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NONLINEAR SCIENCE AND COMPLEXITY

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IN ALPHABETICAL ORDER OF THE SCIENTISTS WHO PRESENT THEM

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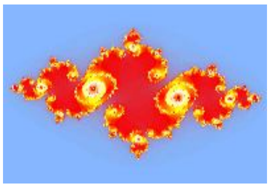

ABSTRACTS OF LECTURES

(in alphabetical order of first author)

ELEMENTS OF FINANCIAL MATHEMATICS

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We present the basic elements of financial mathematics. We first determine the financial assets and try to develop their utility through real situations. We then pass to a quick overview of the three basic tools of "modern" economic theory. We finally formulate the general problem as the satisfaction of a terminal condition.

BIOLOGICAL STRUCTURES MITIGATE CATASTROPHIC FRACTURE THROUGH VARIOUS STRATEGIES

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It has been recently argued by several research groups that load-bearing mineralized hard tissues, including bones, shells, and teeth, are nanocomposites, in which the mineral phase has nanoscale dimensions that ensure optimum strength and flaw tolerance. In particular, it has been claimed that the thickness of these brittle building blocks, being smaller than a critical size of the order of tens of nanometers, renders them insensitive to the presence of crack-like flaws and enables them to achieve near-theoretical strength, which is why Nature employs nanoscale features in mineralized biological composites. I find this point of view unpersuasive and present several counterexamples which show that biological structures, as a result of being comprised of relatively fragile constituents that fracture at stress levels several orders of magnitude smaller than the theoretical strength, adopt various strategies to develop mechanical responses that enable them to mitigate catastrophic failure.

The first example involves the fracture toughness of mollusks. These natural composite materials are renowned for their mechanical strength and toughness; despite being highly mineralized, with the organic component constituting not more than a few percent of the composite material, the fracture toughness exceeds that of single crystals of the pure mineral by two to three orders of magnitude. The judicious placement of the organic matrix, relative to the mineral phase, and the hierarchical structural architecture extending over several distinct length scales both play crucial roles in the mechanical response of natural composites to external loads. Experimental and theoretical results are first used to show that the resistance of the shell of the conch *Strombus Gigas* to catastrophic fracture can be understood quantitatively by invoking two energy-dissipating mechanisms: multiple cracking in the outer layers at low mechanical loads, and crack bridging in the shell's tougher middle layers at higher loads. Both mechanisms are intimately associated with the so-called crossed lamellar microarchitecture of the shell, which provides for tunnel cracking in the outer layers and uncracked structural features that bridge crack surfaces, thereby significantly increasing the work of fracture, and hence the toughness, of the material. Despite a high mineral content of about 99% (by volume) of aragonite, the shell of *Strombus Gigas* can thus be considered 'ceramic plywood' (albeit plywood fails in a different manner than the shell), and can guide the bioinspired design of tough, lightweight structures. A modest attempt to mimic the crossed-lamellar structure using microelectromechanical systems (MEMS) fabrication techniques is described. The prototype beam structure, which relies on polycrystalline silicon (photoresist) to take the role of the mineralized tissue (proteinaceous matrix), is mechanical tested under displacement control using a nanoindenter. While the model structure involves only two distinct length scales, it shows graceful failure.

The second example involves bone, whose constituents have relatively large compliances that result in relatively ineffective crack bridging mechanisms. We demonstrate that bone is intolerant to the presence of cracks of macroscopic length, and thus mitigates the catastrophic structural failure that would result from the growth of cracks of measurable size through continuous biological resorption-regeneration healing cycles of the hydroxyapatite mineral phase. We argue that resorption reduces the stress intensity at sharp cracks and flaws, thereby reducing, by osteoclasis, the risk of crack propagation, and that this strategy of survival is little affected by the nanocomposite structure of the load-bearing mineral phase.

A NEW PARADIGM FOR CRYSTALLIZATION: RECENT INSIGHTS COMING FROM SELF-ORGANIZATION VIA COMBINED STRUCTURE AND DENSITY FLUCTUATIONS IN COMPLEX MATTER.

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Nanosize complex matter materials, like protein solutions, zeolites and certain other forms of colloidal-like complex plasmas, are difficult to crystalize. Recent experiments on protein crystallization show that the formation of the macroscopic patterns of crystalline phase is, indeed, affected by the early nucleation stages. In this early nucleation stages anisotropic critical nuclei and/or clusters of nanoparticles, have been observed. Such evidence of the presence of a second liquid phase, suggests that kinetic effects significantly influence the yield and rates of nucleation. The above nonstandard nucleation mechanism with combined structural and density fluctuations suggests crystallization experiments via favourable pathways in the two order-parameter phase-diagram, where the intermediate fluid phase exerts its enhancing action. On the other hand, recent understanding that complex plasmas behave as colloidal systems and even afford several intermediate states allow for a new line of approach to systems of microplasma particles that self-organize in crystaline states and even afford the application of a few-degrees-of-freedom Hamiltonian formalism.

PHYSICS AND COMPLEXITY

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The concept of complexity has been introduced to explain the failure of the Physics reductionist approach to describe the human-scale Nature. This has been pointed out by the properties of the living matter that is certainly physically based but there is no hope whatever of predicting the behavior only by the underlying physical laws. In our opinion, even if we have a satisfactory fundamental "physics theory of everything", this situation remains unchanged. Therefore, the Physics of living matter opens a new research field where new concepts and new mathematical tools have to be introduced. We use the fundamental features of the living matter to define what are the universal features of a complex system: many degrees of freedom, non linear stochastic dynamics, hierarchical levels structure, non-equilibrium boundary conditions, information based interactions and long range spatial-temporal correlations. We describe the main mathematical tools that are actually used to build models of complex systems: nonlinear stochastic dynamical systems, reaction diffusion equations, agent based models and networks. We outline also a methodology that is usually performed in the construction of a complex system model. Some dynamical properties of complex systems like self-organizing phenomena and emergent properties are presented using simple examples.

APPLICATION OF COMPLEXITY SCIENCE TO URBAN SYSTEMS

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The City is certainly a complex system. It has been realized that reductionist global models are not suitable to describe the urban dynamics whose complex nature implies the presence of emergent properties due to physical interactions and free will of citizens in the urban space. The governing of a modern metropolis is one of the main problems due to the obvious relation with the quality of life. In particular the urban mobility is a fundamental aspect and its modeling requires a multidisciplinary approach. We propose a microdynamical model for urban mobility that takes into account the tendencies and the "intelligent behavior" of citizens. The model has the possibility of choosing among different kinds of mobility (pedestrian, public transportation, private cars). The interaction with the urban space is performed by introducing the concept of "chronotopos", i.e. a macroscopic urban area with time - scheduled activities caused by the required citizens' mobility. The aim of the model is to create a virtual laboratory where the "new physical laws" of urban mobility can be studied taking advantage of the complex systems theory.

STABILITY AND CHAOS IN MULTI – DIMENSIONAL HAMILTONIAN SYSTEMS

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In this lecture, I discuss some aspects of the problem of the stability of motion of N - degree of freedom Hamiltonian systems. It is topic with a long history, which continues to be of interest due to its relevance to many applications. Starting with N small, I shall proceed to the case of N arbitrarily large, in an attempt to understand the thermodynamic limit, where $N \to \infty$ and statistical mechanics is expected to take over from classical mechanics. Of primary importance in this discussion is the connection between local and global dynamics, i.e. the relevance of events occurring in small – scale regions of the energy surface to the stability of motion in large domains affecting the properties of the system as a whole. This link is provided by a study of what I call Simple Periodic Orbits (SPOs), i.e periodic solutions oscillating with equal frequencies and returning to the same values after a single maximum (and minimum) over one period. Applying Lyapunov's theory of the continuation of normal modes of N – degree of freedom Hamiltonian systems to the famous Fermi – Pasta – Ulam (FPU) lattice, I shall explain how these SPOs help us resolve the paradox of the FPU recurrences. I will then discuss how the study of other SPOs, corresponding to in – phase and out – of – phase motions in the FPU and other Hamiltonians, shed new light on the transition to large scale chaotic behavior characterized by invariant spectra of Lyapunov exponents.

COMPLEXITY IN BIOLOGY: SCALE FREE SYSTEMS

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A key aim of post genomic biomedical research is to systematically catalogue all molecules and their interactions within a living cell. There is a clear need to understand how these molecules and the interactions between them determine the function of this enormously complex machinery, both in isolation and when surrounded by other cells. Rapid advances in network biology indicate that cellular networks are governed by universal laws and offer a new conceptual framework that could potentially revolutionize our view of biology and disease pathologies in the twenty-first century.

Basic network nomenclature

The behaviour of most complex systems, from the cell to the Internet, emerges from the orchestrated activity of many components that interact with each other through pair wise interactions. At a highly abstract level, the components can be reduced to a series of nodes that are connected to each other by links, with each link representing the interactions between two components. The nodes and links together form a network, or, in more formal mathematical language, a graph. Establishing the identity of various cellular networks is not trivial. Physical interactions between molecules, such as protein–protein, protein–nucleic-acid and protein–metabolite interactions, can easily be conceptualized using the node-link nomenclature. Nevertheless, more complex functional interactions can also be considered within this representation. For example, small molecule substrates can be envisioned as the nodes of a metabolic network and the links as the enzyme-catalysed reactions that transform one metabolite into another

Networks that are characterized by a power-law degree distribution are highly non-uniform, most of the nodes have only a few links. A few nodes with a very large number of links, which are often called hubs, hold these nodes together. Networks with a power degree distribution are called scale-free, a name that is rooted in statistical physics literature. It indicates the absence of a typical node in the network (one that could be used to characterize the rest of the nodes) .

Depending on the nature of the interactions, networks can be directed or undirected. In directed networks, the interaction between any two nodes has a well-defined direction, which represents, for example, the direction of material flow from a substrate to a product in a metabolic reaction, or the direction of information flow from a transcription factor to the gene that it regulates.

Cellular networks are scale-free. The most networks within the cell approximate a scale-free topology. The first evidence came from the analysis of metabolism, in which the nodes are metabolites and the links represent enzyme-catalysed biochemical reactions As many of the reactions are irreversible, metabolic networks are directed. So, for each metabolite an 'in' and an 'out' degree can be assigned that denotes the number of reactions that produce or consume it, respectively.

CHAOS IN QUANTUM MECHANICS

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Chaos in quantum mechanics can be established by calculating the Lyapunov Characteristic Numbers of Bohmian orbits. Systems that are classically integrable (like a box with potential $V = 0$ and a system of two harmonic oscillators with $V = 1/2\ (x^2 + y^2 + z^2)$) have both ordered and chaotic orbits. We study the transition from order to chaos in various cases. On the other hand there are systems like the standard map that are ordered quantum mechanically, although they are mostly chaotic classically. If the probability p is initially different from the square of the wave function Ψ^2, we find that $p \rightarrow |\Psi|^2$ in the case of chaotic orbits, after a "quantum Nekhoroshev" time. In the case of ordered orbits there is no approach of p to $|\Psi|^2$.

A STOCHASTIC EXCITABLE MODEL FOR ELECTRICITY PRICES

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The aim of this research is to model electricity prices in deregulated markets. This is fundamental to pricing power derivatives for portfolio analysis and energy risk management. Electricity is a very special commodity, in fact it cannot be stored and must be generated at the instant it is consumed. Two different kinds of movements can be observed in the historical behavior: one dynamics which characterizes normal stable periods when prices fluctuate around some long run average and another one for turbulent periods in which prices experience jumps and short-lived spikes. In the last decade, several electricity prices models have been proposed in literature. In all these models, the dynamics is constructed "step by step", spikes and changes in the state of the system are externally imposed, according to a microscopic point of view. Markov probability transition matrices control the switches between regimes. On the contrary, we adopt a macroscopic point of view, looking for a model, which captures the properties and produces spikes because of its own internal logic. So we use a FitzHugh-Nagumo model. The beneficial role of noise in excitable systems allows us to control the switches between different regimes in dynamics of power prices.

THE SITNIKOV PROBLEM: A TOY MODEL FOR NONLINEAR DYNAMICS

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The Sitnikov problem (**SP**) in its original definition can be regarded as a special case of the three – dimensional restricted three body problem. It is defined in the following way: Two equally massive primary bodies orbit around their common barycentre and a third, (massless) body moves perpendicular to the orbital plane of the primaries through the center of mass. It is of special interest for nonlinear dynamics because it can be regarded as a perfect example for chaotic motion. We discuss in details the 'classical Sitnikov problem' and how we can treat it via different perturbation methods. We also deal with an extension of the problem, namely the **Extended SP** where the 3rd mass is no more regarded as small compared to the primaries and the **General SP**, where the motion of the 3rd body off the z-axis is allowed.

