Action Selection within Short Time Windows

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Abstract. In this paper, we study the expansion of a reactive network that is based on a decentralized, heterarchical architecture able to control a hexapod robot. Within this network, problems may occur if more than one task should be addressed within a short time window. Such situations have been studied in so called dual-task experiments in the field of psychology. We take these results as inspiration to develop a structure that can be integrated into our framework. The model focuses on essential aspects of the basic phenomena observed in human subjects as forward masking, backward masking and PRP. While there are detailed models available concentrating on specific paradigms, those do not cover all three types of paradigms. We are not heading for a detailed simulation of the psychological findings, but show how these effects, on a qualitative level, can be implemented in our framework.

1 Introduction

In this paper, we study an expansion of a reactive network representing a decentralized, heterarchical architecture able to control a hexapod robot, in our case robot Hector [1]. The architecture consists of procedural, or reactive, elements, small neural networks that in general connect sensory input with motor output constituting the procedural memory. Inspired by Maes [2], these procedural elements are coupled by a motivation unit network, a recurrent neural network (RNN), forming the backbone of the complete system. This type of architecture has been termed MUBCA (for Motivation Unit Based Columnar Architecture [3]). To start with a thoroughly tested reactive system, we use an insect-inspired network, Walknet [4], that is able to deal with a specific domain of behavior, namely walking with six legs in an unpredictable environment including climbing over very large gaps — which, when performed in a realistic, natural environment is a non trivial task. This network has been augmented by various components [5,3,6,7] which are not addressed here in further detail.

To explain how the basic network will be expanded, we start with a brief description of a simple but representative part of the network, Fig. 1a shows the controller of a single leg. The two most important procedural elements for controlling the movement of a leg are the Swing-net, responsible for controlling a swing movement, and the Stance-net controlling a stance movement (Fig. 1a).

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These procedural elements might receive direct sensory input and provide output signals that can be used for driving motor elements. Motivation units ‘swing’ and ‘stance’ inhibit each other and are coupled via excitatory connections with other motivation units (see [5,3]). As depicted in Fig. 1a, motivation units do not only receive input from other motivation units, but may receive sensory input, too. This is required, in this example, to decide between ‘swing’ and ‘stance’ movement of a leg. A sensory input recording ground contact (GC) of the leg actives motivation unit ‘stance’. A sensory input monitoring the leg having reached a specific extreme position (PEP) can activate the motivation unit ‘swing’.

As long as we remain within the current context of, for example, forward walking and navigation, stimuli able to activate memory elements are normally given with sufficient temporal separation that provides enough time (1) to select the motivation units, (2) to start the procedures and (3) to finish the behavior before the next stimulus is given. Under these conditions a selection of a procedure is possible using a winner-take-all (WTA) network consisting of simple, piecewise linear units with low-pass filter properties [3].

Let us now assume that different procedures have been learnt by the agent that do not belong to a common context. Let us further assume that a stimulation of such a procedure will result in activation of the corresponding motivation unit for some short time (“short term memory”) as it is true for many (if not all) living systems. If, in this case two stimuli connected with different procedures are given more or less simultaneously, due to capacity limits, this situation may lead to a bottleneck and thereby to loss of information. How could an agent deal with such a situation? We will show in this article that under these conditions a WTA network being endowed with more complex dynamics is suited to deal with this case.

We will not ask here how a robot could be constructed that would not suffer from such a situation. Instead, we are interested in how the controller of such an agent could be understood by trying to construct a controller endowed with these properties. This may be of particular interest because the paradigms addressed below are tightly connected with the relation between conscious and non-conscious control of behavior. A controller that is able to switch between these two states may well be of interest for constructing advanced robots [8].

To construct such a system, we will focus on how the elements of the short term memory may be structured. To address this question, we take inspiration from psychological experiments. There is a number of experiments performed with human beings, called dual-task experiments, which show specific phenomena, when the subject has to deal with two tasks, T1 and T2, at the same time. If two stimuli, S1 and S2, that trigger two procedures, T1 and T2, respectively, are following each other within a short time, three possible types of reactions can be observed. (1) Either the first task is executed and the second task is discarded (called forward masking), (2) the first task is discarded and the second one is executed (called backward masking), or (3) both tasks are executed but the second one is delayed. The latter case has been described as the psychological