Niraj Mahajan

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Research Interests

Computer Vision, Deep Generative Models, Medical Vision, Statistical Machine Learning

Education

Indian Institute of Technology, Bombay **July 2018 – May 2022**
Bachelor of Technology with Honors in Computer Science and Engineering *Mumbai, India*

- Major GPA: 9.26/10.0

Publications, Preprints, and Working Papers

1. Narendra Ahuja, **Niraj Mahajan**, Shubhang Bhatnagar, **Why Have Fully Connected Layers When Clustering is All You Need**, *Submitted to CVPR 2022*

Research Experience and Internships

Weak Supervision for Medical Abnormality Classification **Aug 2021 – ongoing**
Guide: Prof. Suyash Awate, Dept. of Computer Science and Engineering *IIT Bombay*

- Achieve state of the art segmentation on the **Breast USG dataset**, with a modified U-Net architecture by using **Pyramid Scene Parsing** and **Efficient Spatial Pyramid** Blocks instead of the conventional Residual Blocks
- Develop an end-to-end **classifier-segmenter pipeline** to classify breast cancer images using various levels of **weak supervision** for training the segmenter, to account for the scarcity of the segmentation labels
- Extend this approach to obtain results on medical vision datasets like BRATS, Malaria Blood cell, Skin Lesions

Machine Teaching in Recommender Systems **Aug 2021 – ongoing**
Guide: Prof. Abir De, Dept. of Computer Science and Engineering *IIT Bombay*

- Formulate and prove a novel problem to incorporate machine teaching based on **subset selection** into the recommender system training paradigm to improve the **precision** metric of the prediction
- Devise and implement a **feasible algorithm** pipeline with an intermediate teacher that enhances the teaching set, and test it out using several standard Link Prediction datasets

Matched Filtering Based Convolutional Blocks **May 2021 – July 2021**
Guide: Prof. Narendra Ahuja, Coordinated Sciences Laboratory *UIUC, USA*

- Condensed the computation of the convolutional blocks of Deep CNNs into cluster-based **representative filters**, based on their extent of activation when convolved with different regions of input images
- Generated activation values from the input by treating these representative filters as **matched filters**
- Visualised the **features** extracted by these filters based on their convolutional output at various spatial locations
- Analysed the Deep Convolutional block behaviour and identified the **pivotal pixels** in the image by tweaking the **backpropagation pipeline** to compute the contribution of pixel positions to the class predictive score

Replacing FC layers with Nonneural Computation **July 2020 – April 2021**
Guide: Prof. Narendra Ahuja, Coordinated Sciences Laboratory *UIUC, USA*

- Performed class-wise **gaussian clustering** of the convolutional block activations of a deep CNN, to replicate the computation performed on them by the FC Layers to enhance their explainability
- Developed a novel algorithm based on shifting and shrinking classwise **targets** to achieve this formulation
- Achieved **at par performance** with the conventional FC layers on datasets like MNIST, CIFAR10, CIFAR100 and ImageNet using the VGG16 architecture

Conditional Diabetic Retinopathy Image Synthesis **Jan 2021 – May 2021**
Guide: Prof. Suyash Awate, Dept. of Computer Science and Engineering *IIT Bombay*

- Optimised the Retinopathy Fundus Image generation using a **two stage pipeline** by first generating the retinal blood vessel filamentary structure followed by overlaying the skeleton with the fundus data
- Experimented with various adversarial Networks and **Variational Autoencoders** by varying the latent space dimensionality to improve the filamentary structure generation
- Incorporated a **Pix2Pix** Network, conditioned over the DR grade to generate **controlled abnormality** images

3-D Registration of CT scan images **April 2020 – July 2020**

Guide: Prof. Mark Pickering, School of Engineering and Information Technology *UNSW, Canberra*

- Employed ResNet in a **siamese network architecture** for improved prediction of the 3D registration parameters on synthetically generated images of the femur
- Incorporated a **half dark channel filter** algorithm for soft tissue removal in the actual knee CT images
- Train the neural network to isolate the Femur and Tibia from CT images using 3D registration parameters

Application to Diagnose Autism **May 2019 – July 2019**

Guide: Prof. Sharat Chandran, Dept. of Computer Science and Engineering *IIT Bombay*

- Developed an Android application to **backup** and **recover survey data** from the master application
- Automated the deployment of back end on **LAMP Servers**, and redefined the parameters of installation
- **Web Hosted** a back end server on a **cloud based infrastructure** with an android front end
- Attempted the implementation of a **Pytorch** model for **eye-tracking** in Android with **Tensorflow**
- Created a bash script for **automated** creation of **port based Virtual Hosting** on the back end

