UNIVERSITY of WASHINGTON

Undergraduate Research Symposium May 18, 2012 Mary Gates Hall

Online Proceedings

POSTER SESSION 1

MGH 241, Easel 155

12:00 PM to 1:30 PM

Using a Mixture Controlled Turbidostat to Increase Sensitivity of Biomolecular Pathways in *E. coli*

Felix Ekness, Senior, Bioengineering
Mentor: Eric Klavins, Electrical Engineering
Mentor: Chris Takahashi, CSE

Tuning the gene expression of biomolecular pathways is an area of intense interest and value to synthetic biologists. Through the use of a mixture controlled turbidostat (MCT), we have been able to streamline, and in many cases enable the processes involved in this area of study. A turbidostat is a continuous culture bioreactor that maintains constant culture volume and cell density while diluting with fresh media to keep cells in an exponential growth phase. With the addition of mixture control, the turbidostat can vary the chemical environment within the culture vessel without altering cell density levels. Tuning gene expression in *Escherichia coli* is a simple matter when using a MCT. Currently, an area of global interest is the industrial production of butanol with *E. coli.* The first step towards this is enabling *E. coli* to live in rich butanol environments. Because butanol is naturally toxic to *E. coli,* an increase in gene expressions of the biomolecular pathways responsible for detoxification of butanol is required. By placing laboratory grade *E. coli* into our MCT, the concentration of butanol can be increased over time while the cell density remains constant. This will allow fitness increasing mutations within the biomolecular pathways responsible for detoxification of butanol to prevail over many generations, with the hope of eventually converging to a final population of *E. coli* that subsists in highly concentrated butanol environments. Through increasing *E. coli's* resistance to butanol, we hope to illustrate the usefulness of MCTs in tuning gene expression of biomolecular pathways.

POSTER SESSION 1

MGH 241, Easel 154

12:00 PM to 1:30 PM

Engineered Evolvability in Bacteria

Rahul Francis (Rahul) Brito, Senior, Bioengineering
Mentor: Eric Klavins, Electrical Engineering
Mentor: Rob Egbert, Electrical Engineering

In a population of organisms, traits that increase fitness, or the ability to survive and reproduce, are passed on to progeny and become more prominent in the gene pool. It has been similarly shown that E. coli with a phenotype that increases or decreases fitness given an environmental pressure can be tuned to correspondingly decrease or increase fitness through random mutagenesis and selection of desired mutants. However, this process does not focus mutations and does not confer the maximum fitness benefit or cost per mutation. In order to isolate mutation location and effect, and increase the rate at which evolution occurs, I am applying a tool called Simple Sequence Repeats (SSRs). SSRs are repeats of short nucleotide sequences (AAA..., ATATAT..., etc.) that have been shown to mutate primarily in the form of insertions or deletions of an SSR and have a rate of mutation four to five orders of magnitude higher than non-repeat sequences. Most importantly, it has been shown that when SSRs are inserted between the ribosome binding site (RBS) and start of a gene, every insertion or deletion has a discrete, predictable effect on the level of expression for that gene. We have inserted SSR spacers in front of lacZ, lacY, and lacI in the lac system, and will show that we can rapidly optimize the expression of the genes. This could serve as a significant tool for tuning other, novel behaviors in bacteria.

POSTER SESSION 1

MGH 241, Easel 156

12:00 PM to 1:30 PM

Engineering a New Yeast Strain: Biosynthesis of Indole-3-Acetic Acid in *Saccharomyces cerevisiae*

Tammy Ting Gu, Senior, Bioengineering
Mentor: Eric Klavins, Electrical Engineering
Mentor: Nick Bolten, Electrical Engineering

