Research Project Title: Effects of hacking an unmanned aerial vehicle connected to the cloud

Student Presenter: Meghan Booker

Faculty Mentor: Abhishek Gupta

Faculty Mentor Department: Electrical and Computer Engineering

Research Abstract: Control systems with commercial and even military applications are utilizing more networked technologies to perform tasks associated with navigation and communication. Increasingly, these systems are experiencing cyber-attacks due to the interconnections with the internet and interoperability protocols. Current research focuses on improving performance of a control system or improving cryptography methods separately; however, there is a need to understand the joint design of control and cyber-security methods in order to combat the growing cyber-attacks on these systems. Here, we seek to begin bridging this gap by determining how commonly employed cyber-attacks impact the performance criteria of control systems so that future research can aim for strong joint design.

For this work, the control system of choice is the Parrot AR.Drone 2.0, which is a quadrotor unmanned aerial vehicle (UAV). The UAV sends various navigation-related sensor data such as sonar and camera data to the cloud to determine a control command to be executed by the UAV. There, we simulate an attacker and leverage ARP spoofing to create a Man in the Middle (MitM) attack. This allows the attacker to read the data streaming in and out of the cloud and manipulate it. To understand the effects of this attacker, we ran simulation and experimental tests using ROS and Gazebo. These tests manipulated sonar height data and velocities sent back to the UAV, which was tasked with locating and landing on a target tag autonomously. Performance metrics such as linear velocities, location, delays, and end state are analyzed for the tests and compared to a UAV not under attack. The analysis of the results highlights the weaknesses in this networked setup along with degree of damage and disruption this type of cyber-attack can impose on a UAV.
Research Project Title: Mapping fentanyl overdose fatalities in Franklin County, Ohio from 01/01/2016-06/30/2017

Student Presenter: Cristin Day

Faculty Mentor: Julie Field

Faculty Mentor Department: Anthropology

Research Abstract: Synthetic opioids such as fentanyl have significantly increased overdose deaths on a national, state and local scale in recent years. This research project examines the disturbing impact and escalation of synthetic opioid overdoses in Central Ohio. In an effort to spatially and temporally contextualize the US opioid epidemic on a local scale, overdose deaths in Franklin County from 01/01/2016 to 06/30/2017 were spatially mapped using the geographic information systems software ArcGIS. Synthetic opioid deaths increased 579% from the first half of 2016 compared to the first half of 2017 in Franklin County, with south, southeastern and eastern zip codes most heavily affected. By visualizing the synthetic opioid crisis in Columbus, this project hopes to facilitate positive community dialogue to prevent future deaths and reduce stigmatization of people struggling with addiction in our community.
Research Project Title: Video frame interpolation

Student Presenter: Chuhan Feng

Faculty Mentor: James Davis

Faculty Mentor Department: CSE

Research Abstract: For my thesis project, I intend to work on a challenging computer vision problem, video frame interpolation, with a goal of achieving state-of-the-art performance on this task. Video frame interpolation is a classic computer vision problem that aims at increasing the number of frames per second of a video sequence to obtain a smoother higher-framerate video. The interpolation is done by inferring the middle states between each pair of successive video frames.

My research will be built on the top of previous works that are approached with the Convolutional Neural Networks (CNN) and the Adaptive Convolution (AC) technique. The research will be conducted from the perspective of improving the interpolation result by using wider input window. This is inspired by the success of the Long Short-Term Memory (LSTM) networks in the field of sequential data prediction. By taking advantage of the temporal pattern recognition power of the LSTM model, the quality of the interpolation results under large object displacement and complex motion pattern are expected to be improved comparing to the existing models.

