Abstract: Science and Engineering Fair of Houston

3415

Investigating Error Detection Efficiency with Hypergraph-Linked Qubit States

Category:

Physics and Astronomy

Avi Singa, Shubam Vennu

Conroe ISD /AST: Academy of Science and Technology

In the modern NISQ era, quantum computers face the challenge of decoherence, which destroys quantum information within microseconds. Despite the introduction of modern Quantum Error Correction codes, which spread quantum information by encoding one “logical” qubit onto many physical qubits, the number of qubits needed for QEC to be effective is unfeasible for current computation. This research proposes the use of k-uniform hypergraph states, graph-like structures that connect k nodes per hyperedge, to potentially reduce the large qubit overhead required for QEC as well as gain the ability to detect correlated errors between multiple qubits, a feature which is impossible for pairwise QEC codes to have. To test the efficacy and efficiency of hypergraph QEC codes, various k-uniform states (2, 3, 4, 5) were tested against modern pairwise QEC codes of similar qubit amount under three noise conditions: uncorrelated, correlated, and real device specifications. The performance of both states were tested and compared by using T1 decoherence, energy relaxation time, T2 dephasing analysis, and syndrome extraction metrics, which were then tested for statistical significance using t-tests. The results demonstrated that 3-uniform hypergraph states provided the most optimal benefits overall, displaying a 33% improvement in T1 coherence time and a 26% improvement in logical error rates when tested in correlated noise environments. The results of this research predict that hypergraph QEC would have 30% less qubit overhead than pairwise QEC, drastically reducing a quantum machine’s requirements when scaled, implying potential application use from quantum molecular simulations to creating denser quantum processors.

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Abstract: Science and Engineering Fair of Houston

3416

High-Fidelity Orbital Propagation Featuring Parallel Processing to Optimize Space Debris Mitigation Systems

Category: Physics and Astronomy

Silas Lovett

Friendswood ISD /Friendswood High School

Due to recent orbital megaconstellation development, Low Earth Orbit (LEO) is becoming increasingly overpopulated. High-density cascading debris growth, also known as the Kessler Syndrome, has evolved from a remote possibility to a real threat, endangering crucial orbital infrastructure and the future of space exploration. Existing space debris research primarily focuses on modelling the orbital debris environment to estimate collision probability. There is a relative lack of simulation research exploring the removal of that debris, a gap this research intends to remedy. This research project concerns the development of a 3D JavaFX orbital debris removal simulation. It implements hybrid analytical-numerical object propagation, switching between velocity Verlet n-body integration and Keplerian propagation based on simulation state, enabling 500,000+ simultaneous objects. Adaptive force model selection further increases accuracy, simulating forces only when required. Active Debris Removal (ADR) methods are controlled through configurable goal-based autonomy. Orbital laser ablation and atmospheric scattering effects are modelled to analyze laser-based debris removal, whereas debris chaser vehicle efficiency is evaluated through the propagation of orbital rendezvous maneuvers. To produce accurate results, debris population growth is approximated through high-speed collision detection algorithms, fracture modelling, and virtual replication of real-world documented breakup events. The efficiency of all processes is increased by parallel processing. This simulation is unique because it unifies both debris generation and multi-method debris removal in a long-term high-fidelity environment. Capable of producing data that can refine space debris mitigation strategies, it is the next crucial step in tackling the growing space debris crisis.

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Abstract: Science and Engineering Fair of Houston

3417

How the radial velocity of hydrogen clouds changes as it reaches the galactic center

Category: Physics and Astronomy

Spencer Teltow

Conroe ISD /ACES: Academy for Careers in Engineering and Scien

How do clouds of neutral hydrogen gas behave as they get closer to a black hole? This project measures just that. It also measures an occurrence that happens once every 10-11 million years. The hydrogen line is a specific radio wavelength (1420.4 Mhz) in which hydrogen atoms emit radio signals. This is through a process called the spin-flip process, where once about every 10-11 million years hydrogen's electron's spin flips relative to the atomic nucleus. This process emits photons at the 1420.4 Mhz frequency. It may seem like it is very common upon first glance, due to this process occurring every 11 million years or so, however when there is a gas cloud with a virtually uncountable amount of hydrogen atoms, there is usually millions of spinflips occurring every second, especially with collisions with other atoms making the atoms enter a "exited" state more often, as it occurs every 10-11 million years for spontaneous transitions. This experiment utilizes this spin flip to detect the hydrogen line and how doppler shifted the frequency was to derive orbital velocity to see how fast hydrogen clouds are moving. The findings of this experiment show that hydrogen clouds nearby 3 Saggitarii (a star very close to our galactic center) had the radial velocity of 48 meters per second while moving towards earth, with a galactic longitude of 1.17, and galactic latitude of 0.21. The next measurement was at 148.8 galactic longitude and -14.9 longitude, with a radial velocity of 21 meters per second moving away from earth. The next measurement was at 107.5 galactic longitude, and 14.03 latitude, with the orbital velocity of 27 meters per second moving away from the earth. This is significant because it shows that the radial velocity was higher closer to the galactic center, with the supermassive black hole Sagittarius A, which is to be expected.

