Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Nikhil S. Gopal
High School: The Lawrenceville School
Mentor: Dr. Linda Brzustowicz
Project Title: Portable Detection of Malaria DNA Using Microfluidic Loop Mediated Isothermal Amplification (LAMP) and a Smartphone

BACKGROUND: Malaria kills nearly a million people per year and disproportionately affects the poor. The parasite cannot reproduce outside of human hosts. Containment efforts are hampered by inability to detect early stages of infection before spread to the liver. Isothermal loop amplification (LAMP) is a technology that detects small quantities of DNA. **METHODS**: A system to detect malaria DNA using LAMP was invented: 1) Heating container 2) Flameless ration heater 3) Microfluidic chip and 4) Smartphone app. The system utilized Meals-Ready-to-Eat MRE heating packs and beeswax as a phase change material. A chip holder and tray was 3D printed using heat resistant filament. A 3-layer acrylic microfluidic chip was constructed using a CO_2 laser with silica membranes. Color was measured using a Java based smartphone app. **RESULTS**: 20 microfluidic LAMP assays (60 samples) were run at various concentrations to amplify HRP-2 and aldolase genes. A standard curve showed high correlation ($r^2 = 0.91$, $p < 0.001$). **CONCLUSIONS**: Current methods to detect malaria are sub-optimal. Microfluidic LAMP may be able to detect very low levels of parasite beyond the limit of detection of current lab based methods. Microfluidic LAMP is portable, easy to use and inexpensive ($5 per sample).

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Andrew Song
High School: Milton Academy
Mentor: Dr. Zachary Slepian
Project Title: The Relative Velocity of Baryonic and Dark Matter within the Milky Way and its Implications

Baryon acoustic oscillations induced by primordial density perturbations cause a differ- ence in velocities between baryonic and dark matter. It has been hypothesized that this relative velocity is responsible for the formation of globular clusters and the formation of counterpart dark satellite galaxies (Naoz & Narayan 2014). Further, it has been suggested that a sufficiently high relative velocity may adequately address the missing satellites prob- lem, which arises from the lack of observed dark satellite galaxies in the Milky Way relative to the number predicted by ΛCDM structure formation simulations (Bovy & Dvorkin 2013). We use data from the 2-MASS Redshift Survey of galaxies within the local volume to estimate this velocity and use this result to assess the viability of these two hypotheses. We estimate the relative velocity to be $2.28\sigma_{v_{bc}}$, where $\sigma_{v_{bc}}$ is the standard deviation of the probability distribution of relative velocities throughout the observable universe. We conclude that the velocity is sufficiently high to cause the formation of globular clusters and dark satellite galaxies, and we address possible sources of error in this measurement and show that they are at the $<$ 10% level and thus unlikely to change our conclusions.

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Andrew Komo
High School: Montgomery Blair High School
Mentor: Dr. Lawrence Ausubel
Project Title: Cryptographically Secure Proxy Bidding in Ascending Clock Auctions

We propose and implement a new protocol for a cryptographically secure ascending clock auction. This protocol is designed for the simultaneous multi-round ascending auction (SMRA), which is a non-homogenous multi-item auction. This protocol also allows a bidder to securely proxy bid using a third party that the bidder trusts not to collude with the auctioneer. In particular, the cryptographic system guarantees privacy and correctness and is also practical to implement. We build upon the preexisting Fujisaki-Okamoto commitment scheme and Boudot zero knowledge proof that a number lies in a given interval. We utilize a random permutation method, something never before done in the field of cryptographic auctions, to maintain the privacy of bids. We propose a new method that uses random polynomial obfuscation to hide a value while still allowing comparisons between values leading to the proxy being able to execute bids with zero knowledge. This cryptographic system can easily be modified to apply to other auction designs such as the Vickrey (sealed second-bid) auction.

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Alexander Liu
High School: Montgomery High School
Mentor: Dr. Wei Liu
Project Title: Synthesis and Characterization of New Luminescent CuX Coordinate-Ionic Hybrids

Crystalline hybrids incorporating ionic and coordinate bonding properties have been reported to exhibit high thermal stability as well as strong optical properties. Four new CuX (X = Cl, Br, I) hybrids were synthesized in various reaction conditions using a cationic ligand containing multiple coordination sites, prompting the formation of robust, highly luminescent materials. Three of these compounds exhibit bright emission in the 550-600nm range under 365nm excitation. Two of these luminescent compounds are crystalline, varying only in the cuprous halide chain. Structural differences seem to differ solely as a result of halide variation, demonstrating potential for emission and bandgap tunability. High thermal stability and apparent quantum yields make them valuable candidates for further exploration and possible commercial use in phosphor-based solid-state lighting systems.