This research project is still under its middle stage. There are still some works left to be done before getting expected results. The initial results are expected to come out later this semester.
Research Project Title: Investigation of reciprocity in the millimeter wave channel

Student Presenter: Ahmed Almostafa Gashgash

Faculty Mentor: Can Emre Koksal

Faculty Mentor Department: ECE

Research Abstract: The millimeter wave (mmWave) band of frequencies between 30 and 300 GHz is expected to host the next generation of wireless cellular networks. As the demand for mobile data and cellular capacity increases, current cellular systems, based on microwave frequencies, are running out of available spectrum. It is expected that by the year 2020, some operators would face demand of about 130 x 1018 bits of data per year. A task that is unrealistic for today’s cellular technology. However, bandwidth availability is much wider in the mmWave bands, and the available spectrum can be 200 times larger than all cellular allocations today. For this reason, researchers and engineers have started to believe that mmWave will play a significant role in 5G cellular systems. Despite the potential of mmWave systems, there are a number of key challenges to be overcome. The main challenges of our concern in this project, are due to the characteristics of the mmWave channel. Since these waves operate at a high frequency, their wavelengths are of shorter length, making it susceptible to attenuation, severe shadowing, rapid channel fluctuations, and intermittent connectivity. Based on these aspects, we assume and set to prove that the mmWave channel is non-reciprocal. We model the mmWave channel, test for reciprocity and analyze the collected data.
Research Project Title: Developing a mathematical model for the opioid epidemic in Columbus, Ohio

Student Presenter: Ashley Dundon

Faculty Mentor: Ayaz Hyder

Faculty Mentor Department: Environmental Health Sciences

Research Abstract: The opioid epidemic is pervasive across the United States and, in particular, the state of Ohio. Though the state of Ohio has put forth recovery programs, overdoses continue to occur and increase. In order to combat this epidemic, it is important to understand the dynamics between overdose and recovery efforts put forth by the government and community. A mathematical model was developed to simulate these dynamics using data acquired from City of Columbus Public Health. Using this model, parameters affecting the numbers of susceptible, overdosing, and recovering individuals in Columbus were determined. It is hypothesized that by adjusting these parameters, the epidemic could be shortened and the severity could be lessened. This model could also give emergency personnel information about when overdoses are most likely to occur and how many people are likely to overdose. Because the opioid epidemic is ubiquitous throughout all levels of society and is a widespread issue, adequate resources are not always available. This model could provide information that would allow for a more strategic and effective allocation of resources across communities. Though the opioid epidemic is a continuing problem, steps can be taken to reduce its impact. By identifying and understanding factors that influence the dynamics between overdose and recovery, more effective actions can be taken to mitigate the effects of the epidemic on the community.
Research Project Title: Lithium ion battery data management and analysis

Student Presenter: Frank Ferrato

Faculty Mentor: Jung-Hyun Kim

Faculty Mentor Department: Mechanical Engineering

Research Abstract: There has been growing research and development (R&D) efforts on electrochemical energy storage/conversion devices that are crucial power sources for everyday electronics and transportation (e.g., electric vehicles). To support this energy-related R&D, researchers heavily rely on electrochemical testing cyclers that is capable of measuring electrochemical performances of multiple cells simultaneously following automated schedules. The electrochemical testing cycler produces raw data from the cells, and individual researchers often reduce, process, and analyze the raw data in many different manners to satisfy their specific interests. Although commercial software is provided together with the cycler for the data analysis purpose, it is usually not customizable and has lack of optimization for processing the raw data. Each raw data consists of tens of thousands data points collected over several months, and one research group handles numerous cell data (few hundreds or thousands) simultaneously. Thus, these raw data is considered as Big Data and requires significant efforts to process and analyzing it. In this regard, my research objective is designing and programming the customized software that can significantly improve the efficiency and quality of such electrochemical data analysis. We have purchased the electrochemical testing cycler from Arbin System, which produces data in SQL databases and should allow for faster data processing. An understanding of this data format will allow for ease of access in MATLAB by creating a connection between the database and the MATLAB Graphic User Interface. Therefore, based on understanding the SQL data format, I will create an open-source program that is user friendly and capable of analyzing the data in many different ways to support diverse R&D applications. The beta version of software will be tested throughout the real electrochemical data collected in our Lab, in order to optimize and debug the software. This program should also be customizable for different types of R&D. I will discuss about the testing results and analytical capability of the software through the presentation. In addition, the outcome of this project will be an opensource program available online and shared to many universities at different countries.
Research Project Title: Developing a test bench for NASA's next generation bistatic reflectometry receiver instrument

