Proceedings of the
International Conference on Mechanical Engineeringand Renewable Energy 2017
(ICMERE2017) 18 – 20 December, 2017, Chittagong, Bangladesh

ICMERE2017-PI-380

Development of Real Time Motion Recognition System Using Accelerometer and Gyroscope to Implement Machine Control

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Abstract- *At present human and robots are working side by side everywhere. Therefore, with the introduction of new technologies, the gap between machines and humans is being reduced to ease the standard of living. Motion controlled system can make such systems more safe and reliable. The idea is to change a perception of remote controls for actuating manually operated robot and to eradicate the buttons, joysticks and replace them with some of the more intuitive technique that is controlling the complete robot by the hand gesture. This project deals with design and implementation of an accelerometer and gyroscope based hand motion controlled system. A sensor is mounted on the human hand, capturing its behavior (gestures and postures) and thus the device moves accordingly. For proper functioning and to reduce the amount of noise from the sensors an algorithm is going to be used for precise output. The process is carried out by a microcontroller unit using a program. The results are studied and evaluated to confirm the accuracy of the method used in this project.*

Keywords: Motion Control, Hand Gesture, MEMS, IMU, Arduino.

1. INTRODUCTION

The interfacing between man and machine is the beginning of a new era. Humans and machines no longer run parallel to each other, but instead, they go hand in hand. This new technology is helping to improve lifestyle which motivates the creation of a better technology for tomorrow. The technology used in robotics earlier was of a joystick, then came in the touch screen, and now it is the advent of gestures using motion control.

Motion control is a sub-field of automation, encompassing the systems or sub-systems involved in moving parts of machines in a controlled manner. It is an important part of robotics and CNC machine tools. Motion control is a topic with the goal of interpreting human gestures via mathematical algorithms. Gestures can originate from the face or hand [1]. Current focuses in the field include emotion recognition from face and hand gesture recognition. Users can use simple gestures to control or interact with devices without physically touching them. Many approaches have been made using cameras and computer vision algorithms to interpret sign language. However, the identification and recognition of posture and human behaviors is also the subject of motion control techniques [2]. Gesture recognition can be seen as a way for computers to understand human body language, thus building a richer bridge between machines and humans than primitive text user interfaces or even GUIs, which still limit the majority of input to keyboard and mouse.

Motion Control enables humans to communicate with the machine (HMI). Human hand can perform several gestures. Those gestures can be used as input signals to control robots and machines [3]. With the rapid development of micro–electro-mechanical system technology (MEMS), the accelerometer-based gesture recognition becomes increasingly popular and already shows potential in practical applications.

Motion based control is unique phase and most popular way. It’s performs task with users hand gesture. That’s why this process is very easy, time saving and efficient. Motion recognition based system is helpful for industrial automations which saves controlling complexity and time, rescue operations and for disabled people. The most unique feature is its synchronous movement with human hand gesture.

However, in this paper a motion recognition system is developed to implement machine control. MEMS 3-axis accelerometer and 3-axis gyroscope are attached to user hand to detect current position i.e. gesture and posture as well as angular position [4]. An artificial algorithm is used to recognize data from sensors, then processed signal sends to control unit. A filter is applied to remove noise from the sensor data. Finally, the results and performance of the developed system are presented and discussed.

2. PROPOSED WORK

2.1 System Overview:

The system mainly focuses on the interaction of human. Gesture originates from any bodily motion but most commonly face and hand is taken into consideration [5]. Figure 1 shows different hand motions.

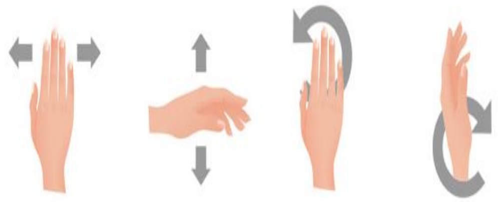

Fig.1: Hand Motion

The system consists of a wearable sensor system that features the measurement of human hand gesture. An Inertial Measurement Unit (IMU) which consists of a tri-axis accelerometer and gyroscope is attached to a microcontroller and the data is transmitted to a graphical user interface via Bluetooth connection to allow real time tracking functions. A quaternion based algorithm is implemented in the sensor device to monitor the orientation with respect to the sensor's position in the user's hand.

