

FROM 1ST ORDER EMBODIMENT TO 2ND ORDER EMBODIMENT: TOWARD A COGNITIVE WALKER

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Studies of control structures underlying insect motor control, in particular walking and climbing, has led to solutions that fit the embodiment approach. The latter has been characterized by R. Brooks as allowing for “intelligence without representation” [1]. Walknet, a system formed by artificial neurones, has proven able to describe quite different aspects of walking and climbing as observed in (stick) insects. This faculty has been confirmed by software simulations [2], [3] as well as by testing this network on hexapod robots. Recently this approach was expanded to the question, only rarely taken into account, of how to deal with the kinematic problem of controlling the extra degrees of freedom (DoF) of stance legs [4]. This poses a problem for insects because there are eighteen DoFs to be controlled (six legs with three active joints each), while the body’s position in space is defined by six DoFs only; this means that there are twelve extra DoFs, i.e. DoFs that remain unspecified by the task. The proposal of applying positive velocity-dependent feedback is a solution that can be realized locally, i.e. at the level of joints. At the same time this solution is a perfect example of application of the embodiment approach in the sense of Brooks’ recommendation to “use the world as its best own model.” (A local solution for the problem of coping with the control of extra DoFs on the dynamic level has been derived from insect studies, but has not yet been applied to the robot [5].).

There is, however, a completely different way of dealing with the kinematics of a mechanical system equipped with extra DoFs. This approach is based on the puppet-principle, as described by the German Romantic writer Heinrich von Kleist [6], which is used to produce elegant movements—a principle that has more recently been termed the “passive motion paradigm” [7]. In applying this principle, a neuronal representation (the “puppet”) of the kinematic properties of the real body in question is required. This model should be “universally manipulable,” i.e. should be able to allow the representation of all—both active and passive—those movements that the real body is able to

perform. Such a model may then be used to solve inverse kinematic problems that occur when the body is moved in whatever way. Furthermore, this model could be used to internally simulate different types of behaviour (probehandeln) without really performing them; this faculty can then be exploited when the actual controller is confronted with a problematic situation. In this case, the model can be used to search for new solutions without running the danger of harming a real body. The concept of using a model of the body to be studied (plus certain relevant props such as an obstacle) follows the recommendation of L. Steels to implement “intelligence with representation” [8]. Note that in the approach proposed here our application of the body-model is not meant to replace the reactive controller Walknet but is—on the contrary—designed to make the latter an indispensable basis for such work.

The application of a model representing the essential properties of the body and certain relevant aspects of the world has been termed “2nd order embodiment” [9] in distinction to “1st order embodiment,” the latter describing the concept, as noted above, of exploiting the physical body for simplifying control.

The concepts proposed here are in agreement with the increasingly accepted idea that brains, at least those of higher animals, contain neuronal networks that are equally responsible for motor control, perception of movement, imitation, and for planning and imagining movements. In other words, these networks form the basis of cognitive abilities.

In my talk I will show how such a universally manipulable body-model can be realized by using an ANN approach and how the reactive controller Walknet, in cooperation with the body-model, is able to generate new ideas and cope with problems that had been unsolvable for the system before probehandeln was applied. Discussed will be the relation of this approach to the representation of categories to reactive versus cognitive control, and to the searchlight hypothesis.

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