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ApproxBioWear: Approximating Additions for Efficient Biomedical Wearable Computing at the Edge

Alish Kanani[1], Rajat Bhattacharjya[2], and Dip Sankar Banerjee[1]

kanani.1@iitj.ac.in, rbhattacharjya@parallelwireless.com, dipsankarb@iitj.ac.in

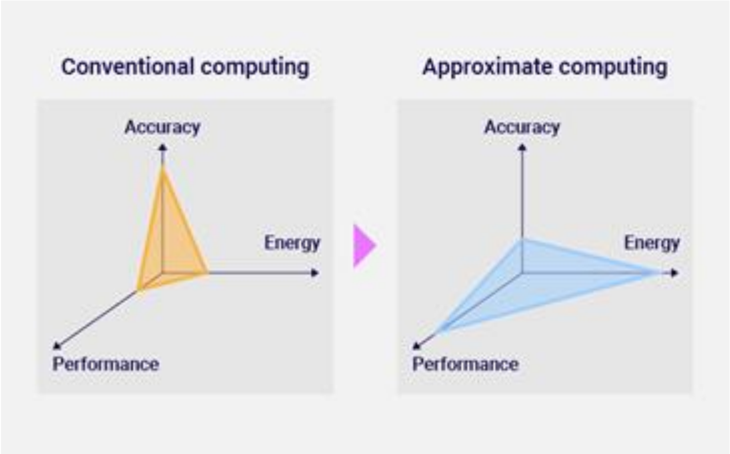
[1] Indian Institute of Technology Jodhpur, India
[2] Parallel Wireless, Inc.

Outline

- Introduction
- Background
- Methodology
- Results and Analysis
- Conclusion

Introduction

- Given the rise of COVID-19, it has become ever important to ramp up efficiency in **wearables** such as FitBit, Apple Watch etc.
- Hence, power efficiency is of utmost importance in any wearable system
- Biomedical signal processing algorithms are error-resilient in nature [1] because of underlying error-resilient algorithm such as FFT, Wavelet Transform etc.
- The domain of **approximate computing** offers the ability to lower area, delay and power parameters for hardware efficiency in exchange for a marginal loss in accuracy.



[1] Bharath Srinivas Prabakaran, Semeen Rehman, and Muhammad Shafique. 2019. XBioSiP: A Methodology for Approximate Bio-Signal Processing at the Edge. In Proceedings of the 56th Annual Design Automation Conference 2019 (DAC '19). Association for Computing Machinery, New York, NY, USA, Article 184, 1–6.

Background

- The Pan-Tompkins Algorithm is a filtering technique that is used to detect QRS complexes in ECG signals.
- QRS complex – main spike seen on ECG line
- There are mainly 6 stages involved in a typical Pan-Tompkins Algorithm.
- Being used in a wide range of wearable ECG monitoring devices.

