power consumption, etc. It is used by the Wiimote. So for communication between Wiimote and Raspberry Pi, we use a Bluetooth USB Adapter.

IV. System Design

The creation in this system architecture, there are four parts of hardware: (1)Wii Remote, (2)Bluetooth module, (3)Raspberry Pi, (4)DE0-Nano, The system architecture shown in Fig.7, Wii Remote mainly used to control the movement of the cannon vehicle and transmitter angle, Bluetooth module transmit data to the Raspberry Pi, communicate with the DE0-Nano through I2C.

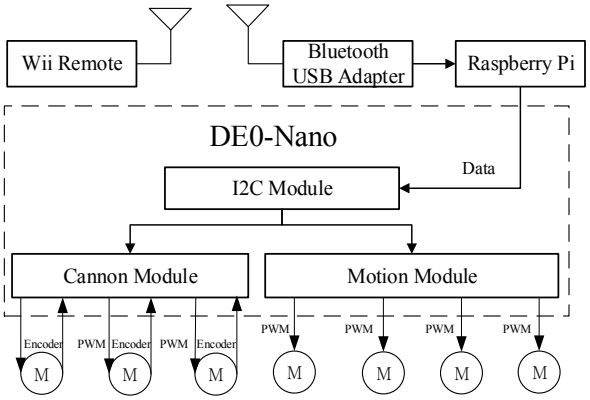

Fig.7 System Architecture

A. Software Architecture

The software part for our design is running on Raspberry Pi with Linux. Main function of the software is the main controller for our platform.

In the first, Raspberry Pi will receive the stick movement on Wii Nunchuk, A button and accelerometer data on Wiimote. Then we transfer x and y value of the stick movement become the mobile platform movement direction and speed. The mobile platform wheels position is shown as Fig.8. The calculation for wheel speed is Formula 5.

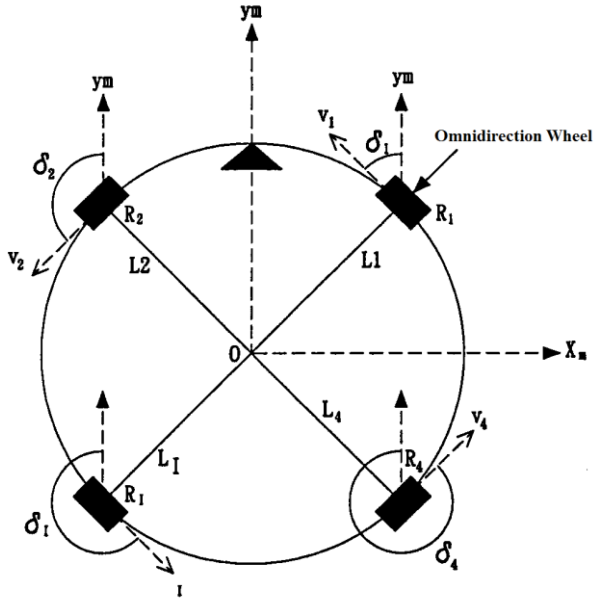

Fig.8 Omni-directional Mobile Platform

$$\begin{bmatrix} v_1 \\ v_2 \\ v_3 \\ v_4 \end{bmatrix} = \begin{bmatrix} -\sin(\delta_1) & \cos(\delta_1) & L_1 \\ -\sin(\delta_2) & \cos(\delta_2) & L_1 \\ -\sin(\delta_3) & \cos(\delta_3) & L_1 \\ -\sin(\delta_4) & \cos(\delta_4) & L_1 \end{bmatrix} \begin{bmatrix} \dot{x}_m \\ \dot{y}_m \\ \dot{\emptyset} \end{bmatrix} \quad \text{.....} \quad (5)$$

B button is the trigger for the cannon. Push B button can fire the ball from the cannon by controlling the shoot motor of cannon.

From the x, y and z value of the accelerometer, cause of the gravity effecting, we can calculate the actual angle of Wiimote. Then we can calculate and adjust two motors of cannon to the same angle. So we can control cannon angle by Wiimote.

After Raspberry Pi done the calculation for all motors control command, it will send them by I2C.