Indole-3-acetic acid (IAA), or auxin, is a plant growth hormone that is vital to the regulation of growth and development in plants. Although auxin's function in plants is to control growth, it potentially regulates any gene in other organisms, making it a powerful regulatory tool. By investigating the synthesis of auxin, it can be generated in organisms besides plants. The goal of this project is to take

the first step towards that reality through the synthesis of auxin in *Saccharomyces cerevisiae* (baker's yeast). Due to the thorough characterization of *S. cerevisiae*, the organism is an optimal choice because the mechanisms involved with the manipulation of its gene networks are well understood. This project integrated the tryptophan-2-monooxyngenase (iaaM) and indole-3-acetamide hydrolase (iaaH) genes from *Agrobacterium tumefaciens* into the yeast genome. The enzymes produced from these genes convert tryptophan into auxin. In an attempt to reproduce this synthesis pathway, the two genes were amplified and integrated into the yeast genome through the use of the Gateway®cloning system and integrating vectors. Checking for successful auxin synthesis utilizes the auxin signaling pathway that was built in *S. cerevisiae* by the Klavins Lab. This system involves interactions between two proteins, an AFB (auxin signaling F-box) and an Aux/IAA (a transcriptional regulator of auxin responsive genes). The presence of auxin triggers the degradation of an Aux/IAA. By fluorescently tagging an Aux/IAA, the expression of the protein was observed. A decrease in fluorescence indicates the production of auxin. Successful auxin synthesis in yeast creates further possibilities for establishing regulatory systems based on the use of auxin in non-plant cells.

SESSION 1O

BIOCHEMICAL, MOLECULAR, AND BIOMEDICAL ENGINEERING

Session Moderator: Daniel Ratner, Bioengineering

Mary Gates Hall 389

1:00 PM to 2:30 PM

* Note: Titles in order of presentation.

Online Quantification of Dynamic Mechanical Properties of *In Vivo* Soft Tissue for Use in Robotic Surgery

Andrew John (Andrew) Hill, Senior, Bioengineering
Mentor: Howard Chizeck, Electrical Engineering
Mentor: Blake Hannaford, Electrical Engineering

Minimally invasive surgical (MIS) techniques, such as laparoscopic surgery (performed through small incisions using specialized tools), are an integral part of modern medicine and the future of surgery. Technologically advanced tools such as MIS robots are promising to replace or augment existing MIS manual tools. MIS robots improve on manual surgery, as they can incorporate increasingly sophisticated features such as force feedback for surgeons, automatic identification of diseased tissues, and partial automation of surgical tasks. These features can reduce patient pain, recovery time and thus healthcare costs by eliminating unintended damage to tissue and providing surgeons with tools to perform surgery more effectively. Each of these new features either requires or would greatly benefit from an accurate mathematical description of the dynamic mechanical properties for the tissues with which surgeons interact. Dynamic tissue property quantification requires that we apply a range of forces to the tissue and measure the resulting displacements. We have designed, built, and calibrated a device capable of collecting the necessary data to obtain an equation relating applied force to tissue displacement for any tissue of interest. We will process the data obtained from this device using an advanced signal processing and system identification algorithm (unscented Kalman filtering), which will evaluate the fit to the data recursively over time. This will allow us to maintain accurate results as the tissue properties change over time. This setup allows us to collect and analyze data from tissues including (but not limited to) *in vivo* abdominal organs in pigs. In addition to being an important study that has not been performed in the literature, the real-time collection and analysis of this data could have profound implications in partially automating surgery.

POSTER SESSION 2

MGH 241, Easel 167

2:00 PM to 3:30 PM

Phase Change Memory Nanowire in the Mesoscopic Scale

Chia Ning (Chia-Ning) Wang, Senior, Electrical Engineering
Xingyi Shi, Senior, Electrical Engineering
Mentor: Anant M.P. Anantram, Electrical and Compuer Engineering
Mentor: Jie Liu

Phase Change Memory (PCM) exploits the difference in resistivity between the amorphous and crystalline solid phases of chalcogenide alloys. With easier scalability, faster write speeds, and higher switch endurances, PCM is set to replace Flash Memory and lead the way to greater functionality of our everyday electronic devices. The major obstacle preventing development of this technology is the power required to transition between the two solid states. In order to switch between phases, the material must first be melted and at greater cell densities, it becomes uncertain if the memory access device can supply enough current for resistive heating. A solution for the high power consumption is to adopt a nanowire (NW) structure whose geometry lowers the melting temperature of the phase change material. Our research was focused on improving simulation codes written by Ph.D. student Jie Liu for Nanowire Phase Change Memory (NW-PCM). As the code was based on macroscopic electro-thermal equations, a significant part of the research became to determine how accurately macroscopic physics could describe the operations of NW-PCM cells with mesoscopic dimensions - where quantum mechanics is known to cause fluctuations from classical results. By simulating published experiments on NW-PCM and comparing the results, we concluded that NW-PCM with

dimensions ranging from 5nm – 200nm can be adequately described by classical physics within an error margin. The conformity of results for NW-PCM dimensions as low as 5nm was unexpected as devices with dimensions smaller than 10nm have been experimentally observed to undergo ballistic electron transport. The anomaly piqued interests in the published experiment that caused it and the data analysis from our research as a whole went towards identifying how the simulation should be improved.

