"111 Centre on Biological Computing and Artificial Intelligence" , Dalian University (DLU)

Advanced Artificial Intelligence Technologies and Applications

Course organiser: A/Prof. Shihua Zhou

Course presenter

Prof Nikola Kasabov

Visiting Professor at Dalian University

Life FIEEE, FRSNZ, FINNS, DVF RAE UK

Founding Director KEDRI

Professor, Auckland University of Technology, NZ

George Moore Chair/Professor, Ulster University, UK

Honorary Professor, University of Auckland NZ , Peking University China

Visiting Professor IICT/Bulgarian Academy of Sciences and Teesside University UK

Doctor Honoris Causa Obuda University Budapest

Director, Knowledge Engineering Consulting Ltd (https://www.knowledgeengineering.ai)

Assistants

A/Prof. Wei Qi Yan

Director of the CeRV Center, AUT

Weiqi.yan@aut.ac.nz

https://academics.aut.ac.nz/weiqi.yan

Ms Iman AbouHassan

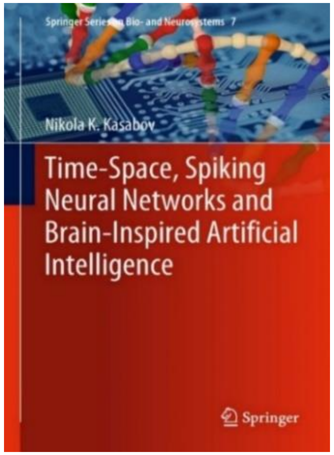
iabouhassan@tu-sofia.bg

abouhassan.iman@gmail.com

Full course DLU, 2023, Lecture Content

Advanced Artificial Intelligence Technologies and Applications

1. AI and the evolution of its principles. Evolving processes in Time and Space (Ch1, 3-19)
2. From Data and Information to Knowledge. Fuzzy logic. (Ch1,19-33 + extra reading)
3. Artificial neural networks - fundamentals. (Ch2, 39-48). Computational modelling with NN. Tut1: NeuCom.
4. Deep neural networks (Ch.2, 48-50 + extra reading).
5. Evolving connectionist systems (ECOS) (Ch2, 52-78). Tutorial 2: ECOS in NeuCom.
6. Deep learning and deep knowledge representation in the human brain (Ch3)
7. Spiking neural networks (Ch4). Evolving spiking neural networks (Ch5)
8. Brain-inspired SNN. NeuCube. (Ch.6). Tutorial 3: NeuCube software (IA)
9. From von Neuman Machines to Neuromorphic Platforms (Ch20 , 22)
10. Other neurocomputers: Transformers.
11. Evolutionary and quantum inspired computation (Ch.7)
12. AI applications in health (Ch.8-11)
13. AI applications for computer vision (Ch.12,13)
14. AI for brain-computer interfaces (BCI) (Ch.14)
15. AI for language modelling. ChatBots (extra reading)
16. AI in bioinformatics and neuroinformatics (Ch15,16, 17,18)
17. AI applications for multisensory environmental data. AI in finance and economics (Ch19)



Course book: N.Kasabov, Time-Space, Spiking Neural Networks and Brain-Inspired Artificial Intelligence Springer, 2019, https://www.springer.com/gp/book/9783662577134

Additional materials: https://www.knowledgeengineering.ai/china

ZOOM link for all lectures: https://us05web.zoom.us/j/4658730662?pwd=eFN0eHRCN3o4K0FaZ0lqQmN1UUgydz09

Lectures 9 and 10

9. From von Neuman Machines to Neuromorphic Platforms
10. Other neurocomputers: Transformers

Lecture 9. Neuromorphic hardware systems

Chapter 20 +

additional paper

Chapter 22. Towards a Symbiosis of Human Intelligence and AI

Lecture 10. Other neurocomputers: Transformers

(additional material)

