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Original Research

Internet of Things Based Smart Shoe Fitness Tracker Prototype

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ABSTRACT

In the modern era wearable smart technologies are highly popular and liked by the people of this generation. Smart shoe being one of the smart technologies, hypermarkets like Nike, Puma, Adidas, Xiaomi, keep launching various types of smart shoes for different purposes. Fitness being a mandatory factor in an individual's lifestyle, people's attention is drawn towards smart technologies meant to improve their fitness and monitor their workout routine on an everyday basis. However, there are few noticeable limitations that hinders people to not own a pair for themselves. In this paper, Internet of Things based smart shoe fitness tracker prototype has been developed considering the factors of cost, efficiency and sustainable energy. The prototype mimics the purpose of smart shoe fitness tracker where the fitness variable and health parameters are measured according to the user's motion. The smart shoe mobile application facilitates as the user interface to monitor their day-to-day vitals and activity at real time using Internet of things. Integrating the concept of sustainable energy and energy harvesting from alternative energy resources using piezoelectric sensors to activate the tracker during fitness performance. As a result, this study has developed a smart shoe prototype that compensates the limitations of the existing smart shoes and motivates people to take up fitness as a part of everyday lifestyle and progressing towards a better future.

INTRODUCTION

Fitness has become a life changing activity in human lifestyle, decreasing potential health risks and keeping us in shape. Implementing smart technologies to execute fitness routine has become the gamechanger in this modern era. Speaking of Wearable Smart technologies, Smart Shoes cannot be left undiscussed when it comes to fitness. These Smart shoes are impeccable in tracking our fitness performance. Engineering efforts have led ways to integrate this smart technology with traditional shoes, enhancing comfort, convenience, and better health (Navneeta et al., 2018). Among the U.S. citizens conferring to the Centers of Disease Control and Prevention in the year 2017-2018, the percentage of obese and overweight adults from the age 20 and over was 42.4%. These tremendous amounts of people are at high risk of acquiring health problems. Considering the factors such as unawareness of possible health issue due to obesity and to motivation; Hypermarkets like Adidas, Nike and many other brands have been contributing to smart shoes to the market for high profit and the betterment of people's lifestyle (Hales et al., 2020; Ledger et al., 2014).

In a study Lazar et al. (2015), Smart sensing devices and activity trackers are adopted by 1 in 10 Americans over the age of 18. Brand commercials and advertising really make people to buy and keep themselves fit using the technology. However, 80% of the buyers fail to use the technology. More than half of the users have completely discarder the technology within a period of six months. Whereas one third of the users no longer use the technology (Lazar et al., 2015). Considering the environmental aspects, non-renewable resources are extensively depleted at an alarming level due to industrial growth and rapid

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population. In 35 to 42 years, resources such as oil, gas and coal are expected to run out of stock. After completely utilizing such resources, it will become a complex situation in replacing them as we are completely dependent on these resources to supply most of our energy needs. Alternative Renewable sources are increasingly researched and implemented in global society as it is the only possible solution to sustainability and avoid the diminution of nonrenewable resources (National Geographic Society, 2016). Super expensive Smart shoes fitness trackers register the user's even number of steps. It can optimize every aspect of the user’s activity, from the shock absorption in the outsole and insole cushioning to light technological materials and ideal fit. To track appropriate variables and deliver that information to the user’s smartphone, there is a basic need of a gyroscope, pressure sensor, accelerometer, processor, and Bluetooth connected to the smart shoe (Findley et al., 2015).

Smart shoes sold by hypermarkets like Puma are retailed for an expensive price in the market, sold for Rs. 53,000. Although the impressive aspects of smart shoes can motivate people to go in for fitness in their everyday life, it is practically not affordable for everyone to own a pair for themselves. In addition to its expensive price, they also need be concerned about maintenance and it also requires frequent charging from external power source for continues functioning (Lazar et al., 2015; Findley et al., 2015). Smart technologies such as smart shoes are being abandoned by individuals after purchase for many reasons and one of them is data collection not being useful. Reports reveal that the number of footsteps exhibited during exercise is sometimes not taken into account by the tracker. And moreover, accuracy of foot step calculation did not meet the expectations of the user. This makes individuals extremely dependent on conventional practice over technological assistance and end up abandoning the use of that technology. Technological complexity is the major reason for this problem to have an effect (Lazar et al., 2015). Hence, this study will elaborate the fabrication of Smart Shoe prototype by coordinating and integrating the relevant technical components for expressing the necessary fitness tracking variables using Arduino programming and IOT technology.

