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ECG T-SHIRT WITH ACTIVE ELECTRODES

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ABSTRACT –

ECG T-shirt is integrated electrodes for wireless monitoring of heart rate and muscular activity. The heart rate monitoring is not affected by the specific placement of the textile sensors as it can record ECG from various positions on the torso. This method minimizes the risk of data loss caused by issues in a single channel. We developed a multi-channel heartbeat detector that can handle disruptions or even missing ECG signals in individual channels. To record electromyographic signals, we currently utilize a padded structure placed above the trapezius muscle that houses commercially available dry electrodes. The additional padding around the electrode site ensures precise positioning of the electrodes and promotes local sweat production, thereby improving recording conditions. The T-shirt is equipped with a specially designed textile electrode system for seamless integration into clothing. While further enhancements are necessary, our goal is to make this textile T-shirt accessible to the research community soon. Apart from personal health monitoring, this system enables long-term monitoring of trapezius muscle activity and heart rate variability, providing insights into psychological stress levels. This feature is particularly valuable for studies on musculoskeletal disorders affecting the neck and shoulder.

Keywords -Electromyographi**c**, Integrated Electrodes, Musculoskeletal.

INTRODUCTION

Unobtrusive monitoring of vital signs, such as cardiac activity and respiration, has seen a rise in usage over the last decade. The aging population has led to an increased demand for medical attention, which cannot always be met. Consequently, there has been a surge in the development of personal healthcare systems to allow sick and elderly patients to remain at home for extended periods instead of enduring prolonged hospital stays. Patients benefit from enhanced comfort while at home, potentially speeding up their recovery process. This, in turn, reduces healthcare costs by shortening hospital stays. The primary motivation behind creating long-term monitoring solutions for home environments lies in these factors. The Holter is a well- established device for long-term cardiac monitoring. It is a portable electrocardiography (ECG) device equipped with up to 12 leads for extended use. Typically, these ECG recorders are utilized to diagnose cardiac conditions over several days, with patients wearing the device as they go about their daily activities.

Commercial Holter devices feature a portable ECG recorder with adhesive electrodes. However, these electrodes pose a significant issue: the gel used for conductivity can cause skin allergies. Furthermore, as the gel dries up over time, signal quality deteriorates, which is common during long-term monitoring. Additionally, in certain situations such as sweating, the electrodes may detach, necessitating reapplication.

Recent advancements in innovative textile materials and structures, along with advancements in communication technology, have paved the way for a new era of healthcare systems. Health monitoring is a prime example of an area where comprehensive research and development in wearable technology is being conducted. An early example of this is the Georgia Tech Wearable Motherboard, which was among the first health applications integrated into clothing. This motherboard establishes a system for soldiers that can alert and transmit vital sign information to medical triage. The sensors within the motherboard are linked to a personal status monitor. Another instance of a wearable computing health monitor is the Life Shirt, a versatile ambulatory system that monitors health, diseases, and medical interventions in real-world settings.

The demand for textile products that prioritize sustainability, flexibility, and washability has led to research focusing on integrating electronic functionality into textile structures. Several projects, such as Vtam, WEALTHY, research at Ghent University, and the Swedish School of Textiles, have demonstrated the integration of textile-based sensors for ECG recording.

Recent progress in wearable health systems has led to the development of various prototypes integrated with textile sensors. These systems provide mobile and adaptable monitoring for different user groups in healthcare, extreme work environments, sports, and more. Textile electrodes offer a pliable and gentle solution that can be seamlessly integrated into garments. However, intermittent disruptions are common in biomedical signals recorded using such solutions due to challenges in achieving optimal contact between the electrode and the skin, unlike with regular pre-gelled electrodes. To address these issues, a novel adaptive method for heartbeat detection has been implemented.

In addition, textile electrodes have been utilized for ECG data collection in research studies. It has been observed that certain dry textile electrodes can yield comparable outcomes to traditional electrodes in resting electrocardiography, although they may exhibit reduced signal quality during movement. However, the majority of dry electrodes exhibit high contact impedances when in contact with the skin. To enhance signal quality, active circuits with buffers are employed on the electrodes, creating an active electrode. An active electrode consists of a sensing component (conductive textile), front-end electronics, and shielding. The input impedance is significantly high, while the output impedance is low. This enables the output to drive a lengthy screened cable, thereby minimizing power lineinterference and cable movement.