Chapter 20. From von Neuman Machines to Neuromorphic Platforms

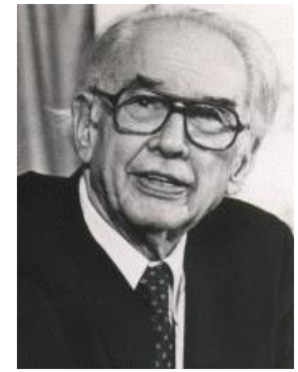
- The computer architecture of John von Neumann separates data and programmes (kept in the memory unit) from the computation (ALU); uses *bits*. First machine ABC by Atanassov and Berry.

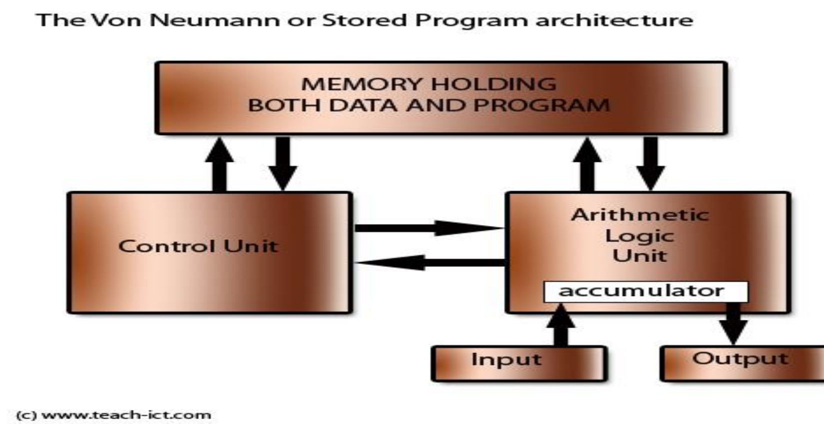
- A Neuromorphic architecture integrates the data, the programme and the computation in a SNN structure, similar to how the brain works; uses *spikes* (bits at times).

- A quantum computer uses *q-bits* (bits in a superposition) .

A SNN application system can be implemented using either of:

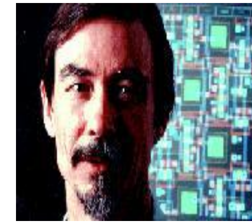
- von Neumann architecture;
- Neuromorphic architecture;
- Neuromorphic/Memristor architecture;
- Quantum computer (not available yet).





N. Sengupta et al, (2018), From von Neumann architecture and Atanasoffs ABC to Neuromorphic Computation and Kasabov’s NeuCube: Principles and Implementations, Chapter 1 in: Advances in Computational intelligence, Jotzov et al (eds) Springer 2018.

Neuromorphic hardware systems



Carver Mead (1989): A hardware model of an IF neuron:
The Axon-Hillock circuit.

SpiNNaker (*Furber, S., To Build a Brain, IEEE Spectrum, vol.49, Number 8, 39-41, 2012).*

INI Zurich SNN chips (Giacomo Indiveri)

Silicon retina (the DVS) and silicon cochlea (ETH, Zurich, Toby Delbruck))

The IBM True North (D.Modha et al, 2016): 1mln neurons and 1 billion of synapses

FPGA SNN realisations (McGinnity, Ulster and NTU)

Intel Loihi

High speed and low power consumption.

nkasabov@aut.ac.nz nk.kasabov@ulster.ac.uk

NeuCube development environment for SNN system design can also include a neuromorphic hardware (e.g. SpiNNaker)

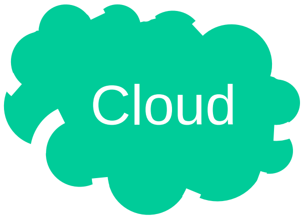
nkasabov@aut.ac.nz www.kedri.aut.ac.nz/neucube/

