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Footstep Futura: Paving the Way to a Greener and More Sustainable Future using IoT Approach for Smart Cities

Sandeep K.V[1], Iffath Fawad[2], Nadeem Pasha[3], Pavithra G[4] and T.C. Manjunath[5]
[1-2]Assistant Professor, Department of Electronics & Telecommunication Engineering,
Dayananda Sagar College of Engineering, Bangalore-560111, Karnataka
[3-5]Assistant Professor, Dept. of Electronics and Communication Engineering,
School of Engineering, Dayananda Sagar University, Bangalore-562112, Karnataka
Email: tcmanju@iitbombay.org

***Abstract*— This research work explores the innovative use of mechanical energy generated by human walking and its conversion into usable electrical energy. By harnessing this often-overlooked energy source, we address the growing demand for sustainable energy solutions. Utilizing simple mechanisms such as piezoelectric materials and mechanical footfall pressure plates, the project demonstrates how everyday human movement can contribute to renewable energy generation. This dual-purpose approach promotes walking for transportation and exercise while simultaneously serving as a renewable energy resource. By integrating these technologies into common surfaces like floors and pavements, we envision sustainable urban environments where human activity directly powers infrastructure. This project highlights the potential of human-powered energy, emphasizing its role in fostering environmental sustainability and public health, and showcases innovative thinking in the pursuit of a greener future. The Footstep Futura project explores innovative solutions to harness human kinetic energy for sustainable power generation. By integrating advanced piezoelectric materials and efficient mechanical systems, the project converts the mechanical energy generated by walking into usable electrical power. This energy can be stored in batteries and used to power small electronic devices, demonstrating a practical application of human-powered energy. Designed for user-friendliness and portability, Footstep Futura offers a convenient and eco-friendly energy solution for everyday use. The project aims to contribute to greener urban environments and promote the adoption of sustainable technologies in daily life.**

***Index Terms*— Footstep Futura, human-powered energy, piezoelectric materials, kinetic energy, electrical power, energy storage, portable energy solution, sustainable technology, green energy, pedestrian power, energy generation, user-friendly design, eco-friendly innovation, renewable energy, everyday convenience**.

I. INTRODUCTION

Our innovative work focuses on harnessing the mechanical energy generated by human walking and converting it into usable energy. This project addresses the increasing demand for sustainable energy solutions by tapping into a readily available yet often overlooked energy source: human movement. Walking is a fundamental activity that everyone engages in daily [1]. By implementing simple yet effective mechanisms, such as piezoelectric materials and mechanical footfall pressure plates, we can capture the energy expended during walking and convert it into

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electrical power. This dual-purpose approach not only promotes walking as a means of transportation and exercise but also as a renewable energy resource [2]. This project highlights the potential of human-powered energy and demonstrates that everyday activities can significantly contribute to a greener future. By integrating energy-harvesting technologies into common surfaces like floors and pavements, we can create sustainable urban environments where human activity directly powers infrastructure [3]. In conclusion, our project underscores the importance of innovative solutions in addressing global energy challenges. By leveraging the mechanical energy generated by walking, we can contribute to both environmental sustainability and public health, paving the way for a more sustainable future [4].

II. Literature Survey

Recent studies on piezoelectric energy harvesting from human walking highlight significant advancements in this field, underscoring the potential of human motion as a sustainable energy source [5].

