International Journal of Enhanced Research in Science, Technology & Engineering
ISSN: 2319-7463, Vol. 13 Issue 2, February-2024, Impact Factor: 8.375

A wearable solar energy harvesting based jacket with maximum power point tracking for vital health monitoring system

Adhilsha S[1], Nikhil S Kumar[2], Subin Babu[3], Anu S S[4]

[1,2,3]UG Scholar, Department of Electronics and Communication Engineering, Dr. APJ Abdul Kalam Technological University Kerala, India
[4]Assistant Professor, Department of Electronics and Communication Engineering, Dr. APJ Abdul Kalam Technological University Kerala, India

ABSTRACT

In the healthcare technology landscape, wearable devices are crucial for continuous health monitoring. This abstract introduces a novel wearable jacket incorporating Maximum Power Point Tracking (MPPT) technology to optimize energy harvesting. The jacket integrates lightweight, flexible photovoltaic cells for efficient solar energy harnessing, with the MPPT algorithm dynamically adjusting the electrical operating point for maximum power extraction under varying conditions. The innovative wearable aims to overcome power limitations in traditional health monitoring devices, extending usage durations. Harvested solar energy powers health monitoring sensors embedded in the jacket, covering vital signs like heart rate, body temperature, respiratory rate, and activity tracking. MPPT integration enhances energy utilization and device autonomy, reducing reliance on external power. The jacket provides seamless, uninterrupted health monitoring, allowing real-time tracking of vital signs. It features wireless communication for data transmission to a dedicated mobile app or cloud platform, enabling comprehensive health analytics and remote monitoring. This wearable introduces a sustainable, eco-friendly approach to powering health monitoring, aligning with the green technology trend. The proposed technology has transformative potential for wearable health devices, addressing power challenges and promoting user-friendly, sustainable healthcare monitoring.

INTRODUCTION

The rapid advancement of wearable technology has ignited significant interest in recent years, offering innovative solutions for various applications. One particularly intriguing avenue of research within this domain is the utilization of low-power wearable devices that can harness energy from their environment, potentially reducing or even eliminating the need for traditional batteries. Solar energy, in particular, has emerged as a promising power source for such wearable gadgets. This paper introduces a groundbreaking development in the realm of wearable technology: a solar energy harvesting-based jacket designed to power an in-situ vital health monitoring system (VHMS). The VHMS incorporates an array of sensors to collect vital health data, with the ability to transmit this data at regular intervals, including an emergency alert option. To seamlessly integrate the Solar Energy Harvester (SEH) and VHMS, the research team has designed, fabricated, and rigorously tested a novel maximum power point tracking (MPPT) system. This MPPT system proves essential, especially during periods of diffused light when power generation can plummet to astonishingly low levels.

The SEH itself consists of ten flexible solar cells, strategically placed within transparent pouches stitched into the jacket's fabric. These solar cells operate in both individual and series configurations, enabling comprehensive testing in both controlled lab conditions and real-world environments..

LITERATURE SURVEY

Y. Tenzer, L.P. Jentoft, R.D. Howe, A. Magazine, “The feel of MEMS barometers: inexpensive and easily customized tactile array sensors”, IEEE Robot Autom. Mag. 21,2014. This article presents a new approach to the construction of tactile array sensors based on barometric pressure sensor chips and standard printed circuit boards (PCBs). The chips includetightly integrated instrumentation amplifiers, analog-to-digital converters, pressure and temperature sensors, and control circuitry that provides excellent signal quality over standard digital bus interfaces. The resulting array electronics can be easily encapsulated with soft polymers to provide robust and compliant grasping surfaces for specific hand designs. The use of standard commercial off-the-shelf technologies means that only basic electrical and mechanical skills are required to build effective tactile sensors for new applications. The performance evaluation of prototype arrays demonstrates excellent linearity (typically <;1%) and low noise (<;0.01 N). External addressing circuitry allows multiple sensors to communicate on the same bus at more than 100 Hz per sensor element. Sensors can be mounted with as close as 3#5-mm spacing, and spatial impulse response tests show that linear solid-mechanics-based signal processing is feasible This approach promises to make sensitive, robust, and inexpensive tactile sensing available for a wide range of robotics and human-interference applications

Y. Wang, Y. Lu, D. Mei, L. Zhu, “Liquid metal-based wearable tactile sensor for both temperature and contact force sensing”, IEEE Sens. J. 21, 2020.
Wearable tactile sensors can be used for haptic perception and are widely utilized in soft robotics, intelligent prosthetics, and other human interface/interface applications. The development of tactile sensors for multifunctional tactile sensing capacity remains a challenge. This article presents the design and fabrication of a wearable tactile sensor based on galinstan liquid metal for the simultaneous sensing of temperature and contact force independently. high force sensing sensitivity of 0.32 N -1 and its temperature sensing sensitivities are 0.41% °C -1 at 20~50 °C and 0.21% °C -1 at 50~80 °C Two wearable tactile sensors are worn on the index finger and thumb of the human hand and are used to detect temperature changes and contact forces during grasping applications. The results show that the developed liquid metal-based tactile sensor has a high flexibility and durability, and can accurately measure the contact forces and temperatures simultaneously. Thus, the developed wearable tactile sensor has great potential for robotic manipulation and healthcare condition