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: David Darrow
High School: Hopkins School
Mentor: Alex Townsend
Project Title: A Novel, Near-Optimal Spectral Method for Simulating Fluids in a Cylinder

Simulations of fluid flow offer theoretical insight into fluid dynamics and critical applications in industry, with implications ranging from blood flow to hurricanes. However, open problems in fluid dynamics require more accurate simulations and lower computational resource costs than current algorithms provide. Accordingly, we develop in this paper a novel, computationally efficient spectral method for computing solutions of the incompressible Navier–Stokes equations, which model incompressible fluid flow, on the cylinder. The method described addresses three major limitations of current methods. First, while current methods either underresolve the cylinder's boundary or overresolve its center (effectively overemphasizing less physically interesting non-boundary regions), this new method more evenly resolves all parts of the cylinder. Secondly, current simulation times scale proportionally as $N^{7/3}$ or higher (where N is the number of discretization points), while the new method requires at most $\mathrm{O}(N \log N)$ operations per time step. For large N, this means that calculations that required weeks can now be run in minutes. Lastly, current practical methods offer only low order (algebraic) accuracy. The new method has *spectral* accuracy, which often represents an improvement of the accuracy of the results by 5–10 orders of magnitude or more.

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Anusha Murali, Evan Chandran
High School: Bishop Brady High School, Phillips Exeter Academy
Mentor: Dr. Murali Thiyagarajan
Project Title: Optimizing Interplanetary Travel Using A Genetic Algorithm

Humanity has been long fascinated with celestial bodies and space travel. In the current work, we investigate a novel approach to efficiently travel between planets. Specifically, we use a genetic algorithm to find the shortest path between planets in a solar system. We develop mathematical expressions to find both the travel distance and the trajectory angle of the spaceship for the orbiting planets. Using the analytical expressions derived and a carefully chosen bimodal fitness function, we demonstrate that our genetic algorithm rapidly converges to an optimal solution for the shortest path between the planets. The experimental results, using a Java implementation of our genetic algorithm, show that our algorithm is many orders of magnitude faster than an enumeration-based technique while providing nearly accurate results. We envision that, in the future, the results of our work could be used to program a space probe to efficiently travel between the faraway planets of a newly discovered solar system, and to collect scientific data from deep space that could provide answers to profound questions about our universe.

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Katherine Tian and Swapnil Garg
High School: The Harker School
Mentor: Dr. Jan Heng
Project Title: Automated Clear Cell Renal Carcinoma Grade Classification with Prognostic Significance

Clear cell renal cell carcinoma (ccRCC) is the most common malignant kidney tumor of epithelial origin. Correctly classifying ccRCC nuclear grade and stage is paramount in guiding clinical management and molecular-based therapies. In this project, we developed an automated 2-tier ccRCC grade classification system using whole slide images (WSI) from The Cancer Genome Atlas (TCGA) ccRCC dataset. For each WSI, nuclear segmentation was performed using Fiji, and 72 quantitative nuclear morphological, intensity, and texture features were extracted. Cases were randomly split into train (85%) and test (15%) sets. Seven machine learning classification algorithms with 10-fold cross validation were used to train and identify image features associated with low and high ccRCC grade. Cox proportional hazard model was used to evaluate the prognostic ability of the computer predicted grade in the test set. Neural network, lasso, and elastic net classification algorithms yielded the highest area under the curve (0.857-0.879) to predict ccRCC low and high grade. Within the test set, cases predicted as high grade had a hazard ratio of 2.029 (95% CI of 1.187-3.469), after adjusting for age at diagnosis, gender and stage. Our automated grade predictions are also strongly associated with cancer prognosis. This is an important step towards improving reproducibility in the diagnosis of ccRCC.

