Energy Harvesting using Piezoelectric Materials

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Abstract— **At present, a great deal of research effort has been directed to finding eco-friendly and renewable sources of energy. In recent years, there has been growing interest in harnessing the power of mechanical vibrations and pressure to generate electricity using piezoelectric materials. The use of piezoelectric materials for generating electricity is of special interest for driving small electronics, such as implantable biomedical devices. This article gives a brief survey of the developments in this upcoming area of research.**

Index Terms— **Renewable sources of energy, Piezoelectric, Nanogenerators**

I. INTRODUCTION

The global energy consumption is steadily increasing due to industrialization and population growth. A large fraction of this energy is generated using fossil fuels (coal, oil, uranium etc). It is well accepted that we have to find alternative sources of energy as fossil fuels are depleting very fast and moreover, they are creating environmental problems such as global warming, carbon dioxide emissions and damage to ozone layer [1-3]. The use of renewable energy sources such as solar energy, wind energy and wave energy is slowly picking up and they meet the requirements of large-scale needs of power. However, there is a need for developing new methods for driving small electronics indoor or concealed environments (such as in tunnels, clothes and artificial skin) and implantable biomedical devices. Energy harvesting using piezoelectric materials is one of the methods for meeting above requirements [4-10].This method exploits the fact that mechanical energy can be converted to electric energy using piezoelectric materials such as quartz, barium titanate ($BaTiO_3$), lead zirconium titanate (PZT) and zinc oxide (ZnO) [4-6]. The fact that above subject of "Energy from Harvesting using Piezoelectric Materials" is an upcoming area of research, the author has read some papers on above subject and summarized them in this article for the benefit of students. It may be mentioned that author has not made any original contribution to the subject.

The use of piezoelectric materials for generating electricity is of special interest in bioengineering and medical fields [11-15]. Research applications in bio-technology usually require various portable, wearable, easy-to-use, and/ or implantable devices that can interface with biological systems. These devices require a power source but the use of a battery, with limited lifetime, is not very convenient. Piezoelectric-based generators [16-20] offer a simple solution as piezoelectric materials can convert vibrational and mechanical energy sources from human activities such as pressure, bending, and stretching motions into electrical energy. For example, efforts have been made to develop shoes that generate power during walking and it is envisaged that this power would be sufficient to charge cell phones, iPad etc [21-23]. Similarly, Wang et al. [16] have used piezoelectric ZnO nanowire arrays to develop generators which can power commercial light-emitting diodes (LEDs), liquid crystal displays and wireless data transmission. These generators can also convert tiny bits of biomechanical energy (from sources such as movement of the diaphragm, the relaxation and contraction of muscle, heartbeat, and circulation of blood) into power sources [12]. The main advantage of piezoelectric generators is their scalability. An Israeli engineer has proposed that if one embeds a net work of piezoelectric generators on the airport run way, it should be possible to harvest electrical energy at time of landing and take-off of aero-planes [24]. He has, in fact, built a 100m stretch of roadway embedded with a net work of piezoelectric generators and shown that an updated version of above roadway could produce about 400 kWh of power from 1 Km stretch of road [7,24]. This paper gives a bird's eye view of the recent developments in this fast emerging field. That is, this paper essentially gives a summary of some important publications/ patents on the subject. The basic principals of electricity generation using piezoelectric materials are, first, given in the next section [4-6]. Section 3 gives the salient features of energy harvesting from airport runways or roadways [7, 24]. Section 4 deals with power generation from shoe mounted devices [21-23, 25]. Section 5 deals with self-powered nanowire devices [16-18, 26] and details of the power conditioning circuits [11, 27-29].

II. FUNDAMENTALS OF PIEZOELECTRIC MATERIALS

Piezoelectricity materials have the property of converting electrical energy into mechanical energy, and vice versa [4-7]. The materials ability to transform mechanical strain into electrical charge is referred to as direct piezoelectric effect, and the materials ability to convert an applied electric potential into

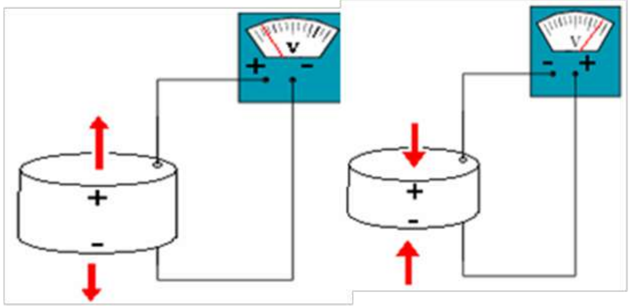

Fig 1 Graphical Description of piezoelectric effect

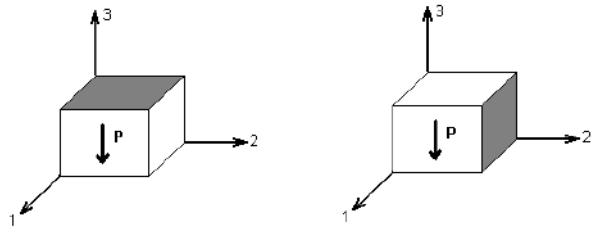

Fig 2A Fig2B

Fig 2 Directions of electrical and mechanical vectors

mechanical strain is referred to as converse piezoelectric materials ability to function as a sensor and the converse piezoelectric effect is accountable for its ability to function as an actuator. Fig.1 shows a simplified graphical description of direct and converse piezoelectric effect.

Quartz, barium titanate and lead zirconium titanate are the examples of piezoelectricity materials, and pressure sensors, gas lighters, quartz oscillators and ultrasonic wave generators are examples of devices that use above materials [5].

Piezoelectricity materials belong to a larger class of materials called ferroelectrics [4]. One of the defining traits of a ferroelectric material is that the molecular structure is oriented such that the material exhibits a local charge separation, known as an electric dipole. Throughout the piezoelectric material composition the electric dipoles are oriented randomly, but when strong electric field is applied, the electric dipoles reorient themselves relative to the electric field; this process is termed polling. Once the electric field is put off, the dipoles maintain their orientation and the material is then said to be poled. After the poling process is completed, the material will exhibit the piezoelectric effect.

The relationship between the applied stress and resulting responses depends on the directions of the electrical and mechanical vector quantities. The directions in a piezoelectric element are termed as 1, 2 and 3 (analogous to three dimensional orthogonal set of axes X,Y and Z) as shown in Fig.2. A large fraction of piezoelectricity materials (e.g. BaTiO3 and PZT etc) have perovskite structure and their material properties along "1" and "2" axes are identical to each other but are different from those along the "3" axis. That is while discussing properties of perovskite ceramics, there are only two directions ("3" and one out of "1" and "2") which are of interest. In the following, the said directions are referred to as "3" and "1" directions. The poling or 3-axis is invariably taken parallel to the direction of polarization within the ceramic (Fig.2A), which involves application of electric field along direction "3". In shear mode operation, electrodes are placed on faces perpendicular to axis 2 as shown in Fig.2B

The mechanical and electric behavior of a piezoelectricity material can be modeled by following matrix equations [4-7]:

Direct Piezoelectric Effect: $D = d.T + \varepsilon^{T}.E$

Converse Piezoelectric Effect: $S = s^{E}.T + d_{t}.E$

Here D is the electric displacement vector, d is the piezoelectric constant matrix,T is the stress vector, ε^{T} is the dielectric permittivity matrix at constant mechanical stress and E is the electric field vector. In 2nd equation, , S is the strain vector, s^{E} is the matrix of compliance coefficients at constant electric field strength, T is the stress vector, d_t is transpose of d matrix and E is the electric field vector. The subscript "t" stands for transposition of a matrix. In short, the piezoelectric constant d is a measure of the charge density per unit stress or the strain per unit field. The coefficients with double subscripts (d_{ik}) link electrical and mechanical quantities, such that the first subscript gives the direction of the electrical field associated with the voltage applied or the charge or the voltage produced. The second subscript gives the direction of mechanical stress or the strain. For example, the element d_{33} of piezoelectric constant matrix corresponds to a situation (Fig.3A), when the material is strained in polling direction (referred to as "3" direction) and the electric voltage is also recovered in "3" direction. Similarly, d_{31} corresponds to situation (Fig.3B) when strain is applied along "1" (or "2") and the charge is collected in direction"3". The pictorial representation of direction of force and the direction of voltage is shown in Fig.3.

The value of d_{33} is $2.3x10^{-12}$ C/ N for quartz. This implies that application of 1N strain to quartz produces 2.3 $x10^{-12}$ Coulomb of charge. Depending on the piezoelectric material, there is a range of values for piezoelectric modulus d_{33}. For example while $d_{33} = 2.3x10^{-12}$ C/ N for quartz, $d_{33} = 560\ x10^{-12}$ C/ N for PZT [7].

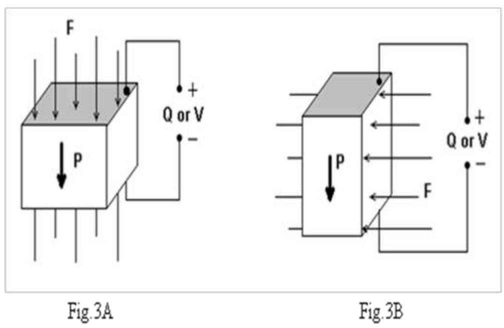

Fig 3 Pictorial representation of directions of stress and voltage corresponding to $d_{33}$and d_{11}

III. Energy harvesting from airport runways or roadways

Power harvesting refers to the practice of acquiring energy from the environment which would be otherwise wasted and converting it into useable electric energy. In particular, it is of interest to develop eco-friendy and renewable sources of energy. Piezoelectricity has the potential to provide us with a great source of green energy if it is properly utilized. Scientists are working diligently to find the best possible ways to harvest piezoelectric energy [7, 9-10, 24]. It is believed that if one places piezoelectric materials underneath busy roadways, it should be possible to use vibration energy of passing cars for generating electricity [7, 10,24]. This method, called parasitic energy harvesting, is currently being tested on a small scale and it is envisaged that a typical 4-lane highway could produce about 2 megawatts of power for every km of roadway. The system could also be potentially used to harvest energy from airport runways and rail systems. In fact, the Tokyo subsystem system currently has about 25 square meter of piezoelectric flooring in place. With millions of travelers walking through the station each day, the flooring produces around 1400 kilowatt of electricity per second, enough to power the system's ticket gates as well as electric lights and displays. Fig.4 is an artistic view of electricity generation from airport runways during landing of an aero-plane.

Haim Abramovich has recently launched a start-up company called "Innowattech Ltd" and this company makes and supplies Innowattech Piezo Electric Generators (IPEG). Fig.5 is a schematic drawing of an Innowattech Piezo Electric Generator. These generators have the ability to harvest energy from weight, motion, vibration and temperature changes. That is, they can be used to create high efficiency generators from roadways, railways and airports. IPEG consists of a thin box around the piezoelectric material, which is then placed underneath a layer of asphalt. When a car drives over the box, it takes the vertical force and compresses the piezoelectric material, thereby generating electricity [24]. The energy can be stored in a nearby battery or super-capacitor, depending on the application, or sent directly to streetlights and other roadside devices. The system can be configured to transfer harvested energy to the grid. The method of analyzing power output from piezoelectric harvesting systems is given in a recent article by Shu and Lin [27].

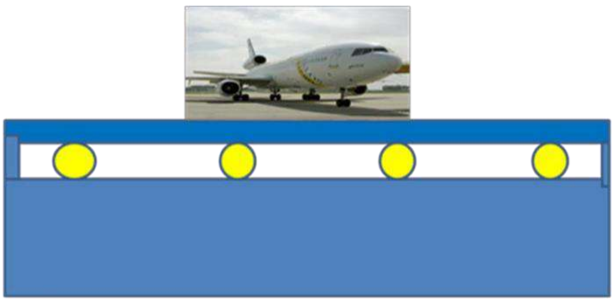

Fig 4 An artistic view of electricity generation from airport runways during landing of an aeroplane

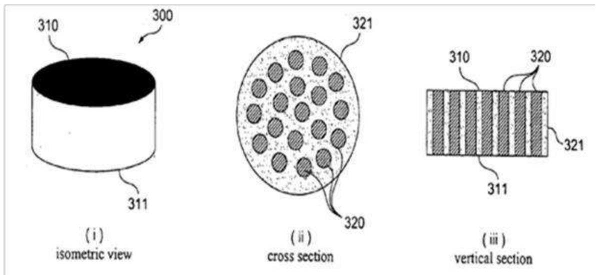

Fig 5 Schematic diagram of Innowattech Piezo Electric Generator [24]

It may be mentioned that Abramovich and his colleagues have carried out actual experiments on generation of electricity from roadways [24]. They built 100 meter stretch of road and embedded a large number of IPEGs in the road. The distance between neighboring IPEGs was 30 cm and these IPEGs were embedded at a depth of 6 cm from the road level. These trial experiments when extrapolated suggest that 1 Km stretch of road would generate about 400 kWh of power if 600 vehicles (each weighing 5 tons) go through that road in an hour. This energy is enough to power 600 – 800 homes. Wafi Danesh et al. [7] have estimated that one can generate 8138 kWh of energy from an airport runway if there are 109 landings or takeoffs of A380 aero planes (weight ~ 560 tons) every hour. So far, there are no roads or run ways, which could be used for producing electricity from running vehicles / aero-planes in a regular way. The subject is still in its infancy.

