Seizure Detection Device

Using TinyML to detect epilieptic seizures

Socrates Gebremedhin,Tim Prause

2025/02/19

TABLE OF CONTENTS

WHAT ARE SEIZURES?

Seizure types:

1. Generalized Seizures (Affect both brain hemispheres)
    - Tonic-Clonic: Loss of consciousness, stiffening (tonic) followed by full-body jerking (clonic).
    - Myoclonic: Sudden, brief muscle jerks.
2. Focal Seizures (Start in one brain region)
    - Focal Motor: Repeated jerking in one limb or face.
    - Focal Nonmotor: Can spread, leading to generalized seizures.

How can they be detected?

1. Electroencephalography (EEG):
    - Gold standard for seizure detection.
    - Used in labs or via portable EEG devices.
    - Effective in Epileptic Convulsion Recognition (ECR) but limited to short-term monitoring.
2. Wearable Technology:
    - Devices transmit data to smartphones and medical staff for enhanced diagnosis.

INTRODUCTION

We need better seizure detection devices

Current seizure detection devices are large, expensive, and not energy-efficient.

They often rely on cloud or phone-based processing, raising privacy concerns.

A wristband-based device can be lightweight, always on, and specifically designed for epilepsy patients

Key Considerations for an Effective Solution

Motion-based detection is non-invasive and cost-effective, but seizure movements are complex.

The device must balance accuracy, power efficiency, and real-time reliability.

A fully on-device system enhances privacy, reduces latency, and lowers costs compared to cloud-based alternatives.

LITERATURE REVIEW

Generalized Models for the Classification of Abnormal Movements in Daily Life and its Applicability to Epilepsy Convulsion Recognition [1]

Objective: identify epilepsy convulsions during daily activities using wearable devices

Method: comparing Support Vector Machines, k-Nearest Neighbors, and Decision Trees with Fuzzy systems

Results: indicated that Fuzzy Systems demonstrated superior generalization capabilities in recognizing clonic convulsions, effectively minimizing false alarms

WISDM Smartphone and Smartwatch Activity and Biometrics Dataset [2]

Objective: accelerometer and gyroscope data collected from 51 subjects performing 18 different daily activities for 3 minutes each, aiming to facilitate research in activity recognition and biometric identification.

Method: sliding window approach to segment the time-series sensor data into labeled examples, for ML applications

[1] https://pubmed.ncbi.nlm.nih.gov/27354194/

[2] https://archive.ics.uci.edu/ml/machine-learning-databases/00507/WISDM-dataset-description.pdf

DATASET CHARACTERISTICS

WISDM DATASET

- collected from 59 subjects
- Doing 18 activities (so 18 labels) - No epilepsy seizure data
- Used accelerometer and gyroscope data sampled at 20HZ
- Each activity lasted for ~ 3 minutess
- We only used data for 9 people and used it to enrich our model to generalize
- Relabeled all data to non-epileptic

EPILEPSY DATASET

- collected from 6 subjects
- Doing 4 activities (including epilepsy seizure simulation)
- Used accelerometer data sampled at 16Hz
- Each activity lasted for ~ 13 seconds
- We used all data to infer epileptic seizures
- Relabeled all data to Epileptic and non-epileptic

DATASET CHARACTERISTICS - DATA SNIPPET

WISDM DATASET

	accX	accY	accZ	Activity
0	9.397051	-1.127401	-1.061029	A
1	6.633513	0.187718	-0.440013	A
2	5.096351	2.329629	-0.079968	A
3	6.510423	1.363041	-0.363211	A
4	12.215082	-0.998780	-0.603777	A

