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MEMS-based Hand Gesture Controlled Robot using Raspberry Pi

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ABSTRACT

This article presents micro electromechanical system (MEMS) accelerometer-based hand gesture-controlled robot which utilizes hand gestures for controlling the directions of robot rather than an ordinary old switches, joystick, and RF remote etc. In future there is a chance of making robots that can interact with humans in a natural manner. Hence our target interest is with hand motion-based gesture interfaces. An innovative Formula for gesture recognition is developed for identifying the distinct action signs made through hand movement. A MEMS Sensor was used to carry out this and an Ultrasonic sensor for convinced operation. To full-fill our requirement a program has been written and executed using a microcontroller system. Upon noticing the results of experimentation proves that our gesture formula is very competent, and it is also enhanced the natural way of intelligence and assembled in a simple hardware circuit.

Keywords: Raspberry Pi, Python, MEMS sensor, motor driver.

1. INTRODUCTION

Technology is the word coined for the practical application of scientific knowledge in the industry. The advancement in technology cannot be justified unless it is used for leveraging the user's purpose. Technology, is today, imbibed for accomplishment of several tasks of varied complexity, in almost all walks of life. The society is exquisitely dependent on science and technology. Technology has played an incredibly significant role in improving the quality of life. One way through which this is done is by automating several tasks using complex logic to simplify the work. Gesture recognition has been a research area which received much attention from many research communities such as human computer interaction and image processing. The increase in human machine interactions in our daily lives has made user interface technology progressively more important. Physical gestures as intuitive expressions will greatly ease the interaction process and enable humans to command computers or machines more naturally. Now a day's robots are controlled by remote or cell phone or by direct wired connection. If we are thinking about cost and required hardware's all these things increases the complexity, especially for low level application. For example, in telerobotic, slave robots have been demonstrated to follow the master's hand motions remotely [1].

Gestures control robots are extensively employed in human non-verbal communication. They allow to express orders (e.g. "stop"), mood state (e.g. "victory" gesture), or to transmit some basic cardinal information (e.g. "two"). In addition, in some special situations they can be the only way of communicating, as in the cases of deaf people (sign language) and police's traffic coordination in the absence of traffic lights, a real-time continuous gesture recognition system for sign language Face and Gesture recognition.

Robots are becoming increasingly useful on the battlefield because they can be armed and sent into dangerous areas to perform critical missions. Controlling robots using traditional methods may not be possible during covert or hazardous missions. A wireless data glove was developed for communications in these extreme environments where typing on a keyboard is either

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Vol-10 Issue-5 No. 6 May 2020

impractical or impossible. This paper reports an adaptation of this communications glove for transmitting gestures to a military robot to control its functions. Novel remote control of robots has been an active area of research and technology, especially over the past decade. For example, a wearable, wireless tele-operation system was developed for controlling robot with a multi-modal display. Remotely controlled robots have been used in environments where conditions are hazardous to humans.

Gestures are physical movements of hand or head with expressive and meaningful motions to convey or interact with surrounding [1]. Gesture recognition system is to interpret movement of hand or head via an algorithm to enable human communication with machine. It has various types of applications such as sign language recognition, socially assistive robotics, alternative computer interfaces, immersive game technology, virtual controller, remote control etc. [2]. There have been many approaches to handle gesture recognition [3], from software to hardware or combination of both. There are many who have developed gesture recognition system by using image processing, accelerometer, gyroscope, or mathematical model for various applications [4-9]. Practical implementation of gesture recognition system based on possibility distribution of movement can utilize signal of movement based on acceleration measured from using MEMS accelerometer [10]. Accelerometer behaves as a damped mass on a spring. When the accelerometer experiences an acceleration, the mass is displaced to the point that the spring can accelerate the mass at the same rate as the casing. The displacement is then measured to give the acceleration. Also, gravitational acceleration value, measured in g, is influencing the accelerometer to generate an offset value when the sensor is on a static state.

