IOT Based Wireless Smart Shoe and Energy Harvesting System

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Abstract*: *In today's generation many technological developments have been taking place for tracing the amount of energy generated from the surroundings. The energy production occurs through various ways (via thermal methods, mechanical vibrations and many more). These energies produced can be helpful in various ways (such as charging devices, electronic gadgets). In addition to this, features such as measurement of distance covered and the calories burnt based on the energy generated can be implemented. Hence people would have a generalized idea of their fitness levels. The main aim of the proposed prototype in this paper is to produce energy and at the same time give some additional information of the user's fitness through a mobile application. The energy harvesting is being done using piezoelectric sensors along with an IoT based pedometer app which will take the step counts in cloud as input and will display distance covered and calories burnt. The product developed is cost efficient and has widespread real time applications.

Index Terms*: *Mobile device, Pedometer, Piezoelectric sensor, Internet of Thing, Cloud, Real time application, Smart Shoe, Smart energy harvesting.

I. INTRODUCTION

Wearable sensors have become smaller and progressively widely used, leading to associate degree increasing want for freelance and compact power provision**.** In today's world there is a rising demand of renewable energy resources due to the exponential depletion of conventional sources of energy. Electrochemical batteries which were one of the most important sources for storing energy have failed to keep up with the rising demands. Due to their manufacturing process and chemical composition affecting the environmental surroundings the need of alternative sources of energy has increased drastically. Hence smart energy harvesters have been a preferred solution. These energy harvesters follow a simple principle. They harvest the energy that is produced by the human beings and converts them to renewable and productive energy [1]. There are many kinds of energy harvesters that have been made so far. These include electromagnetic [2], electrostatic [3], thermoelectric [4], nano-triboelectric [5] and piezoelectric [6] methods of energy harvesting. On comparison, the piezoelectric structures are found to be simpler, basic and more compact than other types of energy harvesters. This paper explains in detail about a smart shoe which follows this principle of harvesting energy. The shoe can also be worn by humans in their own comfort. The harvester is predicated on a specially designed sandwich structure, resulting in a thin geometrical form, high performance and excellent durability. The prototype comprises of layers of insole and plastics. Inside the layer the piezo sensors are kept to produce the energy from the humans' steps. This paper, also discusses an application based on pedometer implementation which will take data as step count and show the distance covered as well as calories burnt by the user.

Contribution of the Authors: Identified the current health problems that can be minimized through smart technology. Proposed a smart shoe model by using Internet of Things. Implemented the smart shoe system using NODE MCU ESP8266. The paper is organized as follows: This section gives the introduction about the limited energy storage in today's world and the need to produce energy. Also different methodologies of producing energy are referred in the section. Section 2 briefs on the work done so far in producing energy through different methods and ideologies. Section 3 describes the basic traditional smart shoe that has been developed so far which currently is in use in today's world. Section 4 proposes a better model of the previous traditional one by implementing additional features in the system such as fitness tracker along with it the charging of any electronic gadget (mobile phone is taken as reference). Section 5 shows the results that are found. The results that are obtained from the proposed system gives rise to the conclusion on how it is better than the traditional one which is currently in use.

II. RELATED WORKS

Zhao [8] explains in their paper on how mechanical energy is being harvested from human motion for electrical energy to charge up wearable devices. This research paper talks about how a smart shoe made up of piezoelectric sensors can be used for producing energy from human activities. People would find it comfortable while wearing the shoe. The two layers of the insole are sandwiched with each other in a thin symmetric form layer and have better efficiency. The structure comprises of the form of a sandwich with very minimal thickness making it fit comfortably in the shoe. When the person wears the shoes and takes steps, the insole layer makes the negatively charged particles (electrons)

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to move with an AC output. Zhao and You have also researched on two types of harvester which are also described in this paper. The first prototype consists of polyvinylidene fluoride layer in multi parts and it is placed in the heel of the insole. The second prototype is also made up of insole layer which consists of a rubber made up of silicon material and polyvinylidene fluoride films. On comparison of both the prototypes, we find out that more power can be produced from the first one than the second, whereas the second model has an advantage of comfort ability. Many tests have been performed to check out the working of these prototypes.

