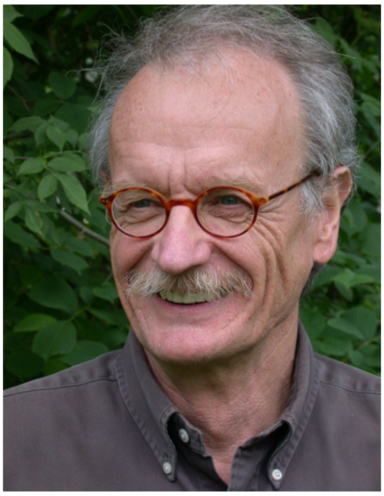

Holk Cruse, Dr. rer. nat.

Professor of Biology

University of Bielefeld

Born in 1942 in Stuttgart

Studied Biology, Physics, Mathematics at the Albert-Ludwigs-Universität Freiburg

FOCUS

PROJECT

The Talking Stick Project

The human brain is often considered the most complex system known. The members of the "understanding the brain" group, Lisa Aziz-Zadeh, Thomas Metzinger, Srini Narayanan, Rafael Núñez, Luc Steels and myself, suppose that a better understanding of how the brain works might be gained if results from quite diverse research domains are combined.

To this end, we exploit the observation that the neuronal system traditionally assumed to be responsible for motor control, i.e., for control of action, has recently been shown to share a common structural and functional basis with sensory analysis of an action, i.e., traditional perception, and also with imagining of an action, i.e., with subjective experience. Furthermore, linguists have advanced another quite contra-intuitive idea postulating that language is directly coupled with basic motor control structures. Our aim is to test to what extent these hypotheses can be combined by a single functioning neural network.

We start with an artificial, i.e., simulated neuronal network that is able to control complex motor behavior, namely the walking and climbing of an insect, the walking stick. The system is furthermore equipped with the ability to plan ahead. Applying Narayanan's ideas to this network will result in a system that, on a low level, can probably be used for language comprehension and language production (therefore called "the talking stick project"). Later the simulation will be endowed with more complex memory structures including procedural and declarative types of memory.

To verify the feasibility of our concept, the final goal will be to test the new memory structure on a robot. Using this strategy, we hope to detect basic principles of the functioning of brains on the system level.

Recommended Reading

Cruse, H. 2003. "The evolution of cognition - a hypothesis." Cog. Science 27, 135-155.

Schilling, M. und H. Cruse. 2007. "The evolution of cognition - from first order to second order embodiment." In Modeling Communication with Robots and Virtual Humans, edited by I. Wachsmuth and G. Knoblich. Berlin: Springer, 2008 (in press). [Springer Series Lecture Notes in Computer Science (LNCS), subseries Lecture Notes in Artificial Intelligence (LNAI).]

Cruse, H., V. Dürr, and J. Schmitz. 2006. "Insect walking is based on a decentralised architecture revealing a simple and robust controller." Phil. Trans. R. Soc. 365, 221-250.

EVENINGCOLLOQUIUM

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12.11.2008

Understanding the Brain: Bewegung, Sprechen, Denken, Fühlen

A system that is able to control behaviour, i.e. movement, and that in addition is able to think and to feel, is often considered a 'cognitive' system. Others postulate that the capability to deal with language is another crucial prerequisite for a system to be defined as cognitive. The goal of our focus group is to develop quantitative models on the basis of computer simulations of neuronal structures that endow these four properties. By doing so, we follow Feynman, who stated that we understand a system only when we are able to construct it. Generally, a model represents a simplified version of the real situation, as it concentrates solely on the essential properties, neglecting less important details. In developing such models, intuition plays a central role. Whether the essential properties have been met can be confirmed only in hindsight.

Our group attempts to understand the mechanisms upon which the function of a brain is based, which, after all, is a prerequisite to our existence as a person. How does a brain control behaviour? According to a traditional view, this process is described by the triad "sense - plan - act". The nature of the processes that are summarized by the term 'plan' is fairly open. These processes concern the selection of relevant sensor data out of a high amount of available sensor data, the decision concerning the actual goal to be reached including possible interim goals, and decisions concerning the choice between a large number of possible motor actions, whereby any constraints have to be taken into account. These kinds of problems have to be solved not only by behaving human beings but likewise by all animals, including insects for example.

In order to understand the underlying mechanisms, we have concentrated these last years on a simple, but by no means trivial behaviour, namely walking and climbing in insects. An insect has six legs and must control at least 18 joints simultaneously. This task is not easy, as is indicated by the fact that any insect outperforms by far even quite recent walking robots.

