



SURP 2022 RESEARCH JOURNAL

SUMMER
UNDERGRADUATE
RESEARCH PROGRAM

INTERIM DEAN'S MESSAGE

The UCLA Samueli School of Engineering's Summer Undergraduate Research Program (SURP) provides a real-world research experience in a wide range of engineering and physical science fields. Through this program, undergraduate students hailing from diverse backgrounds and experiences have an opportunity to conduct research in our faculty's laboratories under their supervision.

In 2022, SURP transitioned back to in-person programming after two years of remote sessions. Students in this year's program have been able to:

- Conduct on-campus research in a cutting-edge field at a world-renowned research institution
- Meet and network with a community of peers who have similar goals and interests
- Create a professional scientific poster and publish a research abstract
- Learn to communicate research outcomes and present a detailed project summary
- Gain a competitive advantage for applying to graduate schools
- Learn how to impact their communities as engineers and scientists

Forty-four undergraduate students were selected to join the 2022 SURP cohort and were mentored by 25 faculty members across six UCLA Engineering departments. UCLA Samueli is committed to fostering a more equitable, diverse and inclusive community. More than 40% of this year's SURP participants are women, 24% are from underrepresented populations, 20% are first-generation students and 18% of the students are from area community colleges.

Creating new knowledge is a challenging but meaningful endeavor, and these high-performing students have done an outstanding job working through the rigors of scholarly research. They should be very proud of all that they have accomplished in a short time this summer. I encourage you to peruse our brochure and learn about their research.

Sincerely,



Bruce Dunn

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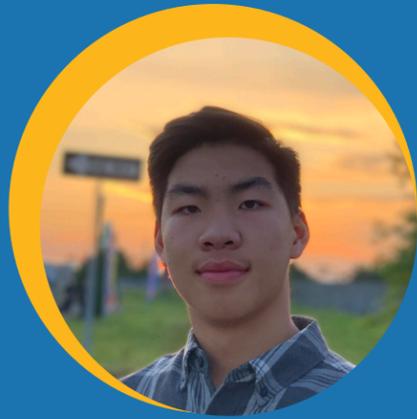
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Texture Chromeleon - A Toolkit for Quick and Rich Electro vibration Texture Rendering

ABSTRACT

Electrovibration is a principle that revolutionizes the way touchscreens are perceived and interacted with. By applying an oscillating voltage to a screen, electrostatic force is induced between user fingers and the touchscreen, and a wide range of tactile feedback is able to be achieved without the use of any moving parts for superior durability. Additionally, electrovibration can render a richer set of texture than what can be offered by mechanical vibrations. Because of this operating principle, computing devices using electrovibration hold a number of advantages to physical vibration that make it an appealing alternative or addition to its current counterpart. From the lack of wear and tear to increased magnitude and spatial uniformity in tactile feedback, electrovibration induces a perceived sense of friction to sliding fingers that when used in conjunction with physical vibration, allow for a much more immersive experience. Conventionally, designs of electrovibration rely on heuristics that demand experience from the user. Trial and error could also be time consuming. In this project, we propose a toolkit to automate the creation of realistic haptics on conductive materials using electrovibration. Specifically, to use our toolkit, all a user needs is to slide their smartphone with our 3d printed attachment across a real life surface and process the audio with the code provided. By analyzing the audio waveforms generated by different surfaces and applying them using the software platform, Processing, we are able to recreate realistic haptics that replicate the roughness of different surfaces on a conductive surface connected to the electrovibration circuit.

Texture Chromeleon – A Toolkit for Quick and Rich Electro vibration Texture Rendering

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Introduction & Background	Audio Processing	Hardware
<p>Toolkit - A collection of adaptable documents that inform and facilitate implementation</p> <p>Haptics - The use of technology to stimulate the senses of touch and motion</p> <p>Electrovibration - A principle that uses an oscillating voltage to induce an electrostatic force on a user's finger to create haptic feedback</p> <ul style="list-style-type: none"> • Electrovibration revolutionizes the way we interact with touchscreens • Wide range of tactile feedback through induced electrostatic force • No moving parts (for superior durability) • Much more immersive experience when used in conjunction with physical vibration <p>Figure 1: The excited electrode with a high oscillating voltage induces a small attractive force between the finger and glass plate that is perceivable only when the finger is sliding along the glass.</p> <p>Customize Haptics = Change Waveform of Voltage</p>	<p>Natural Surfaces</p> <p>Figure 5: Sandpaper</p> <p>Figure 6: Raw Audio File of Sandpaper</p> <p>Figure 7: Red bars represent 80th percentile for peaks in 0.1 second windows</p> <p>Figure 8: Normalize by bringing all bars to the mean</p> <p>Figure 9: Scale up audio</p>	<p>Hardware</p> <p>Figure 16: PCB Design for Electro vibration Circuit</p> <p>Figure 17: Electro vibration Circuit</p> <p>Figure 18: Limit Current in Circuit to 0.5mA for User Safety</p>
<p>Objective</p> <ul style="list-style-type: none"> • Streamline a method to apply electrovibration • Consistent, Quick, Straightforward • Requires only a Smartphone <p>Smartphone Attachment</p> <p>Figure 2: CAD Model of Smartphone Attachment</p> <p>Figure 3: Smartphone Attachment attached to smartphone</p> <ol style="list-style-type: none"> 1. Slide smartphone with attachment across surface and record the audio 2. Send audio to computer 3. Process audio with Python 4. Play processed audio to PCB and feel the texture rendered on screen with electrovibration 	<p>Geometric Surfaces</p> <p>Figure 10: 3d Printed Geometric Surfaces</p> <p>Figure 11: Raw Audio File of Bottom Printed Surface</p> <p>Figure 12: Scale Up Audio</p> <p>Figure 13: Create Corresponding Square Wave</p> <p>Figure 14: Square Wave</p>	<p>Results & Discussion</p> <p>Strengths</p> <ul style="list-style-type: none"> • Quicker method • More realistic textures <p>Weaknesses</p> <ul style="list-style-type: none"> • Reliant on sampling speed • Affected by ambient noise <p>Texture Chromeleon shows similar perform to mechanical textures such as a comb or zipper, but has significant improvement when it comes to less geometric or mechanical surfaces like wood or sandpaper in both time and similarity in texture.</p> <p>User Study</p> <p>We will testing our method of texture rendering quantitatively with the base case of the current method: Online Tone Generator. The procedure below will be done for both methods of texture rendering with the same surfaces</p> <p>Procedure:</p> <ol style="list-style-type: none"> 1. Let user touch 3 real life natural surfaces (metal, wood, sandpaper) 2. Let user touch 3 rendered electrovibration surfaces 3. Ask user to map rendered electrovibration surfaces to real life surfaces 4. Repeat for 3 Geometric surfaces <p>Figure 15: Zipper Demo</p>
<p>Recording App</p> <ul style="list-style-type: none"> • Designed in Swift • Records 1 Second Audio Clips • Automatically stores files in Files App for easy access <p>Figure 4: Recording App</p>	<p>Application Design</p> <ul style="list-style-type: none"> • Processing - Software platform in Java designed for Artist and Designers • Create display screen and graphics • Loop and play audio to render texture surface • Make it interactive: Zipper Demo only renders haptics when zipper is moved up or down 	<p>Conclusions</p> <ul style="list-style-type: none"> • Successfully automated the generation of Electro vibration signal for high fidelity texture rendering • Significantly reduces times it takes for texture rendering (Texture Chromeleon takes less than 5 minutes) <p>Next Steps</p> <ul style="list-style-type: none"> • Use Inertial data to make sampling process more robust to ambient noise and user speed • Test Texture Chromeleon on a richer set of materials • Systematic evaluation with haptic engineers and designers <p>Acknowledgements & References</p> <p>I would like to thank Dr. Yang Zhang and everyone in the HILab for their support this summer and the National Science Foundation for funding this research. A special thanks to Will Herrera and all the SURP staff for making this program possible.</p> <p>[1] Olivier Bau, Ivan Poupyrev, Ali Israr, and Chris Harrison. 2010. <i>TeslaTouch: electrovibration for touch surfaces</i>. In Proceedings of the 23rd annual ACM symposium on User interface software and technology (UIST '10). Association for Computing Machinery, New York, NY, USA, 283–292. https://doi.org/10.1145/1864029.1864074</p> <p>[2] https://www.merrittsupply.com/product/3m-9-x-11-production-sandpaper/</p>



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Deformable Planar to Spatial Deployable Designs

ABSTRACT

We expect deployable designs to be easy, efficient, and practical to use. Auxetics – elastic geodesic grids in this specific research – can be used as a 2D to 3D deployable design that can form a target curved surface. These grids are built from flat flexible rectangular beams that allow for deformation out of plane, shaping the 3D surface. The structures are relatively simple, cost-efficient, and easy to manufacture. Since elastic geodesic grids require flexible materials to deploy to their 3D state, our objective is to find out what kind of different materials we can use to fabricate them as well as how the materials affect the overall deployment efficiency of the structure. Knowing this, we can determine what surfaces we can and cannot approximate with certain sets of materials. To ensure precise fabrication of the beams and pivot points, we use a laser cutter to create an accurate grid approximation. For future works, we would like to investigate further grid applications such as attaching canvas or membranes over the grids.

Deformable Planar to Spatial Deployable Designs

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GOAL: Find different flexible materials to use in the construction of elastic geodesic grids to see the effect on deployment behavior

IMPORTANCE

- Elastic geodesic grids are a type of deformable 2D to 3D design that are made from flexible materials and can approximate target surfaces when deployed to their 3D state.
- Moving away from the theoretical aesthetic-oriented designs of deployable structures, my work determines how the material of an elastic geodesic grid affects its deployment, leading to more efficient deployable structures for specific applications.

PHYSICAL MECHANISM OF DEPLOYABLE GRIDS

Non-parallel grid arrangements exhibits 3D deployed behavior

Flexible materials allow for deformation out of the 2D plane, forming the 3D structure

MATERIALS AND SOFTWARE

Laser cutter

Controlled by
JobControl

Inkscape 2D Design

Clear acrylic sheets

Plywood

Rhinoceros 7
modelling tools for designers
Rhino 3D

ACRYLIC GRID VS WOOD GRID DEPLOYMENT

Acrylic Grid deployment

Wood Grid deployment

Control Group

- Beam length and width
- Number of beams used
- Surface/shape formed

The acrylic grid

- Better deployment
- Less resistance, less force to actuate
- Less friction between pivots

The wood grid

- Less deployed movement
- More resistance with less flexible beams, more force
- More friction between pivots
- More likely to break/permanently deform

Acrylic Grid vs. Wood Grid

Thicker acrylic was too stiff/brittle

FABRICATING GRID STRUCTURES

- 1

Design surface and edit 2D plans
- 2

Preparation for laser-cutting
- 3

Assembly
- 4

Completed elastic geodesic grid

CONCLUSIONS

To build efficient planar to spatial deployable elastic geodesic grids:

- Stiffness of material determines deployed distance
- Choosing a stiffer material like wood will be good for applications that need 2D to 3D deployed structural integrity
- Using a more flexible material would be better for applications that require softer or more pliable surfaces
- Knowing how the material affects the entire structure allows grid construction to be geared for applications

REFERENCES

- [1] Stefan Pillwein, Kurt Leimer, Michael Birsak, and Przemyslaw Musialski. 2020. On Elastic Geodesic Grids and Their Planar to Spatial Deployment. *ACM Trans. Graph.* 39, 4, Article 125 (July 2020), 12 pages.

ACKNOWLEDGEMENTS

- UCLA SURP
- LEMUR Lab
- Ankur Mehta
- Stefan Pillwein
- El Camino College

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A Brighter Future: Next-gen Electron & Photon Probes for Quantum Science Frontiers

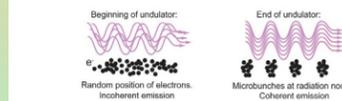
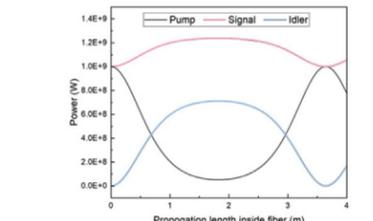
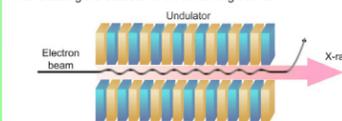
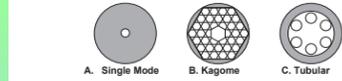
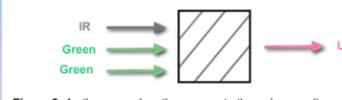
ABSTRACT

In the 1900s, photographer Eadweard Muybridge rigged 12 consecutive cameras with a tripwire to produce sequential pictures depicting a horse's motion. These images were monumental in proving that horses amid their gallop are momentarily airborne, but more importantly, they developed the concept known as time-resolved imaging. Today's frontier in sequential motion photography resides on fundamental questions about quantum dynamics utilizing X-ray free electron lasers (XFELs) to understand interactions between light and matter on the femtosecond scale—a quadrillionth of a second. This is game-changing for our basic understanding of nature's smallest, fastest, and most elusive constituents that play a fundamental role in chemistry, biology, and quantum physics. High-quality electron beams are at the heart of these unique sources, which currently rely on decades-old technologies, thus hampering their advancement. Our project explores emerging theories in quantum electrodynamics combined with nonlinear optical techniques (e.g. four-wave mixing) to enhance the quality of electron beams and XFELs dramatically. Through vigorous calculations and computer simulations, we first prove physical theories and follow by building instrumentation informed by this theory. This sparked the design of our hollow-core fiber system, where high-energy light can be tailored to travel according to a wider range of parameters while maintaining its integrity, differing from traditional optical approaches. By completely redesigning the mechanisms of our electron source, we reach the potential for higher peak energies in our beamlines than ever before, creating a generation of unprecedented XFEL technology.

A Brighter Future: Next-gen Electron & Photon Probes for Quantum Science Frontiers



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<p>Introduction</p> <ul style="list-style-type: none"> The new frontiers of sequential motion photography utilize X-ray free electron lasers (XFELs) to combine consecutive snapshots at the atomic resolution and femtosecond scale — a <i>quadrillionth of a second</i> — to create molecular movies [1]. These photon and electron probes bring insight for the <i>interactions between light and matter</i> by capturing the <i>smallest, fastest, and most elusive</i> constituents that play a fundamental role in <i>chemistry, biology, and quantum physics</i> (i.e. photosynthesis, molecular bonds, etc.) [2]. High quality electron beams generated by XFELs are at the heart of these unique light sources, but rely on decades-old technologies, thus hampering its progress. Our project explores emerging theories in quantum electrodynamics combined with nonlinear optical techniques (e.g. four-wave mixing) to enhance the quality of electron beams and XFELs dramatically. 	<p>Objectives</p> <p>Higher-quality Beam Lines</p> <p>XFELs need high brightness and current (many electrons) to achieve a high-quality electron beam. However, the XFEL performance is hindered due to its inability to adequately shape the laser pulse. One example of this could be attributed to microbunching instabilities that <i>degrade the beam-line</i> [4].</p>  <p>Figure 3: Electrons forming microbunches after undulation [3]. Increasing the number of electrons will increase the beam brightness, however, tightly packing negatively charged electrons is a difficult process.</p> <p>Our solution:</p> <p>Explore how to spatiotemporally (in space and time) shape electron beam by implementing a strict start-to-end control of electron beam to achieve both a high-quality beam with low losses of energy [5].</p>	<p>Results</p>  <p>Figure 5: Simulated energy transfer between 3 waves (<i>input pump and signal with output idler</i>) propagating through HCF.</p> <p>Significance:</p> <ul style="list-style-type: none"> Code simulation shows that the optimal length of the fiber is 1.75m, where idler power is at its max. Energy transfer is efficient (low energy losses) since nearly all of the pump's energy transferred to the idler and signal when the propagation length is (1.75 m).
<p>Principles</p> <p>X-Ray Free Electron Laser (XFEL)</p> <p>We seek to streamline the XFEL process (shown below), by increasing the brightness of the photoinjector, where the light is first produced, thus dictating the success of the remaining events.</p>  <p>Figure 1: X-Ray Free Electron Laser (XFEL) Components [3]. [a] Electrons accelerated near the speed of light. [b] The strong magnetic fields of the undulator (wiggler) causes electrons to emit radiation (X-rays). [c] X-rays are used to carry out experiments (imaging).</p> <p>Quantum Electrodynamics (QED)</p> <p>The branch of physics studying interactions between photons, the smallest particle of light also an electromagnetic wave, and electrons—fundamental to building blocks for XFEL light sources.</p>  <p>Quantum: Smallest unit possible to define a phenomenon Electrodynamics: Physics of Electric and Magnetic Fields</p> <p>At the subatomic scale, particle-particle interactions cannot be accurately predicted by classical theory (Newtonian physics), so we use QED to make predictions on the interactions between photon and electrons.</p>	<p>Optical damage</p> <p>Optical equipment have a damage threshold that once surpassed, will induce ionization damage (irreparable change to equipment).</p> $Intensity = \frac{power}{area} \quad Power = \frac{Energy}{time}$ <p>To create a brighter (more intense) beam, an ultrashort pulse (shorter time) is needed. However, this raises the average peak power, causing catastrophic damage wherever the pulse propagates [5].</p> <p>Our solution:</p> <p>The Hollow Core Fiber (HCF) enables high-energy photons to propagate through vacuum, differing from traditional optical approaches. Additional benefits of the HCF includes light guidance over an unmatched spectral band (wide range of frequencies) and dynamic control of optical properties inside HCF.</p>  <p>Figure 4: [A] is the single mode fiber we will be using, while [B], [C] are other variations of the HCF.</p>	<p>Conclusion</p> <p>Our results indicate the optimal fiber length, gas type, fiber radius, and total energy in our system. These measurements are critical towards our experimental setup for our lab.</p> <p>Overall, the HCF exhibits unique qualities that support the use of brighter electron beams while minimizing material damage from high peak power, thus making it a valuable asset towards the improvement of XFEL technology.</p> <p>Future Directions</p> <ul style="list-style-type: none"> Further validate FWM tech Run more simulations to discover optimal parameters for optical fiber. Examine e- beam control Determine more effective ways to shape electron beams in space and time domain. Transfer designs to facilities Implement to XFELs and make this tech more accessible to the general public.
<p>Four-Wave Mixing (FWM)</p> <p>The Ytterbium laser inherently produces different wavelengths from our desired output, so non-linear optical techniques like FWM are used to convert our input wavelength(s) into our desired output.</p>  <p>Figure 2: As three wavelengths propagate through a non-linear medium their interaction results in a third wavelength made from a combination of the other wavelengths.</p>	<p>Methods</p> <p>Theory to Application: Designing the Hollow Core Fiber</p> <ol style="list-style-type: none"> 1 Simulations <ul style="list-style-type: none"> Apply QED and FWM theory to Python simulations and determine optimal HCF parameters (e.g. gas type, pressure, etc). Create accurate mathematical model of photon behavior in fiber. 2 System Design <ul style="list-style-type: none"> Apply information provided by the simulations to design the HCF. Calculate dimensions for optical equipment (e.g. focal length) to prevent high intensity damage. 3 Experimental Approach <ul style="list-style-type: none"> Acquire affordable components from vendor. Create schematic of system. Integrate the HCF with other components in the lab. 	<p>Acknowledgements</p> <p>I would like to extend my sincere gratitude towards my daily lab supervisor, Brittany Lu, and my PI, Professor Sergio Carbajo, for their continual encouragement and support throughout the summer and school year. Additionally, I would like to thank William Herrera, Danny Katz, Minh-Tam Tran Le, and Zachary Wong for making the SURP program possible.</p> <p>References</p> <ol style="list-style-type: none"> Carbajo Garcia, Sergio. <i>Free Electron Lasers: The Biggest and Brightest Light Sources</i>. United States: N. p., 2021. Web. Carbajo, Sergio. "Light by design: emerging frontiers in ultrashort photon sciences and light-matter interactions." <i>Journal of Physics: Photonics</i> 3.3 (2021): 031001, pp 1 – 2. Nilsen, Daniel. "Zone Plates for Hard X-Ray Free-Electron Lasers." (2013), p. 20. Tang, Jingyi, et al. "Laguerre-gaussian mode laser heater for microbunching instability suppression in free-electron lasers." <i>Physical Review Letters</i> 124.13 (2020): 134801, p. 1. Lemons, Randy, et al. "Integrated structured light architectures." <i>Scientific reports</i> 11.1 (2021): p. 1.





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Optimizing Compacted Biofilter Amendments for Stormwater Treatment in Roadside Soils

ABSTRACT

Transportation infrastructures such as roadways in urban areas contribute to pollution via contaminated stormwater runoff. Implementing soil-based stormwater infrastructure such as biofilters could capture and treat the contaminated runoff. However, required compaction for roadside soil limits biofilter's infiltration and treatment capacity. The addition of bulking agents such as sand or large aggregates such as expanded shale, clay, and slate (ESCS) can increase the infiltration capacity. However, the quantity of the bulking agent required to achieve the desired infiltration rate is unknown. To estimate the optimal amount of bulking agent, we mixed the soil with two bulking agents, sand (0.6 - 0.85 mm), and expanded shale, clay, and slate (ESCS, < 2.8 mm) with different mixing ratios. Further, we amended the soil-bulking agent mixture with biochar to enhance the contaminant removal performance. The result shows that the biofilter media mixture with 50% (v/v) bulking agents, 25% soil, and 25% biochar, meet the required infiltration rate of 1-5 inch.h⁻¹. Under compaction, ESCS-based media exhibited a 3 times higher infiltration rate than sand. While both compacted biofilter media effectively remove *E. coli*, biofilter amended with sand showed relatively higher removal than ESCS-based media owing to higher straining in sand amended biofilters. The results would help develop design guidelines for roadside stormwater treatment systems that require the compaction of filter media.



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Optimizing Compacted Biofilter Amendments for Stormwater Treatment in Roadside Soils

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Background

Impervious surfaces on roadways and compaction of the roadside soil minimize natural infiltration of stormwater and increase stormwater runoff that conveys contaminants accumulated from traffic activities to waterbodies [1].

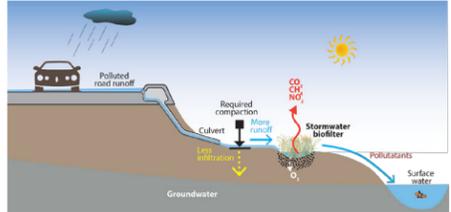


Figure 1: Roadside vegetative stormwater biofilter treats contaminated surface water.

Hypothesis

Soil amendments such as ESCS, sand, and biochar will alleviate the negative impact of compaction and enhance the infiltration rate, contaminant removal, and vegetation health.

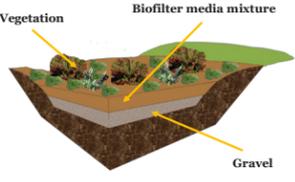


Figure 2: BMP will consist of vegetation, the biofilter media, and gravel at the bottom.

Objective

- Estimate the quantity of biofilter media mixture required to maintain desirable hydraulic conductivity (HC) (at least 1-5 in/hr) in roadside soil.
- Evaluate the contaminant removal capacity of amended soil using fecal indicator bacteria (FIB) such as *Escherichia coli* (*E. coli*) as water quality indicator.



Figure 3: Vegetative stormwater control measures along roadways.

Materials & Methods

Media:	Sand	Soil	ESCS	Biochar
Pros:	<ul style="list-style-type: none"> High HC Resists compaction Removes bacteria 	<ul style="list-style-type: none"> Helps with vegetative growth Removes bacteria 	<ul style="list-style-type: none"> High HC High pollutant removal Economical Resists compaction 	<ul style="list-style-type: none"> Helps with vegetative growth High pollutant removal

Media Composition	ESCS (50%) Soil (25%) Biochar (25%)	Sand (50%) Soil (25%) Biochar (25%)	Sand (75%) Soil (25%)
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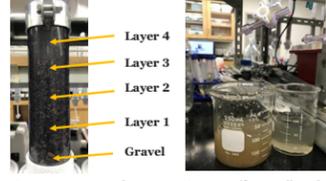


Figure 4: A compacted biofilter column.



Figure 5: Effluent collected while determining HC.

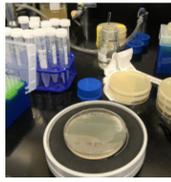


Figure 6: Spreading diluted effluent samples on agar plates.



Figure 7: Counting bacteria colonies.

Results

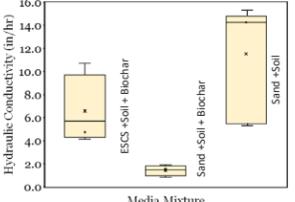


Figure 8: Hydraulic conductivity of compacted media composition. ESCS with a great grain size distribution recorded maximum hydraulic conductivity. The mixture consisting of sand, soil, and biochar also meets the desired expectations.

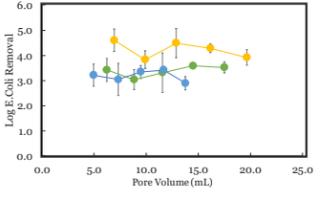


Figure 9: All media mixtures effectively removed *E. coli* at a much higher capacity than expected due to compaction. Unexpectedly, the ESCS-based media was not the most effective in removing *E. coli*. Instead, it was the media blend of sand, soil, and biochar.

Conclusions

- Two mixtures were within the ideal hydraulic conductivity, 1. ESCS, soil, and biochar and 2. sand, soil, and biochar. Both mixtures had the same ratio of soil and biochar meaning the infiltration rate difference was due to the different grain sizes of ESCS and sand.
- The ESCS-based mixture did not perform as well as expected under compaction in terms of *E. coli* removal. The equivalent sand-based blend performed magnitudes better, likely due to the lower infiltration rate and greater retention time, allowing the media to interact with the bacteria more [1].

Future Work

The next steps in this research is to determine the heavy metal and nutrient removal capacity of these compacted mixtures.

References

[1] Ghavanloughajar, Maryam, et al. "Compaction Conditions Affect the Capacity of Biochar-Amended Sand Filters to Treat Road Runoff." *Science of The Total Environment*, Elsevier, 20 May 2020, <https://www.sciencedirect.com/science/article/pii/S0048969720326978>.

Acknowledgement

I would like to thank the Summer Undergraduate Research Program for a great opportunity into research, as well as WE@UCLA and Samueli Research Scholars for awarding me this experience. Additionally, I want to thank my faculty professor Sanjay Mohanty, my daily lab supervisor Tonoy Das, and my lab mates Yuhui Zhang and Lisa Thamiz for their guidance and support.