IV. Power generation from shoe mounted devices

Walking is the most common activity in day to day life. When a person walks, he loses energy to the road surface through foot falls on the ground during every step. A 68 Kgm person, walking with a normal stepping frequency of 2 steps/ sec., delivers energy of about 70 watts (i.e ~ 70 Joules/sec.) to the ground [13]. There are some studies in the literature which deal with harvesting of above energy using piezoelectric based devices [21-23, 25]. A new startup called SolePower has come up with a shoe insert that creates power as you walk. It is envisaged that this power will be sufficient to charge cell phones, iPad etc. The power-generating shoes are of special interest to army as soldiers are often stationed at places where electricity is not available.

Clyde Kendall was the first to demonstrate that electric energy can be fruitfully generated using piezoelectric inserts in a shoe [21]. He used THUNDER™ PZT unimorphs to tap the power generated by pressure during the heel strike. THUNDER™ is a composite material which includes PZT, adhesive and metallic layers (stainless steel, aluminium, brass, copper etc). The above actuators are manufactured by heating the composite at high temperatures (~ 325°C) and then cooling it to room temperature. THUNDER™ (a curved composite strip) is a

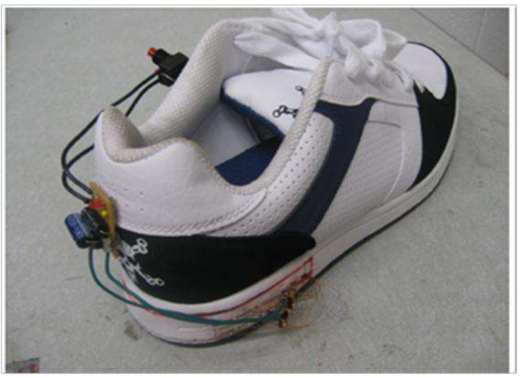

Fig 6 PVDF based shoe with transducer inserted in the heel and capacitor circuit attached [23]

rugged device, whose displacement and force capabilities have been enhanced as compared to a simple ceramic (say PZT). THUNDER^{TM} PZT unimorphs are commercially available from Face International Corp. Kendall used TH 6-R with 7x7 cm^2 modified PZT strip (180 nf capacitance) bonded to a curved piece of 7x9.5 cm^2 modified PZT spring steel. The details of the method of mounting of above unimorphs into the sole of the shoe are given in his thesis [21].

Clyde Kendall, in fact, used three types of shoe – mounts for generating electricity and evaluated their performances. The three devices were (i) unimorph piezoceramic composite THUNDER^{TM} , (ii) a multilayer laminate made from PDVF foil (a piezoelectric polymer) and (iii) electromechanical system. It was seen that power output (~ 5 mW) from PZT unmorph is much better than the power output (~ 0.6 mW) from PDVF system. The main disadvantage of unimorph is its curved shape, which is more difficult to incorporate into a shoe due to space considerations. The difficulty with electromechanical device, which is otherwise quite efficient, is connected with the awkwardness (both its weight and "chunkiness") and its interference with the natural gait. It is desirable that power generation system is innocuous to the user and in that respect PVDF stave is best among the three systems considered here. Fig.6 is a photograph of PVDF based shoe developed by Fourie [23].

The regulation schemes for conditioning the electric energy harvested from shoe-embedded piezoelectric sources, was developed by Nathan Shenck [22]. The power conditioning circuitry consisted of the following stages: Rectification, high-frequency switching (and step-down transformation), CMOS "555" timing and switcher control, low-side output filtering, load stage on/off control, and output regulation [22,27].

V. SELF-POWERED DEVICES USING PIEZOELECTRICITY MATERIALS

The development of wireless sensor and communication mode networks is a subject of current interest. It is envisaged that node networks would find applications in structural health monitoring and environmental control systems, smart homes and tracking devices on animals in the wild. However, as the networks increase in number and the devices decrease in size, the proliferation of these autonomous micro sensors raises the problem of an effective power supply. The conventional solution is to use electrochemical batteries for power. However, batteries not only increase the size and weight of micro sensors but also suffer from the limitations of a brief service life and the need for constant replacement, which is not acceptable or even possible for many practical applications. It is thus not surprising that the subject of self-powered devices is now attracting the attention of scientists and engineers [11-20]. In the following, we discuss results of two recent papers, one [26], dealing with self-powered nanowire devices and the other one [18] dealing with flexible nanocomposite generators.

Sheng etal. [26] have developed a self-powered pH sensor and a self-powered UV sensor. These devices make use of piezoelectric property of ZnO nanowires for energy generation. This work is an extension of their earlier work [16] where they had shown that vertically aligned ZnO nanowire arrays could be used for making a d.c. piezoelectric nanogenerator. However, they found that power produced by single nanowire array is not sufficient for real devices. They improved upon the above generator by integrating a large number of nanowire energy harvesters into a single power source. This involved alignment of nanowires and synchronization of their charging and discharging processes. It was seen that lateral integration of 700 rows of ZnO nanowires produces a peak voltage of 1.26 volt at a strain of 0.19%, which is potentially sufficient to charge an AA battery. The above mentioned pH sensors and UV sensors were powered by a nanogenerator where three layers of ZnO nanowire arrays were integrated vertically. Fabrication details and data on the performance of above devices are given in above referred papers [16,26].

Park et al. [18] have used perovskite ceramic material ($BaTiO_3$) for fabrication of flexible nanocomposite generators (NCG). This involved dispersing $BaTiO_3$ nanoparticles and carbon nanomaterials (single-walled or multi-walled carbon nanotubes and reduced graphene oxide) in polydimethyl siloxane (PDMS). The above nanocomposites were then, spin-casted into a metal coated plastic substrate and cured in oven. It was shown that periodic deformation of NCG (say by biomechanical movements from finger) produced periodic electric signals. This is nicely illustrated in Fig.7 where measured output voltage and current signals from NCG during periodic bending and unbending motion are shown. These studies showed that under the continual bending and unbending cycles, the NCG device repeatedly generates an open-circuit voltage of ~ 3.2 V and a short-circuit current signal of 250 to 350 nA; these output values are produced for a

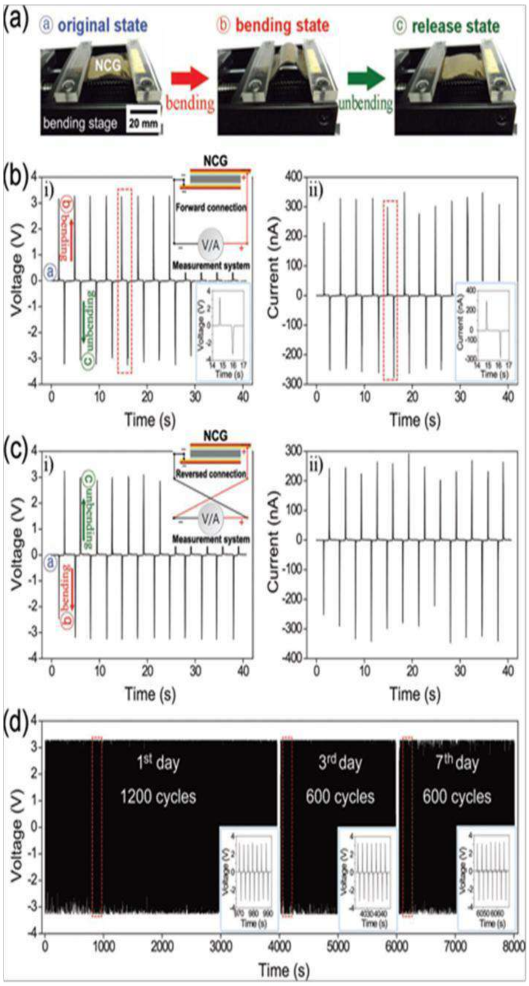

Fig 7 Output voltage and current signals generated from an Nano Composite Generator (NCG)Device [18]

(a) Optical images of NCG devices in their original, bending and release states
(b) The measured output voltage and current signals of the NCG device in the forward connection during the periodic bending and unbending motions
(c) The open circuit voltage and short circuit current signals generated in the reverse connection
(d) The durability test results conducted to confirm the mechanical stability of the NCG device.

horizontal displacement of 5 mm from an original 4 cm long sample at deformation rate of 0.2 m s^{-1}. In general, the voltage output depends on the composition of nanomaterials, the angular bending strain and the strain rate. Park et al. tested the mechanical stability of above NSGs by carrying out durability measurements. These studies showed that voltage amplitude does not change significantly after about 1200 bending cycles (~ one hour of operation).

The voltage and current produced by slow finger motion reaches up to ~ 200 mV and ~ 7 nA respectively. It is possible to generate output signals of 1.5 V and ~ 150 nA if

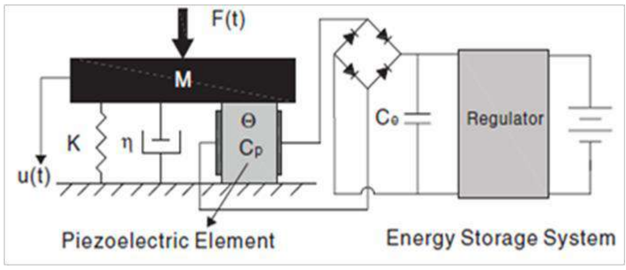

Fig 8 An equivalent model for a piezoelectric vibration energy harvesting system [27]

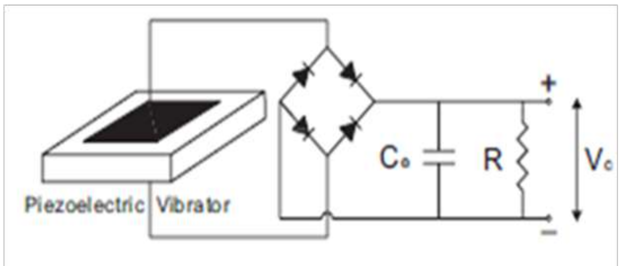

Fig 9 A typical AC-DC harvesting cicuit [27]

one uses large size (5 cm x 7 cm) pad and applies aperiodic force of ~ 200 N. The alternating energy generated from an NCG device is stored in capacitors and subsequently used to light LED device etc.

There are several schemes for conditioning the electric energy harvested from piezoelectric sources [25-29]. A piezoelectric energy harvester is often modeled as a mass + spring + damper + piezo structure together with an energy storage system schematically shown in Fig.8. It consists of a piezoelectric element coupled to a mechanical structure and is connected to a storage circuit system. It may be mentioned that a vibrating piezoelectric element generates an AC voltage while the electrochemical battery needs a stabilized DC voltage. This requires an energy harvesting circuit to ensure electrical compatibility. In Fig.8, an AC–DC rectifier followed by a filtering capacitance C_e is added to smooth the DC voltage. A controller placed between the rectifier output and the battery is included to regulate the output voltage. Fig.9 is a simplified energy harvesting circuit.

VI. SUMMARY

There is a need to find alternative sources of energy as fossil fuels are depleting very fast and moreover, they are creating environmental problems. The popular renewable energy sources are solar energy, wind energy and wave energy. This article deals with use of piezoelectric materials for generation of electricity. This method of energy production exploits the fact that piezoelectric materials can be used for converting mechanical energy to electric energy. It is envisaged that this method of energy generation will be useful for driving small electronics such as mobile phone chargers, implantable biomedical devices etc. During last ten years or so, a large number of papers have been published on the subject. This article has been written for the purpose of introducing the subject to the students, and is based on the available publications in the literature. In addition to a discussion on the principals involved, this article gives the salient features of energy harvesting from airport runways or roadways, power generation from shoe mounted devices and self-powered nanowire devices.

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SEMG BASED ROBOTIC ARM

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***Abstract*— Human robot control interface have received increased attention during the past decade. Control of such devices necessitates real time classification of bio-signals, eg: EMG signal recorded from intact muscles. In this paper we have included robotic arm of 4 degrees of freedom that can be controlled using EMG signal recorded from forearm.A large number of interfaces have been discussed in earlier works ie. using 3D motion of a joystick or a haptic device to the motion desired for the robot. In this paper a new means of control system is proposed in which the user performs natural motion with his/her limbs.**

I. INTRODUCTION

Electromyographic (EMG) signals provide an extremely useful non-invasive measure of on-going muscle activity. They could thus be potentially used for controlling devices such as robotic prosthetics that can restore some or all of the lost motor functions of amputees and disabled individuals. Amputees and partially paralyzed individuals typically have intact muscles that they can exercise varying degrees of control over. Most commercially available prosthetic devices have limited control (e.g., one degree-of-freedom in the case of a prosthetic gripper), nowhere near the original levels of flexibility of the organ they are intended to replace. Further, there is evidence that amputees who have lost their hand are able to generate signals in the forearm muscles that are very similar to those generated by healthy subjects. Thus, the ability to decode EMG signals can prove extremely useful in restoring some or all of the lost motor functionality in these individuals. We demonstrate that this is indeed possible by showing that activation patterns recorded from muscles in the forearm can be classified in real-time to control a 4 degrees-of-freedom robotic arm-and-gripper.

The success of our system is based on a combination of several factors: (1) a careful choice of actions to classify, chosen for ease of classification and their intuitiveness for the control task, (2) selection of muscle activity recording sites that are relevant to these actions, (3) the use of a simple, sparse feature representation that can be computed in real-time, and (4) a state-of-the-art classification method based on linear Support Vector Machines (SVMs). We address the issues of ease of use and quality of control, by choosing an intuitive gesture-to-control mapping, and by comparing control performance against a baseline obtained via keyboard-based control.

In this paper results show that healthy subjects can gain significantly expressive EMG-based control of a prosthetic device, and pave the way for the design of powerful prosthetics with multiple degree-of-freedom control. We believe that techniques can also be applied to the design of novel user interfaces based on EMG signals for human–computer interaction and activity recognition.

