Online Proceedings

Poster Session 1

Commons East, Easel 73

11:00 AM to 1:00 PM

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

Jessy Ha, Senior, Mechanical Engineering
Karley Elisabeth Benoff, Senior, Mechanical Engineering
Mentor: Katherine Steele, Mechanical Engineering
Mentor: Keshia Peters, Mechanical Engineering

Orthotic devices are prescribed for individuals who have partially lost motor control, such as stroke survivors or those with cerebral palsy, to assist with stability and function. Unlike prostheses, devices available for those missing part of a limb, there is a limited market 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 develop a 3D-printed elbow-driven orthosis that is inexpensive, adjustable, and helps users to perform two-handed daily tasks. Inspired by our participant who has limited hand function on her left side due to a seizure reducing brain surgery, we took a user centered design approach. By tuning the cable length running from the elbow to the hand, we took advantage of her existing range of motion to activate a clamp near the palm. We chose a modular approach for the clamp to suit a variety of daily activities, such as picking up small objects and holding a drumstick. In comparison to traditional devices that can reach hundreds of dollars, our cost has been reduced to roughly $20 largely because of the use of 3D printed parts. Through a continuous cycle of prototyping, receiving feedback, and modifying the design accordingly, we have created a device adapted to suit both adult and child sizes. While feedback from unimpaired participants was primarily received, we also plan to further test the device on individuals with limited hand function for more diverse perspectives from potential users. Ultimately, we aim to publish our designs open-source to promote further modifications and availability.

Poster Session 1

Commons East, Easel 74

11:00 AM to 1:00 PM

Impact of Print Settings and Annealing on the Structural Properties of 3D-Printed Materials

Michael B. (Michael) Mac Connell, Senior, Mechanical Engineering
Mary Gates Scholar
Mentor: Katherine Steele, Mechanical Engineering

Additive manufacturing (3D printing) has gone from being relatively unknown 20 years ago to being nearly ubiquitous today. Although 3D printers have become more and more common and the list of different types of 3D printers continues to grow, little work has been done to quantify the material properties of 3D printed materials. Finding relationships between shell thickness, infill percentage, infill shape and other print settings would give the 3D printing community a more quantitative way to increase print strength for a given filament type and print geometry. A relatively new aspect of 3D printing is the use of annealing to increase the strength of the printed part. By doing so the filament softens enough to spread out and form additional bonds between the layers and theoretically increases the strength of the print in the print plane. To facilitate this research and to find relationships between print settings and annealing, tensile testing was performed on dog-bone shaped samples (constructed using a fused deposition printer) using different print settings, and on annealed specimens. At the same time mechanical testing was performed, a computer generated model of 3D printed materials was generated using a method called finite element analysis. Tensile testing data was used to check the model for accuracy and insure the predicted 3D printed material behavior in the model is representative of what is seen in test specimens.

Session 1B

Techniques for Improving Quality of Medical Care

Session Moderator: Eric Seibel, Mechanical Engineering

MGH 228

12:30 PM to 2:15 PM

* Note: Titles in order of presentation.

Improving Accuracy of At-Home, Preventative Oral Health Care through Customized Teeth Models

Hae In (Angel) Lee, Junior, Computer Engineering
Mentor: Eric Seibel, Mechanical Engineering

Recent technology introduced by Phillips Sonicare attempts to address the challenge of improving at-home, preventative oral health care for children by providing users encouragement and guidance on how and where to brush based on rough estimations that are visually represented to the client on a general, perfect teeth model. Although this innovation is a step towards empowering individuals to improve their oral health from information outside dental clinics, there are limitations to the actual improvement that can be made due to its implementation. By combining and creating new tools that will work with advanced intraoral cameras, I intend to take the next step in improving at-home, preventative care through a design that will be more personal and accurate than any existing one. More specifically, my goal is to develop software that can create personalized teeth models, representative of the user's teeth. Through a series of manipulating a perfect, 3D animated teeth model from Animium, I examine the object files, which are 3D model files, treating them as text files and observe how they change for a specific edit through a 3D model editor such as Autodesk 3ds Max. These observations are used to create general algorithms for a specific edit which is combined into a program that can generate personalized teeth models, such as missing or crooked teeth. With a more personal model, the users are more accurately guided to a specific lesion on their teeth, resulting in more effective application of medicinal therapies and optical monitoring of healing.

