Harvesting Kinetic Energy using Piezoelectric Device Embedded in Garden Stepping Stones

Nurzuliza binti Jamirsah[1], Md Marzukee bin Yusof[2], Azilah binti Anuar[3]
Email: munirah.mihat@polinilai.edu.my

Abstract

Evidently, carbon emissions are embedded in all types of process especially in construction and maintenance processes. Especially in Politeknik Nilai, Malaysia, a course for Diploma Landscape Horticulture requires students to construct a garden. Gardens can be as one of much carbon storage mediums. However, the process of constructing a garden involves high carbon emission. Hence this research objective is to produce green garden furniture functioning as power supply to power utilities in the garden. This research proposes stepping stones embedded with piezoelectric devices to harvest kinetic energy from footsteps. Walking is the essential activity frequently encountered in gardens. There are four walking types namely a) leisure walk; b) brisk walk; c) running; and d) jumping. Based on observation in a small green space, usually users spent time from 45 to 60 minutes per visits depending on the visitation purpose. This research investigated the 60 minutes time period for each visitation. Kinetic energy from users' footsteps was collected using piezoelectric devices embedded in the stepping stones. These piezoelectric devices are used to convert vibration on surface (footsteps on stepping stones) to electricity in Volts. The energy harvested will be used to power the utilities in the garden such as lightings during night time. This research conducted experiments to measure how many piezoelectric devices needed enough to generate electricity powering garden utilities. This experiment involved the usage of multimeter to measure the electricity generated from each of the piezoelectric devices. The relationship between kinetic energy (steps from human) and electricity (powering garden utilities) were analyzed.

Keywords: Green Energy, Kinetic Energy, Piezoelectricity.

1. Introduction

Large scale carbon footprints were produced during the processes of garden provision. In other perspective, gardens were visited by users almost daily regardless public holidays, festive holidays, weekend or weekdays (Rasidi, Jamirsah, Said, 2013). Such visitation causes huge amount of carbon footprints derived from human activities. According to Rufty, Ress and Hamon, (2010), Earth's climate is warming due to human (anthropogenic) activities. In micro context, human activities in a garden contribute partly to the carbon emission. This research is attempting to provide micro scale solution to offset the energy usage in a garden with the piezoelectricity concept. Currently, the issues and trend of harvesting

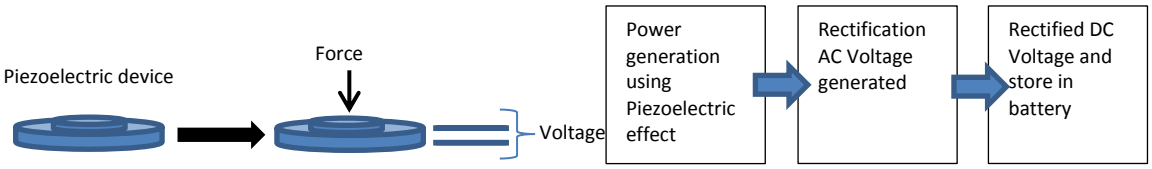
renewable energy is kinetic energy is considered as the low power consumption features. This kinetic energy can be used to generate electricity to power a variety of portable devices, such as power banks, rechargeable batteries, and etc. The concept of energy harvesting from environmental sources and human body has gained a new relevance. In the search of methods and materials that suit this need, are the energy generated from the piezoelectricity, thermoelectricity and electromagnetism, among others.

2. Problem statement

The problem statement of this research is to avoid raw material wastage by creating a single use structure but instead producing a multipurpose structure. Currently, landscape structures and other landscape elements on a park were proposed to be used as single function. However, the existences of raw material nowadays are expensive and hard to find. Thus, to avoid waste of material for single use, a structure must be multipurpose in function. For example, creating a bench as an energy storage medium and stepping stones as kinetic energy harvester. The goal of this research is to propose an alternative medium for energy harvesting embedded in the landscape elements. The objectives of this research are i) to identify the garden utilities commonly used; ii) to estimate amount of electricity needed to power utilities for 25m2 garden; and iii) to calculate the number of piezoelectric devices needed to generate enough electricity to power garden utilities. A landscape architect does not just design a park without thinking and overseeing green technology design embedded in the design. Therefore, landscape design with green technology insertion in the structure design can help reduce cost of maintenance at the later stage. The outcome of this research is proposing a stepping stones embedded with piezoelectric devices that harvest kinetic energy from human footsteps. Kinetic energy electric power generators have emerged as a promising alternative green technology due to their distinct advantages. This alternative green technology converts vibration and stomping of feet motion into mechanical stress energy directly into electrical power. This method can also improve the overall efficiencies of energy conversion system. The waste energy in the forms of footsteps kinetic energy has many potentials to be developed.

