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ROONE ARLEDGE AUDITORIUM
COLUMBIA UNIVERSITY

COLUMBIA ENGINEERING FOR HUMANITY

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DATA SCIENCE • SENSING • IMAGING • VISUALIZATION • MODELING • SIMULATION • MATERIALS • NANOSCIENCE • DEVICES • ROBOTICS

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Laser Crystallization of Metallic Thin Films: Manipulating and Optimizing the Microstructure of 3D-Printed Metals

Project By: *Benjamin Miller*

Advisor: *Dr. James Im*

Additive manufacturing is a powerful technique that can allow for potentially infinite design complexity at a consistent cost. However, the material properties of additively manufactured components underperform other methods of manufacture. If methods for growing crystalline thin films could be applied to vertical growth, the properties of additively manufactured materials could match or exceed that of traditional methods. This project explores the use of laser crystallization methods such as sequential lateral solidification (SLS) to manipulate the microstructure of aluminum thin films. The film was melted, and regions of columnar grains were laterally grown up to hundred-micron length by SLS. Using specialized masks, shape controlled single crystal regions were grown using dot-SLS. The microstructure of the crystalline thin films has been investigated with an optical and scanning electron microscope.

Keywords: Additive Manufacturing, Laser Crystallization, Sequential Lateral Solidification, Dot-SLS, Aluminum, Thin films

Battery Safety: Internal Short Circuit in a Lithium Ion Battery

Project By: *Michael Sargon Hamati*

Advisor: *Dr. Yuan Yang*

Maximizing battery safety and proper function is of critical importance, particularly with Li-ion batteries. There is concern regarding the consequences of unwanted short circuitry within the battery, which can result in the production of heat. This generation of heat and rise in battery temperature can break down the battery's electrolyte and, if severe enough, can result in a thermal runaway and potentially hazardous scenarios. Commonly, a penetrating nail or penetrating microstructural growths within the separator layer, such as a lithium dendrite, can result in these internal short circuits. Multiple short-circuit simulations were made using COMSOL Multiphysics 5.3a to give understanding to how heat generation changes as a result of varying Li-filament size, electrode thicknesses, nail size, and contact resistance.

InsuLead

Project By: *Zhongyue Guo, Sabrina Maliqi, Ivy Mannoh, Christian Park, and Bethany Pohjala*

Advisor: *Prof. Barclay Morrison*

Lipohypertrophy (LH) is a side effect of insulin therapy that affects up to 3 million diabetics in the USA. Characterized by the abnormal growth of fat at the injection site region, LH is unsightly and leads to erratic blood glucose behavior, increasing the risk of hypo- and hyperglycemia. There currently exists no explicit solution for the prevention of LH; patients are simply instructed by their physician to inject insulin at different sites. These instructions often go unheeded as patients preferentially and repeatedly inject insulin at the least painful site. InsuLead provides a novel, easily-implemented solution to this ongoing problem. Upon injection of insulin, the InsuLead device administers mechanical vibrations to increase insulin dispersion in subcutaneous tissues, reducing the adipogenic and lipogenic effects of concentrated insulin to prevent LH. Developed to work in coordination with current injection methods, InsuLead provides a simple, user-friendly solution to an unmet and overlooked need.

EZ Collect

Project By: *Madeleine Gao, Joseph Lozano, Sharon Shu, WeiHao Xu, HaoKang Zhang*

Advisor: *Prof. Elizabeth Hillman*

Over 1 million children in sub-Saharan annually contract tuberculosis (TB.) Detection of TB involves producing and expectorating an uncontaminated sputum sample for subsequent microbial analysis. This process is often difficult for young children who may be uncooperative or simply incapable of coordinating the requisite motor activities. This results in sputum samples that are compromised by saliva, which can reduce the accuracy of subsequent testing. Therefore, we have identified a need for a method to effectively collect sputum samples from young children in low-resource settings. We have created a semi-closed suction device that fits into the child's mouth, with separate sputum and saliva collection tubes to minimize sample contamination. The automated collection of sputum is initiated by the detection of a cough, reducing the need for a child to coordinate the activities to produce the sample. Prototype testing shows rapid, safe, effective suctioning of simulated sputum uncontaminated by saliva.

Milky Way

Project By: *Kimberly Lopez, Swasti Mehta, Christine Sison, Yuchen Song, and Jingyi Wang*

Advisor: *Prof. Samuel Sia*

Clogged milk ducts are a painful problem for around two thirds of breastfeeding mothers and, if not properly treated, can result in infection of the breast tissue (mastitis.) Assistance from lactation consultants is recommended, but this can be expensive and is not always accessible. At-home treatments may be improperly administered and not address the condition or even further exacerbate it. The need arises for mothers to have a safe at-home treatment to relieve clogged milk ducts while breastfeeding. Our solution is a wearable device that provides thermal and massage therapy that mimics a professional lactation consultant. This device has safety features to prevent the application of too much force or heat, which could injure the mother. It is embedded in a bra to maximize discretion and provide hands-free therapy. This device will provide an effective and safe treatment option for women to reduce the pain and inconvenience that accompany clogged milk ducts.

PolypSense

Project By: *Agustin Acosta-Ghioldi, Drew Afromsky, Julia Joern, Jacob Nye, and Seth Shoap*

Advisor: *Prof. Katherine Reuther*

Colorectal cancer, the second deadliest cancer in the United States, can be detected early through the identification of polyps in the colon wall. Once these polyps are detected, they can be removed, stopping the progression of cancer at an early stage. Even though polyps are easy to remove, they are difficult to detect. The current gold standard method for detecting and resecting polyps, colonoscopy, relies on a gastroenterologist's naked eye to identify abnormalities. This current method is clearly not sufficient: up to 25% of polyps are missed during colonoscopy screenings. As a result, there is a need for a biomedical solution to improve detection rates of polyps and screening methods during colonoscopy. PolypSense enhances colonoscopy by integrating depth-sensing technology and a 3D polyp detection algorithm to provide gastroenterologists with assistive identification and highlighting of abnormal colon tissues, improving their ability to identify early-stage polyps.

