Vertically Integrated Projects (VIP) Program

Informational Packet

Fall Quarter 2021-2022

Thank you for your interest in the Vertically Integrated Projects (VIP) Program at Drexel University!

VIP team members work as part of a multidisciplinary group of undergraduate students, graduate students, research staff, and faculty members to tackle novel research and design problems around a theme. Undergraduate students that join VIP teams earn academic credit for their participation in design/discovery efforts that assist faculty and graduate students with research and development issues in their areas of expertise.

VIP teams are:

- Multidisciplinary - drawing students from all disciplines on campus;
- Vertically-integrated - maintaining a mix of freshman through PhD students each academic term;
- Long-term - each undergraduate student may participate in a project for up to three years and each graduate student may participate for the duration of their graduate career.

The continuity, technical depth, and disciplinary breadth of these teams are intended to:

- Provide the time and context necessary for students to learn and practice many different professional skills, make substantial technical contributions to the team project(s), and experience many different roles on a large, multidisciplinary design/discovery team.
- Support long-term interaction between the graduate and undergraduate students on the team. The graduate students mentor the undergraduates as they work on the design/discovery projects embedded in the graduate students' research.
- Enable the completion of large-scale design/discovery projects that are of significant benefit to faculty members' research programs.

In the following pages you will find descriptions of the following VIP teams that are recruiting for the Fall Quarter of the 2021-2022 academic year:

- Applications, Algorithms, & Architecture for Neuromorphic Computing
- Cognitive Neuroengineering for the Brain and Mind
- Deep Learning Based Optical Flow Estimation
- Machine Learning Algorithms for Sleep Scoring
- Measuring Air Quality with Kite-Based Sensors
- Robotic Sensing in Indoor Environments
- The Future of Power and Energy
- Wireless Systems for the Internet of Things

In order to participate in VIP, you must formally apply and be accepted to a specific team. To apply, please log into ForagerOne (www.drexel.edu/foragerone) and search for “VIP”. This will bring up all available open positions tagged as VIP projects. When submitting an application, please be sure to have uploaded an updated résumé to your ForagerOne profile and to include a statement regarding why you are interested in working on the team to which you are applying.

Please note that VIP team participation requires registration for the accompanying VIP course section. The number of credits required per quarter is flexible and will be determined on a case-by-case basis in consultation with the team's faculty mentor and a student's academic advisor; however, most VIP team members will register for a single credit per quarter. Long-term, sustained participation in the program (three or more quarters of working on a single team) is strongly encouraged and may be required in order for earned VIP credits to count towards degree requirements. More information will be provided to all applicants that are offered a position.

Should you have any questions about a particular team, please feel free to reach out to the team's faculty mentor. Any questions regarding the VIP program in general should be sent to Chad Morris via email at cam83@drexel.edu

We hope you'll take the time to consider this compelling new opportunity. We look forward to receiving your application!

Applications, Algorithms, & Architecture for Neuromorphic Computing

Dr. Anup Das (ECE) – Faculty Mentor

GOALS

Machine learning methods such as neural networks have been successfully used in real-time computer vision and signal processing areas. Neuromorphic systems, which mimic biological neurons and synapses, can be used to implement these neural networks in energy-constrained computing platforms. The goal of this VIP project will be to facilitate the development of novel applications, new machine learning algorithms, and energy efficient computing architectures for executing machine learning tasks in hardware, commonly referred to as neuromorphic computing.

METHODS & TECHNOLOGIES

This project will use conventional machine learning tools such as TensorFlow and Theano to develop new applications and explore their performance trade-offs. The project will also use spiking neural networks simulator such as CARLsim, Brian, and Neuron. One of the methodologies we will adopt is to use recurrent neural networks architectures to process time series data. Familiarity with LSTM and Reservoir Computing will be beneficial for the project. On the hardware side, the project will investigate new architectures, especially focusing on the use of non-volatile memories to implement these machine learning tasks. Familiarity with conventional von Neumann computer architecture as well as crossbar-based neuromorphic architectures will be helpful.