MATERIALS AND METHOD

Prototype Module

Based on Fig 1, initially the piezo electric circuit made with 10 piezo plates connected in series. A charging circuit is then connected from the piezo circuit to the batteries, so that the generated voltage recharges the battery. From the battery the output voltage is sent to the regulator to provide constant voltage to the Microcontroller. The heart rate sensor REES52, temperature sensor LM35 and accelerometer sensor ADXL335 are connected to the Arduino Nano. Then via serial communication the determined values of SpO2, heart rate, distance walked, number of footsteps, calories burned and the surrounding temperature are transferred to Node MCU ESP8266. In addition to the all these features, a flat Vibration motor is connected for relaxation purpose. Now, from the Node MCU determined data is pushed to the cloud server. The cloud citation server stores all the values and sends to the smart shoe mobile application. Now the data can be viewed by the user in real time

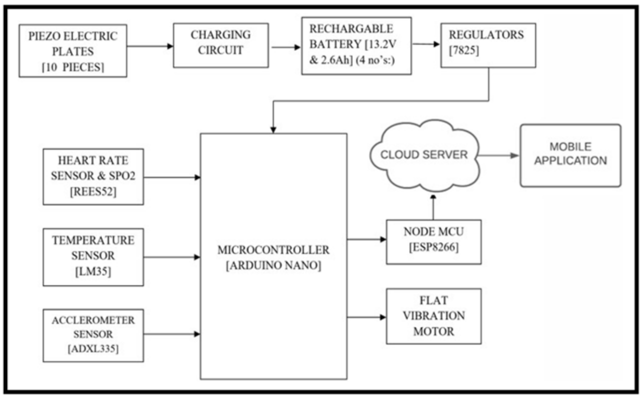

Fig 1 Outline of the integrated smart shoe prototype module.

Technological Outline of Study

Fig. 2 shows the flow chart satisfies the second objective of this study, by providing steps to generate electricity and harvest utilizing it for the tracker’s performance. The circuit is made in series to generate maximum voltage in order to recharge the battery at the earliest time possible.

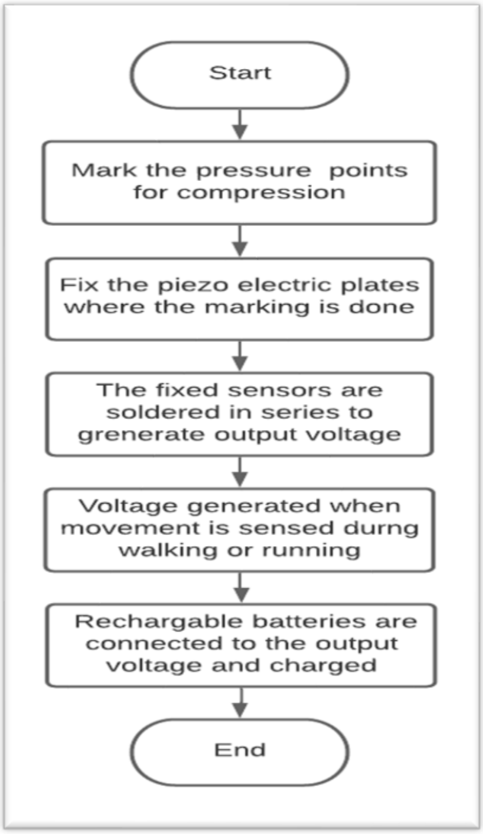

Fig. 2 Flow Chart: Method of charging batteries via piezoelectric sensor.

The Piezo electric sensor in Fig. 3 is the major component is generating electricity and to charge the other components through the rechargeable battery. Its senses the physical energy when there in movement initialized by the user and converts the mechanical pressure excreted onto the circuit electrical energy by satisfying its major purpose.

