Course syllabus

Course title	Cognitive processes modelling II
Instructor(s)	prof. Joanna Rączaszek-Leonardi, dr Julian Zubek, mgr Michał Denkiewicz
Contact details	**E-mails** should preferably be sent to all the instructors: raczasze@psych.uw.edu.pl; j.zubek@uw.edu.pl; mdenkiewicz@student.uw.edu.pl **Office hours:** Joanna Rączaszek-Leonardi: Tuesday 12-14 (or 14-16 on the days of the Faculty Board meeting); Thursday 13-15; J. Zubek, M. Denkiewicz: appointments by e-mail.
Affiliation	Faculty of Psychology, University of Warsaw (JRL, JZ, MD); Centre for New Technologies (MD)
Course format	lecture + lab
Number of hours	30 hours + 30 hours
Number of ECTS credits	**5 ECTS credits**
Brief course description	This course is devoted to a more detailed consideration of concrete models of broadly defined cognitive systems. Having received a solid overview of general classes of models (CPM I) and main topics in cognitive sciences (Advance Topics), the students will continue to explore how particular models can be used as theories for concrete cognitive phenomena. These will range from motor control and coordination, attention, decision making, memory, problem solving and communication. Lab course will consist in learning specific modeling techniques, applications for empirical research, including the available tools and software.
Full course description	This course is devoted to a more detailed consideration of concrete models of broadly defined cognitive systems and their functioning. Having received a solid overview of general classes of models (CPM I) and main topic in cognitive sciences (Advance Topics), the students will continue to explore how particular models can be used as theories for concrete cognitive phenomena. Lectures will be used to explain important theoretical concepts and present examples of models, while seminar/lab/workshop class will give hands-on experience in constructing selected models and applying selected analytical tools. Taking the perspective of embodied and situated cognition we will consider a cognitive system as an entity adapting to the changing environmental demands as well as actively structuring their niches.

	Therefore we will change the usual ordering of cognitive phenomena as starting from perception of stimulus and arriving at a response, and rather start from concerns of action control within environmental demands. We will proceed through the issues of motor coordination and joint action, which acknowledge the presence of others from the earliest moments of cognition in a social species, and to issues in educating attention for such action and co-action. We will show the newest methods for studying and modeling such phenomena, based mainly in dynamical systems paradigm, with illustrations of alternative models. The course will continue into problems more traditionally considered as 'cognitive', such as integration of information in individual and joint decision making, and - again individual and joint - problem solving, including issues in game theory and solving combinatorial problems, where we will present logical and dynamical models. We will arrive at problems of what is being communicated in particular cognitive tasks, the nature of communication in general, and its role in cognition. We will present models of emergence of various forms of communication including language, including agent-based models and network approaches, which allow to take into account not only different levels (individual and collective) but also multiple timescales (developmental, cultural, on-line). Only against this background we will tackle the cores of more traditional approaches to cognitive processes: memory, perception and categorization. Main modeling approaches to memory will be presented, including traditional "data-base" thinking and alternative, more dynamic modeling of history-dependence of cognitive systems and processes. Similarly perception, selected attentional processes and categorization will be presented both in traditional models and in more action-based frameworks. We will summarize the course by showing some potential integratory models.
Learning outcomes	Upon successful completion of the course students will: • be able to describe main cognitive phenomena being modeled computationally, be aware of the main approaches to modelling them and current theoretical debates (K_W01, K_W02, K_W08) • be able to describe main computational models for selected cognitive phenomena, their strengths and weaknesses (K_W01, K_U01) • know the cognitive scientific terminology pertaining to modeling and be able to communicatie concepts within interdisciplinary team (K_W08, K_U01, K_U07) • know and be able to apply principles of model construction, interpretation and evaluation (K_U01, K_U02, K_U04))

