An IoT-based Drug Delivery System for Refractory Epilepsy

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Outline of the talk

- Introduction
- Novel Contributions
- Design of the Proposed System
- Implementation and Results
- Conclusions and Future Research

Introduction

- Epilepsy and Seizures
- Significance of Drug Delivery System
- Internet of Medical Things (IoMT)

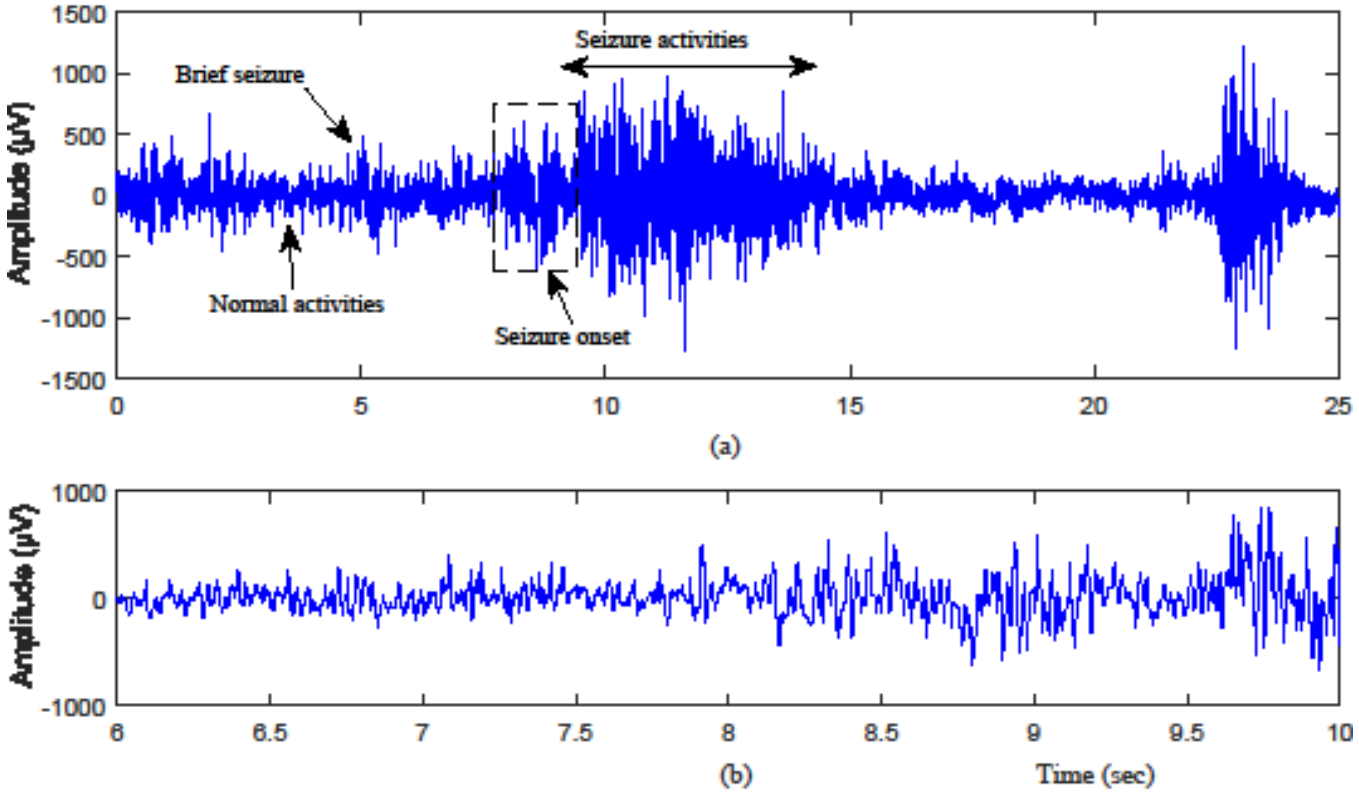
Consumer Electronics for Smart Healthcare

- Smart health care is increasingly important due to the combined pressures of an increasing population and limited resources.
- A Multidisciplinary research is in full-swing by industry and academia to address new issues, entrepreneurs on the smart healthcare domain.
- Consumer electronics integrated in IoT framework in the healthcare domain is getting significant focus.

Epilepsy and Seizures

- Epilepsy is a neurological disorder characterized by recurrent seizures.
- A seizure consists of abnormal activity within the brain which may result in loss of consciousness or convulsions.
- Approximately 1% of the world's population suffers from epilepsy.

