

Match Making Event: MSc. Projects at the Computer Engineering

Hardware AI using Emerging Devices

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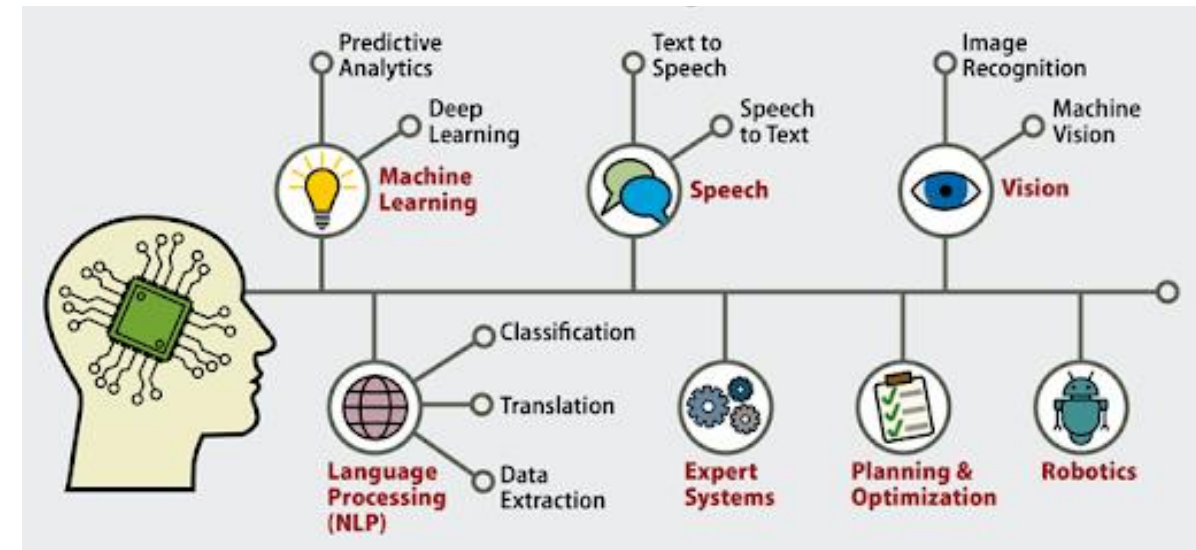
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Artificial Intelligence (AI)

Theory and development of systems able to perform tasks requiring human intelligence



