Machine Learning-Driven Analysis of Carbon Nanotube Accumulation in Cancer Cells via Raman Spectroscopy

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Machine learning offers significant potential for extracting insights from extensive datasets. In this study, we utilized principal component analysis (PCA) and K-means clustering to explore the accumulation of single-walled carbon nanotubes (SWCNTs) in cancer cells. We examined the Raman spectra of cells exposed to SWCNTs capped with either DNA or oligonucleotides (ON) and tracked their temporal evolution. Through unsupervised machine learning techniques, we elucidated the mechanisms and sequences of SWCNT accumulation and distribution in glioma cells, highlighting the chirality discrimination by capping molecules and subsequent selective intracellular transport. PCA facilitated the denoising of Raman spectra and extraction of specific biochemical information, while K-means clustering visualized the distribution of nanotubes and cellular compartments. Utilizing machine learning, we successfully extracted information on carbon nanotube accumulation in cancer cells from Raman spectra datasets, obviating the need for additional research methods.

Self-organization of charged particles in lateral potentials with a high symmetry

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The problem of the optimal configuration of a finite number of particles in a plane has been a difficult problem of both physics and mathematics for many centuries. Back in 1611, Kepler posed the question of why a snowflake has perfect hexagonal symmetry [1]. At present, increased interest in the problem of the optimal configuration is also due to the development of nanotechnologies which make it possible to form systems of similarly charged particles confined by external potentials with a high symmetry. For example, this problem arises when analyzing the behavior of quantum vortices in a Bose condensate [2]; electrons in quantum dots [3]; and the self-organization of colloidal particles at the interface between two different liquids [4, 5].

In this communication we discuss the basic principles of self-organization of one-component charged particles, confined in disk and circular parabolic potentials [6,7]. The main idea is based on the cyclic symmetry and periodicity of the Coulomb interaction between particles located on several rings. Our approach reduces significantly the computational effort in minimizing the energy of equilibrium configurations and demonstrates a remarkable agreement with the values provided by molecular dynamics calculations. With the increase of particle number $n \geq 180$ we find a steady formation of a centered hexagonal lattice that smoothly transforms to valence circular rings in the ground state configurations for both potentials. At the same time, the energetic preferences for nonuniform local density then favor ground states where this locally hexagonal structure is isotropic dilated and contracted throughout the structure. In fact, the equilibrium configuration is determined by the need to achieve equilibrium through the formation of a hexagonal lattice on one side and a ring-like structure on the other. This competition leads to the formation of internal defects in such systems, in contrast to the case of unlimited regions, where the ground state of the system has no defects [8]. Finally, this structure smoothly transforms to valence circular rings in the ground state configurations for both potentials.

We briefly discuss the precursors of the phase transition of the type “hexagonal lattice – hexatic phase” with the increase of a particle number in the system at zero temperature.

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Complex dynamics in Hamiltonian-driven dissipative system

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We study the discrete system that approximates a billiard with oscillating boundaries. It consists of a dissipative 2D map affected by a conservative 2D map. We show that the variety of dynamic regimes including strange non-chaotic exist in this system as well as the multistability with the extreme number of coexisting attractors.

On an approximate formula for functionals with respect to stochastic Poisson measure

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The report proposes a formula for the approximate calculation of mathematical expectations of functionals with respect to a stochastic Poisson measure. The formula belongs to weak methods of approximating the values of functionals and is exact for third-order moments. Examples of application of the formula are given.

Optimizing 3D Ionosphere Reconstruction Algorithm Based on Modified Landweber Method for Enhanced Radiotomography Accuracy

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The report addresses the problem of three-dimensional ionospheric reconstruction using data from global navigation satellite systems. We present a novel algorithm for 3D ionospheric reconstruction based on a modified Landweber method. Key features include setting relaxation parameters and initial values according to the Chapman equation and exponential distribution, smoothness constraints using a nine-point finite-difference approximation of the second-order Laplace operator, and weighting coefficients to account for constraints and initial values. The algorithm structure and operating principle are described. We developed a mathematical modeling framework to investigate ionospheric reconstruction algorithms, utilizing simulated total electron content measurements derived from a realistic ionospheric model. Results show reconstruction quality dependencies on the choice of ionospheric pierce point and weighting coefficients determining smoothness constraints and initial approximations. A methodology for optimizing the 3D reconstruction algorithm parameters, utilizing an ionospheric mathematical model and surrogate multi-parameter optimization is proposed. This approach significantly reduces algorithm tuning time and ensures finding the global extremum. The proposed method advances ionospheric tomography capabilities with potential applications in radio communications, navigation, and space weather monitoring, demonstrating improved accuracy in reconstructing ionospheric electron density distributions.

Geometric Models of Nonwandering Indecomposable Continua

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Recently, I have researched and then announced the topological classification of the Birkhoff curves and the nonwandering continua possessing Wada property. At the same time, I made a fundamental mistake by allowing the existence of more than the only fixed point belonging to the Birkhoff curve.