MoLab

Project By: *Azraf Anwar, Meghana Noonavath, Jason Patterson, and Darnel Theagene*

Advisor: *Prof. Henry Hess*

Diabetic retinopathy (DR), a complication of diabetes mellitus, is a disease that damages microvasculature and neurons in the retina. Almost all Type 1 and an estimated two-thirds of Type 2 diabetics are expected to develop diabetic retinopathy as their disease progresses, and DR may eventually lead to complete blindness if not detected early. However, the only consistent method for early stage detection is screening performed by a retinal specialist. Diagnosis of DR is particularly challenging in low resource settings, like the Indian subcontinent, because of high numbers of patients and very few ophthalmologists as well as the lack of diagnostic equipment, leaving much of the diabetic population in this region susceptible to preventable blindness. MoLab's solution is a portable fundoscopic smartphone camera attachment coupled with a machine learning algorithm that automatically diagnoses DR. This system will significantly increase the capacity of doctors, even those who are not retinal specialists, to detect the onset and progression of DR.

OpiRem

Project By: *Morgan Cambareri, Anthony Chesebro, Claire Choi, Farah Pedersen, Andrew Tieu*

Advisor: *Prof. Elizabeth Hillman*

Opioid overdose has become a national crisis, killing an average of 91 people every day in the US. During an overdose, individuals experience respiratory depression and lose consciousness, resulting in death if not treated within minutes. Current treatments involve having someone nearby to administer Naloxone (an opioid antagonist) or call emergency services. However, bystanders are often not trained or equipped to provide Naloxone, are reluctant to call for assistance, and the overdosing subject is often incapacitated. There is a need to prevent the fatality of at-risk individuals who overdose on opioids. Opirem is a wearable overdose detector and Naloxone administration system. Respiratory depression is detected via a patch that monitors the rise and fall of a subject's chest. When depression occurs, Naloxone is intranasally delivered, halting the effect of the opioid. Initial testing shows that Opirem can accurately detect respiratory depression and deliver Naloxone, demonstrating its potential to successfully intervene during opioid overdoses.

MammaFilter

Project By: *Susanna Betti, Kahmun Lo, Lance Murphy, Ranjodh Singh, and Evie Sobczak*

Advisor: *Prof. Clark Hung*

Millions of HIV infected new mothers worldwide do not have access to or are non-adherent to antiretroviral therapy (ART) after childbirth, putting infants at risk of HIV infection during breastfeeding. Our device is a low-cost way for HIV infected mothers in Sub-Saharan Africa to provide breast milk to infants while reducing the risk of HIV transmission. HIV in expressed breast milk is eliminated via the addition of a small amount of powdered sodium dodecyl sulfate (SDS), an additive that is common in food and personal hygiene products. The SDS inactivates HIV while retaining the nutrients, proteins and fats that are critical for infant development. To prevent infant ingestion of SDS, the additive is extracted by passing the milk through a network of resin beads. The combined effect of these approaches results in a low cost, reusable system that may drastically reduce mother-to-child HIV transmission from breast milk.

PreciPoint

Project By: *Thomas Bernhardt, Kaiyan Cai, Nicholas Cho, Gabriella Ramil, Alexander Shields*

Advisor: *Prof. Lance Kam*

During bone biopsies, clinicians rely on a combination of free-hand needle insertion and CT guidance for sample collection. Deviations in needle trajectory can lead to inaccuracy during the procedure: the accuracy rate for bone biopsies is approximate 68%. Complications from improper needle positioning include tissue injury and the concomitant expenses that accompany repeated biopsies. Our proposed solution to this problem, the PreciPoint Needle Guide, is an external guidance device that increases accuracy by translating the planned trajectory parameters into the operating room. Our device sets the needle at the proper trajectory and enhances needle stability during insertion. The PreciPoint Needle Guide integrates with on-the-market bone biopsy needles and improves bone biopsy procedures through increased accuracy, safety, and time efficiency.

LumiChem

Project By: *Stephanie Michaels, Hana Navarro, Rhiana Rivas, Alessandra Schaszberger, and Jingwei Xiao*

Advisor: *Prof. Edward F. Leonard*

Access to autoclaves, which are the gold-standard in medical sterilization equipment, is limited in low-resource settings either because they are too costly or not compatible with existing infrastructure. In some places, patients undergo surgery without sterilized tools, resulting in millions of people contracting infections from improperly sterilized medical equipment. There is a clear need for an effective sterilization device for use in low-resource settings. The LumiChem device is specifically designed to improve surgical tool sterilization in low resource settings by employing a two-stage process. Ultraviolet light in the C-wavelength band (100 - 280 nm) initially eradicates microorganisms on surgical tools. The light sterilization is complemented by a chemical exposure that eliminates microorganisms that are resistant to the ultraviolet light. The LumiChem prototype's sterilization efficacy has proven comparable to an autoclave, making this a highly viable sterilization option for low-resource settings.

Project Nate

Project By: *Sarah Chiang, Christiana Choi, Madison Cox, and Adriana Echeverria*

Advisor: *Prof. Gerard Ateshian*

Approximately 13 million infants per year receive oxygen therapy, making it the most commonly used intervention in neonatal intensive care units (NICUs) worldwide. Regulation of the delivered flow rate and the concentration of oxygen are critical parameters in respiratory therapy because improper oxygen levels can result in tissue damage and even death. In many resource-poor areas, well-regulated neonatal oxygen therapy is inaccessible, further contributing to neonatal mortality in these countries. Project Nate seeks to improve oxygen delivery to neonates in low-resource settings. Our device allows for the sharing of a single oxygen source between multiple infants, while also providing patient-specific therapy through control of oxygen flow rate and concentration. Project Nate is optimal for low-resource settings, as our device is compact and does not utilize electrical power, allowing for consistent, high-quality, low-cost care.

Vertical Farming

Project By: *Agyei Gregory, Dean Ramos, Adrian Rodriguez, Diane Sagastume, Julia Senkevich, and Julissa Tejeda*

Advisor: *Prof. Tom Panayotidi*

About 70% of Earth's freshwater is reserved for use in the irrigation of crops. With climate change threatening to change weather patterns globally, it's entirely possible that water will become a scarce resource and valued commodity within our lifetimes. In addition, according to the USDA 2012 Census on Agriculture, 40% of the United States is reserved for agricultural production. To accommodate a growing domestic population and export market, commercial farming is expected to increase production capacity, necessitating the further conversion of fertile land into farms, increasing greenhouse emissions into the air because of the need to transport products, and increasing the pollution of nitrates into waterways because of the use of pesticides.

