PNLD 2013: Conference summary and a perspective

PNLD 2013, the fourth of the Perspectives in Nonlinear Dynamics conferences, was held in Hyderabad, India from July 15 to July 18, 2013. Like previous editions of this meeting, it was a satellite to STATPHYS 25 (held in Seoul, South Korea); the linkage between these two series of conferences started when PNLD 2004 (Chennai) and STATPHYS 22 (Bangalore) were held in successive weeks. The pattern continued with PNLD 2007 (Trieste, Italy) and STATPHYS 23 (Genoa), and then PNLD 2010 was held in Bangalore, with STATPHYS 24 being held in Cairns, Australia. As we mentioned in the report on the last PNLD, much of the initial impetus to study nonlinear dynamical systems arose from considerations of statistical physics. The connection between the two families of meetings has worked to our advantage, helping to focus attention and helping to highlight important issues in nonlinear science studies in a sustained manner.

The scientific programme for the meeting consisted of about 25 invited talks and an equal number of contributed talks, and about 60 poster presentations. The conference attracted over 120 participants from about 10 countries. We present here a brief report on the meeting, as well as a summary of the proceedings.

The diversity of talks captured the breadth and interdisciplinarity of the field of nonlinear dynamics and complex systems, and therefore complex networks and coupled nonlinear systems formed a large component of the conference programme, as can be seen from this volume. Acharyya and Amritkar have extended the master stability function approach to analyse the stability of generalized synchronization for coupled oscillators that were nearly identical. From the resulting stability criteria they construct optimal networks with better synchronization properties, with the optimized networks being found to be disassortative in nature. Manish Agrawal investigated the effects of symmetry-preserving and symmetry-breaking interactions in a drive–response system under driving-induced bistability, with the coexisting attractors displaying both in-phase as well as antiphase synchronies. Indrani Bose and Mainak Pal reviewed examples of regime shifts in natural systems and their associated early signatures. They further discussed how such approaches provide useful insights on a cell biological process involving the fold-bifurcation. Pranay Goel presented a realistic model of bursting behaviour of beta-cells in the pancreas, dealing with excitable dynamics. Ranjib Banerjee, E Padmanaban and Syamal Dana presented a coupling designed to control partial synchronization in two chaotic oscillators in a driver–response mode. Numerical examples of an ecological model were presented, along with demonstration in an electronic circuit. Choudhary, Kohar and Sinha reviewed their recent work on the prevention of catastrophes in spatially extended systems through dynamic switching of random interactions. These results have suggested useful mechanisms to suppress blow-ups in complex networks. Hens *et al* reported the existence of a chimera state in an assembly of globally linked identical nonlinear oscillators in a simple planar cross-coupled form. The rotational symmetry breaking of the coupling term appears to be responsible for the emergence of these collective states that display a characteristic coexistence of coherent and incoherent behaviour.

Neeraj Kamal, Pooja Rani Sharma and Manish Shrimali have studied the role of mean-field diffusive coupling on suppression of oscillations for systems of limit cycle oscillators. They showed that this coupling scheme not only induces amplitude death but also oscillation death in coupled identical systems. Kamal and Sinha presented results on diversity-induced coherence in the spike events, with an optimal amount of parametric heterogeneity at the nodal level yielding the greatest regularity in the spike train. These results indicate that the largest coherence in the spike events emerge when the coupling strength is high, and when the underlying connections are mostly random and dynamically changing. Cerdeira and coworkers presented results on synchronization enhancement via an oscillatory bath in a network of self-excited cells. This indicates the possibility of using a dynamic environment to achieve and optimize phase synchronization in a network of self-excited cells with free-end boundary conditions. Saha, Ganguly and Guria discussed coverage maximization under resource constraints using proliferating random walks. These results are relevant to the dissemination of information in communication networks.