2. PROPOSED METHODOLOGY

The main aim of this paper is to control a robot by using a MEMS sensor with hand gestures. MEMS accelerometer sensor is micro electro-mechanical sensor which is an overly sensitive sensor and capable of detecting the tilt. This sensor finds the tilt and makes use of the accelerometer to change the direction of the robot depending on tilt. For example, if the tilt is to the right side then it moves in right direction or if the left side then it moves in the left direction. The movement of robot can be controlled in forward, backward, right, and left directions using the hand gestures with MEMS sensor.

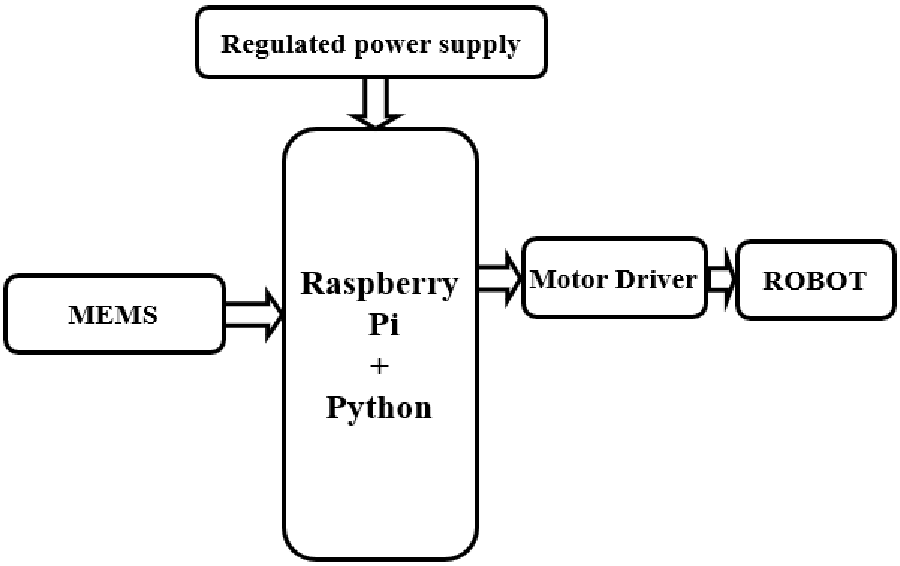

Figure 1. Proposed MEMS-based hand gesture-controlled robot system.

This project makes uses Raspberry Pi processor for controlling all the components or devices connected to it, it is programmed with the help of python script. It will communicate with the motor driver when a gesture is detected by the MEMS sensor based on hand movement and accordingly the robot will move in that direction. In the area of safety, for example, many machines require operators to place each hand on a control switch before the controller starts any action. Instead of having operators move their hands to special switches, why not simply let them hold up their hands with a gesture sensor? This type of control could improve productivity, reduce the effects of repetitive motions, and improve safety. Advanced robotic arms that are designed like the human hand itself can easily controlled using hand gestures only. The arm controller wears the sensor gloves and the robotic arm will mimic the movement of the controller. Advanced robotic arms like these can perform complex and hazardous tasks with ease. Proposed utility in fields of construction, hazardous waste disposal, medical sciences.

3. EXPERIMENTAL SETUP

Cloud storage is a data storage model where the data storage will be in logical pools. The physical storage pairs several hosts (probably numerous areas) and this environment is normally copped to and maintained by a hosting organization. These cloud renders are creditworthy for maintaining this data feasible and approachable with security. Practically, users or any companies will purchase or lease the capacity of storage from the renders for storing company, user, or any application data. Python is an interpreted, object oriented, high level programming language with dynamic semantics. Python's simple. easy to learn syntax emphasizes readability and therefore reduces the cost of program maintenance. Python supports module and packages, which encourages program modularity and code reuse.