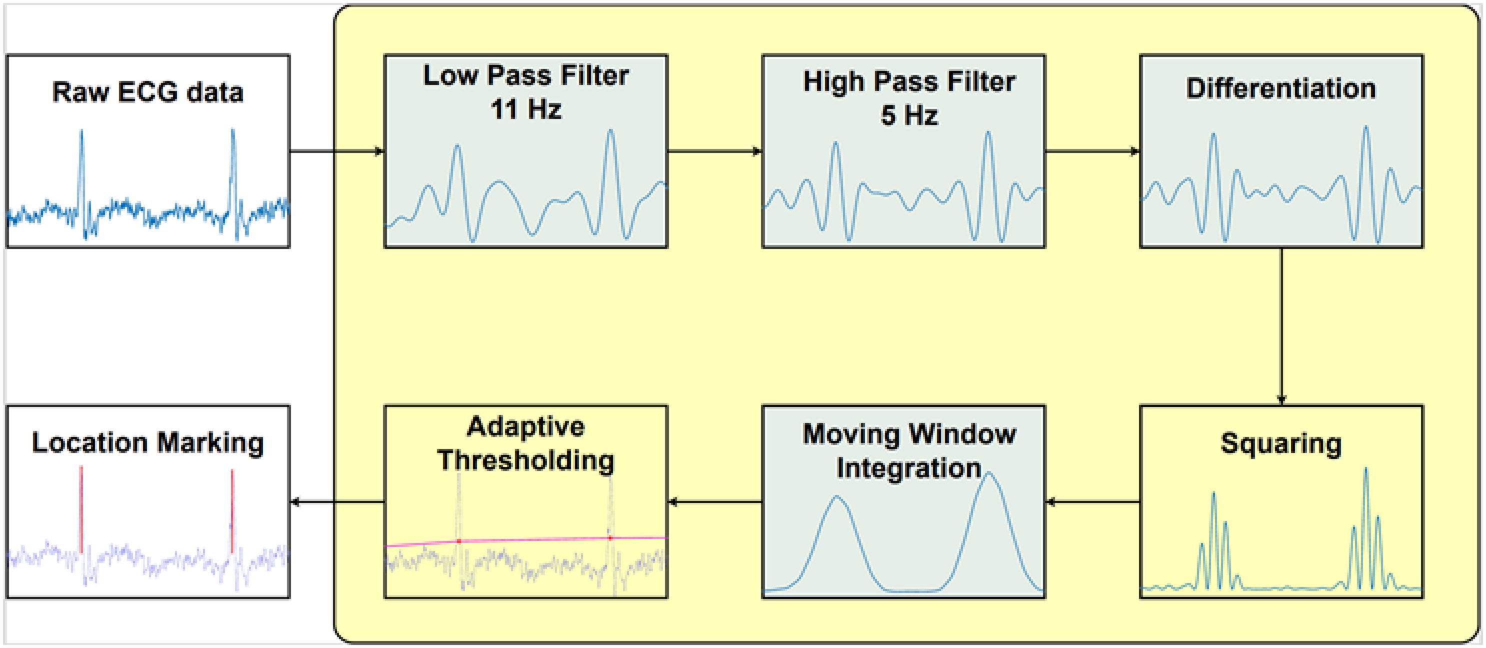
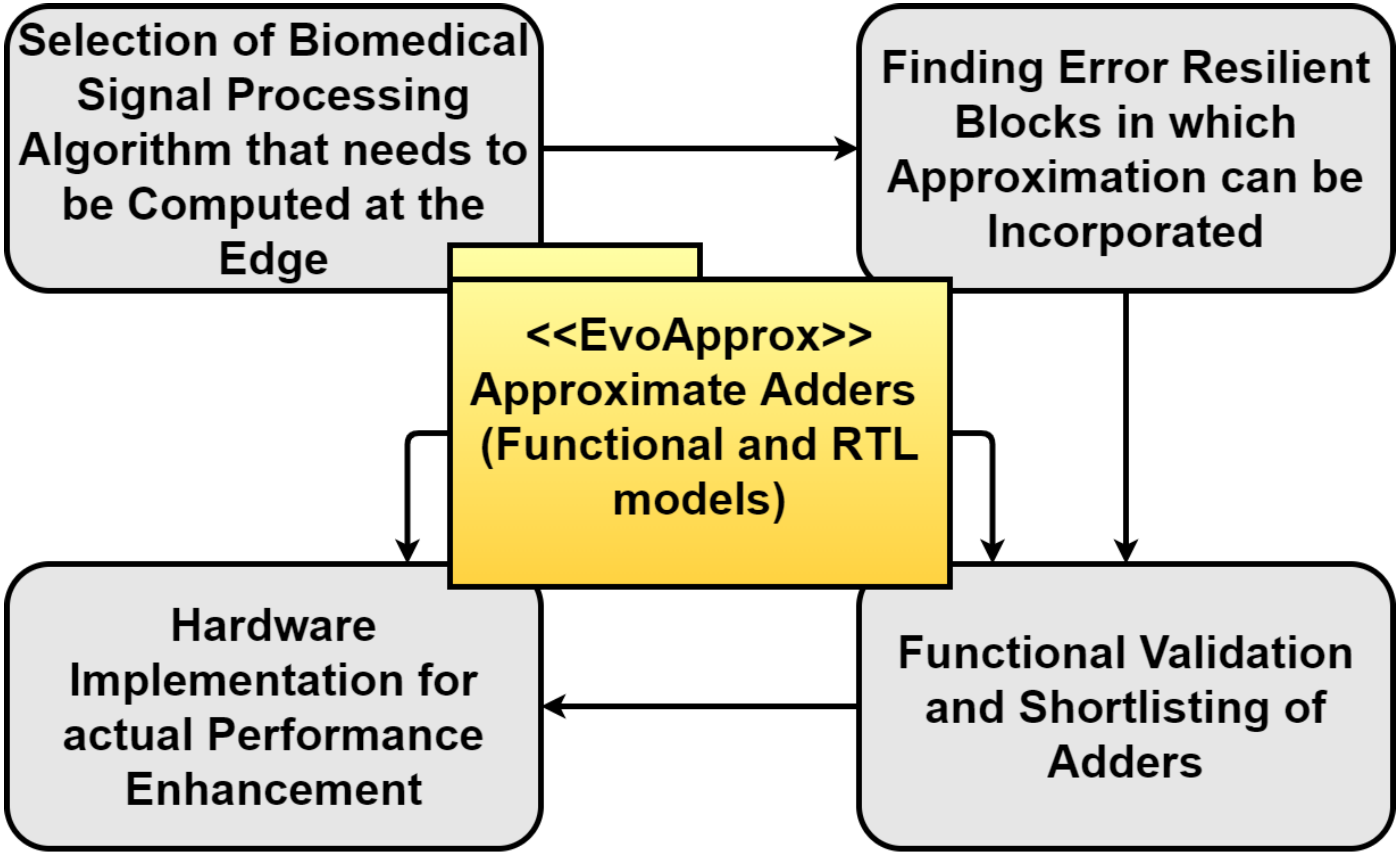