II. METHODOLOGIES

To implement an HCI, the acquired and processed signals need to classify which is the difficult part of the system. The choice of classification methodology depends on the application field.

A. Techniques used in HCI

1) Non-biosignal Approach

Several attempts have been done beside the use of biomedical signals to implement a convenient
solution of HCI for the disabled persons. These devices are based on motor skills and still available to use. However, limitations of these systems have been demonstrated by practical experiments. It was also found that more adaptive techniques required to allow head control for automatic adjustment to the needs and abilities of a particular user.

However, limitation of these systems have been demonstrated by practical experiments. It was also found that more adaptive techniques required to allow head control for automatic adjustment to the needs and abilities of a particular user.

B.Biosignal Based Approach

1) EOG Signal Approach

Some biosignals have also been shown to be suited for the creation of a new communication interface between humans and computers. In this area the use of biosignals offer brand new possibilities when compared to the conventional, mostly audio-visually based HCI. Eye movements are arguably the most frequent of all human movements (Jonghwa Kim et al., 2008). In terms of our primary senses, the eye is one of the main subsystems of the body. The position of the eye directly relates with the visual information of interest. It is possible to provide very intuitive assistive device by using the position the eye. It is possible to provide very intuitive assistive device by using the position of the eye. Position f the eye can be measured optically, mechanically, and electrically. The electrical method of measurement, the EOG, is the least invasive method of determining the eye position

2) EEG Signal Approach

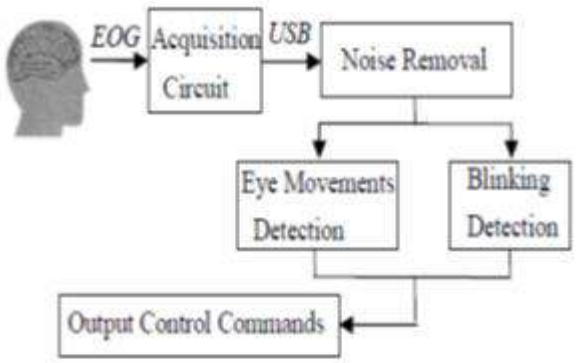

Figure 1: Basic Block Component Diagram of HCI System based on EOG

Numerous studies have shown that individuals with severe neuromuscular disabilities can learn to use a Brain Computer Interface (BCI), by modulating various features in their EEG (Wolpaw et. al., 2002).

The BCI is an emergent multidisciplinary technology that allows a brain to control a computer directly, without relying on normal neuromuscular pathways .The most important applications of the technology for the paralyzed people who are suffering

from severe neuromuscular disorders, as BCI potentially provides them with communication, control, or rehabilitation tools to help compensate for or restore their lost abilities. Among various brain signal acquisition methods, the EEG is of particular interest to the BCI community EEG based BCI technology has seen much development in recent years. Specifically, EEG based BCI technologies that do not depend on peripheral nerves and muscles have received much attention as possible modes of communication for the disabled

3) EMG Signal Approach and Importance

Among these bioelectric signals, EMGs are considered to be the source of a new means of HCI, i.e. an alternative input mechanism. In fact, an input device developed using EMGs is a natural means of HCI because the electrical activity induced by the human's arm muscle movements can be interpreted and transformed into computer's control commands. Furthermore, EMGs can be easily acquired on the surface of human skin through conveniently attachable electrodes. Compared to optical systems, EOG based systems provide favored possibilities for mouse pointer control, and are practical and valuable for people with SCI. However, their complex learning and calibration procedures present the main limitations and require further development (Surdilovic, 2005). On the other hand, one of the major limitations of BCI systems is the high potential for EMG contamination. EEG signals originate in the neurons of the brain and have to propagate through the skull and the pericranial muscles in order to reach the surface electrodes. Because the EEG signals aresmall in amplitude (5–300 μV), the EEG biopotential amplifiers are designed to incorporate high amplification (Taberner et. al., 1998).

Thus, any muscle movement on the head or neck can produce a large noise contamination from the corresponding EMG signal. From an application standpoint, this is a big inconvenience to a user, especially if the user has a condition such as cerebral palsy. Most BCI researchers have tried their best to eliminate any EMG artifacts, especially eye blinks and neck movements. Hand gestures involve relative flexure of the user's fingers and consist of information that is often too abstract to be interpreted by a machine. An important application of hand gesture recognition is to improve the quality of life of the deaf or non-vocal persons through a hand-gesture to speech system. Another major application is in rehabilitation engineering and in prosthesis.

III. EMG CLASSIFICATION MÉTHODOLOGIES FOR HCI

Some artificial intelligence (AI) techniques mainly based on neural networks have been proposed for processingand discriminating EMG signal. Neural network is a computing technique that evolved from mathematical models of neurons and systems of neurons. During recent years, neural networks have become a useful tool for categorization of multivariate data

A. Artificial Neural Network

In 1993, William Putnam et. al. (Putnam et. al., 1993) proposed a real-time computer control system based on neural network for pattern recognition of the EMG from user's gestures. The system consists of two modes of communication are derived from the EMG. The first mode is a continuous control signal, proportional to muscular exertion which control computer software objects such as sliders or scroll bars. The second communication mode is gesture recognition

B. Back-Propagation (BP) based Neural Network

Back-propagation Neural Network (BPN) algorithm applied to EMG based mouse cursor control system as a man-machine interface by Itou et. al. (2001). They used neural network with three inputs, two hidden layer and one output layer which achieved 70% rate of recognition. Any muscle can be used, mouse cursor can be operated using a leg too, whereas, muscle fatigue may appeared for long time use.

C. Log-Linearized Gaussian Mixture Network (LLGMN) and Probabilistic Neural Network (PNN)

The neural network has to estimate the probability that the pointer will move to each base direction, so that the heavy learning calculation and the huge network structure are not necessary. Neural network is used as a pointer controller in the prototype system. This system can adapt itself to changes of the EMG patterns according to the differences among individuals, different locations of the electrodes, time variation caused by fatigue or sweat, and so on.

D.Fuzzy Mean Max Neural Network (FMMNN)

Jong-Sung Kim et. al. (2004) applied fuzzy mean max neural network (FMMNN) as a classifier for online EMG mouse that controls computer cursor. Also, stochastic values such as integral absolute value were used as features for an appropriate classification of the intended wrist motions. He interpreted 6 predefined wrist motions to left, right, up, down, click and rest operation.

E. Radial Basis Function Artificial Neural Network (RBFNN)

A novel method for online estimation of human forearm dynamics using a second-order quasi-linear model is presented by FaridMobasser et al. (2006). Human arm dynamics can be used for human body performance analysis or for control of human-machine interfaces.

F. Other Methodologies used

1) Hidden Markov Model

Wheeler (2003) introduced an approach of designing and using neuro electric interfaces for controlling virtual devices. Hand gestures are used to interface with a computer instead of manipulating
mechanical devices such as joysticks and keyboards. EMG signals are non-invasively sensed from the muscles used to perform these gestures. These signals are then interpreted and translated into useful computer commands.

2) Bayes Network

Alsayegh (2000) presented an EMG-based human-machine interface system that interprets arm gestures in the 3-dimensional (3D) space. Gestures are interpreted by sensing the activities of three muscles, namely, anterior deltoid (AD), medial deltoid (MD), and biceps brachii (BB) muscles. The problem of gesture classification is carried out in a framework of the statistical pattern recognition

Artificial Neural Network (ANN)	Putnam et. al.	• 95% accuracy in classification was achieved • More robust classifier required for persons with disabilities • AR model parameters based feature vector for Neural Network
	Rosenberg • (1998)	• One layer feed-forward neural network • Performance yields 14% according to Fitt's law • More sophisticated neural network and better training methods required for future improvement
	Tsenov et. al (2006)	• Both time and frequency domain features used • MLP based model yield best result compare to RBF and LVQ • Classification accuracy can be as hi as 98% using 4-channel data set, computational time becomes double. • It is hard to determine complete set of relevant discrimination features
	Kyung Kwon Jung et. al (2007)	Yule-Walker algorithm based AR model for spectral estimation • 4th order AR model parameters as input for LVQ neural network • Competitive layer for learning and linear layer for classifying for LVQ • Classifier success rate is about 78%
Backpropagation Neural Network (BPNN)	Itou et. al. (2001)	• New type of EMG based mouse developed • 70% recognition rate in mouse cursor • Not applicable for long term use • Limited to 4 directions and drag action absent
	Naik et. al. (2007, 2008), Eman M. El-Daydamony et. al. (2008)	• ICA based signal extraction method used • Temporal decorrelation source separation (TDSEP) algorithm based ICA gives 97% separation efficiency than others • RMS value of each signal used to form feature vector as input to neural network • Combination of the mixing matrix and network weights to classify the sEMG recordings in almost real-time • Number of hand gesture identification was restricted to three and six
Log-Linearized Gaussian Mixture	Tsuji et. al. (1995) Fukuda et. al. (1999)	• LLGMN for creating LLGM model through learning and calculating the posteriori probability of pointer movement in each base direction depending on EMG patterns
Network (LLGMN)		• Higher discrimination performance can be achieved than other neural network • The direction of pointer movement is achieved by output of neural network • The accuracy of pointer movement depends on number of

		learning data and the accuracy of estimated direction depends on number of base directions
Recurrent LLGMN	Tsuji et. al. (2003) Fukuda et al. (2004)	• (CDHMM) based Recurrent LLGMN • Finite base direction assumed which leads to avoid heavy learning calculation and huge network structure • Higher accuracy for the discrimination of time sequence of signal • Direction errors improved remarkably
LLGMN based Probalistic Neural Network (PNN)	Nan Bu et. al. (2004)	• FPGA implementation of PNN, LLGMN • HCI on FPGA chip much more portable and compact • Classification rate of hardware is 97.9%, more than software • Shortage of memory for hardware language

III.SYSTEM DESIGN.

The roboarm performs similar actions as that perfo rmed by the user.The user is restricted to perform actions fr om selected pre-defined actions i.e here the robo has 4 degre e of freedom. The system records EMG activity from carefu lly chosen locations on the user's forearm with the help of el ectrodes. This stream of data is transformed into feature vect ors that are classified by a linear SVM classifier. The classif ier output serves as a command for the robotic arm. In the fo llowing sections each of these components is described in gr eater detail.

This diagram gives a glance of roboarm using EMG.

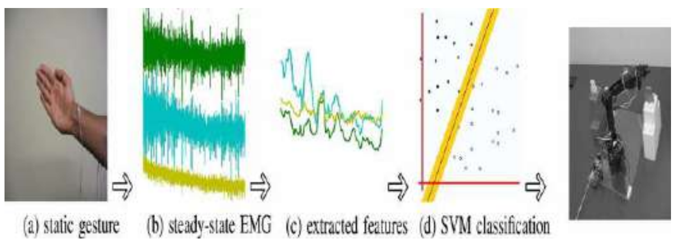

Fig. 1.Schematic for an EMG-based robotic control.

A. Gestures for Robot Arm Control

These gestures are gross movements at the wrist and involve a number of forearm muscles. Further, they lend themselves easily to interpretation and could serve as a basis for control of a prosthesis.

Fig. 2.Static hand gestures chosen for classification.

The goal is to use gross gestures at the wrist, and decode th e gesture from windows of data recorded while the gesture i s maintained (the gestures in the second column show a top down perspective). These gestures intuitively correspond to pairs of actions: grasp–release, left–right, up–down, and rot ate

B. Electrode Placement

In contrast to the differential pair at each recording site tra ditionally used in the literature, an eighth electrode is used o n the upper arm as a reference for all other electrodes, and a s Single electrode at each site of interest. This reference is m ainly used to remove 60-Hz contamination due to line noise. Fig. 3 shows how the individual channels have line noise, b ut the referencing removes this noise.

Muscle	**Function**
Brachioradialis	Forearm flexation
Extensor carpi ulnaris	Extension and adduction of hand at the wrist
Pronator teres	Pronation and elbow fle xation
Extensor communis digi torum	Finger and wrist extensi on
Flexor carpi radialis	Hand flexation and abdu ction at wrist
Anconeus	Antagonistic activity du ring forearm pronation
Pronator quadratus	Initiates pronation

Fig. 3.Electrode positions on the forearm chosen for study.

The particular muscles chosen in the study are implicated in wrist-centered movements and gestures, as shown in the table. The coordinated action of these muscles spans the different movement types which we classify. Although there is redundancy amongst the actions of these muscles as well as redundancy amongst deeper muscles that contribute to the signal, this leads to robust interpretation across subjects and sessions.The recording sites corresponding to these muscles were chosen to make the interpretation of the signal as intuitive as possible and as reproducible from subject to subject as possible.While no electrode position will isolate a single muscle, placing a given electrode on the skin directly above a given superficial muscle should ensure that the largest contribution to the signal at that electrode location is from the desired muscle.This comes with the known caveat that the muscles of deeper layers will contribute to the signal, as will adjacent superficial muscles. Since the goal is classification of discrete gestures into a discrete set of actions, and not the study of individual muscles, we rely on the classifier to extract the important features for each class from this mixture of information from each electrode.

The muscles and their relevant functions are listed in Table I .

Task Performance With Fewer Electrodes

The system will be robust in the amputee setting even if the number of electrodes are decreased

C. Data Collection

The gestures were chosen to correspond to pairs of actions: grasp-release, left-right, up-down, and rotate. The subjects cycled through the actions in order, separated by 5-s rest periods. The sessions were separated by a 20-s rest period. The subjects were asked to relax the forearm/hand and maintain each gesture comfortably without exerting force.The force exerted by the subjects was not measured or restricted while maintaining a given hand pose.Fivesessionswere used in order to prevent overfitting, instrumental errors, etc.

