Special Issue on Approximate Computing: Challenges, Methodologies, Algorithms, and Architectures for Dependable and Secure Systems

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Guest Editorial: Special Issue on Approximate Computing: Challenges, methodologies, algorithms and, architectures for Dependable and Secure Systems

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THE current trend in energy resources shapes how computing systems will address new challenges in the following years. As a matter of fact, following the current trend, by 2040, computers will require more energy than the world's resources can generate. In the very upcoming future, by 2025, data centers alone will consume 20% of all available electricity. A similar trend already impacts the communications side where, for example, energy consumption in mobile broadband networks and mobile terminals is comparable to data centers. These trends can only accelerate by broadening the spectrum of possible mobile applications to the Internet of Things (IoT), which will connect 50 billion devices through wireless connections to the cloud infrastructure within a few years.

In such a scenario, classical approaches to computer system design are no longer adequate to address the problems highlighted, and new ones need to be introduced. More than ten years ago, the scientific literature demonstrated that the Approximate Computing (AxC) paradigm could pave the way to ease the power requirements and reduce the impact of the computation on the energy budget. When coupled with error-resilient applications, AxC achieves significant gains in overhead reduction (i.e., energy and latency) at the cost of a slight (i.e., still acceptable for applications) precision reduction of output. On precise computations, an accuracy degradation can often be controlled and limited in the output space of the application executed on the AxC computing system.

So far, many AxC techniques and CAD tools have been developed targeting different abstraction layers: Circuit, Architecture, and Software. However, in the past four years, AxC has just moved from its infancy to the mainstream, also becoming attractive to the computer industry. Widely adopted Machine Learning algorithms already deeply leverage AxC techniques, i.e., the TinyML trend, and hardware manufacturers started exploiting AxC in their designs (i.e., NVIDIA GPU Volta architecture). Finally, new application domains started to use AxC, such as Testing, Dependability, Safety, and Security. In particular, Dependable systems design often requires power- and area-hungry solutions, such as redundant schemes. The ability of AxC methodology to provide smaller designs is nowadays a new possibility for functional safety experts to exploit fault tolerance and general design optimization with more tools.

Similar considerations can be drawn when dealing with robustness in the security domain. Recent works already point out that AxC techniques, deployed in selected parts of the systems, make the system less prone to external attacks by increasing the data's noise or changing the application's power signature.

The Special issue on "Approximate Computing: challenges, methodologies, algorithms and architectures for Dependable and Secure Systems" met its original goal of collecting scientific contributions that covered connections between the AxC paradigm and the dependability and security of digital designs.

This special issue comprises three highly rated research papers covering a significant part of the original call for paper.

The first paper in the Special Issue by Martin H. et al. extends the classical association of approximate computing with results that show a trade-off between result accuracy and computational efficiency, offering its application in the world of hardware trustworthiness with encouraging results.

The second paper, by Cai M. et al., proposes a design flow combining concepts of timing speculation and approximate storage to achieve a dependable operation of STT-MRAM devices. The STT-MRAM technology is considered a promising candidate for non-volatile memory (NVM), i.e., for caches and implementing embedded NVM.

In the third paper, Liu B. et al., authors proposed a low-power precision reconfigurable tensor multiplication unit (TMU) with approximate computing technologies, applying the multiplication unit to a CNN-based keywords speech recognition. The architecture is configured to use approximate encoding and addition and a lower voltage for the approximate circuits to improve energy efficiency. Results will prove the need for AxC techniques when a system's energy efficiency is the final goal.

These articles provide a snapshot of state of the art and hopefully can also suggest opportunities and challenges of this vital research theme. Enjoy reading!

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