Epileptic Seizure



Consumer Electronics for Seizure

Source: https://spectrum.ieee.org/the-human-os/biomedical/diagnostics/this-seizuredetecting-smartwatch-could-save-your-life

Embrace2: Smartband which uses Machine learning to detect convulsive Seizures and notifies caregivers.

Source: https://www.empatica.com/embrace2/

Medical grade smart watch: It detects generalized clonic-tonic Seizures and notifies physicians.

Consumer Electronics for Seizure

- U.S regulators have recently approved the first medical grade smart watch, a novel piece of consumer electronics product for neurological health, detects epileptic seizure and sends alert to the physician for proper actions.
- A significant research needs to be conducted for the detection of partial seizures and efficient drug delivery system.
- Consumer electronics is available to ECG, but not to EEG. The proposed system advances consumer electronics by bringing seizure detection and control to smart health care system.

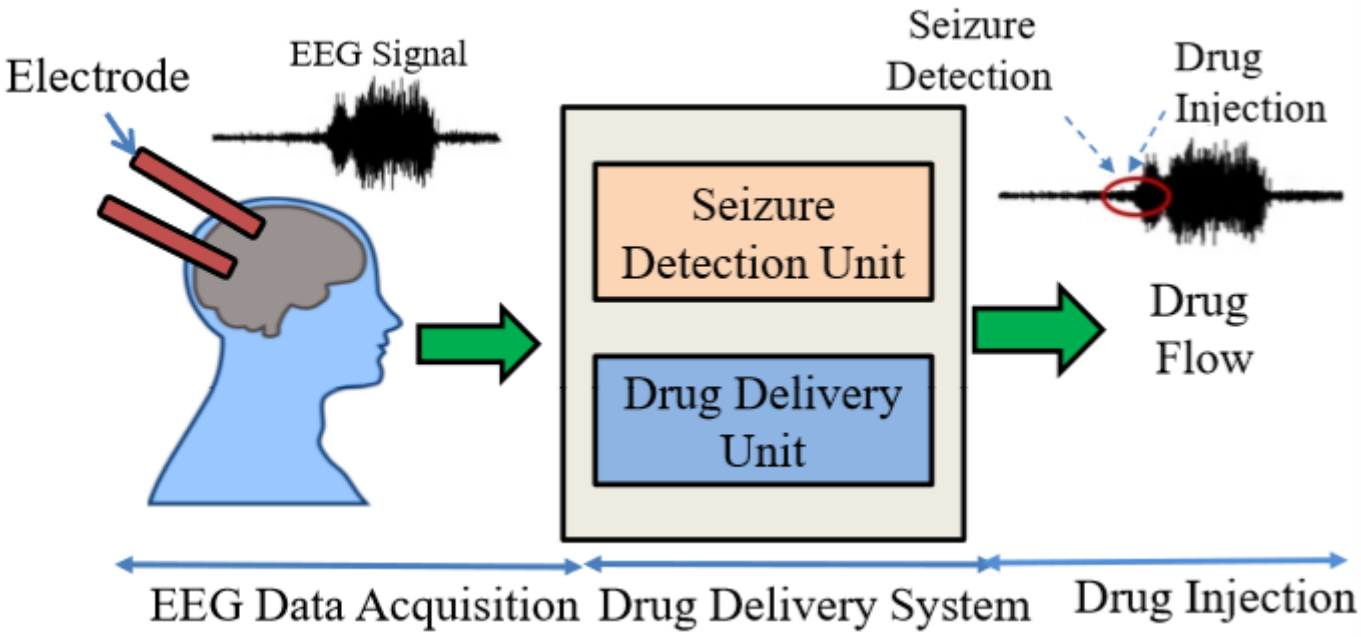
Motivations: Seizure Detection

- Almost 1% of the world population and 3 million people in the US are affected by seizures.
- Anti-epileptic drugs are used to control seizure, but 30% of patients are refractory to medication.
- Surgery is restricted to cases where there can be no damage to the eloquent cortex.
- There is a high rate of sudden unexplained death (SUDEP) in epilepsy in comparison to the general population.

