Session 1R

Population Health

Session Moderator: Clarence Spigner, Health Services
JHN 026
12:30 PM to 2:15 PM

* Note: Titles in order of presentation.

Isotachophoretic Extraction of Nucleic Acids from Human Serum for Point-of-Care Viral Load Test

Amanda Moon Levenson, Senior, Chemical Engineering
CoMotion Mary Gates Innovation Scholar, Levinson Emerging Scholar, Mary Gates Scholar
Mentor: Jonathan Posner, Mechanical Engineering
Mentor: Andrew Bender, Mechanical Engineering

36.7 million people worldwide are living with HIV/AIDS, of which almost 15 million receive antiretroviral therapy (ART). These patients require regular HIV-1 viral load (VL) tests to monitor ART effectiveness and compliance. However, the majority of affected people live in low-resource settings where disease monitoring through medical laboratory-based systems, such as nucleic acid amplification tests (NAATs), are inaccessible. There is an increasing need for accurate, affordable HIV-1 VL tests at the point-of-care (POC). We previously demonstrated the ability to leverage an electrokinetic separation and preconcentration technique, isotachophoresis (ITP), and an isothermal nucleic acid amplification method to develop a proof-of-concept POC NAAT for extraction, amplification, and detection of nucleic acids from human serum. The limit of detection (LoD) of our paper-based test was hampered by the loss of nucleic acids during ITP across the paper membrane. This work is focused on lowering the LoD of our test by improving the isotachophoretic extraction of nucleic acids from human serum. We have addressed the adsorption of nucleic acids by screening membrane types and pre-treatment methods. We have observed significant nucleic acid entanglement of DNA greater than 50,000 base pairs in length, which we can mitigate using DNA shearing techniques. We have also developed specialized ITP chemsitries for increased extraction efficiency. The completion of this work will result in more effective separation and purification of nucleic acids from human serum, ultimately leading to a reduction of target loss and improved test sensitivity. Employing the ITP extraction techniques developed in this work will aid our lab's ongoing efforts to create a POC NAAT for monitoring HIV-1 viral load.

Poster Session 2

Balcony, Easel 98
1:00 PM to 2:30 PM

Design of a High Reliability Micropump for Liquid Cooling High Heat Semiconductors

Molly Veronica Foley, Junior, Mechanical Engineering
Undergraduate Research Conference Travel Awardee
Karl Edward Kintner Meyer, Senior, Mechanical Engineering: Mechatronics
Phillip Dwight Rudolph, Senior, Mechanical Engineering: Mechatronics
Mentor: Elizabeth Rasmussen, Electrical Engineering
Mentor: Alexander Mamishev, Electrical Engineering

Large data centers, such as those built by Google, Amazon, and other information technology leaders consume about 1.3% of the world's energy, of which about 40% is used on electronics cooling [1, 2]. This amounts to 245 TWh per year, which, with the average US price of 12 cents per kWh, amounts to about $29.4 billion dollars spent per year on cooling high heat semiconductors [3, 4]. The work presented here proposes an innovative way to improve this cooling process. The proposed concept features a levitating inner rotor using fluid bearings that result in no physical contact between solid parts, eliminating friction. For the first time, precision-manufactured plastic parts are utilized to achieve both a low cost and a high reliability. The micropump is expected to last in operation for over one million hours Mean Time to Failure. This work emphasizes model-based design verification and optimization to ensure adequate performance for different form factors – so that a drop-in replacement of an air fan passive heat sink can be quickly developed for every microelectronics product. Twenty-four designs and prototypes were used in evaluation of two key criteria in order to optimize the pump's design. Three separate herringbone geometries, square, beveled-step, and circular, of herringbone grooves were prototyped based on experimentation of optimum groove parameters. These findings helped determine the optimal layer height of 100 micron for use in the micropump design. Finally, the application of a sensorless, brushless DC motor reduces overall cost of the pump and increases efficiency due to the removal of friction.

POSTER SESSION 2

Balcony, Easel 123

1:00 PM to 2:30 PM

Noise Impeaded Communication Echo

Maxx Naoyuki (Maxx) Yamasaki, Junior, Extended Pre-Major
Mentor: Santosh Devasia, Mechanical Engineering
Mentor: Rose Hendrix

This work seeks to address some problems faced by deaf and hard of hearing persons who work in confined or hazardous spaces. The issue they face that I am focusing on is the timely access of alerts and alarm, which are commonly provided solely through sound. Many approaches used in more general work conditions, such as flashing wall lights or another person notifying them, are heavily impeded by a confined work area. Additionally, a hazardous environment requires strict safety features regarding electronics. Any tool used must not have exposed electrical connections that could cause a spark or that it could break in such a way that could provide a source of ignition to flammable gases. Currently available bluetooth headsets and pagers do not meet these safety specifications and would be an additional piece of equipment for workers to carry. We have worked to develop a device that can clip onto existing safety equipment, conform to hazardous environment safety standards, and pair with the user's current cell phone and radio to notify them through vibration and light patterns. We are working with people who would benefit from the device as the design improves to its signals are clear in an industrial environment and that it suits their need. Future developments include allowing the device to relay more complex messages from multiple sources.

