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ABSTRACTS

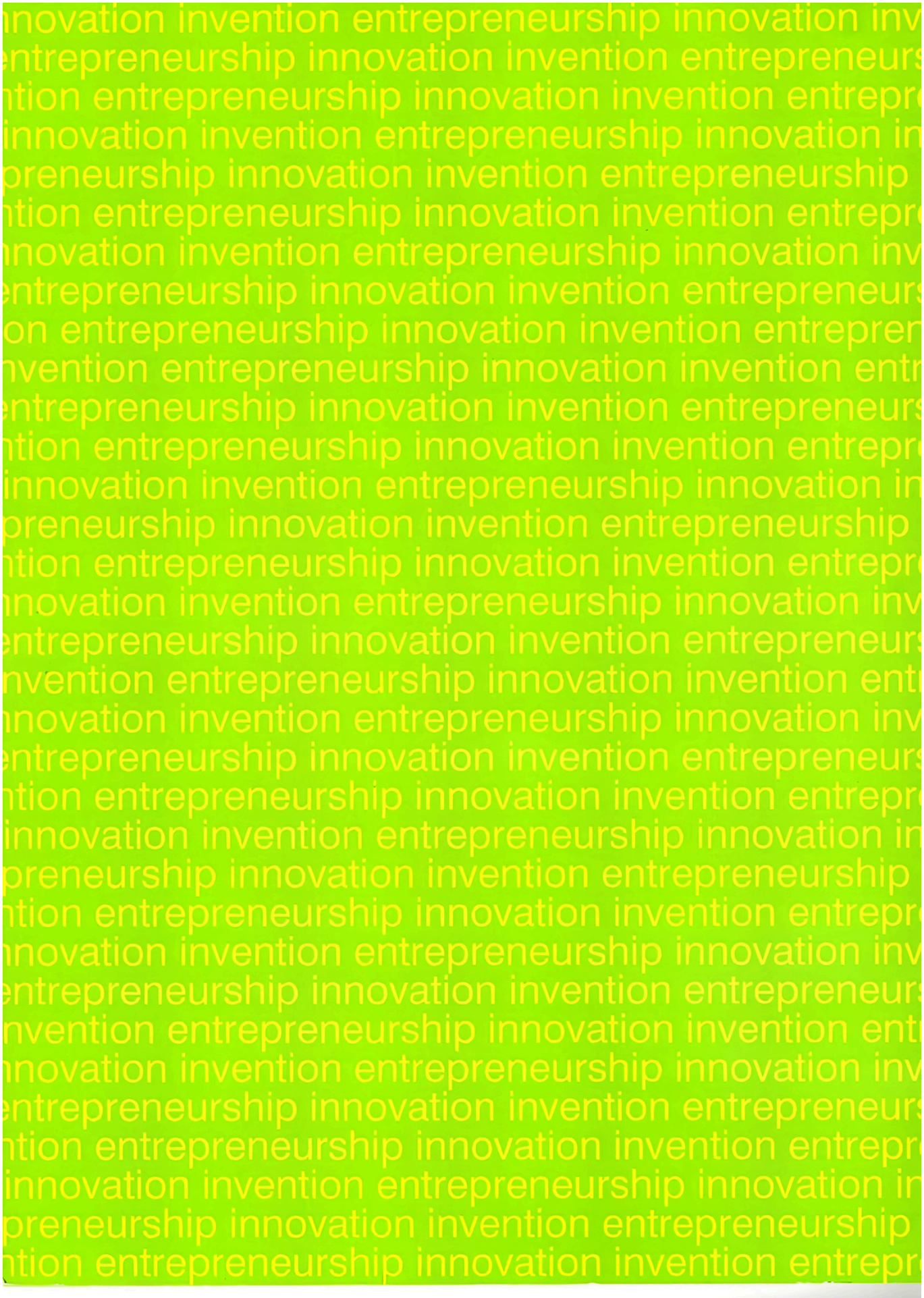
FIRST POLYTECHNIC SYMPOSIUM ON UNDERGRADUATE RESEARCH





discover the power of polythinking

August 28
2007


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Preface

Summer 2007 marked the debut of Polytechnic's Undergraduate Summer Research Program. Seventy-five students participated in the 10-week research program that began in June. The range of research programs was quite diverse and included all science and engineering departments. This brochure contains the abstracts of the posters presented after the 2007 Convocation on August 28, 2007.

The program was composed of two parts: the first is "PolyThinking," an initiative of the Office of the Provost where students performed research under faculty supervision and the second initiative involved working with the Othmer Summer Fellows, faculty members in the Othmer Institute for Interdisciplinary Studies. Together, these initiatives involved 27 faculty members and 75 students.

The students participated in biweekly lunches, where they developed the ability to describe their research to non-specialists and to think across disciplines. Some lunchtime presentations were devoted to the graduate school application process and strategies for seeking post-graduate employment. Seminars where faculty members presented and discussed their research with students enrolled in the program were held on Monday afternoons in July and August.

Polytechnic's faculty participation in the undergraduate research program and financial support of the University's Board of Trustees were essential for the program to be a success. The program was an initiative of Provost Erich Kunhardt with vital assistance from Associate Provost Kurt Becker. Professor Mary Cowman's contribution to poster preparations as well as coordination with the Othmer Summer Fellows is greatly acknowledged. Dr. Michael Hutmaker's efforts in organizing Polytechnic's 2007 Convocation were vital in making the undergraduate summer research poster presentations possible.

