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Research on Key Technologies of Wearable Epilepsy Seizure Monitoring and Alarm Devices

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Abstract. Epilepsy is a common and frequently occurring disease of the nervous system. Long term recurrent epileptic seizures seriously endanger the physical and mental health of patients, and also have profound impacts on families and society. In response to the above situation, this article aims to develop a wearable epilepsy seizure monitoring and alarm device ENP-V2 to help patients monitor seizures in real time and alert them, for the following aims:(1) Reduce the sudden death rate of epilepsy; (2) Promptly detect status epilepticus and urgently seek medical attention; (3) Reduce secondary damage caused by epileptic seizures and improve patients' quality of life; (4) Provide accurate seizure information for clinical practice and achieve precise diagnosis. Experiments on clinical data collected from Xuanwu Hospital demonstrate the performance of the proposed wearable epilepsy seizure monitoring and alarm device ENP-V2.

Keywords: Epilepsy, intelligent monitoring, wearable intelligent device.

1. Introduction

Epilepsy is a common and frequently occurring disease of the nervous system [5]. There are 60 million epilepsy patients worldwide, with over 10 million epilepsy patients in China. Every year, there are 400000 new patients and 6-7 million active epilepsy patients in China [12]. Long term recurrent epileptic seizures seriously endanger the physical and mental health of patients, and also have profound impacts on families and society. Despite the increasing availability of antiepileptic drugs on the market, there is still no significant improvement in the effective control rate of epilepsy. About 30% of patients are still resistant to multiple drugs, which belongs to chronic intractable epilepsy. The biggest danger of epileptic seizures lies in their unpredictability. During repeated epileptic seizures, patients often lose consciousness. If there is no guardian nearby, it may cause many secondary injuries, such as falls, burns, tongue bites, etc. In severe cases, they may even lose their lives, leading to sudden death, status epilepticus, and accidental death [9].

Sudden unexpected death in epilepsy (SUDEP) is a non-traumatic and non-drowning death that occurs unexpectedly or purposelessly in epilepsy patients, often associated with epileptic seizures. Sudden death from epilepsy is second only to stroke in terms of potential years of life loss in neurological diseases, and poses great harm to patients and their families. In the population with chronic intractable epilepsy, sudden death from epilepsy is the most common cause of death, with an incidence rate of 1.1-5.9/1000 person years, accounting for 10-50% of all causes of death; In epilepsy patients with surgical indications or those who still have seizures after surgery, the incidence rate is as high as 6.3-9.3/1000 person years. A cohort study in the UK found that the cumulative risk of sudden death in children with epilepsy within 40 years is 7-12%; Another study showed that out of 1200 epilepsy related deaths within a year, sudden death from epilepsy accounted for 500 cases [11].

The mechanism of sudden death due to epilepsy is complex. Currently, it is believed that sudden death due to epilepsy mainly occurs after generalized tonic clonic seizures (GTCS). The seizures lead to low ventilation and/or asphyxia, accompanied by normal arousal dysfunction, while prone position exacerbates hypoxia, resulting in spontaneous autonomic dysfunction and death. In order to reduce the occurrence of sudden death from epilepsy, the "Incidence and Risk Factors of Sudden Accidental Death from Epilepsy" practice guidelines jointly released by the American Academy of Neurology (AAN) and the American Epilepsy Society (AES) in 2017 pointed out that using monitoring equipment, timely alerting and notifying relevant personnel during epileptic seizures, and taking corresponding measures to reduce respiratory dysfunction and hypoxemia are currently the only confirmed and effective methods to reduce the occurrence of sudden death from epilepsy. In addition, after a seizure, secondary injuries such as suffocation and trauma may occur before the patient's consciousness is fully restored. Some seizures may recur and evolve into a state of sustained epilepsy, which seriously endangers the patient's health. Therefore, timely reporting to the police and notifying the patient's family may minimize the risk [9].