Considering the situation, our project explores the construction of one of the methods that could mitigate the environmental impacts, while significantly increasing food production capacity and efficiency: indoor vertical farming. The objective of this project is to use geotechnical, structural, environmental, and construction management aspects of civil engineering to design an agricultural vertical farm on Columbia University's Manhattanville campus to meet the school's sustainable initiative and to help reduce its food supply demands. The layout of our building was inspired by the idea that "form follows function" made by Dickson Despommier, emeritus professor at Columbia and author of The Vertical Farm: Feeding the World in the 21st Century, each choice of our layout was designed with attention to efficiency and functionality of the production of our vertical farm.

The planned project will involve the construction of a 100 ft x 100 ft vertical farm building which will span 60 ft tall, consisting of four 15 ft high floors in lot 7 of Columbia University Manhattanville campus. The total growing area will be 2500 sq. ft on each floor. Interior work will include ZipGrow vegetation walls, gravity-feeding water system, electrical system, HVAC system, and plumbing system. Aside from the growing area, the building will also include the following amenities: lobby with an exhibit, cafe open to the public, and office space for employees. Because one of our goals is to make our building more sustainable, we are striving to design the building to be LEED accredited. Therefore, part of the design will include a green roof, solar panels, green space on the tiered levels, green streets, and green export methods.

Reclaiming Rikers: LaGuardia Expansion

Project By: *Aaron Appelle, John D'Andrea, Anne Gergen, Rebecca Peet, and Joanna Zou*

Advisor: *Prof. Tom Panayotidi*

New York's regional airports are currently at full capacity and estimates show that 40 million passengers will go unserved by 2030. LaGuardia serves around 30 million customers each year and is the third busiest airport in the region but has the second-worst delay record of all airports in the United States. With a 73.934% on-time rating and limiting footprint, LaGuardia has left travelers disappointed with their airport experience. As the region grows and the demand for air travel continues to increase, it is critical that airports expand capacity and improve efficiency. The LaGuardia Expansion proposes an extension of airport facilities to Rikers Island, with the construction of an additional runway and new terminal. With 30 new gates and lengthened runways, the airport will have the infrastructure to service 50% more flights and accommodate larger aircraft in the future. The Expansion allows LaGuardia to serve a significantly greater number of customers and help meet the region's transportation demand.

NYC Harbor Flood Barrier

Project By: *Bhumipak Auewarakul, Zachary Dansby, Bryan Fay, Kevin Obey, and Saurabh Runwal*

The aim of this project is to consider and design a large-scale flood barrier, levee and gate system, for the New York City outer harbor. Given the recent trend towards resiliency projects, this has the potential to be a unique and landmark project for NYC. After Superstorm Sandy devastated the tri-state area, there was a push from New York Governor Cuomo to propel forward a plan to create infrastructure to protect the city from future storms. In that time a cost/benefit and feasibility analysis has been conducted for implementing floodwalls in the harbor. The study indicated that the project would be feasible, but design has stopped for various financial and political reasons. In particular the city has opted towards more decentralized smaller scale flood prevention projects. Examples over the NYC area being protective measures for the NYCT subway / rail system to the raising houses along the shore line including Rockaway. These efforts show an uncoordinated scramble to meet new design and insurance standards respectively. However, a need to design a floodwall for the harbor is necessary to ensure there is redundancy in the city's resiliency measures. This would be the first large scale infrastructure project solely focused on the protection of the New York City area from impending storm surge and sea level rise. This concentrated effort would hope to pass on construction and cost efficiencies of a large scale phased project to all future NYC projects and the financial capital itself. One project that is of current importance is the $ 30 billion Gateway Tunnel connection, which would certainly be at risk for a significant storm surge event.

This schematic design has been proven to allow for adequate traffic flow without impacting the environmental health of the harbor in terms of water discharge and blockage. Similar large-scale floodwall designs have been implemented in both the Netherlands and Russia and have been proven to work. Since this is such a unique project and of such a massive scale, we would only be considering elements in regard to the Outer Harbor Gateway.

The Bayonne Stacks

Project By: *Serra Akyuz, Stephanie Berrios, Charlotte Broadbent, Alice Boutant, Somtochukwu Uyanna, and Sophia Yamas*

Advisor: *Prof. Tom Panayotidi*

STATEN ISLAND, NY: Of all the boroughs composing New York City, Staten Island is notoriously known to receive a minimal amount of financial resources from the city that can be allocated to further developing infrastructure on the island. While there are many concentrated residential communities, other areas were formerly dedicated to manufacturing activities and have since been abandoned. In an effort to improve the quality of life, particularly within the Port Richmond area, the city developed a plan with the local community in early 2012, re-imagining the North Shore of Staten Island. The main goals the city wishes to achieve with this plan, the Brownfield Initiative, are to “Create quality jobs, reconnect people with the waterfront, support and create neighborhood centers and improve connections and mobility,”1.

The plan was pushed forward with greater force in the wake of Hurricane Sandy, which left the island in a considerable state of disrepair, with an immense amount of damage visible along the waterfront. Taking the goals laid out by the Brownfield initiative, The Bayonne Stacks seeks to address the particular needs of the Richmond Terrace area while triggering the growth of community and encouraging a drive for more improvements. This proposed building is designed to be located at 2265 Richmond Terrace on Staten Island. Previously industrial, the area now faces abandoned lots and a ship graveyard, despite its immediate proximity to a residential area and short commute to the Staten Island ferry. Additionally, the site showcases an immediate view of the Bayonne Bridge. The Bayonne Stacks do not only aim to provide an additional housing option for New Yorkers but also wish to address some of the issues plaguing Staten Island.

In researching the difficulties faced by Islanders, ranging from the lack of adequate transportation lines to service the entire island to drug use particularly among teenage students, the design team decided to develop a structure that would not only be an attractive, structurally complex project but would also offer new amenities to the surrounding community. The Bayonne Stacks will contribute to the redevelopment of the North Shore by offering luxury residential apartments with a view of the Bayonne Bridge but a distance off from the soon-to-be commercial center near the Staten Island Ferry. By incorporating a restaurant and public gym into the complex, the project will interact with the community, providing a location to de-stress. It is hoped that this development will generate more projects of the like across the island, projects that balance addressing public needs and generating revenue for any stakeholders. Additionally, with more sought-out destinations across the island, there will be a push to reform the existing transportation infrastructure to provide easy public access to the many parks and recreational areas available.

