RUDRAJIT DAS

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EDUCATION

Indian Institute of Technology Bombay   **Mumbai, India**
Dual Degree in Electrical Engineering - GPA: 9.37/10.0   *Expected Graduation: May '19*
Minor in Computer Science

FIELDS OF INTEREST

Deep Learning, Machine Learning and Statistical Learning, Probabilistic Analysis, Optimization, Computer Vision and Image Processing, Natural Language Processing, Signal Processing.

PUBLICATIONS & COMPETITIONS

- *An Efficient Randomized Algorithm to Detect and Escape Saddle Points* [1]
  Rudrajit Das and Subhasis Chaudhuri - Submitted for publication to **AAAI 2019**.
  (Manuscript available on request)

- *On the Existence of Sparse Bases for Deep Learning Kernels* [2]
  Rudrajit Das and Subhasis Chaudhuri - Submitted for publication to **AISTATS 2019**.
  (Manuscript available on request)

- *Sparse Kernel PCA for Outlier Detection* [3]
  Rudrajit Das, Aditya Golatkar and Suyash Awate - Selected for **oral presentation** in **IEEE ICMLA 2018**.
  https://arxiv.org/abs/1809.02497

- *iFood Challenge, FGVC Workshop, CVPR 2018*
  Parth Kothari*, Arka Sadhu*, Aditya Golatkar*, **Rudrajit Das*** (* denotes equal contribution)
  Finished 2nd and 3rd in the public and private leaderboards respectively, with team name "Invincibles". Leaderboard link - https://www.kaggle.com/c/ifood2018/leaderboard. Invited to present our method at **CVPR 2018** (slides can be found here).

INTERNSHIPS

PRAIRIE Artificial Intelligence Summer School (PAISS)   **Grenoble, France**
Inria, NAVER LABS Europe   *July '18*
- One of the very few **undergraduates** to be selected for this AI summer school, co-organized by **Inria** and **NAVER LABS Europe**. Attended **lectures** & **practical sessions** conducted by **leading experts** in Computer Vision, NLP, Robotics, Reinforcement Learning, Meta Learning, Unsupervised & Self-supervised Learning.
- Presented a **poster** (can be found here) titled "**Existence of Sparse Basis for Deep Learning Kernels?**".

Institute for Biomechanics, ETH Zürich   **Zürich, Switzerland**
Research Intern under Dr. Patrik Christen, D-HEST   *May '17 - July '17*
- Constructed a **linear model** for **bone re-modelling** with some dependence on initial conditions, obtained a **closed form solution** for it and analyzed its stability using **eigenvalue analysis**, which was **not done earlier**.
- Also built a **directed graphical model** to capture the random nature of the process and simulated it.
- Developed an **automated 2D-3D image registration framework** for histology images from scratch, which included **devising an efficient sampling strategy** to obtain the 2D image across an arbitrary plane of the given 3D image, **formulating a good cost function** (for measuring similarity) in order to mitigate the effect of the existence of **several local minima**, choosing a **suitable optimization algorithm** (tried Levenberg–Marquardt, Powell's method, PSO, Genetic algorithms) and finally coding it all up.

Altisource Business Solutions Private Limited   **Bengaluru, India**
Software Engineering Intern   *May '16 – July '16*
- Developed a **notification system** using **Pagerduty**, a popular incident management software and worked on the user interface(UI) of the company's monitoring dashboard built using JBoss Dashbuilder.
- Used Spring Framework(Java) for backend coding and Hibernate for database handling(MySQL).