STUDY OF PRE-SEISMIC SIGNALS USING COMPLEXITY AND CRITICALITY

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Fracture in disordered media is a complex problem for which a definitive physical and theoretical treatment is still lacking. We view earthquakes as large-scale fracture phenomena in the Earth's heterogeneous crust. Our main observational tool is the monitoring of the microfractures, which occur in the prefocal area before the final breakup, by recording their kHz–MHz electromagnetic emissions, with the MHz radiation appearing earlier than the kHz. Two fundamental questions unanswered yet that scientists in this field ought to address are as follows. Is there a way of estimating the time to global failure? Is the evolution towards global failure irreversible after the appearance of distinguishing features in the preseismic electromagnetic time series? We attempt to put forward physically powerful arguments with regard to answering these two basic questions. Our approach will be in terms of critical phase transitions in statistical physics, drawing on recently published results. We obtain two major results. First, the initial MHz part of the preseismic emission, which has antipersistent behavior, is triggered by microfractures in the highly disordered system that surrounds the essentially homogeneous "backbone asperities" within the prefocal area and could be described in analogy with a thermal continuous phase transition. However, the analysis reveals that the system is gradually driven out of equilibrium. Considerations of the symmetry-breaking and "intermittent dynamics of critical fluctuations" method f1g estimate the time beyond which the process generating the preseismic EM emission could continue only as a nonequilibrium instability. Second, the abrupt emergence of strong kHz emission in the tail of the precursory radiation, showing strong persistent behavior, is thought to be due to the fracture of the high strength "backbones." The associated phase of the earthquake nucleation is a nonequilibrium process without any footprint of an equilibrium thermal phase transition. The family of asperities sustains the system. Physically, the appearance of persistent properties may indicate that the process acquires a self-regulating character and to a great degree the property of irreversibility, one of the important components of predictive capability. Additionally, we attempt to demonstrate that complexity measures, such as *T*-complexity or approximate entropy, gives evidence of state changes leading to the point of global instability. The appearance of a precatastrophic state is characterized by significant lower complexity. Consequently, significant complexity decrease and accession of persistency in electromagnetic time series can be confirmed at the tail of the preseismic EM emission, which could be used as diagnostic tools for the Earth's impending crust failure. Direct laboratory and field experimental data as well as theoretical arguments support this conclusion.

NONLINEARITY AND DISPERSION IN DISLOCATIONS AND JOSEPHSON JUNCTIONS.

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We discuss two physically different problems, that present some common features, where nonlinearity and dispersion play a role in the dynamics. We present a discrete(dispersive) screw dislocation model with a snapping-bond (point-nonlinearity) force law. The model is solved analytically and consistently.
The external stress to balance radiation is given as a function of velocity, showing a window of high velocity near c/2. From the Green's function we can extend to piecewise-quadratic potential, by solving self-consistently over the nonlinear region (around slip plane) in the form of an integral equation. Comparison with sine-Gordon systems and in particular with the S/I/S Josephson junction (JJ), where the nonlinearity is of the sin φ type. An array of JJ resemples a discrete Frenkel-Kontorova model, while a 2D window JJ is described by a non-local sine-Gordon system. A direct analogy with the simple dislocation model is shown. Related to this is that a very narrow JJ is also described by a non-local sine Gordon. The predicted radiation emitted in the window junction was also observed experimentally as substeps in the ZFS. The effect of non-locality is also to inflate the fluxons. We will end with the exploration of the nonlinearity in hybrid JJ where the intermediate layer can be a normal metal, semiconductor or a ferromagnet. The tunnelling of Cooper pairs is mediated through the Andreeev reflection and the current carrying bound states. The supercurrent shows a sin φ form for high temperature, and a "snapping-bond" form at very low temperatures. The current is obtained via the Green's function and the thermal average is done through the Matsubara approach. An interesting result is that we can have a $\pi-$ junction behavior, i.e. a π phase difference in the ground state of the junction. In the region of transition $0 \rightarrow \pi$ we have a strong 2nd harmonic in the supercurrent. Several applications will be presented, while similar heterostructure forms have an interest in spintronics.

RECURRENCE QUANTIFICATION ANALYSIS OF MOLECULAR DYNAMICS SIMULATION

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We performed molecular dynamics simulation of Lennard-Jones fluid at various system states as function of the system density and temperature. We recorded the system instantaneous temperature as function of time and we analyzed the resulting temperature time series using Recurrence Quantification Analysis (RQA). We calculated the RQA variables as function of the system temperature and density. It is of interest that the results are indicative of the fluid dynamics and are related also to characteristic times of the system obtained from physical quantities like mean square displacements.
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THE POINCARÉ MAP AND THE METHOD OF AVERAGING: A COMPARATIVE STUDY

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The method of the Poincaré map on a surface of section is a very useful tool in the study of a nonlinear system. The dimensions of the phase space of the map are lower than the dimensions of the original system, and this makes the study clearer. The method of construction of the Poincaré map is explained, for different dynamical systems (autonomous, non-autonomous, Hamiltonian, nearly integrable Hamiltonian). It is explained, by an example, how the Poincaré map helps us to distinguish between different types of motion (periodic, complicated limit cycle, motion on a torus, chaotic attractor, generalized chaos), which is not easy to distinguish from the orbit itself. Special emphasis is given to nearly integrable dynamical systems, and it is explained why the resonances play an important role in the evolution of the system and the generation of chaos. The method of averaging is also a very useful tool in the study of a nonlinear system, especially in a nearly integrable system (as for example the motion of an asteroid or of an exoplanetary system). The basic theory of this method is described, and it is explained how the number of degrees of freedom is decreased, by generating ignorable coordinates, through a canonical transformation. The topology of the phase space of the averaged problem is compared with that of the Poincaré map (for the same system) and it is made clear that the two topologies coincide only in regions of ordered motion. In a chaotic region, the averaged model does not represent correctly the real system. A simple example is used to make this clear.

STOCHASTIC PROCESSES WITH LONG-RANGE DEPENDENCIES

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For a stochastic process, long-range dependence means that the importance of the past declines as a power-law rather than as an exponential function. Such processes include the families of fractional Brownian motions, fractional Gaussian noises and the family of $1/f$-noises. They are very important and useful in complex systems, all the way from pure mathematics to the social sciences. Despite the widespread importance of these processes, many of their more important properties are frequently ignored. Such properties include the so-called ultraviolet and infrared catastrophes, aliasing of high frequency components and various initial-value problems. If neglected, these can cause serious problems at both the inference and simulation ends of an investigation. In this talk, I will briefly discuss some of the special properties and the common pitfalls associated with these processes and how to avoid them.

COMPLEX PHENOMENA IN NONLINEAR OPTICS AND PHOTONICS

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An overview will be presented on the various aspects of light spatio-temporal localization in bulk and periodic nonlinear media. In particular, special emphasis will be given in waveguide arrays and lattices either structured or dynamically induced. Bright and dark spatial solitary structures and X-waves will be examined in this respect. Recent findings as far as the use of the Hamiltonian dynamics in the construction of robust solitary formations and developments in the three –dimensional X-wave propagation will be presented as well. The underlying mathematical models are based on the coupled nonlinear Schroedinger equations (continuous and discrete). The applications span a wide variety of physical systems and applications, from Bose-Einstein condensates to routing light in complex structures

ANOMALOUS DIFFUSION AND THE RANDOM WALK APPROACH

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A few examples of observed phenomena of anomalous diffusion in laboratory and astrophysical plasmas are given, and existing models for anomalous diffusion are briefly discussed. We then show how diffusion can be interpreted as a stochastic process, which naturally leads to the concept of random walk. In a first step, the classical random walk in position space is introduced, together with an integral equation that describes its evolution (the Einstein-Bachelier equation). Basic properties of the classical random walk are discussed, and it will be shown that classical random walk can only yield normal diffusion. A list of possible necessary conditions that must be met in order diffusion to be anomalous is given from a stochastic process point of view. We then introduce the concept of Continuous Time Random Walk (CTRW), together with the corresponding integral equation. The CTRW is a random walk process able to model super-diffusion as well as sub-diffusion, with basic characteristics that it is non-local in both space and time (non-Markovian). Last, we extend the standard CTRW in position space, so that it describes in parallel both, diffusion in position and velocity space, and we derive the integral equations that describe it. The equations are solved numerically, by applying a variant of the pseudospectral method that is based on expansion in terms of Chebyshev polynomials. Finally, we give a few examples of applications of the extended CTRW to laboratory plasmas, where it turns out that the inclusion of velocity space in the random walk dynamics can naturally interpret observed phenomena of anomalous diffusion.

CLASSICAL CHAOTIC SCATTERING

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This lecture gives an overview of classical chaotic scattering. First we explain in which sense also in scattering with its simple asymptotic limit behaviour something complicated can happen which deserves the name chaos. Next we elaborate the mathematical structure which stands behind the complicated behaviour: It is a Smale horseshoe in an appropriate Poincare section. We discuss the most common development scenarios of this chaotic invariant set under parameter changes. Finally we turn to the inverse problem, namely the question, how the knowledge of asymptotic data allows one to reconstruct many properties of the chaotic set which sits completely in the interaction region.

THE ECHO EFFECT IN CHAOTIC SCATTERING

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It is always fascinating to find properties of the non – chaotic quantum mechanics, which reflect the chaos of the corresponding classical system. In chaotic scattering the echo effect is the most interesting example for this possibility found so far. If we shoot into a classically chaotic scattering system a wave packet then a sequence of small packets (echoes) comes out where the time delay between consecutive echoes is related to the development stage of the corresponding classical chaotic set. This allows one to see the development scenario of the classical chaotic set under parameter changes in the quantum behaviour. This effect has already been tested experimentally in microwave transmission through cavities. This setup can be considered a system of analogy to quantum scattering.

NONLINEAR ELASTICITY AND APPLICATIONS IN CIVIL AND BIO SYSTEMS

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In this presentation we will present some of the nonlinear theories of elasticity for the development constitutive equations that are appropriate for *unfilled* elastomers. This new approach is based on the concepts of statistical mechanics and the theory of rubber elasticity. The cubic model for the network is assumed, where four cubes share each crossling and each cube is structured by twelve crosslings. A cube is consists of twelve over four, i.e. three crosslings and in addition, one link may be several monomers. The *partition function*, for a random walk of the chain of macromolecules can be written as a function of the Langevin equation and the Helmotz free energy is estimated as a function of this equation. The strain energy function, which expresses the Helmotz free energy per unit volume, is expressed as a function of the maximum extensibility of the chain. In addition, the stress tensor is expressed as a function of the shear modulus G, of the unfilled rubber-like material and the maximum extensibility of the chain. Using the Padé's approximation for the Langevin equation a simplification of the final equation can be obtained. For low deformation, the final proposed equation leads to the Neo-Hookean equation. Experimental data for *unfilled* rubbers, which are already posted in the literature, where fitted with the proposed constitutive equation and the results are in a good agreement. The experimental data, taken from the literature, were tested in simple tension, equibiaxial tension or equivalently in simple compression and pure shear deformation. As the principal stretch, approaches to unity the stress approaches to zero and as it goes to maximum extensibility λ_m, the stress goes to infinite. When the strain approaches to zero the ratio of the engineering stress over strain approaches the correct linear limit, i.e. 3G, where G defines the shear modulus of the material. Hence the proposed model is based only on two parameters (G, λ_m), where both of them have a precise physical meaning. The experimental data for various *unfilled* elastomers, published by various researches, follows the proposed constitutive law. For low deformation the ratio σ/ε i.e. the ratio of the engineering stress with the strain, is equal to 3G=E. For large deformation values ($\lambda \to \infty$), the nominal stress σ, is proportional to the third power of principal stretch. The exponent three matches the experimental result, for large values of λ. As the principal stretch approaches unity, the G-term is important, while as the principal stretch approaches infinite, the (K+G/3) term dominates. The parameters of the proposed models were estimated by a nonlinear fitting with the experimental data for unfilled rubbers, published in the literature. The proposed theory will be applied in civil engineering problems as well in bio-systems.

NONLINEAR ANALYSIS AND VISUALIZATION OF THE GENOME OF EVOLUTIONARY NEWER ORGANISMS

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The recent DNA sequencing of common organisms gives the possibility to use computational and statistical tools to correlate the local sequence structure and specific patterns with functionality [1,2]. Along this path we have tried to identify common, long and short range features in recently annotated genomes. We have focused on the statistical processing of oligonucleotides in evolutionary newer organisms, while trying to combine the produced results with known biological experimental data.
We have computed the distance distribution for all possible combinations of oligonucleotides of a given length. We have observed that all oligonucleotides bearing consensus promoter signatures follow power law distributions. On the other hand, sequences with not known biological meaning tend to follow exponential-type distributions, or in general short range distributions [3].
Using a different approach we mapped oligonucleotides according to the parameters that define their distribution curve [3,4]. We have found that oligonucleotides tend to cluster in higher Chordata, and more specifically oligonucleotides that include the binucleotide CG cluster together, away from all the others. In organisms evolutionary remote from mammals and birds this tendency was not obvious.

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SIMULATIONS OF COMPLEX MATERIALS ACROSS MULTIPLE SCALES

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A variety of physical phenomena involve multiple length and time scales. Some interesting examples of multiple-scale phenomena are:

(a) the mechanical behavior of crystals and in particular the interplay of chemistry and mechanical stress in determining the macroscopic brittle or ductile response of solids;

(b) the molecular-scale forces at interfaces and their effect in macroscopic phenomena like wetting and friction;

(c) the alteration of the structure and electronic properties of macromolecular systems due to external forces, as in stretched DNA nanowires or carbon nanotubes.

In these complex physical systems, the changes in bonding and atomic configurations at the microscopic, atomic level have profound effects on the macroscopic properties, be they of mechanical or electrical nature. Linking the processes at the two extremes of the length scale spectrum is the only means of achieving a deeper understanding of these phenomena and, ultimately, of being able to control them.

