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P01

Facilitation's impact on sandpile models at the thermodynamic limit

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Self-organized criticality (SOC) provides a framework for understanding the emergence of criticality in natural systems without the need for external parameter tuning, as observed in phenomena like earthquakes[1]. In SOC models, the critical point becomes a stable equilibrium for the effective dynamics of external parameters. In line with this concept, another class of systems is proposed, wherein a stable limit cycle emerges around the critical point. This phenomenon is known as Self-Organized Bistability (SOB).

A model exemplifying self-organized bistability is based on the sandpile model, with a modification that allows the simultaneous instability of neighboring sites to reduce their threshold, facilitating toppling[2]. This modification introduces a stable limit cycle around the critical point.

Investigating how a stable fixed point of an external parameter evolves into a limit cycle and whether a Hopf bifurcation exists is an intriguing pursuit. We explored variations of this model with a continuously adjustable parameter, enabling a seamless transition from SOC to SOB.

Our findings reveal that, at least within this model, self-organized bistability is not present in large-scale systems. We examined the impact of parameter adjustments in terms of changes in length. Using equations similar to renormalization equations, we observed that this parameter approaches self-organizing criticality in the limit of large scales.

[1] J. M. Carlson, J. S. Langer, B. E. Shaw, and C. Tang, “Intrinsic properties of a burridge-knopoff model of an earthquake fault,” Physical Review A, vol.44, no.2, p.884, 1991.
[2] S. di Santo, R. Burioni, A. Vezzani, and M. A. Munoz, “Self-organized bistability associated with first-order phase transitions,” Physical review letters, vol.116, no.24, p.240601, 2016.

P02

Role of Anistropy in Pulsating Active Matter

When the heartbeat becomes irregular due to tachycardia or fibrillation, spiral waves and turbulence emerge on the surface of the heart. Recently, a many-body model for catching the spontaneous emergence of waves in contractile biological tissues has been proposed: therein, tissues are treated as a dense assembly of active deforming particles. This model examines a dense system of active particles. Each particle has a circular shape and can change its radius following an internal drive and pairwise interactions. However, cells such as cardiomyocytes (heart cells able to contract rhythmically) are not isotropic. Therefore, we add a new degree of freedom represented by the ability of particles to change their eccentricity depending on their phase. Hence, we investigate the role of anisotropy in collective dynamics by using four different models of Dense Pulsating Ellipses (DPEs). The resulting dynamics are studied through numerical simulations and hydrodynamic equations, obtained from the coarse-graining of microscopic dynamics. This model paves the way for simulating contractile biological tissues, elucidates the interplay between nematic order and size synchronization, and gives some insights into how cell deformability might control the emergence of spiral waves and wave turbulence in cardiac tissues.

P03

Contraction of Bare Forces (CBF): A new physical formalism for calculating effective forces

Effective interactions are fundamental in the field of soft matter and complex systems; and many physical phenomena take place in different thermodynamic systems due to such interactions. Depletion forces are a very particular example of effective interactions, being of entropic origin rather than energetic. These forces are fundamental in determining the behaviour of a large number of materials and colloidal dispersions, and have been used for the manipulation of systems whose thermodynamic states are in and out of equilibrium. The effective nature and entropic origin of these effective forces is well understood; however, most theoretical approaches, and also molecular simulations, only work quantitatively in very dilute systems, as large size asymmetries and high particle concentrations are difficult to deal with. Existing approaches to integrate the degrees of freedom of depletant species may fail under these extreme physical conditions. Seeing this, the main objective of this contribution is to introduce a general physical formulation to obtain effective forces. We show that the contraction of the bare forces uniquely determines the depletion interactions. Our formulation is tested by studying the depletion forces in binary and ternary colloidal mixtures. Here we present results for dense systems. Our results open the possibility of finding an efficient route to determine the effective interactions at finite concentration, even under non-equilibrium thermodynamic conditions.

