Avisha Kumar

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Research Interests

Machine Learning, Neural Operators, Computational Physiology, Neuroengineering, Neuromorphic Computing

Education

Johns Hopkins University Whiting School of Engineering — Baltimore, MD
Ph.D., Electrical and Computer Engineering — Aug 2021 - May 2025
Primary Advisors: Nicholas Theodore, Amir Manbachi
Secondary Advisor: Nitish Thakor
GPA: 4.0

Cornell University College of Engineering — Ithaca, NY
M.Eng., Electrical & Computer Engineering — Aug 2019 - May 2020
Advisors: Thomas A. Cleland, Bruce Land
GPA: 3.94

Cornell University College of Engineering — New York, NY
B.Sc., Electrical & Computer Engineering — Aug 2016 - Dec 2019
Advisor: Mason Peck

Research Experience

Johns Hopkins University, Dept. of Electrical and Computer Engineering — Baltimore, MD
PhD Candidate, AI Subteam Lead in Neurosurgical Innovation Lab — Aug 2021 - Present
Advisors: Nicholas Theodore, Amir Manbachi, Nitish Thakor

Yale School of Medicine, Neurology Department — New Haven, CT
Postgraduate Computational Neuroscience Researcher in Blumenfeld Lab — June 2020 - July 2021
Advisor: Hal Blumenfeld

Cornell University, Dept. of Electrical and Computer Engineering, — Ithaca, NY
Graduate Researcher in Computional Physiology Lab — Oct 2019 - May 2020
Advisors: Thomas A. Cleland, Bruce Land

Cornell University, Dept. of Mechanical and Aerospace Engineering — Ithaca, NY
Research Associate in Space Systems Design Studio — Aug 2018 - May 2020
Advisor: Mason Peck (former CTO of NASA)

Cornell University, Dept. of Electrical and Computer Engineering, — Ithaca, NY
Research Associate in Computer Systems Lab — June 2017 - Jan 2018
Advisor: Jose F. Martinez

Thomas Jefferson University, Dept. Cell Biology and Regenerative Medicine — Philadelphia, PA
Research Intern in Risbud Lab — June 2015 - January 2016
Advisor: Makarand Risbud

Industry Experience

Intel Corporation — Folsom, CA
Software Engineering Intern — May 2019 - Aug 2019

- Implemented test code in Python for write zeros, a feature of Non-Volatile Memory Express (NMVe), which clears logical block addresses for drive security to verify pre-production SSDs

- Validated write zeros with concurrent with IO commands, drive tests, and other NVMe features.

- Tested write zeroes behavior in different power states, active versus inactive namespace ids, with safe and unsafe power cycling. Assess combability with both Windows and Linux operating systems.

Lockhead Martin, Rotary Mission Systems — Owego, NY
Electrical Engineering Intern — May 2018 - Aug 2018

- Conducted an engineering checkout of a radio frequency front end circuit card and debugged the 2 major spurs causing loss of data from the phase locked loop using a network analyzer.

- Evaluated the performance of components of a receiver/processor, including base band receivers, digital frequency discriminators using signal generators, and a test bench program.

- Designed bowtie antenna models in HFSS and simulated 3D full-wave electromagnetic fields.

Papers and Preprints

1. "A Fully Automated Algorithm Towards Optimal Placement for Focused Ultrasound Sources in Therapeutic Applications for Injured Patient-specific Spinal Cord Anatomy"
   IEEE EMBS Conference on Neural Engineering 2023, Recipient of Best Student Paper Award
   Kumar A, Punnoose J, Leadingham K , Kerensky M, Theodore N, Thakor N, and Manbachi A.

2. "Computational Modeling Approaches for Placement of Wearable and Implantable Ultrasound Devices: Visualization of Beam Propagation through Patient-Specific Anatomy"
   SPIE Medical Imaging Conference 2023
   Kumar A, Tsehay Y, Gonzalez E, Kerensky M, Bell M, Theodore N, Thakor N, and Manbachi A.

3. "Visualizing Tactile Feedback: An Overview of Current Technologies with a Focus on Ultrasound Elastography"
   Frontiers in Medical Technology, 2023
   Kumar A, Leadingham K, Kerensky M, Sankar S, Thakor N, and Manbachi A.

