Upsilon Lab *Winter 2020 Quarterly Report*

an Official UCLA Physics & Astronomy Department Sponsored Organization

Prepared by Emma Peavler, President & Alexander Tolstov, President

"A lab for undergraduates, by undergraduates."

Mission

The mission of Upsilon Lab is to provide undergraduate students in the UCLA Physics & Astronomy department the opportunity to learn valuable skills to succeed in their future endeavors, whether in research, engineering, or other fields.

Quarter Highlights

- Seven active projects with thirty-one active members. Read about their progress on **pages 4-10**.
- All projects will continue into Winter 2020, along with one new project. Interested in applying? Read more on **page 11**.
- We received a small grant from the Physics & Astronomy Department for our in-house projects.
- We expect to continue adding new members, aiming to include approximately 10% of the Physics and Astronomy Department students
- Contact us through our website! **upsilonlab.org**

Winter 2020 Summary

Upsilon Lab continued its third year at UCLA under the leadership of **Emma Peavler** and **Alexander Tolstov**.

There are seven active projects, each led by at least one outstanding student manager. The seven Upsilon Lab teams consist of thirty one undergraduate members. Upsilon Lab is also introducing one new project and manager for the Spring 2020 quarter.

In the face of COVID-19, we are implementing changes to ensure that our members and managers can continue to teach and learn, but do so in a safe environment. Managers will be conducting group meetings via Zoom or a similar online platform, and all experimental work has been halted. We only have one heavily experimental project, so we will work to ensure that this group can continue to learn valuable research skills despite being unable to work in-person. The rest of our groups focus on computational methods, so we hope that the transition to online meetings will go smoothly.

This quarter's active projects and managers are listed below. More information is included later in the report, on the respective project pages.

Active Projects

Advisory Board

The 2019-2020 Advisory Board is composed of two Department professors:

Prof. David Saltzberg, Chair

Prof. Chris Regan

We would like to profusely thank the Advisory Board for their help and advice throughout the quarter, and their continued support throughout the year.

Waves and Waveguides: From Optics to Oceans

In-House

Managed by Jared Rivera **Contact: jaredrivera2314@gmail.com**

Project Description

Wave motion is pervasive in Physics and Astronomy, so being comfortable with the phenomena as well as its mathematical description is necessary for meaningful understanding of many physical processes. In this project we will investigate multiple types of waves in free space as well as in boundary-condition-enforced geometries (waveguides) through analytic math, numerical solutions, and simulations. We'll look at applications from the theory of wave optics to practical aspects of hydrology.

Quarter Project Highlights

This quarter we split into two main groups for our wave visualization software: the physics engine team and the graphics engine team. The physics engine team worked on numerical solutions for electromagnetic waves and quantum mechanic wavefunctions incident upon interesting boundaries and potentials. Graphics worked on integrating the physics engines into an attractive and functional user interface, where users input initial conditions on sliders and visualize the resulting physics in animations. The wave software effort will continue into the testing and documentation phase in the Spring quarter, with the addition of a new member.

We also began working on prepping an experimental project based around electronic oscillators. The goal would be to power a Geiger tube and take radiation count measurements to do a hands-on study of Poissonian statistics, since that is not covered in depth in the undergrad curriculum. However, once planning for the project and working through the necessary theoretical backgrounds started, COVID-19 forced campus closure and we had to shut down the experimental efforts.

Quarter Membership Roster

Cole Lorch

Katelyn Olson

Veronica Guo

Jagrit Digani

Ruiyao Liu

Modeling Quantum Systems With Machine Learning (Advanced)

In-House

Managed by Joshua Wong **Contact: jolwong@ucla.edu**

Project Description

The study of electrons has driven many important physical discoveries. Due to the large amount of forces acting on an electron within a molecule, it has become extremely complicated to create a wave function solution. As such it has become important to be able to model electron wave functions computationally. This project focuses on attempting to create a model for the complicated electron wave functions through the use of machine learning.

Quarter Project Highlights

A significant portion of the project members finished building their iris identification algorithm. The iris problem involved developing an algorithm to "visually" identify objects, similar to the facial recognition features in phones.

We plan on expanding the project team by taking in some of the Novice ML group members, and assessing member interest in what new project(s) to pursue for the Spring 2020 Quarter. The group plans on working on beginning to create a Schrödinger solver algorithm.

We will be taking in some members who have recently finished their Novice ML group, and we will assess what project(s) our members are interesting in pursuing next quarter. We will most likely have the majority of the class beginning on the Schrödinger solver algorithm, while some may be wrapping up the iris problem.

