AGH University of Science and Technology

Faculty of Electrical Engineering, Automatics, Computer Science and Biomedical Engineering

Department of Biocybernetics and Biomedical Engineering

Computational Intelligence

Project Classes

Teams code: 120vr8k

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Google: Adrian Horzyk

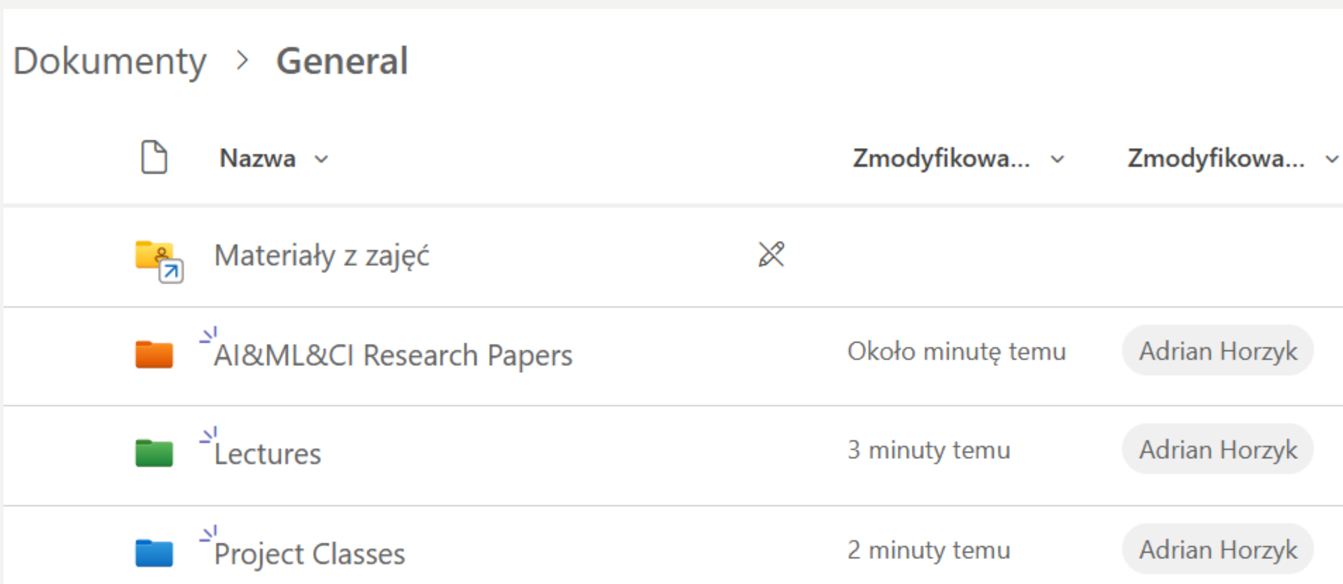
MS Teams Platform

- Lectures and other materials will be provided through MS Teams:

Project Classes

Teams code: 120vr8k

- **The assignments and exam will use MS Teams as well!**



Evaluation and Grading

Laboratory Classes – Plan & Requirements:

During Laboratory Classes

- Work with **examples** presented in the notebooks.
- Concepts will be **explained during lectures and labs** to support your understanding.

Assignments

- You must complete **graded assignments** based on the materials.
- Submit your **solutions for grading**.
- You will have the **freedom to choose** from different assignments:
    - Select topics that match **your level of difficulty and interest**.
    - Build up points gradually for your **final evaluation**.

Attendance Mandatory:

- Sign the attendance list every class.
- Absences must be **justified**.

Evaluation and Grading

Lectures & Exam – Plan & Requirements:

Lectures

- Cover **popular topics, models, methods, and algorithms**.
- Concepts will be **presented, explained, and discussed** during sessions.
- Knowledge gained here will be applied in:
  - **Laboratory classes** (for assignments)
  - **Project classes** (for research, presentations, and final projects)

Final Quiz / Exam

- At the **end of the semester**, you will take a **quiz (exam)**.
- Purpose: to **check your knowledge and understanding** of lecture material.

