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Operation of Wireless Humanoid Robot using Graphene Embedded Bend Sensor and Internet of Things Technology

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***Abstract:** The use of Robots is a trending technology but automation and Artificial Intelligence are not fully achieved till date. This paper aims to propose an innovative system to integrate human intelligence with Robotics. The robots which have been designed to work in harsh conditions are controlled using graphene-based flexible bend sensors. These sensors are applied to the human body and are powered by solar energy. Here a flexible sensor is applied on each bend on the human body and respective data of bend angle is transmitted to the raspberry pi 3 model B kits which are programmed to act accordingly and the same bend is obtained in the Robot. The sensor which we have used in this project removes the messy wiring and there is no need to wear any kind of suit. The required movements for the robot are produced by a human after applying the sensors on each joint. It looks like a pasting that is pasted across the joint. These sensors are made from a biocompatible material, thus does not have any dermatological ill effect on the operator. The graphene-based sensor has a subsequent role in robotics as they develop position matrices that determine the current position of various members of the humanoid robot. Robotic application demands sensors with a higher degree of repeatability, precision, and reliability which is obtained using the Graphene-based bend sensors. Each sensor is self-capable to carry out motion of one degree of motion. The use of an accelerometer attached along with the sensor helps to control the speed of robotic operation. This system is suitable to control the robot from a distance and uses it in critical conditions with the intelligence of the human being who is operating it, the rise in temperature leads to an increase in the time-lapse in command and action. But still, it can be treated as the substitute for artificially intelligent robots as we have not reached the level of intelligence in human beings. This work is based on the combined concepts of mechanical, computer, and electronics engineering.*

***Keywords:** Humanoid Robot; Graphene Materials; Motion Sensor; Accelerometer; Artificial Intelligence; IoT Applications.*

I. INTRODUCTION

The concept of a data-based glove has been traditionally accepted in the Robotics field. The Robotics engineers are developing models and prototypes that are using innovative sensor technologies to recognize the gesture of the hand and work accordingly. In this work, we are using the graphene-based flex sensor technology to control a complete humanoid robot. This system uses a flex sensor at every junction where the angular motion is required. The system with flex or bend sensor uses a flexible sensor that operates on the angular position. These analog resistors vary the resistance using an analog voltage divider. The carbon resistive element is present with a flexible substrate, as the quantity of carbon is increased the resistance is decreased. The bend in the substrate produces the output according to the bend radius. Thin Flexible substrate in flexible sensor provides the better form factor. The Fig. 1a shows the fabrication of graphene-based flexible sensor which is capable of generating the power which is required to transmit the data using solar power, Fig.1b shows the actual sensor of 4.5-inch length.

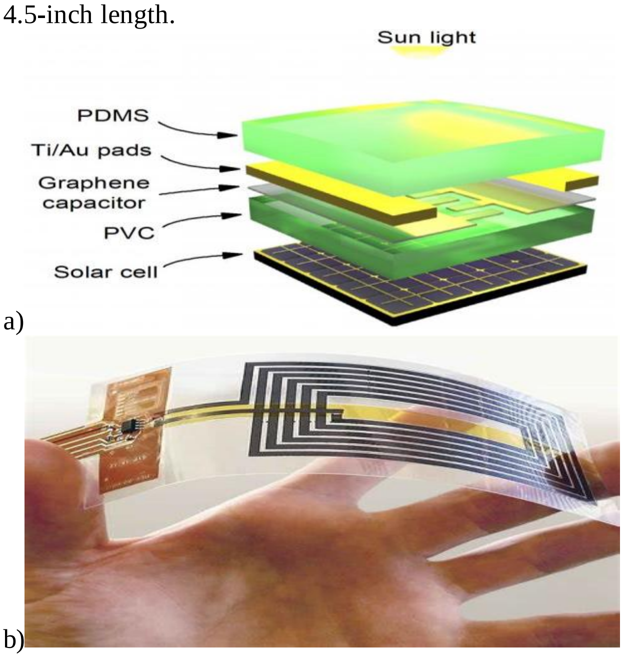

Fig. 1. a) Fabrication of Graphene-based bend sensor, b) Actual graphene embedded flexible sensor of 4.5-inch length

II. RELATED WORK

U.D. Meshram and R. Harke employed FPGA based control to control the motion of a Robotic arm in 2010 [1]. Later, Syed and Abid use microcontroller programming with ease to suit the requirement to control 4 servomotors in the Robotic arm using Flex sensors in a glove in 2012 [2].

