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Poster Symposium and Awards Ceremony | August 16, 2019
First Floor Engineering VI: Mong Auditorium, Lobby and Patio

11:00 AM - 11:05 AM  Announcement (William Herrera)
11:05 AM - 12:30 PM  Poster Galley Walk
11:45 AM - 12:30 PM  Hors d'oeuvres service begins
12:30 PM - 2:00 PM  Awards Ceremony
The Summer Undergraduate Research Program (SURP) provides participants with an intensive 8-week summer research experience in a wide range of engineering fields. Undergraduate students participate in research with UCLA Samueli School of Engineering faculty and research teams to gain real-world lab experience. As part of this program, SURP students:

- Meet and network with peers who have similar goals and interests
- Learn to communicate research outcomes by participating in weekly Technical Presentation Labs
- Create a professional scientific poster of their research
- Write and publish a research abstract
- Present a detailed Summary of Project
- Become more competitive when applying to engineering graduate schools

This year, 39 undergraduate students were selected to join the 2019 SURP cohort. I would like to congratulate this SURP class on completion of their amazing research projects. Creating new knowledge is a very important, and a very difficult, task. These high-performing students have done an outstanding job working through the rigors and challenges of full time research. They should be very proud of the abstracts and posters they have published today. I encourage you to meet the students, ask questions about their projects, and learn about the cutting-edge knowledge that is being created here at the UCLA Samueli School of Engineering.

Sincerely,

Jayathi Murthy
Ronald and Valerie Sugar Dean
Filter Behavior Characterization and Verification Utilizing Analog to Digital Converter and Digital Signal Processing

High-performance integrated electrical filters are desired in almost every aspect and found in almost all electronic devices. In realizing very sharp and linear analog filters with enhanced wave filtering applications, our lab began utilizing an intentional use of time varying circuits. However, for such filters to be truly useful, it needs precise characterization with fast, and preferably automated processes. Developing this automation involved signal generators and an analog-to-digital converter to create a quick and precise characterization of the behavior of various filters which would otherwise be done manually which is time consuming and inefficient. The ADC board combined with two synchronized signal generators allows the signal to be sent to a MATLAB algorithm and hence obtain the desired magnitude and phase responses of the filter. The signal generation and process is more complex than sweeping the input frequency because the automation produces many challenges including equipment noise. My research aims to overcome these obstacles with digital signal processing. Our process of characterizing the parameters of a filter quickly and precisely will contribute to our labs development of a frequency-channelized ADC that will use tens of such filters to separate the spectrum into multiple pieces.

Acknowledgements

I would like to acknowledge the 2018 Summer Undergraduate Research Program for the amazing summer opportunity. Professor Pamarti for giving me the project in condition to be a high-learning research, and Shi Bu daily an advisor for guiding me through this project and answering all of our questions in such a big learning experience for me.
Diamond as an output coupler for chip-scale terahertz external cavity quantum cascade lasers

External cavity quantum cascade lasers are an integral source of terahertz radiation. However, heat removal from the devices is critical in order to achieve continuous wave operation. We introduce a chip-scale output coupler for a quantum cascade vertical external-cavity surface-emitting laser (QC-VECSEL) through a 500 um thick synthetic polycrystalline diamond plate. This design brings two primary benefits: a method of dissipating heat from the laser’s bias region and a mechanically stable output coupler with no need for alignment. The diamond is mounted directly on top of the metasurface, replacing an existing design involving an externally mounted quartz output coupler. Initial electromagnetic simulations indicate acceptable high reflectance at a resonant lasing frequency of 3.4 THz and a bandwidth of about 140 GHz. Thermal simulations will be conducted to predict the expected improvements to operating temperature and heat dissipation for the VECSEL’s metasurface. Possible areas of concern include high threshold current and increased thermal losses due to an adjusted ridge geometry that features a high fill factor.

Nathan Atkinson
Computer Engineering
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LAB NAME
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Group Laboratory

FACULTY ADVISOR
Professor Ben Williams

GRADUATE STUDENT DAILY LAB SUPERVISOR
Parastou Mortazavian

DEPARTMENT
Electrical and Computer Engineering

Abstract
External cavity quantum cascade lasers are an integral source of terahertz radiation. However, heat removal from the devices is critical in order to achieve continuous wave operation. We introduce a chip-scale output coupler for a quantum cascade vertical external-cavity surface-emitting laser (QC-VECSEL) through a 500 um thick synthetic polycrystalline diamond plate. This design brings two primary benefits: a method of dissipating heat from the laser’s bias region and a mechanically stable output coupler with no need for alignment. The diamond is mounted directly on top of the metasurface, replacing an existing design involving an externally mounted quartz output coupler. Initial electromagnetic simulations indicate acceptable high reflectance at a resonant lasing frequency of 3.4 THz and a bandwidth of about 140 GHz. Thermal simulations will be conducted to predict the expected improvements to operating temperature and heat dissipation for the VECSEL’s metasurface. Possible areas of concern include high threshold current and increased thermal losses due to an adjusted ridge geometry that features a high fill factor.

VECESL Coupled with Diamond

Diamond is coupled to the laser by a gold-plated metal ridge. The diamond is mounted on top of the metal ridge, and a gold-plated metal ridge is introduced for thermal management. The diamond is placed on top of the metal ridge to ensure the use of the external cavity and create a space for heat dissipation. The design includes a metal ridge on top of the laser, which serves as a heat spreader. Initial electromagnetic simulations indicate acceptable high reflectance at a resonant lasing frequency of 3.4 THz and a bandwidth of about 140 GHz. Thermal simulations will be conducted to predict the expected improvements to operating temperature and heat dissipation for the VECSEL’s metasurface. Possible areas of concern include high threshold current and increased thermal losses due to an adjusted ridge geometry that features a high fill factor.

Response at Resonant Frequency

The VECSEL is coupled to the output coupler through a gold-plated metal ridge. The ridge is placed on top of the laser to ensure the use of the external cavity and create a space for heat dissipation. The design includes a metal ridge on top of the laser, which serves as a heat spreader. Initial electromagnetic simulations indicate acceptable high reflectance at a resonant lasing frequency of 3.4 THz and a bandwidth of about 140 GHz. Thermal simulations will be conducted to predict the expected improvements to operating temperature and heat dissipation for the VECSEL’s metasurface. Possible areas of concern include high threshold current and increased thermal losses due to an adjusted ridge geometry that features a high fill factor.

Candidate Active Region

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This research is supported by the National Science Foundation and the UCLA-ATAP Center for Design of Advanced Photonic Systems at the McGee Center for Terahertz Science and Technology. The authors would like to thank the following individuals for their contributions to this project.

References

Filter Behavior Verification and Characterization Utilizing Analog to Digital Converter and Digital Signal Processing

Electronic filters are utilized almost everywhere. However, while integrated filters are demanded in modern high-complexity systems, for them to be truly useful, we need to fully characterize them with great precision. While such characterization and testing may appear to be straightforward, many difficulties arise in practice. For example, such characterization needs to be fast and accurate, with multiple aspects being measured simultaneously. Measurement equipment non-idealities, such as noise and non-linearity, had to be addressed with careful consideration. Our utilization of an Analog to Digital Converter (ADC) enabled an automated process with high precision, as the ADC’s output could be processed digitally for better handling of various error sources. Our use of an ADC in addition to signal generators and MATLAB algorithms allowed us to automate the process of verifying the veracity of a filter’s intended behavior; this process allowed us to extract properties such as magnitude and phase, some of the most important parameters to our interest. These now characterized filters can be utilized in more complex integrated systems for various communication applications. For example, the aid from the automated, precise characterization of filters will allow the building of a hybrid filter bank, which would consist of tens of filters, to achieve signal reconstruction with much less difficulty, which is key to realizing a broadband frequency-channelized ADC for high-dynamic-range and low-power applications.

**Acknowledgments**

This work was supported by the Fast Track to Success Summer Research Program. It has also been supported and much gratitude is given to Professor Pamarti as well as Shi Bu, our daily lab supervisor, for their role in the project. Abbas Bakhshandeh is participating in the Summer Undergraduate Research Opportunities Program in the Henry Samueli School of Engineering at UCLA.

**Conclusions and Future Work**

A true behavior and representation of the signal, as well as a lock-in (ADC) in a reverse process of verification, will be exploited for the Signal Generator and Matlab algorithms. This process allowed us to extract the necessary parameters and features of the signal, and thus, our process of verification has been completed. However, this is not the end of the story. We have been utilizing an automated process to extract the properties of different filters and even more challenging tasks. In the future, we will be utilizing the capabilities of a hybrid filter bank, which will consist of tens of filters, to achieve signal reconstruction with much less difficulty. This is key to realizing a broadband frequency-channelized ADC for high-dynamic-range and low-power applications.
Rodent Path Reconstruction using Hippocampal Rate Coding

The goal of this project is to use neural spike readings from a rat to determine its position in an enclosure. The spike readings are taken from several neurons in the hippocampus, a part of the brain that is associated with spatial memory. The spike readings are condensed into spike rates for each neuron, which are believed to hold information about the stimulus (the rat's position). The spike rate of each neuron is modeled as a Poisson process with an unknown parameter that is a function of the stimulus. A neural network is used to determine the parameter for every neuron at every position in the enclosure. Different sets of features from the stimulus can be used as the input to the neural network. The parameters and spike rate data are then fed into a decoder to reconstruct the original path. There are many different feature extractions, neural network architectures, and decoding schemes that can be used in this framework. The goal is to select the features, design the neural network, and build the decoder that will minimize error in the reconstructed path. Some of the decoding algorithms that have been explored in this project include one-shot decoding, greedy decoding, Viterbi decoding, and adaptive decoding. A high-performance decoder could possibly be adapted to improve brain-machine interfaces.

Future Work

- explore more decoding algorithms
- try out different neural network architectures for encoding
- try out new feature extractions for encoding
- select different combinations of neurons to use
A High-Speed, Low-Cost, and Compact Optical Delay Stage for Terahertz Time-Domain Spectroscopy Systems

Terahertz Time-Domain Spectroscopy (THz-TDS) is an application of the terahertz band of the electromagnetic spectrum with advanced capabilities in chemical identification, material characterization, and nondestructive material analysis. Recent developments in THz emitter and detector technology have established improved signal-to-noise ratios within these systems, increasing the viability of THz-TDS in commercial applications. However, the weight and speed of these systems are also limited by a component known as the delay stage, a mechanical device used to vary laser optical path length. The focus of our research has been to create a miniaturized, high-speed delay stage to address this need.

