CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

Ruchir Baronia

Project Number

S0801

Project Title

Rescuer: Emergency Mobile App with Voice Recognition, Volume Key Pattern, Location SMS Reciprocation, & Push-Aid Systems

Abstract

Objectives/Goals

To construct an efficient mobile application that can send panic messages with the user's location in the case of an emergency. It should implement the following four features:

1. Voice Recognition: Rescuer should send out emergency messages with a geocoded location link by recognizing the user's spoken keyphrase.
2. Volume Key Pattern: Rescuer should send out emergency messages with a geocoded location link when a user presses the device's volume buttons in a custom pattern.
3. Location SMS Reciprocation: When another qualified contact sends a specific text message to the Rescuer equipped device, Rescuer should detect the keyword trigger and return the device location.
4. Push-Aid: Rescuer should implement a flexible layout fragment that can be accessed via the phone's home screen as a widget to send emergency messages.

Methods/Materials

To develop Rescuer, I first coded the background Java processes. Here I utilized the CMUsphinx voice recognition library for unique 24/7 recognition and multithreaded my application for optimal CPU usage. After building the brains of the app, I moved on to perfecting the user interface using XML and following Google's Material Design Guidelines. A finished product was created only after testing the application on over 100 emulated devices.

Results

Rescuer not only gathers the most accurate location, but is also memory (0% crash rate), CPU (<30% usage), and battery (<5% per charge) efficient. Response time is instantaneous. Finally, Rescuer does not require access to Wi-Fi or Mobile Data, making it universally available.

Conclusions/Discussion

I have developed a fully functional emergency mobile application that can reach out to custom emergency contacts in a crisis. No mobile app has ever utilized 24/7 voice recognition, background volume button detection, or continuous SMS recognition as tools for signalling for help in an emergency.

Summary Statement

I've developed an emergency mobile app that can send panic texts with location when the user says his/her voice recognition keyphrase, presses the device's volume buttons in a pattern, receives a specific text, or pushes a homesceen widget.

Help Received

Parents bought science fair board.

CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

Guadalupe Bernal

Project Number

S0802

Project Title

Autonomous Off-Road Vehicle Using Computer Vision for Surveillance Applications

Abstract

Objectives/Goals

The goal of this project was to create an algorithm that could effectively maneuver an autonomous robot by analyzing the video stream from a camera. The camera, mounted on a 6WD robot, would send the video to a laptop for processing and determination of the next location to move to. The robot should be able to autonomously drive along a sidewalk, or outdoor trail with a defined path. The algorithm, with no prior knowledge of its environment and a defined trail with adequate lighting, should guide a robot without human intervention.

Methods/Materials

The system consists of a 6-wheeled differential robot using DC motors and an Arduino Mega board, with a camera and laptop mounted on top. The camera sends the input video to the laptop which then analyses the video and sends commands back to the Arduino via USB. The algorithm was developed in C++ using the computer vision library OpenCV 3.1. The algorithm consists of a processing pipeline with an initialization stage and a single processing loop. The first step is the frame acquisition which captures the frame, then a Gaussian blur filter smooths out the input. A set of filters are used to eliminate the undesired background, and finally the next location is calculated and the speed of the motors is transferred to the micro-controller which is derived using the center of mass and computed with OpenCV. I designed the robot on SolidWorks and 3D printed the parts with PLA filament.

Results

I tested the robot on an outdoor trail where it was able to stay in the center of the path even in the presence of strong curves, while moving at maximum speed. There is a limitation on the algorithm that is intrinsic to the use of a threshold to determine the best path. If there is an obstacle with the same contrast and texture as the path, the algorithm may choose the wrong direction.

Conclusions/Discussion

I developed a program, and built a robot to test it, that allows a 6WD vehicle to autonomously navigate a series of paths. The noise produced by this robot is negligible, can operate under any weather condition, and possesses no threats to human bystanders. The characteristics of this robot contrasts that of other surveillance methods, such as drones which are not permitted to fly above populated regions, have weather impact their flights, and noise as a concern. All this combines to make a robot with this algorithm a valid option for real-world applications.

Summary Statement

I designed and built an outdoor robot that uses a computer vision algorithm to navigate itself autonomously.

Help Received

I took engineering courses at my high school that allowed me to learn programming and 3D computer modeling. I have also been a part of multiple robotics teams including the FTC competition where I was the main developer. My main source of information came from the internet.

CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)
Sophie Q. Carter

Project Number
S0803

Project Title
GPS-Denied Navigation Using Altimetry

Abstract

Objectives/Goals
The goal of my project is to be able to navigate outdoors using sensors available on a cell phone, but without GPS. The inertial sensors on a cell phone measure angular and velocity rates of change that must be integrated to calculate position. Small errors in these rates accumulate so that tracking accuracy rapidly degrades. One way to overcome this problem is to use barometer data as a measure of elevation, which can be compared to a reference topographic map and used to reduce position error to a useful level.

Methods/Materials
I created a local elevation map using data available online. I used a cell phone equipped with a magnetometer, gyroscope, accelerometer, and barometer. I walked around a neighborhood block while recording data from these sensors at a rate of 10 Hz.

Starting with an initial GPS position fix, I used a particle filter to process the sensor data. I used the magnetic and inertial sensors to propagate the position estimate from one time step to the next and then updated it using the barometer-estimated elevation. I calculated the accuracy of the position estimate using GPS measurements for ground truth only.

Results
In multiple trials, I was able to track my position to within a few tens of meters over a period of about eight minutes without the aid of GPS. This accuracy is a useful level for navigation and far better than what could have been achieved without the aid of the barometer measurement.

Conclusions/Discussion
GPS signals can be lost due to poor reception in dense forests, urban areas, and mountainous regions or to signal jamming. My navigation technique is very general and would have many important applications. Examples include aiding hikers lost in the wilderness and underwater navigation. It would also have uses in the military such as guiding soldiers through GPS-denied regions.

Summary Statement
My project demonstrated a navigation method that works in the absence of GPS signals by comparing barometer-estimated altitude to a topographic map.

Help Received
I performed the experiment and analysis myself. I used IDL to code my algorithm and generate plots. My father, Dr. Paul Carter, helped me find out more about particle filters.

CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

Alexis Chirco; Olivia Kim

Project Number

S0804

Project Title

Simulating the Effects of Alzheimer's Disease in the Hippocampus: Effects of Change in Ion Equilibrium and Acetylcholine

Abstract

Objectives/Goals

The purpose of this project was to create a simple computational neuron model that simulated the hippocampus's theta wave output in response to changes seen in the progression of Alzheimer's disease.

Methods/Materials

In order to change the equilibrium potentials of Na+ and K+ ions and applied acetylcholine amperage as a proxy for acetylcholine neuron connectivity to produce theta waves, variables, synapses, loop system, and spike and state monitors to track voltage were implemented into the Brian2 software in Python. Before writing the code for the model, importation of the previous models for the neurons and synapses was needed to run this model so stimulated neurons behaved based on previously done experiments.

Results

Ultimately, the data shows that as the equilibrium potential of sodium increases and the equilibrium potential of potassium decreases (becomes more negative) simultaneously, the frequency of the theta waves tends to increase. This trend holds true for both minor and extreme changes to the ENa and EK, but the more extreme the change is, the greater the frequency of theta is. As for the data shown in Part Three, the greater the applied amperage of acetylcholine, the greater the theta frequency while less amperage results in a lower frequency.

Conclusions/Discussion

In the end, the hypothesis was not supported by the data collected. The results showed that the greatest theta wave frequency was produced when the equilibrium potential of sodium (ENa) was increased by an ample increment, specifically from 55 to 85 millivolts. This change resulted in a frequency of 7.400 ± 1.350 Hz, which was a 68.18% increase from the control result. Furthermore, the exact opposite of what was hypothesized, or increasing the ENa and decreasing the equilibrium potential of potassium (EK), produced relatively large results at 5.700 ± 1.059 Hz. By and large, the data showed that individually increasing the ENa always increases theta frequency while individually decreasing the EK always decreases theta frequency. The reason why the results occurred in this manner is most likely due to the fact that increasing ENa excites the cell while decreasing EK inhibits the cell.Further research should most definitely be conducted on how to create a highly accurate computational hippocampus/neural model. Also,research should be conducted on how cell death affects the brain during the progression of Alzheimer#s.

Summary Statement

We simulated the effects of AD when sodium, potassium and acetylcholine amerage were modified.

Help Received

We programmed and performed the simulation by ourselves but received guidance from Conor Cox, a graduate student in the department of Neuroscience at UC Irvine.

CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

Narek Daduryan; Ethan Keshishian

Project Number

S0805

Project Title

Creating a Multilingual Keyboard Utilizing LCD Screens to Aid Multilingual Typers

Abstract

Objectives/Goals

Our project's goal was to create a sort of multilingual keyboard to aid those who type in multiple languages, or wish to learn a new one. Our objective was to make this keyboard so that the user would not have to own multiple keyboard, memorize the locations of letters, or place stickers on a keyboard in order to type in multiple languages. Instead, a single keyboard would be used to type in any language.

