Recent Advances in AI amd Machine Learning @ OsloMet AI Lab

Prof Jianhua Zhang

OsloMet AI Lab

Dept. of Computer Science

OsloMet – Olso Metropolitan University

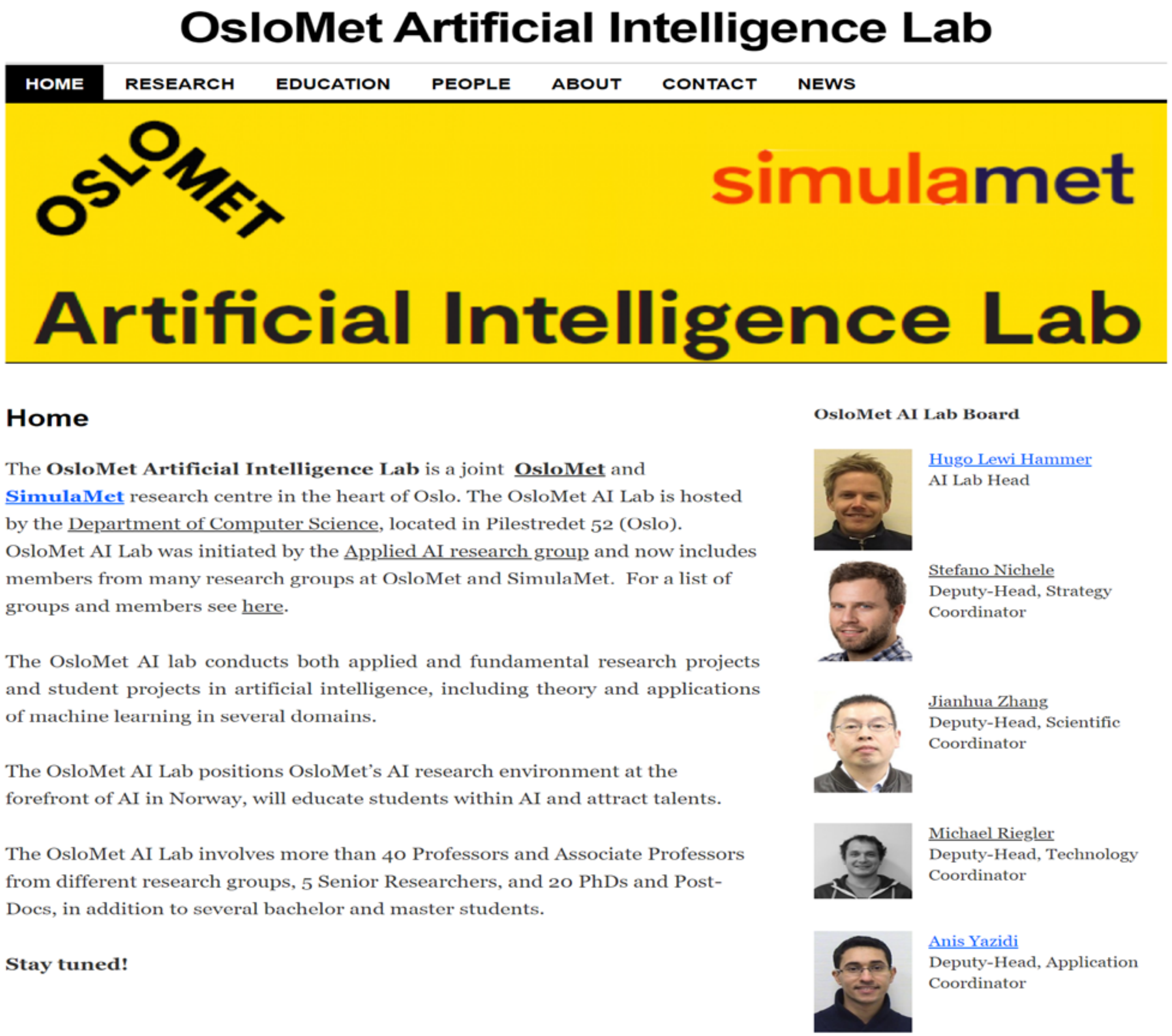
Oslo, Norway

URL: https://ailab.oslomet.no/

A Snapshot of OsloMet AI Lab

MISSIONS

- conduct cutting-edge AI research
- educate graduate (MS and PhD) students and train postdocs.
- bridge the gap between AI theoretical research and real-world applications.
- host academic conferences and other scientific events.
- foster close partnership with national and international research groups and companies in the AI field.



Memebers

Different **research groups**:

- Applied Artificial Intelligence, IT, OsloMet
- Machine Intelligence Department, SimulaMet (Simula Metropolitan Center for Digital Engineering)
- Living Technology Lab
- Autonomous Systems and Networks
- Mathematical Modelling
- Automation, Robotics and Intelligent Systems, MEK, OsloMet
- Motion Analysis Lab
- Digital Innovation and Strategic Competence in Organizations

Figures:

- > 40 Professors and Associate Professors
- 5 Senior Researchers
- 20 PhDs and Postdocs

Focus R&D Areas

FUNDAMENTAL:

- **Machine learning algorithms and optimization**: Improvements of ML and other AI models and hard multi-objective optimization problems (Supervised, unsupervised, and reinforcement learning; Deep/wide learning; Neuro-evolution; Multi-objective evolutionary algorithms)
- **Computational intelligence**: Recurrent neural networks; Fuzzy systems; Evolutionary computation
- **Complex systems and artificial life**

APPLIED:

- **Robotics and IoT**: Adaptive and Autonomous Systems in robotics (HW - vehicles/drones; SW – intelligent control, knowledge-based systems) and IoT across various application domains.
- **Healthcare**: Using AI as intelligent decision support or to develop personalized/individualized systems based on learning from the users.
- **Neuroengineering**: Neurocomputing; Neuroergonomics; Brain-machine interaction; Human-machine symbiosis; Adaptive automation

PARTNERS

- IBM Norge
- Norwegian Artificial Intelligence Research Consortium (NORA)
- Confederation of Laboratories for Artificial Intelligence Research in Europe (CLAIRE)
- Norwegian Open AI Lab

ONGOING PROJECTS (SELECTED)

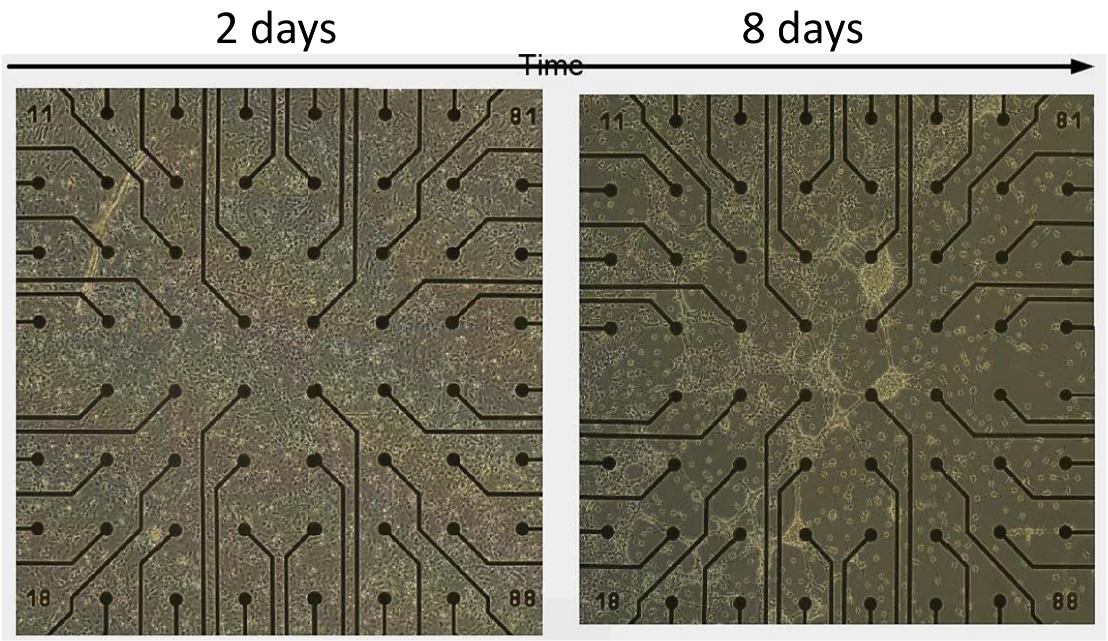
Third-party funding:

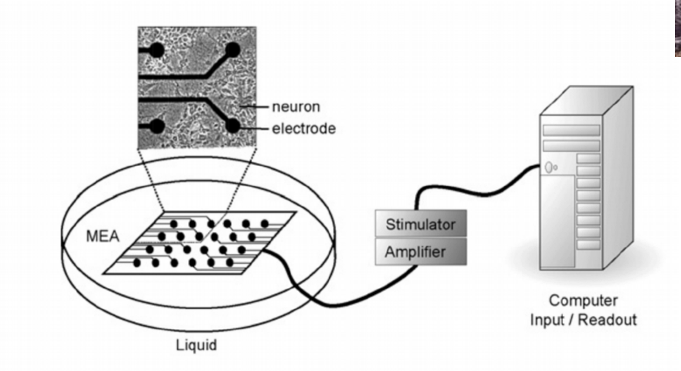
- Socrates – Self Organising Computational Substrates, **NFR**, Nichele
- OASYS – Ocean-Air synoptic operations using coordinated autonomous robotic SYStems and micro underwater gliders, **EU**, Alcocer
- SCOTT – Secure Connected Trustable Things, **EU**, Van Do & Feng
- Pacer – Patient Centric Engineering in Rehabilitation, **NFR**, Mirtaheri & Hammer & Yazidi
- Artificial intelligence – a novel tool in assisted reproduction technology, **NFR**, Hammer & Yazidi
- DeepCA – Hybrid Deep Learning Cellular Automata Reservoirs, **NFR**, Nichele

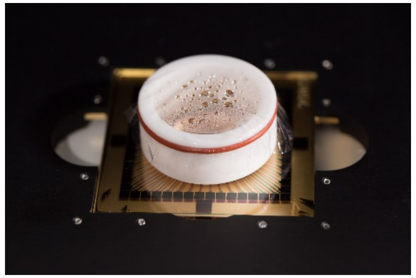
Internally funded:

- Adaptive Automation of Safety-Critical Human-Machine Systems, Zhang
- FELT – Futures of Living Technologies, Bergaust
- CAOS – Complex Adaptive and Self Organising Systems, Nichele
- Personalised Cervical Cancer from Historical data, Naumova
- Multi-modal Data Fusion based on Coupled Factorizations, Acar Ataman

TOPIC 1: *NFR Socrates - Biological Neural Networks*







- Better understanding of neural networks
- Medical: right neural stimulations for rehabilitation/treatment

P. Aaser, M. Knudsen, O. Ramstad, R. van de Wijdeven, S. Nichele, et al. (2017), **Towards Making a Cyborg: A Closed-Loop Reservoir-Neuro System**, *Proc. of European Conf. on Artificial Life (ECAL) 2017.* (BEST POSTER AWARD)