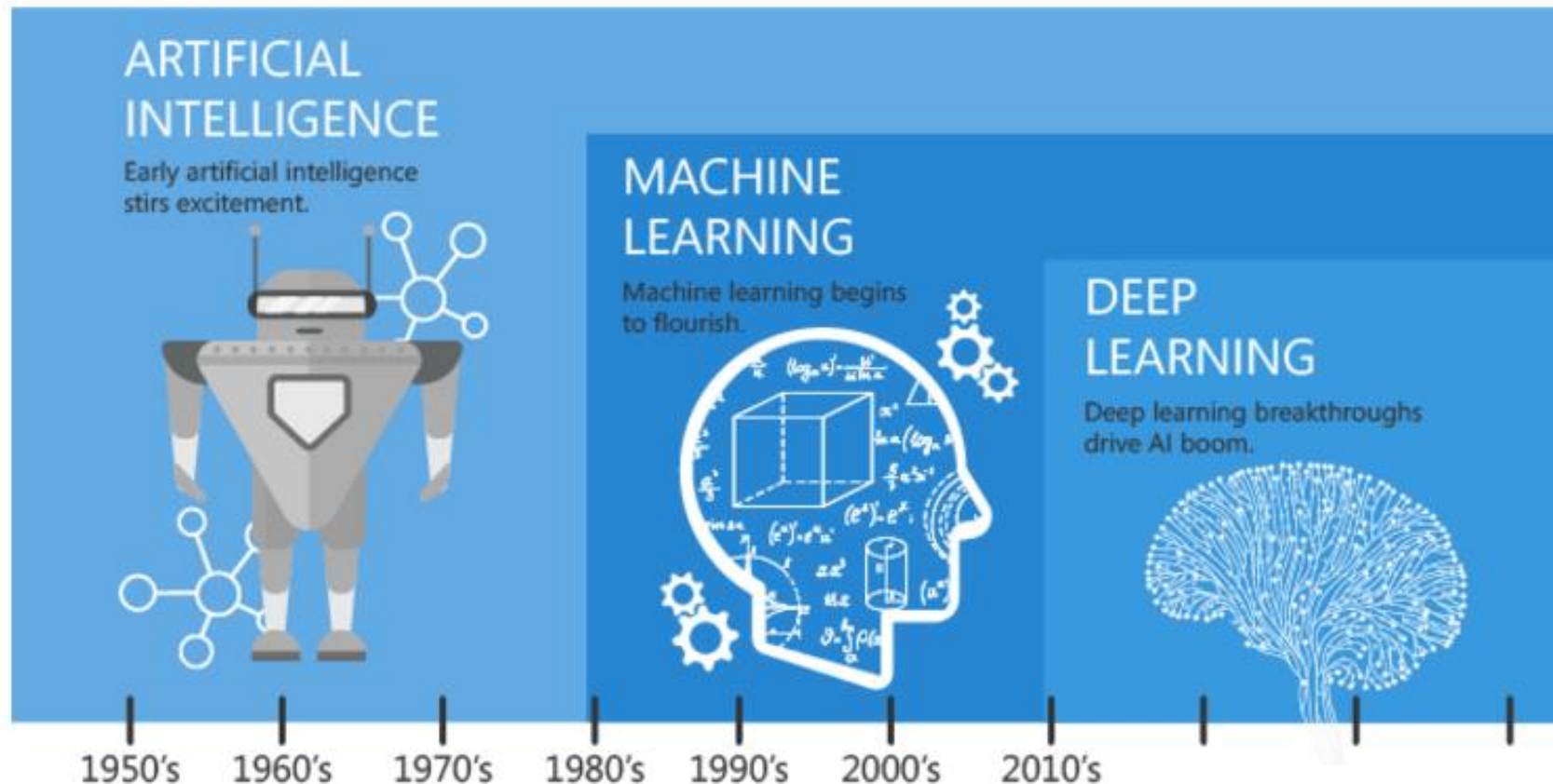
Source: www.javatpoint.com



Source: www.impacttactics.com

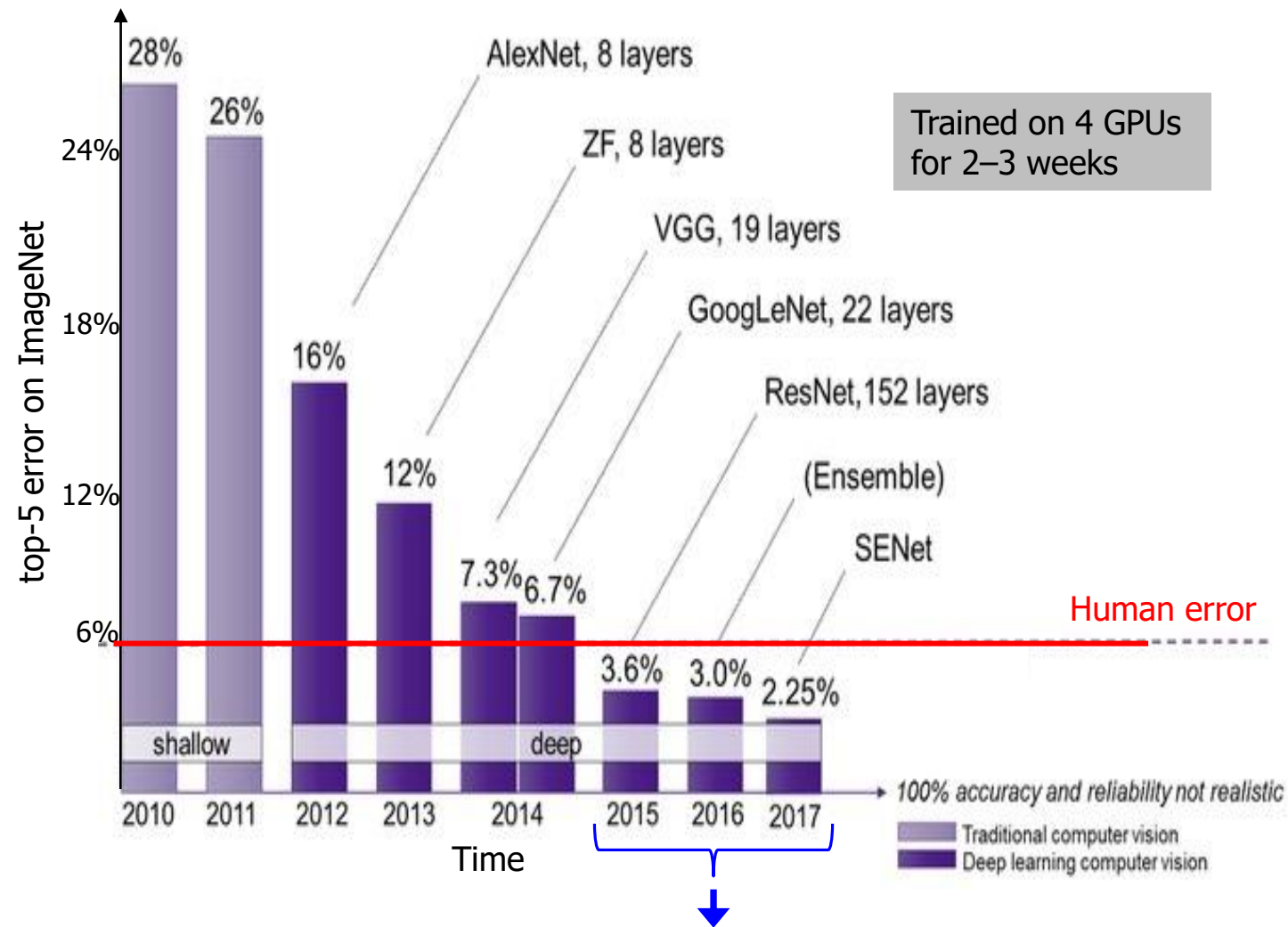
AI vs Machine Learning vs Deep Learning

- ❑ John McCarthy coined the term AI
- ❑ **Machine learning** is the study of computer algorithms that improve automatically through experience
- ❑ **Deep Learning** imitates the workings of the human brain in processing data and creating patterns for use in decision making.