SESSION 1H

HIV: DIAGNOSTICS, DRUG RESISTANCE, AND ANTIBODIES

Session Moderator: Dara Lehman, Global Health, Human Biology

MGH 251

12:30 PM to 2:15 PM

* Note: Titles in order of presentation.

Point-of-Care Nucleic Acid Amplification Diagnostic for HIV-1 Using Isotachophoresis

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

As of 2015, approximately 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 accurate diagnosis and disease monitoring through lab-based instrumentation systems, such as nucleic acid amplification tests (NAATs), are inaccessible. Thus, there is an increasing need for accurate, affordable HIV-1 VL tests at the point-of-care (POC). We have leveraged an electrokinetic separation and preconcentration technique, isotachophoresis, and an isothermal nucleic acid amplification method to develop a fully integrated POC NAAT for extraction, amplification, and detection of HIV-1 nucleic acids in whole blood. We have demonstrated the ability to extract these nucleic acids from human serum and quantify the nucleic acid amplification with fluorescent detection. The fluorescent read-out is correlated to the initial sample concentration, providing semi-quantitative VL information. Our device operates in a single step with limited equipment in 15 minutes, consequently cutting the time, cost, and complexity of NAATs for infectious disease diagnosis, especially in low-resource settings. Our POC NAAT has the potential to improve patient care, and we are currently investigating applying this technology to diagnose other infectious diseases.

POSTER SESSION 2

Commons East, Easel 57

1:00 PM to 2:30 PM

Fabricating Tooth Fixture for X-Ray Computed Tomography 3D Scan

Minh Thu Thu (Minh) Tran, Junior, Mechanical Engineering
Mentor: Eric Seibel, Mechanical Engineering

In modern dentistry, the goal is to remineralize small lesions in the teeth, before there is a cavity. To monitor the healing process in teeth, infrared 3D optical imaging is being developed at the UW that does not have the safety risk of x-ray imaging. However, to calibrate this new prototype, teeth with natural lesions need to be imaged with x-ray to create a gold standard of lesion volume and density. This project will design, build, and test a fixture that will hold a tooth of various shapes, sizes, and orientations for microCT (computed tomography) scanning to obtain a high resolution 3-D image. X-Ray CT scanning can provide a high quality 3D image; however, it is harmful to use directly on humans due to large dose of radiation needed to form 3D images. This research and development project will use the new UW CT Scanning system in Moore Hall with highest 3D resolution of 2 microns. The fixture was designed by taking dimensions of the existing rotational plate of the CT Scanner, and the CAD design file is in the process of being 3D printed. The fixture must mitigate any effects from the CT scanner during operations (such as heating and vibration during scanning), and must be versatile so that it can hold different sizes of teeth at different orientations. The fixture design will be designed to also accept commercially available calibration specimens of known spatial and density values to ensure that image quality is being preserved.

