Faculty: Professor Lei Tian (leitian@bu.edu)
   Title: Deep learning for microscopy image analysis
   Number of students: 1-2 students
   Semester: Summer and Fall
   Expected period of the project: 1 – 2 semesters
   Project Description: The student will work a group of PhD students to develop deep learning algorithms for quantitative microscopy image analysis
   Scope of work: Deep learning algorithm development; Image / data analysis
   Required Background: Coding: Python, Tensorflow or PyTorch
   Application requirements: A CV must be submitted and applicants will be interviewed

Faculty: Professor Lei Tian (leitian@bu.edu)
   Title: Deep learning for image reconstruction
   Number of students: 1-2 students
   Semester: Summer and Fall
   Expected period of the project: 1 – 2 semesters
   Project Description: The student will work a group of PhD students to develop deep learning algorithms for image reconstruction techniques for computational microscopy
   Scope of work: Deep learning algorithm development; Image / data analysis
   Required Background: Coding: Python, Tensorflow or PyTorch
   Application requirements: A CV must be submitted and applicants will be interviewed

Faculty: Professor Luca Dal Negro (dalnegro@bu.edu)
   Title: Quantum correlation measurements of nonlinear optical nanostructures
   Semester: Summer and Fall
   Background: Materials Science, EE, Physics
   Expected period: 6 months to 1 year total with possible extension
   Brief work description: This experimental project involves testing and measuring the single-photon coincidence statistics and intensity correlation function of nonlinear nanostructures and interferometers for novel applications to quantum sensing and computing.
   Application requirements: Candidates must send a CV

Faculty: Professor Luca Dal Negro (dalnegro@bu.edu)
   Title: Quantum deep learning for electromagnetic inverse problems
   Semester: Summer and Fall
   Background: EE, CE, Physics, Materials Science
   Expected period: 6 months to 1 year total with possible extension
   Brief work description: Based on recent advances quantum deep learning, we plan to develop and test a general quantum neural network (QNN) framework for the solution of electromagnetic inverse scattering problems using variational quantum circuits. The recent field of quantum machine learning explores how to devise and implement quantum software that could enable the solution of complex inverse problems exponentially faster compared to classical computers.
   Application requirements: Candidates must send a CV
MS Project / Thesis Topics for Fall & Summer 2024
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Faculty: Professor Luca Dal Negro (dalnegro@bu.edu)
Title: Physics-driven deep learning methods for inverse design of optical nanomaterials
Semester: Summer and Fall
Background: CE, EE, Physics
Expected period: 6 months to 1 year total with possible extension
Brief work description: Using advanced deep learning approaches. We plan to design miniaturized optical devices and diffractive optical elements based on random scattering media for large-scale reservoir optical computing (RC) applications.
Application requirements: Candidates must send a CV

Faculty: Professor Luca Dal Negro (dalnegro@bu.edu)
Title: Nonlinear optical nanoantennas in the quantum regime
Semester: Summer and Fall
Background: EE, Physics, Materials Science
Expected period: 6 months to 1 year total with possible extension
Brief work description: We plan to design, fabricate, and test novel types of highly nonlinear optical nano-antennas in the quantum regime and investigate their potential to achieve quantum computing functionalities at the nanoscale.
Application requirements: Candidates must send a CV

Faculty: Professor Luca Dal Negro (dalnegro@bu.edu)
Title: White-light low-coherence interferometric study of anomalous photon transport in complex media
Semester: Summer and Fall
Background: EE, Physics, Materials Science
Expected period: 6 months to 1 year total with possible extension
Brief work description: We plan to test a state-of-the-art white-light low-coherence interferometric setup and characterize the nature of photon transport in complex scattering media with femtosecond-scale time resolution. Applications to lasing and optical sensing boosted by photon localization phenomena are anticipated as well as discovery of novel optical phenomena in the anomalous transport regime of photons.
Application requirements: Candidates must send a CV

