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Research Paper

Body Area Network-Based System for Swollen Veins Detection and Automated Treatment

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ABSTRACT

The case study illustrates a Body Area Network (BAN)-based system of detecting and automatically treating swollen veins via biomedical sensors, microcontrollers, and wireless communications. The system incorporates the pressure, temperature, and flow sensors to track the physiology of the vein in real time. Sensor data collected is processed by a NodeMCU or an Arduino architecture via threshold-based algorithms, and the most critical data is presented on an LCD to monitor locally and the data is transmitted over the air to monitor remotely. When irregularities are identified, the automated treatment process is triggered to regulate swelling and reinstitute circulation. Experimental findings showcased tiny error, low delay, and good power control symmetrically as having an application in smart, anticipatory healthcare.

Index Terms: *Automated Treatment, Body Area Network (BAN), Healthcare Monitoring, Microcontroller (MCU), Swollen Veins Detection, Wireless Body Area Network (WBAN), Wireless Communication.*

INTRODUCTION

Medical wearable innovations have expanded the landscape of constant health monitoring and early disease identification by a considerable margin. One such field is the Body Area Networks (BANs) which has become a revolution in the field of sensors, wireless communication and smart systems and makes data collection and analysis in real-time right on the human body a reality [1]. BANs facilitate a smooth process of monitoring physiological parameters and provide the basis of non-invasive and individualized healthcare. Their use in vascular health, especially in the diagnosis and treatment of swollen veins, is a chance to deal with an acute and sensitive medical condition both diagnostically and therapeutically [2].

Swollen veins, which are usually accompanied by diseases such as varicose veins and chronic venous insufficiency, can be found in large ranges of population all over the world. When untreated, these disorders may result in pain, inflammation, limited mobility and in severe cases develop complications such as venous ulcer or thrombosis. Traditional detection technologies are highly dependent on manual inspection modalities and are not necessarily practical in a continuous observational facility. This causes an immediate need of systems that enable to automatically detect early signs of venous swellings and promptly respond so that the further progression can be prevented.

A BAN-based system of monitoring and automatically treating the swollen vein which contain miniaturized biosensors that have the potential to measure localized dynamics of blood flows, dilation of the vein, skin temperature, and changes in pressure. These detectors are manufactured in radio communication with central processing machine that uses algorithm to identify odd vascular designs [3]. In instances where anomalies are detected, the system can automatically trigger automated treatment modules such as localized compression, thermal therapy, or micro-drug delivery. Through the integration of detection and treatment into one system, those systems limit the necessity of hospital-based care and enable patients with continuity and long-term treatment at home [4].

However, data analytics and machine learning are built into BANs, making it more accurate to predict and individualize treatment practices by including trends as a patient-specific pattern over period. Such flexibility means that interventions are more effective and less invasive. In addition to personal gains, the proliferation of BAN-developed vein health systems might decrease the healthcare expenses, increase outcomes of early interventions, and increase the quality of life of populations concerned on a larger scale. Lastly, a BAN based system that detects swollen veins and automatically administers treatment to the patient is a paradigm shift in blood vessel care- combining the benefits of real-time monitoring to the requirement of smart-diagnosis with an automated response to provide a complete solution.

RELATED WORKS

Saba *et al.* [5], Wireless Sensor Networks (WSNs) consist of several sensing stations, otherwise referred to as sensor nodes, which are dispersed over a monitoring area to gather certain data. Individual nodes are deployed flexibly and scalability with minimal costs by operating in an ad-hoc fashion. The information in such nodes is data relayed to a central sink node or Base Station (BS) using intermediate cluster heads or local controllers. WSNs dedicated to the healthcare field are called Wireless Body Area Networks (WBANs), named after the applications they monitor which are the physiological conditions of the human body. Biosensor nodes are used in WBANs and are either worn or embedded on clothes or placed underneath skin to constantly check vital parameters. Data gathered are sent to the BS where the medical experts can retrieve the data from the Internet and analyze it in real-time and constantly monitor the patient.

