Addressing the Challenge of Data Deluge: Innovations in Edge Processing and Memory Arrays

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The volume of data communicated between wireless agents and the cloud has surpassed the capacity of current systems to transfer, manage, and process it efficiently. Over the past two decades, advances in materials and electronic devices have extended Moore's law, increased device density and memory, and reduced computation and power consumption. These advancements have also driven the development of sensors capable of continuously collecting data at high bit rates, contributing to what is now known as the Challenge of Data Deluge.

6G aims to support applications such as autonomous driving and holographic communications, which require systems to collect, store, and process raw sensory data on the cloud in real time while conserving energy. However, the experience with 4G and 5G technologies suggests otherwise. As the number of sensors grows logarithmically, wireless data traffic and energy consumption are accelerating. By 2030, the amount of data stored is projected to reach 200 zettabytes (10^{21} bytes) [1]. Due to the lack of comprehensive data on the number and location of global data centers, estimating the electric energy required for data storage and the overall impact on CO_2 emissions is challenging [2]. However, projections based on self-reported data estimate that by 2030, data storage will be the fastest-growing component of ICT, potentially consuming 10-20% of global electric energy usage [3].

One promising solution to manage the increasing volume of stored data is processing with intelligence at the edge. Designing for edge processing and intelligence must meet expectations for real-time response and navigate limitations in available space, leading to requirements for ultra-high-density hardware that operates on limited energy budgets with high levels of security and reliability. Nature's efficiency in linking capacity to the need for survivability and continuous learning offers valuable insights for designing edge sensory platforms. A successful design approach requires the ability to process and store information directly in memory rather than traditional data.

This presentation proposes an approach to electromagnetic sensing based on a memory array and a layered, hierarchical system architecture where analog data is pre-processed as close to the individual sensors as possible. This circuit architecture is scalable to any sensor on any platform and is based on the co-design of analog hardware and deep machine learning algorithms, specifically attention-focused learning algorithms, developed to execute sensory input pre-processing effectively next to the sensor and then perform information fusion for the intended action.

Results will be presented from an analog signal processor designed explicitly for spectrum classification, demonstrating significant improvements in information processing. The approach achieves a reduction in data rate by 10^4 to 10^5 times and a reduction in energy consumption by 10^2 to 10^4 times, highlighting the potential of edge processing and memory arrays in addressing the data deluge challenge.

References

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[2] Statista Inc. Research Department, "Amount-of-data-created-consumed-and-stored-2010-2020-with-forecasts-to-2025," Statista Inc., 2021.

[3] D. D'Ambrosio and P. Gonzalez, "Electricity Sector Analysis - IEA," Paris, France, Sep. 2022.