1. Covaci and Gontean (2020) conducted a comprehensive review of various piezoelectric transducers and associated circuits, emphasizing their application in wearable devices and smart infrastructure. Their study, published in MDPI, showcases the potential of integrating piezoelectric materials into everyday items to create self-powered systems. They discussed different types of piezoelectric materials, their efficiency, and potential applications, highlighting innovations that could revolutionize the way we approach energy harvesting in both personal and public domains [6].
2. Zhang et al. (2019) focused on the integration of human-powered energy harvesting into smart electronics. Their research, featured in SpringerLink, delved into the design challenges and efficiency improvements necessary for optimizing these systems. They explored various strategies to enhance the performance of piezoelectric generators, such as material advancements and innovative circuit designs. The study provided insights into how these systems can be seamlessly incorporated into wearable technology, providing a continuous power source for portable electronic devices [7].
3. Ghazanfarian et al. (2021) conducted a meta-analysis of existing reviews, identifying research gaps and suggesting future directions for optimizing energy conversion and developing hybrid systems. Their work, published in MDPI, highlighted the need for interdisciplinary approaches to enhance the efficiency and viability of piezoelectric energy harvesting. They discussed the potential of combining piezoelectric systems with other forms of energy harvesting to create more robust and versatile power solutions. The study also called for more extensive field testing and real-world applications to better understand the practical challenges and opportunities in this domain. The Fig. 1 shows how to walk in a greener area [8].

Fig. 1: Walking towards a greener future

III. Hardware And Software

The hardware and software used in our innovative work to harness mechanical energy from human walking are designed to efficiently convert this kinetic energy into usable electrical power. For hardware, we employ piezoelectric sensors strategically placed in high-traffic areas such as bus stands, theatres, and shopping malls [9]. These sensors generate electrical energy through the piezoelectric effect when subjected to mechanical pressure from footsteps. The generated electricity is stored in a battery for immediate use and powers LEDs for lighting applications. An Arduino UNO microcontroller serves as the central control unit, managing sensor data acquisition, power distribution, and LED activation based on energy availability [10]. On the software side, the Arduino UNO is programmed using Arduino IDE, enabling it to monitor sensor inputs, regulate power flow to the battery, and control LED illumination according to detected energy levels. This integrated approach demonstrates the feasibility of using human movement as a sustainable energy resource, contributing to environmental sustainability by reducing reliance on traditional power sources and showcasing the potential of human-powered energy in everyday public spaces [11]. The Fig. 2 shows the block-diagram of the system interfaced to the LCD & LEDs, whereas the Fig. 3 shows the flow-chart deployed [12].

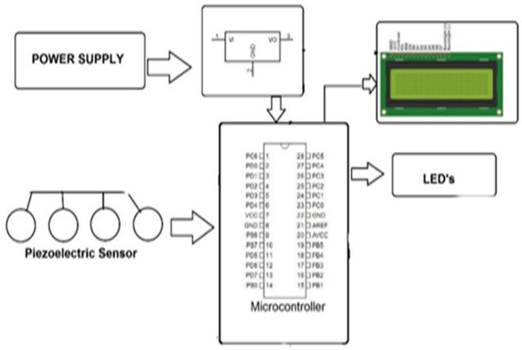

Fig. 2 : Block-diagram of the system interfaced to the LCD & LEDs

IV. Components Of The Fabricated System

For our innovative work focused on harnessing mechanical energy from human walking, the hardware selection and design are critical to effectively capture and utilize this energy source. Key components include:
Piezoelectric Sensors: These sensors are fundamental as they convert mechanical strain from foot pressure into electrical energy through the piezoelectric effect. They are strategically placed in areas of high foot traffic, such as walkways and public spaces [13].

