HAND MOTION CAPTURE THROUGH ACCELEROMETER TO DEVELOP A REMOTE CONTROLLER

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Abstract

This paper describes a remote controller based on hand motion capture, using an accelerometer, to control a car model. This is equipped with two DC engine driven by PWM signals through H-bridge. Communication between controller and model is allowed by Xbee protocol.

I. INTRODUCTION

Today the accelerometers are used in many areas such as build and structure monitoring (used to measure the motion and vibration of a structure that is exposed to dynamic loads),Medical application (for example in Belgium, accelerometer-based step counters are promoted by the government to encourage people to walk a few thousand steps each day), Navigation (to calculate position, orientation and velocity of a moving object) , transport (for example in airbag deployment systems for modern automobiles, orientation sensing (A number of modern notebook computers feature accelerometers to automatically align the screen depending on the direction the device is held), image stabilization, device integrity (Many laptops feature an accelerometer which is used to detect drops. If a drop is detected, the heads of the hard disk are parked to avoid data loss by the ensuing shock).

The recent increasing interest on inertial sensor has suggested to find an application to highlight possibility of using accelerometers to capture motion.

It was developed a system able to acquire hand motion to drive a car model.

This system foresee to positioning an accelerometer on upper side hand to detect roll (fig. 1) and pitch (fig. 2) angles with the assistance of a board (Muin) that include a microprocessor.

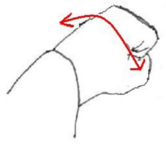

Fig. 1 Roll motion

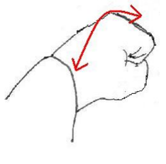

Fig. 2 Pitch motion

A pitch motion determines an acceleration/ deceleration of the model and a roll motion causes a rotation. The acceleration (rotation) is proportional to the detected angle.

The model is equipped with two DC engines driven by a H-bridge that has PWM signals as input.

These signals are generated by a board, installed on the car model, that receives data from an another board on a hand, used as controller.

II. PWM SIGNAL AND H-BRIDGE

In this work to drive each engine on car model has been used a PWM signal and a H-bridge.

A PWM signal (Pulse Width Modulation) is a square wave signal with a variable duty cycle which allows to control the power consumption of an electric load (DC engine in this work).

A H-bridge in look anti-phase configuration (fig. 3) has been used to control each engine.

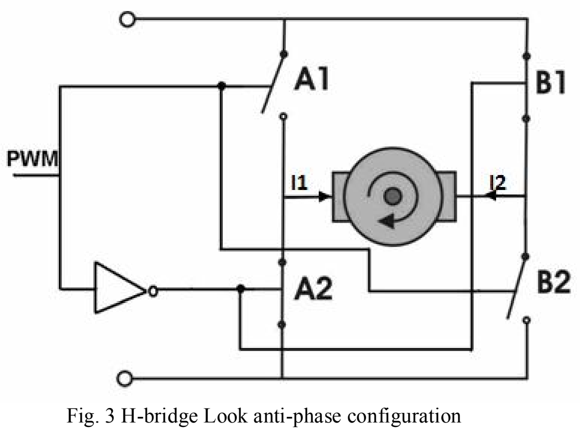

Fig. 3 H-bridge Look anti-phase configuration

In this configuration the H-bridge has two input: one is the PWM signal and the other one is the same, but inverted, so when the switches A1 and B1 are closed (note: PWM not inverted signal is high) the current I1 flows. Instead when A2 and B2 (PWM inverted signal is high) are closed, then I2 flows.

With a 50% duty cycle I1 and I2 both flow in opposite sense so the resulting current is null and engine does not spin.

With a 100% duty cycle PWM not inverted signal is always high (and PWM inverted signal is always low), this condition causes that only I1 flows and engine spins at the maximum power in the specific sense.

With 0% duty cycle PWM inverted signal is always high (and PWM not inverted signal is always low), so only I2 flows, and engine spins at the maximum power in opposite sense at the previous case.

III. REMOTE CONTROLLER

In this section will be described the main components of remote controller: accelerometer and MuIn board (fig. 4).