Faculty: Professor Robert Kotiuga (prk@bu.edu)
Title: Hi-Res audio headphones
Number of students: 1-4
Semester: Summer and Fall
Project Description: This project consists of coming up with a headphone design, either in-ear or electrostatic, with flat frequency response beyond 100kHz, for the purpose of demonstrating the difference in transient detail in Hi-Res Audio (i.e. better than CD quality audio formats.) This project can leverage recent convergence between advances in hearing aid design and in-ear audiophile designs.
Application requirements: Contact faculty member
Faculty: Professor Robert Kotiuga (prk@bu.edu)
Title: Efficient hybrid solar panels for hot water
Number of students: 1-4
Semester: Summer and Fall
Project Description: Solar hot water panels can be 80% efficient, but this efficiency can only be realized with a considerable amount of storage. Photovoltaic panels are little more than 20% efficient but the electricity they produce can be stored, and later heated with a heat pump to produce on-demand hot water with a minimum of hydraulic storage. One drawback to photovoltaics is the efficiency drops with rising temperature. The idea behind a hybrid solar panel is to have a heat pump extract heat from a small solar hot water panel and use a photovoltaic panel to preheat the fluid going into solar hot water panel, increasing the efficiency of the photovoltaic panel in the process. This project will quantify the trade-offs in such a scheme, optimize the design parameters for various scenarios, and build a prototype as proof of concept.

Application requirements: Contact faculty member

Faculty: Professor Ayse Coskun (acoskun@bu.edu)
Title: A Modular Simulator for Evaluating Data Center Sustainability
Semester: Summer and Fall
Expected period of the project: 1 semester for a project
Possibility of extending to a thesis: Yes, but requires advanced discussion with Prof. Coskun.
Project Description: PeacLab directed by Prof. Coskun is working toward an open-source release of a data center power and job-scheduling simulator. The purpose of the simulator is to mimic implementation of algorithms that enable data centers to participate in a smart grid’s emerging programs such as demand response. This project involves reorganizing prototype Python 3 code into a modular design and adding a test suite to validate the correctness of simulations. The desired outcome is a simulator with separate, independently-testable modules for simulation logic, configuration code, and demand response algorithm logic, with the ultimate goal of the simulator’s easy adoption in data center demand response research. The project, if successful, has the potential to lead to one or more publications in collaboration with a PeacLab PhD student.

Application requirements: Interested students should email a CV and an informal transcript (from StudentLink) to acoskun@bu.edu and facun@bu.edu.
Desired Skills:
- Solid programming skills, preferably in developing Python 3 code
- Software development experience (e.g., during internships or other former positions)
- Experience in designing and implementing test suites (e.g., based on documentation from academic papers and in-source-code descriptions)
- Experience with using numpy, pandas, and scipy packages
- Experience with git source control
**MS Project / Thesis Topics for Fall & Summer 2024**

**4.1.24**

**Faculty:** Professor Gianluca Stringhini ([gian@bu.edu](mailto:gian@bu.edu))

- **Title:** Knowledge distillation for efficiently deploying LLM powered text classification methods.
- **Semester:** Summer and Fall
- **Expected period of the project:** 1-2 semesters
- **Description:** Despite the effectiveness of Large Language Models on performing new tasks on the fly with very limited supervision, a major bottleneck to their wide-spread deployment and adoption is the large amount of computational resources needed to run these models. Open source LLMs on the higher-end of the spectrum like Llama-2 and FLAN-T5 are not practically feasible to run, even for the purposes of inference without dedicated GPU resources. To alleviate this problem, fine-tuned LLMs can be distilled for task-specific purposes, where a smaller sized student model is trained from a larger teacher model to retain similar performance for a particular task in hand. This can be particularly useful in real-time systems, with an inherent requirement to be able to keep up with the large amount of requests and provide detection in a timely fashion. While distilling encoder only models such as BERT has been thoroughly investigated, and successfully adopted through distillation of BERT to DistilBERT, distilling generative methods like LLMs is a relatively under-explored area of study. The best recipes to follow for distilling encoder-decoder models for text classification tasks is still unclear. This project aims to explore the different strategies of distilling an encoder-decoder model such as direct knowledge distillation, distillation through pseudo-labelling, and “shrink and fine-tune (SFT)” approach for textual deviation detection. We will also benchmark the performance tradeoff in distilled models with respect to resource requirements (GPU memory of distilled models), inference time, and other factors.

**Application requirements:** Interested students should email a CV to [gian@bu.edu](mailto:gian@bu.edu) and [ppaudel@bu.edu](mailto:ppaudel@bu.edu)

**Required background:** Prior experience in: (1) deep-learning, (2) PyTorch, (3) Transformers, (4) GPU training

**Faculty:** Professor Thomas Little ([tdcl@bu.edu](mailto:tdcl@bu.edu))

- **Title:** Topics in Indoor Positioning
- **Project Description:** We are interested in indoor positioning with variable levels of accuracy depending on context. Available tools include the use of mobile phones, IoT devices, robots, fixed anchors, and benchmark optical tracking. We want a device to be able to (a) localize itself, (b) localize other devices, (c) localize objects within a space. Research includes developing analytical models for different use cases, prototyping, evaluation, and demonstration in wireless testbed.