The abstracts published in this brochure are representative of the poster presentations celebrating the accomplishments of the undergraduate researchers.

Iraj Kalkhoran
Dean of Undergraduate Academics
Polytechnic University
August 28, 2007

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Stabilization of Proteins with the Attachment of Consecutive Arginines

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Faculty Advisor: Professor J. R. Kim

Despite a protein's high selectivity and specificity, its use could still be limited by its insufficient stability. A protein should fold into a right structure to ensure its proper function. Any factor causing structural changes to a protein can alter its stability. The structure of a protein is determined by a large number of intra- and inter-molecular interactions. In particular, hydrophobic interactions are considered to be one of the major driving forces in protein folding. Various attempts have been made to improve a protein's stability or change the strength of driving force for protein assembly. For example, addition of arginine monomers and attachment of highly acidic (negatively charged) domains at the C-terminus of a target protein have been observed to improve its stability. A compound composed of a consecutive six-arginine sequence, increased hydrophobic interaction of proteins. Based on the above observations, we hypothesize that the addition of multiple arginine sequence to the terminus of a target protein should improve its stability. Due to a positive charge associated with arginine, a multiple arginine sequence can serve as a purification tag. To test this hypothesis, 14-arginine sequence has been added to the end of maltose binding protein (MBP) and β-lactamase (BLA). The additional stability provided by the arginines can be quantified by measuring the difference in activity of BLA and BLA-R_{14} at denaturing conditions and by measuring the fluorescence of MBP and MBP-R_{14}.

Assessment of Ferrocene-labeled DNA Stability Using High-Performance Liquid Chromatography (HPLC)

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High performance liquid chromatography (HPLC) is a highly versatile technique for purification of biological and chemical substances. It is an advanced form of column chromatography that separates the components in a mixture based on each component's hydrophilicity. In our laboratory, HPLC is frequently used to purify and to characterize variously modified DNA molecules. In this project, a number of objectives were pursued both to establish a better understanding of how the technique interacts with our samples

as well as to chemically characterize samples of ferrocene-labeled nucleic acids. The four main objectives include: (1) study of the recovery rate of our HPLC process, (2) study of the loading capacity of the HPLC column, (3) calibration of the HPLC absorbance peaks with DNA concentrations, and (4) study of the decay of ferrocene-labeled DNA at room temperature. The results show that our HPLC instrument and associated protocol has a recovery rate of 88%; each time we ran and collected a DNA sample, we expected an estimated 12% loss of sample. For ferrocene-labeled DNA, after one week of storage in water, 52% of the initial ferrocene-labeled DNA decayed to related products due to partial hydrolysis of the label. These results are important when it comes to accurately quantifying our samples and allows us to properly account for the loss of DNA samples. They also help establish key guidelines on storage and handling of ferrocene-modified DNA.

Determination of DNA Surface Coverage Using Electroactive Counterions

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A better method for identifying DNA sequences is always welcomed and urgently needed in diagnosis of genetic disease, environmental protection and other related fields. This project focused on several important elements of developing improved DNA diagnostic technologies, namely the accurate measurement and control of the coverage of DNA chains on electrode sensor surfaces. The main aim of the research was to solve several problems, in particular to evaluate the effect of solution oxygen on the electrochemical behavior of RUHEX, which is a chemical used to measure DNA surface coverage, as well as to examine the electrochemical stability of mercaptopropanol (MCP) films, a chemical used to coat DNA-modified electrode surfaces to block undesirable adsorption of DNA to the electrode. Cyclic Voltammetry (CV) was the main method used in the research. A set of CV graphs, showing current vs. potential, was generated after processing each experiment's data. On the basis of these CV graphs, the following conclusions were reached. (1) The presence of oxygen in the RUHEX solution significantly increases the background current, but has little effect on the potential at which RUHEX undergoes electron transfer to the electrode. Still, the increased background complicates use of RUHEX for determination of DNA coverage, hence deoxygenated solutions should be used. (2) RUHEX solutions appear stable over 10 hours (i.e., decay to another oxidation state does not occur over this time); and (3) 0.5 hours appears sufficient to allow MCP to form a stable monolayer on the surface of the working electrode.

Alternative Mechanisms for Fusion of Liposome Membranes

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Membrane fusion is fundamental in cell life. It is essential for cell growth, intracellular transport, differentiation and morphogenesis. Membrane fusion is the basic molecular process in which separate phospholipid bilayer membranes merge into a single continuous bilayer membrane. Our work investigates alternative mechanisms for membrane fusion that could potentially have a great impact on understanding cell survival solely driven by membranes. Using Fluorescence Resonance Energy Transfer principles, the fusion of liposome membranes can be measured using fluorescently labeled liposome systems. We monitor fusion of liposomes at 37°C in various pH environments to simulate the conditions within the bloodstream, endosome and lysosome. The experimental system monitors the fusion of anionic high Tg liposomes with endosomes. Two control systems monitor the fusion of anionic high Tg liposomes and endosomes with themselves. In our results, the experimental system and endosome control system show gradual increasing fusion. However, within the anionic high Tg liposome control system, the fusion of the system is almost immediate. Understanding of the molecular mechanism of fusion is also applied by our group to the engineering of drug delivery systems to provide efficient transport and release of chemotherapeutic drugs to cancerous tumors while reducing the harmful effects to healthy tissues.