C.L. Choong, M.B. Shim, B.S. Lee, S. Jeon, D.S. Ko, T.H. Kang, J. Bae, S.H. Lee, K.E. Byun, “Highly stretchable resistive pressure sensors using a conductive elastomeric composite on a micro pyramid array”, IEEE Access, vol8,pp.8346–8360, 2014. This paper presents mechanical deformations that can be responded to by the strain sensors through the variation of electrical signals, such as resistance, capacitance or permittivity. However, conventional strain sensors typically have poor stretch ability and sensitivity. With the increasing demand for flexible and wearable electronic devices, the flexible, stretchable and sensitive strain sensors are highly desired. Organic material based flexible strain sensors are not meant to replace silicon-based devices but rather to fill niches in next-generation portable and wearable health care products. In this work, silver nanowires were used as a conductive component, and Polydimethylsiloxane (PDMS) was used as a flexible polymer matrix. Silver nanowires have been synthesized using a polyol process. Then the silver nanowires were characterized by scanning electron microscopy (SEM), and in length and <;100 nm in diameter. Their surface was smooth and uniform in diameter, and length to diameter ratio was up to 200.

A. Phinyomark, E. Scheme, “EMG pattern recognition in the era of big data and deep learning”, in Proc. IEEE/RSJ Int. Conf. Intel. Robots Syst., Chicago, IL, USA, Sep2020. The recognition of hand movements through electromyography signals (EMG) collected based on biosensors is a typical supervised pattern recognition problem. Moreover, effectively extracting spatial and temporal information from sensor temporal data has been a big challenge in machine learning and deep learning. When faced with high-dimensional small sample data, Machine Learning representation learning methods offer advantages over Deep Neural Networks. However, most machine learning approaches rely on feature extraction methods and do not have an advantage in the information extraction of temporal information. In contrast, temporally valid data can be better captured by neural networks. We propose a hybrid network of CNN-GRU and random forest based on existing methods. The CNN-GRU network will be used to fuse temporal and spatial information, and the random forest decision tree will guide the neural network in the lower layer of representation learning. This hybrid network captures the temporal and spatial information of the EMG signal verywell. We obtained an accuracy of 99.72% for the Basic Hand movements Data Set.

Chakraborty, S., Bhowmick, S. Talaga, P. and Agrawal, D.P, "Fog Networks in Healthcare Application," in Mobile Ad Hoc and Sensor Systems (MASS), IEEE International Conference, 2022. Fog computing is a recently proposed computing paradigm that extends Cloud computing and services to the edge of the network. The new features offered by fog computing (e.g., distributed analytics and edge intelligence), if successfully applied for time-sensitive healthcare applications, has great potential to accelerate the discovery of early notification of emergency situations to support smart decision making. While promising, how to design and develop real-world fog computing-based data monitoring systems is still an open question. As a first step to answer this question, in this research, we employ a fog-based cloud paradigm for time-sensitive medical applications and also propose to show the practical applicability and significance of such a novel system. The ubiquitous deployment of mobile and sensor devices is creating a new environment, namely the Internet of Things (IoT) that enables a wide range of future Internet applications. In this work, we present dynamic Fog, ahigh level programming model for time-sensitive applications that are geospatially distributed, large–scale, and latency–sensitive. We also analyze our fog model with healthcare data, more specifically with Heart Rate data that is one of the most time-sensitive medical data which deals with life and death situations.

D. Borthakur H. D., "Smart fog: Fog computing framework for unsupervised clustering analytics in wearable Internet of Things", IEEE Global Conference on Signal and Information Processing (GlobalSIP), (pp. 472-476). Montreal, QC, 2021. The increasing use of wearable's in smart telehealth systems led to the generation of large medical big data. Cloud and fog services leverage these data for assisting clinical procedures. IoT Healthcare has benefited from this large pool of generated data. This paper suggests the use of low-resource machine learning on Fog devices kept close to wearable's for smart telehealth. For traditional telecare systems, the signal processing and machine learning modules are deployed in the cloud that processes physiological data. This paper presents a Fog architecture that relies on unsupervised machine learning big data analysis for discovering patterns in physiological data. We developed a prototype using Intel Edison and Raspberry Pi that was tested on real-world pathological speech data from telemonitoring of patients with Parkinson's disease (PD). Proposed architecture employed machine learning for analysis of pathological speech data obtained from smart watches worn by the patients with PD. Results show that proposed architecture is promising for low-resource machine learning. It could be useful for other applications within wearable IoT for smart telehealth scenarios by translating machine learning approaches from the cloud backend to edge computing devices such as Fog.