D. Feature Extraction

For this process the signals are given to a device in the chain of operation which convert continuous crowded signals which have almost the same function with a standard bold pattern which can be used for comparing in the SVM ie. Support Vector Machine. Extracted features ideally must be without any errors as it contains the message passed by the muscle fibers which are taken up by the electrodes.

The EMG signal were sampled at 2048 Hz. The feature extraction include calculate the rms of steadystate EMG signals from each electrode. The rms amplitude is computed for each of the seven electrodes. This feature vector serves as the input to classifier. The choice of a 128-sample window length is empirical, and results in 16 commands. This update rate is sufficient for developing a responsive EMG-based controller. The study involves only steady-state EMG signals. However, it is possible that these features may further improve the study results.We will explore these feature sets as part of future work.

E. Classification With Linear Support Vector Machines

Linear support vector machines (SVMs) were used for classifying the feature vectors generated from the EMG data into the respective classes for the gestures. SVMs have proved to be a remarkably robust classification method across a wide variety of applications.

a) Binary Classification: Consider a two-class classification problem. Essentially, the SVM attempts to find a hyperplane of maximum “thickness” or margin that separates the data points of the two classes. This hyperplane then forms the decision boundary for classifying new data points. Let ‘W’ be the normal to the chosen hyperplane. The classifier will label a data point as +1 or -1, based on whether W*x + **b** is greater than 1, or less than -1. Here, (W,b) are chosen to maximize the margin of the decision boundary while still classifying the data points correctly.

This leads to the following learning algorithm for linear SVMs. For the classifier to correctly classify the training data Points x1,…,xn with y1,…,yn labels drawn from, the following constraints must be satisfied

$y_i(W^*x_i + b) \geq 1-\xi_i \quad ¥i \; \xi_i \geq 0$

This set of constraints ensures that each data point x_i is correctly classified, allowing for some small amount of error ξ_i since real-life data are noisy. The optimization goal for the noisy classification case is to minimize ½ $w^*w + C\sum_i \xi_i$, where C is a user-specified cost parameter. Intuitively, the criterion is trading off the margin width with the amount of error incurred. This is the formulation we use, and in this formulation, The classifier has a single-free parameter C that needs to be chosen by model selection.

b) Multiclass Classification and Probabilities: The two-class formulation for the linear SVM can be extended to multiclass problems. The system uses the following generic method for combining binary classifiers for multiclass classification for each pair of classes, a separate binary classifier is trained on data from the two classes. In order to classify a test data point, the datapoint is classified by each binary classifier, and each result is counted as a vote for the respective class. The output of the classifier is the class label with the maximum number of votes. In our system, LIBSVM package which implements the SVM classification algorithm, along with support for multiclass classification.

These were the basic way of implement EMG to function the robotic arm. But the topic was started as to how the technology is being benefited for the needful. The needful whom the technology must be aimed to be served are the amputees with cut or disabled limbs. The above explanation was to brief the basic idea and working of the robotic arm with this technology. Now imagine a patient with cut limb say right hand. The body of the patient is just the same as the normal human body and can generate the myoraphic signals. But the signals can be weak which can be aided by increasing the signal conditioning units. This technology is equally beneficial for the people with disabilities and can be implemented in the following ways:-

1. Bind the electrodes to the surface of skin where the signals are important and vital for the movement of the robotic arm to complete the required actions. The electrodes will pick up or sense the weak myographic signals. Convert it to electric steady state signals as earlier steps.
2. Steady state signals are now converted to standard reference signals as it was done earlier. The signal is now ready to represent the action demanded by the limb.
3. The signal is then passed through the identification process to identify the signals feature and compare with the standard signals preloaded in the system.
4. The robotic arm woukd function as per the signal demands as ealier. Hence, it has proven helpful to provide artificial movement for the person.

IV.SIGNAL PROCESSING

The algorithm for estimating the normalized muscle activation level (NAL), based on raw EMG signals, follows the signal processing procedure.

It includes

1) A high-pass filter;

2) Full signal rectification (absolute value);

3) A low pass;

4) A signal normalization with respect to the EMG mean signal during maximal voluntary isometric contraction.

Thus signals are processed to get the muscle activation level i.e force, velocity and level. Signal rectification gives an absolute value of the high frequency EMG signal and then the obtain information is filtered and normalized w.r.t mean signal. Thus activation level of the muscle is determined.

V.CONTROL ALGORITHM

The following block diagram represents the algorithm with which the system performs the task. Various blocks perform their respective operations and thus the entire system of the exoskeleton is synchronised. The whole controlling is done with Bio-signals (EMG signals basically in our case). Then the signal is further processed by various blocks and control action is taken by the system.Obviously it is operated on closed loop control system and has feedbacks. Feedbacks will be from motion sensor and position controller.

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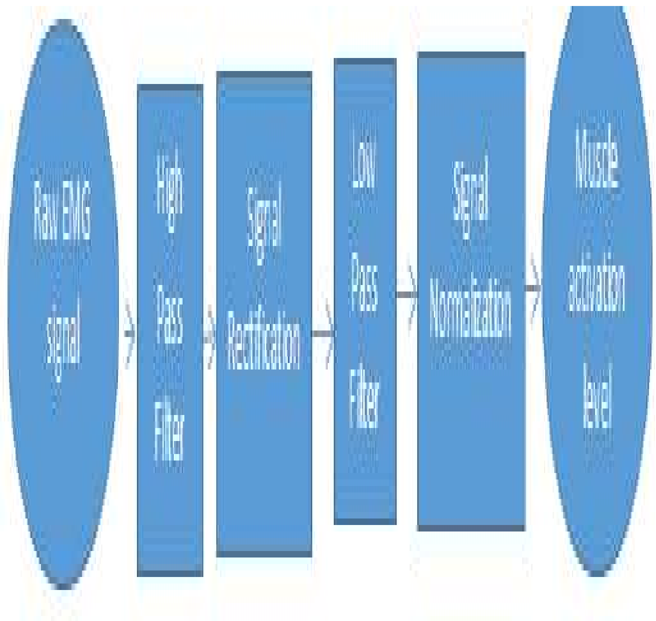
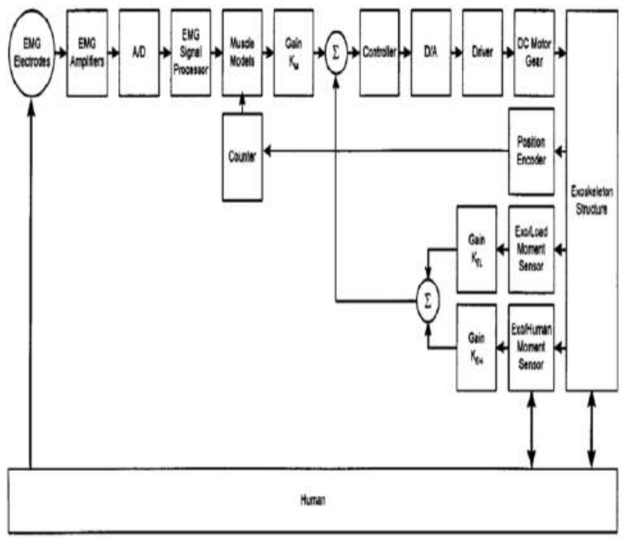


The exoskeleton complex is composed of two subsystems: the human and the exoskeleton. The task of the control algorithm is to achieve a natural integration between these two major components. This task is performed by the operator while preserving a constant mechanical gain in which the operator feels a scaled down version of the load. A full contact is maintained between the operator and the exoskeleton throughout the whole process.The signal obtained from the EMG electrodes are very weak and hence need amplification. Then the signal is digitized and fed to the signal processor which is already mentioned in the previous block diagram. The o/p of the EMG signal processor basically gives the muscle activation level. This is given to the myoprocessori.e Muscle Model and the contr

The o/p of the EMG signal processor basically gives the

A MYOSIGNAL-BASED POWERED EXOSKELETON SYSTEM



muscle activation level. This is given to the myoprocessori.e Muscle Model and the processed o/p is given to the controller. The controller generates a DC signal to drive the motor driver. The controller's inner closed loop (feedback signals) is composed from two sources.1) The external-load/exoskeleton measures the effective moment applied by the load to the elbow joint, and

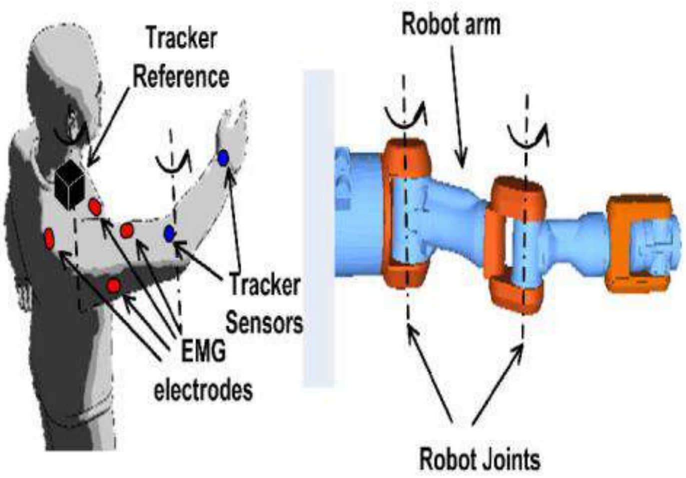
2) The human-arm monitors the moment applied by the operator on the system.

Calculation is made before and after generation of control signals and the required controlling action is altered accordingly as per the feedback obtained. Thus a synchronous controlling action is obtained in the system.

VI.IMPLEMENTATION

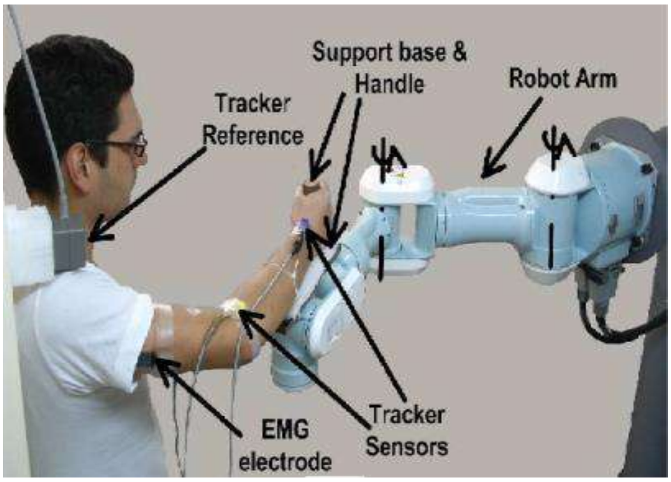
In today's world nothing is impossible. This phrase is truly being justified by the technological advances in the field discussed in this paper. People with disabilities concerned with their limbs or limbs being cut off from their body due to some particular reason are benifitedby the technology of s-EMG (Surface- Electromyographic Signals). By this technology mankind has been truly benifited. Researches have been constantly being carried out all over the globe to just know more means ie. to design new robotic devices which exploits this technology to provide motion to artificially created limbs using the surface sense signals picked up by the electrodes placed at the sense points which pick up the signals convert it using signal processing software such as MATLAB then compare it with standard patterns stored inside the device accordingly the movement of the robotic arm is initiated by activating the concerned motor signals direct towards the motors or other internal parts of the robotic hand.

1. There are two methods in which this technology is implemented to use the EMG signals to initiate motions in the robotic arm. They are as mentioned follows Teleoperation Scenario



The teleoperation set-up used is shown in Fig. . EMG signals are recorded from four muscles of the shoulder and elbow joint of the user, while position sensors are placed on the shoulder and elbow points as shown in figure above.

2. Orthosis Scenario



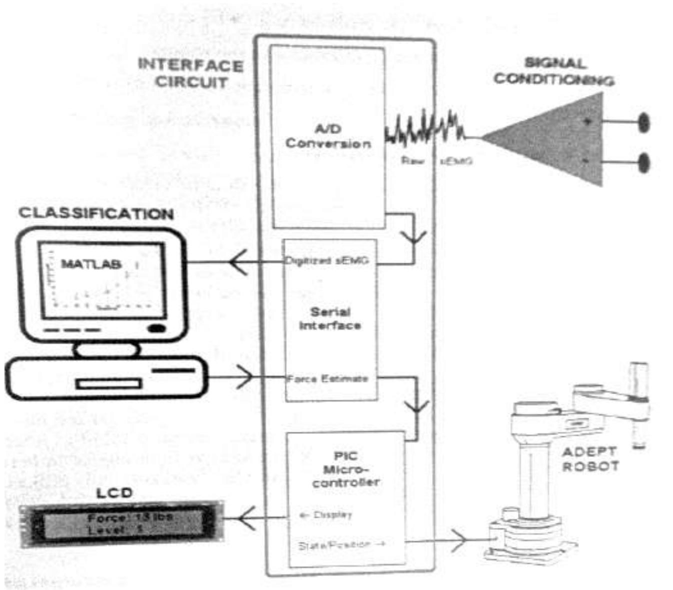
In the case of the orthosis, the robot arm is coupled with the human arm, as shown in figure above. As it can be seen the user's arm motion is restricted to the plane, as the forearm and wrist are immobilized by means of straps that are coupled with the robot forearm, using a support base and a handle. Only two planar robotic joints are free to move, while the others are kept fixed in their initial position via electromechanical brakes. The user's arm is supported against gravitational forces. The user exerts force through the handle, while moving his/her arm.

