17th World Congress on Computational Mechanics
10th European Congress on Computational Methods in Applied Sciences and Engineering
WCCM-ECCOMAS2026
July 19-24, 2026, Munich, Germany

RETHINKING AI: ENERGY EFFICIENCY AND THE FUTURE OF COMPUTATION

TRACK NUMBER 600

MASSIMILIANO DATRES[*], SIFAT REZWAN[†], JUAN ALBERTO CABRERA[¶], ERNESTO ARAYA VALDIVIA[§] AND ALEXANDRU-PAUL DRĂGUȚOIU[‡]

[*] Bavarian AI Chair for Mathematical Foundations of Artificial Intelligence, LMU Munich
Akademiestr. 7, 80799 München
datres@math.lmu.de

[§] Bavarian AI Chair for Mathematical Foundations of Artificial Intelligence, LMU Munich
Akademiestr. 7, 80799 München
araya@math.lmu.de

[†] Deutsche Telekom Chair of Communication Networks, TUD Dresden
Georg-Schumann-Straße 11, 01187 Dresden
sifat.rezwan@tu-dresden.de

[¶] Deutsche Telekom Chair of Communication Networks, TUD Dresden
Georg-Schumann-Straße 11, 01187 Dresden
juan.cabrera@tu-dresden.de

[‡] TUEILTI Lehrstuhl für Theoretische Informationstechnik, TUM Munich
Theresienstrasse 90, Gebäude N4, 4. Stock, 80333 München
alex.dragutoiu@tum.de

Keywords: sustainable AI, neuromorphic computing, analog computing, machine learning

ABSTRACT

Over the past decade, neural networks have been a revolution in the computing landscape. Chatbots [1], medicine [2], robotics [3], and communications [4] are just a few examples of how deep learning has outperformed previous state-of-the-art technologies. The success of deep learning has come at a cost: the energy demands of running such models on conventional hardware architectures are becoming unsustainable. Indeed, the training of deep learning models with millions or even billions of parameters requires servers equipped with specialized GPU or TPU producing roughly the same amount of CO_2 emission as the footprint of five cars [5]. Their development in real-world applications, such as autonomous driving, can be even more demanding due to the need for continuous-time inference.

Therefore, as digital computing nears its energy efficiency limits, especially in AI applications, neuromorphic [6] and analog [7] computing are gaining renewed attention as a necessary and promising alternative. Neuromorphic chips aim to replicate how neurons and synapses process

signals in biological neural networks, where the synergy between parallelism, asynchronous signal propagation, and unified memory-computations unit enables the brain to operate with such high energy efficiency. Despite neuromorphic chips can be used to speed up existing AI models, it is essential to design new models and algorithms that can embrace and exploit these characteristics. On the other hand, analog hardware leverages the continuous dynamics of physical phenomena, such as electrical or material properties, to perform computation with significantly lower energy and latency than digital systems, which abstract computations into discrete logic and memory units. This makes it a compelling path toward sustainable AI, particularly for edge devices and real-time inference tasks where power constraints are critical.

Despite their promises, both neuromorphic and analog computing raise key research questions, such as designing algorithms that are robust to the inherent noise of analog substrates, understanding the levels of precision and reliability for different AI tasks, and co-designing models and circuits to balance benefits with scalability and programmability.

This mini-symposium explores brain-inspired and analog computing paradigms that promise transformative advances in energy-efficient AI. We discuss both theoretical foundations and practical applications of neuromorphic and analog computing, highlighting key challenges, recent breakthroughs, and future directions. The event aims to bring together machine learning researchers and hardware engineers to to promote discussion on the design of new generation AI systems for non-traditional and energy-efficient hardware platforms.

REFERENCES

[1] Dam, Sumit Kumar, et al. "A complete survey on llm-based ai chatbots." *arXiv preprint arXiv:2406.16937* (2024).

[2] Piccialli, Francesco, et al. "A survey on deep learning in medicine: Why, how and when?." *Information Fusion* 66 (2021): 111-137.

[3] Tang, Chen, et al. "Deep reinforcement learning for robotics: A survey of real-world successes." *Proceedings of the AAAI Conference on Artificial Intelligence*. Vol. 39. No. 27. 2025.

[4] Zhao, Jingyuan, et al. "Autonomous driving system: A comprehensive survey." *Expert Systems with Applications* 242 (2024): 122836.

[5] Strubell, Emma, Ananya Ganesh, and Andrew McCallum. "Energy and policy considerations for modern deep learning research." *Proceedings of the AAAI conference on artificial intelligence*. Vol. 34. No. 09. 2020.

[6] Boosting AI with neuromorphic computing. *Nat Comput Sci* **5**, 1–2 (2025). https://doi.org/10.1038/s43588-025-00770-4

[7] K. Hosokawa *et al.*, "Circuit Techniques for Efficient Acceleration of Deep Neural Network Inference with Analog-AI (Invited)," *2021 IEEE International Symposium on Circuits and Systems (ISCAS)*, Daegu, Korea, 2021, pp. 1-5, doi: 10.1109/ISCAS51556.2021.9401128.