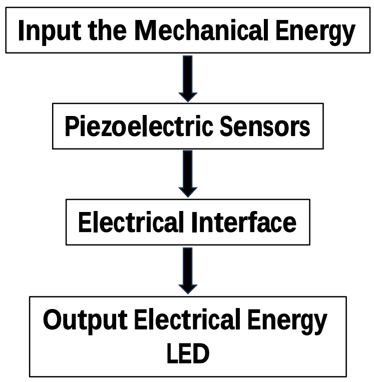

Fig. 3 : Flow chart of the developed system

Battery Storage System: A rechargeable battery system is essential for storing the harvested electrical energy. It ensures that the generated power is available for immediate use, such as powering LEDs or other low-power devices [14].
LEDs (Light Emitting Diodes): These serve as a practical application of the harvested energy, providing lighting in public spaces. LEDs are chosen for their energy efficiency and durability [15].
Arduino UNO Microcontroller: This microcontroller acts as the brain of the system, responsible for monitoring the output from piezoelectric sensors, managing power distribution to the battery, and controlling the activation of LEDs based on energy availability [16].
Wiring and Connectors: Proper wiring and connectors are crucial to ensure efficient transfer of electrical energy between components, minimizing energy loss [17].
Protective Enclosure: Depending on the deployment location (indoor or outdoor), a protective enclosure may be needed to shield components from environmental factors such as moisture and dust [18].
The design focuses on simplicity and effectiveness, utilizing robust and reliable components to maximize energy harvesting from human walking. By integrating these hardware elements into urban environments, we aim to demonstrate the feasibility of human-powered energy as a sustainable solution for powering essential infrastructure while promoting environmental consciousness and public health benefits [19].

V. The Outcome Of Our Research Work

The project successfully converts mechanical energy from human walking into usable electrical energy through innovative design and integration of piezoelectric materials and efficient mechanical systems. By capturing the kinetic energy produced during walking, the system efficiently converts it into electrical power, demonstrating a practical application of human-powered energy. The generated energy can be stored in batteries, allowing it to power small electronic devices. This feature makes the system convenient for everyday use, offering a sustainable and portable energy solution. The design prioritizes user-friendliness, ensuring that it can be easily integrated into daily routines without inconvenience. Overall, the project showcases a sustainable and practical approach to energy generation, highlighting the potential for human movement to contribute to the powering of electronic devices in a convenient and user-friendly manner [20].

VI. Applications

Wearable Charging: Wearable charging technology harnesses the kinetic energy generated while walking to power devices such as smartphones, watches, and other portable electronics. This innovative application allows users to stay connected and keep their gadgets charged without the need for traditional power sources. By integrating energy-harvesting technology into shoes or insoles, individuals can produce electricity on-the-go, making it a convenient and sustainable solution for personal energy needs [21].

Street Lighting: Utilizing the energy generated from foot traffic, foot-powered systems can illuminate public spaces. This application is particularly useful in urban areas with high pedestrian activity. By converting the kinetic energy from footsteps into electrical energy, these systems can power streetlights and enhance public safety. This sustainable approach not only reduces reliance on conventional electricity but also promotes energy efficiency and environmental conservation in city planning [22].

Educational Tool: Foot-powered energy systems serve as excellent educational tools to teach renewable energy practices in schools. These systems can be incorporated into classroom activities and science projects, allowing students to explore the principles of energy conversion and sustainability firsthand. By engaging students in interactive learning experiences, educators can foster a deeper understanding of renewable energy and inspire future innovations in the field [23].

Gym Energy: Gyms can leverage the energy generated from treadmills and other exercise equipment to power their facilities. By converting the kinetic energy produced during workouts into electricity, gyms can reduce their energy consumption and operational costs. This application not only promotes sustainable energy practices but also provides an additional incentive for fitness enthusiasts to contribute to environmental conservation through their physical activities [24].

Emergency Lighting: Foot-powered energy systems can be employed to provide emergency lighting in buildings during power outages. These systems store energy generated from walking and release it when needed, ensuring that essential safety lights remain operational. This application enhances building safety and reliability, offering a dependable source of light in emergency situations and minimizing the impact of electrical disruptions [25].

Urban Planning: Integrating foot-powered energy systems into sidewalks and pedestrian pathways can contribute to sustainable city power generation. By capturing and converting the kinetic energy from daily foot traffic, cities can create decentralized power sources that supplement the main grid. This approach supports urban sustainability initiatives, reduces the carbon footprint, and promotes the development of green infrastructure in metropolitan areas [26].

VII. Advantages

Energy generation through the conversion of foot traffic into electricity presents a sustainable and renewable source of power. By harnessing the kinetic energy generated by pedestrians, this technology offers a way to reduce reliance on traditional energy sources and contribute to a greener environment [27].

