Information and Communication
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Abstracts of talks

Amari, Shun-ichi: Information geometry, its differential-geometrical background and applications

Information geometry emerges from the studies of invariant geometrical structure in a family of probability distributions. Csiszar is a pioneer in this field, who proposed the idea of I-projection and studied the related geometry. Another line emerged from Rao' work, where a family of probability distributions was given structure of a Riemannian manifold and the Fisher information matrix played a fundamental role. The geometry was further developed by Centsov where non-metric affine connections were introduced from the point of view of invariance. The framework was developed by Amari and Nagaoka, where duality between a pair of two affine connections was established. This is a new concept in modern differential geometry.

The present talk gives a concise introduction to dual information geometry, focusing on dually flat manifolds and convex analysis. The dual structure of information geometry has wide applications, not only in information sciences, but also statistical inference, artificial intelligence and machine learning, neural networks, optimization analysis, and neuroscience. After a brief overview of information geometry, we survey the state-of the-art of applications of information geometry to various fields.

Ay, Nihat: Causal information flows and the common cause principle

Commonly used notions of information flow are based on mutual information which, however, quantifies general stochastic dependence without reference to the causal nature of information flow. In order to specify associations due to causal effects, interventional conditioning has to be applied. This idea leads to a new information flow measure which Daniel Polani and I recently introduced. Based on this measure, I discuss refinements of the so-called common cause principle. A first version of it relates general stochastic dependence among a set of random variables to a sum of information flows through "essential channels". A further analysis along this line, mainly developed by Bastian Steudel, yields structural constraints imposed by high stochastic dependence. More precisely, if the stochastic dependence exceeds a threshold value common causes of higher order can be inferred.

Barron, Andrew: MDL procedures with L_1 penalty and their statistical risk

We review recently developed theory for the Minimum Description Length principle, penalized likelihood and its statistical risk. An information theoretic condition on a penalty pen(f) yields the conclusion that the optimizer of the penalized log likelihood criterion log 1/likelihood(f) + pen(f) has risk not more than the index of resolvability, corresponding to the accuracy of the optimizer of the expected value of the criterion. For the linear span of a dictionary of candidate terms, we develop the validity of description-length penalties based on the L_1 norm of the coefficients.

Choda, Marie: Entropies for two subalgebras of operator algebras

We introduce a notion of entropy for two subalgebras A and B of an operator algebra M which we denote by h(A—B), which is a slight modification of the Connes-Stormer relative entropy H(A—B). If M is the n times n matrix algebra, A is the diagonal subalgebra and B is uAu* for a unitary u in M, then h(A—uBu*) equals to the entropy H(b(u)) of the unistochastic matrix b(u) defined by u. Here H(b) is the entropy for a bistochastic matrix b defined by K. Życzkowski, M. Kuś, W. Słomczyński and H.-J. Sommers. We show some results on h(A—B) from the view points of operator algebras.

Datta, Nilanjana: Min- and max- relative entropies and a new entanglement monotone

We introduce two new relative entropy quantities, called the min- and max-relative entropies. The well-known min- and max- entropies, introduced by Renner, are obtained from these. This leads us to define a new entanglement measure, which we refer to as the max-relative entropy of entanglement, and which is shown to provide an upper bound to the relative entropy of entanglement. Its properties are investigated. We also generalize the min- and max-relative entropies to obtain smooth min- and max- relative entropies. These act as parent quantities for the smooth Renyi entropies, and allow us to define the analogues of the mutual information, in the Smooth Renyi Entropy framework. Further, the spectral divergence rates of the Information Spectrum approach are shown to be obtained from the smooth min- and max-relative entropies in the asymptotic limit. We also define the smoothed max- relative entropy of entanglement and relate it to the regularised relative entropy of entanglement in the asymptotic limit.

Batle-Vallespir, Josep: Entanglement and Bell inequalities in three and four qubit systems (poster)

Broniatowski, Michel: Robustness of minimum divergence estimates and tests (based on joint work with A. Toma)

Through duality techniques it is shown that classical parametric statistics can be embedded in the field of divergence based estimators. Also some non-regular problems have convenient solutions when handled through divergence based inference. The class of dual ϕ-divergence based estimators and tests are explored with respect to robustness through the influence function approach. For scale and location models, this class is investigated in terms of trade-off between efficiency and robustness. Also, conditions for robust testing are presented.