Methods/Materials

To create the working prototype, there are two components: hardware and software. Our hardware consisted of an arduino and two (2) LCD-Desplay Switches by NKK, along with other general parts. We put everything together from soldering to placing resistors. Two pieces of software were written: we wrote a desktop program in C# that will run on the user's pc, and a second program, written in Arduino's language (based off C) that runs on the arduino. The two programs communicate with each other using serial communication via a USB cable. All software was written by ourselves, except for the arduino timer interrupt code, to which credit was given.

Results

Our result was a working prototype. The hardware included only two (2) keys ('e' and 'n'), that when pressed, typed the letters on the computer. When the computer's typing language was changed (Pressing 'Shift + Alt' or 'Windows + Space'), the LCD displays on the keys would change their displays to show the corresponding letters in the computer's new language.

Conclusions/Discussion

Since our project was only a prototype, we hope to continue development to be able to provide a full keyboard of LCD-keys. We also only have two built-in languages supported. However, our code is available online, open-source, so any developer can add on to our code.

Summary Statement

We created a (prototype) keyboard, where in place of traditional keys, each key contains a LCD screen. These are used to change the keys to allow the user to type in multiple languages with ease.

Help Received

We created all code, except for timer interrupt code, gotten online by Amanda Ghassaei. We also got help soldering from my uncle. All hardware work was done ourselves, however.

CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)
Dina S. Dehaini

Project Number
S0806

Project Title
Early Fire Detection

Abstract

Objectives/Goals
The purpose of this project is to build and test a prototype hardware and software to detect fire in the earliest stage possible and produce an automated warning response via wifi as well as provide a live feed for when a fire is detected.

Methods/Materials
Materials used for this project include a raspberry pi 3 model b, a gas, UV, IR, temperature, and humidity sensor to detect flame signatures and a 5mp camera to provide a live feed of the area when an alarm is raised to reduce false alarms. The humidity and temperature sensors detected the current risk of fire, while the other sensors detected an actual flame. Natural fire squares were used to test the prototype with a fire at a somewhat consistent size. Sensor outputs that would warrant a fire alert were tested for. A code that would periodically retrieve sensor data and check if the data fell into the range that would suggest the occurrence of a possible flamewas written and deployed to the Pi. If it did, the camera would then capture an image of the area which would be sent with an alert to the recipient using wifi. If the humidity and temperature sensors reached values that warranted a high potential for fire, then a fire hazard warning would be sent. To test the prototype, it was set up in a small room where fire hazards were eliminated in order to start small fires. 3 fire cubes were used in order to start a fire and measure the amount of time it would take for the prototype to recognize the fire at different lengths away from it.

Results
Results showed that the prototype was able to detect a fire both quickly and efficiently. It was able to send a warning message when factors such as temperatures and humidity levels suggested conditions that might lead to a fire starting and then send a different warning when the IR sensor and gas sensors picked up on heat and carbon monoxide caused by the fire. Certain sensors, however, did not work as efficiently when distance increased, which in turn caused the prototype to rely mainly on the gas sensor, increasing the amount of time it took to recognize the fire.

Conclusions/Discussion
All in all, the prototype was able to remain effective in determining a fire without being too costly, costing under $60. This allows for the possibility of it being implemented in homes and fire prone areas at an affordable cost while still maintaining reliability in alerting recipients to fires as early as possible.

Summary Statement
This project tested and built a prototype hardware and software to detect fire in the earliest stage possible and produced an automated warning response via wifi as well as provided a live feed for when a fire was detected.

Help Received
My mentor helped me to learn how to use the Pi.

CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

Shiladitya Dutta; Rishik Reddy; Parth Saxena

Project Number

S0807

Project Title

Accurate, Low-Cost Diagnosis of Parkinson's Disease by Detecting Dysphonic Features through a Machine-Learning Algorithm

Abstract

Objectives/Goals

The objective of this project was to make an accurate diagnostic and telemonitoring tool for Parkinson#s disease through a mobile application - aimed at providing accessibility to everyone, including those who do not have access to proper medical facilities.

Another objective of our project was not only to develop efficient algorithms, but also to develop an easy-to-use, reliable interface for the user.

Methods/Materials

The application takes the .wav audio file and uploads the file via Amazon Web Services to a feature extraction program: PRAAT. PRAAT extracts 16 linear and nonlinear dysphonic features and runs them through multiple trained machine-learning learning algorithms. These machine-learning algorithms serve as a classifier to determine the onset of Parkinson's in a patient. We trained the machine-learning algorithm via 196 unique voice samples from the NCVS (National Center for Voice and Speech) database. The application then displays the results of the voice recordings to the user via the mobile app.

Results

Using ten-fold cross evaluation, we have achieved a fairly high accuracy of 90%, which is significantly higher than the accuracy of the current diagnostic method, which holds a 70% accuracy. Using 195 test samples, our algorithms currently identified 175, leading to an official true positive/negative rate of 90.2%.

In addition, we successfully built an easy-to-use front-end mobile application coupled with a highly reliable back-end infrastructure.

Conclusions/Discussion

We believe that our tool significantly enhances an accurate detection of Parkinson's through our intelligent machine-learning algorithm, and with our reliable backend infrastructure, we can provide this tool to anyone with a smartphone and an internet connection.

Summary Statement

We developed an accurate and low-cost diagnostic tool for Parkinson's disease where users submit a voice sample via a mobile iOS application and get a diagnosis within 15 seconds.

Help Received

We received a dataset from Dr. Max Little, a professor at MIT, whom we have worked with throughout our project.

CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

Kevin Frans; Alex Gao

Project Number

S0808

Project Title

Coordinated Multi-Agent Control Utilizing Deep Reinforcement Learning

Abstract

Objectives/Goals

Due to the necessity for agents to learn precise coordination, control in cooperative multi-agent domains has traditionally been difficult. In previous studies, tasks such as robotic control have been represented as single agent problems, using a central neural network policy to control all joints. We examine the effects of taking a decentralized, multi-agent viewpoint, allowing each individual joint to make its own decisions. We present a novel multi-agent reinforcement learning algorithm based on the policy gradient method, by representing each agent's policy as distinct deep neural network. By training these agents simultaneously, they learn to expect the other agents' behaviors and respond accordingly, leading to cooperation. In addition, our algorithm reduces compute time by training multiple smaller networks in parallel, rather than iterating over a single large network.

Methods/Materials

We demonstrate the success and robustness of the algorithm by applying it to various tasks: 1) a swimming robot 2) a robotic arm; 3) a hopping robot; and 4) a package delivery problem. In each task, ideal performance is defined differently: the agents may be rewarded based on moving forward, or by reaching certain locations.

Our experiment procedure consists of training the algorithm with each environment, then measuring the average return for each training episode. We then repeat multiple trials for each task and compare the results the centralized method.

Results

The agents learned to cooperate in the absence of explicit communication, achieving up to two times the performance of the centralized method, while learning at a faster rate. The performance of our algorithm scaled up to more complex tasks, making it more practical for real life problems.

Conclusions/Discussion

Our work provides a reliable basis for practical cooperative learning in a multitude of environments, and paves the way for future research in the emergent field of multi-agent control. There are countless real-world applications of our algorithm, such as drone package delivery, autonomous car traffic management, and search and rescue systems.

Summary Statement

We developed a novel algorithm that autonomously teaches multiple agents how to act cooperatively.

Help Received

None

CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

Raghav Ganesh

Project Number

S0809

Project Title

A Novel, Fast, and Accurate Machine Learning Based Cell Classification Algorithm for Pathology Labs to Diagnose Diseases

Abstract

Objectives/Goals

Physicians often rely on histology & cytology lab reports to diagnose diseases. Lab report generation needs manual intervention which adds cost and time. These prevent a local point of service in remote, rural, and underdeveloped areas.

Objective: Use Machine Learning and Computer Vision to develop a cell segmentation algorithm (to detect and discriminate individual cells from a microscope slide image), a robust cell classification algorithm (to classify the individual cell images), and demonstrate these on images captured off of microscope slide using a frugal add-on to a cell phone camera.

Design constraints: Algorithm over 80% accuracy validated on over 10,000 cell images, test time under 30 sec/cell, and the image capturing attachment cost under $10.

Methods/Materials

I developed my machine learning algorithm (coded in Java, C++, Batch, Python using OpenCV, SciPy and CImg libraries) using an iterative approach (4 revisions, each using results from prior versions). CUDA integration speeded up the training and segmentation process. I captured images of cheek cell swabs from volunteers using my $3 DIY macro lens cell phone camera attachment.

Training: 1st version - Identified the pros and cons of 9 classification algorithms (K Nearest Neighbors, Linear SVM, RBF SVM, Gaussian, Decision Tree, Random Forest, Neural Net, Adaboost, and QDA). 2nd version - Added iterative thresholding before feeding the data to the classifiers. 3rd version - Focused on detecting FAST & SIFT, and feature matched using FLANN and a FAST Knn classifier, assigned each feature a weight. 4th version - Generated feature descriptors from the locations of FAST and SIFT features, grouped similar features together using agglomerative clustering, and trained Knn classifiers for each cluster.

Testing: Grayscaled the images, performed coarse edge detection, and tested the watershed method, blob detection, k means clustering for cell segmentation. Each cluster#s classifier was weighted and run.

Results

Achieved a classification accuracy of 91% (with 10K cell images) and test time of 1.65 sec/cell (60% saved with CUDA). Data was divided randomly into 10 groups, each run with 90% train-10% test split.