From a structural perspective, the building is a challenge to design. It consists of 9 separate 5-floor modules that are stacked in a semi-circle formation. At its highest point, the structure is 4 modules high, which is equivalent to 280 feet. There are gaps between the modules where they bridge across each other and a cantilever at the far end where a second-level module is supported by a large spiral column. The Bayonne Stacks will provide an alternative form of building residential communities with room for expanding connections across different levels and placing luxury within reach; after all, what is a city without being able to provide a home for the people who shape it?

The Blade at Bay Bridge

Project By: *Bryce Barr, Joseph Belmonte, Isaiah Chapman, Metehan Gunal, and Kris Mizhquiri*

Advisor: *Prof. Tom Panayotidi*

The Blade at Bay Bridge is a spectacular multipurpose skyscraper building located in San Francisco, California. This design-build project is 97 stories and 1400 feet tall, complete with a concrete moment-resisting frame, deep foundation piles and an antenna tower. Additionally, the tower will be designed for large earthquakes and wind, which are part of the environment in the city. The first-floor supermarket/lobby will be approximately 20 feet in height while the rest of the building will be 13 feet per floor, full of lecture halls, office spaces and an observation deck, among other rooms. Our gravity bearing system will be mainly steel columns around the perimeter of the building, with a concrete core providing lateral stability. Two key and innovative features highlight our structure: a Tuned Liquid Column Damper (TLCD)--a form of Tuned Mass Damper (TMD) that allows one to protect against a variety of more frequencies by using multiple TLCD's where one would not otherwise fit other types of TMD's--which will control the sway in the upper floors; and an exterior fan system along one of the building's facades, which will serve to illustrate the building's commitment to sustainability by both generating energy from the wind and to reducing the amount of CO_2 in the local air, thereby improving air quality. Thanks to the above components, we believe this building will be an example for future sustainable tall structures worldwide while simultaneously becoming an iconic part of the San Francisco skyline.

Microgrid Design for Hospital Resiliency

Project By: *Lucy Banter, Charles Harper, Rebecca Miller, Varshimi Parthasarathy, Kenneth Spranzo, and Kathy Welter*

Advisor: *David Vallancourt, Robert Farrauto, Jon Nickerson (Lead Project Manager, National Grid)*

Protecting our critical load infrastructure is crucial to preventing loss of life in cases of power failures. This challenge becomes even more pressing when accounting for the unprecedented storm damage our country faced in the fall of 2017. Additionally, cyberattacks on North American power transmission and distribution systems have already proven to be significant threats. As a result, the value of a microgrid system for a vulnerable load such as a hospital is evident, even before taking into account the benefit of lower fuel costs and emissions during outage scenarios. Microgrids operate by islanding themselves from the rest of an electric system during times of decreased power quality. In order to design the hospital microgrid, load profiles were generated from pre-existing data and scaled to match hospitals of varying size. Implementing these load profiles into a modeling software generated an appropriate resource mix for each scenario. Finally, the microgrid central controller was designed and built to switch the hospital into islanding mode when required, minimize non-critical load, and subsequently dispatch the most efficient generation resource according to feedback from the connected devices.

Keywords: climate change, cybersecurity, microgrid central controller, power outages, renewable integration, resiliency

Filtration Enhancements and Solutions for the Catskill-Delaware Water Supply at the Kensico Reservoir

Project By: *Nicole Babendreier, Luke Cook-Griffin, Jamie Feldman, Julia Lee, and David Kim*

Advisor: *William Becker, Robert Farrauto*

The objective of this research centers on composing an updated design plan for the filtration of New York City's water supply. Currently, water that flows from the Catskill and Delaware watershed systems meets the quality criteria established by the Environmental Protection Agency (USEPA) and the Filtration Avoidance Determination (FAD) standards, meaning it is clean enough to remain unfiltered during the treatment process. However, there is reason to prepare for potential instances of excessive contaminant levels from external factors, including the impact of global warming. As a result, the FAD requires that the New York City Department of Environmental Protection (NYC DEP) have a filtration plant fully planned and ready for construction if the current method of treatment, UV disinfection, is deemed insufficient.

The loss of adequate performance of UV disinfection can occur due to a multitude of reasons. In particular, we emphasize the risks associated with global warming, as it could significantly drive up contaminant concentrations. For one, increases in turbidity from high intensity, high frequency storm events cause this treatment method to be less effective. To address these concerns, the DEP has contracted with Hazen and Sawyer in the past to explore feasible options; however, the old reports utilize water quality data from the 1990s and propose treatment methods based on technologies that are over twenty years old.

Therefore, this project focuses on providing a more comprehensive, modern approach to this issue of filtration. A series of evaluation criteria will be formulated to determine the most appropriate filtration system based on performance, environmental sustainability, and cost-effectiveness. Factors to be considered include the ability to treat the water to acceptable standards based off recent water quality data, compatibility with the UV disinfection plant and site, energy efficiency, and operation/maintenance costs.

The project concept was developed by Dr. William Becker, Vice President and Director of Water Process Research and Technology at Hazen and Sawyer and Adjunct Professor at Columbia University. As Hazen and Sawyer collaborates with the DEP, this undergraduate research encompasses a portion of the project, essentially working as a subcontractor for Hazen and Sawyer. Dr. Becker will guide the direction of this process and allow the group to communicate with the project leaders at Hazen and Sawyer.

Plasma Arc Gasification WTE & Vertical Farming

Project By: *Kelly Conway, Diana Jaramillo, Cassia Patel, and Talia Pinker*

Advisor: *Dr. Robert Farrauto, Dr. Dickson Despommier, Dr. Lou Circeo (Applied Plasma Arc Technologies, LLC), Jack Griffin (Metropolis Farms), Jeffrey Landau (Agritecture Consulting), Dr. Athanasios Bourtsalas*

Vertical farming will be a crucial part of addressing food insecurity and environmental issues with our food system. Currently, vertical farming is a highly energy-intensive process, so finding ways to incorporate renewable energy systems will be a necessary part of establishing a truly sustainable solution. Waste-to-energy (WTE) is one form of renewable energy that can address both energy production and waste management, and plasma arc gasification is on the forefront of making this approach more efficient. This study analyzes the feasibility of pairing plasma arc gasification WTE with vertical farming. Specifically, this study uses energy and financial data from a Metropolis Farm facility and operation data from the Alter NRG Mihama-Mikata plasma arc gasification plant. Our analysis showed that this setup can be feasible and profitable for a high-value crop, but future work should look into applying this approach to nutritious produce in the interest of seeing how these technologies can replace or alter the current food system.