Source: www.peter-doherty.com

AI- Intelligence



AI surpassed human

Google-AI defeated world champions in Go

Ke Jie in 2017



Source: npr.org

Lee Sedol in 2016



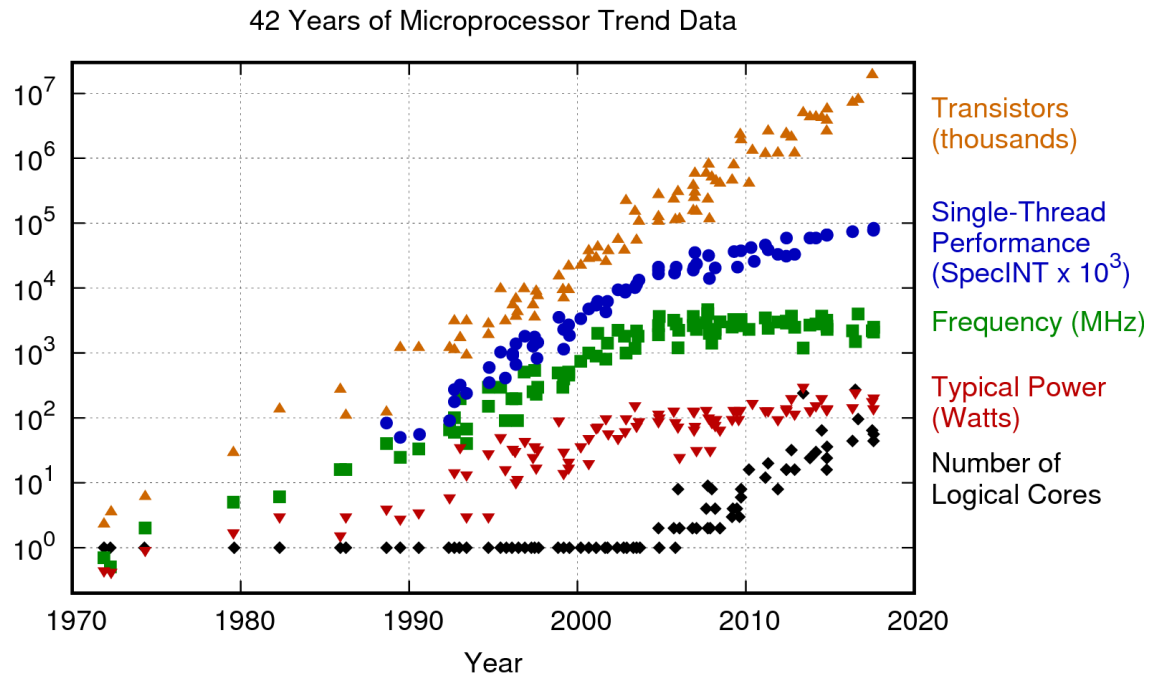
Source: <http://addictive-strategy.com/>

- ❑ Resources: 1920 CPU + 280 GPU
- ❑ AlphaGo ~1MW of Power
- ❑ Electricity bill of USD-300 was generated for a single game

AI requires huge resources & large amount of data

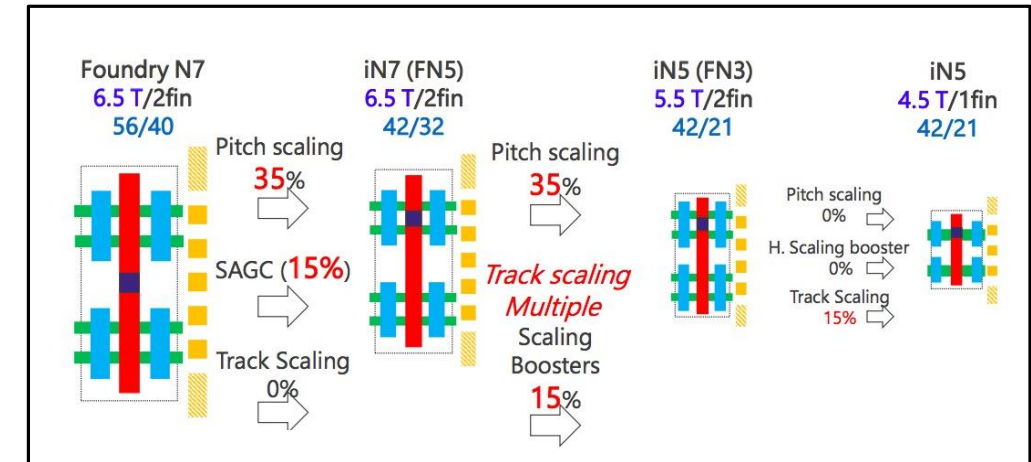
Challenges: Existing Technology

- ❑ AI algorithms run on conventional *Von Neumann* architecture such as
 - ❑ CPUs, GPUs, FPGA's and TPUs
- ❑ Memory bottleneck: data retrieving, transportation and storage lead to high latency and energy



Original data up to the year 2010 collected and plotted by M. Horowitz, F. Labonte, O. Shacham, K. Olukotun, L. Hammond, and C. Batten
New plot and data collected for 2010-2017 by K. Rupp