Summary Statement

Developed a novel machine learning algorithm to classify cells (10,000 images) with an accuracy of 91% and processing time of 1.65 sec/cell (60% reduction with CUDA) and tested on cheek-cell images captured using my macro-lens phone add-on.

Help Received

I am thankful to the contributors to the various online forums and classes, these helped me ramp up on Machine Learning. I thank Prof. Lezoray (U of Caen) for letting me use his images database, and science teacher Mr. Lee.

CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

Ishan Gaur

Project Number

S0810

Project Title

Improving the Rationale for Stock Market Investments to Help Middle Income Households

Abstract

Objectives/Goals

Many families lost decades of wealth during the last economic recession and turning away from financial markets resulted in them being unable to recover their losses fast enough. This paper develops a new investment strategy that helps remedy the systemic problems that put these middle income people#s financial security in peril in addition to a machine learning algorithms to do middle-term stock market predictions.

Methods/Materials

The CAPE ratio was used to do downside management for an aggressive portfolio, a moderate portfolio, and a fluid portfolio. All of the portfolios were dynamically allocated and targeted different risk tolerances. These tolerances represented three possible use cases that were tested with a baseline portfolio, a portfolio using CAPE, and a portfolio with CAPE and 3-year rebalancing. Machine learning algorithms were also used to make one-year forecasts of the market using economic data from the Federal Research Economic Dataset and predicted the NYSE closing price one year in advance.

Results

Both the aggressive and moderate portfolios successfully avoided large losses during economic downturns. The aggressive portfolio (100% stock allocation) beat the market by nearly 1% annually, the moderate portfolio (60% stocks and 40% one-year treasury bills) did not beat the market but beat the original strategy by 0.4% annually, and the fluid portfolio was close but did not beat the original or the market. The Nu Support Vector Regression model was able to predict normalized NYSE closing prices one year in advance with 80.7% accuracy and with an R2 value of 0.594 (out of 1.0); however, it was a better predictor of long-term trends than middle term trends as it predicted movement about an average, but not the absolute magnitude of the prices itself.

Conclusions/Discussion

These results demonstrate correlation between economic trends and changes in markets. They also show that CAPE downside management is effective in combination with a delay, dynamic asset allocation, and half standard deviation CAPE bands. The fact that Nu-SVR can predict middle term trends but not the magnitude of changes also supports the idea that market movement is driven by economic trends but how far up or down the market goes is determined by the information released on that day.

Summary Statement

I made a practical way of applying economic theory to investing, in a way that solved the problems of past attempts and beat the market by 1% annually, in tandem with machine learning algorithms that predict changes in market prices.

Help Received

None. I designed the experiments, gathered the data, and created the algorithms by myself. I learned what was needed to accomplish this using online resources. In order to learn about financial theory I also learned from online lecture series and books such as Shiller's book Irrational Exuberance.

CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

Elias B. Gilbert

Project Number

S0811

Project Title

Is Sprawl Wasting Our Time? Computer Models, Big Data, and Google APIs for City Planning

Abstract

Objectives/Goals

I explored how the way our streets are laid out (sprawl) affects the amount of time we spend doing driving-related activities. My project examined three activities: searching for parking (cruising), waiting at intersections, and the time spent travelling to a resource like a gas station or doctor#s office. I hypothesized that people spend less time cruising in denser cities, but more time at intersections. I also expected that it would take less time to get to resources in a denser area.

Methods/Materials

I created computer models to examine driving activities for different city layouts and then validated them with real data. First, I created a model based on real maps from 10 cities and towns and simulated a car driving around to find randomly generated parking spots, replicating the model for 12 different proportions of open spots. On foot, I mapped open and filled parking spots for 7 neighborhoods in Santa Cruz and used those distributions for more realistic simulations. Next, I created another model using proportions of intersection degrees to calculate how much time a car would spend at intersections in a fictional 1-mile trajectory. Then my dad drove me and I timed how long we spent at intersections in 10 min intervals in the 7 neighborhoods. Finally, I generated 600 random points across the US and found their sprawl using Python and a big database of street connectivity. Then, I calculated the closest resource from 5 categories to those locations with Google Maps APIs.

Results

The computer models showed that cars would cruise less and wait longer at intersections in places with less sprawl (denser cities). However, sprawl only made a difference when the density of cars in the area was high. My real data showed no relationship between sprawl and either cruising or intersection times. In the Google APIs study, I found that it took less time to drive to resources in areas with less sprawl, regardless of the type of destination.

Conclusions/Discussion

Altogether, my data suggests that sprawl affects many aspects of how we waste time while driving, which must all be weighed carefully in city planning. As sprawl affects different components of time-wasting differently, city planners must consider the factors separately based on the needs of their individual communities.

Summary Statement

I used computer models and collected data to test the effects that different street layouts (sprawl) have on the amount of time we spend looking for parking, waiting at intersections and going places.

Help Received

I was advised extensively by Professor Dr. Adam Millard-Ball in the Environmental Studies department of UC Santa Cruz but conducted the actual research on my own. My father drove the car so that I could take my real-life data.

CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

Lauren Hinkley; Sarah Kazmie

Project Number

S0812

Project Title

CardioWatch

Abstract

Objectives/Goals

To create a system to track, monitor, recognize, and diagnose Heart Rate Variability (HRV) in real-time, which can be integrated with or improve upon the current iWatch and Fitbit systems that are limited to tracking and monitoring heart rate. This system would create a way to not only track and monitor pulse, but to measure and monitor heart rate variability (HRV) which can be used to diagnose heart disease, and may be an early indicator of heart attack.

Methods/Materials

Configured and programmed a Cypress PSoC 4 with an embedded analog digital converter (ADC) to monitor and digitize the analogue output from a LED/Sensor pair.
Configured and programmed embedded UART to transmit data and receive simple commands from a PC USB interface.
Using a terminal program (ZOC 7), tested and logged more than 50 sessions of live pulse signal readings.

Implemented automatic data calibration, scaling and normalization.
Implemented original real-time R Wave peak detection algorithm, combing LPF, differentiation and back-buffer ray-casting.
Implemented event offset/beat detection algorithm.
Used data recorded from early pulse signal recordings to pulse width modulate (dim) an LED to create a consistent test pulse.
Using a random number generator, alternately injected delay states into the generated pulse signal to simulate heart rate variability in a controlled and measurable manner.

Results

We we able to successfully track heart rate variability using a simulated heart rate with varying degrees of variability.

Conclusions/Discussion

While there is still much work ahead, results indicate that our CardioWatch device can successfully analyze and detect Heart Rate Variability in real-time, using an LED, a sensor, 2 resistors and an inexpensive (< $2.00) microcontroller.
Our CardioWatch technology could be easily and affordably integrated into consumer devices such as Apple Watches and Fitbits, allowing these devices to provide timely feedback to wearers and their medical providers.

Summary Statement

Using a PSoC 4 chip and external heart rate sensor, we wrote a C program to track and monitor heart rate variability as an indicator of Cardiovascular Disease.

Help Received

Throughout the course of our project, we had a mentor answer questions pertaining to programming and the type of chip that was best to use.

CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)
Holly M. Jackson

Project Number
S0813

Project Title
Unlocking History: An Algorithm to Virtually Unfold 3D Computed Tomography Scans of Unopened Historical Documents

Abstract

Objectives/Goals
In 1926, a trunk filled with 2600 intricately folded and sealed letters from the 17th century was discovered in the Netherlands. Opening the letters risks losing the folding patterns, breaking the seals, and destroying the text. In 2015, researchers at Queen Mary University in London (QMUL) used high-resolution computed tomography (CT) scan machines to image a set of the letters. In my project, I developed an algorithm to virtually unfold the letters and reveal the text inside.

Methods/Materials
Working with CT scans of these letters poses significant challenges including touching pages, intricate folding patterns, scatter from lead seals, double-sided text, and low ink-to-paper contrast. To account for this, my software approach combines point, line, and plane detection algorithms. I divide the 3D CT scans generated at QMUL into thousands of 2D cross-sectional images of the letters. I work on each 2D cross-section by creating a point and line detection algorithm. My point detection algorithm identifies candidate points on paper layers in the cross-section. The line detection algorithm then identifies each paper layer by fitting a smooth line along the approximate center. Once line detection is complete on each 2D layer, I proceed to link the lines in the orthogonal direction forming surfaces. Pixels from the 3D data are then extracted into planes using the coordinates from the identified surfaces. The data is plotted as a flat image allowing someone to read the text within.

Results
After eight months of concentrated algorithm development and refinement, I was able to extract two nearly complete letters. I verified my algorithm's effectiveness by comparing my extracted images from one letter to photos of the real letter's interior. Finally, I used my algorithm to unfold a letter that still remains closed and sealed in real life.

Conclusions/Discussion
The unfolded results I generated using my algorithm achieved my engineering goal and exceeded my initial expectations. Not only was I able to verify my algorithm's effectiveness by testing it on a physically opened letter, but I was also able to virtually open a letter that still remains closed and sealed in real life. The text revealed can now be seen for the first time in over 300 years!

Summary Statement
I created an algorithm to virtually unfold 3D computed tomography scans of fragile, 17th century documents without ever physically opening the documents.