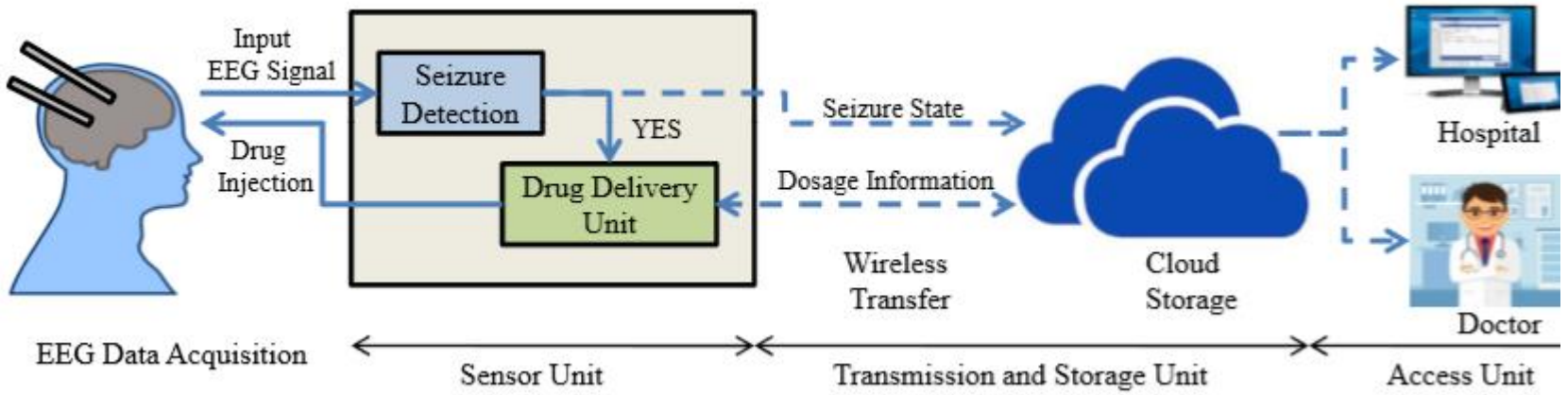
Motivations: Drug Delivery System

- Anti-epileptic drugs are used to control seizure, but 30% of patients are refractory to medication.
- Surgery is restricted to cases where there can be no damage to the eloquent cortex.
- Hence, an alternative approach which can provide an effective solution for controlling seizures is desirable.
- Responsive and localized injection enhances the efficacy of the drug and provides an effective solution for epilepsy.