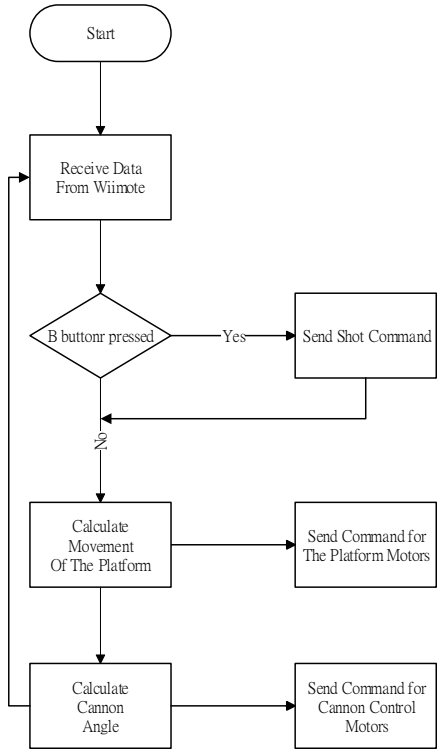

Fig. 9 Flowchart of Software Architecture

B. Hardware Architecture

In this section the hardware design of remote control of cannon vehicle platform talks about control development board, Self-design I/O interface, algorithm, motor driver and motor

Fig.9 shows using DE0-NANO development board as cannon vehicle platform controller which includes two main module vehicle-moving module and cannon rotating module. DE0-NANO development board is one of Altera company product. Using the feature of parallel process, which can control multiple motor rotate different angles in the same time. For synchronous motor rotate, FPGA is the perfect choice for mobile control and trajectory precision control.

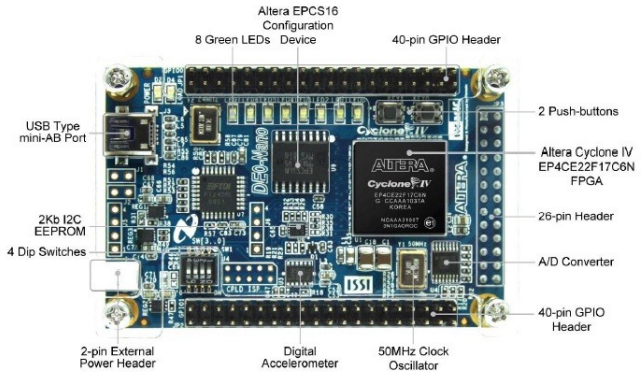

Fig.10 DE0-NANO development board

The command which DE0-NANO receive can separate into two major part, mobile module command and cannon module command, Cannon module also can be separate into two parts barrel moving control and shooting control.

This command contains cannon moving coordinate which can tell each motor where to go and trigger the motor whether shoot balls or not. In Fig.11 when cannon module receives command from Raspberry Pi CMD Module will separate command and sent it into motor module make motors turn into particular angle.

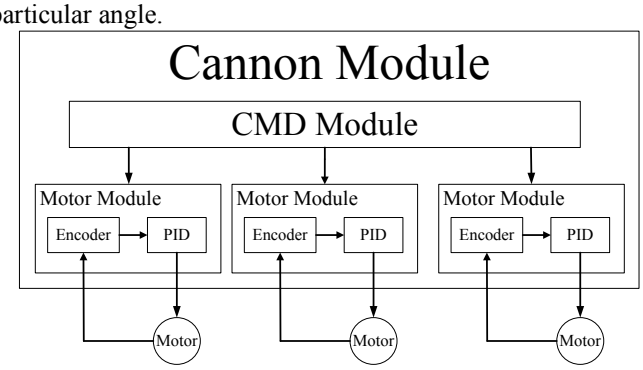

Fig.11 Cannon module

In order to make precise position control, we're using PID a controller (Proportional Integral Derivative Controller) algorithm to control LEGO DC motor and have feedback encoder for comparator to reach precise position control. In Fig.12 PID is a generic control closed loop feedback mechanism widely used in industrial control system.

A PID controller calculates an error values as the difference between measured value and desired set point. The PID controller has three major parts the proportional, the integral and derivative values which variable called Kp, Ki, Kd.