Quarter Membership Roster

Casey Mordini-Bluhm

Caroline von Raesfeld

Atharva Kulkarni

Modeling Quantum Systems With Machine Learning (Novice)

In-House

Managed by Zooey Nguyen and Daniel Levi-Minzi
Contacts: zooeyn@ucla.edu & dleviminzi@gmail.com

Project Description

The study of electrons has driven many important physical discoveries. Due to the large amount of forces acting on an electron within a molecule, it has become extremely complicated to create a wave function solution. As such it has become important to be able to model electron wave functions computationally. This project focuses on attempting to create a model for the complicated electron wave functions through the use of machine learning.

Quarter Project Highlights

This quarter the novice group was able to meet regularly, and as such covered more content than during fall quarter. The project covered: basic definitions/categorisations, applications in physics, basic vectorisation, linear and logistic regressions, gradient descent, multiclass classification, imbalanced dataset treatments, bias-variance tradeoff, regularisation, forward feed neural networks and backprop, as well as some extra notes on cross-validation. The group learned basic Python in Anaconda, and began a project on building a recognition algorithm for sign language.

Quarter Membership Roster

Nitya Ravi

Dory Veksler

Casey Mordini-Bluhm

Ian Ulrich

Garen Shaheideh

Kevin Purdy

Computational Methods for Physics

In-House

Managed by Suyash Kumar **Contact: suyashsep12@gmail.com**

Project Description

The project entails imparting necessary computational methods that can be fruitful to experimental endeavors and data analysis in Physics. In this light, the two key ideas covered by this year-long project are simulation theory and machine learning. Visualizations and simulations are an extremely powerful tool that help provide more context and fuller interpretations to experimental data. Besides interpretation of experimental results, developing fairly accurate predictive theoretical models is also crucial to aid experimental endeavors by providing a theoretical background against which experimental data can be compared. In this context, the recently growing field of machine learning become crucial, and can ensure that both new theoretical models as experiments designed to test them learn from previous data.

Quarter Project Highlights

This quarter's efforts were directed towards establishing a theoretical understanding of machine learning. The quarter began with necessary review of multivariable calculus (partial derivatives, gradients, and multivariable chain rule) and linear algebra (vector spaces and linear transformations). Thereafter, an introduction to foundational machine learning theory was provided. This entailed familiarizing members with problem categories of supervised and unsupervised learning, machine learning pipelines (involving training the model with previous data and judging its performance on new labelled datasets), and basic algorithms like linear regression, polynomial regression, logistic regression, and neural networks. Mathematically rigorous derivations of vectorized gradient descent for linear and logistic regression was performed, and the application ideas for these models to real-life problems was provided.

Quarter Membership Roster

Max Kroft

Sanchit Bawri

Parth Bhatnagar

Shruti Iyer

Decoding Brain Signals with Deep Learning

In-House

Managed by William Zhu **Contact: williamzhu@ucla.edu**

Project Description

Functional Magnetic Resonance Imaging (fMRI) is an imaging technique used to map neural activity in the brain by measuring blood flow. Studies have shown correlations between the visual stimuli presented to a subject and the sites of neural activity in a subject's brain. The goal of this project is to implement and train a neural network that could predict what is in a subject's visual field given fMRI data of neural activity.

Quarter Project Highlights

This quarter, the research team continued working on building the pipeline for the training data. We finished implementing the codes that retrieve data from each of the three data sources specified in the paper. The team's next step is to integrate the retrieved data into a single framework. We have started the discussion on what kind of architecture we should choose for our classification model.

The beginner's track covered more advanced types of neural net architecture, including the Long Short-Term Memory (LSTM) model and video processing models that combine convolutional neural networks (CNN) with recurrent models. We also had a mini project where people implemented their own deep learning model for classifying picture of cars and planes using the Keras API for TensorFlow.

Quarter Membership Roster

Archishman Bhattacharyaa

Lyna Dinh

Audrey Dunn

Johnson Zhou

Shenghua Zhu

```
def geturl(imageName):
    wnid = imageName[:imageName.find('_')]
    image_urls = "http://www.image-net.org/api/text/imagenet.synset.geturls?wnid=" + wnid
    url_mappings = "http://www.image-net.org/api/text/imagenet.synset.geturls.getmapping?wnid
wnid
    '''
    page = requests.get(image_urls)
    soup = BeautifulSoup(page.content, 'html.parser')
    str_soup = str(soup)
    urls = str_soup.split('\r\n')
    #print(urls[:100])
    '''
    imgName = imageName[:imageName.find('.')]
    try:
        mapping_page = requests.get(url_mappings)
    except Exception as e:
        print(e)
    mapping_soup = BeautifulSoup(mapping_page.content, 'html.parser')
    mapping_str = str(mapping_soup)

    i = mapping_str.find(imgName)
    if i == -1:
        return False
    start_index = mapping_str.find(' ', i) + 1
    end_index = mapping_str.find('\r\n', start_index)
    url = mapping_str[start_index:end_index]

    # Parse unicode string to python-safe url
    url = urllib.parse.quote(url, safe=':/')
    return url
```

Simulation for Tracking Elementary Particles

In-House

Managed by Xiaohe Shen **Contact: xiaohe.shen@yahoo.com**

Project Description

Simulation is a crucial component of physics research. It provides important information for the behavior of the object of the researcher's interest. The design of the experiments and the interpretation of the experimental data heavily relies on the accuracy of the simulation results. It is important to not only know how to choose the most ideal simulation model, but also to ensure that the models are producing valid results. In this project, we are going to explore the world of elementary particles from a theoretical perspective by learning some basic programming skills, running simulations using different models, and comparing our results with experimental or analytical ones.