Fig: Pan-Tompkins Algorithm

Methodology



[2] V. Mrazek, R. Hrbacek, Z. Vasicek and L. Sekanina, EvoApprox8b: Library of approximate adders and multipliers for circuit design and benchmarking of approximation methods. Design, Automation & Test in Europe Conference & Exhibition (DATE), 2017, Lausanne, 2017, pp. 258-261. doi: 10.23919/DATE.2017.7926993

Error Resilient Blocks

- Filters are the important stage due to noisy data acquisition systems
- Filters – Noise reduction & Separation of required data => error resilient in nature
- Similar DSP algorithm which deals with noisy data can be out targeted block

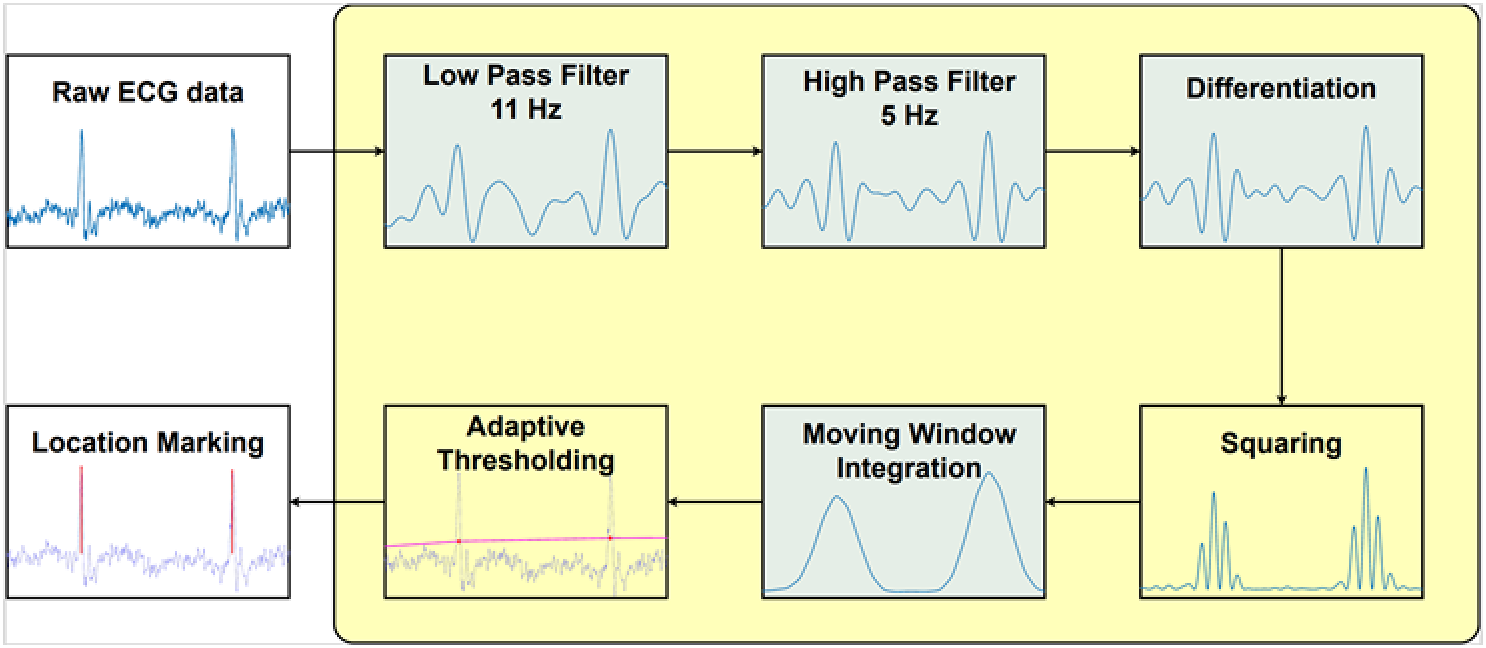


Fig: Pan-Tompkins Algorithm

Functional Validation

- Output of any biomedical signal processing algorithm is used in diagnosis.
- So, accuracy should not be decreased below a certain threshold
- After approximation, if the algorithm clears some predefined cutoff, the adders which are responsible for the approximation can be selected for further processing.