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The lapse in the model is removed by Dhepekar et. al. in 2016 by removing the wired system connectivity by using a wireless system [3]. Later in the same year, Shen et. al. proposed a soft flexible sensor that can be stretched within its elastic limit to provide accuracy and these sensors have many applications in Robotics [4]. In 2017 Rishabh and Jitendra implemented these sensors in a glove to operate a Robotic arm using wireless technology and programming using an accelerometer and microcontroller [5]. Kaidarora et.al. in 2019 presented a wearable multifunctional Laser-induced Graphene sensor where the piezoresistive material is exploited after printing their electrodes on flexible polyamide films. They also Fabricated the LIG Sensor [6]. Kaidarora et.al. in march 2020 designed Laser-Printed graphene pressure sensors and highlighted the suitability of graphene with living beings due to its biocompatibility [7]. Rai et.al. in July 2020 developed an internet of things based wireless Robotics hand actuation system to detect and follow the human hand movement [8]. Shaikh et.al. in August 2020 proposed a multisensory graphene skin to work in a harsh environment with a temperature range up to 650° C [9].Based on previous works and research it is concluded that graphene holds many advantages and can be used as multiple sensor devices and its biocompatibility makes it useful on a human body without showing any side effect.Author (s) can send paper in the given email address of the journal. There are two email address. It is compulsory to send paper in both email address.

III. PROPOSED WORK

Based on the previous research the application of graphene-based flexible sensors is limited to Robot hand or arm which can work only in the work envelop of the Robot arm but it is not implemented on a humanoid Robot which completely can be controlled through a human body. To achieve this target, we have used the multifunctional laser-induced graphene sensor printed on a flexible polyimide film. Since this sensor can be used on the human body directly and can be used for more than 1500 cycles. To control the complete Robot, we have used 13 sensors, the placement of these sensors on the human body are according to the following table.

Table I. Details of Sensors Used in the System

Sr. No.	Joint	D.O.F.	Sensor 1	Sensor 2
1	Neck	2	2	0
2	Shoulder	1	0	2
3	Elbow	1	2	0
4	Waist	3	0	1
5	Hip	3	0	2
6	Knee	1	2	0
7	Ankle	2	2	0

Here sensor 1 is referred to 2.2-inch length Sensor and Sensor 2 is referred to 4.5-inch length sensor. The application of these LIG sensors on various positions of a human body will monitor joint bending motions. The applications of these sensor on elbow, wrist and knee are shown in a, b, and c parts of Fig. 2.

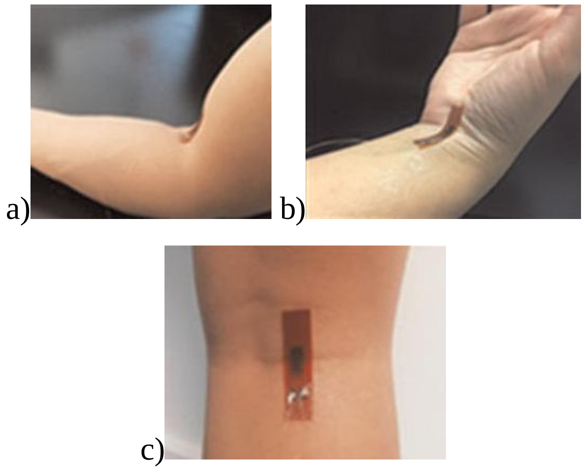

Fig. 2. Application of Graphene embedded bend sensor a) Elbow, b) Wrist and c) Knee

The data collected from these sensors are transmitted to the raspberry pi kit with the aid of a micro transmitter attached to each sensor separately. The main collector of the Raspberry pi kit collects all the data and acts accordingly by providing a data-based command to the humanoid robot to which we have attached the raspberry pi kit. This allows the robot to work in harsh conditions and the positive thing is that we do not have to make the robot to show its intelligence, rather we can operate it from anywhere using the IoT technology and the communication time-lapse is improved with improvement in the internet connectivity in the region where we have to operate through the robot and the region from where an operator is operating.

