NIPS 2013

Workshop on Planning with Information Constraints
http://www.seas.upenn.edu/~ope/workshop/

Program Schedule

Morning Session I

07:30 AM     Introduction
07:40 AM     Bert Kappen     An Introduction to Path Integral Control Methods and its Applications
08:20 AM     Naftali Tishby     Control, Information and the Nature of Time
09:00 AM     Coffee Break

Morning Session II

09:30 AM     Evangelos Theodorou     Learning Stochastic Control, from Theory to Applications in Robotics and Aerospace Systems
10:00 AM     David H. Wolpert     Information Geometry of Influence Diagrams and Noncooperative Games
10:40 AM     Vicenç Gomez     Kullback-Leibler Minimization in Latent Spaces for Robot Motor Control
11:00 AM     Lunch Break

Afternoon Session I

03:30 PM     Jordi Grau     Bounded Rational Decision-Making in Changing Environments
03:50 PM     Tim Genewein     Abstraction in Decision-Making with Limited Information Processing Capabilities
04:10 PM     Brian D. Ziebart     A Unified View of ‘Soft’ Optimal Control
04:30 PM     Daniel Polani     Bot’s Adventures in Empowerment
05:00 PM     Coffee Break

Afternoon Session II

05:30 PM     Daniel D. Lee     An Adversarial Interpretation of Information-Theoretic Bounded Rationality
06:10 PM     Gerhard Neumann     Information-Theoretic Policy Search and Stochastic Optimal Control
06:50 PM     Closing Remarks
Morning Session I

An Introduction to Path Integral Control Methods and its Applications
Bert Kappen
Intelligent systems, whether natural or artificial, must act in a world that is highly unpredictable. It is intuitively clear, that an optimal approach to decision making or planning under such circumstances requires to take these uncertainties into account. However, the optimal control solution is intractable to compute in general and in addition is hard to represent, due the non-trivial state dependence of the optimal control. This has prevented large scale application of stochastic optimal control theory sofar. The path integral control theory describes a class of control problems whose solution can be computed as an inference computation in a graphical model and thus provides an integrated Bayesian viewpoint. In this talk, I will show how the theory naturally arises in the context of information constraints and the large deviation principle, using an argument originally due to Erwin Schrödinger. I will then present a new result that shows how a feed-back control law can be computed efficiently within the path integral framework for continuous stochastic control problems.

Control, Information and the Nature of Time
Naftali Tishby

Morning Session II

Learning Stochastic Control, from Theory to Applications in Robotics and Aerospace Systems
Evangelos Theodorou
Over the past 10 years there has been an increased interest on stochastic optimal control theory. This interest is identified 1) on extensions and reinterpretations of previous results within the machine learning and control theory communities and 2) on the development of algorithms with applications to robotics. In this talk, I will review our work on this topic, present robotic applications and discuss new directions in terms of theory and potential applications to robotics and aerospace systems

Information Geometry of Influence Diagrams and Noncooperative Games
David H. Wolpert
How should one quantify the value to a player in a noncooperative game of some “information” or “information flow” in that game? To answer this we first generalize the concept of marginal utility of a good in a choice problem, to marginal utility of a function of the equilibrium distribution of a choice problem, to directional derivative of a function of the equilibrium distribution of a choice problem, to directional derivative of a function of the equilibrium distribution of a multi-player game. We then exploit Shannon's information theory to quantify various types of information as such functions of the equilibrium distribution. To avoid having the resultant quantification of value of information depend on our choice of coordinate system, we must choose a metric tensor. In turn, our use of Shannon's information theory leads us to choose the Fisher information metric. This forces us to use the information geometry of noncooperative games to quantify value of information in games. We then use this information geometry to prove that generically, for any game, there is always a direction in game parameter space in which value of information is negative. We also establish, via explicit demonstration, simple 2-player games in which it is possible for information to shrink in a way such that both players see a rise in expected utility
Kullback-Leibler Minimization in Latent Spaces for Robot Motor Control  
*Vicenç Gómez*

We propose a method to solve continuous-state problems applying the KL-control framework to a discrete, latent state. The method first learns a Hidden Markov Model representation of the model dynamics and solves the KL control problem in the latent space. The system’s control input is computed using the solution in the latent space in combination with a filtering step. We show initial results using this approach in two simulated robot tasks.

**Afternoon Session I**

**Bounded Rational Decision-Making in Changing Environments**  
*Jordi Grau-Moya*

A perfectly rational decision-maker chooses the best action with the highest utility gain from a set of possible actions. The optimality principles that describe such decision processes do not take into account the computational costs of finding the optimal action. Bounded rational decision-making addresses this problem by specifically trading off information-processing costs and expected utility. Interestingly, a similar trade-off between energy and entropy arises when describing changes in thermodynamic systems. This similarity has been recently used to describe bounded rational agents. Crucially, this framework assumes that the environment does not change while the decision-maker is computing the optimal policy. When this requirement is not fulfilled, the decision-maker will suffer inefficiencies in utility, that arise because the current policy is optimal for an environment in the past. Here we borrow concepts from non-equilibrium thermodynamics to quantify these inefficiencies and illustrate with simulations its relationship with computational resources.