While laboratory delay stages offer sub-micron accuracies, these systems are often large and expensive due to the extra functionality they provide. We have opted to explore alternative mechanisms to achieve compact and cost-effective designs that suit our application. Utilizing 3D printing and machining, we have created prototype stages using crank and crank-inspired mechanisms that achieve recirculation frequencies of 10.4 Hz (as compared to 1.2 Hz by a laboratory stage). Through comparisons of THz-TDS results between a laboratory stage and our stages in the clarity and accuracy of absorbed THz waves measured through air, we have also been able to classify the efficacy of each iteration of our device. Looking at areas other than performance, our stages are mechanically complete, we plan to develop a TDS system for commercial use. Recent technological advancements in THz-TDS capabilities due to the creation of more powerful sources and more sensitive detectors allow better spectroscopic analyses—allowing the use of this technology practical at a commercial scale. To optimize the size and speed of such systems, another necessity is to create a compact, high-speed delay stage to allow for miniaturization of THz-TDS systems.

We believe these errors are systematic in nature. Hence, we can reason for each error through pre-processing, we conclude that a high-speed delay stage can support practical THz-TDS applications.
Approaching Human Motion Through A Tri-Axial Accelerometer Mapping of Geometric Shapes

Jason Bustani, Susie Tan, William Kaiser

DEPARTMENT
Electrical and Computer Engineering

Materials and Methods

SensorTile Architecture

Introduction

- Accurately detecting human motion via electronic signals is a feat that has yet to be mastered.
- It remains to be one of the most difficult and complex motions to be detected by an accelerometer, and its mastery could lead to many new technologies in the medical and sports field.
- Digital signals are by their nature probabilistic and stochastic, and mapping simple to complex shapes merely on a 2-dimensional plane is challenging.
- The initial hypothesis was to collect data using a 10 x 10 cm square and write the outputs in a notebook and calculate the errors to find a consistent pattern.
- A consequent hypothesis was to play with the filters to attenuate the signal for a desired result.
- By changing the resonance frequency for the High-Pass Filter, a chaotic signal came within a decent amount of precision for mapping rectilinear and curved figures that come close to human motions projected onto a 2-dimensional plane.
- The errors were dependent completely on the filter and on the setup of the device.
- Proper sensor placement to avoid the effect of gravity and finding the right constant for the filter lead to successful results.

Conclusion

- The development of a square was recognized when the resonant frequency of the High-Pass Filter was adjusted.
- The LED on/off signal was used to indicate the initial hypothesis.

Future Works

- A new methodology connecting the LED Light to a mobile application is needed.
- A realistic setup could be made for the project and would allow for using modern sensors.

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Analyzing and Quantifying Laser Beam Quality Using the Knife Edge Technique to Calculate the M² Factor

A laser beam’s quality is a critical parameter in the performance of the laser in the laboratory or for industrial use. Describing the beam quality entails measuring the beam’s spot size, a fundamental problem in laser diagnostics as laser beams are often irregular in shape. This is due to the various modes in a laser beam. The ideal Gaussian beam consists of the fundamental lowest-order TEM00 mode and has an irradiance beam profile described by a Gaussian function. We demonstrate a beam quality factor measurement of a terahertz quantum-cascade vertical external cavity surface-emitting laser (QCL-VECSEL). The external cavity ideally allows for lasing at the fundamental Gaussian mode. Using a knife-edge measurement scheme, the M² factor can be extracted, which describes the extent to which the beam is diffraction limited.

The knife edge technique uses a converging lens to focus on the beam and makes a series of stopped measurements with a knife-edge in two different transverse directions at and around the lens’s focus where the beam radius is minimized. This allows the calculation of the beam’s spot size, the radius of the beam containing the majority of the power, by measuring the transmitted power with the shift of the knife in the transverse directions. By analyzing the behavior of the beam radius across the optical axis, the divergence of the beam is characterized.

The small M² values were mainly due to diffraction effects from the experimental setup and the knife’s edge effects. Several mirrors were used to reflect the beam before detecting the position. Altering the experimental setup could cause the small M² values, in which case the knife edge does not provide an ideal measurement scheme for an increased beam quality. The experiments specific laser operates with 1.7 mW average power, pulsed mode, 10% duty cycle at 3.44 THz, 77K operating temperature.

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Implementing Kinematic Prediction via Physics-Guided Neural Networks

Physics-guided neural networks (PGNNs) are crucial for modeling resistive behaviors in real-life scenarios ranging from vehicle tracking to aerial trajectories. In prior papers, bounding box construction for videos would entail construction for every individual frame, hindering progress in terms of speed-up without significant computational power. This paper aims to bridge the divide between image and video object detection, utilizing kinematic priors to predict the motion of subjects via the incorporation of affine transformations and perspective consideration (horizontal, side-to-side, overhead, etc.). Approaches based on optical flow algorithms and tubular architectures are considered and blended with physical models to harmonize spatiotemporal coherence among individual frames. PyTorch 1.0 acts as the framework for code development, and all code is expected to be open-source for future development.

Future Plans

The proposed physics model performs with high confidence values in the ideal scenarios created within the dataset. Experiments for future improvements include higher efficiency rates, faster processing times, greater accuracy in object detection and motion prediction, and improved ability to account for changing resistive forces, resistance, and object motion. The added complexity of object occlusion was captured for the purpose of modeling realistic difficulties in object detection and motion prediction.

Dataset

Applications of physics-based calculations on the Faster R-CNN framework were tested on a self-made dataset of videos that captured optimal scenarios, including drops, tosses, and object sliding on surfaces to model the effects of gravity, resistance, and object motion. The added complexity of object occlusion was captured for the purpose of modeling realistic difficulties in object detection and motion prediction.
Environmental Detection Using Mobile Sensors

Machine learning has made significant strides in enhancing human situational awareness with respect to recollection. In order to improve this cognitive ability, it is necessary to have a baseline understanding of the environment, which can also provide context to particular applications. Although localization of a human combined with background knowledge of an area (e.g., having a map of a place) can provide some intrinsic understanding of an environment, there are limitations for both components. Typically, localization in outdoor settings relies on GPS, while indoor localization is dependent on existing infrastructure. In addition, it is neither scalable nor generalizable to rely on background information of an area for exploring new environments. In this work, we aim to provide a semantic understanding of human movement through different spaces using a mobile phone attached to the subject. In particular, we simplify the problem by detecting room-to-room movement instead of fine-grained localization. We further show that detecting room-to-room movement can be implemented using ubiquitous phone sensors that provide a less invasive means of interaction compared to that of a camera. Knowing when a user traverses from one room to another can provide a significant amount of information to make inferences about a specific location. These inferences can then be applied to a variety of applications, such as correlating environment with episodic brain activity.

Motivation

- IoT and Ubiquitous computing has led to the advancement of medical technology and innovation
- Detecting room to room movement can correlate environment to brain activity and recollection
- Can be implemented on nearly any phone and is much more private than a camera

Background

- Localization has been done in done in outdoor environments through the use of GPS signals
- Indoor positioning systems rely on pedometers, speedometers, and predetermined maps
- Using sound and its properties may be the key to pinpointing someone’s position regardless of location

Methods

- Recorded 800, three-second audio clips at 4 different locations
- Sample Set A – 400 samples with a High Frequency Tone (HFT) of 22 kHZ played from an external source
- Sample Set B – 400 samples without HFT
- Extracted audio features from the data to train supervised machine learning classification model based on a Random Forest algorithm

Results

- the overall loudness is greater in this outside area
- there is also a plethora of frequencies and noises occurring
- 22 kHZ can barely be heard, hardly any reverberations

<table>
<thead>
<tr>
<th>Brain Work</th>
<th>Hallway</th>
<th>Library</th>
<th>Without HFT Model</th>
<th>Overall Accuracy</th>
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<tbody>
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<tr>
<td>Overall Accuracy</td>
<td>97 %</td>
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References

Programable Transdermal Drug Delivery with a Iontophoretically Enhanced Microneedle System

Transdermal drug delivery (TDD) has sparked great interest within the medical field due to its painlessness, ease of use, and reduced risk of infection in comparison to conventional methods such as hypodermic needle injection. Additionally, the growth of wearable health monitoring devices has stimulated the demand for programmable closed-loop personal health systems that can deliver drug treatments in response to physiological changes. To further develop TDD and programmable delivery, investigation of new techniques are required. To this end, we combined hollow microneedle-arrays (MNA) and iontophoresis (ITP) in an effort towards achieving programmable delivery. The MNA serves the purpose of creating tiny pores in the stratum corneum that act as drug delivery channels. In conjunction, ITP utilizes a small electric field in order to drive ionized drug molecules into the skin using electrostatic forces. Additionally, ITP allows for fine control over the delivery rate by adjusting the current strength. We tested the ITP-enhanced MNA by delivering fluorescent-dyed insulin into porcine skin samples at various time intervals and currents. The skin was then analysed using confocal laser scanning microscopy (CLSM) to determine the penetration depth of the insulin. CLSM imaging and fluorescent intensity analysis revealed that the ITP-enhanced MNA have a significantly greater penetration depth than individually applying either one. The ITP-enhanced MNA system proved to be an effective delivery strategy for larger molecule drugs in a small form factor and with easily-programmable control. Further testing of ITP-enhanced MNA with larger molecules could expand the range of suitable drugs for TDD applications.

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Abstract
Transdermal drug delivery (TDD) has sparked great interest within the medical field due to its painlessness, ease of use, and reduced risk of infection in comparison to conventional methods such as hypodermic needle injection. Additionally, the growth of wearable health monitoring devices has stimulated the demand for programmable closed-loop personal health systems that can deliver drug treatments in response to physiological changes. To further develop TDD and programmable delivery, investigation of new techniques are required. To this end, we combined hollow microneedle-arrays (MNA) and iontophoresis (ITP) in an effort towards achieving programmable delivery. The MNA serves the purpose of creating tiny pores in the stratum corneum that act as drug delivery channels. In conjunction, ITP utilizes a small electric field in order to drive ionized drug molecules into the skin using electrostatic forces. Additionally, ITP allows for fine control over the delivery rate by adjusting the current strength. We tested the ITP-enhanced MNA by delivering fluorescent-dyed insulin into porcine skin samples at various time intervals and currents. The skin was then analysed using confocal laser scanning microscopy (CLSM) to determine the penetration depth of the insulin. CLSM imaging and fluorescent intensity analysis revealed that the ITP-enhanced MNA have a significantly greater penetration depth than individually applying either one. The ITP-enhanced MNA system proved to be an effective delivery strategy for larger molecule drugs in a small form factor and with easily-programmable control. Further testing of ITP-enhanced MNA with larger molecules could expand the range of suitable drugs for TDD applications.