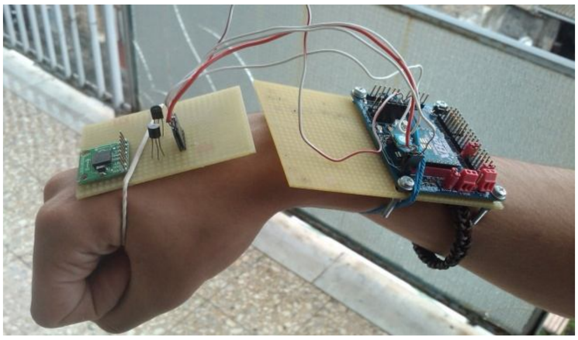

Fig. 4. Remote controller prototype

Accelerometer

This work is based on accelerometer. It is a device that detects acceleration on its three axis. There are two kinds of detectable accelerations: one caused by movement along the axis and one caused by a rotation around an axis. For example a rotation around x-axis causes a variation of gravitational acceleration on y-axis and z-axis. From this acceleration is possible to calculate the inclination angle of accelerometer.

When a axis is oriented along Earth's axis, it detects 1g acceleration, if the axis is oriented in opposite verse the acceleration detected is -1g (fig. 5); while the axis is hold in parallel position to Earth's axis the acceleration detected from accelerometer is 0g (fig. 6).

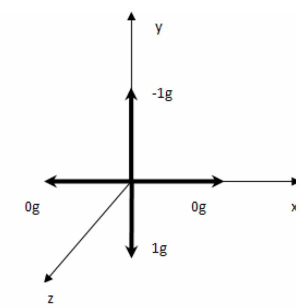

Fig. 5. Orientation-gravitational acceleration examples (a)

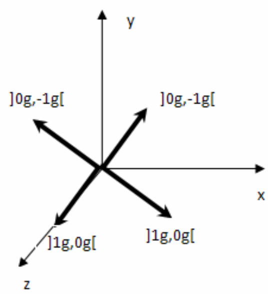

Fig. 6. Orientation-gravitational acceleration examples (b)

Seeing the fig. 5 and 6 it is possible to observe that if an axis has an angle of 45 degree or 135 degree, accelerometer detects the same gravitational acceleration, so it is not possible to distinguish these two cases. To resolve this problem is necessary to consider the gravitational acceleration on another axis.

For example in the case showed in fig. 7 and 8 the acceleration detected on x-axis is the same but we can distinguish the two positions by the different values on y-axis

Fig. 7 Ambiguous position (a)

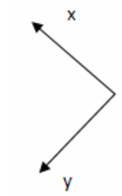

Fig. 8 Ambiguous position (b)

In this work has been used the LIS3LV02DQ accelerometer of STMicroelectronics (fig. 9).

Fig. 9. LIS3LV02DQ accelerometer

This kind of device has as output two 8-bit registers for each axis to make a 16-bit value; after some experiments was noted that less significative 8-bit were too sensitive and they detected also imperceptible vibration; but to identify hand motion only the most significative 8-bit register was necessary. For each axis this register assumes value in according with table 1.

Table 1

Accelerometer output

Accelerometer Output	Gravitational Acceleration
0	0g
192	-1g
]192,255]	] -1g ,0g [
64	1g
]0,64[	] 0g,1g [

MuIn Board

To process the output of the accelerometer has been used the Droid MuIn(Multi Interface) Board. This board is equipped with a 18F2520 PIC, that allows to connect some devices through I2C protocol and also it is able to generate two PWM signals. It also includes a XBEE module to send/receive data in wireless mode.

In this work the accelerometer was connected to I2C interface.

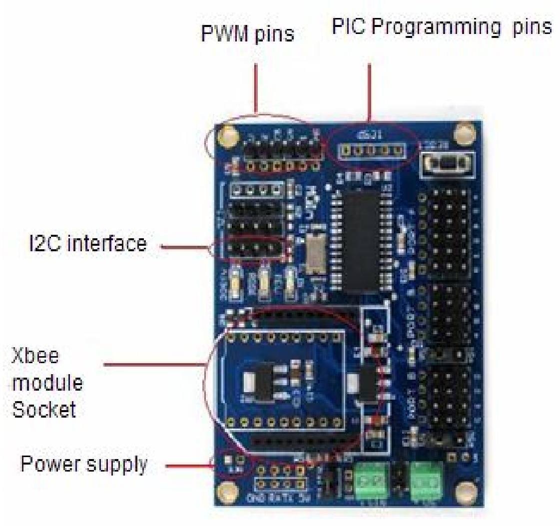

Fig. 10 MuIn Board

Acceleration to PWM signals conversion

Through the PIC is possible to set duty cycle of the PWM signal generated by the MuIn that assign a value between 0 and 1024, in particular the value 0 corresponds at 0% duty cycle and 1024 corresponds at 100% duty cycle.