EvoDynamic: EVOlution of discrete DYNAMIC systems based on self-organization through local interactions

Dynamic system

- Sparsely connected network

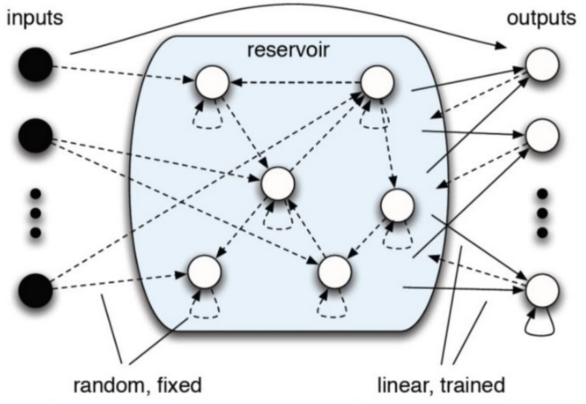
Evolution

- Network structure
- Communication rules
- Learning rules

Goals

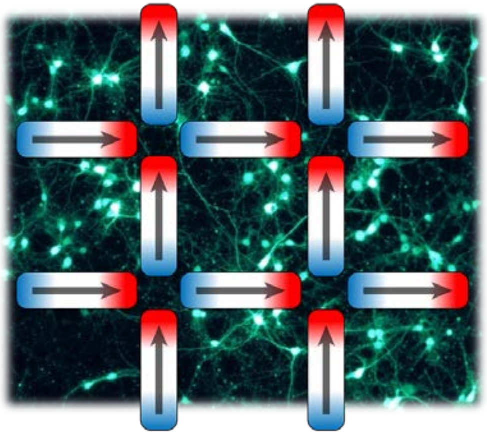
- Improve reservoir quality
- Model dynamic behavior of physical reservoirs
- Self-learning through interaction with environment

- Sparsely connected network for reservoir computing
- Dynamics of reservoir simplify complex inputs



[Schrauwen et al., ESANN, 2007]

- Physical reservoirs for SOCRATES project[1]
  - Biological neurons over microelectrode arrays
  - Nanomagnetic ensembles



[1] https://www.ntnu.edu/socrates

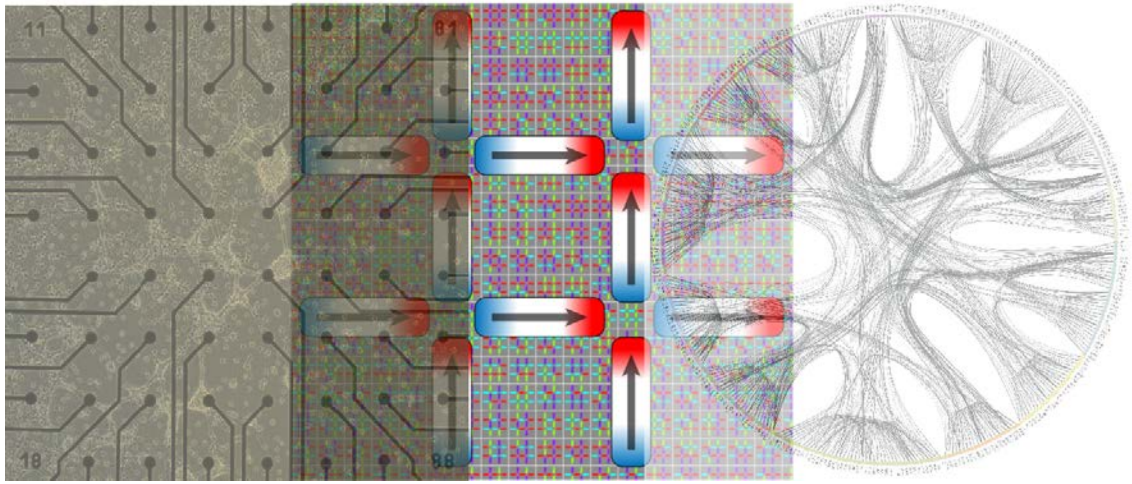
SOMA – Self-Organizing Models of Artificial learning in neural substrates

Data analysis	• Analysis of electrophysiological data recorded from neuronal cultures • Clustering of recordings from different cultures
Self-organizing model	• Sparsely connected network model • Tune model parameters to epitomize neuronal behavior
Proof-of-concept	• Perform classification and computational tasks with both the model and the physical substrate
Perturbed dynamics	• Evaluate dynamics and computational capabilities of cultures with synaptic perturbation • Propose strategies to restore unperturbed dynamics

SOCRATES project:

Inspired by the self-organizing behavior of neurons, to develop arrays of nanomagnets for new computing hardware that is scalable, energy efficient, fault tolerant, and self-learning.

