MSc. Assignments – Approximate Computing

Several digital signal processing applications can tolerate controlled inaccuracies in computations, such as multimedia, search engines and machine learning, and are therefore called *Error Resilient Applications (ERA)*. ERAs have one or more of the following attributes: redundant or noisy input data, healing computational patterns like iterative methods, and a range of acceptable outputs. ERAs introduce an additional design parameter: *quality*, that can be traded for reducing computational costs (area/latency/energy) of a computing system. Think of an image processing output, which is an image, where our perceptional limits may not allow us to differentiate between 100% correct and 95% correct underlying computations. This brings us to think about that the computing systems are overdoing for ERAs, and motivates us to save computational costs by processing only for the required quality. Approximate computing [1] studies the quality-cost tradeoff of a design, where the goal is to achieve the minimum computational cost for a given bound of acceptable quality-loss. Here we propose two related MSc. assignments;

1. Quantifying error resilience of applications for approximate computing

Student's profile: Preferably from computer science, or at least has interests in application analysis.

Assessing applications for error resilience, and quantifying the bound of acceptable quality-loss is very important to deploy approximate computing efficiently [2]. The goal of this assignment is to develop an efficient methodology to analyze applications for error resilience. Where the outcome of the analysis quantifies error resilience and provides the hints towards promising approximation techniques to achieve the optimal design. The key points of the assignment are as follows,

- Overview of state-of-the-art error resilient analysis methodologies
- Utilizing efficient ways to overcome the shortcomings of state-of-the-art methodologies
- Comparison of conventional and proposed analysis methodologies
- Case study of Radio Astronomy signal processing with the help of our PhD student
- Publication of interesting results in international conference/journal (optional).

2. Approximate Multiply-Accumulate (MAC) Processors

Student's profile: Preferably from Electrical Engineering/Embedded Systems, or at least has interests in VHDL/verilog & ASIC design flow.

The goal of this assignment is to study the trade-off between computational cost (area/speed/energy) vs quality (accuracy of computed results) in ASIC designs. In this regard, a multiply-accumulate (MAC) module will be implemented in VHDL that can handle 8-bit (Fixed Point) input stream with various distributions. This 8-bit MAC design will be considered as the reference accurate design. Then, some relatively lower cost (less accuracy) MAC modules will be implemented using *Approximate (Ax) Multipliers and/or Ax Accumulator*. Finally, the computational costs of the aforesaid designs will be compared and reported. The key points of the assignment are as follows,

- Modelling and quality analysis of 8-bit MAC module in Matlab/C for accurate and approximate versions
- Design space exploration to achieve best design by utilizing fixed-point truncation, approximate MUL and approximate accumulator.
- Implementation of 8-bit MAC module in VHDL and comparison of costs among accurate and various approximate designs in terms of area, power and latency (ASIC design flow)
- Case study of Radio Astronomy signal processing
- Publication of interesting results in an international conference/journal (optional)

References:

[1] M. Shafique, R. Hafiz, S. Rehman, W. El-Harouni and J. Henkel, "Invited: Cross-layer approximate computing: From logic to architectures," 53rd ACM/EDAC/IEEE Design Automation Conference (DAC), Austin, TX, 2016, pp. 1-6.

[2] Gillani, G. A., and A. B. J. Kokkeler. "Improving Error Resilience Analysis Methodology of Iterative Workloads for Approximate Computing." Proceedings of the Computing Frontiers Conference. ACM, 2017.