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Methods on Optimizing Sparse Matrix Multiplication

ABSTRACT

Big data and its applications require massive amounts of data computed within the timeframe of milliseconds, and they rely on distributed computations. One such element of distributed computations is large matrix multiplications, and this computation is handled by distributing tasks along worker nodes, as the task is too massive to handle on one machine. Stragglers, nodes that don't finish computations in a timely manner, are bottlenecks for distributed computations. Current solutions mitigating the adverse effect of stragglers inject redundancies in distributed tasks sent to worker nodes, which lowers the recovery threshold, defined as the minimum number of workers needed to recover the result. Here we examine sparsity: the quantity of zero entries in data matrices. Inspiration from previous solutions are applied to lower the recovery threshold when compared to recovery thresholds of non-sparse matrix multiplication. We take advantage of sparsity to directly lower the recovery threshold by compactly packing information from matrices into the shortest possible representation. The results show that improvement in recovery threshold increases as sparsity increases, improving over 70% at high levels of sparsity. While this result demonstrates improvements in tradeoffs between recovery threshold and computation costs, it currently does not account for numerical stability of the algorithms as decimals and errors stemming from finite numerical precision were not explored here. Future work can employ other developed distributed computation methods with sparse matrix multiplications, look into sparsity in multiple matrices, or study the effects of numerical stability.

Methods on Optimizing Sparse Matrix Multiplication

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 SUMMER UNDERGRADUATE RESEARCH PROGRAM



Introduction and Background

- Big data relies on **distributed computing** to handle computations that are too massive for a single machine
- Has a central master node and several worker nodes
- Part of distributed computing is **matrix multiplication**
- **Stragglers** are worker nodes that do not compute results in time, are bottlenecks in distributed computing
- **Recovery threshold** is the minimum number of worker nodes needed to retrieve the final solution
- Redundancy in tasks distributed to worker nodes is effective in mitigating the adverse effect of stragglers and **lowers the recovery threshold**
- **Sparsity** (zero entries) of matrices can lower recovery threshold when compared to non-sparse matrices
- Sparse matrices occur commonly in calculations for machine learning and data analytics algorithms, results here can directly apply in those applications

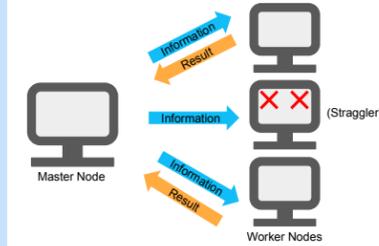
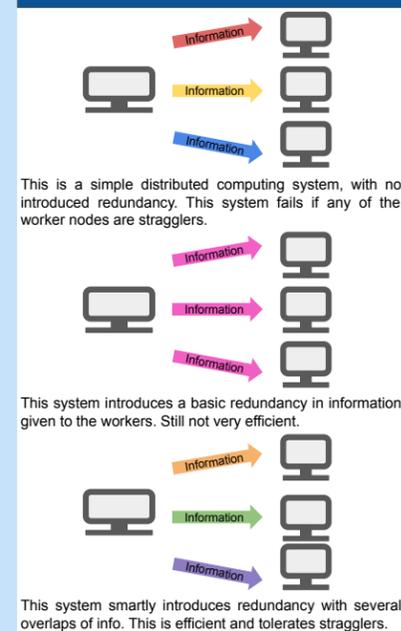


Figure 1. An illustration of a distributed computing system with a master node, and 3 worker nodes, of which one is a straggler.

Previous Work



Methodology

- We simulate calculating the recovery threshold of matrix multiplication, in the case of one sparse matrix.
1. Generate 8x8 matrix with random entries at a set sparsity
 2. Calculate the recovery threshold based off of the randomly generated matrix and encoding methods
 - a. With Polynomial Codes, each row was compacted, then arranged into the shortest combined length of all rows
 - b. With CSA Codes, encode using a multiplied formula, compute number of rational and polynomial terms (This method is not extensively tested, is newly developed)
 3. Plot aggregate results over numerous trials

Mathematical Set Up

One of the current coding schemes tested takes inspiration from Polynomial Codes, and is an adjustment of them. Below is an illustrative example using A split into 3 rows and 2 columns, and B split into 3 rows, and 8 columns, B into 8 rows.

Step 1: Divide Matrices

$$A = \begin{bmatrix} A_{11} & 0 \\ A_{21} & A_{22} \\ 0 & A_{32} \end{bmatrix} \text{ and } B = \begin{bmatrix} B_1 \\ B_2 \\ B_3 \end{bmatrix}$$

Step 2: Encode Submatrices Into Equations

$$A_1(x) = A_{11} + A_{21}x$$

$$A_2(x) = A_{22} + A_{32}x$$

$$A^T(x) = A_1(x)x^2 + A_2(x)$$

$$A^T(x) = (A_{11} + A_{21}x)x^2 + (A_{22} + A_{32}x)$$

and

$$B(x) = B_3 + B_2x + B_1x^2$$

Step 3: Evaluate the Product

$$C(x) = A^T(x)B(x)$$

$$= A_1(x)B(x)x^2 + A_2(x)B(x)$$

$$= A_{11}B_1x^4 + A_{21}B_2x^4 + A_{22}B_2x + A_{32}B_3x + \dots$$

Step 4: Retrieve Product with Decoding Methods

$$A^T B = \begin{bmatrix} (A_{11}B_1 + A_{21}B_2) \\ (A_{22}B_2 + A_{32}B_3) \end{bmatrix}$$

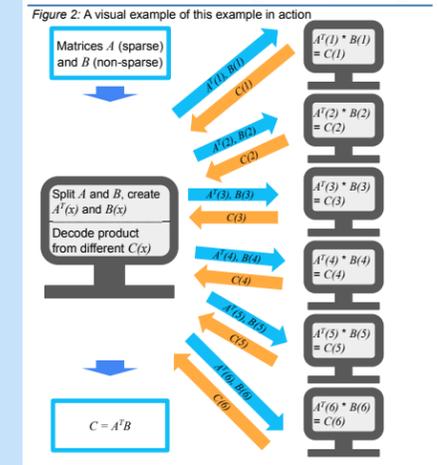


Figure 2: A visual example of this example in action

Results

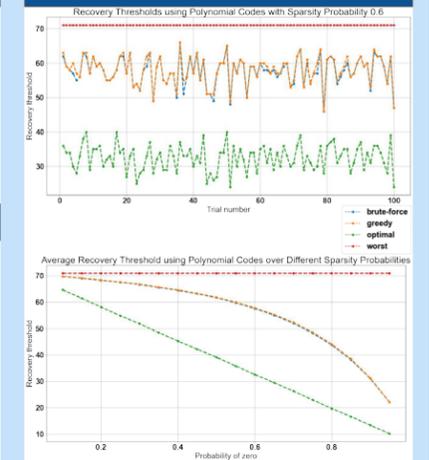


Figure 3
 • Different values of recovery thresholds between trials are due to the random generation of matrices
 • The two new algorithms have similar performance
 • New approaches improves upon the worst case (which assumes non-sparse matrix), still has a gap to reach the optimal

Figure 4
 • As sparsity increases the recovery threshold decreases
 • The concavity of the plot shows that the current method is best at higher sparsities
 • A visible gap between optimal and current approach is present, the gap closes as sparsity increases

Conclusion

- Leverages sparsity to improve on previous solutions by lowering recovery threshold, a gap between current performance and optimal recovery threshold still exists
- Next points of exploration
 - o Other encoding methods
 - o Multiple sparse matrices
 - o Position of sparse entries
 - o Artificial sparsity (round down matrix entries) and accuracy of results
 - o Numerical precision over time and floating point decimals as matrix entries
- Applications with large sparse matrices can see decrease in latency for solution retrieval when using these methods

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Acknowledgements

I would like to thank NSF and other funding sources for funding our project with the LORIS Lab and UCLA Summer Undergraduate Research Program. I would like to thank Lev Taz and Prof. Lara Dolecek for their resources, knowledge, and support. I would like to thank Will Herrera for guidance through the research process.



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BreastBot: A Pneumatically Actuated Soft Robot for Breast Localization in Radiotherapy

ABSTRACT

Radiotherapy is a well-established technique for treating malignant durable cells. In breast radiotherapy, regions of the breast containing cancerous cells are exposed to x-rays to shrink and kill tumors. However, this method of treatment remains unsatisfactory due to crude setups and poor localization techniques that prevent effective normal organ sparing. Overlapping and nearby healthy cells may be unintentionally damaged by radiotherapy in addition to the targeted cancer cells, which results in life-threatening acute and chronic toxicities in breast cancer patients after treatment. To control healthy organ sparing and provide a reproducible setup, this work experimentally develops a pneumatically actuated soft robot to safely isolate the breast from other organs for imaging and treatment using Ecoflex, a silicone elastomer with a low Young's Modulus. We pneumatically actuate the soft robot by pumping air into a network of air channels embedded within the robot's body, causing specific sections of walls to expand and press against the breast. This expansion fixes the breast in a treatable position as far away from the rest of the patient's body as possible. The current working internal pressure of the device is around 5-10 kPa, which is at the 10kPa general comfort limit for patients. Upon actuation, the thickness of the inner wall pressing against the breast is less than 250µm, which minimizes interference with imaging and unwanted radiation exposure. Each device costs less than 5 USD and 4 hours to manufacture excluding the 3D printed mold, so it is practical to custom fit the robot to each patient and dispose of it after treatment. This work demonstrates a promising future for soft robots in medical applications due to their lightweight, adaptable, reproducible, and inexpensive features.

BreastBot: A Pneumatically Actuated Soft Robot for Breast Localization in Radiotherapy

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I. Introduction & Background

In the United States, breast cancer is the second leading cause of cancer-related deaths among women. Although radiotherapy remains the most well-established method of cancer treatment, poor localization techniques and inconsistent setups can lead to life-threatening complications after treatment.

There is a strong need to develop a technique to **consistently** and **effectively** localize the breast during radiotherapy to minimize radiation risk to healthy cells and maximize breast radiation.

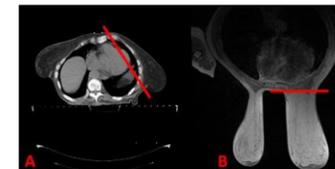


Figure 1: (A). Axial CT scan of a patient in the supine position, in which breast localization is difficult due to gravity. (B). The same patient in the prone position, which increases cardiac exposure and decreases patient tolerance.

II. Project Objectives

We intend to develop a **pneumatically actuated** soft robot with embedded air channels that rests around the breast of a patient's body in the **supine** position. The robot applies a compressive radial pressure to the breast to push it away from the body for **imaging and treatment**.

Design Considerations:

- **Pneumatically actuated**- Achieves motion by inflating air channels (10kPa pressure limit) for an adaptable fit
- **Thin walls** - Parts of the robot in contact with the patient cannot exceed 200µm for optimal imaging and to minimize radiation exposure
- **Inexpensive** - Custom fit to each patient and disposed of after treatment for comfort and sanitation

III. Materials & Methods

The fabrication process starts with a 3D printed mold. **Figure 3:** (A) Detachable 3-part mold for easy demolding. The inner wall and air channel segments are removable. (B) Cross section of the mold.

The yellow segment forms the 250µm outer wall. The green segment forms the air channel gap, and the blue segment forms the 250µm inner wall.

The mold is 3D printed with thermoplastic **ABS** and coated with **Ease Release 200** (Smooth-On Inc, USA), a demolding agent.

Ecoflex (Smooth-On Inc, USA), a commercial silicone elastomer that cures into a soft, elastic material is prepared. The two precursor parts are **mixed**, **degassed**, and **poured** into the mold.

The soft robot is now ready to be tested! Preliminary testing occurred by pumping air into the air channel with a syringe.

After curing the Ecoflex at 75°C for one hour, the soft robot is carefully extracted, revealing air channels with one open end. This open end is sealed with a thin layer of Ecoflex that bonds to the bottom of the robot during the curing process. After the bottom is sealed, any excess Ecoflex is cut away to reveal the finished robot.

IV. Results

Figure 4: (A). Scaled down BreastBot with four air channels. Inner and outer walls are 250µm each. (B). Pneumatic actuation of one air channel on scaled down BreastBot around a phantom breast model. The thickness of the inner wall in direct contact with the breast is estimated to be <200 µm with 10kPa internal pressure.

Figure 5: Time series of the internal pressure in an air channel on BreastBot. A pneumatic control system cyclically pumps air in and out of the air channel until it reaches a threshold pressure of +/- 10kPa, where the pressure is held for 750ms. Pneumatic actuation is achieved with pressures of 5-35 kPa, which can fit within the 10 kPa comfort limit.

V. Conclusion and Future Work

We have developed a consistent fabrication method for a prototypical soft robot that is cheap, flexible, and simple to actuate. Targeting full implementation in breast radiotherapy, the robot must demonstrate consistent and effective localization on breast phantoms and real patients.

Figure 6: For greater positioning control, multiple soft robots are bonded on top of each other. A robust control system and procedure need to be developed before further testing on live patients.

VI. References

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VII. Acknowledgements

We would like to thank Professor Lihua Jin, Professor Ke Sheng, and Boliang Wu for all their guidance and support through our work. We would also like to thank the UCLA SURP program for providing this opportunity. Special thanks to NSF REU and the Samueli Research Scholars for funding our research.



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Object Tracking Using Event-Based Cameras and Gabor Filters

ABSTRACT

Event-Based cameras measure the timestamps of discrete changes in pixel intensity and therefore have higher temporal resolution and lower energy use than frame-based cameras. This makes them extremely useful for tracking objects moving extremely quickly, such as aircraft. Convolutional neural networks, which are typically used for frame-based object tracking, require too much computation and are too slow for event-based vision. One solution is to use Gabor filters, which are convolutional filters that are tuned to detect edges, speed, and direction of motion. We wish to benchmark the tracking accuracy of Gabor filters and determine how much accuracy is traded off for speed in their usage. Objects in frame are identified using the density based spatial clustering with noise method. Gabor Filter information is used to predict the future position of these objects. Regions of interest are created around these predicted positions. In future frames, only regions of interest are convolved, significantly speeding up compute time and allowing for the tracking of multiple objects across time. We use the Measure of Tracking Accuracy metric, which utilizes the number of false positives, false negatives, and identity switches across all frames.



Object Tracking Using Event-Based Cameras and Gabor Filters

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Key Terms

Jaccard Index – The overlap of two boxes divided by their union
MOTA – Measure of Tracking Accuracy. Calculated by the following equation:

$$MOTA = 1 - \frac{\sum_t (FN_t + FP_t + IDSW_t)}{\sum_t GT_t}$$

Eq 1: The MOTA is equal to the summation of the number of false negatives, false positives, and identity switches over time divided by the summation of the number of ground truths over time. In order for a detected object and ground truth to be considered a match, the Jaccard Index between them must be greater than a certain threshold. This threshold is usually set as 0.5

MOTP – Measure of Tracking Precision. Calculated to be the average Jaccard Index overlap for all detected objects throughout all frames.

Introduction

Event-Based cameras return the timestamp and polarity of a change in pixel intensity past a certain threshold. They have greater temporal resolution than frame-based cameras, which makes them useful for tracking objects moving extremely quickly. However, many existing frame-based object tracking algorithms aren't compatible with event-based vision, necessitating the development of specialized tracking algorithms. Gabor Filters are convolutional filters in a sinusoidal shape, commonly used in edge detection. Each Gabor Filter is oriented to a specific edge orientation. In this project, a third dimension, time, is added to the Gabor Filters for detection of object speed and direction. Matching an object's predicted position in the next frame to its actual position in the next frame allows us to track it across multiple frames.

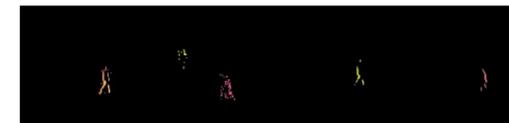


Figure 1: Result of Gabor Filter convolution on event-based video

Because objects are identified by proximity and we can't distinguish between different objects that are close together, using Gabor Filters to track objects will be less accurate than using conventional ML algorithms on frame-based videos. Our goal is to run tests to determine whether Gabor Filter object tracking is accurate enough compared to conventional ML tracking algorithms that its faster compute speed outweighs its drop in accuracy.

Project Objectives

- Write an algorithm that can track moving objects across a frame using Gabor Filters.
- Benchmark the algorithm's accuracy and precision against existing machine learning models run on regular frame-based cameras.

Results

MOTA of ML tracking algorithms and Gabor Filter tracking for different detection similarity thresholds

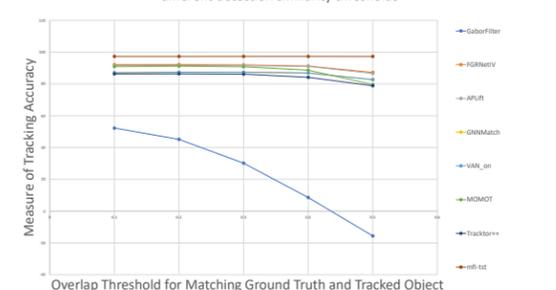


Figure 4: The blue line represents the MOTA of our Gabor Filter tracking algorithm, all other lines represent the MOTAs for different ML algorithms.

In Figure 4, our Gabor Filter tracking algorithm, as well as different ML tracking algorithms, are run on the PETS09-S2L1 dataset of the public Multiple Object Tracking Challenge. 93 different ML algorithms were submitted to the MOTS challenge. We selected seven of the twenty best performing algorithms to compare. As seen in Figure 4, when the Jaccard Index matching threshold is 0.1, the MOTA of the Gabor Filter tracking algorithm is about 52.212, compared to an average of 90.323 for the ML algorithms. However, when the Jaccard Index threshold increases to 0.5, the MOTA of the Gabor Filter tracking algorithm goes down to -15.61, while the MOTA of the ML algorithms barely dips.

Description Of Tracking Algorithm

1. The event-based datastream is reconstructed into a frame-based video.
2. All Gabor Filters, each attuned to a certain edge orientation, are convolved on a frame. Pixels with Gabor values above a certain threshold are identified. These pixels are then grouped into objects using the DBSCAN (Density-Based Spatial Clustering of Applications with Noise). Objects are identified by bounding boxes containing all their pixels.

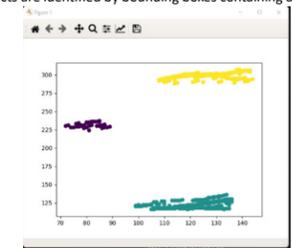


Figure 2: Result of DBSCAN clustering. Points represent pixels exceeding the Gabor Threshold, and the color of the point shows which object it belongs to.

3. Combine all bounding boxes that overlap into the same object.



Figure 3: Bounding boxes that overlap are considered to be part of the same object.

4. For each detected object, determine the predicted bounding box from the previous frame with the highest Jaccard Index overlap. Then, assign the object's ID to be the ID of that predicted bounding box. If no overlapping bounding box from the previous frame is found, set the object's ID to the next available unused ID.
5. Add the object to history.
6. Use the maximum Gabor value of each filter to determine the object's speed and direction.
7. Create a ROI (region of interest) where the object is predicted to be next.
8. Only convolve the Gabor Filters in the ROIs the next frame. Once every 20 frames, convolve the entire frame to detect new objects.
9. Repeat steps 2 through 8 indefinitely until the end of the datastream.

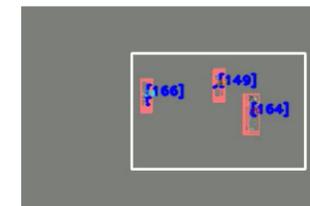


Figure 3: Output of the Object Tracking Algorithm. The white box is the ROI, and the pink boxes are the detected objects, labelled with their object IDs.

Conclusion

Gabor filters and event-based cameras are only meant to detect object edges. Any bounding box created using our Gabor Filter object tracking pipeline is not meant to precisely match the object's actual bounding box. Therefore, the MOTA values at the lowest Jaccard Index threshold, 0.1, are most valuable to us. Future work should include running the comparison between Gabor Filter tracking and conventional ML tracking on datasets that aren't part of the MOTS challenge. The MOTS challenge intentionally includes objects getting close to each other and overlapping each other. While being able to track objects in these circumstances is important for conventional ML algorithms, our pipeline doesn't utilize machine learning and can't distinguish between overlapping objects. Event-based cameras are most useful for sparse videos with very few objects. The MOTA values for our Gabor Filter tracking pipeline will likely be higher in a dataset that better matches its use case.

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Developing Undulators For Compact and Lower Energy Free Electron Light Sources (FEL)

ABSTRACT

Free Electron Light Sources (FEL) create intense bursts of x-rays that are millionths of a billionth of a second long, enabling unprecedented scientific discoveries: capturing the birth of chemical bonds, creating images of biological models, studying diseases, and much more. Access to FELs is limited, however, because there are few FELs in the world; current machines are very expensive (>\$1B) and very long (>1km). This project aims to address both these challenges, and thus increase access, by further developing short-period undulators. The undulator is composed of alternating magnetic fields that transversely accelerate an electron beam as it travels, which generates the x-rays. Shortening the undulator period lowers the required electron beam energy to obtain a given photon wavelength, which in turn reduces the length and cost of the electron accelerator. Conventional undulators used in XFELs have period lengths around 3 cm; we designed undulators with periods of 3 and 6 mm, which would result in an accelerator length reduction of ~68%. Out of the three designs tested, simple, Halbach, and hybrid, the hybrid has the strongest field but also the highest likelihood of unacceptable field variation due to material inhomogeneities. To address this, we developed a novel method of shimming, or local magnetic field adjustment, that works within tight space constraints. Successful development of such strategies for short-period undulators has the potential to transform the field of light sources: democratizing access to discover the world on an atomic scale.

Developing Short-Period Undulators For Compact and Lower Energy Free Electron Light Sources (FEL)

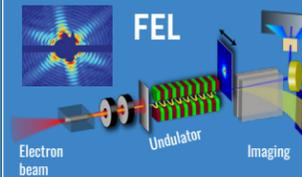
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What is a free-electron light source?

One of the most powerful sources of light on earth that lets us see the world on an atomic level



- High energy electrons are accelerated close to the speed of light
- they are wiggled through arrangement of magnets called UNDULATORS
- X-rays bunches are created and then used in various application (many use diffraction patterns)

What are some applications of FEL?

Making Molecular Movies



To...

- film chemical reactions
- watch proteins unfold
- study processes such as those deep inside planets

Medical applications

- map atomic details of viruses
- cancer therapy/research

What is the Problem with current FEL?

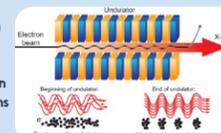
Current light sources are:

- MILES long
- BILLIONS \$'s
- Require GeV electron beams



INTRODUCTION

Undulators accelerate (wiggle) electrons through alternating magnetic fields, usually two rows of magnets with a gap in the center, and release photons as x-rays that can be used



What can be improved?

Current undulators are designed for extremely high energy electron beams that require miles-long accelerators

	Current	Goal
FEL	~5-10 GeV energies	<1 GeV energies
Undulators	2-10 cm periods	< 10 mm periods

Reducing the period, and therefore the energy required, would allow for much shorter accelerators, reducing the cost drastically

Why does a shorter period reduce the Energy Required?

$$\lambda_u = \text{Undulator Period} \quad \lambda_{rad} = \text{Radiation Wavelength} \quad \gamma = \text{Energy}$$

Radiation Wavelength

λ_u or the "Resolution of imaging" can be calculated using this equation

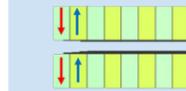
$$\lambda_{rad} = \frac{\lambda_u}{2\gamma^2}$$

Keeping same radiation resolution, but using a lower energy calls for a shorter period undulator. This project aims for 3-6mm period instead of typical 3-10cm, a 10x size reduction

METHODS and DESIGN

- Ran simulations using a python package called Radia to do complex computations of field strengths of magnetic material for 3 different designs of undulators

SIMPLE



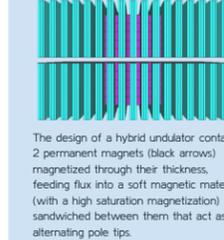
The design of a simple undulator consists of 2 rows of alternating north and south magnets aligned with a gap in the middle for an electron beam.

HALBACH



The design of a Halbach undulator is similar to a simple, however includes rotated magnets (black arrows) that feed extra flux into the alternating north-south magnets, allowing for greater field strengths.

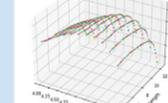
HYBRID



The design of a hybrid undulator contains 2 permanent magnets (black arrows) magnetized through their thickness, feeding flux into a soft magnetic material (with a high saturation magnetization) sandwiched between them that act as alternating pole tips.

Hybrid undulators are able to reach higher field strengths (~1.3T) with a shorter period (2.68mm) due to the use of pole tips. However, due to material inhomogeneities that lead to unacceptable field error, new techniques for tuning, compatible with short period undulators, need to be evaluated

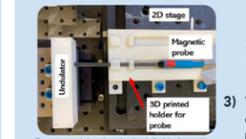
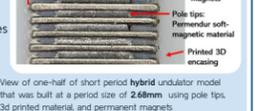
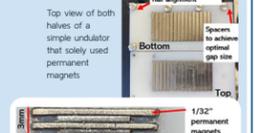
Optimal Size of Pole Tips



Plot of the magnetic field strengths for different sizes of soft magnetic material. From this analysis we determined the optimal pole tip shape to be 5.3mm x 7mm x 0.5 mm.

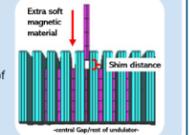
EXPERIMENTATION

- 3D printed an encasing to hold the magnet configuration
- Assembled undulator by placing magnets inside encasing, and used superglue to hold in place
 - For Hybrid undulator, used water jet to cut pole tips out of soft magnetic material avoiding heat that could ruin magnetic properties



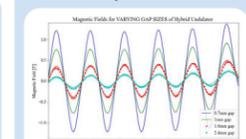
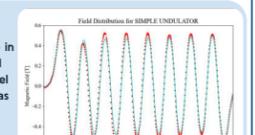
Tested SHIMMING:

Magnetic field correction done by inserting extra soft magnetic material through back to "steal" flux from pole tips, slightly lowering the field strength of that pole. Could be used as a tuning method on each pole tip to achieve uniform peak fields by adjusting the shim distance

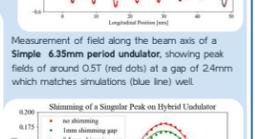


RESULTS

We were limited by measurable gap size in experimental setup, however we showed match between simulation and built model of simple and hybrid undulators, as well as potential for shimming technique to fine tune fields strengths



Magnetic field measurements and simulations of a Hybrid 2.68 mm period undulator. The thickness of the magnetic field sensor limited the gap size to >1 mm. The optimal is ~0.67 mm. Here we compare data taken at 1.6mm and 2.4mm gaps with RADIA simulations, which agree well extrapolate to smaller gaps.



A pole tip was placed at different distances as an adjustable shim, showing the potential to tune the magnetic field due to a single pole-tip. The same approach could be used along the entire undulator to homogenize the peak fields.

CONCLUSION

Why does this matter?

With periods of 3-6mm, we can drastically reduce energy required
EX: LCLS (only XFEL in the USA) energy drops from 5.13 GeV to 16 GeV, meaning a 68% reduction in accelerator size

Next steps?

