

UCLA Samueli
School of Engineering

SUMMER
UNDERGRADUATE
RESEARCH PROGRAM

2019

RESEARCH JOURNAL

UCLA Samueli
School of Engineering

Summer Undergraduate Research Program at the Engineering Student Resource Center
Office of Academic and Student Affairs
UCLA Samueli School of Engineering
420 Westwood Plaza, 6288 Boelter Hall, Los Angeles, CA, 90095-1600
310.825.9478 | www.samueli.ucla.edu





DEAN'S MESSAGE

The Summer Undergraduate Research Program (SURP) provides participants with an intensive 8-week summer research experience in a wide range of engineering fields. Undergraduate students participate in research with UCLA Samueli School of Engineering faculty and research teams to gain real-world lab experience. As part of this program, SURP students:

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

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

Sincerely,

Jayathi Murthy
Ronald and Valerie Sugar Dean



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Electrical Engineering
First Year
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Functional Nanomaterials

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Professor Achuta Kadambi

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Implementing Kinematic Prediction via Physics-Guided Neural Networks

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

Functional Nanomaterials
UCLA ENGINEERING Summer Scholars Program

UCLA Samueli School of Engineering
Summer Undergraduate Research Program

Implementing Kinematic Prediction via Physics-Guided Neural Networks

Brian Chap, Lucas He, Irfan Syed
Guangyuan Zhao, Achuta Kadambi
Department of Electrical and Computer Engineering, UCLA

Fast Track to SUCCESS summer scholars program
Electrical Engineering Department
University of California, Los Angeles

Using Physics-Based Machine Learning to Track Objects

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

Regional Convolutional Neural Networks

Dataset

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

Figure 1 : Improvements such as clearer annotations and bounding box representations were made on a Faster R-CNN framework with 20 different classifications of objects. The physics model resulted from this framework of Faster R-CNN.

Physics-Based Model

```

graph TD
    A[Frame  
Bounding box coordinates  
Class labels  
Confidence probabilities] --> B[Calculate Euclidean distances between bounding boxes of the same class]
    B --> C[Remove "camera motion" if all subjects move consistently between frames]
    C --> D[Identify the shortest distance between bounding boxes of the same class (velocity).]
    D --> E[Find the change in velocity between two pairs of frames (acceleration).]
    E --> F[For next 17 frames]
    F --> G[Use kinematic equations to predict locations of future bounding boxes.]
    G --> H[If ground truth is close to the predicted bounding box, increase confidence probabilities.]
    G --> I[If ground truth is far from the predicted bounding box, decrease confidence probabilities.]
    
```

Future Plans

The proposed physics model performs with high confidence values in the ideal scenarios created within the dataset. Expectations for future improvements include higher efficiency rates, faster processing rates, greater accuracy between multiple objects, and more accurate predictions for accounted complexities such as occlusions, lighting, and camera motion.

Limitations of current model:

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

Applications:

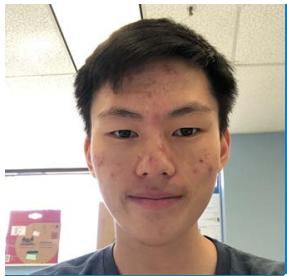
Self-Driving	Defense Industry
Autonomous Drones	Movement Prediction

Preliminary Results

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

References

- Saha, Sumit. A Comprehensive Guide to Convolutional Neural Networks – the ELIS Way. Towards Data Science (2017).
- Ren, F.-F. et al. Detection and Segmentation. Stanford University. (2012).
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- Ren, S., et al. Faster R-CNN: Towards Real-Time Object Detection with Region Proposal Networks. CoRR 1506.01497 (2015).
- Redmon, J., et al. You Only Look Once: Unified, Real-Time Object Detection. CoRR 1506.02640 (2015).