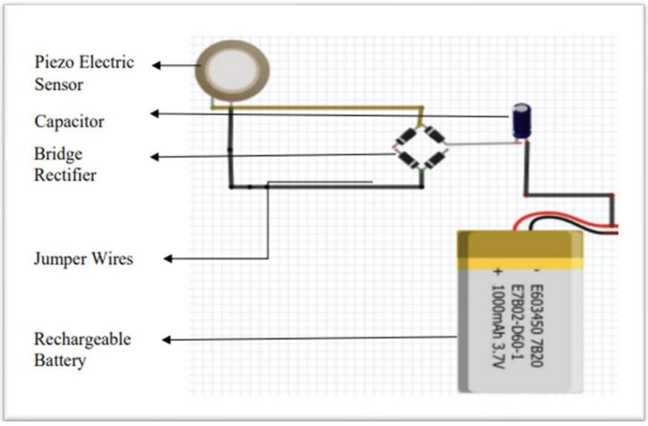

Fig. 3 Piezo Electric Circuit.

Master Circuit

Fig 4 shows the most important circuit which connects the Accelerometer, Node MCU and other sensors to the Arduino Nano. This is where the accelerometer integrates with the Arduino Nano and acts as the pedometer by assessing the number of footsteps during locomotion, distance covered and the number of calories burned in that particular time. This master circuit partially satisfies the first objective of this study, by determining the fitness variables with the extracted data.

Wifi Module

After the data is collected using Arduino Nano and Accelerometer, it is transferred to Node MCU ESP8266 through serial communication. From there the data is sent to the smart phone Mobile application using a Wi-Fi connectivity device. The Wi-Fi acts as a medium between the smart shoe prototype and the smart phone to send data to the cloud server and receive input from the user interface. It is a mandatory constrain to keep the Wi-Fi paired connected to the smart phone for any data transmission to take place in real time.

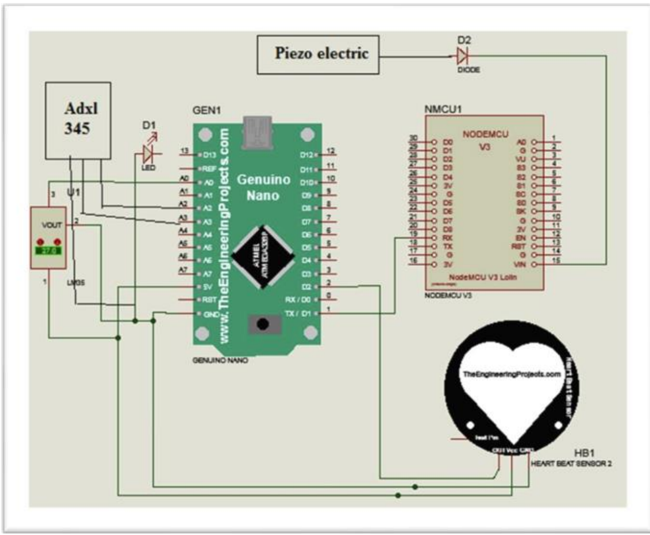

Fig. 4 Master circuit connection of the smart shoe tracking module system.

RESULT AND DISCUSSION

Fitness Tracker Module

The complete prototype is a combination of the piezo electric and the fitness tracker module. The modules were fabricated individually and connected using a charging circuit cable, so that the battery gets charged for the tracker to perform. The Fig. 5 is the fitness tracker module that acts as the main module and also the fitness pedometer of the prototype. The accelerometer is the sensor that determines the step count based on the axial changes of X, Y and Z axis. The sensors are connected to the Arduino nano microcontroller and from there the determined values are transferred to Node MCU via serial communication. The LED is to indication of the prototype at ready phase for utilization.

The tracker functions flawlessly by determining the necessary parameters in accordance to the axial changes in human locomotion. The heart rate sensor calculates the BPM of the human body based the infrared refraction of the sensor. The blood oxygen saturation level is also calculated based on the heart rate sensor. The temperature sensor works with precision by exposing the surround temperature in terms of Celsius. The regulators are bridged together in order to regulate the incoming heavy load from the battery and regulate it to the Arduino. The Information from the sensors is transferred to the Node MCU via serial communication.