Key Technical Projects

Domain Adaptable Feature Learning for Localisation | *CS689: ML - Theory and Method* **Autumn 2021**

- Implemented the **Class Activation Mapping** Algorithm and visualised the features learned by the convolutional layers of a VGG16 model for each class, trained on MNIST, CIFAR10, CIFAR100
- Performed Weakly Supervised object localisation for house number **plate detection** using a binary classifier trained by contrasting CIFAR10 with the SVHN dataset
- Explored and exploited the possible **weaknesses** of the classifier by analysing the changes in the classification score by manipulating object pixels having low and high contribution to the pre-softmax score

Survey of Bandit and MDP Algorithms | *CS747: Reinforcement Learning* **Autumn 2021**

- Experimented with various bandit algorithms like **UCB**, **Thompson Sampling** and implemented them in Python
- Implemented Value Iteration, Howard Policy Iteration & Linear Programming to find the **optimal policy** for a Markov Decision Problem based on a custom "anti-tic-tac-toe game"
- Deployed a finite state **Sarsa**(**0**) agent on the 'Mountain car' problem and contrasted the performance with a **tile coding** based approach

Deep Retinex Decomposition for Low-Light Enhancement | *GNR638: ML for Compressed Sensing* **Autumn 2021**

- Implemented a neural network for low light enhancement using a three stage pipeline for splitting, enhancing and recombining the **reflectance** and the **illumination** components of images
- Trained the architecture in a parallel setup on the **LOL** (LOw Light) **Dataset** containing the normal/low light image pairs, thereby generating the enhanced illuminance map for the input image
- Tested the method empirically on self captured low light images and compared the results with various SOTA methods

Location Controlled Brain Tumour Image Synthesis | *CS736: Medical Image Computing* **Spring 2021**

- Proposed a novel method for generating location controlled abnormality in brain images using **Controllable GANs**, extendable to other medical imaging applications like pneumonia, retinopathy
- Designed a rectifier model based on a **Context Encoder** with a **Pix2Pix** backbone to generate corresponding healthy images of tumors to enhance the GAN training

Fischer Faces for Facial Recognition | *CS663: Fundamentals of Digital Image Processing* **Autumn 2020**

- Implemented the Fischer Faces algorithm for Facial Recognition based on **Fischer's LDA**
- Highlighted the **suboptimal results** of the FischerFaces algorithm compared to the EigenFaces method on the CMU Face dataset based on **high intra-class variance** in the principal features of the data

Popular Link Prediction Algorithms for Social Networks | *CS768: Learning with Graphs* **Autumn 2020**

- Surveyed heuristic-based algorithms like **Adamic Adar**, **Katz Measure**, **Preferential Attachment** and **Common Neighbors** on various link prediction applications
- Compared their performance with embedding-based supervised learning algorithms like **GraphSage** and **node2vec** on the facebook, arXiv, C-elegans and Cora datasets

Face Ageing | *CS763: Computer Vision Theory and Lab* **Spring 2020**

- Designed and trained a **Conditional Generative Adversarial Network** to induce two-way facial age transformation on images using an AlexNet based age classifier on the Wiki-IMDB dataset
- Introduced an **Identity Preserving Module** into the C-GAN by enhancing the generator training with the loss between the facial features of the original and the generated image

Proof Reading Writer | *CS251: Computer Vision Theory and Lab* **Spring 2020**

- Developed a **NLP** based Web App, like Grammarly, to correct **grammatical mistakes** in sentences using **Django**, including Voice Changer and Sentence Rephraser based on **Parsing** and **Text Data Mining**
- Incorporated **Optical Character Recognition** from text mining from images using python's **Tesseract OCR Toolkit**, and ran grammar checks on the same

Other Projects

E-Commerce Recommender System | *CS387: Database Information Systems* **Spring 2021**

- Built an E-Commerce recommendation website using **Neo4j** graph database and **Node.js** runtime environment
- Included the features of user history, trending products and text similarity metrics to generate recommendations

Compiler for C-like Language | *CS316: Implementation of Programming Languages* **Spring 2021**

- Built compiler for a C-like language, constructing Three Address Code and Register Transfer Language incrementally
- Implemented the scanner in lex, parser in yacc and conversion of abstract syntax tree to TAC and RTL in C++