Poster Session 2

Commons East, Easel 58

1:00 PM to 2:30 PM

Surface Imaging System for Needle Biopsy to Detect its Adequacy and Rapid Cancer Lesion through Milli-Fluidic Device

Roujia Wang, Senior, Bioengineering
Levinson Emerging Scholar, Mary Gates Scholar, UW Honors Program
Mentor: Eric Seibel, Mechanical Engineering

Core needle biopsy (CNB) is used as a minimally invasive method to diagnose prostate and other cancers. However, this method still has limitations of getting non-diagnostic and inadequate CNBs due to sampling error. Thus extra CNBs are often taken and other time-consuming tests looking at surface cellularity such as histological evaluation on tissue smears are done to reduce probability of this error, which leads to needless pain and cost. Therefore, we propose to design a rapid-on-site evaluation system by imaging the outer surface of needle biopsy samples. This system generates a whole surface image of CNBs that contain cellularity information as a quicker and more informative adequacy testing of CNBs. This proposed project aims to develop cost-efficient imaging for obtaining sub-cellular and structural information from CNBs at the point-of-care. There are three phases: Design of System, Development Image Stitching Algorithm, and Integration, testing, and generating surface image. Phase I aims to determine the optimal optical imaging system and developing a staining protocol for CNBs. Phase II is developing an image stitching algorithm that takes in images from Phase I. Phase III will integrate I and II and generate a whole surface image of CNBs to provide morphological features for clinicians so that they can determine the adequacy of biopsy and needs for additional biopsies. The main criterion of this design is to perform evaluation within 20 minutes while still maintain intactness of specimen. If the design is successful a commercial device will speed the process by 10x (<2 minutes), while maximizing use of CNBs and reducing the number of biopsies taken to minimize suffering of patients. It may also accelerate diagnosis speed for prostate cancer. Importantly, this design can be applied to other types of cancer diagnosis, such as remote radiology clinics where a pathologist is typically not available.

Poster Session 2

Commons East, Easel 66

1:00 PM to 2:30 PM

Permeability, Diffusivity, and Tortuosity of Polyetherimide Nanofoams

Yuxin Fu, Senior, Mechanical Engineering: Mechatronics
Mary Gates Scholar
Mentor: Vipin Kumar, Mechanical Engineering

My work is concerning polymer nanofoams, a thermoplastic material processed to have an interconnected porous structure with nanometer sized channels. These materials have applications in fluid filtration, medical devices, insulators, catalysts, and templates. While many techniques exist to create such structures, the material discussed here is made by the solid-state foaming process. This is a simple technique in which CO2 blowing agent is dissolved into the polymer in the solid state, and then heated to the glass transition to initiate cell nucleation and expand the polymer. I am in charge of the whole samples foaming process. Besides that, I analyze these samples under SEM (Scanning Electron Microscope) cooperating with my mentor. These expanded polyetherimide (PEI) by foaming process has been shown to have an interconnected porous structure with channels on the order of 50-100 nm. Dye permeation tests conducted by me confirm that the nanostructure will allow fluids to flow through. However, no work has been done to quantitatively characterize this material and obtain its permeability. Krause et. al has done basic experiments where nitrogen and helium gas was flowed through the cross-section of a PEI membrane, but no material property was derived from these experimental results. In my research, a material property known as permeability is computed by experimental data in conjunction with a fluid flow model derived by my mentor. Additionally, the diffusivity of gasses through the nanostructure is also computed and correlated to the permeability. Finally, the relationships between a processing parameter (foaming temperature) and porosity, permeability, and diffusivity are established.

Poster Session 2

Commons East, Easel 71

1:00 PM to 2:30 PM

Swarm Robotics

Jesse Anthony (Jesse) Hernandez, Junior, Physics: Applied Physics
Nini Hong, Junior, Mechanical Engineering
Mentor: Santosh Devasia, Mechanical Engineering