Quarter Project Highlights

This quarter began with a brief review of the programming skills learned last quarter and solving practice problems to get familiar with the algorithms and pitfalls that we might encounter in our project.

We learned how to generate random sample points in a sphere, walked through the Monte Carlo Algorithms, and ended with a simulation for Compton scattering in 3D. We quickly reviewed the classical derivation of Compton scattering in 3D, then moved on to follow the derivation in "A low energy bound atomic electron Compton scattering model for Geant4". The formula presented in the paper is used in the Compton scattering models in Geant4, a simulation toolkit developed by CERN.

We derived a formula in an identical setting, but using a different approach that outlined in the paper. Next quarter we are going to compare our results with the paper.

Quarter Membership Roster

Kexin Yan

Ziyi Zeng

Yujie Wan

Kelving Nguyen

Raspberry Pi for High-Altitude Balloon Applications

In-House Project in collaboration with the Bruin Spacecraft Group

Managed by Trey Knudsen **Contact: 39knudson05@gmail.com**

Project Description

This project will have a team utilize a Raspberry Pi micro-computer in order to control a high-altitude balloon (HAB). HABs are used primarily to collect measurements of the atmosphere at varying altitudes, including near-space! This can help study the weather and climate. Modern balloons generally contain electronic equipment such as radio transmitters, cameras, or satellite navigation systems. This project will focus on developing software that can collect data from an internal measurement unit (IMU) and creating real-time methods to analyze the data. **This project is a collaboration effort with the Bruin Spacecraft Group.**

Quarter Project Highlights

This quarter faced setbacks in that the group was not able to meet much due to manager absense. Trey was touring various graduate school programs, so was not available for many meetings. This, combined with the Covid-19 outbreak caused the group to make little progress.

The group learned more about circuits. They used a breadboard to construct a circuit with a lit LED light that, when a button was pressed, would dim. The goal of this was to demonstrate how to use breadboards and teach various circuitry concepts, such as series, parallel circuits, and diodes.

Since this group is highly experimental, moving forward in the face of Covid-19 is difficult. The group plans on continuing into the Spring 2020 Quarter, but details are still being decided. We will potentially be moving to online-based simulations of breadboards to continue exploring the circuit concepts that apply to our project.

Quarter Membership Roster

Swetha Sankur

Lorraine Nicholson

Rishi Acharya

Emir Izat

Spring 2020 Projects Update

All projects listed above are currently taking members as space allows. We will also be adding two new projects within the first few weeks of the quarter. Apply through our website:
`upsilonlab.pa.ucla.edu/join-member`

Spring 2020 Goals

We would like Spring 2020 to continue on with the same enthusiasm and dedication seen from our members and managers in the previous quarters. With the restriction imposed to combat the spread of COVID-19, we will be pursuing this goal remotely. Upsilon Lab will continue to function, but all experimental work and in-person meetings have been halted. All manager meetings will be conducted via Zoom, and managers have been encouraged to use this or a similar platform for their group meetings. Most of our projects are computational/theoretical, so the hope is that they will be able to implement the transition to online operations and continue teaching and learning.

Since we will still be operational, we hope to continue attracting more active members and help them develop skills that will prepare them for internships, official research positions, and their studies. To best accomplish this, we require the help of ambitious students in the department to join the Upsilon Lab manager team so that we can continue spreading the skills and knowledge necessary to succeed in future career and research endeavours.

Adding more managers to our organization is critical for Upsilon Lab's ability to include all interested students. It is also an excellent way to hone programming skills, practice teaching, and inspire others into more advanced research positions. If you are interested in becoming an Upsilon Lab manager, please apply through our website: `upsilonlab.pa.ucla.edu/join-manager`

Spring 2020 New Projects

We are excited to announce the addition of a new project:

Laser Box Software led by our newest manager, Keqin Yan

Apply for these new and continuing projects through our website at:

Special Thanks

The Presidents would like to thank:

- The Physics & Astronomy Department for their support of Upsilon Lab.
- The Advisory Board for their invaluable advice throughout the course of the quarter.
- Chris Regan for becoming Upsilon Lab's advisor
- All of the professors who have sponsored projects in the previous quarters. Thank you for your willingness to help the department undergraduates learn about physics from a research perspective.