Gia, T. N., Jiang, M. Rahmani, A. M. and Westerlund, T., "Fog computing in Healthcare Internet-of-Things: A Case Study on ECG Feature Extraction", IEEE International Conference on Computer and Information Technology, 2021. Internet of Things technology provides a competent and structured approach to improve the health and wellbeing of mankind. One of the feasible ways to offer healthcare services based on IoT is to monitor human's health in real-time using ubiquitous health monitoring systems which have the ability to acquire bio-signals from sensor nodes and send the data to the gateway via a particular wireless communication protocol. The real-time data is then transmitted to a remote cloud server for real-time processing, visualisation, and diagnosis. In this paper, we enhance such a health monitoring system by exploiting the concept of fog computing at smart gateways providing advanced techniques and services such as embedded data mining, distributed storage, and notification service at the edge of the network. Particularly, we choose Electrocardiogram (ECG) feature extraction as the case study as it plays an important role in diagnosis of many cardiac diseases. ECG signals are analyzed in smart gateways with features extracted including heart rate, P wave and T wave via a flexible template based on a lightweight wavelet transform mechanism.

Sun, G., Yu, F. X. Lei, X., Wang, Y. and Hu, H., "Research on Mobile Intelligent Medical Information System Based on the Internet of Things Technology," in Information Technology in Medicine and Education (ITME), IEEE International Conference, 2020. Research Purpose: Design a mobile intelligent medical information system based on the Internet of things technology. Proposed Methods: First, sort out the basic theory and research status through the literature research, including the Internet of things technology, mobile medical systems and smart hospitals. Then conduct on-site research through field visits, questionnaires, opinion evaluation and other methods, including hospital diagnosis and treatment process, charging process, hospital process and the function of the hospital information system. Finally, according to the survey results, use the method of software engineering to complete system requirement analysis and system design. Results: Based on the mobile phone near field wireless communication technology and indoor navigation technology, complete the various business processes carding, functional design, interface design and software and hardware environment support analysis.

LITERATURE SURVEY COMPARISON

The literature survey explores various advancements and applications in the fields of tactile sensing, wearable sensors, strain sensors, electromyography (EMG) pattern recognition, fog computing in healthcare, and internet-of-things (IoT) technologies in medical systems. Let's compare the key themes and findings across the selected papers:

Tenzer et al. (2014):
Topic: Development of tactile array sensors using MEMS barometers for robotics and human- interference applications. Highlights the construction of robust and inexpensive tactile sensors with excellent signal quality and spatial resolution.

Wang et al. (2020):
Topic: Design of liquid metal-based wearable tactile sensors for simultaneous temperature andcontact force sensing.
Discusses the fabrication of flexible and durable sensors with high sensitivity, suitable for applications in soft robotics and healthcare.

Choong et al. (2014):
Topic: Development of highly stretchable resistive pressure sensors using a conductive elastomeric composite. Focuses on flexible strain sensors with improved sensitivity, suitable for wearable health care products and IoT applications.

Phinyomark & Scheme (2020):
Topic: EMG pattern recognition using machine learning and deep learning techniques. Proposes a hybrid network of CNN-GRU and random forest for accurate hand movement recognition from EMG signals, achieving high accuracy.

Chakraborty et al. (2022):
Topic: Application of fog computing in healthcare for real-time data monitoring and analysis. Explores the use of fog computing for time-sensitive medical applications, particularly in earlynotification of emergency situations.

Borthakur & D. H. (2021):
Topic: Utilization of fog computing for unsupervised clustering analytics in wearable IoT devices for smart telehealth. Presents a fog computing framework for analyzing physiological data from wearable devices, demonstrating promising results for low-resource machine learning.

Gia et al. (2021):
Topic: Implementation of fog computing in healthcare IoT for ECG feature extraction. Discusses the use of fog computing for real-time analysis of ECG signals at the edge of the network, enabling distributed storage and advanced analytics.

Sun et al. (2020):
Topic: Design of a mobile intelligent medical information system based on IoT technology. Describes the development of a system utilizing IoT technology for various medical processes, including diagnosis, treatment, and hospital information management.