Swarm robotics consists of multiple robotic systems that interact with each other within a set environment. Inspiration for swarm robotics comes from behaviors observed in biological systems, namely insect colonies, that migrate collectively. Robots in a swarm are decentralized and behave independently, but their movements are based on that of their surrounding neighbors, thus collective movement is reliant on sensing and modification of each robot. Different algorithms are available for different types of swarms, but the overarching idea of decentralization and simplistic independent behavior persists. The collaborative effort between these robots is critical when performing a task in an efficient and timely manner. However, methods of attaining advanced swarm robotic behavior is limited to expensive laboratory manufacturing. To address this limitation, this work focuses on developing a process for creating low-cost, three-dimensionally printed robots with swarm intelligence. The design of the robotic swarm consists of wheeled robots equipped with sensor electronics, such as proximity and accelerometer sensors, and computer software applications for robot control. Currently, the main application is for tabletop uses such as having the robots work together to form shapes and move small objects. Future applications include human-robot interaction, such as utilizing the robots to provide assistance for the physically disabled. Thus, the main contribution of this work is a manufacturing process for low-cost, three-dimensionally printed swarm robots.

POSTER SESSION 2

Commons East, Easel 59

1:00 PM to 2:30 PM

Characterization and Photostability of a Red Fluorescent Standard

Jasmine Yu Graham, Senior, Bioengineering
Mary Gates Scholar
Mentor: Eric Seibel, Mechanical Engineering
Mentor: Leonard Nelson, Mechanical Engineering

Protoporphyrin IX (PpIX) is a red fluorescent metabolic byproduct of oral bacteria and serves as an indicator of early and late stage caries. PpIX has a strong absorption band centered at 405 nm and exhibits an emission range from 615 to 710 nm. Spectroscopic and imaging devices targeted at PpIX require a fluorescent standard for calibrating their detection sensitivity. However, PpIX lacks photostability and an alternate molecule is needed to represent the excitation and emission fluorescence characteristics of PpIX. Evaluation of instrument performance over time is especially important for long range clinical studies examining changes in fluorescence in response to disease therapies. The scanning fiber endoscope (SFE) is an optical imaging system currently used in clinical dental research to quantitatively monitor the fluorescence of PpIX. Water based solutions of PpIX are unstable and led us to develop a dye-in-polymer standard that offers photostability, portability, and uniform fluorescence. Organic europium complexes model the fluorescence spectrum of PpIX closely, with a similar red emission range from 615 to 710 nm. Preliminary photobleaching experiments using a 405 nm laser illuminating a europium dye embedded in a polyurethane polymer demonstrated that it offers significantly better photostability than PpIX, exhibiting a 3-4% drop in europium fluorescence after one hour of continuous laser excitation. Under similar laser illumination conditions another PpIX phantom molecule, octaethylporphyrin (OEP), suffered a $>20\%$ drop in fluorescence after only 3 minutes of excitation. The photodegradation curve over time for europium was evaluated using the same 405 nm laser and LED excitation sources used for measuring the pH dependence of PpIX fluorescence in oral biofilms. Dye-in-polymer europium materials were also exposed to elevated temperatures in addition to laser illumination to further assess their suitability as fluorescence standards.

SESSION 2E

ADVANCED TECHNOLOGIES FOR HEALTHCARE AND OTHER APPLICATIONS

Session Moderator: Daniel Kirschen, Electrical Engineering

MGH 238

3:30 PM to 5:15 PM

* Note: Titles in order of presentation.

The Impact of Blade Mounting Geometry on Cross-Flow Turbine Performance

Noah E (Noah) Johnson, Senior, Mechanical Engineering
UW Honors Program
Mentor: Brian Polagye, Mechanical Engineering
Mentor: Benjamin Strom, Mechanical Engineering