P04

An information theoretical approach to the estimation of functional connectivity in fMRI signals

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The brain is a complex system composed of a large number of interconnected elements. High-level descriptions of cerebral dynamics use graph-theoretical representations to describe the functional connections between brain areas. Our aim is to construct the weighted graph representing the temporal correlations in healthy subjects undergoing fMRI scans in the resting state, and to study the population variability of the graph. Since practical limitations prevent the scans from lasting more than a few minutes, dimensionality reduction techniques are required in order to infer functional connectivity in the severely undersampled regime.

In this study, an innovative method utilizing Fisher information is proposed and implemented. If only up to second-order correlations between brain regions are assumed to be relevant, the joint probability distribution may be assumed to be Gaussian. In this case, the Fisher information matrix F may be written analytically, and it defines a metric in the space of binary correlations. A similar approach performed with the Ising model has yielded the distinction between stiff and sloppy directions in the space of parameters [1]. In our case, the space of parameters is the space defined by the values of pairwise correlations.

The directions in correlation space defined by the eigenvectors of F with the largest eigenvalues are the stiff directions, and they change dramatically the joint probability distribution. Therefore, if the dimensionality-reduction technique aims at detecting subjects that potentially display highly unusual brain activity, the subspace spanned by the eigenvectors with the largest eigenvalues should be selected. This subspace modulates the temporal correlations between ipsilateral frontal and temporal brain regions. Alterations along these directions may be linked to neurological disorders, such as, for example, the propagation of fronto-temporal epilepsies [2]. We have observed a remarkably small variability of healthy brains along these directions.

Instead, the eigenvectors linked to small eigenvalues constitute sloppy directions, and they describe contralateral connections, and other ipsi-lateral correlations different from the fronto-temporal connection described above. A large population variability was observed along the sloppy directions. Therefore, if the dimensionality-reduction technique is expected to provide a detailed description of the idiosyncratic properties of the individuals in the sample, the subspace spanned by eigenvectors of F with small eigenvalues should be selected, which is similar to what PCA does by choosing the axes with maximal variance.

[1] Machta, B. B., Chachra, R., Transtrum, M. K., Sethna, J. P. Parameter space compression underlies emergent theories and predictive models. Science, **342** (6158), 604-607 (2013).
[2] Lin, H., Leng, X., Qin, C., Wang, W., Zhang, C., Qiu, S. Altered white matter structural network in frontal and temporal lobe epilepsy: A graph-theoretical study. Frontiers in Neurology, **11**, 561 (2020).

P05

On fractional order maps: Stability and Control

Compared to fractional differential equations, there are far fewer studies in fractional order maps. We present some published and ongoing contributions in this regard. We have extended the definition of fractional order maps to complex order. This can have applications in materials science. We have studied the stability of these systems. In this case, we have investigated the existence of chaos, and examples studied indicate chaos can exist in complex order maps only for non-analytic functions. We have also carried out a study on feedback control of fractional order maps as well as stability analysis of maps with feedback. Majoor results of all these studies will be presented in this poster.

P06

Study of Heterogeneous System Modelling & Complex Network Analysis for Social Contagions

Network models are frequently used in studies of social contagions (illness, addiction, opinion, rumor, etc.) to examine how social effects and ideas spread while accounting for social variability. Using a continuous ODE technique and differential equations on graphs, I systematically examine the developments in social media addiction, which is increasingly addictive and leading to many effects, such as anxiety, depression, and health problems. To analyze bifurcations and thresholds mathematically, we first develop a compartmental model. Afterward, we use a network-based analysis to show how social media addiction spreads dynamically over a social network using an epidemiological approach when media influence is present. We investigate the emergence of spatiotemporal patterns in a diffusive social system employing the diffusion-reaction method. Our model demonstrates the system's nonlinearity. We solve this problem by raising public awareness through media campaigns, which may be helpful in the elimination and management of SMA. We also propose control strategies and gain a better understanding of the dynamics' complexity with the help of realistic parameter selection.

P07

Thermodynamic limits of linear regression

This poster presents a study on a physical system designed for linear regression, consisting of springs attached to a plane. We explore the system's behavior as the spring constant k approaches zero, representing a reduction in the system's size. The focus is on understanding how this limit affects the precision of the linear regression model and the entropy production of the physical system. We find a relationship between the precision of inference in the linear model and thermodynamic variables of the physical system. This contributes to the broader understanding of the interface between physical systems and machine learning algorithms.