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Physics-Based Object Temporal Localization Via Video Segmentation

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

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Using Physics-Based Machine Learning to Track Objects

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Regional Convolutional Neural Networks

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

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Physics-Based Model

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Limitations of current model:

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Applications:

Self-Driving	Defense Industry
Autonomous Drones	Movement Prediction

Preliminary Results

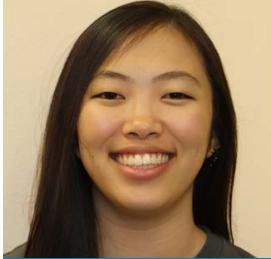
Figure 4: Bottle detection without physics-based learning (left) and with physics-based learning (right)

References

- Saha, Sumit. A Comprehensive Guide to Convolutional Neural Networks – the ELLIS Way. *Towards Data Science*, (2018).
- Lei, F.-F., et al. Detection and Segmentation. *Stanford University*, (2017).
- Girshick, R. Fast R-CNN. *CoRR* 1504.08093 (2015).
- Girshick, R., et al. Rich feature hierarchies for accurate object detection and semantic segmentation. *CoRR* 1311.2524 (2013).
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- Redmon, J., et al. You Only Look Once: Unified, Real-Time Object Detection. *CoRR* 1506.02640 (2015).

Figure 5: Multiple object detection without physics-based learning (left) and with physics-based learning (right)

The physics-based model results indicate significant increases in the accuracy of the model when compared with simply the Faster R-CNN framework. Faster R-CNN with physics-based machine learning increases the confidence of object detection and removes classification errors for objects.



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Ultrafast Real-Time Dynamics of Frequency Microcomb Transitions

Temporally stabilized optical solitons, also known as self-sustaining nonlinear pulses at a mid-infrared frequency, confined in a microcavity driven by a continuous-wave laser has attracted tremendous attention due to its fascinating spectral and temporal features and corresponding intriguing cavity dynamics. A real-time ultrafast oscilloscope characterization system demonstrates the dynamics in the microcavity with picosecond resolution and a 500 picosecond recording length over each frame. However, the recording length is limited by the sampling rate due to the restricted memory depth of the oscilloscope during data acquisition. To bypass this complication, time lens was used to stretch the timescale of the waveform without adding distortion or noise. After finding the optimum recording length and temporal resolution, a Kerr frequency comb is generated in the microresonator with a laser which is then sent through optical fibers to the oscilloscope to be studied. We were then able to record the mode-locking formation and the transitions between different soliton states during the formation process. The real-time observations of the ultrafast optical dynamics provides new physical insight for ultrafast phenomena that happens in the microcavity.

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Ultrafast Real-Time Dynamics of Frequency Microcomb Transitions

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Background

This research focuses on the mid-infrared part of the optical spectrum that encompasses visible light and infrared waves. Ultrafast optical dynamics such as a soliton, an undistorted stable light waveform that sustains its pulse over time, happens at the nanosecond and picosecond scale. Studying its characteristics in a microresonator has immense significance to laser optics. For the further development of optical technology and telecommunication.

Electromagnetic wave spectrum

Aim

Goal: Observe and record all the characteristics of different transitioning states a dissipative Kerr comb soliton in microcavities produce in real time.

Problem: Conventional oscilloscopes can miss extremely fast rare events as they have limitations of both the spatial and temporal domain. This makes the oscilloscope insufficient to characterize ultrafast waveforms.

Solution: Time lens is used to slow down and extend the signal without adding distortion or noise. It magnifies the image dispersing it in time and uses the quadratic phase shift which stretches the temporal domain. The longer recording length allowed the waveform to be analyzed and recorded.

Kerr Frequency Comb

- A frequency comb is generated on an optical spectrum analyzer from a signal on the time domain that uses the Fourier transform in the cavity to the frequency domain creating an equidistant spectrum of pulses.
- The Kerr comb is generated from a continuous wave laser and an erbium-doped fiber amplifier that pumps a power of 35 mW. That signal is then sent to the microcavity in the silicon chip that uses a Fourier transform to create the comb on a frequency and wavelength domain.

Time Lens Setup

Results

- The transmission used the voltage jumps to trigger the signal acquisition and transitions between different soliton states.
- The time lens increased the temporal resolution and abled the magnification of the pulse train to be studied.
- The oscilloscope received the signal and recorded the transition from high-noise to mode locking, 3 to 2 to 1 soliton, and 3 to 1 soliton transitions.

Conclusions and Future Works

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

Acknowledgements

Special thanks to Professor Chee Wei Wong for giving me this opportunity to work with his team and Dr. Wenting Wang for allowing me to be a part of such cutting edge advanced scientific research. Greatly appreciate the support of lab members, Xinghe Jiang, Jaime Flor, and Abhinav Vinod, who took the time to explain concepts. This would not be possible without the SURP program that lead to this incredible experience here at UCLA.