RESEARCH, DESIGN, & TECHNICAL ISSUES

We will address the following challenges:

- Design of recurrent machine learning architectures for sleep apnea classification and video segmentation, using analog, rate, and spike models
- Design of unsupervised approaches to anomaly detection, example in reference to abnormal heart-beats, a pre-processing step towards arrhythmia detection. Another example is the predictive visual pursuit.
- Design of new algorithms that enhance the capability for existing algorithms, such as spike-timing dependent plasticity, Force, etc.
- Develop compiler tool chains to translate a user's machine learning program to low-level languages that can be interpreted by neuromorphic systems.
- Develop Operating System like framework that will allow programmers to easily deploy their machine learning programs on neuromorphic systems.

MAJORS & AREAS OF INTERESTS

This VIP team is interested in recruiting both undergraduate and graduate students from the following majors and/or with a background and interest in the areas listed below.

- Electrical & Computer Engineering – computer architecture, signal processing, machine learning
- Computer Science – machine learning, game design and visualization, data science, software
- Sociology – human factors, technology adoption
- Business – business analytics, marketing, decision sciences
- Economics – smart CRM; customer experience; optimization of employee, inventory, and store layouts

MENTOR CONTACT INFORMATION

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Distributed, Intelligent, and Scalable Computing (DISCO) Lab

PARTNERS & SPONSORS

IMEC Netherlands, UC Irvine, ETH Zurich

Cognitive Neuroengineering for the Brain and Mind

Drs. John Medaglia (PSY) & Gary Friedman (ECE) – Faculty Mentors

GOALS

This team seeks to map and model the brain's neural networks to guide personalized treatments. There will be a particular focus on treatments that employ transcranial stimulation with magnetic and electric fields.

METHODS & TECHNOLOGIES

Computer-guided behavioral testing of humans, EEG (electro-encephalography), MRI (magnetic resonance imaging), transcranial magnetic stimulation (TMS), transcranial direct current stimulation (TDCS), statistical data analysis, neural network models

RESEARCH, DESIGN, & TECHNICAL ISSUES

Undergraduate team members will help design, implement, and analyze new computerized behavioral tests that measure mental flexibility, motivation, and decision making. They will work to correlate behavioral, MRI, and EEG signals and help develop new protocols to applying transcranial magnetic and direct current stimulations that could result in long-term brain and cognitive improvements. Undergraduate team members will also help model the brain's neural networks that are likely to be involved in the behavioral tasks under consideration.

MAJORS & AREAS OF INTEREST

This VIP team is interested in recruiting both undergraduate and graduate students from the following majors and/or with a background and interest in the areas listed below.

- Electrical Engineering - EEG and MRI signal detection and processing, modeling of field penetration into the brain, neural network models, statistical signal processing
- Computer Engineering - software for behavioral tests, implementation of testing protocols over internet, neural network modeling, statistical signal processing
- Psychology - development of behavioral tests, interpretation of EEG data, development of TMS and TDCS protocols, neural network modeling
- Biomedical Engineering - EEG and MRI signal detection and processing, modeling of field penetration into the brain, neural network models, statistical signal processing
- Computer Science - software for behavioral tests, implementation of testing protocols over internet, neural network modeling, statistical signal processing

MENTOR CONTACT INFORMATION

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Professional Profile

PARTNERS & SPONSORS

None

Deep Learning Based Optical Flow Estimation

Dr. Anup Das (ECE) – Faculty Mentor

GOALS

Optical flow or optic flow is the pattern of apparent motion of objects, surfaces, and edges in a visual scene caused by the relative motion between an observer and a scene. Optical flow can also be defined as the distribution of apparent velocities of movement of brightness pattern in an image. [Source: Wikipedia]

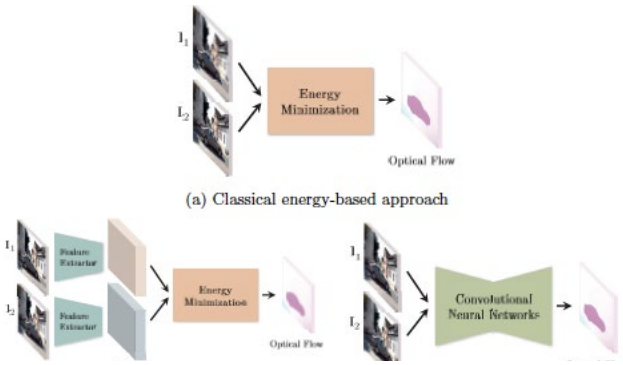

Figure 1: Comparing Classical approach vs. using CNN for optical flow estimation. (Source: Hur et al., arXiv 2020)

As in many subareas of computer vision, recent advances in deep learning have also significantly influenced the field of optical flow. The following figure shows the difference between a classical energy-based optical flow estimation, and that using deep learning approaches such as the convolutional neural networks (CNNs).