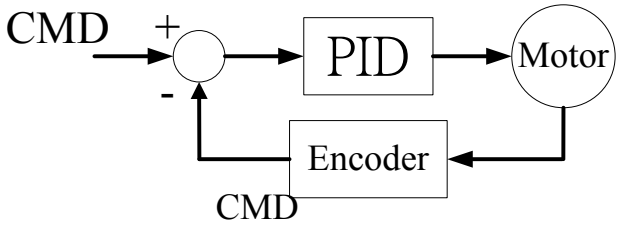

Fig.12 PID Controller

The PID control whose sum constitutes the manipulated variable, proportional, integral, and derivative terms. To sum up the terms and calculate the output of the PID controller. Defining u(t) as the controller output, the form of the PID algorithm is

$$u(t) = K_p e(t) + K_i \int_0^t e(\tau)\,d\tau + K_d \frac{d}{dt} e(t)$$

where

Kp:Proportional gain
Ki:Inregral gain
Kd:Derivative gain
e:Error
t:Time
τ:Variable of integration

Mobile module command can be separate into eight directions up, down, right, left, up-right, up-left, down-right, down left. In Fig.13 according to the CMD module gives clockwise or counter clockwise to each motor and use the command parameter to control motor speed. Even though same motor but still have some fine feature difference which gives same voltage but speed wouldn't be the same. Then use fine tune parameter to fine tune parameter to make every motor have the same speed.

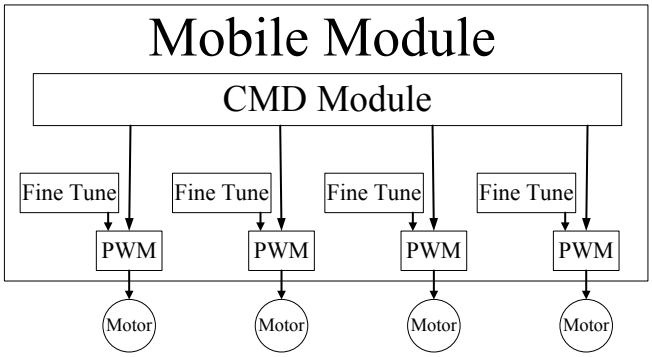

Fig.13 Mobile Module

In Fig.14, Self-design I/O interface PCB, the main commercial component are HCTL-2032 encoder chip and LB1836 motor driver chip. And we use 74LS245 octal bus transmitter/receiver as a buffer, for strengthen the signal from FPGA that can prevent signal disturbance cause motor do something unexpected.

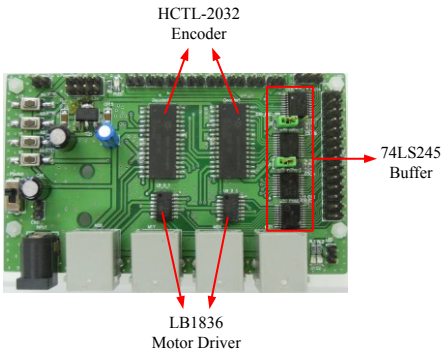

Fig.14 Self-design I/O interface

Encoder is a device that converts the angular position to an analog signal or digital signal. There are two main types: absolute and incremental. The output of absolute encoder shows current angular. The output of incremental encoder shows how many degrees has been rotate according to history information. An incremental encoder works by providing an A and B pulse as shown in Fig.15 and Fig.16. An incremental encoder provides cyclical outputs when the encoder is rotated. The two outputs A & B, which are called quadrature outputs, as they are 90 degrees out of phase. These two signals are decoded to produce a count up pulse or a count down pulse, which called clockwise and counter-clockwise. It can be use external interrupt to trigger counter counts. A & B signals can trigger counter counts by using positive-edge trigger, negative-edge and trigger when signal status changed. The method of trigger can change the resolution of encoder.