Grading & Final Grade

- Your **final grade** will be calculated as the **average of grades** from:
  - **Final quiz (exam)**
  - **Laboratory classes**
  - **Project classes**

All examination terms are included in this calculation.

Evaluation and Grading

Project Class Schedule & Requirements:

1st Project Class

Activity:

- Presentation of course goals and semester plan.

Student Task (before 2nd class):

- Choose **1–3 interesting topics**.
- Prepare a short presentation describing them.
- Use **Internet sources and research papers** to explain goals and motivations behind chosen topics.

2nd Project Class

Activity:

- **Student presentations (5–8 min each):**
  - Present your chosen topics “in a nutshell.”
  - Explain your motivation and what interests you about them.
  - Goal: decide on **one final topic** for your project.

Student Task (before 3rd class):

- Read **3–5 research papers** on your chosen topic.
- Gain deeper knowledge.
- Possibly finalize which topic to pursue.

Evaluation and Grading

Project Class Schedule & Requirements:

3rd Project Class

Activity:

- **Student presentations (5–8 min each):**
  - Present theory and interesting aspects of your chosen topic.
  - Share insights from the research papers you read.
  - Indicate your **final project choice**, if ready.

Student Task (before 4th class):

- Start **working on your project**.
- Prepare first models and collect initial results.

4th–5th Project Classes

Activity:

- Present **intermediate models and results**.
- Show progress, discuss difficulties, and share next steps.
- Use:
  - Charts of training/validation
  - Confusion matrices
  - Visualizations
  - Any other materials to support discussion.

Evaluation and Grading

Project Class Schedule & Requirements:

6th Project Class

Activity:

- Present **release candidate models and results**.
- Discuss final difficulties and questions.
- Show:
  - Training process (charts, metrics)
  - Comparisons of results
  - Confusion matrices and visualizations.

7th Project Class (Final Presentations)

Activity:

- **Final project presentations (10 min each):**
  - Focus on models, methods, results, comparisons, interpretations, and conclusions.
- Submit **final presentation + project code** for grading.

Additional Requirements

Attendance:

- Sign the attendance list at every class.
- Any absence must be justified.

Evaluation of the research presentations

The following will be assessed in the studies of research papers:

- **Up-to-date topic selection**
- **Difficulty** of the selected task and paper(s).
- **Number** of collected materials and their quality.
- **Quality** of the presentation of the methods, techniques, and computational models.
- **Visual presentation** of schemas, ideas, charts, visualisations, and algorithms.
- **Ability** to draw conclusions based on the studied papers, and sources.

Presentations should be carried out by 1-2 students,
but the number of participants must justify:

- ✓ the difficulty of the selected topic,
- ✓ the number of the read papers or other material studied from the other sources,
- ✓ the quality of the presentation and detailed presented.

Final Projects

- Topics and datasets should be **neither too easy nor too difficult** (we have limited time and computational resources!). If you're unsure, we can discuss your proposed topics during the second and third project sessions.
- You can browse [Kaggle] **or other sources** to choose an interesting, non-trivial task, define your project topic, and download data to develop, train, and optimize your models. You can also build on the experience from the first project sessions.
- In your project, **use at least two different training approaches** and **at least three different model architectures and/or types**, compare them rigorously, and **draw clear conclusions** (using consistent evaluation metrics and baselines).

Evaluation of the final projects

The following will be assessed in the final projects:

- **Difficulty** of the selected task and training data set.
- **Selection** of methods, techniques, and computational models.
- **Ability** to adapt, optimize, regularize, etc.
- **Variety** of conducted experiments and comparisons.
- **Visualization** and charts of the training processes and results.
- **Ability** to infer and interpret results.
- **Ability** to apply all computational and optimization methods presented in lectures.
- **The results** obtained in the context of the difficulty of the task and the data set.
- **Quality** and elegance of the final presentation of models and results.
- **Ability** to correctly interpret results and draw conclusions.
- **Compare a**t least 3 different models and at least 2 different learning approaches!