3.1. Raspberry Pi

It is an ultra-cheap minicomputer with 5.5 cm width and 9 cm length. It consists of a component named System on Chip (SoC) which comprises of single core CPU with a supportive processor for computing floating points, GPU and RAM with 512 MB size (SD-RAM). Moreover, it consumes less power, which is just around 5-7 watts. The architecture of raspberry pi is given in figure 2. It has couple of cache memory levels, where first level is of 32KB size and the latter is of 128KB size. These are utilized to store recent programs and ALU is utilized to execute instructions.

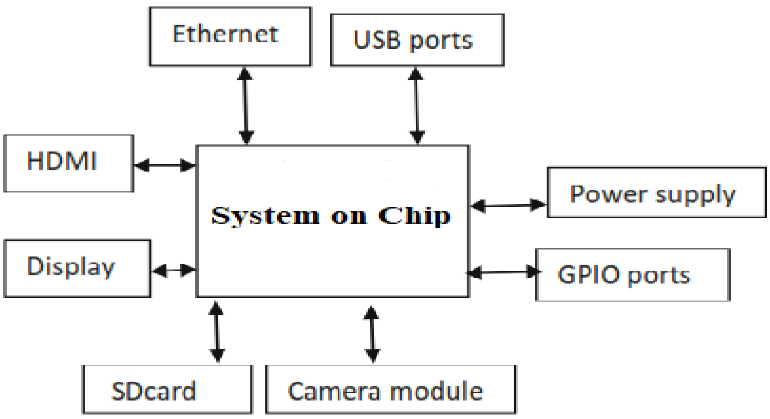

Figure 2. System architecture of raspberry pi

ISSN: 2278-4632
Vol-10 Issue-5 No. 6 May 2020

Table 1. Specifications of Raspberry pi

Chip	Broadcom BCM2835 SoC
Core architecture	ARM 11
CPU	700 MHz Low power ARM1176JZFS
RAM	512 MB (SD-RAM)
OS	Linux
Dimensions	$85.6 \times 53.98 \times 17\ mm$
Power	Micro USB socket, 5 V, 1.2 A

It is an exceedingly small device and can incorporate other devices also. It consists of both the hardware and software. It requires an SD card and a power supply to related mouse and keyboard. Additionally, a display also exists for functioning OS such as Windows and Linux.

Figure 3. Raspberry pi

3.2. MEMS Accelerometer sensor

One of the most common inertial sensors is the accelerometer, a dynamic sensor capable of a vast range of sensing. Accelerometers are available that can measure acceleration in one, two, or three orthogonal axes. They are typically used in one of three modes:

- As an inertial measurement of velocity and position.
- As a sensor of inclination, tilt, or orientation in 2 or 3 dimensions, as referenced from the acceleration of gravity (1 g = 9.8m/s2).
- As a vibration or impact (shock) sensor.

There are considerable advantages to using an analog accelerometer as opposed to an inclinometer such as a liquid tilt sensor – inclinometers tend to output binary information (indicating a state of on or off), thus it is only possible to detect when the tilt has exceeded some thresholding angle.

3.2.1. Operation principles

The basic principle of operation behind the MEMS accelerometer is the displacement of a small proof mass etched into the silicon surface of the integrated circuit and suspended by small beams. Consistent with Newton's second law of motion (F = ma), as an acceleration is applied to the device, a force develops which displaces the mass. The support beams act as a spring, and the fluid (usually air) trapped inside the IC acts as a damper, resulting in a second order lumped physical system. This is the source of the limited operational bandwidth and non-uniform frequency response of accelerometers.

3.2.2. Output

An accelerometer output value is a scalar corresponding to the magnitude of the acceleration vector. The most common acceleration, and one that we are constantly exposed to, is the acceleration that is a result of the earth's gravitational pull. This is a common reference value from which all other accelerations are measured (known as g, which is ~9.8m/s^2).