EPILEPSY DATASET

	0x	0y	0z	1x	1y	1z	204z	205x	205y	205z	206x
0	0.60	-1.72	-0.47	0.60	-1.28	0.02	-0.51	-0.70	1.03	-0.57	EPILEPSY
1	-0.35	-0.99	0.05	-0.44	-2.30	0.05	0.55	-0.14	-0.34	0.83	EPILEPSY
2	-0.08	-1.02	-0.03	-0.01	-2.12	-0.48	-0.62	0.32	-0.67	-0.56	EPILEPSY
3	-0.43	0.78	-0.44	-0.44	0.78	-0.18	-0.46	-0.31	1.08	-0.59	EPILEPSY
4	-0.30	-2.40	-0.31	-0.81	0.80	-0.26	-0.03	-0.80	0.33	-0.02	EPILEPSY

BASELINE MODEL

ACCURACY
95.04%

Metrics for Classifier1

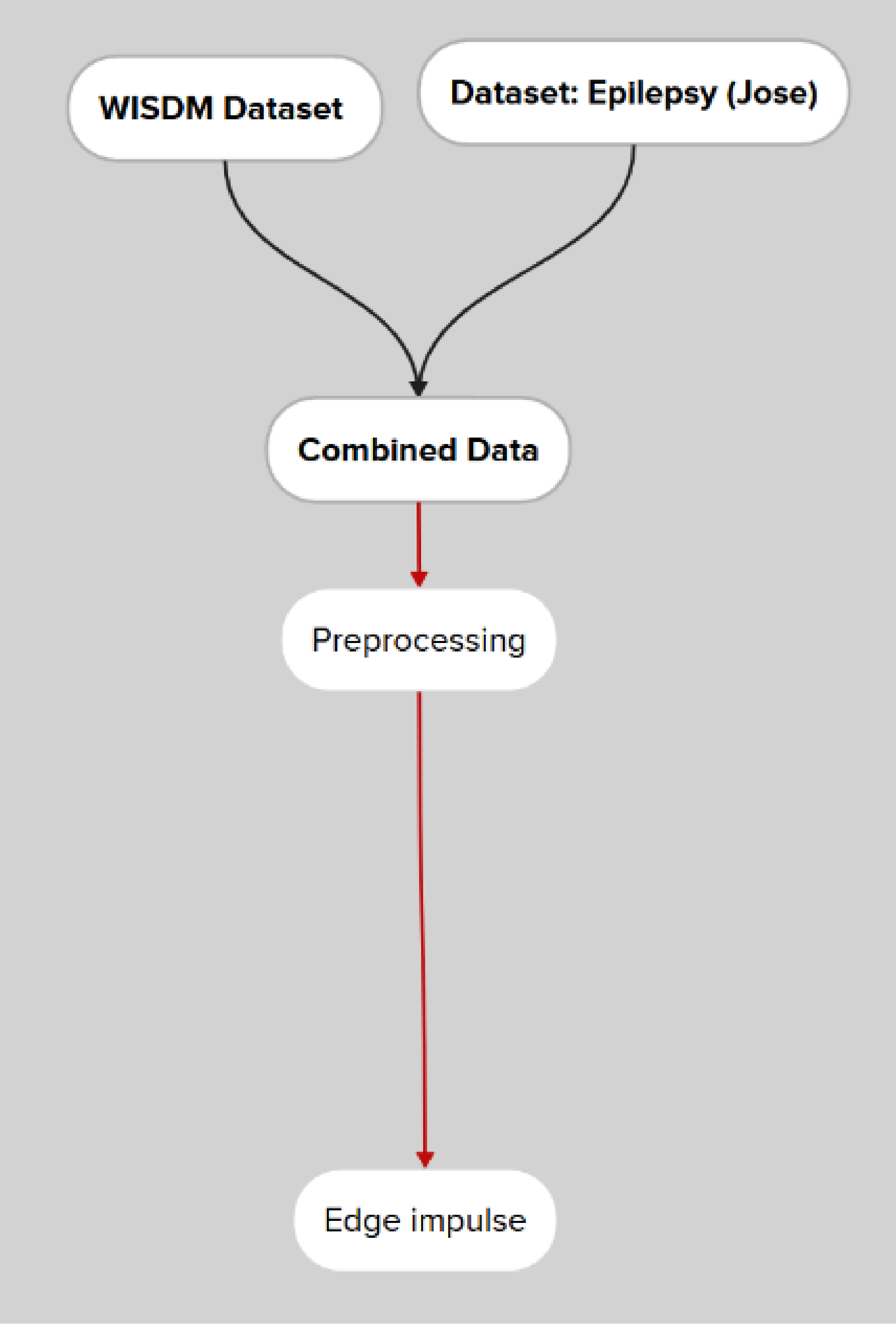
METRIC	VALUE
Area under ROC Curve	0.91
Weighted average Precision	0.96
Weighted average Recall	0.95
Weighted average F1 score	0.95