Projects can be carried out by 1-2 students, but the number of participants must justify the level and quality of implementation and presentations, as well as the difficulty of the solved problem.

Expansion to Research Papers

You have the opportunity to expand your final projects into:

- Research papers — if submitted as a master's thesis, the paper must be accepted or published before the thesis defense.
- ICAISC 2026 (Class B conference)
- PP-RAI 2026
- etc.

Students who wrote research papers in the past with my support and collaboration

- Adrian Horzyk, **Jakub Kosno**, **Daniel Bulanda**, Janusz A. Starzyk, Explainable Sparse Associative Self-Optimizing Neural Networks for Classification, Eds. Biao Luo, Long Cheng, Zheng-Guang Wu, Hongyi Li, Chaojie Li, Proc. of 2023 International Conference on Neural Information Processing (ICONIP 2023), Springer Nature Computer Science (CCIS, LNAI, LNCS), Springer Nature Singapore Pte Ltd. 2024, LNCS (14450), CCIS 1963, Vol. 3, pp. 229–244, 2024. **[rank = 140 || 70]** - presentation
- **Daniel Henel**, **Aleksander Mazur**, **Marcin Retajczyk**, Weronika T. Adrian, Krzysztof Kluza, **Adrian Horzyk**, Neural network for musical data mining for phrase boundary detection, Proc. of SSCI 2023 conference in Mexico City, Dec. 5-8, 2023, IEEE, Xplore, Mexico, 2023, pp. 1310 - 1315. **[rank = 30]** - presentation - **IEEE Travel Grant Award $1000 for Daniel Henel**
- **S. Czaplak**, A. Horzyk, Automatic Optimization of Hyperparameters Using Associative Self-adapting Structures, Proc. of 2022 International Joint Conference on Neural Networks (IJCNN), Padua, Italy, 2022, pp. 1-8, IEEE Xplore, 2022. **[rank = 140]** - poster, doi: 10.1109/IJCNN55064.2022.9892758.
- **M. Wójcik**, A. Horzyk, **D. Bulanda**, Associative Graphs for Fine-Grained Text Sentiment Analysis, Eds. Media Ayu, Kevin Wong, Achmad Nizar, Teddy Mantoro, Minho Lee, Jonathan H Chan, Lance Fung, In: Proc. of 28th International Conference, ICONIP 2021, Sanur, Bali, Indonesia, December 8–12, 2021, Proceedings, Part II, Springer LNCS 13109, pp. 238–249, **[rank = 140]** - video presentation.
- A. Horzyk and **E. Ergün**, *YOLOv3 Precision Improvement by the Weighted Centers of Confidence Selection*, 2020 International Joint Conference on Neural Networks (IJCNN), Glasgow, United Kingdom, 2020, IEEE, Xplore, pp. 1-8, doi: 10.1109/IJCNN48605.2020.9206848 - video presentation **[rank = 140]**

- A. Horzyk, **K. Gołdon**, and J.A. Starzyk, *Temporal Coding of Neural Stimuli*, In: 28th International Conference on Artificial Neural Networks (ICANN 2019), Springer-Verlag, LNCS 11731, pp. 607-621, 2019, DOI: 10.1007/978-3-030-30493-5_56 **[rank = 70]**
- **M. Janowski**, A. Horzyk, *Supervised Neural Network Learning with an Environment Adapted Supervision Based on Motivation Learning Factors*, In: Proc. of 17-th Int. Conf. ICAISC 2018, Rutkowski, L., Scherer, R., Korytkowski, M., Pedrycz, W., Tadeusiewicz, R., Zurada, J.M. (Eds.), Artificial Intelligence and Soft Computing, Springer-Verlag, LNAI 10841, 2018, pp. 76-87, 2018. **[rank = 30]**
- **P. Papież**, A. Horzyk, *Motivated Reinforcement Learning Using Self-Developed Knowledge in Autonomous Cognitive Agent*, In: Proc. of 17-th Int. Conf. ICAISC 2018, Rutkowski, L., Scherer, R., Korytkowski, M., Pedrycz, W., Tadeusiewicz, R., Zurada, J.M. (Eds.), Artificial Intelligence and Soft Computing, Springer-Verlag, LNAI 10841, pp. 170-182, 2018. **[rank = 30]**