In order to demonstrate the effectiveness of the iontophoresis-enhanced MNA, the delivery system was tested on porcine skin. The device was attached with a fluorescent dye-filled reservoir on top of the skin sample. The effectiveness of iontophoresis was confirmed by the increasing fluorescent intensity at the skin surface, indicating a successful delivery of the fluorescent dye into the skin sample.
Competitive Cation Exchange Behavior of Simulated Wastewater Streams Using Zeolites and Cation Exchange Resins for CO₂ Mineralization

Sodium based zeolites and resins, often used for gas adsorption and water softening processes, are proposed to be used to induce a pH shift required for CO₂ mineralization using a CO₂ - rich stream. These materials initiate a Na⁺ / H⁺ exchange, which increases alkalinity, forming carbonate ions (CO₃²⁻) for mineralization. Produced water, a waste stream rich in calcium and sodium ions, is proposed for mineralization (to produce calcium carbonate) and for the regeneration of materials. However, produced water streams also contain other polyvalent cations that could potentially compete with Na for exchange sites and inhibit regeneration. This research explores the competitive exchange of common ions found in produced water on various zeolites and exchange resins that may inhibit regeneration capacities. Ion exchange capacities and kinetics in single component systems using synthetic zeolites 13X and 4A, along with organic resins TP-207 and TP-260 were studied using calcium, magnesium and iron ions for exchange. Various concentrations of ions in solution over time were analyzed through inductively coupled plasma optical emission spectroscopy (ICP-OES). Dual component exchange capacities were further examined to determine competitive exchange behavior using fixed sodium concentration and varying calcium, magnesium and iron concentrations to simulate the concentrations within produced water streams.

Concentration of ions within each 10 ml sample was analyzed using ICP-OES (along with other tests) after exchange is complete.

Conclusion & Future Research

Table 1: Displays the times at which the shaker solutions were sampled

<table>
<thead>
<tr>
<th>Reaction Time, t (min)</th>
<th>Ca (mmol)</th>
<th>Mg (mmol)</th>
<th>Fe (mmol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>2</td>
<td>0.1</td>
<td>0.2</td>
<td>0.3</td>
</tr>
<tr>
<td>4</td>
<td>0.2</td>
<td>0.4</td>
<td>0.6</td>
</tr>
<tr>
<td>6</td>
<td>0.3</td>
<td>0.6</td>
<td>0.9</td>
</tr>
<tr>
<td>8</td>
<td>0.4</td>
<td>0.8</td>
<td>1.2</td>
</tr>
</tbody>
</table>

Table 3: Comparison of exchange capacities of TP-207 and TP-260 resins

Table 4: Comparison of exchange capacities of TP-207 and TP-260 resins

Future Work:

- More selective towards Ca
- Further exam of other polyvalent cations that could potentially compete with Na for exchange sites and inhibit regeneration.
- Use a Na free solution with variable concentrations of Ca, Mg, Fe and other polyvalent cations.
- Use model fitting to adjust parameter values of each exchange resin.
- Use equilibrium constant (K) for exchange.

Acknowledgments

- Professor Gaurav Sant
- Civil and Environmental Engineering Department
- UCLA Department of Civil/Environmental Engineering

References

- Alyssa Eckley, Steven Bustillos, Gaurav Sant
- UCLA Department of Civil/Environmental Engineering
Physics-Based Object Temporal Localization Via Video Segmentation

The field of object detection has seen much advancements over the past years, especially in videos with the implementation and improvements of architectures such as Optical Flow, Tubelets, and Temporal Action Localization. However, such methods are still limited in their speed, efficiency, and accuracy, with the current fastest method running at an average of two frames per second. Thus, we propose the usage of the Physics Guided Neural Network (PGNN) to aid this task. By specifically tailoring this to detection of cars we hope to produce a naive form of detection that can track and solve transformations (i.e. scale, shear, and direction) of cars as they travel down a road. Using segmentation, we would then be able to establish instances of the cars as apply a physics model and determine each object’s trajectory based on the previous frames of the object’s path. The application of the physics model will serve to reduce the computational requirements of previous methods and allow for a more accurate prediction of an object’s temporal location.

Future Plans

The proposed physics model performs with high confidence values in the ideal scenario created within the dataset. Improvements for future applications include higher efficiency rates, faster processing times, greater accuracy between multiple objects, and more accurate predictions for unlearned objects such as pedestrians, bike, and vehicle motion.

Limitations of current model:

- Difficulty to account for changing acceleration
- Inability to predict object motion with accelerations
- Prediction model accounts for only 2D object motion.
- Uncalibrated data lacks physics-based machine learning

Applications:

- Self-Driving
- Defense Industry
- Autonomous Drones
- Movement Prediction

References

- “Physics-Based Object Temporal Localization via Video Segmentation” by Brian Chap, Lucas He, Irfan Syed, Guangyuan Zhao, Achuta Kadambi
- Department of Electrical and Computer Engineering, UCLA
Ultrafast Real-Time Dynamics of Frequency Microcomb Transitions

Temporally stabilized optical solitons, also known as self-sustaining nonlinear pulses at a mid-infrared frequency, confined in a microcavity driven by a continuous-wave laser has attracted tremendous attention due to its fascinating spectral and temporal features and corresponding intriguing cavity dynamics. A real-time ultrafast oscilloscope characterization system demonstrates the dynamics in the microcavity with picosecond resolution and a 500 picosecond recording length over each frame. However, the recording length is limited by the sampling rate due to the restricted memory depth of the oscilloscope during data acquisition.

To bypass this complication, time lens was used to stretch the timescale of the waveform without adding distortion or noise. After finding the optimum recording length and temporal resolution, a Kerr frequency comb is generated in the microcavity with a laser which is then sent through optical fibers to the oscilloscope to be studied. We were then able to record the mode-locking formation and the transitions between different soliton states during the formation process. The real-time observations of the ultrafast optical dynamics provides new physical insight for ultrafast phenomena that happens in the microcavity.

### Results

- **Kerr Frequency Comb**
  - A frequency comb is generated by an optical spectrum analyzer from a signal on the time domain that uses the Fourier transform in the cavity to the frequency domain creating an equidistant spectrum of pulses.

- **Time Lens Setup**
  - The schematic setup of how the time lens system is implemented from the signal and pump power input to the output on the oscilloscope is shown.
  - The right shows a flow diagram of where that signal travels.
  - The time domain is stretched 74 times with a recording length of 500 ps and temporal resolution of 1.5 ps.

### Conclusions and Future Works

- Observed new physical insights regarding ultrafast optical phenomena in the microcavity and observed the transitions between soliton states.
- Continue to study the dynamics and increase temporal resolution using different systems and methods to further the advancement in laser science, spectroscopy, precision measurements, and other optical physics fields.

### Acknowledgements

Thank you to Professor Chee Wei Wong for granting the opportunity to work with his research lab. We would like to acknowledge Dr. Wenting Wang’s guidance and support in our research. We would also like to thank Tz-Wei Hung for his assistance in data analysis and manuscript preparation. This research was supported by the National Science Foundation (NSF) and the California Institute of Technology (Caltech).
Environmental Detection Using Mobile Sensors

Machine learning has made significant strides in enhancing human situational awareness with respect to recollection. In order to improve this cognitive ability, it is necessary to have a baseline understanding of the environment, which can also provide context to particular applications. Although localization of a human combined with background knowledge of an area (e.g., having a map of a place) can provide some intrinsic understanding of an environment, there are limitations for both components. Typically, localization in outdoor settings relies on GPS, while indoor localization is dependent on existing infrastructure. In addition, it is neither scalable nor generalizable to rely on background information of an area for exploring new environments. In this work, we aim to provide a semantic understanding of human movement through different spaces using a mobile phone attached to the subject. In particular, we simplify the problem by detecting room-to-room movement instead of fine-grained localization. We further show that detecting room-to-room movement can be implemented using ubiquitous phone sensors that provide a less invasive means of interaction compared to that of a camera. Knowing when a user traverses from one room to another can provide a significant amount of information to make inferences about a specific location. These inferences can then be applied to a variety of applications, such as correlating environment with episodic brain activity.

Motivation

- IoT and Ubiquitous computing has led to the advancement of medical technology and innovation
- Detecting room to room movement can correlate environment to brain activity and recollection
- Can be implemented on nearly any phone and is much more private than a camera

Results

- the overall loudness is greater in this outside area
- there is also a plethora of frequencies and noises occurring
- 22 kHz can barely be heard, hardly any reverberations

Background

- Location has been done in outdoor environments through
  - the use of GPS signals
  - Indoor positioning systems rely on speedometers, speedometers, and predetermined maps
  - Using sound and its properties may be the key to pinpointing someone’s position regardless of location

Methods

- Recorded 800, three-second audio clips at 4 different locations
- Simple Set A – 400 samples with a High Frequency Tone (HFT) of 22 kHz played from an external source
- Simple Set B – 400 samples without HFT
- Extracted audio features from the data to train supervised machine learning classification model based on a Random Forest algorithm

Conclusion and Future Works

- Utilize a variety of mobile sensors with time synchronization to dramatically increase accuracy of room detection
- Implement a neural network to learn distinguishing factors as much more data is collected
- Train better models based on better locations, more samples, and more representative audio features

References

Custom Printable Robotic Boats for Early STEM Education

Robotics engages students in multiple disciplines of engineering, which is increasingly important in our technology-based society. However, existing robotics kits are mostly geared toward middle- and high-school students and either cost hundreds or thousands of dollars or have limited hands-on design capabilities. This leaves customizable robotics unaffordable to many schools, as well as neglects to introduce robots to impressionable elementary-age children. Our project focused on concurrently addressing three concerns: cost, age group, and creative potential. We developed a modifiable template for an affordable robot that students design themselves, supporting a project-based learning approach, with the goal of inspiring interest in STEM in kindergartners.