Help Received
I worked in the MIT Center for Bits and Atoms under the guidance of graduate student Amanda Ghassaei. Although my algorithmic work was independent, my mentor gave advice and helped answer any questions. In addition, the 3D CT data was provided by QMUL with help from the MIT Libraries.

CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

Patrick D. Kao

Project Number

S0814

Project Title

Developing a Sentry Drone for Area Protection

Abstract

Objectives/Goals

Drones are being flown in sensitive locations where they pose a risk to human safety and security (e.g., near the White House and over forest fires or airports too close to manned aircraft).

One possible solution to this problem is to create a network of "police drones" to secure an area's perimeter against intruder drones. My project seeks to address one facet of this problem: creating a single drone that can detect and intercept intruder drones using visual information.

Methods/Materials

I built a sentry drone that uses a camera to capture images and a computer to interpret those images to guide it towards intruders. It uses a PixHawk flight controller with ArduCopter firmware installed to perform basic flight functions, and a more powerful companion computer, the Odroid XU4, to process images from the depth camera, an Intel Realsense R200.

I partitioned the software into 2 modules: a detection module which locates the intruder, and a control module which moves the sentry towards the intruder. To prevent program bugs from causing crashes, I used Software-in-the-Loop simulation combined with a manual override of the autonomous flight control systems.

Results

I solved a number of technical problems. First, I wrote software running on the Odroid to control the flight of the drone. Next, I wrote software on the Odroid to read and interpret data from the RealSense camera. I wrote subroutines to create point clouds from the camera data, separate these point clouds into objects, and identify intruder drones from those objects. I used Matlab and OpenCV to visualize results.

I was able to get a hardware sentry drone to track a simulated intruder drone and a simulated sentry drone to track a hardware intruder drone.

Conclusions/Discussion

I learned that the efficiency of the point cloud segmenter is critical to the efficiency of the system. I also discovered that although open source software contains bugs, it is possible to fix them. I also learned that it can be surprisingly difficult to integrate numerous disparate software packages into a cohesive system, especially because different APIs were developed by different people. It is possible to design a system efficient enough to locate, identify, and intercept an intruder drone in real time.

Summary Statement

Through careful software optimization, I designed and built a sentry quadcopter that can detect and intercept an intruder quadcopter to secure an area.

Help Received

My Dad paid for all of the hardware used for the experiment.

CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

Sarkis Karibyan; Alexander Sanchez

Project Number

S0815

Project Title

Development of Symmetry Evaluation Methods for Determining the Degree of Ventricle Symmetry in Ischemic Stroke

Abstract

Objectives/Goals

The objective of the project was to identify and develop effective methods of symmetry evaluation in images and apply these techniques to an imaging-based stroke rehabilitation phase I clinical trial named Dose Optimization for Stroke Evaluation (DOSE), Also detecting changes using the shape of the lateral ventricles to understand adjustments in the rest of the brain. The symmetry of the left and right lateral ventricles is an effective indicator of spatially altered regions of the brain.

Methods/Materials

Open patients MRI image of the brain on MRIcron software, Segment the lateral ventricle, 3D fill the ventricle, Overlay pre and post images of the ventricle, save file as volume format (v.o.i.), Use Bayes' rule to incorporate into Matlab for contrast from CSF and image background, Provide image to Matlab to generate ventricle volume.

Results

84 MR image studies were processed and the symmetry ratios were calculated. The ratios will be utilized to evaluate potential correlation with the enrolled subjects# MAL(Motor activity log) scores and WMFT(wolf motor function test) scores over time. We expect the symmetry ratios to correlate with improved arm and hand function from the two scores over time, Evaluated from the CSF volume in the lateral ventricle.

Conclusions/Discussion

This method of symmetry detection is novel because it provides a quantitative measure of the symmetry between non-uniform regions. The lateral ventricles have a non-uniform shape, which is unique between patients and contributes to the difficulty of applying current symmetry detection methods. This algorithm effectively and accurately provides meaningful quantitative data. The symmetry evaluation method and the projected correlations will be very valuable for diagnostic and therapeutic applications in stroke and other clinical trials.

Summary Statement

To find a new way to treat stroke as accurately as possible, by providing a quantitative measure of the symmetry between non-uniform regions.

Help Received

My mentors Ximing Wang and Kevin Ma provided the patients files assigning us to segment and to calculate the volume of the ventricles.

CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

Gaeun Kim

Project Number

S0816

Project Title

Assessing Treatment Response in Colorectal Cancer Patients through Novel Volumetric Ultrasound Methods

Abstract

Objectives/Goals

The objective of this study was to develop a motion correction algorithm to obtain high-resolution volumetric liver ultrasound images. Combining motion correction with parametric mapping methods, the overarching goal was to accurately assess tumor growth and monitor cancer treatment response.

Methods/Materials

Selected 4D contrast-enhanced ultrasound (4DCE-US) sequences and performed preliminary image processing through standard deviation intensity projection. Use a supervised machine learning algorithm to isolate ultrasound beam from ribs and other organs. Created a binary mask to specify region of interest (ROI) around tumor using fslview and MeVisLab. Registered images using a pyramidal window-to-master-average approach. Used findings to develop a parametric blood perfusion mapping method.

Results

Tumor motion range was reduced by an average of 2.17 pixels, and time-intensity perfusion curve analysis showed that the corrected images were closer to the clinically used manual gold standard. The random forest classifier and pyramidal registration scheme were also confirmed to be robust methodologies, based on a high mutual information (MI) metric between corrected samples and the manually corrected samples.

Conclusions/Discussion

Motion correction through image processing reduces the distortion and movement of 4D volumetric contrast-enhanced ultrasound images, and parametric maps of corrected images provide a clearer view of blood perfusion in the tumor. This research has implications in rapid assessment of treatment response in cancer patients, as well as the early detection of cancer.

Summary Statement

I developed a novel motion correction algorithm and parametric response mapping method for the early assessment of treatment response in colorectal cancer patients.

Help Received

Dr. Ahmed El Kaffas, a postdoc at the lab I intern at (Translational Molecular Imaging Lab at Stanford) taught me how to read ultrasounds and how to use certain computational tools. The project methodology design and execution was done largely on my own.

CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

Karena Kong

Project Number

S0817

Project Title

Traffic Network Management: Novel Approach Using a Deep-Learning System Driven by Dynamic Data and an Adaptive Algorithm

Abstract

Objectives/Goals

The objective was to create a traffic management system called VRAA (Visual Recognition based Adaptive Algorithm) that could determine the most optimal traffic light sequences to produce the most successive green light waves and reduce starvation using an adaptive algorithm and data input through an image processing sequence of live traffic footage.

Methods/Materials

I created an adaptive algorithm in Java that adjusted according to fluctuations in traffic flow. To begin, VRAA internalizes data points through the visual based car detection module. A clean background image is first captured followed by a series of frames depicting traffic flow, each individually taken using a 1 second timer. Both background image and captured frame are gray scaled and contoured to erase noise. Subtracting the background image leaves the remaining clusters that are fused and recognized as vehicle data points. VRAA#s second module aims to simulate different worlds using data from prior module to depict traditional controls versus novel traffic smart controls, which adopt the adaptive algorithm.

Results

In all three modes, the smart control system showed a faster response and greater efficiency. Even under stress (contingent load), drive lanes saw a 9 second shorter wait time and travel time overall improved by 24%. The traffic management simulation also showed environment benefits and significant decreases of CO2 emissions when idling time at intersections are reduced#an 88,000 grams decrease in CO2 emissions for every thousand cars in the real load

Conclusions/Discussion

VRAA calculates the most optimal traffic light signaling to extend green waves by assessing four variable factors through novel mathematical algorithms. VRAA accounts for the starvation factor, priority queue, aging factor, and neighboring traffic for all possible sources and destination routes at an intersection. The smart traffic control consistently proves faster travel time and reduced traffic through a simulation process.

Summary Statement

I created a traffic control system called VRAA that improves traffic flow through an interdisciplinary approach leveraging computational analysis of live traffic footage, using a novel adaptive algorithm, and validating improvements through

Help Received

I designed, built, and programmed VRAA myself. My parents reviewed some parts of this project and provided input.

CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

Shadaj R. Laddad

Project Number

S0818

Project Title

Direct Control of Autonomous Mobile Robots via Deep Reinforcement Learning

Abstract

Objectives/Goals

When designing robot software, some of the most important components are the controllers, which produce actuator commands based on sensor input. While many different control algorithms exist, they all require human work to perform calculations and tuning. Developments in machine learning, however, make it possible to produce low level commands that can challenge human control by training neural networks with an technique called deep reinforcement learning.

By shifting the work of learning an optimal control policy from humans to computers, this project brings the possibility of robots that can teach themselves how to control different systems. Furthermore, by exploring different robot control responses, neural networks open up the capability to control complex systems without the limitations of traditional control algorithms. If deep neural networks can be trained to produce low-level motor commands for mobile robots based on sensor inputs, then they can be used as alternatives to traditional control techniques.

Methods/Materials

In this project, I used the Deep Deterministic Policy Gradient technique to develop an algorithm that can learn to control different types of mobile robots to perform low level tasks such as moving to a specific position. My algorithm employs machine learning optimization techniques such as a replay history and batch normalization to quickly learn an optimal controller for many different control tasks. The algorithm was implemented using the Scala programming language and TensorFlow machine learning library.