Electron beam testing to ensure designs are capable of fine tuning
• Build a longer undulator

FEL's could start to be built and supported by universities, instead of relying on national labs for groundbreaking research

Optimize shimming methods and manufacturing of short period undulators

ACKNOWLEDGMENTS and REFERENCES

I would like to thank Ben Pound, my PhD supervisor, Katherine Sohn, my undergrad partner, as well as professor Rob Candler, the SURF team at UCLA and NSF grant #1736598 for supporting and funding this project

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Stereo Depth Mapping in YOLO

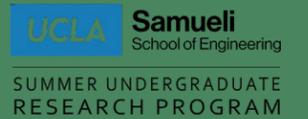
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Stereo Depth Mapping in YOLO

Angela Duran, Kunal Kulkarni, Melissa Cruz, Alex Deal, Mark Diamond, Andrew Krupien, Shawn Mosharaf, Katsushi Arisaka

Department of Physics and Astronomy, University of California – Los Angeles



SUMMER UNDERGRADUATE RESEARCH PROGRAM

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Objective

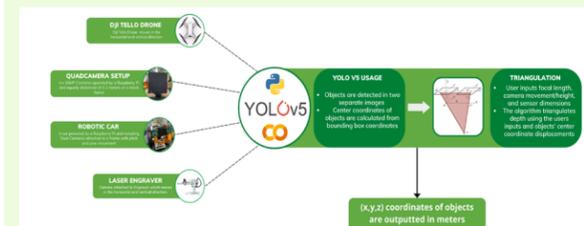
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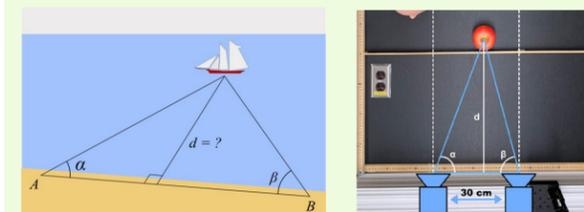
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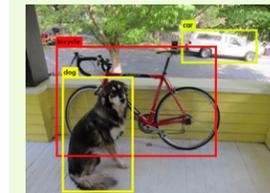


Writing the algorithm

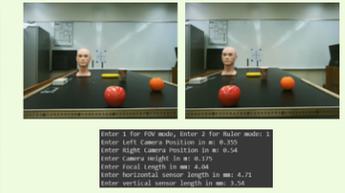


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Re-interpret algorithm into code



Process images using various hardware



YOLO is an object detection algorithm capable of processing 2D egocentric images at a minimum of 45 fps. With the use of neural networks, the program finds patterns in various regions and compares that information to a database of pre trained objects. We would modify the source code to find depth, recreating 3D allocentric space.

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Results



Depth Estimations in Meters			
	Apple	Orange	Cup
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Conclusion

Though not as accurate as LiDAR, our stereo depth algorithm can be applied for a significantly cheaper price. Making it more accessible for a broader range of applications. We believe most of the error to come from pixel discrepancies with the YOLO algorithm between the two images..

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Acknowledgements

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Electrical and Computer Engineering

Optimizing Electroencephalograph Neural Networks to Decode Human Imagination for Mind-Controlled Prosthetics

ABSTRACT

Brain-computer interfaces (BCI) enable humans to control technology, such as prosthetic limbs and computer games, with thoughts. The highest performing BCIs on the market require brain implants that read signals from hundreds of individual neurons, a surgery that can be risky and unaffordable. Electroencephalography (EEG) is a non-invasive alternative used to detect neural activity from one's scalp using a wearable cap that contains 64 electrodes. When a user imagines performing a physical movement, the electrodes record activity produced by populations of neurons firing in the sensorimotor cortex. We repeatedly trained an EEGNet convolutional neural network across multiple sessions of closed loop BCI control with the goal of producing an accurate output for a given input. To optimize this decoder, we designed and updated a game in which the cursor on a computer screen moves in a direction that corresponds to a specific thought. The user trains the cursor to move left, right, up, and down by imagining their left hand, right hand, tongue, and feet moving, respectively. To keep the cursor still, the user practices meditative rest which generates its own distinct wavelength. We hypothesize that with enough training data, the decoder will grow increasingly accurate and eventually allow for complete control of the cursor's movement on a 2-D plane. In the future, we wish to apply this neural signal processing to 3-D systems, which will allow users to have control over prostheses in a manner that is as natural as moving one's own body. Ultimately, decoding electroencephalographic data could provide the general public with access to mind-controlled technology.

UCLA Samueli
School of Engineering

SUMMER UNDERGRADUATE RESEARCH PROGRAM

Samueli Research Scholars
UCLA Samueli

OPTIMIZING CONVOLUTIONAL NEURAL NETWORKS TO DECODE IMAGINED MOVEMENTS FROM ELECTROENCEPHALOGRAPHIC DATA

Victoria DaSilva, Sangjoon Lee, Johannes Lee, Jonathan Kao

Department of Electrical and Computer Engineering, University of California – Los Angeles

Fast Track to SUCCESS
summer scholars program
Electrical Engineering Department
UCLA Henry Samueli School of Engineering and Applied Science

Background

Invasive Brain Computer Interfaces (BCI)

- Thought-controlled technology (prostheses)
- Brain implant needed – expensive, risky

Electroencephalography (EEG) Cap

- Non-invasive BCI
- Streams brain voltage from scalp

Figure 1 Mentally moving each limb activates different areas of motor cortex.

Training Model

EEGNet Training

Figure 10 EEGNet maps 200 EEG inputs (2 second sample lengths) to label vector.

Loss function

$$\text{Loss} = - \sum_{i=1}^{\text{output size}} y_i \cdot \log \hat{y}_i$$

Figure 11 Loss function used to update function parameters during training.

Objectives

Optimizing EEGNet

Hypothesis: More training data will improve function parameters and increase validation accuracy to result in better BCI control.

Figure 2 EEGNet maps input data to label vector of intended direction by updating function parameters in Figure 3.

Figure 3 EEGNet maps input data to label vector of intended direction by updating function parameters in Figure 3.

Implementing Rotation and Target Acquisition

Rotation

- Target acquisition uses all four directions during an episode.
- Classification matrix is relative cursor position with respect to target.

Figure 12 Rotation disregards data when projected direction lies within 10 degrees of diagonal.

Four Directions Imagined Movements Task

Set Up EEG Cap

Figure 4 EEG cap with 64 electrodes.

Figure 5 Applying Electro-Gel in electrodes using syringe.

Open Loop Session

Figure 6 All four target directions displayed. Game shows one of four directional targets in 10 second intervals.

Figure 7 Intended direction of a training sample is represented as label vector y .

Repeat Closed Loop Sessions

Figure 8 Closed loop game displays white cursor giving live feedback of signal inputs.

Figure 9 EEGNet generates probability vector \hat{y} with existing parameters. Cursor moves in direction with the highest probability.

Results

Figure 13 Chart of validation and training accuracy across 10 sessions of closed loop BCI training for subject.

Session	Validation Accuracy (%)	Training Accuracy (%)
1	43	74
2	52	72
3	44	65
4	39	64
5	56	69
6	45	92
7	40	82
8	48	71
9	87	79
10	84	77

Figure 14 Graph showing dramatic increase in validation accuracy (+ 39%) after target acquisition and rotation decoding was implemented during session 9.

Conclusion

Results from subject #1 reveal an upward trend in validation accuracy as the decoder is provided with increasing long term closed loop data. The cause for the nonlinearity in validation accuracy is attributed to artifacts that were present from day to day. The cause for the upward trend can be attributed to using rotation, which captured the user's directional intentions rather than the absolute target direction. By session 10, the user had complete control over cursor for the four directions task and could acquire most targets.

Future Directions

- Decoding imagination for 3-D task (robotic arm)
- Implementing other EEG models to improve performance

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Acknowledgments

This research was funded by UCLA's Fast Track to Success undergraduate fellowship in the Electrical and Computer Engineering Department. I would like to thank Will Herrera, Professor Jonathan Kao, Sangjoon Lee, and Johannes Lee for their leadership, guidance and encouragement in this research.



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Ankur Mehta

DAILY LAB SUPERVISOR

Ankur Mehta

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Electrical and Computer Engineering

Intuitive Gestural Interfaces: Development of Intuitive input controls for complicated XR Engineering Environments.

ABSTRACT

When a designer wants to create a robot to achieve an objective, augmented reality (AR), where a user is embedded in a virtual world, has much promise due to the immersiveness of the designer computer interface and the lower overhead of computation for the creation. My research focuses on making better use of the capacity of communication from the user to the computer by interpreting more motions of the user's hands, which allows the creator to be more expressive in the scope of robot objectives. I quantified hand gestures into three vectors: the positioning of skeletal points in the hand, the rotation of the palm, and the motion of the center point of the hand. Consulting a movement expert, we were able to create a few gestures that represented the objectives of robot creation. I developed an algorithm to interpret the vectors associated with those gestures to match them to the objectives. To facilitate this match, I developed a function partitioning the vector space to map to each objective. I executed gestures multiple times with slight variations and computed the bounds of the space to create this partition. With my implementation created by refining my algorithm, an engineer with design experience within a few minutes was able to perform interpretable gestures with very little instruction. This implementation will decrease the time to learn the inputs of the augmented reality and either increase the time available to develop more robots or get a final robot out quicker.

Intuitive Gestural Interfaces:
Development of intuitive input controls for complicated XR engineering environments for non-technical users.

Valen Dunn | Dr. Ankur Mehta
The Laboratory for Embedded Machines and Ubiquitous Robots
UCLA, Electrical and Computer Engineering

Summary

- Uses sensors in the headsets of extended reality (XR), a broad term for systems embedding users in a virtual world, to scan the user's hand and input its motion into the development space.
- Creates a system which first breaks down the motion of the user's hand, or gestures, and turns them into vectors
- Then uses my algorithm and boundaries developed experimentally to interpret the inputs.

Development Resources

Implementation of Building Blocks into Motion Interface

Measure values to define boundaries for each gesture

Repeat measurements multiple times with slight variations to form boundaries

↓

Building Blocks

Motion Recognition

- Able to ascertain these vector values from the HoloLens.
- Able to find values to bound all motions by just using these three building blocks.

Hand Rotation

Hand Key Point Mappings (3)

Discussion

- Fulfills the capacity available for interaction from the user to the HoloLens.
- Allows for a smaller learning curve when first interacting with the development space.
- Minimizes the need for needless buttons as the full range of hand motions are now interpretable.

Future Development Goals of Project

- Implement machine learning Network to take the job of the algorithmic detection to increase the freedom of input.
- Improve environment by allowing user input of new gestures and motions.
- Improve the ease of development for implementation of new gestures.
- Create of a model that learns towards the input of specific users.

Acknowledgements

Ankur Mehta - Principal Investigator www.ee.ucla.edu/ankur-mehta/
 UCLA LEMUR Lab - uclalemur.com
 Kate Ladenheim - www.kateladenheim.com/about
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Electrical and Computer Engineering

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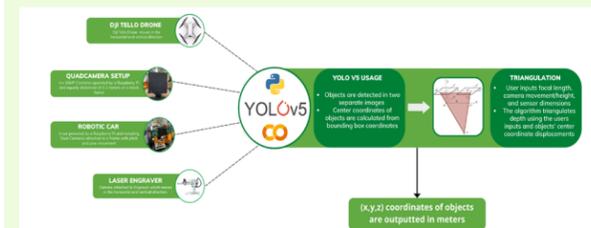
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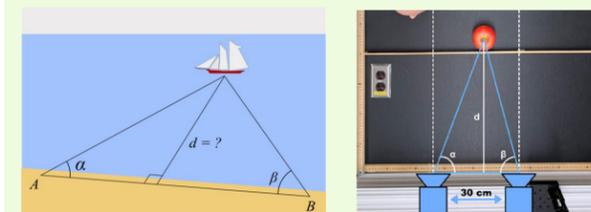
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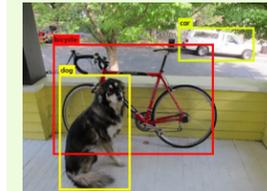


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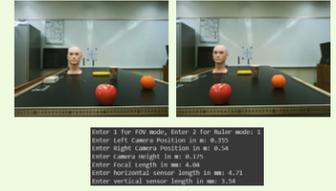


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Chemical and Biomolecular Engineering

Self Assembly of Perovskite Nanocrystals

ABSTRACT

With climate change on the rise and only so limited time to save the earth, sustainability is at the forefront of issues that we need to solve. A viable solution is converting to renewable energy especially solar power, however our current technology has many limitations that make it hard to harness these natural resources. Luminescent solar concentrators are one such device which concentrate sunlight and direct it to the solar cells. Though this technology has been around for a long time, LSC's are inefficient because a significant amount of sunlight is lost due to isotropic light emissions from the LSC's. Hence having anisotropic light emission from the solar concentrator plays a major role in determining the effectiveness of the LSC's and solar cells. This project proposes an idea of orienting light emission (anisotropic) from the LSC's by forming self-assembled 2-D and 1-D perovskites lattices. This was achieved by non dimensionalizing the formed 3-D perovskite nanocubes to 2-D nano wires or 1-D nanowires (shrinking the dimensionality of the structures would lead to less scattering of the sunlight) through solvent dependent interactions of surface passivating ligands and manipulating environmental conditions such as temperature. Self-assembled superlattices perovskite structures lead to uniform monodisperse layers and optically stable nanocrystals which is required for large scale applications.

Self Assembly of Perovskite Nanocrystals

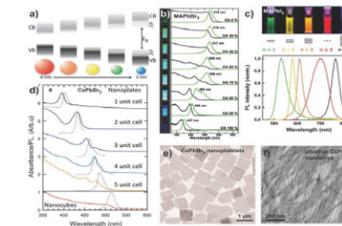


Leonna Gaither, Mounika Dudala, Daniel Katz, Dr. Carissa Eisler
UCLA Department of Chemical and Biomolecular Engineering



Background: What Can We Achieve with Nanocrystal Assemblies

Why Nanocrystals? Nanocrystals are highly tunable and can be made in a variety of shapes and sizes. Their emission wavelength is tunable because of quantum confinement: **as the size gets smaller, the emission increases in energy.** They can exhibit **directional emission** based on their shape.

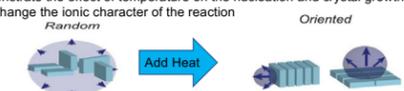


Why Self-Assembly? Self-assembly is a process of **spontaneous organization of nanocrystals to form ordered structures or patterns.** Ordered structures maintain and exaggerate the interesting properties (polarization, directionality) of individual nanocrystals.

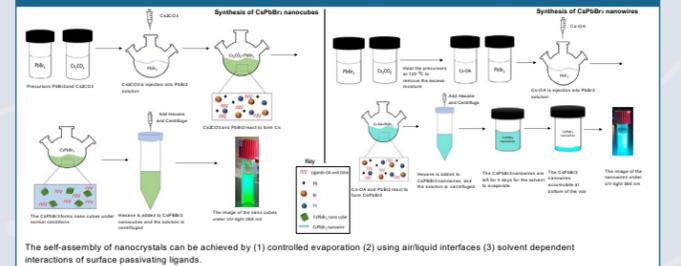
Why Halide Perovskite Assemblies? Halide perovskites have demonstrated extraordinary optical properties. Assembly into organized structures would make them ideal for **high efficiency LEDs, inexpensive solar concentrators, and quantum light sources.**

Objectives: To Create Interesting Assemblies, We Must...

1. Demonstrate the formation of 1-D nanorods and pseudo-1-D nanowires from 3-D nanocubes.
2. Demonstrate the effects of drying time on the formation of the shape of the unit and the superlattice structure.
3. Demonstrate the effect of temperature on the nucleation and crystal growth kinetics which in turn change the ionic character of the reaction

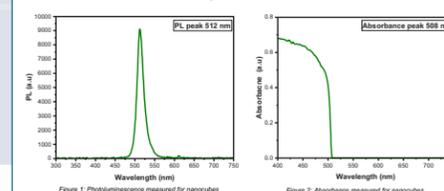


Methods: How to Get Optically Interesting Assemblies



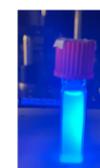
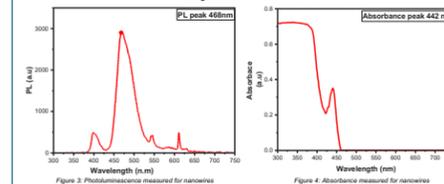
Results

Synthesized Nanocubes



We can observe a clear blue shift of 46nm in the PL peak from 512nm to 468nm in Figure 1 and Figure 3 which signifies the formation of nanowires from cubes. The additional features on the absorbance peak in Figure 4 is due to quantum confinement of the nanoparticles.

Synthesized Nanowires

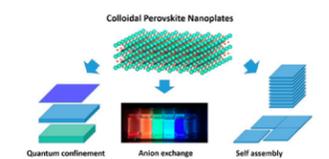


Conclusion: The Next Steps

Through this work, we have demonstrated facile, in-air syntheses of CsPbBr₃ nanocrystals of varying shapes and confinements. Our results also showed how, as the nanocrystals went from 3D to 1D (in other words as their confinements got smaller) there was a blue shift in the energy that they emitted.

Future Steps

The next steps are to perform other types of self-assemblies and explore their range of shapes and angular emissions. **We hope to observe very bright and directional emission. We can use the quantum yield and angular emission to calculate how this organization will improve the efficacy of a full device (i.e. LED or a solar concentrator)**



Acknowledgements

I would like to give special thanks to Mounika Dudala and Dr. Carissa Eisler for their able guidance and support throughout this research process. I would also like to thank WE@UCLA for funding my research project.

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3. Highly Luminescent Colloidal Nanocrystals of Perovskite Quantum Rods and Their Oriented Assemblies. *Nanocrystal Superlattices*, Daniel A. Koshar, Samuel W. Eaton, Peidong Yang, and A. Paul Alivisatos. *Journal of the American Chemical Society* 2015 137 (51), 16008-16011 DOI: 10.1021/jacs.5b11159



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Designing High-Rank Distance-Spectrum-Optimal CRC polynomials for High-Rate Convolutional Codes

ABSTRACT

5G technology has been enabled by recent advances in coding theory, such as polar codes. However, many applications remain out of reach. Without sufficiently low error-rate and low latency, a class of applications, dubbed “mission-critical” applications due to their strict error and latency requirements, remain out of reach of current wireless communication technology. However, much progress has been made to close this gap. One such area, list-decoding, is a subject of research at Professor Wesel’s Communications Systems Laboratory. It has already been shown that both high-rate and low-rate zero-terminated and tail-biting convolutional codes (ZTCCs and TBCCs) with cyclic-redundancy-check (CRC)-aided list decoding techniques closely approach the random-coding union (RCU) bound for short blocklengths. However, current program implementations have limited our ability to design higher-rank CRCs in these papers. In our research, we use software engineering techniques to improve the performance of the current CRC search algorithm and mitigate an important memory-bandwidth bottleneck. We are then able to use these performance improvements to design higher-rank CRCs.

Designing High-Rank Distance-Spectrum-Optimal CRC polynomials for High-Rate Convolutional Codes

By Holden Grissett Advisors: Jacob King, Hengjie Yang Professor Richard Wesel



Introduction

In wireless communication, certain “mission-critical” applications require very low latency and very low error rates. We have made much progress in reducing both of these quantities, but more work remains. In our work, we use novel combinations of cyclic redundancy checks (CRCs) and convolutional codes (CCs) to improve error rate while maintaining very low latency.

We have been successful in designing CRCs to this end, but would like to collect more data on them. Longer CRCs could potentially improve error rates without a large increase in latency. Our research is ongoing, but has faced performance bottlenecks in the search for longer CRCs.

Objective

Our objective is to design a program that can bypass this bottleneck. We can then use this program to find high-rank CRCs.

Key Techniques

Convolutional Codes

Convolutional Codes (CCs) are a way of encoding a stream of bits in a way that allows us to do both error detection and error correction.

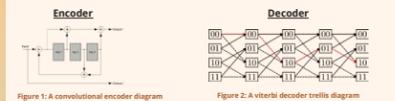
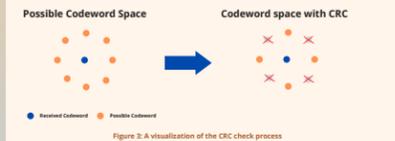


Figure 1: A convolutional encoder diagram. Figure 2: A Viterbi decoder trellis diagram. The decoder uses the pattern generated by the encoder to find the input sequence that would produce an output that is most similar to the received output. [2]

Cyclic Redundancy Check

Cyclic Redundancy Check (CRC) generator polynomials can provide additional error detection capability to a CC. We optimize our CRCs so that they can provide the best error detection possible.



The CRC allows us to rule out a large subset of possible paths in the decoder. Imagine that in fig. 2 we are able to reduce the amount of possible valid paths we can follow because of the CRC. [2]

CRC Search Algorithm

Finding the optimal CRC for a convolutional code requires two phases. The first is to collect all possible irreducible error events (IEEs). These are possible codewords that our decoder can never rule out. We'll want to minimize the possibility of these events, so each CRC will be chosen based on its ability to rule out these events in such a way that we maximize the distance between the remaining possible error events. We also have a computationally significant middle step where we need to rule out “catastrophic” (useless) IEEs. [1]



Figure 4: A block diagram of the 3 most computationally relevant phases.

Materials

Programming Languages: Rust, Matlab
Computing Resources: personal laptop

Methods

The Algorithm

The two main algorithms for obtaining CRCs can be conceptualized with the following pseudo-code:

```

def collect_IEEs(m, search_distance, v):
    IEEs = [1] + (2^m - 1)
    for i in range(2^m - 1):
        IEEs[i] = viterbi_search_for_IEEs(i, search_distance)
    return IEEs

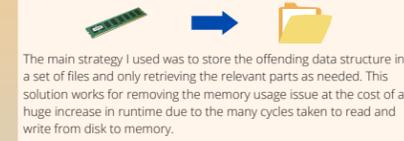
def search_for_best_CRC(m, search_distance):
    candidate_crcs = generate_all_permutations_of_CRC(m)
    non_catastrophic_IEEs = discard_catastrophic_IEEs(IEEs)
    candidates = [1] + search_distance
    candidates = [c for c in candidates if c not in candidates]
    for d in range(0, search_distance):
        count = 0
        for CRC, i in enumerate(candidate_crcs):
            codewords = non_catastrophic_IEEs[i]
            count += sum_of_codewords_divisible_by_CRC_at_distance(codewords, CRC)
            min_divisible_at_distance = min(count)
            candidates[d + 1] = current_candidates(min_divisible_at_distance, d, CRC)
            if candidates[d + 1].len() == 1:
                return candidates[d + 1]
    
```

Figure 5: The collection algorithm [1]

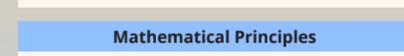
Figure 6: The search algorithm [1]

Two Speedups

Our main memory bottleneck lies in the `discard_catastrophic_IEEs` function, though the first algorithm does present a secondary memory bottleneck. In this work, produced a strategy to reduce the memory consumption of the program.



The main strategy I used was to store the offending data structure in a set of files and only retrieving the relevant parts as needed. This solution works for removing the memory usage issue at the cost of a huge increase in runtime due to the many cycles taken to read and write from disk to memory.



The secondary strategy is to reduce memory usage by implementing these algorithms on a more memory efficient language. For this, I chose Rust. This strategy is still a work in progress.

Mathematical Principles

CRCs are modeled as polynomial functions within a binary Galois field [2]. This means that they're only able to take on the coefficient 1 or 0. Modeling the message and CRC this way, we can use the division of the message by the CRC polynomial to create bits to get a remainder. We can then use this remainder as **check bits**. Adding these to our total message, we can then **check** if the received message is evenly divisible by the CRC polynomial. The ones that aren't divisible evenly can be ruled out as impossible messages. We can use this property to rule out a massive chunk of potential received messages. Take for example the polynomial $x^2 + 1$, which we will model as **101**. We can take a bit sequence we want to add the check into, for example **11**, like so:

```

11 00 (shift left by (m - 1) bits)
10 1 (divide by CRC polynomial)
-----
11 0 (divide once more)
10 1 (These are our CRC check bits)
-----
11 11 Our new CRC checked code looks like this
    
```

If we were to send this bit sequence, we could expect that a correct sequence would be exactly divisible by our CRC polynomial!

Results

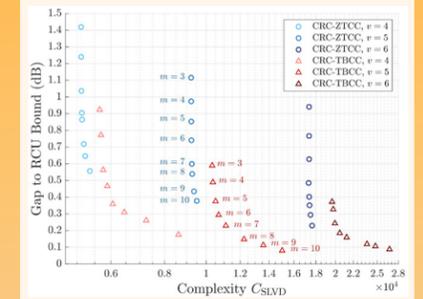


Figure 7: A comparison of the RCU Bound Gap and decoding complexity [3]

The results show that CRC rank does affect the decoding complexity of tail-biting convolutional codes (TBCCs). It is still unclear what the limiting behavior is specifically for zero-terminated convolutional codes (ZTCCs).

For both cases, increasing CRC rank consistently reduces RCU gap across different convolutional codes. The TBCC, however, does seem to exhibit diminishing returns.

Conclusions

While we have seen that the behavior of the CRCs does seem to follow a pattern across TBCCs, it is still unclear how closely the ZTCCs follow this trend as well. Even if the ZTCCs follow the same limiting behavior, it remains an open question whether they can achieve a smaller RCU gap for the same decoding complexity.

Future Work

With this in mind, I will be continuing in my effort to move our codebase over to Rust. Preliminary tests our currently written code indicate that Rust may provide a runtime speedup of >100x. This is very promising, though the space complexity has yet to be comprehensively analyzed. If we can expect this benefit to carry-over to reading and writing files, then the performance boost will be a boom regardless of the implementation details.

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Acknowledgements

I'd like to first thank everyone in my lab: to my wonderful mentors Hengjie Yang, Jacob King, Brendan Towell, and Ava Asmani. Thank you to Professor Richard Wesel for giving me the opportunity to work in this lab and produce results in this fascinating field.

I'd also like to thank SURP staff Minh-Tam Tran, Daniel Katz, and William Herrera for creating such a great program within which we can present our research.

This work was supported by Zeta Associates and National Science Foundation Grant CCF 2008918.



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Development of Photonics Spacecraft Propulsion using Novel Materials and Nanophotonic Designs

ABSTRACT

New methods of spacecraft propulsion have been continuously studied since the emergence of astronautics in order to make space travel cheaper and faster, while still collecting data that teaches us more about the universe. Solar sails utilize the momentum of reflected photons to accelerate low mass spacecraft to unprecedented speeds without needing to carry onboard fuel, meaning that they are not limited by the rocket equation as compared to a chemically or electrically propelled vehicle. If successful, a vehicle powered by a solar sail would accelerate near the sun and be able to fly at solar latitudes outside the ecliptic plane and obtain new information about the Sun. To effectively accelerate, it must be ultra lightweight and reflect as much light as possible, it should also be made of a material that withstands extreme temperatures close to the sun while passively cooling the spacecraft and that which it carries. This requires a low density material with a low solar absorptivity and high thermal emissivity. Coating an ultrathin metal such as titanium nitride with an inorganic substrate such as carbon or boron nitride nanotube combines the strength and reflectivity of the metal with the thermal emissivity of the substrate, allowing for a material that could make up a functional solar sail. Here I will overview our work on design and fabrication of such thin films. I will show that ~1 micron thick films can be fabricated by solution process methods and transferred onto various substrates for subsequent post processing.