You can also do it!

Conference Financing using IDUB grants for Master students

For those considering completing their master's thesis in the form of a research article, there are several opportunities to submit papers to conferences or journals and obtain up to PLN 7,000 in funding from AGH IDUB to support the work or cover conference participation:

https://www.idub.agh.edu.pl/inicjatywa-doskonalosci-uczelnia-badawcza/aktualnosci/info/article/i-edycja-dofinansowania-badan-w-zakresie-projektow-dyplomowych-oraz-prac-dyplomowych-badawcza-scie/

[III edycja konkursu w ramach działania 12 „Integracja procesu kształcenia z badaniami naukowymi”]

[3rd edition of the competition under Action 12 "Integration of the education process with scientific research"]

The IDUB application deadline for up to PLN 7,000 from IDUB support grants is September 10:

Rules for applicants & Criteria of evaluations

Expectations & Deliverables for the 2nd Project Classes

Pick Topics

- Find or choose 1 to 3 **candidate** topics from the proposals/papers.
- Submit a 2–3 sentence rationale, **2–3 primary references**, and links to **candidate datasets**.

Prepare a Mini-Presentation (5–8 slides)

- Problem statement & motivation (why this matters).
- Key terms, models, methods, and algorithms (with **small examples/diagrams**).
- Preliminary **baseline plan** (data, model(s), metrics).
- Constraints & resources (compute, libraries), risks, and a rough **timeline**.
- If in a team: roles.

Background Reading

- Find at least **2–3 complementary sources** (papers/books/tutorials).
- Add 1-sentence takeaways for each.

Presentation & Knowledge Sharing

- **4–6 min presentation** + **1–2 min. Q&A and a discussion**.
- Use visuals: schemas, charts, images, toy examples.
- Aim to explain *how* the methods work, not just *what* they are.

Syllabus Essentials

Period	Method of verification of the learning outcomes	Number of ECTS credits
Semester 2	Exam **Activities and hours** Lectures: 28 Laboratory classes: 14 Project classes: 14	4

Student workload

Activity form	Average amount of hours* needed to complete each activity form
Lectures	28
Laboratory classes	14
Project classes	14
Preparation for classes	14
Realization of independently performed tasks	43
Examination or final test/colloquium	2
Contact hours	5
Student workload	**Hours** 120
Workload involving teacher	**Hours** 56

You should be familiar with the syllabus of this course.

Syllabus Essentials

Goals

C1	They know how to select and apply appropriate state-of-the-art methods, architectures, and training techniques (e.g., Transformers, Graph Neural Networks, Diffusion Models, GANs, Reinforcement Learning, Meta-Learning) to optimize performance, generalization, and interpretability of computational intelligence solutions. They have broad and up-to-date knowledge of neural networks, deep learning architectures, generative and self-supervised models, as well as associative, relational, and motivated learning paradigms, and understand their applications and limitations. They gain practical experience in constructing, adapting, fine-tuning, and training modern models (e.g., LLMs, Vision Transformers, multimodal models, federated and continual learning systems) using Python 3, Jupyter Notebook, and frameworks such as PyTorch, TensorFlow, Hugging Face, and PyTorch Geometric. They are able to design and implement intelligent learning systems of various kinds, including multimodal, generative, and trustworthy AI solutions, with awareness of ethical, fairness, and explainability requirements. They develop good practices in modeling, experimentation, hyperparameter optimization, and efficient training techniques (quantization, pruning, distillation, LoRA) and are capable of deploying lightweight AI solutions on limited computational resources (Google Colab, personal laptops, Edge AI). They can apply explainable and responsible AI principles, using modern interpretability frameworks (e.g., SHAP, LIME, Captum), and evaluate AI models in terms of trust, bias, and accountability in line with contemporary standards and regulations (e.g., EU AI Act).

