Course: Multi-modal Data Science and Engineering (MDSE)

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Multimodal Data Science and Engineering (MDSE)

Course by research papers.
Every topic will include:

1. Topic/task/problem specification
2. Previously published methods for solving the problem
3. Description of the new method and the publication where it is published
4. Software implementation, experimental results and discoveries
5. Applications
6. Future work to be done for this problem and questions for individual work

Additional materials: - relevant papers;
- https://www.knowledgeengineering.ai/china

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

What is MDSE and why we need it?

Definition: MDSE is a new discipline in science and engineering that develops new methods and their engineering implementations for integrated processing of multiple modalities (e.g. different types) of data into one system, including *different time and space scales*, for a better performance when compared with systems that deal with single modalities.

Advantages:

- MDSE offers a *wholistic approach* to a better problem solving, considering multiple related factors.
- MDSE can extract novel associations between different modalities of data for new knowledge discovery.
- MDSE can offer a better prediction of future events.

Examples:

- Integrating multiple medical factors in health predictive modelling
- Integrating multiple sensory information for environment prediction
- Integrating audio and visual information
- Integrating multiple factors for financial and economic prediction

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Full List of Topics/Lectures:

1. Introduction to the course: What is MDSE and why we need it?

2. Methods for MDSE:

- *paper: S.Budhraja, B.Singh, S.Tan, M.Dobrojeh, Z.Doborjeh, W.Goh, E.Lai and N.Kasabov, Mosaic LSM: A Liquid State Machine Approach for Multimodal Longitudinal Data Analysis, Proc. International Joint Conference on Neural Networks (IJCNN), Gold Coast, Australia, 2023, pp. 1-8, doi: https://doi.org/10.1109/IJCNN54540.2023.10191256; https://ieeexplore.ieee.org/document/10191256. IEEE, 2023, ISBN:978-166548867-9*
- *Software NeuGems: https://kedri.aut.ac.nz/news-and-events/introducing-neurogems*

3. MDSE for biomedical engineering

- *Paper 1: M. Doborjeh, N. Kasabov, Z. Doborjeh, R. Enayatollahi, E. Tu, A. H. Gandomi, Personalised modelling with spiking neural networks integrating temporal and static information, Neural Networks, 119 (2019),162-177.*
- *Paper 2: Sengupta, N., McNabb, C. B., Kasabov, N., & Russell, B. R. (2018). Integrating Space, Time, and Orientation in Spiking Neural Networks: A Case Study on Multimodal Brain Data Modelling. IEEE Transactions on Neural Networks and Learning Systems, 29(11). doi:10.1109/TNNLS.2018.2796023*
- *Paper 3: Li, Jiawei; Liu, Jinyuan; Zhou, Shihua; Zhang, Qiang; Kasabov, Nikola, , "GeSeNet: A General Semantic-guided Network with Couple Mask Ensemble for Medical Image Fusion" , IEEE Transactions on Neural Networks and Learning Systems, DOI: https://doi.org/10.1109/TNNLS.2023.3293274, 21 July 2023.*

4. MDSE for predictive modelling of multisensory streaming data

- *Paper 1: Maciag, Pi; Bembenik, R; Piekarzewicz A, Del Ser L, Javier; L, Lobo, J; N Kasabov;, Effective Air Pollution Prediction by Combining Time Series Decomposition with Stacking and Bagging Ensembles of Evolving Spiking Neural Networks, Environmental Modelling and Software, vol.170, on line: 16.10.2023, Dec 2023, 105851, https://doi.org/10.1016/j.envsoft.2023.105851; https://www.sciencedirect.com/science/article/pii/S1364815223002372*
- *Paper 2: H Liu, G Lu,Y Wang, N Kasabov, Evolving spiking neural network model for PM2.5 hourly concentration prediction based on seasonal differences: A case study on data from Beijing and Shanghai, Aerosol and Air Quality Research, vol.21, Issue 2, Feb. 2021, 200247, https://doi.org/10.4209/aaqr.2020.05.0247*
- *Paper 3: Laña I, Lobo JL, Capecci E, Del Ser J, Kasabov N, Adaptive long-term traffic state estimation with evolving spiking neural networks, Transportation Research Part C: Emerging Technologies **101**:126-144 2019, https://doi.org/10.1016/j.trc.2019.02.011*