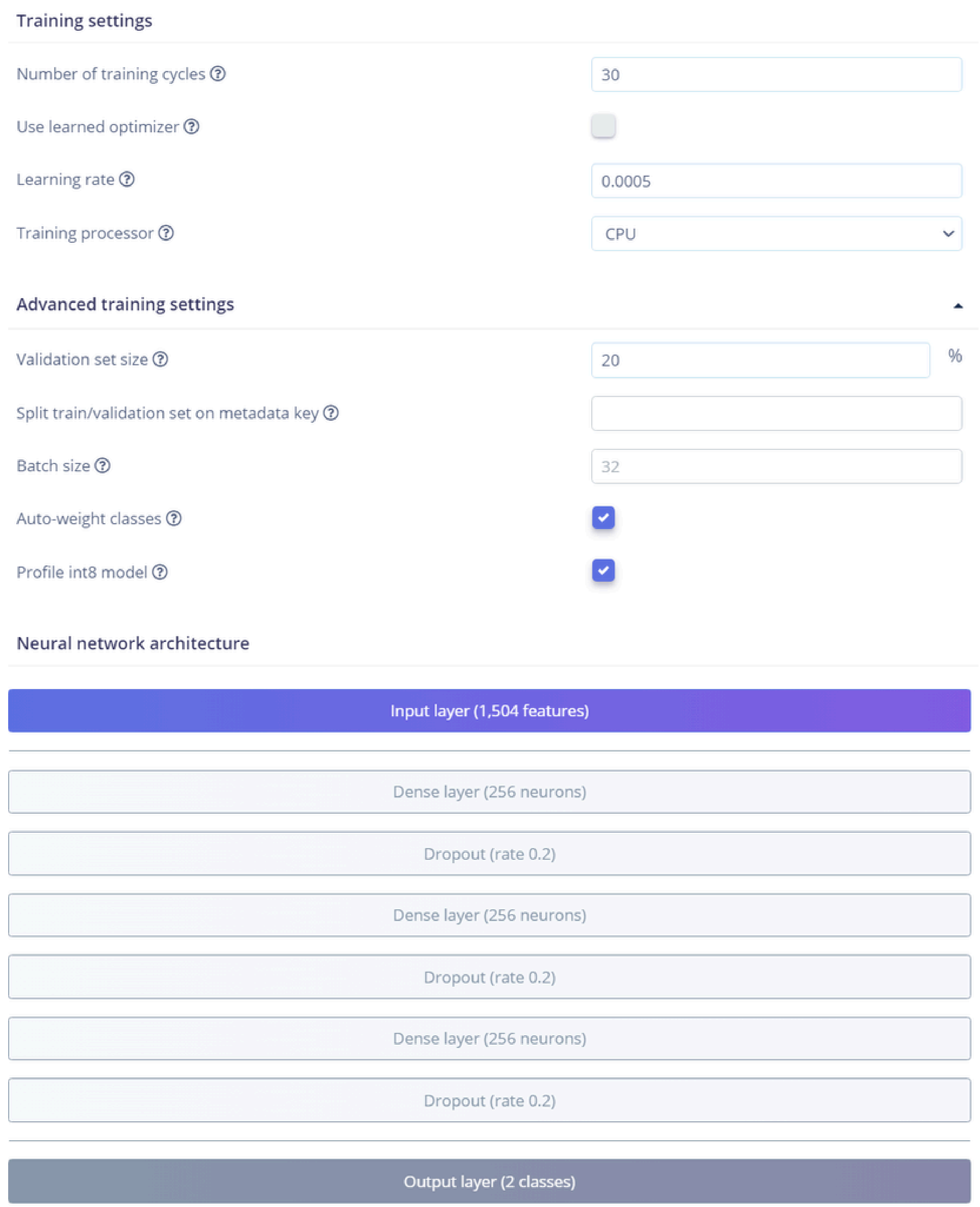
Confusion matrix

	EPILEPSY	NON-EPILEPTIC	UNCERTAIN
EPILEPSY	82.3%	16.1%	1.6%
NON-EPILEPTIC	0.1%	99.9%	0.1%