On the other hand, only by recording and summarizing these epileptic seizure information as detailed as possible can the most effective reference be provided for medical treatment, so that doctors can make accurate judgments on the condition as soon as possible and provide the best treatment plan. However, despite the importance of epilepsy logs for patient treatment, there is currently a lack of unified standards and convenient tools. Patients have weak compliance and cannot cooperate well with doctor requirements, resulting in non-standard records, incomplete content, and weak readability. However, the symptoms of epileptic seizures are invisible and intangible, and seeking medical attention mainly relies on the patient's description of the seizure symptoms and medical history. Most patients with epilepsy have unclear consciousness during seizures, and it is difficult to have detailed memory of the seizure afterwards. Without detailed seizure logs or close observation by family members, it is difficult to provide accurate and detailed medical information when seeking medical treatment. This makes it difficult for doctors to quickly, comprehensively, and accurately understand the patient's medical history and provide targeted treatment advice [1].

This article aims to address the above two issues by designing and developing a new wearable epileptic seizure monitoring and alarm device EMP-V2. Patients can identify epileptic seizures by wearing this device and notify their families through phone and text messages. At the same time, EMP-V2 can automatically record and synchronize each monitored epileptic seizure information to the epilepsy log management software, supplemented by manual information supplementation, to form a complete and detailed epileptic seizure information record, and achieve real-time data statistical analysis to analyze the relationship between the patient's condition at each stage and related triggering factors, medication types and doses, medication time and seizure time, etc., presenting accurate and detailed data for patients to seek medical treatment, facilitating doctors to adopt precise personalized treatment, and maximizing the effectiveness of patients.

The EMP-V2 studied in this project will introduce a closed-loop machine learning algorithm with the ability to learn autonomously. Without human intervention, it can automatically track and statistically analyze the patient's usage effects, and adjust the algorithm's model and parameters accordingly based on the patient's actions during use, achieving greater accuracy as it is applied. And compared to FDA approved Embrace devices, it has the following three major advantages: (1) Separate from mobile phones for independent use, suitable for China's national conditions; (2) By adding electromyographic sensors, more relevant indicators can be monitored, theoretically resulting in higher accuracy and applicability to a wider range of types of epileptic seizures; (3) Connect the electronic medical record system to record, summarize, and analyze the patient's condition, achieving precise diagnosis and treatment. It can be expected to archiving the following aims by developing a wearable epilepsy seizure monitoring device to help patients monitor seizures in real time and alert them: (1) Reduce the sudden death rate of epilepsy; (2) Promptly detect status epilepticus and urgently seek medical attention; (3) Reduce secondary damage caused by epileptic seizures and improve patients' quality of life; (4) Provide accurate seizure information for clinical practice and achieve precise diagnosis.

2. Related Work

The international attention to wearable seizure monitoring devices is increasing. In the 72nd Annual Meeting of the American Epilepsy Society (AES) held in 2018, a special topic was set up to discuss "How to choose and use wearable devices to monitor seizures". American scholars believe that the future trend of epilepsy rescue treatment is to integrate devices for predicting and monitoring epileptic seizures with rapid treatment methods, with the former achieved through wearable devices [1].

At present, there are three main wearable devices for monitoring epileptic seizures internationally, including: 1. Smart Watch/EMG BrainSentinel for monitoring seizure movement and electromyographic activity; 2. Embrace for monitoring skin electrical activity, and 3. EpiWatch for monitoring heart movement and responsiveness. The Embrace product developed by the MIT team has been industrialized and approved by the US FDA in 2018 for monitoring a highly dangerous type of epileptic seizure (GTCS). This is the first smartwatch approved by the US FDA for use in the field of neurology. These devices worn on patients can collect real-time physiological parameters such as electrocardiogram, respiration, movement, skin electrical activity, and electromyography. Through these data, the number of epileptic seizures can be accurately calculated to optimize treatment; Developing family based epilepsy monitoring; Trigger alarms/notifications, promptly notify family members/neighbors/doctors to make corresponding medical treatment; Capture the characteristics of epileptic seizures; Identify risk factors for sudden death from epilepsy (SUDEP); Restore cardiopulmonary arrest induced by epileptic seizures; Obtain dynamic information on epilepsy recurrence to optimize treatment and predict epileptic seizures.