5. MDSE for integrated audio-visual information processing

- *Paper 1: N. Kasabov et al, AVIS: a connectionist-based framework for integrated auditory and visual information processing. Inf. Sci. 133, 137–148 (2000)*
- *Paper2: N Kasabov, B Bhattacharya, D Patel, N Aggarwal, T Bankar, I AbouHassan, Cognitive Audio-Visual Associative Memories using Brain-inspired Spiking Neural Networks with Case Studies on Moving Object Recognition (IEEE Trans. Cognitive and Devel. Systems, 2023).*

6. MDSE for integrating times series and text data in finance and economics (Ms Iman AbouHassan)

- *Paper: I AbouHassan, N Kasabov, V Jagtap, P 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, Springer-Nature, Sci Rep 13, 18367 (2023). https://doi.org/10.1038/s41598-023-42605-0*

7. MDSE for integration of brain data and face image data for emotion recognition

- *Paper: C Tan; G Ceballos; N Kasabov; N Subramaniyam, FusionSense: Emotion Classification using Feature Fusion of Multimodal Data and Deep learning in a Brain-inspired Spiking Neural Network, Sensors (ISSN 1424-8220), MDPI Publisher, September 2020*

8. Revision of the course

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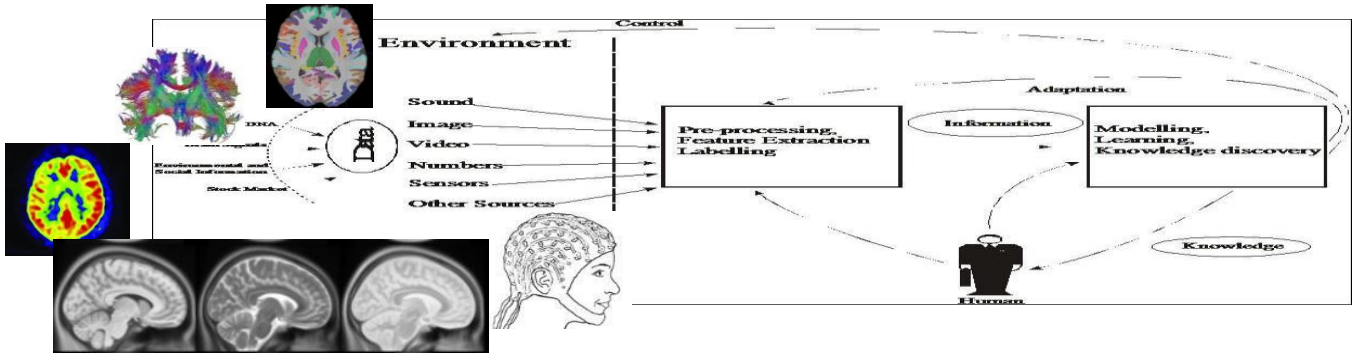
Lecture 3. MDSE for biomedical engineering

Problems of multimodal data in biomedical engineering:

- clinical, genetic, temporal signals, different images, brain EEG, fMRI, etc. multimodal data are difficult to process together;



