iDDS: An Edge-Device in IoMT for Automatic Seizure Control using On-Time Drug Delivery

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Outline of the talk

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

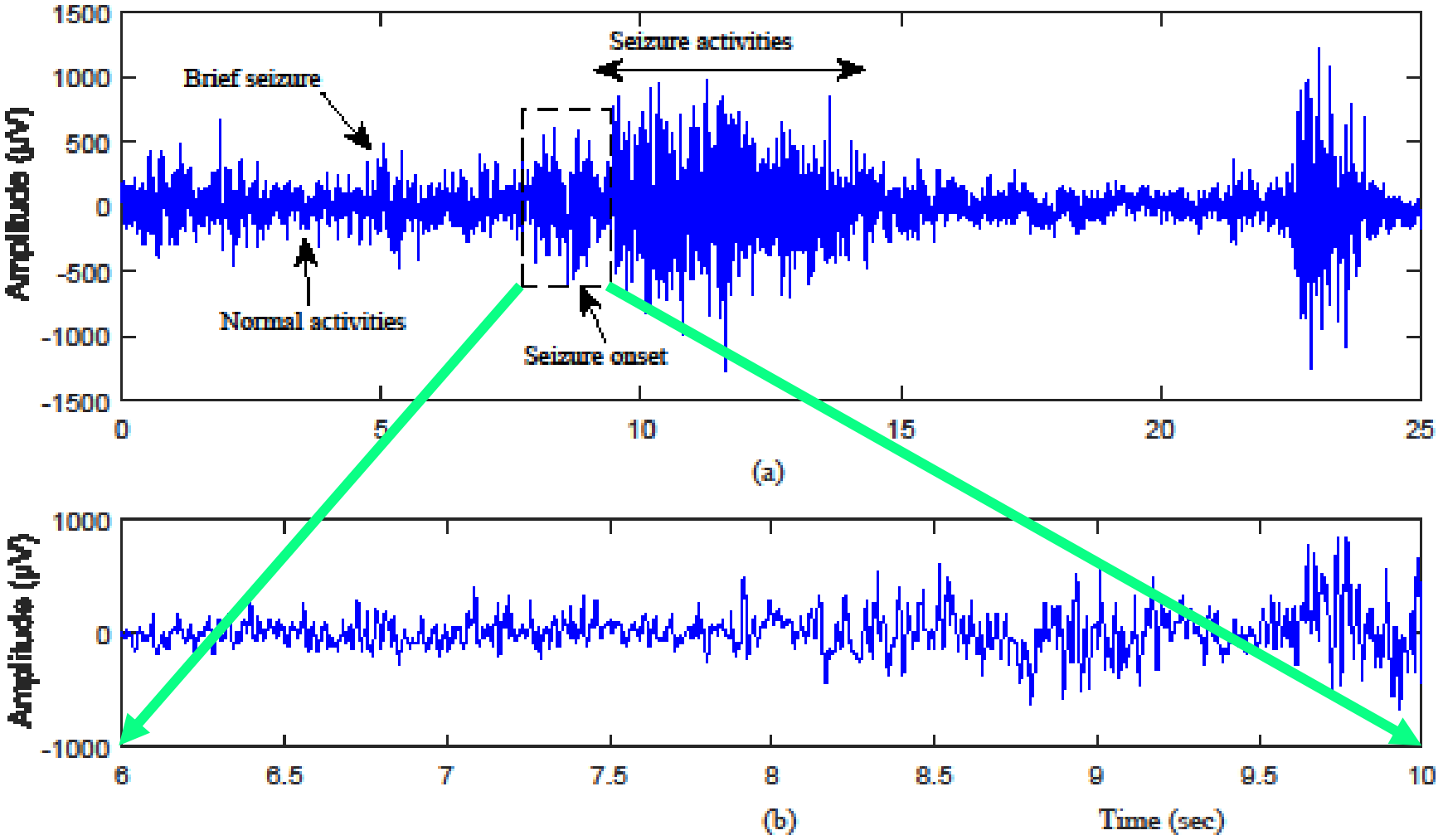
Consumer Electronics for Smart Healthcare

- Smart healthcare is gaining significant attention to address the increasing needs of the citizens.
- A significant portion of research is in full-swing by industry and academia to address new issues, entrepreneurs on the Smart healthcare domain.
- Internet of Things (IoT) plays a crucial role in implementing smart healthcare applications.

Epilepsy and Seizures

- Epilepsy is a neurological disorder characterized by recurrent seizures.
- A seizure is an abnormal electrical activity in the brain, marked by sensory disturbance or loss of consciousness.
- Approximately 1% of the world's population suffers from epilepsy.