Development of Photonic Spacecraft Propulsion using Novel Materials and Nanophotonic Designs

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Mission and Goals

Objectives

- Fabricate ultrathin films made of inorganic materials to be used as a substrate for solar sails.
- Prove that the films are acceptable solar sail material by analyzing optical properties and verifying their ability to be transferred onto different substrates
- Increase efficiency of space travel and make production and usage lower cost
- Create a method of spacecraft propulsion that uses radiation pressure to achieve unprecedented speeds for deep space exploration

Proposal

Background and Limitations

- In order to travel at 50 AU/year, the solar sail must reach a perihelion of about 2-5 R_{\odot} , which requires that the sail be lightweight and able to withstand the extreme temperatures that come with that proximity to the Sun

Figure displaying the relationship between the perihelion and velocity for sails of different mass. Lighter sails can achieve higher speeds at any perihelion.

- Previous solar sails have been launched into Earth's orbit

- Their masses range from 1.3 m^2/kg , all of which are too heavy for interstellar flight and cannot carry a payload anywhere near the Sun.

Requirements

- The sail must be able to get close enough to the sun to be accelerated to desired velocities, which requires materials with extremely high maximum temperatures.

- Commonly used materials such as Aluminum, Kapton, Mylar, and CP1 do not have a high enough emissivity and melting point in order to allow for sufficiently near trajectories to the sun
- Layering other materials to create a metamaterial is required for sufficient material characteristics

Coating Material

Titanium Nitride (TiN)

- Close approach to the Sun is vital
- Refractory metals (circled in red) offer a small enough perihelion
- Maximum temperature 3000 K, which allows for a perihelion <math>< 3R_{\odot}</math>
- Density 5.4 g/cm^3 , lightweight enough to allow for sufficient sail acceleration
- Refractory metal, strong and heat resistant
- Requires support from a substrate for structural integrity and thermal control

Substrate Materials

Carbon Nanotube (CNT)

- Density of 2.26 g/cm^3 , lightweight addition to TiN
- Higher melting point (3800 K) allows for closer trajectory to the sun
- Electrically conductive
- Thermally emissive, allows for passive cooling of the sail

Close up photo of fabricated CNT on aluminum substrate.

Acknowledgements

I would like to thank Artur Davoyan and Ho-Ting Tung for their continued guidance on this project and the Summer Undergraduate Research Program at UCLA for their unyielding support. I would also like to thank the Samueli Scholar Research program and the NASA Innovating Advanced Concepts program for their generous funding.

Experimental Methods

Requirements

- To ensure the validity of CNT as a substrate for the sail, we have to test its optical properties
- Ideally, the CNT has little diffusion and maximum light reflection

CNT Fabrication

- Solution of water multi-walled carbon nanotube is deposited onto a vacuum filter (upper left)
- Water passes through the filter, leaving behind an ultrathin CNT film (upper right)
- Film is deposited onto either aluminum, Kapton, or mylar substrate and filter residue is removed using acetone and heating methods (Kapton pictured on center right)
- Nonrigid substrates are placed onto a 3-D printed PETG frame (lower)

Data Acquisition Setup

- A CNT sample was mounted in the center of the setup
- A laser was reflected off the sample
- A power detector moved around it along a circular track collecting data

Results and Conclusions

Control Data

Power Reflected off an Aluminum Mirror

- Light is diffused over about 4 degrees
- Smooth curve

Sample Data

Power Reflected off a CNT Sample

- Light is diffused over 30 degrees

Conclusions

- Compared to the mirror sample, the CNT diffuses a lot of light.
- Further study of radiation pressure momentum transfer is needed to account for proper solar sail function
- CNT was able to be successfully transferred onto many substrates.

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Fracture Mechanics of Liquid Crystal Elastomers

ABSTRACT

Liquid Crystal Elastomers (LCEs) are a unique type of soft material combining flexible polymer network and rod-like liquid crystals (LCs) that can withstand higher strain than classical elastomers due to the reorientation of LCs. With more applications of LCEs starting to be realized, it will be crucial to understand the fracture mechanics of LCEs so future engineers would be able to prevent possible failures. The purpose of this research is to understand the fracture mechanics of LCEs by investigating the strain and displacement fields and the director rotation around a crack tip. To achieve strain and displacement measurements, we fabricated main-chain monodomain LCEs films with a small edge-crack, and stretched parallel, perpendicular and oblique to the initial director with different angles. The Digital Image Correlation (DIC) method through the Ncorr program on MATLAB was utilized to track the displacement and strain distribution in the LCE samples. The rotation of the director was measured using the optical polariscope method. In general, we found the directors around the crack tip field rotate to be tangential to the crack surface, and the directors at remote regions realigned to the stretching direction. The overall strain and displacement fields match with the simulation where displacement concentration around the crack tip shifts for the specimens with different initial directors. Future work on fatigue cycle and internal imperfection of LCEs would have to be done to understand the fracture mechanics of LCE thoroughly.

Fracture Mechanics of Liquid Crystal Elastomers

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INTRODUCTION

Liquid Crystal Elastomers (LCEs) are a category of soft materials combining flexible polymer network and rigid liquid crystals (LCs) that can withstand higher strain than traditional elastomers. LCEs can also be actuated in response to light and heat, which make them useful in various applications. However, the problem is that the fracture mechanics of LCEs are not well studied.

OBJECTIVES

- Determine the displacement and strain field around a crack
- Investigate the director rotation around the crack

BACKGROUND

- LCEs are composed of liquid crystal mesogens embedded within the polymer chains
- Monodomain nematic elastomer (MNE) has one domain where all mesogens align in one direction. This direction refers to as the director
- θ is the angle between the director and the horizontal axis, while stretching is applied in the vertical direction
- MNE has anisotropic properties, that means the properties such as Young's modulus are different based on the orientation of LCEs.

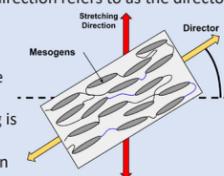


Figure 1. Structure of LCE (Monodomain Nematic Elastomer)

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ACKNOWLEDGEMENTS

I would like to thank Professor Lihua Jin and my Daily Lab Supervisor, Chen Wei, for guidance through the project, and I would like to thank National Science Foundation for funding me to do the research with Summer Undergraduate Research Program at UCLA.

METHODS AND MATERIALS

Fabrication: Two-stage thiol-acrylate Michael addition-photopolymerization (TAMAP) Method

Fig. 2 Fabrication Process for Monodomain LCE Samples

Director Observation

- Fit the light intensity through LCE samples with the following equation to determine the director angle

$$I = I_0 \sin^2 \left(\frac{2\pi(\theta - c)}{180} \right) + d$$

Fig. 3 Optical Polariscope Method
Director (a) 45° (b) 15° (c) 5° with the polarizer

DIC (Digital Image Correlation) Analysis

- Conduct uniaxial tensile test on Tensile Testing Machine (Instron 68SC) with stretch rate of 0.01%/s
- Record the process through camera
- Use Ncorr (MATLAB) to calculate the displacement and strain field

Fig. 4 DIC Analysis Process

Fig. 5. DIC recording setup on the tensile testing machine

RESULTS

Simulations

Fig. 6 Vertical Displacement for 30° LCE Sample

Fig. 7 Horizontal Displacement for 30° LCE Sample

Fig. 8 Strain (E_{xx}) for 30° LCE Sample

Fig. 9 Director Angle Field for 30° LCE Sample

Experimental Results

Fig. 10 Horizontal Displacement for 30° LCE Sample

Fig. 11 Vertical Displacement for 30° LCE Sample

Fig. 12 Strain (E_{xx}) for 30° LCE Sample

Fig. 13 Director Angle Field

- Different strain, displacement, and director angle field for samples with 0°, 30°, 45°, 60°, and 90°
- Observe high strain and director rotation diagonal to the sample as a result of boundary conditions

- Experimental result matches with the simulation
- Director near crack rotates to be tangential to crack surface for all orientations
- Noticeable high strain concentration at or near crack tip independent of the boundary condition

CONCLUSIONS

- Experimental results match with the simulation, proving underlying theory for fracture mechanics of LCEs.
- Successfully using DIC method to evaluate strain and displacement field and notice high strain concentration at the crack tip for samples of all different orientations.
- Observe that directors near the crack rotate to be tangential to the crack surface while directors in remote region tend to align with the tensile direction



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Design of Bio-Inspired Cut-and-Fold Robot Bodies

ABSTRACT

We live in an era of technology and innovation where robots are taking inspiration from nature in order to solve complex problems. However, not everyone has access to these advancements due to the complexity of robot design and manufacturing. By introducing an inexpensive, streamlined, and simplified approach— cut-and-fold robots— we aim to increase the accessibility of bio-inspired robot creation. Our objective is to diversify the functionality of cut-and-fold robots by translating the natural ability of a three banded armadillo to enclose itself. I adapted a two-dimensional cut-and-fold template for an armadillo, which I then sent to a desktop paper cutter to ensure precise fabrication. Prototypes were fabricated using cardstock and thin plastic sheets since they are relatively inexpensive, easily deformable materials. I found that the cardstock better mimicked the rolling motion of an armadillo; the plastic sheets were too rigid. We wanted an easy way to roll and unroll the body, so we implemented a string system by sewing fishing line into its sides. When pulling the fishing line, we could transition the armadillo between its rolled and unrolled state. For future works we would like to explore additional bio-inspired mechanisms. Adapting bio-inspired designs to the cut-and-fold context will aid in making a larger variety of robotic functions more accessible to a general audience.

Design of Bio-inspired Cut-and-Fold Robot Bodies

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01

Increasing Access to Bio-inspired Robot Designs

Robots are taking inspiration from nature to solve complex problems. However, due to the complexity of robot design and manufacturing not everyone has access to these advancements. By introducing an inexpensive, streamlined, and simplified approach— cut-and-fold robots— we aim to increase the accessibility of bio-inspired robot creation.

Goal: Explore the design process of translating a natural ability to the cut-and-fold medium.

Motivation: Diversify cut-and-fold functionalities and increase accessibility of bio-inspired designs.



Acknowledgements

- Dr. Ankur Mehta, UCLA LEMUR
- William Herrera, Summer Undergraduate Research Program

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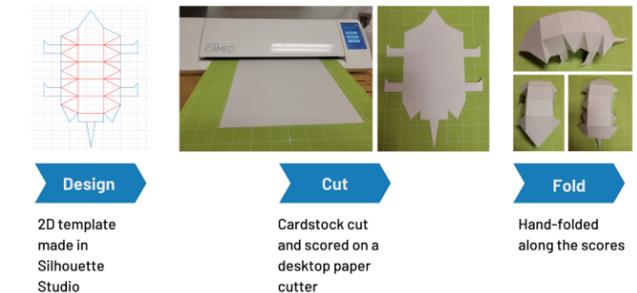
02

Materials



03

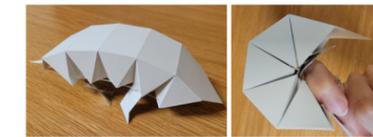
Cut-and-Fold Design and Fabrication Process



04

Results

- User manually actuates the curling mechanism
- Actuation achieved by sewing fishing line into cardstock



05

Conclusion

Current limitations:

- Manual actuation is imprecise, electronic actuation could improve precision
- Using cardstock limits downstream applications, alternative materials such as thin sheets of metal should be explored

Ideas for future work:

- Development as a simple and inexpensive educational tool
- Exploring other natural shapes for surgical applications, etc.
- Testing the effectiveness of various designs and actuation methods



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Biological Effects of Moderate Static Magnetic Fields

ABSTRACT

Evidence spanning decades indicates that weak magnetic fields affect various types of organisms in many different ways. For example, this is seen in animals that display magnetoreception, which is the ability to detect the Earth's magnetic field navigation during migration season. However, more research is needed to determine how magnetic fields interact with or affect smaller organisms at the cellular level. We seek to determine how weak magnetic fields are altering the physiology of organisms. We also aim to systematize and corroborate or refute the evidence found in previously published experiments. Towards that goal, we are first constructing our own 3-Axes Helmholtz Coils to have greater control over the way the magnetic field interacts with a given cell culture. After building the coils, we will test their efficiency, making sure they perform relatively close to our simulations. Finally, the instrument will be placed inside an incubator. Up to 4 standard 12-well cell culture plates will be hosted within the Helmholtz Coils, and we will observe any changes on them as a function of DC magnetic field strength and exposure times. Preliminary results done with a one-directional Helmholtz coil on Actin, Tubulin, and Mitochondria within smooth muscle cells for 4 hours with a magnetic field of 6 mT show some deformation of mitochondrial and actin structures.

Introduction

Quantum biology studies how quantum mechanics can be used to answer the failings of classical mechanics in biological systems. Many animals, such as robins, have magnetoreception, or the ability to detect the Earth's magnetic field, indicating that magnetic fields are able to influence biological processes.

Static magnetic fields (SMFs) are magnetic fields in which their intensity and direction are held constant over time. Magnetic fields interact with the spin of electrons thereby also influencing chemical reactions in living organisms. Smaller SMFs have a less negligible impact than those of larger or higher intensity SMFs.

We hypothesize that weak magnetic fields are able to alter physiological functions of living organisms.

Objective

Construct a device that allows you to manipulate magnetic fields to varying degrees

Determine how weak static magnetic fields effect organisms

Corroborate and systematize the current knowledge on the effects of moderate SMFs on living organisms

Materials and Methods

1. Designed and assembled 3-Axis Helmholtz coil out of an acrylic frame and 3D printed feet and a sample holder



Figure 1a. Acrylic frames for the individual coils in each direction

2. Used orthocyclic winding to wrap ~10,000 ft of 22 AWG wire around frame



Figure 1b. Assembled frame including sample holder designed in CAD

3. Created a Faraday Cage out of mu-metal and plywood to place the coils into in order to remove any influence of external magnetic fields on the samples



Figure 2. 3-Axis Helmholtz Coil placed on the inside of a Faraday Cage

4. Tested points in the coils to determine the efficiency of the magnetic field in comparison to simulations

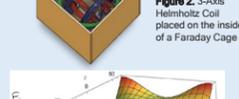


Figure 3. Simulations of expected magnetic field. Red indicate points of maximum magnetic field strength and purple, minimum.

5. Placed cell samples in coils for periods of time and measured any changes in structure.

Results and Discussion

Preliminary Results

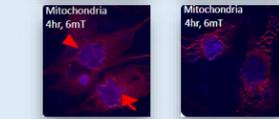
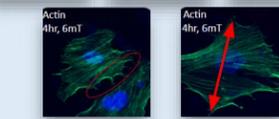
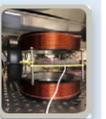


Figure 4. Comparison between control group of A7RS smooth muscle cells and a group exposed to a 6 mT magnetic field for 4 hours. Notable samples selected for non-control group.

Figure 5. Temporary Helmholtz Configuration used to do some preliminary tests while constructing the 3-Axis Helmholtz Coil.



In the preliminary tests, using the Helmholtz coil in shown in Figure 4 were done with the Helmholtz Coil arrangement shown in Figure 5. This is just a single axis Helmholtz Coil done while the actual 3-Axis Helmholtz Coil was being made just to start on the experiments to save time.

Out of the 300 samples placed in the magnetic field, there were about 30 or so samples that seemed to be affected by the magnetic field (some of which are shown in Figure 4). Tubulin did not seem to be affected. There might have been a potential confounding variable, that being temperature as the wires increased in temperature as more current was passed through them. This could have potentially affected the cells. This could potentially be solved by adding a cooling mechanism in the coil system.

Conclusion

Through the experiments conducted, there seems to be some indication that weak magnetic fields alter some physiological functions or structures of cells when they are exposed for a certain period of time (4 hours). The preliminary results show deformation of cell structure in the actin and mitochondria of smooth muscle cells. Because of the low number of affected cells out of all the batch, there is a possibility that this is due to the increase in temperature of the coils, which can affect the cells.

Once the 3-Axis Helmholtz is fully built with the Faraday and possibly a more efficient cooling system, we seek to confirm these results as well as see how different variations in the magnetic field may affect the cell samples.

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I'd like to thank the National Science Foundation (NSF), the UCLA Summer Undergraduate Research Program (SURP), and the UCLA Fast Track to Success program for this research opportunity as well as Professor Clarice Aiello for her knowledge and support.

An additional big thanks to Abasalt Bahrami for providing the images of the preliminary results.



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Identification of Embedded Devices via Electromagnetic Emissions

ABSTRACT

Securely identifying an electronic device can be extremely difficult. The majority of current solutions, such as RFIDs or printed barcodes are either too expensive to realistically use at industrial scale, or too easy to spoof and therefore insecure. Due to these limitations, finding an alternative that fulfills both criteria is highly desired. Electromagnetic emissions have been proven to be unique enough to identify individual devices from one another, and add no extra cost to device manufacturing. However, it has yet to be shown that it is possible to identify devices at extended ranges, especially when such devices do not have wireless transceivers. We show that by analyzing the emanations for common features across device types while still retaining individuality, it is still possible to recover enough data at range (>1 meter) to uniquely identify separate devices. Electromagnetic emissions from several development boards in various states (idle, running a simple program) were obtained using a USRP Software-Defined Radio and GNURadio. This data was then processed in MATLAB to first extract useful features that are both unique to individual devices and consistent over time, for usage in feature based classification models. The extracted features were then supplied to a Random Forest classifier to identify specific devices. Initial results from the model show that it is possible to identify devices at 1 meter of range with a success rate of 91%. Therefore, our feature-based machine learning model is able to determine not only the type of the device in range but also the exact individual device, demonstrating the feasibility of this method for secure identification.

Identification of Embedded Devices via Electromagnetic Emissions

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UCLA Samueli School of Engineering
SUMMER UNDERGRADUATE RESEARCH PROGRAM
Summer 2022

Motivation

Identifying billions of devices with security in mind can be extremely complex.

Existing solutions have issues:

- RFID – Too expensive for large scale
- Printed barcodes – Easily spoofed, insecure
- Encrypted keys – Software dependent

Therefore, a solution that is both secure and inexpensive is desired.

Figure 1: Visually identical devices could be malicious without proper identification.

Experimental Setup

- Setup A: DUT (Arduino Uno pictured) is placed 1 meter away from a TV antenna.
- Setup B: DUT is directly measured using a nearfield probe.

Data is collected through a USRP SDR (Software-Defined Radio) connected to a PC running GNURadio, a real-time signal processing program.

- Automated Python scripts enabled rapid data collection at various frequency harmonics.
- Samples were taken across various days and ambient noise levels.

Figure 2: Flow diagram of experimental setups. Displays the PC connected to the USRP SDR, which connects to either setup A (TV Antenna) or setup B (Nearfield Probe). The DUT is swapped to be either a Nucleo or Arduino Uno.

Background and Goals

Background

- Electromagnetic Emissions (EME) are a byproduct of a device's normal operation and are caused by unique variances in device to device.
- EME have been used previously to identify devices, however only at extremely nearfield (<1cm) using a probe to classify devices.^[a]
- We have found in previous work that the clock signal from a device is much stronger than other EME.

Research Goals

- Utilize features of the stronger clock signal to extend the range of identification.
- Enable more accurate identification using advanced machine learning algorithms.

Data Analysis and Classification

Figure 3: Data analysis flowchart. Raw data is collected, features are extracted in MATLAB, then a machine learning classifier determines the device identification.

Feature Extraction

Several different features are extracted from the raw data using MATLAB. These are unique to each device and used by an ML model to classify them.

Figure 4: Illustration of various examples of features extracted for classification.

Machine Learning Classifier

- Random Forest classifier
- Trained on either antenna or probe data collected over various days

Results

Predicted \ Actual	ard1	ard2	ard3	stm1	stm2	stm3
ard1	9	0	1	0	0	0
ard2	0	14	0	0	0	0
ard3	0	0	4	0	0	0
stm1	0	0	0	7	0	3
stm2	0	0	0	0	10	0
stm3	0	0	0	1	0	7

Predicted \ Actual	ard1	ard2	ard3	stm1	stm2	stm3
ard1	11	0	0	0	0	0
ard2	0	15	0	0	0	0
ard3	0	0	7	0	0	0
stm1	0	0	0	6	0	1
stm2	0	0	0	0	7	0
stm3	0	0	0	1	1	9

Figure 5: Confusion matrices for trained classifier for antenna and probe setups.

Notable results:

- Antenna Model Accuracy: **91.1%**
- Probe Model Accuracy: **94.8%**
- STM1 and STM3 were the most likely to be misclassified, however there is no significant difference between the performance of the two setups.

Conclusion and Future Work

- At range, it is possible to identify a device using solely its EME with extremely strong accuracy.
- Additional data should be collected to form a more rigorous model and test in alternate environments.
- Future work could explore potential use cases for EME identification in authentication, localization, and secure communication.

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Acknowledgements

Special thanks to Professor Sehatbakhsh for his knowledge and support as well as the opportunity to work in the Secure Systems and Architectures Lab. We would also like to thank Will Herrera and the Summer Undergraduate Research Program staff for their guidance throughout the research process.

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Electrical and Computer Engineering

Compression of Convolutional Neural Networks on One-Dimensional Datasets via Weight Pool Networks

ABSTRACT

Convolutional neural networks are often used in a variety of classification and prediction models, most commonly in the field of image processing. However, as some of these neural networks become increasingly deep and complex, their requisite computational power and storage size may start to look unviable for resource-constrained devices. Compression techniques such as weight pooling serve to cluster neural network weights together and reduce the number of weights needed to be stored. We specifically used channel-wise weight pooling to allow for groupings on arbitrary 2D filter sizes while minimizing accuracy drop. As this approach has exhibited an adequately low drop in accuracy when run on an image dataset, we applied the same methods to one-dimensional datasets such as Deepsig's RadioML dataset. Generating weight pools of size 64 allows for 7.6x compression while showing similar levels of accuracy compared to the original network.

Compression of Convolutional Neural Networks on One-Dimensional Datasets via Weight Pool Networks



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Introduction

- ❖ Objectives
 - Many neural networks nowadays too advanced for deployment on resource-constrained devices
 - We seek to achieve optimal compression of NNs with minimal accuracy drop in order to reduce requisite computing power or memory
 - We would like to evaluate the efficacy of weight pool networks along the z-axis dimension (channel-wise pooling) on datasets other than images
- ❖ Background
 - Convolution involves altering each element of a matrix by combining information from its surrounding elements and a particular filter
 - Pooling is the process of directly compressing a matrix down by aggregating data into clusters and extracting a single value from each cluster
 - Convolutional Neural Networks (CNN) use a combination of convolution and pooling layers to compress the input layer down to a much smaller size
 - Instead of pooling on a two-dimensional scale, we cluster weights on a channel-wise basis to allow for arbitrary filter size

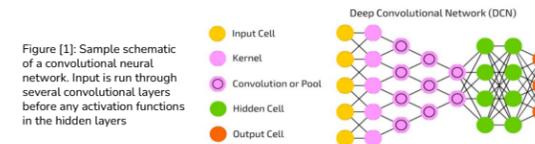


Figure [1]: Sample schematic of a convolutional neural network. Input is run through several convolutional layers before any activation functions in the hidden layers

Materials and Methods

- ❖ Materials
 - PyTorch: Machine learning framework allowing for operations on weights with parallelism
 - Deepsig RadioML 2016.10A Dataset: Synthesized RF dataset with pre-classified modulations
 - Speech Commands audio dataset
- ❖ Methodology
 - Conducted training on Deepsig RadioML dataset using two convolutional layers (1x3 and 2x3 filter, respectively) and Adam optimization algorithm
 - Conducted training on Speech Commands dataset using 4 convolutional layers
 - Trained using 256 samples per batch
 - By stacking filters and pooling weights along the channel-dimension, we can represent each weight with an index to the weight pool's center instead
 - After 8-bit channel-wise pooling using K-means clustering algorithm, there will be 32, 64, 128, or 256 groups of vectors

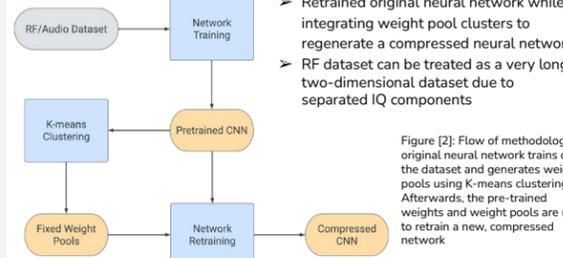


Figure [2]: Flow of methodology; original neural network trains on the dataset and generates weight pools using K-means clustering. Afterwards, the pre-trained weights and weight pools are used to retrain a new, compressed network

Results

- All neural networks were trained until average classification accuracy converged (between 100 and 200 epochs)
- Accuracy on both datasets converge at around 80%, and remains roughly the same after compression
- Neural network on audio dataset was trained using varying sizes of weight pool networks (ranging between 32 and 256 groups)
- Neural network on RF dataset was trained only using weight pool size of 64
- Increasing size of weight pools would theoretically increase accuracy, but lead to issues when measuring speedup later on
- RF dataset consists of subsets of varying signal-to-noise ratios; modulation classification accuracy should be higher for stronger relative signal strength
- Weight pooling was excluded on the first layers of both networks, so the compression factor for the RF dataset is 7.7x (two layers) while the compression factor for the audio dataset is 4.6x (four layers)

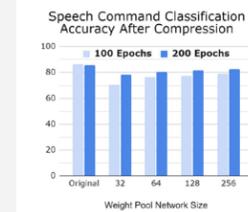


Figure [3]: Audio neural network accuracy according to varying weight pool sizes

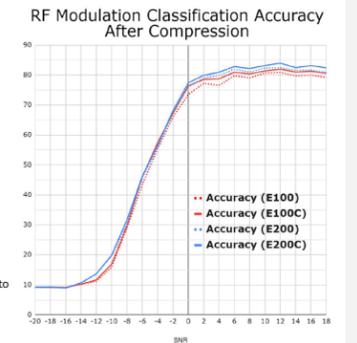


Figure [4]: Radio frequency signal neural network accuracy according to varying SNRs

Conclusions

- Classification accuracy drop for RF dataset is negligible after compression and increases in some cases (since network was trained for 200 epochs both before and after compression)
- Accuracy drop in speech command classification is larger but still insignificant especially when trained with weight pool size of 256 clusters
- Results show that weight pooling allowed for compression of convolutional neural networks with satisfactory accuracy retention
- Future progress can be found in combining channel-wise weight pooling with other compression techniques to improve accuracy or increase compression

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Acknowledgements

I would like to thank Professor Puneet Gupta for allowing me to work in his lab as well as Shurui Li for mentoring and guiding me through this project. I would also like to thank the Interactive Systems REU site for funding this project.



