BIOROBOTICS

Bio-robots step towards brain-body co-adaptation

In animals, both body and neural control have co-evolved to be adaptable to the environment. While a newborn foal learns quickly how to use its legs, traditional robotic approaches require careful engineering and calibration for stable walking robots. Bio-inspired robotics aims to bridge this gap.

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Robotics engineers aspire to design walking robots with the locomotor capabilities that are seen in animals. However, bridging the divide between industrial settings and the real, unstructured world continues to be a challenge. To thrive in the real world, robots, like animals, need to have adaptable physical structures and computer algorithms. Enter 'robot Morti', a quadruped robot developed by Felix Ruppert and Dr. Alexander Badri-Spröwitz at the Max Planck Institute for Intelligent Systems[1], which learns to use its legs' passive dynamics using two feedback loops similar to neural adaptation .

The development of robot Morti is an exciting demonstration of 'animal-like' adaptation of key physical and algorithmic components for locomotion. It has bioinspired flexibility in its joints while using a data-driven hierarchical control algorithm to enable short- and long-term learning and adaptation at different functional levels. Morti is therefore an example of embodied intelligence for locomotion to reduce energy consumption by adapting the physics of its body. Like a foal after birth, robot Morti can learn to walk with reasonable energetic efficiency in a laboratory setting after ~1 h of self-driven trial-and-error training.

It is particularly encouraging to see work that brings to bear the latest computational thinking to a fundamental principle of biology: the co-adaptation of the brain and body. Traditional robotics has an approach and perspective that emphasizes the use of prescribed computer algorithms to control rigid bodies. By contrast, the neural circuits and bodies of animals have co-evolved at the species level to co-adapt at the individual level to perform at enviable levels of physical performance.

The drive to build machines inspired by the versatile capabilities of animals (Fig. 1), and the converse idea of seeing animals as machines, is already explicit in the biomechanics writings (and drawings) by Leonardo DaVinci in the fifteenth century and Giovanni Alfonso Borelli in the seventeenth century. Alfred Russel Wallace and Charles Darwin further documented and marvelled at the endless variety of morphological and functional adaptations (that is, brain–body co-evolution) in nature.

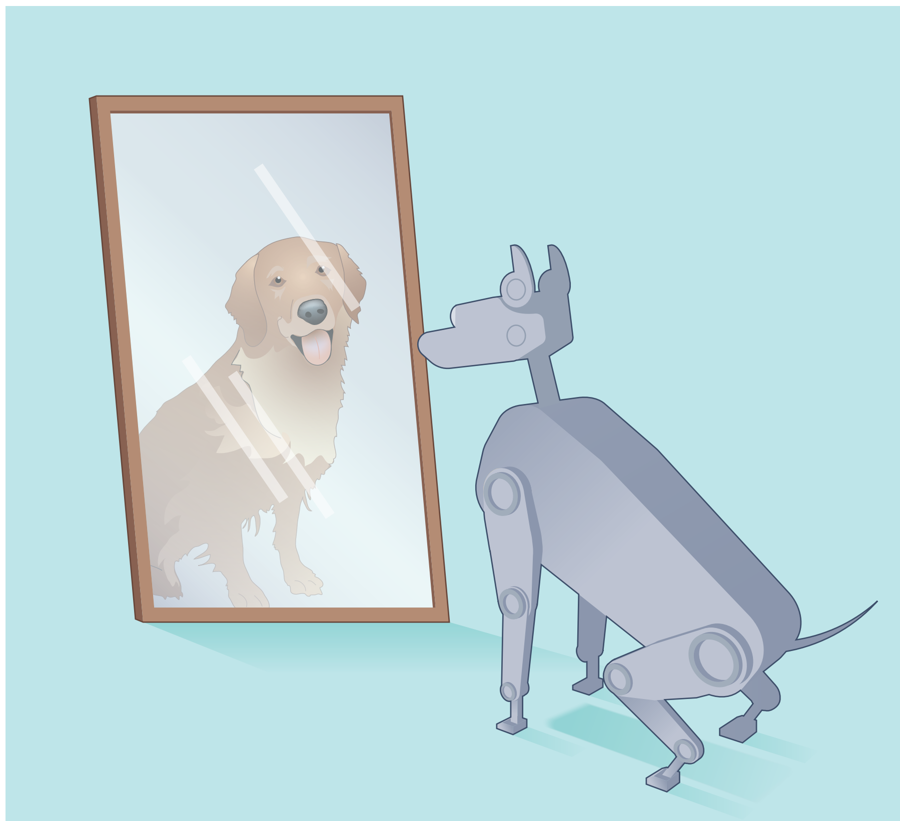

Fig. 1 | Bio-inspired robotics. A biorobot reflects on its inspiration and possibilities.

For several centuries, engineers have been stretching the spectrum of machines, from traditional mechanics (for example, wheeled vehicles), to bio-inspired transportation (for example, aeroplanes) up to biomimetic limbs (for example, leg prostheses[2]). Biorobots, like Morti, combine elements of engineering, bio-inspiration and biomimicry to suit a particular purpose. Robot Morti is a timely example of advances and current opportunities in moving from industrial robotics to biorobotics through brain–body co-adaptation to achieve locomotion.

As the current era of computationally intensive, bio-inspired AI and data-driven robotics progresses, we must remember to build upon the lessons biology has for machine learning[3] and the breakthroughs roboticists were able to make without our current exceptional computational capabilities. For example, robot Morti emphasizes the maxim that more computational power is not always necessary or better. Locomotion can be achieved with minimal actuation and control by leveraging physical properties, as has long been demonstrated by bipedal toys and the robots of Tad McGeer[4] or the Rhex hexapod robot with rotating curved legs[5]. Notably, both Rhex and robot Morti use elastic limbs to facilitate locomotion.

Nature has additional practical lessons; muscles are nature's miracle tissue that locally and efficiently provide tunable viscoelasticity to match limb impedance to the task and environment while powering the limbs. McKibben's pneumatic bladders[6] set out in this direction, and roboticists continue to aspire to create actuators that are closer to musculotendons and their associated low-level neural circuitry. In fact, there is evidence in simulation that the elasticity of musculotendons may be a critical enabler of learning[7]. Taking this a step further points to offloading learning and control, as nature leverages neural middleware and musculotendinous structures. This inspires advances in smart materials to incorporate a form of edge-computing that may revolutionize the physical and learning capabilities of robots.

At a higher level of skill acquisition, 'play' in the form of random, or non-goal-directed, trial-and-error 'motor babbling' in animals and robots is an efficient path to autonomous learning[8]. Another promising — and more controversial — idea is the emerging notion that biorobotics could make faster and better progress by dispensing with its emphasis on optimality in learning and control, no matter how mathematically well-founded and computationally convenient. Nature continues to do very well using suboptimal habitual learning and control[9].

Although there are still gaps between animals and biorobots, it is now possible to build robots like Morti. We now have the confluence of materials and fabrication methods coupled with realistic physics-based simulation environments that allow a rapid prototyping and exploration of brain–body co-adaptation. This empowers the field of evolutionary robotics to take brain–body co-adaptation one step further to 'evolve' robots that more easily bridge the simulation to reality (sim2real) divide, as in ref. [10].

Moving forward, the expanding field of biorobotics will greatly accelerate its progress by continuing to leverage the astonishingly elegant examples of brain–body–environment symbioses that nature has provided us. Robot Morti takes us several steps in the right direction. ❐

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Competing interests

The authors declare no competing interests.