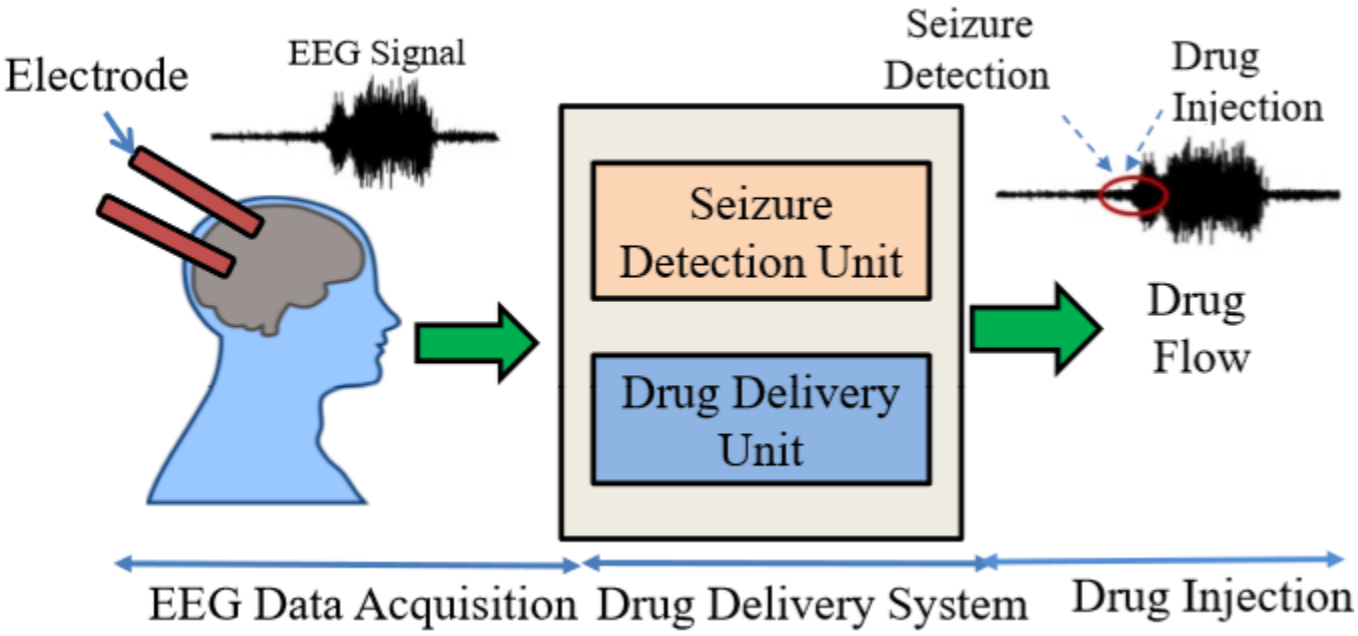
Epileptic Seizure



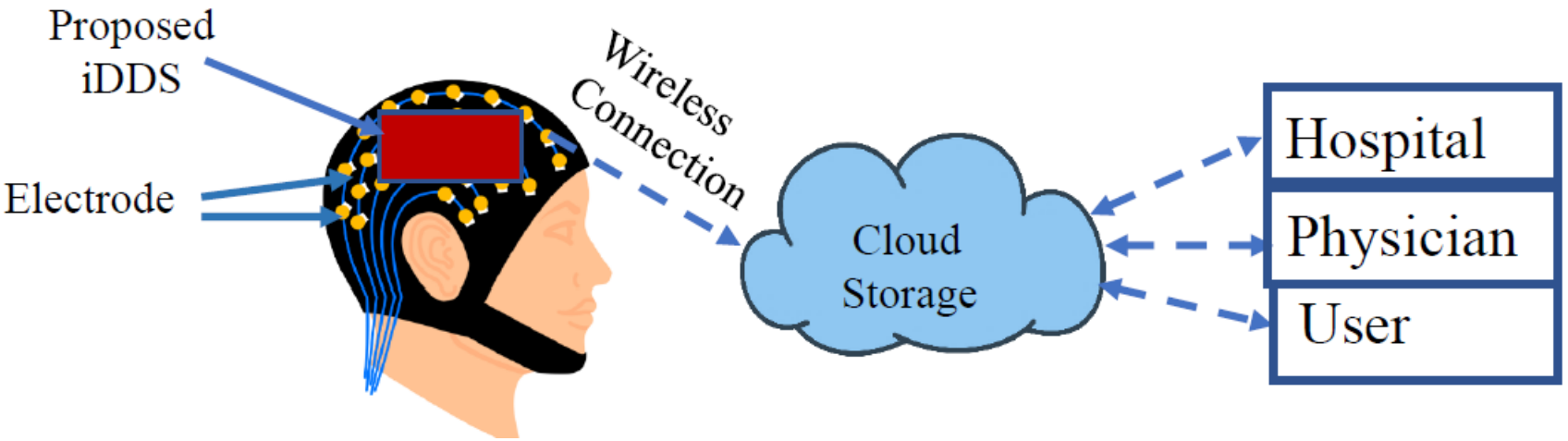
Research Question Address in the Current Paper

- Rapid Seizure Detection
- Seizure Control Through Drug Delivery
- Efficient Seizure Control System

Epileptic Seizure Detection and Drug Delivery System



Internet of Medical Things (IoMT)



- IoT record patient's healthcare data remotely and enables remote health monitoring.