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Automation of High-repetition Rate Spectral Measurement for Use in Research of Infrared Supercontinuum Generation

ABSTRACT

Optics research and applications often require accurate and precise measurements of the power, time-of-flight, or spectral content of a laser. Examples of this include lidar, spectroscopy or supercontinuum (SC) generation, a nonlinear optical process in which a short pulse laser experiences extreme spectral broadening after passing through a material. Current data acquisition systems for spectral measurements operate at an acquisition rate of around 1 Hz using a monochromator, photodetector, and oscilloscope. High speed data acquisition systems must be implemented to accurately measure the spectral content of lasers operating at a repetition rate of 1 kHz. We created a mock-up experimental setup with a variable pulse length 656.6 nm diode laser to focus on automating the spectral data collection process. Communication with the oscilloscope and monochromator was accomplished by Python code. We produced an acquisition rate of around 50 Hz, the maximum frequency before the oscilloscope collected repeated values. We tested the data acquisition framework by first mapping the spectrum of the diode laser to determine its central wavelength and bandwidth. Then, we measured spectra consisting of multiple diffraction orders over a wide range of grating angles. Future steps will focus on implementing the automated data collection process in experiments in the mid-infrared spectral range.

UCLA Samueli School of Engineering
FAST TRACK TO SUCCESS
UCLA Electrical and Computer Engineering

SUMMER UNDERGRADUATE RESEARCH PROGRAM

Automation of high-repetition rate spectral measurements for use in research of infrared supercontinuum generation

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Department of Electrical & Computer Engineering — University of California, Los Angeles

INTRODUCTION

BACKGROUND

Optics research and applications often requires accurate and precise measurements of the spectral content of a laser. Some applications include supercontinuum (SC) generation and spectroscopy.

In particular, SC generation measures the extreme spectral broadening of a laser after it passes through some medium.

SC generation is a nonlinear optical process that can only be accomplished with light of high-intensities, namely short-pulsed, high-powered lasers.

Figure 1. Experimentally measured supercontinuum generated in a GaAs crystal. A short-pulsed, high-powered IR laser is converted to ultra-broadband IR light spanning a large range of wavelengths in the SC than before [1].

Spectroscopy measures the emission spectrums of different elements. Matter absorbs or emits light at specific portions of the electromagnetic (EM) spectrum to create a "spectral signature."

Figure 2. Atmospheric absorption for different common molecules in the air. Emission and absorption spectrums can be used to identify matter.

PROBLEM

At the UCLA Neptune Lab, data acquisition systems for spectral measurements have an acquisition rate of around 1 Hz.

High speed data acquisition systems must be implemented to accurately measure the spectral content of lasers operating at a repetition rate of 1 kHz.

OBJECTIVE

Automate the spectral data collection process to achieve an acquisition rate higher than 1 Hz.

RESEARCH

MATERIALS & METHODS

Figure 3. A diffraction grating is a device in the spectrometer that diffracts or divides light by wavelength.

Equation 1. The diffraction grating equation. When light is normally incident on the grating, the diffracted light travel at different diffraction angles θ_m , calculated by

$$d \sin \theta_m = n\lambda$$

$d = 1/N$ where N is the number of grooves per mm on the grating. n is the order of grating. By fixing θ_m as the angle light must travel to exit the spectrometer, it can control what wavelength passes through the slit.

Figure 4. The optical path for light in a Czerny-Turner monochromator. Light is focused on the entrance slit. It is reflected on a curved mirror where it's collimated or focused to infinity. The collimated light is diffracted from a grating and is collected by another mirror. The second mirror focuses the diffracted light on the exit slit. A single monochromatic ray of a specific wavelength exits the spectrometer.

The experimental setup is a mock-up design similar to ones for SC generation. We used a variable pulse length 656.6 nm diode laser with a repetition rate of 1 kHz. Two oscilloscopes were tested for acquisition. Oscilloscope #1 was the Tektronix TDS-3064 Oscilloscope. Oscilloscope #2 was the 3 Series MDO Mixed Domain Oscilloscope.

Figure 5. A Stanford Research DG535 Digital Delay and Pulse Generator is attached to the laser. It defines the laser pulse length and triggers when it fires. Laser light is focused into the entrance slit of a HR-550 Spectrometer. The light is separated or dispersed by a diffraction grating such that light exiting the spectrometer is of a specific wavelength.

The spectrometer includes a program to rotate the grating and change the wavelength selected by the monochromator.

Figure 6. The photodetector collects the light and converts it to electrical signals. These are passed to the oscilloscope where it can take spectral measurements like amplitude and frequency.

Figure 7. Automation of the data collection process in Python. Oscilloscope #1 was connected to the computer by ethernet and Oscilloscope #2 was connected by USB.

RESULTS

Figure 8. Spectrum of the laser acquired by Oscilloscope #1 and #2 and its spectrum from first to second order acquired by Oscilloscope #2. The dotted lines are guides.

Figure 9. Spectrum of the laser using an Ocean Insight Flame Spectrometer.

Oscilloscope #1 acquired data at a maximum frequency of 20 Hz for a 1 μ s pulse. Oscilloscope #2 acquired data at a maximum frequency of 50 Hz for a 1 μ s pulse and 10 ns pulse.

The effective acquisition rate of Oscilloscope #2 and the spectrometer is 25 Hz.

CONCLUSION

CONCLUSION

While Oscilloscope #1 had a slower acquisition rate, the data has less spread than Oscilloscope #2. The laser spectrum of Oscilloscope #2 contains several outliers where the instrument likely recorded excess energy or information coming from the time domain (Figure 10). The laser was firing at a 1 μ s pulse, a potential source of error for the oscilloscope to resolve other noise in a long pulse. We can attenuate the beam or adjust the size of the slits of the spectrometer to control how much light is collected by the photodetector. This can limit the amount of noise the oscilloscope receives and narrow bandwidth.

Figure 10. Scope trace at an arbitrary wavelength during data collection. It is picking up extra signal from the photodetector.

Both oscilloscopes ran with the same python script, but Oscilloscope #2 had a faster acquisition rate. We can conclude that it takes longer for Oscilloscope #1 to process the instructional code sent by the computer to record a measurement.

Pulse length does not affect the acquisition rate of the oscilloscope. A 1 μ s pulse and 10 ns pulse were tested on Oscilloscope #2 and produced the same frequency of around 50 Hz.

Future steps will focus on implementing the automated data collection process in experiments in the mid-IR range.

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ACKNOWLEDGEMENTS

This work was supported by the National Science Foundation Grant #2003354 in the UCLA Summer Undergraduate Research Program. We would like to thank Prof. Joshi for his knowledge and support. We would like thank Daniel Matteo and Dr. Tochitsky for their guidance in the research process.

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Windowed Cauchy Estimation for Multi-State Systems

ABSTRACT

Bayesian state estimators use both noisy measurement data and prior knowledge about the stochastic dynamics of a system to make an inference about the true value of the state. Since 1960, only one estimation scheme in which the dynamic generation of the conditional probability density function given the measurement history is recursive and analytic - the celebrated Kalman filter. A Kalman filter applies Bayesian estimation for linear dynamics over discrete time steps to estimate a state over time. However, the Kalman filter assumes the state to be a normal (Gaussian) distribution, a light tailed distribution, and thus is inadequate for systems with heavy-tailed noise, or those with higher probability of data distributed towards the tails of the probability density function. Thus, the analytic and recursive Cauchy estimator was developed basing the (modeled) process and measurement noises on the heavy-tailed Cauchy distribution. Because the amount of memory and computation required for the Cauchy estimator grows indefinitely with each discrete time step, a sliding window approximation was implemented to ensure an estimator with a fixed amount of computation and memory could be made at any given time step. This windowed Cauchy algorithm was tested on a nonlinear three-state model of a homing missile with radar measurement. When the algorithm was used to estimate the position, relative velocity, and target acceleration of the missile over time, it was found to significantly outperform the Kalman filter, even with smaller window sizes. Because larger window sizes require more computation and memory, different window sizes were tested against each other. Little significant decrease in estimation accuracy was measured at smaller window sizes, thus implying that the windowed Cauchy filter can practically be applied without excessive computational power. Future research will include testing the Cauchy estimator on different applications which are found to have heavy-tailed noise.

Windowed Cauchy Estimation for Multi-State Systems

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Introduction

When faced with the problem of estimating the distribution of a state (i.e. position, velocity, acceleration, orientation) which changes over time, there are two intuitive approaches: measuring data and modeling. However, neither approach can perfectly account for noise, or randomness in how the state changes. Thus, modern estimators leverage both approaches to generate conditional probability distributions in attempt to estimate the true state. Estimators which incorporate the Gaussian probability density function, like the Kalman Filter, are to date the status quo in state-estimation.

The Cauchy estimator is the only estimator that is both an analytic and recursive function of the measurement history for heavy-tailed data, by modeling noise as a Cauchy distribution. Heavy-tailed data has an undefined second moment and thus a higher probability of being farther towards the tails than the center of the distribution. For example, atmospheric and underwater noise that come into play in radar and sonar measurements tend to be heavy-tailed, and existing estimators perform poorly in these conditions.

Materials and Methods

Stage 2: Implementation
Use the PuTTY SSH Client to access the XSEDE Expanse cluster. Running our code on the cluster grants us the computational power to run Cauchy filter with 10+ windows to understand how windowing improves the performance of the algorithm.

Stage 4: Analysis
Use NumPy and Matplotlib to compare estimation data between different numbers of windows and with the Kalman filter.

Stage 1: Development
Develop CUDA-C code to apply the windowed Cauchy filtering algorithm with parallelization capability

Stage 3: Testing
Run the algorithm on selected simulated models with randomly generated noise. Generate estimation data corresponding with measurement data.

Objective

We aim to develop an estimator that effectively uses a Cauchy distribution to estimate multiple states in a system with (possible) heavy-tailed noise.

Sliding Window Approximation

The sliding window approximation is essential to the Cauchy estimator due to the increasing term count of the equation for Cauchy estimation. At each time step, the amount of memory and computation required would increase indefinitely, which would make the estimator impractical to implement. However, previous research [1] suggested that the term number can be truncated without significant loss in accuracy.

Thus, several staggered windows were implemented in parallel using CUDA's parallelization capability. At each time step a constant amount of memory and computational power can be used. Window size and count can be adjusted based on the user device's memory and computation speed.

Bayesian State Estimation

What we observe
SIGNAL + NOISE
Isolated noise from signal
SIGNAL
NOISE

Imagine we are using radar to track the location of a missile in flight - random disturbances in the signal and turbulence of the missile can skew the readings. Thus, this data alone can't always be used as the most accurate estimator for the true value of a state.

Now imagine that we have some model of how we expect our state to behave, such as the flight plan for the missile. Then, we can leverage this information with our measurements to estimate how much each change in the measured location of the plane is due to the actual movement of the missile versus random changes in our measurements. This is the basis for Bayesian estimators.

Optimal State Estimate
Predicted State Estimate (Using Model)
True State (position)
Measurement (Contains Noise)

Bayesian state estimators use some model of the noise in a system to determine the likelihood of a change being due to noise or to actual change in the system. The Kalman filter was the only Bayesian state estimator that can generate a probability density function for the state analytically (at any given time) and recursively (as a function of the previous estimation) before the development of the Cauchy Estimator.

Results

Figure 1: Simulated homing missile position over time

Figure 2: Measurement noise in position readings - note spikes at steps 84 and 96

Figure 3: True State with Kalman and windowed Cauchy estimates overlaid - note similarity in different windowed estimations

Figure 4: Cauchy (5 windows) vs. Kalman estimation errors with standard deviations overlaid

Cauchy vs. Kalman Estimators

The Kalman filter assumes the state to be a normal (Gaussian) distribution, a light tailed distribution, and thus is inadequate for systems with heavy-tailed noise.

The Cauchy estimator, instead, utilizes the heavy-tailed Cauchy Distribution. Using a heavy-tailed distribution leads to more accurate estimations than the Kalman filter when noise is very impulsive.

Conclusions

The homing missile experiment suggests that the windowed Cauchy estimator can generate much more accurate estimations of the three states than the Kalman filter can, especially when the noise is very impulsive (see step 84, figure 2). Window analysis leads to the conclusion that no more than five windows are required for the sliding window approximation to yield accurate estimations as larger windows lead to diminishing increase in accuracy.

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Future Work

Future experimentation will include review of the estimator's effectiveness on systems with different noise distributions, as evidence has been found to suggest that it is effective in some of its intended use-cases.

Acknowledgements

I would like to thank the National Scholarship Federation for funding my research through the UCLA Samueli Summer Undergraduate Research Program. I would also like to thank Professor Jason Speyer and Nat Snyder for their invaluable guidance and support.



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Intuitive Environmental Design in Virtual Reality for Robotic Simulation

ABSTRACT

The field of robotics needs simpler tools to create robots, especially for nonexperts, as the complete process is tedious and not user-friendly. A part of testing a robot is evaluating how it will physically interact with an environment through handling an obstacle or traversing certain terrain. With intuitive tools to design a robot's environment, robot creation becomes simpler. Virtual reality provides the best 3-dimensional visualization of real life, which makes for more intuitive design. Using virtual reality I created an easy-to-use tool that allows anyone to design a robotic environment. I developed a simple user interface that allows a user to design terrain 3-dimensionally. The design tool enables spawning, resizing, and placing multiple objects to form an environment that a robot may travel through. The tool extracts a numerical measurement of each object when resizing, allowing for scaled design necessary for practical robotic simulation. Overall, the tool simplifies environmental design and can help those who may not be well versed in robotics. With my simplified environmental design tool, future work involving structural design automation will allow nonexperts to create their own robots.



Intuitive Environmental Design Tool In Virtual Reality for Robotic Simulation

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SUMMER UNDERGRADUATE
RESEARCH PROGRAM

Goal: Create an easy-to-use **environmental design tool** that is intuitive and enables 3-dimensional visualization in virtual reality to simplify robotic simulation and design.

INTRODUCTION AND BACKGROUND

- Help nonexperts delve into robotics
- Current tools for robotics not **intuitive** and do not help **visualize**

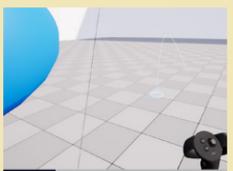
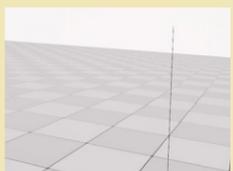
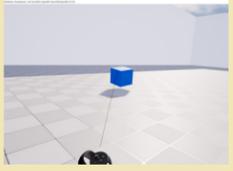
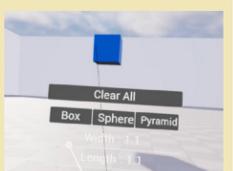
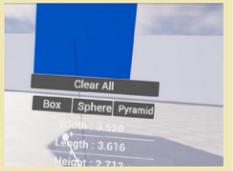
Aspects to Robotic Design:

- Structural Robotic Creation
- Environmental Design

- Testing robots requires viewing robot in environment

We need intuitive environmental design tools to simplify robotic design.

RESULTS

<p>Movement: Teleportation based on where player is looking</p>  <p>Front side of objects</p>	<p>Spawning Objects: 1. Empty World</p>  <p>2. Open Menu and Select Object</p>  <p>3. Spawn Object</p> 	<p>Resize Objects: Slider used to resize width, length and height</p>  <p>Regular Spawned Cube</p>  <p>Resized Cube</p> 
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PROCESS/METHODS

MATERIALS

Oculus Quest 2



C++ / Blueprint (1)



Unreal Engine 5 (2)



CONCLUSIONS AND FUTURE WORK

Current Applications:
Freedom in designing environment and visualizing environment



Next Steps:
Make structural robotic creation tool to use with environmental design to help simplify robotic design

ACKNOWLEDGEMENTS AND REFERENCES

- William Herrera, Summer Undergraduate Research Program
- Dr. Ankur Mehta and the LEMUR Lab
- Professor Gregory Pottle
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Measuring, Prediction, and Application of Pressure Profiles for Lithium-ion Batteries

ABSTRACT

In this project, we create a setup to measure the pressure profile of eight lithium-ion batteries simultaneously that can be charging at different protocols. We then collect cycling and pressure data and use this data to train a machine learning model that can be used for prediction of pressure profiles. We then seek to create a dynamic charging protocol using a PID control with our machine learning predictions in loop. We found that pressure has distinct behavior that can be used for many applications. Our preliminary results show that our machine learning model is accurate for the data we have but needs more data and more tuning to be accurate on a wider range. Our early PID control implementation shows that fast charging can be done with a smaller percentage of time causing lithium plating, but more tuning is needed to use this protocol for complete prevention of lithium plating. This work improves upon the slow constant current-constant voltage charging conventionally done. This will allow for increased charging rates, decreasing the required charging time. In addition, future experimentation will explore the use of machine learning predicted pressure profiles as a means of estimating battery lifetime. Differential pressure sensing, machine learning predictions, and PID control implementation will allow batteries to be charged faster and last longer.

Measuring, Prediction, and Application of Pressure Profiles for Lithium-ion Batteries

Matthew Margason, Yungunn Ko, Aakash Varma, Steven Zhou, Professor Yuzhang Li

Background and Motivation

Applications for electronic devices, electric vehicles, and energy storage are causing lithium-ion batteries to become increasingly important. One of the most sought after improvements in battery technology is increasing the charging speed. Particularly in the electric vehicle industry, this will allow for increased consumer acceptance propelling the transition from gasoline vehicles.

Volume expansion occurs in Lithium-ion pouch cells normally during charging. As shown in figure 1, a measurable increase in volume change occurs when lithium plating occurs. Lithium plating is where it becomes favorable for the lithium ions to deposit on the surface of the anode rather than intercalating in it. This causes dangerous dendrite formation. In a rigid container this volume change can be measured as a pressure change. Because lithium plating is destructive to the cell, it is necessary to charge conservatively to avoid lithium plating. Pressure sensing can be used as a physical metric to detect and avoid lithium plating while charging faster.

To meet our goal of increasing charging rate, our project had three phases. In phase A we setup hardware and collect data. In phase B we develop a machine learning model to predict pressure. In phase C we begin development of a PID control to increase charging speed.

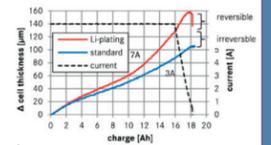
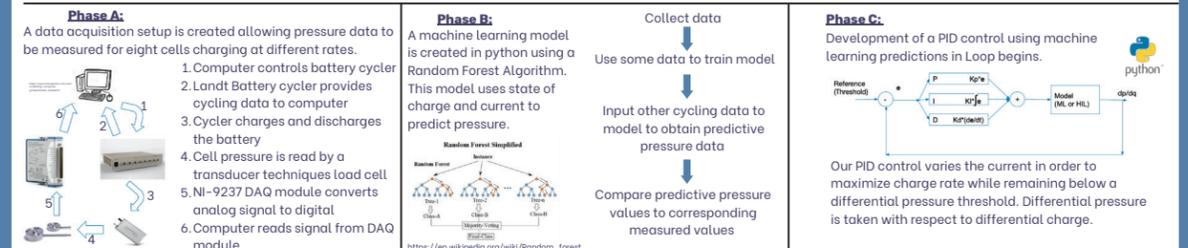


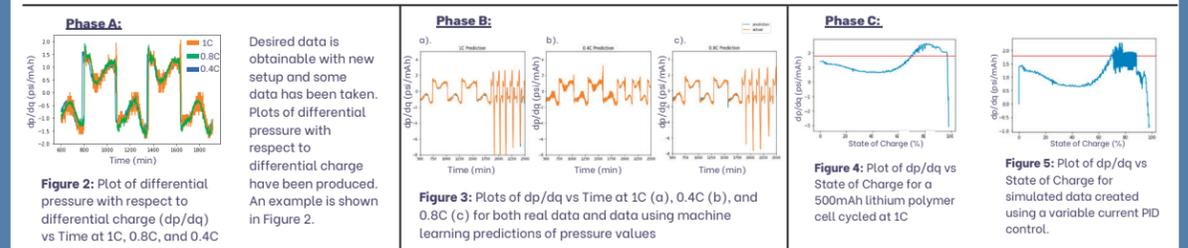
Figure 1: Change in cell thickness with and without lithium plating during one charge step

Bernhard Bitzer, Andreas Gruhle, A new method for detecting lithium plating by measuring the cell thickness, Journal of Power Sources, Volume 262, 2014.

Methods



Results



Discussion and Conclusions

- We were able to create a setup that allows us to measure multiple pressure profiles of cycling batteries simultaneously.
- As shown in figure 3, our early machine learning pressure profile predictions are nearly perfect, but this is likely due to small data sets and limited ranges. In order to improve our model, we must collect more data and charge at higher rates.
- While still in its early phase, as shown in figures 4 and 5, our initial PID control shows the ability to reduce the time spent above the threshold of lithium plating.
- Further experimentation will explore the use of real time hardware recorded pressure values in the PID loop and how those results compare to the software in loop PID control we are using now.
- The progression of this research will allow battery charging speeds to be safely increased. This will have widespread impact on the use of batteries.
- Future studies will also include application of pressure profiles to prolong battery lifetime.

Acknowledgements

I would like to thank Professor Li and my lab-mates for a great summer. I would also like to thank the UCLA Summer Undergraduate Research Program and the Samueli Research Scholars Initiative for providing me with this opportunity and supporting me throughout the summer.



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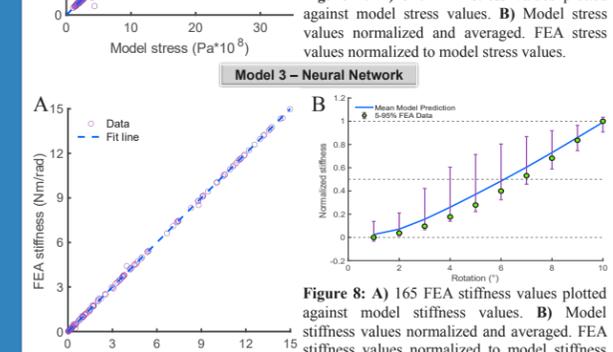
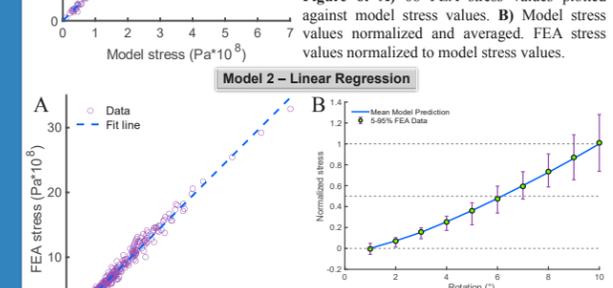
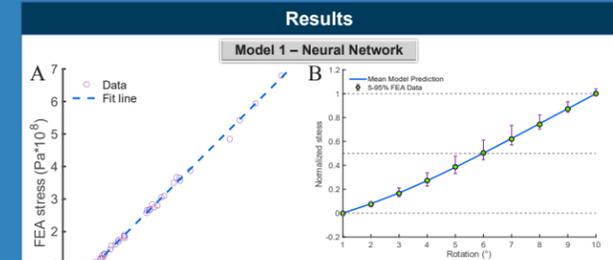
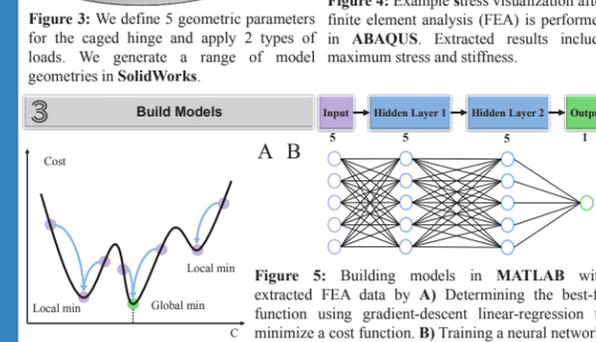
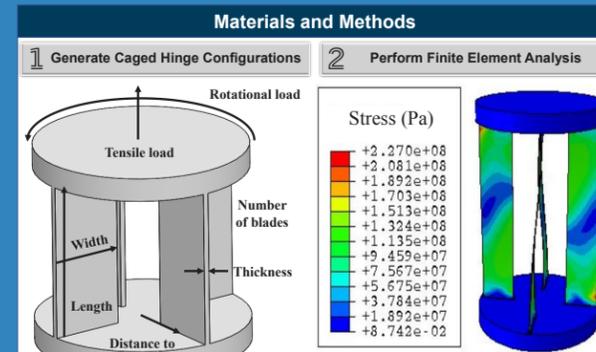
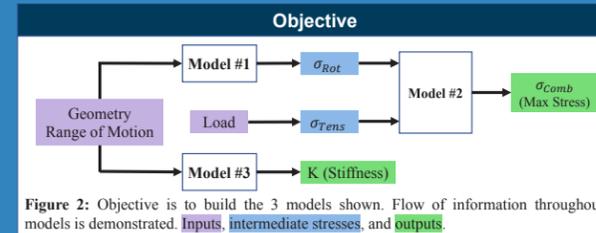
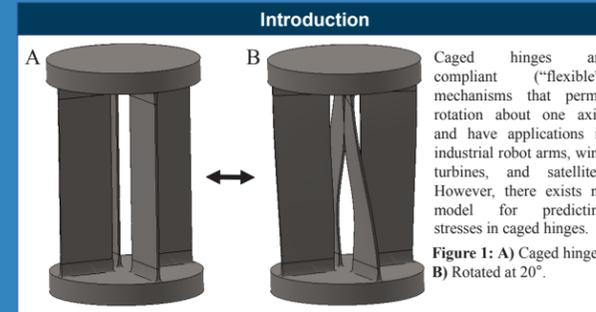
Design and Modeling of Application-Specific Caged Hinges

ABSTRACT

Compliant mechanisms are parts or systems of parts that flex and bend to achieve desired motions. They are often manufactured as a single piece, eliminating sliding and rubbing motions between separate components; this significantly reduces wear and friction. As a result, compliant mechanisms require less maintenance and can be designed to have a longer lifespan than dynamically-equivalent, rigid mechanisms. Additionally, compliant mechanisms are incredibly precise, and can maintain this high precision throughout their entire lifespan. Consequently, in fields where maintenance, lifespan, and precision are top priorities, compliant mechanisms may be superior to rigid, over-constrained alternatives. A caged hinge is a particular type of compliant mechanism that permits rotation about one axis via elastic deformation, while remaining strong in tension along that same axis. Caged hinges have applications in industrial robot arms, wind turbines, satellites, and medical devices. However, there is currently no analytical tool to assist in the design of application-specific caged hinges. In this work, we present a model for predicting maximum stress in caged hinges of different sizes. More specifically, our model maps the relationship between geometry and load to both maximum stress and rotational stiffness. To build this model, we first performed finite element analysis (FEA) in ABAQUS on 65 mechanisms of different geometries, under varying loads. We then used linear-regression gradient-descent optimizations and simple neural networks to construct a multi-step model. Our model predicts maximum stress within a margin of error of 5% compared to FEA results. Future work includes validating stiffness values and using our model to determine the optimal caged hinge geometry for various prosthetics applications.

