Intersection of Information theory with other disciplines

Ideas discussed during meeting held on Sept 28, 2010, at UIUC.

Feedback in information theory

As a toy example, consider the setup in Fig. **??**. Here the plant/source is modeled by a markov chain $\{x_n\}$. The aim of the encoder is to encode and transmit the source over a noisy memoryless channel. Delayed noiseless feedback of the channel output is available to the encoder. The decoder wants to maximize the reward

$$J(e,d) \;=\; E_{e,d}\left\{\sum_{n=1}^{N} c(x_n, z_{n-1}, z_n)\right\}. \tag{1}$$

The parameters e and d in the definition of the reward J refer to the encoding and decoding policies. x_n can be a continuous random variable, and z_i can be a belief or a probability distribution. The cost function $c()$ can be, say, $\log \frac{dz_{n-1}}{dz_n}(x_i)$.

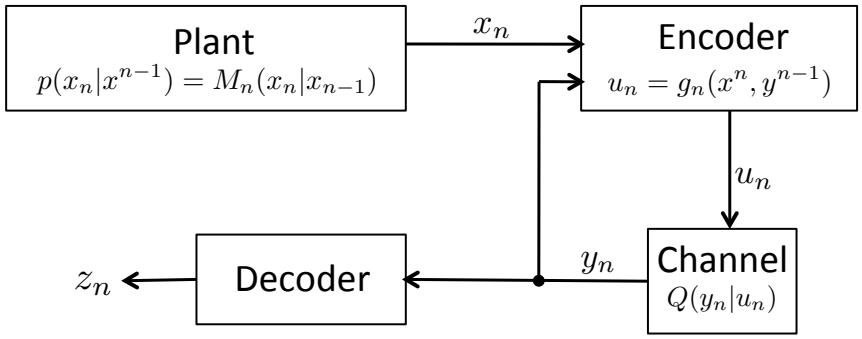

Figure 1: An estimation problem

Solving this problem could impact the design of practical systems. One example is using signals from the brain to remotely fly a plane. The source in this case is the user's path for the plane. The encoder is the user and he communicates his path to the computer via his brain signals. The brain signals are constrained to lie in a finite alphabet by asking the user to "think" about one of a finite number of actions. The channel is noisy because the signals from the brain are read into the computer and there could be

errors in the signal processing algorithm or in the transmission of signals by the user. There is visual feedback available to the user since he can view the path of the plane. There are interesting issues regarding feedback, delay, and dynamics of the system in a rich tapestry of models which are influenced by such practical systems.

Other issues involve understanding feedback in real systems like neurological systems.

Incorporating delay and dynamics in communication problems

- How to model the temporal value of information, say in the above feedback communication problem?
- What are the limits to information transmission at finite blocklengths?
- How to extend the theory of real-time systems?
- What are the feasible regions under constraints on delay?

Fusion of information in networks

- What are the fundamental limits of *in-network computation*? What is the *computing* capacity of networks for different functions?
- Need to study the communication complexity of distributed computation protocols in wireless and wired networks
- What can information theory say about aggregation techniques for scalable query processing in distributed databases (a la MapReduce)
- Extending the paradigm of one-way communication of data, to interactive communication for collaborative computation

Others . . .

- How to model soft-information (beliefs) in rate distortion theory?
- Modeling semantics in information – what is the framework? Is there a probabilistic framework for the problem?
- Evolution – what is the model for evolution?
- Systems biology – what is the model for stimuli?
- Are there other relevant objective functions than mutual information?
- Models to predict the behavior of animals.

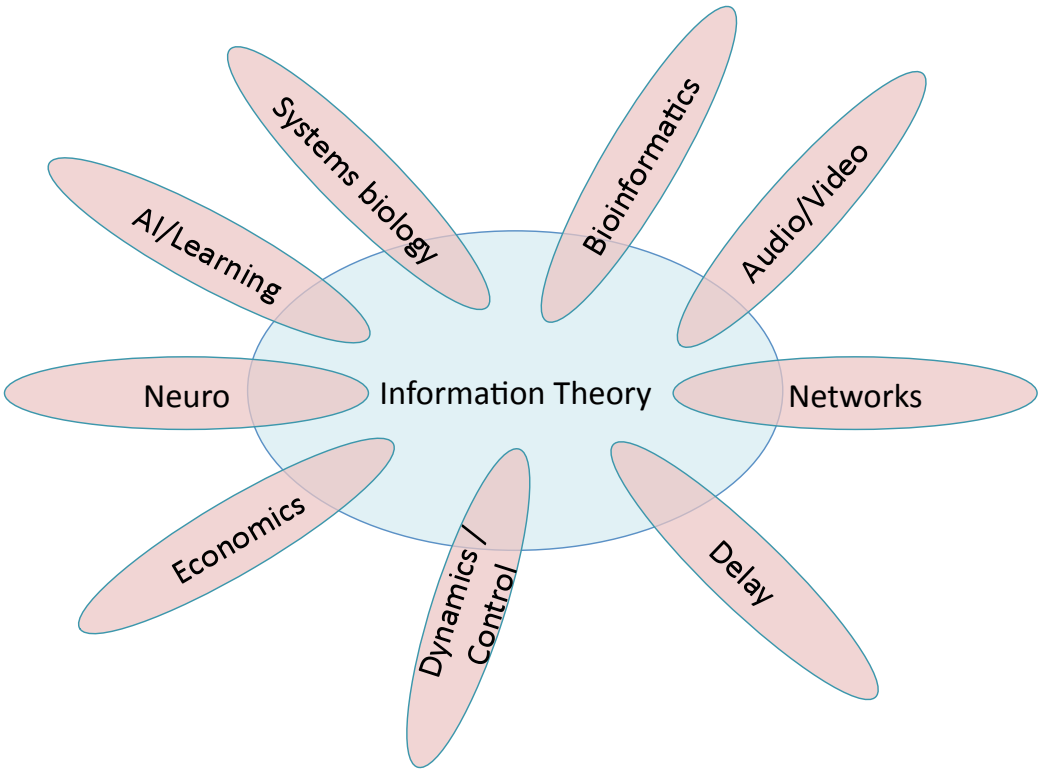

Figure 2: Intersection of Information theory with other disciplines