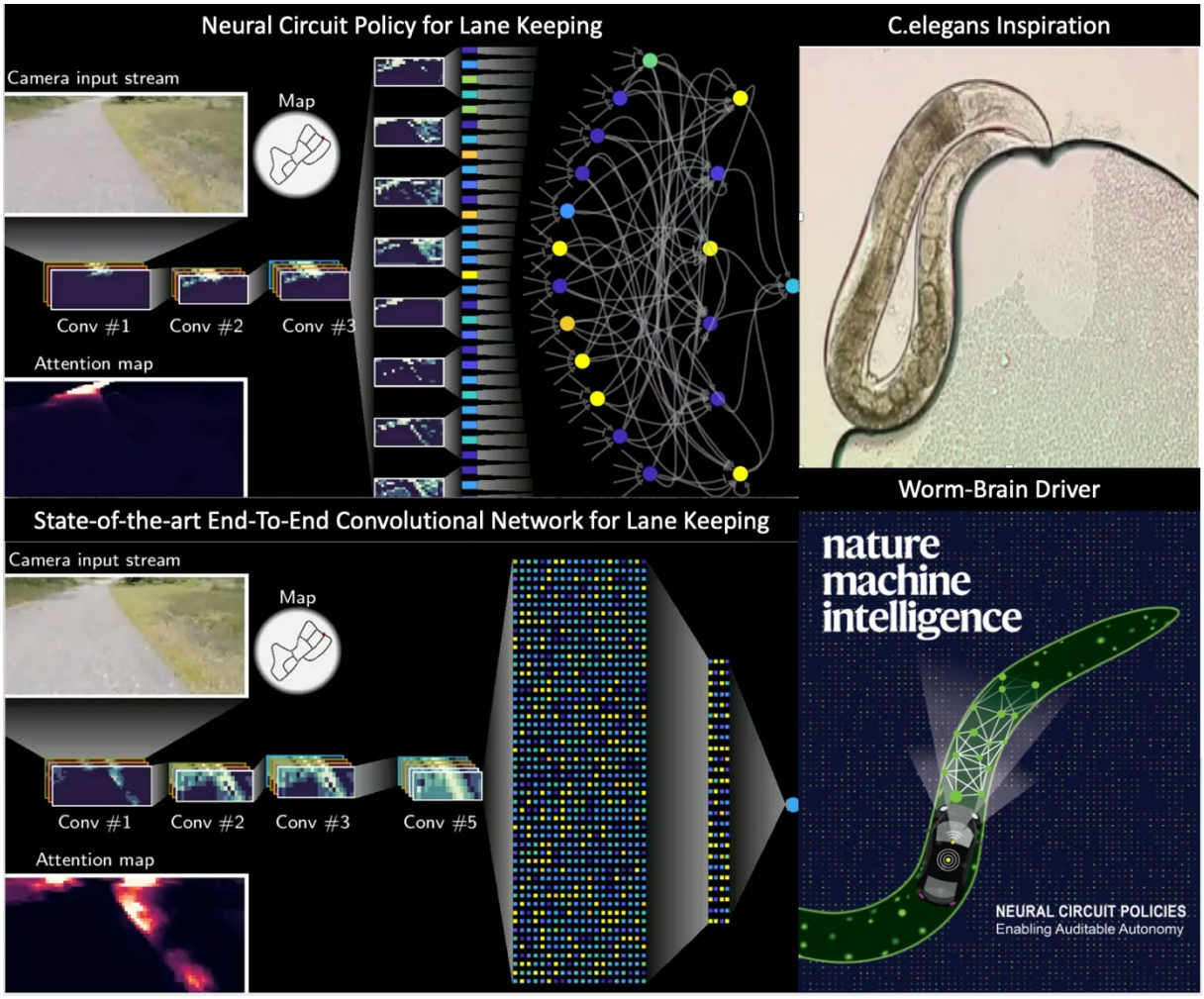
Reinforcement and Supervised Learning With Neural Circuit Policies



Supervisory Team[1]

Primary Supervisor: *Radu Grosu, Head of the CPS Division, Fakultät für Informatik, TUW*
TU Wien project partners: *Clemens Heitzinger, Gerhard Schütz, Heinz Wanzenböck*
External academic partners: *Daniela Rus, MIT, Tom Henzinger, IST*
External industry partners: *Peter Priller, AVL*

Project Description

In recent work we have shown that state of the art artificial neural networks, such as deep neural networks, residual neural networks, neural ordinary-differential-equations networks, and continuous-time recurrent neural networks, are particular neural circuit policies (NCPs),

[1] The Early Stage Researchers (ESRs) will be accompanied during their thesis by an individual "Thesis Advisory Committee" (TAC), which will guide the ESR through the graduate studies. The TAC will consist of the thesis primary supervisor, and two additional members of the Supervisory Team selected by the ESR.

a biophysical model for non-spiking neurons, that we have developed at the TUW. The main difference between NCPs and the other networks, is that NCPs associate the nonlinear activation function with synapses instead of the pre-synaptic neurons, and multiply this with the membrane potential of the post-synaptic neurons, in order to produce a current. This multiplication is justified by the capacitive nature of the neuron's membrane potential, whose rate of change is equal to the sum of the currents passing through the membrane. This difference in the modelling of a neural networks, results in similar expressiveness, for a much smaller number of synapses and neurons, which considerably increases their explainability. The purpose of this project is to develop supervised and reinforcement learning techniques for NCPs, and apply them in the control of the autonomous microscopy system for adaptive experimentation in cell biology, available in the lab of our project partner Gerhard Schütz.

Key Goals and Tasks

The first objective is to develop a systematic and fully automated method for learning NCPs through supervised and reinforcement learning. This method should take advantage of the state-of-the-art tools and techniques developed for artificial neural networks.

The second objective is to explore how the motifs NCPs share with gene regulatory networks can explain the behaviour of the learned networks. One should start with binary motifs, such as activation, inhibition, sequentialization, mutual exclusion, and synchronization, and then proceed to higher order motifs, which involve more sophisticated architectural patterns.

The third objective is to apply the methods developed above to the autonomous microscopy system for adaptive experimentation in cell biology available in the lab of Gerhard Schütz. The results should be explained by using the methods developed in the second objective. This will thus serve for evaluating the usefulness and expressive power of the learned NCPs.

Project-specific Requirements

- Completed master (bachelor of honors) in computer science, mathematics, or physics.
- Knowledge in AI in general, and machine learning in particular.
- Experience and skills with Python, TensorFlow, Keras, Pytorch or other DNN tools.
- Interest in working with the experimental setup in the Schütz lab.
- Enthusiasm for machine learning, neuroscience, and control theory.
- Affinity for biologically-inspired techniques in machine learning.
- Willingness to travel to project meetings and scientific conferences.
- Excellent English language skills in scientific field.
- Personal skills: Independence, problem-solving, team work, and communication skills.