F1 SCORE	0.90	0.97	

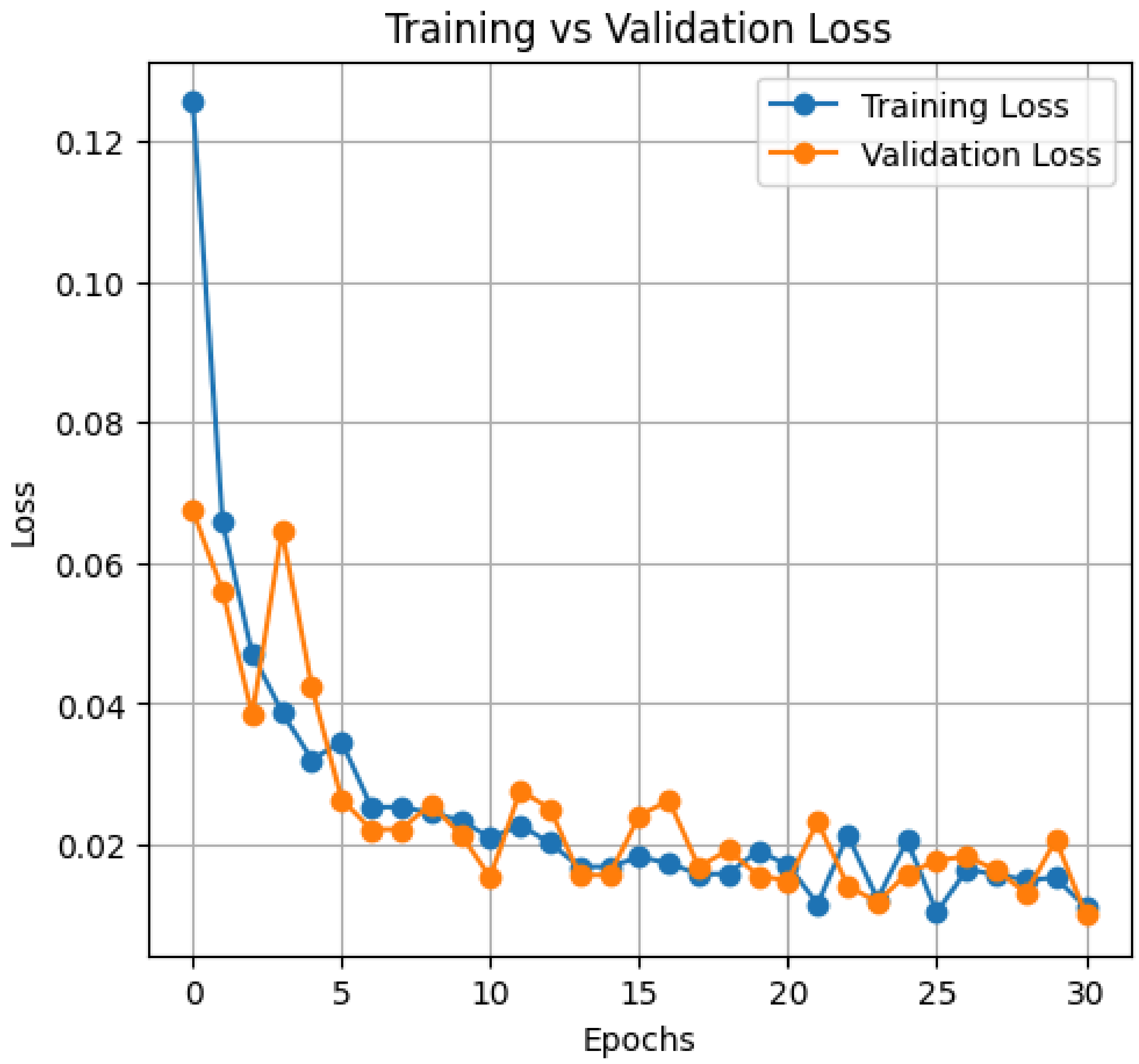
- Only used the Epileptic data
- Default edge net impulse model used