The signals to generate, and send by Xbee protocol, are two: one for each engine in car-model (engine are one for wheel).

To imprint an forward movement to the model, both PWM signasl are set with a value between 0 and 512 (note that 512 value correspond to 50% duty cycle, so 0 corresponds to maximum power), instead for a backward movement the value is between 512 and 1024.

To imprint a rotational right movement is necessary to give more power to engine that control the left wheel and vice versa.

Considering that the accelerometer is positioned on the upper side of the hand, the three axis appear as in figure 10. The hand position, with y-axis and x-axis parallel to the Earth's axis and z-axis oriented in opposite verse respect Earth's axis, causes car-model motion less state.

A forward pitch movement causes a gravitational acceleration on the y-axis between 0g and 1g, in according to table1 the accelerometer output is between 0 and 64. This motion is mapped with an acceleration on the car model, that corresponds to a PWM value between 0 and 512 (when accelerometer output is 64, the PWM value must be 0).

A backward pitch motion causes a gravitational acceleration on the y-axis between -1g and 0g, therefore an accelerometer output between 192 and 255. These values must be mapped on PWM values between 512 and 1024 (when accelerometer output is 192, the PWM must be 1024).

For a higher stability around 0g, more values are been associated with a 50% duty cycle (PWM value as 512), in particular the intervals [0, 10] and [245, 255].

To allow rotational movement the values 0 and 1024 are never reached, so new limits are 100 and 850.

The resulting function is

$$PWM1 = PWM2 = \begin{cases} 512, & 0 \le OUTy < 10 \text{ or } 245 \le OUTy < 255 \\ -6.8 \cdot OUTy + 546, & 10 \le OUTy < 65, \\ -6.57 \cdot OUTy + 2156, & 191 \le OUTy < 245 \end{cases} \quad (1)$$

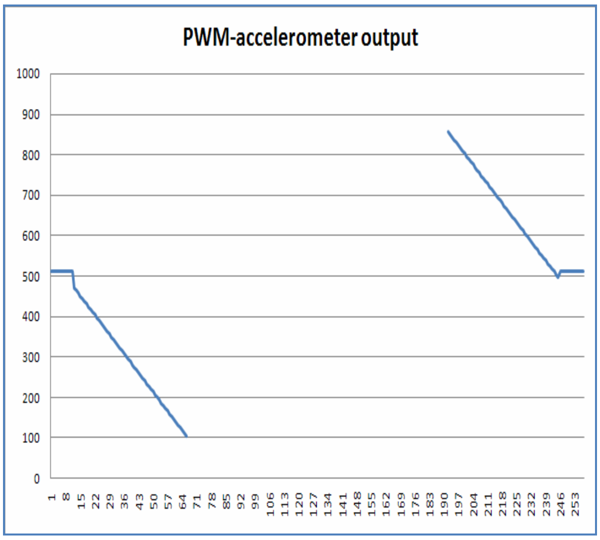

Fig. 11. Relation between accelerometer output and PWM data

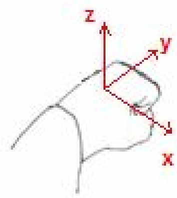

Fig. 12 Three axis of the accelerometer

A roll motion causes a car model rotation, if PWM signals are between 100 and 512 the model is going forward: a left (right) rotation is obtained adding power to right (left) engine. This is possible subtracting a value to PWM signal proportionally to the roll angle.

Similarly if the PWM signals are between 512 and 850 the car is going backward. A left (right) rotation is obtained adding a value to PWM signal of right (left) engine.

