

## Statistical methodology in decision sciences\*

The idea behind the meeting on 'Statistical Methodology in Decision Sciences' was to get together a group of statisticians and probabilists on one hand and engineers on the other to talk about topics of common interest, with a view to learn from each other and to foster interaction. The format was that a few individuals from either discipline gave a short series of lectures on some relevant topic, leaving plenty of time for discussion.

Rahul Roy's (ISI, Delhi) lectures covered minimal spanning trees in probability. Beginning with the classical computer science algorithms, he introduced minimal spanning trees on random graphs and gave a complete exposition of the strong law of large numbers for these. This was based on the work of Aldous and Steele, with some important simplifications by Roy's colleague, Aneesh Sarkar. He also mentioned the central limit theorem for minimal spanning trees on random graphs, a recent result from his own joint work with his colleague, Abhay Bhatt.

Ramesh Hariharan's (IISc) lectures dealt with rapidly mixing Markov chains and combinatoric algorithms. He introduced the notion of rapid mixing for Markov chains and its significance in combinatorial algorithms and gave a detailed exposition of two main techniques for verifying rapid mixing: the method of canonical paths and the method of coupling, developed by Jerum, Sinclair and others. He did so using random walk on the permutation group as a running example, which brought out the underlying ideas very clearly. Hariharan briefly mentioned his own contributions to the area with his student Anilkumar. He also gave an exposition of techniques for exact sampling from the stationary distribution of a Markov chain using backward coupling, based on the work of Propp and Wilson.

T. Krishnan (ISI, Chennai) spoke on the EM (Expectation–Maximization) algorithm and its engineering applications. He introduced the EM algorithm as a scheme for doing maximum likelihood estimation with missing data, illustrating it by means of a simple example. He presented a detailed convergence analysis of the algorithm, and then dealt in some detail with its applications to unsupervised pattern recognition, positron emission tomography (PET), hidden Markov models in speech recognition and neural network training, mentioning *en passant* application to active noise cancellation. He highlighted some standard pitfalls in the application of the scheme. His talks were supplemented by a brief presentation by Samudravijaya (TIFR) on the details of how hidden Markov models are applied in existing speech recognition systems.

Abhinanda Sarkar (IBM India Research Centre, Delhi) discussed 'Function estimation: from linear regression to wavelets'. Beginning with the simplest regression problem, that of linear regression, he introduced the bias–variance trade-off and motivated the use of wavelets for nonlinear regression, leading to the wavelet-based regression scheme suggested by Donoho and Johnstone. He also gave an account of his own work with Sudeshna Adak (Harvard) on time–frequency analysis of financial data, which combines ideas from tree-based classification techniques with regression. His lectures were supplemented by concrete demonstrations of application of these techniques to actual data on a laptop.

Vinod Sharma (IISc) lectured on large deviations with applications to communication networks. He introduced the basic large deviation theorems, viz. Cramer's theorem and Gartner–Ellis theorem, sketching the proof of the former in some detail. He then introduced the contraction principle and the Dawson–Gartner projective limit theorem, using these to arrive at Mogulskii's theorem for sample path large deviations. He also mentioned large deviation principles for Brownian motion: Schilder's theorem for small noise asymptotics and the Friedlin–

Wentzell theorem for exit time from a domain, indicating their extensions to stochastic differential equations. As applications to communication networks, he described the work of Kavita Ramanan and Dupuis on large deviations for the diffusion limits of queuing networks, the work of Majewski which establishes the robustness of such results, and his own recent work with colleagues on performance analysis of RED, the random packet dropping scheme for congestion control which is gaining wide acceptance.

P. S. Sastry (IISc) covered support vector machines. This is perhaps the most important development in pattern recognition in recent years. Introduced by Vapnik (Lucent Tech.), this is an algorithm for two-class classification problems that yields tremendous computational advantage over older methods when the problem size is large. Sastry indicated how the classification problem can be cast as an optimization problem that seeks to maximize the separation between a pair of hyperplanes that separate the two classes. Dualizing this problem, one arrives at the support vector machine algorithm, named thus because it effectively operates in the space dimension equal to the number of support vectors, i.e. the vectors that lie on the classification boundaries given by the maximally separating pair of hyperplanes. This number is usually much smaller than the total number of examples, hence the computational gain. Sastry sketched the currently popular variations of the algorithm, including the case of possible misclassifications. Finally, he outlined how this is a natural outgrowth of Vapnik's theoretical work on statistical learning theory.