Device downscaling is challenging

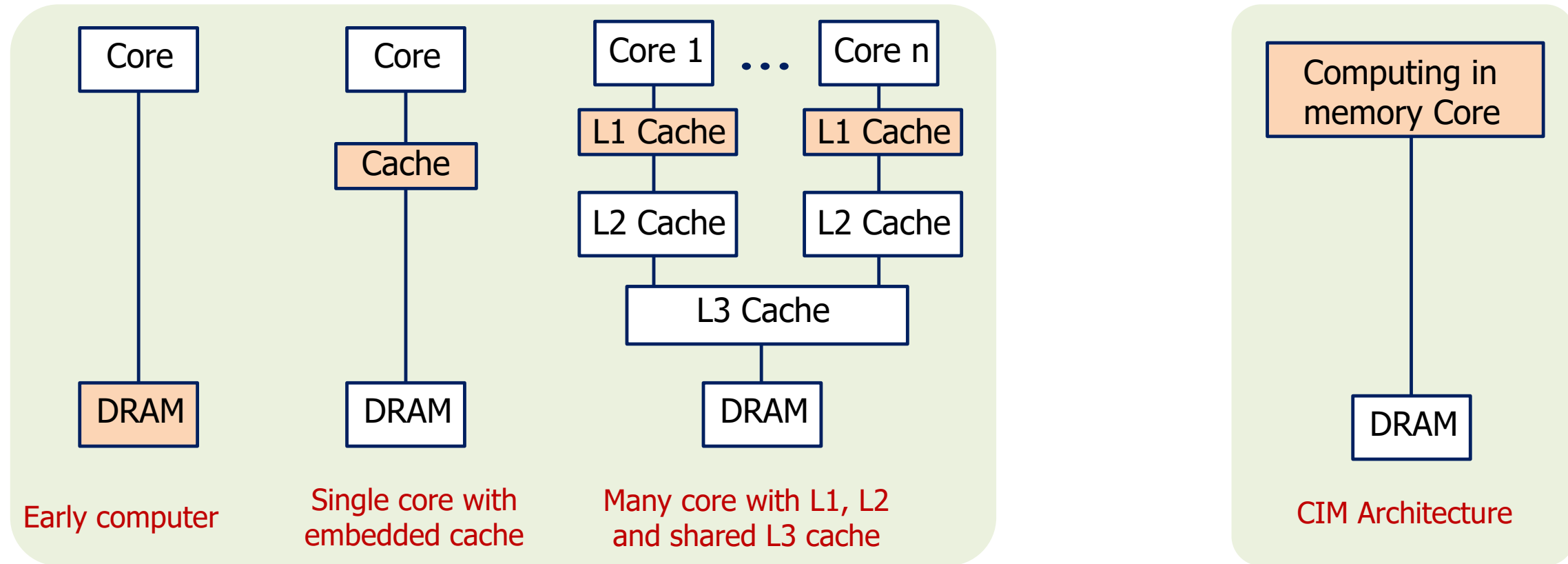


Source: IMEC and cadence

Need of new architectures and new device technologies

Research in CE department

- ❑ Computing based on “Computation-in-memory” (CIM) platform
 - ❑ Complementary to *von Neumann* systems
 - ❑ It equips the memory subsystem with the ability to perform computation

