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Tradeoff of Information Transmission and Decoding with Intracellular Kinetics

A variety of cellular processes functions reliably by intracellular reactions even though substantial noise is inevitable. In particular, detection of relevant information from environment is crucial for the fate of cells.

From the viewpoint of information theory, such information processing is composed of three parts: encoding, transmission and decoding. Here, for a simple setup in the context of biochemical reactions, the roles of the three parts can be played by environment, receptors on membranes, and intracellular reactions, respectively. In engineering, much efforts have been generally made to reduce noise in encoding and transmission parts. By contrast, decoding may also play equally important role in biological systems, which is suggested by the substantial noise in microscopic cellular systems.

While decoding is to extract as much information as possible from the transmitted signals, such processing, in reality, should be implemented in the chemical reactions. For example, kinetics with dual positive feedback structure can implement a dynamic Bayesian inference, which gives the statistical limit for the decoding[1][2]. However, the efficiency of decoding would be limited by physical constraints such as amount of available energetic cost. We still lack a general framework to quantify how the transmission and decoding work.

Here, we consider this problem by calculating mutual information among encoding, transmission, and decoding parts of simple models with several intracellular reactions. By the quantification, we clarify the tradeoff of transmission and decoding. When the transmission part carries a large amount of information, decoding need not necessarily work effectively, since it is clear from the transmitted information to detect the state of environment. On the other hand, decoding by intracellular reactions becomes essential to obtain information when detecting from transmitted information is not straightforward.

References

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[2] T. J. Kobayashi and A. Kamimura, *Dynamics of Intracellular Information Decoding*, submitted Physical Biology (2011).