Epileptic Seizure Detection and Drug Delivery System

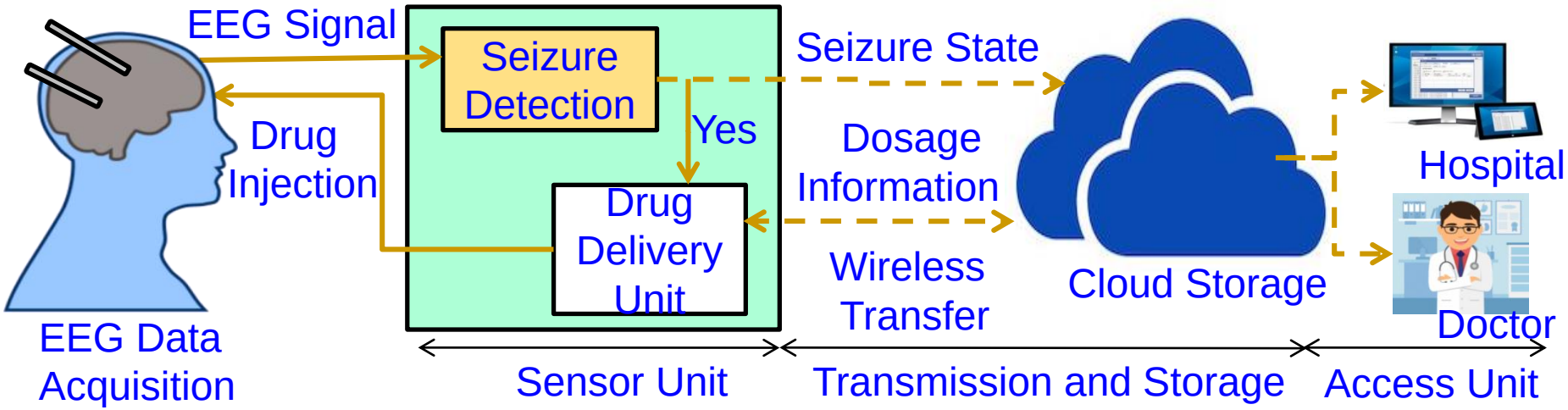


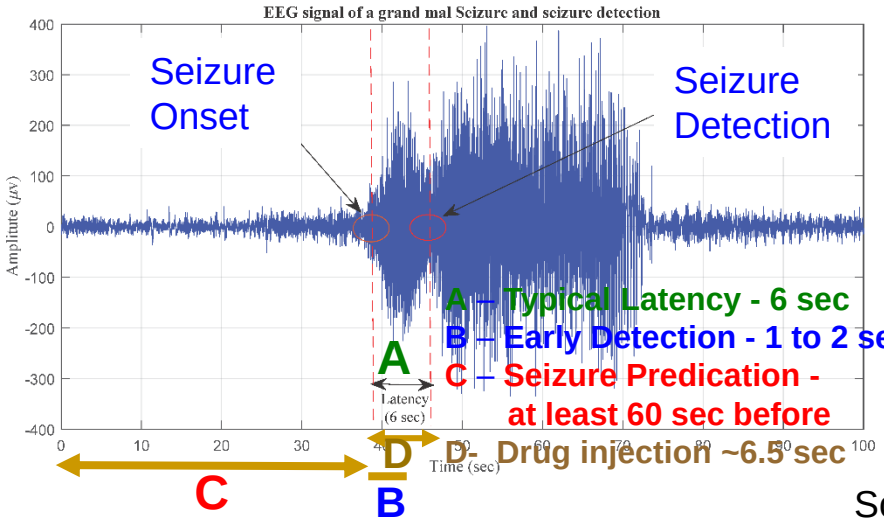
Internet of Medical Things (IoMT)



- IoT enables remote health monitoring and analysis of health behavior.
- Patient data and system performance can be accessed and analyzed remotely.

Smart Healthcare – Seizure Detection and Control Problem





Automated Epileptic Seizure Detection and Control System

Source: Mohanty iSES 2018, and IEEE Smart Cities 2018

Related Research - Detection

Several seizure detection methods have been proposed.

The algorithms are based on the following:

- Cepstral analysis and generalized regression neural network (Yavuz, et al. 2018).
- Weighted Permutation entropy and support vector machines (Tawfiq, et al. 2016).
- DWT and neural network classifier (Kumar, et al. 2014).
- Permutation entropy and support vector machines (Nicolaou, et al. 2012)

Related Research - Control

So far, few methods have been proposed for seizure control.

- An electrophoretic drug delivery device (Proctor, et al. 2018).
- Custom hardware device: seizure initiated drug delivery system (Muller, et al. 2017).
- Electromagnetic based Micropump (Hamie, et al. 2013).
- Asynchronous drug delivery system (Salam, et al. 2012)