Results

The algorithm developed in this project has stellar results on a wide variety of robot types. The algorithm was tested to learn positional control in both simple environments such as a point-robot in a 1-dimensional space and complex ones such as a differential drive robot in a 2-dimensional space. In all environments, the algorithm was able to learn efficient control policies with less than 500 training episodes.

Conclusions/Discussion

This project demonstrates the potential for deep reinforcement learning to be applied to low-level robot control tasks. By using deep neural networks to learn nonlinear policies, reinforcement learning has the ability to learn policies that compete with hand-tuned PID and state-space controllers without the need for manual tuning.

Summary Statement

I developed a machine learning algorithm that can learn optimal control policies for low level robot control through deep reinforcement learning.

Help Received

I designed, implemented, and tested the algorithm by myself with help from internet resources. I received help from my advisor on keeping track of changes to my algorithm as I improved it.

CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

Chinmay K. Lalgudi

Project Number

S0819

Project Title

Investigating Methylation to Explain Gene Expression Patterns between Glioblastoma and Alzheimer's Disease

Abstract

Objectives/Goals

Studies show inverse correlation between Alzheimer#s Disease(AD) and Glioblastoma(GBM), both diseases of the brain. AD and GBM are both associated with epigenetic factors. Can epigenetics explain this correlation? Can cancer or AD drugs, that treat via methylation, cause higher risk of the other disease?

Methods/Materials

Laptop, Excel. Inputs: results of past studies done on AD, GBM and Epigenetics. These results were published in journals (Nature, JAMA), or reports from GDAC for GBM. AD inputs are genes, CpGs, DMR (differentially methylated regions) and SNPs (single nucleotide polymorphisms). GBM inputs are genes related to clinical features and CpG methylation. Genes correlated with AD and GBM are tested to see if methylation is significant for AD, GBM or both (p-value < 5E-04)

Results

AD and GBM genes are divided into 4 categories depending on methylation significance (AD and GBM, AD only, GBM only, none). Four genes (MGMT, PPT2, SMC1B, MTCH2) show significant methylation in both GBM and AD with CpG features (island, shore and promoter). These genes are inversely expressed in AD and GBM. MTCH2 has been studied for breast cancer and needs additional study for GBM. The genes SMC1B and PPT2 need further study to identify the role in AD/GBM.

Conclusions/Discussion

4 genes (MGMT, PPT2, SMC1B, MTCH2) have significant methylation and are inversely expressed in AD and GBM. MGMT, which repairs DNA damage, is shown to be correlated with AD in cerebrospinal fluid. Methylation of the promoter region of MGMT has shown direct correlation with GBM. DNA methylation in MGMT
is targeted by GBM drug, TMZ or Temozolomide. Further clinical study is needed to identify AD risk factors in patients treated by TMZ.

Summary Statement

My research shows significant methylation of 4 genes that have inverse correlation in Glioblastoma and Alzheimer's Disease.

Help Received

None. I downloaded data for GBM from GDAC and from research papers for AD. I compared the results with previously published work.

CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

Michelle Li

Project Number

S0820

Project Title

A Machine Learning Approach for the Diagnosis of Parkinson's Disease via Speech Analysis

Abstract

Objectives/Goals

There exist no single, reliable methods of diagnosis for Parkinson's Disease, which motivates a machine learning approach. The purpose of this experiment is to perform a comparative analysis of various classes of machine learning algorithms to identify the best models predicative of Parkinson's. It should be reasonable to create a model achieving at least 90% accuracy and a Matthews Correlation Coefficient (MCC) of at least 0.9, which would provide a significant improvement over current methods of diagnosis.

Methods/Materials

The following equipment were used in this project: a laptop equipped with Python 3.6, a code editor, and the University of Oxford / National Center for Voice and Speech dataset for Parkinson's. My procedure trained and validated each of the following models using 10-fold cross validation: Logistic Regression, Linear Discriminant Analysis, k Nearest Neighbors, Decision Tree, Multilayer Perceptron (MLP) Neural Network, Naive Bayes, and Gradient Boost. For each of these models, I used two versions of the Oxford Dataset: the raw dataset and a scaled version. I analyzed the accuracy and MCC of these models for 3 different train-test splits: 80-20, 75-25, and 70-30. I used Python's Sci-kit Learn package for the algorithms and data processing.

Results

The two best performing models, k Nearest Neighbors and the MLP Neural Network, both produced a validation accuracy, sensitivity, specificity, ROC, and F1-score of 0.98 (98%). KNN produced a MCC of 0.94, and the Neural Network produced a MCC of 0.96 (1.0 being a perfect classifier). These models tended to perform better on the rescaled dataset than on the raw dataset, and achieved the best results with a 75-25 train-test split.

Conclusions/Discussion

Overall, my results show that KNN and MLP NN produce very robust, promising results that far exceeded my engineering goal and most literature on this subject. This suggests that a machine learning model can be implemented to significantly improve diagnosis methods of Parkinson's Disease. Not only is my machine learning method of diagnosis more reliable and robust, it is also more cost-effective (requiring only features of the patient's voice) to implement, meaning it can be utilized in less developed countries. These results are significant because millions of Parkinson's patients would benefit from a more reliable method of diagnosis.

Summary Statement

Using a Neural Network and the k Nearest Neighbors algorithm, I achieve 98% accuracy with a cost-effective method of diagnosing Parkinson's disease.

Help Received

None

CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

Marcus Luebke

Project Number

S0821

Project Title

Running on Water: AI to Design Optimized H2 Production Systems Based on User Priorities of Cost, Efficiency, and Rate

Abstract

Objectives/Goals

This project is a continuation of a three-year effort to generate hydrogen in real time to power automobiles. To do this effectively, a large design trade space needed to be optimized, with the optimum results depending on a competing set of priorities: namely production rate, efficiency & monetary cost of the chemical system.

My objective was to create a computer simulation of my hydrogen production system and develop an artificial intelligence to identify the optimum solution based on input priorities, to complement my experimental research and enable consideration of exotic materials and geometries that would have been too expensive and complex to test in my garage laboratory.

Methods/Materials

For the model, high fidelity conductivity data was required, so I measured conductivity over a series of temperatures and Na2CO3 electrolyte concentrations.

For the code, I created a chemical simulation model (based on known scientific equations, experimental data and mathematical derivations), a utility function (incorporating user input priorities), and an artificial intelligence algorithm (inspired by the biological process of natural selection). The artificial intelligence interacted with the model and utility function, to return optimal designs after tens of thousands of iterations.

Results

The AI returns optimum designs based on the priorities placed on hydrogen production rate, efficiency & cost. As an example, for a weighting and threshold of: Production Rate [45%, 0.007 mol/s], Cost [10%, $100], & Efficiency [45%, 80% efficient] the AI can output a design of 700mm x 460mm x 1mm plates, spaced 0.7mm apart, made of an Aluminum Cathode and Anode, with an electrolyte concentration of 0.6M and a temperature of 82C, at 1.48 Volts.

Conclusions/Discussion

The results returned by the artificial intelligence (AI) lead to new understandings and new directions to pursue in research and demonstrate that AI is a viable technique for scientific work.

The AI enables rapid identification of optimum designs based on user preferences and trade-offs including but not limited to production rate, efficiency, and cost. It allows researchers to consider a wide range of system options, including exotic materials & geometries, and to test designs and ensure feasibility before investing in experimental systems to validate the performance of these system designs.

Summary Statement

A computer model of a complex real-time hydrogen generating system and an artificial intelligence algorithm for optimization were created to find the optimal setup based on relative importance of Production Rate, Efficiency & System Costs.

Help Received

I designed and programmed the code myself. I consulted with the Stanford Graduate Department of Chemical Engineering to validate the science and approach behind my chemical model.

CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

Saurabh Narain

Project Number

S0822

Project Title

A Cloud Based Machine Learning Wearable Device to Monitor, Predict, and Prevent Cardiac Arrest

Abstract

Objectives/Goals

Sudden cardiac arrest (SCA) is a condition in which the heart experiences irregular heartbeats known as arrhythmias. When SCA occurs, it is fatal, killing people within minutes. SCA is the leading cause of death in the US, accounting for more than 360,000 deaths every year. SCA immobilizes the victim, rendering them incapable of asking for assistance. This medical emergency needs immediate CPR followed by the use of an defibrillator, but most of the time, the required help does not arrive quick enough to save the victim. My solution is a wearable device that detects if a person is experiencing SCA and notifies the user's family using communication methods such as a phone call, text, or social media. Once the phone call is received, the family can immediately engage emergency services to save the victim.

Methods/Materials

My wearable device works by using an optical pulse sensor to capture the user's pulse rate. The user's pulse rate is sent to the cloud, where it is processed using a machine learning algorithm to identify whether or not the user is suffering from SCA. If the user is identified as suffering from SCA, my cloud based application will notify the user's family. I have verified authenticity of my pulse sensor data by comparing it with pulse rate data from a blood pressure monitor and oximeter with 95% accuracy. I have tested my device using simulated pulse rates of a victim to make sure that it detects SCA and sends notifications correctly. I used a laptop running the Arduino IDE, a cloud based application called Thingspeak, an OLED display, and an ESP-8266 microcontroller to create my wearable device.