Investigations of such insect behaviour have now led to a computer model that consists of artificial neurons. By means of this model, including the crucial contribution of body mechanics, it is possible to control a behaviour that corresponds very closely to the behaviour observed in the animals. To allow such a comparison, software simulation and hardware simulations (i.e. robots) have been applied.

This neuronal model can be considered a procedural memory. Such 'reactive' structures, however, do not permit any prediction of the extent to which the behaviour performed will influence the state of the world. To allow such predictions, the neuronal system has to be expanded by a new element, a so-called manipulable world model. As the own body, seen from the brain's point of view, represents the most important aspect of the world, a body model comprises a central part of this world model. Such a body-world model is a prerequisite for the capability of imagined action ('Probehandeln'), which S. Freud already proposed as a synonym for thinking (at this stage we are dealing with pre-categorial thinking). Our first task will be to develop such a body-(part-of the) world model.

The most crucial step relies on what is at first sight a devious idea. The capability to use human language, including both production and comprehension, shall be based on a neuronal structure that corresponds to that of a simplified insect brain. Of course, this allows only a first step. To make it, we will use an element of an elaborated concept developed in the lab of S. Narayanan. Memory elements that are due to recognition as well as production of a given word will be directly connected to memory elements that represent the corresponding behavioural elements. Such a system would allow an insect-like robot, for example, not only to perform its behaviour, but at the same time to report on its actual behaviour using single words or sequences of words. Applying its body model, the robot might also report on imagined (internally simulated) behaviours. Conversely, the robot could interpret spoken words by either simulating the corresponding behaviour or by actually performing it. A further level could be reached if the image of an (e.g. visually) perceived fellow robot could be mapped onto its own body model. In this case, the robot would be able to interpret the observed behaviour of its fellow and to report on this behaviour. The so-called mirror system ('mirror neurons'), which is the subject of L. Aziz-Zadeh's work, is considered the basis of this ability.

To further approach the capabilities of human language, the neural system has to be equipped with the ability to deal with grammatical structures and - if it comes to cope with very large storages - with specific solutions to manage the dynamic binding of individual memory elements. S. Narayanan and L. Steels are working on solutions to these problems. These two colleagues, as well as R. Núñez, are also concentrating on the question of how concepts used in motor control might be applied to those dealing with abstract concepts.

To begin with, we will proceed such that the association between word and related action is given by the designer of the program. Will this system be able not only to learn, but also to invent categories by itself and to ascribe meaning to randomly chosen symbols? In his Talking Heads experiment, L. Steels has indeed shown structures that make such faculties possible.

In order to fully understand the abilities of a cognitive system in the sense mentioned above, there remains one further crucial question: Might it be possible that any physical system consisting of - real or artificial - neurons has the capability of subjective experience, i.e. to feel? This capability refers to the fact that, for example, a strong stimulus may not only lead to neuronal and behavioural reactions (that can also be registered by an external observer), but also that the system experiences pain, an experience that is accessible solely to the system itself. Time allowing, I will speculate on properties of the neuronal system that might be necessary to equip a physical system with the ability to have subjective experience. T. Metzinger will critically accompany these speculations.

Cruse, Holk (2017)

ReaCog, a minimal cognitive controller based on recruitment of reactive systems

https://kxp.k10plus.de/DB=9.663/PPNSET?PPN=1040832334

Cruse, Holk (2016)

Perception

https://kxp.k10plus.de/DB=9.663/PPNSET?PPN=856657948

Cruse, Holk (Warszawa,2016)

A grain of sand in the pupil of the eye

https://kxp.k10plus.de/DB=9.663/PPNSET?PPN=856656313

Cruse, Holk ([Piscataway, NJ],2014)

Bridging an interspecies gap? toward human-insectoid robot interaction

https://kxp.k10plus.de/DB=9.663/PPNSET?PPN=1686705018

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How and to what end may consciousness contribute to action? : attributing properties of consciousness to an embodied, minimally cognitive artificial neural network

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Cruse, Holk (San Francisco, Calif.,2011)

No need for a cognitive map : decentralized memory for insect navigation

https://kxp.k10plus.de/DB=9.663/PPNSET?PPN=778191478

Cruse, Holk (2009)

From 1st order embodiment to 2nd order embodiment : toward a cognitive walker

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Neural networks as cybernetic systems : [Elektronische Ressource]

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Brains, minds & media

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The evolution of cognition - from first order to second order embodiment

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Cruse, Holk (2008)

Winching up heavy loads with a compliant arm : a new local joint controller

https://kxp.k10plus.de/DB=9.663/PPNSET?PPN=786504471