Design and Modeling of Application-Specific Caged Hinges

John McCullough, Brandon Peterson, Alex Uphill-Brown, Tyler Clites
Department of Mechanical and Aerospace Engineering, University of California – Los Angeles



Conclusion & Future Work

Our mathematical models have less than a 5% error relative to FEA results. These models serve as a tool to synthesize optimal caged hinges for different applications. Preliminary validation trials are currently underway on our KR-210 robot (KUKA, Augsburg, Germany). Future work will include optimizing the caged hinge geometry to minimize maximum stress or stiffness.

Acknowledgements

I would like to thank Robert Kelly Foundation for funding my project through the UCLA Summer Undergraduate Research Program. I would like to thank Professor Tyler Clites, Brandon Peterson, and Dr. Alex Uphill-Brown for their knowledge and support.



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A Distribution Matcher for Asymmetric Probabilistic Amplitude Shaping

ABSTRACT

A communication system, which consists of a transmitter and a receiver, models the process by which the information is sent and received. The transmitted symbols that are generated by a transmitter go through a noisy channel and reach the receiver end. The receiver needs to estimate the transmitted symbols by their noisy version. Claude Shannon developed a theory that determines the maximum rate at which the receiver can reliably estimate the transmitted symbols based on the noise's statistics. To achieve the maximum rate, the transmitted signals need to approximately follow an optimal probability distribution, which can be done through probabilistic shaping. One method for probabilistic shaping is using a distribution matcher that takes a sequence of bits equally likely to be ones and zeros and maps it bijectively to a new sequence of symbols with the desired probability distribution. There are two types of distribution matchers denoted as constant and multi-composition distribution matchers or CCDMs and MCDMs. We coded a CCDM and a MCDM, which is a union of CCDMs. Two different versions of the MCDM based on a high probability and typical set rule were constructed. We found that MCDMs outperformed CCDMs in both normalized Kullback–Leibler (KL) divergence, a measure of how well the desired distribution is met, and matching rate, meaning we can send more information using less bits. By applying MCDMs to channels, we can achieve higher transmission rates and better noise correction to increase the efficiency and speed of the internet and communication systems around the world.

A Distribution Matcher for Asymmetric Probabilistic Amplitude Shaping

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Introduction

Communication systems describe the way by which we transmit and receive information.

Binary communication systems use on and off bits represented by zeros and ones. Errors in a binary communication channel otherwise known as noise can flip a one to a zero.

Claude Shannon developed a theory that determines the optimal probability distribution to reach maximum transmission rates.

Objective

Our objective is to make a distribution matcher that will make transmitted signals approximately follow an optimal probability distribution.

Principles

Communication System

Figure 1: A system of a computer, a modem, and a cell tower is a simple communication system. Information is transmitted in a binary form.

Probabilistic Shaping

Probabilistic Shaping (PS) optimizes the shape and probability mass function (PMF) of a constellation set. This allows us to achieve optimal transmission rates.

Figure 2: Probabilistic Shaping. 2(a) displays the PMF before Probabilistic Shaping and 2(b) displays the PMF after PS.

Distribution Matcher

A Distribution Matcher maps Bernoulli($\frac{1}{2}$) distributed input bits into a sequence of output symbols that follows a desired distribution. A Constant Composition Distribution Matcher (CCDM), can only map to one type of codeword distribution.

Figure 3: CCDM encoding mapping. 2-bit inputs are mapped bijectively to 4-bit codewords that follow a desired distribution. [2]

A Multi-Composition Distribution Matcher (MCDM), which is a union of CCDMs, permits more accurate distributions.

Figure 4: Outline of a MCDM structure with a 10-bit input and a 5-bit output codeword.

Materials

We implemented the CCDM and MCDMs in C++, a general-purpose programming language for development. We created helper functions to determine MCDM thresholds and mitigate numerical overflow issues.

Plots were generated using Python, a high-level, interpreted, general-purpose programming language, and matplotlib.pyplot, a library for creating static, animated, and interactive visualizations.

Mathematical Methods

SECTION I: Choosing Children Codebooks

Highest Probability Rule

$$P(A_i) = \underset{P(A^*) \in \mathcal{P}(P(A_1), \dots, P(A_{i-1}))}{\operatorname{argmax}} \sum_{a=1}^{|A_i|} P_{A^*}(a) \log P_{A_i}(a)$$

The Highest Probability (HP) Rule ranks the CCDM codebooks based on most likely sequence of bits to occur. In Table 1, if $P(1) = 0.8$, then the most likely 4 bit output sequence is 1111 because the probability of 1111 occurring is $0.8 \cdot 0.8 \cdot 0.8 \cdot 0.8$.

Typical Set Rule

$$P(A_i) = \underset{P(A^*) \in \mathcal{P}(P(A_1), \dots, P(A_{i-1}))}{\operatorname{argmin}} D_{KL}(P(A^*) || P(\hat{A}))$$

The Typical Set (TS) Rule ranks the CCDM codebooks based on the output distribution's "distance" to the target distribution. In Table 2, if $P(1) = 0.8$ the closest distribution is one with 3 1's and 1 0's because for this distribution $P(1) = 0.75$.

#0s	#1s
0	4
1	3
2	2
3	1
4	0

#0s	#1s
1	3
2	2
0	4
3	1
4	0

SECTION II: Evaluation Metrics

KL Divergence

$$D(P_{\hat{A}} || P_A) = \sum_{a \in \operatorname{supp}(P_A)} P_{\hat{A}}(a) \log_2 \frac{P_{\hat{A}}(a)}{P_A(a)}$$

KL Divergence, also known as relative entropy, is one type of statistical distance between two distributions. Intuitively, it measures the difference between two distributions. Lower KL Divergence indicates the two distributions match better.

Normalized KL Divergence

$$\frac{D(P_{\hat{A}} || P_A)}{n} = -\frac{1}{n} \log_2 |c| + H(P(\hat{A})) + D(P_{\hat{A}} || P_A)$$

The performance of a distribution matcher is measured by Normalized KL Divergence. Since the size of a codebook grows exponentially, the first term in the Normalized KL Divergence counteracts that effect.

Matching Rate

The Matching Rate (MR), or transmission rate, is defined as $\frac{k}{n}$, with k being the length of input bits and n being the length of output symbols or codewords. We do not consider compressing the data, hence MR is less than 1. Higher MR in CCDM indicates more efficient encoding.

Results

Figure 4: The performance of all three different types of distribution matchers are illustrated. 4(a) depicts the performance under specific output block lengths and 4(c) depicts the performance for specific matching rates. 4(b) and 4(d) quantifies the improvement in Normalized KL divergence.

- According to 4(b) the MCDMs had a 40% better performance in the 10-50 block length range, 30% in the 60-100 range and 20% in the 100-1,000 range than the CCDM.
- MCDM HP performed only around 2% better than MCDM TS.
- Based on 4(d), the MCDM TS and CCDM in the matching rate range of 0 to 0.62 performs 60%-80% worse than MCDM HP. For matching rates past the CCDM's capabilities, MCDM TS and HP perform similarly.

Conclusions

For matching rate, the MCDM TS utilizes the CCDM up to a matching rate of around .62, thus we see that their performance is equivalent in that range. However, the MCDM TS is favored because it can achieve higher matching rates. The MCDM HP clearly outperforms the CCDM.

After a matching rate of 0.62, MCDM HP or TS can be used. Before a matching rate of 0.62, the MCDM HP should be used.

Future Directions

By applying MCDMs to optical channels, we can achieve higher transmission rates and better noise correction. This increases the efficiency and speed of the internet and space systems.

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Acknowledgements

This work was supported by the National Science Foundation through grant CCF 1911166 and by a Qualcomm Research Award. We would like to thank Professor Richard Wesel and Linfang Wang for providing guidance and mentorship during the research. We would also like to Will Herrera for organizing the SURP program.



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Proactive Signal Strength using 2D Deep Learning Model

ABSTRACT

An essential tool to furthering dynamic spectrum sharing, which allocates spectrum based on user demand, is knowing the signal strength on particular frequencies and at locations, allowing optimized base station placement for efficient use of the spectrum between many devices in an area. Given the location of existing fixed transmitters and the locations and signal strength of their respective receivers, our goal is to find the signal strength at any point in an area of interest due to a transmitter at any location, but without any active transmission from the transmitter. The path loss model, employing a least squares linear regression, is a traditional method for this problem; however, finding the signal strength in an urban area, because of building obstacles, has a complex pattern of loss, so we attempt to predict that strength through a deep learning model. Specifically, we use a 2D format to feed in data, ideally giving the model spatial context of multiple receivers' signal strengths at once. We use the U-Net architecture, which is a type of convolutional neural network with an image-to-image translation: the input is two matrices, one representing the transmitter location and the other representing all the receivers' locations, and the output is an image of the predicted signal strengths at the receiver locations used in the input. Using simulation-based evaluation, we find that, on using a wide range of available transmitters and receivers to train the model, this method does achieve a more accurate prediction of signal strength than the path loss model. Future work includes tuning this model with additional information, such as the area's terrain and buildings, and verifying results with real data collected or crowdsourced, instead of using datasets obtained through simulations.

Proactive Signal Strength Prediction using a 2D Deep Learning Approach



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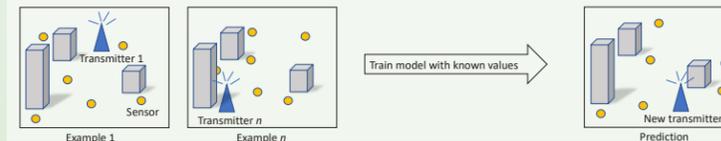
Objective

Given a transmitter's location, we want to find an efficient deep learning model to predict signal strength at different locations, by training a model where data is fed in as matrices, which is a 2D format, to give the model spatial context.

Background

Signal strength is the amount of power transmitted through an electromagnetic signal, and it is affected by obstructions, like buildings, making it hard to model the strength at different points in an urban area.

Scenario



Previous efforts have used the path loss model:

$$P_R = P_0 - 10n \log\left(\frac{d}{d_0}\right)$$

P_0 and n are determined through least square linear regression
 P_0 is Power at a reference distance d_0 from transmitter (in dBm)
 d is Distance from transmitter to receiver
 n is Path loss exponent, depends on environment

Results

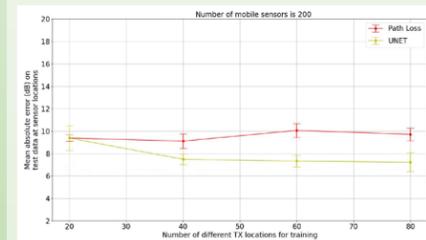


Fig. 2. Performance due to varying the number of transmitters used.

A lower number of receivers is much more detrimental to the model's accuracy than a low number of transmitters.

However, in varying the transmitters, there is an optimal number around 40, where there is a significant drop in error. After that, the negligible increase in accuracy comes with a significant increase in training computation time.

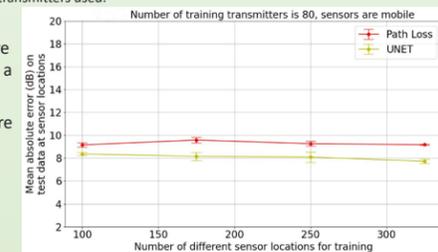


Fig. 3. Performance due to varying the number of receivers used.

Reference

[1] E. Krijestorac, S. S. Hanna, and D. Cabric. Spatial signal strength prediction using 3d maps and deep learning. *IEEE International Conference on Communications*, 2021.

Methods

Data used for training and testing was obtained through simulations in a ray-tracing software.

The indices of the input and output matrices of the deep learning model represent corresponding gridded locations in the area of interest.

Input

Receiver locations (50 x 50):

0	0	0	...	0
0	0	1	...	0
0	0	0	...	1
...
0	1	0	...	0

Transmitter location (50 x 50):

0	0	0	...	0
0	0	0	...	0
0	1	0	...	0
...
0	0	0	...	0

No receiver at (1, 3)
 Receiver at (3, 50)
 Only one transmitter, at (3, 2)

Output

Predicted signal strength (in dBm) (50 x 50):

0	0	0	...	0
0	0	-77.11	...	0
0	0	0	...	-66.18
...
0	-105.50	0	...	0

Values are only at indices where there was a "1" in the receiver locations matrix

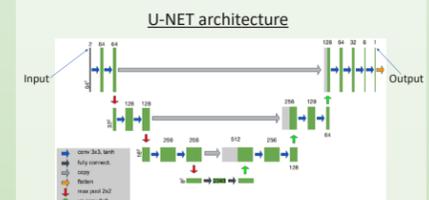


Fig. 1. A type of convolutional neural network, used to train the model. It specifies the way the matrices are dimensionally transformed, through filters and pooling.

The model is tuned mostly through changing the number of receivers sampled per transmitter, transmitters used for training, and epochs.

Conclusions & Prospects

Improving the model
We can evaluate performance when information of building locations [1] is incorporated in the model as another matrix input.

- More, and accurate, training data**
- (1) Crowdsourcing signal strength from receivers of existing communication systems
 - (2) Collecting data through software-defined radios

Significance of predicting signal strength
Used in dynamic spectrum sharing, by helping the placement of future base stations such that spectrum can be smartly allocated to many devices.



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Phonon Modes and Raman Signatures of MnBiTe₄ Magnetic Topological Heterostructure

ABSTRACT

The intersection of magnetism and topological electronic structure in momentum space has gained great interest in the field of condensed matter physics and quantum electronics. There has been great effort in observing magnetic ordering within 2D and quasi-2D materials since their discovery. Novel phenomena such as the anomalous quantum Hall effect, Weyl Fermions and axion insulator phases can be realized in such systems, only that it has proven difficult to engineer well controlled doping concentrations over large areas. MnBi₂Te₄ and its family MnBi_{2n}Te_{3n+1} overcome these difficulties as it is easily synthesized into uniform bulk single crystals. Using a laser, photons are directed onto the MnBi₂Te₄ sample to have its back scattered photons collected and sorted by wavelength within a spectrometer. A charge couple device then detects the number of photons, or intensity, per wavelength to provide a unique signature of the molecule. The Raman signatures of MnBi₂Te₄ demonstrate the E modes at 27 cm⁻¹, 67 cm⁻¹, & 104 cm⁻¹ and A modes at 47 cm⁻¹, 124 cm⁻¹ and 140 cm⁻¹ with the newly observed E mode peak measured at 27cm⁻¹. A 1D scan of the MnBi₂Te₄ is performed on silicon substrate using a motorized stage to provide a gradient of each material's intensity across the sample's surface. With this enhancement of the Raman spectrum to MBT-124, the pronouncement of the vibrational modes will provide a new scope in observing its magnetic ordering when subjected to a range of cryogenic temperature and magnetic field variances.

Phonon modes and Raman signatures of MnBi₂Te₄ magnetic topological heterostructure

Samueli
School of Engineering



Arturo Ramirez, Jin Ho Kang, Jiahui Huang, Madeline Taylor,
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RESEARCH PROGRAM

Introduction

Modern computer devices are volatile and highly inefficient as they need circulating electrical current to operate and therefore causing heat to be dissipated. Magnetic topological insulators aim to solve this problem.



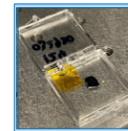
Figure (1) A spinning charged particle constitutes a magnetic moment. Spin defines the direction of a particle's "angular" momentum. Spin's orientation can be influenced externally by a variety of perturbations, such as an applied magnetic field. Magnons are a collection of electron spin waves and can be used to represent 0 and 1 depending on their direction of spin.

Figure (2) Topological Insulators (TIs) are materials with insulating interiors and conductive boundaries. Additionally, TIs are protected by time reversal symmetry, meaning electrons travel in only one direction reducing interference and heat dissipation.



Combining the efficiency of TIs with spin can provide a platform for the exploration of fundamental questions in science and the advancement of magnetic devices.

MnBi₂Te₄



MnBi₂Te₄ (MBT-124) is an **antiferromagnetic** compound composed of the topological insulator Bi₂Te₃ and the paramagnet (at room temperature) Mn-Te that when intercalated with a certain number of additional layers of Bi₂Te₃ becomes **ferromagnetic**.

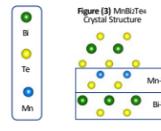


Figure (4) The MBT-124 sample nested on silicon. The MBT-124 can be synthesized uniformly into a few mm of bulk material. The electrons spins in Mn provide configurable magnons depending on the layering of the MBT.



Figure (5) The MnBi₂Te₄ family

Raman Spectroscopy

Lasers provide a tool to direct photons onto materials and observe its scattering providing unique information about its crystal, electronic and magnetic structure. The phonon vibrational modes of MBT are investigated using linear Raman spectroscopy measurements.

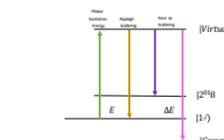


Figure (6) Photons raise the material's energy to a virtual state and then returns to either the original state retaining the same energy E (Rayleigh scatter) or a different state with a change in energy ΔE (Raman scatter).

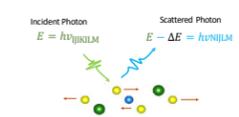


Figure (7) Raman scattering produces a new frequency ν_{in}|ΔE| for the scattered photon.

Physics Terms

- Photon: the quanta, or measurement, of light
- Phonon: quanta of a lattice vibration's energy
- Mode: pattern of vibration
- Planck's Equation: ΔE = hν
- Planck's constant: h
- Photon's frequency: ν
- Dirac notation of a system's 1st energy state: |1>
- Emitted photons leaving with a higher energy are Stokes while anti-Stokes leave with a lower energy

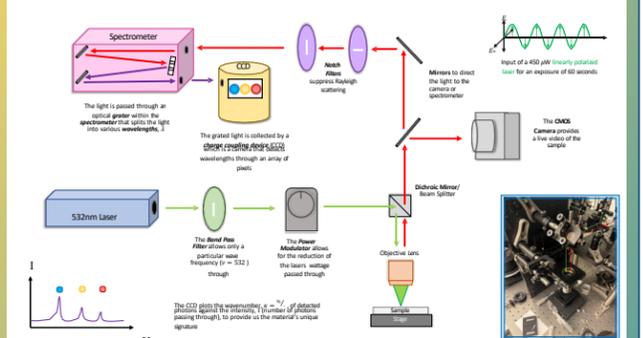
Acknowledgements

I would like to thank Professor C.W. Wong for providing the opportunity to participate in SURP and Dr. Anna Bezyadina for her guidance into the arrangement. Special thanks to Jin Ho Kang, Jiahui Huang & Madeline Taylor for the training, education and support they provided throughout the program. I thank my family and friends for all their love and inspiration. I acknowledge and thank the support of NSF in this work.

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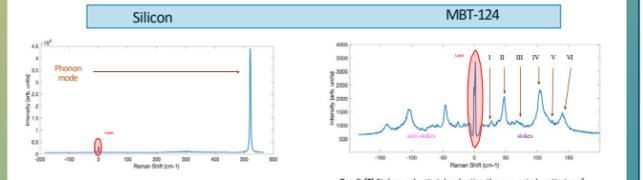
Phonon modes and Raman signatures of MnBi₂Te₄ magnetic topological heterostructure, Yuhui Cho, Jin Ho Kang, C.W. Wong
Collective excitations in 2D atomic layers: recent perspectives, Yuhui Cho, Jiahui Huang, C.W. Wong
Van der Waals heterostructures and devices, Yuan Liu, Xiangfeng Duan

Optical Setup



Raman Signatures of Phonon Modes

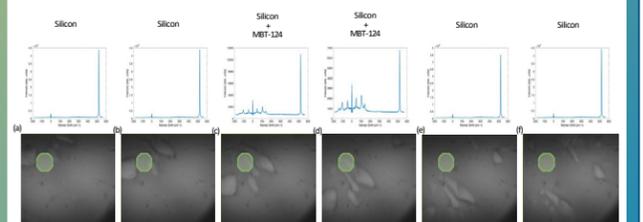
The Raman signatures collected demonstrate the peaks related to the crystallographic point group with E modes in peaks I, III & IV and A modes in II, V, & VI (notice that the laser's peak within the spectrum references the 0 of the Raman shift)



Result (1) For calibration, silicon is measured for Stokes scattering and demonstrates a peak at 521 cm⁻¹

Result (2) Stokes and anti-stokes (notice the symmetry) scattering of MBT-124 demonstrating peaks at the A and E modes

1-D Scan of MBT-124 Sample

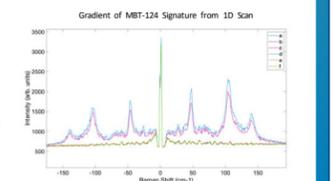


Result (3) Since the MBT-124 sample is mechanically exfoliated onto Silicon, scanning the material for the most optimal signatures is crucial. A motorized stage was programmed to perform a scan along a line across the sample producing the top images and plots (a-f) with MBT-124 most defined in (c) and (d).

Conclusion and Discussion

The Raman signatures of MnBi₂Te₄ demonstrate the E modes at 27 cm⁻¹ (I), 67 cm⁻¹ (III), & 104 cm⁻¹ (IV) and A modes at 47 cm⁻¹ (II), 124 cm⁻¹ (V), and 140 cm⁻¹ (VI) with the newly observed E mode peak measured at 27cm⁻¹.

With this enhancement of the Raman spectrum to MBT-124, the pronouncement of the vibrational modes will provide a new scope in observing its magnetic ordering when subjected to a range of cryogenic temperature and magnetic field variances.





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Revealing Effects of Physiological Stimuli on Neuroepithelial Development in Forebrain Organoids

ABSTRACT

Human brain organoid models create unprecedented opportunities for study of neurological diseases and early neurologic development. Unfortunately, such a promising system often exhibits impaired growth and suboptimal structure in traditional culture due to the insufficient diffusion of oxygen and nutrients within organoids. To improve solute transport and supply, many engineering tools including hyperoxic incubation and fluidic flow have been routinely incorporated in organoid culture. While these physiological stimuli are known to play an equally important role as their chemical counterparts (e.g., growth factors), their impacts on organoid development are relatively undefined. As a result, effectively engineering the culture microenvironment to optimize organoid differentiation remains challenging. We investigated the individual and combined impacts of flow and hyperoxia, two essential solute transport enhancement tools, by culturing forebrain organoids either in static wells or in our unique culture device in both normoxic and hyperoxic environments. The samples were collected at various time points for various characterizations. Compared to the static normoxia control, we found that organoids cultured in flow and hyperoxia had a significant increase in size and neural architecture, with the maximal benefit imparted by both stimuli together (i.e., flow + hyperoxia). We observed that flow led to an enhanced growth of the cortical plate region due to increased mechanotransduction on the periphery of the organoids. Our results suggest that flow and hyperoxia culture produce structurally improved organoids, suggesting the importance of modulating environmental stimulation in organoid differentiation.

Revealing Effects of Physiological Stimuli on Neuroepithelial Development in Forebrain Organoids

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UCLA Samueli
School of Engineering
SUMMER UNDERGRADUATE
RESEARCH PROGRAM

Samueli
Research
Scholars
UCLA Samueli
School of Engineering

Background

Human brain organoid models create unprecedented opportunities for study of neurological diseases and early neurologic development. Unfortunately, such a promising system often exhibits impaired growth and suboptimal structure in traditional culture due to the insufficient diffusion of oxygen and nutrients within organoids.

To improve solute transport and supply, many engineering tools including hyperoxic incubation and fluidic flow have been routinely incorporated in organoid culture¹². While these physiological stimuli are known to play an equally important role as their chemical counterparts (e.g., growth factors), their impacts on organoid development are relatively undefined. As a result, effectively engineering the culture microenvironment to optimize organoid differentiation remains challenging.

Results

Flow and hyperoxia have additive effects on enhancing organoid growth.
Brightfield images were taken of organoids in each condition, and the cross-sectional area fold change from the initial size was measured to quantify growth. Organoids subjected to either flow or hyperoxia independently increased growth, and organoids subjected to a combination of fluidic flow and hyperoxia displayed the most significant growth.

In addition, when immunostaining was done for neural progenitor marker FOXG1 and adhesion junction marker NCAD, longer neural rosettes were seen in higher numbers in the flow hyperoxia condition.

These results suggest that the mechanisms by which flow and hyperoxia operate to enhance organoid growth are separate, allowing for additive benefits when performed in combination.

Cortical plate growth is enhanced by flow.

The ventricular (VZ), subventricular (SVZ), and cortical plate (CP) regions of the organoids were visualized by staining for PAX6, TBR2, and CTIP2, respectively. The VZ and SVZ layer thickness were consistent across conditions, but the CP had a higher thickness in flow conditions.

This could suggest that one of the mechanisms by which flow operates is through increased mechanotransduction on the periphery of the organoids, enhancing growth.

Unique metabolic profiles are generated in each condition.

When a metabolism assay was run, organoids in all condition consumed similar metabolites, but the level at which they consumed each metabolite was different. Flow and hyperoxia independently shifted the metabolic phenotype to show an increased consumption of several more metabolites than static normoxia, while the flow hyperoxia condition had many more significantly consumed metabolites, displaying a more diversified consumption profile.

Materials & Methods

We investigated the individual and combined impacts of flow and hyperoxia, two essential solute transport enhancement tools, by culturing forebrain organoids either in static wells or in our Microwell Flow Device (MFD) in both normoxic and hyperoxic environments.

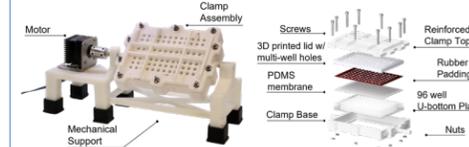


Figure 1. Microwell Flow Device. Our culture device for applying gravity-induced shear stress to the organoids, and an expanded view of the clamping system used to create a water-tight seal in the 96 well plate.

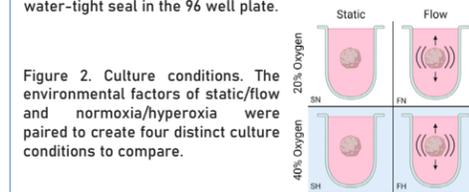


Figure 2. Culture conditions. The environmental factors of static/flow and normoxia/hyperoxia were paired to create four distinct culture conditions to compare.

Forebrain organoids were obtained at day 18 and separated into the four conditions until day 56. The samples were collected at various time points for RNA analysis, metabolomics, or immunomaging.

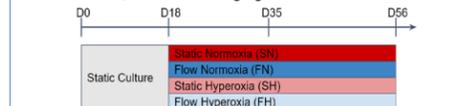


Figure 3. Experimental timeline. Organoids were cultured statically from seeding until day 18, when they were transferred to one of our 4 experimental conditions. Important physiological timepoints include D35 and D56.