Results

During my project, I discovered differences between the pulse rate of a person undergoing SCA and a person in a normal state. By identifying these differences, I was able to create a machine learning algorithm to identify whether or not a person is suffering from SCA and notify the family if SCA is detected.

Conclusions/Discussion

I am able to make an inexpensive device that can monitor, predict, and prevent SCA for less than $20. In the future, I plan to miniaturize my wearable device and improve the machine learning algorithm to minimize false predictions of SCA. Other devices exist, but they are bulky, invasive, and cannot be used all the time for continuous monitoring. My device addresses all these problems, making it a practical solution to monitor, predict, and prevent SCA.

Summary Statement

I have created an inexpensive cloud based machine learning wearable device to monitor, predict, and prevent sudden cardiac arrest.

Help Received

None. I designed, built, and tested the wearable device myself.

CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

Jennifer R. Pan

Project Number

S0823

Project Title

Quantifying Binding Free Energies in Amyloid Systems Related to Alzheimer's and Enhancing Antibody Binding Affinities

Abstract

Objectives/Goals

Amyloids comprise of the amino acids that, when misfolded, are the primary cause of Alzheimer's; an antibody that binds with high affinity to the amyloid has great potential of being an improved drug candidate. Current calculations of binding energies between amyloids and antibodies remain unrefined; this project proposes a novel thermochemical and computational approach to accurately quantify the binding free energies and uses the developed model to optimize mutations for enhanced drug targeting.

Methods/Materials

I developed a new thermochemical and computational model using implicit solvent models and the Generalized Born equation derived from the linearized Poisson-Boltzmann equation. In this model, the energy difference between the bound and unbound state of solvated molecules were found by conducting binding energy computations in vacuum and solvating each individual step. This model was certified by comparing calculated binding energies with Gardberg's dataset of known energy values. Visualization software and molecular docking were applied to manually program the properties of each amino acid so that Autodock could predict the nature of amyloid interactions once the structure was docked. I created a machine learning algorithm to determine optimal mutations on the antibody as it interacts with the amyloid of given properties, based on the new model and looking for the absolute minimum in the energy graph. The computational results of selected antibodies were compared with nuclear magnetic resonance results from the Protein Data Bank for similarity validation.

Results

The results show high accuracy in numerical and structural comparisons between the simulated and actual antibody-amyloid binding mechanism. Also, >92% of optimized mutations proposed by the algorithm decreased binding energies by thousands of joules/mole (further confirmed experimentally), enhancing antibody binding affinities and specificity.

Conclusions/Discussion

My computational model allows me to calculate the binding Gibbs free energy of amyloid-antibody interactions. Given that binding energies can be computed, I developed an algorithm based on molecular docking and custom-programmed properties of amino acids to optimize antibody mutations. This can improve drug design by revealing the most favorable modifications of antibody receptors while reducing side effects such as mental impairment caused from lack of drug specificity.

Summary Statement

I developed a computational approach using implicit solvent models and the Poisson-Boltzmann equations to calculate binding energies and enhanced drug affinities through a novel machine-learning algorithm based on molecular docking.

Help Received

I would like to thank D'Artagnan Greene from the UCI's Biochemistry/Molecular Biology Lab for his assistance with technical issues I faced while programming. I also used UCI's supercomputers to quickly test my algorithms to expedite the debugging process

CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

Gautam V. Prabhu

Project Number

S0824

Project Title

Kinetic Modeling of Signal Transduction in the Intra-S Phase DNA Damage Checkpoint

Abstract

Objectives/Goals

The objective is to create a kinetic model of the Intra-S Phase DNA Damage Checkpoint, which is important in cancer, in order to better understand its inner workings.

Methods/Materials

Ordinary differential equation (ODE) modeling was used to model the reaction network using mass action chemical kinetics. Rate constants were inferred from models of other checkpoints or derived from experimental data in other publications. Using the model, knockout and sensitivity analysis simulations were executed in MATLAB to learn more about which proteins and reactions are most critical to the system.

Results

The model, validated through comparison to experimental results from other publications, shows that one of two parallel paths in the checkpoint is dominant. Additionally, crosstalk between the two paths is negligible in wild-type cells. Since the model is a valid predictor of experimental results, researchers in the field can use the model to run experiments in code before lab experiments to get a quick estimate of the results.

Conclusions/Discussion

The model's simulations accurately (within around 10%) replicate the results of experiments from the literature. The idea that one parallel path is dominant implies that diseases that damage the dominant path are much more likely to cause complications such as cancer. Since crosstalk negligible in wild-type cells, it is likely heavily favored in non-wild type cells in which one path is knocked out.

Summary Statement

I designed a model using chemical kinetics that helps researchers better understand the intra-S phase DNA damage checkpoint, which is important in cancer.

Help Received

None. I researched, programmed, and analyzed the model myself. My advanced science research teacher provided a space to work, help with scheduling, and general advice.

CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

Evani Radiya-Dixit

Project Number

S0825

Project Title

Identification of Diagnostic Biomarkers and Therapeutic Targets across Adenocarcinomas Using DNA Methylation Analyses

Abstract

Objectives/Goals

Adenocarcinomas are complex tumors that form in mucus-secreting glands. Their formation and progression are associated with DNA methylation alterations. Methylation, the process of adding methyl groups to DNA, plays a vital role in gene expression. The objective of this study is to identify diagnostic biomarkers and therapeutic targets across adenocarcinomas using methylation analyses.

Methods/Materials

I addressed the limitations of cancer methylation studies by studying more gene regions for differential methylation. I also accounted for biases via appropriate preprocessing methods. Further, I analyzed lung, pancreatic, and rectal cancers, the three most common adenocarcinomas accounting for 42% of cancer deaths in the US in 2016 alone, to find similarities. In my research, I analyzed the Illumina HumanMethylation450K datasets. I applied preprocessing methods of probe filtration, intra-sample normalization, and batch effect removal to each dataset. Next, I identified the differentially methylated loci (DMLs) that distinguish between tumor and normal samples. I clustered the tumor samples into methylation-based subgroups and identified the DMLs that distinguish between the clusters. Finally, I conducted gene-set enrichment analysis using the two sets of loci for each adenocarcinoma.

Results

I found 604 DMLs distinguishing between tumor and normal samples across the adenocarcinomas, 64% of which are outside the gene promoter region. I identified four common proteins and pathways involved in adenocarcinoma progression: Polycomb-group proteins, extracellular matrix proteins, G protein-coupled receptor signaling, and epidermal growth factor signaling.

Conclusions/Discussion

With wet laboratory experiments for validation, the common DMLs can be used as blood-based diagnostic biomarkers. Adenocarcinoma therapeutic drugs can be developed to target the common proteins and pathways and help reduce the high risk of recurrence. My pipeline can also be extended to sarcomas, melanomas, and lymphomas.

Summary Statement

I identified diagnostic biomarkers and therapeutic cancer targets for the three deadliest adenocarcinomas, cancers of the lung, pancreas, and rectum, using genome-wide DNA methylation analyses.

Help Received

I received project guidance and research paper feedback from Dr. Andrew Beck at Harvard Medical School, Mr. Benjamin Glass at Harvard Medical School, and Dr. Tim Triche at USC Norris Comprehensive Cancer Center.

CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

Ashmita Rajkumar

Project Number

S0826

Project Title

MedHack: The Impact of Malware Attack upon Biomedical Devices

Abstract

Objectives/Goals

The purpose of this project concerns the security of medical devices and preventing them from various malware attacks. While the field of technology and medicine revolutionizes daily, the amount and different types of threats also evolve.

Methods/Materials

To simulate this condition, a blood pressure monitor was utilized and manipulated to see how malware impacts a blood pressure reading. Different types of manipulations occured on each day of the testing period.

Results

The data was scattered. After simulating the malware, vitals were drastically impacted. The prevention code, however, proved to be accurate 99% of the time.

Conclusions/Discussion

Interferences and uncertainty based off of incorrect blood pressure readings endanger the lives of many as these uncertain readings happen in other types of medical devices as well. In order to maintain a prospective health care system, it is important and necessary that these concerns are taken care of as soon as possible.

Summary Statement

This project examines the impact of malware attacks on data produced by a blood pressure monitor and how to prevent such attacks.

Help Received

Dr. Rajkumar Thirumalainambi, Dr. Ahalya Joisha

CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

Pravin Ravishanker

Project Number

S0827

Project Title

ALZCan: Machine Learning Based Multimodal Neuroimaging Genetics Framework to Predict Future Onset of Alzheimer's Disease

Abstract

Objectives/Goals

To create an accurate diagnostic and prognostic machine learning based methodology for Alzheimer's early detection by using polygenic risk scores constructed from single nucleotide polymorphism (SNP) genotype data; cerebrospinal fluid (CSF) levels; cognitive tests; demographic info; 3 neuroimaging modalities (678 Resting State Functional MRI (rs-fMRI), 427 Fluorodeoxyglucose PET (FDG-PET), 407 Florbetapir PET brain scans).

Methods/Materials

Using R programming language and data from Alzheimer's Disease Neuroimaging Initiative (ADNI), I considered 23 neuroimaging and CSF phenotypes linked to AD pathology: 3 CSF protein levels; FDG-PET cerebral metabolic activity in 5 brain regions; Florbetapir-PET beta-amyloid plaque levels in 7 regions; and 8 rs-fMRI functional network connectivity (FNC) measures (3 ROI-to-Voxel Ratio + 5 Graph-theory based). Graph-theoretic FNC metrics were extracted from each rs-fMRI scan using ICA, signal Cross-Correlation, and graph-rendering algorithms.