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Abstract: Science and Engineering Fair of Houston

3418

The Effects of Quantum Noise on the Quantum k-Nearest Neighbors Algorithm in Accuracy and Variance

Category: Physics and Astronomy

Azhmeer Jesani

Clear Creek ISD /Clear Creek High School

The purpose of this research was to investigate the impact of quantum noise on the accuracy of the Quantum k-Nearest Neighbors (QkNN) algorithm, as well as to assess the feasibility of running the QkNN classification algorithm on current quantum computers. This study proved that Combined Error affected the accuracy of the QkNN algorithm the least, while the Z Rotation Error affected the accuracy of the QkNN algorithm the most. Additionally, the study presented that the combined error noise simulation had the lowest mean absolute difference value, indicating that the QkNN algorithm can be run on current quantum computers and is expected to achieve accuracy similar to that of future noiseless quantum computers due to destructive interference. However, the Combined simulation came with the cost of the second-highest variance, suggesting that real-world runs could produce inaccurate results. Even so, insightful results of the effects of noise on the QkNN algorithm were still discerned. This research creates a step forward in unlocking the potential of quantum machine learning in real-world, present-day applications.

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Abstract: Science and Engineering Fair of Houston

3419

Galaxy Morphology and Internal Density's Possible Effects on Velocity

Category: Physics and Astronomy

Mihir Prabhu

Katy ISD/Seven Lakes - HS

Galaxy morphology can be split into three primary categories, spiral, elliptical, and irregular, each with different appearances and individual traits. Galaxy evolution describes how galaxies interact with each other and how those interactions change the galaxies themselves as well as their features such as composition, velocity, and density. The internal density of galaxies helps to define their ability to be affected by ram-pressure stripping, the movement of a body through another removes material and gas, and tidal pressure stripping, where tidal pressures and forces act as a mechanism of evolution; this potentially introduces a correlation between density and recessional velocity, peculiar velocity, and velocity dispersions. This would allow future science to better understand the implications of internal properties on galaxy evolution and allow the further study of the effects of density on the nature and effects of galaxy interactions and evolution. By utilizing the Simbad database to gather redshift data as well as multiple scientific papers from the Harvard astrophysics data system (ADS) and IOP-science, data on the velocity of galaxies can be determined which would allow the comparison of morphology and internal density trends with velocity. The data analysis indicated elliptical galaxies have higher internal densities as well as higher velocities meaning they are more resistant to tidal and ram pressures and instead gain materials from galactic interactions while spiral galaxies demonstrate the opposite of this trend. This exhibits a clear correlation between the internal densities of galaxies and their morphologies with their recessional velocity, peculiar velocity, as well as potential velocity dispersions, affecting the timeline and process of galactic evolution.

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Abstract: Science and Engineering Fair of Houston

3420

Investigating Noise-Resilient Adaptive Variational Quantum Simulation for Quantum Chaos: A Quantum Kicked Top Benchmark

Category:

Physics and Astronomy

Samarth Muralidhara

Cypress Fairbanks ISD/Bridgeland - HS

The emergence of classical chaos from fundamental quantum dynamics continues to be a central puzzle in modern physics, which becomes even more pronounced when one wants to simulate such complexities on the soon-to-be-available near-term noisy quantum hardware. We explore the ability of Variational Quantum Simulation (VQS) to capture the transition from ordered motion to strongly scrambling dynamics in a controlled setting, namely the Quantum Kicked Top. By correlating classical diagnostics with quantum signatures of instability and information spreading, we map the dynamical requirements of the system to identify where standard low-depth approaches start to fail. We find that while a fixed-depth, hardware-efficient ansatz serves as a baseline, it struggles to capture the full complexity of the chaotic regime. To address this, we first implement a leakage-triggered adaptive method that dynamically increases circuit depth only when an instantaneous residual signal indicates the current ansatz is no longer expressive enough. Building on this, we propose a noise-aware adaptive controller that adds a gatekeeper rule, ensuring depth is only increased when the expected accuracy improvement is worth the added noise and measurement overhead. Our findings illustrate that these adaptive algorithms are able to detect chaos accurately and provisionally assign computational effort. We show that in addition to being a numerical ingredient, the variational circuit depth can be interpreted as an operative probe of physical complexity. Methods allowing for adaptive depth allocation are therefore crucial when simulating non-integrable quantum dynamics.