Related Research - Detection

Several seizure detection methods have been proposed.

The algorithms are based on the following:

- Support Vector Machines
- k Nearest Neighbor classifier
- Naïve Bayes classifier
- Weighted Permutation entropy
- DWT and neural network classifier.
- Permutation entropy and support vector machines
- Deep neural network (DNN) classifier

Consumer Electronics for Seizure Detection

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.

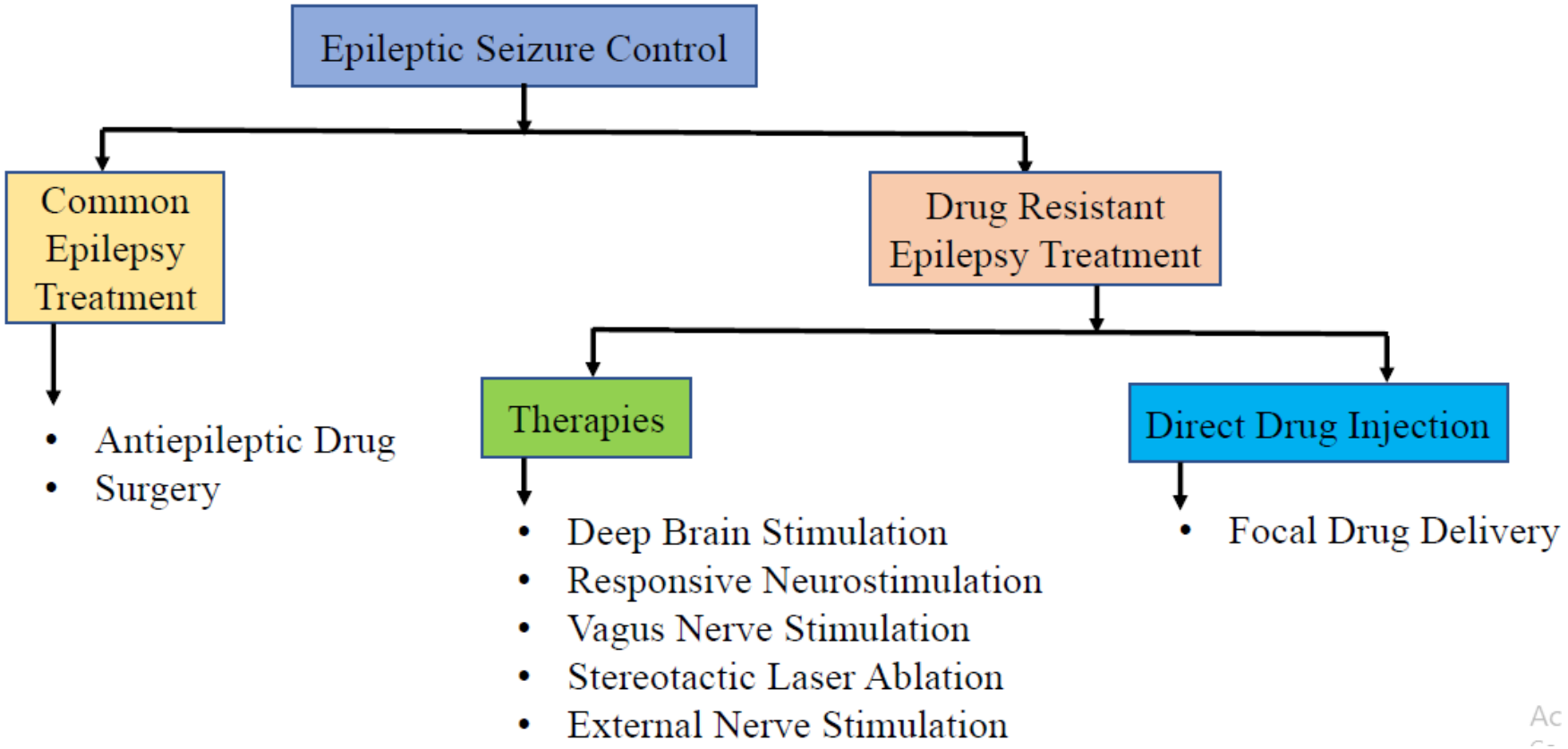
Source: https://www.empatica.com/embrace2/

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

Motivations: Drug Delivery System

- Antiepileptic drugs (AEDs) can not work for patient with refractory epilepsy.
- Surgery leads to the damage of eloquent cortex
- Responsive and localized drug injection into the target area enhances the efficacy of the drug and provides an effective solution for epilepsy.