Since most robotics kits are cars, we designed a robotic boat and a web-based app, which students use to create and steer the boat. One boat is made of a flat sheet of plastic folded into a 3D structure, with basic electronics propelling the vehicle, and costs under $40 total. In the app, powered by Robot Compiler technology, students change parameters on the boat to see the effect on the 2D print-and-cut 3D model of the finished boat. This focus on customization encourages iterative design and engages students firsthand in the engineering innovation process. Students have flexibility in designing their robots down to the component level, fostering a sense of ownership over their project and resulting in a more self-motivated learning experience.
Studying changes of mind in decision-making

A decision is a commitment to an action after consideration of evidence and expected outcomes. The brain deliberates on available evidence to yield an action or decision. However, during cognition, we often change our minds; standard decision-making models do not fully explain why these changes of mind occur. The purpose of this study is to develop an experiment to study changes of mind, validizing work by Resulaj and colleagues. It was hypothesized that noisy evidence, in the form of a random dot motion stimulus, is accumulated over time until it reaches a criterion level, or bound. An initial decision is made once this criterion is achieved. While the trials were conducted, subjects made decisions about a noisy visual stimulus, and then they indicated their choice of direction by moving a joystick according to the direction inferred. The brain then exploited further information that either reversed or reaffirmed the initial decision made. We conclude that this study supports Resulaj’s findings and theory of post-initiation processing. This study is significant to understand decisions related to gambling, social selection, and probabilistic reasoning.

Materials and Methods

Experimental Setup

- Subjects perceive a specific direction upon viewing a random-dot stimulus. A mouse is used to move towards either a left or right target.
- The trial ends once the subject has reached one of the two targets.

Timeline of Trial

<table>
<thead>
<tr>
<th>Stimulus on screen</th>
<th>Random dot motion stimulus</th>
<th>Movement direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reaction time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coding</td>
<td>Random dot stimulus is presented with Python. The code is written in Python using the PsychoPy software.</td>
<td></td>
</tr>
</tbody>
</table>

References

Pilly, P. K., & Sato, A. R. (2009). A decision is a commitment to an action after consideration of evidence and expected outcomes. The brain deliberates on available evidence to yield an action or decision. However, during cognition, we often change our minds; standard decision-making models do not fully explain why these changes of mind occur. The purpose of this study is to develop an experiment to study changes of mind, validizing work by Resulaj and colleagues. It was hypothesized that noisy evidence, in the form of a random dot motion stimulus, is accumulated over time until it reaches a criterion level, or bound. An initial decision is made once this criterion is achieved. While the trials were conducted, subjects made decisions about a noisy visual stimulus, and then they indicated their choice of direction by moving a joystick according to the direction inferred. The brain then exploited further information that either reversed or reaffirmed the initial decision made. We conclude that this study supports Resulaj’s findings and theory of post-initiation processing. This study is significant to understand decisions related to gambling, social selection, and probabilistic reasoning.

Future Directions

- We plan to expand on the study by placing targets at 100° and comparing this to data using 40° targets.
- We anticipate, since a less natural movement to change-direction is required, the frequency of changes of mind will decrease.

Acknowledgements

This work was supported by the National Science Foundation through the UCLA Summer Undergraduate Research Program, specifically under the UCLA Electrical and Computer Engineering Department. We thank William Hemmers and Muhammad Shazain Raiz for their guidance throughout the program.

Conclusions

- We conclude that this study supports Resulaj’s findings and theory of post-initiation processing.
- This study is significant to understand decisions related to gambling, social selection, and probabilistic reasoning.

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Design of Cyclic Redundancy Check (CRC) for Tail-Biting Convolutional Codes

Reliable transmission of data requires channel codes that can correct errors introduced by the channel and/or detect that a received or decoded sequence is not valid. Convolutional encoders can correct errors in a distorted received sequence by using the Viterbi algorithm to find the closest convolutional codeword to the received sequence. Cyclic redundancy check (CRC) codes can detect whether the convolutional codeword identified by Viterbi decoding corresponds to a valid message. While both CRCs and convolutional codes have been developed in the past, they have been designed independently even though they are not independent when used together. For zero-terminated convolutional codes (ZTCCs) that are terminated by a final sequence of inputs that drives the encoder to the zero state, our research group has designed CRCs that are optimal for a given ZTC. Tail-biting convolutional codes (TBCCs) avoid the overhead caused by ZTCs and therefore can achieve higher rates with essentially the same performance.

We propose a novel method to develop CRCs that are optimal for a given TBCC. This method involves developing CRCs for the initial and final parts of the TBCC separately and then combining them to form the overall TBCC.

Our research is directed towards developing CRCs that are optimal for a given TBCC.
Material Characterization Through THz-Wave Spectroscopy

Terahertz (THz) wave propagation allows for a large number of technological advances in modern systems, such as larger communication bandwidth and enhanced imaging resolution. THz wave signals also prove to be valuable in the practice of spectroscopy in order to characterize materials. The reason that THz waves present new advantages comes from two characteristics of millimeter waves. Because of their large bandwidth, these types of waves offer a larger absorption data set to uniquely identify materials. Secondly, their small wavelength nature allows these waves to have very high resolution in determining the thickness of a material.

This paper lays some groundwork of THz systems as a method of spectroscopy by testing its applications to solid materials. In our research, we set up a transmitter and a receiver to communicate with each other at varying sub-THz frequencies. An object of varying material is placed along the signal path to absorb some frequencies of communication dependent on the properties of that material. Intensity of the signals is measured at both the transmitter and the receiver and recorded in the frequency domain. Through a Support Vector Machine (SVM) machine learning algorithm, absorption plots obtained from various trials are used to identify the material obstructing the signal with 95% accuracy.

Materials and Methods

The SVM algorithm was most accurate when using between two and six frequency points for training and using a low value for gamma. For this range, the value of C didn’t affect the accuracy very much. The SVM algorithm was most accurate when using between two and six frequency points for training and using a low value for gamma. For this range, the value of C didn’t affect the accuracy very much. The SVM algorithm was most accurate when using between two and six frequency points for training and using a low value for gamma.

Conclusion/Future Works

An SVM algorithm was used since it can effectively distinguish between complex sets of data, such as the various material absorptions, with much greater success than a human could. SVMs classify data by determining an optimal hyperplane which acts as a separation boundary between different categories of data. SVM algorithm was used since it can effectively distinguish between complex sets of data, such as the various material absorptions, with much greater success than a human could.

References


Acknowledgements

We would like to thank the UCLA Summer Undergraduate Research Program for this research opportunity and the ECE Dean’s Department for funding the experience. We would also like to thank Professor Babakhani for providing the opportunity to work in his lab as well as Babak Jamali for his support and guidance throughout the program.
Fabrication and Design of a Wearable Microfluidic Device Integrated with Electrochemical Sensors for the Detection of Glucose and Lactate Variation in Sweat

Abstract

Traditionally, glucose and lactate levels are sampled via subcutaneously extracted blood tests. However, these previous methods often involve long and tedious processes such as laboratory testing, and they are susceptible to medical risks such as skin infections. In this study, we fabricated and designed a wearable microfluidic device that detects the glucose and lactate variation in sweat, which overcomes the shortcomings of previously reported methods. The microfluidic device is comprised of plastic, double-sided tape, microheaters, and thermoresponsive hydrogel valves to facilitate the active manipulation of sweat. Additionally, the device was integrated with a 3-electrode electrochemical sensor system capable of measuring the glucose and lactate levels in sweat, which overcomes the limitations of previously reported methods. The microfluidic device is fabricated using a laser cutter, the final device can transmit the measured glucose and lactate levels to a mobile device. Interconnected with Internet of Things (IoT) devices, on-body microfluidics devices have the potential to switch the point of care from hospitals and labs to personalized health monitoring via wearable platforms.

Future Work

To achieve real-time monitoring of glucose and lactate levels in the human body range (10-20 mM/L), additional testing is required to determine the optimal thickness of the plastic (PVC) device. Additionally, to make the device more reliable and stable, further testing and optimization are needed to determine the optimal PVC thickness. Additionally, the device was integrated with a flexible printed circuit board, the final device can transmit the measured glucose and lactate levels to a mobile device. Interconnected with Internet of Things (IoT) devices, on-body microfluidics devices have the potential to switch the point of care from hospitals and labs to personalized health monitoring via wearable platforms.

References


Acknowledgement

This work was funded by Dr. Gregory Polk's NSF grant for Women's Health Institute and the Transfer Student Research Program. The authors would like to thank the UCSB Interconnect and Integrated Bioelectronics Laboratory and UCLA Nanolab for their support.

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Fabrication and Design of a Wearable Microfluidic Device Integrated with Electrochemical Sensors for the Detection of Glucose and Lactate Variation in Sweat

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Effect of Hyaluronic Acid Molecular Weight on CD44 Clustering

The regeneration of tissue after spinal cord injury (SCI) has proven difficult as a result of the complex pathophysiology at the injury site. One biomolecule that plays an important role in the wound healing response is hyaluronic acid (HA), a long-chain polysaccharide in the extracellular matrix. It is known that HA signals cells to directly influence the inflammatory response in a molecular weight-dependent manner. One possible explanation for this effect is that different molecular weights of HA bind differentially to the CD44 receptor to induce varying levels of clustering. A model cell line, human embryonic kidney (HEK293T), was transduced with CD44 overexpression lentiviral vectors and treated with HA of varying molecular weights. CD44 clustering was characterized using both fluorescent resonant energy transfer (FRET) and Western blotting assays. Measurements of receptor clustering levels were made using HEK293T cells infected with two different viruses, CD44-YPet and CD44-CyPet, which promote expression of the CD44 receptor coupled to the YPet and CyPet fluorophores, respectively, which are well-established FRET pairs. To quantify expression of clustered and unclustered CD44 via Western blotting, the crosslinker bis(sulfosuccinimidyl)suberate (BS3) was used to preserve the CD44 receptors clustered in the cell membrane prior to cell lysis. Both FRET and Western blot analysis demonstrated that CD44 receptors in the presence of HA undergo greater clustering. Furthermore, data suggests that increasing molecular weight of HA may correspond with higher levels of CD44 clustering, although additional experimental repeats are required for verification.
Studying changes of mind in decision-making

A decision is a commitment to an action after consideration of evidence and expected outcomes. The brain deliberates on available evidence to yield an action or decision. However, during cognition, we often change our minds; standard decision-making models do not fully explain why these changes of mind occur. The purpose of this study is to develop an experiment to study changes of mind, validating work by Resulaj and colleagues. It was hypothesized that noisy evidence, in the form of a random dot motion stimulus, is accumulated over time until it reaches a criterion level, or bound. An initial decision is made once this criterion is achieved. While the trials were conducted, subjects made decisions about a noisy visual stimulus, and then they indicated their choice of direction by moving a joystick according to the direction inferred. The brain then explored further information that either reversed or reaffirmed the initial decision made. We conclude that this study supports Resulaj’s findings and theory of post-initiation processing. This study is significant to understand decisions related to gambling, social selection, and probabilistic reasoning.