POSTER SESSION 2

MGH 241, Easel 162

2:00 PM to 3:30 PM

Development of Diamond Based Magnetometer for Nanotag Sensing at Room Temperature

Zhiting Zhu, Junior, Electrical Engineering, Computer Engineering
Mentor: Kai-Mei Fu, Physics/ECE

The ability to detect magnetic nanoparticle tags could be an important technique in a wide variety of biological applications such as particle tracking and immunoassay labeling. We aim to detect magnetic fields at the nanometer scale using the optical detection of the electron spin resonances of Nitrogen Vacancy (NV) centers in diamond. This system combines the possibility of high spatial resolution with magnetic sensitivity. I am developing a diamond based magnetometer designed for biomagnetic nanotag sensing at room temperature. The magnetometer is a diamond substrate with a dense layer of NV centers at the surface. Magnetic nanoparticles are placed on the surface and detected by utilizing wide-field photoluminescence imaging. The intensity of the NV photoluminescence is highly sensitive to magnetic field; therefore we can obtain information about the local magnetic field magnitude and direction and thus the position of the nanotags. I am working on building data acquisition and instrument control software for the magneto-optical microscope. It involves instrument control of a Radio Frequency (RF) signal generator, automated data acquisition using an EMCCD camera, integration of RF unit with data acquisition and real time image processing.

POSTER SESSION 2

MGH 241, Easel 154

2:00 PM to 3:30 PM

Dietary Data Recorder System

Eric Philip (Eric) Pepin, Senior, Electrical Engineering
Mary Gates Scholar, NASA Space Grant Scholar
Mentor: Alexander Mamishev, Electrical Engineering
Mentor: Junqing Shang, Electrical Engineering

In recent years, electronic sensors, database technologies, and digital devices have been successful in improving the automated collection of personal activity data in a pervasive manner. Through these developments and advancements in mobile computing, the ability to accurately record and maintain complex health records has been realized. Yet, although an instrumental tool in preventative medicine, dietary assessment still lacks automated and objective means of data collection and analysis. Current methods of clinical dietary assessment are paper-based, burdensome, costly, and subject to bias, especially in terms of the estimation of food volume intake. To improve upon these deficiencies, we have developed the Dietary Data Recording System (DDRS). The DDRS incorporates a client-server architecture to efficiently collect, process, and store dietary data. The client is a mobile sensor package that is used for data collection, and the server runs image processing algorithms and maintains a database where organized and processed intake information can be accessed by clinicians through a specialized interface. The foundation of the sensor package is a Mobile Structured Light System (MSLS), which uses a laser to project patterns on viewed food and a mobile phone camera to capture video. The distinctive feature of the DDRS is the use of the MSLS and image processing techniques to determine the volume of food from recorded video without the aid of scale-identifying fiducial markers. Preliminary results prove the feasibility of this approach for assessing dietary intake with the DDRS, and future work will focus on automating and integrating the entire processing pipeline. The automated diet intake tracking resulting from this future development could provide clinicians with an invaluable tool in definitively correlating the long term intake of certain foods to cancer, heart-disease, diabetes, and various health disorders.

POSTER SESSION 2

MGH 241, Easel 163

2:00 PM to 3:30 PM

Detection and Correction of Errors in Statistical Machine Translation Output for Translation of Public Health Materials

Adrian Andrew Laurenzi, Senior, Computer Science, Biology (General)
Levinson Emerging Scholar, Mary Gates Scholar
Mentor: Katrin Kirchhoff, EE