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Abstract: Science and Engineering Fair of Houston

3421

Why aren't string landscapes covered in the unification goal?

Category:

Physics and Astronomy

Araoluwa Akinsanmi, Esther Akinsanmi, Michelle Borche

Harmony Public Schools - South District/Harmony Science Academy-Houston

The unification goal, a fundamental aspect into explaining every part of string theory. Or so we think, we have this significant groundbreaking goal that explains it all, except for the string landscapes. However, why is that? If it’s supposed to explain everything why leave that out? Our team will try to find an answer to this question by using 3D simulations, mathematical equations, and clay models to demonstrate to others and prove our findings. Our project is something that has rarely been explored because of the difficulty in physics and mathematics. Nevertheless, my team will make sure that we can answer this question on why the string landscapes aren’t in the unification goal. And how we can back our claims up with evidence and tell researchers and the judges our findings. We hope to solve this problem and hopefully open new doors to scientists all around the world.

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Abstract: Science and Engineering Fair of Houston

3422 **Novel CNN-Based Hurricane Cell Prediction Model Integrating Navier-Stokes Vortex Singularity Dynamics**	**Category:**
Arsh Kudariya Katy ISD/Seven Lakes - HS	Physics and Astronomy

Tropical cyclones are among the most destructive and unpredictable natural phenomena, where the inability of current models to resolve nonlinear, multiscale dynamics directly impacts tens of millions of lives, infrastructure collapse, and large scale economic damage. A hybrid hurricane simulation framework is developed that tightly couples an incompressible Navier-Stokes solver with a convolutional neural network (CNN) to model tropical cyclone dynamics, intensity evolution, and track motion. The atmospheric flow is evolved on a two-dimensional grid using a projection based Navier-Stokes formulation, explicitly resolving nonlinear advection, viscous diffusion, pressure gradients, and vorticity generation through a Poisson-based pressure correction. This approach allows coherent vortex structures, velocity amplification, and secondary circulations to emerge dynamically from the governing equations. Storm motion is determined by Lagrangian advection of the cyclone center through the resolved environmental wind field, ensuring physically consistent translation driven by background flow rather than empirical track forcing. This incorporates unresolved processes and large scale synoptic influences, a CNN is integrated to provide corrective tendencies to steering flow and intensity, trained on historical hurricane data and informed by multi-channel atmospheric state inputs from the HURDAT2 database. The resulting hybrid system combines fundamental fluid dynamics equations with data driven machine learning, demonstrating a physically interpretable and consistent pathway for improving tropical cyclone simulation and prediction.This advances on the forefront of the expanding field of visual adapting machine learning.This allows tropical cyclone forecasts to remain accurate up to 120 hours before landfall, compared to the current standard of only 48 hours.

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Abstract: Science and Engineering Fair of Houston

3423

Next-generation Electro-optic Modulator Enabled by SAW-driven Bragg Grating

Category: Physics and Astronomy

Nathan Zhang

Klein ISD/Klein Cain - HS

The rapid growth of artificial intelligence (AI) driven data traffic in recent years has significantly increased the demand for high-efficiency optical communication systems. An estimated five billion fiber-optic cables constitute the global backbone for information transmission. However, conventional electro-optical modulators (EOMs) suffer from substantial power losses, contributing to an estimated 5% loss of transmitted electrical energy nationwide due to modulation inefficiencies. Inspired by the wave interactions observed in acoustic instruments, this work proposes a physical conversion model based on an electrical signal-to-surface acoustic wave (SAW)-to-optical signal transduction pathway. Building on this model, a novel EOM architecture is designed using a SAW-driven Bragg grating implemented on a lithium niobate substrate, aiming to achieve low power loss and high modulation reliability. Three hypotheses are investigated: (1) a multi-interdigital transducer (multi-IDT) configuration enables more efficient electrical-to-SAW conversion than a single-IDT design; (2) standing SAWs induce spatial aggregation of quantum dots (QDs) at nodal positions, forming a periodic stripe pattern; and (3) the resulting QD stripe pattern functions as a Bragg grating that satisfies Bragg's condition for an incident laser, enabling optical signal modulation. Experimental results confirm that the multi-IDT configuration more effectively drives QD stripe formation, and that the 5 mW incident laser light is extinguished at propagation angles of 75° and 165°. Furthermore, the applied electrical signal is successfully modulated onto the transmitted optical signal with a loss below 0.5 dB, significantly outperforming conventional commercial EOMs, which typically exhibit losses at or exceeding 10 dB. Future work will focus on evaluating system-level performance by transmitting and decoding over 1,000 encrypted words to continue to improve modulation accuracy and robustness.