- **Number of students:** 1-2
- **Semester:** Summer and Fall
- **Background:** Embedded systems, software, signal processing.
- **Expected Time:** 1-2 semesters
- **Possibility of Extending to a Thesis:** yes
- **Application requirements:** A CV should be provided along with a statement of interest.
Faculty: Professor Michelle Sander (msander@bu.edu)
Title: Photothermal microscopy of biological samples with a novel mid-infrared photothermal microscope
Description: The aim is to characterize various biological samples and identify protein and lipid structures.
Semester: Summer and Fall
Required Background: EE, Physics, Materials Science
Expected period of the project: 1 semester or longer
Possibility of Extending to a Thesis: yes
Application Requirements: Please send a CV and unofficial transcript to msander@bu.edu

Faculty: Professor Michelle Sander (msander@bu.edu)
Title: Numerical evaluation of ultrashort pulse generation
Description: The aim is to modify existing pulse propagation simulations to identify under what conditions stable ultrafast pulses with varying characteristics can be generated
Semester: Summer and Fall
Required Background: EE, Physics, Materials Science, expertise in Matlab/programming
Expected period of the project: 1 semester or longer
Possibility of Extending to a Thesis: yes
Application Requirements: Please send a CV and unofficial transcript to msander@bu.edu

Faculty: Professor Eshed Ohn-Bar (eohnbar@bu.edu)
Title: Adapting Large Vision and Language Models for Real-World Systems
Project Description: The goal of this project is to explore the usability of multimodal large language models for robotics and intelligent systems, such as autonomous vehicles and assistive technologies. Students will work with a PhD student.
Semester: Summer and Fall
Desired Background: Programming (Python, PyTorch), machine learning, graphics
Expected Time: 1-2 semesters
Application requirements: CV and an Academic Transcript

Faculty: Professor Eshed Ohn-Bar (eohnbar@bu.edu)
Title: Expressive 3D Perception and Reinforcement Learning for Self-Driving
Project Description: Students will work with a PhD student on state-of-the-art models for navigation. The goal of this project is to add new modules for a high-fidelity simulation related to 3D computer vision, and use the improved 3D reasoning to develop effective models for navigational decision-making.
Semester: Summer and Fall
Desired Background: Programming (Python, PyTorch), machine learning, graphics
Expected Time: 1-2 semesters
Application requirements: CV and an Academic Transcript
Faculty: Professor Eshed Ohn-Bar (eohnbar@bu.edu)
Title: Low-cost and Resource-constrained Assistive Systems
Project Description: Students will develop novel low-cost design and models for efficient assistive and robotic systems, the project is a collaboration with Red Hat Research.
Semester: Summer and Fall
Desired Background: Programming (Python, PyTorch), machine learning, graphics
Expected Time: 1-2 semesters
Application requirements: CV and an Academic Transcript

Faculty: Professor Tianyu Wang (wangty@bu.edu)
Project Description: The student will work with PhD students to train optical neural networks for image sensing tasks for high-throughput biomedical assays. The student will learn how to computationally model optical diffraction, how to use a spatial light modulator and train it to perform neural-network computation, and how to construct an optical neural network for image sensing.
Semester: Summer and Fall
Number of students: 1-2 students
Expected period: Summer and Fall with the possibility of extension.
Extendable to a thesis: Yes
Desired Background: Python coding; machine learning by Pytorch; experimental experience with lasers and optical imaging is a plus; experience with cell culture is also a plus; optical system design with Zemax or Code V is a plus.
Application requirements: CV, academic transcript, and meeting with the faculty advisor.