While methodologies for describing the physics at a single scale are well developed in many fields of physics, chemistry or engineering, methodologies that couple scales remain a challenge, both from the conceptual point as well as from the computational point. In this presentation I will discuss the development of methodologies for simulations across disparate length scales with the aim of obtaining a detailed description of complex phenomena of the type described above. I will also present illustrative examples, including hydrogen embrittlement of metals, DNA conductivity and translocation through nanopores, and affecting the wettability of surfaces by surface chemical modification.

PREDICTING PROPERTIES OF NANOSTRUCTURED MATERIALS THROUGH ATOMISTIC SIMULATIONS

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As the quest for new functional nanostructured materials continuously increases, the role of atomistic simulations in predicting and analyzing their properties becomes very important. Atomistic simulations on the computer offer two major advantages: (a) It is possible to study the behavior of matter under extreme conditions which are difficult to access experimentally, such as under high temperature and pressure. (b) Simulations follow the trajectories or positions of discrete atoms and molecules, giving us a detailed microscopic picture of matter. Thus, it is possible, for example, to study in detail the structure of liquids and amorphous materials, characterized by the absence of medium and long-range order, as well as of nanocomposite and nanostructured materials, where surfaces and interfaces and other inhomogeneous environments are crucial to understand. Their role in controlling and tailoring the mechanical and optoelectronic properties is well documented.

In this lecture, a thorough introduction to the essence, philosophy and utilization of atomistic simulations in predicting properties of nanostructured materials is given. First, the uses and limitations of simulations, in general, are described. Then, a detailed theoretical background is presented, which includes the description of a number of simulation methods, ranging from stochastic Monte Carlo (MC) to deterministic Molecular Dynamics (MD), of the various statistical ensembles used to simulate the equilibrium state of physical systems, and of the energetics underlying the simulations, from empirical potentials to tight-binding (TB) Hamiltonians and first-principles methods. This will conclude the first half of the lecture.

The second half will be devoted to applications of atomistic simulations to specific nanomaterials. The common characteristic of these systems is the strain and disorder build up at the interface, where the bonding elements of the nanoparticles merge with those of the embedding medium, usually due to size mismatch and/or due to different bonding arrangements. Thus, not only the topology, i.e., bond-length and bond-angle distortions, but also the chemical nature of the interface (bond types and their percentage) need to be studied and if possibly controlled. The applications to be discussed include MC simulations of Ge/Si(100) heteroepitaxial quantum dots, where segregation and intermixing of species are important for strain relaxation and for tailoring the optoelectronics, MC simulations and *ab initio* calculations of the structure and optoelectronic properties of Si nanodots embedded in amorphous silica (Si-NC/a-SiO_2), and TBMD simulations of nanocomposite carbon, consisting of carbon nanostructures (diamonds, nanotubes, etc.) embedded in amorphous carbon matrices. In all examples, comparison of simulation to experimental results will be presented, to show the predictive power but also the limitations of the various techniques.

NANOMECHANICS: APPLICATIONS IN NANOENGINEERING AND NANOTECHNOLOGY

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Rapid advances in nanotechnology have created great demands for basic science and engineering at submicrometer scales Because of the unique physical laws governing material behavior at the atomic and molecular levels, new engineering approaches and different thinking processes must be adopted. Representative nanotechnology examples from various sectors including information data storage, nano-/micro-electromechanical systems, and biotechnology will be presented to illustrate the promises of nanotechnology and nanoengineering, in conjunction with scientific and technology challenges that must be overcome for further growth. The origins of surface forces, significance of self-affinity in surface topography, material response to localized deformation, self-assembly of monolayers, and unusual mechanical behaviors of metallic and polymeric surfaces at submicron and molecular levels will be discussed next. Results from surface nanomachining, nanostructuring and nanomodification studies performed with mechanical, electromechanical, and chemical methods, based on microprobe, ultrafast laser, and spectroscopy techniques, will be shown followed by selected numerical results from nanomechanics and molecular dynamics analyses of surface contact. The presentation will conclude with a view toward future trends and challenges in nanoscale surface science and engineering.

THE COMPLEXITY OF NONLINEAR TIME SERIES ANALYSIS

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The use of advanced nonlinear methods stemming from the theory of dynamical systems and chaos, broadly used in the recent years under the term nonlinear analysis of time series, have evidently contributed significantly in the understanding of complex random-like phenomena in many sciences, ranging from biology (analysis of EEG, ECG) to economy (analysis of exchange rates, stock indices). I will present the main methodology of the nonlinear analysis, namely the state space reconstruction, the etsimation of nonlinear measures, such as the correlation dimension and the Lyapunov exponents, the nonlinear modeling and prediction, and the statistical testing for the presence of nonlinear dynamics. In the presentation, a critical view of the existing application of the methodology to real time series will be highlighted with focus on EEG from epileptic patients.

SYMMETRY AND THE TERMINAL CONDITION

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The Black-Scholes equation represents a typical evolution partial differential equation in financial mathematics with the solution subject to a terminal condition. We demonstrate the solution of this problem by means of Lie point symmetry analysis. The Black-Scholes equation is a typical example of the class of equations of Hamilton-Jacobi-Bellman equations which frequently occur in the analysis of the pricing of options and commodities etc.

COMPLEXITY IN INTERNATIONAL DIPLOMACY

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As is well – known, the interactions between different parties engaged in international diplomatic exchanges are characterized by a high degree of complexity. In this lecture, we demonstrate that recent advances in the Theory of Games may dictate the proper moves that a given party should make in order to advance its own interests. The case of the diplomatic exchanges between Greece and Turkey with respect to the Cyprus issue is used as an example.

ORDERS WITH TEN ELEMENTS ARE CIRCLE ORDER

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With a new method based on the notion of genetic algorithms and the explicit enumeration of orders, we prove that all orders on at most 10 elements are circle orders. This theorem represents the best partial result known to date on the Sidney-Sidney-Urrutia Conjecture.

LOCALIZED PERIODIC AND QUASIPERIODIC SOLUTIONS IN THE DISCRETE NLS WITH DIFFRACTION MANAGEMENT

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We present results on the existence of periodic and quasiperiodic localized solutions in a discrete NLS equation with periodic parametric forcing. The equation models a system of coupled waveguide arrays with a special geometry that reduces diffraction effects. The solutions are obtained by continuing breather periodic solutions of autonomous approximate systems. A main ingredient is a continuation argument for invariant tori of for Hamiltonian systems with symmetries.

NONLINEARITY EFFECTS IN THE DYNAMICS OF A SEMICONDUCTOR QUANTUM WELL STRUCTURE

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A problem of fundamental interest in semiconductor nanostructures is the potential for controlled population transfer and Rabi oscillations in intersubband transitions in the conduction band of semiconductor quantum wells. The semiconductor two-subband system behaves quite differently from an atomic-like two-level system due to the existence of the many-body effects arising from the macroscopic carrier density of the two-dimensional electron gas. In particular the optical Bloch equations that describe the dynamics of the interaction of an electric field with the two-subband system become nonlinear differential equations, due to the existence of the electron-electron interactions [1-7]. In this work we explore the effects of the nonlinear terms in the optical Bloch equations in a two-subband system. We first simplify the nonlinear Bloch equations by using the rotating wave approximation and present analytical solutions in cases that the two-subband system interacts with continuous wave and pulsed electric fields. In addition, a specific condition that leads to complete inversion of the electronic population in the two-subband system that interacts with a pulsed electric field is also presented. We finally compare our analytic findings with numerical solutions of the effective nonlinear Bloch equations for a semiconductor QUANTUM WELL STRUCTURE BASED ON GAAS.

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THE 26th OF DECEMBER 2004 INDIAN OCEAN MEGATSUNAMI

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The Sumatra earthquake was a gigantic event (Mw=9.3). The co-seismic fault rupture and the aftershock distribution extended 1200 km northward along the trench between the Indian and Burma tectonic plates. As the main results of this earthquake a large and devastating Seismic Sea Wave (Tsunami) was generated by slip on this faulted plate boundaries (trust), that spread out all over the Indian ocean.
A short description and definition of tsunami waves are given (infrequent phenomenon, High energy, long period, soliton, magnitude and intensity etc). Post tsunami field surveys results and measurements from Sri Lanka, Maldives and N. Sumatra are presented, such as coastal height waves (2 to 11 m in Sri Lanka, 5 to 30m in N. Sumatra and 2 to 3 m in Maldives), erosion, sand deposition, infrastructure destruction and human victims.

ESTIMATING THE BORDER OF STABILITY OF SYMPLECTIC MAPS USING EVOLUTIONARY ALGORITHMS

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Προτείνεται μια νέα μέθοδος για τον αριθμητικό υπολογισμό των περιοχών ευστάθειας μη γραμμικών συμπλεκτικών απεικονίσεων. Τα βασικά συστατικά της προτεινόμενης μεθόδου είναι οι Διαφοροεξελικτικοί Αλγόριθμοι, η μέθοδος του Μικρότερου Δείκτη Ευθυγράμμισης (SALI) και ο υπολογισμός της διάστασης συσχέτισης των αντικειμένων που προκύπτουν. Η μέθοδος εφαρμόζεται στο πρόβλημα της εύρεσης των μέγιστων περιοχών ευστάθειας της συμπλεκτικής απεικόνισης του Hénon στις 2 και 4 διαστάσεις αντίστοιχα. Επίσης προτείνεται ο καθορισμός της τιμής των συχνοτήτων που εμφανίζονται στις συμπλεκτικές απεικόνισεις του Hénon να προκύπτει από μια διαδικασία βελτιστοποίησης.

HAMILTONIAN CHAOS IN CLASSICAL AND QUANTUM MECHANICS

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First I shall review the basic elements of the classically chaotic motion in Hamiltonian systems, and then we shall consider the problem of quantum chaos, the notion of the Heisenberg time and some aspects of dynamical lozalization. The main part of the lectures will be devoted to the stationary problem of quantum chaos of bound systems. We shall address the problem of the structure and statistics of eigenstates and energy spectra. First we shall review the universality classes of spectral fluctuations and the basic notions of the theory of random matrices (RMT), especially the GOE and GUE ensembles for chaotic systems and Poissonian statistics for the classically integrable systems. Then we shall proceed to the difficult problem of mixed type statistics, for classically generic systems, which have regular motion on invarinat tori for some initial conditions and chaotic motion for some other complementary initial conditions. We shall demonstrate the excellent agreement between the theory, the so-called Berry-Robnik (1984) picture, generalized towards the Principle of Uniform Semiclassical Condensation (PUSC) of Wigner functions, and the numerical calculations, and show, that the so-called E(k,L) probabilities are the best mathematical tool to describe such mixed-type systems. The agreement between the predicted and calculated E(k,L) is excellent. We then discuss the limitations of universality and the effects of dynamical lozalization and tunneling, resulting in correlations between regular and chaotic energy level sequences at low (not sufficiently high) energies, and shall report on recent results on this topics.

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EXACT ANALYSIS OF THE ADIABATIC INVARIANTS IN A TIME-DEPENDENT HARMONIC OSCILLATOR

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The theory of adiabatic invariants has a long history, and very important implications and applications in many different branches of physics, classically and quantally, but is rarely founded on rigorous results. We treat the general time-dependent one-dimensional harmonic oscillator, whose Newton equation $\ddot{q} + \omega^2(t)q = 0$ cannot be solved in general. We follow the time-evolution of an initial ensemble of phase points with sharply defined energy E_0 at time t = 0 and calculate rigorously the distribution of energy E_1 after time t = T, which is fully (all moments, including the variance μ^2 determined by the first moment $\bar{E}_1$. For example, $\mu^2 = E_0{}^2[(\bar{E}_1/E_0)^2 - \omega^2(T)/\omega^2(0)]/2$, and all higher even moments are powers of μ^2, whilst the odd ones vanish identically. This distribution function does not depend on any further details of the function *ω(t)* and is in this sense universal. It is equal to $P(E_1) = \pi^{-1}(2\mu^2 - x^2)^{-1/2}$, where $x = E_1 - \bar{E}_1$. In ideal adiabaticity $\bar{E}_1 = \omega(T)E_0/\omega(0)$, and the variance μ^2 is zero, whilst for finite T we calculate $\bar{E}_1$, and μ^2 for the general case using exact WKB-theory to all orders. We prove that if *ω(t)* is of class C^m (all derivatives up to and including the order m are continuous) $\mu \propto T^{-(m+1)}$, whilst for class C^∞ it is known to be exponential $\mu \propto \exp(-\alpha T)$.

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TRAVELLING WAVES IN TWO-DIMENSIONAL LATTICES

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We study the travelling waves on a two—dimensional lattice with linear and nonlinear coupling between nearest particles and a periodic nonlinear substrate potential. Such a discrete system can model molecules absorbed on a substrate crystal surface.
We show the existence of periodic and librational travelling waves in a two-dimensional sine-Gordon lattice equation using topological and variational methods.