Cross-flow turbines are a promising approach for extracting renewable energy from tidal and river channels. These turbines consist of a set of blades rotating about an axis perpendicular to the water flow direction. While blade mounting geometry has implications for parasitic drag, lift-induced drag, and blade lift generation, which strongly influence turbine performance, little research has been published on this topic. The impact of blade mounting geometry on turbine performance was evaluated by comparing the power conversion efficiency of ten two-bladed turbines with varying mounting geometries in a recirculating water flume. Each turbine was also tested without blades to evaluate interactions between blades and mounting geometry. A servomotor rotated the test turbine at constant angular velocity and two six-axis load cells were used to measure the torque produced by the turbine rotor. Six tests were performed with connecting struts at each end of the blades. Cross sectional geometry (rectangular, rounded, and foil) and thickness were varied (chord length held equal to the blade). Three tests were also performed with solid disks of varying radii mounted to each end of the blade. Finally, one test was performed with a single foil strut mounted at the center of blade span. Complete performance curves at four Reynolds numbers were generated for each mounting geometry by varying the free stream velocity. At the highest Reynolds number, the thin foil strut performed with greatest efficiency, followed by the thin rounded strut and thick foil strut. The smallest disk, thin rectangular strut, and thick rounded strut performed similarly. Strut and disk drag was analytically modeled and compared with experimental data to characterize power loss from each mounting geometry. These results offer insight into cross-flow turbine design for optimal efficiency and encourage investigation of additional mounting geometries such as winglets or curved mounting interfaces.

POSTER SESSION 3

Commons East, Easel 66

2:30 PM to 4:00 PM

Streaming GPU Singular Value and Dynamic Mode Decompositions

Seth Daniel (Seth) Pendergrass, Senior, Computer Engineering
Mary Gates Scholar
Mentor: Steven Brunton, Mechanical Engineering
Mentor: J. Nathan Kutz, Applied Mathematics

This work develops a parallelized algorithm to compute the dynamic mode decomposition (DMD) on a graphics processing unit using the streaming method of snapshots singular value decomposition. This allows the algorithm to operate efficiently on streaming data by avoiding redundant inner-products as new data becomes available. In addition, it is possible to leverage the native compressed format of many data streams, such as HD video and computational physics codes that are represented sparsely in the Fourier domain, where a signal is analyzed in terms of sinusoidal frequencies rather than time. This massively reduces data transfer from central processing unit (CPU) to graphics processing unit (GPU) and enables sparse matrix multiplications. Taken together, these algorithms facilitate real-time streaming DMD on high-dimensional data streams. We demonstrate the proposed method on numerous high-dimensional data sets ranging from video background modeling to scientific computing applications, where DMD is becoming a mainstay algorithm. The computational framework is developed as an open-source library written in C++ with CUDA, and the algorithms may be generalized to include other DMD advances, such as compressed sensing DMD, multi resolution DMD, or DMD with control. Keywords: Singular value decomposition, dynamic mode decomposition, streaming computations, graphics processing unit, video background modeling, scientific computing.

POSTER SESSION 3

Commons East, Easel 61

2:30 PM to 4:00 PM

Scalable Synthesis Method for Monodisperse Silica Nanoparticles

Brandon Y. (Brandon) Chen, Senior, Mat Sci & Engr: Nanosci & Moleculr Engr
Mentor: Devin MacKenzie, MSE and ME
Mentor: Holly Brunner, Materials Science and Engineering

Composite materials utilizing nanoparticles can exhibit improved properties and qualities. Silica (SiO_2) nanoparticles exhibit unique optical, electrical, and mechanical properties and are an ideal candidate for the dispersed phase in many applications, such as precursors for optical films with controlled optical properties and rheology. Atomic forces dominate when particles shrink to sizes below the visible wavelength spectrum, generating unique phenomena. One problematic phenomena, however, is the agglomeration of primary particles into a polydisperse collection of dimer, trimer, or larger secondary particles when calcined or mixed into the continuous phase of the composite. Monodisperse colloids and nanopowders are critical for consistent and optimized performance of composites and nano features. Silica particle synthesis has been well researched, but the practicality of producing pure, monodisperse, and non-agglomerated particles at scalable operations is still in question. This research investigates the factors leading to the agglomeration of spherical silica nanoparticles when synthesized with variations of the Stöber method, and evaluates changes in synthesis parameters that can reduce agglomeration in order to determine the most viable process for scalable production. Parameters that are manipulated include the ratio of ammonia catalyst with tetraethyl orthosilicate (TEOS) in ethanol or methanol solvents and the addition of anionic electrolytes. SEM imaging is then used to evaluate the distribution of the particles. Surface treatments for anti-agglomeration as incorporated into the synthesis process or as post processing are also evaluated, with minimal remnant impurities in the product as a priority. The end goal of this research is to successfully synthesize monodisperse sub-10 nanometer silica particles for pseudoplastic shear-thinning precursors used in fast throughput nanoimprinting of an antireflective layer for solar cells.