**Abstraction in Decision-Making with Limited Information Processing Capabilities**  
*Tim Genewein*

A distinctive property of human and animal intelligence is the ability to form abstractions by neglecting irrelevant information which allows to separate structure from noise. From an information theoretic point of view abstractions are desirable because they allow for very efficient information processing. In artificial systems abstractions are often implemented through computationally costly formations of groups or clusters. In this work we establish the relation between the free-energy framework for decision-making and rate-distortion theory and demonstrate how the application of rate-distortion for decision-making leads to the emergence of abstractions. We argue that abstractions are induced due to a limit in information processing capacity.

**A Unified View of 'Soft' Optimal Control**  
*Brian D. Ziebart*

Much recent interest has been brought to bear on a class of algorithms that can be thought of as “soft” or approximate optimal control that balance uncertainty and information with optimality. Intriguingly, similar equations and approaches have been developed across multiple disciplines with each providing new insights. We survey the approaches, comparing and contrasting the assumptions, computational requirements and generality of each.
**Bot's Adventures in Empowerment**  
*Daniel Polani*

In the last decade, information-theoretic considerations have attained significant interest in modeling learning and other cognitive mechanisms. Though there are many arguments in favour of informational treatment of cognitive processing and learning, for instance evolutionary and general biological motivations, the connection to physics of computation, or, from a machine-learning point of view, PAC-Bayes type robustness arguments, one still often encounters the attitude that information theoretic models provide essentially only yarm ("yet another regularization method") and could be replaced by some other method of choice.

We would like to argue that information theory is more than just that: it is essentially a "language" in which cognitive dynamics can be expressed. By considering information as "first class object" of the universe of discourse, it opens the path to construct concepts which perhaps otherwise would not have been considered.

One salient example is "empowerment" which was introduced as the maximum amount of information an agent could (but does not have to) inject into its future world which it can later observe. It can be causally interpreted as the maximum "causal effect" that an agent can have on its environment, and know about it. It is, on one hand, an information-theoretic generalization of combined controllability/observability. Biologically, it can be interpreted as an "informational impedance match" of an organism's sensors and actuators in the niche of interest. Information-theoretically, it is simply a measure of the external channel capacity of the agent.

Empowerment has over the last years been demonstrated to work well in many scenarios in identifying salient or plausibly important states in the world of an agent, and is especially (but not exclusively) successful in survivability scenarios. The talk will visit some better-known and some lesser known as well as newer scenarios to demonstrate the versatility of the notion of empowerment. Via that it will emphasize the promise that a more aggressive use of the information-theoretic perspective holds.

**Afternoon Session II**

**An Adversarial Interpretation of Information-Theoretic Bounded Rationality**  
*Daniel D. Lee*

Recently, there has been a growing interest in modeling planning with information constraints. Accordingly, a decision maker maximizes a regularized expected utility known as the free energy, where the regularizer is given by the information divergence from a prior to a posterior choice probability distribution. While this approach can be justified in various ways, most importantly from statistical mechanics and information theory, it is still unclear how it relates to game theory. This connection has been suggested previously in work relating the free energy to risk-sensitive control and to extensive form games. In this work, we present an adversarial interpretation that is equivalent to the free energy optimization problem. The adversary can, by paying an exponential penalty, generate costs that diminish the decision maker’s payoffs. It turns out that the optimal strategy of the adversary consists in choosing costs so as to render the decision maker indifferent among its choices, which is a defining property of a Nash equilibrium, thus tightening the connection between free energy optimization and game theory.
Information-Theoretic Policy Search and Stochastic Optimal Control

Gerhard Neumann

A basic problem in policy search and reinforcement learning is how to choose the metric of the policy update. In our recent work, we use the relative entropy between the old and the new policy as such a distance metric which resulted in the relative entropy policy search (REPS) algorithm. In REPS we want to find the policy that maximizes the expected reward while bounding the relative entropy to the old policy. Due to the relative entropy bound, we fix the step-width of the policy update in the space of policies, where a policy is given as a conditional probability distribution over the actions given a state. As a consequence, we result in a smooth and stable policy update that shows an improved learning speed to most competing methods. This optimization problem can be applied to a wide variety of formulations of the reinforcement learning problem, from episodic policy learning to infinite horizon reinforcement learning to stochastic optimal control. We can also extend the relative entropy bound to not only act on the policy, but also on the resulting state distributions of the policies. Such extension allows for a new form of value function approximation that ensures that the approximation of the value function does not damage the resulting policy, that caused instabilities of most value-function based approaches. In this talk I will review all these different formulations of REPS and show first promising results.
Recommended Reading