THE GENERALIZED ALIGNMENT INDEX (GALI) METHOD: DETECTING ORDER AND CHAOS IN CONSERVATIVE DYNAMICAL SYSTEMS

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We investigate the dynamics of conservative dynamical systems by studying the evolution of volume elements formed by deviation vectors about their orbits. The behavior of these volumes is strongly influenced by the regular or chaotic nature of the motion. The different time evolution of these volumes can be used to identify rapidly and efficiently the nature of the dynamics, leading to the introduction of quantities that clearly distinguish between chaotic behavior and quasiperiodic motion. More specifically we define the Generalized Alignment Index of order k (GALI$_k$) as the volume of a generalized parallelepiped, whose edges are k initially linearly independent unit deviation vectors from the studied orbit. We show analytically and verify numerically on particular examples of N degree of freedom Hamiltonian systems and $2N$--dimensional symplectic mappings that, for chaotic orbits, GALI$_k$ tends exponentially to zero with exponents that involve the values of several Lyapunov exponents, while in the case of ordered orbits, GALI$_k$ fluctuates around non--zero values for $2\\leq k \\leq N$ and goes to zero for $N < k \\leq 2N$ following power laws that depend on the dimension of the torus and the number of deviation vectors initially tangent to it. The GALI$_k$ is a generalization of the Smaller Alignment Index (SALI) as GALI$_2$ $\\propto$ SALI. However, GALI$_k$ provides significantly more information on the local dynamics of the system, allows for a faster and clearer distinction between order and chaos than SALI and works even in cases where the SALI method faced difficulties.

COMPOSITE MODELS FOR NONLINEAR STRESS-STRAIN CURVES IN SEMI-CRYSTALLINE POLYMERS

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In order to describe the mechanical properties of semicrystalline polymers usually several types of composite models have been applied [1-3]. For the physical understanding of phase specific micromechanical processes, however, it is necessary to derive specific stress-strain curves which are characteristic for each of the phases, i.e. the amorphous and the crystalline one. Especially the latter is mandatory to know if one wishes to investigate the role of dislocations for the hardening characteristics, as the dislocations seem now accessible by a recently developed XRD method [4].

For modelling, experimental stress-strain relationships are correlated with two simplified approaches of a rheological composite model by Ahzi et al. [1], a lower-bound and an upper-bound one. Both satisfactorily fit the experimental stress-strain characteristics although the stress controlled lower-bound approach yields a better coincidence [5].

There are serious hints that crystallographic slip in semicrystalline polymers occurs through dislocation motion. Almost no knowledge is available on the density and distribution of dislocations, nor on their influence on the hardening coefficient. In the further development of our work in the context of the RTN-DEFINO network it is therefore planned to combine modelling, mechanical tests and XRD to characterize the micromechanical processes responsible for strain induced strengthening.

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HIERARCHICAL MODELLING OF POLYMERIC MATERIALS

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Within the last twenty years, computer simulations of materials have evolved from an academic curiosity to a predictive tool for addressing structure-property-processing-performance relations that are critical to the design of new products and processes.
The computational prediction of physical properties is particularly challenging for polymeric materials, because of the extremely broad spectra of length and time scales governing structure and molecular motion in these materials. This challenge can only be met through the development of hierarchical analysis and simulation strategies encompassing many interconnected levels, each level addressing phenomena over a specific window of time and length scales.
In this seminar we will discuss the fundamental underpinnings and example applications of some new methods and algorithms for the hierarchical modelling of polymers. Questions to be addressed will include: How can one equilibrate atomistic models of long-chain polymer melts at all length scales and thereby predict thermodynamic and conformational properties reliably? How can one quantity the structure of entanglement networks present in these melts through topological analysis and relate it to rheological properties? Are there ways to predict the microphase-separated morphology and stress-strain behaviour of multicomponent block copolymer-based materials, such as pressure sensitive adhesives? Is it possible to anticipate changes in the barrier properties of glassy amorphous polymers brought about by modifications in the chemical constitution of chains?

MOLECULAR MOTOR PROTEINS AS ELECTROSTATIC MACHINES

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Kinesin and related motor proteins utilize ATP fuel to propel themselves along the external surface of mictrotubules in a processive and directional fashion. We show that the observed step-like motion is possible through time varying charge distributions furnished by the ATP hydrolysis circle while the static charge configuration on the microtuble provides the guide for motion. Thus, while the chemical hydrolysis energy induces appropriate local conformational changes, the motor translational energy is fundamentally electrostatic. Numerical simulations of the mechanical equations of motion show that processivity and directionality are direct consequences of the ATP-dependent electrostatic interaction between kinesin and microtubule.

PASSIVE TARGETED ENERGY TRANSFER PHENOMENA IN SYSTEMS OF COUPLED OSCILLATORS WITH STRONG SYMMETRY-BREAKING NONLINEARITIES

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By nonlinear targeted energy transfer (TET) we denote the one-way, irreversible transfer of vibrational energy from a main structure to a local attachment with damping and essential stiffness nonlinearities, where the energy is confined without 'spreading' back to the main structure (Kerschen et al., 2006). The underlying dynamical mechanism causing nonlinear energy pumping is a 1-1 resonance capture (Arnold, 1988; Quinn, 1997), e.g., an instantaneous transient resonance of the local nonlinear attachment with one of the modes of the main structure, providing the necessary and sufficient conditions for the one-way transfer of energy from the structure to the attachment. Then the attachment acts, in essence, as a nonlinear energy sink (NES). We note that due to its essential nonlinearity, the NES lacks a 'preferential' resonant frequency and, as a result, can resonate with any of the modes of the main (linear) structure, depending on the instantaneous energy of the vibration.

Moreover, as shown in (Vakakis et al., 2003), cascades of resonance captures are possible, wherein the NES resonates with a sequence of modes, extracting from each mode a certain amount of energy before proceeding to the next. Resonance capture cascading is caused by energy dissipation in the system, which, with increasing time (and decreasing overall energy) induces resonances of the NES with modes of the linear subsystem at monotonically decreasing frequencies. Hence, multi-mode TET may result as the dynamics transits from one resonance capture to another. The mere fact that an NES can passively interact sequentially with all or a subset of modes of an arbitrary linear subsystem, extracting from each mode a significant amount of energy before cascading to the next, is a very appealing finding with clear applications from an engineering point of view. In addition, the NES is capable of absorbing broadband energy, thus acting as a broadband, adaptive, passive boundary controller.

By studying nonlinear TET in complex systems, one can analyze complicated interactions between their 'slow' and 'fast' dynamics. Such multi-scale dynamics govern resonant interactions between components of a complex system that possess drastically different flexibilities ('soft' or 'hard'). By taking into account slow-fast energy exchanges one can explain or predict a variety of complicated dynamical phenomena that are observed in extended systems or in systems with multiple structural components (for example, crank-shaft mechanisms on elastic foundations). Hence, the mentioned nonlinear TET concepts are especially applicable to a broad range of applications, such as vibration and shock isolation, seismic mitigation, and instability control.

The lecture will focus on mathematical techniques specially developed to study the strongly nonlinear, transient dynamics involved in the aforementioned phenomena, as well as, on theoretical (Lee et al., 2005), computational (Georgiades et al., 2006) and experimental results (McFarland et al., 2005) of applying single- or multi-DOF NESs to engineering structures. Applications of the TET concept to vibration and shock isolation (Georgiades et al., 2006; Tsakirtzis et al., 2006), aeroelastic flutter suppression (Lee et al., 2006), and seismic mitigation will be presented.

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THE COMPLEXITY OF GRANULAR MATTER: SOLID, FLUID, AND GAS

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Granular matter is of great scientific and economic relevance. Scientific, because it is intriguingly different from any ordinary solid, liquid, or gas, and exhibits a multitude of new phenomena. Economic, because no less than 5 per cent of the global energy budget is wasted due to problems with the transport and processing of granular materials in conveyor belts, sorting machines, mixers, and other industrial machinery. Here we highlight three granular phenomena:

1 *Clustering in a granular gas*: Unlike in an ordinary gas, the particles in a granular gas have the tendency to spontaneously cluster together. We will explain this counter-intuitive behavior by a flux model, which quantitatively describes the clustering effect in a setup divided in connected compartments – resembling a sorting machine – filled with particles that are brought into a gaseous state by vertically vibrating the system.

2 *The granular Leidenfrost effect*: When a bed of granular particles is vibrated sufficiently vigorously, a dense cluster is elevated and held afloat by a dilute layer of very fast particles underneath. This is similar to the original Leidenfrost effect of a water drop hovering over a very hot plate, floating on its own vapor layer. We will show that the granular Leidenfrost is well described by a hydrodynamic model, with proper modifications to capture the characteristic properties of the constituent particles.

3 *Faraday heaping*: Already in 1831, Faraday noted that a mildly vibrated granular bed does not keep a flat surface, but instead turns into a landscape of small heaps, which in the course of time merge into a single larger heap. Over the years, several rivaling theories for this behavior have been suggested, without however yielding a clear conclusion. Our numerical simulations, which also include the ambient air, now reveal that the heaps are formed and stabilized by the airflow forced through the bed during the vibrations.

The three phenomena are studied through a combination of experimental, numerical, and theoretical techniques. Special attention will be paid to the question whether (and to what extent) granular materials can be described by continuum theories.

METEOR IMPACT AND GRANULAR JET FORMATION

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A steel ball is dropped onto loose, very fine sand ("dry quicksand") and creates an upward jet exceeding the release height of the ball. There is a striking similarity with the impact of an object in a liquid, as well as a strong analogy with the impact of giant meteors on a planet: The jet is generated by the gravity-driven collapse of the void created by the ball, and the focused pressure pushes the sand straight up into the air. Using a 2-dimensional experimental setup and high-speed imaging, the collapse of the void is visualized. All the experimental observations are quantitatively explained by a Rayleigh-type continuum model.

DYNAMICS AND STRUCTURE OF AMORPHOUS MATERIALS USING METHODS OF MOLECULAR DYNAMICS

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The dynamical and structural properties of amorphous materials constitute today a very active area of research in the natural sciences. Their study is significantly limited by the lack of periodicity of the glass lattice and consequently the corresponding mathematical analysis of periodic crystal structures cannot apply to amorphous materials. For this reason, alternative methods have been devised based on simulation algorithms and extensive numerical computation. More specifically, the study of glasses using molecular dynamics techniques offers a powerful tool for the determination of the microscopic parameters of position and momentum of the glass particles, at every given moment. The dynamical properties of the glass then follow from the evaluation of time correlation functions between positions and momenta. In this talk, we will describe the results of a molecular dynamics calculation of the structural as well as dynamical properties of ionic borate glasses, which are of great use in technological applications. Our simulation results are then compared with the corresponding experimental ones on the same type of glasses.

NORMAL AND ANOMALOUS DIFFUSION

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The purpose of this tutorial is to introduce very basic concepts on the probability theory in physics, providing an introduction to the problem of the random walk and its applications. In its simplest form, the random walk describes the motion of an idealized drunkard and is a discreet analogy of the diffusion process. A thorough account is given of the theory of random walks on discreet spaces (lattices or networks) and in continuous spaces, including those processed with random waiting time between steps. Applications discussed include dielectric relaxation, turbulent dispersion, diffusion through a medium with traps,. Prior knowledge of probability theory would be helpful, but not assumed.

A STUDY OF RESONANCES AND CHAOS IN PLANETARY MOTION

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Resonances play an important role in the stability of multiple planet systems. In this work we study the stability of a planetary system in the framework of the general planar three body problem. The exact mean motion resonance corresponds to periodic motion, in an appropriate rotating frame, which can be symmetric or asymmetric. Stable periodic orbits are surrounded by invariant tori and the planetary motion is regular. Thus, by determining the periodic orbits of the system and their stability we get the phase space regions where a planetary system may exists. We consider, as an example, the 3:1 resonance and the 55Cnc extrasolar system. We calculate all the families of symmetric periodic orbits and we show the bifurcation of asymmetric ones. The 55Cnc extra-solar system is located in a stable domain of the phase space, centered at an asymmetric periodic orbit. The study of the distribution of regular and chaotic motion in phase space shows that the asymmetry is a crucial property for the stability of the above planetary system.

PROPERTIES & PROCESSING OF BULK NANOCRYSTALLINE MATERIALS BY MEANS OF SEVERE PLASTIC DEFORMATION

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Nanomaterials are becoming more and more important in everyday life. This is especially true for nanocrystalline metals, because of their enhanced mechanical properties, excellent hard- and soft-magnetic properties and enhanced diffusion. In comparison with other methods, nanocrystallization by Severe Plastic Deformation (SPD) has a lot of additional advantages like bulk shape, 100% density, and a high strength but at the same time good ductility or even superplastic properties. Other improvements concern the increases in fatigue life time and in fracture toughness. On the other hand, SPD can induce marked changes of the phases in alloys e.g. increase the solubility of alloying atoms. In case of hydrogen storing metals, SPD achieves an enhancement of ab- and desorption rate of hydrogen.

The lecture tries to shed some light on the physical reasons for the SPD specific enhancements of nanocrystalline metals. The enhanced ab- and desorption rates of hydrogen seem to be a consequence of the strongly increased density of deformation induced lattice defects; the latter appears to be also responsible for the changes of phases in SPD alloys. As concerns the high strength, this is mainly caused by the presence of an elevated hydrostatic pressure which allows for extensive grain size decrease due to large strains reached as well as due to restriction of edge dislocation annihilation. The hydrostatic pressure seems to account also for the enhanced ductility due to recovery processed launched after SPD. However, for this effect several other explanations exist like e.g. the initiation of grain boundary sliding even at low deformation temperatures. Within the DEFINO framework it has been planned to implement careful in-situ investigations of the deformation slip by means of an AFM-STM, in order to clearly differ between the usual surface relief formation on the grain surface, and the true grain boundary sliding.