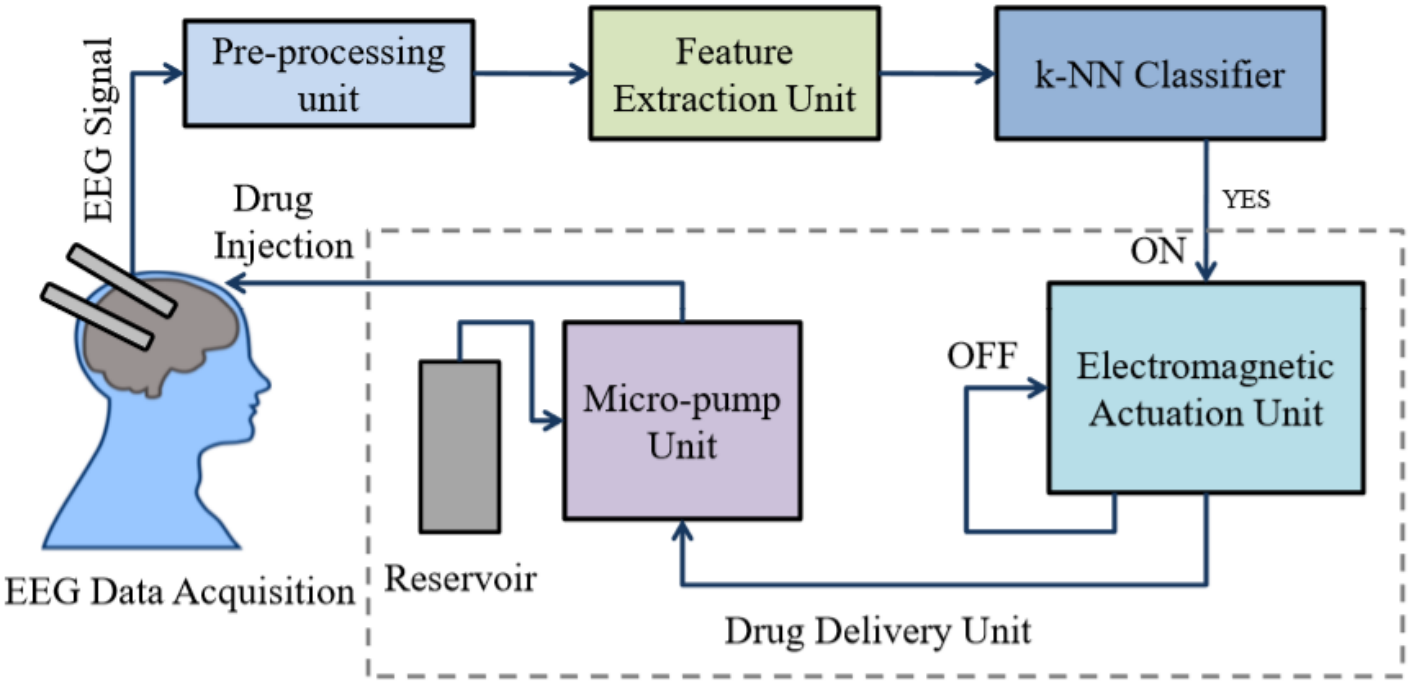
Novel Contributions

- The Discrete Wavelet Transform (DWT) provides a conjoint time and frequency characterization which is highly effective for capturing complex EEG dynamics, and leads to improved accuracy.
- Electromagnetic actuation requires a lower actuation voltage for a desired membrane displacement, which is essential for low power applications.
- The proposed IoT framework provides considerable enhancement to the quality of life of epilepsy patients.

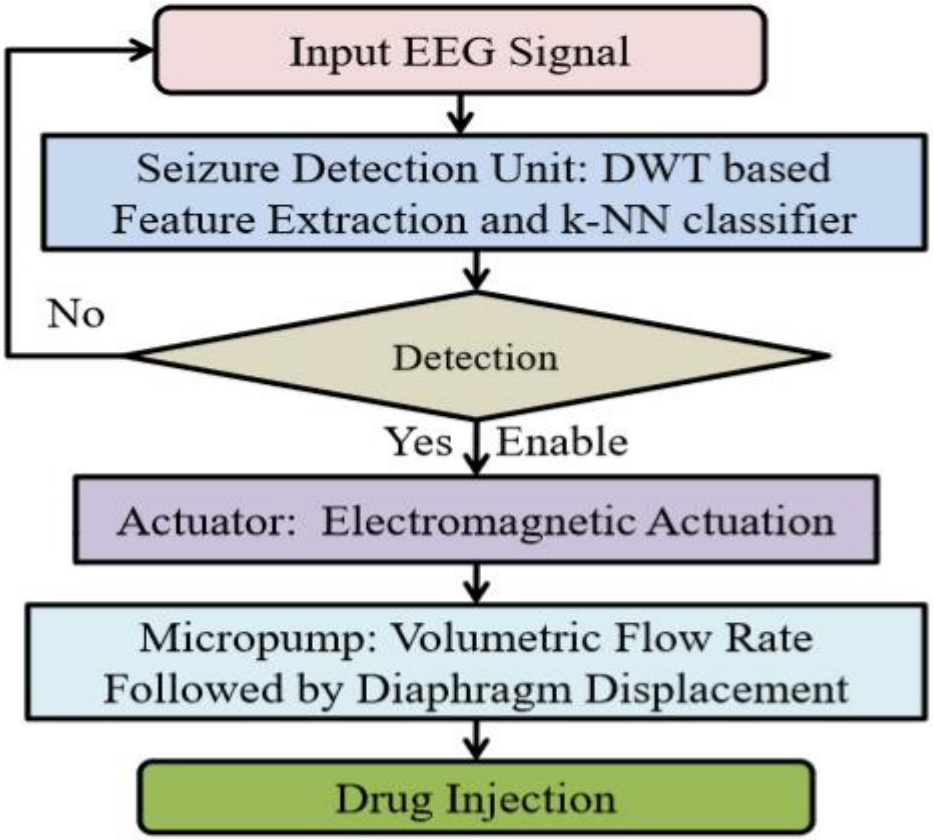
Details of the Proposed System

- K-NN based seizure detection subsystem
- Drug delivery subsystem
- Implementation of the proposed design
- Experimental Results