	● be able to pose their own research questions and create their own computational models of the chosen phenomena in selected programming environments (K_U02, K_U03, K_U05) ● be able to find information pertinent to main models in cognitive science, understand the fast pace of changes in the field (K_U08, K_K01) ● be able to work in a team and present the results of assignment in class (K_U06, K_K03) ● be sensitive to ethical issues related to the use of artificial intelligent systems and their relation to human agency within relevant ecosystems (K_K02, K_K07)
Learning activities and teaching methods	Participatory lecture with questions/discussion at the end of each class; Seminar/workshop with in-class assignments and homework; team or individual projects consulted with instructor and presented in class
List of topics/classes and bibliography	**1. Course Introduction; Motor coordination** Lecture: Haken-Kelso-Bunz model of coordination. Methods for measuring synergies. Applications of fractal dimension to gait dynamics. Lab: Solving differential equations numerically. Plotting phase portraits. Playing with HKB model. Literature: http://www.scholarpedia.org/article/Haken-Kelso-Bunz_model *Kelso, J. A. S., Tuller, B., Bateson, E.-V., & Fowler, C. A. (1984). Functionally specific articulatory cooperation following jaw perturbations during speech: Evidence for coordinative structures. Journal of Experimental Psychology: Human Perception and Performance, 10, 812–832.* **2. Body dynamics in "higher cognition"** Lecture: Interaction-dominant systems revisited; Dynamics of Insight; Recurrence Quantification Analysis - applications Lab: Recurrence Quantification Analysis Literature: Stephen,D.G.,Boncoddo,R.A.,Magnuson, J. S., and Dixon, J. A. (2009). The dynamics of insight: mathematical discovery as a phase transition. Mem Cogn, 37(8):1132-49. doi: 10.3758/MC.37.8.1132. *Vasu Reddy, Gabriela Markova, Sebastian Wallot (2013). Anticipatory adjustments to being picked up in infancy. PLoS One, 8 (6). e65289. ISSN 1932-6203* **3. Interpersonal coordination**

Lecture: Emergence of interpersonal coordination in development, measuring in adults: examples of research, intro to cRQA (cross-recurrence quantification analysis).
Lab: Quantifying synchrony using cRQA.
Literature: Constructing interaction Nomikou, et al. (2015)

4. Information aggregation. Multisensory aggregation and aggregation in groups.
Lecture: As in the title: Bahrami and the like, aggregation from SDT perspective.
Lab: Fitting information aggregation models - classical and bayesian.
Literature: Bahrami, B., Olsen, K., Latham, P. E., Roepstorff, A., Rees, G., & Frith, C. D. (2010). Optimally interacting minds. Science, 329(5995), 1081-1085.

5. Individual and collective strategic thinking
Lecture: Applications of game theory.
Lab: Game theory exercises.
Literature: Shoham, Y., & Leyton-Brown, K. (2008). Multiagent systems: Algorithmic, game-theoretic, and logical foundations. Cambridge University Press., selected chapters.

6. Planning and problem solving
Lecture: Classic combinatorial problems: route planning, resource allocation. Algorithmic solutions: exact and approximate. Hopfield network applications to discrete optimization. Boltzmann Machines and their hardware implementations (D-Wave quantum computer).
Lab: Algorithmic methods for problem solving
Literature: TBA

7. Evolution of communication/Emergence of signs and compositionality
Lecture: The role of communication in cognition; models of language emergence
Galantucci, B. (2009). Experimental Semiotics: A new approach for studying communication as a form of joint action. Topics in Cognitive Science, 1(2), 393-410.
Garrod, S. and Galantucci, B. (2011)
https://www.frontiersin.org/articles/10.3389/fnhum.2011.00011/full
Kirby, S., Cornish, H. & Smith, K. (2008). Cumulative Cultural Evolution in the lab.