DYNAMIC PHASE TRANSITIONS, CRITICAL BEHAVIOR AND SCALE INVARIANCE IN NON-EQUILIBRIUM SYSTEMS

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The dynamics of slowly driven non-equilibrium systems is often characterized by temporal intermittency where the evolution of a system proceeds in a stochastic sequence of discrete bursts ('avalanches') which are characterized by scale-free (power law) probability distributions of the burst parameters. At the same time, the spatial conformation of such systems is often characterized by the spontaneous emergence of scale invariant (fractal or self-affine) patterns. These phenomena can be interpreted in terms of the existence of non-equilibrium phase transitions between different dynamical 'phases' of the system, which may be treated theoretically in some analogy with the behavior of systems near equilibrium critical points. We revisit some of the concepts associated with the theory of phase transitions and critical behavior, and then proceed to discuss different types of critical behavior - including 'self-organized criticality' in driven non-equilibrium systems. Examples discussed range from magnetic systems such as the driven random-field Ising model, over sandpiles and related systems, to the motion of interfaces in random media.

POSTER PRESENTATIONS

PARTICLE DYNAMICS IN 3-D RECONNECTING CURRENT SHEET

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We study the dynamics of charged particles (electrons and protons) in a non-neutral 3D reconnecting current sheet model. The properties of the orbits are reproduced by analytical methods based on a hamiltonian formalism. There are both trapped and escaping orbits. Trapped orbits are analyzed in terms of Poincare surfaces of section and by means of the Lie normal form. Formulas are given relating the kinetic energy gain of escaping particles to the initial particle energy and the physical parameters of the current sheet.

CHAOTIC DYNAMICS OF N - DEGREE OF FREEDOM HAMILTONIAN SYSTEMS

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We investigate the connection between local and global dynamics of two N – degree of freedom Hamiltonian systems with different origins describing one - dimensional nonlinear lattices: The Fermi – Pasta - Ulam (FPU) model and a discretized version of the nonlinear Schrφedinger equation related to the Bose - Einstein Condensation (BEC). We study solutions starting in the immediate vicinity of simple periodic orbits (SPOs) representing in--phase (IPM) and out – of - phase motion (OPM), which are known in closed form and whose linear stability can be analyzed exactly. Our results verify that the destabilization energy E_c per particle goes to zero as $N \to \infty$ following a simple power - law, $E_c / N \propto N^{-a}$, with a being 1 or 2 for the cases we studied. However, we find that the two Hamiltonians have very different dynamics near their stable SPOs. Furthermore, the IPM orbit of the BEC Hamiltonian never destabilizes, even for very high N and E. Still, when calculating Lyapunov spectra, we find for the OPMs of both Hamiltonians that the Lyapunov exponents decrease following an exponential law and yield extensive Kolmogorov - Sinai entropies per particle $h_{KS} / N \propto const$, in the thermodynamic limit of fixed energy density E / N with E and N arbitrarily large. We, also, show that there is a relatively high q mode $\mathrm{q=2(N+1)/3}$ of the linear lattice, having one particle fixed every two oppositely moving ones (called SPO2 here), which can be exactly continued to the nonlinear case for $\mathrm{N=5+3m,m=0,1,2,\ldots}$ and whose first destabilization, $\mathrm{E_{2u}}$, as the energy (or the parameter of nonlinearity) increases for any N fixed, practically coincides with the onset of a

“weak” form of chaos preceding the break down of FPU recurrences, as predicted recently in a similar study of the continuation of a very low ($q=3$) mode of the corresponding linear chain. This energy threshold per particle behaves like $E_{2u} / N \propto N^{-2}$. We also follow exactly the properties of another SPO (with $q=(N+1)/2$) in which fixed and moving particles are interchanged (called SPO1 here) and which destabilizes at higher energies than SPO2, since $E_{1u} / N \propto N^{-1}$. We find that, initially, after their first destabilization, these SPOs have different (positive) Lyapunov spectra in their vicinity. However, as the energy increases (at fixed N), these spectra converge to the same exponentially decreasing function, thus providing strong evidence that the chaotic regions around SPO1 and SPO2 have “merged” and large scale chaos has spread throughout the lattice. Since these results hold for N arbitrarily large, they suggest a direct approach by which one can use local stability analysis of SPOs to estimate the energy threshold at which a transition to ergodicity occurs and thermodynamic properties such as Kolmogorov - Sinai entropies per particle can be computed for similar one - dimensional lattices.

DIFFERENTIAL CROSS SECTION FOR SCATTERING FROM AN OSCILLATING TARGET

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We study the planar classical scattering of a particle from an oscillating infinitely heavy hard disk. We determine the scattering functions as well as the differential cross section of the system. Despite the absence of unstable periodic orbits we observe complicated structure associated with rainbow singularities of the cross section, due to parabolic orbits. These singularities wash out if the emission of the incoming particle beam is asynchronous, due to phase averaging. However, in this case the shape of the cross section is influenced by the direction of the oscillation axis of the disc. The inverse problem of the determination of the dynamics of the target through the experimentally countered differential cross section is also studied.

MODELING OF ETCHING OF FRACTAL SURFACES AT NANOSCALE

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Etching is one of the fundamental processes for micro and nanopatterning of films in nanoelectronics, Microelectromechanical Systems (MEMS), Bio-MEMS and sensors. It has been shown that this process affects the nano-roughness of the treated surfaces which, at nanometer scale, becomes extremely important since it degrades device performance. Thus, last years several works have attempted to understand and control both by modeling and experiments the effects the etching process has on surface roughness.

However, the majority of these works was devoted to the study of the roughness formation when the initial surface is flat. The aim of this work is to examine the effects of the etching process on an initially rough surface. The motivation for this study comes from the fact that usually in laboratory the surface to be etched has been previously fabricated by another process (for example deposition) and thus it has an initial roughness.

Two kinds of etching processes will be examined. The first is wet etching and it will be modeled by an appropriate version of the level set method. The second is dry (plasma) etching with isotropic flux of neutral etchants and kinetic Monte Carlo method will be used for its simulation. In both cases, the initial rough surfaces can be either periodic (harmonic or no) or self-affine fractal. The results include the evolution of the roughness parameters (rms value, periodicity, fractal dimension, correlation length) as etching proceeds and its dependence on the roughness parameters of the initial surface. Both etching processes lead to roughness reduction and our main concern is to understand how fast it occurs and what side effects has on spatial surface morphology. Further, scaling arguments for the spatio-temporal dependence of roughness will be presented and will be compared with traditional scaling theories developed for surface growth processes.

JOSEPHSON JUNCTION ARRAYS AS EFFICIENT IMPLEMENTATION OF A GEOMETRICAL OVERPROTECTED QUANTUM COMPUTER.

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Σχολή ΕΜΦΕ,
Ε.Μ.Π.

We investigate the feasibility by of an over protecting computational schema based on the topological quantum computer proposed by Kitaev. We explore such possible implementations by apply ab initio calculations on a Josephson junction array, by assigning the qubit to a fluxon and exploring their quatiparticle behaviour.

ΜΟΡΦΟΚΛΑΣΜΑΤΙΚΕΣ ΣΥΝΑΡΤΗΣΕΙΣ ΠΑΡΕΜΒΟΛΗΣ

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Η Ευκλείδεια Γεωμετρία και ο Απειροστικός Λογισμός μας εδίδαξαν να σκεφτόμαστε σχετικώς με την προτύπωση των μορφών τις οποίες αντικρύζουμε στον φυσικό κόσμο βάσει ευθειών, κύκλων, παραβολών και άλλων στοιχειωδών καμπύλων γραμμών. Απόρροιες αυτού του τρόπου σκέψης υπάρχουν άφθονες στην καθημερινή μας ζωή: ο σχεδιασμός οικιακών συσκευών, η συνήθης χρήση πινάκων σχεδίασης, ευθειών και διαβήτη κ.ά. Οι στοιχειώδεις συναρτήσεις, όπως οι τριγωνομετρικές και οι ρητές, έχουν τις ρίζες τους στην Ευκλείδεια Γεωμετρία και αποτελούν τη βάση των παραδοσιακών μεθόδων για ανάλυση πειραματικών δεδομένων, όπου ως πείραμα μπορεί να θεωρηθεί μία απλή αριθμητική εφαρμογή σε έναν υπολογιστή έως και μία πολύπλοκη φυσική μέτρηση. Το κοινό τους γνώρισμα είναι ότι, αν οι γραφικές παραστάσεις τους μεγεθυνθούν αρκετά, μοιάζουν τοπικώς με ευθείες γραμμές. Επί πλέον, η διάσταση των γραφικών τους παραστάσεων είναι πάντα ίση με τη μονάδα. Ο τύπος τους είναι απλός, άρα ο τρόπος υπολογισμού τους είτε είναι εύκολος, είτε μπορεί να πραγματοποιηθεί με απλούς υπολογισμούς σε σύντομο, σχετικώς, χρονικό διάστημα. Τα συστήματα γραφικής σχεδίασης που βασίζονται στην παραδοσιακή γεωμετρία, μπορούν να δημιουργήσουν εικόνες που έχουν όμως ένα κοινό χαρακτηριστικό: Έχουν κατασκευασθεί από το ανθρώπινο χέρι. Τι συμβαίνει όμως με αντικείμενα τα οποία δεν έχουν κατασκευασθεί από ανθρώπινο χέρι, όπως όρη, σύννεφα, κορυφογραμμές ή ένα τοπίο? Αυτές οι εικόνες αποτελούν ένα περίπλοκο σύστημα, το οποίο δεν μπορεί να περιγραφεί ικανοποιητικά χρησιμοποιώντας συστήματα γραφικής σχεδίασης βασιζόμενα στην Ευκλείδεια Γεωμετρία. Μια λύση στο πρόβλημα αυτό δίνεται με τη χρήση μορφοκλασματικών συναρτήσεων παρεμβολής. Οι γραφικές παραστάσεις αυτών των συναρτήσεων μπορούν να χρησιμοποιηθούν για την προσέγγιση των συστατικών μίας εικόνας, όπως οι κατατομές των οροσειρών, οι κορυφές των νεφών και οι ορίζοντες υπεράνω των δασών. Έχουν ακόμη το πλεονέκτημα, επειδή η μορφοκλασματική τους διάσταση είναι διάφορη της μονάδας, ότι μέσω αυτών μπορούμε να υπολογίσουμε, άρα και να εμφανίσουμε, το διάγραμμα συναρτήσεων που δεν καλύπτουν οι βασιζόμενες στην Ευκλείδεια Γεωμετρία τεχνικές. Οι μορφοκλασματικές συναρτήσεις παρεμβολής παρέχουν και έναν καινούργιο τρόπο προσαρμογής πειραματικών δεδομένων. Η μέθοδος λ.χ. των Ελαχίστων Τετραγώνων δεν θα ταίριαζε σε διάσπαρτα πειραματικά δεδομένα, όπως αυτά θα προέκυπταν, για παράδειγμα, από την ανάλυση του ηλεκτρομαγνητικού πεδίου σε ένα σημείο του ανθρωπίνου εγκεφάλου, από τις μετρήσεις ενός σεισμογράφου ή από τις μετρήσεις των δεικτών του χρηματιστηρίου. Τα κοινά σημεία των ΜΣΠ και των στοιχειωδών συναρτήσεων είναι ο γεωμετρικός τους χαρακτήρας, η ακριβής αναπαράστασή τους από ((τύπους)) και ο ταχύς υπολογισμός τους. Η κυριότερη διαφορά τους είναι ο μορφοκλασματικός χαρακτήρας των πρώτων. Η ανάλυση τέτοιου είδους συναρτήσεων απαιτεί να δουλεύει κανείς με σύνολα παρά με σημεία χρησιμοποιώντας επαναλαμβανόμενα συστήματα συναρτήσεων και κηδεστικές απεικονίσεις.

IMAGE COMPRESSION USING AFFINE FRACTAL INTERPOLATION ON RECTANGULAR LATTICES

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Two methods are discussed for representing discrete image data on rectangular lattices using fractal surfaces. They offer the advantage of a more general fractal modelling compared to previous one-dimensional fractal interpolation techniques resulting in higher compression ratios. Theory, implementation and analytical study of the proposed methods are also presented.

ΔΥΝΑΜΙΚΗ ΣΥΜΠΕΡΙΦΟΡΑ ΚΥΚΛΩΜΑΤΟΣ CHUA ΜΕ ΚΥΒΙΚΗ ΧΑΡΑΚΤΗΡΙΣΤΙΚΗ

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Στην εργασία αυτή μελετήθηκε το γενικευμένο κύκλωμα Chua, στο οποίο αντικαταστήσαμε τον κατά-τμήματα γραμμικό αντιστάτη με ένα, ο οποίος έχει ομαλή κυβική χαρακτηριστική. Στην περίπτωση αυτή παρατηρήθηκαν ορθές και ανάστροφες ακολουθίες διπλασιασμού περιόδου, και μελετήθηκε η εξέλιξή τους ως συνάρτηση των παραμέτρων του κυκλώματος.