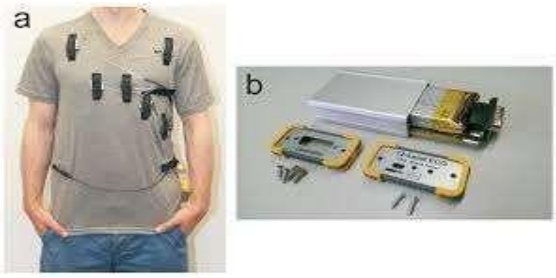

Figure: ECG T-Shirt with electrodes

LITERATURE SURVEY

Wireless monitoring of heart rate and electromyographic signals in ECG T-Shirt published by, J. Stefan Karlsson, Urban Wiklund, Lena Berglin, Marcus Karlson(2023). We have successfully created a prototype T-shirt that incorporates electrodes for wireless monitoring of heart rate and muscular activity. The heart rate monitoring is not affected by the specific placement of the textile sensors, as it can record ECG from various positions on the torso. This approach minimizes the risk of data loss caused by issues in a single channel. To ensure reliable detection of heartbeats, we have developed a multi-channel heartbeat detector that can handle disturbances or even missing ECG signals in individual channels. For capturing electromyographic signals, our current solution involves using commercially available dry electrodes housed in a padded structure above the trapeziusmuscle.

ECG T-Shirt with active electrodes published by, Bhagyashree J. Bhoyar, Smita R. Londhe(2023) We have designed an ECG T-shirt that includes a portable recorder for inconspicuous and extended multichannel ECG monitoring using active electrodes. Traditional 12-lead ECGs typically involve uncomfortable adhesive gel electrodes that can lead to skin irritations and allergic reactions over time. To address this issue, we have incorporated comfortable patches made of conductive textile into the ECG T-shirt to replace the adhesive gel electrodes. Additionally, to enhance signal quality and prevent signal degradation, we have included active circuits on the exterior of the T-shirt in conjunction with the dry electrodes. Our ECG T-shirt was tested against a commercial Holter ECG with healthy volunteers in various positions such as lying down, sitting, and walking.

Wearable Measurement of ECG Signals Based on Smart Clothing published by Ming Li, Wei Xiong, and Yongjian Li(2022). The increasing aging population necessitates the development of smart clothing that can monitor the health status of individuals by measuring electrocardiogram (ECG) signals. However, the conventional method of measuring ECG signals is complex and can cause skin irritation due to the use of electrodes. This makes it unsuitable for integration into smart clothing. This research proposes a new approach to measuring ECG signals using wearable technology. The fabric of the smart clothing is embedded with only three ECG textile electrodes. These electrodes capture the ECG signals, which can then be transmitted to a smartphone via Bluetooth.

TECHNOLOGIES USED IN ECG T-SHIRTECG AND EMG RECORDINGS

Three ECG and two EMG channels were recorded at a sampling rate of 1 kHz, utilizing a wireless multichannel data acquisition system (Fig. 2) [12]. To eliminate baseline drift, an analogue high-pass filter at 0.1 Hz was applied. Furthermore, the EMG signals underwent digital high-pass filtering at 20Hz to eliminate potential movement artifacts in the low-frequency range. The ECG was measured in a bipolar manner with textile electrodes positioned on the chest. The surface EMG signal was captured from the right upper trapezius muscles using commercially available dry electrodes (Roessingh Research and Development, Enschede, The Netherlands), spaced 20 mm apart on a T-shirt. Conventional, pre-gelled Ag-AgCl electrodes (Medicotest, Ølstykke, Denmark) were positioned 20 mm apart (center-to- center distance) alongside the dry electrodes to obtain a traditional EMG for comparison purposes. These electrodes were placed at a point two-thirds of the distance from the spinous process of the seventh cervical vertebra (C7) to the lateral edge of the acromion. A large textile electrode situated at the back served as a reference electrode for both sets of electrodes. Prior to measurement, a test contraction was performed to ensure optimal electrode-skin contact in both scenarios.