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Jinhyung (David) Park and Eric Lin
High School: The Hill School and Thomas Jefferson High School for Science and Technology
Mentor: Dr. Andreas Züfle
Project Title: *Protecting User Privacy: Obfuscating Discriminative Spatio-Temporal Footprints* (Computer Science)

In recent years, applications that collect and store location data have become ubiquitous, allowing users to engage in a variety of interactions with other users and services in their digital or physical vicinity. However, usage of these geolocation services put users at risk of serious privacy threats. For instance, state-of-the-art user-identification methods use geospatial trajectories derived from location based services to identify users at an alarmingly high accuracy. In this work, we address the problem of protecting user identities by presenting methods for obfuscating discriminative location data in users' profiles. We utilize data provided by the public Twitter API, collecting tweets with geolocation tags from a select group of prolific users in a 12-week time period. To minimize the amount of data obfuscated, we present two methods to identify the most discriminative tweets. The first solution is to use an Entropy-Maximizing Observation Function based on the number of tweets the user has posted and the number of people who have posted in that specific location. This ensures tweets by infrequent users in unique locations are changed first. The other solution is to use the identification algorithm to figure out what users can be identified and only change tweets from those users. For both methods, to perturb a tweet, we move it to a location nearby with more tweets to mask the identity of the user. A thorough experimentation of other baseline approaches shows that our model exhibits a significant decrease in user identification accuracy while keeping the percentage of changed data at a minimum.

Siemens Competition

Math : Science : Technology

Regional Finalist

Names: Nadine Meister and Andrew Zhao
High School: Centennial High School
Mentor: Dr. Xuan Luo
Project Title: Exploring Borophene for Spintronics

With the size and speed of conventional electronics and data storage approaching its physical limitations, spintronics presents a novel new path for data storage by using the electron's spin as an additional degree of freedom. One of the newest materials in the field of spintronics is a two dimensional sheet of boron, called borophene, which shows many desirable properties for spintronics. Using first principle calculations, we predict the electronic and magnetic properties of the 3d transition metals Cr, Mn, Fe, and Co doped in two sublattices of the 8-Pmmn borophene allotrope for possible spintronics applications. Dopants introduced to the ridge sublattice of borophene resulted in ferromagnetic order and half-metallic electronic properties, with magnetic moments ranging from 1.53 μ_B to 3.98 μ_B. All ridge doped structures exhibited metallic properties in the majority spin, and semiconducting band gaps ranging from 23.8 to 354 meV in the minority spins. Our results show that substituting Cr and Mn into borophene's ridge sublattice induced a shift from a nonmagnetic metal to a magnetic half-metal with the highest magnetic moments, making them the most promising candidates for spintronics applications.

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Cindy Huang[1], Robert Yang[2], Jessie Ma[3]
High School: [1]Thomas Wootton High School, Rockville, MD; [2]Montgomery Blair High School, Silver Spring, MD; [3]Winston Churchill High School, Potomac, MD.
Mentor: Dr. Calvin Johnson
Project Title: Towards Precision Diagnosis of Lymphoma Subtypes Using Big Data and Machine Learning Modeling

A cancer misdiagnosis can mean the difference between life and death. The diagnostic challenges are particularly prominent for lymphoma, which is the leading cancer in teenagers and the most often misdiagnosed cancer. The inaccurate diagnosis of lymphoma occurs due to the existence of many distinct but closely-related subtypes, and the lack of highly discriminative diagnostic tests. We initiated this project to address whether a combination of big data machine learning modeling with genome-wide mutation profiles can improve differential diagnosis of two closely-related lymphoma subtypes including Burkitt lymphoma (BL) and diffuse Large B-cell Lymphoma (DLBCL). We first constructed the world's most comprehensive lymphoma mutation database, named LymphoDB, by integrating ~1.5 million genetic data points from >2,900 worldwide patient samples across 13 lymphoma subtypes. Then, a set of machine learning algorithms were applied to build a genome-wide mutation-based diagnostic model, which enabled differential diagnosis of BL and DLBCL, with 100% accuracy. This pioneering study suggests the promising potential of the big data-driven machine learning combined with genome-wide mutation profiling as a new and effective tool for precision differential diagnosis of lymphoma subtypes. Finally, we made the LymphoDB database freely accessible via a dedicated website at http://lymphodb.heliohost.org, hoping to facilitate lymphoma research.