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Studying changes of mind in decision-making

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

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Ideas and Principles

Motivation

- A decision is a commitment to an action after consideration of evidence and expected outcomes.
- Standard decision-making models do not fully explain why changes of mind occur during the decision-making process.
- The purpose of this study is to develop an experiment to study changes of mind, validating work by Resulaj and colleagues.
- It was hypothesized that noisy evidence, in the form of a random dot motion stimulus, is accumulated over time until it reaches a criterion level, or bound.

Random Dot Motion Stimulus

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

Figure 1. Random Dot Motion.
Image of the random dot motion.

Figure 2. Motion Coherence.
Motion coherence is defined as the number of dots in a designated direction divided by the number of dots total. We performed trials at motion coherencies of 0%, 3.2%, 6.4%, 12.5%, 25.0%, 51.2%.

Materials and Methods

Experimental Setup

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

Timeline of Trial

Coding

- Random dot stimulus is generated with Python, primarily tested with the PsychoPy IDE.
- The general structure of the experiment is based on the one presented in Resulaj's paper.
- Stimulus will be implemented on LiCoRICE machine to collect real-time data every millisecond of the cursor's position.

Data Collection

Figure 5. Accuracy Improves Through Practice.
Data is shown for subjects (A, B, and C). The top row shows the probability of a correct decision (blue), probability of change (red), and probability of a correct decision after change of mind (green) according to motion coherence strengths. Probability of a correct decision increases with motion strength, while probability of change decreases with motion strength. The bottom row shows that reaction times are higher for weaker motion strengths.

Conclusions

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

Future Directions

Figure 7. Contrast in movement.
Arrows showing contrast in movement for targets placed at 45° versus 180°.

Figure 8. Experimental Setup.
Schematic of the monitor viewed by the subject in a possible future study.

References

Pilly, P. K., & Seltz, A. R. (2009). What a difference a parameter makes: a psychophysical comparison of random dot motion algorithms. *Vision research*, 49(13), 1599–1612. doi:10.1016/j.visres.2009.03.019

Resulaj, A., Kiani, R., Wolpert, D. M., & Shadlen, M. N. (2009). Changes of mind in decision-making. *Nature*, 461, 263–266.

Acknowledgements

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Design of Flexible, Wireless Surface Electromyography System

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

Design of Flexible, Wireless Surface Electromyography System

M. Molter, A. Alam, and S. S. Iyer (UCLA CHIPS)



Design of Flexible, Wireless Surface Electromyography System

M. Molter, A. Alam, and S. S. Iyer (UCLA CHIPS)



Motivation

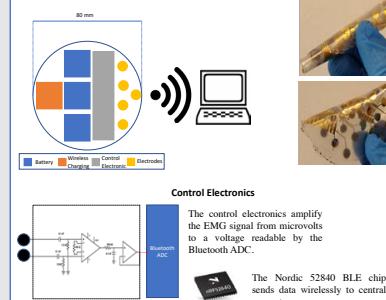
- According to the CDC Muscular dystrophy effects 1 in 7250 males
- Surface Electromyography (EMG) measures the electrical activity of muscles for diagnoses of muscular disorders
- Existing Surface Electromyography systems are bulky, non-flexible, and heavy making them difficult to use
- FlexTrate™ is a flexible electronic platform based on Fan Out Wafer Level Packaging allowing integration of high performance dies
- FlexTrate™ is an ideal platform for a complete, flexible and lightweight EMG system due to flexibility and ability to integrate many high performance dies



System Design

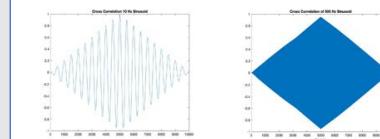
Surface EMG on FlexTrate™ Layout

In the figure below, we see the simple layout and size of the system. Total system thickness will be less than 1 mm and weigh approximately 10 g.



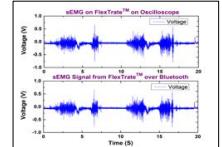
Verification of Wireless Communication

Cross Correlation of a sinusoid from a signal generator was recorded simultaneously from an oscilloscope and our Bluetooth controller at 10 Hz and 500 Hz. High correlation coefficients of 0.9923 and 0.9545 were calculated from cross correlation of both signals sources.



Verification of Wireless Communication Cont.

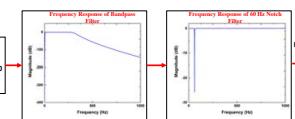
A comparison of EMG signals gathered simultaneously from an oscilloscope and Bluetooth controller. We can see that the EMG signals are visually the same from both.