2.2 Requirements behind the Project:

For the system, the following items are required:

- Sensor: MPU-6050
- Microcontroller: Arduino Mega
- Bluetooth Module
- Voltage Regulator
- Servo Motor
- Aluminum Bracket
- Power Supply:
    - Microcontroller: +6V
    - Sensor: +5V
    - Bluetooth Module: +5V
    - Servo Motor: +6V

2.3 Block Diagram:

At first the sensor reads data from hand gesture which is sent to arduino microcontroller for calculation. A graphical user interface receives the data using Bluetooth communication. The main board utilizes these data for movement of the actuators. This whole system can be expressed as follows (Figure 2):

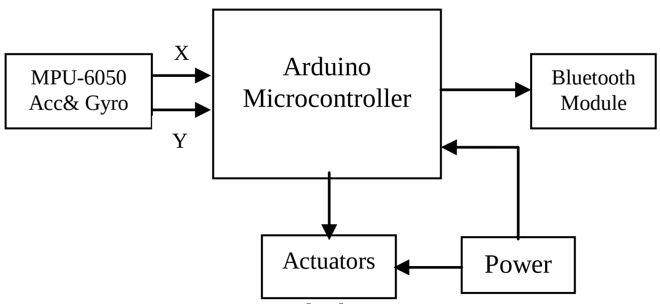

Fig.2: Block Diagram

2.4 Methodology:

The sensor board i.e. MPU-6050 is placed horizontally on top of a hand glove. When hand moves in different angle then the sensor detect its acceleration as a raw value and also detects gyros raw value. These values are fed by main board and raw data is converted to meaningful angle. For processing purpose arduino microcontroller board is used which has Atmega2560 microcontroller and 16MHz crystal oscillator. Different library function and geometrical calculation are used to find out exact angle of gesture and behavior. By combining accelerometer data and gyro data proper angle along a specific axis is measured. It is seen that the normal calculation has small deviation from the world frame and time. To solve this problem a filter is used. This filter re-calculates the angle each time to get real time exact angle and compare it with world frame. Basically this calculated angle range is 0-360 degree. The actuator movement range is 0-180 degrees, that's why to maintain synchronous movement, 0-360 degrees are scaled down to 0-180 degree by movement mapping in algorithm section.

In this system IEEE standard series HC-05 Bluetooth module is used. AT mode and high baud rate is selected for better performance.

At receiving section transmitted data are received by a graphical user interface. It shows the hand motion and the performance of the filter applied. Main board contains mapping instruction which help to move the actuators with proper angle [6]. This ensures a synchronous movement with hand gesture.

2.5 Complementary Filter Algorithm:

Complementary filter is used in an infinite loop. The gyroscope data is integrated every time step with the current angle value. Then the data is combined with low pass data from the accelerometer. The filtering system is given in Figure 3:

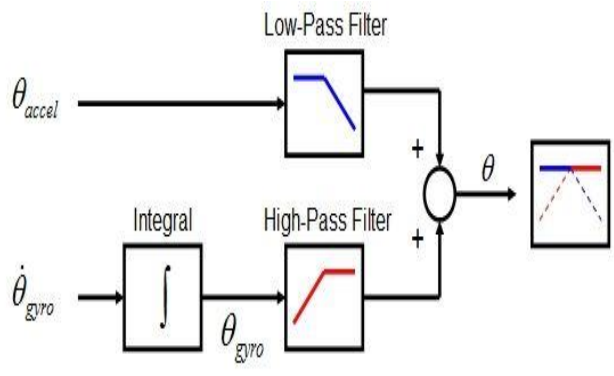

Fig.3: Complementary Filter for Orientation

Filtered angle= $\alpha \times$ (previous angle + gyro data $\times$ dt) + $(1-\alpha) \times$ (acc data)

Where $\alpha = \tau/(\tau + \Delta t)$
Δt = sampling rate, τ = time constant

The filter then checks if the magnitude of the force seen by the accelerometer has a reasonable value that could be the real g-force vector. If the value is too small or too big, it is a disturbance that does not need to take into account. This ensures that the data will be very accurate.

3. CONTROL SYSTEM

3.1 Movement Control:

For synchronous movement of the device an ideal frame containing (x, y) axis is considered. In the system world frame is considered as ideal and then calculate the sensor displacement along with (x, y) axis. Then the angle is mapped with servo angle.

The device consists of two servo motor. Each motor can move 0-180 degree. Motors are specified for definite axis rotation. That means x-axis data is used to control a motor which set for x axis rotation. As a result the device moves along x-axis. y axis data is used to control other servo motor. Their control strategy is in same way. That's why movement of the device is synchronous with human arm gesture.