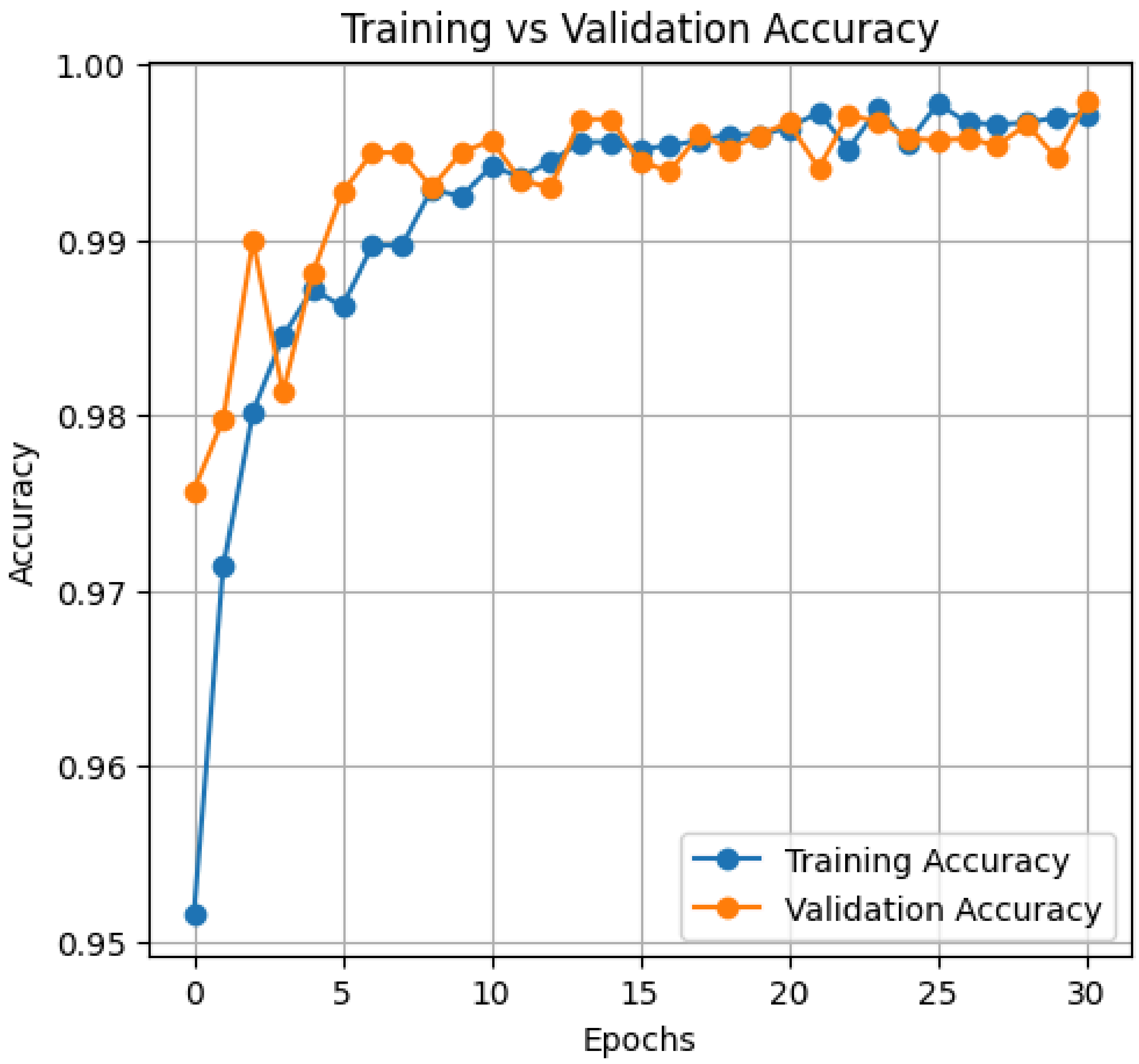
MODEL DEFINITION AND EVALUATION





RESULTS





- combined data used for 9 people in WISDM dataset
- Optimized edge model with auto weights and more epochs

RESULTS

ACCURACY
99.76%

Metrics for Classifier1

METRIC	VALUE
Area under ROC Curve	0.99
Weighted average Precision	1.00
Weighted average Recall	1.00
Weighted average F1 score	1.00

Confusion matrix

	EPILEPSY	NON-EPILEPTIC	UNCERTAIN
EPILEPSY	99.1%	0.8%	0.1%
NON-EPILEPTIC	0.2%	99.8%	0.0%
F1 SCORE	0.96	1.00	

- combined data used for 9 people in WISDM dataset
- Optimized edge model with auto weights and more epochs
- Accuracy as well as the Epilepsy F1 score improved

CHALLENGES AND ERRORS

- Combining different datasets from different sources