To this end, researchers have proposed FlowNet (https://github.com/NVIDIA/flownet2-pytorch) is the first work that demonstrated an end-to-end CNN regression approach for estimating optical flow based on an encoder-decoder architecture.

The Drexel's Distributed, Intelligent, and Scalable COmputing (DISCO) lab is looking for VIP student engineers to develop deep learning techniques for optical flow estimation. This is a joint project between Drexel University and Imec, Leuven. The VIP students are expected to explore conventional and non-conventional machine learning algorithms using to enable optical flow estimation. The work will also involve data preprocessing, feature, extraction, as well as building new learning architectures. The VIP students are expected to work with professors, post-docs, and phd students. The student will have weekly meeting with the entire team to discuss progress. There will be opportunity for publications at top machine learning venues.

METHODS & TECHNOLOGIES

This project will use conventional machine learning tools such as Keras and PyTorch to develop baseline optical flow estimation. Students will work on fine-tuning the model hyper-parameters, such as convolution layers, kernel size, etc. The project will also use two non-conventional approaches, such as that using unsupervised machine learning and spiking neural networks (SNN) to design optical flow estimation. To this end, students will SNN simulators such as Brian, and Neuron to train SNNs. Finally, students will work on mapping the SNN onto to neuromorphic hardware, using tools developed in the DISCO lab.

RESEARCH, DESIGN, & TECHNICAL ISSUES

This team will address the following challenges:

- Design of machine learning architectures for optical flow, using analog, rate, and spike models.
- Model hyper parameter tuning and exploration of the search space using greedy heuristics.
- Design of new spiking algorithms that enhance the performance for optical flow.
- Mapping spiking-based models of optical flow to neuromorphic hardware

MAJORS & AREAS OF INTERESTS

This VIP team is interested in recruiting both undergraduate and graduate students from the following majors and/or with a background and interest in the areas listed below.

- Electrical & Computer Engineering –signal processing and machine learning
- Computer Science – machine learning, data science, software

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PARTNERS & SPONSORS

IMEC Netherlands, KU Leuven

Machine Learning Algorithms for Sleep Scoring

Dr. Anup Das (ECE) – Faculty Mentor

GOALS

Machine learning methods such as neural networks have been successfully used in real-time computer vision and signal processing areas. Drexel's Distributed, Intelligent, and Scalable COmputing (DISCO) lab is looking for VIP team members to develop machine learning techniques for sleep stage classification. This is a joint project between Drexel University and Penn Medicine. VIP team members are expected to design machine learning algorithms using convolution neural networks (CNNs) and long-short-term memory (LSTM), among others, to classify sleep stages of subjects. The work will involve applying data preprocessing techniques such as fast-Fourier Transforms, and other time-frequency joint distribution to over 1TB of sleep data collected till date. The student will perform feature extraction as well as build new machine learning approaches involving spiking neural networks. Team members are expected to work with professor Das and his doctoral students at Drexel and sleep doctors from Penn Medicine. VIP team members will have weekly meeting with the entire project team to discuss progress. There will be opportunities for publications at top machine learning venues.

METHODS & TECHNOLOGIES

This project will use conventional machine learning tools such as Keras and PyTorch to develop baseline classification algorithm using EEG signal from the brain. The project will involve working with the sleep doctors at Penn Medicine to understand the scoring mechanism and implement the same for automatic scoring. The auto scorer will be compared against machine learning approaches that will be developed during the project. The objective will be to train the machine learning model to achieve similar or comparable accuracy as the auto scorer. The project will also use spiking neural networks (SNN) simulators such as CARLsim, Brian, and Neuron to develop the spiking version of the algorithms developed.