Finding Water in Puerto Rico: A Water Recovery/Recycling and Infrastructure Remodeling Plan Post-Hurricane Maria

Project By: *Serena Kumalmaz and Alexis Woodhouse*

As a result of a history of colonialist power structures, Puerto Rico possesses the worst drinking water violation rate of any of the states and territories of the United States. With an already compromised water system, extreme weather events such as Hurricane Maria, which pummeled the island in September 2017, are especially threatening to islanders' ability to have access to clean, reliable water. The objective of this project was two-part. The first was to design a sustainable and accessible wastewater recycling system based in Mayagüez, Puerto Rico, which could eventually be extrapolated and applied to the entire island, given the challenges presented by its infrastructure pre-Hurricane Maria. The goal of the design was to take additional burden off the current water supply infrastructure and broaden the scope of provision. In planning, the design was influenced by issues of accessibility by region, class, and socioeconomic status. The second part of the project involved a suggested recovery plan for Puerto Rico's drinking water infrastructure post Hurricane Maria based on ongoing research. The plan considers the limitations surrounding funding, the problem of the water-energy nexus, and how to enact sustainable methods of widespread distribution.

Automatic Beer Pong Table

Project By: *Ryan Davies, Benjamin Fechter, and Jun Hyek Jang*

Advisor: *David Vallancourt*

The Automatic Beer Pong Table is our way of improving the game experience of this perennial favorite by automating several key elements of the game. For example, on startup the cups will automatically rise to the surface of the table, and once a ball is fairly scored into a cup, the cup will be lowered beneath the table. To reinforce friendly sportsmanship, arrays of ultrasound sensors can detect certain rules violations. The table has LCD screens for each player to monitor progress and change game options easily throughout a tournament.

Keywords: Automatic Beer Pong Table, Automatic, Beer, BeerPong, Fun, Drink Game

Lost Item Finder

Project By: *Tianen Chen, Willian Chiu, Tyler Hiller, and Lucas Lalima*

Advisor: *David Vallancourt*

The Lost Item Finder is a compact GPS tracker that broadcasts its location via public WiFi and emits sound when called by a Bluetooth signal. The purpose of this device is to keep track of larger valuables such as backpacks, purses, or musical instruments within the city or other areas with freely available public Wifi should they be lost or stolen. The Lost Item Finder passively broadcasts its GPS coordinates, viewable on a web-based map interface. It can also be called via Bluetooth if the device and the user are in close enough proximity.

The Butterfly Effect

Project By: *Louisa Sainz de la Maza and Saarthak Sarup*

Advisor: *David Vallancourt*

The ubiquity of IoT has created a security challenge due to the need for encryption at very low power. A promising approach to low power secure wireless communication employs Lorenz Attractor circuits, analog chaotic systems that sidestep the power-intensive digital computations required in standard secure public-key encryption and universal hashing. We build upon concepts explored in recent papers on Chaotic circuits for encryption, using a Lorenz Attractor circuit and RF transceiver to achieve a lower power and low-cost solution. The Lorenz Attractor acts as the transmitter's random number generator, the output of which is digitally modulated by the message. A slave circuit in the receiver decodes the message by synchronizing with the master Lorenz circuit. Our PCB implementation points the way to IC realization for a practical system.

Autonomous Fruit Fly Robots

Project By: *Amol Kapoor (Computer Engineering) and Seungmin Lee (Computer Science)*

Advisor: Dr. Aurel A. Lazar

Though fruit fly brains do not have many neurons, they exhibit complex behavior including optomotor avoidance responses, navigation, and foraging. There is significant research interest in understanding how the fruit fly brain operates, with the ultimate goal of building robotic systems with on-board intelligence designed by emulating known circuitry of the fruit fly brain. This project describes and implements key infrastructure of an autonomous robotic system and provides initial tests on the feasibility of such a system. The autonomous robotic system consists of a cloud server, called NeuroCloud, and remote ground-based robotic modules, called FlyRemotes. The NeuroCloud provides computational power for executing computationally demanding tasks such as progressively training a brain circuit model based on information gathered by FlyRemotes. The behavior of each FlyRemote is governed by the trained models/circuits. We experimentally validate the infrastructure of the FlyRemote robot platform with a vision-based color detection task. We compare the learning performance of visual neural circuit/deep neural network hybrids against pure deep neural networks. Through these experiments, we examine the information processing capabilities of the neural circuitry and determine which model has the optimal learning efficacy for the given task. We conclude by exploring how the novel FlyRemote platform can be used as a way to better understand the fruit fly brain.

Real Time Harmonizer

Project By: *D'Arcy Anderson, Rebecca Murray, Anita Rao, Cindy Xiao, and Jimmy Ye*

Advisor: *David Vallancourt*

Our real time harmonizer allows a singer to produce multiple notes at once. It takes in a voice signal and outputs the original and pitch shifted voice signals in real time. There is a preset selection of harmonies that can be produced, including thirds and fifths above or below the original note, which can be chosen by the user. Digital logic is then used to generate the notes to harmonize with the input signal, and the user will also have the option to add a reverb and phasor effect to the output.

Discrete Alcohol Sensor

Project By: *Avery Feit, Miguel Gutierrez, Garrett Kaighn, Bernard Nguyen, and Sarah Thompson*

Advisor: *David Vallancourt*

We have built a portable, hand-held, capacitive alcohol meter that can be used to measure the alcohol content of a variety of mixed drinks. Other portable alcohol measurement systems work by measuring the mass densities of solutions, but they are only accurate in the absence of sugar, since water, ethyl alcohol, and sugar all have different mass densities. But as a solution of water and ethyl alcohol becomes more alcoholic, its relative permittivity decreases, and by switching to a capacitive method, we were able to exploit the fact that dissolving sugar in water lowers the permittivity of the overall solution much more slowly than adding ethyl alcohol does. Our alcohol meter also is much smaller and less expensive than mass density measurement systems. The combination of these factors leads to an alcohol meter that is suited to consumers rather than distillers; something that, to our knowledge, did not exist.