A study conducted by the University of Tennessee and Stanford University evaluated the functionality of SmartWatch in monitoring epileptic seizures. The research results from Stanford University show that the Smart Watch has a recognition rate of 92.3% for generalized tonic clonic seizures (GTCS), accompanied by a high seizure false alarm rate of 87%; The research results from the University of Tennessee showed that the recognition rate of SmartWatch for generalized tonic clonic seizures was 31%, and the false positive rate of seizures was reduced to 0%. In addition, this type of detection device is expected to reduce the incidence of sudden epileptic death (SUDEP). Sudden epileptic death is usually secondary to tonic clonic seizures, especially during nighttime seizures. Detection by epilepsy monitoring devices can help guardians detect patients' nighttime spastic seizures in a timely manner, avoid ventricular death by correcting the patient's position in a timely manner, and intervene with cardiopulmonary resuscitation in a timely manner to reduce the occurrence of SUDEP [9,11].

Wearable epilepsy seizure monitoring device is the crossing field of medical field [13], Internet of Things (IoT) [2], and cloud computing [6]. At present, the main problem with this type of epilepsy monitoring device is that different types of seizures have different clinical manifestations, and any wearable monitoring device cannot detect all types of seizures. The way to adapt is to develop corresponding monitoring devices based on the characteristics of different types of seizures. Artificial intelligence technologies, which can automatically learn how to adapt, can be a promising direction for epilepsy monitoring [10,4]. Deep learning, as one of the most important artificial intelligence technologies, has achieved different success in fields including clustering [7], semantic mining [3], and enterprise management [8]. However, due to its "black box" nature, wide application of deep learning may be still too early to make sure medical safety before its interpretability has a great progress. In addition, in recent years, there have been reports on the development of portable epilepsy monitoring devices in China, but ultimately, due to the failure to break through core technologies such as sensors, processing technology, and artificial intelligence algorithms, they have not been truly commercialized or industrialized.

3. Methodology

The proposed wearable epilepsy seizure monitoring and alarm device ENP-V2 is shown in Figure 1. It can monitor abnormal body movements in real time, alert guardians, and reduce secondary injuries. At the same time, the identified epileptic seizure events can be automatically recorded, including the duration and severity of the seizures, forming a report to assist doctors in accurate diagnosis and treatment, as shown in Figure 2. The detailed design of ENP-V2 is listed in the following subsections.

Fig. 1: The proposed wearable epilepsy seizure monitoring and alarm device ENP-V2.

3.1. Hardware Design

The hardware part of EPM-V2 consists of a wristband and a host. The wristband contains skin electric wires sensors, epidermal electromyography sensors, acceleration sensors, angle sensors, and body temperature sensors, which is responsible for collecting relevant biological signals and sending them to the host. The host's functions include: (1) real-time discrimination and analysis of the collected signals, (2) making different responses based on the discrimination results, (3) if it is epilepsy, triggering the alarm process and automatically recording occurrence events, (4) compressing and uploading locally collected biological signals to the cloud, and (5) medication reminders for patients. On the basis of the hardware part, the software part of EPM-V2, i.e., the epilepsy seizure monitoring algorithm can work well.

3.2. Epilepsy Seizure Monitoring Algorithm

The epilepsy monitoring algorithm is the core of epilepsy seizure monitoring equipment and also a difficult point in the development process. ENP-V2 collects real-time wrist shaking data from the wearer, marks accurate alarms, missed alarms, false alarms, and other events by the wearer, and uploads them to the cloud. Due to the different

Fig. 2: The functions of ENP-V2.

seizure manifestations of different wearers, and the different seizure manifestations of the same wearer at different stages of illness, the cloud server uses self-developed patented methods to learn and record its own epilepsy seizures based on the data and marks, and can adapt to changes in the patient's epilepsy condition.

