Fast non-hebbian learning in the limbic system simulated in a robot food-retrieval task

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Fast learning, common to animals and humans, has so far only been achieved in very few physical/technical systems. A new learning scheme, called input correlation learning (ICO learning) achieves fast learning in real world situations like robotics or process control. ICO learning has a striking similarity to the limbic system in animals which is responsible for basic emotional reactions like feeding. These reactions are usually learned very quickly. ICO learning is an unsupervised learning rule. Its structure can be split up into two distinct processing layers (Fig.1, right). The first layer is responsible to maintain homeostasis (reflexive layer), thus, it establishes a classical feedback system. The second layer is the part that is actually learning (adaptive layer). It develops instrumental actions (forward models) to improve the homeostasis defined by the reflexive layer. The underlying learning rule is $d\rho/dt = \mu\, u_1\, du_0/dt$, with ρ the synaptic weight, μ the learning rate and where u_0 is the activity in the reflex layer and u_1 is the activity in the adaptive layer. Note, ICO learning is not a Hebbian learning rule: Hebbian rules correlate a presynaptic signal with a postsynaptic signal whereas ICO learning correlates only input signals with each other. Thus, it is a form of heterosynaptic learning. The limbic system is one of the oldest parts of the brain and is well known for its role in the mediation of motivation and reward pathways. The algorithmic structure of ICO-learning is reflected in the limbic system by the lower reflexive pathway and the upper adaptive pathway shown in Fig. 1, left. Of central importance here is that the nucleus accumbens consists of two distinct areas: shell and core. The shell is generally accepted as controlling homeostatic processes that include appetitive behaviours such as food intake and sexual activity. Thus, the shell implements classical feedback control. The core seems to be responsible for the control of adaptive instrumental actions such as lever pressing or in general targeting food. In this study we show that it is possible to implement ICO-learning in a robot emulating the reflexive and adaptive structures of the limbic system. The robot starts with only a basic food-retrieval reflex (reflexive layer). During learning the robot acquires targeting behaviour and the reflex is superseded by more plan-full anticipatory actions (adaptive layer). Furthermore we observe that learning succeeds after only one of two trials. A theoretical proof is derived that this type of learning can approach the limit of one-shot learning in a stable convergence domain. Hence the novel learning rule suggests that heterosynaptic learning could play a major role for the fast acquisition of adaptive behaviour.

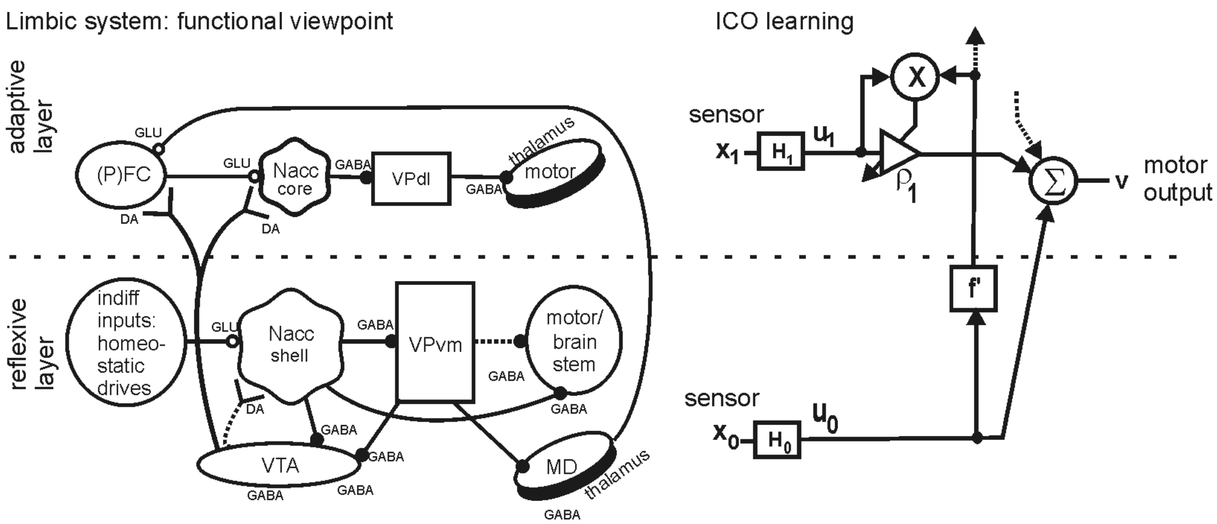

Fig. 1) Relations between ICO-learning and the limbic system. VPdl=Ventral Pallidum (dorso-lateral), VPvm=Ventral, Pallidum (ventral medial), PFC=prefrontal cortex, VTA=Ventral Tegmental Area, NAcc=Nucleus Accumbens, MD=MedioDorsal thalamus.