VII.PIC MICROCONTROLLER

After the the signals are received they must be implemented to our robotic arm. This is done in 2 steps:

Firstly a PIC microcontroller is used to convert the analog s/g to digital s/g which is given to the computer to process it.. This is the first basic part. Here the computer computes the force and theposition from the received signal. For A/D conversion the sampling frequency must be at least twice the maximum frequency as per sampling theorem. Many PIC micro controllers can satisfy this criterion but PIC16F819 was chosen. The reason was its better resolution.

Secondly another PIC microcontroller is used for interfacing the robotic arm with the computer.PIC16F876 was chosen by considering the number if i/o's. although not much i/o's are required but still the provision is made for future purpose in case any upgrades are made.



VIII.CONDITIONING CIRCUIT

The conditioning circuit is the network which is used to sense the signals which is having low signal power ie. low current and voltage strength. The network in EMG technology cannot work in such low strength signal environment hence to raise the signal strength without hampering the data passed on by the myologically generated signals a unit called Conditioning circuit is connected in the network just the next unit after the surface electrodes.

This circuit consists of an instrumentation amplifier, a high pass filter, a sallen key low pass filter, a inverting amplifier and lastly precision amplifier. This network is realized using OPAMPS. The specialty of each unit is that the instrumentation amplifier has a gain of 939 with the typical resistors value used(shown in the diagram). The function is to increase the signal strength of the incoming weak signals coming from electrodes. The next stage is a simple RC filter followed by a buffer opamp. If the buffer is not connected resistance of the following stage would load the filter and change the behavior. Next a 2-pole Sallen-Key low pass filter which functions to attenuate unwanted frequencies. The filter specifications are clearly indicated on the diagram. The next stage is a inverting amplifier where the feedback branch is a potentiometer which is used to vary the value of resistance on the branch to vary the overall gain of the system. Precision rectifier is used instead of normal rectifiers because we donot want to miss out on any of the minute details of the signals. They get rectified to DC effectively with merely no loss of data.

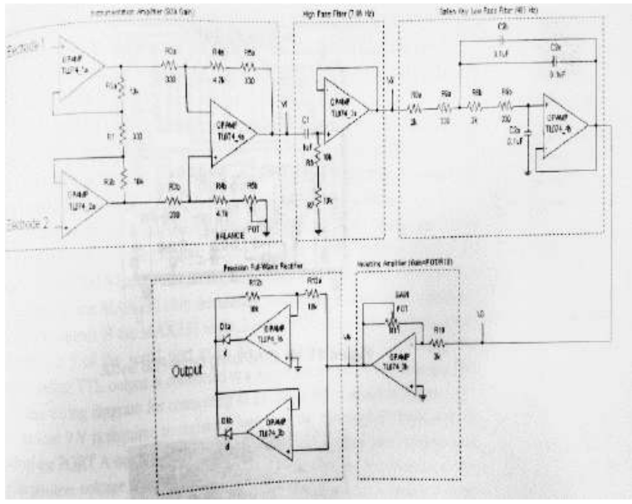


Fig of conditioning circuit.

CONCLUSION& FUTURE WORK

We have shown that EMG signals can be classified in real time with an extremely high degree of accuracy for controlling a robotic arm-and-gripper. Classification accuracies of over 90% were obtained using a linear SVM-based classifier and a sparse feature representation of the EMG signal. We then demonstrated that the proposed method allows subjects to use EMG signals to efficiently solve several reasonably complex real-time motor tasks involving 3-D movement, obstacle avoidance, and pick-and-drop movements using

a 4 degrees-of-freedom robotic arm.On-going work is focused on extending our results to other types of movements, e.g., discriminating finger movements. A parallel study involves combining EEG signals from the scalp (reflecting underlying brain activity) with EMG signals for more accurate classification of motor patterns, with potential applications in brain-computer interfaces (BCIs). An interesting theoretical question that we are beginning to study is whether the EMG-based control system can be adapted online rather than only at the start of an experiment. This is a difficult problem since the subject is also presumably adapting on-line to generate the best muscle activation patterns possible for control and to compensate for changes in electrode conductivity with the passage of time. We intend to explore variations of our SVM-based classification technique to tackle this challenging non-stationary learning problem.

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Gesture Sensing Device

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Abstract— **A Gesture Sensing device is precisely a device which will bridge the gap between the physical world and digital world. Today to do any form of computing we have to make use of certain input devices and output devices with which we can communicate with the computer and perform various work. But This device removes this wall of physical objects. Any work like dialling a phone number , can be easily done using this device without any keypad to enter numbers or any LCD to display the dialled number. Using this device u can project the the display anywhere u want and by just doing the gesture of dialling a number, the number actually gets Dialled. This Device will hence give a new revolution in the Technological World.**

Keywords— **Sixth Sense Device , Gesture Sensing ,**

I. INTRODUCTION

Gesture Sensing Device As the name suggests will sense your gestures and will give u a response . The device can sense many gestures by image recognition ,colour recognisation and image processing and gives u a very intuitive environment to play with the digital World. The device will be more helpful for day to day work and will make the work flow more and more easy.With the help of your hands and some colour markers you make some gestures, the device tracks the gestures and responses and show you were your hand is actually moving. In the following paper we have given a broad idea of the device Construction and Working .This device thus make u free from the physical limitations of the computing world.

WHAT IS A GESTURE??

A gesture is a form of non-verbal communication in which visible bodily actions communicate particular messages, either in place of speech or together and in parallel with spoken words. Gestures include movement of the hands, face, or other parts of the body. Gestures differ from physical non-verbal communication that does not communicate specific messages, such as purely expressive displays, proximus, or displays of joint attention.[1] Gestures allow individuals to communicate a variety of feelings and thoughts, from contempt and hostility to approval and affection, often together with body language in addition to words when they speak.

II. GESTURE SENSING EXAMPLES

A. Making a Drawing On the Wall

Using the hands and colour markers as shown in the Figure we can draw various images just on any wall. Here the camera is tracking the movements of the colour markers on the fingers

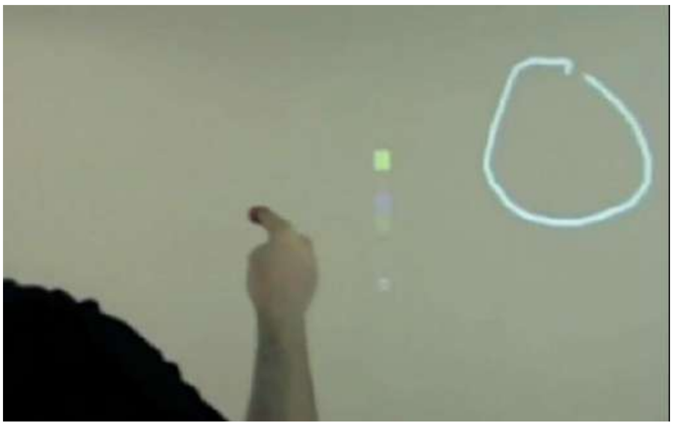


Figure No.1

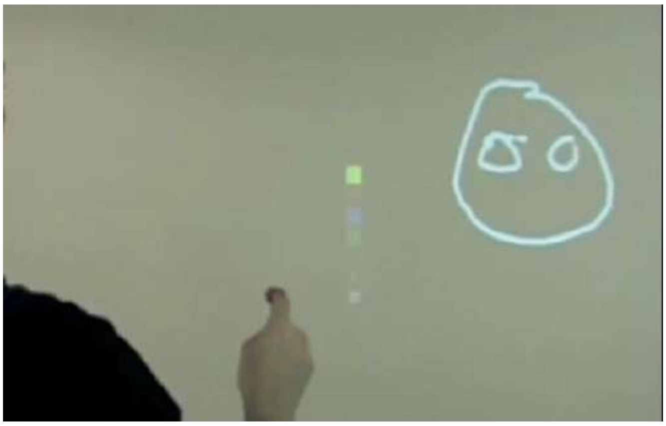


Figure No.2

B. Clicking on Objects Displayed on Wall

Then by using projector we can display the menu or any wall and click the objects. Here also the camera is sensing our gestures using image processing

Figure No.3

C. Clicking Photos just by making Gesture

In this you just do a gesture of clicking a photo and the device clicks the photo for you. In this the device senses the gesture and by using various algorithms of image processing it clicks the pic for you.Here u need not depend on a Camera to click the camera and all

Figure No.4

Figure No.5

D. Dialling A Phone Number

This is also an interesting example in which u use your palm to put the numbers and then click on the numbers using your hand and directly click on the numbers and u can call. Here u don’t need a keypad nor a LCD..but everything is so simple

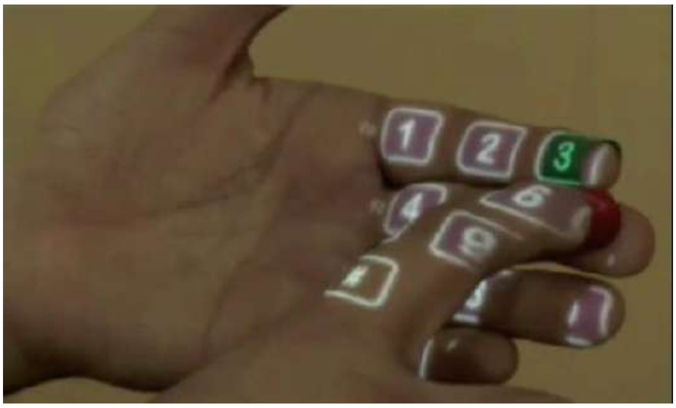


Figure No.6

Figure No.7

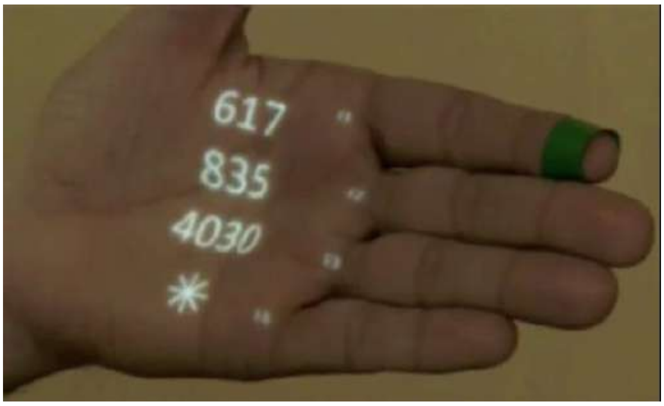


Figure No.8

E. Playing a Game

This example shows how this device uses a microphone and helps u to play games and do work on a piece of paper. The device tracks the sound of your hand wherever u touch on the paper

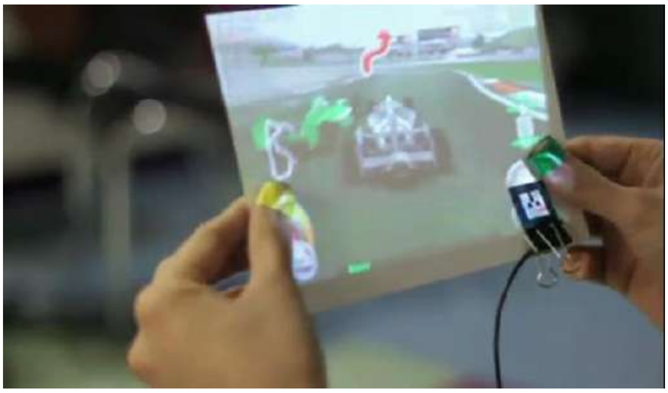


Figure No.9

F. Watching a live video

Figure No.10

1) Browsing on a piece of Paper

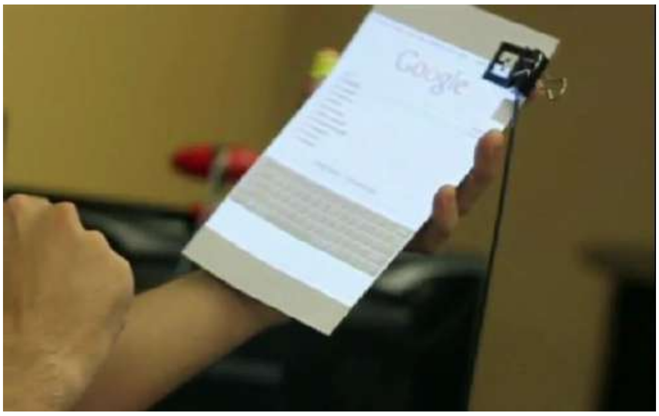


Figure No.11

2) Check your Weather For the Day

Figure No.12

3) *Editing Document*

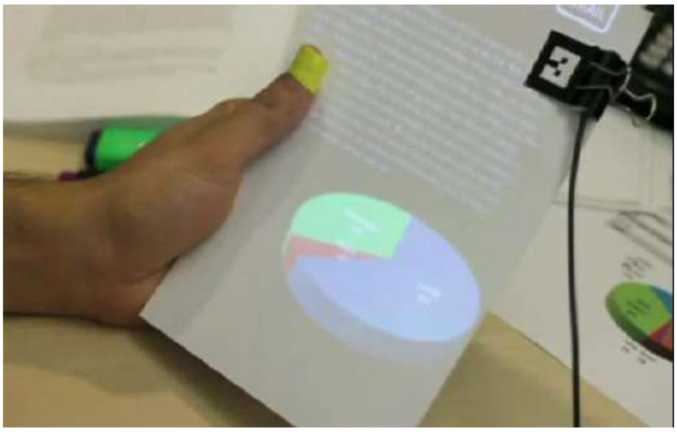


Figure No.13

III. CONSTRUCTION OF THE DEVICE

A. *Camera*

The camera is the key input device of the Sensing system. The camera acts as a digital eye of the system. It basically captures the scene the user is looking at. The video stream captured by the camera is passed to mobile computing device which does the appropriate computer vision computation. The major functions of the camera can be listed as:

- Captures user's hand movements and gestures (used in

on the paper. Here, the sound signal captured by the microphone provides time information whereas the camera performs tracking. The applications enabled by this techniques are explained earlier.