Using GLMs, Genome-Wide Association Analyses evaluated 14 million+ interactions between 608,586 SNP genetic variants (393 participant genotypes) and the aforesaid 23 AD phenotypes. 23 polygenic risk scores per subject were computed by combining weighted additive effect of each subject's multiple SNP variants, with association results determining each SNP's weight in risk scores.

Results

Based on a subject's 23 polygenic risk scores, demographic info, and cognitive scores; gradient boosting machine learning could differentiate between Healthy Control, Mild Cognitive Impairment (MCI), Alzheimer's (AD) with diagnostic accuracy of 98.10%; and predict onset of AD and MCI 6, 12, 24, 36 months into future with prognostic accuracies of 91.89%, 91.72%, 85.38%, 70.67% respectively. Polygenic risk scores constructed from top genetic variants affecting 1) Posterior Cingulate/Left Angular Gyrus metabolic activity; 2) Precuneus beta-amyloid plaque levels; 3) rs-fMRI FNC as measured through Default Mode Network ROI-to-Voxel ratio and Transitivity; 4) CSF phosphorylated tau levels were most capable of predicting MCI and AD status in the future.

Conclusions/Discussion

With power of polygenic risk scores for risk prediction/intervention/personalized medicine and machine learning's promise to discover relationships amongst massive genomic/neuroimaging datasets, we can precisely pinpoint Alzheimer's future onset and prevent irreversible brain damage.

Summary Statement

I created a novel machine learning framework for Alzheimer's and Mild Cognitive Impairment's early diagnosis and prognosis, fusing signal processing, graph theory, neuroimaging, genome-wide association analyses, and polygenic risk scoring.

Help Received

I thank the Alzheimer's Disease Neuroimaging Initiative (international effort tracking AD biomarkers) and its investigators for the vital data repository. I am grateful to all who have supported me throughout my 4-year progressive computational neuroscience research on Alzheimer's prediction.

CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

Vinay Senthil

Project Number

S0828

Project Title

A Three Dimensional Modeling and Real Time Data Analysis Algorithm for Bronchoscopy Enhancement

Abstract

Objectives/Goals

The objective of the project is to create a 3D computer model of the lung using simply the video feed from the tip of a bronchoscopy tool with minimal hardware modifications.

Methods/Materials

Laptop with MATLAB R2016b. A yoga mat was rolled to form a dark tunnel that provided me with a simulated bronchial tube. Then, I attached a webcam and flashlight to one end of a long stick using the masking tape to act as the bronchoscopy tool. I connected the webcam to my laptop's USB port and used the image processing toolbox to process snapshots from the real time video feed and curve fitting toolbox for creating the splines for the model.

Results

As the stick was pushed into the yoga mat tube, a 3D model is created by adding the ellipses the algorithm had calculated every second. The resulting model is hollow and also shows texture similar to the inside of the lungs. After each iteration, a new layer that is generated is added to the existing model in order to save time and memory rather than creating a whole new model from scratch. The tool is also able to pick up bends in the tube, indicating that lateral motion can be considered as the bronchoscope moves through the lung.

Conclusions/Discussion

It is possible to create a 3D model of the lungs without exposing the patient and doctor to harmful radiation. Moreover, one does not need to follow the traditional methods of 3D reconstruction. It is possible to use only a video feed without a depth sensor to create a streamlined process that produces a 3D model in real time. Through this project, I have accomplished 3 goals: Image Conversion to 3D Model, Real Time Image Processing, and the generated 3D model shows what is ahead.

This algorithm can be used by doctors as a tool to prevent repetitive bronchoscopies as well as for the future of robotic endoscopic surgeries in which computer vision software will be paramount.

Summary Statement

I created an algorithm to process and analyze the video feed from the bronchoscopy tool to create a real time 3D model of the lung's airways without the need for radiation.

Help Received

None. I designed, coded, and implemented the algorithm and analyzed data myself.

CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

Jayasuriya Senthilvelan; Jacob Yee

Project Number

S0829

Project Title

Detection of Forest Fires Using Autonomous Drones

Abstract

Objectives/Goals

The goal of this project is to prevent the spread of forest fires by detecting them as early as possible. In order to accomplish this, our project uses autonomous drones to monitor a forest along a planned route, detecting temperature spikes and reporting their locations if these spikes match the experimentally determined patterns of fires. This data will be sent to a ground station through radio signals for evaluation.

Methods/Materials

The main materials used in this experiment are the Raspberry Pi 3 Model B, carbon fiber frame, motors, electronic speed controllers, temperature sensor, accelerometer/gyroscope/barometer/magnetometer sensor, lithium polymer battery, Rpi900, and DNT900 (for radio communication).

Methods:

1. Assemble drone body and wire all devices
2. Access all sensors and motors in code through their various communication protocols
3. Use sensor data to control stable flight
4. Use GPS to fly along a predetermined path
5. Test drone's capacity to detect fire in a closed environment

Results

According to data that was collected, temperature values collected from the thermal sensor's field of view (view temperature) were better for recognizing the flame than ambient temperature (which is a reading of the temperature of an object that directly touches the sensor) values. This can be seen as the prominent peaks in all three graphs were from view temperature data. However, the ambient temperature value stayed relatively constant. In addition, as the height of the drone decreased, more and more closer toward the candle flame, the peak of the view temperature increased significantly, from 26.3 to 28.68 degrees Celsius when moved from 2.0 feet to 0.5 feet, respectively (approximately 9% increase). Eventually, the view temperature rose above the ambient temperature in 0.5 ft. graph.

Conclusions/Discussion

Due to peaks in temperature compared with surrounding temperatures in the graphs, the presence of a flame can be detected. In order to implement this in an efficient fire detecting algorithm, collected temperatures must be compared with a baseline temperature. Deviations from this baseline and the intensity of these deviations would then indicate the presence of a fire as well as its intensity.

Summary Statement

An autonomous drone was created that uses various sensors to control its flight and detect forest fires.

Help Received

CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

Kaushik Shivakumar

Project Number

S0830

Project Title

A Machine-Learning Approach to Correlate Environmental and Demographic Factors to Cancer Incidences across US Counties

Abstract

Objectives/Goals

About 80% of all cancer incidences are sporadic and largely caused by environmental factors. This implies that cancer incidence varies widely based on geography, and my preliminary findings for lung cancer confirm this by showing elevated levels in the eastern U.S. Thus, it is hypothesized that cancer incidence for a county is linearly correlated with factors relating to the local demography and environment. This study focuses on identifying these underlying causes of the majority of cancer incidences.

Methods/Materials

Two types of data are used to analyze the cancer (lung, colorectal, pancreatic, and overall) incidences: 69 demographic factors and, based on EPA toxic emissions data, 274 chemicals.

For demographic data, the features with absolute value of Pearson correlation coefficient>0.3 are selected and normalized. The linear regression model is built and features with $p<0.05$ are chosen as statistically significant. The coefficients are compared to see which factors have the greatest impact on cancer incidence.

Chemical data, however, is sparse, making it difficult to perform linear regression on. For each chemical, counties are marked as having levels signifying contamination (>3 times average) or not. Then the compound is checked for whether it shows a statistically significant increase in cancer incidences when present in increased levels.

Results

The number of demographic factors (eg: ethnicity, diabetes) that are statistically significant range from 9 to 15, depending on the cancer type. Also, predicting using the machine learning model trained on 3/4th of the data yields accurate predictions of cancer rates for the remaining counties (~10% error), confirming that the factors in the model strongly relate to incidences.

The number of chemicals that are statistically significant, showing increased cancer rates when present in elevated levels (eg: Methyl Isocyanate; 2,4-Dinitrotoluene), range from 5 (pancreatic) to 18 (all cancer).

Conclusions/Discussion

Looking at data by county offers a means for identifying sources for increased cancer incidence rates and can also be applied to other diseases. This type of analysis enables each county to identify and fix its specific problems, for instance, by improving living conditions or regulating emissions of certain chemicals. Overall, analyzing data available by county is very powerful and can lead to a major step forward in preventative medicine.

Summary Statement

This project focuses on using machine-learning and statistical methods to identify environmental and demographic factors that are responsible for the majority of cancer incidences.

Help Received

Dr. Anu Aiyer and Dr. Srikant Ramakrishnan advised me on the statistical analysis and machine learning techniques. My father guided me on the use of SQL for data cleaning and Ms. Anu Datar was the mentor for the project.

CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

Kimberly A. Stahovich

Project Number

S0831

Project Title

Using Machine Learning to Predict Postprandial Blood Glucose in Type 1 Diabetics

Abstract

Objectives/Goals

People with Type 1 Diabetes (T1D) must compute an insulin bolus dose for every meal to cover the carbohydrates and return the blood glucose (BG) level to euglycemia (normal level). The goal of this project is to create an algorithm to accurately predict BG levels two hours after a meal, which will enable people with T1D to compute insulin doses more accurately. Typically, bolus doses are computed using a carb to insulin ratio (i.e., "carb counting") and the current BG level. This approach is inaccurate because it ignores many factors such as prior BG dysregulation, exercise, food composition, stress, hormones, and sleep. This project will examine several of these factors.