Nagraj [9] discuss about their research on how a wearable system can be varied based on today's trending technologies. The footwear-based system discussed in the paper has variety of uses. It can vary from simple basic uses to highly technical uses for different kinds of people (differently abled). An insole developed for gait monitoring is described in this paper. There are various types of gait monitoring techniques. One is temporal and the other is spatial. In this field a lot of footwear – based systems are used. Force sensitive resistors which are one of those sensitive and delicate elements are used in the system to find out the parameters such as cadence, step time and other parameters. Another application includes measuring of pressure map at one phase. The support is provided by the ankle and the foot. It plays a vital role in analysis of patients who are having diabetes. It is also used in identifying the problems associated in neurological, muscular and skeletal parts of the body.

Heung [10] explains how energy can be harvested from the vibrations of piezoelectric materials efficiently. Piezoelectric materials can be categorized into piezo ceramics and piezo polymers. The former comprises of electro based couplings. The energy is converted in a nominal rate to provide better performance and efficiency. The latter however has smaller couplings on comparison to the former. These also have flexibility property which becomes very useful for many purposes. There is also another energy harvesting system having a structure of cantilever type providing vibrational energy harvesting and can produce a large deformation under vibration. The structure that is made of cymbal shaped material produces an external force which becomes vital for the energy harvesting system. A large amount of electricity is produced from the transducers. The reason behind this large production of electricity is due to the d33 principle and of its capacitance. The performance of the energy harvesting system improves through the above mechanisms.

Henry [11] describes about the production of electric charge output using piezoelectric sensor**.** The electrical and the mechanical energy can be exchanged by using piezo materials which is what was implemented in this paper. Many devices are powered through the transferring of motions from one form of energy to other form. In this case the electrical energy is being produced for powering various electrical devices. There are many systems that have been manufactured which do not rely on conventional sources of power due to the principle of renewable methods of energy harvesting. Various kinds of properties are being induced such as mechanical energy (obtained though vibrations from workplaces) being absorbed from the environment. These properties also play a vital role in powering up devices. By applying mechanical vibrations for acquiring energy to displace the electromagnetic based coil could be one such method.

Thomas [12] explains about their research on their app which is called the Energy-efficient Real-time Smartphone Pedometer (ERSP)**.** This app reads the count values of the humans via accelerometer. It is an android made app. The motion of the walking of the human can be detected by the app comprising of various features such as accelerometer and GSM modules. It has three types of switching process. These include the time, distance and count switching process. The user can shift to any switching process depending on his/her comfort. Each of these modes concentrate on their particular parameter (measured time, distance measured and recorded count.)**.** This system is to be worn on the waist by the user. Other parts where it can be attached on the body include the user's palm.

III. TRADITIONAL ENERGY HARVESTED SHOES

The traditional smart shoes are based on polymer energy harvester in which harnessing kinetic energy from human motion and converting it into usable electrical energy as is the basic approach to powering electronic devices. The energy harvesters will be connected to the sole the footwear ready to track various parameters like movement of the user, speed and recording temperature. The energy harvesting system has been developed based on emergent electroactive polymers, which is small enough to be embedded in the sole of a shoe [6]. The mechanical-to-electrical device is predicated on skinny films of polymers of huge relative permittivity. As compared with traditional piezoelectric concepts, such a device is able to generate energy only in microwatts when subjected to mechanical deformation of pressure and frequency range specific to human walking, explained by Yiming Liu[7]. Contrastingly, this paper has a prototype which will be able to generate power in watts. The generated energy can be stored and used to power up electronic devices such as mobile phones, additionally this paper also depicts a mobile application based on pedometer implementation where data in the form of step count is being taken, from this the distance covered as well as calorie burnt by user will be calculated based on user data, this implementation has wide range of applications in daily life such as it can be used by a sports-person.

IV. PROPOSED IOT BASED PEDOMETER TRACKING SYSTEM

The proposed IoT based system will operate in two real-time applications.