Gütschow, Johannes: Clifford memory channels: a new approach to quantum convolutional codes

Quantum convolutional error-correcting codes [1] are a promising approach for reliable and efficient protection of quantum information. Yet their properties are not fully known. In this talk a new approach towards quantum convolutional codes will be presented; the representation of the encoders by clifford memory channels. Clifford channels can be described classically as symplectic transformations. The encoder is thus represented by a symplectic matrix as in [2]. With the formalism of forgetful memory channels [3] it is possible to derive a simple criterion for the catastrophicity of the encoder. Namely an encoder of a quantum convolutional code is completely non-catastrophic, iff the respective memory channel is strictly forgetful, i.e. the influence of the original memory input vanishes after finitely many uses of the channel. In the classic picture this property is represented by a nilpotent submatrix of the symplectic matrix representing the channel. As an example quantum turbo codes will be considered.

References

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György, András: Efficient tracking of the best of many experts (based on joint work with Tamas Linder and Gabor Lugosi)

In the framework for prediction of individual sequences, sequential prediction methods are to be constructed that perform (asymptotically) as well as the best expert from a given class. We consider the powerful class of switching strategies that can segment the given sequence into several blocks, and follow the advice of different "base" experts in each block. Our goal is to provide efficient prediction strategies even in the case when the set of base experts is large. Earlier work on this problem resulted in algorithms whose cumulative regret on a sequence of length n (with respect to the class of switching predictors) is of the order of $\log(n)$ for each switch of the best "meta"-expert, for large base expert classes of size polynomial in n (and even for some special infinite expert classes) and a large class of loss functions, including, e.g., exp-concave losses. However, these algorithms either have complexity that is linear in time and the number of base experts and thus cannot handle large base expert classes, or they admit efficient implementations for large expert classes at the price of quadratic complexity in n. In this work we give an algorithm that aims to unify the advantages of the above two approaches. This new algorithm has time complexity proportional to $n \log(n)$ and cumulative regret on the order of $\log^2(n)$ per switch, and is particularly suitable for large base expert classes. The new method generalizes a low-complexity algorithm by Willems for stochastic sources and the log loss. Among other applications, our method can be used to improve the performance-complexity trade-off in sequential lossless or limited-delay lossy source coding, and in sequential routing algorithms.

Harremoës, Peter: Rényi divergence and absolute continuity

A classical result in information theory is that information divergence given by an integral can be approximated by information divergences of discretized spaces. It is also known that this result can be extended to Rényi divergencess of order greater than 1. We shall show that it can also be extended to orders in $]0, 1[$. An interesting extension of this result is that P is absolutely continuous with respect to Q if and only if $D_\alpha(Q|P)$ tends to 0 for α tending to zero, and this result also holds if absolute continuity is replaced by continuity. An information theoretic proof of the Radon Nikodym Theorem will also be presented. Finaly we shall see to what extend these results can be generalized to cases where discretizations are replaced by Markov kernels that gives small distortion for some specified distortion function.

Hayashi, Masahito: Universal information protocols in quantum information theory

Csiszár & Körner unifiedly treated universal information protocols in the classical case by using the type method. In this talk, I will treat quantum universal information protocols by using group representation theory.

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K. Matsumoto, and M. Hayashi, "Universal distortion-free entanglement concentration," Physical Review A, 75, 062338 (2007).

Hiai, Fumio: Mutual information and mutual pressure

One of the most important quantities in information theory is the mutual information of two (or several) random variables. Another important one is the pressure for potentials, which is in dual relation with mutual information via Legendre transform. In the previous paper of Hiai and Petz (A new approach to mutual information, Banach Center Publications, Vol. 78, pp, 151–164), we provided a new expression of mutual information as a certain asymptotic limit via "discrete microstates" of permutations. In this talk I introduce a new notion of mutual pressure and its Legendre transform, and establish their exact relations with usual pressure and mutual information based on the Sanov large deviation.