8. Modeling language acquisition and linguistic interaction with neural networks

Elman, J. L. (1990). Finding Structure in Time. Cognitive Science, 14, 179-211

9. Networks and information propagation
Lecture: Examples of classical social network research, extend information aggregation.
Lab.: Analyzing networks using networkx package. Experimenting with random networks.
Literature: Barabási, A-L. Network Science (http://networksciencebook.com/) chapters: 1, 2.1-2.6, 2, 3, 4, 4.1-4.3, 5, 7.1-7.2, 7.3, 7.5, 10

10. Models of memory
Lecture: Memory as databases and as dependence on history of experience; dynamic models of memory. Hopfield, ART, Hamming
Lab: Properties of the Hopfield network
Literature:
Sederberg P B and Norman K A (2010) Learning and Memory: Computational Models. In: Koob G.F., Le Moal M. and Thompson R.F. (eds.) Encyclopedia of Behavioral Neuroscience, volume 2, pp. 145–153 Oxford: Academic Press.

11. Visual attention, active perception
Lecture: main models of attention: classical, bayesian. Active perception: Friston; perception-for-action and educating attention.
Lab: Bayesian models of attention
Literature:
Ingold, T. (2001). From the transmission of representations to the education of attention. In H. Whitehouse (Ed.), The Debated Mind: Evolutionary psychology versus ethnography (pp. 113-153). Berg, Oxford.
S.S. Chikkerur, T. Serre, C. Tan, and T. Poggio, "What and where: A Bayesian inference theory of attention," Vision Research, May. 2010.

12. Dynamics of perception
Lecture: Multistable perceptual phenomena (for instance, Necker cube) and phase transitions.
Lab: Analysing perceptual phenomena with RQA.
Literature:
Fürstenau, N. (2009). Computational Nonlinear Dynamics Model of Percept Switching with Ambiguous Stimuli.

13. From similarity to categorization
Lecture: What is similarity? Bases/dimensions of categorization; basic models of categorization
Lab: MDS, types of classifiers; ML in categorization

	Literature: TBA **14. Bottom-up sensorimotor learning** Lecture: Using Kohonen networks (aka self-organizing map) to organize sensory input in bottom-up manner. Building dynamic sensorimotor maps. Lab: Playing with Kohonen networks, growing neural gas etc. on various data. Literature: Mici, L., Parisi, G., Wermter, S. (2018). An incremental self-organizing architecture for sensorimotor learning and prediction. IEEE Transactions on Cognitive and Developmental Systems 10 (4), 918-928 typu playful machines: Butz, M. V., Shirinov, E., & Reif, K. L. (2010). Self-Organizing Sensorimotor Maps Plus Internal Motivations Yield Animal-Like Behavior. Adaptive Behavior, 18(3–4), 315–337. https://doi.org/10.1177/1059712310376842 **15. Integration of models: Multi-level and multi-timescale models** Multiscale integration in multiagent systems / individual / population / evolution Lec.: Modeling decisions in and evolution of multiagent systems. Lab.: Implementing and experimenting with parameters of multiagent systems. Lit.: Steels, L. and Belpaeme, T. (2005). Coordinating Perceptually Grounded Categories through Language: A Case Study for Colour. Behavioral and Brain Sciences, 28(4), 469-89; Igor Mordatch and Pieter Abbeel. 2017. Emergence of grounded compositional language in multi-agent popu- lations. arXiv preprint arXiv:1703.04908 .
Assessment methods and criteria	Lecture: written exam covering the lectures and selected literature. Workshop/Lab: students have to complete assignments in class and prepare and present a group project. Additionally, students can improve their grade by actively participating in exercises and discussions during classes.
Attendance rules	Two absences permitted both in the Lecture and in the Lab
Prerequisites	Cognitive Process Modeling I or equivalent. Advanced topics in cognitive science or equivalent. Basics of cognitive psychology and statistics. Programming in Python or R. Course indicated for 3-5th year students.

Academic honesty	Students must respect the principles of academic integrity. Cheating and plagiarism (including copying work from other students, the internet or other sources) are serious violations that are punishable and instructors are required to report all cases to the administration.
Remarks	Since there is no textbook for the course material covered in lectures will be the main basis for the exam.