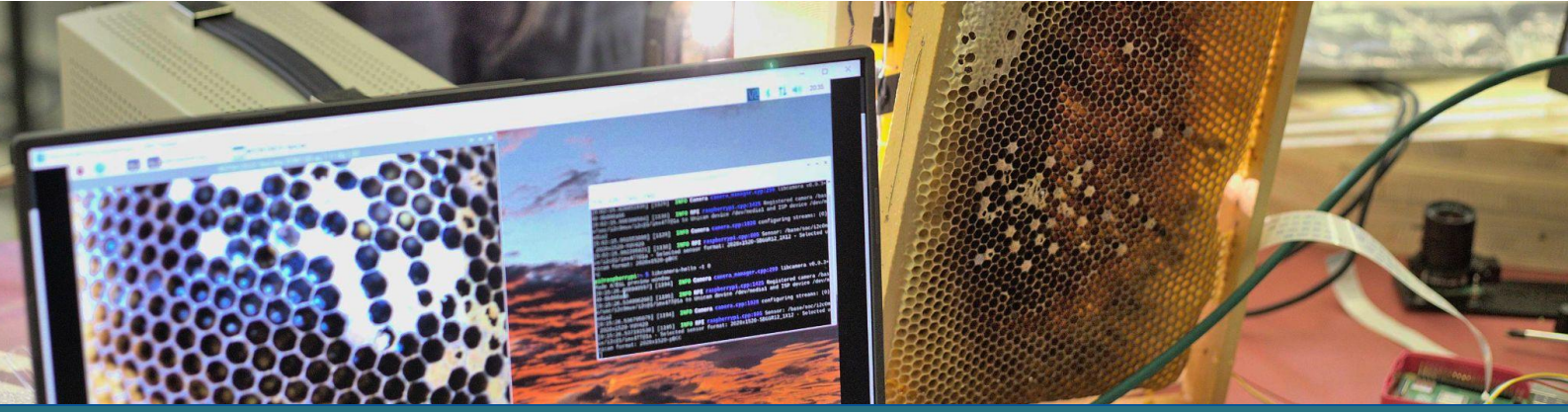

SUMMER SCHOOL

on **Modelling and Measuring Biohybrid Multi-Level Complex Systems**

8 - 11 August 2023

University of Graz, Austria

The goal of this summer school is to teach state-of-the-art methods to study bio-hybrid systems that are composed of technological agents and living agents which both interact with each other and across the aisle. Often, in such systems the living component is comprised of social organisms which can be humans, social insects, swarm-forming organisms or even plant or bacterial communities. It is pivotal to study such dense systems from a connectivity-oriented perspective as often emergent properties arise from non-linear interactions that create pattern-forming feedback loops within the overall system. In order to sufficiently model and comprehensively measure such systems the perspective to be taken is a multi-level one: observations and modelling both have to consider the individual behaviours, the resulting global collective behaviours and potentially also diverse group behaviour between those system layers. In this summer school we will study systems that are comprised of technology and honeybees, technology and plants and technology and humans and investigate technology that observes aquatic organisms that respond to changes in the quality of their habitat. The program will be completed by an opening keynote talk, a discussion round, thematically connected lectures given by selected researchers and a networking event. This summer school will give an opportunity to interested students and young researchers to widen their knowledge in the field of bio-hybrid systems and multi-level modelling. We especially foresee that participants from the field of bio-robotics, swarm-robotics, swarm biology, ethology, ecological modelling and modelling of swarm-intelligent systems/algorithms will benefit from attending this summer school.

Information & Fees

Lectures and practicals will take place at the Institute of Biology (https://biologie.uni-graz.at/en/) and the Artificial Life Lab (https://alife.uni-graz.at/) of the University of Graz. The summer school will provide coffee breaks after the lectures and a networking event. Travel, accommodation and meals are at the expense of the participants (for grants see “Travel grants for women in STEM” below).

Accepted participants will have to pay a fee of 60,- EUR in advance. The fee secures the place in the summer school and is non-refundable.

Organizing Committee: Martina Szopek, Thomas Schmickl, Miriam Autenrieth, Alexander Goritschnig (University of Graz)
Contact: summerschool@uni-graz.at

APPLICATION

The number of participants will be limited to the available places in the practicals. Students interested in participating should submit their **CV**, a **short motivation letter** and a **list of their preferred practicals** to **summerschool@uni-graz.at**.

