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Hebb-like Learning for the Grounding of High-Level Symbols in Sensorimotor Trajectories

Martin F. Stoelen[1], *Davide Marocco*[2], *Angelo Cangelosi*[2], *Fabio Bonsignorio*[1,3], *Carlos Balaguer*[1]

[1]RoboticsLab, Universidad Carlos III de Madrid, Madrid, Spain
[2]Centre for Robotics and Neural Systems, University of Plymouth, Plymouth, UK
[3]Heron Robots, Genova, Italy

(mstoelen,fbonsign,balaguer)@ing.uc3m.es, (davide.marocco,acangelosi)@plymouth.ac.uk

Abstract

The symbol grounding problem [1] is currently an active topic in both cognitive modeling and robotics. It refers to the need for grounding the symbols used to represent thoughts and beliefs in something other than just more symbols. This paper describes work on an artificial neural network that grounds symbols in sensorimotor trajectories through a local Hebb-like learning performed online. This is of interest for exploring the development of higher-level cognitive abilities in humans through experiments with robots [2]. For example the grounding of action words in the sensorimotor interaction with the world [3]. It is also relevant for assistive robots. Here it may be desirable to learn online the correlation of multimodal inputs over time [4].

An architecture with a time-delayed input structure and no hidden layers was used. Each input for each time delay was represented by a set of neurons, the number of which depended on the discretization desired. A Gaussian distribution was used to distribute activation over neurons for a given input value. Each delayed input layer was given full connectivity with a layer representing the current time inputs. A Hebb-like [5] learning rule was then used to associate all inputs in the past with all inputs in the present online. No activation was propagated during training of the neural network. Causality was thus assumed to arise implicitly from the time-delayed input structure of the neural network and its embedding in the sensorimotor loop. The learned weights were then used to predict into the future by one time delay value, by propagating the activation resulting from inputs in the past and present. Predicting low-level actuation as well as the high-level descriptive labels grounded in the low-level actuation. The ability to learn online distinguishes the approach from recent work on Multiple Time-scales Recurrent Neural Networks (MTRNN) [6].

First results from benchmarking trials on a simulated iCub humanoid robot [7] are presented. A set of Cartesian trajectories were executed with one 7 Degree Of Freedom (DOF) arm, and 4 descriptive labels where given to different phases of the trajectories. Six DOF were actuated and used as low-level inputs. Two overlapping number 8 shape movements were learned, rotated 90 degrees with respect to one another. The labels indicated the top/bottom and left/right part of the trajectories, as well as the respective movement directions. During prediction, number 8 shapes that were 25% faster and 25% smaller were also attempted. For the worst case scenario used the root mean square error for the prediction of the joint angles was kept within 7 degrees and the labels were predicted correctly more than 80% of the time. This indicates that the approach is reasonably robust to the ambiguity introduced by partially overlapping and non-exact trajectories.

Index Terms: Symbol grounding, Hebb rule, sensorimotor coordination, developmental robotics, assistive robotics, benchmarking, online learning

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2. References

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