
1 reflexes

His denouncement of forward-model force control is direct, perhaps even obvious. It is based on the observation that while the limb is stationary / maintaining a posture, there is usually very little EMG activity. If the cortex were a force controller followed by SC reflex circuits, there should be tonic EMG when stationary posture != default posture. A way to amend this model would be to inhibit reflexes during non-neutral stationary postures, but this is inconsistent with rapid & strong reflexes during perturbation from any posture. This force-controller hypothesis is silly because it assumes that the SC system is linear: reflex = a * (defaultposture – actualposture(Ia, Ib, γ)). What is wrong with: reflex = a * (posturesuggestedbyPTNs – actualposture(Ia, Ib, γ)) ? This - termed later in the paper threshold control (similar to the equilibrium point hypothesis) - would also account for the rapidly activating (30ms latency) silent period observed when the passive load on a moving arm is suddenly removed. This, perhaps overly simplistic, model seems to make sense: the motor system is not an implementation of a theory / mathematical principle of optimality, nor is the spinal cord & interneurons things to be worked around by the cortex. Our motor system may be adhoc but it is an efficient and hierarchal system for controlling mammalian bodies. <philosophee> In animals like deer, much of the system is reflexive & tuned by evolution, whereas in humans the reactions have been usurped by the cortex. This is why, as Joey pointed out, babies flail about for the first year of their life. They have to learn the dynamics of their environment cognitively. (...) A theory of motor control in humans is inherently a cognitive theory. </philosophee>

2 inverse dynamics

The conclusion that Purkinje cells are involved in the computation of inverse dynamics (of eye movements) seems fundamentally flawed (this conclusion was drawn from the observation that the firing rate is a function of kinematic variables of eye motion - and kinematic variables would be the output of an inverse dynamic calculation): other brainstem structures anticipate eye movement and ocular EMG 30-40 ms (for example, antagonist muscles are silenced 40 ms prior to a saccade) before a saccade, whereas purkinje cells very their firing rate just
10ms before saccade. Not the heaviest argument, but still valid.
In terms of arm movements, their objections are sensible - computing the inverse dynamics of a full body is a difficult and both redundant / under-determined problem with many nonlinearities / near singularities. ¹

3 forward models

You cannot prove the existence of a model-based controller because every model-based controller can be simulated with a pure feedforward (non model based control) controller with the same input/output relationship. The Smith predictor can be dismissed under similar mathematical arguments - though it defies intuition that the brain does not use some model of the world. The authors also point out that a pure feedforward controller would improperly stabilize a task like balancing a stick on your finger; a more parsimonious explanation is that your brain knows that pushing the stick in the direction to right it usually achieves the desired result. (I personally think that I need to learn more control theory to make an active commentary on stability ...). Additionally, once you account for 'preflex' (nearly instantaneous changes in force due to muscle properties when position/velocity changes), the purported reason for a forward model - to compensate for prorioceptive delays - is invalidated; the Smith predictor actually makes the system unstable.

4 conclusion

His arguments are fine, though sometimes difficult to wade through. I agree that threshold control seems more plausible and biological than mathematical forward/inverse models. Might have been nice if he could propose some experiments to test this - have to see what they are up to presently / what they have published in the meantime.

¹I'm not sure how this is relevant, but people have shown that octopi simplify their ultra-articulated limb into rigid segments when manipulating things, i.e. fish