4. "Tension in tethered spinal cord syndrome can be quantified with ultrasound shear waves"
   Nature Communications Medicine
   Kerensky M, Paul A, Routkevitch D, Hersh A, Leadingham K, Davidar D, Judy B, Punnoose J, Williams A, **Kumar A**, ..., and Manbachi A.

5. "Understanding Impaired Consciousness in Frontal Lobe Seizures Investigated with Intracranial EEG" *Submitted*
   Salardini E, **Kumar A**, . . . , and Blumenfeld H.

6. "Automatic Hematoma Localization and Anatomical Segmentation in Ultrasound Spinal Cord Images: Dataset and Performance Benchmarking" *In Prep*
   Kumar A, Kotkar K, Li R, Manbachi A, and Thakor N.

7. "The Evolution of Ultrasound Based Prosthetic Control and the Potential of Hybrid Human-Machine Interfaces" *Submitted*
   Reategui C, **Kumar A**, Dias S. Jr. A, Thakor N, Soares A.

8. "Simulated Driving in the Yale Epilepsy Monitoring Unit"
   Epilepsia 2021
   Kumar A, ..., and Blumenfeld H.

9. "Design of the Alpha CubeSat: Technology Demonstration of a ChipSat-Equipped Retroreflective Light Sail"
   AIAA 2021 SciTech Forum
   Umansky-Castro J, Mesquita J, **Kumar A**, ..., and Peck M.

10. "Unidirectional brain-computer interface: Encoding visual stimulus to human f-MRI responses" Submitted
    IEEE International Conference on Acoustics, Speech and Signal Processing 2024
    Ruixing Liang, Xiangyu Zhang, ..., **Kumar A**, ..., and Manbachi A.

11. "Can Ultrasound Nerve Modulation Overtake Electrical Stimulation?" *In Prep*
    Lopez A, **Kumar A**, Thakor N.

Conference Abstracts

1. "Simulated Driving in the Yale Epilepsy Monitoring Unit"
   American Epilepsy Society Conference 2020.
   Kumar A, Martin R, and Blumenfeld H.

2. "Distinct Ictal and Postictal Changes in Intracranial EEG Power of Mesial Temporal Lobe Seizures with Impaired Consciousness"
   American Epilepsy Society Conference 2023.
   Yadav T, Litvinov B, Culler G, **Kumar A**, . . . and Blumenfeld H.

3. "Mechanism of Impaired Consciousness in Frontal Lobe Seizures Investigated with Intracranial EEG"
   American Epilepsy Society Conference 2020.
   Salardini E, Vaddiparti A, **Kumar A**, . . . and Blumenfeld H.

4. "Mechanisms of Impaired Consciousness in Medial Temporal Lobe Seizures Investigated with Intracranial EEG"
   Society for Neuroscience 2021.
   Litvinov B, **Kumar A**, ..., and Blumenfeld H.

5. "Increased Intracranial EEG Power and Duration in Temporal Lobe Seizures with Impaired Consciousness"
   American Epilepsy Society 2021.
   Litvinov B, **Kumar A**, ..., and Blumenfeld H.

6. "A Novel Experimental Paradigm to Investigate Awareness of Action"
   Society for Neuroscience 2021.
   Jin D, Khurana M, Aerts S, Siff E, Kronemer S, Christison-Lagay K, Li J, **Kumar A**, . . . , and Blumenfeld H.

Awards & Honors

Johns Hopkins Institutional Nominee for Apple Scholars in AI/ML	2023
IEEE Neural Engineering (NER) Conference Best Student Paper Award ($500)	2023
Intel Undergraduate Research Program Scholar ($5000)	2019
Cornell University School of Engineering Dean's List	Fall 2018 – Spring 2020
Cornell University School of Engineering Honor's List	Fall 2016 – Spring 2018
International Genetically Engineered Machines Conference Gold Medalist	2017
Engineering Learning Initiative Award ($5000)	Summer 2017

Research Projects

HEPIUS Neurosurgical Innovation Lab

Optimal Placement of Implantable Device with Physics-informed Deep Operator Networks:

- Developing deep operator network for real-time prediction of focused ultrasound pressure maps across spinal cord anatomy based on transducer location and patient specific geometry to maximize therapy to site of injury while minimizing heat damage to surrounding regions

- Determining optimal placement of epidural ultrasound sensor by performing parameter calibrations using surrogate model from the deep neural operator trained on high-fidelity simulation data.