Muscle activity was normalized to a specific effort level by having the subject stretch both arms at a 90-degree angle in the coronal plane, serving as a reference contraction. The myoelectric activity recorded during this reference contraction is referred to as RVE (reference voluntary electrically activation) and is estimated to correspond to approximately 10% of the maximal voluntary contraction (MVC).

Figure2: ECG and EMG Recordings

DATA PROCESSING

1. ECG Heartbeat detection

Our multichannel approach is based on the concept of designing a filter that produces output signals with distinct peaks at the time instances when the ECG QRS complexes occur, while maintaining values close to zero elsewhere. In this signal, the majority of data points have amplitudes close to zero, while the peaks have significantly larger values and appear as a prominent tail in the histogram, exhibiting a super gaussian distribution. The primary objective of the filter is to maximize the super gaussianity of the output signal. To achieve this, an adaptive multichannel filter that combines both spatial and temporal filtering techniques was utilized [10].

To ensure stability, the algorithm employed high-pass filtering on the input signals to suppress baseline drift. Additionally, the signals were normalized to have a zero mean and unit variance. internet of Things (IoT) and wearable's have emerged as essential technologies for integrating AI into healthcare practice. Numerous advantages are provided by these technology, including real-time data collection, ongoing health monitoring.

2. EMG Exposure variation analysis

To quantify the EMG activity, an Exposure Variation Analysis (EVA) was conducted based on the method proposed by Mathiassen and Winkel [13]. The EMG signals were filtered using an RMS filter with a moving average window of 0.1 s and normalized to the corresponding RVEs. Subsequently, the signals were averaged in consecutive intervals of 1/3 s and categorized based on the duration of uninterrupted intervals spent in specific amplitude levels. The signals were categorized into periods of 0- 0.3-1-3-7-15 s and amplitude levels of 0-1-3.3-10-23.3-50-103.3-210% RVE. This resulted in a matrix where each element represented the percentage of time in a "period per amplitude category" (Fig. 3). The categories were arranged logarithmically to enhance sensitivity to variations at low amplitude levels with short period lengths. Plotting the EVA matrix yielded a three- dimensional representation of EMG activity, with each colu

indicating the percentage of total time spent in each level per period category. Brief, unconscious interruptions in EMG activity, referred to as "gaps," occur when the EMG activity is less than 0.5% MVC. Short gaps are interruptions lasting between 0.2-0.6 s, while long gaps are interruptions lasting longer than 0.6 s. In the EVA matrix, gap levels are represented by the shaded elements in the lowest amplitude level (0-1% RVE), corresponding to periods of 0.3 s or longer.