Automatic Data Collection and Preprocessing Based on the labeling of events such as accurate alarms, missed alarms, and false alarms, corresponding sensor data can be automatically collected and read, and the data can be preprocessed in segments of a certain length. Based on the consideration of reducing computational complexity and improving subsequent operational accuracy, ENP-V2 distinguishes between motion and rest modes, and performs simple discrimination after data filtering. Relevant data has been excluded, avoiding situations where the amplitude of the action is too low, the action is intermittent, the directionality and correlation of the action are significantly different from epilepsy, the frequency or ratio of each frequency component of the action is significantly different from epilepsy, and the main frequency range or periodicity of the action is significantly different from the data corresponding to epilepsy and entering subsequent operations, as shown in Figure **??**.

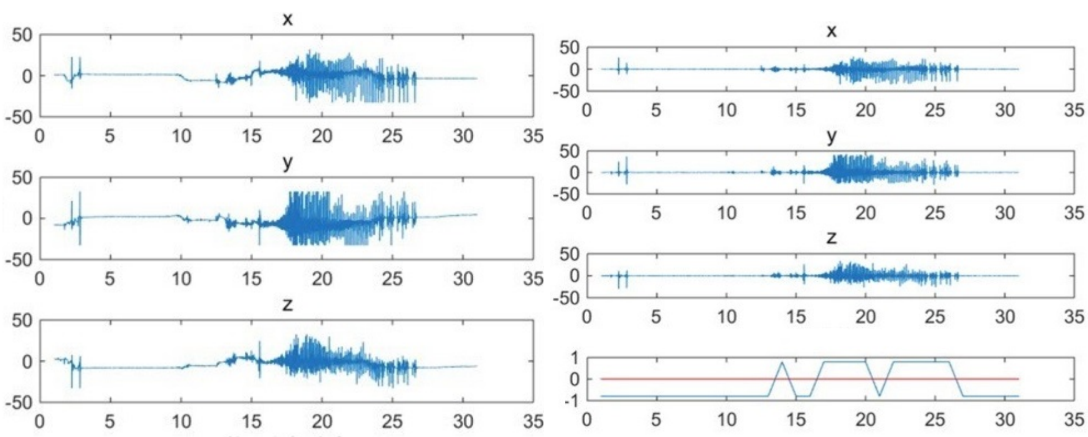

Fig. 3: Automatic collected (left) and preprocessed (right) original data of epileptic seizures.

Feature Calculation Feature parameter extraction is a crucial step in autonomous learning. ENP-V2 uses extracted feature parameters of the data as inputs for self-learning, and extracts more than ten types of feature parameters with different physical meanings in the time and frequency domains for each segment of data to ensure that the data can be comprehensively and effectively described.

Self Learning and Automatic Device Updates ENP-V2 inputs the results of feature calculation into the automatic training model in the form of a matrix, and generates parameter files related to the rules used to determine whether epilepsy has occurred. Update the results of self-learning (generated parameters) on the device side, continue to collect data, and mark events such as accurate alarms, missed alarms, and false alarms. Repeat the above four steps in this way to achieve more comprehensive and accurate recording of epileptic seizures for individuals.

4. Clinical Data Validation

A validation of the effectiveness of ENP-V2 was conducted on patients hospitalized at Xuanwu Hospital who underwent long-term video EEG monitoring. The experiment included 23 GTCS seizures in 17 epilepsy patients. The monitoring results were compared and analyzed with the video EEG results. To further increase the difficulty, 9 healthy individuals conducted a 10 day wearing experiment. From the data collected from 26 enrolled individuals, ENP-V2 identified 22 epileptic seizures, as shown in Figure 4. Only an epileptic seizure from the twelfth patient was not identified and blacked in Figure 4.

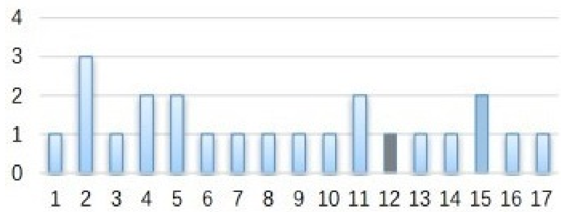

Fig. 4: ENP-V2 identified 22 epileptic seizures for total 23 epileptic seizures in 17 epilepsy patients. The

5. Conclusion

Epilepsy is a common and frequently occurring disease of the nervous system. In this paper, a wearable epilepsy seizure monitoring and alarm device ENP-V2 is developed to help patients monitor seizures in real time and alert them. Experiments on clinical data collected from Xuanwu Hospital demonstrate the performance of the proposed wearable epilepsy seizure monitoring and alarm device ENP-V2.