Conclusions & Future Directions

Compared to the static normoxia control, we found that organoids cultured in flow normoxia and static hyperoxia, respectively, had a significant increase in size and neural rosette structure, with the maximal benefit imparted by both stimuli together (i.e., flow + hyperoxia). We observed that flow increased the thickness of the cortical plate on the periphery of the organoids, suggesting that flow increases mechanotransduction on cells in the periphery, causing the enhanced layer growth.

We also saw that flow and hyperoxia induced a metabolic change on the organoids, changing the diversity of consumed metabolites. The shifted profiles demonstrate how flow and hyperoxia may cause an upregulation of other metabolic pathways, increasing organoid growth.

Our results suggest that flow and hyperoxia culture produce structurally improved organoids, suggesting the importance of modulating environmental stimulation in organoid differentiation. Future directions for our work include performing RNAseq to verify upstream responses to physiological stimuli match our observed downstream responses, as well as staining for oxidative/glycolytic stress markers to analyze the effects of flow/hyperoxia on organoid growth.

References

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Acknowledgements

I want to thank my PI Neil Lin along with my graduate student mentor Marie Payne for supporting me throughout this project. I also want to thank my fellow lab members Nathan Cai and Kathryn Saxton for all the work they have contributed to this project. I also want to thank the Novitch lab for providing us with organoid samples and reagents and for providing us feedback.



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Implementation of AR4JA LDPC Encoding and Decoding Using min* Algorithm

ABSTRACT

Low Density Parity Check (LDPC) codes are linear block codes with high throughput and error-correction capabilities, making them relevant for transmission of information over constrained or noisy transmission channels in communications. Iterative message passing algorithms are used to decode LDPC codes passed between variable nodes corresponding to the received channel bits and check nodes. While Sum-Product Algorithm (SPA) achieves high decoding performance at the expense of high computational complexity, reduced complexity decoding algorithms such as Min-Sum Algorithm (MSA) meanwhile can suffer decoding performance degradation as a tradeoff for simplified computation of outgoing check node messages. Through an implementation of a modified MSA with correction term, also known as min* algorithm, in a LDPC decoding on both software and hardware, we seek to demonstrate and verify improved decoding performance over MSA. The min* LDPC decoder is implemented in a MATLAB testing script via a forward-backward algorithm -based message passing operation, demonstrating clear improved performance over standard min-sum decoding in both bit-error-rate (BER) tests for parameters of 100 trials, 50 maximum iterations and frame-error rate (FER) tests measures across set parameters of 20 error frames calculation threshold, 20 maximum iterations. BER and FER curves generated from these tests verify the postulation of improved decoding performance in min*- based LDPC decoding over min-sum LDPC decoding. Future work is expected to continue on the development of a hardware-based min* LDPC decoder that is being written in SystemVerilog to run on a ZCU106 FPGA.



Implementation of AR4JA LDPC code Encoding and Decoding Using min* Algorithm

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Introduction

Low Density Parity Check (LDPC) codes are linear block codes with high throughput and error-correction capabilities, making them useful for transmission of information over constrained or noisy transmission channels, and particularly promising in emerging communications schemes such as 5G NR [1]. Iterative message passing algorithms are used to decode LDPC codes passed between variable nodes corresponding to the received channel bits and check nodes. Sum-Product Algorithm (SPA) achieves high decoding performance at the expense of high computational complexity, while reduced complexity decoding algorithms such as Min-Sum Algorithm (MSA) meanwhile can suffer decoding performance degradation as a tradeoff for simplified computation of outgoing check node messages. By implementing a modified MSA with correction term, also known as min* algorithm, in a LDPC decoder on both software and hardware, we seek to demonstrate improved decoding performance over MSA and approach performance close to that of SPA.

LDPC Iterative Decoding Algorithm

An LDPC code of n-bit length can be thought of as containing k bits of relevant message information, n - k bits of parity check bits. LDPC Decoding is usually implemented via iterative message passing algorithms between the variable nodes, which correspond to n individual bits of received channel codes, and the n - k number of check nodes which compute updated LLR's to each of their respective connected variable nodes. The iterative algorithm can be outlined as follows [2]:

1. Initialization variable node (VN) LLR's (Log Likelihood Ratios; more negative -> 1, more positive -> 0):

$$L_j = L(v_j|y_j) = \log \left(\frac{\Pr(v_j = 0|y_j)}{\Pr(v_j = 1|y_j)} \right)$$
2. Check nodes (CN) accumulate incoming LLR's from extrinsic VNs to calculate outgoing messages for each Vn to connected CN's and calculate an updated CN -> VN message:

$$L_{a,v} = 2 \tanh^{-1} \left(\prod_{v' \in N(a) \setminus \{v\}} \tanh \left(\frac{1}{2} L_{v',a} \right) \right)$$
3. VN's accumulate updated messages from CN's and extrinsically calculate next iteration of outgoing VN -> CN messages:

$$L_{j-i} = L_j + \sum_{v' \in N(j) \setminus \{i\}} L_{v',j}$$
4. Each VN $j = 0, 1, 2 \dots$ calculates its updated total LLR, which is then used to determine whether a tentatively decoded bit at a certain VN is either 0 or 1.

$$L_j^{total} = L_j + \sum_{i \in N(j)} L_{i-j} \rightarrow \hat{v}_j = \begin{cases} 1 & \text{if } L_j^{total} < 0, \\ 0 & \text{else,} \end{cases}$$
5. Hard decision performed on whether parity check 0-syndrome condition is satisfied:

$$H = \begin{bmatrix} 1 & 1 & 1 & 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 1 & 0 & 1 & 0 \\ 1 & 1 & 0 & 1 & 0 & 0 & 1 \end{bmatrix} \quad c = [c_1, c_2, c_3, \dots, c_7] \quad Hc^T = \{0\}$$
 - a. Satisfied: Stop iterative passing procedure
 - b. Not Satisfied: repeat at step (ii) until maximum number of allowed iterations reached

Methodology (continued)

- ♦ FER tests:
 - > Set maximum allowed iterations = 20
 - > Set the error threshold to 20 frame errors; trial will continuously run for each SNR ratio until 20 frame errors are reached if there are not 100 consecutively correct frames in the first 100 decoding iterations at an SNR ratio
 - > Obtain FER values over SNR Range of $E_b/N_0 = [0.5, 2.5]$, interval = 0.1

Results

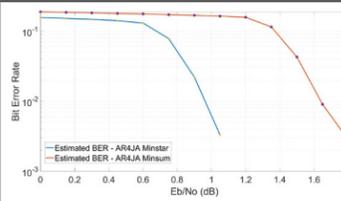


Fig. 1 - Bit Error Rate, Minstar vs. Minsum Decoding

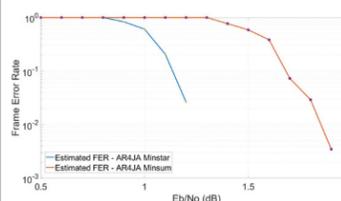


Fig. 2 - Frame Error Rate, Minstar vs. Minsum Decoding

♦ As shown in Fig. 1 to the left, the Min* implementation of the decoder demonstrates a clear improvement in decoding performance over standard min-sum decoder. The BER for the Min* decoder is consistently lower and decaying more rapidly than the Minsum decoder over the tested SNR range.

♦ Fig. 2 on the left supports a similar observation of improved decoding performance of the Min* decoder implementation over standard Minsum decoding. The FER for the Min* decoder starts decaying at a lower SNR range, around 0.8-1.2 dB, and far more rapidly than the Minsum decoder, which only starts decaying around 1.3 - 1.9 dB, over the tested SNR range.

Conclusion, Future Works, and Limitations

- ♦ The observations in the BER and FER tests for both Min* and Minsum decoders demonstrates support for the theory of clear improvement in decoding performance of the Min* message passing algorithm over standard Minsum algorithm for LDPC decoding in software implementation
- ♦ Currently, the hardware implementation of the AR4JA Min* decoder is still in development, which is why this poster only includes data for the MATLAB software implementation of the decoder. Once fully implemented, we intend to similarly compare the performances of the hardware implementations of Min* and Minsum decoders.
- ♦ While Min* decoding provides improved decoding performance of standard Minsum decoding, it will also be useful to quantify its performance and limits, such as error floor limitations especially in the context of comparison with SPA decoding.

References

- [1] Wang, L. (2021). Implementation of Low-Density Parity-Check codes for 5G NR shared channels. KTH, School of Electrical Engineering and Computer Science (EPCS).
- [2] Ryan, W. E., & Lin, S. (2009). Channel codes: Classical and modern. Cambridge: Cambridge University Press.
- [3] In-Woo Yun, Hee-ran Lee, Joon Tae Kim, "An Alternative Approach Obtaining a Normalization Factor in Normalized Min-Sum Algorithm for Low-Density Parity-Check Code", Wireless Communications and Mobile Computing, vol. 2018, Article ID 1398191, 7 pages, 2018. <https://doi.org/10.1155/2018/1398191>

Acknowledgements

We would like to thank Dean Wesel for his guidance and leadership throughout the research process. This research was supported by NSF grants CCF 1911166 and CCF 2008918 through the Summer Undergraduate Research Program and the UCLA Electrical and Computer Engineering Department. Finally, we would like to thank Beryl Sui, Linfang Wang, and Caleb Terrill for their assistance with the technical aspects of our project.

Methodology

- ♦ Min* algorithm will first be implemented in MATLAB using backwards-forwards algorithm in the min* operation of the decoder; the correction term will be implemented as a two-input logarithmic function.
- ♦ Test, quantify, and verify performance of Min* decoder software implementation relative to standard Min-sum decoding on a codeword blocklength $n = 8192$ bits, code rate = $\frac{1}{2}$
- ♦ BER tests:
 - > Set maximum allowed iterations = 50, trials = 100
 - > Obtain BER values over SNR Range of $E_b/N_0 = [0, 2.4]$, interval = 0.15
 - > Average trial values for each SNR ratio to obtain curve



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End-to-End Design Process for Cut-and-Fold Modular Robots

ABSTRACT

Robot development is a challenging and resource-consuming process requiring the integration of mechanical, electronic, and computational subsystems. In addition, many iterations of designing and testing are required to customize robotic technology to fit individual needs. Our goal is to increase accessibility and streamline the robot development process by using a modular approach to assembly. This would aid introductory-level roboticists in producing simple designs while facilitating their creativity. We use Robot Compiler (RoCo), a framework for visualizing and generating cut-and-fold robots whose mechanical parts are fabricated as flat sheets of material that can be easily folded into a prescribed 3D form. We compiled a library of modular robotic components that are relevant to ground locomotion. This database of parts enables designers to realize new robot designs which can be paired with electronics and software to simulate different types of ground locomotion such as rolling, crawling, and walking. We present some of the many potential robot designs that can be constructed to demonstrate this modular procedure of designing cut-and-fold robots with RoCo. Our research provides a rapid process that allows users to create affordable and versatile robots with a short turnaround time.

End-to-End Design Process for Cut-and-Fold Modular Robots

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SUMMER UNDERGRADUATE RESEARCH PROGRAM



Introduction

Background

- Robot development is a challenging and resource-consuming process
- Requires extensive knowledge and many iterations of designing and testing to customize robotic technology

Research Goals

Create library of robotic components that users can select from to create a wide variety of simple ground locomotion robots

Key Terms

Cut and Fold Robots — mechanical parts fabricated as flat sheets and folded into their 3D form

Robot Compiler (RoCo) — LEMUR's framework for generating cut-and-fold robots

Materials

RoCo Library



Design Software

- Silhouette Studio
- Inkscape



Laser Cutter

- Cameo
- PET and cardstock



Arduino IDE



Electronics

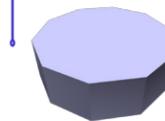
- Jumper Wires
- Servo Motors
- Microcontroller



Design Process for Modular Components

Production

- Code shapes
- Connect to create geometries



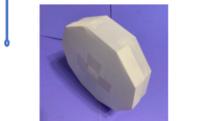
Adjusting

- Measure cutouts and slots
- Scale designs

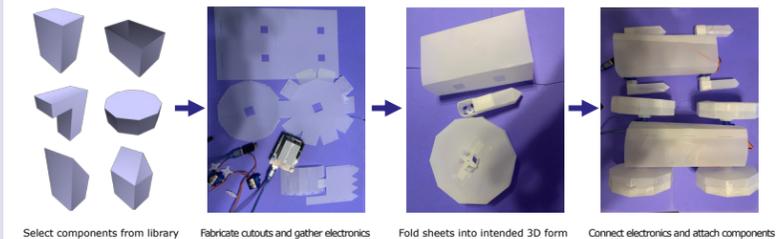


Fabrication

- Cut
- Fold
- Validate



Modular Assembly of Robots



Discussion



Capabilities

- Load-carrying and stability
- Crawling, walking, and rolling motions

Limitations

- Thin material weight efficiency
- Complex and small-scaled designs
- Post-fabrication assembly work

References

- [1] Schulz, Adriana, et al. "Interactive Robogami: An End-to-End System for Design of Robots with Ground Locomotion." *The International Journal of Robotics Research*, 2017
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Acknowledgements

I would like to thank Professor Mehta and the LEMUR Lab as well as the Samueli Engineering Summer Undergraduate Research Program and the Fast Track Program for this research opportunity and the support and resources throughout this process. I would also like to thank the Office of Naval Research for funding this project.



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Utilizing PathFX to Analyze Drug-Gene Associations in Diabetes and Lung Cancer

ABSTRACT

Protein-Protein Interaction (PPI) network methods are an increasingly popular way to predict drug downstream effects. For example, PathFX is a novel algorithm that uses PPI network methods to identify drug pathway associations and drug-related phenotypes. However, these algorithms often predict more drug effects than evidence supports. These predictions can be tested by conducting observational studies in the Electronic Health Record (EHR). However, instead of testing each individual drug-disease prediction in the EHR, it is more practical to test groups of drugs based on shared gene pathways. This study will focus on the specific disease areas of diabetes and lung cancer to illustrate how PathFX can be used to analyze drug-gene and drug-disease associations to identify hypotheses for shared drug-gene pathways. We analyzed PathFX networks for drugs used to treat diabetes and lung cancer. We analyzed the frequency of shared genes and shared phenotypes, and used downstream proteins to cluster treatment drugs. We identified 44 and 34 drugs for diabetes and lung cancer respectively, and found drug network clusters are distinct from ATC groups. We used GO enrichment to discover functions associated with network clusters and found that diabetes and lung cancer pathways had distinct functional categories. We hypothesize that we will be able to distinguish clinical and non-clinical drugs by their downstream pathways and provide a means to reduce PathFX over-prediction. We will later use observational studies in the EHR to test the utility of network-identified clusters and expand this analysis to other disease areas.

Utilizing PathFX to Analyze Drug-Gene Associations in Diabetes and Lung Cancer

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Introduction

PathFX provides mechanistic insights into drug effects that can be used to identify disease specific gene pathways

Identified gene pathways can be used to inform drug development and repurposing opportunities

PathFX
A Protein-Protein Interaction Network Method for Predicting Drug Downstream Effects

- Drug
- Cell Signaling
- Effected Phenotypes

Legend:
▲ User specified drug
● PathFX identified drug target
○ Network genes associated with drug target
■ PathFX predicted disease phenotype

Overprediction
A Common Problem in Network Modeling

Instead of brute force testing every drug-disease prediction, it is more practical to test groups of drugs based on shared gene pathways

Figure 2. PathFX network for Metformin identifies its approved indication, Diabetes. However, PathFX also predicts many other indications that must be validated. Wilson et. al., PLoS Comp Bio, 2018.

Results

Certain genes are more prominent than others, pointing to hypothesis for drug groups based on gene pathways

ATC drug classification does not necessarily match up with drug clustering based on gene pathway

Drug Clustering by Known Effect Genes vs ATC Classification

Diabetes **Lung Cancer**

Figure 3. (a) Diabetes drugs are clustered by all genes from the PathFX known effect pathways. Drugs are mapped to their corresponding Level 4 ATC classification seen in the "ATC Group" columns. Some drugs have more than one ATC drug class, represented by the two "ATC Group" columns. (b) Lung cancer drugs are clustered by all genes from the PathFX known effects pathways. Drugs are mapped to their Level 5 ATC classification.

GO enrichment was used to discover functions associated with network patterns. It was found that both the diabetes and lung cancer pathways had distinct functional categories.

Objective

Identify hypothesis for gene pathways important to the Diabetes and Lung Cancer disease areas, respectively, to inform network validation experiments

Methods

- Run drugs through PathFX
44 Diabetes Drugs
34 Lung Cancer Drugs
- Separate data into 2 groups
Known Effects Phenotypes
Predicted Effects Phenotypes
- Analyze Gene Pathways
Gene and drug clustering
Gene Ontology Enrichment

Conclusion

Protein-protein interaction network methods, like PathFX, can be used to identify hypothesis for shared gene pathways, which can be used for the following experiments:

- Observational Studies in the Electronic Health Record
- Identify Opportunities for Drug Repurposing
- Potentially Reclassify Drugs Based on Gene Pathway

References

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Wilson JL, Wong M, Chalke A, Stepanov N, Petkovic D, Altman RB. PathFXweb: a web application for identifying drug safety and efficacy phenotypes. *Bioinformatics*. 2019 Nov 1;35(21):4504-4506. doi: 10.1093/bioinformatics/btz419. PMID: 31114840; PMCID: PMC6821302.

Acknowledgements

Special thanks to Dr. Jennifer Wilson, the Lab for the Understanding of Network Effects @ UCLA, the UCLA Department of Bioengineering, the Samueli Research Scholars Initiative, and the UCLA Summer Undergraduate Research Program.



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Current Sheet Quadrupole Focusing for Short-Period Undulators

ABSTRACT

X-ray free-electron lasers (XFELs) produce short, high-energy pulses of X-ray radiation by wiggling a beam of relativistic electrons through a magnetic array called an undulator. While these distinctly powerful X-ray pulses enable unprecedented research in a broad range of fields, XFELs are large, cost billions of dollars, and are only able to serve a few experiments at time, resulting in severely limited facility access. So-called “short-period” undulators have the potential to reduce the cost and size of an XFEL; however, these tend to be drastically less efficient than undulators with longer periods. One way to target this inefficiency is by focusing the electron beam as it passes through the undulator. This increases the efficiency of the FEL process, leading to a shorter overall undulator length and higher photon beam power, but previous techniques employing permanent magnets are not tunable and difficult to manufacture and align. We propose using copper current sheets instead, which are both tunable and simple to install. In this experiment, we investigate the practicality of this design through simulation and modeling. Our results illustrate the optimum width of current sheet at 4.75 mm for our chosen gap height of 2.5 mm, creating a “good field” region 2.4 mm wide while maintaining a gradient of 0.25 T/m at a small current density of $1.92e7 \text{ A/m}^2$. The gradient could reasonably be increased by two or three orders of magnitude with larger currents, commensurate with desired gradient levels in upcoming FELs.

Current Sheet Quadrupole Focusing for Short-Period Undulators

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Introduction

X-Ray Free-Electron Lasers (XFELs) use relativistic electrons to produce distinctly bright and short pulses of coherent radiation that enable us to study our world with atomic resolution. An array of magnets at the end of the electron accelerator, called an **undulator**, wiggles the beam of high-energy electrons transversely, converting electron kinetic energy into photons. It is desirable to use short period undulators to reduce cost and the required electron beam energy; however, these small-period, small-gap undulators are **highly inefficient** and thus far impractical to be used industrially. In this experiment, we will demonstrate that it is possible to increase the efficiency of compact undulators by implementing **strong focusing** using a parallel **copper current sheets** to create a **quadrupole focusing field**.

Results

Comparison of Experimental Data and Simulation Readings: The measurements closely matched simulation, with minor errors due to fabrication imperfections. *note that only half of gradient plot is shown as the data is symmetric in x*

4.75 mm wide, 50 μm thick copper sheets, 4.56 A current, $1.92e7 \text{ A/m}^2$ current density

Background/Theory

Pierce parameter

$$\rho = \left[\frac{1}{16} \frac{I_c}{I_A} \frac{K_0^2 [JJ]^2}{\gamma_0^3 \sigma_A^2 k_A^2} \right]^{1/3}$$
determines undulator length, decreases as ρ increases

gain length

$$L_{G0} = \frac{\lambda_u}{4\pi\sqrt{3}\rho}$$
determines undulator length, decreases as ρ increases

peak power

$$P_{sat} \approx \frac{1.6}{(1+\Lambda)^2} \rho P_{beam}$$
determines power of X-ray beam, increases as ρ increases

σ_r – size of beam cross section

To increase undulator efficiency, we can reduce the gain length and increase the X-ray beam power. Seeing that the Pierce parameter affects both of these attributes, we will **maximize** the Pierce parameter by **decreasing the size of the beam cross section** by **focusing** the beam.

Quadrupole: A Magnetic Lens
Sheets of parallel current create a transverse **quadrupole field** between them. The magnetic field acts like a **lens**, directing electrons as they pass through it.

$$\text{focal length} \propto \frac{1}{\text{gradient}}$$
 distance to the focal point is inversely proportional to the gradient of the field

Gradient: “Good Field” Region
The **gradient** refers to the **change** in field strength. We chose to inspect the gradient of the vertical component of our field. If the gradient is **constant** over a region, electrons passing through that region are proportionally forced towards a single focal point. A quadrupole magnet creates a “good field” **region of constant gradient** around its center. Our goals are to:

- 1 Find the width of copper sheet that maximizes the width of the “good field” region *maximize*
- 2 Maximize the value of this constant gradient, increasing focusing strength to decrease focal length *minimize*

Materials & Methods

STEP 1: Simulate

 simulate copper sheets, plot gradient and “good region” width

STEP 2: Model and Measure

 two halves fit together, creating a small gap between the copper sheets
 copper tape
 3D printed base
 washers fix gap at 2.5mm
 connection to DC Power Supply
 Hall probe
 cut different widths of copper, run scans, plot field data

Conclusion

In this experiment, we demonstrated the possibility of **implementing strong focusing using copper current sheets** in small-gap undulators. This focusing could improve the efficiency of compact undulators by decreasing beam size, and hence increasing peak power and decreasing gain length. In addition to being tuneable, inexpensive, and simple to install, this method could help move small-gap undulators towards industry use, enabling small X-ray free-electron lasers for laboratory research over large, expensive XFEL facilities.

Future Work

test actual electron beam
 simulate ray tracing and observe decrease in beam size

cryogenic improvements
 achieve higher gradients with cryogenic operation

Acknowledgements & References

We gratefully acknowledge funding from the National Science Foundation (Grant No. 1936598). We would also like to thank Professor Candler and our supervisor Ben Pound for their support this summer. Finally, a thank you to Will Herrera and all the staff at the 2022 UCLA Summer Undergraduate Research Program for making this research opportunity possible.

Huang, Zhong, and Kwang-Je Kim. “Review of X-Ray Free-Electron Laser Theory.” *Physical Review Special Topics - Accelerators and Beams*, vol. 10, no. 3, 12 Mar. 2007, <https://doi.org/10.1103/physrevstab.10.034801>.

Rubio-Lopez, G., et al. “Measurement and optimization of the VISA undulator.” *Proceedings of the 1999 Particle Accelerator Conference (Cat. No. 99CH36366)*, Vol. 4, IEEE, 1999.

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GroundSight: Floor-Sensing Shoe Wearable for Inferring User Location

ABSTRACT

Real-time location systems (RTLS) are increasingly being used in healthcare and warehouse facilities to monitor the activity of people and equipment. Unlike global positioning, RTLS are a type of local positioning system used for localization within a closed area. Most RTLS use large networks of transmitters and receivers, which can be very expensive to implement. The large overhead and cost make these systems inaccessible to users and smaller facilities with low budgets. Current RTLS solutions also raise privacy concerns with their constant surveillance and monitoring of user location data. To develop a more affordable and secure user localization method, position tracking and identification should be fully performed by the user without any external signals and allow them to control access to their location data. Here, we present a new localization method: GroundSight: a smart shoe accessory that coarsely tracks a user's positioning by sensing micro environments the user is in with discernable floor patterns. Attached to the heel, the low-profile wearable captures images of the ground in-sync with the user's steps. The device then classifies and matches these images to a set of user-defined locations in real-time and logs the location data in an SD card or the user's smartphone. The user is given full control over their location logs and has the choice to share their data. With affordable components and processing done all on-device, GroundSight offers a low-cost alternative to more expensive RTLS systems and an assurance on privacy and protection through user autonomy.

GroundSight: Floor-Sensing Shoe Wearable for Inferring User Location

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HUMAN-CENTERED COMPUTING & INTELLIGENT SENSING

Introduction

What is localization?

- Determining the positioning of objects or individuals based on their local environment
- Can be used to monitor and log activity

Drawbacks of current solutions

- Lack of affordable and accurate indoor location tracking with an emphasis on user privacy
- Need large, expensive systems of transceivers

How to improve localization

- Using a smart wearable to determine position fully on-device without any external support
- Enables low-cost systems and user autonomy

Materials

- ESP32 Wi-Fi/Bluetooth SoC with OV2640 image sensor
 - Signal processing
 - Inference tasks
 - Wireless communication

- MPU-6050 6-DoF IMU
 - Measure acceleration and angular velocity
 - Motion-based interrupt

- TensorFlow Lite for Microcontrollers
 - Synthesize CNN model
 - Quantize values for low-memory devices

- Jupyter / SciPy
 - Data augmentation
 - Model training
 - Digital filter generation

Location Inference Pipeline

1 Step Detection

- User begins walking with the wearable
- Footstep triggers camera and inference processes



Figure 1: Device worn on the shoe heel

2 Image Capture

- Ground images captured during each footstep
- Data transferred to CNN for classification



Figure 2: Examples of different floor materials

3 Classification

- Convolutional neural network (CNN) classifies image into its material label
- Label is mapped to location (i.e., bedroom, kitchen)



Figure 3: CNN model with feature extraction and classification layers

4 Data Logging

- Store location inference results in SD card or through a Bluetooth app
- Log each inference with a timestamp to create a timeline of locations



Conclusion

- Inferred step-detection through low-pass filtering can be difficult to implement due to timing issues
- Classifying floor materials is a viable alternative for low-cost and secure coarse localization

References

- C. Soaz and K. Diepold, "Step Detection and Parameterization for Gait Assessment Using a Single Waist-Worn Accelerometer," in IEEE Transactions on Biomedical Engineering.
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Results / Discussion

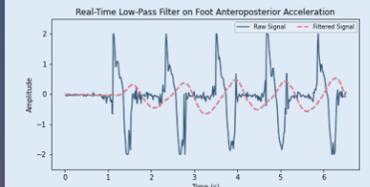


Figure 4: Low-pass Butterworth filter on the acceleration of five footsteps.

