Pedestrian Detection & Locomotion Tracking using Piezoelectricity & MATLAB

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Abstract— This paper showcases use of the principle of piezoelectricity to harvest energy through pedestrians' footsteps and collect data about pedestrians like locomotion pattern and tracking. The configuration of piezoelectric material underneath a plywood panel allows it to be interconnected to cover an area of any given size and shape. These interconnected panels help visualize the area as an array of panels and view information about presence of a pedestrian, locomotion pattern and pattern prediction, as well as to control the state of a variable. This pedestrian locomotion pattern data can be used for making decisions about designing a floor layout at railway stations, airports, similar public places, and for product placements in shops, malls and supermarkets. The energy generated can be used to power up streetlights, public Wi-Fis and helps in contributing towards generating more renewable energy, as non-renewable energy resources are plummeting and it may not be possible to harness solar or hydro power at all times.

Key words: Renewable Energy, Piezoelectricity, Pedestrian Data Analytics, MATLAB

I. INTRODUCTION

Conventional energy harvesting methods cause an appalling damage to the atmosphere and environment, resulting in global warming and depletion of the fossil fuels. They're inefficient and will disappear in forty years. While there have been some serious attempts for renewable energy, there's nothing which works best for India mainly due to lack of ancillary services (solar power), land and social/environmental challenges (hydropower), or supply constraints (natural gas). [1] Even with 20 percent more sunlight than Germany and lower Labour costs, the cost per kilowatt hour remains approximately four times higher than average household electricity tariff. Furthermore, the huge energy demands of India's population widens the supply demand gap. India needs to solve both the energy and capacity problem. [2] The global renewable energy consumption level has risen and this trend will continue for next two to three decades, as fossil fuels continue decreasing in volume. Alongside solar and hydro power, vibration energy can be exploited to meet the nation's energy needs. To tap the vibrational energy, the principle of piezoelectricity has been used in this project. Piezoelectric effect is electrical voltage induced in the crystalline materials subjected to an external mechanical stress on the material. Piezoelectric effect is exhibited by natural crystals such as quartz, Rochelle salt, lead titanate, and synthetic crystals like langasite ($La_3Ga_5SiO_{14}$). Synthetic ceramics are also fabricated to exhibit piezoelectricity like barium titanate ($BaTiO_3$), Lead zirconate titanate ($Pb[Zr_xTi_{1-x}]O_3$ with $0 \leq x \leq 1$)—more commonly known as PZT.

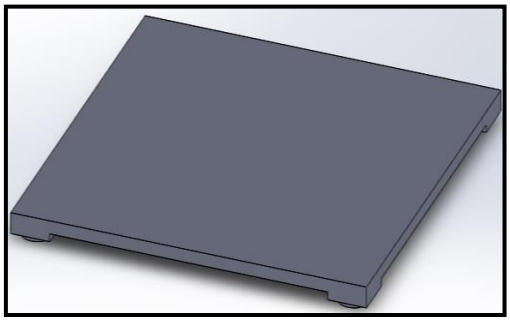

Fig. 1. Design of the Piezoelectric Tiles, with Five Piezo Electric Discs Underneath

II. EXPERIMENT

The project showcases the proof of the proposed concept of uses piezoelectricity for the objective of harvesting energy as well as collecting data about the pressures experienced and concurring meaningful information of pedestrians' or consumers' locomotion patterns, which can be used for decision making on altering layouts and designs of stores.

The piezo electric element is placed on tiles, which are placed on the ground over which pedestrians will walk. These tiles are interfaced with microcontrollers and a PC to charge the battery as well as collect and store locomotion information. The information collected over a period of time is then analysed through our algorithms to process this data into meaningful conclusions.

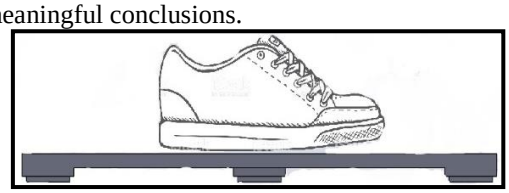

Fig. 2: Side View of the Piezoelectric Tiles used for the Experiment

A. *Hardware Components*

- Piezoelectric discs
- 6-millimetre-thick plywood
- Microcontroller (AVR ATmega328)
- Battery
- DC-DC Converter
- Inverter
- USB to interface Arduino with Laptop

B. *Software*

- Arduino IDE
- MATLAB
- Arduino Support Package for MATLAB

C. *Piezoelectric Discs*

Piezoelectric effect can be mathematically defined as

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$$E = d_{33} * \sigma \quad (1)$$

Where,

- E is the electric displacement (Coulomb/meter^2)
- d_{33} is the piezoelectric coefficient (Coulomb/Newton)
- σ is the stress applied (Newton/meter^2).

