*Mathematics/Applied Mathematics/Computer Science*
*Planning Group Members: Tomoyuki Higuchi and Alois Knoll*

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***Speaker:***

*Eiji Uchibe, Okinawa Institute of Science and Technology*

**Title:** Reinforcement Learning with Multiple Heterogeneous Modules

Reinforcement learning (RL) is an attractive learning framework with a wide range of possible application areas. An RL agent attempts to learn a policy, namely, the selection of an action in a given state of the environment, in order to maximize its total amount of reward received during the interaction with the environment. However, critical unsolved problems in the real-world applications of RL are the choices of state representations and learning algorithms. In practice, experimenters test different combinations in order to select the best one, since their appropriate combination is unknown before the application of RL.

To deal with the above problem, we propose a new framework termed cooperative competitive concurrent learning with importance sampling (CLIS) for selecting an appropriate policy from a set of heterogeneous reinforcement learning modules and training all the modules by the resulting episodes. Based on the method of importance sampling, CLIS accurately improves the policies of all learning modules including those not selected. Thus, multiple heterogeneous learning modules that share the same hardware can compete to act and cooperate to learn, thereby enabling the entire learning system to achieve a good performance quickly.

We apply the CLIS architecture into a robotic task of foraging for battery-packs. CLIS successfully achieves fast learning by allowing complex learning modules to exploit task-relevant episodes generated by suboptimal but fast-learning modules. On the contrary, a complex module trained alone fails to obtain purposive behaviors within practical time constraints. These results suggest that CLIS is a promising learning architecture for real robot learning.