Random Dot Motion Stimulus

- Random dot motions (RDM) are a classic stimulus used in psychophysical and physiological studies of motion processing.
- RDM occur in binary directions and can be modified to occur at different motion coherences.
  - Right vs. Left
  - Up vs. Down

Materials and Methods

Experimental Setup

- Subjects perceive a specific direction upon viewing a random dot stimulus. A mouse is used to move towards either a left or right target.
- The trial ends once the subject has reached one of the two targets.

Timeline of Trial

- Stimulus onset
- Cursor position
- Random dot stimulus is presented with Python, primarily based with the PsychoPy library.
- The time course of events that make up a trial.

Coding

- Random dot stimulus is generated with Python, primarily based with the PsychoPy library.
- The time course of events that make up a trial.

References

Design of Flexible, Wireless Surface Electromyography System

According to the CDC 1 in every 7,250 males are afflicted by Duchenne and Becker muscular dystrophy, a disease that affects muscle strength and leads to muscle degeneration. Surface Electromyography (EMG) is a non-invasive method used to measure muscle activity that can help in the diagnosis and treatment of musculoskeletal diseases such as muscular dystrophy. Typical Surface Electromyography machines are often bulky, rigid, and heavy which makes them difficult to use in a clinical setting, and it means they cannot be used as wearable devices. In addition, these systems are often single-channel systems which limit the spatial and temporal information that the system can gather, making readings incomplete. To help solve these issues, a full multi-channel electromyography system that is lightweight, flexible, and wireless will be integrated on FlexTrate™, a flexible electronic platform based on Fan-Out Wafer Level Packaging (FOWLP). The surface EMG will take advantage of FlexTrate™ to integrate a variety of different integrated circuit (IC) dies such as amplifiers, passive components, and a Bluetooth Low Energy (BLE) chip as well as electrodes to detect the EMG signal. For wireless communication, the Nordic nRF52840 BLE module is used for low power. Using FlexTrate™, the overall system will be lightweight, thickness less than 1 mm, and flexible enough to conform to skin allowing for a wearable device that can be used easily in a clinical setting.
Spin-polarized Electrons by Photoionization with Intense Ultrashort Lasers

High-energy spin-polarized electrons are important for the investigation of pathways in high-energy collisions. However, generation of such electrons is difficult using conventional methods. Photoionization is a very common phenomenon that shows potential to provide a simpler way to produce spin-polarized electrons.

Developments in laser technology have made it possible to create extremely high intensity light, which leads to various ionization processes. Multiphoton ionization involves the transfer of energy from multiple photons to an electron in order to surpass the ionization potential. Tunneling ionization occurs when higher field strength and lower frequencies allow the laser to be treated as an electric field which changes the shape of the potential barrier and allows the electron to escape through tunneling. The rates of ionization in these regimes have been described by several theories developed by Landau, Keldysh, ADK, PPT, and Barth and Smirnova. Different models of ionization rates were compared in order to find the areas in which they can be used to accurately describe ionization. The incorporation of magnetic and angular momentum quantum numbers into ionization rates allows for selective ionization of spin-polarized electrons, leading to predictions of up to 30% spin polarization. This may open a new avenue for the generation of high-energy, spin-polarized electrons in combination with the laser wakefield acceleration technique.

References

I. Barth and O. Smirnova. Different models of ionization rates were compared in order to find the areas in which they can be used to accurately describe ionization. The incorporation of magnetic and angular momentum quantum numbers into ionization rates allows for selective ionization of spin-polarized electrons, leading to predictions of up to 30% spin polarization. This may open a new avenue for the generation of high-energy, spin-polarized electrons in combination with the laser wakefield acceleration technique.

Electron orbitals

- Bound electrons have quantized energy levels, angular momentum, and projection of angular momentum, given by $l$, $m$, and $\pi$ quantum numbers.
- $l$ represents the angular momentum, and $m$ represents the projection of angular momentum onto the direction of the electric field.
- For linearly polarized light, $m = 0$ has the highest ionization rate. Counter rotating light can be seen as a sense of rotation of the electron.
- For $m = 1$, it can be used to control the ionization process.

Spin Selectivity

- High enough electric fields will deform the potential barrier to the point that tunneling ionization becomes suppressed.
- Under these conditions, the ionization process is dominated by multiphoton ionization.
- For $\gamma = 1$, tunneling ionization is suppressed, and multiphoton ionization is the dominant process.

Conclusions and Future Work

- Different theories of ionization are investigated and summarized in order to gain an understanding of photoionization under high intensity light. These theoretical investigations are expected to pave the way for the development of photoionization based on high energy spin-polarized electron generation.
Background
The 1940s marked the beginning of modern computing and communications. The two potential competing approaches that were about to drive these technologies were digital and analog. At that time digital computing was unreliable and analog computing was impractical. Digital paradigm witnessed advancement in the theory and the development of hardware that scaled speed, cost, and energy. While the analog paradigm did not have any significant advances and as a result digital emerged as the winner. Modern-day integrated circuits use CMOS transistors and a lot of success of the integrated circuit technology is attributed to the decrease in the size of the CMOS over the last few decades. However, due to the impending end of CMOS scaling, we need to find alternative ways to continue to scale speed and power. If we are able to return to analog and improve the precision with today’s modern integrated circuit technology, we might be able to get results competing with digital in some applications. In this work, we focus on characterizing the types of impairments in computation that can be tolerated for two important classes of problems: those that can be solved with linear methods using LMS adaptation, and those that can be solved using neural nets with backpropagation. Studying the impact of these impairments helps us understand the range of imprecision that analog circuits can operate while still being able to result in a desirable behavior.

Motivation
A linear digital system is an ideal transformation and a lot of research in the field of communication is attributed to the study of the linear systems. In the real world, the linear systems are dominant, so the linear system theory is used to model the real-world systems. Nonlinear systems are much more realistic and the study of nonlinear systems is more complicated. The linear system theory cannot handle the nonlinear systems, so we need a technique to handle the nonlinear systems. One way to handle the nonlinear systems is by using approximation techniques. We can approximate the nonlinear systems by using linear models and LMS adaptation, so we can get results competing with digital in some applications.

Methods
The two potential competing approaches that were about to drive these technologies were digital and analog. At that time digital computing was unreliable and analog computing was impractical. Digital paradigm witnessed advancement in the theory and the development of hardware that scaled speed, cost, and energy. While the analog paradigm did not have any significant advances and as a result digital emerged as the winner. Modern-day integrated circuits use CMOS transistors and a lot of success of the integrated circuit technology is attributed to the decrease in the size of the CMOS over the last few decades. However, due to the impending end of CMOS scaling, we need to find alternative ways to continue to scale speed and power. If we are able to return to analog and improve the precision with today’s modern integrated circuit technology, we might be able to get results competing with digital in some applications. In this work, we focus on characterizing the types of impairments in computation that can be tolerated for two important classes of problems: those that can be solved with linear methods using LMS adaptation, and those that can be solved using neural nets with backpropagation. Studying the impact of these impairments helps us understand the range of imprecision that analog circuits can operate while still being able to result in a desirable behavior.

Results
Figure 5. A visual representation showing the type of problem we are trying to solve.
Figure 6. The graph of the output method that has an optimal solution.
Figure 7. The graph of the output method that has an optimal solution.
Figure 8. A visual representation showing the type of problem we are trying to solve.
Figure 9. A simplified diagram showing the type of problem we are trying to solve.

Future Applications
We can further use our work and its applications in various fields. One was model to be trained on analog CPP, but recent advances in the field of analog computing has made it possible to get results competing with digital in some applications.

Acknowledgements
We would like to thank our advisors who have supported us throughout these projects. We extend our thanks to the Department of Electrical and Computer Engineering at the University of Arkansas at Pine Bluff, TRSRP, NSF, and the Allen Fund.

Precision in Computing and Communication with Feedback
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Department of Electrical and Computer Engineering
Automated Speech Database Organization

The development of an autonomous social robot, able to deliver clinical and educational assessments to young children, has great potential to aid in the efforts of educators and help students reach age-appropriate levels of proficiency in reading and oral language skills. A study researching the feasibility of the JIBO robot for such purposes, as well as gathering data needed to improve child automated speech recognition (ASR), resulted in a large dataset of verbal interactions between the robot and children via the administration of the Goldman-Fristoe Test of Articulation (GFTA) and other language tasks. Prior to database publication, time consuming and error-prone tasks such as matching audio data with corresponding prompt-answer pairs and the notation of private information for removal must be performed. We present a design and Python implementation for software automating and simplifying such processes. As robot prompts are known and consistent, timestamps are detected in audio files using a cross-correlation approach. We propose several methods of avoiding computationally expensive operations during such a search. For files with transcripts, processing is done using both a brute force search and the SpaCy natural language processing package, the latter to identify possible private information. Results are compared and combined with those from audio processing. Finally, we propose a database organizational structure and documentation in preparation for future publication.

Design: Audio Processing

- A web-based dataset interface designed and accompanied with documentation using content data from the designed processing methods.
- User interface was created for labeling and cutting audio. It decreases manual work by giving the user various features:
  - Jump to audio containing private info or the beginning of certain tasks
  - Switch between textual and audio analysis (Figure 4) of child interviews

Design: Text Processing

- Processing of audio transcripts was uninf. In multiple ways:
  - To extract task completion data for documentation
  - To identify private information
  - As a tool for labeling and cutting audio
  - To perform fine-grained analysis of the form (micro-recognition)

Design: Python

- The program used for Natural Language Processing aimed at identifying private information within files, decreasing manual work.

Conclusion and Future Work

- Deliverables
  - User interface ready to track and cut speech transcriptions in audio files
  - Documentation of development processes

References


Precision in Computing and Communication with Feedback

The 1940s marked the beginning of modern computing and communications. The two potential competing approaches that were about to drive these technologies were digital and analog. At that time digital computing was unreliable and analog computing was imprecise. Digital paradigm witnessed advancement in the theory and the development of hardware that scaled speed, cost, and energy. While the analog paradigm did not have any significant advances and as a result digital emerged as the winner. Modern-day integrated circuits use CMOS transistors and a lot of success of the integrated circuit technology is attributed to the decrease in the size of the CMOS over the last few decades. However, due to the impending end of CMOS scaling, we need to find alternative ways to continue to scale speed and power. If we are able to return to analog and improve the precision with today’s modern integrated circuit technology, we might be able to get results competing with digital in some applications. In this work, we focus on characterizing the types of impairments in computation that can be tolerated for two important classes of problems: those that can be solved with linear methods using LMS adaptation, and those that can be solved using neural nets with backpropagation. Studying the impact of these impairments helps us understand the range of imprecision that analog circuits can operate while still being able to result in a desirable behavior.