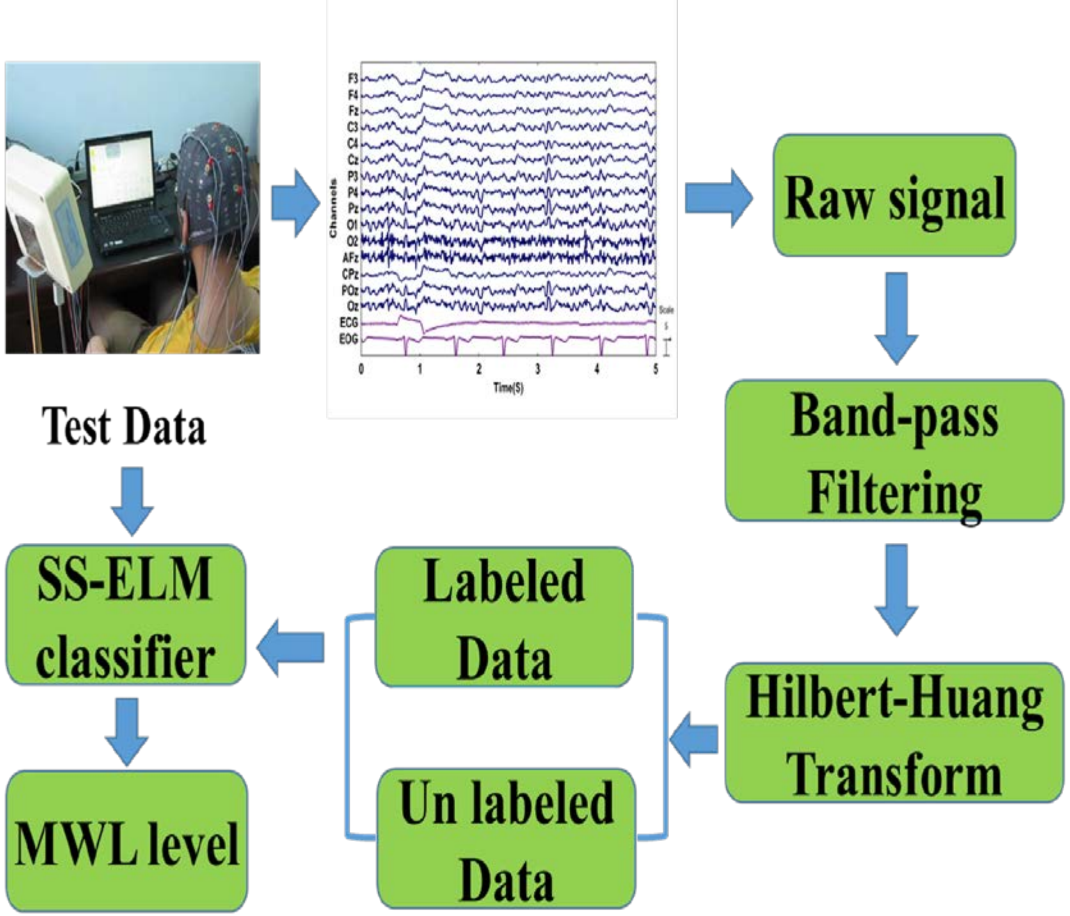
https://www.ntnu.edu/socrates



Kristine Heiney, PhD fellow
Supervisor: Stefano Nichele

TOPIC 2: *Pattern Classification of Cognitive Workload based on Semi-Supervised Learning*

- The real-time mental workload (MWL) monitoring is crucial for designing adaptive aiding/assistance systems.
- Although data-driven approaches have potential for MWL recognition, it is usually difficult or expensive to acquire sufficient labeled data.
- This work applied semi-supervised extreme learning machine to MWL classification based only on a small number of labeled physiological data.



