Cognitive Systems Engineering

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Lecture 16: CogSysEng Course Revision

Cognitive systems (CogSys) are software-hardware systems that have their structure and functionality based on principles of information processing in the human brain. They are part of AI, but AI includes also other systems that manifest cognitive behaviour, such as speech and image recognition, learning and reasoning, but using other methods , such as statistical, empirical, abstract logic , etc.

The course is by research papers.
Every topic will include:
1. Topic/task/problem specification
2. Previously published methods for solving the problem
3. Description of the method and in the paper under discussion
4. Software implementation, experimental results and discoveries
5. Applications
6. Future work to be done for this problem and questions for individual work

Expected results:
1. Students obtain new knowledge and skills in the area of CogSys for AI applications.
2. Students can learn to take a critical approach to the existing methods and systems.
3. Students can get confidence that they can suggest new methods and to publish them in good journals.

Additional materials: https://www.knowledgeengineering.ai/china
ZOOM link for all lectures:
https://us05web.zoom.us/j/4658730662?pwd=eFN0eHRCN3o4K0FaZ0lqQmN1UUgydz09

CogSysEn: Lecture Topics

1. Introduction to the course

Part I : Learning systems

2. Deep learning and deep knowledge representation in the human brain

-Chapter 3 from: N.Kasabov, Time-space, spiking neural networks and brain-inspired artificial intelligence, Springe-Nature, 2029

3.Modelling brain dynamics

- Benuskova, L., Kasabov, N. Modeling brain dynamics using computational neurogenetic approach. Cogn Neurodyn 2, 319–334 (2008). https://doi.org/10.1007/s11571-008-9061-1

4. Evolving learning systems

- N. Kasabov, "Evolving fuzzy neural networks for supervised/unsupervised online knowledge-based learning," in IEEE Transactions on Systems, Man, and Cybernetics, Part B (Cybernetics), vol. 31, no. 6, pp. 902-918, Dec. 2001, doi: 10.1109/3477.969494.

- NeuCom software (https://theneucom.com): EFuNN

5. Neuro—fuzzy learning and inference systems: DENFIS

- Kasabov, N. K., & Song, Q. (2002). DENFIS: dynamic evolving neural-fuzzy inference system and its application for time-series prediction. IEEE transactions on Fuzzy Systems, 10(2), 144-154.

- DENFIS software in Python.

6. Spatio-temporal learning systems: SNN

- N. Kasabov, K. Dhoble, N. Nuntalid, G. Indiveri, Dynamic evolving spiking neural networks for on-line spatio- and spectro-temporal pattern recognition. Neural Networks, 41(1995), 188–201 (2013). https://doi.org/10.1016/j.neunet.2012.11.014.

- Software deSNN

7. Reservoir computing and Brain-inspired SNN

- *N. Kasabov, NeuCube: a spiking neural network architecture for mapping, learning and understanding of spatio-temporal brain data. Neural Netw. 52(2014), 62–76 (2014).*
- *N. Kasabov et al, Evolving spatio-temporal data machines based on the NeuCube neuromorphic framework: Design methodology and selected applications, Neural Networks, v.78, 1-14, 2016. http://dx.doi.org/10.1016/j.neunet.2015.09.011.*

8. Integrated learning systems:

- *P. Koprinkova-Hristova, D. Penkov, S. Nedelcheva, S. Yordanov and N. Kasabov, "On-line Learning, Classification and Interpretation of Brain Signals using 3D SNN and ESN," 2023 International Joint Conference on Neural Networks (IJCNN), Gold Coast, Australia, 2023, pp. 1-6, doi: https://doi.org/10.1109/IJCNN54540.2023.10191974,*
- AbouHassan et al, *NeuDen: Integrating evolving Neuromorphic spiking neural networks and Dynamic evolving neuro-fuzzy systems for predictive and explainable learning of multiple time series*

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CogSysEn: Lecture Topics

Part II. Associative memories

9. Evolving Associative Memories in bio-neuro systems and in SNN

- *Kasabov, Nikola (2023). STAM-SNN: Spatio-Temporal Associative Memories in Brain-inspired Spiking Neural Networks: Concepts and Perspectives. TechRxiv. Preprint. https://doi.org/10.36227/techrxiv.23723208.v1*

10. Associative memories for neuroimaging data: EEG and fMRI

- *N K. Kasabov, H Bahrami, M Doborjeh, A Wang, Brain Inspired Spatio-Temporal Associative Memories for Neuroimaging Data: EEG and fMRI, Bioengineering 2023, MDPI 10(12), 1341 https://doi.org/10.3390/bioengineering10121341, www.mdpi.com/journal/bioengineering*

11. Audio-visual associative memories

- *N Kasabov, B Sen Bhattacharya, D Patel, N Aggarwal, T Bankar, IAbouHassan, Cognitive Audio-Visual Associative Memories using Brain-inspired Spiking Neural Networks with Case Studies on Moving Object Recognition .*

12. Predictive associative memories for time series

- *AbouHassan, I; Kasabov, N; Bankar, T; Garg, R; Sen Bhattacharya, B (2023). PAMeT-SNN: Predictive Associative Memory for Multiple Time Series based on Spiking Neural Networks with Case Studies in Economics and Finance. TechRxiv. Preprint. https://doi.org/10.36227/techrxiv.24063975.v1, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4665533*

Part III. Software and Hardware Implementation of CogSys.

13. Neuromorphic hardware for CogSys implementations

- *J. Behrenbeck, Z. Tayeb, C. Bhiri, C. Richter, O. Rhodes, N. Kasabov, S. Furber, J. Conrad, Classification and Regression of Spatio-Temporal EMG Signals using NeuCube Spiking Neural Network and its implementation on SpiNNaker Neuromorphic Hardware. J. Neural Eng. (IOP Press, Article reference: JNE-102499) (2018). http://iopscience.iop.org/journal/1741-2552.*

  - *paper for CogSys on Loihi chip*

14. CogSys design and software/hardware implementation

- *NeuCubePy, NEST, PyNN for SpiNNaker, Lava for Loihi, Software for China chips*

15. Quantum computation

- *Ravi , N. Kasabov et al, (2023). From Quantum Computing to Quantum-inspired Computation for Neuromorphic Advancement – A Survey. TechRxiv. Preprint. https://doi.org/10.36227/techrxiv.24053250.v1*

16. Revision of the course

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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,

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