Student Presenter: Ryan Linnabary

Faculty Mentor: Andrew O'Brien

Faculty Mentor Department: Electrical and Computer Engineering

Research Abstract: Since the early 2000's, scientists have exploited navigational (GNSS) satellite signals for geophysical remote sensing using "reflectometry". An airborne or spaceborne reflectometry receiver observes direct and reflected GNSS satellite signals, enabling scientists to infer properties of Earth's scattering surface at the reflection point. NASA launched a constellation of eight micro-satellites (called CYGNSS) for this purpose in December of 2016. CYGNSS tracks GPS signals to measure ocean wind-speeds for hurricane forecasting. GPS signals have unique features which allow CYGNSS to out-perform traditional remote-sensing techniques in speed, cost, and spatial coverage. Researchers at Ohio State were involved in the Science Team and testing of first generation CYGNSS receivers and the success of the project so far has motivated a potential follow-on mission, as researchers are identifying opportunities for improvement. An improved receiver should be capable of tracking more than the GPS L1 C/A-coded signal to increase the number of visible reflections. The current test-bench could not simulate other GNSS bands, could not generate long-duration signals, and did not incorporate GNSS meta-data or navigational messages. The purpose of this project is to improve the quality of the test bench hardware and software used to test GNSS-R instruments and add support for the new instrument's enhanced features. In this work we have modified the program for parallel assembly of output files, support for the L1, L5, E1bc, and E5a bands, and incorporation of actual satellite meta-data including navigational messages and realistic timing information. An interface to the software-defined radios was written to facilitate playback. The test signals have been analyzed in MATLAB and each was successfully output from a software-defined radio. As of January, 2018, the following tasks remain incomplete: an upgrade of storage media is needed for a full 24-hour playback; full analysis of space-vehicle dynamics is required; and design and completion of the test procedure will conclude project requirements. This system should enable the development team to characterize through tests how well the improved instrument will process such signals in space. It may allow NASA to address any problems with the new receiver instrument before their future space deployment.
Research Project Title: Canonical height on elliptic curves

Student Presenter: Adrian Neff

Faculty Mentor: Ghaith Hiary

Faculty Mentor Department: Mathematics

Research Abstract: In 1978, Serge Lang conjectured a lower bound for the canonical height of points on elliptic curves defined over the field of rational numbers. He conjectured this bound in terms of the logarithm of the discriminant of the curve. Since then, there has been much work on proving a lower bound for the canonical height, and this conjecture has been generalized to number fields, instead of just the rational numbers. In this project, we computationally test a modern form of Lang’s conjecture on a certain family of curves over the rational numbers with a shared rational point. In our verification, a trend arose in the growth of the height of the rational point in question, which has led to a conjectured formula for the height of this point. This formula depends on the coefficients of the curve and the value of the coefficients modulo 4. A similar trend arose in the growth of the height of a shared point on other families of curves, and how the height of the point grows seems to be related to the prime factorization of a coefficient of the curve. This points to the possibility of a conjectural formula for the height of the shared point on each of these families of curves.
Research Project Title: How practical is the Pollard-Strassen Method?