Related Research - Control



Seizure Control- Drug Delivery Systems

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)
- Focal drug delivery (Stein, et al. 2000)

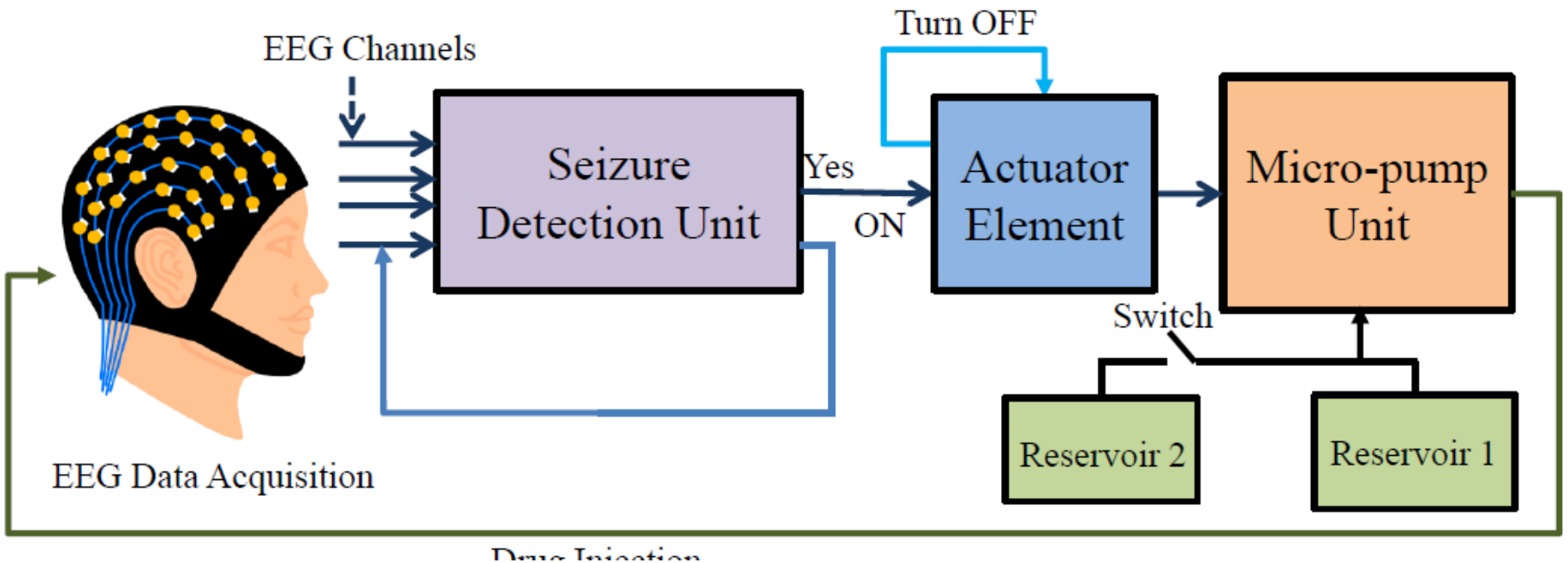
Novel Contributions

- A Doule reservoir micropump has been introduced. If one reservoir does not work due to insufficient drugs, the reservoir will become active, which enables continuous release of drugs.
- The proposed system reduces latency, while increasing sensitivity, making it a potential candidate for the use as a low latency implantable device for practical biomedical Applications.