Detection of "Raft Switches" Using Fluorescence Markers in Rigid Liposome Membranes

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Faculty Advisor: Professor S. Sofou

Lipid membrane heterogeneity in the form of lipid domains may alter the permeability of membranes. In nature, membrane heterogeneity is prevalent in cells, therefore, understanding the physics of domain formation could be of great significance. We are testing the effect of pH on the domain formation in high-glass transition temperature (T_g) anionic liposomes. The liposomes are labeled with Pyrene, a fluorophore that has different maxima emission spectra for 'monomers' and 'excimers'. Measurements are obtained using fluorescence spectrometry, and a lower monomer to excimer ratio corresponds to greater domain formation. We observed that as the pH is dropped domain formation increases. We have also seen that these domain formations are reversible, i.e., if the pH is increased the domains disappear, and if the pH is decreased, the domains

reform. We call these reversible domains 'raft switches'. As a control for these experiments, the same experiments were performed with low T_g, zwitterionic liposomes and it was observed that there is no change in the monomer to excimer ratio with change in pH. A potential application of these liposomes is their use as drug delivery carriers to enhance drug availability at the target site because they are engineered to form domains (and have, therefore, enhanced permeability) only at pH's that correspond to the endosomal pathway.

Electrochemical Quartz Crystal Microbalance: Monitoring of Biointerfacial Events

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This research project dealt with the initial installation and testing of an electrochemical quartz crystal microbalance (EQCM) CHI 440A. The project required learning the electrochemical measurement technique. A quartz crystal microbalance (QCM) is an extremely sensitive mass sensor used to perform measurements of interfacial mass in the order of nanograms. An electrochemical QCM, or EQCM, can in addition carry out electrochemical characterization of the interface. The goal of this research was to perform initial testing of such an instrument in support of future studies of competitive interfacial reaction kinetics involving biological molecules such as nucleic acids and proteins. An EQCM consists of an electrochemical cell, an oscillator, and a potentiostat. A computer is used to display signals. Initial experiments revealed large noise, of unknown origin, that prevented resolution of desired experimental data. Through further experimentation it was discovered that the noise related strongly to the volume of solution used in the cell, possibly because of the free liquid surface. An optimized protocol was developed in which a fixed volume of solution is charged into the cell that minimizes the measurement noise. In addition, it was found that purging the solutions free of oxygen was important to realizing a stable signal from the adsorption of thiol compounds onto the QCM sensor.

Heat Sterilization of Hyaluronan for Medical Applications: Effect of Heating and Cooling Protocols on Hyaluronan Molecular Weight and Solution Viscosity

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Faculty Advisors: Professors M. Cowman and J. Mijovic

The polysaccharide hyaluronan has numerous medical applications, chiefly as a viscoelastic aid to eye surgery and as a pain relieving fluid in treatment of osteoarthritic joints. For such uses, the polysaccharide solution must be sterile. The sterilization process, however, can affect the polysaccharide structure. The molecular size and binding interactions of the polysaccharide hyaluronan are reported to be changed by heating and cooling treatments. Some of the altered binding interactions of special interest include binding to the proteins of the complement system for immune response. In this study, the molecular size and shape of hyaluronan molecules in solution were examined by dynamic mechanical spectroscopy (low-shear viscosity measurement) and gel electrophoresis (determination of molecular mass). No effect of the heating and cooling protocols was found.

Incorporation of Fluorinated Phenylalanine Analogs into Histone Acetyltransferases

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Faculty Advisor: Professor J. K. Montclare

The introduction of fluorinated amino acids into proteins has been used to design proteins with improved thermal stability and increased resistance to denaturants. Proteins that exhibit increased stability have great potential as medicinal therapeutics. Histone acetyltransferases (HATs) represent a group of proteins that acetylate histone tails using acetyl coenzyme A. Our goal is to explore the effects fluorinated amino acids have on the stability and function of HAT tGcn5. In this study, we have biosynthetically replaced phenylalanines in tGcn5 with a series of fluorinated analogs: *p*-fluorophenylalanine (pFF), *o*-fluorophenylalanine (oFF), and *m*-fluorophenylalanine (mFF). We demonstrate high levels of substitution and will investigate the effects that these fluorinated phenylalanines have on the protease stability and function of tGcn5.

Development of a Novel Pull-down Assay Utilizing a Photo-crosslinkable Non-natural Amino Acid

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Determining protein-protein interactions is essential for understanding most biological pathways. However, identifying protein pairs is often limited because the weak forces by which proteins interact are not sufficient to preserve the protein-macromolecule complex. To circumvent this limitation, we are working towards introducing a photocross-linkable non-natural analog of para-azidophenylalanine in a residue-specific manner into FnTm. FnTm is a novel transmembrane protein found to be up-regulated in the learning system in birds and other mammals. Identifying FnTm protein partners will allow us to clarify the FnTm signaling pathway in the brain.