Translation of public health materials to Spanish is important because many Spanish speakers in the U.S. have limited English proficiency. Health departments generally outsource translation of health materials and cannot afford to translate many important materials to Spanish. Use of statistical machine translation (SMT) software combined with post-editing to correct errors in SMT output by bilingual staff could reduce the cost of translating documents and dramatically increase access to public health information for the Spanish-

speaking population. Raw SMT output such as that from Google Translate is not accurate enough to be used in published materials. Our goal is to develop technology that, given an English document and a statistical machine translation to Spanish, detects and corrects translation errors to minimize the need for post-editing. We analyze linguistic features of machine translations to automatically detect translation errors. We focus on detection and correction of error types found to be most displeasing to potential readers of translated materials. We employ a language model (LM) as an information source for error detection. An LM predicts the probability of words within a sentence appearing in the given language given a contextual history. We observed that incorrectly translated words tend to have lower probabilities than correctly translated words suggesting this approach would be a useful metric for error detection. In addition to the word-based LM approach, we will also apply a similar LM approach that is based on word classes such as parts-of-speech. But since LMs gather word probability statistics from a finite set of training data they cannot reliably distinguish rare word sequences from truly erroneous ones. For this reason we plan to incorporate other sources of error information such as measuring discrepancies in word alignments between original and translated sentences.

POSTER SESSION 2

MGH 241, Easel 171

2:00 PM to 3:30 PM

Optimal Resource Allocation in Wave Propagation and the Subgradient Marching Algorithm

Palma Alise Den Nijs (Palma) London, Junior, Mathematics, Electrical Engineering
Mentor: Maryam Fazel, Electrical Engineering
Mentor: De Meng, Electrical Engineering

We consider a mathematical optimization problem that can be used to describe various physical situations that arise in physics and EE applications. In its general form, we study the following physical setting: There is some substance emanating from a source, which propagates through an inhomogeneous medium and reaches a drain. As a motivating application, we imagine a spark of fire igniting and spreading through a forest landscape. Alternately, light may be emitted from a point source and travel in a space with lenses of varying indices of refraction. In each case, we would like to influence the substance's movement by optimally altering the medium in which it propagates. In the case of a forest fire, this corresponds to locating optimal places on the forest landscape to place water, in order to minimize the first arrival time of the fire at a specific location. To solve this convex optimization problem, we perform two tasks. In its general form, our first task relates to finding the shortest distance between a pair of points on a curved space, which is the solution to the Eikonal partial differential equation. Secondly, we take the derivative of the Eikonal solution with respect to a medium parameter. Due to the nature of our problem, these operations cannot be performed analytically. The results are approximated with the Subgradient Marching Algorithm. The unique element of this project has to do with the way we preform the algorithm. Once the shortest-path-length solution and its subgradient are known, we recognize a strategic location on the forest landscape to place a fire deterrent. In this work, we study and implement the overall optimization algorithm, and demonstrate an application to the forest fire problem.

POSTER SESSION 2

MGH 241, Easel 155

2:00 PM to 3:30 PM

Water Purification System

Mohamed Abdi (Mohamed) Mohamed, Junior, Pre Engineering
Mentor: James Peckol, Electrical Engineering, university of washington

Clean water reserves have become difficult to obtain for much of the world's population, due to drought as well as heavy use by certain industries in some regions. There are multiple solutions to this issue but they all require high costs that are only affordable to large corporate institutions. Therefore this project proposes a solution that attempts to be financially accessible and environmentally conscientious utilizing the analysis and critique of previous work. Building on the previous work my research suggest that the sun and seawater can work together to produce a purified form of water by using a magnifying glass to evaporate seawater and condense it into a container. I think that the availability and simplicity of this device would make it financially accessible and environmentally conscientious.

SESSION 2I

DATA ANALYSIS AND COMPUTATION IMPROVE DAILY LIFE

Session Moderator: Werner Stuetzle, Statistics

Mary Gates Hall 258

3:30 PM to 5:00 PM

* Note: Titles in order of presentation.