P08

Active Granular Intruders: Controlling the Irregular Sinking of Imperfect Bodies in Granular Media

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Imperfect objects exhibit irregular sinking behavior when released into a granular medium. A subtle asymmetry in an object's density or shape can cause significant tilt and deviation from a vertical path when released from the free surface of a granular bed. This can be inconvenient, and even catastrophic, in scenarios ranging from building foundations to space rovers. Through experimental observations, computational simulations, and mechanical models, we demonstrate that minor surface irregularities and non-homogeneous density distributions can significantly alter the penetration process [1]. Leveraging the pronounced sensitivity of settlement dynamics in granular media to the shape asymmetry of penetrating objects, we introduce a granular intruder equipped with an inflatable elastic region that autonomously expands from the intruder's surface in response to unwanted tilt. In this way, we minimally manipulate the intruder's symmetry, successfully rectifying the unwanted tilt.

[1] M. Espinosa, L. Martínez-Ortíz, L. Alonso-LLanes, L. Rodríguez-de-Torner, O. Chávez-Linares, and E. Altshuler, Sci. Adv. **9**, eadf6243 (2023).

P09

Comparison of the Gene Regulatory Network of Cancerous and Healthy Cells in the Presence of Disorder

Cancer is recognized as a genetic disease. While gene expression generates a biological process, there is evidence that genes do not operate independently from each other in the process of gene expression and interconnected within a gene regulatory network. In this article, by introducing the tension factor into the gene expression regulation network of healthy and cancer cells, we will study how the two networks evolve and their differences from the point of view of structural balance. For this purpose, by using the structural balance dynamics in non-zero temperature and with the help of Boltzmann's equilibrium distribution function, we assign energy to each triangle at each specific temperature and measure the balance of the network. We observe that both networks are completely balanced at zero temperature. The balanced structure breaks down when the amount of tension increases at a characteristic temperature that is different for both networks; The cancer network exhibits a stronger resistance to destroying the balanced structure that it has created. Also, by examining the behavior of single genes, we understand the structural role of some of them; We observe that certain genes have a greater impact on the formation of balance in the network than others.

P10

Dynamic Patterns due to Follower Activity in Connected Particles

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Active Polymer Model has been widely used to understand a broad range of biological as well as non-biological phenomena. For example, to study the active driving of DNA by Polymerase, active forces are modelled as force monopoles acted on each bead along the local orientation of bond vectors[1]. In this model, active forces of constant magnitude is applied along the local tangent to the polymer and it has been shown that with increasing activity, the chain tends to form densely packed globular state in the presence of noise.

We studied the conformation of such chains in the presence of a unidirectional external drive. We observed, that in the presence of low thermal fluctuations, the chain shows a number of dynamic morpho-states as a function of the ratio of the external driving force to the internal activity. For example, we observed a transition from a complete collapsed state to a travelling helical wave and eventually, to a travelling planar wave. These morphological states are remarkable since they are formed in the absence of any bending rigidity.

We quantified these configurations and studied their variations as a function of changing activity ratio. Further we have examined the stability of such configurations to show their robustness. Our studies show that a combination of external drive and a constrained internal activity can give rise to a range of dynamic structures in a system containing many degrees of freedom.

[1] V. Bianco, E. Locatelli and P. Malgaretti, Phys. Rev. Lett. **121**, 217802 (2018).

P11

Statistical Properties of Learning in the Hopfield Model

This work focuses on the capacity of a variant of the Hopfield model, a type of neural network, where the nodes are connected with a certain probability. Increasing the number of memories that the network has learnt leads to a phase transition from an associative memory state to a not working one. Through simulations, it emerges that this transition is proportional to the square root of probability that two node are connected. We analyze also the structure of the graph, mainly the Laplacian and the graph entropy, to look for any correlation with the phase transition. The simulations do not reveal any significant relationship between the phase transition and the structure of the graph. This result suggests that the phase transition is predominantly a dynamical effect.