The Effect of NaCl on the Non-photochemical Laser-induced Nucleation of Supersaturated Aqueous Glycine Solutions

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Faculty Advisors: Professor B. Garetz, with X. Sun

Supersaturated aqueous glycine solutions with sodium chloride added (glycine to sodium chloride ratio equaling 3:1) were exposed to intense pulses of linearly and circularly polarized light with a wavelength of 532 nm. Solutions not exposed to the laser crystallized in both α- and γ-polymorphs of glycine, with an increasing tendency to form γ-glycine as higher concentration. Solutions exposed to the laser light surprisingly showed a tendency to crystallize in the α-glycine form regardless of the polarization of the light it was exposed to.

Cooling Rate Dependence and Elevated Temperature Hold Time Effect on Nucleation of Supercooled Phenyl Salicylate

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Supercooled liquid phenyl salicylate (salol) is being studied to see if it exhibits non-photochemical laser-induced nucleation (NPLIN). As a preliminary step, the spontaneous nucleation rate of supercooled salol has been studied as a function of cooling rate and elevated temperature hold time. Interestingly, recycled samples and samples subjected to long hold times exhibit slower nucleation rates. We speculate that dissolved microscopic bubbles formed when a granular sample is first melted act as sites for heterogeneous nucleation, and that recycling and long hold times help to remove these bubbles.

Optimizing Expression and Purification of Cartilage Oligomeric Matrix Protein

Hanna Barra, Natalya Voloshchuk, Wendy Hom, Jennifer S. Haghpanah, Soumya R. Nanda, Mandy Lee, Susheel Kumar Gunasekar
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Cartilage Oligomeric Matrix Protein (COMP) is a member of the Thrombospondin family found in cartilage, tendons, and ligaments. It is a protein composed of 5 domains: the N-terminal Tail, the Association Domain, the Type 2 Repeat EGF-like Domain, the Type 3 Repeat Ca^{2+}- Bnding Domain, and the C-Domain along with a five stranded coiled-coil (COMPcc) region. The N-terminal coiled-coil domain self-assembles to form a hydrophobic pore that allows for the binding of small hydrophobic molecules such as Vitamin D3 and all-*trans* retinol. To investigate the binding properties of COMPcc for small molecules, optimal expression, purification, and concentrations, determination of the COMPcc protein have been completed. To monitor the binding of small hydrophobic molecules to COMPcc, we performed fluorescence titrations with all-*trans* retinal. Once dissociation constants are determined for all-*trans* retinal and other small hydrophobic molecules, we plan to use this protein as a vehicle for drug delivery.

Role of the Polysaccharide Hyaluronan in Inflammation

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Faculty Advisor: Professor M. Cowman

The polysaccharide hyaluronan participates in the process of inflammation. While native high molecular weight hyaluronan is anti-inflammatory, lower molecular weight fragments of the polymer can be pro-inflammatory. Hyaluronan can also participate in the response to inflammatory stimuli via interaction with specific proteins, some of which become attached to the polysaccharide. We are developing analytical methods suitable for the analysis of hyaluronan size and protein binding, in samples obtained from inflamed tissues such as colon smooth muscle cells in inflammatory bowel disease, or lung tissue damaged by ventilator use.

Protease Catalyzed Oligo Peptide Synthesis

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Peptides are conventionally prepared by solid and solution phase peptide synthetic methods. These procedures involve multiple protection-deprotection steps and are performed in organic solvents. In this paper, we describe the development of simple and 'environmentally friendly' enzyme-catalyzed methods to prepare oligo peptides. Protease catalysts were used to prepare oligo-peptides from amino acid esters under mild conditions in aqueous media. The aim of my current research is to develop methods that allow determination of protease specificity during oligo-peptide copolymerizations.

PPM Compression-Based File Fragment Type Analysis

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This research investigated the effectiveness of the PPM (Prediction by Partial Matching) data compression algorithm as a tool for diagnosing the type of a file fragment. A PPM implementation by Mark Nelson[1] was adapted, so that it created a model from files of a given type, then compressed each of a group of file fragments using that model. The type of file used to create the model was varied between runs of the adapted code; the group of fragments used was the same for each run. Under the assumption that a fragment would be compressed most efficiently by a model of like type, a file type was predicted for each fragment. Despite defects in the adaptation of the Nelson algorithm, this method of fragment type analysis appeared to be competitive with other methods.

[1] http://www.dogma.net/markn/articles/arith/part1.htm

A Study of GPGPU for Web Search Engine

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The amount of web pages out there is enormous. Web search engines collect textual information from a large set of these web pages and as a consequence, it can be quite slow when utilizing the computation power of a CPU for such a large set of data. One can use many CPUs to compute these data sets, but the problem that arises is efficiency. The inherent parallel computing nature and high-memory bandwidth of GPUs are desirable traits for computations of large data sets. Also, the fact that GPU is predicted to likely outgrow CPU gives another reason to study general-purpose computing for web search engines on the GPU.

Machine Learning Designs for Artificial Histone Acetyltransferases

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In vivo incorporation of non-natural amino acids can be used to improve protein stability. However, there is a trade off; improved stability of the protein may lead to loss in activity. One way to improve function is to employ machine-learning algorithms to identify the variants that improve activity. Our target protein *Tetrahymena* GCN5 (tGCN5), a member of the Histone Acetyltransferases (HAT), acetylates the lysine residues of the histones, enabling transcriptional regulation. Experimental data have shown an increase in stability against protease, but loss in activity with the incorporation of *p*-fluorophenylalainine into tGCN5 *in vivo*. With the aid of computer guidance, we plan to design a set of fluorinated variants. Using information from biochemical and structural data, we identified 11 residues to mutate. One of the supervised machine learning algorithms, Linear Regression Analysis, will be used to identify the residues that have positive impact on the mutated sequences.