3.2 Algorithm for Control System:

The internal data acquisition and processing algorithm can be given as follows (Figure 4):

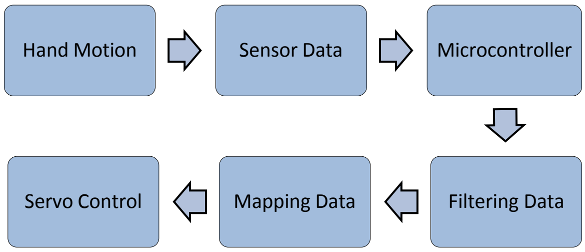

Fig.4: System Algorithm

3.3 Mode of Operation:

The device is moved depending on the gesture made by human hand. The Arduino microcontroller reads the analog output values i.e., x-axis and y-axis values of the accelerometer and gyroscope sensor. It converts the analogue values to respective digital values.The digital values are processed by the arduino microcontroller and according to the data it sends the commands to drive the motors to a particular direction [6]. The device moves when hand is tilted in upward, downward, right and left respectively. Table 1 shows the control system for different hand gestures.

Table 1: Control System for Different Actions

Hand Gestures	Movement
Upward	Tilt Upwards
Downward	Tilt Downwards
Right	Pan Right
Left	Pan Left
Parallel	Parallel to Ground

4. CONSTRUCTION AND PERFORMANCE:

4.1 Final Assembly:

The device is setup by placing the whole circuit onto an Arduino prototyping breadboard. The setup consists of an Inertial Measurement Unit, Bluetooth HC-05 and power supply unit and the actuators. A buck converter is used to get the desired voltage from the power supply unit. The sensor is attached to an arm band for controlling the device. Figure 5 shows the final assembly of the system.

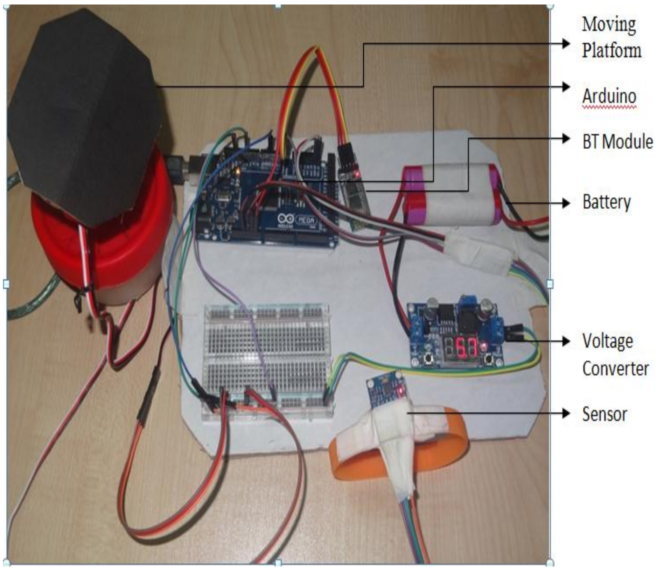

Fig.5: Final Assembly

The arm band is placed in the human hand to capture its gestures. The x axis and y axis data are measured and a filter is applied to it.

The graphical user interface in Figure 6 shows the corresponding orientation of the human hand. The pitch circle shows the x axis data and the roll circle shows the y axis data from the sensor. The blue line represents the raw data from the sensor and the red line is the filtered angle.

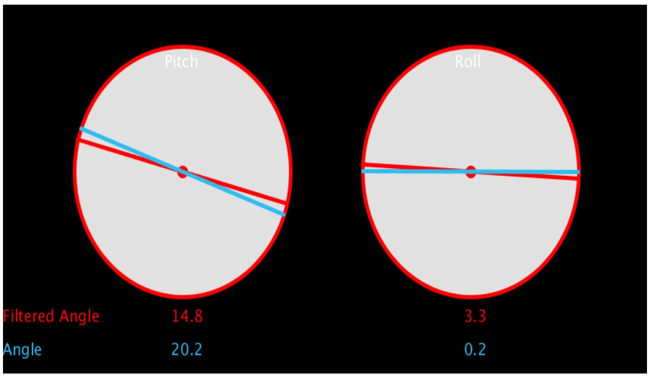

Fig.6: Graphical User Interface

4.2 Schematic Diagram:

The schematic diagram in Figure 7 shows the connections between the sensor, module and actuators to the microcontroller used in this system.

