Workshop on New Perspectives for Intelligent Goal-Directed Behaviour in the Real-World Robotics Domain

1. Introduction

One of the main goals of robotic research is the autonomous production of goal-directed behaviour in real world environments. The robotic community almost agrees on the fact that both, symbolic deliberative planning as well as analogue reactive execution of actions is necessary to achieve intelligent behaviour. Without symbolic planning an agent may never be able to reason about consequences of future actions and to determine consecutive sequences of actions that lead to a desired goal. On the other hand the executions of actions have to be reactive due to dynamic changes in the world and uncertainty about the current state of the world during the planning phase. Representative for the analogue layer are reactive systems [Braitenberg, 1984; Brooks, 1986] while symbolic planning is the major subject of the traditional AI community. The workshop will present current models of reactive and symbolic systems and make an endeavor to develop a concept for combining the two approaches.

2. Workshop Focus

We will discuss possibilities for an integration of reactive behavior execution with symbolic planning by first identifying existing overlaps and potential interfaces between the two approaches. We will then try to derive general principles for interactions between them, and assess potential benefits for robot behaviour. Specific questions that will guide the discussion include:

- How can symbolic representations be generated if robot control structures for robot behaviour are learned autonomously?
- Can the results of hierarchical learning algorithms serve as symbolic descriptions of the properties of the environment?
- How to make effective use of communication in a population of robots?
- How can robot actions and action sequences be represented with respect to temporal aspects of multiple sensor and actuator trajectories? Is a mathematical formulation, like sparse distributed memory, suitable for representing, learning and regenerating reactive robot behaviour?
- Which atomic skills are necessary for future service robot applications?
- How to design an interface of atomic robot skills for deliberative planning components? What are important parameters to allow symbolic planning while encapsulating the details of a reactive execution of robot action?

3. Programme

Keynote 1

Topic to be announced by the speaker

by external keynote speaker Prof. PhD Alessandro Saffiotti, AASS Mobile Robotics Lab, Örebro University, Sweden

Abstract: to be announced by the speaker

Keynote 2

Learning and Evolution for Real Robots

by external keynote speaker Dr. Eiji Uchibe, Okinawa Institute of Science and Technology

Abstract: Our daily behaviours are guided by rewards in multiple ways, such as appetitive, aversive, sexual, and social rewards. What is the origin of such multiple reward systems? The goal of the Cyber Rodent project (http://www.nc.irp.oist.jp/crp/) is to explore the design principles of the reward systems for artificial agents to realize self-preservation and self-reproduction, and thereby try to better understand the origins of reward systems of biological agents. Reinforcement learning (RL) is an attractive learning framework with a wide range of possible application areas. The RL framework has been conceived as a model of animal and robot behavioural learning. However, critical unsolved problems in the real-world applications of RL are the choices of state representations, learning algorithms, reward functions, and meta-parameters. To deal with these problems, we introduce two learning frameworks called CLIS and CPGRL.

CLIS: Our brain can be seen as a heterogeneous mixture of multiple agents: simple, hard-wired controllers in the spinal cords and the brainstem to highly adaptive functions the cerebrum and the cerebellum. A recent brain imaging experiment suggests that there are parallel reinforcement learning pathways in the human brain, each specialized for reward prediction at different time scales. CLIS, derived as a practical means for accelerating learning by maximally utilizing limited number of experiences, might give a clue for understanding the parallel learning mechanism of the brain. The robot possesses multiple modules with different state representations, learning algorithms, and meta-parameters and improves their multiple policies simultaneously to accomplish a particular task. Some of the modules can have fixed hand-coded policies. The CLIS framework can select an appropriate module for action and accurately improve the policies of all learning modules, including those that are not selected, based on the method of importance sampling. It is possible to obtain purposive behaviours efficiently and rapidly because the modules that are not selected can learn from the experience derived by the actions of another module.

CPGRL and Embodied Evolution: Reward functions can usually be classified into two types: those directly representing the successful achievement of the task and those aimed for facilitating efficient and robust learning. We assume that the former, “extrinsic rewards”, are fixed for a given task and consider how the latter, “intrinsic rewards”, can be optimized by the robots during their lifetime or within their colony by evolution. Typical examples of intrinsic rewards are the curiosity for novelty that promote exploration and innate preference for certain sensory features that promote goal-directed search. CPGRL maximizes the average of intrinsic rewards within the bounds specified by the extrinsic rewards. This enables optimization of intrinsic rewards without compromising the main task goals specified by the extrinsic rewards. For optimization of intrinsic rewards, we take the embodied evolution approach. Each agent in a colony has a genetic code for its own intrinsic rewards and exchanges the codes with fellow agents as they pass by. Additional information about the fitness, which is closely related to the task achievement represented by extrinsic rewards, specifies the intrinsic rewards in the new generation.