POSTER SESSION 2

MGH 241, Easel 161

1:00 PM to 2:30 PM

Development of 3D Pathology For Early Diagnosis of Pancreatic Cancer

Jessica Pensiri Yeh, Junior, Industrial Engineering
Mentor: Ronnie Das, Bioengineering / Mechanical Engineering
Mentor: Eric Seibel, Mechanical Engineering

Cancer is the 2nd leading cause of death in the United States. Of these cases, 6-7% are pancreatic cancer (PC), yet this disease is ranked 1st in mortality because what causes PC and how it manifests is still relatively unknown. Early detection is difficult and in a majority of cases, patients are diagnosed after the cancer has progressed to final stages. For the last 7 years, the Human Photonics Laboratory (HPL) has been dedicated to early detection and diagnosis of PC through the next generation 3D pathology (and all aspects of its infrastructure: 3D microscopy, 3D reconstructions/supercomputing, millifluidic device development/whole tissue processing, clinical evalution/validation). For PC, cell and tissue specimens which have been imaged in 3D and reconstructed in an advanced 3D visualization software (Amira) require an appropriate gray scale and RGB color scheme to determine accurate cancer diagnoses. Ideal and non-ideal samples may then be passed onto collaborating pathologists for clinical evaluation and validation. This research project seeks to satisfy three primary aims: (1) properly match the color metrics/scheme of the raw optical 3D microscope datasets to 3D computer reconstructions and analyze (qualitatively/quantitatively) the gray scale/RGB color histogram between normal/cancerous (human) pancreatic samples, (2) compare/contrast the pathological metric known as the nuclear-to-cytoplasmic (N/C) ratio between a small sample of normal/cancerous specimens, (3) choose 5-10 ideally processed/matched specimens and submit to pathologists for clinical evalution. The outcome of this project is expected to accelerate the diagnosis of PC.

POSTER SESSION 2

Balcony, Easel 101

1:00 PM to 2:30 PM

Can Simple Mobile Health Interventions affect Providers' Disease Management Protocols in Pediatric Dentistry?

Hae In (Angel) Lee, Senior, Computer Engineering
Mary Gates Scholar, McNair Scholar, Undergraduate Research Conference Travel Awardee
Mentor: Eric Seibel, Mechanical Engineering

Telehealth is being widely adopted in medicine, but is still novel in the field of dentistry, especially in therapy. Dentists rely on in-clinic visits and application of therapies rather than prescribing drug treatments outside the clinic. In this paper, we have developed and introduced an app that dentists can use to establish and maintain trust for fluoride treatments to be conducted correctly at home. Pediatric patients and their caregivers can access the client app on their phone to guide them remotely and record progress. A unique aspect of this app is rapid and accurate display of the child's own emerging teeth and the sites for fluoride therapy. In our study, we surveyed 16 dentists that were equally divided into two groups, half being exposed to a demonstration of the tool before taking the survey, and the other half taking the survey without any exposure. Although the randomly selected group which saw the app received their dental degrees on average 8 years earlier, four times the number of these dentists would allow off-label at-home use of the highest level of fluoride varnish for the youngest ages of patients. The tools present in this pilot study appear to influence pediatric dentists' management plans and attitudes towards home treatments, demonstrating the potential of expanding teledentistry to incorporate at-home care and treatment in addition to self-monitoring and tracking.

SESSION 2O

BIOMARKERS AND DIAGNOSTICS

Session Moderator: Paul Yager, Bioengineering

MGH 389

3:30 PM to 5:15 PM

* Note: Titles in order of presentation.