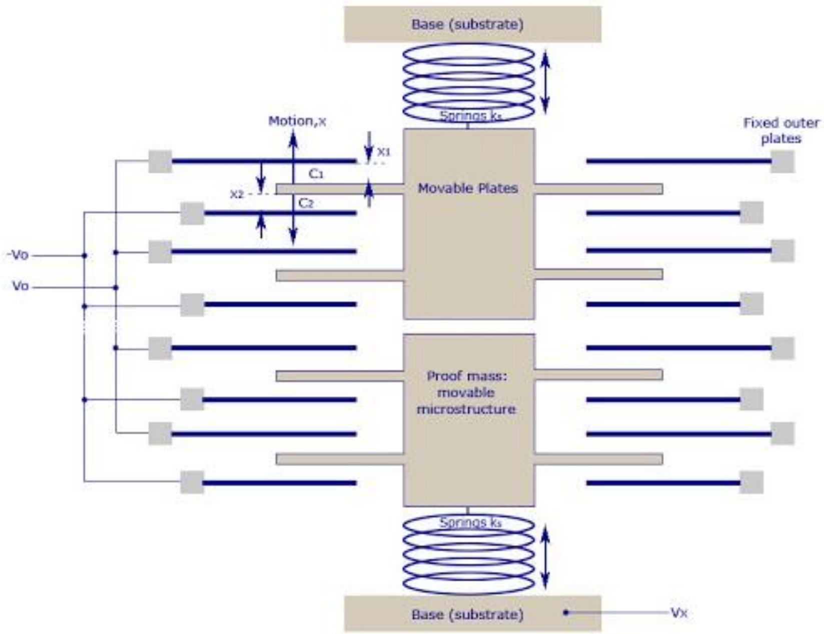

Figure 4. Working of MEMS accelerometer.

3.2.3. Usage

The acceleration measurement has a variety of uses. The sensor can be implemented in a system that detects velocity, position, shock, vibration, or the acceleration of gravity to determine orientation. A system consisting of two orthogonal sensors is capable of sensing pitch and roll. This is useful in capturing head movements. A third orthogonal sensor can be added to the network to obtain orientation in three-dimensional space. This is appropriate for the detection of pen angles, etc. The sensing capabilities of this network can be furthered to six degrees of spatial measurement freedom by the addition of three orthogonal gyroscopes.

 ISSN: 2278-4632
Vol-10 Issue-5 No. 6 May 2020

As a shock detector, an accelerometer is looking for changes in acceleration. This jerk is sensed as an overdamped vibration.

Verplaetse has outlined the bandwidths associated with various implementations of accelerometers as an input device. These are:

Location	Usage	Frequency	Acceleration
Head	Tilt	0-8 Hz	xx
Hand , Wrist, Finger	Cont.	8-12 Hz	0.04-1.0 g
Hand, Arm, Upper Body	Cont.	0-12 Hz	0.5-9.0 g
Foot, Leg	Cont.	0-12 Hz	0.2-6.6 g

Depending on the sensitivity and dynamic range required, the cost of an accelerometer can grow to thousands of dollars. Nonetheless, highly accurate inexpensive sensors are available.

3.3. Motor Driver

Using this L293D motor driver IC is amazingly simple. The IC works on the principle of Half H-Bridge, let us not go too deep into what H-Bridge means, but for now just know that H-bridge is a setup which is used to run motors both in clock wise and anti-clockwise direction. As said earlier this IC can run two motors at the any direction at the same time, the circuit to achieve the same is shown below.