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Abstract: Science and Engineering Fair of Houston

3424

Vanquishing Vignettes in Astrophotography

Category: Physics and Astronomy

Olivia Gano

Clear Creek ISD /Clear Falls High School

An issue astronomical photographers face is the presence of vignetting on images. This project was designed to evaluate the theory that vignetting could be reduced by changing the brightness, and consequently, the exposure length, of flats taken. To test this claim, a telescope was used to photograph an empty area of the sky. Then, flats were taken using various light levels and exposure lengths. These flats were applied to the images of empty sky previously mentioned and were processed and analyzed. There was a significant increase in vignetting on photos that used flats with the highest light settings. However, photos using flats taken with neutral density (ND) filters that limited brightness resulted in astronomical photos with less vignetting. A second test was also conducted to see if the ND 9 filter was causing inconsistent results, but the tests confirmed that it was functioning properly. This experiment found that flats taken with ND 6 filters applied resulted in images with the lowest vignetting. This proved the original hypothesis that ND 9 filters would be most effective incorrect.

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Abstract: Science and Engineering Fair of Houston

3425

The Panspermia Probability Calculator: Simulating Interstellar Travel for Life

Category: Physics and Astronomy

Ky-Minh To, Daniel Levin

Friendswood ISD /Friendswood High School

This study develops a computational probability simulation to assess the feasibility of the panspermia hypothesis: the interstellar transfer of microbial life inside ejected planetary fragments. Focusing on extremophiles like Deinococcus radiodurans and tardigrades, the model integrates published microbial survival curves, cosmic radiation dose rates, and rock-shielding effects to calculate survival probabilities over interstellar travel times. A Monte Carlo approach was used to analyze key variables, including fragment size, shielding depth, and travel distance, with data visualized through survival probability curves and heatmaps. Results indicate a strong threshold effect based on fragment size. Small fragments (<1 m) almost always result in lethal radiation exposure, while larger fragments (>1–10 m) provide sufficient shielding to reduce radiation doses below critical levels, enabling non-zero survival probabilities. Survival rates increase sharply with size before reaching a point of diminishing returns. Sensitivity analysis confirmed that fragment size is the most critical parameter. Although the majority of simulated scenarios yielded very low survival probabilities ($<10^{-6}$), a subset of well-shielded fragments demonstrated survival rates above 1% for shorter interstellar transfers. The simulation concludes that while rare, interstellar panspermia is a statistically plausible mechanism, contingent upon transport within sufficiently large rocky bodies to shield microbes from cosmic radiation over long-duration spaceflight. Future work will incorporate more detailed radiation models and planetary capture dynamics.

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3426

Category: Physics and Astronomy

Integrating Leptogenesis Through Heavy Sterile Neutrino Generation by Hawking Radiation into Baryon Asymmetry with Antibaryon Capture by Primordial Black Holes

Gokul Srinivasan

Conroe ISD /AST: Academy of Science and Technology

Baryon asymmetry is the mystery of the abundance of matter over antimatter. This is due to antimatter and matter being produced and destroyed in equal ratios, which means that no difference could be made without interference. An attempt is being made to incorporate leptogenesis through heavy sterile neutrino emission by the primordial black holes (PBHs) with a work by A.D. Dolgov and N.A. Pozdnyakov. This is a model of baryon asymmetry generated by asymmetric baryon capture by PBHs. This essentially states that a PBH can capture enough antibaryons to create a difference between baryons and antibaryons, resulting in the desired asymmetry. This project is focused on combining Dolgov and Pozdnyakov's model of PBH-assisted baryogenesis through capture with leptogenesis through Hawking radiation of the PBHs generating sterile neutrinos, which can decay to contribute to lepton asymmetry, and then be transformed into baryons through sphaleron transitions to contribute to baryon asymmetry. The programs BlackHawk v2.3 and ULYSSES v2 were used to compute the emission spectra of the black holes and to compute the transfer of the heavy sterile neutrinos, respectively. The conclusions of this research were that the aforementioned model of baryogenesis and leptogenesis are incompatible, as lower masses lead to PBH lifetimes so short that very little particles can be absorbed, and larger masses lead to a miniscule Hawking temperature and very little leptogenesis.