P12

Thermalization and hydrodynamics in an interacting integrable system: the case of hard rods

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A classical Hamiltonian many-body system will generally thermalize to Gibbs Ensemble (GE) if left alone for a long time. However, there may exist systems that do not thermalize to GE, because of the existence of extra conservation laws which restrict their motion in the phase space. Thus, dynamical many-body systems can be thought of as constituting a spectrum, with systems having only Hamiltonian as the conserved quantity at one end of the spectrum, and systems having infinitely many conservation laws at the other end. The latter end consists of integrable many-body systems, which are believed to thermalize to the Generalized Gibbs Ensemble (GGE). They have a number of conservation laws equal to the number of degrees of freedom, and thus an infinity of them in the thermodynamic limit. Their non-equilibrium states close to local GGE is described by generalised hydrodynamics (GHD). In this poster, we will study thermalization to GGE of an interacting integrable system, which is that of hard rods, starting from an initial non-equilibrium state. We will also solve the GHD equations at the Euler level exactly by mapping it to a free particle Euler equation. We will also include the Navier-Stokes corrections to the GHD equations and solve it exactly for certain non-equilibrium initial conditions. We will compare our analytical results with those of molecular dynamics simulations, thus providing a verification of GHD. This poster is based on [1]

[1] S. K. Singh, A. Dhar, H. Spohn, and A. Kundu, arXiv:2310.18684.

P13

In-Gap States and Spin Dynamics For Superconducting Molecular Junctions

In this work, it is investigated the behavior of paramagnetic molecules in superconducting molecular junctions, building upon previous works that have shown the emergence of an effective RKKY-like interaction among spin degrees of freedom using the Jauho-Meir-Wingreen out-of-equilibrium Greens function formalism. We have calculated the density of states of a two-level molecule with two spins and identified the presence of Yu-Shiba-Rusinov-like states within the superconducting energy gap, attributed to the influence of spin degrees of freedom on the superconducting substrate. Our exploration sets the ground for the investigation of the robustness of these anomalous states under heat flow and their coupling through the emerging RKKY-like interaction, aside from its effects on molecular spin dynamics. This work aims to theoretically predict the behavior of interplay between spin dynamics, superconductivity, and transport in molecular junction systems.

P14

Decoding the Emergence of Chaotic Griffiths Phases in Networks of Map-Based Neurons

This study significantly advances the understanding of the chaotic Griffiths phase in coupled map networks. We extend their foundational work by exploring neuron-based dynamics. This finding supports the hypothesis that this phase may underlie the critical behavior observed in neural systems. We introduce the Dispersion of the Fraction of Clusters (DFC) as a robust statistical measure for characterizing this complex phase. Our results indicate that the chaotic Griffiths phase emerge from heterogeneity in control parameters. We also observe other states, such as complete synchronization and chimera states, which have implications for diseases brain. Additionally, our findings with Mechanism 2 and Mechanism 3 align closely with experimental observations of Self-Organized Criticality in brain dynamics, specifically covering slopes across -3/2, further validating the significance of our research.

P15

Dynamical models in neuroscience: the delay FitzHugh-Nagumo equation

The neuron model developed by R. FitzHugh and J. Nagumo serves as a crucial starting point for research in the neuroscientific exploration of neuronal dynamics. The complexity of neurons and inter-neuronal dynamics entails that many aspects in this field are not yet fully understood. This work delves into a model inspired by FitzHugh and Nagumo's original work, incorporating a self-coupling term with time delay into the system of differential equations that describe the model. This formulation allows a mean-field description of the macroscopic states of a neuron ensemble. The introduction of time delay produces a richer and more complex dynamical behavior of the system compared to the original model, and provides a more realistic description of neuronal systems. The existence of a limit cycle solution in the delayed model will be demonstrated, where this solution cannot be interpreted within the framework of Hopf bifurcations. To explore fundamental aspects of neuron modeling, we will primarily employ theoretical tools from Dynamical Systems Theory and numerical methods for the integration of delay differential equations.