- Smart Shoe
- Mobile Charging system

4.1 Smart Shoe

The limitations specified in the traditional setup are addressed in the proposed system for keeping track of data. The setup counts the number of steps, calculates the calories burnt and distance travelled based on the user details. This processed data is stored in an online database and displayed to the user through a website and mobile application.

The mobile application would suggest the user certain exercise schedules based on the logged walking patterns in the database.

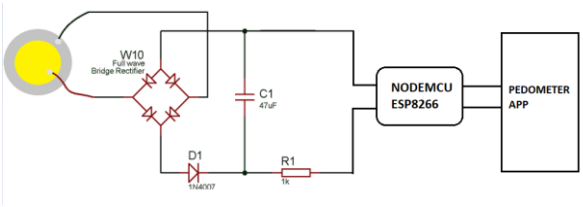

Fig.1 IoT based Smart Footwear system

The following hardware components are involved in the proposed IoT based smart footwear.

- Piezoelectric sensors
- Diodes
- NodeMCU

Piezoelectric sensors

Such sensors are available in various dimensions and the power generated mainly depends on the acoustic impedance. The sensor's size does not directly affect the response in terms of energy and amplitude. Sensitivity at higher frequencies would be less in the case of sensors with large crystal. Similarly sensors with small crystals will be less sensitive to lower frequencies. These sensors mainly convert mechanical energy to electrical energy. It is evident from the block diagram in Fig.1 that the piezoelectric transducers power the whole circuit. The electrical energy obtained is in alternating form. The equations for energy generated were studied [12].

Diodes

A diode is an electrical device that allows current to pass easily in one direction compared to the opposite direction. Of all the different types of diodes the semiconductor based ones are most commonly used. The voltage generated from the piezoelectric sensors was converted from alternating to direct by incorporating a full bridge rectifier made out of diodes. The diodes used were IN4007. Another diode is added further in the circuit to prevent the possibility of back flow of current safeguarding the piezoelectric sensor from overvoltage and other possibilities of damage.

NodeMCU

The ESP8266 WiFi Module follows TCP/IP protocol giving any microcontroller access to a WiFi network. It is produced by Shanghai-based Chinese manufacturer, Espresso. This microcontroller is pre-programmed with an AT command set firmware which helps give any Arduino device WiFi-ability as much as a WiFi Shield offers. Selection of this board was due to its cost effectiveness and ever growing community of developers. The board is powered by batteries for it to function. It has many GPIO pins with minimal development up-front. The ESP8266 supports APSD for VoIP applications and Bluetooth co-existence interfaces; it contains a self-calibrated RF allowing it to work under all operating conditions, and requires no external RF parts. The incoming power to the ESP8266 WiFi Module is in digital form. A program is coded onto the board for functions such as WiFi connection, step counting, and updating step count of user in the database. Step calibration is a very important aspect of counting steps. The database used works on PHP and MySQL. The steps registered in the database are presented in the form of a dashboard hosted on a website using HTML 5. Event-driven APIs are implemented for network applications. Similar implementation is done on Android mobile platform. Thus this data is logged into the users account and can be accessed easily through many platforms.

1.2 Mobile Charging System

The following hardware components are involved in the proposed mobile charging system.

- Piezoelectric sensors
- Diodes
- Capacitor bank
- Voltage Regulator
- USB Data Cable

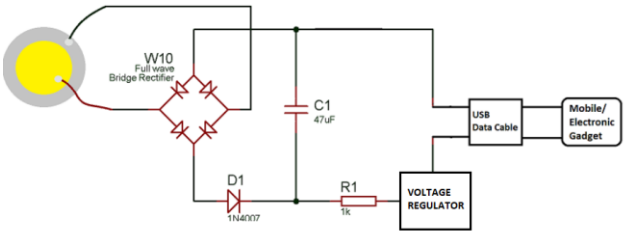

Fig.2 Mobile Charging System

Capacitor bank

A capacitor is passive device which stores energy in electrical form. A group of capacitors connected in parallel can hold a lot of charge in order to form a capacitor bank. A capacitor bank C1 as shown in Fig.2 is used to store the incoming energy. This capacitor is connected in parallel and swallows any high-speed glitches sent to the microcontroller. It also reduces AC ripples making the power as purely DC. The power can be used for charging the mobile phone.