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Abstract: Science and Engineering Fair of Houston

3427

Category: Physics and Astronomy

Biochemical Effect of Rac1 and CREB on memory consolidation probabilities

Arnav Pajjuru, Girishwar Sathish Kumar, Neal Sharma

Fort Bend ISD /Dulles High School

Current science indicates research in a field called Engram in which a set of neurons when fired replicates a memory in an organism. There are many genes in neurons that modulate Engram behavior whether it's Hebbian or non-Hebbian. This research focuses on Rac1 (weakens memories) and CREB(strengthens memory). Modern science has created graphs depicting Rac1 and CREB over time using differential equations, but they have failed to put Rac1 and CREB in the same plot. This is due to conflicting environmental dynamics as Rac1 and CREB do opposing tasks, making it hard to model. This problem was solved by using preexisting differential equations that model calcium, CREB protein, excitability, and synaptic weight. These equations when modeled in silico can be interconnected as the inputs of some differential equations affecting outputs of others. This models ideal condition for RAC1 vs CREB but fails to consider realistic scenarios. To solve this, a novel approach known as Markov chains was used which works by following the rule of large numbers. This helped create a heat phase map that showed accurate dynamics and probabilities of memory consolidations. With this, a notable model was created that predicts memory consolidation through RAC1 and CREB dynamics and identifies the exact probabilities of consolidation that were proportional to actual values of memory consolidation depending on state of the Engram. After this we decided to improve on the model by finding exact values of memory consolidation rather than proportional substitutes. This was implemented via LaGrange's principle of least action which helped conclude the exact values of memory consolidation because proper engram systems ensure minimum energy(John Hopfield).Even though this model may seem complete, Scientists can further this model by adding stochasticity using laboratory engrams rather than in silico helping determine buffers and other environmental factors which disallow ideal conditions.

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Abstract: Science and Engineering Fair of Houston

3428

Optimizing Bun Placement on a Swimmers Head to Reduce Drag

Category:

Physics and Astronomy

Jonathan Zwart, Emily Zwart

Clear Creek ISD /Clear Lake High School

In competitive swimming, many women must deal with long hair under their swim cap and where to place it for meets when even a few milliseconds will matter. In this project we measured different positions of a tennis ball (bun) under a swim cap on a mannequin head and specifically measured different angles in relation to the ear. We measured the velocity of the head moving through water using a pulley system. We constructed a track with two metal rods as rails that hooked on to our pool and measured the velocity of different bun angles on the mannequin head as it went down the track. Based on our results we concluded that the bun at 45 degrees, or the lowest position on the head near the neck, would be the optimal position to place a bun for swimmers with long hair.

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Abstract: Science and Engineering Fair of Houston

3429

Category: Physics and Astronomy

Fast Fourier Isolation of Planetary Caustics: Overcoming Stellar Noise in Automated Exoplanet Discovery

Ram Magathala

Cy-Fair ISD/Cypress Ranch - HS

Gravitational microlensing is a vital tool for detecting cold wide orbit exoplanets yet the field faces a critical computational bottleneck. Current Bayesian inference models are too computationally intensive to scale for massive next generation datasets often failing to distinguish low mass planetary signatures from high amplitude stellar variability. This research introduces Fast Fourier Isolation (FFI) which is a high speed computational framework designed to autonomously extract transient planetary signatures. By treating light curve analysis as a signal processing problem, FFI utilizes a High Pass Fast Fourier Transform (FFT) filter to deconstruct frequencies and suppress dominant stellar magnification. This reveals a Residual Map of planetary perturbations often overlooked by traditional time domain models. Benchmark testing against standard stochastic models yielded an 88.9% accuracy rate in discriminating known planetary anomalies from binary stellar noise. Following iterative optimization of the filtration algorithm, a blind study of 5000 unclassified OGLE survey light curves using the FFT pipeline was conducted. The FFI pipeline successfully filtered 4,567 targets as stochastic noise within minutes, proving to be more efficient compared to standard models. Utilizing a signal to noise ratio (SNR) thresholding of over 5.0, the pipeline finally identified two high priority candidates: a sub stellar planet (SNR 10.5) and a terrestrial scale anomaly (SNR 5.9) which are currently under peer review. These results represent a 0.32% yield, consistent with predicted Galactic Bulge event frequencies and represent FFI as a critical framework for future surveys such as the Nancy Grace Roman Space Telescope. By providing autonomous characterization of low mass worlds, FFI enables the efficient discovery of previously invisible planetary systems in the era of big data astronomy.

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Abstract: Science and Engineering Fair of Houston

3430

Integrating MoS_2, Photonic Crystals, and CPI in Solar Sails for Light-Momentum Management

Akshar Manjunath

Houston ISD/Carnegie Vanguard HS

Category:

Physics and Astronomy

Solar sails convert photon momentum into continuous propulsive force without onboard propellant, enabling long duration, low-cost missions and new mission profiles (e.g., sustained solar observations, low-thrust deep-space transfers, or precursor missions for optical/laser propulsion). The performance of a solar sail depends primarily on its solar-spectrum weighted reflectivity and its areal mass (kg·m^-2). Conventional sails employ aluminized polymer films (e.g., aluminized Kapton) which are significantly slower and absorb more light than heat which results in less reflectivity of photons. Recent advances in nanophotonics and 2-D materials suggest alternative multilayer designs could improve broadband reflectivity or redirect momentum through diffraction, yielding higher radiation pressure per unit mass.