POSTER SESSION 3

Commons East, Easel 58

2:30 PM to 4:00 PM

Study of Diffusion Lengths in MAPI Perovskites through Photoluminescence Spectroscopy

Doc Daugherty, Senior, Mat Sci & Engr: Nanosci & Molecullr Engr
Mentor: Devin MacKenzie, MSE and ME

Single-junction solar cells that employ metal-halide perovskites have generated intense interest due to their rapid increase in demonstrated power conversion efficiency. In contrast with previously explored solar cell active materials, perovskites are solution-processable, tunable band-gap materials with small energetic losses. Because of this they are ideal candidates for use in tandem solar cells, which integrate a large-bandgap and a small-bandgap solar cell into one structure, significantly increasing maximum efficiency. Current tandem solar cells can have marked efficiency loss due to excess window layers and poor layer design leading to absorptive losses. Additionally, the comparatively poor understanding of perovskite processing methodology can result in suboptimal perovskite active layers. Our goal was to explore the feasibility of using a metal grid-type electrode collection layer in place of a standard transparent window layer, in order to minimize absorptive losses for successful integration into a tandem structure. Principally important to characterizing this structure was exploration of device fabrication and perovskite processing methods that resulted in effective carrier extraction. The mean diffusion length of charge carriers in a material is one of the primary factors that affect carrier extraction. Current literature gives a diffusion length ranging from 0.3 – 10 um for methylammonium lead iodide (MAPI) perovskite layers. We fabricated test cells with electrode grid pitches ranging from 0.4 – 10 um using photolithography techniques. We then explored the effect of variable deposition method, heat treatment and solution composition as well as observed layer morphology on diffusion length and charge extraction using photoluminescence spectroscopy.

Poster Session 3

Commons East, Easel 60

2:30 PM to 4:00 PM

Impact of Zinc Oxide on Quantum Efficiency of Perovskite Solar Cells

Neema Rostami, Senior, Mat Sci & Engr: Nanosci & Molecullr Engr
Gavin Wayne (Gavin) Ames, Senior, Mat Sci & Engr: Nanosci & Molecullr Engr
Mentor: Devin MacKenzie, MSE and ME

In the last 10 years, perovskite solar cell efficiencies have increased from four to over twenty percent. Perovskite materials possess great application in thin-film photovoltaics and roll to roll processing. Unlike in traditional silicon solar cells with layer thicknesses on the order of 100 microns, the perovskite layer in a thin-film photovoltaic can be fewer than 100 nanometers. This study looks at the suitability of zinc oxide nanoparticles for use as an electron transport layer in a lead halide perovskite thin-film. Of particular interest is the ability to adjoin the zinc oxide and perovskite layers without any degradation of the perovskite. The effects of solvents, additives (i.e. surfactants), and particle size are analyzed using a variety of methods such as x-ray diffraction, transmission electron microscopy, and photoluminescence spectroscopy to determine optimal interfacial properties and exciton separation in the electron transportation layer. The success of the ZnO layer is further analyzed by comparing the quantum efficiencies and current-voltage characteristic curves of the assembled solar device to an identical solar cell that uses PCBM as the electron transport layer. PCBM is one of the most effective electron transport layers, but due to high cost, the need for alternatives such as ZnO was made necessary. The overall goal of this project is to attain efficient solar cells, using cost-effective materials and processing methods. By doing so, it will open up the field of solar energy for a wider market and broader applications.