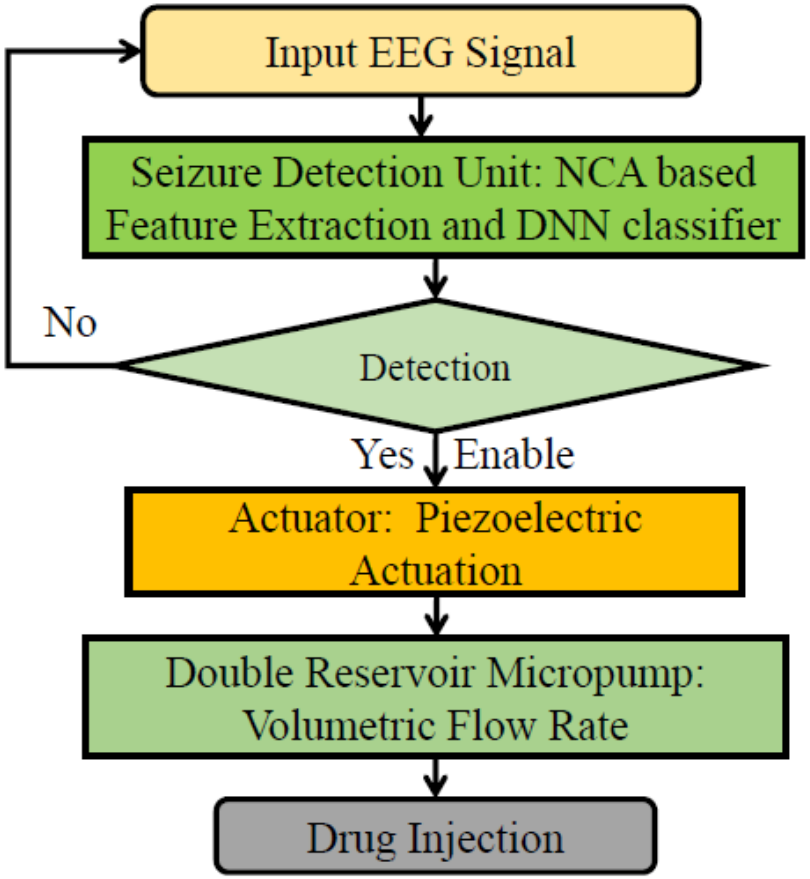
Details of the Proposed System

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

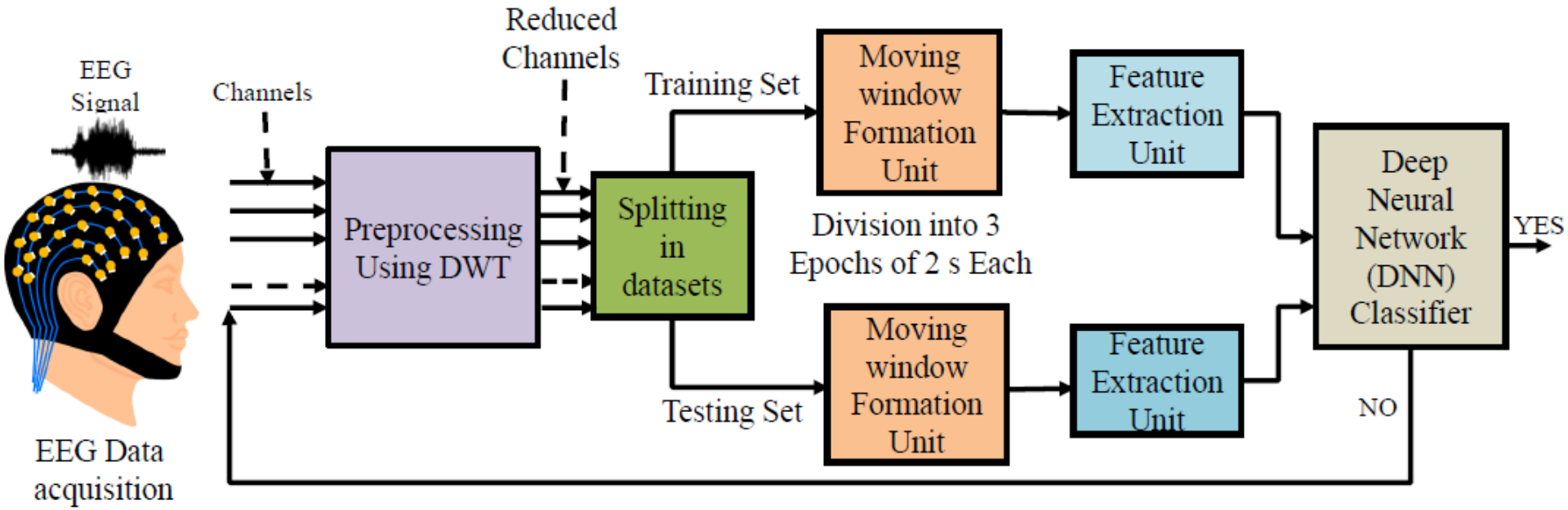
Architecture of the Proposed Drug Delivery System