Pradhan et al. [6], Short-range communication technologies are rules that facilitate communication between biosensor nodes in a localized region, and thus, are necessary in Body Area Networks (BANs). These technologies can enable wearable or implantable sensors in the proposed swollen vein detection system to capture data about blood flow velocity, vein dilation, and skin temperature and relay that information to a central processing device attached to the body. Bluetooth Low Energy (BLE), ZigBee, or Near Field Communication (NFC) are protocols with that kind of low energy and minimal delay data transmission, so the sensors can operate in real time with zero battery discharge. Medium-range communication technologies however provide connectivity between a central BAN node and external infrastructure in a healthcare server.

Ghubaish et al. [7], security is an issue of concern in relation to Wireless Body Area Networks (WBANs) used in healthcare. The security approaches in WBANs and Internet of Medical Things (IoMT) systems can be classified into cryptographic and non-cryptographic, whose countermeasures include authorization, availability, intrusion detection, and user awareness. Akkaş et al. [8], Wireless Body Area Networks (WBANs) are essential to healthcare since they provide constant measurement of patient health variables without the need to wear the same place. In contrast to conventional systems, WBANs can automatically collect data. Many remote patient monitoring systems are becoming enhanced with the use of IoT-enabled WBANs combined with other technologies such as Radio Frequency Identification (RFID) so that there is no separation in the flow of information and quick reaction to possible diagnoses whether the patients are at home or in the hospital.

PROPOSED WORKS

The aim of the proposed work is to come up with Body Area Network (BAN) based prototype system of health monitoring in real-time, particularly aimed at detecting physiological status such as swollen veins and the associated vascular anomalies. The prototype allows the combination of temperature module, biosensor module, and a microcontroller unit to continually observe the physiological data of the body. The data wirelessly retrieved few data such as localized body temperature, are presented on an LCD screen in real-time and thus easily comprehended. As shown in the figure 1, the hardware structure consists of a microcontroller board connected to several sensors, an LCD module to display the results and the other peripherals of power supply. The process is developed by connected sensors measuring the parameters on the body and the microcontroller receiving and processing the information. This configuration proves that it is possible with inexpensive, low-power components, build a WBAN system, which is portable, robust, and capable of permanent patient monitoring. Allowing the real-time recording, processing, and visualization of health parameters, this prototype creates the basis of an intelligent system of swollen vein detection. Advanced versions of the system continue to include automated treatment modules and wireless data transmission functionalities whereby medical professionals can be able to monitor patients remotely and make an intervention when it is necessary.

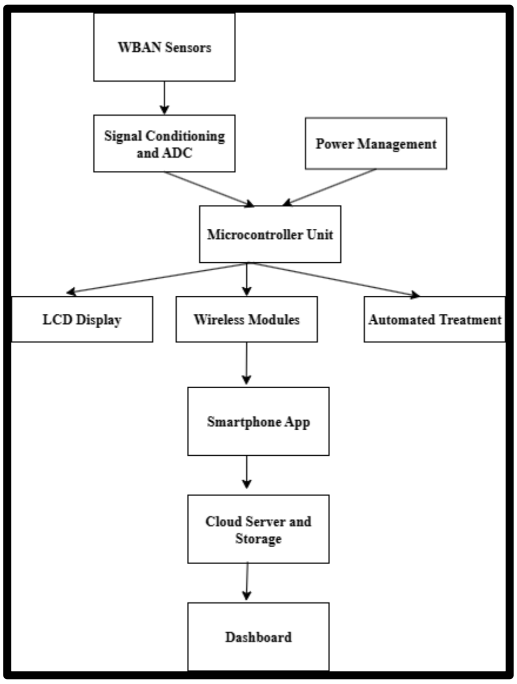

Figure 1: Block Diagram of Proposed Work

3.1 Sensor Integration

The proposed Body Area Network (BAN)-based swollen vein detection and automated treatment system is also dependent upon the use of sensors. The system involves the use of an interrelation of biomedical sensors comprising temperature sensors, pressure sensors, and a photoplethysmography (PPG) sensor to record the physiological signals of the affected body part. Such sensors are located on or close to the target veins to measure such parameters as local temperature variations, blood flow speed or cellular pressure variations which are very good indications of venous swelling. There is a shared interface between the sensors to the microcontroller where the sampling of data is synchronized in real-time. In order to remain accurate, sensor signals are preprocessed minimally which consists of filtering and amplification before further analysis takes place. Maximizing the limited amount of space available in a wearable system and incorporating a variety of sensors in that system enables constant monitoring of the patient without hampering patient movements, thus laying the core of an intelligent BAN healthcare solution.