NeuCube Implementations

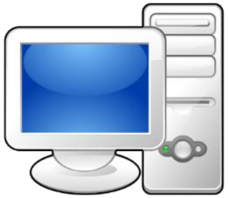
Software versions:

MATLAB Java python

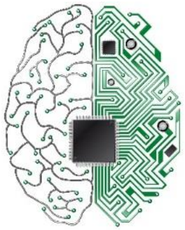
C++



Hardware-specific versions:



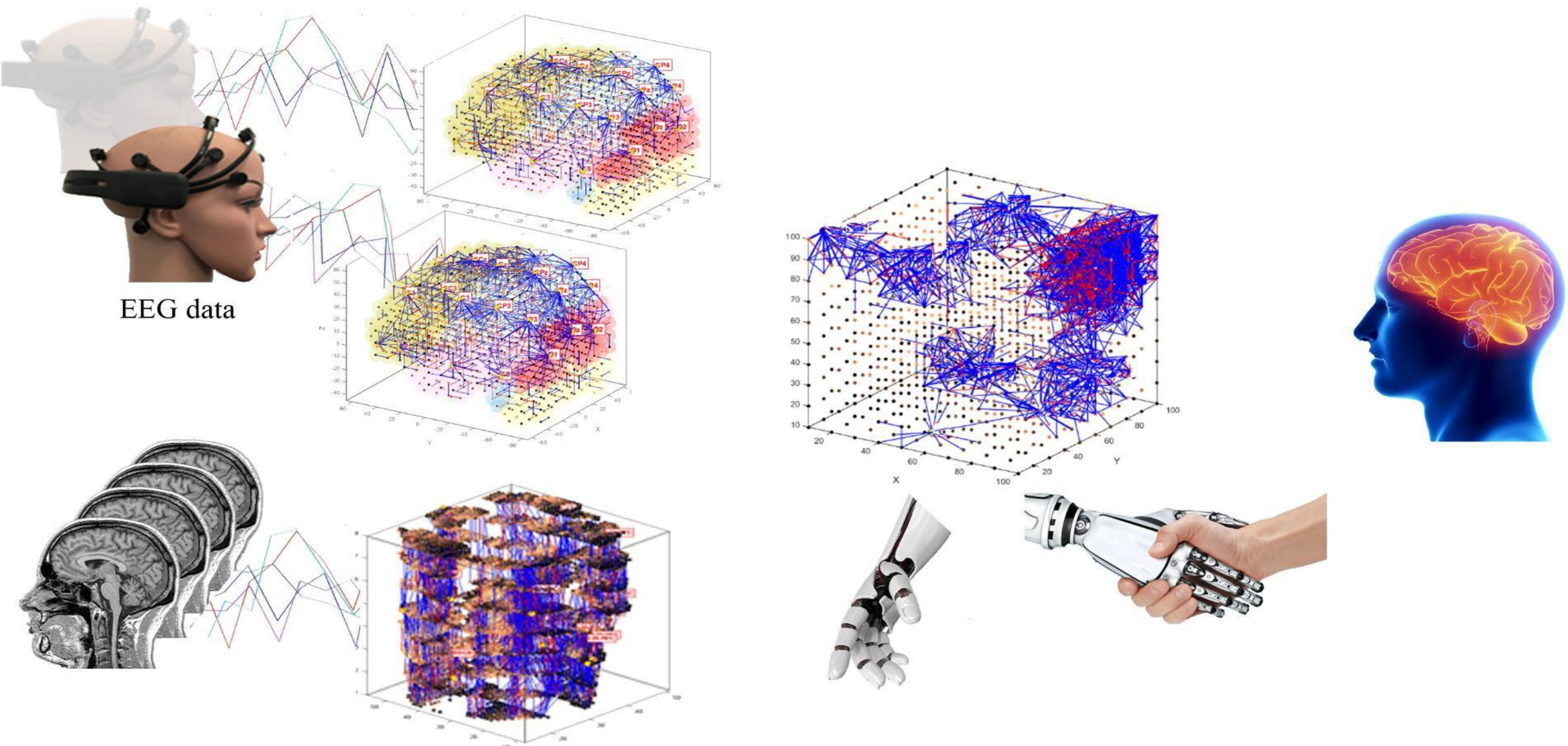
RaspberryPi



Future development: NeuCube chips for AI applications

Chapter 22. Towards a Symbiosis of Human Intelligence and AI

Knowledge-based human-machine interaction and symbiosis based on deep learning, knowledge representation and knowledge transfer with BI-SNN architectures (www.darpa.mil/program/explainable-artificial-intelligence)



nkasabov@aut.ac.nz

AUT

Lecture 10. Other neurocomputers: Transformers

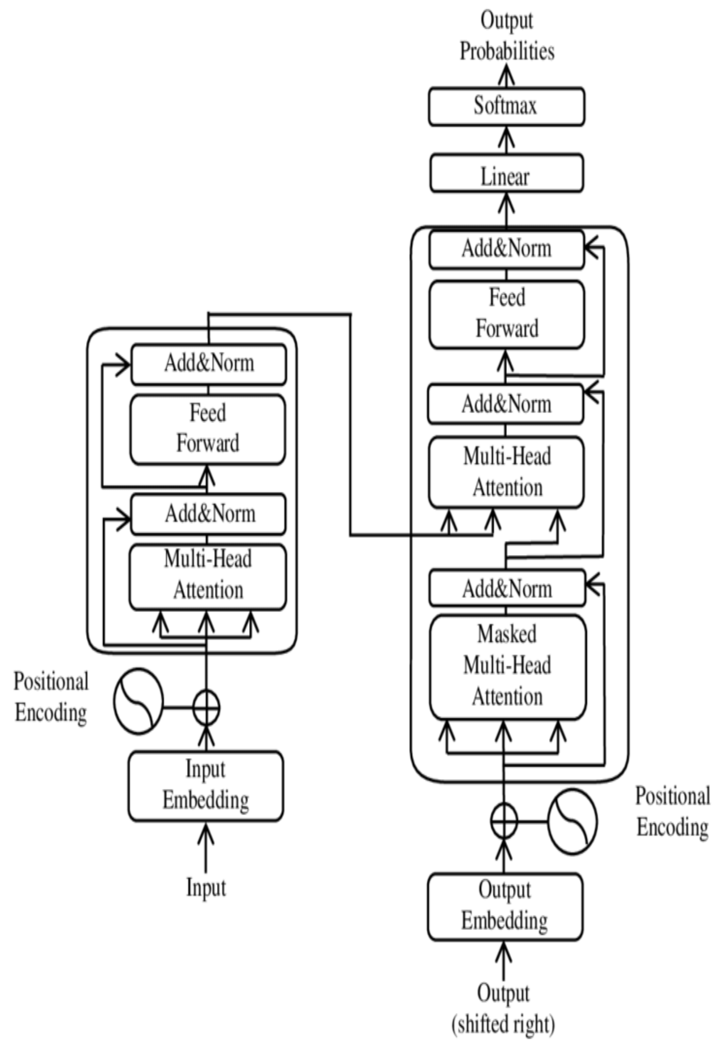
From Wikipedia:

A **transformer** is a deep learning model. It is distinguished by its adoption of self-attention, differentially weighting the significance of each part of the input (which includes the recursive output) data. It is used primarily in the fields of natural language processing (NLP)[1] and computer vision (CV).[2]

Transformers are designed to process sequential input data, such as natural language, with applications towards tasks such as translation and text summarization. Transformers process the entire input all at once. The attention mechanism provides context for any position in the input sequence. For example, if the input data is a natural language sentence, the transformer does not have to process one word at a time. This allows for more parallelization than other RNNs and therefore reduces training times.[1]

Transformers are more amenable to parallelization, allowing training on larger datasets. This led to the development of pretrained systems such as GPT (Generative Pre-trained Transformer), which were trained with large language datasets, such as the Wikipedia Corpus and Common Crawl, and can be fine-tuned for specific tasks.