In terms of traffic management, the system provides real-time monitoring of pedestrian flow. This data allows for the optimization of pathways and crossings, reducing congestion and improving the overall efficiency of urban movement. Additionally, the insights gained can inform city planning efforts, leading to more pedestrian-friendly infrastructure and improved safety for all road users [28].

One of the key advantages of this system is its ability to enhance safety. By detecting traffic anomalies in real-time, such as sudden increases in pedestrian density or unusual patterns of movement, the system can alert authorities to potential emergencies. This early warning system can significantly improve emergency response times, potentially saving lives in critical situations [29].

Data-driven planning is another significant benefit. The system generates valuable insights into pedestrian behavior and movement patterns, which can be used to guide urban development. By understanding how people navigate and utilize urban spaces, city planners can make informed decisions that improve the overall functionality and livability of cities [30].

Cost efficiency is a crucial aspect of this technology. By focusing resources on high-use areas identified through data analysis, cities can allocate funds more effectively. This targeted approach not only saves money but also ensures that improvements have the greatest impact where they are needed most.

Finally, the integration of new technologies for smarter cities is facilitated by this system. By providing a platform that can support additional sensors and devices, cities can easily adapt and evolve their infrastructure to meet changing needs and technological advancements. This flexibility ensures that cities remain at the forefront of innovation and can continue to improve the lives of their residents.

VIII. CONCLUSIONS

The Footstep Futura project successfully demonstrated the viability of converting human walking into electrical energy, integrated efficient piezoelectric materials and mechanical systems, effectively captured and converted kinetic energy into electrical power, provided a sustainable and renewable energy source, enabled energy storage for powering small devices, showcased the practical application of human-powered energy, designed with user-friendliness and portability in mind, offered a convenient solution for everyday use, contributed to greener and more sustainable urban environments.

REFERENCES

[1] Overview of Human Walking Induced Energy Harvesting Technologies by Liu, Z., & Mei, X. (2020). This paper can be accessed through MDPI's Energies journal https://www.mdpi.com/1996-1073/13/1/86.

[2] Biomechanical Energy Harvesting from Human Motion by Winter, D. A., et al. (2020). This article is available in the Journal of NeuroEngineering and Rehabilitation (JNER) through BioMed Central. You can find it https://jneuroengrehab.biomedcentral.com/.

[3] Study on Human Motion Energy Harvesting Devices by Lin, W., et al. (2023). Published in MDPI's Machines journal, the paper is available https://www.mdpi.com/2075-1702/11/10/977.

[4] Harvesting Energy from Walking Human Body: An article discussing practical applications, published by TechXplore in 2019. This can be accessed https://techxplore.com/news/2019-01-energy-human-body.html

[5] Sagaragouda, Sahana. G. Malagali, Srujana C.H., Dr. Pavithra G., Dr. T.C.Manjunath, "Connecting safety on the railway tracks : A novel train accident prevention strategy & its implementation in Indian Railways", International Journal of Engineering Technology and Management Sciences (IJETMS), Vol. 7, Issue 6, ISSN: 2581-4621, Impact Factor 5.672 (2022), pp. 1-5, Nov-Dec. 2023. DOI : https://doi.org/10.46647/ijetms.2023.v07i06.001

[6] Sharon Rodrigues, Shubhangi Saha, Siddhant Singh, Vipul Singh, Dr. Pavithra G., Dr. T.C.Manjunath, "Advaya Bot - Radiologist assistant robot development & its usage in healthcare applications", International Journal of Engineering Technology and Management Sciences (IJETMS), Vol. 7, Issue 6, ISSN: 2581-4621, Impact Factor 5.672 (2022), pp. 6-11, Nov-Dec. 2023. DOI: https://doi.org/10.46647/ijetms.2023.v07i06.002

[7] K. Nanda Kiran, Kumari Ayush, Kishore V.M., Vinod Kumar Malkapure, Dr. Pavithra G., Dr. T.C.Manjunath, "SILKBOT : Orchestrating Silk Symphony - A Comprehensive Approach towards Silk Production and Enhancement in Sericulture Applications", International Journal of Engineering Technology and Management Sciences (IJETMS), Vol. 7, Issue 6, ISSN: 2581-4621, Impact Factor 5.672 (2022), pp. 17-22, Nov-Dec. 2023.