STRONG INDICATIONS OF LOW DIMENSIONAL CHAOTIC DYNAMICS CONCERNING THE EARTHQUAKES OF GREECE

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In this work we present results derived from the application of the chaotic analysis algorithm on the geometrical and dynamical characteristics of an earthquake time series, produced by the crust dynamical system in Greece, the most active part of western Eurasia, in order to test the assumption that the earthquake process could be a manifestation of a chaotic low dimensional process. For this study we have used a time series consisting of the time differences, $\{\Delta t_n = t_{n+1} - t_n\}$, between two sequential earthquake events with magnitude over 3.2 Richter, which contains N_T = 11937 data points and was recorded by the National Observatory of Athens, during the period 1968 – 1993. The power spectrum of the time series shows a clearly aperiodic profile, while the slopes of the correlation integrals show an apparent plateau at the scaling region, which saturates at the value $D \approx 2.5$. The false neighbours and the singular values spectrum have shown that the phenomenon possesses about $n \approx 5 - 6$ independent degrees of freedom. The indication for low dimensionality of the underlying deterministic process of the original signal was further supported by the saturation of the slopes of the correlation dimension of the signal's first derivative. In order to obtain information about the dynamic evolution of the system in phase space, we estimated dynamical characteristics such as: the Lyapunov exponents, the average mutual information, local linear predictors and nonlinear modelling. In particularly, the L_{max} is positive, the mutual information's profile showed nonlinearity and predictability, as the number of the state vectors in the training set increases. Moreover, the strong null hypothesis, supposing that a linear stochastic process perturbed by a static nonlinear distortion causes the earthquakes' time series, was tested for all the above – mentioned characteristics. This indicates that the signal of the earthquake events does not belong to the same family with the surrogate data and this occurs with probability greater than *0.99*. Furthermore, in order to understand further the underlying dynamical process of the earthquake time series, we studied the first component (V_1-component), the reconstructed time series (V_{2-8} component) and their surrogate data, according to the Singular Value Decomposition (SVD) analysis. The results reveal that the earthquake process consists of two clearly distinguished dynamical regimes, which exhibit low dimensional deterministic chaotic behavior.

HOPF BIFURCATION AND STRUCTURAL INSTABILITY IN AN OPEN ECONOMY

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This paper attempts to contribute to the debate in macroeconomic dynamics by presenting the neoKeynesian challenge. Proof is presented regarding the behavior of an open-economy two-sector growth model in the neoKeyenesian tradition of non-market clearing. It has been shown that there possibly exists a Hopf-bifurcation type of structural instability in a nonlinear dynamical model of the macroeconomy by which a stable region is connected to an unstable region situated in a center manifold in the state space of the resulting dynamical system. The Keynesian view that structural instability globally exists in the aggregate economy is put forward, and therefore the need arises for policy to alleviate this instability in the form of dampened fluctuations is presented as an alternative view for macroeconomic theorizing. 2000 Mathematics Subject Classification. 91B62, 37N40

ΜΟΝΤΕΛΟΠΟΙΗΣΗ ΕΓΧΑΡΑΞΗΣ ΦΡΑΚΤΑΛ ΕΠΙΦΑΝΕΙΩΝ ΣΤΗ ΝΑΝΟΚΛΙΜΑΚΑ

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Η εγχάραξη αποτελεί μία από τις βασικές διεργασίες σχηματοποίησης επιφανειών λεπτών υμενίων στη νανοκλίμακα. Στην ίδια κλίμακα ωστόσο η παρουσία της τραχύτητας στις επιφάνειες των υμενίων επηρεάζει σημαντικά τις ιδιότητές τους. Κατά συνέπεια η διερεύνηση της επίδρασης της διεργασίας της εγχάραξης στην εμφάνιση ή την εξάλειψη της τραχύτητας αποτελεί απαραίτητη προϋπόθεση για τον έλεγχο των ιδιοτήτων και της λειτουργίας τους.
Έως τώρα, οι σχετικές εργασίες είχαν επικεντρώσει το ενδιαφέρον τους στην εμφάνιση της τραχύτητας που προκαλεί η εγχάραξη ενός αρχικά επίπεδου υμενίου. Στην εργασία αυτή στόχος μας είναι να κατανοήσουμε την εξέλιξη της τραχύτητας επιφανειών υμενίων που εγχαράσσονται όταν η αρχική επιφάνειά τους δεν είναι επίπεδη αλλά έχει τραχύτητα. Η αρχική τραχύτητα επιλέγεται να έχει αυτοσυσχετιζόμενα φράκταλ χαρακτηριστικά σε συμφωνία με τις επιφάνειες που χρησιμοποιούνται στο εργαστήριο.
Πιο συγκεκριμένα, θα μελετήσουμε δύο είδη εγχάραξης: την υγρή που γίνεται με τη βοήθεια υγρού διαλύματος του εγχαράκτη και την ξηρή που πραγματοποιείται σε αντιδραστήρα πλάσματος. Η μελέτη γίνεται με τη βοήθεια μεθόδων προσομοίωσης. Για την υγρά εγχάραξη χρησιμοποιείται η μέθοδος level set ενώ για την ξηρή κατάλληλα διαμορφωμένη κινητική Monte Carlo για πλέγματα. Οι αρχικές επιφάνειες χαρακτηρίζονται εκτός από τη φράκταλ διάσταση από το μήκος συσχέτισης και την τυπική απόκλιση των σημείων τους από τη μέση τιμή τους. Τα αποτελέσματα περιλαμβάνουν την εξέλιξη αυτών των μεγεθών με το χρόνο όπως και την μεταξύ τους αλληλεπίδραση και στις δύο περιπτώσεις εγχάραξης. Επίσης, εφαρμόζονται έννοιες και μέθοδοι από τη θεωρία κλιμάκωσης για την καλύτερη κατανόηση και ταξινόμησή τους.

ΤΟ ΠΕΡΙΟΡΙΣΜΕΝΟ ΠΡΟΒΛΗΜΑ ΤΩΝ 3-ΣΩΜΑΤΩΝ-ΕΦΑΡΜΟΓΗ ΣΤΗ ΔΥΝΑΜΙΚΗ ΜΕΛΕΤΗ ΤΗΣ ΖΩΝΗΣ KUIPER

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Στην εργασία αυτή μελετάμε τη δυναμική της κίνησης μικρών σωμάτων κοντά σε συντονισμούς της ζώνης *Kuiper* μεταξύ 48 και 63 A.U. Θεωρούμε ως βασικό μοντέλο το επίπεδο κυκλικό περιορισμένο πρόβλημα των 3-σωμάτων και υπολογίζουμε οικογένειες συντονισμένων περιοδικών τροχιών. Η δομή του χώρου των φάσεων μελετάται με τη βοήθεια της απεικόνισης Poincare. Στο ελλειπτικό πρόβλημα και για μία συγκεκριμένη τιμή της εκκεντρότητας των πρωτευόντων σωμάτων, οι περιοδικές τροχιές είναι απομονωμένες. Οι εν λόγω οικογένειες περιοδικών τροχιών διακλαδίζονται από τις οικογένειες των περιοδικών τροχιών του επιπέδου κυκλικού προβλήματος και φαίνεται να συνεχίζουν μέχρι το «ευθύγραμμο πρόβλημα»**.** Ευσταθείς και ασταθείς τροχιές βρίσκονται σε κάθε περίπτωση. Κατόπιν δημιουργούμε ένα πλέγμα 100×50 τροχιών στο διάγραμμα a-e (μεγάλος ημιάξονας-εκκεντρότητα). Κάθε τροχιά ολοκληρώνεται για χρόνο περίπου 8.25 Myrs και υπολογίζεται ο εκθέτης Lyapounov. Με τη βοήθεια κατάλληλης κλίμακας χρωμάτων γίνεται διάκριση ανάμεσα στις κανονικές και χαοτικές τροχιές. Έτσι, κατασκευάζεται ένας χάρτης, ο οποίος δείχνει τις περιοχές κανονικής και χαοτικής κίνησης.

ΎΠΑΡΞΗ ΚΑΙ ΕΥΣΤΑΘΕΙΑ MULTIBREATHERS ΣΕ ΣΥΣΤΗΜΑΤΑ ΣΚΟΝΙΣΜΕΝΟΥ ΠΛΑΣΜΑΤΟΣ

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Μελετάται η ύπαρξη και η ευστάθεια χωρικά εντοπισμένων κινήσεων τύπου multibreather σε μια αλυσίδα klein-Gordon που χαρακτηρίζεται από ένα νόμο αντίστροφης σκέδασης. Τα αποτελέσματα εφαρμόζονται για την περιγραφή της εγκάρσιας κίνησης φορισμένων κόκκων σε συστήματα σκονισμένου πλάσματος.

DISCRETE BREATHERS IN NONLINEAR MAGNETIC METAMATERIALS

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Magnetic metamaterials composed of split-ring resonators or U- type elements may exhibit discreteness effects in THz and optical frequencies due to weak coupling. We consider a model one-dimensional metamaterial formed by a discrete array of nonlinear split-ring resonators with each ring interacting with its nearest neighbours. On-site nonlinearity and weak coupling among the individual array elements result in the appearance of discrete breather excitations or intrinsic localized modes, both in the energy-conserved and the dissipative system. We analyze discrete single and multibreather excitations, as well as a special breather configuration forming a magnetization domain wall and investigate their mobility and the magnetic properties their presence induces in the system.

DYNAMICAL ESTIMATION OF CALENDAR EFFECTS

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The paper introduces a method for estimation and reduction of calendar effects from time series, which their fluctuations are governed by a nonlinear dynamical system and additive normal noise. Calendar effects can be considered deviations of the distribution(s) of particular group(s) of observations that have a common characteristic related to the calendar. The concept of this method is the following: since the calendar effects are not related to the dynamics of the time series, the accurate estimation and reduction will result a time series with a smaller amount of noise level (i.e. more accurate dynamics). The main tool of this method is the correlation integral, due to its inherit capability of modeling both the dynamics and the additive normal noise. Experimental results are presented on the Nasdaq Cmp. index.

GEOMERY AND DYNAMICS VISUALIZED

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We demonstrate the use of the Spherical Self-Organizing Feature Maps (SOFMs) as a visualization tool of an attractor\'s geometry and dynamics. The spherical topology makes this kind of SOFMs fully adaptable to the complexity of a strange attractor in arbitrary dimensions. The geometry and the dynamics of an attractor are visualized in similar ways, so that the user is able to receive integrated visual information about a data set on a colored anaglyph sphere. Examples on both artificial and real data are given using a software with a friendly Graphical User Interface, running under Matlab. This software (namely the \"Spherical Self-Organizing Maps Toolbox\") is developed by the authors, and it is freely distributed.

DETECTION OF CHAOTIC AND ORDERED ORBITS IN BARRED GALACTIC MODELS OF 2 AND 3 DEGREES OF FREEDOM.

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The qualitative nature of orbits in galactic models is an important issue, since it can influence the whole dynamical evolution. In order to distinguish the chaotic or ordered trajectories, we use the **S**maller **AL**ingment **I**ndex - (**SALI**). We describe here briefly the basic concepts of this method and its advantages. We present applications to 2D and 3D barred galaxy potentials. In particular, we examine the fraction of chaotic and ordered orbits in such potentials and present how this fraction changes when the main parameters of the model are varied. For this, we consider models with different bar mass, bar thickness or pattern speed.

DETECTION OF CHAOTIC AND ORDERED ORBITS IN BARRED GALACTIC MODELS OF 2 AND 3 DEGREEES OF FREEDOM

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The dynamical evolution of barred galaxies depends crucially on the fraction and distribution of chaotic orbits in them. In order to distinguish between ordered and chaotic motion, we use the Smaller ALignment Index (SALI) method, a very powerful method which can be applied to problems of galactic dynamics. Using model potentials, and taking into account the full 3D distribution of matter, we discuss how the distribution of chaotic orbits depends on the main model parameters, in particular the mass and thickness of the bar.

ΜΕΛΕΤΗ ΚΑΙ ΥΛΟΠΟΙΗΣΗ ΤΟΥ ΑΛΓΟΡΙΘΜΟΥ ΤΟΥ WOLF

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Η εργασία διαπραγματεύεται (α) την αναλυτική παρουσίαση του τρόπου σχεδίασης και υλοποίησης του αλγορίθμου του Wolf για τον αριθμητικό υπολογισμό του μέγιστου θετικού εκθέτη Lyapunov μιας άγνωστης χρονοσειράς δεδομένων και (β) την παρουσίαση μιας εφαρμογής που έχει υλοποιηθεί στο λειτουργικό σύστημα των Windows και επιτρέπει τον εύκολο υπολογισμό του εν λόγω μεγέθους μέσα από ένα εύχρηστο και φιλικό περιβάλλον υποστηρίζοντας ταυτόχρονα πολύ περισσότερες δυνατότητες σε σχέση με τις αρχικές εφαρμογές BASGEN και FET.

A STUDY OF BOUSSINESQ SYSTEMS IN TWO DIMENSIONS

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Θεωρούμε μια κλάση συστημάτων Boussinesq σε δυο διαστάσεις, που αποτελείται από τρεις μη-γραμμικές κυματικές διαφορικές εξισώσεις με όρους διασποράς και η οποία προσεγγίζει τις τρισδιάστατες εξισώσεις του Euler. Οι εξισώσεις αυτές περιγράφουν τη διάδοση μακρών θαλάσσιων κυματισμών μικρού πλάτους ενός ιδανικού ρευστού πάνω από οριζόντιο πυθμένα. Για ένα υποσύνολο της κλάσης αυτής, αποδεικνύεται ότι το πρόβλημα Cauchy είναι καλά τοποθετημένο σε κατάλληλους χώρους Sobolev. Επιπλέον ένα υποσύνολο της κλάσης αυτής διακριτοποιείται αριθμητικά, χρησιμοποιώντας τη μέθοδο Galerkin/πεπερασμένων στοιχείων, και αποδεικνύονται εκτιμήσεις σφαλμάτων για το ημιδιακριτό πρόβλημα. Αποτελέσματα διαφόρων αριθμητικών πειραμάτων παρουσιάζονται με σκοπό την μελέτη ιδιοτήτων των μοναχικών κυμάτων καθώς και συμμετρικών κυματισμών. Για την αριθμητική μελέτη του περιοδικού προβλήματος γίνεται χρήση φασματικής μεθόδου και παρουσιάζονται διπλά-περιοδικά κυματικά φαινόμενα καθώς και cn-ωειδή κυματισμοί.