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Abstract: Science and Engineering Fair of Houston

3431

Spectra: Towards the Development of a Fully Photonic Von-Neumann Computer Processor Architecture

Category: Physics and Astronomy

Aniket Chakraborty

Conroe ISD /AST: Academy of Science and Technology

Modern binary computer processors comprise billions of electronic silicon semiconductor transistors that switch current flow on/off via voltage application. However, in today's world, data centers demand both daily civilian usage and intensive machine learning algorithm operation, requiring sub 20nm, 208B+ transistors densely packed into individual processing units, dangerously concentrating immense electron heat dissipation and current leakage damages. American data center processors last 1-5 years, draw 415 TWh energy (nearing 12% of national consumption), and over 500 billion liters of freshwater annually for thermoregulated operation. The goal of this project was to develop a more energy efficient, fast, and durable transistor design fully controlled by light, leveraging minimal photoabsorptive heat loss and high speeds. Since photons do not affect one another, binary controllable/switchable states were demonstrated through light and material interactions in electrooptic effects. Multiple material principles were tested, including gain conversion with III-V semiconductors (as in amplified LASERs), and saturable absorptivity with graphene. A continuous wave laser of corresponding frequency was flashed to the materials via a 1:2 switch controlled fiber optic cable. Energy thresholds for switching, cycle speeds for threshold saturation, and output light strength were measured. Results demonstrated speed increases orders of magnitude faster than the 20 nanosecond electronic transistor switching. Gain media required more time than graphene saturation due to optical stimulation needs, but graphene conversely required higher energy laser pumping. Since data is already transmitted using fiber optic cabling globally, the plausible photonic computer designs demonstrated could someday eliminate lossy conversion to electronics.

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Abstract: Science and Engineering Fair of Houston

3432

Building a Quantum Computing Approach to Effectively Design Integrated Circuit Boards

Category: Physics and Astronomy

Aman Wairkar

Clear Creek ISD /Clear Springs High School

Printed circuit boards (PCBs) are the heart of electronics and are etched with thin wire paths that conduct power and data between components. While classical algorithms provide 'good enough' design solutions to build PCB circuits, they are time-consuming and laborious for complex PCB circuits, that are required in aerospace engineering, telecommunications, medical imaging, and industrial automation. Though classical algorithms exist, they are often inefficient as problems scale in complexity. With their ability to leverage superposition to explore multiple solutions simultaneously, quantum computing approaches could potentially accelerate optimization, simulation, and other PCB design problems of increasing complexity that overwhelm classical algorithms. The goal of this study was to build and benchmark a new quantum computing method for optimizing complex PCB routing. In this study, the classical algorithm with the standard 'temperature-cooling' (simulated annealing) algorithm and the quantum model with the Quantum Approximation Optimization Algorithm (QAOA) were built. Upon comparing the performance of both the algorithms, the study found that the QAOA had a slightly longer runtime (0.552 sec vs 0.482 sec for classical), but as the complexity of the circuit increased, the size of the current loop increased steadily for the classical algorithm but was reduced for the QAOA. A reduction or sharpening of the current loop size indicates less electromagnetic interference and crosstalk, improved signal integrity, and efficient utilization of chip space. Thus, this study demonstrates a new quantum approach that produces more accurate, compact wire traces, and is progressively more efficient than the classical algorithm for complex PCB circuits.

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Abstract: Science and Engineering Fair of Houston

3433

Exploring the Spring Constant and Elastic Response of Hookean Springs

Category: Physics and Astronomy

Sebastien Dietlein

Fort Bend ISD /Clements High School

This project explores the spring constant and elastic response of Hookean springs to understand how springs store elastic potential energy and how applied force correlates with tension and displacement. Hookean springs behave predictably within their elastic limits, where force increases proportionally with displacement. This relationship is essential for safety and efficiency in applications such as structural design, electronics, and mechanical systems. The objective was to determine the spring constants of multiple springs with varying stiffnesses and examine the linearity of the force–displacement relationship, as well as analyze how increasing force affects elastic potential energy and identify deviations from Hooke's Law. It was hypothesized that force and tension are directly proportional to displacement within a closed system, provided the springs remain within their elastic limits. Four extension springs of differing tensions were suspended vertically from a weighted overhead support. Masses were added in 0.1 kg intervals, producing forces from 0.98 N to 9.8 N, calculated using $F = ma$ (or $F = mg$) with $g = 9.8\ m/s^2$. The initial unstretched length of each spring was measured, and displacement was calculated as the difference between stretched and initial lengths. Force versus total displacement graphs were created, and linear regression was used to determine spring constants. The results showed a strong linear relationship for all springs, with R^2 values ranging from approximately 0.93 to 0.99, confirming Hooke's Law. Spring constants increased with stiffness: approximately 80.6 N/m, 102.1 N/m, 131.7 N/m, and 193.5 N/m. Minor variations were attributed to non-ideal elasticity but had minimal error. These findings reinforce the proportionality of force and displacement in Hookean springs within elastic limits and highlight the importance of understanding material behavior in engineering design.