Keywords: Alcohol, Sensing, Consumer Devices, Food Safety and Regulation, Capacitance Measurement

Swarmbots

Project By: *Alexander Colton, Julia Di, Bailey Fryer, Chuck Poklikuha, and Connie Zhang*

Advisor: *Mike Massimino, Fred Stolfi, David Vallancourt*

Robotic swarms are a perfect example of the axiom divide and conquer: the power of many over the power of one. We built four small mobile robots that are capable of dynamically-coordinated movement within a controlled arena. This project explores the motion and applications of a small robotic swarm. Coordination in a multiagent system is a complicated controls problem, and our approach was to control the four robots wirelessly from a separate computer. The computer is informed of robot position through computer vision using a camera mounted above the arena. These robots successfully work together to locate themselves and move in formation, which can be used for tasks like navigating obstacles during terrain exploration or moving and picking up objects — tasks that one robot cannot accomplish alone.

RockEm SockEm Robots

Project By: *Joseph Campo, John Cervone, Elon Gordon, James Harrison, and Nikiander Pelari*

The Rock ‘em Sock ‘em robots senior design team is revamping your most nostalgic boxing game with a fun twist. Two players face off in the ring, each controlling a boxing robot with sensor packs on their wrists and head. When a player throws a punch, the robot mimics their movement. A left-hand punch is aimed towards the chest, while a right-hand punch is aimed at the head. Each player can dodge left, right, forward, and back; so, to make a point count you must be on target. When a player scores enough points on their opponent, the losing bot’s head pops up, as an homage to the original game.

Microgrid Design for Hospital Resiliency

Project By: *Lucy Banter, Charles Harper, Rebecca Miller, Varshimi Parthasarathy, Kenneth Spranzo, and Kathy Welter*

Advisor: *David Vallancourt, Robert Farrauto, Jon Nickerson (Lead Project Manager, National Grid)*

Protecting our critical load infrastructure is crucial to preventing loss of life in cases of power failures. This challenge becomes even more pressing when accounting for the unprecedented storm damage our country faced in the fall of 2017. Additionally, cyberattacks on North American power transmission and distribution systems have already proven to be significant threats. As a result, the value of a microgrid system for a vulnerable load such as a hospital is evident, even before taking into account the benefit of lower fuel costs and emissions during outage scenarios. Microgrids operate by islanding themselves from the rest of an electric system during times of decreased power quality. In order to design the hospital microgrid, load profiles were generated from pre-existing data and scaled to match hospitals of varying size. Implementing these load profiles into a modeling software generated an appropriate resource mix for each scenario. Finally, the microgrid central controller was designed and built to switch the hospital into islanding mode when required, minimize non-critical load, and subsequently dispatch the most efficient generation resource according to feedback from the connected devices.

Keywords: climate change, cybersecurity, microgrid central controller, power outages, renewable integration, resiliency

Design and Implementation of High-Performance Electric Drivetrain

Project By: *Albert Gao, Ibrahima Niang, Dawei Ren, and Xuexin Wei*

Advisor: *Matthias Preindl*

The goal of our project is the design and implementation of a high-performance drivetrain for electric vehicles (EVs), following the specifications and requirements of the FSAE Electric Vehicles Competition. Our environmentally-friendly EV is powered by an electric motor instead of a gasoline engine. The motor receives its energy from a lithium battery, regulated by a motor controller based on input from a human driver. Using system-level modeling software Plecs, we modified an existing electric motor model and investigated velocity, electric torque, phase currents, and acceleration under unloaded and loaded conditions. To meet our specifications, it is necessary to maximize the performance of the drivetrain up to 80 kilowatts, with a peak current of 320A.

Breaking Bitcoin: Computational Approach to Valuing Blockchain Networks

Project By: *John Benenati, Dillon Sean Biddiscombe, Aakanxit Khullar, and Omer Faruk Yatkin*

Advisor: *Dr. Karl Sigman, Dr. Miquel Alonso, Lawrence Temlock*

With the rise of global interest in a decentralized ledger, Blockchain technology and its more commonly recognized applications, cryptocurrencies Bitcoin and Ethereum, have become widely integrated within the financial ecosystem since their introductions in 2008. A powerful result of network economics is Metcalfe's law. Metcalfe's law states the effect of a telecommunications network is proportional to the square of the number of connected users of the system (n2). A generalized approach to Metcalfe's law can be used to approximate the value of the Blockchain networks and cryptocurrencies. Three jointly significant factors explaining variation in Bitcoin and Ethereum price are distinct active users, volume per user, and wallets on the respective networks. Simulating these underlying network drivers through a combination of discrete autoregressive processes and stochastic extreme value processes allow cryptocurrency price forecasting. Application of machine learning, specifically, neural networks are used to improve results over traditional ordinary least squares (OLS) forecasting.

All-Terrain Robot

Project By: *Mark Cartolano, Kevin Dean, Alicia Dagle, Erika Soto, and Sarah Wang*

Following natural disasters, difficult terrain impedes emergency response teams from exploring for survivors and assessing damage. To address this problem, our team proposed to design a hexapedal, all-terrain robot with wifi-enabled navigation and camera stream. Inspired by the Boston Dynamics RHex design, the robot has 6 legs that rotate in sets of 3 so that the robot walks in an alternating tripod gait. The C-shaped, fiberglass legs are designed to support the weight and propulsion of the robot on uneven surfaces while 6 independently actuated motors allow the robot to compensate when it encounters an obstacle. A closed loop controller is used to monitor motor torque supplied to each leg for the desired modes of movement: forward, backward, left-turning and right-turning operation.

