ECE 750 Topic 33 **Artificial Life: Embodied Intelligence**
(Winter 2024)

Instructor:
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with guest lectures by Professor Chrystopher Nehaniv

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This course in Artificial Life addresses the foundational role of *embodiment* and *interaction* in living and life-like systems as a paradigmatic approach for Embodied Intelligence in living organisms, complex adaptive systems, agents and interactive social robots. This is fundamental for understanding and modeling social and physically grounded intelligent behavior of living systems, and for the synthesis of embodied intelligence in artificial interactive systems and AI robotics.

Texts: Readings (articles, journal papers, book chapters) to be made available to students, assigned weekly. These should be read before the next class meeting. Also,

Required Books:

- V. Braitenberg (1986), *Vehicles: Experiments in Synthetic Psychology*, MIT Press.
- F. Varela, E. Thompson, E. Rosch (1991/2017), *The Embodied Mind: Cognitive Science and Human Experience*, 1st or 2nd edition, MIT Press.

Recommended Books (certain chapters, ideas or concepts will be covered):

- Ronald C. Arkin (1998) *Behavior-based Robotics*, MIT Press.
- Maja Mataric (2007) *The Robotics Primer*, MIT Press.
- Robin R. Murphy (2019) *Introduction to AI Robotics*, 2nd edition, MIT Press.
- Rolf Pfeifer, Josh Bongard (2007) *How the Body Shapes the Way We Think: A New View of Intelligence*. MIT Press.
- Rolf Pfeifer, Josh Bongard, Don Berry (2011) *Designing Intelligence: Why Brain's Aren't Enough*, Starmind.
- Angelo Cangelosi, Matthew Schlesinger (2015) *Developmental Robotics- From Babies to Robots*, MIT Press.
- Jakob von Uexküll (2010 [1934]), *A Foray into the Worlds of Animals and Humans*, translated by J.D. O'Neil, University of Minnesota Press. [or any other edition].

Course Grading:

- **40% Problem Worksheets.** Frequent worksheets and assignments (including programming, writing) will check and develop student understanding of concepts covered in-class.
- **60% Individual term project:** Students propose an individual project to carry out, and critically evaluate an individual project using artificial life techniques in a particular application area. An 8-page IEEE conference-style formatted report to which all code and additional appendices must be added. All projects must be demoed to the instructors. The report has to demonstrate background review, software/system development, experimental results and analysis, and critical evaluation. Students are required to give a presentation on their project in class, including a demo of the software developed. **Note, the report will serve as the main basis of assessment.**

Course Outline: (Target topics, subject to modification*)

1. Logic of Life vs. Embodied Artificial Life; Braitenberg Vehicles; Role of the Observer; Emergence; Self-Organization; Self-* Properties (autopoiesis, self-maintenance, etc.)
2. Embodied agents, classification, issues of autonomy and design, degrees of embodiment
3. Enactive, Connectionist, and Cognitivist concepts and paradigms
4. Life-like believable robots and agents, varieties of social intelligence
5. Subsumption and other behaviour-based robot architectures; behaviour selection and modulation techniques, potential fields, behaviour-orientation.
6. Cognitive and developmental approaches to AI robotics; social learning and imitation.
7. Embodied AI in Human-Robot Interaction (HRI), and applications
8. Definitions of different types of agents
9. Ethics of artificial life agents
10. Post-Reactive Natural and Artificial Intelligence & Robotics:
    Topics chosen from perception-action loop, Shannon information and empowerment; the temporal horizon: reactive / affective / learning / deliberative / post-reactive agents and robots; autobiographic agents, sensor evolution; interaction games; experience histories; and narrative intelligence.

* The instructors reserve the right to modify the content and order of topics covered in the lectures which may be adjusted, e.g. due to recent developments in the field.

No classes during Reading week 19/21 February 2024.

Students are expected to attend all lectures, take detailed notes, and participate in class discussions. *In-person lectures are **not** recorded.* We plan to complete all course activities in-person. In the event of disruption due to Covid-19, we may have to move to online synchronous classes, e.g., for a short time (one week), or longer time in case of lockdown.

Important Dates **(tentative, to be confirmed):**

Thursday	15 February 2024	– Individual Project Proposals Due by 5 p.m.
Thursday	28 March 2024	– Final Project Reports Due by 5 p.m.
Mon/Wed	1,3 April 2024	– Project Demo/presentations in class.

Important. ***To succeed in the course, students should be able to program well*** in at least one high-level computer language. M.Eng. students wishing to enroll should have achieved a good mark in ECE 650 prior to taking this course (80% or higher), or be able to present evidence of equivalent strong programming ability.

It is expected that students understand the university position on copying (in terms of assignments) and plagiarism (in terms of the project). All work / figures which are not your own must be explicitly identified.

Students enrolling agree to have their work checked on Turn-It-In to guard against plagiarism and collusion. (If you enroll but do not agree, please contact Professor Dautenhahn to discuss within the first two weeks of term.)

Auditors (those not enrolling for credit), if any, are required complete all course elements except for the final project report.

Rules for Collaboration. Students are strongly encouraged to talk about assigned work, share ideas, or share code fragments. However, each final submission is to be composed individually. Direct copying of a solution, or providing the copy, is considered cheating. Two key things to remember are "separation" and "disclosure."

Separation means that, after you discuss an assignment with other people, you separate yourself from them and from any shared materials while you then individually compose your solution to hand in. In addition to avoiding direct copying, this will significantly improve your speed of learning.

Disclosure means you indicate on the submitted work any significant help you received, and specify any component which you took directly from another source. You may lose whatever portion of the grade relates to the copied part. However, you won't be cheating and you will be learning from the parts you were able to complete on your own.