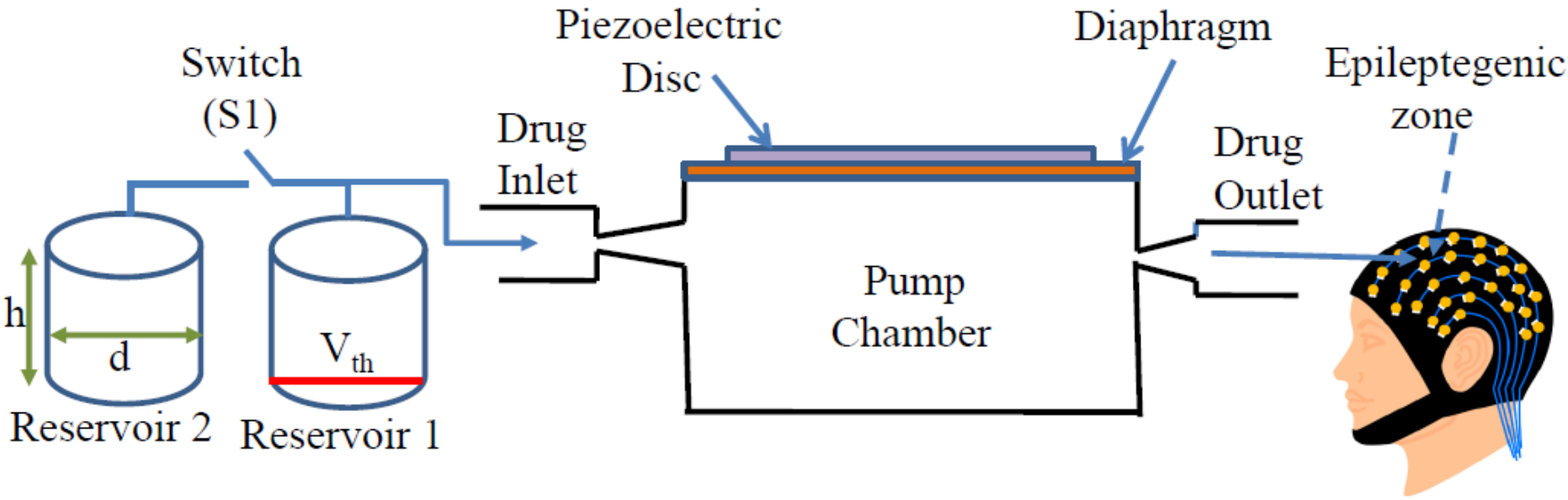
Flowchart of the Proposed System



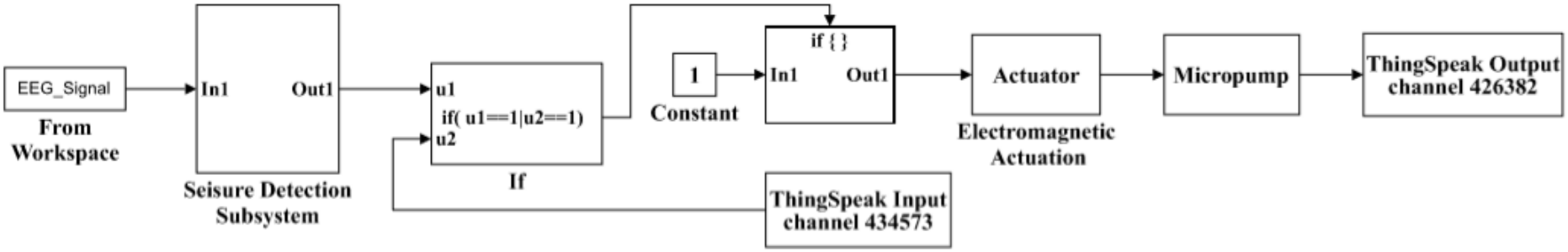
Epileptic Seizure Detection Using DNN Classifier



Drug Delivery Subsystem

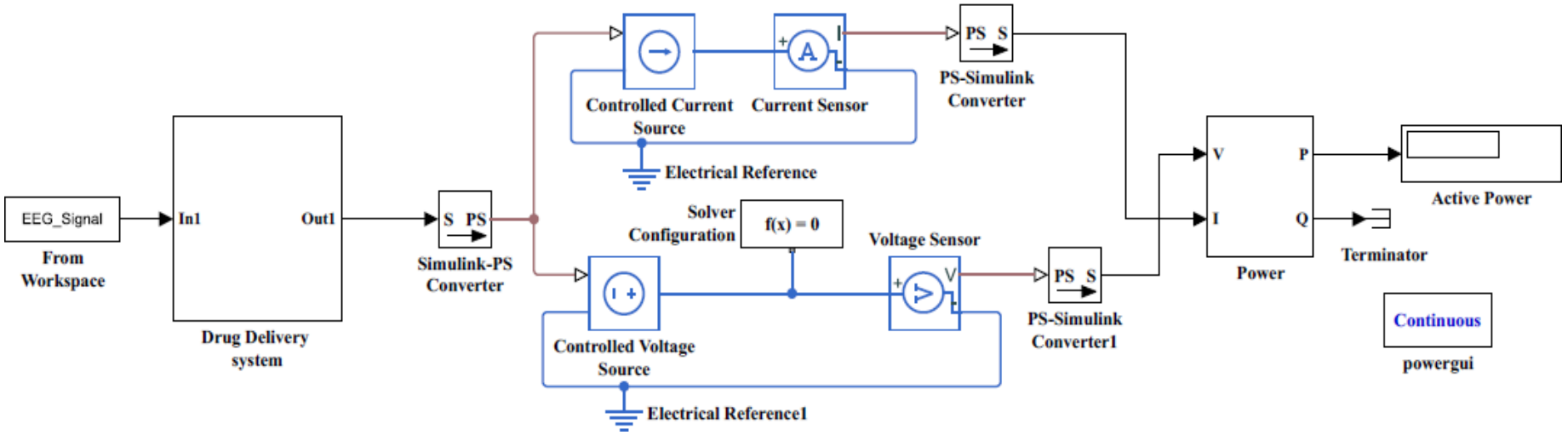


Implementations: Using Simulink



- Upon seizure detection, the drug delivery unit becomes active and the coil acts as an electromagnet.