Video Streaming through a Peer-2-Peer Architecture

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Faculty Advisor: Professor Y. Wang

In this project, our objective was to design a Peer-to-Peer (P2P) test bed for handling live video streaming where the streaming clients also act as servers for other clients. Compared to current architectures which utilize a set of dedicated servers to store and distribute the content to the clients, the P2P architecture eliminates the need for dedicated servers and the bandwidth thereby saving money needed for the servers and maintaining their dedicated Internet connections because they are borne by the users. It also offers the benefit of improved scalability when there are more clients to serve because the overall bandwidth improves as there are more clients. This does not happen in current architectures. As part of a larger project on P2P video streaming, our specific objective was to design the test-bed prototype to simulate the behavior of clients in a Peer-to-Peer (P2P) architecture.

Using C++, I was primarily responsible for the implementation of the buffer map, an object that kept track of what pieces of the video each peer had, and for implementing the client scheduler, which determines which piece of data to request at a client, and from which server to request this data. My code was designed with two goals in mind: that the code would be both generic and adaptable so that it would be usable by others as progress with this project continues and that it be designed in a test-oriented manner, so it can be ensured the code works.

Initial testing verified the code functionality (where the server and client are on the same computer), but has yet to be tested for simple cases of one (1) or two (2) peers with the server to ensure it worked over the network. Continued testing will confirm whether our prototype indeed functions as intended in the design when handling a larger number of peers. Future tests need to take into account flooded networks, firewalls and other security measures and the fact that not all peers will have the same uplink capacity or connection speed.

Wireless Cooperative Networking (Coopmac)

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With the growing demand for mobile data networks and the limited unlicensed bandwidths in rural areas, users have been forced to share the same medium for the transmission of their data. Therefore, it is very important to reduce the interference as much as possible and to increase the efficiency of the usage of the bandwidth. Conventional wireless systems are designed in a way that there are only two parties involved in the transmission of data. In my presentation I will explain how we can obtain improvement in throughput and reduction of interference by using the broadcast nature of wireless signals and by simply using the parties that normally would not participate in the transmission. By doing this, we introduce a third node between the source and the destination – a helper. Helpers have a high data rate and are located in between the source and the destination. Its mission is to assist the two stations during their transmission by helping the source station to forward its package. Every low data rate node maintains a table that is called a "Cooptable". The Cooptable has some information about the potential helpers that can improve the transmission of data; the source station chooses a helper by examining the Cooptable. The idea of Coopmac is very simple and backward compatible with the legacy IEEE802.11 protocol.

A Compact Pre-processor to Support Hash Tables

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Today's network applications such as Intrusion Detection and Prevention, Route Lookup and TCP State Processing, require large data storage, fast queries and frequent updates. Hash table, a data structure that associates items with values, is a good way to address this issue. Unfortunately, hash table's lookup speed is not constant, due to collisions of multiple items in a single bin. In the summer research project, we developed an effective on-chip pre-processor architecture to have a hash table with a constant worse-case lookup time. The pre-processor scheme is based on a simple data structure, using a single hash function. During a query, the group this query belongs to is received from the pre-processor according to the hashing result. The corresponding group in off-chip hash table is read in parallel to access the actual item queried. Two novel insertion algorithms based on Ternary Content Addressable Memory (TCAM) were developed to resolve the overflow that is caused by too many collisions during updating and causing a varying lookup speed for ordinary hash tables. We have developed a C++ model of the proposed

system to test its performance and memory usage. Our simulation results shows that for the total of 49,152 items, the proposed system requires 3.14 bits on-chip memory per item on average and has constant time query and delete. The insert takes 0.76 extra memory access per item on average.

Temporal Video Segmentation Based on Source Identification

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An image or video can be presented as proof of occurrence of the depicted event. However, today many powerful image/video processing tools, compatible with low-cost hardware, are widely available. Thus, the authenticity of visual evidence cannot be taken for granted anymore. This undermines the credibility of digital images presented as evidence in a court of law, as news items, as part of a medical record or as financial documents since it may no longer be possible to distinguish whether a given digital image is the original or a (maliciously) modified version or even a depiction of real-life occurrences and objects.

To address this problem, a recently proposed method looks into the noise pattern specific to the photo sensor of each camera or camcorder. This allows for fingerprinting any camera, and thus matching a digital image or video to its source. This project implements an efficient method for video authentication. Our purpose is to determine whether a video has any insertions that come from different camcorders, and thus to segment the video into portions that come from separate sources. Experimental results demonstrate the reliability and generality of this approach.