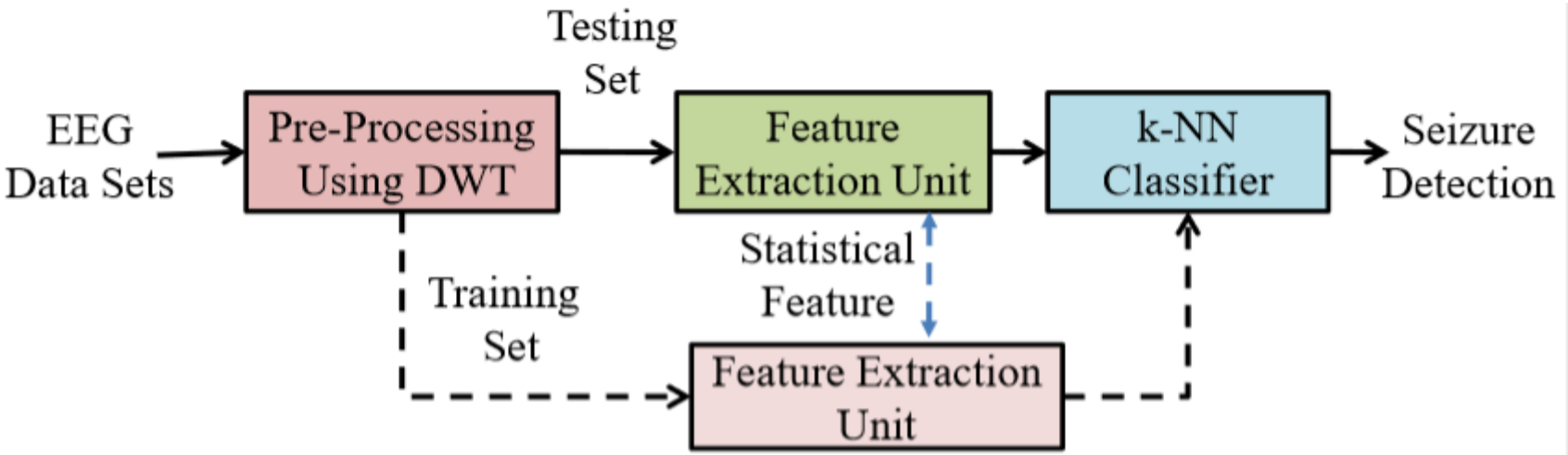
Architecture of the Proposed Drug Delivery System