DEADLINE: 11 July 2023

Please include in your application a list of preferred practicals as follows (practical description can be found at the end of the document)::

- **Day 2:** Indicate your first and second choice (participants will be able to attend one of the three parallel practicals).
- **Day 3:** Participants will attend both practicals, no selection needed.
- **Day 4:** Indicate your preferred practical (participants will be able to attend one of the two parallel practicals).

Example:
Day 2: first choice: A, second choice: C
Day 4: F

Please note: Certain practicals require prior knowledge (see "Requirements"). The organizers will take the selections of the applicants as well as their respective background into account, but cannot guarantee a place in the first choice practicals as the number of participants in each is limited. Every participant has to **bring their own laptop**, practical specific software requirements will be sent out to the participants beforehand.

Applicants will be notified of their acceptance and their assigned practicals by **17 July 2023.**

Involvement of participants

We expect from each participant the following effort to obtain the certificate:
- Preparation for practicals: paper reading (10 hours)
- Lectures (4 hours)
- Discussion (3 hours)
- Practicals (16 hours)

Total: 33 hours (1,3 ECTS)

Travel grants for women in STEM:

To support women in STEM, the project HIVEOPOLIS is awarding travel grants to three female student applicants. The decision will be made by the Summer School Organisation Committee based on the applications and cannot be contested. Eligible expenses are travel and accommodation costs up to € 1.000,- which will be refunded after the summer school.*

Eligibility:
- Female students studying full-time in a STEM field (bachelor, master or PhD program)

Application Requirements (in addition to the summer school application):
- A letter of recommendation
- Proof of college/university enrollment

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* Economy class (flight) or 2nd class (train); accommodation max. € 80,-/night, for max. 5 nights in total. Invoices and payment confirmations must be provided. Students employed in the project HIVEOPOLIS are not eligible to apply for the travel grant.

PROGRAM

Time	Day 1 8.8.2023		Day 2 9.8.2023				Day 3 10.8.2023			Day 4 11.8.2023	
09:00 - 09:30	Registration	09:00 - 09:45	Lecture 1				Lecture 3			Lecture 5	
09:30 - 10:30	Welcome & Keynote talk	09:45 - 10:30	Lecture 2				Lecture 4			Lecture 6	
10:30 - 10:45	Coffee break										
10:45 - 11:30	Introduction to the practicals		Practical A	Practical B	Practical C		Practical D (Group 1)	Practical E (Group 2)		Practical F	Practical G
11:30 - 13:30	Discussion round										
13:30 - 14:30	Lunch break										
14:30 - 15:30	Discussion round		Practical A	Practical B	Practical C		Practical E (Group 1)	Practical D (Group 2)		Practical F	Practical G
15:30 - 16:30	Networking event (until 19:30)										
16:40 - 17:30										Evaluation & Certificates	

Keynote

Thomas Schmickl (University of Graz): **Biohybrid Multi-Level Complex Systems**

Lectures

- **Anticipatory mechanism for complex decisions in a bio-hybrid beehive**
  (Heinrich Mellmann, Humboldt University of Berlin)
- **The history of biohybrids in water**
  (Ronald Thenius, University of Graz)
- **Time series analysis for intelligent plants**
  (Till Aust, Eduard Buss, University of Konstanz)
- **Modelling of storage dynamics in honeybees and/or cooperation between hives** (Stamatios Nicolis, Free University of Brussels)
- **Daphnids - The detective life-form**
  (Wiktoria Rajewicz, University of Graz)
- **Synchronization of the brain with the metaverse**
  (Silvia Kober, University of Graz)

Practicals

Day 2 (9.8.2023):

A From Micro to Macro: Exploring Complex Systems through Measurements and Modeling
B Phytosensing - Using Plants as Sensors
C Bio-hybrids in Water - Approaches and Methods

Day 3 (10.8.2023):

D Simple Bee Colony Temperature Measuring Process
E Modelling Bio-hybrid Multi-level Complex Systems

Day 4 (11.8.2023):

F Brain-Computer Interface – Controlling Virtual Reality with Brain Signals
G Modelling and 3D Printing for Bio-hybrids

PRACTICALS DESCRIPTION

DAY 2 (9.8.2023, 3 parallel practicals):

A From Micro to Macro: Exploring Complex Systems through Measurements

D. Hofstadler, S. Wang, L. Fedotoff
Institute of Biology, Artificial Life Lab, University of Graz

Explore the behavior of eusocial insects through careful observation and film analysis in two distinct experimental setups (one complex swarm robotic device for up to 300 honeybees and multiple smaller DIY arenas to observe fewer individuals in detail). Utilize advanced computer-based methods for precise data acquisition and analysis, ensuring mitigation of bias and systematic errors. Gain valuable insights into the intricate world of social insects through this methodical approach.