Signal Post Processing

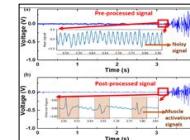
Filtering Process

Surface EMG signals have only been recorded in the range of 5 – 500 Hz allowing filtering outside those ranges. Filtering allows removals of DC and low frequency noises associated with wire movement below 5 Hz and high frequency noises above 300 Hz.



The pre and post processed signals. Filtered EMG signal can be seen in the figure to the right.

In the close up view, we can see the pre-processed signal is subject to a large power line noise. Removing noise allows us to clearly see muscle activation signals that are not visible before.



Conclusions/Future and Ongoing Work

Demonstrated the beginning steps towards a fully flexible, wireless surface EMG system including:

- Flexible electrodes
- Robust Wireless system capable of recording EMG
- Design of control electronics

Full System integration onto FlexTrate™ including the Bluetooth controller and control electronics.



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- [2] G. Eshelman et al., JEDM, 2019.
- [3] Romitti PA, Zhu Y, Puzhankara S, et al. Prevalence of Duchenne and Becker Muscular Dystrophies in the United States. Pediatrics. 2015





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Millimeter-Scale Electroplated Multilayer Magnetic Shielding

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

Millimeter-Scale Electroplated Multilayer Magnetic Shielding

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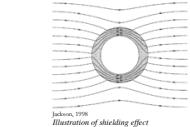
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Introduction

Motivation

- Devices like atomic clocks and sensors require magnetic shielding because of sensitivity to external magnetic fields
- Using high magnetic permeability materials, magnetic shields can create protected regions of low magnetic field
- Current manufacturing methods are limited to larger scales
- We use electroplating to fabricate more compact and efficient magnetic shields
- Successful implementation of chip-scale magnetic shields can lead to new innovations like GPS-free location tracking



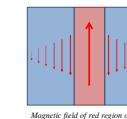
Jackson, 1998
Illustration of shielding effect

Design and Fabrication

Magnetic Shielding Mechanism

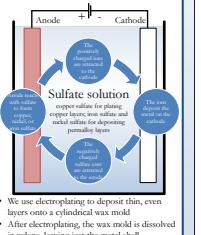
Multilayer Shielding Design

Fabrication



Magnetic field of red region opposes magnetization of blue regions

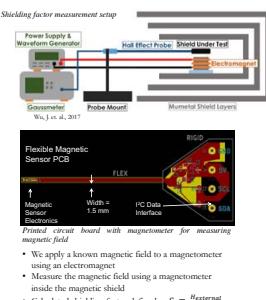
- Magnetization of a region opposes magnetization of neighboring regions
- By removing a layer of magnetic material, the neighboring regions reach higher magnetic saturation
- A multilayer shield can better oppose external magnetic fields



- We use electroplating to deposit thin, even layers onto a cylindrical wax mold
- After electroplating, the wax mold is dissolved in xylene, leaving just the metal shell

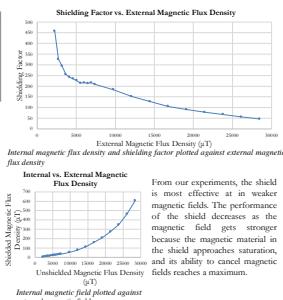
Results

Measurement Procedure



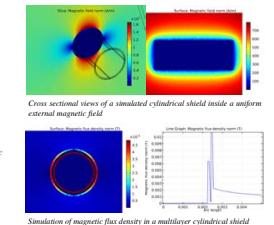
Shielding factor measurement setup
Wu, J. et al., 2017

Experimental Results



Internal magnetic flux density and shielding factor plotted against external magnetic flux density

COMSOL Physics Simulation



Cross sectional view of a simulated cylindrical shield inside a uniform external magnetic field
Surface Magnetic Field Density (T)
Line Depth Magnetic Flux Density (T)

From our experiments, the shield is most effective at in weaker magnetic fields. The performance of the shield decreases as the magnetic field gets stronger because the magnetic material in the shield approaches saturation, and its ability to cancel magnetic fields reaches a maximum.

Discussion and Future Work

Results Analysis

In comparison with current methods of magnetic shielding, our cylindrical shield is more effective at protecting regions from magnetic fields. For weaker magnetic fields, we recorded a shielding factor higher than 400, while a flat sheet of similarly high permeability metal, as those found in current methods of magnetic shielding, could not achieve a shielding factor higher than 12.