ΔΥΝΑΜΙΚΕΣ ΤΑΛΑΝΤΩΣΕΙΣ ΣΕ ΑΝΑΔΙΑΤΑΣΣΟΜΕΝΑ ΠΛΕΓΜΑΤΑ

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Σε ανοικτά συστήματα, τα οποία βρίσκονται εκτός ισορροπίας, είναι δυνατόν να εμφανιστεί αυτο-οργάνωση. Τέτοια συστήματα απαντώνται και στις διεργασίες αντίδρασης-διάχυσης σε επιφάνεια (πλέγμα), όπου συναντώνται χαρακτηριστικά όπως ταλαντώσεις, μορφώματα ή και χάος. Στη μελέτη αυτή επιχειρείται η προσομοίωση των ταλαντώσεων που λαμβάνουν χώρα στο σύστημα καταλυτικής οξείδωσης του CO πάνω σε Pt(100) λόγω αναδιάταξης της επιφάνειας, υπό συνθήκες χαμηλής πίεσης. Η μεσοσκοπική συμπεριφορά του συστήματος αυτού μελετάται με τη μέθοδο Kinetic Monte Carlo. Ένα μοντέλο εμπνευσμένο από αυτό των Ziff-Gulari-Barshad (ZGB model) χρησιμοποιείται για να διερευνηθεί η συμπεριφορά του συστήματος σε τετραγωνικό και σε εξαγωνικό πλέγμα. Στις παραμετρικές περιοχές όπου το σύστημα τετραγωνικού πλέγματος και το σύστημα εξαγωνικού πλέγματος τείνουν σε διαφορετικές στάσιμες κατάσταση, η εναλλαγή μεταξύ των δύο πλεγμάτων οδηγεί σε ταλάντωση. Μελετάται επίσης η επίδραση της διάχυσης του CO και του συντελεστή προσκόλλησης του οξυγόνου στη συμπεριφορά του συστήματος.

UNIVERSAL PROPERTY OF COMPLEXITY OF QUANTUM MANY-BODY SYSTEMS

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The "statistical" measure of complexity according to Lopez-Ruiz, Manciny and Calvet(LMC)is calculated as function of the number of particles N for various quantum many-body systems i.e. atoms, atomic nuclei, nuclear matter, liquid helium, electron gas, correlated atoms in a trap-bosons. These systems obey different statistics(fermions or bosons), various interactions, have various sizes and different numbers of particles. However, it is seen that C(N) satisfies the same qualitative trend for the above systems i.e. does not increase as N increases. This trend indicates that quantum many-body systems cannot grow in complexity (or self-organize) as the number of particles increases. It is conjectured that this is a universal property of quantum systems.The question naturally arises what happens if quantum systems form larger or more complex structures. The issue of organized complexity is a hot and much debated subject in the community of scientists interested in complexity. Reference: K.Ch.Chatzisavvas, Ch.C. Moustakidis, and C.P.Panos, "Information entropy, Information Distances and Complexity in Atoms", J.Chem.Phys. 123 (2005) 174111

ΑΜΟΙΒΑΙΑ ΣΥΖΕΥΞΗ ΔΥΟ ΚΥΚΛΩΜΑΤΩΝ 4ΗΣ ΤΑΞΗΣ. ΜΕΛΕΤΗ ΤΗΣ ΕΠΙΔΡΑΣΗΣ ΤΩΝ ΧΩΡΗΤΙΚΟΤΗΤΩΝ ΣΤΟ ΣΥΓΧΡΟΝΙΣΜΟ

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Στην παρούσα εργασία μελετούμε τη δυνατότητα συγχρονισμού δύο όμοιων, αμοιβαία συζευγμένων, μη-γραμμικών κυκλωμάτων 4ης τάξης, διαμέσου γραμμικής αντίστασης σύζευξης RC. Μελετώνται οι τρόποι αλληλεπίδρασης των κυκλωμάτων ως προς τις παραμέτρους τους και εξάγονται συμπεράσματα για τους δυνατούς συγχρονισμούς που επιτυγχάνονται. Βασική παράμετρος που μεταβάλλεται είναι η γραμμική αντίσταση σύζευξης, μέσω της οποίας ελέγχουμε το ρεύμα που διέρχεται από τον κλάδο σύζευξης. Η αναζήτηση καταστάσεων συγχρονισμού επικεντρώνεται σε καταστάσεις όπου τα βασικά κυκλώματα παρουσιάζουν χαοτική συμπεριφορά. Η σύζευξη πραγματοποιείται αρχικά στους πυκνωτές C1 των κυκλωμάτων και κατόπιν στους πυκνωτές C2. Τόσο τα θεωρητικά, όσο και τα πειραματικά αποτελέσματα αποδεικνύουν ότι ο συγχρονισμός είναι εφικτός μόνο στην περίπτωση της σύζευξης στους πυκνωτές C2 των κυκλωμάτων.

DETECTION OF LEVEL OF NON-LINEARITY IN TIME SERIES WITH MEASURES OF DEPARTURE FROM LINEARITY

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The objective of this work is to investigate measures that can detect the presence of nonlinear correlations in time series without using the computationally expensive surrogate data test for nonlinearity. For this we attempt to measure directly the departure (declination) from linearity. A natural first candidate is the difference between the estimated mutual information $I_x(\tau)$ for a delay τ on a time series $\{Xt\}$ and the mutual information $I_x^g(\tau)$ corresponding to a normal standard process with the autocorrelation $r_x(\tau)$ of $\{Xt\}$, $dI_x(\tau)= I_x(\tau)- I_x^g(\tau)$. However, a positive $dI_x(\tau)$ may not solely assign to non-linearity, but may also be due to deviations of the distribution of $\{Xt\}$ from normality. In order to dump the effect of non-normality of the data, we normalize the marginal distribution of $\{Xt\}$ using the static transform $y_t = \Phi^{-1}(F_x(x_t))$, where Φ is the standard normal cumulative density function (cdf) and F_x is the cdf of $\{Xt\}$. Then we define the difference above with regard to $\{Yt\}$ as $dI_y(\tau)= I_y(\tau)- I_y^g(\tau)$. We want to use this measure in the investigation of changes in the linear and nonlinear structure of real-world systems, such as the brain potential measured by EEG. Using Monte Carlo simulations on known linear and nonlinear systems undergoing change of a control complexity parameter, we assess the ability of the $dI_y(\tau)$ (or $dI_x(\tau)$) measure to detect the changes only in the nonlinear structure and compare with $I_y(\tau)$(or $I_x(\tau)$, respectively).

ΠΟΛΥΠΛΟΚΑ ΣΥΣΤΗΜΑΤΑ ΘΕΩΡΙΑ ΚΑΙ ΕΦΑΡΜΟΓΕΣ

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Η μη γραμμική δυναμική διακριτών συστημάτων με λίγους βαθμούς ελευθερίας είναι κατανοητή σε μεγάλο βαθμό. Εκεί όμως που η μη γραμμική δυναμική παραμένει ακόμα ένα ασαφές πρόβλημα είναι τα κατανεμημένα συστήματα με πρακτικά άπειρους βαθμούς ελευθερίας. Τέτοια συστήματα, μακριά από ισορροπία, συναντούμε συνεχώς μέσα στην φύση, υπό μορφή στερεών, υγρών, πλάσματος, χημικά συστήματα, βιολογικά συστήματα, οικοσυστήματα, χρηματαγορά κ.λ.π. Στα κατανεμημένα συστήματα μακριά από ισορροπία είναι δυνατόν να εμφανίζεται πολύπλοκη τυχαία δυναμική κρίσεων όπως είναι τα φαινόμενα ηλιακών εκλάμψεων, οι μαγνητικές καταιγίδες στη γαιομαγνητόσφαιρα, οι σεισμοί στη γήινη λιθόσφαιρα, η επιληψία, η καρδιακή αρρυθμία, η δυναμική των πληθυσμών, η κρίση στα χρηματιστήρια κ.λ.π.

Πρόσφατα έχουν αναπτυχθεί δύο ανταγωνιζόμενες θεωρίες προκειμένου να εξηγηθούν φαινόμενα τέτοιου είδους: α) Η θεωρία του χαμηλοδιάστατου χάους των παράξενων ελκυστών και β) Η θεωρία της αυτοοργανούμενης κρισιμότητας. Στην εργασία αυτή διευκρινίζονται οι θεωρητικές αυτές εικόνες και επιχειρείται μια σύνθεση των δύο αυτών ανταγωνιστικών υποθέσεων σε μια ενιαία θεωρητική εικόνα, υποστηριζόμενη από νέα πειραματικά ευρήματα στον Ήλιο, στην γήινη μαγνητόσφαιρα και λιθόσφαιρα και στον ανθρώπινο εγκέφαλο.

CRACK AND SLIP INSTABILITIES IN FRACTURED ROCKS

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Rock is a complex polycristalline material divided by different sorts of discontinuities, sources of weakness, such as joints and faults. Their geometrical relationship and mechanical behaviour are complicated and responsible for a variety of natural phenomena occurring on a wide span of time and length scales. In day-to-day life, the slip instabilities of these discontinuities cause natural hazards such as earthquakes and are important to study for geotechnical purposes. On wider scales, the brittle behaviour of rock corresponding to the frictional sliding along pre-existing faults is thought to be essential to Plate Tectonics because the brittle/ductile transition determines the strain rate of the lithospheric plate, and then its velocity. Moreover, although it is believed that the propagation of fracture plays a secondary role in seismogenesis and that the frictional stick-slip instability is more likely to be responsible for the sudden energy release and the small stress drop characteristic of earthquake phenomenology, velocity jumps or relaxation oscillations in the propagation of a moving fracture can appear in brittle solids. It is further remarkable that, in both cases, these oscillations are produced when the friction law or the specific fracture energy show a velocity weakening. For these various reasons, we are thus interested in developing homogenized constitutive models whose microstructure consists of a network of pre-existing fractures which can propagate or slide with friction. In relation with this motivation, having in mind the complex structure of a fault zone, we are concerned with understanding the selection and interaction of active fault planes. To undertake these questions, we need to deal with the study of the evolution and stability of the microstructure in order to determine the nature and the conditions of existence of stable microstructures. In a first attempt, model microstructures consisting of an elastic medium which contains a finite number of parallel frictional interfaces or fractures are considered.

We first report a preliminary approach to tackle the question of how active fault planes are selected in a network of faults. Precisely, we study the stability of the steady-state sliding of two parallel frictional interfaces which divide an elastic body sheared at a constant velocity applied at one edge of the medium. We determine under which conditions different steady states exist and are stable, restricting the analysis to the framework of rate-and-state friction. In this context, when the sliding is steady with a homogeneous shear stress, we expect indeed the interfaces to be able to slide with two different slip rates if the steady-state friction coefficient is a non-monotonic function of the slip velocity. As a result, we show that the sliding of a multislip system brings a strong motivation to develop non-monotonic friction laws in the sense that it allows fast and slow interacting interfaces whereas only the weakest interface remains active if a purely velocity-weakening friction law is considered. From analytical results of sliding stability and numerical bifurcation analysis using a continuation method performed with a non-monotonic friction law that we propose, we show how the symmetric steady state for which the two interfaces slide with the same slip rate bifurcates to an asymmetric solution at critical values of the driving velocity equal to twice the slip rates at which the friction coefficient reaches an extremum. The domains of existence of these various sliding states, occuring via different kind of bifurcations, is summarised in the phase plane defined by the driving velocity and the stiffness of the system. Further work needs to be done to understand the bifurcations of the asymmetric oscillatory solutions existing in this system.

Concerning the oscillatory propagation of fracture, the peeling of adhesive tape is revisited in order to determine the degree of physical complexity we must take into account to describe erractic dynamics existing in such a system. Here again, a key feature is to consider a non-monotonic variation of the fracture energy with the crack velocity. Regarding the model of Maugis and Barquins which describes the time evolution of the crack tip speed and the strain energy release, we are exploring the range of parameters values from which relaxation oscillations appear. Very interestingly, we find that there exist periodic orbits containing canards, that is part of trajectory following the unstable branch of the specific fracture energy. This phenomenon might allow the system to jump erratically from the relaxation cycle to small amplitude periodic orbits. We hope to be able to draw a map of the parameters phase space which would motivate experiments to better constrain the measurements of the velocity-weakening part of the fracture energy. This preliminary work will be used to tackle the question of stick-slip fracture of rocks.