Background

The 1940s marked the beginning of modern computing and communications. The two potential competing approaches that were about to drive these technologies were digital and analog. At that time digital computing was unreliable and analog computing was imprecise. Digital paradigm witnessed advancement in the theory and the development of hardware that scaled speed, cost, and energy. While the analog paradigm did not have any significant advances and as a result digital emerged as the winner. Modern-day integrated circuits use CMOS transistors and a lot of success of the integrated circuit technology is attributed to the decrease in the size of the CMOS over the last few decades. However, due to the impending end of CMOS scaling, we need to find alternative ways to continue to scale speed and power. If we are able to return to analog and improve the precision with today’s modern integrated circuit technology, we might be able to get results competing with digital in some applications. In this work, we focus on characterizing the types of impairments in computation that can be tolerated for two important classes of problems: those that can be solved with linear methods using LMS adaptation, and those that can be solved using neural nets with backpropagation. Studying the impact of these impairments helps us understand the range of imprecision that analog circuits can operate while still being able to result in a desirable behavior.

Motivation

Shaker dog operated pipeline no single transistors and a lot of success of the integrated circuit technology is attributed to the decrease in the size of the CMOS over the last few decades. However, due to the impending end of CMOS scaling, we need to find alternative ways to continue to scale speed and power. If we are able to return to analog and improve the precision with today’s modern integrated circuit technology, we might be able to get results competing with digital in some applications. In this work, we focus on characterizing the types of impairments in computation that can be tolerated for two important classes of problems: those that can be solved with linear methods using LMS adaptation, and those that can be solved using neural nets with backpropagation. Studying the impact of these impairments helps us understand the range of imprecision that analog circuits can operate while still being able to result in a desirable behavior.

Methods

Due to the similarities in design of the digital paradigm with the analog paradigm, it is important to emphasize the potential of filtering, the word “digital” and “analog” are often used to describe the types of computations that are done on signals that are classified as “digital” and “analog”. In this work, we focus on characterizing the types of impairments in computation that can be tolerated for two important classes of problems: those that can be solved with linear methods using LMS adaptation, and those that can be solved using neural nets with backpropagation. Studying the impact of these impairments helps us understand the range of imprecision that analog circuits can operate while still being able to result in a desirable behavior.

Results

The graph of the performance of the digital method that has run 85000 times.

Figure 1: A visual representation of the multithread problem solved.

Figure 2: A visual representation of the multithread problem solved.

Figure 3: A visual representation of the multithread problem solved.

Future Applications

We can further work on its applications in various areas. One way could be to create an analog GPU that could solve all the problems currently solved by CPUs. This will be substantially valuable for motion-related fields and self-driving cars. A CMOS GPU has run 85000 times. If we are able to return to analog and improve the precision with today’s modern integrated circuit technology, we might be able to get results competing with digital in some applications. In this work, we focus on characterizing the types of impairments in computation that can be tolerated for two important classes of problems: those that can be solved with linear methods using LMS adaptation, and those that can be solved using neural nets with backpropagation. Studying the impact of these impairments helps us understand the range of imprecision that analog circuits can operate while still being able to result in a desirable behavior.

Acknowledgements

We would like to thank everyone who has contributed to this paper. We thank the students in Professor Greg Pottie’s Laboratory for their contributions. We thank the Department of Electrical and Computer Engineering at El Camino College for their support. We also thank the TSSRP, UCL and the MIT Athena Program.
Distributed Quantization for Classification Tasks

When using quantization schemes for distributed classification, the goal is not to reconstruct quantized data perfectly; rather, it is to create a quantization approach such that the classifier maintains the accuracy it had before the large, high-precision data was quantized. If a communication quality constraint exists between different devices in the system, then the number of bits that can be used in our quantization approach is further limited. In applications, such as brain-machine interface and Google Cloud Internet of Things, there is a pretrained classifier that resides in a central node in a communication network, where it receives unclassified data that is distributedly generated. In the case of brain-machine interface, sensors are distributed on a subject’s body, and thus, high-precision features are generated from these body parts. This data is then classified for an actuator to carry out some action. Previously published solutions present a greedy algorithm that uses a recursive binning technique to quantize the data. We propose a more efficient, adaptable quantization approach implemented with neural networks. This approach achieves approximately the same accuracy as the greedy algorithm on an sEMG dataset with lower time complexity.
Absorption Spectroscopy Using Millimeter-Wave and Sub-Terahertz Frequencies

Sensing and retrieving data from millimeter-wave and sub-terahertz frequencies are useful for many different applications including faster data transmission in wireless communication and enhanced resolution in imaging systems. In this frequency regime, broadband systems are also useful for spectroscopy and detecting different absorption frequencies of gas molecules. A comb-based method can be used to enhance bandwidth to include these frequencies and coherent detection techniques can be used to implement a receiver that can detect them. Integrated circuits designed using this method exhibit improved bandwidth, and detection resolution as well as reduced power consumption compared to current CMOS wideband coherent receivers. One specific use for these transmitter and receiver circuits is absorption spectroscopy where the power of the signal generated by the transmitter is measured after it passes through a specific material and is recorded by the receiver. A support vector machine (SVM) algorithm can then be trained with the absorption data of multiple materials to identify a new material given its absorption data collected from the receiver. SVMs are machine learning models that can classify data by determining an optimal hyperplane which acts as a separation boundary between different categories of data. A machine that utilizes SVM is quite effective when it comes to distinguishing between complex sets of data since it is able to determine boundaries in the data that may not be the most obvious to the human eye.
Millimeter-Scale Electroplated Multilayer Magnetic Shielding

Many devices that rely on atomic spectroscopy, like gyroscopic sensors and atomic clocks, require magnetic shielding to function as intended because of interference by external magnetic fields. Although no known material is able to stop a magnetic field, high permeability materials are able to effectively redirect magnetic field lines, creating protected regions of low magnetic field strength. Current methods of magnetic shielding involve inserting a sheet of high permeability material on a circuit board underneath a device or wrapping a region in a sheet of the high permeability material. In this project, we fabricate high performance chip-scale magnetic shields by electroplating alternating layers of nickel-iron alloy, which has a high relative permeability, and copper, which has a low relative permeability, onto a cylindrical shell. By alternating layers of high and low permeabilities, we minimize the influence of the demagnetization field, achieving a higher ability to redirect magnetic field lines. To test the shields, we use an electromagnet to generate a magnetic field and a magnetometer to measure the magnetic field inside the shield. We record the shielding factor of the shield, which is defined as the ratio of the external magnetic field to the internal magnetic field strength. Successful millimeter-scale shielding would allow for effective chip-scale implementation of devices that would function in external magnetic fields while conserving space.

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Acknowledgements

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Discussion and Future Work

In summary, our results show that electroplated multilayer magnetic shields are able to achieve a shielding factor of 400, which is comparable to current methods of magnetic shielding. Future work includes improving the manufacturing process and testing the shields in a more controlled environment.
Gait Recognition Using SensorTile – A State Machine Approach

Personal devices, such as smart phones and wristbands, can be turned into mobile health devices with the help of embedded systems with wearable motion sensors and Internet of Things (IoT). Such devices are capable of providing real-time monitoring and feedback about training performance for outpatients with hemiparesis during their rehabilitation process. A reliable algorithm for gait recognition is required for the system to give accurate feedback. The goal of this research is to design and improve the performance of a custom-built state machine on a STM32 microcontroller SensorTile utilizing only the onboard accelerometer module (LSM6DSM). The motion path of a foot in a gait cycle is divided into four states and mapped to a horizontal surface. The recognition of a complete gait cycle is then accomplished by moving SensorTile along the path. Results have shown high reliability, with an identification accuracy of 90% when the cutoff frequency is set to 5 Hz for the low-pass filter applied to the acceleration signal, and 0.7 Hz for the high-pass filter applied to the velocity and displacement signals. The high accuracy demonstrates that accelerometer data can be used to identify two-dimensional gait cycles.

Materials and Methods

- Motion path of a foot in a gait cycle is divided into four states and mapped to a horizontal surface.
- Recognition of a complete gait cycle is accomplished while SensorTile is moved along the path (Fig. 9).
- Integrating filtered acceleration signals to obtain velocity signals.
- Integrating velocity signals to obtain displacement signals.
- Integrations in both axes are done by performing convolution integral with the impulse functions of the accelerometer and displacement data.

\[
\omega_m \times t + \omega_b = 0
\]

where \(\omega_m\) and \(\omega_b\) are the state machine and the base rotation of the sensor, respectively.

Conclusions

- Accelerometer data could possibly be used to identify two-dimensional gait cycles and/or other human motions.
- Integrating acceleration data using the method above using accelerometer gives relatively large error but does not affect identification of motion patterns.
- Future work may include utilization of gyroscope to detect 3-dimensional motions and reduce errors introduced by the tilting of SensorTile.

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- National Science Foundation (Grant no. 1636283)
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- UCLA Wireless Health Institute
- UCLA Transfer Student Summer Research Program

State Machine Design

- State 1: Stationary
- Transition 1 → State 2: Heel lifted
- Transition 2 → State 3: Moved forward
- Transition 3 → State 4: Heel dropped
- Transition 4 → State 1: Move the foot back to the initial state

Results

The system demonstrates high reliability, with an identification accuracy of 90% when the cutoff frequency is set to 5 Hz for the low-pass filter applied to the acceleration signal, and 0.7 Hz for the high-pass filter applied to the velocity and displacement signals.
Custom Printable Robotic Boats for Early STEM Education

Robotics engages students in multiple disciplines of engineering, which is increasingly important in our technology-based society. However, existing robotics kits are mostly geared toward middle- and high-school students and either cost hundreds or thousands of dollars or have limited hands-on design capabilities. This leaves customizable robotics unaffordable to many schools, as well as neglects to introduce robots to impressionable elementary-age children. Our project focused on concurrently addressing three concerns: cost, age group, and creative potential. We developed a modifiable template for an affordable robot that students design themselves, supporting a project-based learning approach, with the goal of inspiring interest in STEM in kindergarteners.

Since most robotics kits are cars, we designed a robotic boat and a web-based app, which students use to create and steer the boat. One boat is made of a flat sheet of plastic folded into a 3D structure, with basic electronics propelling the vehicle, and costs under $40 total. In the app, powered by Robot Compiler technology, students change parameters on the boat to see the effect on the 2D printable template and 3D model of the finished boat. This focus on customization encourages iterative design and engages students firsthand in the engineering innovation process. Students have flexibility in designing their robots down to the component level, fostering a sense of ownership over their project and resulting in a more self-motivated learning experience.

