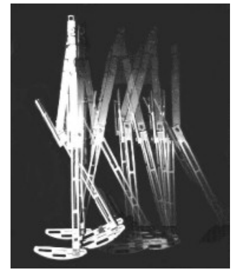
Synergies between movement neuroscience and control engineering

1. The brain is the most advanced control system in existence. Understanding the underlying computational mechanisms can lead to breakthroughs in robotics and automation. There is an emerging trend towards biologically-inspired engineering solutions to complex control problems:

- exploiting the natural dynamics of the body,
- imitating the movements of human experts,
- inferring the “cost function” of human experts.



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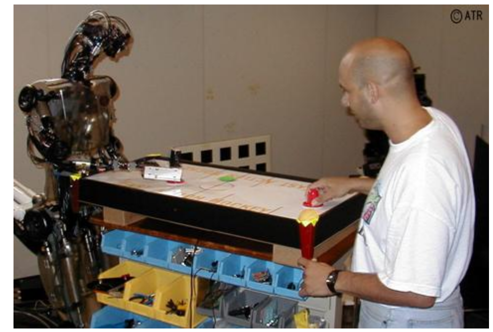

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2. Engineering insight into what works and what doesn’t can guide computational theories of motor function. Presently, most data comes from simple behaviors where almost any theory can be made to work. Some of these theories have little hope of scaling to real-world scenarios, at least in their current form, however researchers in movement neuroscience are rarely aware of that:

- equilibrium-point control is still argued to be the way the brain controls movement, ignoring the fact that its engineering analog (servo control) has many limitations, especially when applied to complex dynamics,
- dynamical systems models are often fit to data, ignoring the importance of behavioral goals and the difficulty of constructing dynamical systems which happen to accomplish such goals,
- optimal control models demonstrate that many behaviors are as efficient/accurate as possible, but do not address the learning processes which enable such performance (note: RL is too slow).

Understanding how the brain finds near-optimal solutions to seemingly intractable problems

good The evidence for optimality in neural computation is growing:

- sensory processing is often studied in the framework of Bayesian/optimal inference,
- motor processing is often studied in the framework of optimal control,
- neural coding is often studied in the framework of information theory (which emphasizes optimality),
- learning and adaptation are often seen as forms of iterative optimization.

Most methods in Artificial Intelligence and Machine Learning come down to solving optimization problems.

The shared emphasis on optimization creates a strong and concrete link between AI/ML and Neuroscience. In complex problem domains we are not yet able to construct Bayesian estimators, or optimal controllers, or communication systems that achieve the Shannon limit. The AI/ML community is traditionally interested in Neuroscience, hoping that Neuroscience will unlock some of the algorithmic secrets of the brain and thus enable the construction of more intelligent machines.

bad However, this interest is on the decline. Indeed the new conference CoSyNe (Computational and Systems Neuroscience) was created in large part because AI/ML conferences like NIPS became less relevant to neuroscience. Why is that? I don't know, but here are some possible answers:

- Neuroscience is increasingly dominated by molecular techniques as well as "translational" research, which shift the emphasis away from system-level computation and neural basis of behavior,

- advances in mathematical methods and computer hardware have made it possible to attack more complex problems without insight into how the brain solves the same problems; this approach is unlikely to get very far, but at least for now it is working.

The NSF should work to strengthen the interactions between AI/ML and Neuroscience.