Transformers are NOT suitable for explanation of the solution or for on-line adaptation of new data. They are not suitable for spatio-temporal data either.



Course References

1. N.Kasabov, Time-Space, Spiking Neural Networks and Brain-Inspired AI, Springer 2019 (course book).
2. N. Kasabov Foundations of Neural Networks, Fuzzy Systems, and Knowledge Engineering, MIT Press, 1996 (additional reading)
3. N.Kasabov, Evolving connectionist systems, Springer 2003 and 2007 (additional reading)
4. Kasabov, N. (ed) (2014) The Springer Handbook of Bio- and Neuroinformatics, Springer. (additional reading)
5. NeuCube: http://www.kedri.aut.ac.nz/neucube/
6. NeuCom: https://theneucom.com
7. KEDRI R&D Systems available from: http://www.kedri.aut.ac.nz
8. N. Kasabov, et al, Design methodology and selected applications of evolving spatio- temporal data machines in the NeuCube neuromorphic framework, Neural Networks, v.78, 1-14, 2016. http://dx.doi.org/10.1016/j.neunet.2015.09.011.
9. Furber, S., To Build a Brain, IEEE Spectrum, vol.49, Number 8, 39-41, 2012.
10. Benuskova, L., N.Kasabov (2007) Computational Neurogenetic Modelling, Springer, New York
11. Indiveri, G. et al, Neuromorphic silicon neuron circuits, Frontiers in Neuroscience, 5, 2011.
12. Kasabov, N. (2014) NeuCube: A Spiking Neural Network Architecture for Mapping, Learning and Understanding of Spatio-Temporal Brain Data, Neural Networks, 52, 62-76.
13. Kasabov (2010) To spike or not to spike: A probabilistic spiking neural model, Neural Networks, v.23,1, 16-19
14. Merolla, P.A., J.V. Arhur, R. Alvarez-Icaza, A.S.Cassidy, J.Sawada, F.Akopyan et al, “A million spiking neuron integrated circuit with a scalable communication networks and interface”, Science, vol.345, no.6197, pp. 668-673, Aug. 2014.
15. Wysoski, S., L.Benuskova, N.Kasabov (2007) Evolving Spiking Neural Networks for Audio-Visual Information Processing, Neural Networks, vol 23, issue 7, pp 819-835.
16. Kasabov, Nikola; Tan, Yongyao Tan; Doborjeh, Maryam; Tu, Enmei; Yang, Jie (2023): Transfer Learning of Fuzzy Spatio-Temporal Rules in the NeuCube Brain-Inspired Spiking Neural Network: A Case Study on EEG Spatio-temporal Data. TechRxiv. Preprint. https://techrxiv.org), https://doi.org/10.36227/techrxiv.21781103.v1, licence CC BY 4.0)
17. Nikola K. Kasabov, Iman AbouHassan, Vinayak G.M. Jagtap, Parag Kulkarni, Spiking neural networks for predictive and explainable modelling of multimodal streaming data on the Case Study of Financial Time Series Data and on-line news, SREP, Nature, pre-print on the Research Square, DOI: https://doi.org/10.21203/rs.3.rs-2262084/v1, licence CC BY 4.0,

- https://orcid.org/0000-0003-4433-7521
- https://knowledgeengineering.ai
- http://scholar.google.com/citations?hl=en&user=YTa9Dz4AAAAJ&view_op=list_works
- https://www.scopus.com/authid/detail.uri?authorId=35585005300

Questions, exercises, assignments and project work

1. What are neuromorphic hardware systems?

2. What neuromorphic chips you have heard about?

3. What are the neurocomputers called transformers?

https://www.knowledgeengineering.ai/efunn-denfis-neucube-club