- Captures the scene in front and objects the user is interacting with (used in object reorganization and tracking)
- Takes a photo of the scene in front when the user performs a 'framing' gesture
- Captures the scene of projected interface (used to correct the alignment, placement and look and feel of the projected interface components)

B. Projector

The projector is the key output device of the Sensing system. The projector visually augments surfaces, walls and physical objects the user is interacting with by projecting digital information and graphical user interfaces. The mobile computing device provides the projector with the content to be projected. The projector unit used in prototype runs on a rechargeable battery. The major functions of the projector can be listed as:

A. *Microphone*

- Projects graphical user interface of the selected application onto surfaces or walls in front
- Augments the physical objects the user interacting with by projecting just-in-time and related information from the Internet

C. *Mirror*

The mirror reflects the projection coming out from the projector and thus helps in projecting onto the desired locations on walls or surfaces. The user manually can change the tilt of the mirror to change the location of the projection. For example in application where the user wants the projection to go on the ground instead of the surface in front, he can change the tilt of the mirror to change the projection. Thus, the mirror in the Sensing Device helps in overcoming the limitation of the limited projection space of the projector.

D. Microphone

The microphone is an optional component of the Sensing Device. It is required when using a paper as a computing interface. When the user wants to use a sheet of paper as an interactive surface, he or she clips the microphone to the paper. The microphone attached this way captures the sound signals of user's touching the paper. This data is passed to computing device for processing. Later, combined with the tracking information about user's finger, the system is able to identify precise touch events device and those images which r in use are saved rest are discarded.

E. Mobile computing device

The SixthSense system uses a mobile computing device in user's pocket as the processing device. The software program enabling all the features of the system runs on this computing device. This device can be a mobile phone or a small laptop computer. The camera, the projector and the microphone are connected to this device using wired or wireless connection. The detail of the software program that runs on this device is provided in next section. The mobile computing device is also connected to the Internet via 3G network or wireless connection.

IV. WORKING OF THE DEVICE

- The device has a camera which continuously captures the images of all the gestures happening around your device
- U wear colour markers on your fingers.These colour markers have specific grey levels
- When the images of the gestures are taken then the computing device through various algorithms searches for these grey levels in the images taken by the Camera
- The co- ordinates of the specific grey levels searched are been processed by various algorithms and hence the Gesture is been sensed
- This working is a simple explanation of the working of the device. Some algorithms are been made whereas some are under process
- Thus by using Digital Image processing these device can be made

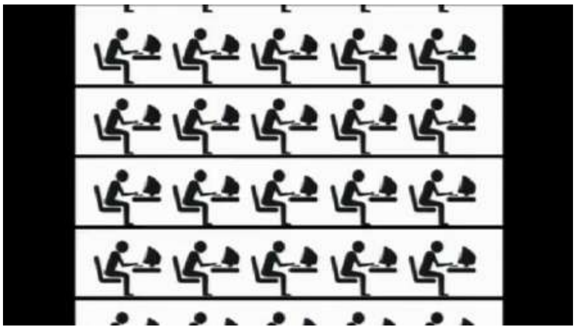
The computing Device uses a microcontroller and some memory.

V. APPLICATION

- This Device has a Wide Range of applications
- The Device can be used by Deaf and Dumb people For them to speak out
- The device can be used by physically challenged people to interact with the World
- People who have Dislexia and other such problems can interact and learn easily
- Work Flow and information can be done easily
- The Best application is in all the day uses whereas the limitation of modern day computing to use input output Devices is removed
- Mobile Companies can use it for Their own technology
- Hence this sensing Device has a Wide Range of Applications

VI. CONCLUSION

- This Device removes the Limitation of inputting and outputting Data using a input or output device interfacing. This device hence bridges the gap between physical world and Digital world and hence rather than making humans sit in front of the computer regularly, it makes the people the freedom of movement and removal of all bonds. Using this device humans can Do computing any how and any where



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Spy Robot for Surveillance and Weather Monitoring with GPS

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Abstract— **This dissertation gives an overview about an unmanned spy aerial vehicle which focuses on surveillance and weather monitoring. This vehicle is a quad copter based on 4 propellers which is RF controlled to autonomously patrol an area and wirelessly report suspicious findings by using an array of onboard sensors. The board consisting of gyroscopes is used as flight stability controller to control the pitch, roll and yaw of the copter. The PIC microcontroller processes the sensor data and thereby transmitting it through GSM module to the remote base station.**

***Keywords* –Quadcopter, on-board sensors, flight stability.**

I. I. INTRODUCTION

Quadcopters are compact aircraft with an ability of vertical takeoff and landing. Like a conventional helicopter they can hover, but have significant other advantages such as ease of piloting and mechanical simplicity— they have no swash-plate mechanism. Because of its unique design comparing to the traditional helicopters, it allows a more stable platform, making them ideal for tasks such as surveillance and aerial photography.

The prototype consists of a light weight aluminum frame attached to which are four motors that receive power from electronic speed controllers that allow communicate with the microprocessor, which will in turn control the speed of each individual motor. Using four brushless motor, we are able to change directions, elevation, and tilt rapidly by simply manipulating how much voltage goes into the motors while the copter is in the air.

The main board of copter consists of flight controller. It deploys ATMEGA microcontroller which controls the onboard gyroscopes thereby controlling the pitch, yaw and roll of the copter. The quadcopter consists of peripheral circuitry other then the main board. It consists of temperature sensors, fire detector and humidity sensor. The PIC microcontroller continuously monitors these sensed parameters and communicates it to the remote base station via GSM module. The quadcopter also carries a camera which will facilitate the procurement of live feed of the region over which it is hovering.

Fig.1 Prototypequadcopter.

The block diagram in figure 2 below provides an overview of the Quad-Copter’s subsystems.

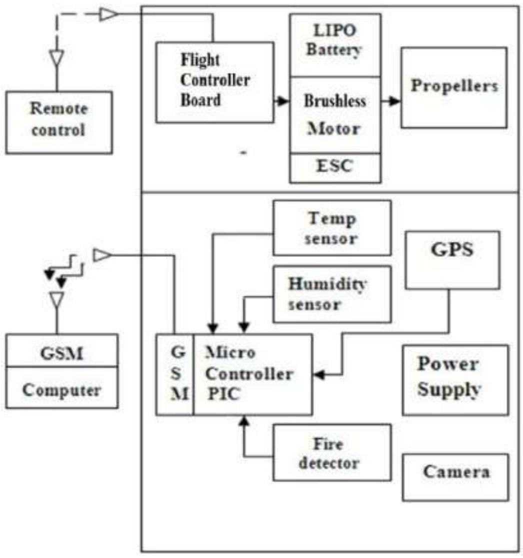

Fig.2 Block diagram of Spy robot.

II. ONBOARD SYSTEM

The quadcopter entails various systems that perform different functions along with the flight controlling. These functions include weather monitoring, video capturing and global positioning.

A. Flight Stability Controller

The flight controller is a control board for 4 rotor UAV (Quad copter). Its purpose is to stabilize the aircraft during flight. To do this it takes the signal from the three on-board gyros (roll, pitch and yaw) then passes the signal to the Atmega168 IC. The on board Atmega168 chip gives users the extra space to load expanded firmware with higher refresh rates to enhance stability. The IC unit then processes these signals according the users installed software and passes control signals to the installed Electronic Speed Controllers (ESCs). These signals instruct the ESCs to make fine adjustments to the motors rotational speed which in turn stabilizes the Quad copter. The three adjustable potentiometers increase or decrease gyro gain for all three axis (Roll, Pitch and Yaw) and can be used to calibrate the ESCs and reverse the gyro directions if necessary during pre-flight setup.

The control board also uses signals from the radio systems receiver (Rx) and passes these signals to the Atmega168 IC. Once this information has been processed the IC will send varying signals to the ESCs which in turn adjust the rotational speed of each motor to induce controlled flight (up, down, backwards, forwards, left, right, yaw).

B. Gyroscope

A gyroscope is a device for measuring or maintaining orientation, based on the principles of angular momentum. Mechanically, a gyroscope is a spinning wheel or disc in which the axle is free to assume any orientation. Although this orientation does not remain fixed, it changes in response to an external torque much less and in a different direction than it would without the large angular momentum associated with the disc's high rate of spin and moment of inertia. The device's orientation remains nearly fixed, regardless of the mounting platform's motion, because mounting the device in a gimbal minimizes external torque.

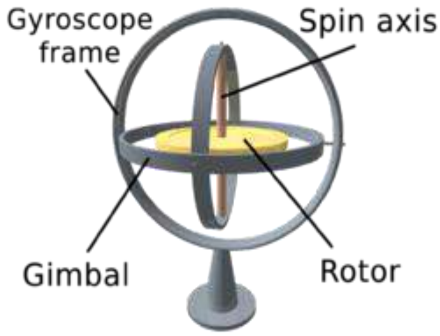

Fig.3 Principle of Gyroscope.

The quadcopter is not aware of the angle, stabilization-balancing is the act of keeping or trying to keep the same tilt angle.

Gyros are the most useful sensor for this task, because of the following reasons:

- Its response is very fast compared to other sensors such as accelerometer.
- It measures angular velocity fast and accurately.

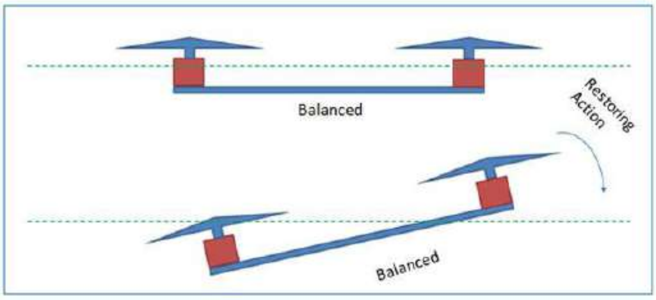

Fig.4 Copter orientation using Gyros.

The quadcopter's movement is controlled by varying the relative thrusts of each rotor. These rotors are aligned in a square, two on opposite sides of the square rotate in clockwise direction and the other two rotate in the opposite direction. If all rotors turn in the same direction, the craft would spin would spin just like the regular helicopter without tail rotor. Yaw is induced by unbalanced aerodynamic torques. The aerodynamic torque of the first rotors pair cancelled out with the torque created by the second pair which rotates in the opposite direction, so if all four rotors apply equal thrust the quadcopter will stay in the same direction.

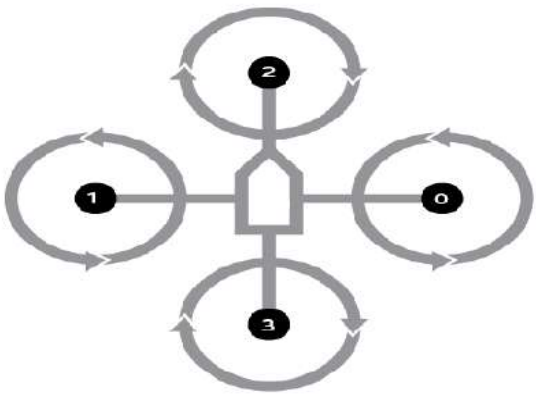

Fig .5 Rotations of Motors.

To maintain balance, the quadcopter must be continuously taking measurements from the gyros, and making adjustments to the speed of each rotor to keep the body level. A quadcopter has three controllable degrees of freedom: Yaw, Roll and Pitch,. Each degree of freedom can be controlled by adjusting the thrusts of each rotor.

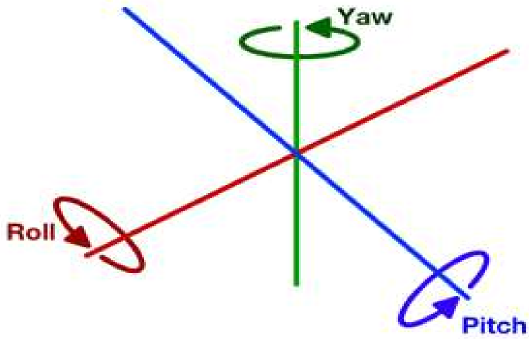

Fig.6 Degree of Freedom.

- Yaw (turning left and right) is controlled by turning up the speed of the regular rotating motors and taking away power from the counter rotating motor.
- Roll (tilting left and right) is controlled by increasing speed on one motor and lowering on the opposite one.
- Pitch (moving up and down, similar to nodding) is controlled the same way as roll, but using the second set of motors.