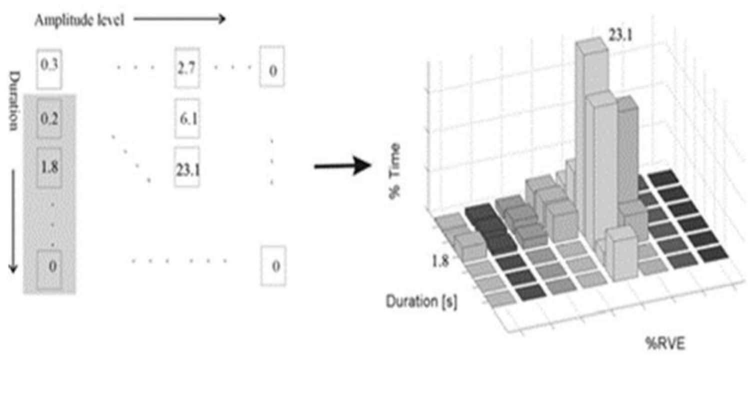

Figure3: EMG Variation analysis

BLUETOOTH TECHNOLOGY

A smartphone-installed mobile application can receive and showcase ECG data sent by an ECG T-shirt through Bluetooth technology. This integration allows for wireless communication between the T-shirt and other devices like smartphones or tablets. The ECG T-shirt has electrodes woven into the fabric to monitor the heart's electrical activity. By utilizing Bluetooth technology, the ECG data collected by these electrodes can be wirelessly transmitted to a mobile device or a specific receiver. Bluetooth Low Energy (BLE) is ideal for ECG T-shirts due to its minimal power consumption. Given that the shirt is worn for extended periods, reducing power usage helps prolong battery life, ensuring prolonged operation without frequent recharging. This application may provide functions such as real-time heart rate monitoring, ECG waveformvisualization, storage of historical data, and alerts for irregular cardiac rhythms.

Figure4: Bluetooth technology

SIGNAL ACQUISITION

The ECG T-shirt is equipped with strategically placed electrodes on the chest area, which are typically made of conductive materials and directly touch the wearer's skin. When the wearer puts on the ECG T-shirt, the electrodes establish contact with their skin, ensuring accurate signal acquisition. During each heartbeat, the heart produces electrical signals as it contracts and relaxes. These signals travel through the body and can be detected by the chest electrodes. The conductive pathways provided by the fabric of the shirt allow the electrical signals to effectively transmit from the electrodes to the signal processing components of the ECG T-shirt. The fabric's conductive properties enable efficient signal transmission. Once captured by the electrodes, the electrical signals are usually amplified and filtered by the integrated signal conditioning circuitry of the ECG T-shirt. This process enhances signal quality by reducing noise and interference.

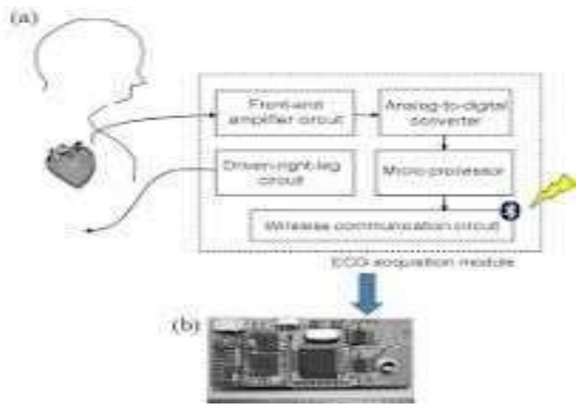

Figure4: Signal acquisition in ECG T-Shirt

APPLICATIONS

- Health and fitness tracking
- Screening for cardiac health
- Monitoring at home for chronic conditions
- Remote patient monitoring and telemedicine

ADVANTAGES

- The ECG signal in its raw form, depicted as a waveform, can be viewed on a screen, either directly on the ECG T-shirt device or on a connected smartphone, tablet, or computer.
- The heart rate is typically determined by analyzing the time intervals between consecutive R waves in the QRS complex.
- Through algorithms, the ECG waveform is examined to identify R peaks and calculate the time gap between them, which is then used to derive the heart rate.
- Various signal processing techniques can be utilized to improve the quality of the ECG signal, eliminate noise, and rectify any artifacts. ECG data has the option to be stored locally on the device or transferred to a cloud-based platform for prolonged storage and accessibility.

CONCLUSION

The emergence of ECG T-shirts signifies a significant breakthrough in wearable health technology. These garments are equipped with sensors that constantly track the wearer's heart activity, providing valuable information for both medical professionals and individuals. A key finding from the use of ECG T-shirts is their ability to transform remote patient monitoring and preventive healthcare. By seamlessly integrating into everyday clothing, these shirts offer a non-intrusive method of monitoring heart health, enabling early detection of irregularities or abnormalities. This proactive approach can result in timely interventions, potentially averting severe cardiovascular incidents. Moreover, ECG T-shirts hold promise in enhancing the monitoring of athletic performance. Athletes and fitness enthusiasts can benefit from real-time heart rate data,

allowing them to optimize their training routines and prevent overexertion or injuries. However, challenges persist in ensuring the accuracy, reliability, and comfort of these wearable devices. Progress in sensor technology and material science is imperative to address these concerns comprehensively. Additionally, issues concerning data privacy and security must be carefully tackled to establish user trust and compliance. In conclusion, ECG T-shirts represent an exciting fusion of fashion and healthcare technology, with the potential to revolutionize the way we monitor and manage heart health. Continued research and development are crucial to unlock their full potential and overcome remaining obstacles.