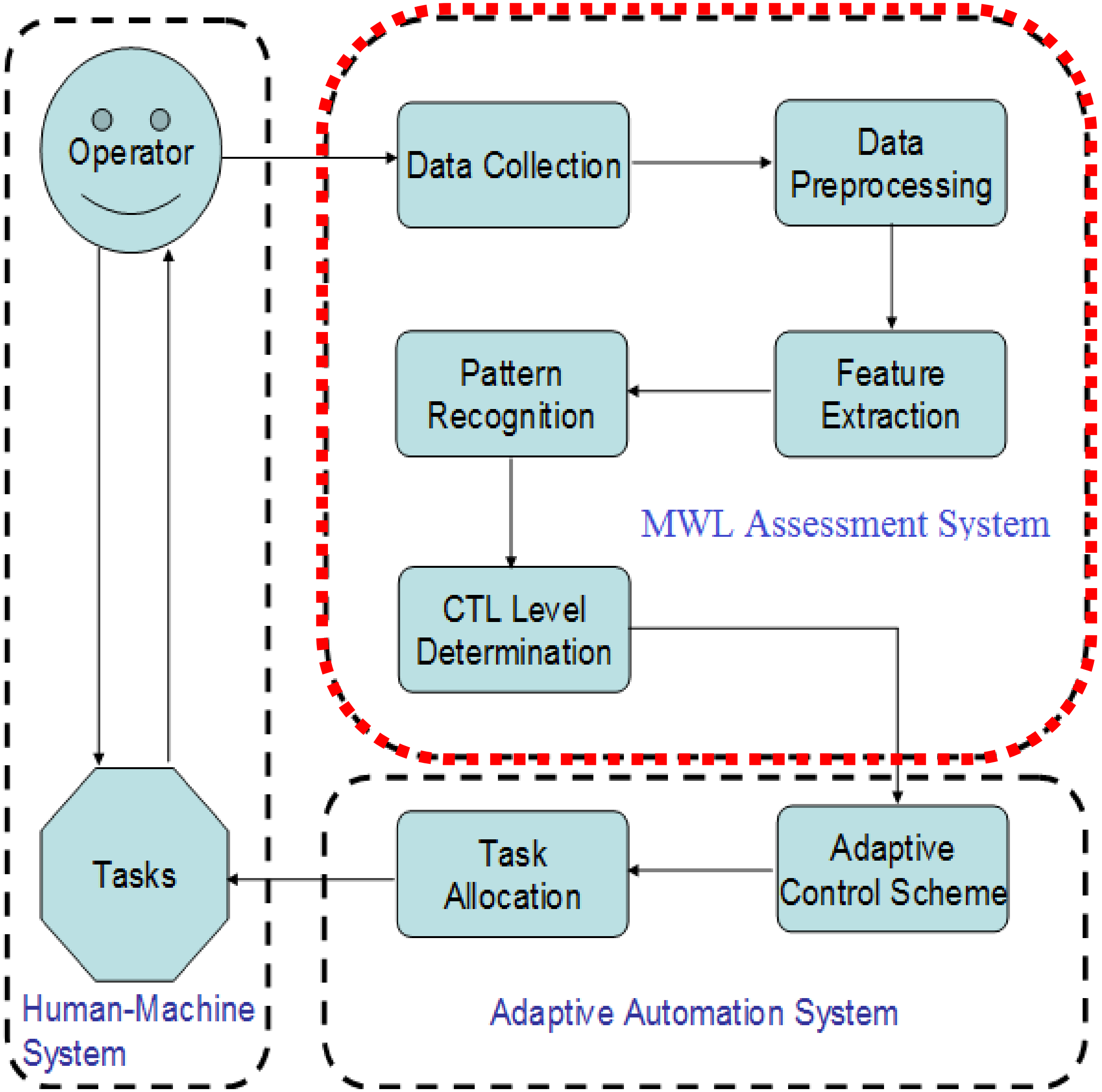
Conclusion

- The proposed SS-ELM method can effectively improve the accuracy and efficiency of MWL classification.
- When only a small number of labeled data are available in practice, SSL algorithm is suitable for online real-time MWL pattern recognition task.

References

1. **J. Zhang***, X. Cui, J Li and R. Wang, Imbalanced Classification of Mental Workload Using a Cost-Sensitive Majority Weighted Minority Oversampling Strategy, ***Cognition, Technology & Work***, vol. **19** (4), pp. 633-653, 2017.
2. J. Li, **J. Zhang***, J. Xia and P. Chen, Mental workload classification based on semi-supervised extreme learning machine, ***J. of East China University of Science and Technology*** (Natural Sci. Ed.), 2019 (to appear).
3. J. Li and **J Zhang**, Mental workload classification based on semi-supervised extreme learning machine, ***26th Int. Conf. on Artificial Neural Networks** (ICANN17)*, 11-15 Sep. 2017, Alghero, Sardinia, Italy.

TOPIC 3: *Pattern Classification of Cognitive Workload Using Deep Learning*



Motivations

Mental Workload (MWL) is an important indicator of mental activity of human operator in Human-Machine System (HMS).

Aims & Objectives

- ✓ Recognition of Momentary MWL using electrophysiological data.
- ✓ Application of deep learning to MWL classification.

Conclusion

- The two deep learning architectures proposed can extract features automatically and are also computationally efficient.
- The selected optimal EEG channels can be used to design wearable devices for high-risk MWL detection.