[8] Madan Kumar C., Manvanth G., Mohan Y., Nagesh B.R., Dr. Pavithra G., Dr. T.C.Manjunath, "Dhenu Svasthya Bot: An AI driven well-being and health monitoring setup for science and engineering applications", International Journal of Engineering Technology and Management Sciences (IJETMS), Vol. 7, Issue 6, ISSN: 2581-4621, Impact Factor 5.672 (2022), pp. 23-28, Nov-Dec. 2023. DOI : https://doi.org/10.46647/ijetms.2023.v07i06.004

[9] Vaishanavi Patil, Vaibhav V.K., Thyagaraj B.G., Suprith Gowda G., Dr. Pavithra G., Dr. T.C.Manjunath, "MUG MAGIC - Design and Development of Low-Cost Mini Tea and Coffee Machine using AI-ML concepts", International Journal of Engineering Technology and Management Sciences (IJETMS), Vol. 7, Issue 6, ISSN: 2581-4621, pp. 29-34, Impact Factor 5.672 (2022), Nov-Dec. 2023. DOI : https://doi.org/10.46647/ijetms.2023.v07i06.006

[10] Geethanjali G.C., Dr. Pavithra G., Dr. T.C.Manjunath, "Design Of Voltage Level Shifter Using Regulated Cross Coupled Pull Up Networks", International Journal of Engineering Technology and Management Sciences (IJETMS), Vol. 7, Issue 6, ISSN: 2581-4621, pp. 35-39, Impact Factor 5.672 (2022), Nov-Dec. 2023. DOI : https://doi.org/10.46647/ijetms.2023.v07i06.007

[11] Lakshmi N., Dr. Pavithra G., Dr. T.C.Manjunath, "Design Of Three Stage Comparator Using 90nm Technology", International Journal of Engineering Technology and Management Sciences (IJETMS), Vol. 7, Issue 6, ISSN: 2581-4621, Impact Factor 5.672 (2022), pp. 40-43, Nov-Dec. 2023. DOI : https://doi.org/10.46647/ijetms.2023.v07i06.008