Kafedziski, Venceslav: Applications of random ergodic operators in information theory

This lecture will summarize the results of our work in applying random ergodic operators to information theoretic problems, such as channel capacity and rate distortion of an information source. When deriving channel capacity of time invariant frequency selective channels or rate distortion of stationary sources, Toeplitz matrices arise. We consider more complex channels and sources: (i) frequency selective fading channels modeled as FIR (Finite Impulse Response) channels, where coefficient variation is described by stationary, ergodic processes, and (ii) autoregressive sources, where coefficient variation is described by stationary, ergodic processes. In our initial work from 1997, we used random matrix interpretation to derive capacity of the channels from (i) in terms of Stieltjes integrals with respect to limiting eigenvalue distribution function of channel matrices of increasing size. Subsequently, we employed the random ergodic operators, used in physics to study disordered systems, to derive capacity of the channels from (i) and rate distortion of the sources from (ii). By using results from the spectral theory of random ergodic operators, we were able to characterize the limiting eigenvalue distribution function. We also address capacity of MIMO (Multiple Input Multiple Output)

frequency selective fading channels, modeled as matrix FIR channels, and rate distortion of vector autoregressive sources, where, in both cases, coefficient variation is described by stationary ergodic processes. Random processes that characterize random operators arising in these cases are block stationary. By introducing the process stationary mean in place of process measure, we were able to solve these problems as well, by straightforward generalization of their scalar counterparts.

Koetter, Ralf: Separation in networks - a network coding perspective

Network coding, pioneered by Ahlswede, Cai, Li and Yeung is by now established as a tool in the operation of networks. The topic of this talk is the interaction of network coding principles with noisy channels. In the case of multicast connection this interaction has been studied by Song, Yeung, Cai and separately by Borade. In this talk we extend the separation results to arbitrary networks of point-to-point channels. Moreover we consider networks that include some simple multi-point to multi-point channels and provide bounds on their performance under separation.

Malyutov, Mikhail: Capacity of screening experiments under linear programming analysis

Screening experiments (SE) deal with finding a small number s of significant factors out of a vast total number t of inputs in a regression model. Of special interest in the SE theory is finding the so-called maximal rate (**capacity**) defined as $\log t/N(s,t,\gamma)$ such that a *random* $(N \times t)$*-design matrix with* $N \geq N(s,t,\gamma)$ *enables identifying* s *randomly chosen significant variables out of* t *with the probability exceeding* $1-\gamma$. The capacity was found asymptotically as $t \to \infty$ in a very general setting for the '**brute force**' analysis of experiments in (Malyutov(1979)) and its relation to the capacity region of Multiple Access Communication Channel was outlined. In this paper, we use a simple tractable linear programming relaxation instead of the brute force analysis, and we use simulations to approximate the quantity $N^*(s,t,\gamma)$ such that the same property as above holds, if $N \geq N^*(s,t,\gamma)$ for analysis of experiments using linear programming relaxation. We find that the linear programming relaxation is often successful in finding the significant variables, but the hypothesis $N^*(s,t,\gamma) = N(s,t,\gamma)$ is not supported by our simulation, i.e. it turns out that the capacity of screening under this practical method of analysis is less than that for the brute force analysis. We review also recent results on the capacity of nonparametric screening in general noisy models.

Malyutov, Mikhail: The MDL-principle in attributing authorship of texts (poster)