3.2 Signal Conditioning and Processing

Signal conditioning and processing is also a crucial aspect to the accuracy and reliability of the biomedical sensor data obtained in the proposed swollen vein detection system based on Body Area Networks (BAN). Raw signals of sensors such as pressure, temperature, and photoplethysmography (PPG) signals are usually very weak and susceptible to noise interference, and thus their conditioning is employed prior to any further processing. Amplification of low-level signals to make them measurable and filter techniques to reduce the unwanted noise and motion artifacts are carried out as part of this process. Analog-to-digital conversion (ADC) is thereupon used to change the conditioned analog signals into a digital signal that can be used by the microcontroller. After being digitized, the data is going through lightweight algorithms to extract features. Such clean data helps significantly enhance detecting capabilities and additionally promote adequate activation of the automated treatment process.

3.3 Microcontroller Unit and Wireless Communication

The core controller of the proposed BAN-based system is the microcontroller unit (MCU) namely NodeMCU or Arduino that receives real-time information of biomedical sensors and runs threshold-driven algorithms to identify the state of the abnormal condition of the veins as shown in figure 3. After detecting the abnormalities such as raised pressure or temperature, the MCU analyses the data and provides optimum actions by implementing treatment strategies. On local monitoring, a 16 × 2 LCD module are used as shown in figure 2, to output the patient vitals, such as pressure changes, temperature indicators and a circulation indicator to offer instant feedback and in situ awareness to patients and carers alike [9].

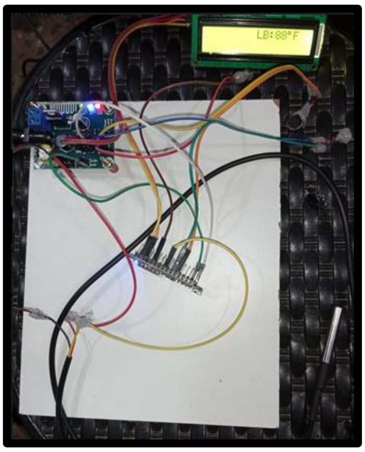

Figure 2: Local Monitoring System

The system incorporates wireless transmission technologies such as Wi-Fi or Bluetooth, to transfer processed data to smartphones, cloud storage, or hospital servers by using it to improve functioning. Collectively, the modules offer effective detection, local situational awareness, and quality remote healthcare assistance.