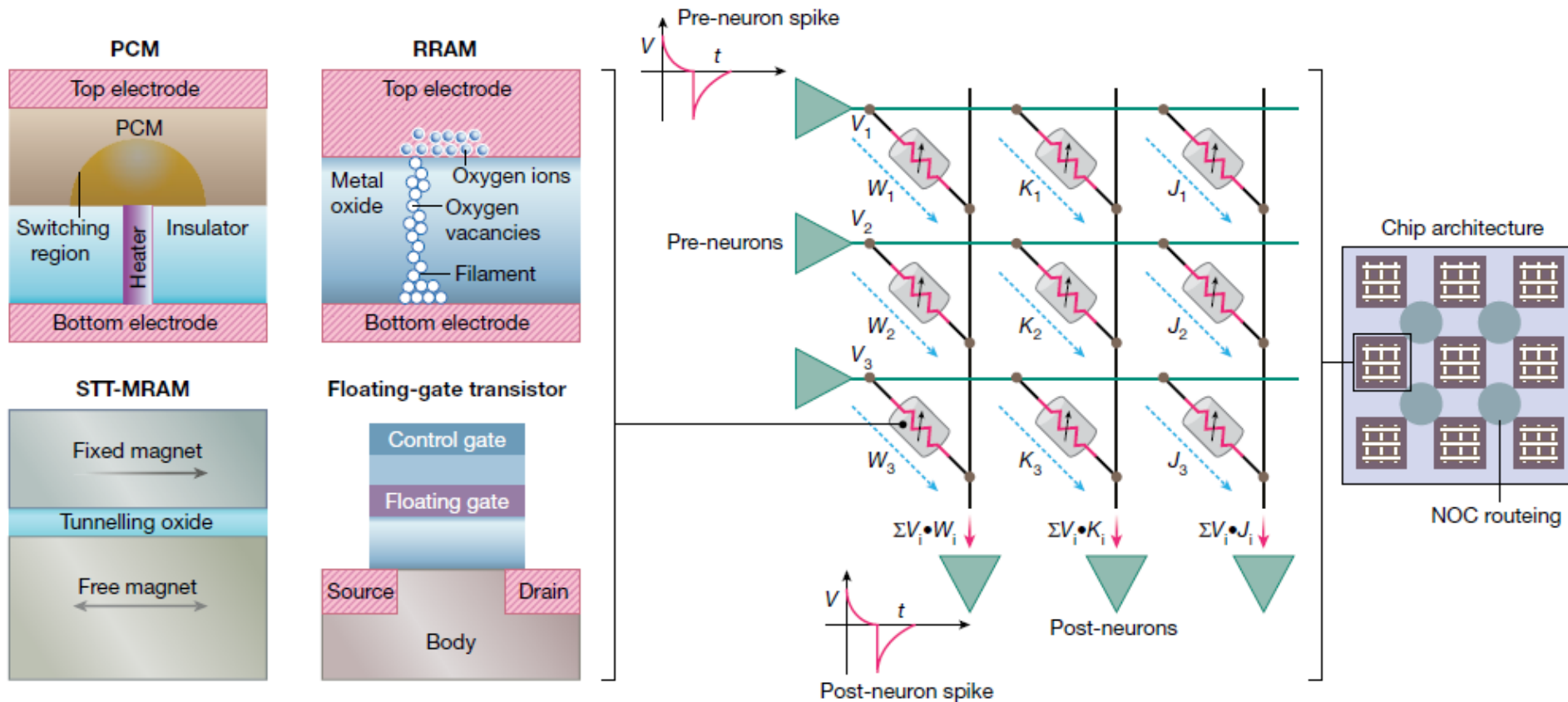


Source: Hamdioui-DATE'2015

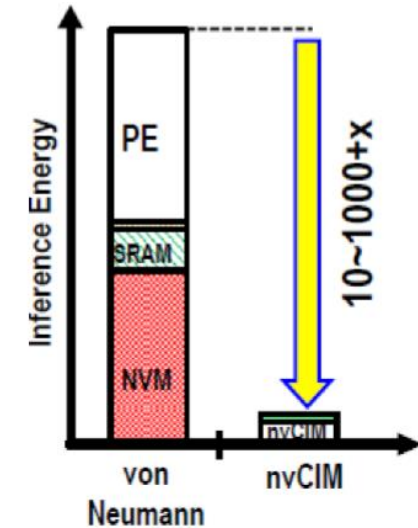
Working set location

Research in CE department

- Emerging bio-inspired computing using non-volatile technologies based CIM platform
 - Advantages: highly connected and parallel, scalable, low-power, small size and better memory processing



Source: K. Roy-nature'2019



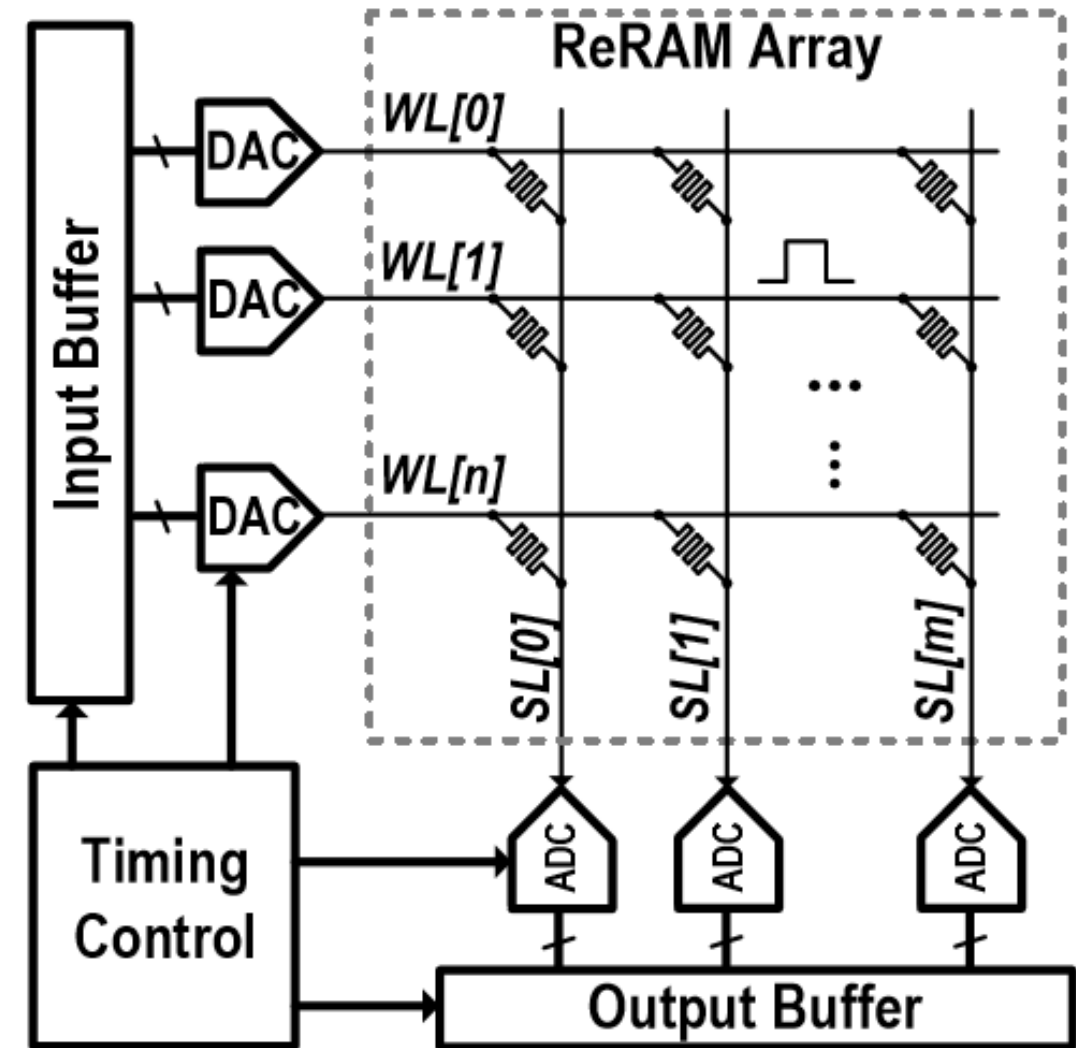
Source: W.-H. Chen, ISSCC 2018

Master thesis project

Design of cross-bar structure and periphery circuits

Tasks:

- Design of appropriate bit-cell required for cross bar structure
- Design of periphery circuits such as DAC, ADC, input/output buffers and control units
- Improve the power and delay efficiency
- A part of this work may go into the planned chip prototype