CONCLUSION

The wearable flexible solar-based jacket represents a groundbreaking advancement in wearable technology and energy harvesting. Its adaptability to diverse environmental conditions, efficient solar energy harnessing during the day, and effective energy management at night showcase its practicality. By powering health monitoring sensors and communication modules, it extends its impact beyond mere novelty, offering significant potential in healthcare and other sectors. In terms of performance, the jacket's ability to produce a maximum voltage of 45 V and generate 1282.57 mW of power under optimal outdoor conditions is noteworthy. This demonstrates its effectiveness in capturing solar energy, emphasizing its functionality in various settings. Moreover, the power management circuit's efficiency during nighttime conditions, yielding a voltage of 62 mV and power generation of 7.95 × 10^-5 mW at a 10 kΩ load, highlights its capability to operate with minimal available energy. These quantitative results underscore the jacket's potential to be a reliable power source for continuous health monitoring and alert systems. The successful integration of solar power generation, robust power efficiency design, and effective power management positions this jacket as a significant innovation in sustainable, wearable technology. Its impact extends beyond personal use, suggesting broader applications and implications for the future of wearable energy solutions.

REFERENCES

[1]. Atif Sardar Khan and Farid Ullah Khan, " A Wearable Solar Energy Harvesting Based Jacket With Maximum Power Point Tracking for Vital Health Monitoring Systems" IEEE Journal, vol.10, pp. 1-21, 09 November 2022.
[2]. W. Y. Toh, Y. K. Tan, W. S. Koh and L. Siek, "Autonomous wearable sensor nodes with flexible energy harvesting", *IEEE Sensors J.*, vol. 14, no. 7, pp. 2299-2306, Jul. 2014.
[3]. D. Dondi, A. Bertacchini, D. Brunelli, L. Larcher and L. Benini, "Modeling and optimization of a solar energy harvester system for self-powered wireless sensor networks", IEEE Trans. Ind. Electron., vol. 55, no. 7, pp. 2759-2766, Jul. 2008.
[4]. T. Sanislav, G. D. Mois, S. Zeadally and S. C. Folea, "Energy harvesting techniques for Internet of Things (IoT)", IEEE Access, vol. 9, pp. 39530-39549, 2021.
[5]. A. S. Khan and F. U. Khan, "Experimentation of a wearable self-powered jacket harvesting body heat for wearable device applications", *J. Sensors*, vol. 2021, pp. 1-22, Dec. 2021.
[6]. L.-Q. Tao, H. Tian, Y. Liu, Z.-Y. Ju, Y. Pang, Y.-Q. Chen, et al., "An intelligent artificial throat with sound-sensing ability based on laser induced graphene", *Nature Commun.*, vol. 8, no. 1, pp. 14579, Apr. 2017.
[7]. C. Beach and A. J. Casson, "Inertial kinetic energy harvesters for wearables: The benefits of energy harvesting at the foot", *IEEE Access*, vol. 8, pp. 208136-208148, 2020.
[8]. F. Shaikh, M. A. Meghani, V. Kuvar and S. Pappu, "Wearable navigation and assistive system for visually impaired", *Proc. 2nd Int. Conf. Trends Electron. Informat. (ICOEI)*, pp. 747-751, May 2018.
[9]. *A Brief Overview of Wearable Technology Market—Global Opportunity Analysis and Industry Forecast 2014–2022*, Dec. 2017
[10]. F. U. Khan and T. Ali, "A piezoelectric based energy harvester for simultaneous energy generation and vibration isolation", *Int. J. Energy Res.*, vol. 43, no. 11, pp. 5922-5931, Sep. 2019.

[11]. H. Sharma, A. Haque, and Z. Jaffery, ‘‘Modeling and optimisation of a solar energy harvesting system for wireless sensor network nodes,’’ J. Sensor Actuator Netw., vol. 7, no. 3, p. 40, Sep. 2018.
[12]. A. Castagnetti, A. Pegatoquet, C. Belleudy, and M. Auguin, ‘‘A framework for modeling and simulating energy harvesting WSN nodes with efficient power management policies,’’ EURASIP J. Embedded Syst., vol. 2012, no. 1, Dec. 2012.
[13]. A. S. Weddell, G. V. Merrett, and B. M. Al-Hashimi, ‘‘Ultra low-power photovoltaic MPPT technique for indoor and outdoor wireless sensor nodes,’’ in Proc. IEEE Conf. Design, Automat. Test Eur., Grenoble, France, Mar. 2011 12.Fitbit 2016 an Overview of Wearable Fitbit Watch, Dec. 2021
[14]. D. Brunelli, C. Moser, L. Thiele, and L. Benini, ‘‘Design of a solar-harvesting circuit for batteryless embedded systems,’’ IEEE Trans. Circuits Syst. I, Reg. Papers, vol. 56, no. 11, pp. 2519–2528, Nov. 2009
[15]. D. Dondi, A. Bertacchini, D. Brunelli, L. Larcher, and L. Benini, ‘‘Modeling and optimization of a solar energy harvester system for self-powered wireless sensor networks,’’ IEEE Trans. Ind. Electron., vol. 55, no. 7, pp. 2759–2766, Jul. 2008.