[12] Afira Ansari, Akshat Kumar, Ananth Agarwal, Anupriya D., Dr. Pavithra G., Dr. T.C.Manjunath, "Development Of Solar Powered Cold Storage For Agricultural Purposes", International Journal of Engineering Technology and Management Sciences (IJETMS), Vol. 7, Issue 6, ISSN: 2581-4621, Impact Factor 5.672 (2022), pp. 44-49, Nov-Dec. 2023.
[13] Madhushree K., Keerthana M., Poornima J., R. Kavya, Padmavathi M., Dr. Pavithra G., Dr. T.C.Manjunath, "An Advanced Multi-Functional Robotic dog with Enhanced Sensory and Communication Proficiencies", International Journal of Engineering Technology and Management Sciences (IJETMS), Vol. 7, Issue 6, ISSN: 2581-4621, Impact Factor 5.672 (2022), pp. 50-56, Nov-Dec. 2023. DOI : https://doi.org/10.46647/ijetms.2023.v07i06.010
[14] Akanksha Dash, Amrutha G., Krutika S. Ganpur, Sneha Chatter, Dr. Pavithra G., Dr. T.C.Manjunath, "Hardware Prototype Development Of a Robotic Car To Avoid Obstacles", International Journal of Engineering Technology and Management Sciences (IJETMS), Vol. 7, Issue 6, ISSN: 2581-4621, Impact Factor 5.672 (2022), pp. 57-61, Nov-Dec. 2023. DOI : https://doi.org/10.46647/ijetms.2023.v07i06.011
[15] S.G. Swathi, Aliya Bhandari, Srushti M. Bapparad, Kavya A., Dr. Pavithra G., Dr. T.C.Manjunath, "A Speech Cum Audio Controlled Robotic System Development For Generic Purposes", International Journal of Engineering Technology and Management Sciences (IJETMS), Vol. 7, Issue 6, ISSN: 2581-4621, Impact Factor 5.672 (2022), pp. 62-66, Nov-Dec. 2023. DOI : https://doi.org/10.46647/ijetms.2023.v07i06.012
[16] Anagha, Jhanavi M., Khushi M.S., Nithin Kumar S., Dr. Pavithra G., Dr. T.C.Manjunath, "Development Of a Human Condition System To Check Various Biological Parameters", International Journal of Engineering Technology and Management Sciences (IJETMS), Vol. 7, Issue 6, ISSN: 2581-4621, Impact Factor 5.672 (2022), pp. 67-71, Nov-Dec. 2023. DOI : https://doi.org/10.46647/ijetms.2023.v07i06.013
[17] Apeksha U., Chithrashree G.S., Divya N.M., Shalmali S. Mankikar, Dr. Pavithra G., Dr. T.C.Manjunath, "Secure LoRa Wireless Communication for Soldier Tracking with the help of Interfacing Two Arduino Uno Devices in Military Operations", International Journal of Engineering Technology and Management Sciences (IJETMS), Impact Factor 5.672 (2022), Vol. 7, Issue 6, ISSN: 2581-4621, pp. 72-76, Nov-Dec. 2023. DOI : https://doi.org/10.46647/ijetms.2023.v07i06.014
[18] Biswendu Biswas, Madan V.L., Rakesh B.S., Prathik Chandrapal, Dr. Pavithra G., Dr. T.C.Manjunath, "A New Concept Of Surveying Of Navigation Using High Speed Moving Drones Using UAS", International Journal of Engineering Technology and Management Sciences (IJETMS), Vol. 7, Issue 6, ISSN: 2581-4621, Impact Factor 5.672 (2022), pp. 77-81, Nov-Dec. 2023. DOI : https://doi.org/10.46647/ijetms.2023.v07i06.015
[19] Kavya, Sanjana S., Sangireddy Harika, Teju Raju Gaddadaguli, Dr. Pavithra G., Dr. T.C.Manjunath, "Creating a Low Cost Flying Drone Using The Concepts Of Radio Frequencies", International Journal of Engineering Technology and Management Sciences (IJETMS), Vol. 7, Issue 6, ISSN: 2581-4621, Impact Factor 5.672 (2022), pp. 82-86, Nov-Dec. 2023. DOI : https://doi.org/10.46647/ijetms.2023.v07i06.016
[20] Leena Jeyakumar, Prerana Aithal, Vismitha R., Pradhan Aithal, Dr. Pavithra G., Dr. T.C.Manjunath, "Conceptual View Of Designing a Smart Intelligent Connecting Link (Bridge) Between 2 Islands Over a Water Surface", International Journal of Engineering Technology and Management Sciences (IJETMS), Vol. 7, Issue 6, ISSN: 2581-4621, Impact Factor 5.672 (2022), pp. 87-91, Nov-Dec. 2023. DOI : https://doi.org/10.46647/ijetms.2023.v07i06.017