Predicting Tooth Decay with a Non-Contact pH Measurement

Jasmine Yu Graham, Senior, Bioengineering
Levinson Emerging Scholar, Mary Gates Scholar
Mentor: Eric Seibel, Mechanical Engineering

A pH measurement of oral biofilms is helpful for monitoring the impact of acidogenic bacteria in the caries process. Demineralization of dental enamel is closely related to the time dependent pH of human plaque. Therefore, providing a means to easily measure the local pH of biofilms is a useful clinical diagnostic in the arsenal of caries prevention tools. Optical measurement methods of plaque metabolism can use intrinsic fluorescence or extrinsic fluorescence from added dyes. Autofluorescence spectral features of human oral biofilms at green (500 nm) and red (634 nm) fluorescence wavelengths using 405 nm excitation did not demonstrate a spectral or intensity shift between neutral and acidic conditions. Chlorin e6, an ingredient in chlorophyllin food supplement, exhibited a spectral and intensity shift of fluorescence emission in buffered solutions, but this quantitative pH-dependence was not transferable to a human plaque environment. Finally, a ratiometric quantitative pH measure was achieved by exciting (405 nm laser) a mixture of two dyes, fluorescein and rhodamine B. This two-dye mixture produced two strong fluorescent bands centered at 515 nm (fluorescein) and 580 nm (rhodamine B), where the 515 nm band was pH sensitive and the 580 nm band served as a pH insensitive reference. This dual-dye fluorescence ratio exhibited a linear response over pH 7 to 5 in human oral biofilms during a sugar challenge. We have explored methods to use non-contact, optical measures of local acidity levels in difficult to access dental locations such as occlusal fissures using various pH sensitive fluorescent dye systems.

SESSION 2S

HOT TOPICS: ROBOTS, AR, CV, AI

Session Moderator: Kurtis Heimerl, Computer Science and Engineering

JHN 175

3:30 PM to 5:15 PM

* Note: Titles in order of presentation.

Insect Inspired Jumping Robot with Passive Ceiling Landing

Maxx Naoyuki (Maxx) Yamasaki, Junior, Extended Pre-Major
Mentor: Sawyer Fuller, Mechanical Eng

Small biologically inspired robots have difficulty landing after flight. This work is intended to explore a possible method for small robots in flight to attach to an overhanging surface. The goal of this work is to create an insect sized robot that is capable of jumping from a horizontal surface to an inverted surface and mechanically grip its destination. Previous work on attaching to a surface from flight have used electrostatic or electromagnetic copper coils or adhesive. My method for attaching to a surface was inspired by the sharp-hooked feet of beetles and uses hooks the same size as ten stripe beetle's to hold the surface. The advantage of this attachment method is that it does not need to be electrically powered to maintain a hold on the surface and is lighter weight than adhesives or copper coils used in other methods. I used an iterative design process to build and test different shapes and angles of hooks as well as to develop a jumping robot base structure that could support the grabbing arms and quickly repeat jump tests. I captured photos and video of beetle and grasshopper legs in motion and recreated the hooks they have on their legs as a starting point for the hooks I developed. In the future, this mechanism could be attached to robots capable of controlled flight, allowing them to perch on a surface indefinitely and then release the surface to resume flight.

SESSION 2S

HOT TOPICS: ROBOTS, AR, CV, AI

Session Moderator: Kurtis Heimerl, Computer Science and Engineering

JHN 175

3:30 PM to 5:15 PM

* Note: Titles in order of presentation.

Principles for Applying Augmented Reality to Manufacturing

Lexi Leo Rohrer, Freshman, Pre Engineering
Mentor: Rose Hendrix
Mentor: Santosh Devasia, Mechanical Engineering

Augmented Reality, the superimposition of digital features into the real world environment, has already made great strides in fields such as entertainment and advertising. However, the use of compound technology that bridges reality and the digital world has yet to be implemented cogently and thoroughly into the manufacturing field. This first part of this research paper explores the range of augmented reality hardware and software interfaces in fields such as medicine, academics, entertainment and advertising through a review of other scientific studies on augmented reality. Next, this research applies these observations to the current preliminary augmented reality trends specifically in the manufacturing field. Taking into account the positive and negative cognitive effects of augmented reality systems on attention, motivation, and ease of use, this paper then further delves into the potential uses of augmented reality in manufacturing. In the next section, this paper uses its examination of augmented reality's ability to cater the manufacturing community's needs to evaluate the advantages of implementing augmented reality technology in conjunction with human ability to improve the manufacturing process. Finally, the last section of this paper synthesizes the ideas presented into a set of principles for augmented reality use in manufacturing, and gives real-world examples of these principles' efficient applications.