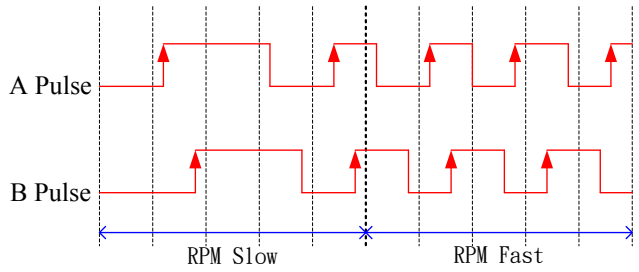

Fig.15 Encoder Clockwise

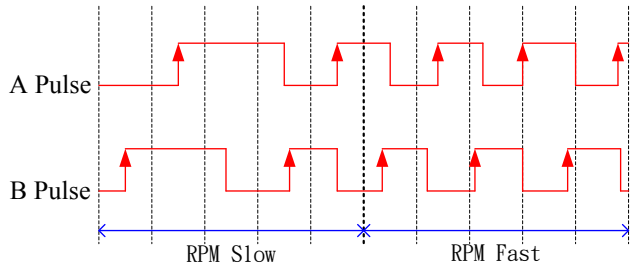

Fig.16 Encoder Counterclockwise

Motor driver chip LB1836 as shown in Fig.17 ,which can provides voltage and current the needs of motors. It can drive two DC motors and provide several functions: Clockwise, Counter clockwise, Brake, Stop and build-in over load protect circuit and over heat protect circuit.

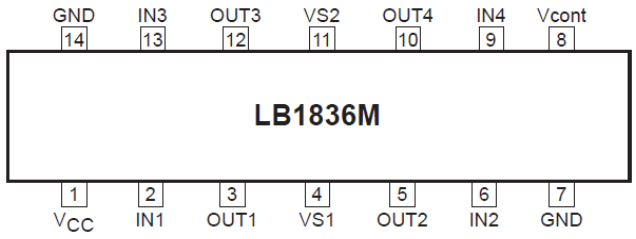

Fig.17 LB1836 Footprint

LB1836 is a motor driver chip that main circuit is H-Bridge circuit as shown in Fig.18. H-Bridge circuit main idea is using four transistors to control DC motor clockwise and counter-clockwise. In order to control motor speed, PWM (Pulse Width Modulation) is a good method to do the job. It is a modulation technique that conforms the width of the pulse. The definition of PWM is modulating the "ON" width of signal in a unit cycle, that high speed switch turning on and off to control the motor speed.

The frequency of controlling DC motor generally will be in 1KHz, and switching pulse sampling time is $T_s = T_{ON} + T_{OFF}$ The Duty-Cycle is $d = \frac{T_{ON}}{T_s}$, More heavier the duty-cycle is more voltage difference is and more speed the motor turns.

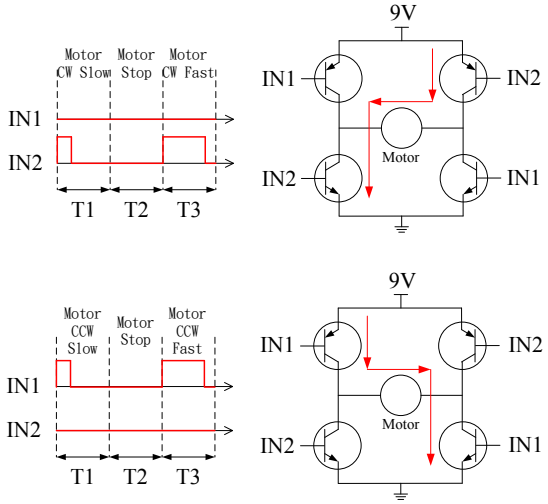

Fig.18 Motor Control

For the vehicle, we use the product of LEGO Company as shown in Fig.19, it has eight gears, gear radio is 1:48 that can torque of motor more powerful.

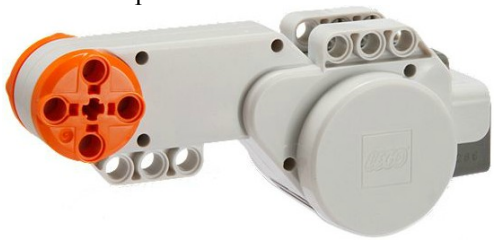

Fig.19 LEGO DC motor

Fig.20 LEGO transmission line header

It has incremental encoder inside which can transmit the angular motor rotate to FPGA. So that according to the feedback signal controller can calculate motor current angular, speed and direction.

LEGO DC motor has six pins for transmit signals, as shown in Fig.20, and white pin and black pin is motor power, when white pin get high, black pin get low the motor will clockwise. When black pin get high and white pin get low, motor will counter-clockwise, Green pin is 5v for encoder, Yellow pin and blue pin is the encoder signal.

V. CONCLUSIONS

We designed a mobile platform with a cannon successfully. The mobile platform can be controlled stability by the stick on Wii Nunchuk. The cannon also can move to the right direction that Wiimote point to. This is because of the precision control design by FPGA.

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