Four articles focus on the random matrix approach to understanding and characterizing complex systems. Sarika Jalan provided an overview of the importance of random matrix framework to complex systems research with biological systems as examples. Bhadola and Deo studied the Penner interaction, known in studies of moduli space of punctured Riemann surfaces, in the context of random matrix model of human RNA. Chavda presented a study of the distribution of level spacing ratios using one- and two-body random matrix ensembles, while Sunil Kumar and Nivedita Deo applied random matrix theory to investigate the structure of cross-correlation in 20 global financial time series after the global financial crisis of 2008. The usual connection between random matrices and quantum chaos did not attract much attention, though a few presentations were focussed on quantum chaos. The quantum mechanics of simple quasi-integrable systems was the focus of Sudhir Jain's presentation, wherein he looked at the level spacings of such billiards. Arul Lakshminarayan dealt with the connection between quantum chaos and entanglement. Transport in one-dimensional chains has been extensively studied in recent years, and Tomasz Prosen presented his work on driven lattice gases which allow for non-trivial exactly solvable (integrable) instances of non-equilibrium steady states. Haris Skokos also presented a related study on chaos in disordered nonlinear lattices.

There are two papers on integrable systems and solitons. The first by Kanna *et al* focusses on the formation of solitons, their propagation and collision behaviour in multicomponent long wave–short wave resonance interaction system. The second paper by Vishnupriya, Senthilvelan and Lakshmanan deals with breathers and rogue waves in coupled nonlinear Schrödinger family of equations.

A number of talks focussed on the very current area of 'active matter'. Francesco Ginelli highlighted the importance of nonlinearity in the study of active matter, particularly with reference to a continuum version of the Vicsek model. Sriram Ramaswamy spoke about novel instabilities in active membranes. Some of the same issues were highlighted by Madan Rao in his work on cell surface organization. Phase coherence in oriented active matter formed the subject of

Sebastian Fürthauer's presentation on nanoscale molecular motors and micron-sized swimming micro-organisms. Unfortunately, none of these presentations resulted in contributions to this volume.

Broader and more formal questions were also addressed. In this direction, Ouellette examined empirical questions for modelling the collective behaviour of groups of social animals; this has been an active topic of study across many disciplines. He posed a set of questions, and by explicitly stating the choices made in response to each of these questions, models can be more easily categorized and compared, and their expected range of validity can be clarified. Balasubramanian, Nair and Nagaraja presented a classification of periodic, quasiperiodic, chaotic and random sequences using approximate entropy and Lempel–Ziv complexity measures. These results contribute to the understanding and use of such measures as a signal diagnostics tool. Carineña, Ghose-Choudhury and Guha gave a geometrical description of the virial theorem of statistical mechanics using the symplectic formalism. Specifically they determined the character of the Clausius virial function for Lienard-type equations.

There were three contributions in the area of fluid dynamics. Kiran Kolwankar *et al* investigated the effect of a heat source on the growth of dendritic drying patterns, by shining a tightly-focussed but low-powered laser beam on an absorber dispersed in biologically relevant fluids. They observed that the growth velocity of branches in the dendritic patterns can decrease below the value expected for natural drying. Samriddhi Shankar Ray presented an overview of the connection between thermalized solutions, statistical mechanics and turbulence, through detailed studies of finite-dimensional, Galerkin-truncated equations of hydrodynamics. He discussed recent developments in this direction, as well as open problems for the future. Perlekar spoke about his recent work on turbulence-induced coarsening in binary mixtures. Thampi and Govindarajan's study of rolling motion in moving droplets figures in this collection of articles. Their results provide an answer to a natural question of whether drops roll or slide on a surface and carry implications for various applications where rolling motion may or may not be preferred.

Lastly, there were a number of talks that focussed on applications. Herbert Levine gave an exciting presentation on the movement of cells, bringing concepts from statistical physics, nonlinear processes as well as multiphase fluid dynamics to give some quantitative understanding of how cells aggregate in the Dictyostelium amoeba. Chakrabarty and Kar examined the bifurcation behaviour of a single-phase induction motor, a system that is widely used in domestic and commercial applications. Their study provides a picture of the dynamical behaviour of the system under change of parameters, and may be useful in controlling the operation of the induction motor. The nonlinear dynamics of pulse combustors – an unusual application of nonlinear science in power engineering – was reviewed by Mondal, Mukhopadhyay and Sen. Cross, Kenig and Allen reviewed their recent theoretical results on using nonlinear dynamics and pattern formation to reduce the effects of noise and improve the frequency precision of oscillators, with particular reference to ongoing experiments on oscillators based on nanomechanical resonators. They further discussed, using resonator nonlinearity, novel oscillator architectures, and the synchronization of arrays of oscillators, to improve the