Ab initio implementation of CNN | *CS335: Artificial Intelligence and Machine Learning* **Autumn 2020**

- Designed and implemented the forward and backward pass for Pooling, Convolutional and FC layers in numpy
- Tested out the implementation with various activation functions like relu and softmax on CIFAR and MNIST datasets

Kernel PCA | *CS663: Fundamentals of Digital Image Processing* **Autumn 2020**

- Implemented the Fischer Faces algorithm for Facial Recognition based on **Fischer's LDA**
- Highlighted the **suboptimal results** of the FischerFaces algorithm compared to the EigenFaces method on the CMU Face dataset based on **high intra-class variance** in the principal features of the data

Technical Skills

Programming Languages: Python, Java, C, C++, Bash, HTML/CSS, JavaScript, SQL, Make, CMake, VHDL
Libraries: PyTorch, Keras, TensorFlow, OpenCV, NLTK, Scipy, NumPy, Pandas, Matplotlib
Software/Frameworks: Linux, GitHub, Matlab, LaTeX, Solidworks, GNUPlot, Docker

Major Honors and Scholastic Achievements

- Secured **All India Rank 157** in JEE Advanced out of **231,000** candidates *(2018)*
- Scored **99.9 percentile** in JEE Mains out of **11,35,084** candidates *(2018)*
- Ranked **first in college** in the Higher Secondary Certificate Intermediate Examination *(2018)*
- Awarded certificate for **top 1%** in India in **National Standard Examination for Chemistry** *(2018)*
- Qualified amongst **top 1%** from State in **National Standard Examination for Physics** *(2018)*
- Secured **All India Rank 112** in the prestigious **Kishore Vaigyanik Protsahan Yojana** *(2017)*
- Stood **first** pan India in **Technical Drawing**, and **Marathi** in ICSE exam for matriculation *(2016)*
- Bagged **first position** in **school** in the ICSE Matriculation Exam *(2016)*
- Received **High School Scholarship** by Maharashtra State Government for Academic Excellence *(2011)*

Relevant Coursework

Computer Science: Medical Image Computing, Computer Vision+Lab, Machine Learning For Remote Sensing, Foundations of Intelligent and Learning Agents Machine Learning: Theory and Methods, Digital Image Processing, Artificial Intelligence and Machine Learning, Learning with graphs, Data Analysis and Interpretation
Mathematics and Statistics: Data analysis and Interpretation, Numerical Analysis, Linear Algebra, Calculus, Ordinary and Partial Differential equations

Teaching, Mentoring and Leadership Roles

Teaching Assistant **Autumn 2021 – Present**

Computer Vision: Theory and Lab[1]*, Fundamentals of Digital Image Processing*[2] *IIT Bombay*

- Served as a Teaching Assistant in several graduate courses carrying out a set of diverse duties
- [1]Personally mentored and monitored all the course affairs of two of the ten teams in the course, including grading assignments, projects, examinations, and conducted weekly help and viva sessions
- [1]Responsible for setting lab assignments on Generative Adversarial Networks and Introduction to Computer Vision
- [2]Graded theory and programming assignments, as well as answer copies of 150+ students enrolled in the course

General Secretary **Spring 2021 – Present**

CSEA, Department of Computer Science and Engineering *IIT Bombay*

- Spearheading a council of 15 members, committed to serve socio-academic and sportive interests of the students
- Drafted and proposed the CSEA budget and handled the distribution of funds over all council activities
- Member of the committee for interviewing and appointing the department Class Representatives

WiDS Mentor **Winter 2021**

Analytics Club *IIT Bombay*

- Selected as a project mentor for the Winter in Data Science Program at IIT Bombay
- Mentor and guide a team of three students to work on a project based on the paper **Enjoy your editing: Latent space navigation for controllable GANs**, by Zhuang *et al.*

Extra Curricular Activities

- Participated in the Intra-IIT Football General Championship for consecutive two years *(Spring 2019, 2020)*
- Awarded Certificate of Participation in the Crossy General Championship *(Spring 2019)*
- Participated in the Woofle(Woodland Football League) Intra Hostel 8 football League *(Spring 2019)*
- Won inter-department football tournament organised within IIT-Bombay *(Spring 2019)*
- Built an Arduino based Remote-Controlled Car and was among top 5 competing teams *(Autumn 2018)*
- Bagged the second prize in the Energize quiz, conducted by the Energy Club *(Autumn 2018)*
- Qualified for National Sports Organization's (NSO) Kho-Kho Team of IIT Bombay *(Autumn 2018)*