Information, Control, and Learning: The Ingredients of Intelligent Behavior.

September 2016, Jerusalem

Abstract:

We would like to use the general concepts surrounding perception-action loops in order to understand brain responses and behavior of real animals in (almost) natural environments. I will discuss here two simple test cases, one at the sensory side of the loop, the other in the control/action side of the loop, in which the application of information bounds provides explicit solutions that can be usefully compared with experimental results. The first case involves stimulus-specific adaptation (SSA), the reduction in the responses to a repeatedly-presented sound ('standard') that does not fully generalize to another, rare, sound ('deviant'). We interpret SSA as the expression of a prediction error signal. Using the Information Bottleneck principle, we show that the neuronal responses are consistent with a prediction error signal that is based on an internal representation that has a long memory (>10 stimuli back) which is coarse but still almost optimally predictive. Thus, information bounds allow us to estimate interesting properties of the neuronal code. The second case involves the application of information-limited control ideas to learning in the Morris Water Maze (MWM). We developed a simple LQG control model for the mouse in the MWM, and solved it explicitly with information constraints on the swimming paths. The model provides two quantifiers for actual swimming paths: one is 'value', which is closely related to the swimming time to platform, the standard quantifier of behavior in the MWM. The other is 'complexity', which quantifies the deviation of the swimming paths from the no-control distribution. While the value continuously increases during training, the complexity may be a non-monotonic function of training session, is sensitive to genetic background and mouse gender, and may be a new, sensitive quantifier of behavior in the MWM. In the future, we will use a full model of the perception-action loop in order to study animal behavior in complex, but well-controlled, environments.
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