RESEARCH EXPERIENCE

Improving Optimization in Deep Learning [1] - Master's Thesis *June '18 - Aug '18*
Guide : Prof. Subhasis Chaudhuri, EE Department, IIT Bombay

- Proposed a **novel randomized iterative algorithm** to detect whether a critical point (i.e. a point where the derivatives of the loss function with respect to the parameters are zero) is a local minima or a **saddle point** and to escape that point if it is a **saddle point**, without requiring to compute the **Hessian**.
- Derived an **upper bound** on the **expected number of iterations**, which is **logarithmic** with respect to the number of positive eigenvalues of the Hessian at that point and **faster than linearithmic** with respect to the inverse of the magnitude of the minimum eigenvalue of the Hessian. The **complexity wrt the minimum eigenvalue** is **better** than that of Perturbed Gradient Descent (PGD) proposed in "How to escape saddle points efficiently." by Jin et al. (2017) and CNC-GD proposed in "Escaping Saddles with Stochastic Gradients." by Daneshmand et al. (2018).
- Also in relation to the complexity of the proposed algorithm, obtained approximate **upper and lower bounds** for the **expected number of negative eigenvalues** of the Hessian (known as the **index**) at a point, as a function of the loss value at that point, for a single hidden layer neural network with the **cross-entropy loss function**. This is the **first attempt** at index computation for the cross-entropy loss function.
- Paper submitted to **AAAI 2019**.

On the Existence of Sparse Bases for Deep Learning Kernels [2] - Master's Thesis *Aug '18 - Sep '18*
Guide : Prof. Subhasis Chaudhuri, EE Department, IIT Bombay

- Derived a **probabilistic proof** to suggest the possibility of the **existence of sparse basis** using few training points, for the **final layer** of binary classification networks before sigmoid (i.e. the transformed input which is linearly separable and the **kernel** being the transformation function) with the cross-entropy loss. The number of training points constituting the aforementioned sparse basis is much lesser than the dimension of the transformed input (or the dimension of the co-domain of the kernel function).
- Hypothesis corroborated by experimental results on 2 fully connected network and 2 CNN architectures.
- This has an **important implication** - even though a large number of examples might be required to train deep learning networks, perhaps the **learnt kernel** can **generalize well** using only a **few of the training examples**.
- Paper submitted to **AISTATS 2019**.

Sparse Kernel PCA (SKPCA) for Outlier Detection [3] *Nov '17 - May '18*
Guide : Prof. Suyash Awate, CSE Department, IIT Bombay

- Proposed a **novel SKPCA algorithm** by formulating it as a **constrained optimization problem** with **elastic net regularization** in the kernel space, solving it using **alternating minimization**. Tested it on **5 real world datasets** and showed that it **outperforms** the most recent SKPCA method with **lesser parameter tuning**.
- Also presented a **new probabilistic proof** to justify the **existence of sparse solutions** in KPCA using the RBF kernel, which is the **first attempt** in this direction.
- **Paper accepted** for **oral presentation** in **IEEE ICMLA 2018**. [Code]

Non-linear blind compressed sensing *June '18 - Present*
Guide : Prof. Ajit Rajwade, CSE Department, IIT Bombay

- Working on an algorithm for **non-linear blind compressed sensing** (jointly estimating the sparse basis & sparse codes) under the **Anscombe** transform (square root transform) for **Poisson measurements**, which has not been done before.
- Obtained a **novel multiplicative update rule** (like in NMF) to maintain positivity constraints of the sparse basis and sparse codes. Currently working on deriving an **upper bound** on the algorithm's **expected value of the squared norm of the error** (difference between the actual and estimated signal) using a Bernoulli sensing matrix.

Multiple Instance Learning (MIL) in Breast Cancer Histology Images *Feb '18 - Present*
Guide : Prof. Amit Sethi, EE Department, IIT Bombay

- **MIL** is an **unsupervised learning problem** where the label of the entire image ("bag") is given and the labels of the patches ("instances") in the image are to be determined from this.
- Working on **self-supervised learning** using the proxy tasks of **colorization** with different loss functions, to learn good **embeddings** which can be used for **deep attention based MIL**.
- Tried **Bayesian Learning** for MIL using features extracted from **auto-encoders** and obtained **results comparable to state of the art** for the **Bisque** data set. However, this method did not generalize well. [Report]

Sentence Compression Using Deep Learning *Mar '18 - May' 18*
Guide : Prof. Sunita Sarawagi, CSE Department, IIT Bombay