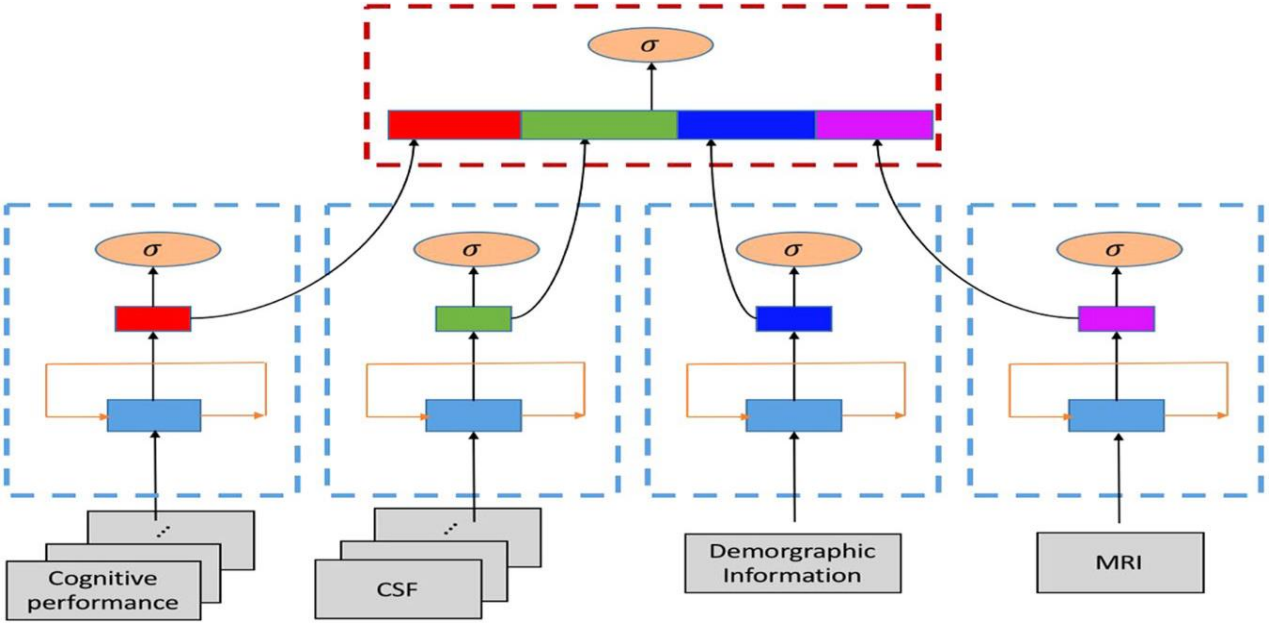
Generic methods for multimodal data integration (from last lecture):

- Early integration of different modalities:
Forming single vectors of all modality variables and then creating a model based on these vectors
- Late integration:
Each modality is used to create a separate model and then the models are integrated
- Mixed integration: Some of the modality variables are integrated early and some late, with a final late integration at the output

Software NeuGems: https://github.com/KEDRI-AUT/NeuroGeMS/releases/tag/v0.0.1-alpha

Methods for multimodal data integration for personalised modelling (this lecture)