RESEARCH, DESIGN, & TECHNICAL ISSUES

We will address the following challenges:

- Translating auto-scoring specifications to computer software.
- Design of machine learning architectures for sleep scoring, using analog, rate, and spike models.
- Model hyper parameter tuning and exploration of the search space using greedy heuristics.
- Design of new spiking algorithms that enhance the performance for sleep classification.
- Mapping spiking-based models to neuromorphic hardware.

MAJORS & AREAS OF INTERESTS

This VIP team is interested in recruiting both undergraduate and graduate students from the following majors and/or with a background and interest in the areas listed below.

- Biomedical Engineering
- Electrical & Computer Engineering –signal processing, machine learning
- Computer Science –machine learning, game design and visualization, data science, software

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PARTNERS & SPONSORS

Penn Medicine

Measuring Air Quality with Kite-Based Sensors

Dr. Richard Cairncross (CBE) – Faculty Mentor

GOALS

The goal of this team is to demonstrate the use of kites to perform environmental monitoring and evaluate their advantages and disadvantages over current solutions including manned aircraft, drones, and weather balloons. The team will implement flight control of multi-line stunt or traction kites that allows maneuvering the kite within a three-dimensional wind window and enables mapping measurements of air quality.

METHODS & TECHNOLOGIES

Data acquisition, wireless communication, location tracking, air quality sensors, air sampling systems, environmental science, power management, mechanical design, motor control, tension measurement, flight dynamics, flight control, aerodynamics, software design, systems analysis

RESEARCH, DESIGN, & TECHNICAL ISSUES

The proposed kite-based environmental monitoring and mapping system includes several sub-systems that all need to be designed to function for integration into the system. The lifting sub-system in the kite provides lift; the use of stunt kites also enables maneuvering within a three-dimensional wind window downwind of the anchor point. The flight control sub-system modifies tension on multiple lines and controls both the kite orientation and location. An “Evans Loop” ground tether involving two motors on the ground enables deploying a kite to achieve stable flight, and later lifting a sensor platform or air sampling system. The aerodynamically-stabilized sensor platform houses microprocessors to collect data from multiple lightweight sensors. The air sampling sub-system suspends an air sampling tube from the kite tether and then pumps air to equipment on the ground.

MAJORS & AREAS OF INTEREST

This VIP team is interested in recruiting both undergraduate and graduate students from the following majors and/or with a background and interest in the areas listed below.

- Environmental Engineering - air quality metrics, sensors, sampling techniques, fluid (air) mechanics, data analysis, dispersion of pollutants in the environment
- Mechanical Engineering - aerodynamics, mechanical behavior of materials, mechanical design, structures, motors, robotics
- Electrical & Computer Engineering - wireless communication, power management, renewable energy (wind/solar), control systems, data management
- Computer Science - structure from motion video analysis, synchronization of data-logging with video and GPS measurements, display of data
- Biology & Environmental Science - air quality metrics, dispersion of pollutants in the environment, volcanology
- Sociology - public perception of technology
- Public Policy - evaluation of decision-making processes for environmental regulations, the use of data to inform public debates

MENTOR CONTACT INFORMATION

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PARTNERS & SPONSORS

Collaborator: Geoff Bland (NASA/Goddard Space Flight Center)
Funding received from the EPA People, Prosperity and the Planet (P3) Program

Robotic Sensing in Indoor Environments

Dr. James Lo (CAEE) – Faculty Mentor

GOALS

The goal of this team is to implement hardware/software developments related to the autonomous robotic platform which will host a variety of sensing package for indoor environmental quality.

METHODS & TECHNOLOGIES

Hardware development, software design, signal processing, data acquisition and analytics, building physics

RESEARCH, DESIGN, & TECHNICAL ISSUES

Indoor environmental sensing traditionally has been hampered by high cost in installation and power requirements. By integrating sensing packages with autonomous vehicles (both land and air vehicles), a novel approach of data acquisition without wired installation can be realized; however, both the robotic platform and sensor package still face key challenges when considering them as tools for both building designers and engineers. Therefore, research in this VIP section will be separated into two areas: 1) extension of current robotic platform capability for indoor navigation and deployment and 2) improvement of wireless sensor packages for a wide range of data acquisition. Design of customized robotic vehicles and hands-on experience will be an integral part of this team, as well as building various sensor modules for indoor environmental parameters. An additional objective will be the post-processing of data obtained by sensors as a means for further development of indoor sensing strategies.