Future Work

- Shielding factor greatly dependent on geometry of the shield
- From Maxwell's equations, the magnetic field around the surfaces of the magnetic material satisfies the boundary conditions at every surface:
$$(\mathbf{B}_\text{ext} - \mathbf{B}_\text{int}) \times \mathbf{n} = 0$$
- Using electroplating to generate the shields, it is possible to create shields of more complex geometries not achievable with traditional machining methods
- Electroplated magnetic shield directly onto devices
- Conerves space and improves shielding factor



NIST, 2018
Chip-scale atomic clock

Acknowledgements

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Tracking Objects Using Physics-Guided Neural Networks

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

Functional Nanomaterials
UCLA ENGINEERING Summer Scholars Program

UCLA Samueli School of Engineering
Summer Undergraduate Research Program

Implementing Kinematic Prediction via Physics-Guided Neural Networks

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Fast Track to SUCCESS
summer scholars program
Electrical Engineering Department
com/ece/undergrad/programs

Using Physics-Based Machine Learning to Track Objects

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

Regional Convolutional Neural Networks



Dataset



Figure 1 : Improvements such as clearer annotations and bounding box representations were made on a Faster R-CNN framework with 20 different classifications of objects. The physics model resulted from this framework of Faster R-CNN.

Applications of physics-based calculations on a self-made dataset of videos that captured optimal scenarios, including drops, tosses, and object sliding on surfaces. The model utilizes effects of gravity, resistance, and object motion. The added complexity of object occlusion was captured for the purpose of modeling realistic difficulties in object detection and motion prediction.

Physics-Based Model

```

graph TD
    A[Frame  
Bounding box coordinates  
Class labels  
Confidence probabilities] --> B[Calculate Euclidean distances between bounding boxes of the same class]
    B --> C[Remove "camera motion" if all subjects move consistently between frames]
    C --> D[Identify the shortest distance between bounding boxes of the same class (velocity)]
    D --> E[Find the change in velocity between two pairs of frames (acceleration)]
    E --> F[For next 17 frames  
Use kinematic equations to predict locations of future bounding boxes]
    F --> G[If ground truth is close to the predicted bounding box, increase confidence probabilities]
    F --> H[If ground truth is far from the predicted bounding box, decrease confidence probabilities]
    
```

Future Plans

The proposed physics model performs with high confidence values in the ideal scenarios created within the dataset. Expectations for future improvements include higher efficiency rates, faster processing rates, greater accuracy between multiple objects, and more accurate predictions for accounted complexities such as occlusions, lighting, and camera motion.

Limitations of current model:

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

Applications:

Self-Driving	Defense Industry
Autonomous Drones	Movement Prediction

Preliminary Results



bottle
0.816



bottle
0.967



0.998



0.998

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Millimeter-Scale Magnetic Shielding

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

Purpose

Devices that rely on atomic spectroscopy (atomic clocks, NMR gyroscopes, etc) are sensitive to external magnetic fields. In order to miniaturize these devices while maintaining precision, we must enclose them in small-scale magnetic shields.

Our research serves primarily to test and fabricate potential shield designs.

Magnetic Shielding Overview

Shields created from high permeability ferromagnetic material. When an external magnetic field (B_{ext}) is applied, the previously randomly ordered dipoles align in the direction of the applied field, generating an opposing magnetic field. These fields interact, redirecting B_{ext} away from the device.

Magnetic material reaches saturation when a strong enough external magnetic field is applied that the material cannot magnetize further, decreasing effectiveness of shielding.

Shield Design

Figure 1: Chip-scale atomic clock[2].

Methods

Test Setup

Figure 4: Photo of test setup.

Fabrication

Figure 5: Visual representation of electroplating process.

Results & Discussion

COMSOL Simulations for Multilayer Cylinder

Figure 6: Visualized longitudinal and transverse views of the cylinder and the resulting magnetic field norm. Illustrates the efficiency of the design, as the magnetic field norm drastically decreases within the cylinder.

Plate vs. Cylinder Design

Figure 7: Comparison between cylindrical shield of single and multiple thicknesses of same material. As the total thickness increases, the shielding factor increases. The results prove that multilayer shields have higher shielding factors than single layer designs before saturation. The shielding factor is considerably larger for cylinders of the same thickness, inner radius, and external magnetic field.