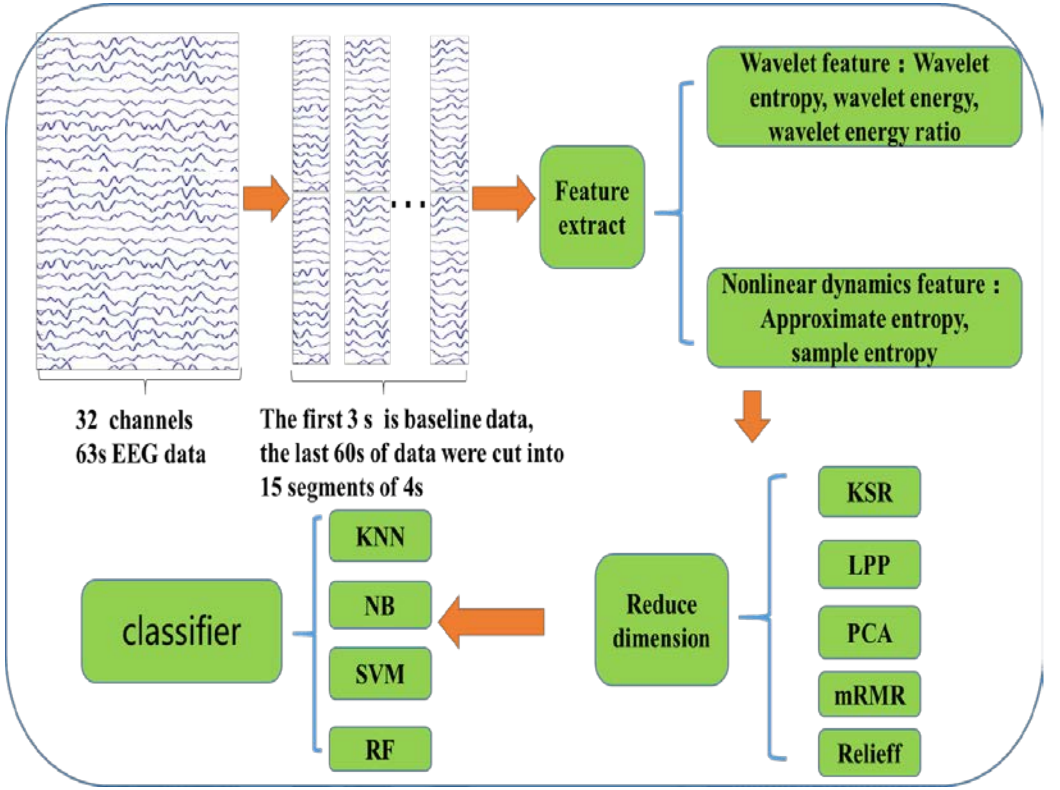
References

1. **J. Zhang***, S. Li and R. Wang, Pattern Recognition of Momentary Mental Workload Based on Multi-Channel Electrophysiological Data and Ensemble Convolutional Neural Networks, ***Front. Neurosci***., vol. **11**, Article 310, pp. 1-16, May 30, 2017, doi: 10.3389/fnins.2017.00310.
2. **J. Zhang***, Y. Wang, and S. Li, Cross-subject Mental Workload Classification Using Kernel Spectral Regression and Transfer Learning Techniques, ***Cognition, Technology & Work***, vol. **19** (4), pp. 587-605, 2017.
3. **J. Zhang*** and S. Li, A Deep Learning Scheme for Mental Workload Classification based on Restricted Boltzmann Machine, ***Cognition, Technology & Work***, vol. **19** (4), pp. 607-631, 2017.
4. J. Li and **J Zhang**, Mental workload classification based on semi-supervised extreme learning machine, in A. Lintas, S. Rovetta, P. Verschure and A. Villa (Eds.), ***ICANN 2017***, *Part II, LNCS* **10614**, pp. 297-304, Springer Int. Publ. AG, 2017.
5. **J. Zhang***, S. Li and R. Wang, Pattern Classification of Instantaneous Mental Workload Using Ensemble of Convolutional Neural Networks, in ***Proc of 20th IFAC World Congress***, Toulouse, France, July 2017.

TOPIC 4: *EEG-based Emotion Recognition Using Machine Learning*

- Used clustering to determine 4 target classes of human emotion.

- Performance comparisons:
  - 2 feature extraction methods: wavelet transform, nonlinear dynamics
  - 5 feature reduction algorithms: KSR, LPP, mRMR, ReliefF, PCA
  - 4 classifiers: k-nearest neighbor (kNN), naïve Bayesian (NB), support vector machine (SVM), random forest (RF)



Conclusion

- 4-class emotion classification accuracy can be significantly improved by taking into account baseline EEG features.
- Nonlinear dynamics features lead to higher accuracy than wavelet-derived features.
- EEG gamma-band features are more salient than other frequency bands.
- Best combination: Kernel Spectral Regression (KSR) for dimensionality reduction + RF for classification.

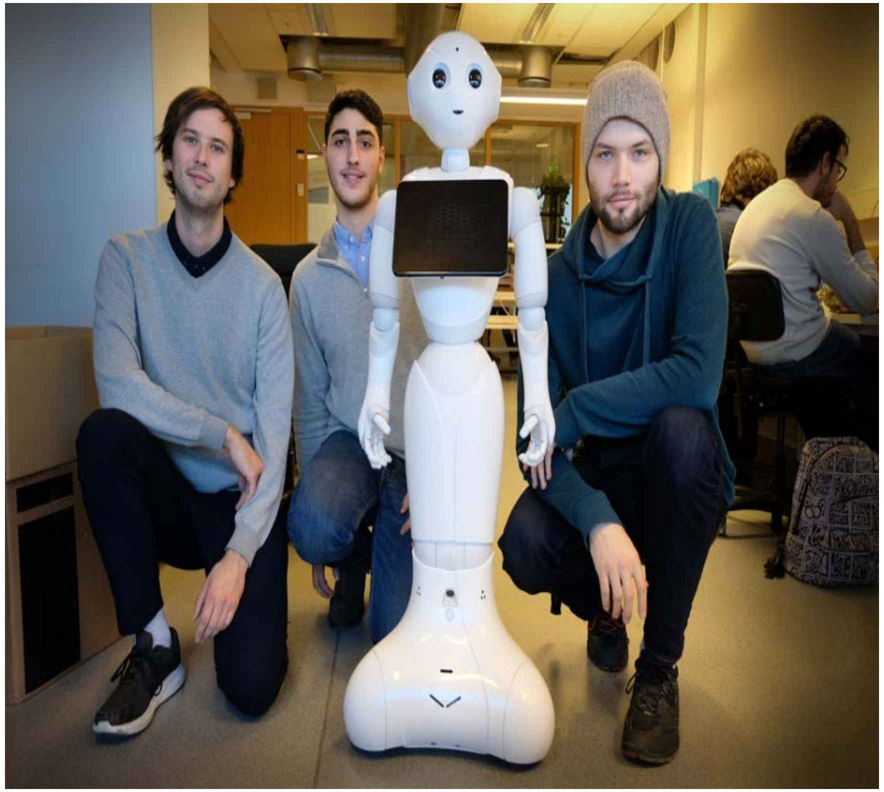
References

1. P. Chen and **J Zhang**, Performance comparison of machine learning algorithms for EEG-signal-based emotion recognition, in A. Lintas, S. Rovetta, P. Verschure and A. Villa (Eds.), ***ICANN2017****, Part I, LNCS* **10613**, pp. 208-216, Springer Int. Publ. AG, 2017.
2. P. Chen, **J. Zhang***, Z. Wen, J. Xia and J. Li, EEG-based emotion recognition through kernel spectral regression and random forest approaches, ***J. of East China University of Science and Technology*** (Natural Sci. Ed.), vol. **44** (5), pp. 744-751, 2018.
3. P. Chen and **J Zhang**, Performance comparison of machine learning algorithms for EEG-signal-based emotion recognition, ***26th Int. Conf. on Artificial Neural Networks*** *(ICANN17)*, 11-15 Sep. 2017, Alghero, Sardinia, Italy.