POSTER SESSION 3

Balcony, Easel 91

2:30 PM to 4:00 PM

3D-Printed, Elbow-Driven Orthosis for Individuals with Limited Hand Function

Makoto Eyre, Non-Matriculated, Mechanical Engineering, North Seattle College
Karley Elisabeth Benoff, Senior, Mechanical Engineering
Mentor: Katherine Steele, Mechanical Engineering
Mentor: Keshia Peters, Mechanical Engineering

Upper- and lower-limb orthotic devices are prescribed for individuals who have partially lost motor control, such as stroke survivors or those with cerebral palsy, to assist with the stability and function of a limb. Unlike prostheses, devices available for those missing part of a limb, there are few current solutions available for upper-limb orthoses. As a result, options for users can be clunky, expensive, and hard to customize. The goal of this research was to further develop a 3D-printed elbow-driven orthosis that is inexpensive, adjustable, and helps users with impaired dexterity perform two-handed daily tasks. In comparison to traditional devices, which can cost hundreds of dollars, this orthosis can be assembled for approximately $30 predominantly because of the use of 3D printed parts. Originally designed for an individual whose seizure reducing brain surgery limited use of her left hand, this orthosis takes advantage of existing elbow range of motion to operate a clamp near the user's palm by using a cable extending from the elbow to the hand. Cable tension activates the clamp near the palm in two distinct ways, depending on chosen part placements; the cable can either voluntarily open the clamp, or voluntarily close the clamp with elbow flexion. To compare clamp activation methods, we conducted a study that evaluated muscle activity and time to complete activities of daily living using the adjustable orthosis. These results will help inform which device setting, voluntary opening or voluntary closing, is easiest to control for common tasks and inform future device improvements. Participants involved in this study included individuals with impaired and unimpaired hand function. Through a continuous cycle of prototyping, feedback, and device modifications, we have created a customizable, affordable, 3D printed upper-limb orthosis that will be open-sourced to promote further innovation to support individuals with limited hand function.

POSTER SESSION 3

Balcony, Easel 90

2:30 PM to 4:00 PM

Designing a Web Application for the Presentation of Muscle Synergies for Clinicians

Claire Lindsey Mitchell, Senior, Bioengineering
Mentor: Katherine Steele, Mechanical Engineering
Mentor: Benjamin Shuman, Mechanical Engineering

Patients with cerebral palsy tend to have altered muscle activations during walking compared their unimpaired peers. Quantifying these changes is important for clinicians to be able to proscribe treatment protocols. Every brain injury with cerebral palsy is unique, requiring patient specific measures of motor control. Muscle synergies are used to quantify a patient's motor control by using the electrical activity of individual muscles during walking. The resulting electrical activity of the muscles, electromyography, are processed using matrix factorization algorithms. These algorithms identify weighted groupings of muscles which are commonly activated during activities such as walking. However, across clinical institutions differences in data gathering protocols and resources, as well as muscle selection can make the interpretation of synergies challenging. Moreover, calculation of synergies requires programing and data processing expertise not uniformly available to clinicians. The aim of this research was to design a web application that could intuitively represent synergy results for clinicians and patients based upon the data they collect at their institution. This web application uses processing and factorization scripts in Python and integrates the results into JavaScript and HTML for an accessible and flexible display. The application allows the user to select the muscles they want to include in the analysis, as well as how many synergies they want calculated. Each synergy solution is displayed by presenting the weighting of every muscle in each synergy. Additionally, the application shows how accurately the synergies reconstruct the electromyography signals. Generated results from the application can be exported as a report for the patient and clinician to refer to. Because of the differences in data gathering practices across institutions, this research also looked to identify if there are specific ways to quantify how individual muscles impact synergy results so that synergy results can be more translatable across institutions.

POSTER SESSION 4

MGH 206, Easel 173

4:00 PM to 6:00 PM

Effective Utilization of Experimental and Modeling Data in Innovation via Machine Learning, Data Analytics, and AI: Looking inside the Black Box

John Taylor (John) Hamann, Senior, Mechanical Engineering
Jack Otto Ryan, Junior, Pre Engineering
Benjamin (Ben) Mac Millan, Sophomore, Pre-Sciences
Antonio R. Crowe, Junior, Chemistry, Materials Science & Engineering
Mentor: Mehmet Sarikaya, Materials Science & Engineering
Mentor: Siddharth Rath, Materials science and engineering, Genetically Engineered Materials Science and Engineering Center
Mentor: Burak Berk Ustundag, Materials Science and Engineering
Mentor: David Starkebaum, MSE