Student Presenter: Xinyi Zeng

Faculty Mentor: Ghaith Hiary

Faculty Mentor Department: Dept. of Mathematics

Research Abstract: The Pollard-Strassen Method is an integer factorization algorithm. It is a deterministic and proven method that terminates in about $O(n^{1/4}(\ln\ln n)^2)$ steps, where $n$ is the integer being factored. This method requires high-precision fast Fourier transform for integer multiplication. However, its critics argue that it is less efficient in practice and requires large memory space compared to other integer factorization algorithms. We implemented the Pollard-Strassen Method using C++ programming and GNU MP Library, and tested its running time. It turns out to be the most efficient algorithm among all deterministic algorithms for integer factorization, and took less than 2 hours to factorize a 40-digit number but trial division may take several months.
Research Project Title: Monte Carlo tree search evaluation in imperfect information environments through euchre

Student Presenter: Matias Grioni

Faculty Mentor: Marie-Catherine de Marneffe

Faculty Mentor Department: Linguistics

Research Abstract: Artificial intelligence agents for games such as chess and go have seen tremendous success in the past few years using an algorithm called Monte Carlo tree search (MCTS). MCTS's success in various applications has been seen as a step toward a general form of artificial intelligence; however, a substantial amount of the work for MCTS has been done in perfect information games, where there is no hidden information. In chess, for example, the positions of all pieces are known by both players. Nonetheless, a general form of artificial intelligence must perform well in both perfect and imperfect information domains. This project seeks to evaluate MCTS's performance in an imperfect information environment, the card game Euchre. Euchre is a valuable environment to test MCTS due to its various sources of uncertainty. There is uncertainty in the cards an opponent has and in how one's own partner will play. Success in Euchre would support MCTS's ability to generalize to imperfect knowledge environments, and support its promise as a step toward general artificial intelligence. This research creates a MCTS library modified to support imperfect information environments, and evaluates MCTS's performance against a rule based algorithm and a baseline that randomly selects a valid action from those available. Results show that the modified MCTS algorithm outperforms the rule based algorithm and random baseline, achieving an optimal outcome nearly 10% more often than the rule based approach. The MCTS algorithm was only given the rules of Euchre and no Euchre based heuristics or optimization to guide its search. This supports the fact that even a basic, unoptimized MCTS algorithm is generalizable to both perfect and imperfect information domains.
Research Project Title: Smartphone-based intelligent system: Using AI and motion sensors for real-time intervention during heavy alcohol consumption events

Student Presenter: Jackson Killian

Faculty Mentor: Passino Kevin

Faculty Mentor Department: ECE

Research Abstract: Introduction

Excessive alcohol consumption is an avoidable health risk, yet it causes a significant percentage of yearly deaths and injuries on college campuses. Recent work showed that weekly mobile-based interventions can effectively reduce alcohol consumption in students. However, few studies investigate delivering mobile interventions in real-time during drinking events where interventions could reduce risks like drunk driving, alcohol poisoning, and violence. Such studies require measuring real-time intoxication levels outside of a lab setting at scale. Some technologies exist for this purpose but are impractical or expensive. To address these shortcomings, I built an intelligent system to passively track smartphone accelerometer data to identify heavy drinking events in real time on a mobile device.

Methods

I collected smartphone accelerometer readings and transdermal alcohol content (TAC) readings from 19 subjects participating in an alcohol consumption field study. The TAC readings served as the ground-truth when training the system to make classifications. The TAC sensors and smartphone accelerometers both provided noisy readings which I cleaned with the MATLAB signal processing toolbox. I then mined walking events from the cleaned accelerometer readings by identifying windows of data with frequencies near 2Hz (average human walking frequency). Next, I developed an algorithm to extract from these windows features known to change when humans lose control of their center-of-mass (i.e. become intoxicated). Finally, I built and trained an MLP network to classify each window as a sober walk or intoxicated walk.

Results

The system currently identifies a subject’s sobriety with 65% accuracy. Promisingly, the result suggests that one aspect of motion data alone (center-of-mass) has significant classification power. I will now improve the system by including techniques from advanced studies analyzing the human gait as well as upgrading the windowing method to account for additional smartphone placements (jacket, purse, etc.).