We study a new context-free stylometry-based attributor: the *sliced conditional compression complexity of literary texts* which is inspired by the incomputable Kolmogorov conditional complexity. Whereas other stylometry tools can occasionally almost coincide for different authors, our sliced CCC-attributor introduced in Malyutov (2005) is asymptotically strictly minimal for the true author, if the query and training texts are sufficiently large, universal compressor is good and sampling bias is avoided. This classifier simplifies the Ryabko and Astola (2006) homogeneity test (partly based on compression) **under the natural condition of insignificant difference between the unconditional mean complexities of training and query texts**. It is **consistent** under large text approximation as a stationary ergodic sequence which follows from the **lower bound for the minimax compression rate of piecewise stationary strings (Merhav (1993))**. After tuning both the texts' preprocessing and relative sizes (design) and our classifier in Malyutov, Wickramasinghe and Li (2007), we attributed the Federalist papers (Madison vs. Hamilton) in agreement with various previous established classifiers. We also showed there the *consistency* of the CCC-attributor for IID sequences by elementary combinatorial arguments and by simulation and used the **empirical CCC-asymptotic normality** (which can be justified along the lines of Szpankowski (2001)) for approximating the P-value of our inference. Some new attribution results were also included.

We demonstrate good discrimination on test example of CCC-divergence between different translations of Shakespeare sonnets into Russian, lack of discrimination on two short novels by the same author (who tried to mimic childish language in one of them) and show a significant difference in style of the two parts of M. Sholokhov early short novel (1925).

Matus, Frantisek: On the quadratic variance functions

The contribution focuses on the standard exponential families of probability measures (pm's) on Euclidean spaces that have finite supports and are parameterized by means. Limiting with the mean along a segment inside the convex support of such a family towards an endpoint on the boundary, a first-order approximation of the pm's is explicitly described. This provides insight into behavior of information divergences and variance functions around boundaries. Resulting expansions of variance functions at boundary points can be employed to prove that an exponential family has a finite support and quadratic variance function if and only if it is an affine transformation of the product of multinomial families.

van der Meulen, Edward: On bounding differences of mutual information via variation distance (based on joint work with V.V.Prelov)

We consider the problem of bounding the absolute value of the difference between the mutual information functions $I(X;Y)$ and $I(X';Y')$ of two pairs of discrete random

variables (X, Y) and (X', Y') via the variational distance between the probability distributions of these pairs. We thereby continue the investigations in [1, 2, 3] and report on some of the results obtained in [4]. Several upper and lower bounds on the maximum of $|I(X;Y) - I(X';Y')|$ are obtained via the variational distance, which coincide in some special cases. Our upper bound improves on the upper bound in [3]. Details, proofs, and further results can be found in [4].

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Mosonyi, Milan: Asymptotic hypothesis testing in correlated quantum lattice systems

Asymptotic hypothesis testing in its simplest form is about discriminating two states of a lattice system, based on measurements on finite blocks that asymptotically cover the whole lattice. In general, it is not possible to discriminate the local states with certainty, and one's aim is to minimize the probability of error, subject to certain constraints. Hypothesis testing results show that, in various settings, the error probabilities vanish with an exponential speed, and the decay rates coincide with certain relative-entropy like quantities. Apart from giving computable closed expressions for the error exponents, the importance of these results lies in providing an operational interpretation for the given relative entropy-like quantities. Here we present these equalities in the settings of Stein's lemma and the Chernoff and the Hoeffdings bounds for various classes of correlated states on square lattices, including certain finitely correlated states and the global Gibbs states of translation-invariant finite-range interactions in one dimension as well as fermionic quasi-free states in any dimension.

Narayan, Prakash: The Poisson fading channel (based joint work with Kaushik Chakraborty)

The Poisson fading channel is a model for a free-space optical communication link over which an information signal is transmitted by modulating the intensity of an optical beam, and individual photon arrivals are counted at the photodetector receiver. The

intensity of the transmitted optical signal undergoes "fading," caused by random variations in the refractive index of air arising from atmospheric turbulence. We consider a single-user single input single output shot-noise limited Poisson fading channel, in which the transmitted signal undergoes multiplicative fading over coherence time intervals of fixed duration, in each of which the fade coefficient (channel state) remains constant, and varies across successive such intervals in an independent and identically distributed fashion. We obtain the capacity of this channel when the receiver is provided with perfect channel state information (CSI) while the transmitter CSI can be imperfect. The special cases of perfect and no CSI at the transmitter are explicitly characterized.