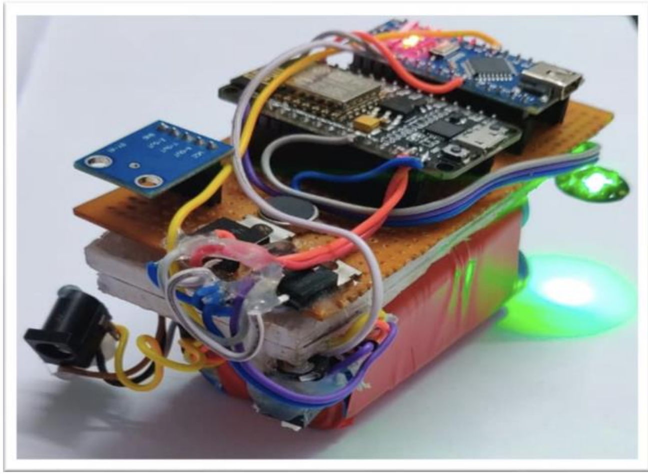

Fig. 5 Fitness tracker module

Application Interface

The smart shoe application consists of an android smart shoe application. The application encompasses of two main pages. One page is meant to view the values of the fitness variables in real time. And the other page is to view the history of the fitness performance form the initial moment of the smart shoe initialization until the latest performance recorded. The main page is also used for the use as a control interface in activating the vibration motor for relaxation purposes after a day of long run and exercise, as the user desires (Bathula et al., 2017).

Prototype Testing

The prototype is tested by the comparative data testing method along with the calculation of percentage of error of the value acquired from the testing during performance of the tracker. This is to check the accuracy of the determined data with the existing technology in the market. The accuracy of the prototype's fitness variables was tested among similar existing fitness technologies for two different time intervals. Table 1, represents the data collected in 5 minutes performance duration and Table 2, represents the data collected in 6 minutes performance duration. The wearable technologies tested simultaneously for comparison are; Apple watch S7, Xiaomi Smart shoe and Xiaomi Mi watch. From Table 1 and Table 2, the type of technologies used for comparison were, two mart watches and a smart shoe for the testing. Since the chosen smart shoe doesn't support every fitness variable in comparison with the smart shoe prototype, smart watches were involved in compromising the limitation for testing. The smart watches were efficient enough to test as it covers all the fitness parameters included (Wong et al., 2020).

Based on Table 1, by testing the prototype for five minutes duration and it is very evident that all the variable doesn't match the determined values. Each technology had a different output exhibited in comparison with the other but the readings aren't much different from each other. Readings of the heart rate and blood oxygen saturation are within normal range and almost similar to the reading of the Apple watch. And the values of calories burnt and total distance waked are relevant to the step counts of the respective technologies. The surrounding temperate is faultless and accurately calculated in all the three technologies. However, there is a slightly higher difference in the step count and total distance covered readings, amongst the Smart Shoe prototype and the Xiaomi Smart Shoe. It is very evident that the smart shoe doesn't support most of the parameters in comparison with the smart watches and smart shoe prototype (CrossFit, 2019).

Table 1 Five minutes performance duration data of the existing technologies and the smart shoe prototype

Technology	Heart rate [BPM]	SPO2 [%]	Step Count	Total Distance [m]	Calories Burnt [Kcal]	Temp [C]
Apple watch S7	88	96	352	123	16	32
Xiaomi Mi Watch	85	94	354	123	19	32
Xiaomi Smart Shoe	Not supported	Not supported	355	125	Not supported	Not supported
Smart Shoe Prototype	90	95	355	125	16	32

Based on Table 2, the prototype was tested for six minutes duration and it is very obvious that all the variables don't coordinately match the determined values. Each technology had a different output exhibited in comparison with the other but the readings aren't much different from each other. Even here, readings of the heart rate and blood oxygen saturation are within normal range and almost similar to the reading of the Apple watch. The values of the calories burnt is accurate with the Apple watch reading. But the total distance waked are irrelevant to the step counts of the respective technologies. The surrounding temperate is faultless and accurately calculated in all the three technologies. However, there is a slightly higher difference in the step count reading, amongst the Smart Shoe prototype and the Xiaomi Smart Shoe (Abdul Razak et al., 2012).