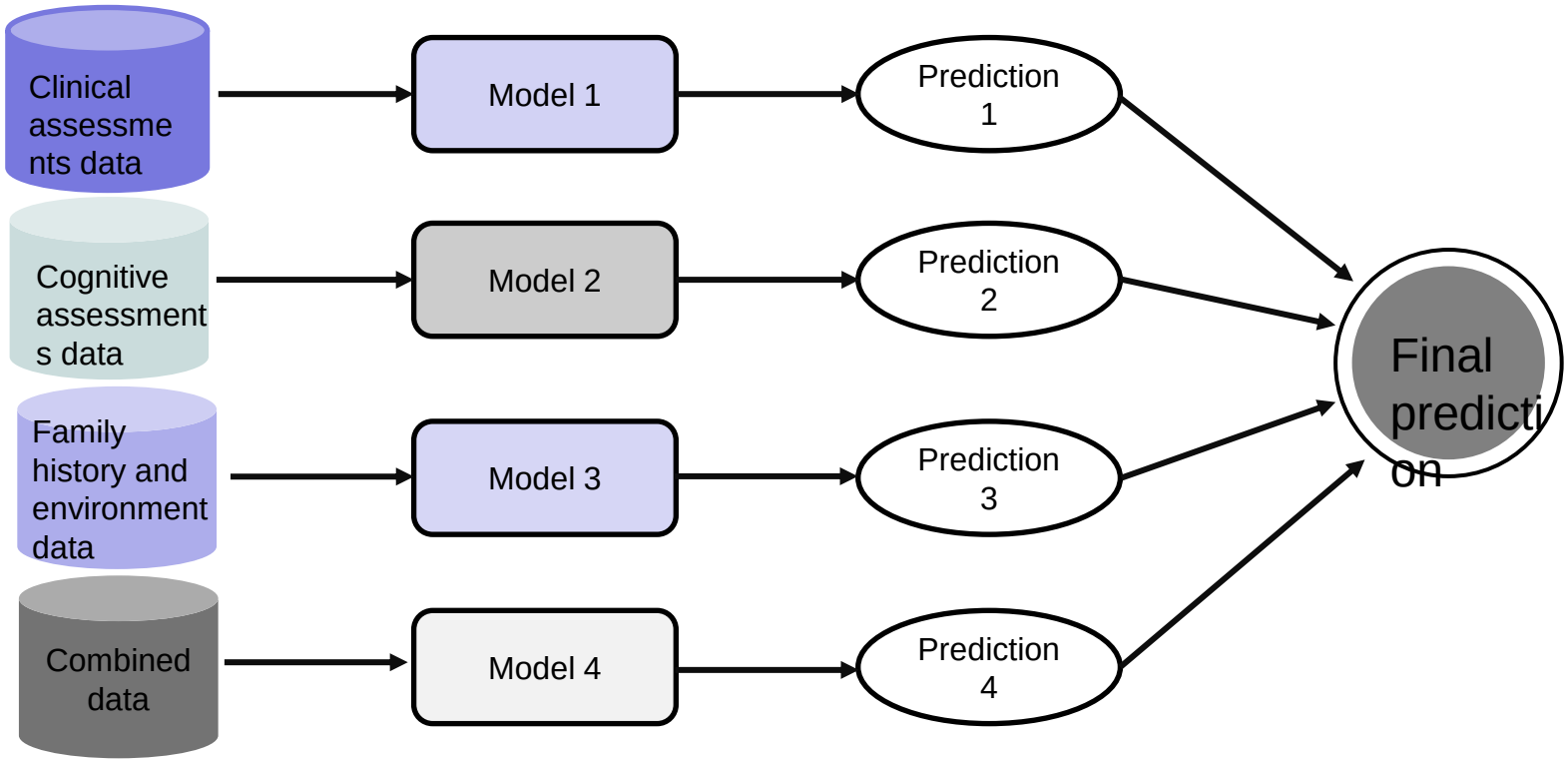
Example of early integration of multiple modalities



Paper: Garam Lee1, Kwangsik Nho, Byungkon Kang, Kyung-Ah Sohn, Dokyoon Kim, Predicting Alzheimer's disease progression using multi-modal deep learning approach, Scientific **Reports** | *(2019) 9:1952* | https://doi.org/10.1038/s41598-018-37769-z