C. Temperature Sensor

The Temperature sensor used here is IC LM35.The LM35 series are precision integrated-circuit temperature sensors, with an output voltage linearly proportional to the Centigrade temperature. Thus the LM35 has an advantage over linear temperature sensors calibrated in ° Kelvin, as the user is not required to subtract a large constant voltage from the output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±¼°C at room temperature and ±¾°C over a full −55°C to +150°C temperature range. Low cost is assured by trimming and calibration at the wafer level. The low output impedance, linear output, and precise inherent calibration of the LM35 makes interfacing to readout or control circuitry especially easy. The device is used with single power supplies, or with plus and minus supplies. As the LM35 draws only 60 µA from the supply, it has very low self-heating of less than 0.1°C in still air. The LM35 is rated to operate over a −55°C to +150°C temperature range, while the LM35C is rated for a −40°C to +110°C range (−10° with improved accuracy). The LM35 is applied easily in the same way as other integrated-circuit temperature sensors. Glue or cement the device to a surface and the temperature should be within about 0.01°C of the surface temperature. This presumes that the ambient air temperature is almost the same as the surface temperature. If the air temperature were much higher or lower than the surface temperature, the actual temperature of the LM35 die would be at an intermediate temperature between the surface temperature and the air temperature.

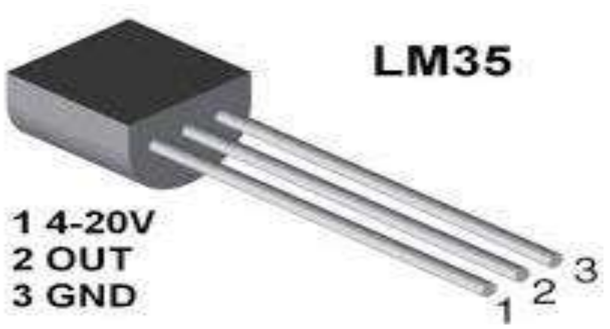

Fig.7 LM35 Temperature Sensor.

Here the LM35 will sense the temperature of the surrounding air and converts it into a proportional output voltage. This output will be sent through the shield board microcontroller to the remote base station via GSM module.

D. Humidity Sensor

The SY-HS-220 is used for humidity sensing of the environment around the quad copter. Along with easy operation, it has high reliability and long term stability. It produces a linear DC output voltage proportional to the relative humidity of the air.

The variations in relative humidity form 10% to 90% results in a proportional output of 660mV to 2790mV.

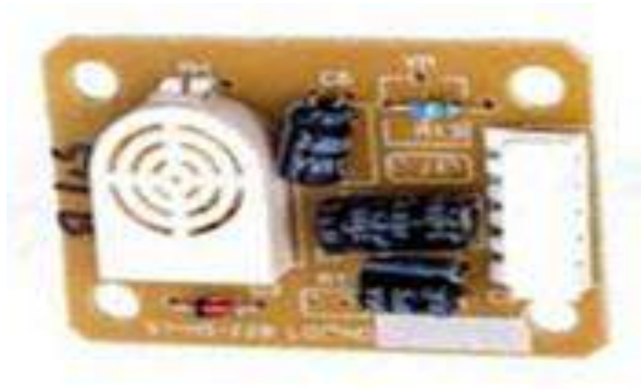

Fig.8 Humidity sensor.

Thus output voltage is send to the micro controller. The micro controller then sends it to the remote station using GSM module.

Table1. Specifications of Humidity Sensor

Parameters	**Specifications**
Rated Voltage	DC 5.0V
Rated Power	≤3.0mA
Operating Temperature	0-60˚C
Operating Humidity	30-90%RH
Storage Temperature	-30-85˚C
Storage Humidity	Within 95%RH
Standard Output	DC 1,980mV (at 25˚C 60%RH)
Accuracy	±5%RH(at 25˚C, 60%RH)

E. Fire Sensor

The fire sensor will sense fire at the vicinity of the copter and inform the PIC as an interrupt. Fire sensor is made using a bimetallic strip. A bimetallic strip is simply two strips made from different metals or metal alloys that are joined together which expand when heated.

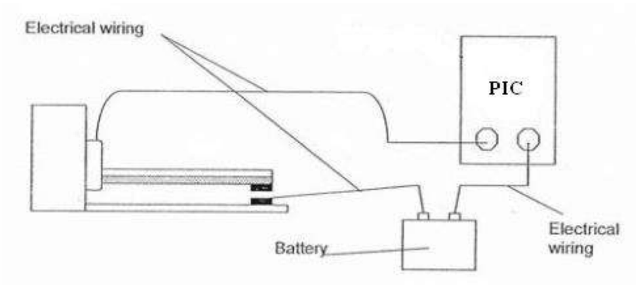

Fig.9 Fire sensor circuit.

When a fire occurs, the heat would cause the bimetallic strip in the sensor to bend. This would close the circuit that allows current to flow and activate the interrupt for PIC.

E. Power Unit

The Power Unit is been divided into two subsystems. The first subsystem consists of LI-PO battery for the quad copter flight stability operation. The second subsystem is our normal battery of 25volts for the On-Sensors Board. Li-Po batteries are usually composed of several identical secondary cells in parallel to increase the discharge current capability, and are often available in series "packs" to increase the total available voltage. Li-Po batteries are rechargeable with advantages of lower weight and greatly increased run times. The second subsystem power is further divided into different voltages as required by the respective shield board systems as 5V, 9V, 12V etc.

F. Spy Camera

The SPY Camera we have used is WS-309AS 1.2G Wireless Mini Camera. The transmission unit of video camera consists of 1/3’’1/4” image sensors with PAL/CCIR NTSC/EIA system. The effective pixel for PAL is 628x582 with image area of 5.78mm x 4.19mm and for NTSC effective pixel is 510 x 492 with image area of 4.69mm x 3.45mm. The horizontal definition of camera is 380 TV lines for minimum illumination of 3LUX.The output frequency of camera is 1.2GHz and Linear Transmission distance is 50-100M with power dissipation of 640MW. The receiver unit has sensitivity of 18dB with receiving frequency of 1.2GHz. The modulation used here is Frequency Modulation.

G. GPS

A GPS module talks to the satellite and retrieve accurate location information. The GPS module used here is 5volts TTL GPS Receiver. This is a high gain GPS Receiver (5V Serial) with 4 Pin 2.54mm pitch Berg strip. Receiver makes use of third generation POT (Patch Antenna On Top) for the GPS module. The built in 3V3 to 5V level converter enable it to interface with normal 5V Microcontrollers. Its low pin count (4 Pin) berg strip makes the interfacing easier. The 4 Pins are 5V, TX, RX, GND.

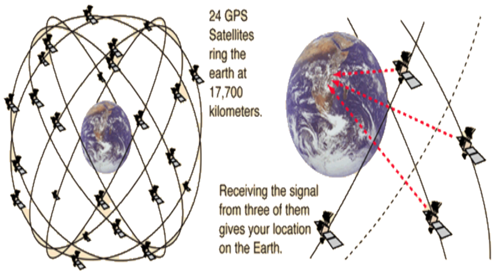

Fig.10 GPS satellites.

This is a standalone 5V GPS Module and requires no external components .It is built with internal RTC Back up battery. It can be directly connected to Microcontroller's USART.

The 24 satellites of the GPS are placed in orbits at about 3.75 times the radius of the earth. A GPS receiver which may be a small hand-held unit can triangulate its position on the earth’s surface within 30 meters or less with signals from three of the satellites.

Fig.11 GPS module.

The module provides current time, date, latitude, longitude, speed, altitude and travel direction/ heading among other data, including navigation, tracking systems. The module can support up to 51 channels. The GPS solution enables small form factor devices. They deliver major advancements in GPS performances, accuracy, integration, computing power and flexibility. They are designed to simplify the embedded system integration process.

III. WIRELESS

The communication with quad copter is done using wireless RF module for flight control and GSM for sending the sensed data from the sensors to the base station.

A. Flight Control RF Module

The RF module is used for controlling the quad copter. An RF Module (Radio Frequency Module) is a usually small electronic circuit used to transmit and/or receive radio signals on one of a number of carrier frequencies. The FS CT 6B, a transmitter with 6 channel, 2.4GHz frequency is used for controlling the copter. The frequency at which it transmits the modulated signal is received by a FS-CT6B receiver which de-modulates the signal to get the original signal.

Table2. Specifications of RF Module

Transmitter	**Receiver**
Channels: 6	Channels: 6
Frequency band: 2.4GHz	Frequency band: 2.4GHz
Power resource: 1.5V*8"AA"battery	Power resource: 1.5V*4''AA''battery
Program type: GFSK	Program type: GFSK
Modulation type: FM	Modulation type: FM
RF power:19db	RF receiver sensitivity: -76db

B. GSM

For wireless transmission of the data from the sensor the GSM module Sim900 is used. Sim900 is a quad band GSM engine that works on frequency GSM 850Mhz. Sim900 features GPRS multi-slot class 10/class8 and supports the GPRS coding schemes. This module is integrated with the TCP/IP protocol; extended TCP/IP AT commands for customers to use the TCP/IP protocol easily, which is very useful for those data transfer applications.

Fig.12 GSM module.

In our case, the data from the sensors is sent to the microcontroller. The microcontroller then converts this analog data into digital and sends it to GSM module. This data now is transmitted to base station through GSM module.

At the receiver side, data is acquired through GSM receiver module and then displayed on the Base Station system.

IV. FRAME

Frame is the important part of the quad copter. It is the structure that holds all the components together. The Frame should be rigid, and be able to minimize the vibrations coming from the motors. It is made of aluminum which is of light weight and strong.The copter is expected to hover a disctance of 100meters and 10-15fts high from ground level A Quadcopter frame consists of two to three parts which don’t necessarily have to be of the same material:

1. The center plate where the electronics are mounted
2. Four arms mounted to the center plate
3. Four motor brackets connecting the motors to the end of the arms.

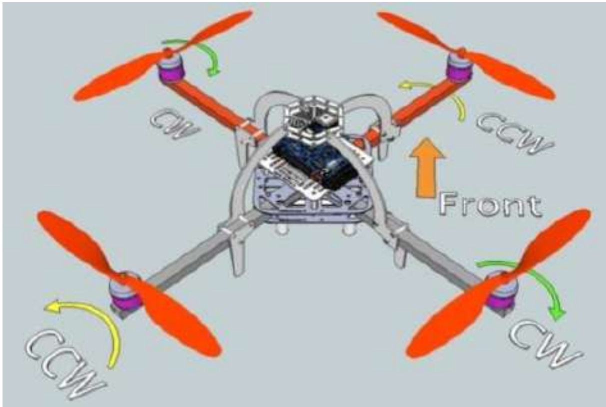

Fig.13 Quadcopter design.

The best way to keep the copter from spinning is to have the propellers moving in opposition to each other. To maintain balance the quadcopter must be continuously taking measurements from the sensors, and making adjustments to the speed of each rotor to keep the body level. Usually these adjustments are done autonomously by the fight stability controller board on the quadcopter in order to stay perfectly balanced. A quadcopter has four controllable degrees of freedom: Yaw, Roll and Pitch.

V. FUTURE SCOPE

Future of a quad-copter is quite vast based on various application fields it can be applied to. Quad-copter can be used for conducting rescue operations where it’s humanly impossible to reach. In terms of its military applications it can be more widely used for surveillance purposes, without risking a human life. As more automated quad-copters are being developed, there range of applications increases and hence we can ensure there commercialization. Thus quad-copter can be used in day to day working of a human life, ensuring their well-being. The main advantage in the future use of a quad-copter for various purposes is that risk to human life, may it be because of war or due to commercial accidents can be greatly avoided. The future of quad-copter sure is bright and not far ahead.

VI.CONCLUSION

As per the design specifications, the quad copter self stabilizes using the array of sensors integrated on it. It attains an appropriate lift and provides surveillance of the terrain through the camera mounted on it. It acts appropriately to the user specified commands given via a remote controller.

Its purpose is to provide real time audio/video transmission from areas which are physically in-accessible by humans. Thus, its functionality is monitored under human supervision, henceforth being beneficial towards military applications. It is easy to maneuver, thereby providing flexibility in its movement. The system can further be enhanced for future prospects.

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Oxygen and Energy Production Using Artificial Tree

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***Abstract*-This is an artificial tree which is constructed using aluminium rods as they do not corrode easily. Leaf shaped solar panels are attached at the ends of these rods. The panels are used for collection and conversion of solar energy into electrical energy. This energy is then stored in a battery. Electrolysis of waste water is done in order to obtain oxygen and hydrogen. A membrane filter is attached at the inlet so that only water can pass through it. After electrolysis is done oxygen is released in air and hydrogen is stored for various purposes. The energy stored in battery is then used as supply for street lights. Turning on the street light according to the light intensity, turning off the electrolysis process during high temperatures (to avoid blast of hydrogen), and limiting the amount of energy transferred to battery(charge that is stored) so that it does not get damaged are all controlled by using relays and a microcontroller. Also lcd screen can be set up for displaying various kind of updates and flash messages.**

***Keywords* –Artificial Tree, Hydrogen, oxygen, microcontroller, electrolysis.**

I. INTRODUCTION

Trees naturally convert the carbon dioxide into oxygen. But today because of Greed Selfish Humans are cutting trees and forests and on that place we humans are building white cement forest. Thus we humans are not getting pure air. Population is increasing and number of tress are decreasing , just like mad society people are cutting tress after tress , even they are cutting hills to build a building to earn money.Co2 is not good for humans but Trees convert water into oxygen which we humans need to survive. This will lead to Global warming problems, Acid Rain, respiratory disease many more. But do not worry now Artificial Trees will do this Job in future. Research and experimentation on the concept of lighting; innovation and technology in the utilization and control of light; extreme attention to eco-compatible materials and to environmental needs in general. Solar oxygen Tree is the successful marriage of the most advanced technology and the aesthetic requirements of the urban environment by way of renewable energy. Oxygen tree is a revolutionary urban lighting concept that represents a perfect symbiosis between pioneering design and cutting-edge eco-compatible technology. Solar Tree opens up new prospects for urban lighting in that it satisfies today's most pressing environmental, social, cultural and aesthetic demands. But still we will need these artificial trees to produce the Oxygen as humans have started to build very tall buildings and as we go higher and higher Oxygen level gets reduced and one will need these artificial trees to produce Oxygen in 100th floor Apartment or 50th floor apartment. With the earth's population ever growing, air pollution and air quality is a major issue for many countries around the world. Air pollutantscan lead to respiratory related illnesses in humans and animals, create acid rain, and deplete the ozone layer.