Conditions and the manner of completing each form of classes, including the rules of making retakes, as well as the conditions for admission to the exam

Lectures - active participation and presence.
Laboratory classes - carrying out exercises and obtaining correct results.
Project classes - project implementation and achieving satisfactory results.

Method of determining the final grade

The course grade is the weighted average of laboratory and project grades. In the case of completing the course within a correction period, grades of all terms are taken into consideration when computing the weighted average grade of the course, where the grades from the previous terms influence the final grade in 50% only to emphasize the final achievements of the students.

Manner and mode of making up for the backlog caused by a student justified absence from classes

Agreed individually with the teacher depending on the type of classes abandoned. Lack of student attendance does not release him from the obligation to complete all exercises and the project. If possible, he should take part in another parallel-group or do his homework individually after agreeing with the teacher.

You should be familiar with the syllabus of this course.

I wish you a great loaf of knowledge!

See you the next time talking about neurons and AI!

Inspiring examples of topics for research and presentations

1. Classical & Modern Machine Learning

Focus: Comparative learning paradigms and interpretability.

Comparative Study: Evaluate *k-NN, Decision Tree, SVM* vs. *XGBoost, MLP, or Transformer-based tabular models* on a real-world dataset.
(Approaches: supervised, ensemble, meta-learning)

Feature Engineering & Pattern Mining: Integrate *Apriori/FP-Growth* for frequent pattern discovery into a downstream *classifier* or *recommender system.*
(Approaches: unsupervised + supervised)

Explainable Baselines: Compare interpretable models (*LogReg, RuleFit*) with "black-box" *deep networks* using *SHAP/LIME/Captum* for post-hoc explainability.
(Approaches: interpretable ML + deep learning)

2. Deep Learning Architectures

Focus: Comparing architectures and representation learning.

Vision Transformers vs. CNNs: Apply *ResNet, EfficientNet, ViT* to image classification; evaluate trade-offs in accuracy, efficiency, and interpretability.
(Approaches: supervised + self-supervised pretraining)

Autoencoders for Anomaly Detection: Compare *Denoising AE, VAE, and Transformer AE* for outlier detection in tabular, financial, or medical data.
(Approaches: unsupervised + semi-supervised)

GANs for Data Augmentation: Evaluate *DCGAN, StyleGAN, Diffusion-based augmentation* for improving downstream classification accuracy.
(Approaches: generative + supervised)

Papers with Code to analyze!

Get familiar with one topic deep and share your knowledge with the other classmates!

Some papers available on MS Teams!

Inspiring examples of topics for research and presentations

3. Generative & Diffusion Models

Focus: Generation and augmentation across modalities.

Text-to-Image Systems: Compare *Stable Diffusion, DALL·E-mini,* and *StyleGAN* for prompt-based image synthesis.
(Approaches: diffusion + adversarial + supervised fine-tuning)

Data Augmentation with Diffusion Models: Combine *Diffusion, GAN,* and *VAE* for synthetic data creation; test impact on downstream accuracy.
(Approaches: generative + transfer learning)

Style Transfer: Implement *CycleGAN, UNIT,* and *Diffusion-based stylization* for artistic or cross-domain transfer.
(Approaches: unsupervised + adversarial)

4. Reinforcement Learning

Focus: Adaptive agents and learning from interaction.