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Abstract: Science and Engineering Fair of Houston

3434

Quantum Tunneling Through Barriers: An Application Of State Transfer To Superconducting Quantum Circuits

Category: Physics and Astronomy

Saketh Kalidindi

Katy ISD/Freeman - HS

Quantum state transfer (QST) is an important process that allows quantum information to be transferred from one part of a device to another. This is necessary for different components of a quantum computer, such as processors and memory, to communicate with each other. Unlike classical information, quantum states cannot be copied or moved directly without preserving important properties, such as coherence or entanglement. Because of this, special methods are needed to transfer quantum states without destroying them. In this study, we examine how QST works in systems with barriers, which are common in real quantum hardware due to limitations in how the components are connected or controlled. We focus on one- and two-dimensional grids of qubits that interact only with their neighbors, and we use quantum tunneling to help the quantum state traverse these barriers. We study how well the transfer works as a function of the barrier height and width, the system size, and whether we are transferring a single qubit or an entangled pair such as a Bell state. To do this, we build a mathematical model of the system and use optimization methods, such as annealing Monte Carlo, to find the best way to transfer the state. By making small changes to the system and accepting them if they improve QST, we find a clear paths towards transporting entanglement. Our results help show how quantum information can be moved in systems with barriers, which is important for building better quantum computers, connecting processors and memory, and testing hardware that has limits on how its parts are connected.

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Abstract: Science and Engineering Fair of Houston

3435

Category: Physics and Astronomy

Identifying Metal Rich Asteroid Candidates Using Machine Learning on Sparse Radar Albedo Observations

Sreejit Mukherjee

Katy ISD/Seven Lakes - HS

Asteroids preserve primordial records of Solar System formation, being the primary source with which scientists can study the early Solar System. While carbonaceous (C type) and silicaceous (S type) asteroids have been extensively studied through missions like Hayabusa2 and OSIRIS-REx, metallic M type asteroids remain underexplored, with 0 missions launched and few identified metal candidates. This lack of metal asteroid data constrains our potential to learn about planetesimal core differentiation, the primary mechanism by which metal asteroids form. The challenge lies in their spectrally featureless reflectance profiles, which make them difficult to classify using traditional methods. Instead, we must use radar albedo measurement, which are extremely expensive and are limited to a small subset of asteroids. Beyond their scientific importance, the high density and structural integrity of metallic asteroids make them capable of delivering maximal kinetic energy to Earth's surface. Additionally, their collection of Platinum group metals have immense economic potential ranging to the quintillions. To address this challenge, my project develops a machine learning framework that leverages correlated physical parameters—including thermal inertia, diameter, and albedo—to classify metallic asteroids without reliance on radar albedo. By utilizing readily available data, this approach enables broader identification of metallic asteroid candidates, advancing planetary science, strengthening planetary defense strategies, and informing future resource utilization.

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Abstract: Science and Engineering Fair of Houston

3436

Apollo Egg-leven

Category: Physics and Astronomy

Kylie Roberts, Sachi Gaha, Joshua Bader

Conroe ISD /ASHP: Academy for Science and Health Prof

This project posed the question of how different materials can protect a fragile payload without significantly increasing the gross mass. Understanding this can help with transporting supplies to outer space or to high altitudes. The engineering goal of this project was to design a rocket that successfully reaches 750 ft and keeps an egg intact after launch and recovery with optimal efficiency.The rocket was designed using the Open Rocket simulation, where it was expected to reach 750 ft with an F-class motor.The rocket was assembled using primarily Estes rocketry parts. Then, 2 identical rockets were launched in a field, one of them using a large parachute and a F-class motor; however, the rocket took 1 minute and 40 seconds to fall, far longer than the 40 seconds required. So we went to a less powerful D-class motor and a smaller parachute so the rocket falls faster. As a result, the rocket didn't reach the desired altitude, so further testing with an E-class motor is needed. A simulation was run to see the expected height of the new rocket, however the rocket consistently went 60-70 ft higher than estimated. Due to the limited sample size, the results are inconsistent so no conclusions can be derived, but looking at what is there it is a possibility that Open Rocket is under estimating the high of rockets. And the same height under estimate continues with the F-class motors,but as much as 100 feet of height.

