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

Talk 1

Sparse Distributed Memory for Robot Action Manipulation and Prediction
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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.

This presentation slot within the context of the workshop on *New Perspectives for Intelligent Goal-Directed Behaviour in the Real-World Robotics Domain* aims to address the following questions:

- Are sparse distributed memories suitable for learning robot manipulation behaviours?
- Which benefits are provided by using SDMs?
- What's the problem of appropriate encoding of perceptual units?
- How is information about the world encoded in a sparse and distributed memory?
- How to overcome problems of networks storing solely first-order state transitions? Can recurring movements be encoded in such memory?

References

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