Voltage Regulator

A voltage regulator is an electrical device that maintains a constant voltage level automatically. According to standard output from chargers, mobile phones require a DC supply of 5V to charge. This could be achieved using a voltage regulator. The voltage regulator used is IC7805 which gives a +5V regulated power supply.

USB Data Cable

USB which stands for Universal Serial Bus is a standard type of connection for different kinds of devices. It is mainly used by mobile phones for charging purposes. With four signal wires that are VBUS, D+, D-, GND the connections are made accordingly as shown in Fig.2. The proposed charging circuitry uses a Type B USB data cable.

V. RESULTS AND DISCUSSION

The proposed system is made of piezoelectric transducers, full bridge rectifier made out of diodes, capacitor bank and voltage regulator for stable charging. This setup is connected to the ESP8266 WiFi module for IoT applications. The system is implemented in the following way:

5.1 Smart Shoe

The piezoelectric sensors are layered over a foam based shoe sole. This setup can be fit into any shoe easily. As depicted in Fig.3 the piezoelectric sensors are connected in parallel in order to store more charge. Connection with a multimeter has shown that each sensor generates a voltage between 1V and 2V. This range of output voltage from the piezoelectric sensor counts as a step taken by the user which is in turn fed into the database. Hence the parallel connection spread all over the sole increases the accuracy of the steps measured.

Fig.3 Piezoelectric sensors connected in parallel

In order to improve tracking of step count a threshold value for input power is set in the program. When the user is standing but not walking the force exerted on the piezoelectric sensor will the lesser than the threshold set in the program. This minimizes false steps from being registered into the database. Periodically the ESP8266 chip updates the step count in the database once certain amount of steps have been detected by the microcontroller. This optimizes the processing of the microcontroller such that most of its energy is not consumed in updating steps with a minimal delay.

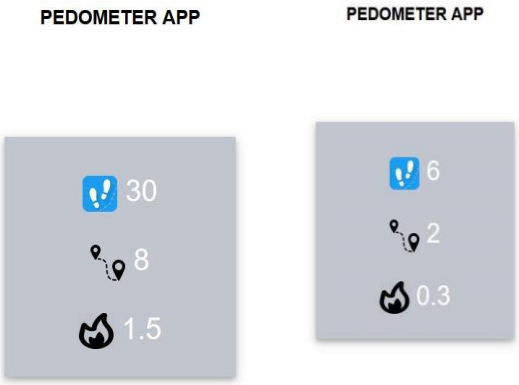

Fig.4 Software implementation as a website and Android Application

The dashboard depicted in Fig.4 consists of step count, calories burnt and distance travelled. This data is calculated based on user data. The user data used is gender, height, weight, body mass index (BMI). If the user does not enter any data, calculations are done based on default data. The average foot length of a person is 273cm. It can be noted that on an average 20 steps burn 1 calorie. Hence based on the steps counted the distance and calorie calculations are implemented. The output voltage from the full bridge rectifier is in digital form. This voltage varies a lot and which is not suitable for charging purposes. Hence a voltage regulator is used as shown in Fig.2. It observed that the output voltage from the voltage regulator is a constant +5V. The connections of the voltage regulator are shown in the charging circuitry. These readings are suitable for charging most of the mobile phones.

VI. CONCLUSION

A new prototype is made for measuring the step counts, distance covered and the calories burnt by the person via the pedometer app. This would help in large scale to a sport person as well as the coach staff members to analyze the fitness levels of the players during the progress of the match .Also via the smart shoe a normal person can see his health parameters via the pedometer app. Future work into this system could include designing of the smart shoe in an efficient manner so that the circuit can be placed inside the shoe in such a way that the person won't find it difficult while wearing the shoe and he feels comfortable and spacious**.** Also it could be made more cost efficient by using recyclable materials for manufacturing the shoe.

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