  - different measurement devices
  - different measurement times
  - other unknowns?
- Simulating seizures ourselfes
- Limited data for Seizures
- Deployment

DISCUSSION

- This is a proof of concept that it does work and be implemented in embedded systems.
- We cannot account for multiple forms of seizures yet
- We need more epileptic seizure data
- We have good test scores, but what do they mean?

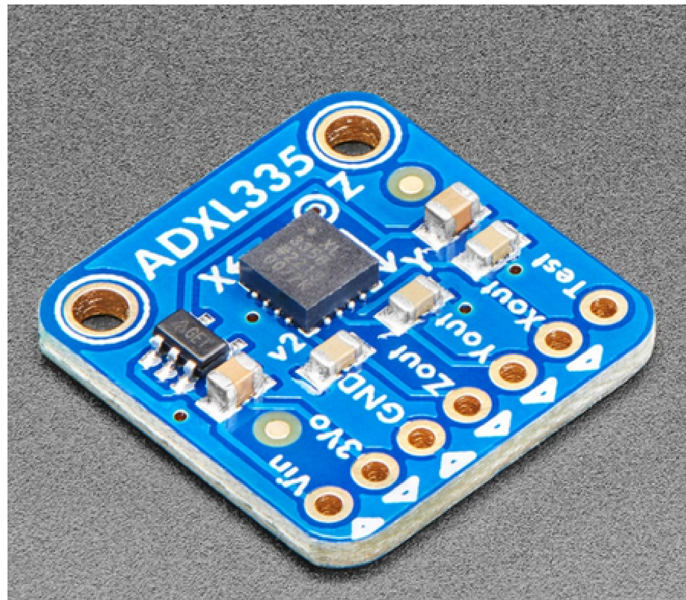
CONCLUSION

We implemented a Deep learning model in an embedded system to infer epileptic seizures with good test accuracies and F1 scores, proving that our model could accurately classify real time seizures with a wrist worn device and assist people with epilepsy.