Cooperative Layered Wireless Video Multicast

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Due to the increase in wireless video applications, video multicasting over wireless has come into prominence these recent years as an effective method of transmission. But a major drawback of conventional multicasting system is that, as the source has to send the video file to all the users within the targeted area, it chooses the bit rate of transmission based on the furthermost receiver. This lowers the receiver video quality and users with high-channel quality unnecessarily suffer. Much of this problem can be overcome by

using cooperative multicasting which basically denotes a process where targeted area of transmission is broken down into sub-regions and once they have received the video file from the source, receivers at the edge of the central sub-region cooperates with the source by themselves transmitting the signal to allotted areas on the outer sub-region. This ensures overall better video quality for all the users of the entire region. Cooperative multicasting can be done in two ways; the first method uses omni-directional antennas and is the cheaper and simpler one among the two, whereas, the second method that uses directional antennas covers a wider area and provides higher video quality due to its ability of simultaneous transmission. This project focuses on optimization of the parameters such as user partition, relay selection, transmission scheduling etc., that govern both processes. Programs were developed to determine the optimal values of the parameters for a given area with fixed radii for the region and sub-regions.

The Tibetan Book of the Dead: Live Theatrical Multimedia Presentation

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The Tibetan Book of the Dead is highly descriptive text of the teachings of the great eighth century Buddhist master Padmasambhava. The text describes the intricate structure of the ego and the mind and is traditionally read aloud to a dying person. Many artists have attempted to portray these complex and vivid visions and dream states of dying in thangka paintings. The Tibetan Book of the Dead: Live Theatrical Multimedia Presentation (commissioned by the Asia Society and the Golden Sun Foundation for World Culture) seeks to incorporate traditional thangka paintings with live music and 3D graphics. The 3D graphics is constructed with the high-end program, Autodesk Maya, that is used by professionals. In this project, the complex models were sculpted from simple polygons such as cubes and spheres. Details added to the models were done with textures and normal maps, which are the methods used in 3D graphics of today's videogames. These 3D models produced during this summer research program are to be rendered real time, in a program with elaborate lighting effects and animation to present an ancient esoteric text to a modern audience.

Universal Curve, Biological Time, and Dynamically Varying Scaling Exponent in Growth Law

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A general quantitative model for ontogenetic growth of organisms was derived by West *et al* based on fundamental principles for the allocation of metabolic energy in which a universal parameterless growth curve was established in terms of the biomass ratio and a dimensionless biological time. This model was then extended by Guiot *et al* to account for the growth of tumors *in vivo* in which the fractional scaling exponent p becomes a dynamic parameter depending on time t. In this paper, we present a method that may be used effectively to construct a generalized universal growth curve for such a growth law model with an arbitrary dynamically varying fractional exponent. As by-products of this method, we show that the assumption that a biological time variable flows forward in the universal curve allows us to predict τττthe behavior of p with regard to the developmental stages of organisms characterized by body mass which is consistent with the findings of Guiot *et al* based on biomedical data, and that, the universal curve is independent of the properties of p as a function of t. We also consider the situation when time increases discretely and the fractional scaling exponent is periodic. We observe the familiar, but superimposed, period-doubling and transition-to-chaos phenomenon.

Generalized Growth Laws and Universal Curve in Quantitative Biology

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Starting from a differential equation relating the biomass m, with respect to real time t, biologists recently discovered a universal growth curve. The universal growth curve can be used to model growth patterns in biology, is independent of specific biological growth situations, and may be expressed in terms of a dimensionless 'biological time' τ and a rationalized mass r. In this work, we prove that the universal curve is valid if and only if the biomass m evolves with respect to the real time t through a generalized class of differential equations when the suitably defined rationalized mass r and biological time τ depend monotonically on m and t, respectively. In other words, the universal curve is shown to be truly universal for a much broader class of growth laws.

Development of a Lightweight Syntactic Foam for Naval Applications

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The project is aimed at developing vinyl ester matrix syntactic foams and characterize their environmental degradation characteristics for Naval application. These lightweight composites are synthesized by mixing hollow glass particles in vinyl ester resin. Such composites can be used as core materials in sandwich structures for Naval and aerospace structural applications. Syntactic foams are capable of providing lightweight, high-damage tolerance and high-dimensional stability to these structures. Accelerated weathering tests are performed on the specimens in order to quantify the moisture uptake and damage caused by it. The testing is conducted using a QUV Accelerated Weathering Tester for prolonged periods of time. Specimens are subjected to temperature and humidity fluctuations to simulate the environmental exposure under natural conditions. At fixed time intervals, specimens are tested for tensile properties to evaluate the effect of moisture absorption.

Energy Harvesting Via Magnetics and Beam Vibrations

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Alternative methods for energy gathering are at a great deficit. Massive government fundings are invested in this research topic. Energy harvesting is a booming research field; it is also the topic of this research project. Most modern mechatronic systems rely on sensors to relay information of incoming and outgoing phenomenon. These sensors are critical to measurement systems of environmental quantities and control loops for mechatronic systems themselves. Sensors can be made wireless and generally require power to operate. Most of the time it is not feasible to use batteries, since they require constant replacement, which is costly and inefficient. For wireless sensors placed on airplane wings to measure vibrations, ambient temperature and other such applications, it is apparently very inefficient to provide power through batteries. Mechanical vibrations of the host structure can be indeed used to provide energy to the sensor. The same can be done via other methods like solar, hydro and thermal harvesting. A good amount of work has been done on the use of mechanical vibrations to generate power using the laws of

induction and electromotive force, but most of it has been devoted to rather high-vibration frequencies (>60Hz). Such high-frequency vibrations exist in several systems like automotive vehicles. However, these techniques are not directly applicable to human-portable electronics like iPods or cellular phones since, in this case available vibrational energy is that generated by human locomotion. Such low frequency vibrations (~3Hz) are the ones being targeted in this research project. This problem is particularly challenging since through magnetic induction, low speed motion generally result in low produced power. The important factor in this process is the maximization of the change in magnetic flux since the faster the motion the easier it is to extract power. Thus, an attempt to optimize the characteristics of the harvester to produce the maximum power within the given system is proposed in this project.