For this hand the motion gravitational acceleration on x-axis is valued. With the same reasoning for y-axis, the follow formula is obtained for x-axis:

$$\text{if } PWM1 = PWM2 \in [512, 850]$$
$$\begin{cases} PWM1 = PWM1 + (8.5 * OUTx) - 42.5, & 10 \le OUTx < 65 \\ PWM2 = PWM2 + (-8.7 * OUTx) + 2175, & 192 \le OUTx < 245 \end{cases} \quad (2a)$$
$$\text{if } PWM1 = PWM2 \in [100, 512]$$
$$\begin{cases} PWM1 = PWM1 - (8.5 * OUTx) - 42.5, & 10 \le OUTx < 65 \\ PWM2 = PWM2 - (-8.7 * OUTx) + 2175, & 192 \le OUTx < 245 \end{cases} \quad (2b)$$

If the upper side of the hand is downward, the data would be ignored, to do this is necessary check that the gravitational acceleration on z-axis is always a negative value.

Data Transmission

The two PWM values are sent to MuIn builded on car-model that control two H-bridges.

To do this both Muin are equipped with a Xbee module.

To avoid an overload caused by too many transmission not all data are sent, but only if the difference between current data and previous data is at least 5. For example if in a generic instant t the value of a PWM signal is 600 and in instant t+1 it values 604, the new data is not sent to model.

IV. CAR MODEL

The car model has three wheel: two on backside and one in front side (fig. 13). The two wheel on back side are driven by two DC engines.

This model is equipped with a MuIn and with two H-bridges (one for engine).

The MuIn, through Xbee Module, receives data from remote controller that are processed by PIC. The received data are used to generate two PWM signals that represent the input for the two H-Bridges.

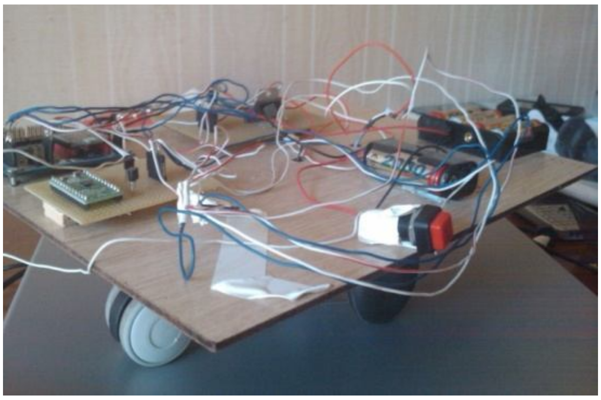

Fig. 13 Car Model Prototype

V. PROBLEMS ENCOUNTERED

A Further idea is to build a second car model that follows the first one. To do this an accelerometer has been put on the first model to detect his movement and send it to the second model. In this case the accelerometer does not detect the gravitational acceleration but the acceleration caused by a motion along the three axis.

In this situation a forward (backward) motion causes an negative (positive) acceleration on y-axis while a rotational movement causes an acceleration on x-axis. But because of centrifugal force a rotation causes a negative acceleration also on y-axis.

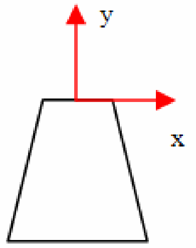

Fig. 14. Axis of the accelerometer on car model

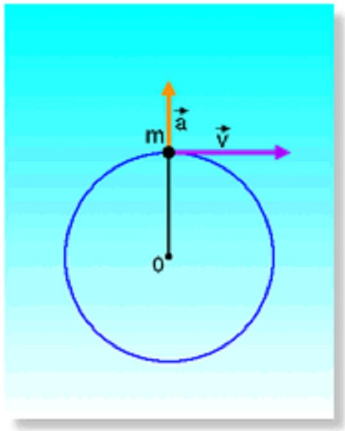

Fig. 15. Acceleration caused by a rotation movement

For example a forward movement combined with a rotation movement cause an acceleration on x-axis and y-axis as well as a simple rotation movement. So the two cases are indistinguishable.

One solution might be to integrate with accelerometer a gyroscope or to add more accelerometer to obtain more complete data.

VI. CONCLUSION

The data of the remote controller are very accurate and allow the car model to make precise movements. This shows how the accelerometer is well suited for detect inclination in absence of vibrations, in fact an inappropriate hand motion can cause incorrect data. To detect linear movements accurately a single accelerometer is not sufficient, but it must be integrated with more devices.

REFERENCES

[1] "LIS3LV02DQ data sheet" STMicrolelectronics.
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[3] "LIS3LV02DL data sheet" STMicroelectronics.