MAJORS & AREAS OF INTERESTS

This VIP team is interested in recruiting sophomore to pre-junior undergraduate students to be part of the following three areas.

- Rover development - some background on rover and ROS, some hardware skills (pin connection, soldering, etc)
- Drone development - software development in Python and TCP/IP socket programming
- Sensor development - Arduino programming and hardware skills

MENTOR CONTACT INFORMATION

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Building Science and Engineering Group

PARTNERS & SPONSORS

National Institute of Standards and Technology - Energy and Environment Division

The Future of Power and Energy

Dr. Fei Lu (ECE) – Faculty Mentor

GOALS

The goal of this team is to acquire the theoretical knowledge and hand-on skills in electrical power and energy needed to affect the future of the field. Undergraduate team members will be trained in both fundamental and advanced technologies in power electronics; moreover, together with the graduate team members, undergraduate team members will investigate cutting-edge research topics in electrical power and energy.

METHODS & TECHNOLOGIES

Power electronics circuit design, three-dimension electromagnetic fields simulation, finite element analysis (FEA), thermal design, intelligence design, connected and automated vehicles, electric vehicles, autonomous driving

RESEARCH, DESIGN, & TECHNICAL ISSUES

Modern power electronics system design aimed at addressing problems in the future power and energy need to be highly efficient, compact in size, low cost, reliable, and operate intelligently. To achieve these features, team research will chiefly move in two directions: 1) circuit hardware design, including the notable circuit topology of power conversion; and 2) system management design, including algorithms for controlling predesigned circuits.

MAJORS & AREAS OF INTEREST

This VIP team is interested in recruiting both undergraduate and graduate students from the following majors and/or with a background and interest in the areas listed below.

- Electrical & Computer Engineering - power electronics, power system, motor driving, circuit simulation, finite element analysis, electromagnetic field analysis, experimental experience
- Mechanical Engineering - electromechanical system design, thermal design, structure design, computer aid design (CAD) software experience
- Computer Science - software development, embedded system programming
- Materials Science & Engineering - magnetic material analysis, dielectric material analysis
- Chemical Engineering - electrochemical analysis, power battery design and analysis

MENTOR CONTACT INFORMATION

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Professional Profile

PARTNERS & SPONSORS

None

Wireless Systems for the Internet of Things

Dr. Kapil Dandekar (ECE) – Faculty Mentor

GOALS

The future Internet of Things (IoT) will consist of a large number of wireless devices and sensors with profound implications for the economy and society. The Drexel Wireless Systems Lab (DWSL) is focused on developing new experimental wireless transceivers and sensors for future IoT networks. These systems require a wide variety of protocols (wireless local area networks, radio frequency identification, Zigbee, Low-power wide area networks, real-time localization systems, etc.) which can be implemented using flexible software defined radios (SDR) in DWSL. Target applications include: applications of radio frequency identification (RFID), wearable transceivers for biomedical sensing, smart grid and smart city infrastructure, effective omni-channel retailing, real-time localization, collaborative intelligent radio networks.

METHODS & TECHNOLOGIES

Software defined radio, wireless communications and networking, signal processing, machine learning, antenna and wireless transceiver design, augmented reality, cybersecurity, unmanned aerial vehicles

RESEARCH, DESIGN, & TECHNICAL ISSUES

Using RFID and sensors for biomedical sensing and real-time localization, wireless networks and sensors for smart infrastructure applications enabling a smart and connected omni-channel approach in retail environments, software defined radio for collaborative intelligent radio design, research and education with competition-based radio networks, cybersecurity for wireless networks, unmanned aerial vehicle communications and sensing

MAJORS & AREAS OF INTEREST

This VIP team is interested in recruiting both undergraduate and graduate students from the following majors and/or with a background and interest in the areas listed below.

- Electrical & Computer Engineering - wireless communications and networks, signal processing, machine learning
- Computer Science - software defined radio, machine learning, game design and visualization, cybersecurity
- Sociology - human factors and technology adoption
- Business - business analytics, marketing, decision sciences
- Economics - smart CRM; customer experience; and optimization of employee, inventory, and store layouts

MENTOR CONTACT INFORMATION

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PARTNERS & SPONSORS

Currently in discussions with Comcast machineQ, Impinj, and Centrak