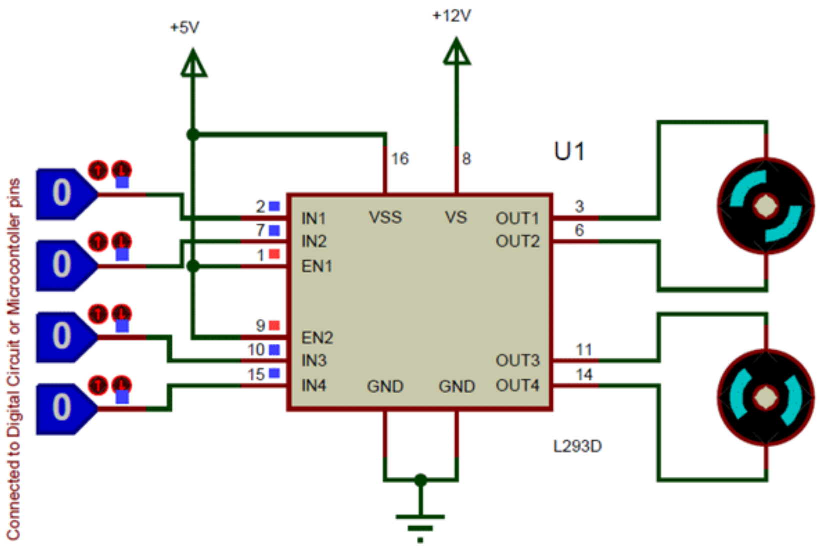

Figure 5. L293D circuit.

All the Ground pins should be grounded. There are two power pins for this IC, one is the Vss (Vcc1) which provides the voltage for the IC to work, this must be connected to +5V. The other is Vs (Vcc2) which provides voltage for the motors to run, based on the specification of your motor you can connect this pin to anywhere between 4.5V to 36V, here I have connected to +12V.

ISSN: 2278-4632
Vol-10 Issue-5 No. 6 May 2020

The Enable pins (Enable 1, 2 and Enable 3,4) are used to Enable Input pins for Motor 1 and Motor 2 respectively. Since in most cases we will be using both the motors both the pins are held high by default by connecting to +5V supply. The input pins Input 1,2 are used to control the motor 1 and Input pins 3,4 are used to control the Motor 2. The input pins are connected to the any Digital circuit or microcontroller to control the speed and direction of the motor. You can toggle the input pins based on the following table to control your motor.

Input 1 = HIGH (5v)	Output 1 = HIGH	Motor 1 rotates in Clockwise Direction
Input 2 = LOW (0v)	Output 2 = LOW	
Input 3 = HIGH (5v)	Output 1 = HIGH	Motor 2 rotates in Clockwise Direction
Input 4 = LOW (0v)	Output 2 = LOW	

Input 1 = LOW (0v)	Output 1 = LOW	Motor 1 rotates in Anti-Clockwise Direction
Input 2 = HIGH (5v)	Output 2 = HIGH	
Input 3 = LOW (0v)	Output 1 = LOW	Motor 2 rotates in Anti -Clockwise Direction
Input 4 = HIGH (5v)	Output 2 = HIGH	

Input 1 = HIGH (5v)	Output 1 = HIGH	Motor 1 stays still
Input 2 = HIGH (5v)	Output 2 = HIGH	
Input 3 = HIGH (5v)	Output 1 = LOW	Motor 2 stays still
Input 4 = HIGH (5v)	Output 2 = HIGH	

3.3.1. Applications

- Used to drive high current Motors using Digital Circuits.
- Can be used to drive Stepper motors.
- High current LED's can be driven.
- Relay Driver module (Latching Relay is possible).

ISSN: 2278-4632
Vol-10 Issue-5 No. 6 May 2020

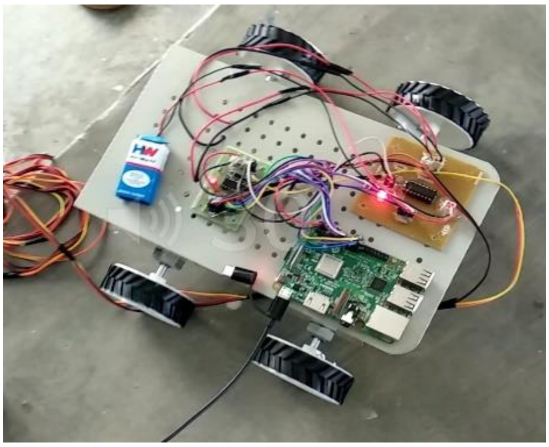

Figure 6. Hardware setup.