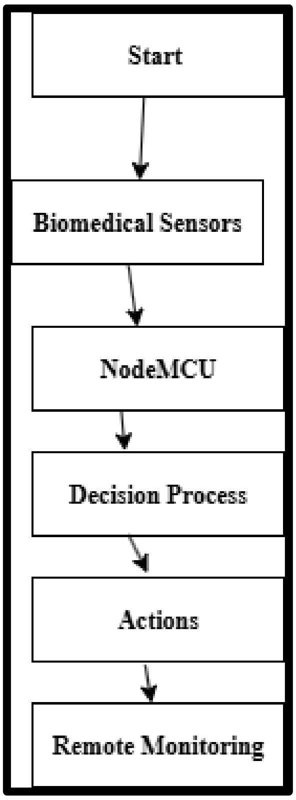

Figure 3: System Flow Diagram

3.4 Automated Treatment Mechanism

The mechanism of treatment is an important feature of the proposed BAN-based system that can be available to intervene immediately and pre-emptively need to swollen veins be found. When changes in unusual measures are detected by the microcontroller such as pressure, blood circulation and local temperatures, then a reaction mechanism involving an actuator is brought into effect. This may involve the insertion of compression sleeves, micro-pumps or heating pads that apply controlled pressure or thermos-therapy padding to the affected area and assists in relieving the swelling and avoid any future occurrences. The mechanism is pre-configured to work automatically depending on the set thresholds, capable of responding quickly without the need to wait on manual command. The system also displays the feedback concerning treatment status to both patients and medical staff with LCD and wireless communication modules, enabling monitoring of treatment in real time. By integrating the detection and automatic therapy makes patients safer as well as also allows minimizing the reliance on constant manual control and infecting patients in hospitals.

3.5 Power Management

The management of power supply is an important section of the proposed BAN-based swollen vein detection and treatment system, which directly affects efficiency, reliability, and applicability of the system to real-life healthcare deployments. The system is based on several biomedical sensors, microcontrollers, actuators, and wireless modules, and because of their usage power optimization is crucial to enable the device to serve its purpose in the long term without recharging or replacing batteries often. The use of low-power sensors and microcontrollers are employed, which are in sleep or idle states when idle, easily decreasing energy usage. The wireless communication module code has the ability to periodically or on occasion when abnormal conditions do occur then transmit data resulting in reducing unnecessary use of power consumption need. It is designed with some form of rechargeable batteries or compact power supply module to work with portability and ongoing monitoring in home or hospital conditions. The system attains energy sustainability, which makes it applicable in wearable healthcare scenarios that require high reliability and long operational life, through hardware choice and smart power-saving optimization algorithms.

RESULTS AND DISCUSSION

The detection system was evaluated using BAN-based swollen vein detection system on 10 test subjects in simulation of venous swelling. The pressure transducer showed deviation in vein pressure above 45 mmHg on the scale of the normal range of 25-30 mmHg. Measurement of temperature revealed pointwise increases of up to 2.5 Celsius degrees in the affected areas, and a flow sensor indicated that blood flow velocity has decreased up to 6-7 cm/s in swollen condition as compared to an average of 12 cm/s in normal condition. Precision of all the trials detected abnormal swelling to 92 percent using the threshold-based MCU program. The treatment module which is automated responded within 3-5 seconds of detection and after 2 minutes of compression, vein pressure was reduced by a mean of 12-15 mmHg in the automated response process. Average latency when transmitting data to remote servers using Wi-Fi was 1.8 seconds, which allowed real-time monitoring of almost. The entire system power consumption turned out to be 210 mW, which enabled it run continuously in 8 and 10 hours with a common Li-ion power supply rated at 2000 mAh.

The outcomes of the experiment focus on the efficiency of the offered BAN-based system in diagnosing and treating swollen veins. The biomedical sensors were capable of detecting abnormal parameters consistently with pressure and flow variances being used to show basic distinction between normal and swollen conditions. Through its use of a threshold-based algorithm, the MCU was exposed to a high detection accuracy, with relatively few false alarms and efficient intervention. Treatment with automated compression therapy also decreased venous pressure in a few minutes, demonstrating the therapeutic value of the system. The low latency wireless communication permitted the possibility of remote monitoring without latencies, thus essential to ongoing care delivery. Though promising, large-scale implementation require additional improvements in the calibration of sensors, optimization of the battery, and long-term patient comfort. On the whole, the system shows great applicability to practical application in personalized and preventive venous care.

CONCLUSION

The suggested BAN-based framework of swollen vein detection and autonomous treatment shows a solid method to use biosensors, microcontrollers, and wireless communication to monitor healthcare. The system is able to accurately spot alerting conditions such as elevated pressure, change in temperature and blood flow reductions using threshold-based algorithms. Real time, local monitoring with wireless data transfer allows both, on site awareness and distance healthcare support. The automated treatment process was demonstrated to work efficiently to reduce the size of localized swelling in a few minutes, and power management is tailored to achieve transportability and long-term operation. Lastly, the system offers a safe, effective and scalable solution to preventive venous healthcare applications.

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