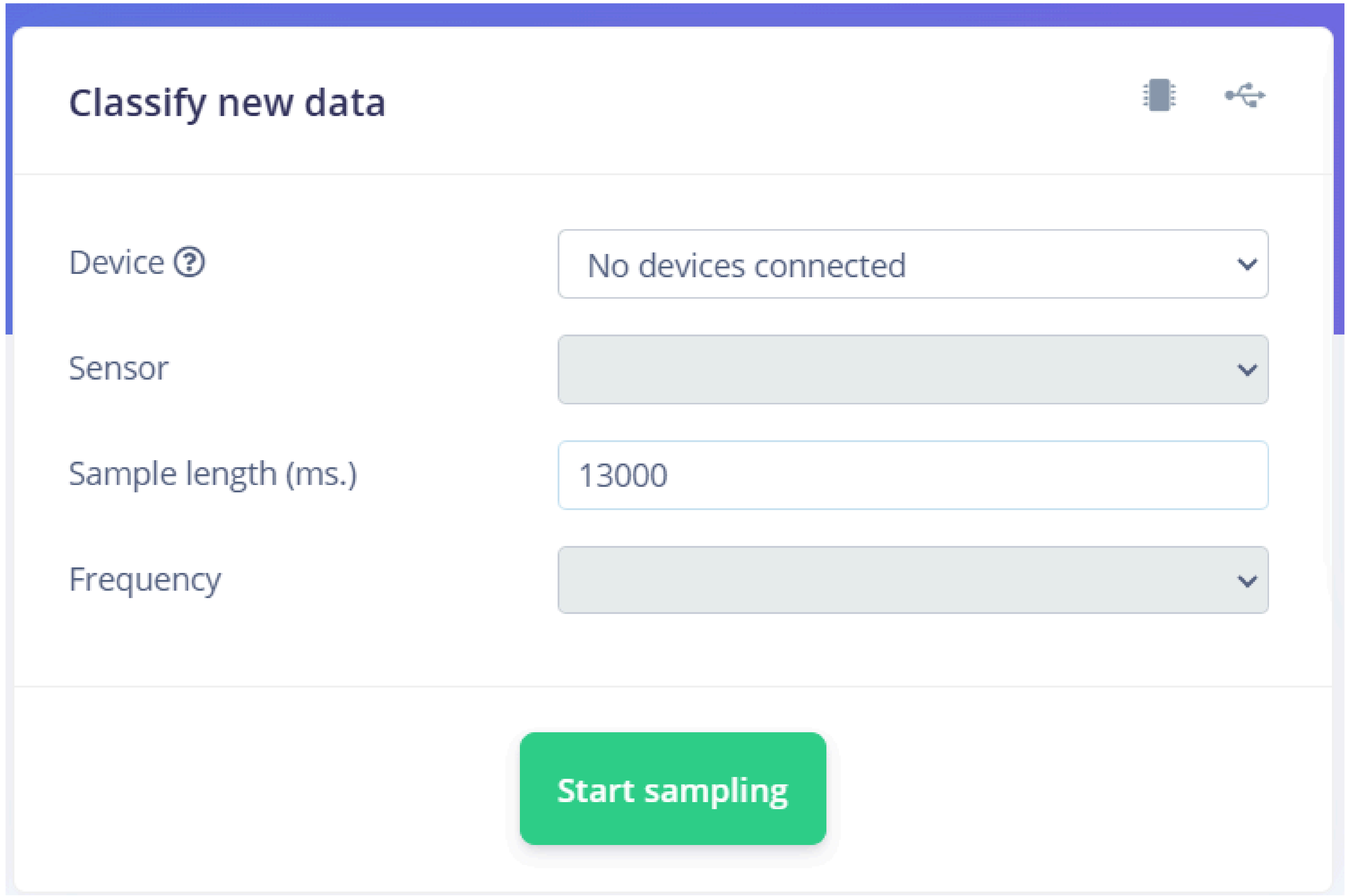
FUTURE WORK

- Collect more data related to seizures to further test and train our model
    - https://github.com/OpenSeizureDetector/OpenSeizureDatabase
- Try out different model architectures
- Add more sensors
- Deploy our model on a prototype (Arduino, STM boards...) and design a wristband
- Start clinical testing with control and experimental group

https://thepihut.com/products/adafruit-adxl335-5v-ready-triple-axis-accelerometer-3g-analog-out



LIVE DEMO


Classify new data
Device
No devices connected
Sensor
Sample length (ms.)
13000
Frequency
Start sampling

Q&A

Thank you!