Game-Playing Agents: Implement *Q-Learning, DQN,* and *PPO* on simple environments (*CartPole, Gridworld*).
(Approaches: reinforcement + deep reinforcement)

RL with Human Feedback (RLHF): Combine *DQN, PPO, Supervised preference model* for fine-tuning via ranked feedback.
(Approaches: RL + supervised fine-tuning)

Resource Optimization: Use *DQN, A2C, Neuro-evolutionary RL* for scheduling or routing problems.
(Approaches: RL + evolutionary)

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Inspiring examples of topics for research and presentations

5. Meta-, Few-Shot & Continual Learning

Focus: Adaptation, generalization, and memory.

Few-Shot Image Classification: Implement *Prototypical Networks, MAML,* and *Matching Networks* on small labeled datasets.
(Approaches: meta-learning + supervised)

Continual Learning: Evaluate *EWC, Replay Buffers,* and *Online Distillation* to mitigate catastrophic forgetting.
(Approaches: continual + regularization-based)

Adaptive Personalization: Build an adaptive recommender using *Meta-Learner, CL Agent,* and *Fine-Tuned Transformer.*
(Approaches: continual + reinforcement)

6. Efficient & Responsible AI

Focus: Model optimization, fairness, and sustainability.

Model Compression: Compare *Pruning, Quantization (INT8),* and *Knowledge Distillation* for CNNs or Transformers.
(Approaches: optimization + supervised)

Edge AI Deployment: Evaluate lightweight models (*MobileNet, TinyBERT, Quantized ViT*) deployed locally; assess latency and accuracy.
(Approaches: transfer learning + deployment optimization)

Explainable & Fair AI: Apply *SHAP, LIME, Counterfactual Explanations* to models and test *fairness-aware* methods (reweighing, adversarial debiasing).
(Approaches: interpretability + fairness-aware learning)

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Inspiring examples of topics for research and presentations

7. Relational, Associative & Cognitive Learning

Focus: Structured and cognitively inspired representations.

Graph Neural Networks: Implement *GCN, GraphSAGE,* and *GAT* on molecular, citation, or social graph data.
(Approaches: graph-based + semi-supervised)

Associative Memories: Compare *Hopfield Networks, Associative Knowledge Graphs,* and *Transformers-as-memory* for sequence recall.
(Approaches: memory-based + self-supervised)

Cognitive-Inspired Systems: Prototype models integrating *symbolic reasoning, motivation signals,* and *neural learning* (e.g., rule-based + LSTM).
(Approaches: neuro-symbolic + reinforcement)

8. Integration & Applications

Focus: Multimodal, domain-specific, and hybrid systems.

Multimodal Learning: Combine *CLIP, BLIP-2,* and *LLaVA* for text–image retrieval or captioning.
(Approaches: multimodal + contrastive)

Biomedical Applications: Apply *CNN, Transformer, Graph-based models* to ECG or medical image analysis; integrate interpretability tools.
(Approaches: supervised + self-supervised)

E-sports/Game Analytics: Predict player or match outcomes using *Tree-based ML, RNN/LSTM,* and *GNNs* with temporal data.
(Approaches: supervised + sequence modeling)

Finance & Forecasting: Build hybrid systems combining *Association Rules, LSTM, and Gradient Boosting* for time series or sentiment-based prediction.
(Approaches: hybrid + supervised)

Papers with Code to analyze!

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Some papers available on MS Teams!

Inspiring examples of topics for research and presentations

9. Hybrid Neuro-Symbolic Systems

Focus: Integrating reasoning with learning.

Symbolic + Neural Models: Combine *Decision Logic, MLP,* and *Graph Reasoners.*
(Approaches: symbolic + neural)

Causal Inference Learning: *Do-calculus-inspired models (SCM, Causal GNN, Transformer).*
(Approaches: causal + supervised)

Rule-Guided Learning: Embed logical rules in *Transformer attention.*
(Approaches: neuro-symbolic + self-supervised)

10. Self-Supervised & Contrastive Learning

Focus: Learning from unlabeled data.