In scientific research labs, in general, experiments are generally treated as a black box: a prepared sample goes in, something happens, and one gets results that are then obtained via elaborate characterization steps. Several important dependent or correlated parameters are either discarded or ignored because of a lack of coherent dependency analyses that require critical thinking, linking, and pattern recognition. In this research we are working to stop treating experiments and computational simulations as black boxes, and create a cohesive platform where materials used, processes and parameters utilized and results achieved can be brought together as separate but related sets of databases. In the next step, the relationships between all the different parameters can then be connected, analyzed and visualized. Machine learning and AI techniques can then be used to predict results using these databases, thereby reducing experiment time, and taking away the traditional 'trial and error' method of experimentation. The research involves creation of a software interface, with numerous image and signal processing tools and applications running on libraries made customizable to research fields, types of experiments, etc. Assorted variety of services such as parallelization, compression, data analysis, and visualization, caching (among others) are also provided. We are improving the accuracy of time series data analysis and using fingerprinting to depict all parameters for improved predictability, flexibility and accuracy. When fully developed, we anticipate that the program will enable experimental and computational researchers to extensively use, customize and apply data analytics, machine learning and AI even in niche research in the hard sciences at the intersection of biology and genetics, materials science (physics, chemistry) and engineering, and computational modeling and informatics, enabling faster and accurate cross disciplinary innovation in technology and medicine. The research is supported by NSF-DMREF (DMR-1629071) program at GEMSEC-MSE, as part of National Materials Genome Initiative.

POSTER SESSION 4

Commons West, Easel 29

4:00 PM to 6:00 PM

A Two-Year Prospective Longitudinal Gait Analysis of Total Ankle Arthroplasty Patients

Alyssa Anne Ricketts, Senior, Bioengineering, Computer Engineering
Mary Gates Scholar, Undergraduate Research Conference Travel Awardee
Mentor: William Ledoux, Mechanical Engineering
Mentor: Christina Stender, Center for Limb Loss & MoBility

Osteoarthritis, a disease in which the cartilage that cushions joints is lost, affects 27 million people each year. Ankle arthroplasties, or total ankle replacements —i.e., replacement of joint surfaces with artificial materials— have become the procedure of choice for many end-stage ankle arthritis (ESAA) patients. The purpose of this study is to compare foot joint kinematic differences in end-stage ankle arthritis patients pre- and postoperative to receiving a total ankle replacement. Hypotheses over the recovery period include (1) increased range of motion in joint and planar angles, (2) negative correlation between patient pain and ankle function, and (3) ankle function converging towards that of normal gait patterns. Twenty adults with ESAA scheduled for ankle arthroplasty surgery were evaluated preoperatively and at 12 and 24 months postoperatively. A validated five-segment foot model was applied to the affected limb using retro-reflective markers. The model allowed for five three-dimensional joint angles and eight planar angles to be calculated. Subjects completed follow-up surveys self-assessing function and pain preoperatively and at 3, 6, 12, and 24 months postoperatively. Results are limited as the longitudinal study is still ongoing.

Thus far, mean joint rotations show increased range of motion at the ankle joint, decreased range of motion between the midfoot and forefoot, and decreased toe splay during the stance phase of gait 24 months postoperative. Correlation between patient pain and ankle function show a trend in decreasing ankle range of motion with increased patient pain, both preoperatively and 24 months postoperatively. Patient pain also significantly decreased between every survey administration time point. These findings will likely aid ESAA patients when considering ankle arthroplasty surgery, informing them about expected recovery and comparing trade-offs between pain and function. Future work includes the ongoing collection of control data for comparison.

POSTER SESSION 4

Commons West, Easel 15

4:00 PM to 6:00 PM

The Aortic Dissection Calculator

Alyssa L. Schul, Senior, Bioengineering
Mentor: Alberto Aliseda, Mechanical Engineering

The Aortic Dissection Calculator, focuses on applying demographics, various genetic risk factors, and Computational Fluid Dynamics(CFD) to each patient case to create a predictive model of when a patient's dissection will become problematic, requiring intervention. Risk factors include: genetic diseases, lifestyle choices, and demographic information. The necessity of this research lies within the ability to change the course of an otherwise dismal outcome by identifying patients at risk of this condition, and provides features that will help reduce the risk of death related to type B aortic dissections (TBAD). This project will be able to provide a more detailed timeline and better treatment plan to allow preventative measures and decrease the likelihood of death. CT scans of patients with TBAD are used as a building block for the construction of the 3-D vessel analysis portion of the project. These cases are imported into VMTK (Vessel Modeling Tool Kit) where a rough draft of patients' aorta is created by a semi-automatic vessel creation software. Once this rough vessel has been created and exported, the case is moved into Slicer to be cleaned up. SolidWorks, a fluid modeling software, is utilized to model blood flow from the heart. Each patient has a unique pulse rate and blood pressure, thus by applying these specific constraints to the modeling software it produces forces identical to those found in the patient's body. The material collected from multiple trials is analyzed to discover where the vessel is the weakest and where the dissection is most likely to occur based upon growth over time. These simulations allow us to test the wear and tear on the aorta over time. Tests for failure will be used in the predictive modeling of the calculator.