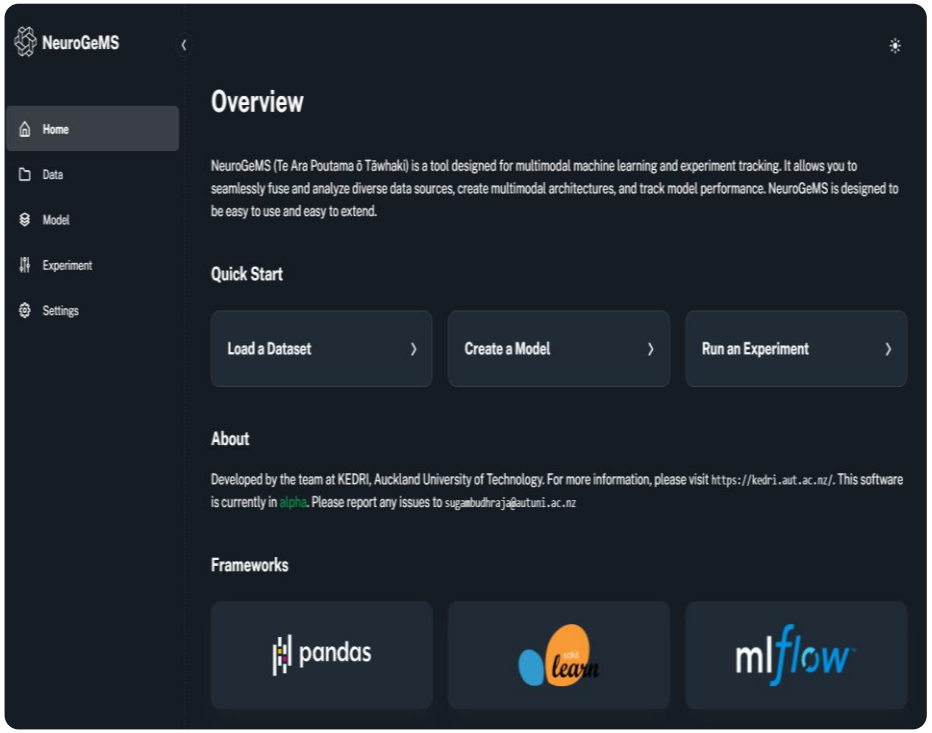
Multiple modules accept each modality of the dataset. At the first training step (blue dashed rectangle), each component takes both time series or non-time series data to produce fixed-size feature vectors. And then the vectors are concatenated to form an input for the final prediction in the second training step (red dashed rectangle)

Example of late integration multi-modal system



NeuroGeMS

https://github.com/KEDRI-AUT/NeuroGeMS/releases/tag/v0.0.1-alpha



1.Multimodal Fusion: Effortlessly integrate data from diverse sources and modalities. NeuroGeMs empowers you to harness the full potential of your data and extract valuable insights through advanced fusion techniques.

2.Interpretability: Gain deeper understanding and build trust in your models with NeuroGeMs 's comprehensive interpretability module. Easily analyse and explain model decisions, making your AI applications more transparent and ethically sound.

3.Efficient Dataset Management: Organise and manage your datasets like a with NeuroGeMs' user-friendly tab for handling data. Seamlessly import, clean, and preprocess data to ensure the highest data quality for your experiments.

4.Intuitive Model Creation: NeuroGeMs provides a smooth workflow to create, customise and fine-tune machine learning models, accommodating both beginners and seasoned data scientists.

5.Streamlined Experimentation: Run, monitor, and save experiments with ease using NeuroGeMs 's smart experiment management feature. Spend less time on logistics and more time on innovation.

6.Data Visualisation at Your Fingertips: Visualize your data and model performance with NeuroGeMs 's interactive data visualisation tools. Gain valuable insights and communicate your findings more effectively.

Selected applications and papers

1. Integrating clinical and temporal data (EEG) for personalised modelling

Paper 1: M. Doborjeh, N. Kasabov, Z. Doborjeh, R. Enayatollahi, E. Tu, A. H. Gandomi, Personalised modelling with spiking neural networks integrating temporal and static information, Neural Networks, 119 (2019),162-177.

2. Integrating spatial-, temporal and direction data for personalised modelling

Paper 2: Sengupta, N., McNabb, C. B., Kasabov, N., & Russell, B. R. (2018). Integrating Space, Time, and Orientation in Spiking Neural Networks: A Case Study on Multimodal Brain Data Modelling. IEEE Transactions on Neural Networks and Learning Systems, 29(11). doi:10.1109/TNNLS.2018.2796023

3. Integrating different image data

Paper 3: Li, Jiawei; Liu, Jinyuan; Zhou, Shihua; Zhang, Qiang; Kasabov, Nikola, , "GeSeNet: A General Semantic-guided Network with Couple Mask Ensemble for Medical Image Fusion" , IEEE Transactions on Neural Networks and Learning Systems, DOI: https://doi.org/10.1109/TNNLS.2023.3293274, 21 July 2023.