IV. PROJECT DESCRIPTION

The main components used in this project work are as follows:

A. Graphene Embedded bend sensors:

In this system, we are using a graphene-based flexible strain sensor which is made up of microfluidic liquid metal, piezoresistive graphene, and stretchable 151 elastomers. Liquid metal was put into microfluidic channels to achieve flexibility in electrical contacts with graphene sensing elements. The micro transmitter is connected with the LIG terminals in the sensor. The micro transmitter detects the change in resistance of the sensor and transmits that data to the main form where the data is shared with raspberry pi to take the necessary action. The length specification for one inch graphene embedded bend sensor is shown in Fig.3 [10]

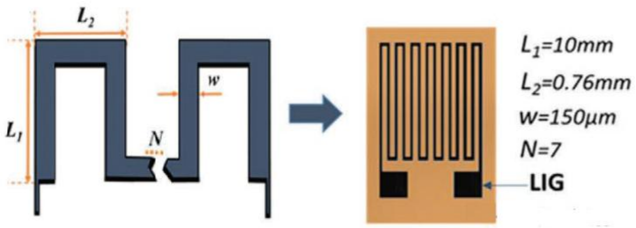

Fig. 3. Length Specification of 1-inch Length Graphene Embedded Bend Sensor [10]

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B. Raspberry pi 3 model B

In our system, we have used Raspberry pi 3 Model B. This model of Raspberry pi is a third-generation kit that can be connected using wireless LAN and Bluetooth as shown in Fig. 4.

Fig. 4. Length specification of 1-inch length graphene embedded bend sensor

This kit comes with Quadcore 1.2 GHz Broadcom BCM2837 64Bit CPU, 1 GB RAM, BCM43438 wireless LAN and Bluetooth low energy (BLE) on board, 100 Base ethernet, 40 pins extended GP10, 4 Pole stereo output, and composite video port, 4 USB 2 ports, full-size HDMI, CSI camera port for connecting Raspberry pi camera which is used to monitor Realtime location and surrounding of the Robot, DSI display port for connecting a raspberry pi touchscreen display, 16 GB micro SD port for loading the operating system and storing the programming data and upgraded switched micro USB power source of 2.5 A [11]

C. Accelerometer Chip

The ADXL335 is a three-axis accelerometer that is small, thin and operates on low power with signal accustomed voltage outputs. It uses a single structure to sense all the three axes, due to which sense directions are highly orthogonal with very little cross-axis sensitivity. The measurement of the minimum full-scale acceleration range of ± 10g. The measurement of the static acceleration due to gravity due to shock, vibration, or motion can be done using tilt sensing. This accelerometer chip also has the capability of setting the bandwidth using the capacitors and by limiting X out, Yout, and Zout pins. Three capacitors namely CU, CV, and Cw are required to be attached at the pins to implement low pass filtering for noise reduction and antialiasing. For a 3 DB bandwidth, the equation used is

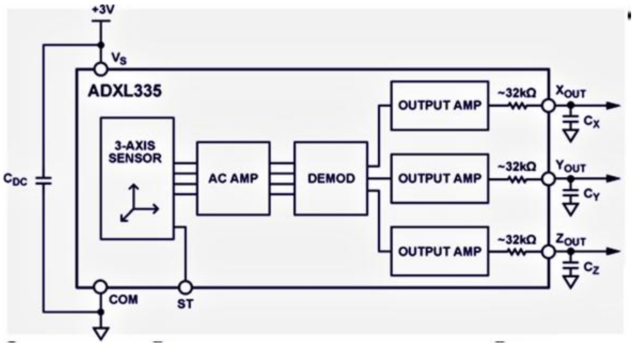

Fig. 5. Circuit diagram of accelerometer

$$F_{-3\ dB} = 1/(2\pi(32\ k\Omega) \times C(U, V, W)) \quad (1)$$

or

$$F_{-3\ dB} = 5\ \mu F/C(U, V, W) \quad (2)$$

For our project work bandwidth for X-axis and Y-axis can be selected within a range of 0.5 Hz to 1600 Hz and a range of 0.5 Hz to 550 Hz can be used for the Z-axis [12]. The circuit diagram of accelerometer is shown in Fig. 5.

D. RF Module

The CC2500 is a cheap 2.4 GHz transceiver which is designed for low-powered wireless applications. This transceiver is unified with a configurable baseband modem which supports several variations of formats and contains a configurable data rate up to 500 kB and. CC2500 delivers extensive hardware support for many operations. The operating parameters and the 64- byte transmit/receive FIFOs of CC2500 can be controlled by using the SPI interface. Generally, the CC2500 is used along with a microcontroller and a few additional submissive components [13]. The detailed circuit diagram of the radio frequency module of CC 2500 is shown in Fig. 6.