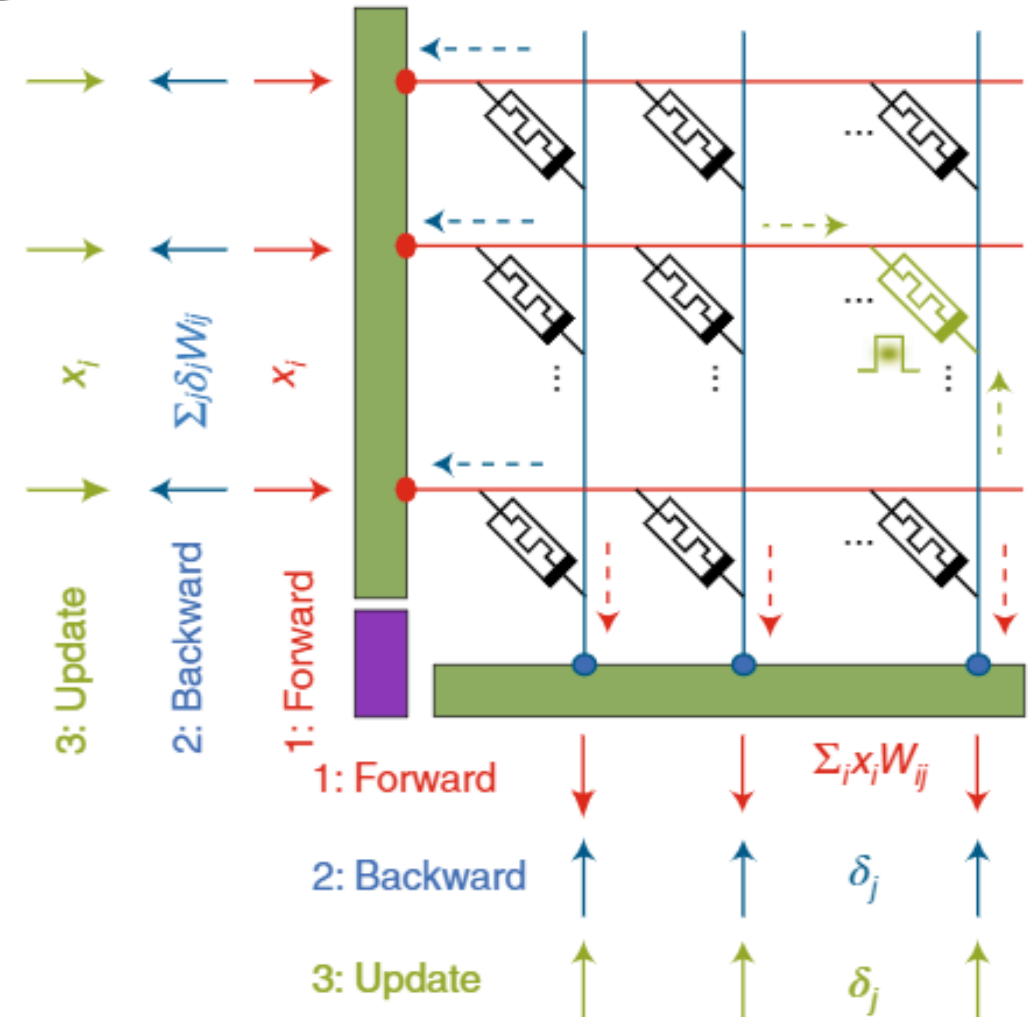
Source: Qu Liu, ISSC-2020

Master thesis project

Design of innovative training circuits

Tasks:

- Hardware support for learning algorithms for edge computing
 - Continuous learning
 - Fast learning
 - High energy efficiency



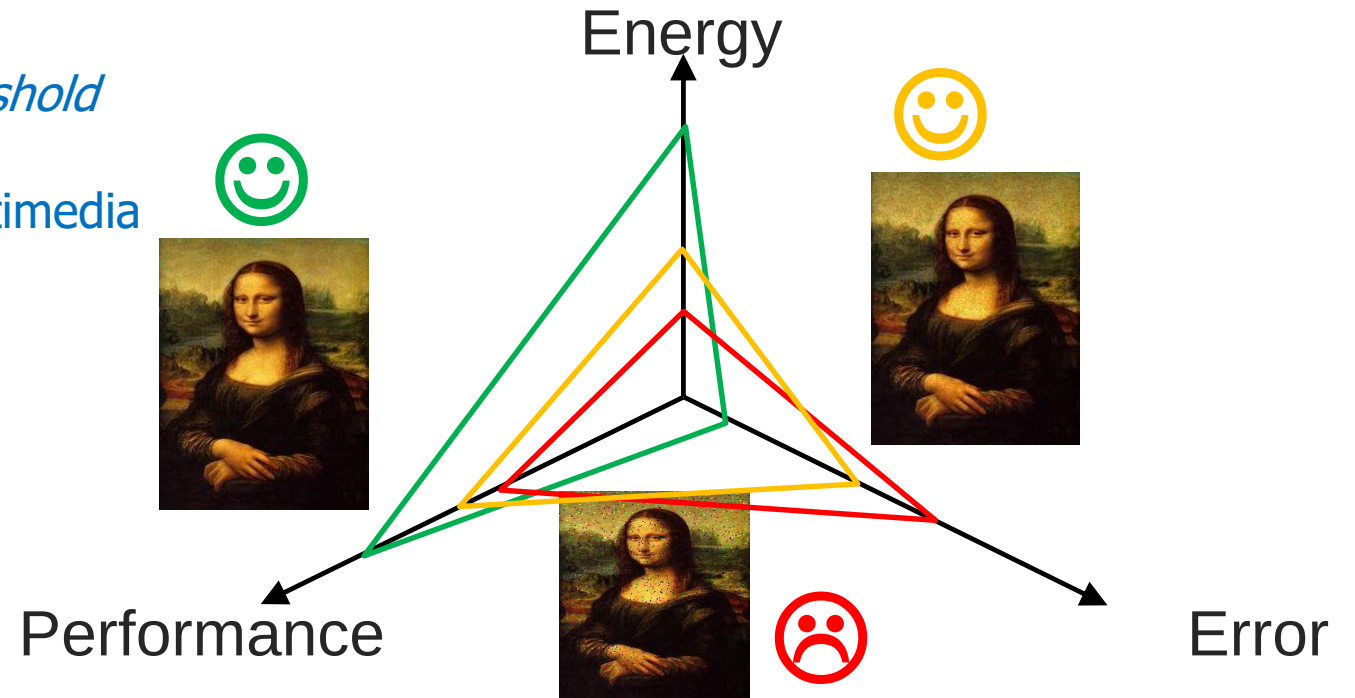
Source: Sebastian, Nature nano-2020

Master thesis project

Ultra low-power spiking neural network computing for edge-devices

Tasks:

- Improve the energy efficiency by
 - Design circuits that can support *near threshold computing*
 - *Approximate computing approach* for multimedia and big data applications
 - Trading-off accuracy to improve energy

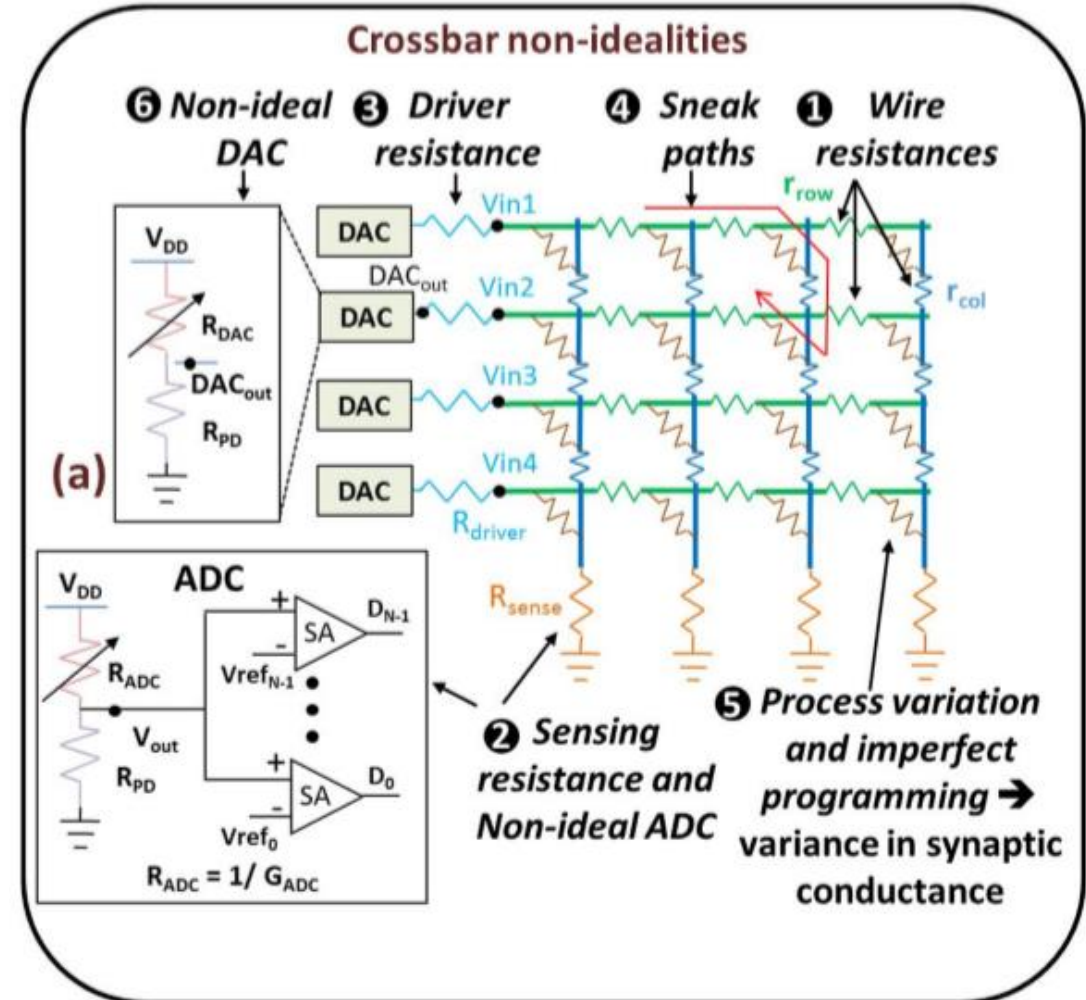


Source: Gebregiorgis, DAC-2017

Reliability enhancement in neural network design

Tasks:

- Characterize the impact of crossbar non-idealities on errors incurred in neural network operation
- Non-idealities mitigation scheme