V. S. Borkar (TIFR) dealt with learning algorithms for Markov decision processes, beginning with an exposition of the stochastic approximation algorithm and its variants. He gave examples from 'increasing return' economics, evolutionary games, neural networks, statistics and electrical engineering, where such stochastic dynamics is encountered. He then described the 'ODE' (Ordinary Differential Equations) approach for analysing stability and convergence of these algorithms. Borkar

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briefly sketched issues and results pertaining to unstable equilibria and other more general attractors, rates of convergence, bias-variance trade-off and the effect of step-size on these, and motivation for and analysis of multiple time scale and distributed algorithms. He then introduced Markov decision processes, giving an overview of the dynamic programming approach and the associated iterative algorithms. He highlighted the need for reinforcement learning schemes when the exact model is unknown and gave a brief account of the two main strands of such schemes: Q-learning and actor-critic methods, in the context of discounted cost problems.

Mohan Delampady (ISI, Bangalore) gave two talks. The first was on Bayesian analysis of Poisson counts wherein he described his recent work based on a hierarchical Bayesian model using two alternative techniques, importance sampling for accelerated Monte Carlo and a saddle point approximation. The second talk was on the correlation between a parameter and its estimate, where he indicated how this makes sense in a Bayesian framework and can lead to useful performance criteria.

There was also an evening popular lecture by Ayesha Kidwai (JNU) on 'Modelling the language instinct: a case for universal grammar', wherein she

described the issues in language acquisition that lead to Chomsky's theory of universal grammar. The rather strong dose of technical discourses was punctuated by a trek in the Dubare forest, several walks in and around the plantation, a social evening with a bonfire, and daily chat sessions by the poolside. It is hoped that this meeting has built bridges across the disciplines which will last (and be used) well into the future.

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## Vetiver grass technology for environmental protection and sustainable development

Vetiver plant (*Vetiveria zizanioides* L. Nash.), a native grass of India has been extensively used for land protection and an essential oil used in perfumery industry (Figure 1). Systematic efforts to develop applications of Vetiver Grass Technology (VGT) to mitigate soil erosion and water conservation were first initiated in India in 1986 through several World Bank-funded projects in the low rainfall areas. Researches conducted over the last 10 years demonstrate that VGT is one of the most effective and natural low cost methods of environmental protection. Lately, in view of its ecofriendly nature, vetiver grass has found new uses for construction purposes (bioengineering) and remediation of contaminated sites (phytoremediation). The 2nd International Conference on Vetiver: Vetiver and Environment (ICV-2) was organized in Thailand from 18 to 22 January 2000, by the Royal Projects Development Board, Bangkok. The conference was attended by 325 participants from 31 countries. Besides scientific deliberations, one of the most important attractions of the conference was the technical tour to vetiver project sites. In all 10 plenary lectures were followed by panel discussion on experience in putting together countrywide vetiver programme, policy issues, expectations and

results (6 presentations); vetiver and natural disaster (4 presentations); reports on regional and national networks (9 presentations). The conference theme was divided into three paper sessions: (i) Soil and water attributes (16 papers), (ii) Basic research and general studies (14 papers), and (iii) other topics (16 papers) covering 7 broad topics, and a poster session (34 posters). The concluding session had projection about the theme of the next conference and recommendations.

In his opening plenary lecture, Richard Grimshaw (Vetiver Network, USA) emphasized that ever since the first pilot testing of VGT in India in 1986, currently 138 countries know about this technology, 100 are using it in one form or the other, over 800 NGOs and an equal number of government agents are associated with the use of VGT. In 1986, VGT was solely applied as a erosion control measure. In the year 2000 it was used for highway stabilization, mine land rehabilitation, river, canal, drainage bank stabilization, sea shore stabilization, wind breaks, pollution control mitigation associated with municipal trash dumps, and housing construction site stabilization. There is an increasing involvement of private sector in the establishment of VGT enterprises that serve the engineering sector.

Diti Hengchaovanich (APT Consult Company, Bangkok) highlighted the unique characteristics of vetiver *vis-à-vis* its utility as bioengineering option for environmental conservation and protection. He further supplemented a remark that 'Vetiver is a living wall' and illustrated its unique properties with respect to tensile strength and growth pattern of its roots. He provided evidence that the grass is able to form a dense hedge within 3-4 months, resulting in the reduction of rainfall run-off velocity, and an effective sediment filter. Its vigorous, massive and dense subterranean root network reaches vertically from 2 to 3 m depth facilitating soil binding and aeration. Further, in view of growing interest of plants for phytomining and phytoremediation/rehabilitation of contaminated soil and wetlands<sup>1</sup>, he emphasized use of vetiver to rehabilitate gold, platinum, coal and other mines. Realizing the significance of VGT for rehabilitation of landfills, Diti Hengchaovanich mentioned that a test section has been established for planting of vetiver at a major landfill at Kamphaengsaen, 90 km northwest of Bangkok, where 5000 t of garbage is being dumped. It has been observed that vetiver plants were able to survive fairly well, despite the presence of leachate and high toxicity. Paul N. V.