frequency precision. Subash, Chandrasekar and Lakshmanan focussed on the collective dynamics of synchronized arrays/networks of spin-transfer nano-oscillators (STNO). They enhanced efficiency by applying a common microwave magnetic field to an array of STNOs. In order to make the system technically more feasible, they established suitable electrical connections between the oscillators as well. The transition from low-amplitude, aperiodic, combustion noise to high-amplitude, periodic, combustion instability in confined combustion environments was studied experimentally using two laboratory scale turbulent combustors. This work was presented by R I Sujith. Shashi Thutupalli gave a fascinating presentation on an experimental realization of chimera states in a system of metronomes in a two-dimensional lattice. His experiments suggest a link between the origins of synchronization and the occurrence of chimera states. The final talk by M H Jensen on vorticity patterns induced by cell division in tissues brought together the areas of biology, nonlinearity, pattern formation and hydrodynamics, giving a panoramic view of the range of applications wherein the ideas of nonlinear dynamics were crucial.

Dr Pranay Goel and Dr Skokos had wanted to contribute articles on their talks (on excitability in the pancreatic islets of Langerhans and on disordered nonlinear lattices, as mentioned earlier) to this volume, but were unable to do so. There were several other interesting talks which also regrettably did not result in contributions to this volume. These included G Casati's discussion of the application of dynamical systems methods to heat transport, Clemens Gneiting's discussion of optimal coherent control to counter dissipation, S Bannerjee's discussion of discontinuous maps and their circuit realizations, E Kaniusas's talk on the effects of nonlinearties on biomedical engineering sensors, F Ginelli's talk on continuous theories of active matter, Awadhesh Prasad's talk on amplitude death in coupled nonlinear systems, P Gade's talk on persistence exponents in continuous systems and R E Amritkar's discussion of extreme-value statistics on networks.

The conference ended with a round table discussion that focussed on the perspectives of some of the participants regarding nonlinear dynamics, and it was very heartening to note that speakers shared their viewpoints both on the technical aspects of the subject, and also on what could be done to strengthen the subject. Herbert Levine made the point that the diversity of the field is both its strength and its weakness, pointing out that applications are the key to further progress in the subject. Ecology and neural systems are areas where applications of nonlinear dynamics can yield the most fruitful insights. Møgens Jensen said that the methods of nonlinear dynamics provide an extensive tool box that could be applied to many problems. He said that the dynamics of extended systems provided many open problems, and also felt that neural systems and biological applications are the direction in which much progress could be made. Commenting on the way in which the field was perceived by those outside the area, he pointed out that nonlinear science has a very low profile due to the lack of recognition in terms of awards and honors: there has been no Nobel prize awarded for any work in the field and something like 80% of the Physics Nobel prizes go to work in the area of high-energy physics, and another 20% to quantum problems. Giulio Casati also enlarged on the theme of the profile and relevance of the field.

He advised practitioners to focus on problems which are pressing in the view of funding agencies. Examples of these are energy-related problems, ecosystems and climate studies. He also said that he would advise young researchers getting in the field to stay in contact with more traditional disciplines.

Mike Cross drew attention to quantum coherence problems which may require the use of techniques from the nonlinear dynamics. Other techniques from the field which could make a strong contribution were data mining and visualization techniques, as well as statistical tools. Sriram Ramaswamy, basing his comments drawn from his impressions on the talks at the conference, said problems of synchronization were important. He noted that active matter was an area where there was much potential for future development, notably with flocking, swarms and self-organization being important to understand. He highlighted the fact that nonlinear dynamics was an area where there was a constant close association between theory and experiment: this was one of the strongest points of the discipline.

In summary, the PNLD 2013 programme was extremely successful, resulting in lively discussions and leading to several fruitful collaborations. The Indian Academy of Sciences has kindly agreed to bring out the proceedings in the present issue of the journal Pramana. We hope this record of the conference will make a lasting contribution to the nonlinear dynamics activity in this country.

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