TOPIC 5: *Intelligent Robotics*

Pepper Humanoid Robots

- 1) Speech to text, 2) Text input to chatbot, 3) Chatbot response to speech
- Using different IBM Watson modules



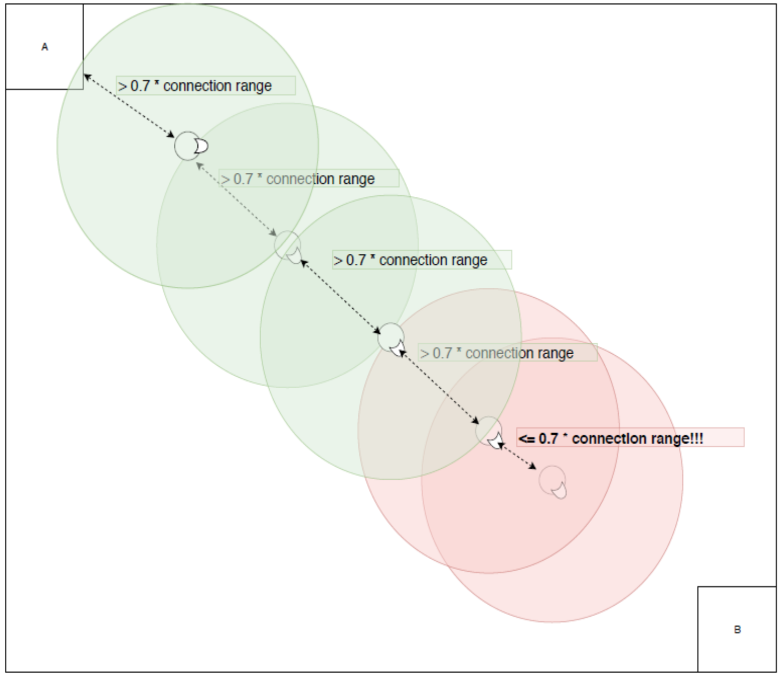


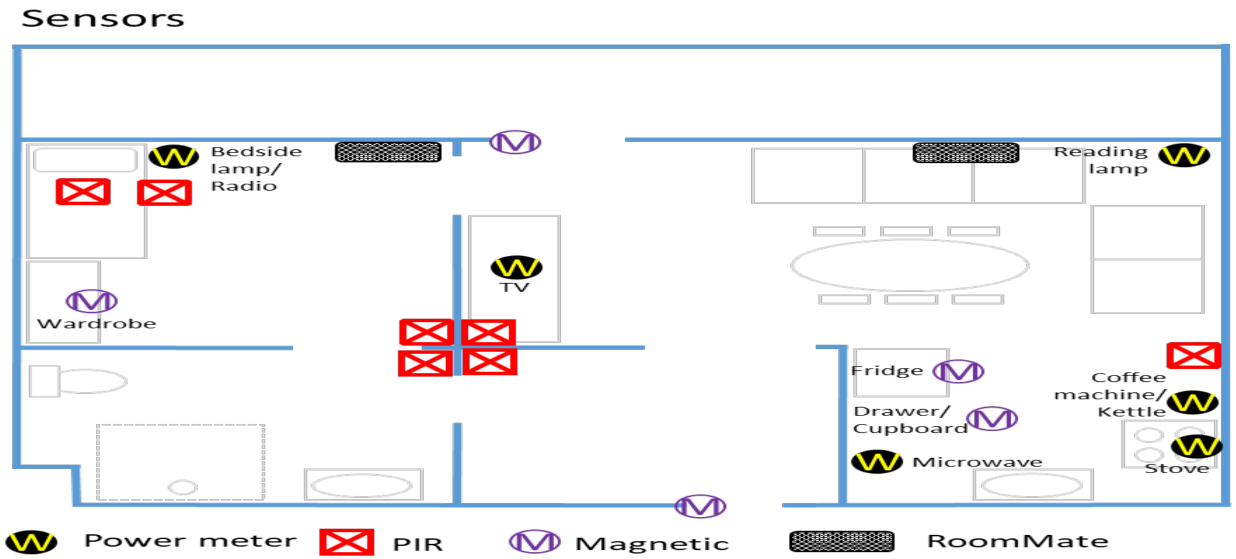
Fig. 6. Illustration of components involved in task being solved.