Requirements: Some basic experience in Python and programming. No known bee venom allergy (work with living honeybees).

B Phytosensing - Using Plants as Sensors

T. Aust, E. Buss
Department of Computer and Information Science, Cyber Physical Systems, University of Konstanz

In the practical session, we will begin by providing a brief overview of our idea of utilizing plants as environmental sensors. Following that, we will present a selection of gathered plant physiological data from already conducted experiments. The participants will use this data to learn about data preprocessing, including tasks such as data cleaning, smoothing, data augmentation, and feature extraction in the context of plant physiological signals. Further, the participants will learn about machine learning techniques, i.e., deep learning or statistical approaches for classifying time series, which they will apply to the preprocessed data to infer the environmental condition of the plant based on its physiological signals.

Requirements: Some basic experience in Python and programming

C Bio-hybrids in Water - Approaches and Methods

R. Thenius, W. Rajewicz, N. Helmer
Institute of Biology, Artificial Life Lab, University of Graz

In this practical different methods to detect substances in the environment will be presented, and methods to detect changes in the environment will be discussed. Further the participants have the ability to work with real-world data to learn how to evaluate behavioural and physiological changes in life forms, induced by changes in the environment.

Requirements: Experience in Python 3, especially regarding handling of CSV-files. Experiences with Pandas or Python statistical packages are advantageous.

DAY 3 (10.8.2023, 2 practicals):

D Simple Bee Colony Temperature Measuring Process

V. Komasilovs, A. Kviesis
Faculty of Information Technologies, Latvia University of Life Sciences and Technologies

The aim of this practical workshop is to demonstrate implementation of a simple bee colony temperature monitoring solution. Within the workshop the following topics will be discussed: overall architecture for end-to-end data handling, hardware components and assembly, peculiarities of embedded software, cloud software and its deployment specifics, data visualisation using Grafana.

Requirements: Basic knowledge of electronics and programming are beneficial. Examples will be in C++, Python, Docker, MQTT

E Modelling bio-hybrid multi-level complex systems

M. Stefanec
Institute of Biology, Artificial Life Lab, University of Graz

In complex, biological, self-organising social systems, group or swarm effects occur at a higher system level through interactions at the microscopic level (interactions between individuals). These phenomena often lead to group effects, new properties emerge through the interactions. In this practical session, we will approach such complex biological systems from the modelling side, using a bottom-up approach to model a system that exhibits swarm intelligent properties.

Requirements: none

DAY 4 (11.8.2023, 2 parallel practicals):

F Brain-Computer Interface – Controlling Virtual Reality with Brain Signals

S. Kober
Institute of Psychology, Neuropsychology & Neuroimaging, University of Graz

In this practical, we will record brain signals using the electroencephalogram (EEG) and use these signals to control virtual reality (VR) scenarios. Therefore, the recorded EEG signal will be processed in real-time, a virtual environment will be designed, and finally, the EEG signals and the virtual environment will be synchronised. The aim is to use the brain signals to control the VR.

Requirements: none

G Modelling and 3D Printing for Bio-hybrids

A. Ilgün
Institute of Biology, Artificial Life Lab, University of Graz

In the project HIVEOPOLIS, we put the emphasis on technological (software and hardware) and material design-led mechanisms to create closed feedback loops between honeybees and their immediate environment as well as the ecosystem at large. Many structural, mechanical, modular, thermal, biological, and environmental requirements must be met in order for a beehive design to support all technologies and an entire honeybee colony. We take advantage of the potentials of 3D printing in two key ways to compromise many competing criteria, such as durability and precision, with biologically compatible, and ideally 100% biologically resourced or grown materials: scaffolds made of porous, quickly produced parts and mechanically precise, durable parts. We will practise these two types of 3D modelling techniques in this practical, which are geared toward 3D printing as a fabrication method. In an associative parametric modelling environment, we will base our design thinking on individually established -or in teams- biohybrid design scenarios, and produce finished prototypes that combine these two ends of material needs.
Objectives: 1. Create hybrid designs that are part human invention and part systemic living entities or use a living system to participate (guide you) in the design of something. Which functional criteria need more top down design methods and engineered materials? Which functional criteria can be fulfilled via using porous mycelium materials? 2. And in all cases, use hypothesis testing as a design method.

Requirements: none