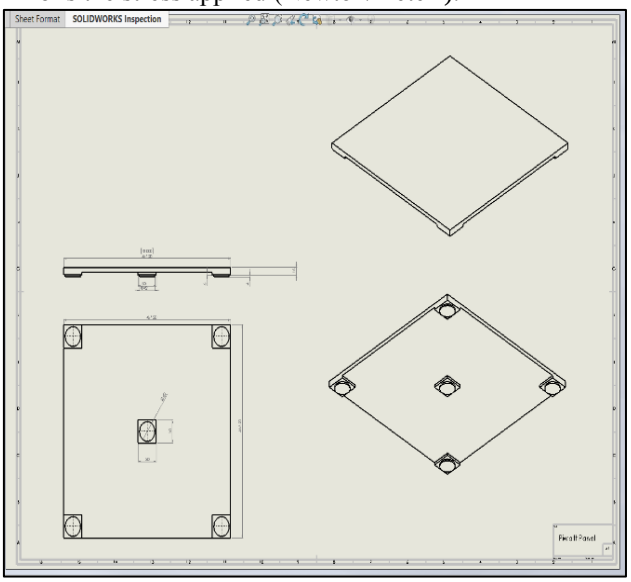

Fig. 3: CAD Drawing for the Tiles (Piwatt Panels)

The performance of any piezoelectric crystal, other than the applied mechanical stress, is a function its shape, size. The physical properties of a material determine the value of the piezoelectric coefficient. Lead Zirconate Titanate (PZT) crystals are widely used as they offer high piezoelectric effect. Also, they are easy to fabricate into complex shapes, resistant to humidity and high temperature, and have high material strength. Thus, PZT can generate more energy with thinner material compared to other natural and synthetic crystals.

The piezoelectric crystal available in the form of piezo sensors and transducer discs was used for the experiment. First, a single disc was used to test and evaluate the essential readings of a generic piezo – sensor. The piezoelectric sensors used for the experiment purpose were 27-millimetre diameter discs. When a single piezoelectric sensor was tested for its voltage and current outputs for the stress generated by footstep of a person with a weight of 50 kg, we get an average voltage of 65 V, and a current in the order of few microamperes. Thus, the current was found to be insufficient and needed to be increased. This was done by using more than one crystal to react to the applied stress caused by a footstep. Connecting the piezo sensors in parallel to each other increases the current to a sufficient amount which solves this problem.

Five piezoelectric discs were attached on a single panel as shown in Figure 3. The total power generated by them is approximately the same amount regardless of where the foot is placed, but each sensor produces a different amount of power individually which can help in estimating the position of the foot, which can be further be used for analysing the locomotion data and finding patterns for future planning.

1) *Plywood*

The plywood forms the main body of the tile in which the piezo materials are housed. A 6-millimetre plywood has enough strength to withstand the weight of a human body. The strength of a thinner plywood or other material cannot be commented upon without looking at its datasheet. A thicker plywood must work as above.

2) *Microcontroller (AVR ATmega328)*

ATmega328 is an 8-bit microcontroller with modified Harvard architecture and RISC processor core. It has 23 general purpose input-output pins and 6 channels 10-bit analog to digital converter sufficient to interface six piezo tiles.

3) *Battery*

Energy generated from the piezo tiles is stored here.

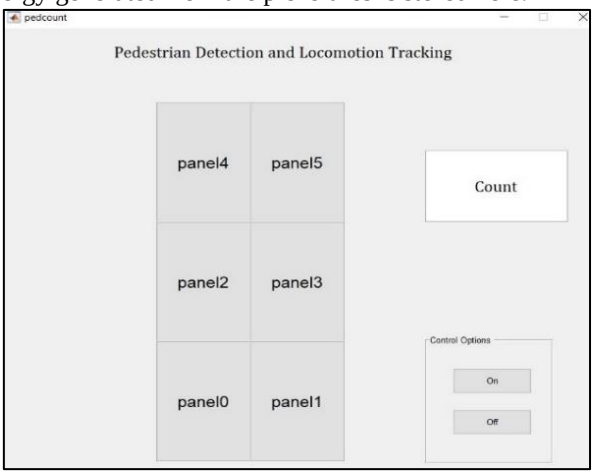

Fig. 4: MATLAB GUI Application

4) *DC-DC Converter*

The DC-DC converter is used to step down the voltage and step up the current to a few milliamperes. It helps maximize the energy harvest for the piezoelectric tiles.

5) *Inverter*

Inverter converts 12V DC supply to single phase 230V AC supply. This component is optional, depending upon the load attached.