Implementations: Using Simulink



- The power consumption of the proposed IDDS has been computed by pattern independent approach.

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: Seizure Detection Subsystem

Parameters	Value
Sampling Frequency	256 Hz
Band Pass Filter Frequency Range	0-32 Hz
No. of Hidden Layers	2
No. of Hidden Neurons/Layer	10
Sensitivity	100%
Latency	1.802 sec

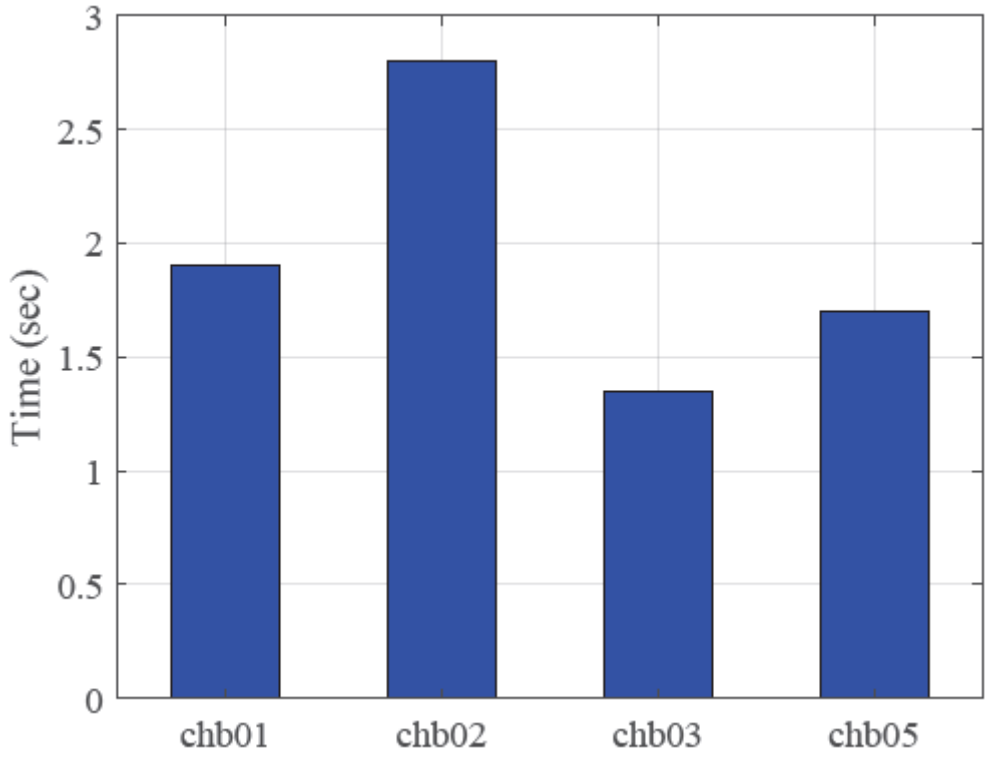
Experimental Results: Drug Delivery Unit

Parameters	Value
Piezoelectric (PZT) Disc Diameter	9 mm
Piezoelectric (PZT) Disc Thickness	150 µm
Membrane Diameter	10 mm
Membrane Thickness	100 µm
Possion's Ratio	0.49
Fluidic Diodicity	2
Liquid Density	1000 kg/m^3

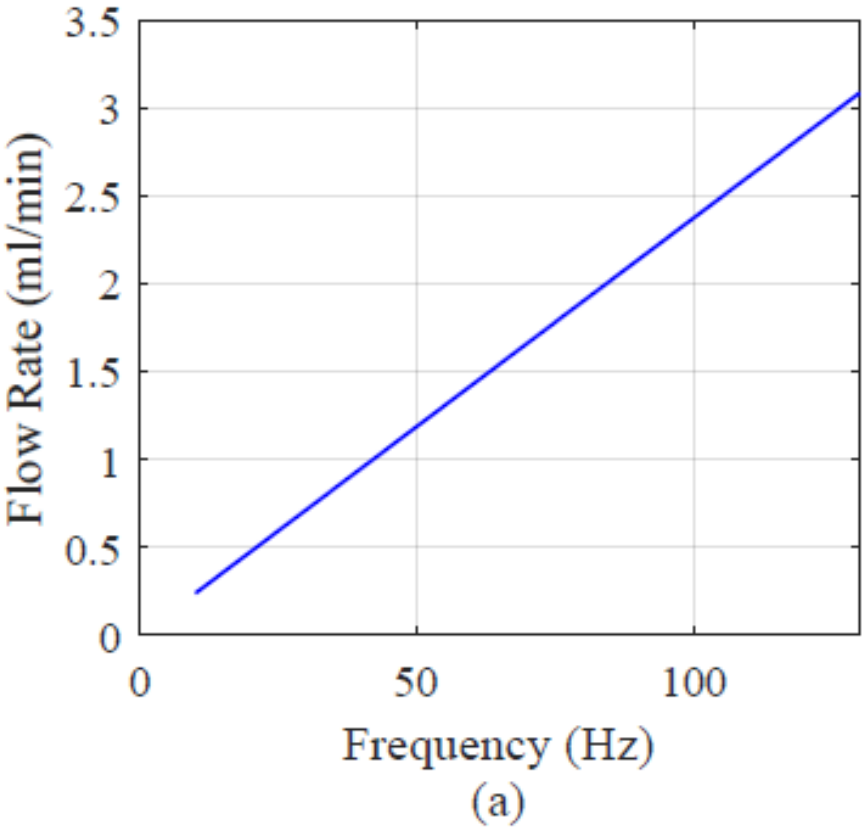
Experimental Results: Drug Delivery System