- Designed a **bi-directional 3-layer LSTM** model for **sentence compression** by modelling it as a binary classification problem (which words to retain/delete). Compared it with the method proposed in "**Sentence Compression by Deletion with LSTMs**" by **Google NLP Research** and got **marginally better results**. [Code] [Report]

Speeding up Kernel PCA (KPCA) *July '17 – Oct '17*
Guide : Prof. Suyash Awate, CSE Department, IIT Bombay

- Used the **improved Nyström** method to obtain a **low rank** approximation to the Gram matrix. Using this, developed a **fast algorithm for eigenvector computation** in KPCA, **improving time complexity** from $O(n^2p)$ to $O(np^2)$, where n is the number of data points and $p << n$ is the rank of the approximated Gram matrix.
- Implemented the proposed algorithm and obtained almost a **linear speed up** over MATLAB's "eigs" function with **negligible error** in the obtained eigenvectors and eigenvalues. [Code] [Report]

KEY ACADEMIC PROJECTS

Using the Kernel Trick in Compressed Sensing *April '18 - May '18*
Guide : Prof. Animesh Kumar, EE Department, IIT Bombay

- Implemented the paper **"Using the kernel trick in compressive sensing: Accurate signal recovery from fewer measurements."** which performs **compressed sensing** in higher dimensional feature space by utilizing the **kernel trick**.
- Extended the proposed method in the paper, to the case of directions sampled from a **Bernoulli distribution**, thus making it more **hardware realizable**. Also provided a **theoretical proof** for this extension. [Report] [Presentation]

Extractive Text Summarization using Neural Networks *Sep '17 - Nov '17*
Guide : Prof. Ganesh Ramakrishnan, CSE Department, IIT Bombay

- Implemented the paper **"A Simple but Tough-to-Beat Baseline for Sentence Embeddings"** and used the embeddings to select key sentences (modelled it as a binary classification problem) in a document (**extractive summarization**) by **ensembling neural networks**.
- Also designed a **CNN** architecture based on the EMNLP paper "**Convolutional Neural Networks for Sentence Classification**" which further **improved results**. [Code] [Report]

Image segmentation using Grab Cut Algorithm *Feb '17 - April '17*
Guide : Prof. Suyash Awate, CSE Department, IIT Bombay

- Implemented **Grab Cut** which employs Gaussian Mixture Models (**GMMs**) along with the **Graph Cut** algorithm, for interactive extraction of foreground in a complex environment with reduced user interactions.
- Simulated the algorithm on medical and natural images, obtaining good results. [Code] [Report]

Real Time Tracking of Non-Rigid Objects *Feb '17 - April '17*
Guide : Prof. Ajit Rajwade, CSE Department, IIT Bombay

- Built a **real time object tracking model** for videos using **mean shift algorithm** with **Bhattacharya coefficient** to determine the object trajectory. It was **robust** to partial occlusion, clutter, rotation & camera position.
- The model was successfully able to track humans, objects, vehicles etc. in real world videos. [Code] [Report]

Visible Light Communication(Li-Fi) *Jan '17 - April '17*
Guide : Prof. Kumar Appaiah, EE Department, IIT Bombay

- Built an optical channel to transfer a **Manchester encoded** data stream synchronously.
- Used Tiva-C micro-controller to transmit encoded data, which was received by a Clock Recovery Circuit; successfully decoded and displayed on an LCD at the receiving micro-controller.
- **Synchronously** transferred encoded data at speed of **100 kbps** over a distance of **3 meters**. Also built an **asynchronous system** with a data rate of **30 kbps** over **0.5 meters** distance.

Flow Based Image Extraction *Sep '16 - Nov '16*
Guide : Prof. Suyash Awate & Prof. Ajit Rajwade, CSE Department, IIT Bombay

- Implemented a non-photorealistic rendering method to give stylized effect to images.
- Applied a flow based difference of Gaussian filter for line extraction and then a flow based bilateral filter for region smoothing to produce a stylized version of natural images. [Code]

Min-cut based approach to find pathways in biological regulatory networks *Dec '15 - Jan '16*
Guide : Prof. Supratik Chakraborty, CSE Department, IIT Bombay

- Worked on implementing an **efficient semi-automated approach** for finding pathways in systems biological regulatory

networks using min-cuts.