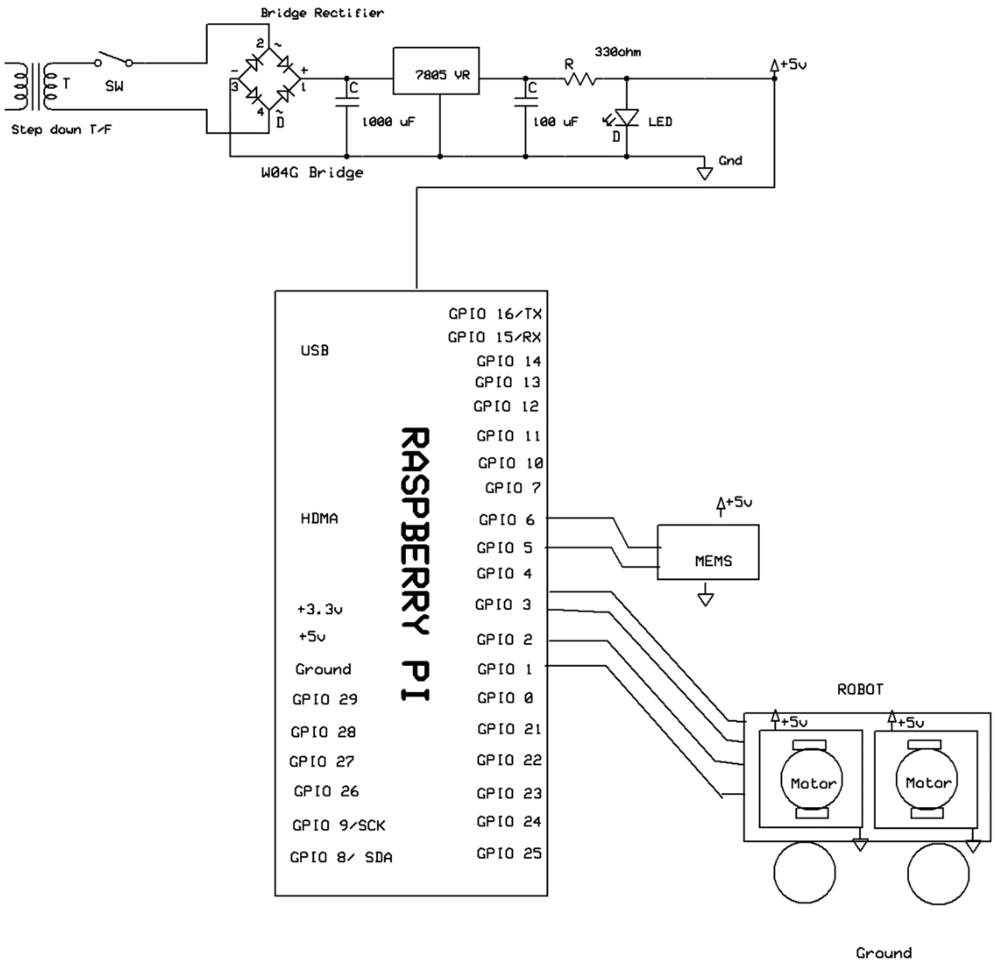

Figure 7. Schematic circuit of proposed model.

4. CONCLUSIONS

This article presented MEMS-based hand gesture recognition for controlling robot using Raspberry Pi, where MEMS sensor is utilized to recognize the gestures of hand by moving it forward, backward, right and left directions based on the tilt of MEMS sensor. Then accordingly, the robot moves in the same direction. Further, this can be extended by adding obstacle detection and auto avoid with a wireless surveillance camera.

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