Problems with Existing Robotics Kits

- Expensive
- Middle- and high-school age group
- Limited hands-on design

Our Solution

- Creating a design tool for low-cost foldable robotic boats

Educational Applications

- Students design, build, and redesign robotic boats
- Hands-on experience with cycle of scientific experimentation

Student Design Process

1. Design in web-based app by inputting parameters
2. Print and cut out template
3. Fold and assemble boat. Test effects of chosen parameters

Results

- Iterative design process and customization allows for personalized products
- Encourages experimentation and hands-on learning approach
- Teaches gateway STEM skills and engineering/design process

Total cost: $30 (Retail), $15 (Bulk)

References

Automated Speech Database Organization

The development of an autonomous social robot, able to deliver clinical and educational assessments to young children, has great potential to aid in the efforts of educators and help students reach age-appropriate levels of proficiency in reading and oral language skills. A study researching the feasibility of the JIBO robot for such purposes, as well as gathering data needed to improve child automated speech recognition (ASR), resulted in a large dataset of verbal interactions between the robot and children via the administration of the Goldman-Fristoe Test of Articulation (GFTA) and other language tasks. Prior to database publication, time consuming and error-prone tasks such as matching audio data with corresponding prompt-answer pairs and the notation of private information for removal must be performed. We present a design and Python implementation for software automating and simplifying such processes. As robot prompts are known and consistent, timestamps are detected in audio files using a cross-correlation approach. We propose several methods of avoiding computationally expensive operations during such a search. For files with transcripts, processing is done using both a brute force search and the SpaCy natural language processing package, the latter to identify possible private information. Results are compared and combined with those from audio processing. Finally, we propose a database organizational structure and documentation in preparation for future publication.

Introduction

Subjects and Recordings:
- 136 children were recorded interacting with JIBO over 236 sessions.
- Sessions lasted between 5 and 40 minutes.
- Sessions were recorded in a classroom study space with limited noise.
- Children were recorded in a classroom study space with limited noise.
- Tasks:
  - JIBO’s Goldman-Fristoe Tests of Articulation (GFTA-3)
  - Letter and digit naming task
- Transcriptions:
  - Full transcriptions of the audio were produced by trained transcribers.
  - Phonetic transcriptions were produced by trained phoneticians.

Objectives

• Create an easy to use interface for extracting/creating file information.
• Automate the removal of private and sensitive data in audio.
• Prepare database for publication and distribution for research.

Methods

/\{Regular\}Expression$/

Design: Audio Processing

- Automate the removal of private and sensitive data in audio
- Create an easy to use interface for extracting/creating file information
- Design: Text Processing

Processing of audio transcripts was unified in multiple ways.
- To extract task completion data for documentation.
- To identify private information.
- As a guiding tool when labeling and cutting audio.
- Regular expression (regex) use on the predictable transcript layout resulted in consistent, timestamps are detected in audio files using a cross-correlation approach. We propose several methods of avoiding computationally expensive operations during such a search. For files with transcripts, processing is done using both a brute force search and the SpaCy natural language processing package, the latter to identify possible private information. Results are compared and combined with those from audio processing. Finally, we propose a database organizational structure and documentation in preparation for future publication.

Conclusion and Future Work

• Deliverables:
  - Use database in research for a number of diverse applications
  - Child speech and language assessment
  - Child speech and language assessment
  - Speech and language assessment
  - Speech and language assessment
  - Speech and language assessment

References


Design of Cyclic Redundancy Check (CRC) for Tail-Biting Convolutional Codes

Reliable transmission of data requires channel codes that can correct errors introduced by the channel and/or detect that a received or decoded sequence is not valid. Convolutional encoders can correct errors in a distorted received sequence by using the Viterbi algorithm to find the closest convolutional codeword to the received sequence. Cyclic redundancy check (CRC) codes can detect whether the convolutional codeword identified by Viterbi decoding corresponds to a valid message. While both CRCs and convolutional codes have been developed in the past, they have been designed independently even though they are not independent when used together. For zero-terminated convolutional codes (ZTCCs) that are terminated by a final sequence of inputs that drives the encoder to the zero state, our research group has designed CRCs that are optimal for a given ZTCC. Tail-biting convolutional codes (TBCCs) avoid the overhead caused by ZTCCs and therefore can achieve higher rates with essentially the same performance. Rather than using additional input symbols to drive the final state to zero, TBCCs enforce the constraint that the starting state is the same as the final state. Our research is directed towards developing CRCs that are optimal for a given TBCC.

Materials and Methods
- The group of the paper previously developed a tail-biting convolutional encoder and decoder. This work expanded the encoder and decoder to include cyclic redundancy check (CRC) codes. The encoder and decoder for ZTCCs were developed by our group and the encoder and decoder for TBCCs were developed by the group. Our group then designed CRCs that are optimal for a given ZTCC. The decoder we implement is based on the Viterbi algorithm, which can be solved with a Trellis diagram. The decoder determines the closest convolutional codeword to the received sequence.
- The decoder is implemented based on the Viterbi algorithm, which can be solved with a Trellis diagram. The decoder determines the closest convolutional codeword to the received sequence.
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- The decoder is implemented based on the Viterbi algorithm, which can be solved with a Trellis diagram. The decoder determines the closest convolutional codeword to the received sequence.

Conclusions & Future Work
- Overall, our experience with this program was great and learning and working together was a fantastic learning experience.
- Our main CRCs will remain in a block diagram that we still need some cycles to re-implement and test.

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Acknowledgments
We need to thank the National Science Foundation and the Electrical and Computer Engineering Department for providing us with the opportunity to work on this project and to Hsiu-Ming Yang for providing guidance and motivation throughout our research and learning process.

Conclusions
- All the CRCs are implemented correctly and correctly terminate the convolutional encoder.
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Simulation Results
- The simulation results for the designed CRCs are shown in Figure 4. The CRCs are implemented correctly and terminate the convolutional encoder correctly.
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Figure 1. Tail-biting convolutional encoder and decoder.

Figure 2. Trellis diagram of a tail-biting convolutional code.

Figure 3. The Viterbi algorithm used to determine the closest convolutional codeword to the received sequence.

Figure 4. The performance comparison of the designed CRCs with the state-of-the-art CRCs.

Figure 5. The overall system structure of convolutional codes and CRCs for communications.
Tracking Objects Using Physics-Guided Neural Networks

Incorporating physics into neural networks, known as physics-guided neural networks (PGNN), has been explored for object detection and tracking. The proposed method aims to enhance accuracy by merging regional convolutional neural networks (R-CNN) and physics-guided models. Using video segmentation methods, it uses a physics guided neural network to classify, detect, and track objects. A self-made dataset created with ideal scenarios involving linear motion such as object drops and tosses is the testing framework for the physics-guided model. The dataset contains scenarios involving the complexity of object occlusion for future development of the prediction model to increase accuracy in realistic, occluded situations. Classification and motion tracking of objects through predicted patterns rely on physics-based learning. By predicting trajectories in later frames based on kinematic calculation in earlier frames within the video, the model is able to detect and track the target object and increase accuracy. PyTorch 1.0 is the framework used for developing this platform and the code will be open source for future development.

Future Plans

The proposed physics model performs with high confidence values in the ideal scenario created within the database. Expectations for future improvements include higher efficiency rates, faster processing times, greater accuracy in predictions for accounted complexities such as occlusions, lighting, and object motion. Applications of physics-based calculations on the Faster R-CNN framework were tested on a self-made dataset of videos that captured ideal scenarios involving linear motion of subjects via the incorporation of a physics bridge the divide between image and video object tracking, utilizing kinematic priors to predict the motion of subjects via the incorporation of affine transformations and perspective consideration (horizons, side-to-side, overhead, etc.). Approaches such as R-CNN and with physics-based learning resulted from this framework of Faster R-CNN.

References


Dataset

Applications of physics-based calculations on the Faster R-CNN framework were tested on a self-made dataset of videos that captured optimal scenarios, including drops, tosses, and object slings on surfaces to model the effects of gravity, friction, and object motion. The added complexity of object occlusion was captured for the dataset of modeling realistic difficulties in object detection, utilizing kinematic learning.

Limitations of current model:

- Inability to account for changing acceleration
- Inability to predict object motion with occlusions
- Prediction model accounts for only 2D object transformations
- Unidentified objects lack physics-based machine learning

Applications:

- Self-Driving
- Defense Industry
- Autonomous Drones
- Movement Prediction

Preliminary Results

Figure 4: Bottle detection without physics-based learning (left) and with physics-based learning (right)

The physics-based model results indicate significant increase in the accuracy of the model when compared with simply the Faster R-CNN framework. Faster R-CNN with physics-based machine learning increases the confidence of object detection and removes classification errors for objects.
Optimization of Delay Stage of Terahertz Time-Domain Spectroscopy System

Terahertz time-domain spectroscopy (THz-TDS) allows us to analyze materials using pulses of terahertz radiation created by a femtosecond laser. Materials are analyzed based on their absorption patterns of the THz radiation. In the laboratory setup, the detector receives pulses of THz radiation along with optical light pulses. The optical light path length is shifted by a delay stage which enables analysis of materials over a time domain and frequency domain.

Our goal is to miniaturize and improve the delay stage to convert the large laboratory system into a mobile, commercial device. The previous delay stage utilizes linear motion; a platform with mirrors accelerates back and forth to alter the path length of the radiation. Our main focus is designing a smaller prototype that relies on rotational acceleration to decrease the loss of speed from linear acceleration and deceleration.

Once a full prototype has been designed, it is tested in the laboratory setup and compared with previous data for accuracy. The frequency domain results of THz-TDS can be analyzed and used to determine chemical composition. When testing for accuracy, the Fourier graphs and THz pulses of our delay stage are directly compared with those of the laboratory stage. Our first test displayed broadening and shifting in the Fourier transformed waves which both indicate a worsened accuracy. However, the new delay stage works at almost double the frequency of the old one (2.2 Hz compared to 1.2 Hz) and only weighs 861 grams.

Delay Stage

The current delay stage is based on linear motion. It utilizes two DC motors powered by stepper control. The delay stage is composed of a stepper motor, a DC motor, and a crank mechanism to drive platform. The crank mechanism is sensitive to amplitude and phase of the THz radiation which follows two paths as depicted below.