Automatic Injury Localization and Spinal Cord Segmentation in Ultrasound Spinal Cord Images:

- Using experimentally acquired B-mode images of porcine spinal cord before and after injury, benchmarked state-of-the-art deep learning models (YOLO v8, Faster RCNN, SSD, RFCN, U-net, DETR, RetinaNET) to localize the site of injury, achieving accuracies as high as 99.5

- Benchmarked segmentation models (Mask RCNN, DeepLab, U-net, SAM) to segment the spinal cord

- Developing novel deep learning architecture building on SAM to improve segmentation of sagittal spinal cord ultrasound images

Modeling and Simulations of Ultrasound Beam Propagation in Patient-specific Anatomy:

- Developed computational models in k-Wave and Wave 3000 Plus to study the effects of focused ultrasound beam propagation in spinal cord anatomy through simulation
- Using image processing and machine learning, automatically denoised and preprocessed a dataset of ultrasound images of injured spinal cord to develop a patient pre-planning algorithm

(won best paper award at IEEE Neural Engineering Research Conference)

A Novel Multi-modal Blood Pressure Prediction Algorithm:

- Developing a segmentation and prediction algorithm using a novel blend of blood vessel size from B-mode images, stiffness from elastography images, blood flow from color Doppler images, and clinical covariates of the patient to predict blood pressure

Blumenfeld Lab, Yale Neurology

Mechanisms of Impaired Consciousness in Frontal Lobe Seizures:

- Conducted quantitative analysis of data from iEEGs of epileptic patients in MATLAB to determine the effects of seizures on consciousness, relating power across brain regions to behavior impairment
- Consolidated, interpreted, and statically analyzed data from video-EEGs from patients experiencing seizures while driving using a realistic driving simulator in the Epilepsy Monitoring Unit

Mechanisms of Impaired Consciousness in Medial Temporal Lobe Seizures:

- Developed intracranial EEG preprocessing pipeline to analyze in MATLAB the differences in power values and ictal onset between clinical, subclinical, unilateral and bilateral temporal lobe seizures

Space Systems Design Studio

Design of Nanosatellite for Light-Sail Propulsion:

- Conducted component and electrical subsystem verification tests using software in Arduino and a Teensy 3.5 microcontroller
- Created schematics for electrical systems on the spacecraft and designed 8 printed circuit boards using Altium for the electronics used in the satellite, including the radio, camera, solar charger, solar panels

Computer Architecture Lab

Set and Way Partitioning on a Cavium Server

- Conducted research on the fine-grain cache partitioning in server-class and application of SWAP, which combines Set and Way Partitioning, on a Cavium server

M.Eng. Thesis Project

Neuromorphic Circuits for Rapid Learning and Robust Classification of Olfactory Signals:

- Developed a system consisting of an array of chemo sensors for signal detection, an Arduino Mega for temperature control, a Raspberry Pi for signal processing and normalization, and an Intel Loihi neuromorphic chip to implement "learning in the wild" machine learning algorithm
- System samples from the chemo sensors during online inference stage to classify odors, aiming to emulate a mammalian olfactory system

International Genetically Engineered Machines (iGEM) Project Team

Oxyponics:

- Used CAD software, 3-D printing, and machining to prototype hardware components (camera, LED and Raspberry Pi mount, waterproof case, planter cups) to design a hydroponic system for real-time monitoring and control of oxidative stress in plant water to increase yield and consistency by $15 - 20$.
  (won gold medal in international competition)

Course Projects

Theoretical Machine Learning II

Using Random Convolutional Features on Satelite Imagery to Predict Wildfire Presence

- Developed a patch-based learning model using random convolutional filters drawn from training data.

- Compared standard CNN performance with ablated random convolutional kernels.