Conclusions

By introducing a free, reliable, and widely adoptable application that tracks intoxication in real-time, I will enable development of effective real-time mobile-based interventions which can later be delivered via the application to reduce unnecessary alcohol-related injury and death. The results and application will also benefit future studies as new sensor-bearing technologies become widely adopted.
Research Project Title: Chorus: coordinating data across multi-device data visualizations

Student Presenter: Stephen Wu

Faculty Mentor: Arnab Nandi

Faculty Mentor Department: Computer Science Engineering

Research Abstract: Recent proliferation of touch devices and external displays has promoted new methods for exploring and displaying data. Despite this, few open-source generic solutions exist to promote real-time collaboration of this data in a browser environment. Chorus presents a novel method of using web sockets to create chatrooms for data, coordinating data through sockets across multiple devices, indifferent to the type of device utilized. Each device, monitor, or projector serves as a node in this network of chatrooms. Each chatroom allows each node to interact with the Main display, which is dispersed to each node upon a Push. Creating a shared source of Main data, Chorus also allows each user to disconnect and enter an Auxiliary display, disconnecting from the Main server and pushing their updates when desired. Typical multi-device data software uses expensive and specialized queries to a database from each individual client; Chorus improves upon that by re-using shared data and allowing for shared rooms, coordinating individual actions and changes through the network. The use-cases for Chorus include classrooms, workplaces, and essentially anywhere that two devices may desire to have shared data sources and actions. Chorus was demonstrated with the JavaScript libraries D3, Crossfilter, Leaflet, React, and MIDI, demonstrating a wide array of use-cases for real-time data coordination, including data visualization of spatiotemporal fleet data, collaborative musical keyboard notes, and a typical flight data dashboard.
Research Project Title: Invariants for tricolorable knots & links

Student Presenter: Will Hoffer

Faculty Mentor: Chmutov

Research Abstract: The foundational problem in knot theory here investigated is generating knot and link invariants which identify diagrams that differ by finite sequences of Reidemeister moves. This work establishes a new class of invariants concerning tricolorable knots and links, both classical and virtual.

A knot or link diagram admits a nontrivial tricoloring when exactly three colors are utilized in the tricoloring and every crossing contains either three colors or one color. (Trivial tricolorings would only yield an invariant that behaves the same as the Jones polynomial.) To construct this invariant for a specific diagram, the colors are designated a number (0, 1, or 2), and the diagram is given an orientation. Crossings are designated into six classifications based on the arrangement of colors and orientation. The crossing may be positive or negative in the usual sense, and then there are three possible color configurations concerning the understrand counterclockwise from the outward portion of the overstrand.

Next, a system of Skein relations defines how a crossing of the diagram is split, with coefficients dependent on the crossing types. Similar to the Kaufman bracket, a polynomial is obtained by summing over all the possible states with weight given by the product of the appropriate splitting coefficients. An overall factor multiplied by this sum gives the final polynomial associated to the diagram. The research outlines the specific choices for the variables present in the polynomial which yield invariance under all three Reidemeister moves. The generality in the result permits the choice of multiple different invariants, e.g. the coefficients may take values in a Galois field represented by a polynomial quotient ring. Appropriate choices for the coefficients ease computations and distinguish knots that other invariants cannot tell apart.

One last element is required to make the above process yield a formal knot/link invariant. The ambiguity in choosing an orientation and colors may be subsumed by taking the invariant to be the set of the polynomials obtained from each of the different diagrams after orientation and the tricolor labelling.
Research Project Title: Weierstrass points on tropical curves

Student Presenter: Nik Henderson

Faculty Mentor: Chmutov No

Faculty Mentor Department: Sergei

Research Abstract: Background:

On a tropical curve (a metric graph with unbounded edges), one may introduce the so-called "chip-firing game." Given a configuration of chips on the tropical curve, with possibly negative numbers of chips, one may determine whether it is possible, through a set of approved "moves," to reach a configuration in which every point on the tropical curve has a nonnegative number of chips. More formally, we may determine which divisors on the curve are linearly equivalent to effective divisors. We may restrict our attention to starting configurations which have a large number of chips on a single point and some negative chips placed elsewhere in the tropical curve. It turns out that there is a meaningful way to measure how good a given point is at distributing its chips around the curve; points which have a special affinity for this are called Weierstrass points. We wish to determine the topological properties of the set of Weierstrass points, namely whether there are finitely many connected components, whether the set of all Weierstrass points is closed, and whether non-smooth Weierstrass points on a bridgeless graph are isolated.

Methods:

We employed the notion of reduced divisors as well as placing a cell structure on the linear system for a given divisor (often the canonical divisor) on a tropical curve. Since a map on the linear system known as "Red" is continuous with respect to this topology, we rephrased the problem by creating a metric on the linear system which induced the same topology.

Results:

We used the continuity of the Red map to prove that the set of Weierstrass points is closed. We believe we can also exploit further structure of the Red map to show that the set of Weierstrass points has finitely many connected components.

Conclusions:

The set of Weierstrass points on a tropical curve is likely never as pathological as one may worry. Indeed, these results suggest that it could consist only of finitely many closed intervals.
Research Project Title: Crossroads: spatiotemporal data exploration

Student Presenter: Trey Hakanson

Faculty Mentor: Nandi No

Faculty Mentor Department: Arnab

Research Abstract: As the availability of computing resources increases and the ease of generating spatiotemporal data decreases, the interface a person uses to interact with said data quickly becomes the bottleneck in determining insights. In addition, the barrier to entry for analyzing data via database queries has not improved much since SQL was invented. An interface that supports intuitive gestures to constrain queries and that has real time feedback is necessary to make gathering insights from large data sets accessible to anyone, technical or otherwise.

To solve this problem, we created an interactive visualization tool that is compatible with any movement data set, which we define as having timestamped departure and arrival coordinates. This tool has a multitude of features to facilitate garnering insights from spatiotemporal data sets: the data is displayed in multiple formats and in aggregate, visualizations update real time with changes to constraints, user-uploaded data sets are joined and displayed as overlays, and time-lapses/snapshots can be created to highlight trends.

The visualization tool provides the user with a variety of constraining options, all of which can be used together to effortlessly ask complex questions about the data at hand. After applying the constraints, a heatmap of the results is generated real time. The heatmap shows densities and differences in arrival and departure concentrations. Available constraints include: time of day for departure and arrival, subsetting a range of dates, specifying days of the week, trip distance, trip time, drawing geofences to designate areas of interest for departure and arrival, and more. All constraints are supplied via simple UI widgets, such as sliders, toggles, etc. Animations are also able to be generated, allowing for the visualization of flows across changing query sets. These animations are available for download as well, to facilitate easy sharing of novel results.
Research Project Title: Power optimization of livestock farms

Student Presenter: Logan Morris

Faculty Mentor: Illindala No

Faculty Mentor Department: Mahesh

Research Abstract: My name is Logan Morris, a third year electrical and computer engineering major at Ohio State. I was fortunate enough to participate in research under ECE professor Dr. Mahesh Illindala this last year in his energy optimization project of Ohio agricultural livestock farms. The farmers have many different types of power electronics they use to insure the safety, quality and productivity of their farms. When these power electronics are used simultaneously, the farmer can experience massive spikes in the energy they pull from the grid. If too much energy is pulled at any one point in time, farmers can be unfairly charged at a much higher rate for the energy bill for the entire month. The team combated this issue by attaching sensors to different types of farm equipment, then determine when and where these energy peaks are occuring. When the problem areas were located, the team asked the farmer to make adjustments in their daily routine, add lower cost equipment or modify equipment already present. This in turn results in a much lower cost of operation for the farm. This can then be scaled to many other farms in Ohio, hopefully resulting in much more profitable livestock farms.