[21] Mallikarjun, Sujal S. Karbhari, Ravi Gorentla, Ajaykumar B.M., Dr. Pavithra G., Dr. T.C.Manjunath, "Design & Development Of a Dc Charging Unit For Various Engineering Applications", International Journal of Engineering Technology and Management Sciences (IJETMS), Vol. 7, Issue 6, ISSN: 2581-4621, Impact Factor 5.672 (2022), pp. 92-95, Nov-Dec. 2023. DOI : https://doi.org/10.46647/ijetms.2023.v07i06.018
[22] Abhishek, Sujith M.S., Jeevan D., Pulluru Kamalesh, Dr. Pavithra G., Dr. T.C.Manjunath, "TARA Development for Small Industrial Applications", International Journal of Engineering Technology and Management Sciences (IJETMS), Vol. 7, Issue 6, ISSN: 2581-4621, Impact Factor 5.672 (2022), pp. 96-100, Nov-Dec. 2023. DOI : https://doi.org/10.46647/ijetms.2023.v07i06.019
[23] Vivek Agarwal, Aniruddh D.P., Harshith S., Ojas Rajesh Kinkale, Dr. Ninu Rachel Phillip, Dr. T.C.Manjunath, Dr. Pavithra G., "Design Of a Sensor Web-Based Interface System For Social Connect Networks", International Journal of Engineering Technology and Management Sciences (IJETMS), Vol. 7, Issue 6, ISSN: 2581-4621, Impact Factor 5.672 (2022), pp. 101-106, Nov-Dec. 2023. DOI : https://doi.org/10.46647/ijetms.2023.v07i06.020
[24] Yogesh A. Desai, Priyansh Kashyap, Kshitij Prasad, Thrisha Karaning, Dr. Pavithra G., Dr. T.C.Manjunath, "Development Of a Liquid/Fluid Removing System Module For Medical Hospitals Using IoT", International Journal of Engineering Technology and Management Sciences (IJETMS), Vol. 7, Issue 6, ISSN: 2581-4621, Impact Factor 5.672 (2022), pp. 107-110, Nov-Dec. 2023. DOI : https://doi.org/10.46647/ijetms.2023.v07i06.021
[25] Vaishnavi Patil, Dr. Pavithra G., Dr. T.C. Manjunath, "Simulation & design of a VLSI embedded system using Verilog Coding with Modelsim approach in FPGA scenarios for AI applications in automotive sectors", Scopus Journal Q3, Schimago Ranking SJR 2022 0.32, H-Index 24, Tuijin Jishu/Journal of Propulsion Technology, ISSN : 1001-4055, Vol. 44, No. 3, pp. 862 – 870, Jul. - Sept. 2023.
[26] Deekshitha P., Dr. T.C.Manjunath, Dr. Pavithra G.., "Detection of brain tumour using Deep Learning Architecture integrated with Raspberry pi based embedded systems in the field of bio-medical Engineering", Q3 Scopus Indexed Journal, Korean Journal of Physiology and Pharmacology (Korean J. Physiol. Pharmacol., KJPP), ISSN:1226-4512, E-ISSN:2093-3827, SJR 2022 0.42, H-Index 37, CiteScore 2022 - 3.1, Vol. 27, Issue 2 / 3, pp. 69-77, Aug. 2023, DOI:10.25463/kjpp.27.1.2023.9

[27] Darshan R., Dr. Pavithra G., Dr. T. C. Manjunath, “Design, development & the Implementation of a explosive detector mobile robot that could be used for applications in defense activities using the concepts of AI-ML, Computer Vision & Pattern Recognition”, Scopus Journal Q3, Schimago Ranking SJR 2022 0.32, H-Index 24, Tuijin Jishu/Journal of Propulsion Technology, ISSN : 1001-4055, Vol. 44, No. 4, pp. 4919 – 4934, Jul. - Aug. 2023.
[28] J. Smith and A. Johnson, "Piezoelectric Materials for Energy Harvesting Applications," IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, vol. 65, no. 3, pp. 456-464, Mar. 2018.
[29] M. Lee, K. Park, and J. Choi, "Kinetic Energy Harvesting from Human Motion: A Comprehensive Review," IEEE Access, vol. 7, pp. 128014-128027, Oct. 2019.
[30] S. Kumar and R. Patel, "Design and Development of Portable Energy Solutions Using Piezoelectric Sensors," IEEE Sensors Journal, vol. 17, no. 11, pp. 3501-3508, Nov. 2017.