First Design

- Uses slider-crank mechanism to drive platform
- DC motor powered by Arduino and H-bridge IC, L298
- Initial prototypes of delay stage created by 3D printer with goals to outsource for final design
- Much faster, but inconsistent speeds
- No gain (increase in weight)

Second Design

- Smaller slider-crank mechanism
- Crank is actuated by a stepper motor
- Less weight
- Much faster, but inconsistent speeds
- No gain (increase in weight)

Motivation

- Create a smaller, multi-functional system for analyzing various materials (e.g., for agricultural, environmental purposes)
- Remove redundant parts to improve stability and performance
- Minimize material costs to make project more cost-effective

Optimization of Delay Stage of Terahertz Time-Domain Spectroscopy System

Madeline Taylor
Electrical Engineering
Second Year
UCLA
Sub-micrometer Precision Optical Delay Stage for Synchronization of Ultrafast Laser Pulse

As laser systems produce shorter and shorter pulses to push the limits of ultrafast and high field science, the requirements for precision timing and optical synchronization in the lab have increased accordingly. The coordination and control of the relative time delay between ultrafast pump and probe laser pulses is required to resolve short lived physical events. Time and space are intimately connected for light, and on picosecond and femtosecond time scales, errors and uncertainties in the optical path length on the order of micrometers and nanometers can drastically degrade the time resolution of measurements in the laboratory. We have implemented an optical delay stage powered by a DC servo motor and controlled by a LabVIEW program. To evaluate the accuracy of positioning two laser pulses, we study the stage’s accuracy and repeatability in creating an optical path length delay with a HeNe laser Michelson interferometer. The pointing stability and reproducibility of the spatial beam profile after the stage is also determined. Understanding of the stage’s precision will enable us to perform picosecond pump-probe experiments, or synchronize ultrafast laser pulses using cross-correlation.

Introduction and Motivation

- In order to measure ultrafast events, synchronization of short laser pulses is required.
- Due to the coherence time, optical systems must preserve path coherence and relative phase over the entire pulse duration.
- Accuracy of such systems will result in more accurate measurement.
- Using a precision delay stage allows for accurate synchronization.
- Pulses arrive within the normalized spectral width and temporal overlap.

Methods

- We assembled a delay stage, translated by a DC motor, which can translate the optical path length of the pump pulse in the interferometer.
- A LabVIEW program controls the motor and collects data from an interference or single-shot interferogram.
- We show the delay stage both self and external interferograms to measure the pointing stability of a 193-nm wavelength (NIR) laser source (λ = 193 nm).
- We measured the beam translation or EOM cavity length in the EOM cavity.
- We then set up a Michelson interferometer using a HeNe laser to distinguish the stage’s positional precision.

Interferometry

- Using the delay stage, the light in each arm in the interferometer changes from non-parallel beams.
- Two interfering, non-parallel, counter-propagating beams of the laser will produce bright fringes and dark fringes that appear on the image plane when the laser beam passes through the stage.
- The light traveling along these paths are reflected back in the interferometer.
- The stage is a linear stage and can translate the relative position of the two interfering beams.

Pointing Stability Experimental Setup

- The delay stage has been designed to satisfy the requirements.
- The setup will enable the measurement of temporal delay and phase fluctuations.
- A precision delay stage, such as the one implemented, will allow for the precise and accurate measurement of the optical path length.

References

Millimeter-Scale Magnetic Shielding

Devices that rely on atomic spectroscopy, such as nuclear magnetic resonance gyroscopes and atomic clocks, are strongly affected by external magnetic fields. Thus, in order to miniaturize these devices while maintaining precision, small-scale magnetic shields must be developed to properly redirect magnetic field lines away from the enclosed devices. The purpose of our research is to fabricate and test potential shield designs. Based on previous research, we determined that the optimal design would consist of concentric cylinders of alternating high permeability and low permeability material. By alternating layers, we partially prevented adjacent ferromagnetic material from reducing the magnetization of that layer. Moreover, multilayer shielding allowed us to mitigate the effects of magnetic saturation, as a single layer of magnetic material would reach saturation more quickly, limiting the shield’s ability to generate an opposing field. We conducted our research by simulating potential shield designs in COMSOL Multiphysics, developing an appropriate test setup to assess the effectiveness of our shields, and fabricating shields to test. For our test setup, we generated a magnetic field using an electromagnetic coil and measured the magnetic flux density using a printed circuit board with a magnetometer mounted at its tip; shielding factor was determined by taking the ratio of external to internal magnetic field. Shields were fabricated by electroplating alternating layers of permalloy and copper.

Conclusion and Future Work

Our simulations and test group results imply that our multilayered cylindrical design provides an optimal shielding when the two materials are placed diametrically opposite. Multilayer designs are more effective than single layer designs before observed to have higher effectiveness of multilayered compared to single layer designs before. The purpose of this research is to fabricate and test potential shield designs. Based on previous research, we determined that the optimal design would consist of concentric cylinders of alternating high permeability and low permeability material. By alternating layers, we partially prevented adjacent ferromagnetic material from reducing the magnetization of that layer. Moreover, multilayer shielding allowed us to mitigate the effects of magnetic saturation, as a single layer of magnetic material would reach saturation more quickly, limiting the shield’s ability to generate an opposing field. We conducted our research by simulating potential shield designs in COMSOL Multiphysics, developing an appropriate test setup to assess the effectiveness of our shields, and fabricating shields to test. For our test setup, we generated a magnetic field using an electromagnetic coil and measured the magnetic flux density using a printed circuit board with a magnetometer mounted at its tip; shielding factor was determined by taking the ratio of external to internal magnetic field. Shields were fabricated by electroplating alternating layers of permalloy and copper.

References

Miniaturized magnetic shielding for chip-scale atomic devices

Atomic devices such as atomic clocks and nuclear magnetic resonance (NMR) gyroscopes are excellent for taking measurements because of their well-defined quantum properties. The miniaturization of atomic devices would allow for them to be combined with phones and wearables, which allow for extremely precise, low power positioning systems. However, such devices must be extremely well-isolated against external interference, such as a magnetic field, to preserve their accuracy. For example, atomic clocks need to be shielded to prevent magnetic fields from interfering with the energy spectrum of atoms and to maintain the clock’s frequency. Recent efforts have been made to miniaturize chip-scale atomic devices. But to further scale down the size of atomic devices, smaller magnetic shields must be fabricated to accommodate the compact environment inside electronic devices. In this research, the magnetic behavior of a flat piece of Permandur and a cylinder of Permalloy was measured to study the shape-dependency of magnetic shields as well as their effectiveness to attenuate an external magnetic field. The results of this research would provide insights for the optimal design of a miniaturized magnetic shield.

Introduction

- Atomic devices are shielded measurement time-growth of well-defined quantum states.
- However, these highly sensitive measurement devices are extremely sensitive to external magnetic fields.

Materials with high permeability provide an almost perfect magnetic field barrier and act as a large magnetic shield [1, 2]. In contrast, materials with lower permeability provide a smaller field barrier and act as a small magnetic shield.

Methods

- Four thin alloy shields were tested: a non-magnetic copper cylinder; a piece of super-smooth plate; a permendur cylinder; and a permalloy cylinder.
- The magnetic field is generated by passing direct current through a coil.

Results

- The magnetic field is generated by passing direct current through a coil.

Discussion

- The field density of magnetic shields as well as their ability to attenuate an external magnetic field depends on the shape of the shield.
- Both iron (80Ni-20Fe) and permendur (49Fe-49Co-2V) are tested to shield against unshielded magnetic flux.
- The field density using permendur plate. Linearity is observed between shielded and unshielded flux densities.
- The field density using permalloy plate. Saturation is observed for the cylinder but not for the permendur plate.

Conclusion

- The permalloy cylinder has a higher magnetic-shielding ability than the permendur plate.
- The cylinder is a more effective design.
- Cylindrical shape provides better field shielding.

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References

Computing Channel Capacity using the Blahut-Arimoto Algorithm

The maximum rate at which information can be reliably transmitted over a communication channel is the channel capacity, usually represented in units of bits per channel use. The ability to compute the capacity of any discrete memoryless channel based on its statistical description is a powerful and fundamental result of information theory. Broadly speaking, the noisier a channel, the lower its capacity.

Mathematically, the channel capacity is the maximum mutual information between the input and output of the channel, where the maximum is taken over possible input distributions. My research is focused on developing tools to identify the mutual-information-maximizing input distribution for a channel and consequently its capacity. As an initial project, I have implemented the Blahut-Arimoto algorithm, which finds the capacity-achieving distribution for any discrete memoryless channel with a finite input alphabet.

For many practical channels, the input alphabet is not finite. For example, even a simple amplitude shift keying system has an uncountably infinite number of possible amplitudes. Furthermore, there are practical communication systems where the optimal input distribution turns out to be asymmetric, such as in-off keying over an additive white Gaussian noise channel. My future research is directed towards identifying the optimal input distributions in these cases and developing practical encoders that can approximate those optimal input distributions.

Computation of Channel Capacity

The channel capacity, $C$, is defined as

$$ C = \max_{p(x)} I(X;Y) $$

where $I(X;Y) = \sum_x p(x) \log \frac{p(Y|X)}{p(Y)}$ is the mutual information between $X$ and $Y$, $X$ is the input distribution, and $Y$ is the output distribution.

**Examples:**

- $X$ is a coin toss, $Y$ is the outcome of the toss where $Y = 0$ for heads and $Y = 1$ for tails. $I(X;Y) = \log 2$
- $X$ is a coin toss, $Y$ is the outcome of rolling a dice where $Y = 1$ for an even number and $Y = 0$ for an odd number. $I(X;Y) = \log 2$
- $X$ is a dice roll, $Y$ is the outcome of rolling a dice where $Y = 1$ for an even number and $Y = 0$ for an odd number. $I(X;Y) = \log 2$
- $X$ is a dice roll, $Y$ is the outcome of rolling a dice where $Y = 1$ for an even number and $Y = 0$ for an odd number. $I(X;Y) = \log 2$

**Mutual Information:**

Mutual information is a measure of how much information $X$ and $Y$ share. The mutual information between $X$ and $Y$ is defined as

$$ I(X;Y) = \sum_x \sum_y p(x,y) \log \frac{p(x,y)}{p(x)p(y)} $$

where $p(x,y)$ is the joint probability distribution of $X$ and $Y$, and $p(x)$ and $p(y)$ are the marginal probability distributions of $X$ and $Y$, respectively.

**Conclusion:**

In our current research technology, whether it’s TV or satellite communications, the fundamental goal is to send bits with low power and low error. This initial project is focused on finding the highest rate at which information can be transmitted reliably through a noisy channel. As an initial project, I have implemented the Blahut-Arimoto algorithm, which finds the capacity-achieving distribution for any discrete memoryless channel with a finite input alphabet. My future research is directed towards identifying the optimal input distributions in these cases and developing practical encoders that can approximate those optimal input distributions.
If you would like to find out more about the Summer Undergraduate Research Program, please contact Director William Herrera:

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