Representation Learning: *SimCLR, BYOL, MoCo* on vision/text datasets.
(Approaches: self-supervised + transfer)

Cross-Modal Contrastive Models: *CLIP, ALIGN, DeCLUTR.*
(Approaches: self-supervised + multimodal)

Fine-Tuning for Downstream Tasks: Evaluate embeddings across *classification, retrieval, clustering.*
(Approaches: transfer + supervised)

11. Transfer Learning & Domain Adaptation

Focus: Generalization across domains.

Cross-Domain Vision: *Fine-tune ResNet, ViT, CLIP* on new dataset.
(Approaches: supervised + transfer)

Text Transfer: *BERT, DistilBERT, AdapterFusion* comparison.
(Approaches: transfer + continual)

Domain Adaptation: *DANN, CORAL, MMD-based methods.*
(Approaches: unsupervised + supervised)

Papers with Code to analyze!

Get familiar with one topic deep and share your knowledge with the other classmates!

Some papers available on MS Teams!

Inspiring examples of topics for research and presentations

12. Evolutionary & Swarm Intelligence

Focus: Optimization and emergent collective behavior.

Genetic Algorithms vs. Particle Swarm vs. Differential Evolution on optimization tasks.
(Approaches: evolutionary + stochastic search)

Neuroevolution: *Evolve CNN/RNN architectures (NEAT, CoDeepNEAT, Genetic RL).*
(Approaches: evolutionary + deep)

Hybrid Search + Learning: Combine *PSO + Gradient-based learning.*
(Approaches: hybrid + reinforcement)

13. Graphical Models & Probabilistic Reasoning

Focus: Structured uncertainty modeling.

Bayesian Networks, Conditional Random Fields, and Deep Probabilistic Models on relational data.
(Approaches: probabilistic + supervised)

Variational Inference Comparison: *VAE, Bayesian NN, Normalizing Flows.*
(Approaches: probabilistic + generative)

Causal Graph Discovery: *NOTEARS, DAG-GNN, PC Algorithm.*
(Approaches: causal + graph)

14. Multi-Agent Systems & Collective Intelligence

Focus: Cooperation, competition, and coordination.

Cooperative RL: *QMIX, MADDPG, MAPPO* for multi-agent tasks.
(Approaches: multi-agent RL + policy gradient)

Emergent Behavior: Simulate *Swarm, Boids, Cellular Automata.*
(Approaches: agent-based + evolutionary)

Communication Learning: *Graph-based messaging networks* between agents.
(Approaches: graph + reinforcement)

Papers with Code to analyze!

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Some papers available on MS Teams!

Inspiring examples of topics for research and presentations

15. Robustness, Uncertainty & Adversarial Learning

Focus: Safe and reliable model behavior.

Adversarial Training: Compare *FGSM, PGD, TRADES* on CNNs or Transformers.
(Approaches: adversarial + supervised)

Uncertainty Estimation: *MC Dropout, Deep Ensembles, Bayesian NNs.*
(Approaches: probabilistic + ensemble)

Robust Evaluation: Cross-domain stress testing and calibration.
(Approaches: supervised + robustness-aware)

16. Human–AI Interaction & Cognitive Modeling

Focus: Adaptive and interpretable human–machine systems.

User-Adaptive Learning: *RLHF, Preference Learning, Meta-personalization.*
(Approaches: reinforcement + continual)

Cognitive Simulations: *ACT-R-inspired or Predictive Processing Models.*
(Approaches: cognitive + neural)

Interactive Explanations: Evaluate *explainability tools* in a user study.
(Approaches: explainable + supervised)

17. Time Series, Forecasting & Sequence Modeling

Focus: Temporal prediction and pattern discovery.