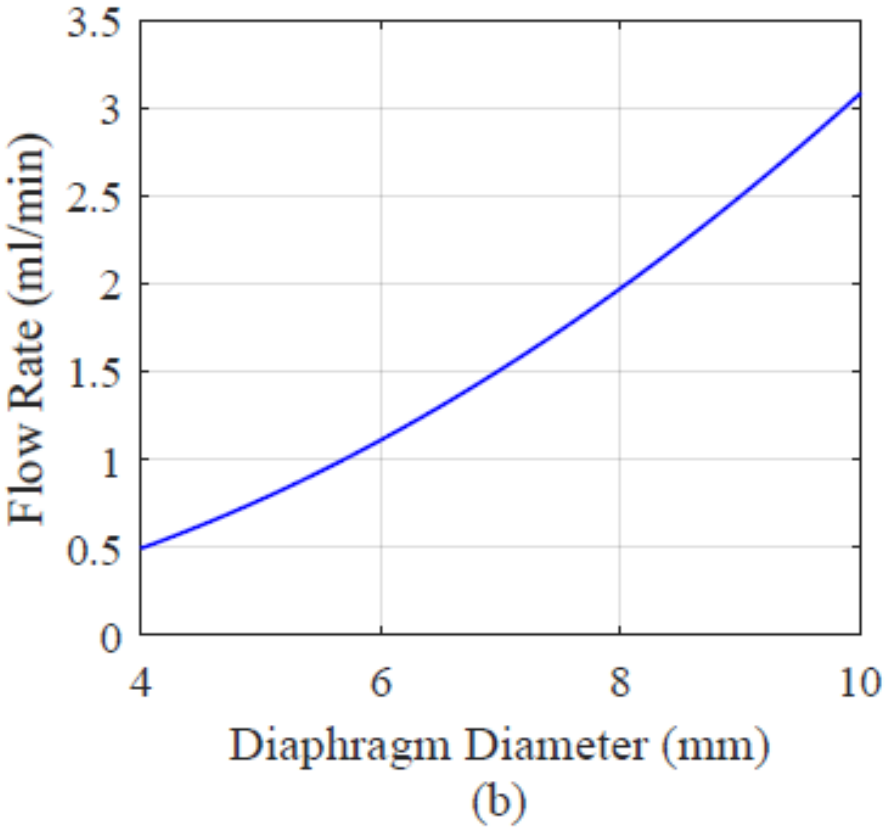
Parameters	Value
Input voltage	5 V
Divergence Angle	10 degree
Frequency	130 Hz
Power Consuption	130 mw
Volume flow	3.08 ml/min

Experimental Results: Variation of Latency



Experimental Results ...





Volumetric Flow Rate as a Function of:
(a) Actuation Frequency (b) Diaphragm Diameter.

Experimental Results..

- The DNN classifier was trained with 2-4 hours of interictal data and 0.5-1 hour of normal EEG. The DNN classifier reported a sensitivityof 100% for two hidden layers with 10 neurons in each layer.
- The number of hidden layers as well as the number of neurons were determined by trial and error. It is observed that a sharp increase in hidden layers or neurons affects the performance of the classifier.

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Experimental Results: Comparison

- A pattern independent method has been adopted to measure the power consumption, and the total power consumption has been calculated as ≈29 mW.
- The proposed design reports a maximum flow rate of 3.08 ml/min.

Conclusion and Future Research

- The validation with MIT scalp datasets demonstrates that the proposed system reduces latency considerably, which is essential for effective seizure control.

- A double reservoir mechanism improves the lifetime, making it a viable tool for practical biomedical applications.

Thank You !!!

Slides are Available at:

http://www.smohanty.org