iDDS: An IoT-based System for Refractory Epilepsy in Smart Healthcare

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Abstract

- Epilepsy affects approximately 1% of the world's population, necessitating innovative solutions for seizure control.
- This work presents a unified drug delivery system within the IoT framework which provides drug injection upon seizure detection.
- The proposed system reduces power consumption considerably (10-30%) while maintaining high accuracy.

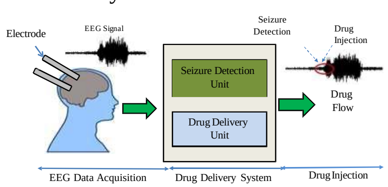


Fig. 1 Model of Drug Delivery System

Engineering Problem Overview

- The detection of EEG abnormalities has been a challenging task because of its high complexity. Detection accuracy is one of the main concerns.
- Existing seizure detectors consume significant amount of power which makes them ineffective for low power biomedical applications.
- A significant portion of refractory patients do not respond to stimulation, which necessitates an alternate approach which could be more effective.
- The integration of IoT is becoming a growing need as it provides universal connectivity as well as ambient intelligence.

Design of the Proposed Drug Delivery System (DDS)

- EEG Signals are initially decomposed using the DWT. Statistical features are extracted from the decomposed EEG and submitted to a k-NN classifier for seizure detection.
- The following statistical features were used: variance, standard deviation, and energy.
- An electromagnetically actuated valveless micropump, with a diaphragm composed of PDMS is used for drug delivery.
- Once a seizure is detected, AEDs are injected into the onset area to stop the seizure propagation.
- The IoT framework performs remote monitoring of the performance of the solution as well as drug injection upon seizure detection.

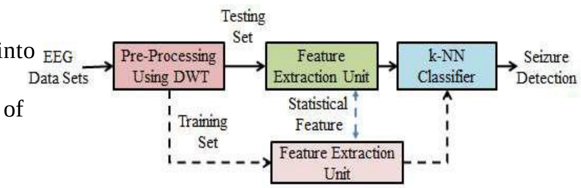


Fig. 3. Seizure Detection Unit

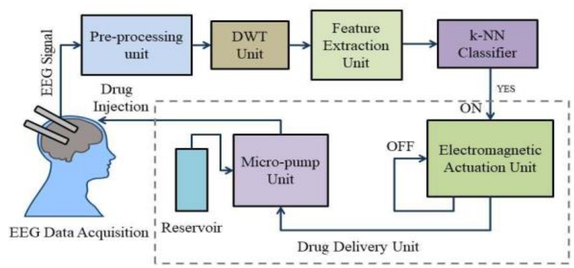


Fig. 2. Architecture of Drug Delivery System (DDS)

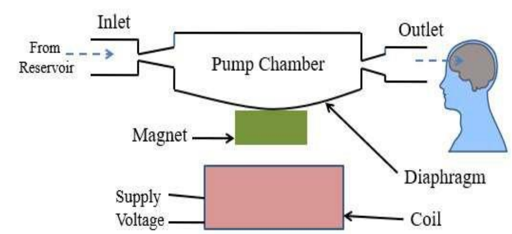


Fig. 4. Drug Delivery Unit

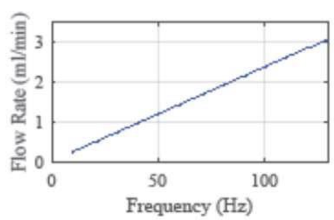
Implementation of the Proposed Design

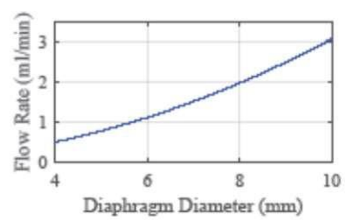
- A prototype of the solution was implemented using Simulink® and ThingSpeak.
- A pattern-independent method was used for the measurement of power consumption.

Parameter	Value
Seizure Detection Unit	
Detection Accuracy	98.65%
Latency	1.4 sec
Power Consumption	3.2 mW
Drug Delivery System	
Actuation frequency	133 Hz
Power Consumption	12.68 mW

Experimental Results

- The required EMF to get a deflection of 10 μm is 22.3 μN.
- A smaller change in diaphragm diameter leads to a drastic change in the volumetric flow rate.
- The total power consumption for the proposed system was measured as 12.68 mW, with a maximum flow rate of 3.08 ml/min.





Conclusion and Future Research

- An energy efficient DDS is presented, which could be useful for epilepsy treatment.
- Future work will include hardware implementation of the proposed system for commercial biomedical applications.

References

- M. A. Sayeed, S. P. Mohanty, E. Kougianos, and H. Zaveri, " An Energy Efficient Epileptic Seizure Detector," in Proc. IEEE Int. Conf. Cons. Elect. (ICCE), 2018, pp. 1–4.
- M. A. Sayeed, S. P. Mohanty, E. Kougianos, and H. Zaveri, " A Fast and Accurate Approach for Real-Time Seizure Detection in the IoMT ," in Proc. IEEE Int. Conf. Smart Cities (ISC2), 2018, pp. 1–5.