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Abstract: Science and Engineering Fair of Houston

3437

Category: Physics and Astronomy

Spectral Signatures of Early-Universe Phase Transitions: Linking Quantum Field Models to Cosmic Microwave Background Perturbations

Aadi Sharma

Fort Bend ISD /Dulles High School

Early-universe physics may include symmetry-breaking phase transitions in scalar fields, similar to those found in particle physics. These transitions can produce distinctive patterns in primordial density fluctuations, which may leave observable signatures in the cosmic microwave background (CMB). This project develops a theoretical and computational model to investigate and determine whether such early-universe phase transitions can produce measurable deviations in the CMB angular power spectrum. A scalar field with a temperature-dependent potential was modeled to represent a cosmological phase transition. Linear perturbation equations were derived and solved numerically for a range of wavenumbers k, producing modified primordial power spectra P(k). These spectra were then processed through a simplified Boltzmann-transfer model to generate predicted CMB power spectra $C\ell$. Parameter sweeps were performed on phase-transition strength, critical temperature, and coupling constants to identify distinguishable patterns. The results show that scalar-field phase transitions can introduce characteristic features, such as localized bumps or shifts in spectral amplitude, at intermediate multipole moments (approximately $100<\ell<800$). These deviations were compared to baseline ΛCDM expectations and found to be potentially detectable depending on field parameters. This research demonstrates that early-universe phase transitions may leave observable imprints on the CMB and provides a simplified theoretical foundation for identifying such signatures. The findings contribute to continuing efforts in cosmology to understand the physics of the early universe and lead the way for future observational searches for beyond-standard-model phenomena.

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Abstract: Science and Engineering Fair of Houston

3438

From Dust to Dome: Making Moon Concrete

Category: Physics and Astronomy

Evan McCoy, Elliot Swiney, Blake Lantagne

Conroe ISD /ASHP: Academy for Science and Health Prof

This project investigates the construction of concrete using simulated lunar regolith combined with three additives: cornstarch, powdered plastic, and xanthan gum. An effective mixture could reduce material costs and improve efficiency for future infrastructure on the Moon. It was hypothesized that xanthan gum would produce the strongest concrete due to its natural binding properties and ability to retain water. Three batches of bricks were constructed, each with a different additive. Compressive strength was initially tested by gradually adding sand and stacking weighted plates until sample failure. ANOVA testing revealed that powdered plastic produced significantly stronger samples than the other additives, while cornstarch produced the weakest. This initial method was limited to about 160 kg (350 lb), requiring a secondary testing approach after several samples reached the maximum load without failure. Researchers were granted access to an ADMET testing machine at Sam Houston State University to further evaluate the samples. Results were consistent with the initial testing and confirmed that the powdered plastic additive produced statistically stronger samples than xanthan gum, with an average compressive strength of 3005 kg (6625 lb). Although this strength represents only 7–9% of industrial concrete strength, this is due to the lack of professional equipment and insufficient material to produce optimal samples. The hypothesis was not supported; however, the results demonstrate that a solid, testable material can be constructed primarily from lunar regolith. This research supports the feasibility of using lunar resources for infrastructure while promoting plastic recycling on Earth and in space.

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Abstract: Science and Engineering Fair of Houston

3439

Category: Physics and Astronomy

SuryaNet: Physics-Informed Machine Learning for Thermospheric Neutral Density Forecasting

Kaushal Pemmaraju

Katy ISD/Tompkins - HS

More than 10,000 satellites in Low Earth Orbit experience orbital decay due to the thin atmosphere present at high altitudes. Thermospheric neutral density increases by orders of magnitude during a geomagnetic storm, amplifying drag. In practice, forecasting is not possible with empirical "nowcasting" models that primarily capture the current state of the atmosphere, leaving operators no time to boost satellite altitudes or delay launches. To resolve this, SuryaNet, a hybrid temporal machine learning model, was trained to predict thermospheric density at 3 - , 6 - , 12 - , and 24 - hour horizons, using datasets from satellites spanning 8 years to improve generalizability. SuryaNet analyzed near - Earth solar wind records from the OMNI dataset, satellite observations, and geomagnetic indices at an hourly cadence. SuryaNet uses a Multilayer Perceptron architecture to correct the residual of an estimated current density value computed by the NRLMSIS 2.1 empirical model. This corrected density was used in a Gated Recurrent Unit architecture that analyzed past trends for predictions. SuryaNet was evaluated using the Mean Absolute Error (MAE) metric, with lower values indicating better performance. When evaluated on a test dataset, compared to an NRLMSIS 2.1 nowcast evaluated at the target time, SuryaNet reduces density MAE by approximately 64.4% at 3 hours, 62.3% at 6 hours, 56.5% at 12 hours, and 48% at 24 hours, demonstrating an effective forecasting aptitude. We argue that SuryaNet's global objective, as a protective measure for humanity at risk of satellite burnup, provides a robust way to forecast density.

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