Ogawa, Tomohiro: On statistical equivalence for sets of quantum states (based on joint work with Hiroshi Nagaoka)

A quantum channel (trace preserving CP map) is called sufficient (reversible) for a family of quantum states, if there exists a reverse channel which recover the original state from the output. In this case, we can say that the input/output families of quantum states are statistically equivalent. In the literature, several characterization of sufficient channel are known, that is, reversibility, preservation of information quantities, and the decomposition theorem.

On the other hand, for any given two families with the same parameter, we can not necessarily conclude that they are statistically equivalent even if information quantities are same. In this talk, we show a necessary and sufficient condition for statistical equivalence for any given families of quantum states.

Ohno, Hiromichi: Quasi-orthogonal algebras of matrix algebras

Abstract provided in separate file (very long).

Petz, Dénes: From f-divergence to quantum quasi-entropies

The f-divergence of two probability distribution was defined by Imre Csiszár in the 1960's. This was the motivation for Petz to introduce the quantum quasi-entropies in the 1980's. The lecture is an overview aboutthe monotonicity property which leads also to quantum Fisher information and covariance.

References

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Rásonyi, Miklós: Identifying AR(1) processes from imprecise measurements

We consider a Gaussian AR(1) process which is observed with a given precision h (i.e. we observe quantized values of the process only) and wish to investigate the consistency of the maximum likelihood estimator of the mean, the variance and the autoregression coefficient.

We establish geometric ergodicity of the predictive filter and a law of large numbers for the log-likelihood function, uniformly in the parameters.

Reischuk, Rüdiger: Learning-based steganography (based on joint work with Maciej Liśkiewicz and Ulrich Wölfel)

In order to embed secret messages reliably and without being detectable into unsuspicious covertexts, a stegosystem has to draw samples from a covertext source/channel to estimate the distribution. For stegosystems that use a black-box sampler (there is no a priori knowledge of the covertext distribution), an exponential lower bound (with respect to the length of the secret message) has been shown for the query complexity of the sampling procedure. However, it is assumed that the attacker has complete knowledge of the covertext distribution.

We consider a more fair and realistic situation where the stegoencoder and the attacker have the same state of knowledge concerning the covertext distribution. Both have to learn the distribution by sampling. It is investigated how algorithmic learning techniques can be used to design secure, reliable and computationally efficient stegosystems. Positive results are obtained one the one hand for covertext channels with simple descriptions (concepts and hypothesis spaces) and on the other hand for pseudorandom channels.

Ruszinkó, Miklós: Superimposed codes and related problems

A superimposed (n, t, r) code is a collection $\mathcal{C}$ of subsets of an n-set with $|\mathcal{C}| = t$, such that no set is contained in the union of r others. A superimposed (n, t, r) design is a

collection $\mathcal{C}'$ of subsets of an n-set with $|\mathcal{C}'| = t$, such that the unions of different at most r-tuples of subsets are different. In this talk we will survey old and new results about about these codes and designs and their relation to other mathematical problems.

Simonyi, Gábor: Additivity theorems for graph entropy

Graph entropy is an information theoretic functional on graphs that was introduced by Körner in the 1970's and was generalized to hypergraphs by Körner and Marton about 15 years later. One of its key properties that found several applications in combinatorics is that it is subadditive with respect to (hyper)graph union. Conditions of exact additivity were investigated in several papers and this talk is intended to be a survey of such additivity and related results.

Stramaglia, Sebastiano: Granger causality and the analysis of dynamical networks

Granger causality has become the method of choice to determine whether and how two time series exchange information. We propose a method of analysis of dynamical networks based on a recent measure of Granger causality between time series, based on kernel methods. The effectiveness of the approach is demonstrated on artifical and real data sets.

References

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Stummer, Wolfgang: Some distances between measures and stochastic processes, with applications

We first discuss some properties of a modified version of phi-divergences of finite measures. Special attention is drawn on generalizations of relative entropy (cross entropy, Kullback-Leibler information measure, Tsallis measure, Cressie-Read measure, power divergence). We also show some applications to random right censoring (used e.g. in medical and biological statistics). The second part of this talk is devoted to a fundamental study of Bregman distances between probability measures and stochastic processes, which are "extensions" of the Bregman distances between deterministic functions (used e.g. in industrial inverse problems concerning image reconstruction as well as finance). Several examples on statistically and mathfinancially important distributions will be given.