Robofish: Preliminary Research on Underwater Propulsion Methods

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Advancing technology in robotics and biomimetics opens new doors to existing applications. A newly discovered electro-active polymer (EAP) called ionic polymer-metal composite (IPMC) provides a way to make innovative designs of underwater vehicles, such as robotic fish. A robotic fish could have many uses such as observing collective behavior and migration patterns. What makes this autonomous underwater vehicle extremely well suited for these applications is its capability to establish peer-to-peer relations with live fish. This project focuses on mimicking the movement of carangiform locomotion using engineered propulsion methods for miniaturized robotic fish. Two approaches were considered to achieve this. The first was to use a vibrating cantilever beam with a movable lumped mass as the robotic fish's beating tail. It was hypothesized that with the mass moving along the beam undergoing base excitation, the desired undulatory motion would occur. This method showed limited efficacy for small miniaturized robots. The second method chosen was to use an IPMC actuator controlled by a PIC microcontroller. This method showed very good promise, and future research into segmented IPMC actuators will be conducted in the future.

Audio-enabled Emergency Hexapod: A Mechatronics Project

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The Audio-enabled Emergency Hexapod (AEEH) is a legged robot that detects sound waves in its surrounding environment and moves towards the sound emitting object. The robot uses the principle of "tripod gait" to perform walking motion using two pairs of three legs. Each three-leg pair is driven by a continuous turn servo motor. The robot is endowed with sound sensing capability using a forward facing and two side facing microphones. A microcontroller processes the output from the three microphones and commands the two motors so that the front of the robot moves towards the direction of the sound source. An AEEH testbed was designed by Mr. D.Y. Ko, a former undergraduate assistant in the mechatronics lab. Our efforts have been focused on developing a rugged mechanical system and circuitry for sound sensors. In addition, we are focused on characterizing the performance of the system vis-à-vis distance from sound source, orientation relative to sound source, different types of sound sources, etc. This system may be effective in disaster recovery, search-and-rescue, and military operations.

Autonomous Mail Delivery System: A Mechatronics Project

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Autonomous control systems provide numerous opportunities to reduce and eliminate human effort in carrying mundane, routine, and boring tasks. For example, consider the job of mail/package delivery to staff in an office building. If mail is delivered by a designated individual, s/he finds the mail delivery task boring. Alternatively, if the mail is to be picked up by office workers from a centralized mailroom in the building, the workers may need to make multiple trips to the mailroom, leading to inconvenience. In this effort, we focused on developing an Autonomous Mail Delivery System (AMDS) to significantly reduce human effort in delivering/collecting mail, in an office environment. Our AMDS system exploits (1) iRobot's robotic development kit as a programmable mobile robot platform, (2) an RFID reader that is used to identify the identity of the occupant of an office from an RFID tag embedded in the office door, and (3) additional sensors and actuators to create an effective AMDS. The AMDS performs following tasks to achieve its goal: (1) store the received mail, sorted by recipients, (2) execute a planning algorithm to determine the quickest mail delivery route to offices whose

corresponding mailbox slots are occupied, and (3) navigate corridors in the office building to visit various offices. This project allowed us to learn the fundamentals of robotic and RFID technologies. In addition, we had ample opportunities to undertake hands-on integration of various electro-mechanical hardware, microcontrollers, and RFID components. Our on-going activities are focused on investigating various strategies to integrate robotic and RFID technologies for domestic, hospital, industrial, and office environments.

Characterization of Vinyl Ester Glass-Microballoon Syntactic Foams for Marine Applications

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Hollow particle (microballoon) filled composites, called syntactic foams, are known as highly damage tolerant lightweight composites. Epoxy and aluminum matrix syntactic foams containing glass microballoons have been widely studied for marine and aerospace applications and have been found suitable for structural and a variety of other applications. The present study is focused on synthesis and characterization of vinyl ester matrix syntactic foams. Vinyl ester resins have lower density, comparable tensile strength, higher modulus of elasticity, and lower coefficient of thermal expansion than epoxy resins. The tensile and compressive properties of vinyl ester matrix syntactic foams are characterized. The results show promise in these materials in marine structural applications.

Experimental Investigation of Flow in a Model Artery with Stenosis

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Atherosclerosis, a cardiovascular disease resulting from blockage of the arteries, is the primary cause of heart disease and stroke. The Endothelial cells (EC), which line the artery walls play a key role in vessel homeostasis, by controlling diffusion into and out of the arteries. Many studies have shown that EC morphology and their expression of biochemicals are influenced by the local blood flow dynamics via the wall shear stress, through a process known as mechanotransduction. This and other findings suggest that hemodynamics play a major role in atherogenesis. The first goal of the research study was to formulate a compatible fluid with a refractive index that matches that of the model

apparatus, in order to enable accurate near-wall velocity measurements. A mixture of Diethyl phthalate and ethanol was found to be compatible and to match the indices of the model apparatus materials, Plexiglas and Borosilicate glass. The effect of ethanol concentration was analyzed for the two index matching solutions. The Index Matching Fluid was found to reduce the error in position of the laser beam measuring volume in circular tubing to 3 percent or less of the radius (from 10 percent in the mismatched case). The second goal was to understand flow downstream of an eccentric stenosis, a local constriction in the artery due to plaque buildup. The fluid dynamic parameters, Reynolds number and Womersley number were matched to physiological values using water as the working fluid. A simple harmonic, sinusoidal wave was input to the model artery by using a programmable pump. Measurements were taken using laser Doppler velocimetry, a point velocimetry technique, to acquire cross-sectional streamwise velocities. It was found that the stenotic jet, which results from sudden narrowing of tubing, propagates to 8 diameters and beyond.