ΝΕΑ ΚΑΤΗΓΟΡΙΑ ΑΝΤΙΣΤΡΕΠΤΩΝ ΚΥΨΕΛΙΚΩΝ ΑΥΤΟΜΑΤΩΝ ΧΩΡΙΣ ΜΝΗΜΗ

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Διεύθυνση Τεχνολογικών Εφαρμογών
Δημόκριτος

Σαν συνέχεια της εργασίας των Fredkin και Toffoli, δείχνουμε ότι είναι δυνατόν να οριστεί μια δεύτερη κατηγορία κυψελικών αυτομάτων στα οποία γίνεται χρήση αντιστρεπτών (1-1) απεικονίσεων σε τρία χρονικά βήματα. Η αναστρεψιμότητα δεν απαιτεί πληροφορία από προηγούμενα χρονικά βήματα. Ο χώρος των απεικονίσεων αυτής της κατηγορίας είναι εκθετικά μεγαλύτερος από εκείνο των στοιχειωδών αυτομάτων και αυξάνει με το πλήθος των μεταθέσεων της δύναμης του αριθμού των πλησιεστέρων γειτόνων. Γίνεται απόπειρα ταξινόμησης των διαφόρων απεικονίσεων ως προς τον τύπο της παραγόμενης δυναμικής με βάση ιδιότητες των δυαδικών προτύπων ενώ συζητείται η πιθανή σχέση των αυτομάτων αυτών με την Υπόθεση Fredkin-Zuse.

PROBABILITY OF EXTINCTION UNDER THE FOREST FIRE MODEL

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The standard forest fire model offers a simple way to model the complex dynamics of a landscape undergoing disturbance. Under this model, habitat (i.e. the part of the landscape where the simulated population can live) regenerates randomly across the landscape with a constant probability in time (p) and each point in the landscape, may be the start of a fire event with a very low probability (f). Once a fire starts it will propagate to all its neighboring habitat cells iteratively, until it reaches unsuitable landscape. The distribution of burnt patch sizes follows a power law, like fires in real life forests. The distribution of available habitat at each time step displays self-similarity. This model was described as an example of self-organized criticality. We simulated a population of known demography living in a landscape where habitat availability determined by the forest fire model. To separate the effect of the temporal pattern of the disturbance from the spatial configuration of the habitat, we compared the results of the forest fire model with the ones from a random landscape, that at each time step had the same habitat availability as the forest fire model. Our results showed that the probability of fire ignition (f) was inversely proportional to the average habitat availability, and this had a direct effect on the average population size persisting. However, as f increased, the temporal variation of habitat availability, and consequently the temporal variation of population size, decreased. And even though, smaller f had higher average population sizes their minimum population sizes were less than that of similar populations living under higher f. On the other hand as the probability of habitat regeneration increased, the average burnt patch size increased, and so the average habitat availability and thus the average population size. Acknowledgement: The authors wish to acknowledge the financial contribution from the Pythagoras (environment) project.

ΦΑΙΝΟΜΕΝΑ ΓΩΝΙΑΚΟΥ ΣΤΡΩΜΑΤΟΣ ΣΕ ΜΙΑ ΚΛΑΣΣΗ ΧΑΜΙΛΤΟΝΙΑΝΩΝ ΣΥΣΤΗΜΑΤΩΝ

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We study heteroclinc connections for a class of singularly perturbed Hamiltonian systems where standard methods of dynamical systems don't apply due to lack of smoothnes and normal hyperbolicity.

ΕΠΙΔΡΑΣΗ ΤΗΣ ΑΝΤΙΣΤΑΣΗΣ ΣΥΖΕΥΞΗΣ ΣΤΗ ΣΥΜΠΕΡΙΦΟΡΑ ΤΡΟΠΟΠΟΙΗΜΕΝΟΥ ΑΥΤΟΝΟΜΟΥ ΚΥΚΛΩΜΑΤΟΣ CHUA

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Στην εργασία αυτή μελετήθηκε ένα τροποποιημένου, μη οδηγούμενο κύκλωμα Chua 4ης τάξης, με κατά τμήματα γραμμικό αντιστάτη στενής περιοχής λειτουργίας (ως προς τάση). Η τιμή του αντιστάτη σύζευξης παίζει καθοριστικό ρόλο στη μεταφορά ενέργειας από το μη-γραμμικό στοιχείο στο κύκλωμα ταλάντωσης και την αρνητική αγωγιμότητα. Μελετήθηκε για μεγάλο φάσμα τιμών η επίδραση του αντιστάτη αυτού, καταγράφονται και σχολιάζονται τα αποτελέσματα και καθορίζονται οι περιοχές πιο αναλυτικής μελέτης, στις οποίες παρατηρούνται χαρακτηριστικά δυναμικά φαινόμενα.

ΦΥΣΑΛΙΔΕΣ, ΑΝΤΙΜΟΝΟΤΟΝΙΚΟΤΗΤΑ ΚΑΙ ΚΡΙΣΗ ΣΕ ΑΥΤΟΝΟΜΟ ΚΥΚΛΩΜΑ 4ΗΣ ΤΑΞΗΣ

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Στην εργασία αυτή μελετήθηκε ένα αυτόνομο κύκλωμα 4ης τάξης, ιδιαίτερα ευαίσθητο στις αρχικές συνθήκες, με μη-γραμμικό αντιστάτη RN, χαρακτηριστικής τύπου N, μονού σπασίματος. Ερευνήθηκε για διάφορες τιμές των παραμέτρων του κυκλώματος (C1, C2) η συμπεριφορά του. Επεξεργάσθηκαν περιοχές όπου εμφανίζονται συμπεριφορές αντιμονοτονικότητας, διπλασιασμού περιόδου και φυσαλίδων. Εντοπίστηκαν περιπτώσεις κρίσης του συστήματος μέσα στις φυσαλίδες που φαίνεται να οδηγούν σε καταστροφή των παραπάνω φαινομένων.

THEORETICAL AND NUMERICAL STUDY OF VAN DER POL OSCILLATOR

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Πτυχιακή εργασία - Επιβλέπων Σ. Ιχτιάρογλου In this work, we present the basic theoretical efforts (theory of averaging, succesive approximations) that are known in order to deal with non-trivial solutions at the Van der Pol oscillations. We also construct a set of diagrams (phase portaits, bifurcation diagrams, Fourier power spectra) and maps, based on numerical investigations, corresponding to the expected theoretical results. Furthermore we examine closely the existence of chaotic attractors, both theoretically (with Lyapunov exponents) and numerically (period doubling cascades). Finally we outline other applications and modeling with coupled Van der Pol oscillators (heartbeat model, relativistic parametrically forced oscillator). We study numerically some modified cases of this equation for different dumping functions. All diagrams and numerics have been made with Mathematica (version 5.2) and C++ programming languages

TIME SERIES CLUSTERING FOR OSCILLATING DYNAMICAL SYSTEMS BASED ON LINEAR, NONLINEAR AND OSCILLATION-RELATED FEATURES

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Clustering techniques have been recently applied for data mining from time series data bases. In this work, we concentrate on time series from dynamical systems that exhibit oscillatory behavior, such as electroencephalographs (EEG). We consider clustering on features extracted from the time series (feature-based clustering) rather than clustering directly on the time series (subsequential clustering). In addition we apply standardization of the features prior to clustering. As features we include simple linear and statistical measures, such as the skewness, kurtosis and autocorrelation, nonlinear measures, such as the three point autocorrelation, mutual information and largest Lyapunov exponent, as well as features related to the oscillations of the time series, such as the mean local peak and the mean oscillation period. The objective is to find the features that contribute most to accurate clustering of time series that regard different dynamical states. The clustering accuracy is measured by the Corrected Rand index (CRI). To obtain statistically significant results we generate Monte Carlo realizations, where each realization regards a data base of groups of time series and each group represent a different dynamical state. To simulate the dynamical states we used the Lorenz-95 system at three chaotic regimes of varying complexity, the Mackey-Glass also at three chaotic regimes (for delay parameter 17,23,30) and a set of three systems, a pseudo-periodic system at four dimensions, the hyper-chaos Roessler system and a systems that generates stochastic oscillations. For the search of the best feature combination we used the sequantial forward selection method (SFS). The results showed the oscillation-related features contributed most and often in combination with a nonlinear feature. We applied the clustering set-up with the same features on epileptic EEG data from interictal state (much before seizure onset) and preictal state (few minutes before seizure onset). The two pre-epileptic states could be classified with high accuracy and the \"best feature set\" was comprised always of a nonlinear measure (most often largest Lyapunov exponent) and often an oscillation-related feature.

NON-LINEAR ANALYSIS AND MODELLING OF EEG FOR PATIENTS WITH EPILEPSY

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We compare different physiological and pathological brain states using the chaotic analysis algorithm, applied in brain electrical activity (EEG) time series from different recording regions. We analyze three sets of EEG time series from epileptic patients: 1 hour before seizure attack, 30-15 min pre-seizure activity and on seizure attack, with the following results:

1. 1 hour before seizure attack the slopes of the correlation integrals do not reveal saturation profile, while as the system approaches the pathological state, the results showed a saturation of the slopes at a value, $D \approx 4.5$.
2. The strongest indications of nonlinear deterministic dynamics were found for seizure activity
3. The power spectrum of the time series shows an aperiodic profile, while the slopes of the correlation integrals show an apparent plateau at the scaling region, which saturates at the value $D \approx 2.5$. The maximum Lyapunov exponent (Lmax) attains a positive value.

Moreover, we have also estimated the correlation coefficient between predicted and real values of the time series as a function of the prediction step. Finally, the strong null hypothesis, supposing that a linear stochastic process perturbed by a static nonlinear distortion produces the EEG time series, was tested for all the above - mentioned characteristics. Thus, the results of our study suggest that is possible to predict the seizure attack by using the chaotic analysis algorithm of the EEG signals, as it seems that there is a transition from high dimensionality (physiological brain state) to a low dimensional attractor (epileptic seizure).

GRANGER CAUSALITY, LINEAR AND NON-LINEAR PREDICTION FOR MULTIVARIATE TIME-SERIES OF OSCILLATION FEATURES

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In the study of natural dynamical systems one often encounters oscillating time series, comprised of patterns of upward trends followed by downward trends without evident periodicity, e.g. electroencephalographs, electrocardiographs, solar sunspots etc. Typically the model fitting and/or prediction for these time-series is performed with high order linear autoregressive (AR) models or with non-linear models, like local linear models and neural networks, at a reconstructed state space of high dimension. The disadvantages of this approach are the inclusion of redundant information from consecutive observations and the inability to adequately predict the next extreme point of the oscillation. In this paper we transform the univariate time-series of oscillations to a multivariate time series by assigning to each oscillation the maximum, the minimum, the oscillation period and the time from minimum to maximum. For the prediction of the peak (maximum) of the oscillation we fit on the time-series of local maxima a dynamic regression model and a local linear (i.e. non-linear) model by expanding the state space reconstruction so that it contains components from lags of other variables. The optimal model for each case is chosen by means of the Granger Causality Index, i.e. by evaluating whether the inclusion of one of the other variables (at different lags) improves the prediction. Finally we compare these models with each other and also with the optimal AR model and the optimal local linear model on the oscillating time series with respect to their predictive ability for prediction of maxima. Monte Carlo simulations have shown that there is significant differentiation of the features time series interaction with regard to linear and nonlinear systems and confirm the usefulness of such an analysis for peak prediction.

ΣΥΓΧΡΟΝΙΣΜΟΣ ΔΥΟ ΧΑΟΤΙΚΩΝ ΚΥΚΛΩΜΑΤΩΝ ΜΕ ΤΗΝ ΜΕΘΟΔΟ ΤΟΥ ΑΝΤΙΣΤΡΟΦΟΥ ΣΥΣΤΗΜΑΤΟΣ

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Μελετήσαμε πειραματικά τον συγχρονισμό μεταξύ δύο χαοτικών συστημάτων με την μέθοδο του αντιστρόφου συστήματος (Inverse System Approach). Στην μέθοδο αυτή κατασκευάζουμε ένα κατοπτρικό σύστημα του αρχικού, το οποίο έχει μια σχέση σήματος εισόδου - εξόδου αντίστροφη από εκείνη του αρχικού. Εφαρμόσαμε τη μέθοδο αυτή στην περίπτωση της σύζευξης δύο κυκλωμάτων που υλοποιούν την εξίσωση Duffing, καθώς και στην περίπτωση της σύζευξης δύο κύκλωματων τύπου - Chua. Παρουσιάζουμε τα αποτελέσματα της σύζευξης για διάφορες τιμές της παραμέτρου ελέγχου και διαπιστώνουμε την επίτευξη συγχρονισμού στην περίπτωση που τα συζευγμένα κυκλώματα έχουν ακριβώς τα ίδια στοιχεία. Επίσης πραγματοποιήσαμε τη σύζευξη μέσω ενός γραμμικού αντιστάτη (Rx) και διαπιστώσαμε ότι ο συγχρονισμός διατηρείται για μικρές τιμές του αντιστάτη.

SOME DEVELOPMENTS IN THE THEORY OF ATTRACTORS AND APPLICATIONS TO DYNAMICS OF VISCOELASTIC MEDIA

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We shall describe sufficient conditions for existence of minimal trajectory attractors and global attractors of autonomous evolution equations in Banach spaces without assumptions of any invariance of the trajectory space of an equation. We shall also describe sufficient conditions for existence of minimal uniform trajectory attractors and uniform global attractors of non-autonomous equations. Unlike the earlier results, here it is not assumed that the symbol space of an equation is a compact metric space and that the family of trajectory spaces corresponding to this symbol space is translation-coordinated or closed in any sense. Then we shall discuss some properties of the attractors and apply the results to the motion equations of an incompressible viscoelastic medium with the Jeffreys constitutive law.