Swarm Robots

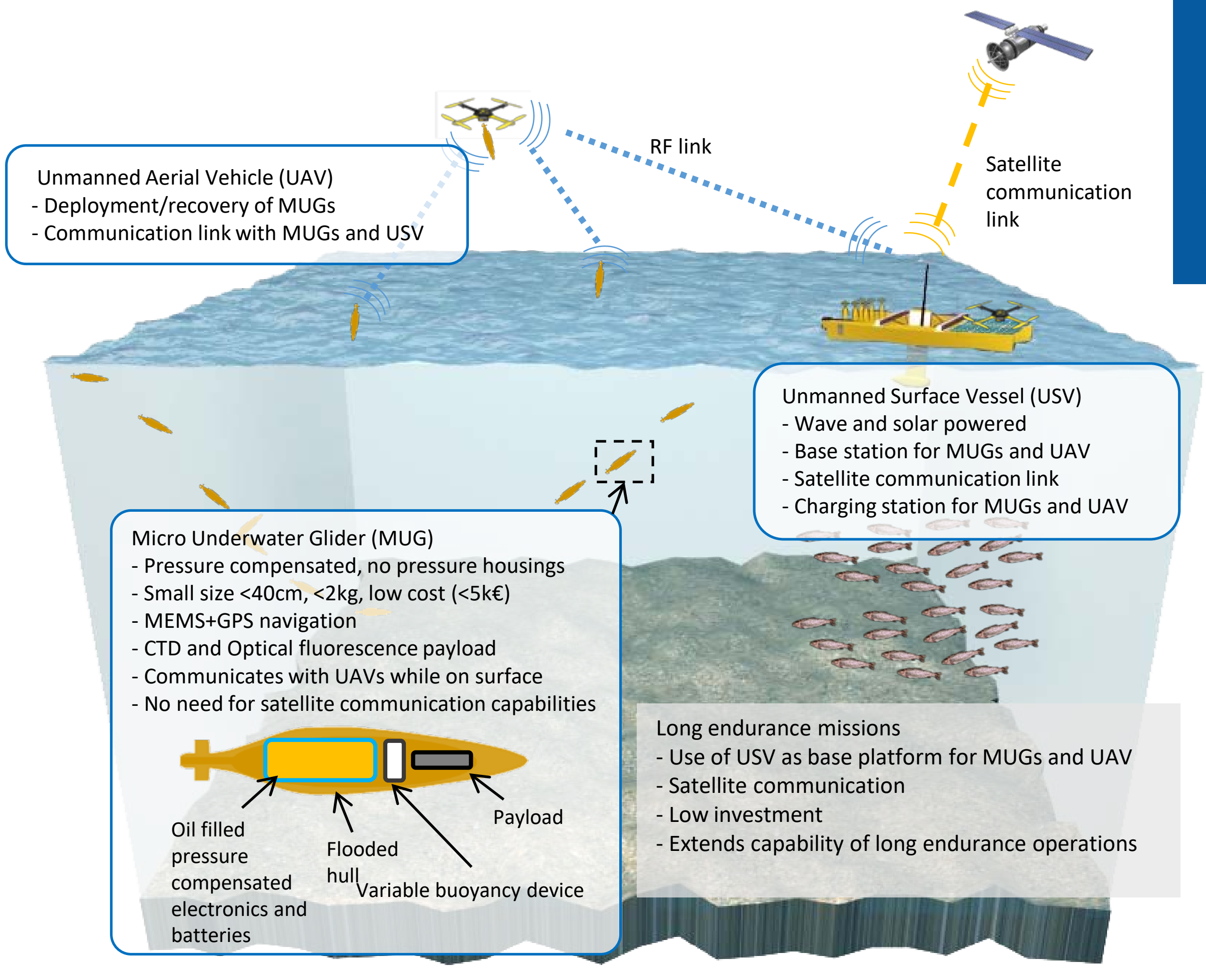
TOPIC 6: *Assisted Living Technology (ALT) for People with Mild Cognitive Impairment or Dementia*

- Predict the next sensor to be activated/deactivated in a sequence.
- Useful for automation functions, such as:
  - turn on the coffee machine, when such event is predicted
  - turn on the lights in the kitchen, when the person wakes up at night

Skøyen Omsorg+



TOPIC 7: *Ocean-Air synoptic operations using coordinated autonomous SYStems (OASYS)*

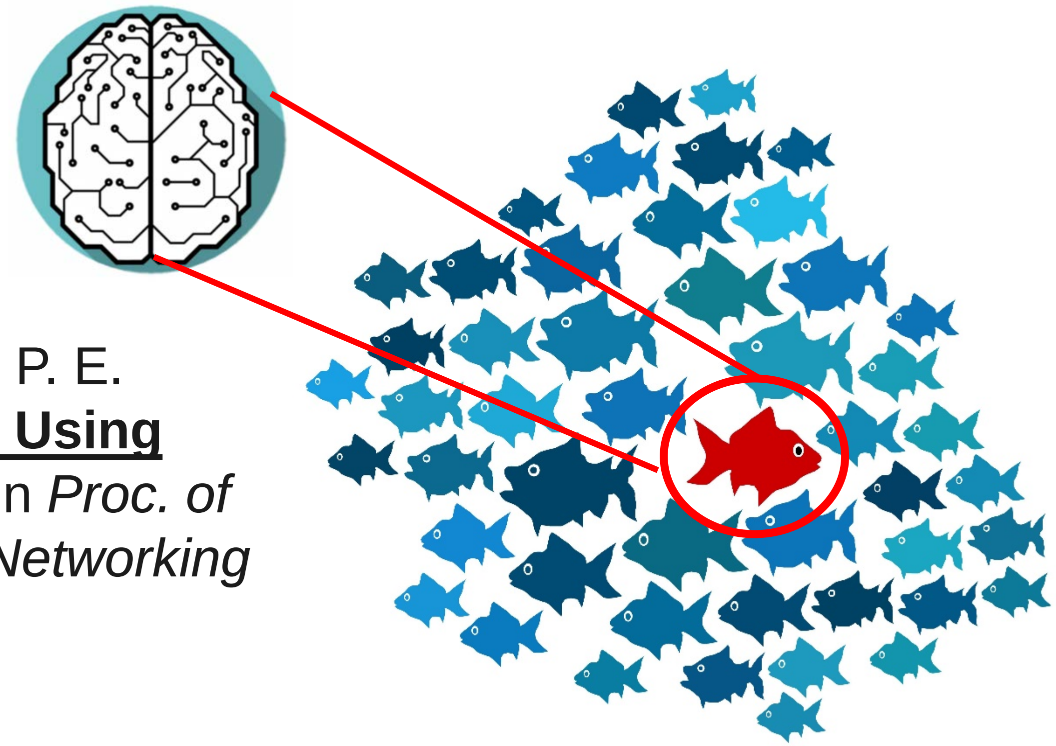


Funding: 1M €

Duration: 3 yrs

- Drones (UAVs): Deployment and recovery of gliders (MUG)
- Gliders (MUG) measure environmental parameters
- USV plays the role of mothership
- Drones (UAVs) are charged on board of the mothership

TOPIC 8: *Intrusion Detection using ML*



Hagos, D. H., Yazidi, A., Kure, Ø., & Engelstad, P. E. (2017), **Enhancing Security Attacks Analysis Using Regularized Machine Learning Techniques**. In *Proc. of 31st IEEE Int. Conf. on Advanced Information Networking and Applications (AINA),* pp. 909-918.