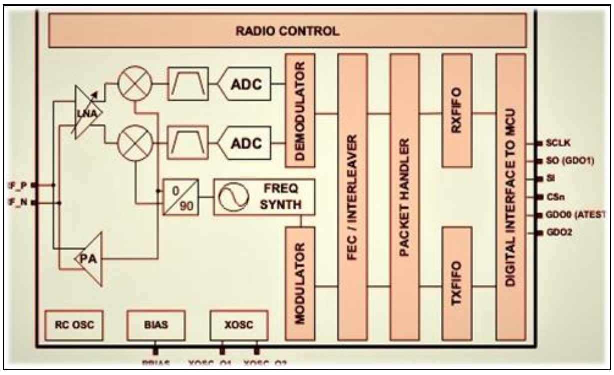

Fig. 6. Circuit Diagram of RF module Cc2500

V. RESULTS AND DISCUSSION

In this system, we have tested the robot after using two Raspberry Pi 3 Model B kits one installed in the robot and the other is placed in the control room where the operator will be operating the robot. We have used two mobile phones for the testing one mobile is in the Bluetooth range of raspberry pi kit with an operator and another in the Bluetooth range of Robot operating in the harsh condition and we have experienced a time-lapse in transmitting the signal from the operator end to Robot end. There are three main reasons behind this first is internet speed in both mobile phones and another reason is the quality of hardware which can be improved in future hardware kits. The third reason which we expected is the temperature dependency of Robot components. Therefore, we performed the same experiment of transmitting input signal for four different temperatures i.e. 25°C, 50°C, 75°C, and 100°C, and monitored the response time which was observed according to the following graph.

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To achieve the accuracy and precession for each temperature range, we have bent the input flexible sensor with the help of the automated system. The robot performance is measured in the cabin designed for elevated temperature. The data is collected from the same application used in android mobile to transmit signal at 0.1 seconds duration for 10seconds and response curve is generated using the same data. The response curves for the above-mentioned curves are shown in Fig. 7.

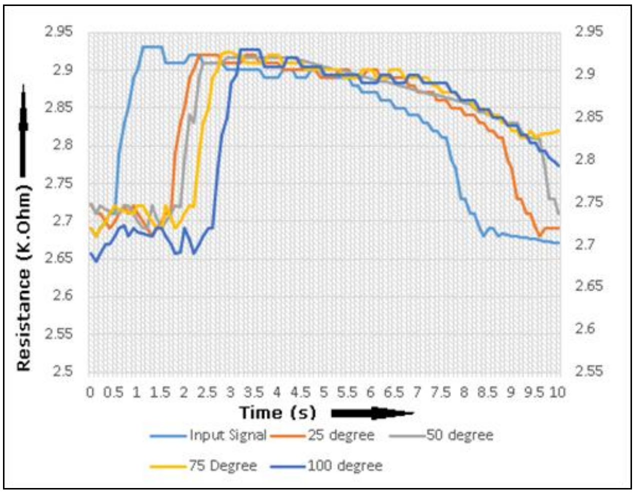

Fig. 7. Resistance Time Graph of Robot Operation

It is observed from the response in Figure 7 that the temperature dependency is very little in the selected range but can vary more at higher temperatures. We can also observe that the lag is slightly increasing as the temperature is increasing. The response curve almost follows a similar pattern as that of the input Signal which justifies the suitability of graphene embedded bent sensor for high accuracy and precession.

VI. CONCLUSIONS AND FUTURE SCOPE

In this system, we aimed to build a semi-automated Humanoid robot using IoT technology which receives data from graphene-based flexible sensors applied to the human body. In this system we have used a small robot with fewer degrees of freedom, therefore less programming has done the task but the advanced robot with a large number of degrees of freedom requires large space to save the program and more complex program. The robot which is controlled is doing its task accurately but the time lapse between the command and action is slightly larger than expected and it further increases as the temperature increases. The further advanced RF module and Accelerometer in the future can be used to minimize the time-lapse and increase the accuracy of the complete system. The robot can be developed using integrated AI and IoT based technology to decrease the time-lapse and improve performance.

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