BLOCK DIAGRAM

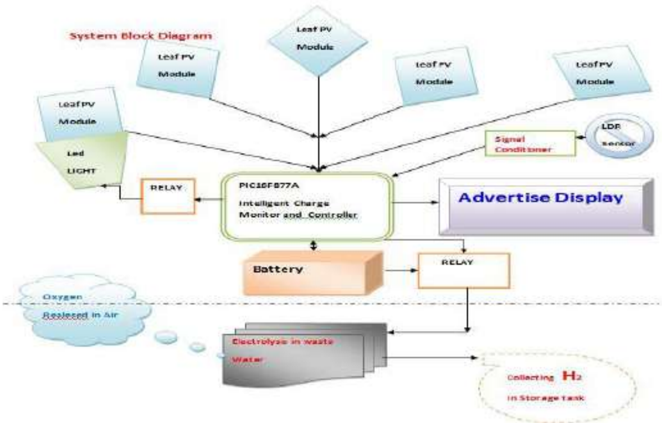

Figure 1.Block Diagram of oxygen and energy production using artificial tree

A. *Leaf type PV module*

PV panels collect energy from the sun and convert it into electricity. PV systems convert sunlight directly into electricity. "Photo" refers to light and "voltaic" to electricity. A PV cell is made of a semiconductor material, usually crystalline silicon, which absorbs sunlight. You've seen PV cells at work in simple mechanisms like watches and calculators. The utility grid is the power source available to your local electricity provider. PV cells are typically combined into modules, or panels, containing the loss about 40 cells. Roughly ten modules constitute a PV array, or grouping of panels.

4V 100mA Solar Panel

Heavy Duty Solar Panel with excellent power output. Ideal for use as a basic charger or to

4V 100mA Solar Panel

Heavy Duty Solar Panel with excellent power output. Ideal for use as a basic charger or topower small motors, radios, etc.

Features

AP Monocrystalline Blue Solar Cell

Peak Voltage (Vmp): 5.76V

Open Circuit Voltage (Voc): 6.0V - 6.8V

Peak Current (Imp): 400mA

Short Circuit Current (Isc): 400mA - 432mA

Maximum Power (Pmax): 2.5W

Dimensions: 165mm x 120mm x 3.0mm (LxWxD)

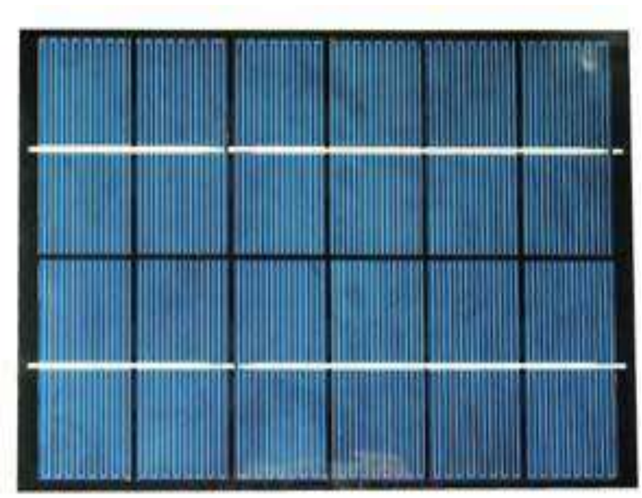

Figure 2. Solar Panel

Figure 3. Leaf type Photo Voltaic Module

Most PV panels contain a top protective layer, two specially treated layers of silicon with collecting circuitry attached to the top layer, and a polymer backing layer. The top layer of silicon is treated to make it electrically negative; the back layer is treated it make it electrically positive. When sunlight knocks electrons loose from the silicon, electrons move up from the bottom layer of silicon and crowd the electrons in the top layer. The electrons freed from the top layer are collected by electrical contacts on the surface of the top layer and routed through an external circuit, thus providing power to the electrical system attached to the panels.

B. Sensing and switching Section

Switching:

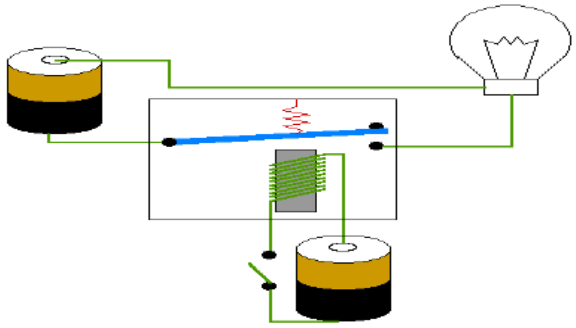

Figure 4. Relay

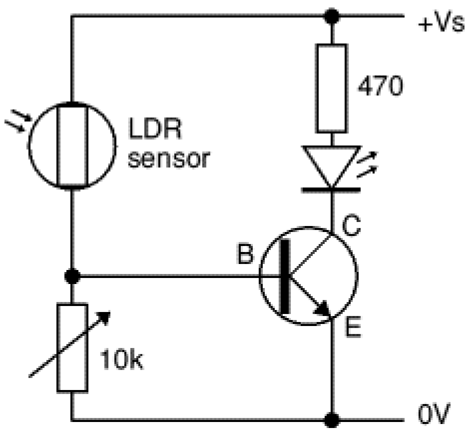

Figure 5. Light Dependent Resistor

B. RELAY

A relay is an electrically operated switch. Many relays use an electromagnet to operate a switching mechanism, but other operating principles are also used. Relays find applications where it is necessary to control a circuit by a low-power signal, or where several circuits must be controlled by one signal. The first relays were used in long distance telegraph circuits, repeating the signal coming in from one circuit and re-transmitting it to another. Here three relays are used of which two are normally close and one is normally open. These electro mechanical switches are used for triggering or stopping certain process.The simplest relay, is the Single Pole, Single Throw (spst) relay. It is nothing more than an electrically controlled on-off switch. It's biggest property, is the ability to use a very small current, to control a much larger current. this is desireable because we can now use smaller diameter wires, to control the current flow through a much larger wire, and also to limit the wear and tear on the control switchUsing a transistor switch with sensors

The top circuit diagram shows an LDR (light sensor) connected so that the LED lights when the LDR is in darkness. The variable resistor adjusts the brightness at which the transistor switches on and off. Any general purpose low power transistor can be used in this circuit.

The 10kΩ fixed resistor protects the transistor from excessive base current (which will destroy it) when the variable resistor is reduced to zero. To make this circuit switch at a suitable brightness you may need to experiment with different values for the fixed resistor, but it must not be less than 1kΩ. If the transistor is switching a load with a coil, such as a motor or relay, remember to add a protection diode across the load.

The switching action can be inverted, so the LED lights when the LDR is brightly lit, by swapping the LDR and variable resistor.A thermistor is a type of resistor with resistance varying according to its temperature. The word is a portmanteau of thermal and resistor.

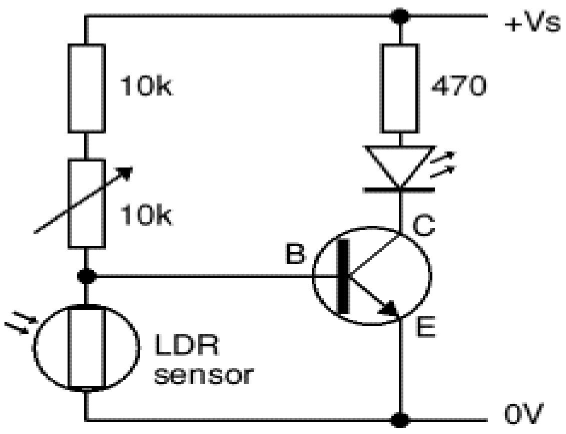

Figure 6. Inversion of switching action

Self-heating effects

Though commonly used, "self-heating" is a misnomer. Thermistors are passive devices and thus cannot heat themselves. It is the external circuit that supplies the energy that causes the heating. "Resistive heating" is a more accurate term.

When a current flows through a thermistor, it will generate heat which will raise the temperature of the thermistor above that of its environment. If the thermistor is being used to measure the temperature of the environment, this electrical heating may introduce a significant error if a correction is not made.Alternatively, this effect itself can be exploited. It can, for example, make a sensitive air-flow device employed in a sailplane rate-of-climb instrument, the electronic variometer, or serve as a timer for a relay as was formerly done in telephone exchanges.In this case the fixed resistor can be omitted because the LDR resistance cannot be reduced to zero. Note that the switching action of this circuit is not particularly good because there will be an intermediate brightness when the transistor will be partly on (not saturated). In this state the transistor is in danger of overheating unless it is switching a small current. There is no problem with the small LED current, but the larger current for a lamp, motor or relay is likely to cause overheating. Other sensors, such as a thermistor, can be used with this circuit, but they may require a different variable resistor. You can calculate an approximate value for the variable resistor (Rv) by using a multimeter to find the minimum and maximum values of the sensor's resistance (Rmin and Rmax):

Variable resistor, Rv = square root of (Rmin × Rmax)

For example an LDR: Rmin = 100Ω, Rmax = 1MΩ, so Rv = square root of (100 × 1M) = 10kΩ.

You can make a much better switching circuit with sensors connected to a suitable IC (chip). The switching action will be much sharper with no partly on state.

C.LED Lightning

Nowadays every person tries to save energy and be part of making our world greener and a better place to live. The largest users of electricity are governments and metropolitans that want to illuminate their streets to make them safer to walk through. For that the traditional streetlights are massive consumers of electricity that are a big part of our contamination of our world. Large electricity plants consume a huge amount of coal and carbon to let those lights of all metropolitans and cities burn at least 8 hours a day. With highpower LED streetlights it ispossible to achieve to save up to 80% of energy, and besides they cost less to maintain.

Figure 7. LED lightning

D. LCD display

Liquid crystal Display (LCD) displays temperature of the measured element, which is calculated by the microcontroller. CMOS technology makes the device ideal for application in hand held, portable and other battery instruction with low power consumption.

GENERAL SPECIFICATION:

Drive method: 1/16 duty cycle

Display size: 16 character * 2 lines

Character structure: 5*8 dots.

Display data RAM: 80 characters (80*8 bits)

Character generate ROM: 192 characters

Character generate RAM: 8 characters (64*8 bits)

Both display data and character generator RAMs can be read from MPU.Internal automatic reset circuit at power ON.Built in oscillator circuit.

I. PRINCIPLE OF ELECTROLYSIS

Water electrolysis to produce hydrogen and oxygen is an old technology originating in The early 19th century shortly after Volta introduced the first battery in 1800. The Principle chemical equations are shown in reactions below**,** where the electrochemical flow is:

Net Reaction: H_2O --> H_2+ ½ O_2

Acidic Reaction Alkaline Electrolysis

anode: H_2O --> ½O_2 + $2H^+$ + $2e^-$ $2OH^-$ --> ½O_2 + H_2O + $2e^-$

Cathode: $2H^+$ + $2e^-$ --> H_2 $2H_2O$ + $2e^-$ --> H_2 +2OH

Shown for acidic and alkaline environments. This work involves the alkaline reactionPathway.To understand the principles of electrolysis, perhaps the most basic experiments is the use of two pencils sharpened at both ends with the top being connected to a battery and the bottoms inserted into alkaline water. Figure 6 illustratesthe concept showing many bubbles appearing at the negative pencil and half that many appearing at the positive. The reactions are:

Positive: $2OH^-$ --> ½O_2 + H_2O + $2e^-$

Negative: $2H_2O$ + $2e^-$ --> H_2 +2OHThis is the same principle of even the most sophisticated water electrolysis machines with the difference being in efficiency and production rate.

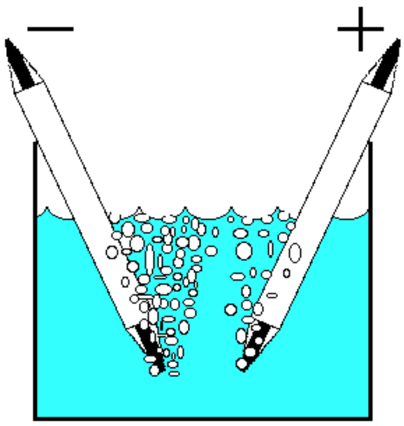

Figure 7. Pencils used to illustrate the principle of electrolysis.

Advantages:

1) It can avoid water pollution by waste water electrolysis.

2) It does not create any type of pollution.

3) Uses solar energy for electricity production.

Disadvantages:

1) Maintenance cost is high.

2) If malfunctioning of relays takes place, then it can be very dangerous.

Applications:

1) In urban areas where electricity consumption is more, solar tree can be used in place of street lights which will save around 80% of the total electricity consumption.

2) Generation of hydrogen which can be used as a fuel for various industrial processes.

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IV. CONCLUSION

The artificial tree, if maintained properly is very useful in energy conservation. Electricity production using fossil fuels like coal causes pollution to a great extent. An artificial tree is not designed to replace the natural tree, rather it can never do that, but if an artificial tree is used in place of a natural tree, it can function as street light, saving around 80% of total electricity consumption required for the same purpose. It can also display flash messages sent from control room in real time i.e. without any delay.

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