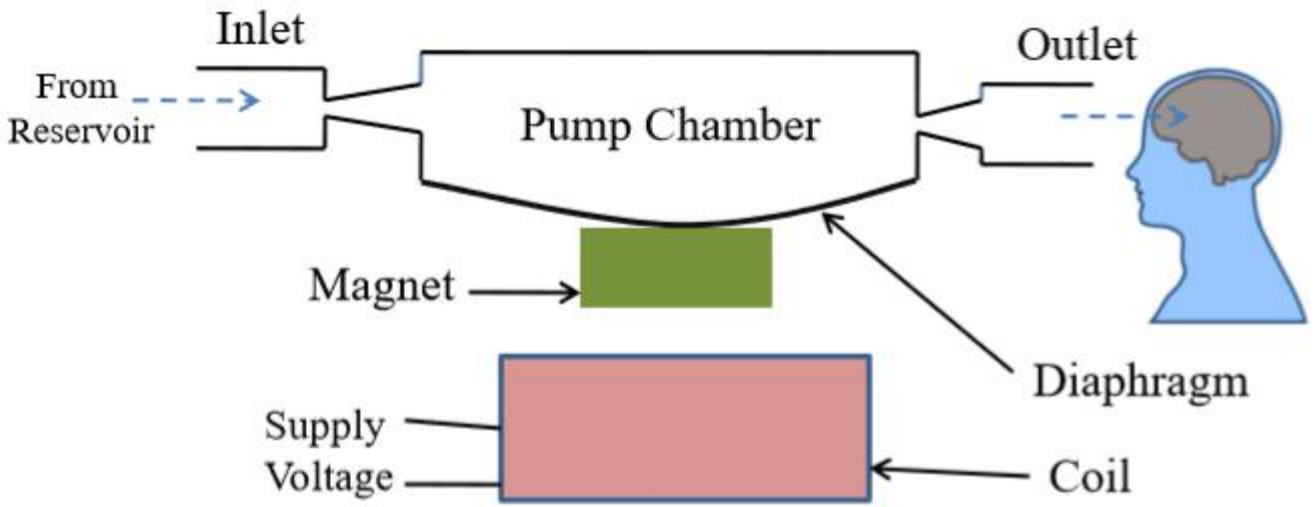
Flowchart of the Proposed System



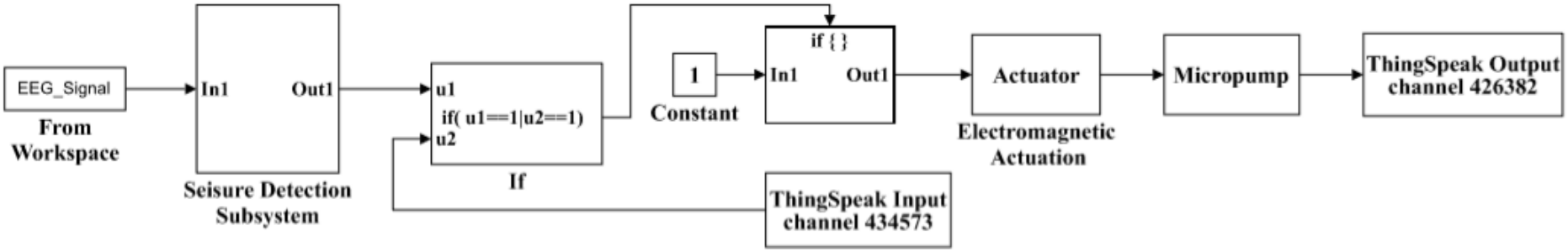
Epileptic Seizure Detection Using k-NN Classifier



Drug Delivery Subsystem



Implementations: Using Simulink



- The k-NN classifier was trained using 85% of each dataset, while the remaining 15% was used for testing.
- Upon seizure detection, the drug delivery unit becomes active and the coil acts as an electromagnet.

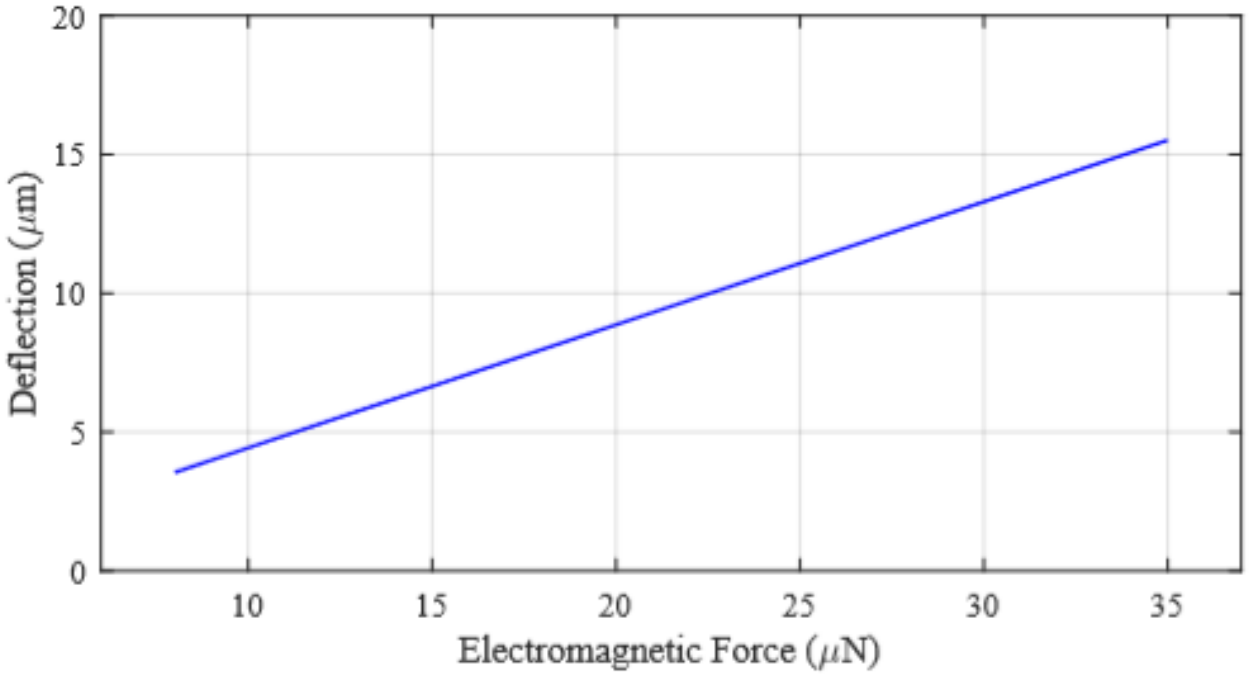
Experimental Results: Detection

- The k-NN classifier was trained using 85% of each dataset, while15% of each dataset was used for testing.
- The proposed approach provides 98.65% classification accuracy for normal and interictal vs. ictal EEG.
- The classifier shows an accuracy of 100% for normal VS ictal EEG.