However, there are still some shortcomings of ENP-V2 due to its pioneering exploration research on wearable epilepsy seizure monitoring and alarm. For example, the scale of current clinical data validation is still small, more large scale experiments are needed for more accurate performance validation of ENP-V2. In addition, due to the epilepsy's hazards to people's life and health, compared to avoiding false alarms, making sure all epilepsy seizures are alarmed may be a more important aim. In future researches, these shortcomings will be addressed.

6. Conflict of Interest

The authors declare that there are no conflict of interests, we do not have any possible conflicts of interest.

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References

1. Donner, E., Devinsky, O., Friedman, D.: Wearable digital health technology for epilepsy. The New England Journal of Medicine 390(8), 736–745 (2024)

2. Gao, J., Li, P., Laghari, A.A., Srivastava, G., Gadekallu, T.R., Abbas, S., Zhang, J.: Incomplete multiview clustering via semidiscrete optimal transport for multimedia data mining in IoT. ACM Transactions on Multimedia Computing, Communications and Applications 20(6), 158:1–158:20 (2024)
3. Gao, J., Liu, M., Li, P., Zhang, J., Chen, Z.: Deep multiview adaptive clustering with semantic invariance. IEEE Transactions on Neural Networks and Learning Systems 35(9), 12965–12978 (2024)
4. Han, K., Liu, C., Friedman, D.: Artificial intelligence/machine learning for epilepsy and seizure diagnosis. Epilepsy and Behavior 155, 109736 (2024)
5. Klein, P., Kaminski, R.M., Koepp, M., Lscher, W.: New epilepsy therapies in development. Nature Reviews Drug Discovery 23, 682–708 (2024)
6. Li, P., Chen, Z., Yang, L.T., Zhao, L., Zhang, Q.: A privacy-preserving high-order neuro-fuzzy c-means algorithm with cloud computing. Neurocomputing 256, 82–89 (2017)
7. Li, P., Gao, J., Zhang, J., Jin, S., Chen, Z.: Deep reinforcement clustering. IEEE Transactions on Multimedia 25, 8183–8193 (2023)
8. Li, P., Laghari, A.A., Rashid, M., Gao, J., Gadekallu, T.R., Javed, A.R., Yin, S.: A deep multimodal adversarial cycle-consistent network for smart enterprise system. IEEE Transactions on Industrial Informatics 19(1), 693–702 (2023)
9. Li, R., Zhao, D., Hu, B., Li, N., Li, J., Lin, W.: Incidence and risk factors of sudden unexpected death in epilepsy in rural northeast China. Seizure: European Journal of Epilepsy 126, 99–105 (2025)
10. Lucas, A., Revell, A., Davis, K.A.: Artificial intelligence in epilepsy – Applications and pathways to the clinic. Nature Reviews Neurology 20, 319–336 (2024)
11. Wang, Y., Luo, L., Li, H., Li, M., Huang, Y., Huang, Y., Luo, G., Liu, M.: Clinical profile, management and risk factors for seizure-related burn injuries among patients with epilepsy in southwest China. Heliyon 10(1), e23908 (2024)
12. Yang, Y., Wei, P., Shi, J., Mao, Y., Zhang, J., Lei, D., Yang, Z., Song, S., Qian, R., Li, W., Shan, Y., Zhao, G.: Early assessment of responsive neurostimulation for drug-resistant epilepsy in China: A multicenter, self-controlled study. Chinese Medical Journal 138(4), 430–440 (2025)
13. Zhang, J., Gao, J., Chen, Z., Zhou, J., Liu, Y., Li, P.: A latent adversarial Cauchy-Schwarz autoencoder for medical image segmentation. In: Proceedings of the 2023 IEEE International Conference on Bioinformatics and Biomedicine. pp. 3962–3967. IEEE, Istanbul, Turkiye (2023)

Biography

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