Sequence Models: *RNN, LSTM, Transformer, TCN* comparison.
(Approaches: supervised + self-supervised)

Hybrid Forecasting: *ARIMA + LSTM + Prophet* ensemble.
(Approaches: hybrid + supervised)

Anomaly Detection in Streams: *Autoencoder, Isolation Forest, Transformer AE.*
(Approaches: unsupervised + continual)

Papers with Code to analyze!

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Some papers available on MS Teams!

Inspiring examples of topics for research and presentations

18. Quantum & Neuromorphic-Inspired Computing

Focus: Beyond-classical paradigms in computation.

Quantum ML: Compare *QNNs, VQC, Hybrid Quantum–Classical networks.*
(Approaches: quantum + supervised)

Spiking Neural Networks: Implement *LIF models, Reservoir Computing, Neuromorphic Transformers.*
(Approaches: neuromorphic + temporal)

Cross-Paradigm Evaluation: Benchmark vs. classical baselines for accuracy and energy.
(Approaches: comparative + efficient learning)

19. Motivated & Embodied Learning

Focus: Biologically inspired adaptive and self-regulating systems.

Motivated Agents: Implement agents with *intrinsic motivation* (e.g., curiosity or novelty-based rewards) using *DQN, PPO,* and *SARSA.*
(Approaches: reinforcement + cognitive)

Homeostasis-Inspired Control: Model *energy or need-based behavior* using *rule-based feedback, simple neural controller,* and *evolutionary agent* to maintain internal balance.
(Approaches: reinforcement + continual)

Adaptive Cognitive Behavior: Integrate *motivated learning principles* with *Associative Memory Networks, RNNs,* and *policy heuristics* for goal-driven adaptation.
(Approaches: continual + biologically inspired)

Papers with Code to analyze!

Get familiar with one topic deep and share your knowledge with the other classmates!

Some papers available on MS Teams!

Innovative examples of topics for research and presentations

New State-of-the-Art Additions (cross-cutting topics):

- **LLM Fine-Tuning & Prompt Engineering** *(methods for adapting large language models via LoRA, SFT, or prompt design to specific domains and tasks — connects to transformer architectures and meta-learning paradigms).*
- **Multimodal Foundation Models** *(joint learning across modalities such as vision–language or speech–text; includes models like CLIP, BLIP, and Whisper-style fusion).*
- **Diffusion Beyond Images** *(extending diffusion models to non-visual data types like text generation, molecular graphs, or protein folding — exploring generative stochastic dynamics).*
- **Federated Learning & Privacy-Preserving AI** *(distributed model training across devices while maintaining user data privacy — includes differential privacy, secure aggregation, and on-edge training).*
- **Green AI & Sustainable Computing** *(optimizing models and infrastructure for energy efficiency, reduced carbon footprint, and computational sustainability — quantifying environmental cost of AI).*
- **Neuro-Symbolic & Cognitive AI** *(combining neural networks with symbolic reasoning, logic rules, or cognitive architectures to achieve interpretable, generalizable intelligence).*

Applied / Experimental Directions:

- **Laptop-friendly LLM:** *lightweight large language model fine-tuning via LoRA-SFT combined with RAG pipelines and systematic evaluation of hallucination rates and fairness metrics (focus on resource efficiency).*
- **Multimodal Retrieval & Grounding on Small Checkpoints:** *efficient multimodal search and reasoning using compact models; grounding text to image/audio features under constrained compute.*
- **Continual Learning & Memory:** *lifelong learning through Elastic Weight Consolidation (EWC) and minimal episodic memory buffers for active recall and task retention over time.*
- **Neuro-Symbolic & Pattern Mining:** *hybrid modeling via FP-Growth–based pattern extraction, integrating tabular and graph data representations; explainability through SHAP or causal feature analysis.*
- **Edge/Quantized Continuous Inference:** *quantization-aware training (QAT) and INT8 optimization for deployment on CPUs or embedded hardware like NVIDIA Jetson — enabling real-time edge AI inference.*

[Papers with Code to analyze!]

Get familiar with one topic deep and share your knowledge with the other classmates!

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