Faculty: Professor Tianyu Wang (wangty@bu.edu)
Project Description: The student will work with PhD students to construct optical neural networks on a silicon photonic chip. The student will acquire hands-on experience on integrated photonics and explore state-of-the-art training algorithms for machine learning.
Semester: Summer and Fall
Number of students: 1-2 students
Expected period: Summer and Fall with the possibility of extension.
Extendable to a thesis: Yes
Desired Background: Python coding; machine learning by Pytorch; experience with FPGA is a plus; experimental experience with optical waveguides and laser is a plus; waveguide modeling with Lumerical is a plus; experience with distributed training with multiple GPUs is a plus.
Application requirements: CV, academic transcript, and meeting with the faculty advisor.
Faculty: Professor Janusz Konrad (jkonrad@bu.edu)

Title: People detection and tracking using embedded overhead fisheye camera

Number of students: 1  
Semester: Summer and Fall  
Expected period of the project: 1 – 2 semesters

Project Description: The goal of the project is to demonstrate the capability of a prototype fisheye camera mounted on a ceiling to detect, and potentially track, people in a room. This camera was developed in VIP lab (vip.bu.edu) and uses Sony IMX219 image sensor for image capture and Nvidia Jetson Nano embedded GPU for inference. The basic functionality of the camera has been verified but its capability to perform advanced visual analysis of a scene with people has not. The project activities will consist of implementation of deep-learning methods to perform people detection, tracking, action recognition, etc. on Jetson Nano. While the development of new methods would be welcome, porting and fine-tuning (to overhead fisheye images) of existing algorithms is sufficient.

Required background: Prior experience in: (1) development of deep-learning algorithms for image inference in PyTorch; (2) embedded computing, ideally familiarity with Jetson Nano

Application requirements: CV and interview

Faculty: Professor Janusz Konrad (jkonrad@bu.edu)

Title: Room clutter classification using deep learning and generative AI

Number of students: 1  
Semester: Summer and Fall  
Expected period of the project: 1 – 2 semesters

Project Description: The goal is to classify clutter in a room (such as bedroom, living room, kitchen, bathroom) from images. Room clutter is one of the manifestations of the Hoarding Disorder (HD) - excessive collection of items in living space that might prevent daily activities (e.g., cooking, bathing) and can be a significant hazard (e.g., fire, infestation). Recently, a numerical scale, called Clutter Image Rating (CIR), was developed to formalize assessment of clutter: CIR=1 corresponds to a very tidy room, whereas CIR=9 corresponds to a fully-cluttered room where it is almost impossible to move. To date, we have collected over 1,200 images of room clutter from online resources and have developed learning-based algorithms to estimate CIR by the following approaches: Histogram of Gradients (HOG) combined with SVM classification, ResNet18 with single/multi-class loss, and a method based on the Visual-Transformer (ViT). With each new method we have improved the classification accuracy, but the key obstacle is data scarcity. Our most recent effort is to expand our dataset by using generative AI tools, in particular DALLE-2 and DALLE-3 combined with ChatGPT-4. The main objectives in this project are to continue expansion of the dataset and develop new clutter-classification algorithms.

Required background: Prior experience with deep-learning algorithms

Application requirements: CV and interview
Faculty: Professor Roberto Paiella (rpaiella@bu.edu), Professor Janusz Konrad (jkonrad@bu.edu), and Professor Lei Tian (leitian@bu.edu)

Title: Image classification and reconstruction with directional image sensors

Project Description: The goal of the project is to demonstrate basic image classification and reconstruction tasks using convolutional neural networks (CNNs) combined with pixel arrays of specially designed directional image sensors. These devices have been developed in our lab based on a new type of photonic nanostructures, and their experimental characteristics will be made available for use in the project. The project activities will consist of numerical simulations involving various data sets for object recognition and image reconstruction.

Number of students: 1
Semester: Summer and Fall
Expected period of the project: 1-2 semesters
Possibility of extending to a thesis: Yes.

Required background: Prior experience in developing deep learning algorithms in TensorFlow / PyTorch, as well as very basic knowledge of optics and imaging systems

Application requirements: CV and interview

Faculty: Professor James Galagan (jgalag@bu.edu)

Title: Neural Network Framework for Analyzing Genomic Data

Project Description: The student will gain valuable first-hand experience with both the practical coding and theoretical aspects of machine learning and neural networks. The project also has a very high potential for one or more independent publications.

Semester: Summer and Fall

Number of students: 1 - 2

Desired Background: The work requires strong Python coding skills, and experience with tensorflow is highly desirable. Also desired, but not required, are experience working in a shared code environment and basic familiarity with SQL.

Application requirements: CV and an Academic Transcript

Note: This project is not with an ECE faculty member, in order to complete this as an MS project or thesis course you will need to find an ECE faculty member to co-advertise you