Talk 1

Sparse Distributed Memory for Robot Action Manipulation and Prediction

by Sascha Jockel, University of Hamburg

Abstract: Sparse distributed memory (SDM) was developed as a mathematical model of human long-term memory. The correspondence of the distance between concepts in our mind and the distance between points of a high-dimensional1 space led to the idea of the model. Even if a one-to-one comparison between an abstract high-level model, such as the SDM, and the human brain, whose complexity is far from understood, should be taken with caution, Kanerva [Kanerva, 1988] and other authors noted a similarity between SDM circuits and those of the cerebellum. A sparse distributed memory is a form of associative memory that is popular in both computer science and psychology. In the latter discipline associative networks are used primarily to model human processes underlying the retrieval of information. An individual's long-term memory of a concept is given by the strength associated with the node representing the concept. The memory model can be seen as both a generalised form of a random-access-memory and as a two-layer feed-forward neural network with generalised Hebbian learning with weightless nodes within a Hopfield network.

Until now, in the field of robotics mainly navigational capabilities of an SDM have been investigated sparsely. Storage and retrieval for mobile manipulation capabilities have been neglected so far. Rao [Rao and Ballard, 1995] mentioned that SDM "provides a convenient platform for learning the association between an object's appearance and its identity". Also in neuroscience the sparse coding strategy is an appropriate theory on neural coding of sensory inputs.

SDM shares many features with human long-term memory at the conceptual level: It is content-addressable, storage locations are gradually removed, it degrades smoothly, information is widely distributed, it is massively parallel, it can handle noisy or corrupt data, it processes high-dimensional data, and each memory location encodes for multiple stored data pattern. Although the cerebellum is not generally considered as a memory area of the brain, it is involved in coordinating movements, and recent neurophysiological evidence supports the hypothesis that the cerebellum learns from experience. Especially the encoding of percepts and high level events / concepts in the brain is still a mystery and thus, difficult to implement in technical systems.

The SDM mechanism was implemented to investigate biological inspired representation of robot arm configurations for neural learning and prediction of robot behaviour sequences feed by robot arm joint angles and Cartesian positions of an end-effector. First experiments showed and proved that the SDM concept is suitable for learning sequences of actions carried out with a 6-DoF robot arm. These promising results are currently extended to further action sequences to be learned and categorized by the SDM. A first-order machine is adequate for predicting events generated by a first-order stochastic process. By using higher-order predictions it is also possible to predict robot behaviours with recurrent parts within an action sequence as well as cross-sequences, e.g. beckoning or writing an 8. This talk will give an overview on learning and representation of analogue and reactive robot behaviours, as well as their prediction by a biologically inspired memory, by the SDM.

Talk 2
Multisensory Memory Representations of Robot Actions
by Martin Weser, University of Hamburg

Abstract: The remarkably small number of publications that describe the combination of two or more robot actuators into a multi-purpose service robot shows the complexity of such systems. One reason for this is that the development of complex tasks requires expertise in processing and control of all actuator and sensor modalities that are involved. The development of robots can be greatly simplified if basic robot operations (skills) will be reused and not developed from scratch each time they take part in complex behaviours. The implementation of a set of basic robot skills forms the basis for future investigations on more complex robot behaviour. The construction of a memory base that provides access to robot skills as well as to composed skill sequences is still a big step on the way to embodied cognitive systems and the major goal of this PhD project. The service robot TASER together with a user interface to the intended memory base will be used to demonstrate the feasibility of the proposed approach. Experiments with high-level robot tasks such as <collect all rubbish cans> will be used for verification of the systems applicability. In this presentation the current progress of this project will be presented.

4. Workshop Format

The workshop will last one day. After a short, general introduction, the keynotes and talks will be given in order. Presentation time is 1:15 hour for keynotes and 45 minutes for talks including discussions. Optionally other student presentations will follow in the afternoon. The final session is intended as a discussion and a summary of the key results from the workshop. Coffee breaks and lunch will be provided.

5. About the Organisers

Martin Weser joined the CINACS International Graduate Research Program in 2006. He is a PhD candidate in the Technical Aspects of Multimodal Systems Group (TAMS), Department of Informatics of University of Hamburg. There he received also his Diploma degree in Informatics in 2006.

During his PhD program he studied more than four months in China, most of the time at the Tsinghua University, Beijing. His research focuses on multisensory memory representation of robot actions, high level robot control and action planning.

Sascha Jockel now in the third year of his doctorate candidature in the Technical Aspects of Multimodal Systems Division TAMS at the Department of Informatics of Hamburg University. His main areas of interest are robotics, models of cognition, artificial intelligence with respect to biological archetypes, multimodal processing and interaction, 3d vision and reconstruction, image processing, teleoperation and medical informatics.

Sascha holds a B.Sc. (2002) in computer science with a minor in musical methodology and a Diploma (2006) in computer science with a minor in medicine, both degrees from University of Hamburg. Sascha's research focuses on modelling biological plausible memory systems for robot action sequence learning and prediction via content-addressable memory structures. His approach is based on sparse distributed memories that earlier has been proposed as model of human long-term memory. His experimental work focus on mobile robot manipulation task recognition of a 6-DoF robot arm.