2.1 Concept of piezoelectric

Piezoelectric devices convert mechanical energy into electrical energy. This is why they are referred to as "generators". The principle of piezoelectricity lies behind the crystalline material. As shown in Figure 2.1, electrical voltage is induced when crystalline materials on top of piezoelectric devices are subjected to external force, pressure, or strain. More energy is produced with increase in mass or force (Kour and Charif, 2016).



*Source: Guo and Lu (2017).
Figure 2.1: Piezoelectric concept

*Source: Guo and Lu (2017).
Figure 2.2: Piezoelectric diagram for AC to DC Voltage conversion.

Piezoelectric stepping stone innovation is a new green energy evolution in landscape architecture field. By having a fossil-less electricity generator, i.e. piezoelectric stepping stone, a self-sustained garden can be achieved. A sustainable solution in terms of environment, economy, and social needs. Figure 2.2 illustrates piezoelectricity underwent certain processes before it had been converted to energy output. AC voltage is generated as pressure or force is exerted on piezoelectric device. The generated voltage is then adjusted and converted into DC voltage and stored in battery, power bank or capacitors for electric application purposes. For this research the electric application is tested to charge a smartphones and LED lightings.

3. Research Methodology

3.1 Study Sites

The study site chosen (refer figure 3.1) is a 25m2 garden. Gardens were designed with landscape elements such as shelter, seating, stepping stones (pavement), entrance structure, planting, and lawn.

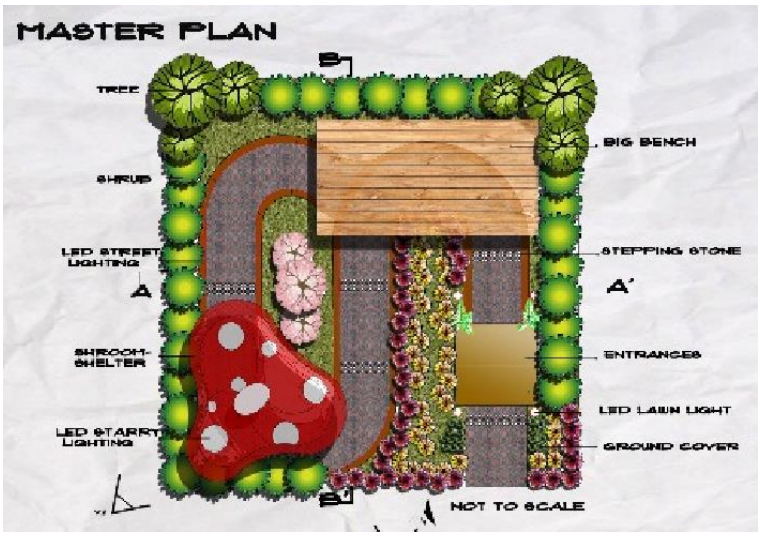


Figure 3.1: Garden Simulation is design with common landscape elements.

4. Results and Discussion

Based on discrete observations in parks, users come to parks often. Each visitation usually last up to an hour to 2 hours depending on what occasion of the visitation. Thus, such visitation causes the park to receive a lot of wasted kinetic energy derived from footsteps. There are four types of steps that can be observed frequently in a park which are a) leisure walk; b) brisk walk; c) running; and d) jumping. Figure 4.1 shows the readings of voltage for different types of steps applied onto a stepping stone embedded with 5 numbers of piezoelectric devices.

Table 4.1: Estimated voltage generated from piezoelectric device in the garden simulation.

