Microelectronic Circuits Centre Ireland

Low Power IoT Sensor with Embedded AI for Healthcare Monitoring

Abstract

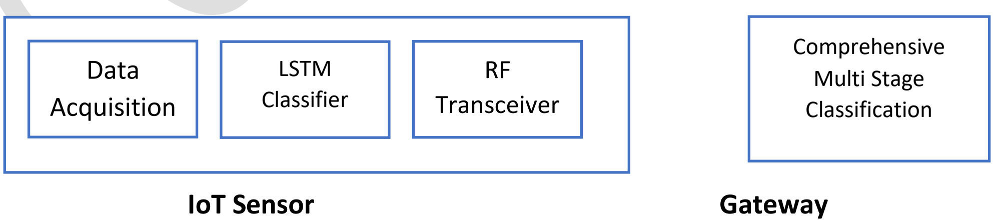
This proposal addresses the high-power consumption issue of wearable devices for CVD patients. Power consumption is too high due to continuous RF transmission of data. The idea is to process the physiological signals locally at the sensor using machine learning techniques to detect potential arrhythmias or health conditions. Wireless transmission can be enabled only when deemed necessary by the processing techniques to save power. Existing machine learning (ML) algorithms are not "light" enough to be implemented in IoT devices. This project aims to develop Edge/Near-Sensor computing techniques in IoT devices to opportunistically disable RF transmission.

Introduction:

To address the above-mentioned issues, we are developing a new algorithm where instead of looking for individual arrhythmias, only anomalies in the data are identified. Anytime an anomaly is detected, the wireless transmission can be enabled for real-time streaming, so that a more comprehensive analysis can be done in a cloud server or manually by a clinician. This solves the problem of computational complexity, personalisation and still achieves the power reduction in the sensor.

We aim to develop distributed ML algorithms for IoT devices in which

- A ***light*** first stage which makes binary decisions to be implemented in an IoT device.
- A second stage which makes a more comprehensive classification on a gateway device.

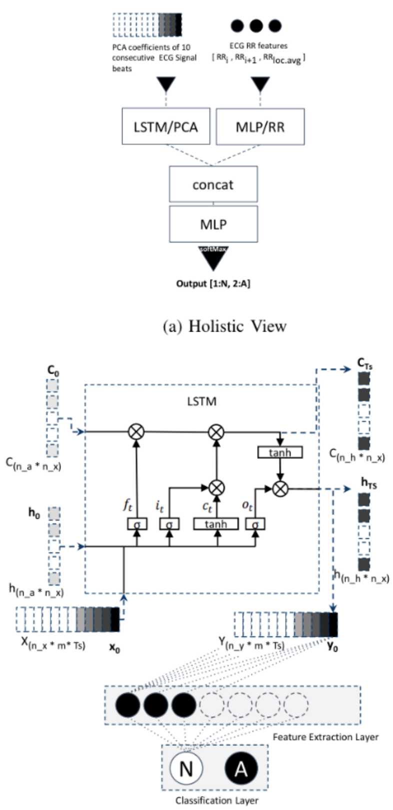


- Research distributed machine learning techniques with 2 stages.
    - Develop binary stage 1 classifiers to be implemented in the IoT
    - Develop stage 2 algorithm for comprehensive analysis

- Test the detection accuracy of the techniques at Stage 1 and Stage 2 using public datasets
- Develop a sensor prototype and implement the algorithms in firmware and measure improvements.

Algorithm Development:

LSTM based classifiers have been developed in Matlab from scratch. The algorithm is tested with free and open database. The binary classification accuracy in floating point is ~97%. SMOTE algorithm was used for data augmentation to deal with class imbalances. The accuracy with the SMOTE algorithm for floating point is 96%. A fixed-point version of the same algorithm for embedded implementation achieved 96% classification accuracy as well. For stage 2, we developed a CNN algorithm which achieved an accuracy of 98%.



(a) Holistic View

(b) LSTM Cell Pipelinee

Fig. 2: Neural Network Architecture

		REC	TN	FN	TP	FP	Total	Acc
1	1	**100**	1857	4	26	13	1,900	*99%*
2	3	**103**	1725	1	1	1	1,728	*100%*
3	4	**105**	1975	8	26	145	2,154	*93%*
4	8	**111**	1765	0	1	9	1,775	*99%*
5	10	**113**	1498	0	5	2	1,505	*100%*
6	14	**117**	1282	0	1	0	1,283	*100%*
7	17	**121**	1434	0	2	123	1,559	*92%*
8	19	**123**	1261	0	3	3	1,267	*100%*
9	21	**200**	1413	50	680	24	2,167	*97%*
10	23	**202**	1671	22	49	128	1,870	*92%*
11	29	**210**	1964	60	133	44	2,201	*95%*
12	30	**212**	2283	0	0	1	2,284	*100%*
13	31	**213**	2099	151	339	109	2,698	*90%*
14	32	**214**	1510	7	208	152	1,877	*92%*
15	34	**219**	1710	17	41	4	1,772	*99%*
16	36	**221**	1668	15	301	35	2,019	*98%*
17	37	**222**	1626	49	160	279	2,114	*84%*
18	39	**228**	1392	4	301	5	1,702	*99%*
19	41	**231**	1264	0	0	10	1,274	*99%*
20	42	**232**	298	39	1127	20	1,484	*96%*
21	43	**233**	1781	63	639	75	2,558	*95%*
22	44	**234**	2151	30	23	85	2,289	*95%*
	Test Set:		**35,627**	**520**	**4,066**	**1,267**	**41,480**	***96%***

For the experiment we have considered first 20 records in the MIT-BIH Arrythmia database consisting of more than 40 thousand beats. Less than 7,000 beats

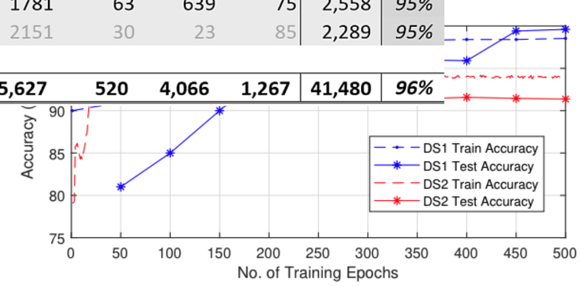


Fig. 4: Training Summary of the proposed Neural Network on DS1 (100 - 124) and DS2 (200 - 234)

among the first 1,000 beats of each records (from 20,000 beats) were selected for training the neural network.

The development of version 1 of the prototype sensor is completed. The LSTM based classifier is ported into an embedded device running Cortex M4 CPU. The power savings have been verified in an embedded development kit.