Step Detection through Real-Time Filtering

- Low-pass IIR filter to analyze foot acceleration
- 1-2 Hz matched slow to medium walking paces
- Difficult to maintain a constant sampling rate when deployed on the microcontroller



Figure 5: Confusion matrix for classification of six materials (gray painted wood, gray rug, gray wood, light brown wood, rubber stairs, stone tile)

Floor Material Classification with CNN

- Very high accuracy with small, quantized models (less than 30,000 parameters)
- Discrimination ability dependent on difference between each material's distinctive features
- Lower accuracy for smooth materials (rubber stairs) when other materials have similar color

Acknowledgements

I would like to thank Professor Yang Zhang, Khushbu Pahwa, and the HiLab for their guidance and support. I also want to thank NSF, the Interactive Systems REU, and Professor Greg Pottie for helping fund this experience.



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3D Printed Liquid Crystal Elastomers

ABSTRACT

Liquid crystal elastomers (LCEs) are soft stimuli-responsive materials that contract along the orientation of mesogen, called director, upon heating due to a transition from the nematic to isotropic phase. LCE structures can be utilized for applications requiring remote actuation, cyclic actuation and miniaturization. Direct Ink Writing 3D printing allows fabrication of LCE structures with variable spatial orientation and order parameter due to the shear forces acting during the extrusion process. Literature contains various simple 2D LCE structures, such as spiral and radial alignments in disks, which exhibit intriguing shape-morphing capabilities. However, an understanding of complex LCE orientations is yet to be achieved to get extreme shape morphing, snapping and locomotion. In this study, we design structures with complex print patterns by developing custom G-Codes. We prepare a standard LCE ink by mixing the mesogen, RM- 82, cross-linker, n-Butylamine, and a photoinitiator, HHMP, and oligomerizing the mixture at high temperatures. To reduce the temperature-dependent viscosity of the ink during printing, we fabricate an in-house syringe heater that uniformly heats the ink. UV curing was performed during and after printing to fix the director orientation. We first printed several unidirectional rectangular specimens to characterize the effect of nozzle velocity and syringe pressure on the actuation stretch. Higher printing velocities and pressures result in greater shear forces, which produce higher actuation shrinkage. We also found that the shrinkage increases with the actuation temperature. More complex shapes such as a disk with spiral print pattern were printed, which actuates from a planar disc to a 3D cone, due to circumferential shrinkage and radial expansion. We also computationally simulated bilayer structures that can snap to a new configuration and instantly release energy in this process.



3D PRINTING LIQUID CRYSTAL ELASTOMERS

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School of Engineering
SUMMER UNDERGRADUATE
RESEARCH PROGRAM

INTRODUCTION AND BACKGROUND

- Liquid crystal elastomers (LCEs): soft stimuli-responsive materials

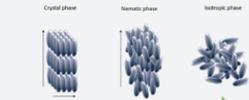


Figure 1. Molecular orientations of liquid crystal elastomers at each state

- Heating can induce a nematic-to-isotropic phase transition
- LCEs contract along the orientation of the mesogen director when transitioning from the nematic state to the isotropic state, causing shape morphing
- Direct ink writing 3D printing allows fabrication of LCE structures with variable spatial orientation and order parameter due to the shear forces acting during the extrusion process
- Printing parameters such as nozzle velocity, syringe pressure, temperature, and layer thickness affect director orientation

OBJECTIVES

- Use custom G-codes to design structures with complex print paths and observe actuation behavior
- Observe effect of printing parameters on actuation behavior

MATERIALS AND METHODS

LCE Ink Preparation

Composition:
1.1:1 RM-82 and n-Butylamine; 1.5% HHMP by mass

- 90° C for 40 min
- Mix for 1-2 min
- 90° C for 15 min
- Degas for 30 min
- 75° C for 12 hrs

Printing Method

Prepare LCE ink in syringe and attach to printer
 Heater around syringe set to 72° C
 Printer deposits the LCE ink according to the programmed G-code

MATLAB script to generate print path for any angle within a convex polygon
 Create G-code using MATLAB path

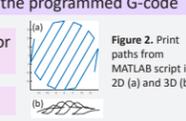


Figure 2. Print paths from MATLAB script in 2D (a) and 3D (b)

Expose LCE ink to UV light as it is extruded to induce crosslinks between reactive end groups
 Cure LCE by exposing to lower intensity UV for 20 min on each side to fix the director orientation
 Actuate LCE by heating it past the nematic-isotropic phase transition temperature

DESIGN OF HEATING COMPONENTS

- Reduce layer thickness variation through syringe heater and glass plates
- Syringe heater uniformly heats the syringe and reduces temperature-dependent viscosity of LCE ink

DESIGN OF HEATING COMPONENTS

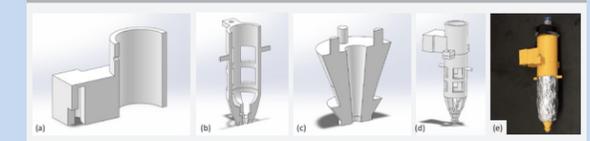


Figure 3. In-house syringe heater. a) Attachment to printer. b) Syringe holder, which is filled with foil and wrapped in the heater to uniformly heat the syringe. c) Nozzle attachment. d) Complete CAD model of the syringe heater. e) Complete model of the syringe heater, pictured with the foil and the syringe.

RESULTS

Unidirectional Rectangles: Nozzle Velocity and Syringe Pressure



Figure 4. Images of actuated LCEs at 107° C (left) and 116.3° C (right) printed at 30.2 mm length using a unidirectional print path. a) and c) Nozzle velocity of 100 mm/min and syringe pressure of 10 psi. b) and d) Nozzle velocity of 500 mm/min and 20 psi

Circumferential Circle

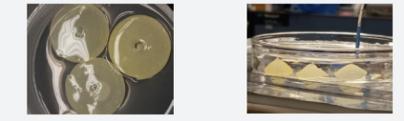


Figure 5. Images of printed (left) and actuated (right) LCEs with a circumferential print path.

Saddle Bilayer: Perpendicular Print Path

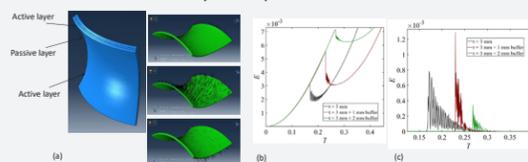


Figure 6. LCE bilayer printed in a saddle configuration with a perpendicular print path. a) Design of the bilayer and each layer's print path. b) Plot of strain energy after actuation. c) Plot of kinetic energy after actuation

CONCLUSIONS

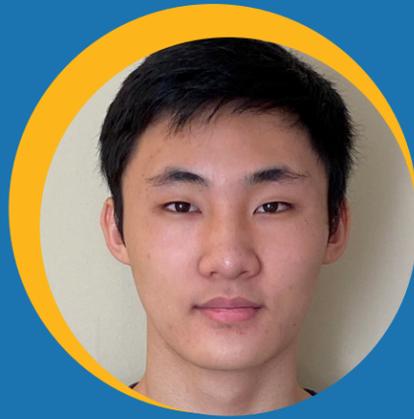
- Higher printing velocities and pressures result in greater shear forces, causing higher actuation shrinkage
- Shrinkage increases as temperature increases in the isotropic state

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ACKNOWLEDGEMENTS

Thank you to Professor Lihua Jin and the Mechanics of Soft Materials Laboratory for their support and resources. Special thanks to Shivam Agarwal for all his guidance and for developing the MATLAB script to generate print paths and simulating the LCE saddle bilayer. Thank you to National Science Foundation for funding my research.



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Fingerprinting RF Devices

ABSTRACT

Common methods of radio frequency (RF) device authentication, such as RFID tags, cost time or energy. An ideal authentication scheme identifies transmitters from data collected in situ. We investigate such a scheme here. Due to hardware imperfections, identically manufactured RF devices transmit slightly different signals. We attempt to extract this discrepancy for use as a fingerprint. A dataset was created consisting of data collected from seven transmitters sending WLAN packets to one receiver. Since wireless channels can distort these transmitter fingerprints, we also introduced the effects of seven different channels on the signals. The received short and long training fields were extracted and used as input to train a neural network to classify the transmitters and evaluate the effect on accuracy of the channels. Further work may be aimed towards eliminating channel distortion.

FINGERPRINTING RF DEVICES

Daniel Yang, Tianyi Zhao, Professor Danijela Cabric
ECE Department, UCLA; CORES Lab



INTRODUCTION

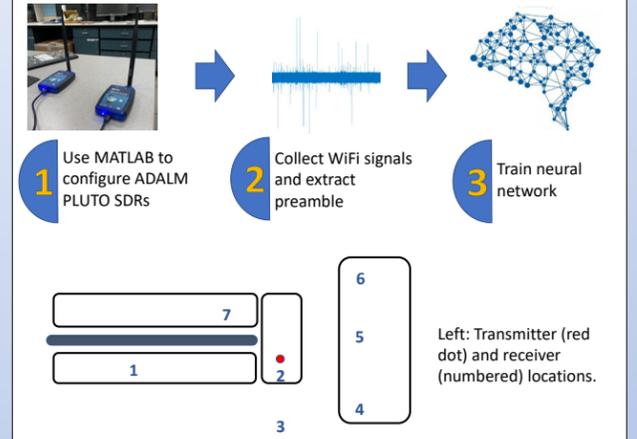
Wireless communication involves a transmitter sending signals to receivers. Security is a rising issue as the number of radio devices in the Internet of Things (IoT) increases. Determining which transmitter sent a signal is called classification and is an important step to ensure that only known transmitters are allowed to transmit on a network. Classical authentication methods, such as username/password schemes, take time and energy. Ideally, authentication happens in situ and automatically, with minimal energy and time costs.

BACKGROUND & GOAL

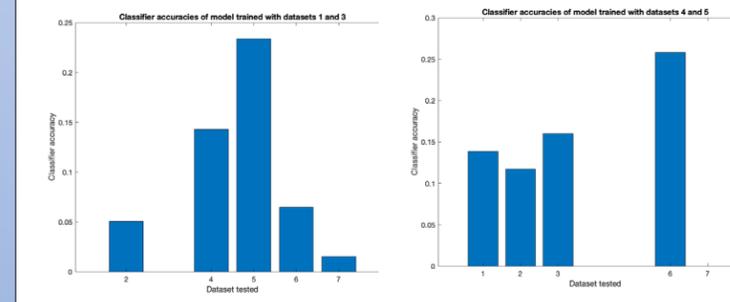
Radios manufactured using the same process possess slight hardware differences, due to tolerances in components such as resistors. As a result, identical signals sent by identically manufactured radios have slight differences.

The goal of this project is to extract these discrepancies and use them to train a neural network to classify transmitters.

METHODS



RESULTS



- Classifier accuracy used here refers to probability of the training model in correctly deciding which transmitter a signal set was sent by. For example, when trained with datasets 4 and 5, the model correctly identifies signals sent from transmitter 6 roughly 25% of the time.
- Classifier accuracy is lower for channel 2. In this case, the receiver and transmitter are placed close enough together to cause signal saturation.
- Classifier accuracy is also lower for channel 7. This is the only channel in which there is no line of sight from the receiver to the transmitter. This channel therefore introduces more noise than in other channels.
- Other channels have higher accuracy, but are not yet at accuracy levels suitable for transmitter authentication.

CONCLUSIONS & FUTURE WORK

Longer, noisier wireless channels negatively affect classifier accuracy.

This dataset only contains data from 7 transmitters sending to 1 receiver. A clear next step is to develop a larger and more robust dataset of signals collected over many days using more transmitters and receivers.

Another possible direction concerns the effects of channels. In this dataset, the only fact known about the channels is that they are different. In future datasets, it might be of interest to introduce channels in a more controlled way to allow for easier analysis of their effect on the training model, as well as attempt to equalize channel noise.

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- S. Hanna, S. Karunaratne, and D. Cabric, "Open set wireless transmitter authorization: Deep Learning Approaches and dataset considerations," *IEEE Transactions on Cognitive Communications and Networking*, vol. 7, no. 1, pp. 59–72, 2021.

ACKNOWLEDGEMENTS

I would like to thank Professor Gregory Pottie's NSF REU for funding my research during the UCLA Summer Undergraduate Research Program. I would also like to thank Professor Danijela Cabric and the CORES lab, and especially Tianyi Zhao and Shamik Sarkar, for their guidance and support.



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Characterization of a Radiative Emitter

ABSTRACT

Materials that passively cool themselves are of particular interest in our society, particularly with the rise of climate change. Since air conditioning actively requires energy to operate and no process is 100% efficient, air conditioning temporarily cools an internal environment at the expense of the world at large. As such, alternative cooling methods are needed that are less energy-intensive. Prior research has demonstrated that materials can be engineered such that they experience a net loss of heat to the cold of space. However, this effect requires a clear view of the sky and minimal view of the ground, conditions rarely met in urban environments. In this experiment, we characterize a directional emitter designed to exhibit high emittance in the 0-180° azimuthal angles about its normal axis, and high reflectance elsewhere. Our samples were tested with a thermal camera at different angles of incidence with respect to a cold background and the resulting temperatures were recorded.

Characterization of a Radiative Emitter

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INTRODUCTION

BACKGROUND

Motivation:
Climate-change-induced temperature increases will result in greater demand for air conditioning. Air conditioning (AC) itself is an unsustainable method of cooling that merely moves heat from inside to outside. A better alternative to AC is needed.

Experiment:
Here we test an alternative to traditional AC that operates off of radiative effects. The design uses simple geometric principles and additive manufacturing to create a material with directionally-tuned optical properties.

THEORY

- An object can cool itself by radiating more heat than it absorbs.
- Typical, omnidirectional emitters, absorb and emit all wavelengths of light.
- In a hot environment, an omnidirectional emitter on a building may absorb more light than it emits.
- By reflecting both sunlight and terrestrial heat, a Directional Emitter can cool itself when an omnidirectional emitter would get hot.



RESEARCH

MATERIALS

- Directional Emitter
- Aluminum reference
- Liquid nitrogen
- Styrofoam
- Container
- Thermal camera



Figure 1: View of small-scale setup used in the first phase of our research

ANALYSIS

From our phase one data, we find that the Directional Emitter's properties vary as a function of angle of incident light, plateauing as the angle increases.

This should that our idea has promise.

Iterating upon this, we proceeded to phase two: large-scale tests. The results of which are seen in Figure 3.

METHODOLOGY

Phase One: Using a thermal camera, we took pictures of our sample at various angles. From the thermal data from the pictures, we then calculated the emittance of our Directional Emitter

Phase Two: A large-scale test was then done pitting the Directional Emitter against a Broadband Emitter.



Figure 2: Outside, large-scale set-up used to compare the Directional Emitter (blocked out) to the Broadband Emitter.

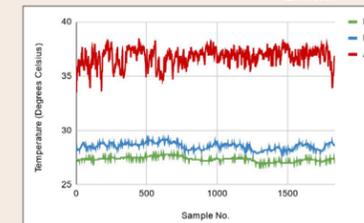


Figure 3: Temperature data from the large-scale set-up (Figure 2) of our tests/ Notice that the Directional Emitter (DE, Green) is cooler than the Broadband Emitter (BE, Blue), for nearly the entire hour-long duration of the test.

CONCLUSION

DISCUSSION

Phase One:
Our data indicated a notable dependence of the emissivity of our sample as a function of azimuthal angle. With higher angles of incidence correlating with greater emissivity. We have also shown that the structure of the directional emitter can be altered to change the angular emittance.



Phase Two:
From Figure 3, it is clear that our directional emitter can perform better than a broadband emitter in terms of cooling by 1.3 degrees Celsius.

Future Steps:
From our data from phase 2, it is clear that we have a design that has advantages when compared to traditional broadband emitters for cooling structures. Future research should focus on refining the design and developing ways to construct samples in a scalable way for real-world application.

ACKNOWLEDGEMENTS

Thank you Professor Raman, postdoc Jyotirmoy Mandal, and the Raman Lab for their support and guidance, as well as the Summer Undergraduate Research Program and Will Herrera for organizing such an opportunity.
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Adhesion Characterization of Hydrogels For Wound Dressing

ABSTRACT

Hydrogels are three-dimensional polymer networks that are crosslinked using various chemical or physical crosslinkers and are attractive candidates for medical applications such as wound dressing and tissue engineering. Gelatin methacryloyl (GelMA) is a widely studied hydrogel for tissue engineering due to its similarity to native extracellular matrices. Methacrylate modification of gelatin allows this hydrogel to be covalently crosslinked upon exposure to ultraviolet light leading to robust mechanical stiffness. However, this application has been limited due to its weak mechanical strength before crosslinking, leading to undesired flows on wet surfaces. We propose to overcome the low mechanical strength of GelMA by incorporating oppositely charged block polyelectrolytes (bPE) that self-assemble ionically when mixed in aqueous mediums, resulting in hybrid hydrogels with higher mechanical robustness prior to photocuring. To quantify hydrogel's mechanical properties, we built an ASTM F2392 – 04 standard burst pressure apparatus to measure the maximum pressure that hydrogel acquires to burst. We compared the burst pressure of GelMA with varied concentrations as well as block polyelectrolytes supplemented with GelMA (bPE-GelMA) systems in dry and wet environments. The results showed that increasing GelMA concentration from 5 wt.% to 10 wt.% doubled the burst pressure. In underwater environments, GelMA solutions undergo significant declines in burst pressure. The burst pressure of bPE-GelMA system is nearly equal to the burst pressure in dry environments, showing controlled application underwater compared to rapid dilution of GelMA. This work assessed hydrogel applications and relevant mechanical properties in environments that resemble physiological conditions.

Adhesion Characterization of Hydrogels For Wound Dressing

Tianyue Yu, Chad Nishimura, Fahed Albreiki^{DL}, Dr. Samanvaya Srivastava^{PI}



Chemical and Biomolecular Engineering Department

SRIVASTAVA LAB



Introduction

Hydrogels are three-dimensional polymer networks that are crosslinked using various chemical or physical crosslinkers. Their toughness, as well as swelling without dilution in aqueous environments, make them attractive candidates for medical applications such as wound dressing, drug delivery, tissue engineering, and regeneration.

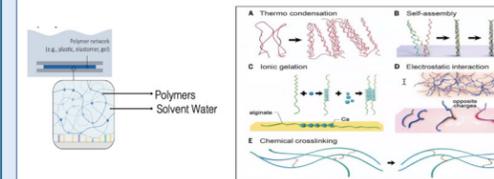


Figure 1: 3D network illustration [1]

Figure 2: Interaction illustration [1]

GelMA (Gelatin methacryloyl) is a hydrogel that resembles some characteristics of the native extracellular matrix, which helps the cell to grow and spread. The methacrylate modification of gelatin allows this hydrogel to be covalently crosslinked upon exposure to ultraviolet light. However, this application has been limited due to its weak mechanical strength before crosslinking, leading to undesired flows on wet surfaces. How can we design and characterize the adhesive hydrogels with tunable properties without dilution?

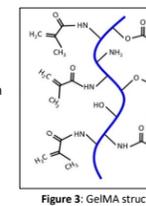


Figure 3: GelMA structure

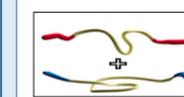


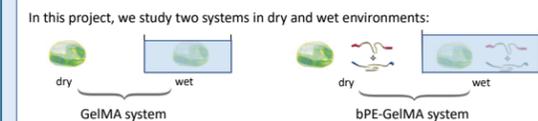
Figure 4: block polyelectrolyte structure [2]

We propose to overcome the low mechanical strength of GelMA by incorporating oppositely charged block polyelectrolytes (bPE) that self-assemble ionically when mixed in aqueous mediums, resulting in hybrid hydrogels with higher mechanical robustness prior to photocuring.

Objective and materials

Objective: To quantify hydrogel's mechanical properties, we built an ASTM F2392 – 04 standard burst pressure apparatus to measure the maximum pressure that hydrogel acquires to burst. We compared the burst pressure of GelMA with varied concentrations as well as block polyelectrolytes supplemented with GelMA (bPE-GelMA) systems in dry and wet environments.

- Materials:**
- Collagen casing
 - Hydrogel (GelMA)
 - block Polyelectro
 - OriginLab



Burst Pressure Apparatus

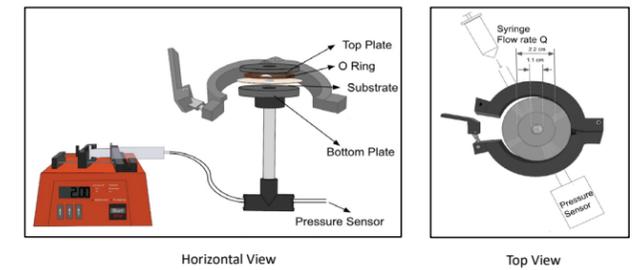


Figure 5: ASTM Standard burst pressure set up (F2392 – 04)

Results

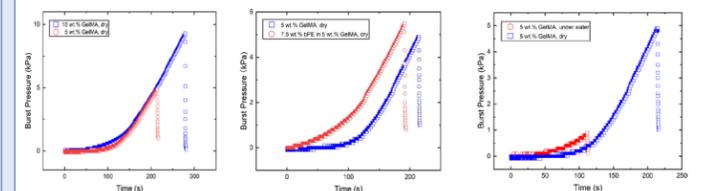


Figure 6: Burst pressure of 5 wt.% and 10 wt.% GelMA in dry environment

Figure 7: Burst Pressure of 5 wt.% GelMA and 5 wt.% bPE-GelMA in dry environment

Figure 8: Burst Pressure of 5 wt.% GelMA in Dry and underwater environment

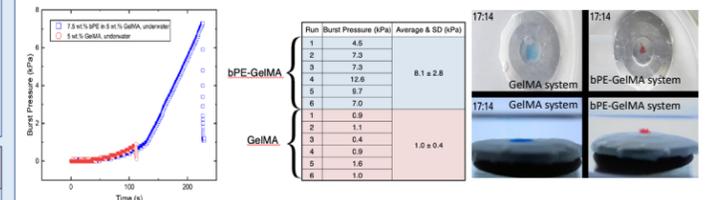


Figure 9: Burst Pressure of 5 wt.% bPE-GelMA and 5 wt.% GelMA underwater

Table 1: Burst Pressure Statistics of bPE-GelMA and GelMA underwater

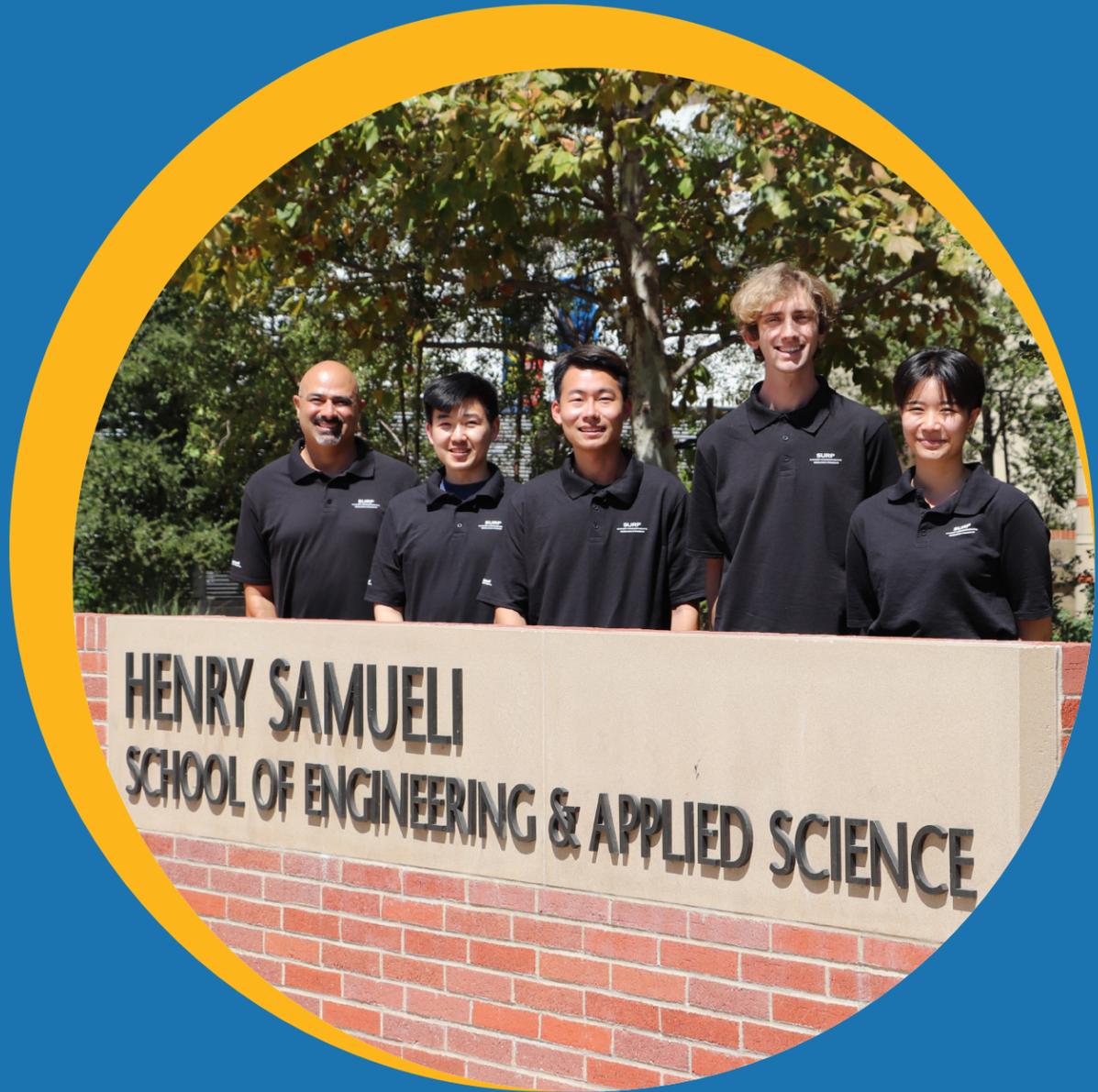
Figure 10: Applying Both Systems Underwater Collaboration with Chad Nishimura

Conclusion

The results showed that increasing covalently crosslinked GelMA concentration from 5 wt.% to 10 wt.% doubled the burst pressure. In underwater environments, GelMA solutions undergo significant declines in burst pressure. The burst pressure of bPE-GelMA system is nearly equal to the burst pressure in dry environments, showing controlled application underwater compared to rapid dilution of GelMA. This work assessed hydrogel applications and relevant mechanical properties in environments that resemble physiological conditions. Future work will aim at studying the influence of block polyelectrolytes concentrations and the addition of salts into the aqueous medium of the set-up.

References

- [1]: Advances in Engineering Hydrogels
- [2]: Li et. Al. *Macromolecules*. 2022



If you would like to find out more about the UCLA Samueli Summer Undergraduate Research Program, please contact our team at surp@seas.ucla.edu or visit our website at www.seasoasa.ucla.edu/surp.



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