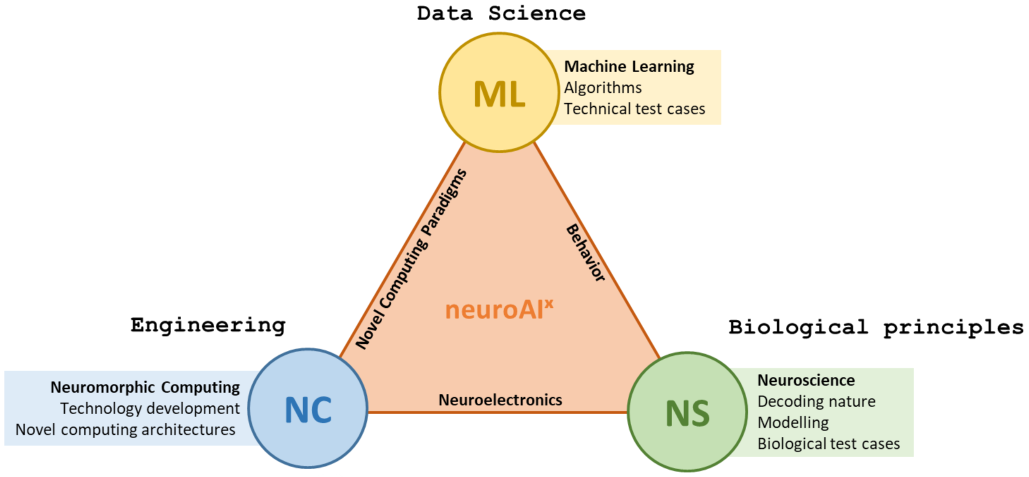
INNOVATION | RWTH AACHEN UNIVERSITY

Frontiers Workshop – NeuroAI^x

In the last 60 years, semiconductor technology has gone through an unprecedented development providing humankind with enormous computing capabilities. This has provided the basis of impressive innovations in many domains – out of which the field of machine learning is probably the most prominent in public perception.

Today, the underlying technological progress following Moore's law is facing physical limits, which has the potential to endanger future progress. RWTH seizes this challenge as a driver for innovations. With the pre-existing expertise, it appeared natural to join forces in order to establish the NEUROTEC and NeuroSys research activities, which connect the fundamental findings on the technology side with the needs of upcoming applications. On each design entry level - from the electrical device to modern machine learning algorithms – our neuroscientists thereby interject their latest concepts related to the "compute" processes in the brain. Fundamental research in neuroscience uncovers the biological construction and communication principles of the brain and in particular the rules governing its plasticity on multiple time scales. This knowledge encoded in equations and algorithms guides the conception of neuromorphic computing architectures. Thereby, physical constraints are exposed and questions about the brain are raised that were hidden in a blind spot – as Richard Feynman pointed out: "What I cannot create I do not understand". With each step hardware takes to absorb biological-inspired features, it will also provide more powerful computing resources for neuroscientists to substantiate their new theories in simulation – this is especially true for the process of plasticity and learning in biological networks. The principles of cognitive processes in the brain, using essentially the same structure for all sensory modalities and actions as well as higher cognitive functions, are just emerging. These findings provide the fundamental knowledge for new algorithms in machine learning from perception to symbolic AI. Thereby, advances in algorithmic performance are relayed back to materialize in new hypotheses about the computational principles of the brain. Quite pragmatically, new tools on the machine learning front help to analyze and better understand the complex neuroscientific data. Last but not least, we witness a tremendous industry drive to co-design algorithms and hardware, which is guided by research output including functional prototypes pushing the limits ever further. Together, we visualize a triangle spanned by corner stones located in the domains of neuromorphic computing (NC), machine learning (ML), and neuroscience (NS), respectively.



Going one step further, there are actually three additional domains with close relation to the ones discussed so far. First, there is the integration of novel devices into hardware systems executing related algorithms far more efficiently than classic von-Neumann architectures. Secondly, novel organoids, smarter microelectronics and cell engineering – the so-called wetware – provide deeper insights into the behaviour of clusters of living neurons, hence locating this domain between NC and NS. Thirdly, sizing up to the macro level, multi-area simulation models of the brain and physically observed patterns in the human cortex interface in the clinical domain are (still) relying on classic high-performance computing hardware to simulate and sift through the massive amounts of generated data applying – besides others – methods from the domain of machine learning.

It is essential to consider any of the connecting lines as bidirectional links between the domains. One has to realize the enormous potential of cross-pollination across the domains involved. Together, they span a wide space for exploration – a tilled field ready to sprout innovations, which is expedited by a team of internal and external business experts.

One example of such interdisciplinary activity is the research and development of an artificial retina implant. On one side, it addresses the persistent interfacing between inorganic electronics with living neurons. On the other side, it turns out that directly feeding luminance information using an array of photodiodes is insufficient. To interface in a biological meaningful way, communication with the Ganglia cells is necessary with requires a first level of processing in artificial neurons to pull off the feat such that blind see again.

Another example is given by mobile robots and intelligent vehicles that perceive their environment, i.e., they aim to understand what is happening around them in order to act upon this information – a key aspect when manoeuvring in human environments. Machine Learning has played a key role in enabling recent progress in this area with core challenges lying in more scalable, unsupervised learning approaches including interfacing to high-level cognition, which is the basis for meaningful capabilities of understanding a scene.

Seizing the future, major investments into human capital and infrastructure should be shared in a smart way as best practices are rapidly overhauled. Join us to set the basis of fruitful partnerships riding this dynamic development. In a stimulating environment at the research campus your ideas will ripen faster, supportive eco-systems will be created, and business opportunities will be uncovered within the wide fields of leading-edge research.