- How to approximate whole algorithm?
  - ➢ Replace add operation with approximate adder from library and give some random yet relevant input and produce error metrics.

Hardware Implementation

- Actual benefit can be explored by hardware implementation
- Based on application, different hardware synthesis flow can be used.
- First step is common => RTL implementation
- Synthesise RTL and produce Power-Performance-Area (PPA)
- Compare PPA and error metrics to choose adder based on application requirement.

Results and Analysis (Functional Validation)

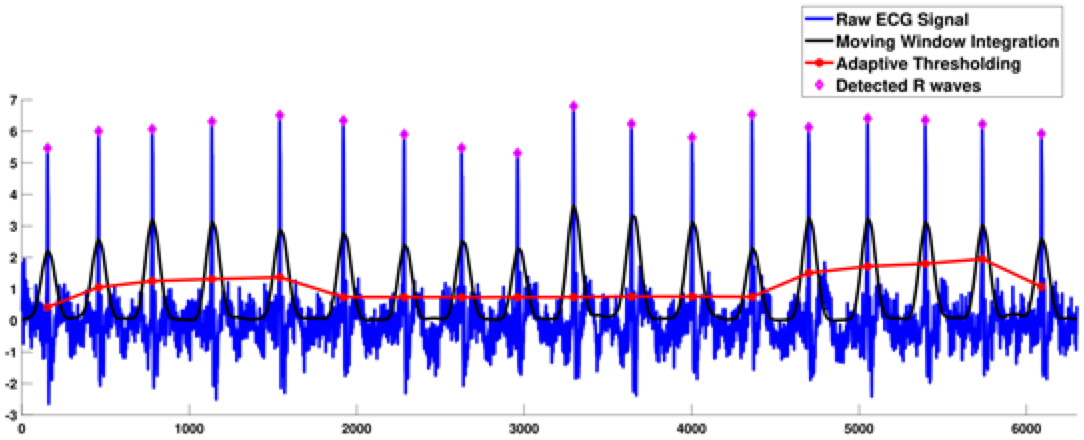


Fig 1: Accurate Adder

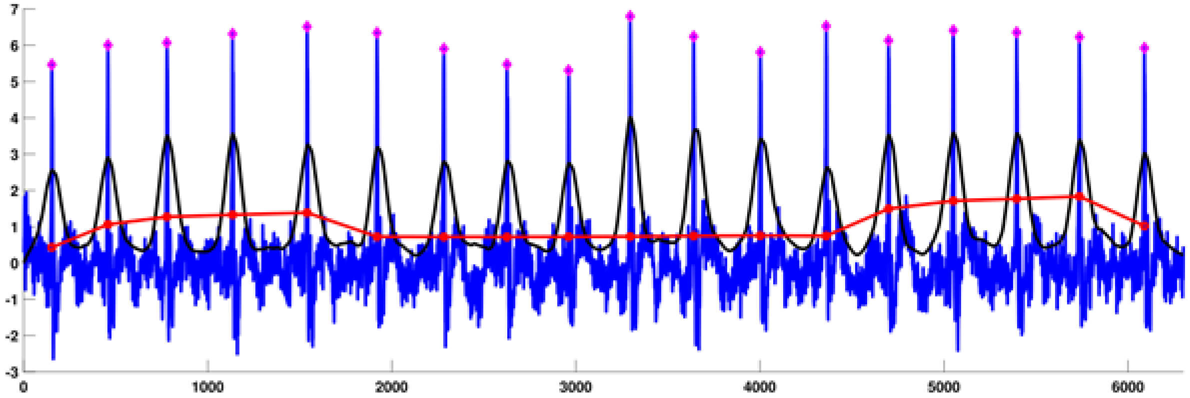


Fig 2: add16se1Y7 adder; SSIM=0.615

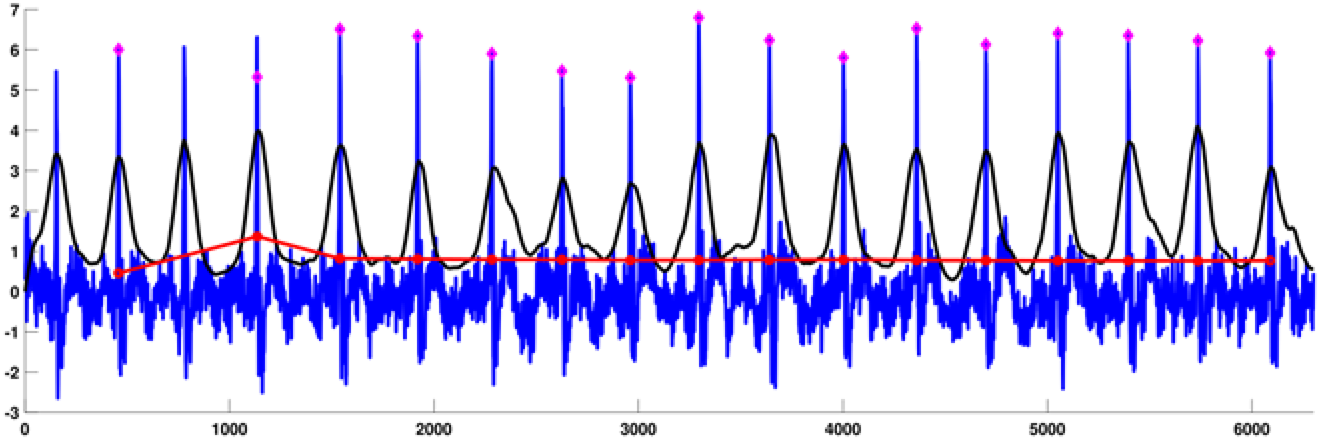


Fig 3: add16se29A adder; SSIM=0.49

Results and Analysis (Functional Validation)

Adder	SSIM	PSNR	MSE of threshold
add16se_1Y7	0.6147	7.3008	0.0011
add16se_2E1	0.4144	-1.5748	0.3699
add16se_2H0	0.973	34.0319	0.0001541
add16se_2JY	0.8193	18.3554	0.0016
add16se_2LJ	0.8934	24.3307	0.0002917
add16se_20J	0.9515	30.4783	0.0000077959
add16se_25S	0.4743	0.9262	0.3752
add16se_26Q	0.9929	42.365	0.0000085203
add16se_29A	0.4955	1.4894	0.277
add16se_294	0.6263	7.9271	0.061

Results and Analysis (Hardware Evaluation)

- Overall, there is **19.27%** power saving
- **7 detect peaks accurately** and these can be used in a **real clinical setting**.
- Area requirements, we can see that the FIR filter with approximate adder **add16se_2E1** provides an **area-saving of 24.63%**
- On average area saving **19.71%** compared to accurate adders.
- Worst-case delay on an average are **5.13% faster** than the accurate adders.

Table 1: Area, Worst-case delay and Power metrics of 100 point FIR filter with different approximate and accurate adders