Methods/Materials

The following data was collected over a 30 day period: insulin infusion data from a Tandem t:slim pump, BG data from a Dexcom G5 continuous glucose monitor, heartrate data from an Apple Watch, and nutritional information from the MyFitnessPal app. Data was extracted from these sources and used to create variables to predict BG levels. The Weka machine learning toolkit was used to train models using these variables and to determine which of the variables have the most effect on blood glucose.

Results

Variables were created to characterize BG dysregulation, heartrate (exercise), and meal composition. These variables were used to train a machine learning algorithm to predict 2-hr postprandial BG levels. This approach is much more accurate than the standard method, carb counting, at predicting 2-hr postprandial BG levels. Carb counting achieved a correlation of $R = 0.35$, while the new approach achieved $R = 0.74$.

Conclusions/Discussion

I was able to build a model that accurately predicts 2-hr postprandial BG levels. This model will enable patients to optimize bolus doses to achieve their target postprandial BG level. The project has resulted in several findings. First, machine learning can be used to improve insulin dosing. Second, the project demonstrated that heartrate, prior BG levels, and food composition are all important for computing accurate insulin bolus doses. Third, measuring BG levels 1-hr postprandial can enable more accurate glycemic control. This work is a step toward creating a completely closed-loop insulin delivery system. However, more immediately, the project has resulted in a method (1-hr postprandial BG measurement) that can enable people with T1D to more accurately control their BG levels.

Summary Statement

Using machine learning techniques with data about heartrate (exercise), blood glucose dysregulation, and meal composition enables accurate prediction of two-hour postprandial blood glucose levels in Type 1 Diabetics.

Help Received

I came up with this project topic on my own. I also collected the data and constructed the machine learning models by myself. My father helped me in extracting raw data from the various devices and converting it to a useable format. He also assisted me by critiquing my writing and poster.

CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

Nikhil Sundrani; Sameer Sundrani

Project Number

S0832

Project Title

SmartRate: An Innovation in Early Detection, Warning, and Prevention of Cardiac Death

Abstract

Objectives/Goals

Within the United States alone, 326,000 people die each year due to cardiac arrest caused by underlying cardiac arrhythmias. Most or all these deaths would have been prevented if the Emergency Medical Services (EMS) had reached them within the necessary period of time, or they had prior knowledge of their fatal arrhythmia. We sought to solve both of these problems by creating a wearable heart rate analysis wristband that can automatically trigger notifications and warning upon a cardiac event, analyze user data for specific arrhythmias, minimize human error, and contact EMS faster (regardless of the user#s consciousness), saving the life of the user.

Methods/Materials

To make our prevention apparatus, we used an Atmel microcontroller coded using the C/C++ compiler in Arduino. The board was Adafruit based with Bluetooth configuration. The iOS application was made through Xcode using the Swift language. For heart rate, we used photoplethysmography, converting light reflection into signal values. After making the prototype, we tested various subjects ranging from 15-50 years old and both genders in comparison to modern wristbands, then chest electrodes, and finally to an electrocardiogram.

Results

Our device triggers a warning 100% of the time on all ages and genders with no false positives, due to mitigation procedures taken in algorithmic design. The device also had high correlation to hospital-level machines.

Conclusions/Discussion

Our device works efficiently and at a low cost to be able to save someone#s life, even without prior knowledge of the user#s cardiac health. We plan to manufacture the wristband in the future as well as add additional vital measurements through light reflection technology, such as blood pressure and oxygen saturation, both of which currently do not exist for portable technology. In addition, we plan on implementing this technology into hospitals, drastically reducing the size of the current monitors while retaining accuracy.

Summary Statement

We invented an innovative utilization for wrist-based heart rate analysis by developing our own wristband and iOS application using a novel notification algorithm, saving the life of the user by preempting cardiac arrest.

Help Received

No professional help was received. However, we received some guidance regarding fixing issues within our coding and algorithm order.

CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

Robert G. Tacescu

Project Number

S0833

Project Title

Safecopter: Developing a Collision Avoidance System Based on an Array of Time-of-Flight 3D Cameras

Abstract

Objectives/Goals

Multicopters have a wide range of applications from surveillance to package delivery and medical support. Although growing in popularity, they are not used yet on an industrial scale for safety reasons. The goal of Safecopter is to develop a modular collision detection and avoidance system that would make flying a multicopter in autonomous or tele operated mode completely safe. Integrating an array of time of flight 3D cameras, the algorithm uses coordinate transformations to convert point clouds provided by each camera into one main one, creating a 360° snapshot of the environment within a six meter radius. The challenge is to develop an algorithm fast enough to provide collision avoidance decisions in real time.

Methods/Materials

To be able to process the point cloud produced by the 3D cameras, I use a compact onboard computer running the Ubuntu Linux operating system. The software system is programmed in C++ using ROS (Robot Operating System) as a development platform. My project uses the Gazebo 3D physics simulator to test in various situations.

Results

Based on the research of multiple collision detection algorithms, the octree spatial partitioning system proved to be the most efficient. In comparison to the point cloud based algorithm, it was more than 320 times faster. Developed in C++, it was able to achieve this level of performance by organizing the data into tree like hierarchies and performing binary operations. A key element of developing an advanced collision avoidance algorithm is the ability to simulate complex indoor and outdoor environments. Safecopter was modeled in 3D and, using the Gazebo physics simulator, I was able to test different scenarios, without running the risk of causing an expensive crash.

Conclusions/Discussion

Based on the testing performed, the system can reliably detect and avoid collisions in real time and route the multicopter to a collision free path in order to reach a specific motion goal.

Summary Statement

The goal of my project is to create a multicopter that doesn't collide with nearby objects. It is based on a modular collision avoidance system which includes an array of 3D cameras to detect and avoid objects in the way.

Help Received

None. I designed, built, and programmed the system myself.

CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)
Christopher L. Tan

Project Number
S0834

Project Title
Using Machine Learning to Predict the Flu

Abstract

Objectives/Goals
Use machine learning to prevent illness and prevent epidemics by predicting strains of H1N1 and H3N2 influenza viruses.

Methods/Materials
Accessed online databases to get large quantities of amino acid sequences for hemagglutinin and neuraminidase proteins, researched characteristics of the influenza virus as well as the surface glycoproteins, and used that information to create predictive algorithms in Python to produce possible epidemic-inducing strains of the influenza virus.

Results
Created machine learning algorithms to predict possibly infectious strains of influenza virus. There was little difference between the additive and the multiplicative algorithms, which both conserved parts of amino acid sequences while allowing enough variability for the antigens (the surface glycoproteins) to be effective. By testing similarity to common strains from previous years, I determined the efficacy of each algorithm.

Conclusions/Discussion
Although I was not able to test the strains my machine predicted in reality, the results suggested that the strains my computer produced using the machine learning algorithms could be viable and possibly predictive, since they were able to conserve parts of the amino acid sequences while changing enough to alter the antigens, preventing the immune system from recognizing them and thus allowing them to infect us. This project demonstrates the possible applications of bioinformatics to prevent illness, and specifically, how machine learning can be applied to diseases that change rapidly, such as viruses, to help predict their mutations.

Summary Statement
I created machine learning algorithms to predict amino acid sequences of surface proteins for H1N1 and H3N2 influenza viruses.

Help Received
Mr. O'Shea and Mr. Heyward suggested viable ways to expand original project. I conducted research and created machine learning algorithms on my own.

CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

Ethan M. Uetrecht

Project Number

S0835

Project Title

Reducing Reliance on the DSN: Autonomous Satellite Location Determination

Abstract

Objectives/Goals

Space vehicles that venture beyond an Earth orbit rely on the Deep Space Network (DSN) for determining their trajectory. As concurrent missions increase, DSN may become overbooked, resulting in a reduction in trajectory update frequency, vital communications, or both. The purpose of this project is to study methods to reduce reliance on the DSN by providing autonomous satellite location determination.

Methods/Materials

A simulation of the solar system, including the eight planets, three large asteroids, and a satellite, was created using MATLAB software. The satellite was modeled to periodically image solar system objects with respect to local star backgrounds and solve for its position using these references. The position was then refined using an Earth beacon ranging function. Multiple simulations were run with varying parameters to assess the performance of the method, which was compared to those of the DSN and AutoNav systems.

Results

This autonomous method resulted in performance for inner solar system missions somewhere between those provided by DSN and AutoNav. The beacon significantly improved radial accuracy and improved overall performance by approximately 20%. Real-time updating of satellite position and velocity instead of batch processing provided continuously accurate trajectory data. Reliance on only the brightest celestial objects reduced requirements for camera sensitivity and therefore complexity and cost.

Conclusions/Discussion

The results of this project show that DSN support for most inner solar system missions can be minimized through key improvements to the AutoNav system. This method is primarily successful in the inner solar system but remains viable for certain outer solar system missions.

Summary Statement

The purpose of this project is to study methods to reduce reliance on the Deep Space Network by providing autonomous satellite location determination.

Help Received

I did the research and coding myself with the exception of the functions required to graphically visualize the results, which were written by my mentor, Mr. David Uetrecht, Technical Fellow at Boeing. My mentor also answered my questions and helped me with Matlab syntax as needed.