Email Policy:
Only emails from a valid uwaterloo email address will be responded to. The email must contain the full student name and student ID, and include your course number in the subject line. We endeavour to respond within 24 to 48 hours during working hours.

Academic Integrity: Avoiding Plagiarism, Cheating & Collusion:

Academic integrity: In order to maintain a culture of academic integrity, members of the University of Waterloo community are expected to promote honesty, trust, fairness, respect and responsibility. [Check the Office of Academic Integrity for more information.]

Grievance: A student who believes that a decision affecting some aspect of their university life has been unfair or unreasonable may have grounds for initiating a grievance. Read Policy 70, Student Petitions and Grievances, Section 4. When in doubt, please be certain to contact the department's administrative assistant who will provide further assistance.

Discipline: A student is expected to know what constitutes academic integrity to avoid committing an academic offence, and to take responsibility for their actions. [Check the Office of Academic Integrity for more information.] A student who is unsure whether an action constitutes an offence, or who needs help in learning how to avoid offences (e.g., plagiarism, cheating) or about "rules" for group work/collaboration should seek guidance from the course instructor, academic advisor, or the undergraduate associate dean. For information on categories of offences and types of penalties, students should refer to Policy 71, Student Discipline. For typical penalties, check Guidelines for the Assessment of Penalties.

Appeals: A decision made or penalty imposed under Policy 70, Student Petitions and Grievances (other than a petition) or Policy 71, Student Discipline may be appealed if there is a ground. A student who believes they have a ground for an appeal should refer to Policy 72, Student Appeals.

Generative AI tools: This course includes the independent development and practice of specific skills, such as designing, analysing and writing up a research work. Therefore, the use of Generative artificial intelligence (GenAI) trained using large language models (LLM) or other methods to produce text, images, music, or code, like Chat GPT, DALL-E, or GitHub CoPilot, is not permitted in this class. Unauthorized use in this course, such as running course materials through GenAI or using GenAI to complete a course assessment is considered a violation of Policy 71 (plagiarism or unauthorized aids or assistance). Work produced with the assistance of AI tools does not represent the author's original work and is therefore in violation of the fundamental values of academic integrity including honesty, trust, respect, fairness, responsibility and courage (ICAI, n.d.).

You should be prepared to show your work. To demonstrate your learning, you should keep your rough notes, including research notes, brainstorming, and drafting notes. You may be asked to submit these notes along with earlier drafts of their work, either through saved drafts or saved versions of a document. If the use of GenAI is suspected where not permitted, you may be asked to meet with your instructor or TA to provide explanations to support the submitted material as being your original work. Through this process, if you have not sufficiently supported your work, academic misconduct allegations may be brought to the Associate Dean.

In addition, you should be aware that the legal/copyright status of generative AI inputs and outputs is unclear. More information is available from the Copyright Advisory Committee: https://uwaterloo.ca/copyright-at-waterloo/teaching/generative-artificial-intelligence

Students are encouraged to reach out to campus supports if they need help with their coursework:
Student Success Office for help with skills like notetaking and time management
Writing and Communication Centre for assignments with writing or presentations
AccessAbility Services for documented accommodations
Library for research-based assignments

Problem worksheet assignments: Assignments will generally be completed in class during lecture time.

Individual Project Reports. Make sure to carefully cite the sources of all assertions made in your report, writing *in your own words* and using *quotation mar*ks around any direct quotes. Cite sources and authors of all software code you use or modify in your project. Paraphrasing or quoting long sections of text (more than one sentence), even with citations, from other sources is generally not appropriate, and might constitute academic misconduct. When writing your project reports you may consult your readings, course notes, and materials posted in, or directly linked from, the course LEARN site, and also online materials. Inclusion of other material is permitted, but if this is done without proper citation, you may be subject to academic discipline. Use of any other resource without citation (including file- sharing services such as chegg.com, coursehero.com, stackexchange.com, ...) is prohibited.

Assignments, project proposal and project reports need to be completed on an individual basis, you must write up your text and solutions yourself in your own words. You must fully cite any material (e.g. text, figures, diagrams, tables, pictures etc.). See statements above about generative AI tools which ***must not be used****.*

All coursework and software code is subject to checking for collusion and plagiarism using Turn-It-In.

Turnitin.com: Text matching software may be used to screen assignments in this course. Turnitin® is used to verify that all materials and sources in assignments are documented. Students' submissions are stored on a U.S. server, therefore students must be given an alternative (e.g., scaffolded assignment or annotated bibliography), if they are concerned about their privacy and/or security. Students will be given due notice, in the first week of the

term and/or at the time assignment details are provided, about arrangements and alternatives for the use of Turnitin in this course.

In case we need to move online for some part of the course:

Course materials and videos provided by the instructors must not be shared on social media or otherwise distributed in any form (including sharing links to them).
They are for your own personal use while studying at the University of Waterloo only, and are subject to copyright and intellectual property laws, and university privacy policies.
By taking part in the course, you agree not to share this material or any links to it to anyone outside the course without instructor agreement. Please discuss with the instructors if you have concerns.

Auditors (those not enrolling for credit), if any, are required complete all course elements (including project proposal) except for the final project report.

Compassionate Accommodation: If you are facing challenges that are affecting more than one course contact the Associate Chair Graduate Studies. They will review your case and coordinate a reasonable and fair plan in consultation with appropriate others (for example: instructors, Department Graduate Studies Committee, Chair, AccessAbility Services, Engineering Counselling services, Registrar's Office).