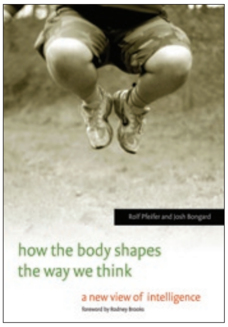
How robots will teach us how the brain works



How the Body Shapes the Way We Think: A New View of Intelligence

By Rolf Pfeifer & Josh Bongard

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Judging by the frequency of media reports, the robot revolution is upon us. New developments, from running robots to rescue robots to robot companions for the elderly, are coming at us from industry, academia and the military. Indeed, several countries are now addressing the ethical implications of robot surgeons, soldiers and sex workers. This onslaught of new and practical robot technologies owes much of its success to the changing focus of artificial intelligence (AI) research from highly specialized and disembodied 'rational agents' (good old-fashioned AI) to the behavior-based robotics pioneered by Rodney Brooks—a biologically inspired approach in which robots are designed to operate autonomously under real-world constraints. Beyond their practical and ethical implications, can the construction and behavior of such robots tell us anything about biological cognition?

Rolf Pfeifer and Josh Bongard, computer scientists working in AI, seem to think so. In *How the Body Shapes the Way We Think*, they make a convincing argument that neuroscientists have much to learn from robotics. Their philosophy is that if we can understand how to design and build intelligent systems, then we will have a better understanding of the nature and mechanisms of behavior more generally. Typically, the problems facing researchers in biology have multiple possible solutions, but biases in our thinking make us more likely to choose certain kinds of solutions over others. This is where robots can aid us. Building a robot that can reproduce some aspect of an animal's behavior forces the researcher to reinterpret problems, see limitations in old solutions and find new solutions. One could say that an artificial agent not only acts to solve tasks in a physical environment, but also acts as a cognitive aid, helping us to see solutions to problems that we otherwise would have missed. Robots are a potential scaffold for neuroscientific thought.

Pfeifer and Bongard present the insights gained by this approach by putting forth a set of design principles, the main points of which can be summarized as follows. First, keep in mind the ecological niche to be filled and desired behaviors as you design the agent. Second, given a certain task environment, the complexities of an agent's sensory, motor and neural systems must be appropriately matched. It makes little sense to have color vision if the organism's mode of life does not require it. Furthermore, there must be a task distribution between the morphology of the agent, its composition, the control system and the environment. As in biological evolution, if agents are built to exploit the properties of their ecological niche (that is, its statistical structure), then their design and construction will be more energetically efficient.

The essential idea behind these design principles, and the thesis of the book in general, is that intelligence emerges from interactions among the brain, body and environment. It is not hierarchical in the traditional sense, but rather a dynamical system in which none of these factors alone is sufficient to drive behavior.

One important concept that emerges from this approach is morphological computation, the notion that certain processes can be carried out by the body that would otherwise be the task of the control system. That is, exploiting the shape and material properties of an agent can markedly reduce the amount of control required. This is best illustrated in the domain of locomotion. When you think of the stereotypical robot moving, what usually comes to mind is the rigid movements of a humanoid robot, such as C3PO in Star Wars. Such awkward movements are the result of the combination of rigid structural materials and tight control of exact limb trajectories and positions. Given the degrees of freedom of a normal body in a natural environment, the number of possible trajectories and limb positions becomes astronomical. Paying greater attention to material properties and the shape of real limbs has inspired the development of very simple robots with impressively flexible movements.

The robot Stumpy is a great example; although essentially 'brainless', it is capable of walking, dancing, hopping and turning. Its morphology is critical for this achievement. If Stumpy's springy feet were made rigid or its upper body removed, none of these movement patterns could emerge. For most neurobiologists, morphological computation may seem a somewhat odd, if not radical, idea. Most of us implicitly operate under the assumption that the bottleneck in producing complex behaviors is at the level of the brain, the control system.

This outstanding book contains much more that has important implications for neuroscientists, but the key point is that the brain cannot be uncoupled from the body or the environment. Adaptive behavior emerges from their interactions. Thus, for example, it makes little sense from this perspective to probe the brain with simple, artificial stimuli that the brain was not designed by developmental and evolutionary history to process. Embodied and situated behavior-based robotics provides a solid, empirical approach for illuminating the design principles of adaptive agents—real or artificial. The sooner we, neuroscientists (particularly, those of us who study mammalian brains), realize that the brain does not work in isolation, the sooner we can label our current state as good old-fashioned neuroscience. ■

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