Machine Learning for Signal Processing

Manipulation of cartoons using sketches:

- Developed a machine learning model for modifying cartoon images with sketch-based alterations that are provided by the user, achieving 95

- Using an automatic data synthesis pipeline for deep network training and an edge detection algorithm to determine a mask that the user inputs as a modification sketch

Design of Biomedical Instrumentation

Bio-gaming system for transhumeral amputees:

- Developed a system in which transhumeral amputees can control certain keys on the keyboard and a mouse using their leg and mouth, with no reliance on hand, wrists, forearms, or elbows with innovative sensor design. *(won first place in a class-wide competition)*

Bioimpedance Measurements to Determine Skin Hydration

- Designed a well-isolated, frequency stable, constant current source for bioimpedance measurements based on a mirrored Howland current source and computed the impedance measurements with the data collected from skin electrodes. *(won "most innovative design" award in class competition)*

Bio-inspired Coordination for Multi-Agent Systems

Utilizing Cooperative Perception to Increase Safety of Autonomous Vehicles:

- Developed a highway traffic simulator in Python to increase safety and traffic speed using vehicle-to-vehicle communication (V2V) in autonomous vehicles (AV)

- Developed the algorithm used in the simulator to randomly generate vehicles with the appropriate sensors, communication, and behavior, and analyzed the number of collisions and average vehicle speed in scenarios with different obstacles

- Demonstrated that the average speed of AVs with V2V in traffic is 1.5 times faster than the human model for every obstacle, and the human model can have up to 28 times more collisions than V2V

Design with Microcontrollers

Hand-Controlled Bluetooth Vehicle

- Designed a Bluetooth controlled vehicle that can be maneuvered depending on the hand motions of the user. Transmitted information about the position of the user's hand using an accelerometer, PIC32 microcontroller programmed in C, and a Bluetooth module.

- Programmed the vertical and lateral movement of the vehicle with a motor, servo, and h-bridge.

Teaching

BME 580.471. Principles of Design of Biomedical Instrumentation	Fall 2022	JHU	Teaching Assistant
ECE 4450. Computer Networks and Telecommunications	Spring 2020	Cornell	Teaching Assistant
ECE 3400. Intelligent Physical Systems	Fall 2018	Cornell	Teaching Assistant

(updated: December 26, 2023)

Mentoring

- Siddharth Krishnan M.S., JHU Research Scientist in Biomedical Engineering. June 2023 - Present

- Kunal Kotkar, JHU Computer Science Master's student. December 2022 - Present
  Thesis Topic: *AI based spinal cord injury localization and semantic segmentation.*

Skills

Languages English (native), Hindi (advanced proficiency)
Programming MATLAB, Python (PyTorch, TensorFlow), C, C++
Tools Git, LaTeX, Linux, Bash, Verilog
Softwares Altium (PCB design), Autodesk Fusion 360 (CAD), HFSS (High Frequency Structural Simulator), Persyst (EEG Analysis)
Ultrasound simulation softwares: Wave 3000 Plus, K-wave, Field-II
Fabrication Operation of lathes and mills, circuit development, 3D printing

Service

- ADD THE PAPERS YOU REVIEW

- Volunteer computer science, chemistry, calculus, and SAT/ACT tutor for 13 high school and undergraduates.

- IEE NER Post Conference Event Planning Committee

Relevant Coursework

Ph.D. Optimal Transport and Manifold Learning, Theoretical Machine Learning I (Python), Theoretical Machine Learning II (Python), Data Science, Ultrasound and Photoacoustic Beamforming (MATLAB), Compressed Sensing and Sparse Recovery (MATLAB), Machine Learning for Signal Processing (MATLAB), Principles of Design of Biomedical Instrumentation

MEng. Bio-Inspired Coordination for Multi-Agent Systems (Python); Embedded OS (Python); Computer Systems Programming (C), 5G Cellular Communications

B.Sc. Embedded Systems (C); Intelligent Physical Systems (C); Design with Microcontrollers (C); Computer Networks & Telecommunications, Computer Architecture (Verilog), Operating Systems (C)

(updated: December 26, 2023)