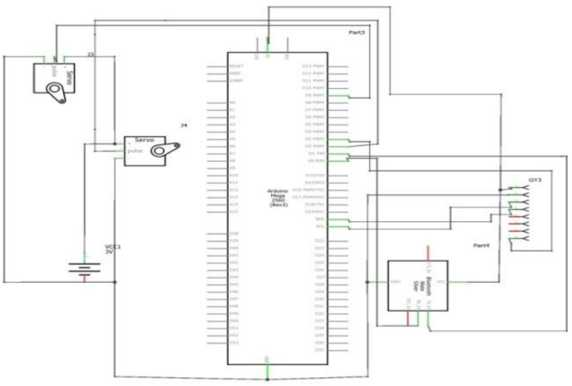

Fig.7: Schematic Diagram

4.3 Results:

Due to unwanted or slight movement of human hand the stability of the system downfalls. Therefore, to stabilize the signals of the sensor, complementary filter is used. The scattered line demonstrates unfiltered sensor data which is very sensitive and noisy. The red line shows the filtered result which is smooth and eliminates all the noise. The Figure 8 shows the x and y axis filtered data in graph.

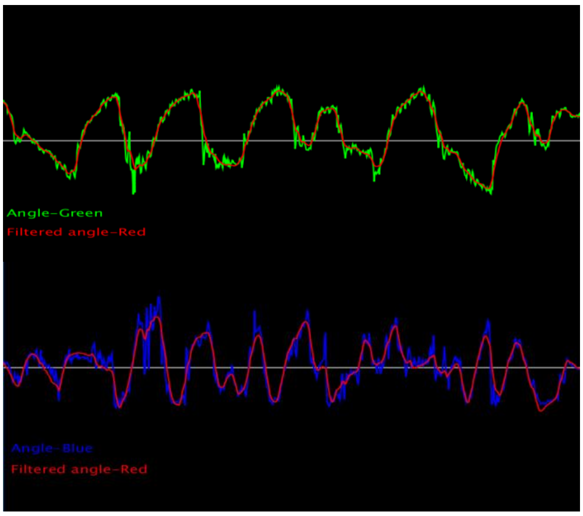

Fig.8: Raw data and Filtered Data in Graph

The angle of the device for different data of the sensor is measured. The difference between the data shows the error of the system. The accuracy of the device is calculated to analyze the performance. The x axis and y axis data is shown in Table 2.

Table 2: Motion Recognition Data

No of Observation	Sensor Angle	Actuator (x-axis)	Actuator (y-Axis)
1	30	27	24
2	45	40	41
3	60	54	56
4	-30	-24	-25
5	-45	-40	-41
6	-60	-57	-56

X axis accuracy=88.6%
Y axis accuracy=89.1%
Overall accuracy=88.8%

5. CONCLUTION AND FUTURE WORK

The system developed in the project presented an approach to compensational modeling that enables the construction of a human hand motion controlled device. The work is different from the existing approaches in the sense that it does not use the conventional control system rather uses different hand gestures to get the desired motion from the device.

This motion control method is expected to overcome the problem of dealing with hazardous object in a very fast and easy manner. The accelerometer and gyroscope sensor are selected as the input device of this system which captures the human gestures. When compared with the other methods, it is easier to work and offers the possibility to control a robot. Physical hardship to the user can be avoided through the use of sensor as with the twist of the hand, the user gets the ability and freedom to turn the device into the desired direction. This system uses extremely simple ideas and mechanisms to achieve a complex set of actions and is intended to imitate the actions of the user in a convenient way.

Future work will build upon the improvement of the average of correctly recognized gestures. One approach might be the implementation of more accelerometer and gyroscope into the system.

6. REFERENCES

[1] Pedro Neto, J. Norberto Pires, A. Paulo Moreira, “Accelerometer-Based Control of an Industrial Robotic Arm” Available at: http://arxiv.org/ftp/arxiv/papers/1309/1309.2090.

[2] Dr. R. V. Dharaskar, S. A. Chhabria, Sandeep Ganorkar, “Robotic Arm Control Using Gesture and Voice”, In International Journal of Computer, Information Technology & Bioinformatics (IJCITB), Vol. 1, Issue 1, pp. 41-46

[3] S. Waldherr, R. Romero and S. Thrun, 2000, “A gesture based interface for human-robot interaction”, In Autonomous Robots in Springer, vol. 9, Issue 2, pp. 151173

[4] K. Brahmani, K. S. Roy, Mahaboob Ali, April 2013, “Arm 7 Based Robotic Arm Control by Electronic Gesture Recognition Unit Using Mems”, International Journal of Engineering Trends and Technology, Vol. 4 Issue 4

[5] S. Perrin, A. Cassinelli and M. Ishikawa, May 2004, “Gesture Recognition Using Laser-Based Tracing System”, In Automated Face and Gesture Recognition. Proceeding, Sixth IEEE Conference, pp. 541-546

[6] S. Waldherr, R. Romero and S. Thrun, “A gesture based interface for human-robot interaction”, In Autonomous Robots in Springer, vol. 9, Issue 2, pp. 151-173, 2000.