FUTURE SCOPE

Future iterations of ECG T-shirts could potentially include even smaller and lighter components, facilitating the seamless integration of electrodes and monitoring electronics into everyday clothing. Progress in sensor technology, like flexible and stretchable electronics, nanomaterials, and bio-compatible sensors, might pave the way for ECG T-shirts with enhanced sensing capabilities and signal accuracy. Additionally, upcoming ECG T-shirts may integrate extra sensors to support multimodal biometric monitoring, merging ECG data with various physiological parameters such as blood pressure, respiration rate, temperature, and movement. The incorporation of artificial intelligence (AI) and machine learning algorithms into ECG T-shirts is expected to enable real-time analysis of ECG data, automated detection of irregularities, and personalized insights into heart health and patient communications and clinical note capture.

REFERENCES :

[1] S. Park, K. Mackenzie, and S. Jayaraman, “The wearable motherboard: A Framework for Personalized Mobile Information Processing (PMIP),” in Proc. of 39th Design Automation Conference, DAC, 2024, New Orleans, Louisiana,USA.

[2] P. Grossman, “The Lifeshirt: A multi-function ambulatorysystem that monitors health, disease, and medical intervention in the real world,“ in Proc. of New generation of Wearable Systems for ehealth, International Workshop, 2024, Tuscany, Italy.

[3] J-L. Weber, D. Blanc, B. Comer, C. Corroy, N. Noury, R. Baghai, S. Vaysse, and A. Blinowska, “Telemonitoring of vitalParameters with newly designed biomedical clothing VTAM,”in Proc. of New generation of Wearable Systems for health, International Workshop, 2024, Tuscany, Italy.

[4] R. Paradiso, G. Loriga, M. Pacelli, and R. Orselli, “Wearable system for vital signs monitoring,” in Proc. of Newgeneration of Wearable Systems for health, International Workshop, 2023, Tuscany, Italy.

[5] C. Hertleer, M. Grabowska, L. van Langenhove, B. Hermans, R. Puers, A. Kalmar, H. van Egmond, and D. Matthys, “The use of electroconductive textile material for the development of a smart suit,” in Proc. World Textile Confernce – 4th AUTEX Conference, 2023, Roubaix, France.

[6] L. Berglin, M. Ekström, and M. Lindén, “Monitoringhealth and activity by Smartwear,” in Proc. of 13th Nordic Baltic Conf on Biomed Eng and Med Phys, 2023, Umeå,Sweden.

[7] M. Pacelli, G. Loriga, N. Taccini, and R. Paradiso, “Sensing Fabrics for Monitoring Physiological and Biomechanical Variables: E-textile solutions,” in Proc. of the 3rd IEEE-EMBS. International Summer School and Symposium on Medical Devices and Biosensors, 2023, MIT, Boston, USA.

[8] M. Di Rienzo, F. Rizzo, G. Parati, G. Brambilla, M. Ferratini, P. Castiglioni, “MagIC System: a New Textile-Based Wearable Device for biological Signal Monitoring. Applicability in Daily Life and Clinical Setting,” in Proc. of the 2005 IEEE Engineering in Medicine and Biology 27th Annual Conference, 2023, Shanghai, China.

[9] L. Sandsjö, L. Berglin, U. Wiklund, K. Lindecrantz, and JS. Karlsson, "Self-administered long-term ambulatory monitoring of electrophysiological signals based on smart textiles,"in Proc. IEA, 2022, Maastricht, Netherlands.

[10][10]U. Wiklund, M. Karlsson, N. Östlund, L. Berglin, K. Lindecrantz, S. Karlsson, and L. Sandsjö, "Adaptive spatio- temporal filtering of disturbed ECGs: a multi-channel approach toheartbeat detection in smart clothing," Med. Biol. Eng. Comput., vol. 45, pp. 515–523, 2022.