Type of Adder	Adder	Area (μm^2)	Delay (ns)	Power (μW)
	add16se_1Y7	25639.20	2.24	15009
	add16se_2E1	24767.52	2.18	14309
	add16se_2HO	27691.92	2.16	16208
	add16se_2.JY	26166.95	2.16	15209
Approximate	addiose_2LJ	27979.20	2.21	16348
	add16se 20	27083.05	2.24	16072
	add16se_255	25377.46	2.36	14619
	add16se_26Q	27163.92	2.16	15697
	add16se_29A	25688.42	2.3	15219
	add16se_294	26288.51	2.24	15622
	Brent-Kung adder	33272.08	2.23	18919
	Carry-Lookahead adder_2	29111.31	2.14	16274
	Carry-Lookahead adder_4	29111.31	2.15	16273
	Carry-Lookahead adder_8	30849.35	2.12	17850
	Carry-Select adder_2	38735.72	2.17	23593
Accurate	Carry-Select adder_4	39602.88	2.31	24171
	Carry-Select adder_8	36241.98	2.36	21428
	Carry-Skip adder. 2	31905.37	2.6	18937
	Carry-Skip adder-4	32376.72	2.74	18916
	Carry-Skip adder_8	31498.65	2.61	17786
	Ripple-Carry adder	28768.96	2.37	16214

The FIR filter was described with Verilog HDL using various adders. The area, power and delay statistics were obtained by synthesizing the Verilog codes in Synopsys Design Compiler with a 45nm technology node.

Conclusion

- Here, we presented an approach ApproxBioWear. ApproxBioWear can be used to increase hardware efficiency in wearables.

- The core concept behind this approach is approximating the addition operations involved in filtering steps of a biomedical signal processing algorithm so as to mainly save power and area.

- Upon employing the ApproxBioWear approach, we see that the application accuracy stays almost the same after approximation as compared to accurate operations. On average, the presented methodology provides an **area-saving of 19.71%** and **power-saving of 19.27%**.

Thank You

Questions?