One-Degree Controlled Platform

Project By: *Jonathan Chang, Ilaria Ferrari, Nikita Komachkov, Veronica Over, and Max Smith*

This project was inspired by a team member's personal experience on crutches. She often found herself wishing for a "third arm" to help her carry objects without disturbing their orientation. While there are many applications for a self-stabilizing platform including marine, film, rescue, and medical - we will demo our project as a 1 degree of freedom interactive device, designed so that a passerby can interact with the system. The platform will be able to hold a glass of water or a plate of food steady while the user is disturbing the system. This demo is the first step to creating a six degree of freedom self-stabilizing platform. The platform will greatly improve the autonomy of people with disabilities and injuries by allowing them to carry precarious objects while using both hands to crutch or walk with a walker. Four+One has created a platform that rejects single-axis rotational disturbances to the motor housing as well as torques applied by a load on the platform itself. Attention was focused on creating a well-tuned control system that can correct for displacements made by hand within a range of 180 degrees; the platform may be displaced with up to 16 Nm of force and with a speed of up to 40 rpm before the controls fail. This project takes the first step towards designing a multi-link base-disturbance rejecting robotic platform that can correct in all six degrees of freedom. Ultimately, a six degree of freedom disturbance rejecting robot would have applications helping in industries such as the film, rescue, and medical industries.

Trash Collecting Robot

Project By: *James Palladino, Jae Park, Jeong Soo Kim, and Frank Yeh*

Our senior design project focused on the idea of automating a process that people could do but really didn't want to do, cleaning up trash. To solve this problem, we designed a remote-controlled robot with an assembly that would go around a park or playground type environment to pick up trash. The robot has a mounted brush assembly that is actuated via a motor driven timing belt, all of which pushes the trash into the waiting bin for disposal after the robot is done with the operation. It is our contention that a robot designed to clean trash at a speed above 1 foot per second can clean an area with a brush going in excess of 30 revolutions per second at a faster rate than a human can. Our demonstration shows how long it takes for the robot to pick up several bottles, either plastic or glass, with various amounts of liquid in them. In this way, we compare the time it takes for a robot to pick up trash and how long a human would take to pick up trash and see where the difference is.

Swarmbots

Project By: *Alexander Colton, Julia Di, Bailey Fryer, Chuck Poklikuha, and Connie Zhang*

Advisor: *Mike Massimino, Fred Stolfi, David Vallancourt*

Robotic swarms are a perfect example of the axiom divide and conquer: the power of many over the power of one. We built four small mobile robots that are capable of dynamically-coordinated movement within a controlled arena. This project explores the motion and applications of a small robotic swarm. Coordination in a multiagent system is a complicated controls problem, and our approach was to control the four robots wirelessly from a separate computer. The computer is informed of robot position through computer vision using a camera mounted above the arena. These robots successfully work together to locate themselves and move in formation, which can be used for tasks like navigating obstacles during terrain exploration or moving and picking up objects — tasks that one robot cannot accomplish alone.

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Self-Righting Robot

Project By: *Robert Kydd, Wing-Sum Law, Fabian Stute, and Francesco Zampetti*

Conventional orientation adjustment systems rely on aerodynamics and/or using thrusters, however we wanted to design a system that uses spinning masses to rotate the system to a desired orientation. We aimed to adjust the attitude of a robot in mid-air without relying on air resistance or drag, by spinning up and down steel flywheels to correct and counter any initial angular displacement or velocity. Inertial measurement units paired with hall sensors measure the exact orientation and velocity of the robot and the speed of the flywheels respectively to calculate in real time the corrections that need to be made to ensure the robot lands right side up. Similar systems are used in satellites and spaceships to make fine adjustments to keep them on course. Our robot represents a proof of concept, proving that flywheels are a viable option to make quick near-real time attitude adjustments with a completely self-contained system.

Bionic Arm

Project By: *Xiaotong Geng, Carlos Romero, and Edgar Vanoye*

The A.E.G.I.S. (Arm Exoskeleton Generating Improved Strength) group is creating an exoskeleton arm that will be used in the realm of rehabilitation. The arm will be able to help the user follow the full range of motion of the arm bending at the elbow joint. The target users for the exoskeleton arm are people undergoing biceps or triceps who will be executing a full range of motion of flexion and extension of both muscles. The arm is adjustable, meaning that it is one size fits all which helps reduce the cost of having to make one exoskeleton arm per person. The arm will also be made of soft materials limiting the weight and cost of traditional exoskeleton arms and making them more portable as well. The group expects to see the exoskeleton arm being used by physical therapists and research doctors to aid those that require special rehabilitation. The A.E.G.I.S. group's idea to make an exoskeleton arm came from a brainstorming session where we emphasized that we wanted a product that could help people. The idea of an exoskeleton suit came up and after discussing how to make this idea more feasible, the group decided to make an exoskeleton arm. One of the inspirations for the arm came from a group member having a relative that ruptured his biceps muscle while working in the construction industry that, after attending physical therapy for over 3 years after surgery, did not feel that he had returned anywhere close to normal movement in his arm. With this in mind, we decided that the direct application for our exoskeleton arm would be for therapeutic treatment of biceps and triceps trauma.

Braille Printer

Project By: *Kennedy Keys, Juliet Kirk, Manjul Pahwa, and Caroline Weinberg*

90% of children in the United States who are blind do not learn how to read Braille. There are fewer than 10,000 full-time qualified Braille teachers for nearly 100,000 blind students. Our project is an inexpensive and portable embossing device designed to help students learn Braille. Through the use of a custom manufactured Braille pin plate and a cam follower system to emboss characters onto Braille paper, our project is able to print the alphabet, simple words, and sentences. Our user-friendly system is 6” x 12” x 4.75” and includes a physical reading port, LED screen, and speaker to help facilitate the learning process for all individuals. Parents, guardians and educators who have not received training in reading or teaching Braille can also use our device to participate in the student's learning process. With several pre-programmed lessons, students of any level can use our device to achieve their goals of reading Braille.

Robotic Hand

Project By: *Benito Apreza, Ceasar Chabla-Sarmiento, Emile Motta de Casto, Saul De La O, and Maria Nadal*

Robotic arms are used for a wide variety of purposes, ranging from repairing components on the International Space Station to performing surgeries. Current designs for robotic arms focus on dexterity or optimization of precision and response time between the motion of the user and that of the robot. The purpose of this project is to incorporate both of these aspects of robotic hand design in order to allow a user to remotely grip and lift objects. Dexterity comparable to that of human fingers has been achieved by designing the gripper such that the joints match their anthropomorphic locations on the hand and each digit contracts at a rate proportional to that of a human hand. Additionally, the precision of the robot has been refined through the incorporation of a Leap Motion sensor. This sensor tracks individual bones in the hand in order to identify the precise location of a user's digits within a workspace, which translates to the ability of the robotic hand to accurately move to the location necessary to grasp an object. Based on the favorable outcome of this project, it is evident that this technology can be used to successfully locate, grip, and transport objects. The applications for this project can extend beyond lifting simple objects to improve the safety of laboratories by allowing for safe transfer of hazardous materials while avoiding contact with the user.