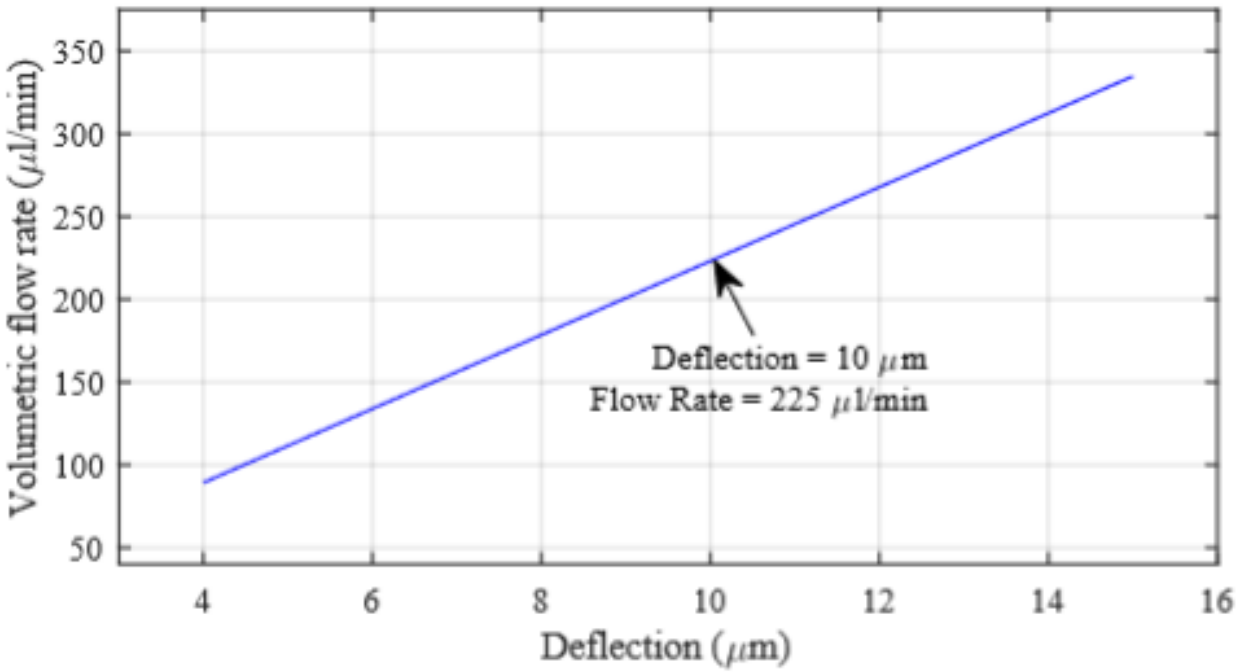
Experimental Results: Micropump Characterization

Parameters	Value
Supply Voltage	5 Volts
Frequency	130 Hz
Coil Turn	100
Pump Chamber Diameter	4 mm
Possion's Ratio	0.5
Yield Strength	20 Kpa

Experimental Results ...



Experimental Results ...



Experimental Results: System Characterization

Parameters	Value
Accuracy	98.65%
Sensitivity	97.81%
Specificity	98.14%
Maximum Flow Rate	340 µL/min
Power Consumption	12.81 mW

Experimental Results: Comparison

- It is seen that flow rate increases linearly with the applied input voltage which supports the fact that membrane deflection also has a linear relationship with input voltage.
- The calculated power consumption of the proposed system was 12.81 mW, which is 10-30 % less compared to previous works.

Conclusion and Future Research

- The system level simulation results show that the proposed system enhances the detection accuracy and reduces the power consumption, which makes it suitable for use as an implantable device.
- The proposed prototype could be useful for epilepsy treatment.
- In future work we will implement the proposed system for commercial biomedical applications.

Thank You !!!

Slides are Available at:

http://www.smohanty.org