	Steps count occurrence in garden according to diff. step types	Voltage generated from piezo on stepping stone surface, kV
Leisure Walk	6588	1647
Brisk Walk	8865	2216.25
Running	4356	1089
Jumping	2727	681.75
Total		**5634**

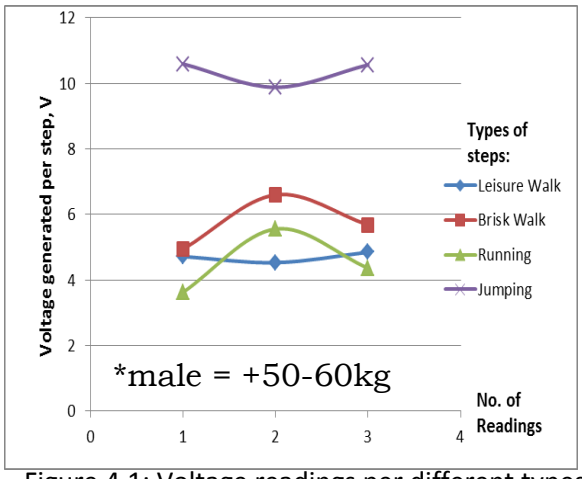


Figure 4.1: Voltage readings per different types of steps.

* no. of piezoelectric devices embedded in stepping stones + 2500 nos.

Table 4.2: Amount of leftover voltage potentially stored.

Amount of Voltage per daily usage, MV	Voltage generated from piezo on stepping stone surface, MV	Amount of leftover voltage generated after subtraction of voltage usage, MV
0.018	5.63	5.62

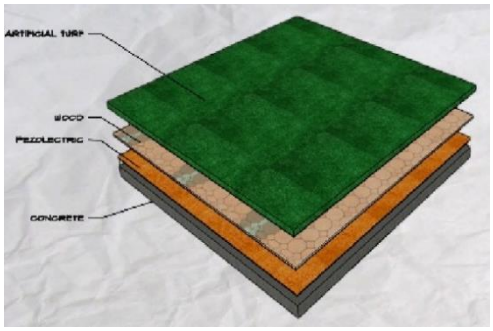


Figure 4.2: Piezoelectric Stepping stone Prototype

Based on table 4.2, the amount of total voltage usage in the simulation garden is 0.018 MV. Estimated electricity generated from the total + 2500 numbers of piezoelectric devices was 5.63 MV. After subtraction of volts generated and volts used in the 25m2 garden, a total of 5.62MV power potentially harvested and stored in rechargeable battery. Providing the number of volts used is only 0.018 and additional 5.62 MV can be used and channeled to our appliances. The 5.62 MV is equivalent to power another 300 numbers of 25m2 gardens (provided that the other gardens use the similar garden utilities in this research).

Conclusion

These stepping stones design and technology can be used by local authorities and municipalities in urban areas to generate electric energy for public green space illumination, outdoor advertising, traffic lights, or electrical supply.

References

Fernandez-Raga, M., Fraile, R., Keizer, J. J., et.al., (2010). The Kinetic Energy of Rain Measured with an Optical Disdrometer: An Application to Splash Erosion. Journal of Atmospheric Research. Science Direct.

Guo, L. and Lu, Q., (2017). Potentials of piezoelectric and thermoelectric technologies for harvesting energy from pavements. Journal of Renewable and Sustainable Energy Reviews. Research Gate. DOI: 10.106/j.resr.2017.01.090

Jose V, T., Boban, B., and Sijo, M.T., (2013). Electricity generation from footsteps; A regenerative energy resource. International Journal of Scientific and Research Publications, Vol.3, Issue 3. ISSN 2250-3153.

Kour, R., and Charif, A., 2016. Piezoelectric Roads: Energy Harvesting Method Using Piezoelectric Technology. Innovative Energy & Research Vol (5). Coventry University, UK. ISSN:2576-1463.

Mallick, R.B., Bhowmick, S., (2009). Harvesting energy from asphalt pavement reducing the heat island effect. International Journal of Sustainable Engineering. Research Gate. DOI: 10.1080/19397030903121950.

Rasidi, M.H., Jamirsah, N., and Said, I., (2013). Development of Urban Green Space Affects Neighborhood Community Social Interaction. Published by Centre for Environment-Behaviour Studies (cE-Bs), Faculty of Architecture, Planning & Surveying, Universiti Teknologi MARA, Malaysia. AJEBs Vol 4 No. 14 (final).indd 107.

Rufty, T., Rees, R., & Hamon, N. (2010). Carbon Footprints of Urban Landscapes. Verywellfit, (2017).Medicine and Science in Sports and Exercise. "Pedometer-Measured Physical Activity and Health Behaviors in United States Adults.".

Zhao, H., Yu, J., Ling, J., (2010). Finite element analysis of Cymbal piezoelectric transducers for harvesting energy from asphalt pavement. Journal of the Ceramic Society of Japan. J.Stage. ISSN: 1348-6535.