Table 2 Six minutes performance duration data of the existing technologies and the smart shoe prototype

Technology	Heart rate [BPM]	SPO2 [%]	Step Count	Total Distance [m]	Calories Burnt [Kcal]	Temp [C]
Apple watch S7	89	96	382	135.4	17	32
Xiaomi Mi Watch	85	92	399	130	20	32
Xiaomi Smart Shoe	Not supported	Not supported	383	133.7	Not supported	Not supported
Smart Shoe Prototype	87	94	383	133.7	19	32

Percentage of Error

The error percentage of the prototype's fitness variables is calculated. In this case, the values of apple watch 7s have been considered to be the most trusted technology amongst the wearable technologies used for comparison. Thereby, it is considered to be the actual value and the rest are the observed values. From Table 3, the percentage of error in the heart rate readings is same as the Xiaomi smart watch and the blood oxygen saturation percent error is comparatively with the Xiaomi smart watch. But the percent error for step count and the distance covered is same as the Xiaomi smart shoes, it identically minimal and weigh less in comparison with the other technologies. There percent error for the number of calories burnt is 0 and flawless in terms of efficiency. Finally, the surrounding temperature values of all the three technologies is perfectly coordinating with the true values of apple watch 7S (Rai et al., 2006; Nilesh et al., 2020).

Table 3 Percentage of Error for the 5 Minutes performance duration data.

Technology	Heart rate [BPM]	SPO2 [%]	Step Count	Total Distance [m]	Calories [Kcal]	Temp [C]
Apple watch 7s	**88**	**96**	**352**	**123**	**16**	**32**
Xiaomi Mi Watch	3.41%	2.08%	0.57%	0	6.25%	0
Xiaomi Smart Shoe	Not supported	Not supported	0.85%	1.62%	Not supported	Not supported
Smart Shoe prototype	3.41%	1.04%	0.85%	1.62%	0	0

The Table 4 has a percentage of error in the heart rate readings, is evidently lower than the Xiaomi smart watch and the blood oxygen saturation percent error is comparatively with the Xiaomi smart watch. However, the percent error for step count and the distance covered is very minimal and weigh less in comparison with the other technologies. There percent error for the number of calories burnt is drastically lower and has a significant value claiming it to be efficient. To finish, the surrounding temperature values of all the three technologies is perfectly coordinating with the true values of apple watch 7S (Vignesh et al., 2018; Prasad et al., 2019).

Table 4 Percentage of Error for the 6 Minutes performance duration data

Technology	Heart rate [BPM]	SPO2 [%]	Step Count	Total distance [m]	Calories [Kcal]	Temperature [C]
Apple watch 7s	**89**	**95**	**383**	**135.4**	**17**	**32**
Xiaomi Mi Watch	4.40%	3.15%	1.80%	3.98%	5.88%	0
Xiaomi Smart Shoe	Not supported	Not supported	0.26%	1.25%	Not supported	Not supported
Smart Shoe Prototype	1.10%	1.05%	0.26%	1.25%	1.11%	0

CONCLUSION

The smart shoe fitness tracker prototype has been fabricated with relevant fitness variables and successfully achieved the objective. It has incorporated several features in the prototype, compared with the existing fitness smart shoe in the market. The determined values are acceptable with an error percentage less than 5%. Moreover, by generating electrical energy, recharging the battery during the compression of piezo electric circuit and utilizing the harvested electrical energy for the tracker's performance. The determined output values of the chosen fitness variables are interfaced on an android smart phone application and accomplished the last objective. This healthcare technology will help to motivate the society and begin a better lifestyle by taking up fitness (Farago et al., 2020). Smart shoe ware is going to upgrade people from using the normal shoes to smart shoes, as part of progressing to a better future.

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