Energy Saving Butler
Justin Thomas (Justin) Brown, Junior, Extended Pre-Engineering
Austin Christopher Briggs, Junior, Pre Engineering
Tariq Yusuf, Junior, Extended Pre-Major
Antonius Denny (Denny) Harijanto, Junior, Computer Engineering
Jun Sang Yoo, Sophomore, Chemistry
Robert Paul (Robert) Vienneau, Senior, Electrical Engineering
Mentor: Daniel Kirschen, Electrical Engineering

As consumers continue to face high energy bills and the efficient use of resources becomes vital to the sustainability of modern society, the need for a device to intelligently manage electricity consumption grows. The Energy Saving Butler, a computer system to be installed in homes and workplaces, seeks to meet this need by simultaneously minimizing the cost and unnecessary use of electricity–all without inconveniencing the users. The Butler is true to its name: acting behind the scenes and within the confines of the household's schedule, while working to allocate electricity efficiently and discreetly. Our team has conceptualized the features and functions that will drive the future technical design of this device. Based on data from the power company and data on appliance use, the Butler can delay or initiate tasks, such as laundry and dishwashing, so that they occur at times where power rates are at their lowest. Using a complex and dynamic priority level system, this control of power allocation is designed to work within the user's schedule. If the user is having a dinner party one night, for example, the Butler will automatically suspend its own activities so as to not interfere with any social functions. If that user also finds his or herself driving home on a cold night, that user's smart-phone can notify the Butler when it is within a 10-mile radius, so that the Butler can turn on the home's heating. With these and a wide array of other practical features, we feel that the Energy Saving Butler will go a long way in saving consumers' money and working to stabilize the over-burdened power grid. It's appealing to the consumer; it's appealing to the utility companies; it's a step in the right direction for a more sustainable society.

POSTER SESSION 3

Commons East, Easel 78
4:00 PM to 5:30 PM

Incentives for Wind Energy: A Case Study
Sarah Anne (Sarah) Szewczyk, Fifth Year, Electrical Engineering
Mentor: Richard Christie, Electrical Engineering
Mentor: Karen Studarus

Wind is highly variable and unpredictable, unlike conventional generation resources such as coal. The U.S. grid system is ill-equipped to accommodate resources that are stochastic in nature. Policies exist at the federal, state, and local levels that attempt to subsidize the production cost of wind generation, but how will these incentives impact system operations? We explore how the power generation mixture will change due to policies that incentivize wind. Our approach involves an analysis of a case study of three different incentive schemes: a base case (un-incentivized), the federal production tax credit (PTC) for wind, and a feed-in tariff (FIT) system modeled on the FIT proposed in California. Computer simulations will be developed to qualitatively model how these policies impact system operations using the economic dispatch algorithm, which is used in practice to deploy generation resources to serve the load and meet all power system constraints at the lowest cost. Comparing these cases will show which of these incentives have an impact on the total energy cost over a given time frame, as well as give an idea about the resulting generation profile.

POSTER SESSION 3

Commons East, Easel 45
4:00 PM to 5:30 PM

Flat Surface Ratchets for Drop Transport
James Forrest (James) Parsons, Senior, Computer Engineering
Mary Gates Scholar
Mentor: Karl F. Bohringer, Electrical Engineering

Digital microfluidics is an advantageous lab-on-a-chip platform that prevents cross contamination between samples and avoids dilution by diffusion. The majority of digital microfluidic technologies transport drops by establishing thermodynamic gradients. An emerging alternative to gradient transport is ratcheting. Ratchets utilize a predetermined asymmetry (either in input actuation or fabrication) to rectify an energy input into controlled microfluidic droplet transport. To realize a ratchet on a flat surface, we introduce chemically patterned hydrophilic regions on a hydrophobic background. The flat surface ratchet utilizes a semi-circular periodic chemically heterogeneous pattern to induce asymmetric contact angle hysteresis. Chemical ratchets reduce the actuation amplitudes of previously reported texture ratchets by over 3x for a 10 μl droplet. They are optically flat making it possible for fully transparent devices. The microscopically flat device has a simple fabrication (that could be achieved in a number of ways), is easily cleaned, integrated with electrodes and sensors and is compatible for down-scaling to nanoscale features for improved performance. We report two surface modification techniques using both oxide and gold adhering self-assembled monolayers (SAMs) to pattern the wettability of a surface (trimethylsilanol-dodecanethiol), as well as a trimethylsilanol-perfluorooctyltrichlorosilane pattern. In this report, we investigate the role of rung curvatures in estab-

lishing asymmetry and improving performance in flat surface ratchets. We compare the minimum energy input required to achieve droplet transport across a variety of ratchet designs, and identify design characteristics which result in the most efficient operation. Future applications of this improved technology include enhancements to lab-on-a-chip diagnostic devices for disease detection, and surface coatings on components such as windshields or condensers to enhance water removal capabilities.