PotBot

Project By: *Kieran Birch-Desai, Steven Cardenas, Xuelong Mu, Luke Pelessone, and Nicholas Villalobos*

Pottery is one of the oldest art forms, with origins that date back before the dawn of writing. For our senior design project, we wanted to create a machine that could imitate this ancient art. We believe that the challenge of creating pottery with a machine is a fitting senior capstone project, given that it involves various disciplines within mechanical engineering, including controls, machine design, materials and manufacturing processes, and solid mechanics.

The embodiment of this venture is PotBot, the pottery making robot. Many mechanisms exist to mass produce clay goods, but these robotic systems utilize stamping methods to shape the clay which causes the pottery to lose its human-crafted aesthetic. Offering a solution to this problem, PotBot is capable of shaping clay goods such as cups, vases and bowls, while emulating the human touch of shaping in order to give the pottery a more authentic look. Additionally, PotBot technology could be applied to mass production methods to transfer the clay good industry and could be sold to hobbyists who wish to create their own clay goods without the hassle of learning how to throw pottery.

The PotBot system architecture consists of four subsystems including the (1) overhead arm, (2) radial arm, (3) pottery wheel, and (4) frame. Together, the overhead arm and radial arm manipulate the inner radius and outer radius of the clay, respectively. The pottery wheel was constructed from in-house motors, allowing us the benefit of more customization and easier tuning. The frame is made up of 80/20 aluminum slotted rods.

Although challenging, PotBot has taught us much about the design and manufacturing process. Unfortunately, we have to become expert potters ourselves!

Heating/Cooling Pads

Project By: *Nick Barclay, Nicholas Burgess, Benjamin Kunrath, Connor Rigg, and Avi Steinberg*

Icing and heating muscle injuries and wounds can decrease pain, swelling and inflammation. However, precise knowledge and control of the therapeutic temperature hasn't been possible, until now. Our product uses Thermoelectric Peltier Modules to cool or heat circulating fluid without ice, avoiding trips to the freezer. You can plug the system into the wall, select your desired strength of heating or cooling and get fast relief from muscle pain. Our team analyzed the heat transfer requirements for effective temperature control and built a compact, aesthetically pleasing design to dissipate the excess heat from the Peltier Modules. We also designed control systems to limit the maximum and minimum temperatures possible for the fluid, increasing safety over ice-based systems. The external temperature display allows for quick verification by physicians or physical therapists that the temperature is in a safe and effective range. Our design criteria for this product was focused on achieving and maintaining ideal temperatures for wound healing, unlike traditional icing and heating methods which can vary in temperature. In addition, we wanted an attractive and inexpensive design that could be used safely in hospitals, physical therapy offices, and at home. With a user-friendly interface of one button and one switch, customers can choose what feels best to them within a range of temperatures proven to be most effective. Our total assembled cost is estimated to be less than $150, compared to over $500 for units with similar functionality.

Whiteboard Cleaner

Project By: *Alex Gutierrez, Arjun Gupta, Jared Hanley, George Ko, and Scout Pepper*

Have you ever walked into a classroom and wished that the whiteboard was already clean or that you could clean it with the press of a button? MAG is a Roomba robot that autonomously cleans whiteboards. This whiteboard cleaning robot will clean either a portion or the entirety of your whiteboard given a set of user inputs. MAG will be about the size of your palm, stick to any magnetic whiteboard using permanent magnets and communicate with your phone using Bluetooth Low Energy technology. Additionally, the robot will include a newly designed cleaning system that will utilize a set of rotating pads to increase cleaning efficiency. Our goal is to make sure users never have to waste time cleaning another whiteboard again, while making an accessible, user friendly product that anyone can use.

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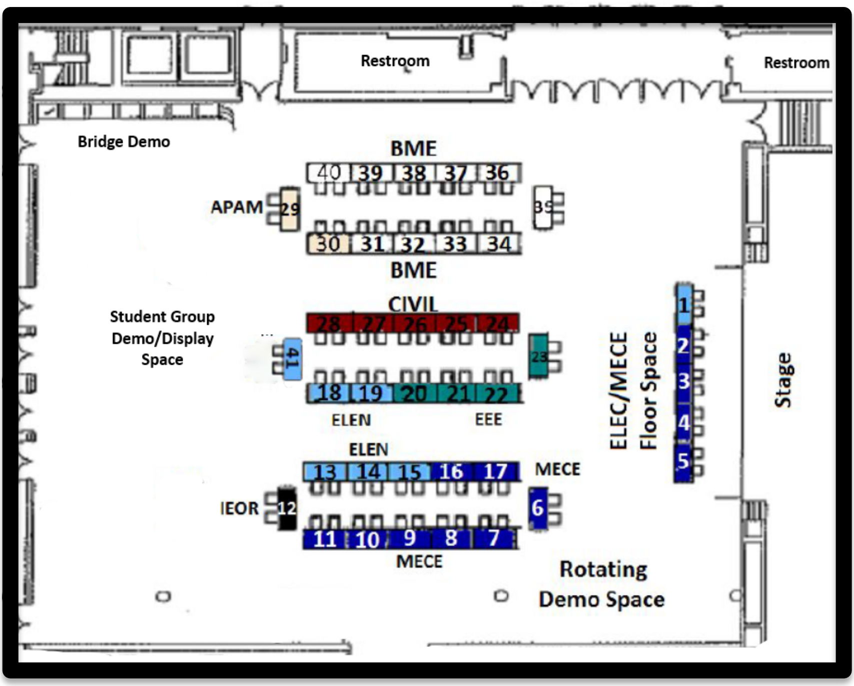

Applied Math

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Biomedical Engineering

Industrial Engineering and Operations Research

Civil Engineering

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Earth and Environmental Engineering