Topsøe, Flemming: Information and games

Information operates in the interface between Truth and Belief. If Belief is "shaky opinion", Truth is "less shaky opinion", rather than Absolute Truth. Anyhow, it is fruitful to think in more absolute terms with Truth lying beyond humans and generated by "Nature", "Reality", "God" - or you may choose other acronyms for what we do not understand but want to encompass by our mind. "Belief" is a simpler concept, representing knowledge accumulated by human endeavour and ingenuity.

When expressing philosophical speculations as above in mathematical terms, modelling by two-person zero-sum games appear as a natural choice. The players are Nature, a being without a mind but holder of Truth, and Observer, a human and as such provided with a mind but restricted to Belief.

Information Theory provides us with several examples of games of the nature indicated. They are connected with concepts such as capacity, redundancy and information projection.

Recently it was observed that an axiomatic approach is feasible which, though inspired by information theory, has a broader impact on optimization- and existence results of mathematics, including certain separation- and duality theorems. Also, the notion of an exponential family makes sense more broadly than for inference problems of probability and statistics and is closely related to the notion of Nash equilibrium.

The indicated connections are presently under development. The talk will aim at presenting the overall picture, probably with main emphasis on the notion of exponential families and on the route (either via Bregman-type constructions or via a new notion of interaction between Truth and Belief) to central concepts of non-extensive statistical physics.

To a great extent, the topics outlined will relate to the interests and results of Csiszar as expressed in his many publications related in one way or another to issues here indicated.

Vajda, Igor: Divergence-based statistical decisions

Divergences of distributions: From Shannon to Kullback, Rényi and Csiszár. Decision information: Divergence of hypothetic and empirical distribution. Divergence statistics. Maximum likelihood method. Representation and approximation of divergence statistics: hypothetical expectation, smoothing by additive noise, hypothetical quantization, empirical quantization. General minimum divergence method.

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Vajda, István: Growth optimal portfolio selection strategies with transaction costs (joint work with László Györfi)

Discrete time infinite horizon growth optimal investment in stock markets with transactions costs is considered. Cover and Iyengar published the pioneering work on the problem of horse race markets, where in every market period one of the assets has positive pay off and all the others pay nothing. Their model included proportional transaction costs and they used a long run expected average reward criterion. In the case of discrete time, the most far reaching study was done by Schäfer who considered the maximization of the long run expected growth rate with several assets and proportional transaction costs, when the asset returns follow a stationary Markov process. In contrast to the previous literature we assume only that the stock processes are modelled by homogeneous Markov processes. We also step forwards from expected growth rate: showing two recursive investment strategies such that, in the long run, the growth rate on trajectories is greater than or equal to the growth rate of any other investment strategy with probability 1.

Winter, Andreas: New results on quantum identification and approximate randomization (based on joint work with Patrick Hayden)

One of the central insights about quantum error correction is that the existence of a decoding operation for a channel is equivalent to the complementary channel (to the environment) being randomising. Here we determine a matching duality for the weaker property of the complementary channel being approximately randomising. It turns out that

the main channel then still preserves the pairwise fidelities between input states. This is closely related to the task of identification, where the receiver only wants to simulate measurements for any pure state and its complement. We prove that the entanglement-assisted capacity is an upper bound on the quantum identification capacity of a channel, and show achievability, if correctly interpreted.

Zheng, Lizhong: Simplified geometry of some information theory problems

Modern information theory, concerning either networked applications or communication over dynamic environments, often requires the understanding of variations in high dimensional probability distributions. The approach to understand or simply to describe such problems, based on large deviations, leads to the development of a natural geometric view the space of distributions. We argue that such geometric view, to develop notions of inner products, projections, and coordinate systems for distributions, is a crucial tool needed in the current research. We demonstrate that an over simplified approach, by simply focusing on the local geometry, gives some valuable insights to some well known problems, including the design of universal receivers for compound channels, as well as Gaussian broadcasting channels.