A Robot That Builds a Simulator of Itself: A Counterrevolutionary Tale

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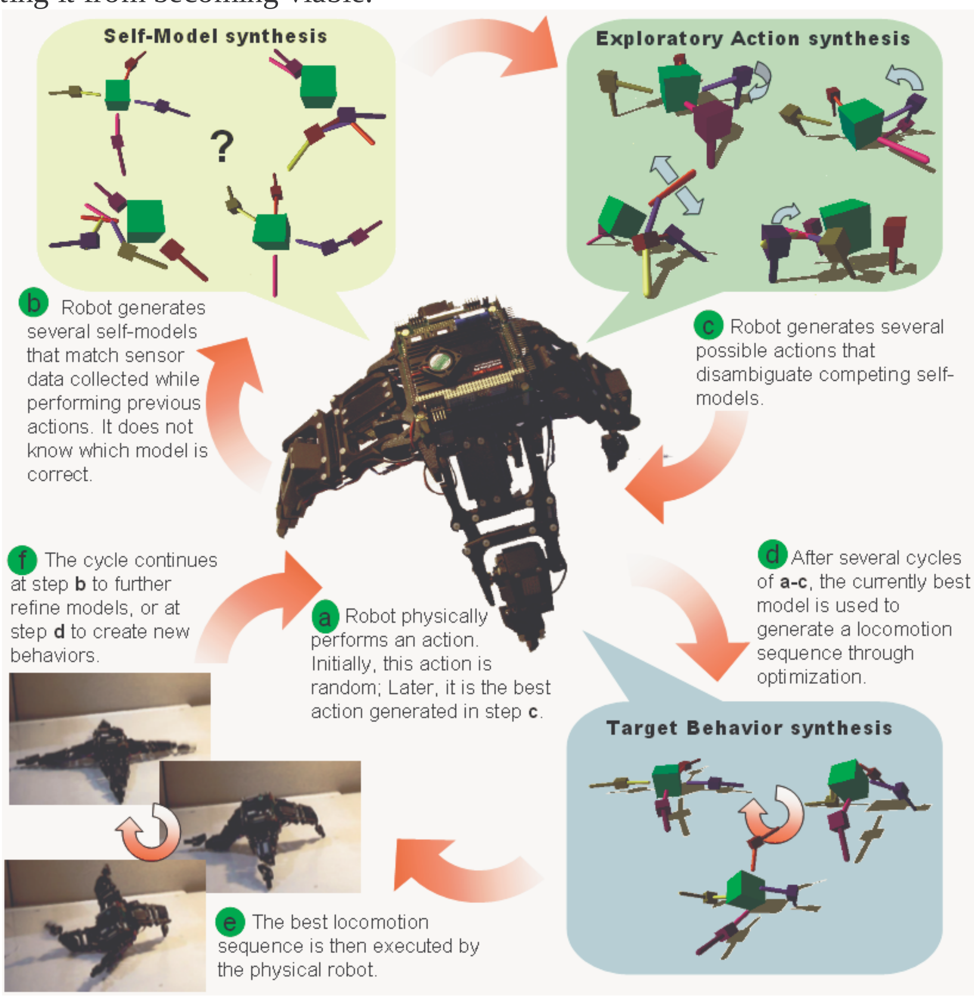
Higher animals use some form of an internal model of themselves for planning complex actions and predicting their consequence[i,ii,iii,iv,v], but it is not clear if and how these self-models are acquired or what form they take. Despite this, Brooks' AI revolution in the 1980s[vi] was a response to the slow progress of model-based robotics since the 1950s, and ushered us into the current AI epoch in which model-free robotics is fashionable. Although simple and robust behaviors can be achieved without a model at all[vi,vii], Brooks himself anticipated the "tantalizing possibility"[viii] that a robot could one day autonomously create models of itself along with new behaviors, but cited "deep issues" preventing it from becoming viable.



A robot that can build a simulator of itself. The robot performs a random action (a), then synthesizes candidate models of its own morphology (b). Those models are then used to synthesize a new action (c) that induces maximal disagreement among the models. This cycle repeats until a sufficiently accurate model is achieved. At that point, the best model is used to synthesize a locomotory behavior (d), which is then executed by the physical robot (e).

Here I report a successful physical realization of this concept, and further demonstrate the reward mechanism for directing the self-modeling phase: disagreement among competing internal models.

More specifically, I will show how low-level sensor-motor correlations can give rise to an internal predictive self-model, which in turn can be used to develop new behaviors (see figure). I will demonstrate both computationally and experimentally how a legged robot automatically synthesizes a predictive model of its own topology (where and how its body parts are connected) through limited yet self-directed interaction with its environment, and then uses this model to synthesize successful new behaviors: behaviors synthesized in simulation that transfer well to the physical robot.

In the experiments I will present, the physical robot learns how to move forward based on only 16 brief self-directed interactions with its environment. These interactions were unrelated to the task of locomotion, and are driven only by the objective of disambiguating competing internal models. This method is superior to the three current approaches to automated behavior generation for robotics (evolving behaviors all on a physical device, which requires at least hundreds of evaluations on a physical robot[ix]; evolving in a robot simulator, which requires the manual construction of the simulator first[x]; or adapting a previous behavior online, which assumes the existence of a previous behavior[xi]) because it does not require extensive physical trials, and does not assume a simulator or previous behavior.

This finding may help develop more robust machines, as well as shed light on the relation between curiosity[xii] and cognition[xiii] in animals and humans: creating models through exploratory action, and using them to create new behaviors through introspection.

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