6) *USB Cable to Interface Arduino with Laptop*

The ATmega328 is used to interface with the piezo tiles. The microcontroller sits on the Arduino Uno. The Arduino is connected to a PC through the USB. The Arduino acts as a slave while the PC as a master. Voltage information is fed serially to the PC through Arduino. USB cable is used to establish this serial communication between the two devices.

III. MATLAB CODE & GUI APPLICATION

MATLAB was used for the project as it's easier to manipulate and operate with data. This requires Arduino Support Package for MATLAB, a support package which updates Arduino's firmware to enable running MATLAB code (.m extension files) instead of conventional .ino files. MATLAB also enable to visualise the data with heat maps for the layout and plot graphs for the tiles. MATLAB GUI (Graphical User Interface) application was developed to access and data collected, control the program and observe the heat maps and individual tile graphs on single window.

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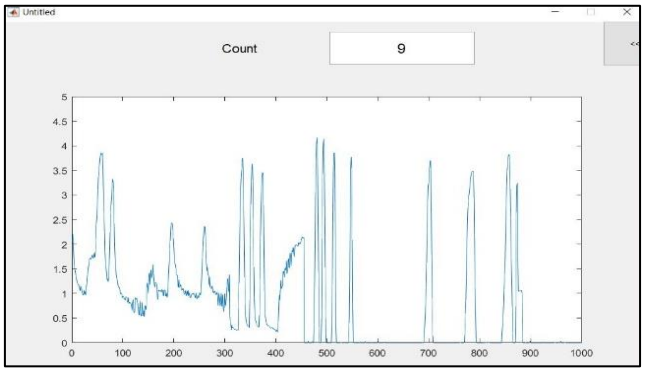

Fig. 5: Visualisation of Time vs Pedestrian Step for a Panel

The code used for this project can be accessed at the author's GitHub repository (https://github.com/jash101/Pedestrian-Detection-Locomotion-Tracking).

The GUI application offers an intuitive interface to access the information. As shown in fig. 4, the panels are presented according to the layout of the tiles in the real environment which gives a virtual map of the environment. The on and off button in the control area are used to initiate or terminate the program. Count text box is where the count of pedestrians walking is displayed. Panels change colour from blue to red depending on how much a panel is walked on, with blue being the lowest used and red being most used panel.

Double clicking on a panel opens up a Time vs. Weight graph to see an approximate analysis of weight of pedestrians walking over the time. It can also be used to estimate the time interval between any two pedestrians walking on a given panel.

IV. DATA COLLECTION

The Arduino Uno board sends voltage readings of the piezo tiles at a baud rate of 9600 or 960 bytes per second. All the voltage measurements for six tiles is collected continuously and stored in a comma separated value (CSV) file. This CSV file can then be accessed to draw plots and to analyse patterns and draw heat maps for the layout.

The six CSV files are auto generated through the MATLAB code and gets rewritten and saved automatically till the program runs.

V. PEDESTRIAN COUNT ESTIMATION ALGORITHM

Accurately estimating the number of pedestrians walking in a given area can be a challenging task. An accurate and tested method has been proposed. In the experiment shown, six panels have been used. A panel covers an area of 1 sq. ft. It is assumed only one person can stand or step on a panel at any given instant, which is a reasonable assumption. There are two panels to cover the frontage of the passage and three panels for depth. Hence two people can walk at any given time. Hence an area can be virtualised into an array of these tiles. The pedestrian count then becomes the average of the sum of each row of this array.

$$count = average\ [\ (p0+p1)\ ,\ (p2+p3)\ ,\ (p4 + p5)\ ]\ldots. \quad (2)$$

where pi = Panel number i and i = 0,1,2,3,4,5,6

VI. CONCLUSION

This paper discusses feasibility of using piezoelectricity for energy harvesting and simultaneously collect data through footsteps of pedestrians.

Piezoelectricity can be used where there is a high density of pedestrians. Piezoelectric tiles can be planned to be applied at places like railway and metro stations, malls, airports or any such public place. Piezoelectricity generated from these places can be used to power lighting and public Wi-Fi, hence making it more sustainable. The data analytics can play a huge role in shop and public place layout optimisation by observing locomotion patterns and investigating highly dense and low dense areas and try to spread out locomotion or to design entry and exit points. Consumer's locomotion techniques can be studied and most popular area of a supermarket can be found, which can be used to place certain products to guarantee it more customer attraction.

Further, logistic regression techniques can be employed on a selected dataset of the panel voltages for learning the locomotion pattern and then use it to predict where a person is likely to go. This can further help in managing crowd at public areas.

Apart from using it for outdoor applications, these piezo panels can also be used for domestic purpose where panels can be used to detect the presence of number of humans in a room to automatically and efficiently control the lights and temperature of air conditioner of the room.

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