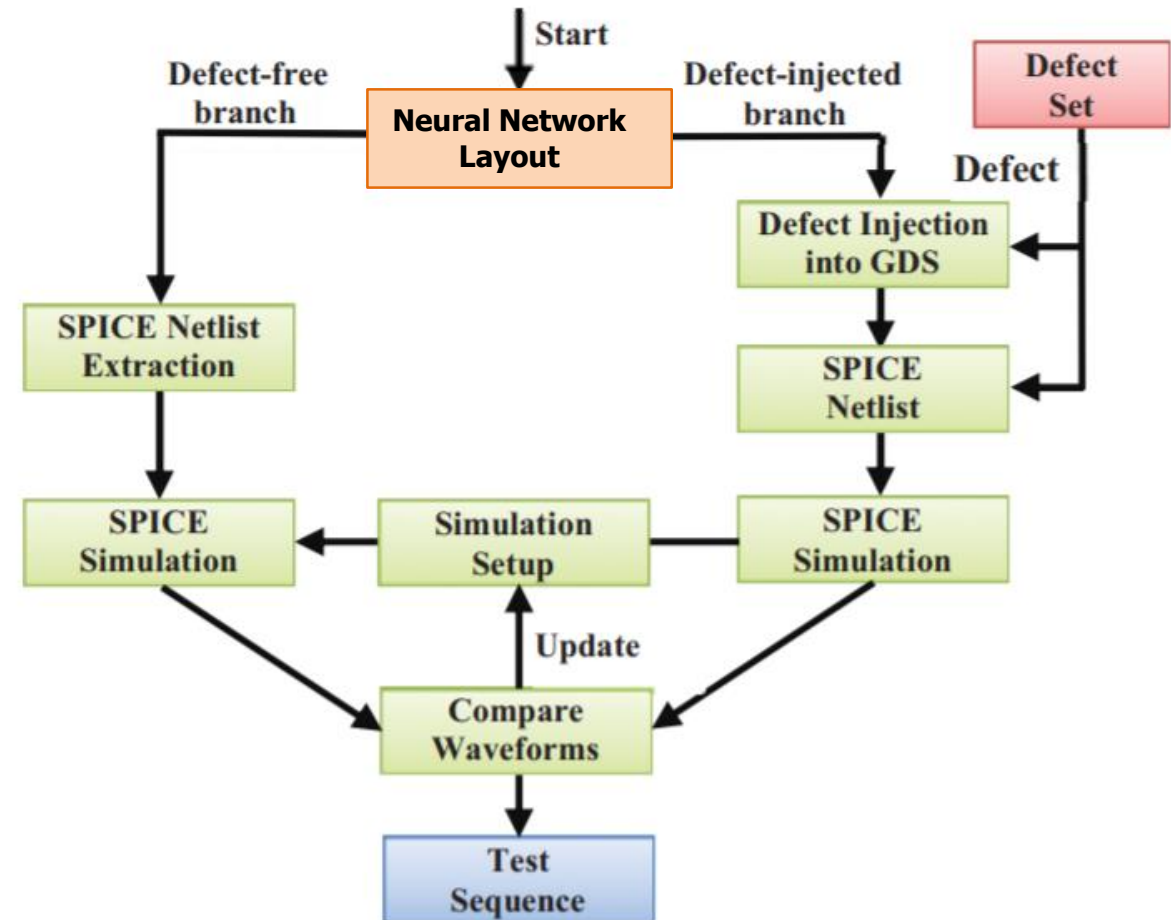
Source: Jain, arXiv-2019

Master thesis project

Functionality testing of neural network design

Tasks:

- Novel test methodologies are required
 - New architecture with new devices
- New *Design-for-Test* circuitries

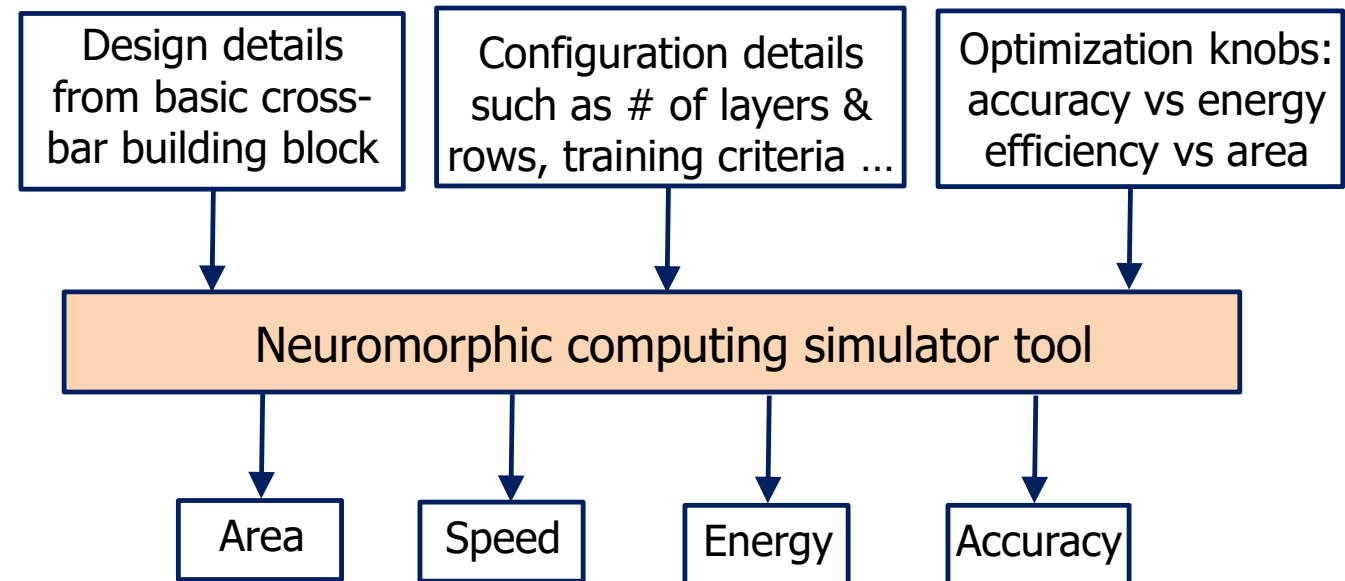


Master thesis project

Ncsim: Neuromorphic computing simulator tool

Tasks:

- A circuit-level accuracy, performance, energy, and area model for neuromorphic computing
- A python language based framework
- Design space exploration to determine the best required output for the given parameters



Thank You

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