Observation of Surface-enhanced Raman Scattering Using Low-power Lasers and a Fiber-Optic Spectrometer

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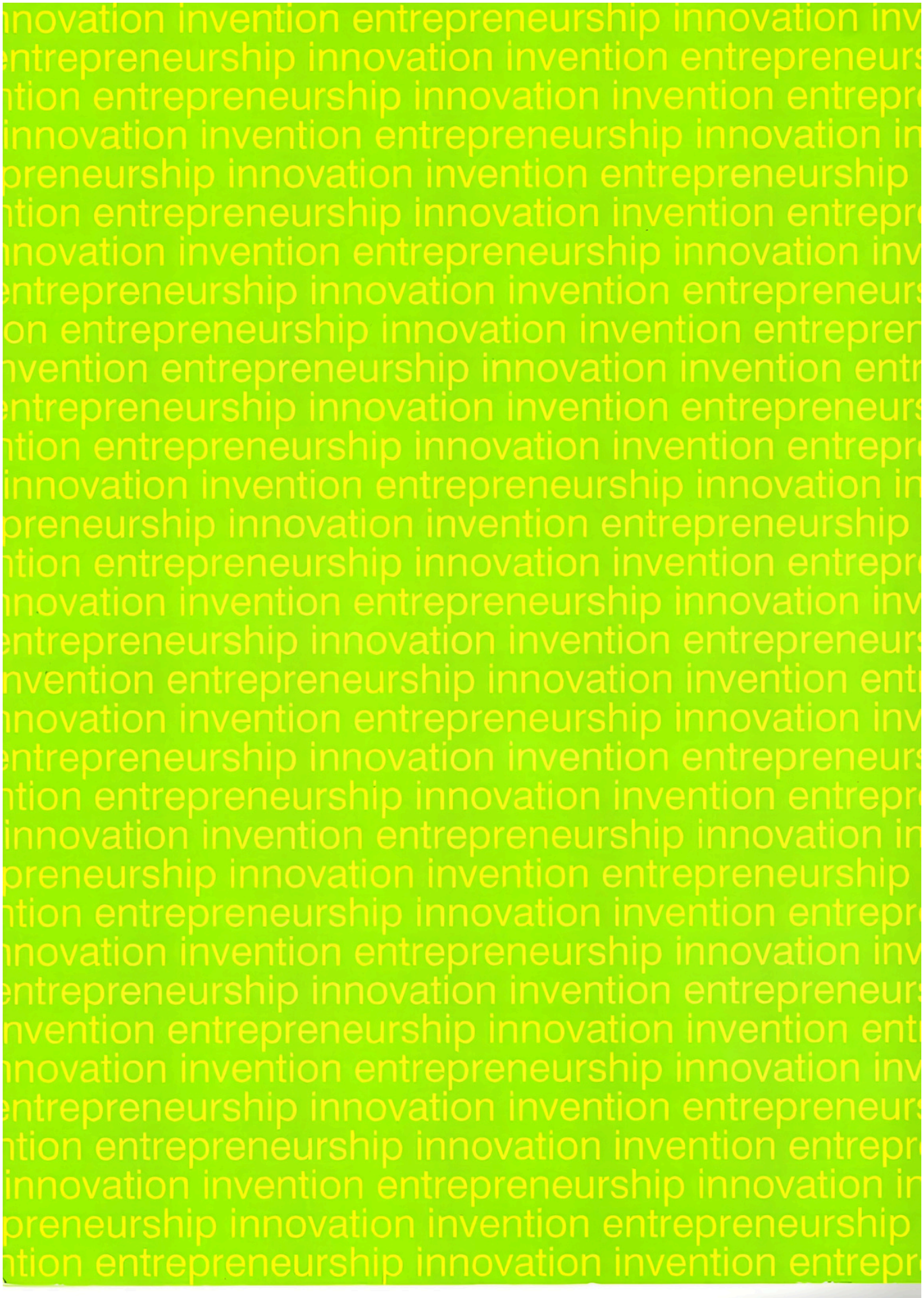
In order to study/identify molecules, techniques such as IR and UV/Vis spectroscopy, NMR, and MS are used. Another technique is Raman scattering, for which the difficulty is the small scattering cross section. To remedy this problem, one experimental technique employed is Surface-enhanced Raman Scattering (SERS). We use a silver colloid to create the SERS effect in a Rhodamine 6G solution. A He-Ne laser, a green laser pointer, a red laser pointer, and an argon ion laser act as sources of incident light. The spectrometer\CCD detector we use is the USB2000 fiber optic spectrometer from OceanOptics.

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