Conclusion and Future Work

- Our simulation and test setup results imply that our multilayer, cylindrical design provides more optimal shielding than a plate design.
- COMSOL simulations compare that alternating layers of high and low permeability material produced a higher shielding factor than a single layer of the same thickness, inner radius, and material.
- By applying different magnetic fields and measuring B_{int} and B_{ext} , we found that our cylindrical design had higher shielding factors overall and that B_{int} increased at a much slower rate when increasing B_{ext} compared to the plate design.
- In the future, we plan on testing and fabricating more shields of different geometries and examining the possibility of electroplating metal directly onto devices.

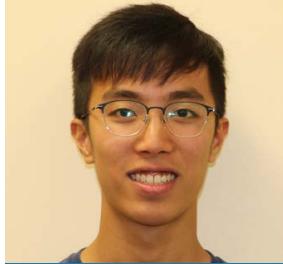
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Miniaturized magnetic shielding for chip-scale atomic devices

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

UCLA Samueli School of Engineering

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UCLA Bruin Research Institute of Higher Education and Applied Science

Miniaturized magnetic shielding for chip-scale atomic devices

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SURP 2019
Functional Nanomaterials UCLA ENGINEERING Summer Research Program

Introduction

- Atomic devices are excellent measurement tools given their well-defined quantum states.
- However, their fragility toward external interferences such as magnetic fields is a significant limitation.
- Materials with high permeability provide an alternate path for magnetic field lines to travel through.

Fig. 1: Schematic of a magnetic shield. When the shield has the same permeability as air ($\mu_r = 1$), it does not affect the magnetic field. When $\mu_r = 8000$, field lines travel along the shield instead of cutting through the shield.

Cylinder

Plate

Results

	Permalloy cylinder	Permandur plate
Max. shielding factor measured	134.2	1.25
saturation	at 6927uT EXT	Not observed

Fig. 2: Photo of setup.

Fig. 3: Close-up photo of the magnetometer.

Fig. 4: Dimensions of shields. The plate is made up of Permandur (48%+49%Co+2V) and the cylinder is made up of wax electroplated with Permalloy (80Ni+20Fe). Both iron alloys have high permeability ($\mu_r \geq 8000$).

Fig. 5: The X-Y-Z magnetic flux density mappings of two shields. Magnetometer is scanned across a horizontal plane on the shield.

Fig. 6: (Cylinder) Shielded and unshielded magnetic flux density against voltage. It is apparent that the shielded flux density is lower than the unshielded flux density as voltage increases.

Fig. 7: (Plate) Shielded and unshielded magnetic flux density against voltage. Both are linear as voltage increases.

Fig. 8: (Cylinder) Shielded against external magnetic flux density. The effect of saturation is noticeable after 7500T external flux density where the shielding factor peaks.

Fig. 9: (Plate) Shielded against external magnetic flux density. No apparent effects of saturation are observed. However, the overall shielding factor is considerably lower than the cylinder's.

Fig. 10: Unshielded Magnetic Flux Density (G)

Fig. 11: (Plate) Shielded against unshielded magnetic flux density using Permalloy plate. Linearity is observed between the shielded and unshielded flux densities.

Discussion

- Saturation effects are apparent for the Permalloy cylinder after 10000uT EXT in figure 10 where the plot loses linearity. This is confirmed by a previous work.¹ The decrease of shielding factor after 7500uT EXT in figure 8 also suggests for saturation. This is consistent with another previous work.² The saturation point in the table above is the point at which the shielding factor is the highest.
- Based on the x-y-z mappings, the Permalloy cylinder is able to attenuate the magnetic flux density more effectively than the shielded region in both x, y and z directions. This is consistent with the results of our COMSOL simulations.

Fig. 12: COMSOL simulations of the shielding effects of the Permalloy cylinder. Permeability (μ_r) is set to 8000. The deep blue area of the cylinder's interior shows that the magnetic field is attenuated as one moves away from the center.

- However, the Permandur plate manifested poor shielding abilities relative to the Permalloy cylinder. This is partly due to the fact that Permandur has a lower permeability than Permalloy. The lower permeability could have contributed to their shielding capabilities as well. The plate seems to attenuate the magnetic field symmetrically in one direction yet nonuniformly across different directions.

Conclusion

- The Permalloy cylinder has a higher maximum shielding factor than the Permandur plate.
- Saturation is observed for the cylinder but not for the plate.
- Cylindrical shape is a more effective design.

Acknowledgements

OSTL MESA

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