- Implemented the **Gusfield algorithm** in C++ to construct the **Gomory Hu tree** of the equivalent undirected graph which was used to obtain the min-cut edges between all pairs of nodes of the graph in $O(n)$ time, instead of the naive algorithm which takes $O(n^2)$ time, thereby providing a **linear speed up**.
- Also optimized the code in terms of memory by utilizing the sparsity of the adjacency matrix.

ACADEMIC ACHIEVEMENTS

- Awarded the only **AP (Advanced Performer)** grade in **Applied Linear Algebra** for securing the highest marks and for outstanding performance in the course.
- Stood **first** in **Foundations of Machine Learning Course** in a batch of **170** students and was one of the **10** students in a batch of **166** students to receive an **AA** grade in Advanced Machine Learning course.
- Secured **3rd** rank in **IIT Bombay Mathematics Olympiad 2015**.
- Awarded **Merit Certificates** in National Standard Examination in Physics - 2014 and National Standard Examination in Chemistry - 2014 for being within **top 300** students across the country.
- Selected for **Indian National Physics Olympiad** 2014 & **Indian National Chemistry Olympiad** 2014.
- Secured **All India Rank 6** in ICSE Examination 2012 amongst 0.1 million candidates.
- Received a Letter of Appreciation from the Education Minister of Maharashtra for being **top 1%** of the state in the Higher Secondary Examination 2014.
- Awarded a scholarship of **Rs 80,000 per year for five years**, for higher education under the INSPIRE scheme by the Government of Maharashtra.

RELEVANT COURSES

- **Computer Science :** Advanced Machine Learning, Advanced Image Processing, Discrete Structures, Foundations of Machine Learning, R&D Project, Computer Vision (both traditional & using Deep Learning), Algorithms for Medical Image Processing, Fundamentals of Digital Image Processing, Design & Analysis of Algorithms, Data Structures & Algorithms, Computer Networks, Computer Programming.
- **Electrical Engineering :** Optimization*, Supervised Research Exposition, Recent Topics in Analytical Signal Processing, Wavelets, Markov Chains & Queuing Systems, Advanced Topics in Signal Processing, Estimation & Identification, Speech Processing, Applied Linear Algebra, Advanced Concentrations Inequalities, Digital Signal Processing, Probability & Random Processes, Control Systems, Microprocessors, Digital Communications, Digital Systems, Data Analysis & Interpretation, Network Theory.
- **Mathematics :** Calculus, Linear Algebra, Complex Analysis, Differential Equations.
  ∗ : To be finished by November 2018.

TECHNICAL SKILLS

- **Languages : Python**, **MATLAB**, **C++**/C, Java, Octave, VHDL, Arduino.
- **Deep Learning : Keras**, PyTorch, Tensorflow.
- **Others :** HTML, CSS, Javascript, Jekyll, LaTeX.

TEACHING EXPERIENCE

- Appointed as a **Teaching Assistant** for **Applied Linear Algebra** course taken by about **70 students** which involves providing practice problems, organizing tutorials & help sessions and preparation, invigilation and grading of exams.

EXTRA CURRICULAR ACTIVITIES

- Ranked 1st among all freshmen & 2nd overall in Maths Olympics 2014 conducted by the MnP Club, IIT Bombay.
- Presented a poster on the mathematics of X-Ray CT images in MHRD-TEQIP-KITE workshop under the initiative of the Government of India.
- Keen interest in watching and playing cricket & football, was part of my school cricket team.
- Recently started blogging about my research.
- Passionate foodie and interested in learning about new cultures.

REFERENCES

Suyash Awate	**Subhasis Chaudhuri**	**Ajit Rajwade**
Associate Professor	KN Bajaj Chair Professor	Assistant Professor
Computer Science & Engineering,	Electrical Engineering,	Computer Science & Engineering,
IIT Bombay	IIT Bombay	IIT Bombay
email	email	email