Megh Shukla, M.Tech.

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Research Interests: Uncertainty Estimation, Active Learning, Human Pose Estimation, X-Shot Learning

HIGHLIGHT

I have the privilege of leading data-centric research and its implementation at Mercedes-Benz R&D India! Specifically, I lead end-to-end R&D in **active learning for human pose estimation**. This included providing a proof-of-concept and engineering a production pipeline, identifying key limitations with existing methods. Consequently, my research [1,2,3] addressed these limitations, making theoretical and applied contributions in **uncertainty estimation** and active learning. My recognition at Mercedes-Benz includes an Innovation Award, granted annually for high quality patent applications, and the Star Award (alluding to Mercedes' three pointed star), a special award to commemorate 25 years of Mercedes-Benz R&D India. My research ideology of fundamentally improving existing methods has its origin in my Master's thesis on **dimensionality reduction**, which addressed the curse of dimensionality prevalent in high-dimensional hyperspectral imagery [4]. I was awarded the Institute Silver Medal by IIT Bombay in 2019.

AWARDS

Mercedes-Benz Young Achiever (Rising Star) Award 2021 | *Mercedes-Benz R&D India* 2021
- **25 out of 6000+ engineers** awarded across various categories to commemorate 25 years of Mercedes-Benz R&D India.

Mercedes-Benz Innovation Award 2021 | *Mercedes-Benz R&D India* 2021
- High Quality Patent Application [3], **annual award for top-5% inventions** at Mercedes-Benz R&D India

Institute Silver Medal 2019, IIT Bombay | *Indian Institute of Technology Bombay* 2019
- Master of Technology class of 2019: Secured **Department Rank 1, Institute Rank 3**
- Advanced Performer (AP), IIT Bombay (Awarded for exceptional performance in credit courses):
  - *Introduction to Machine Learning EE 769*: **Top 3 out of 178** were awarded AP
  - *Advanced Satellite Image Processing GNR 602*: **First AP since 2014**
- Graduate Aptitude Test in Engineering **(GATE): Top 1.5%** candidates in Electronics and Communication Engineering

EDUCATION

Indian Institute Of Technology Bombay | CPI: 9.98 2019
Master of Technology in Geoinformatics and Resources Engineering (Satellite Imagery)
Teaching Assistant: *Satellite Image Processing, Prof. Buddhiraju; Machine Learning and Visual Computing, Prof. Banerjee*
Thesis: LEt-SNE: A Hybrid Approach to Data Embedding and Visualization of Satellite Imagery [4] GitHub/IEEE

University Of Mumbai | CPI: 9.00 2017
Bachelor of Engineering in Electronics and Telecommunication Engineering
Alumni Member: Board of Studies (2021-Present), Electronics and Telecommunication, DJ Sanghvi College of Engineering
Thesis: Resonance Frequency Estimation for Microstrip Antennas Using Artificial Neural Networks GitHub/Springer

RESEARCH

1. Bayesian Uncertainty and Expected Gradient Length - Regression: Two Sides Of The Same Coin? Theory
Proceedings of the IEEE/CVF Winter Conference on Applications of Computer Vision (**WACV**) 2022
Author(s): ***Megh Shukla*** (arXiv)

Description: Expected Gradient Length (EGL) is a classical active learning technique with extensive use in speech, text and biomedical applications. While EGL in classification is well studied, the formulation for regression remains intuitively driven and lacks theoretical background. This paper makes two key contributions: a theory that **proves equivalency between EGL-regression and Bayesian uncertainty in vision**, and an algorithm (EGL++) that emphasizes on improving the overall model performance. EGL++ extends the principles of uncertainty estimation to a single deterministic network, achieving SOTA results in active learning for human pose estimation.

2. A Mathematical Analysis of Learning Loss for Active Learning in Regression Theory
Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition Workshops (**CVPRW**) 2021
Author(s): ***Megh Shukla***, Shuaib Ahmed (CVF Open Access)

Description: We provide rigorous analysis for Learning Loss (Yoo and Kweon, CVPR '19), a popular active learning algorithm which achieved state-of-the-art results in multiple computer vision tasks. Our improvements are based on **examining why Learning Loss works and modelling the probability of sampling a pair of 'losses'**. Consequently, our studies show that the original objective is a hard approximation of the KL Divergence, the latter adding smoothness in learning. We further show that learning improves as a result of this smoothness. Our proposed modification, LearningLoss++, outperforms Learning Loss in identifying scenarios where the model performs poorly. Identifying faulty model inferences is a prerequisite step in deploying reliable models for open world usage.

3. Reducing Annotation Costs For Human Pose Estimation: A Bayesian Network Approach

Applied

"Method and System For Annotating One Or More Images Of A User", Daimler AG, India **Patent** Office. Filed 2020
Inventor(s): ***Megh Shukla***, Shuaib Ahmed

Description: Previous active learning approaches did not leverage human-specific constraints (skeleton) in the sampling process. To address this issue, we augment Multi-Peak Entropy, Active Learning for Human Pose (Liu and Ferrari, ICCV '17) with Bayesian Networks, where each link in the skeleton is represented by a univariate normal distribution. The **Bayesian Network acts as a learned prior** over the joint distances, and has a high degree of interpretability since poses where the peaks do not fit the prior are selected for annotation. The strength of this approach is in its simplicity; active learning assumes a small pool of labelled data, and any complex solution will have insufficient data to learn meaningful patterns.

4. LEt-SNE: A Hybrid Approach to Data Embedding and Visualization of Hyperspectral Imagery

Applied

Proceedings of the IEEE International Conference on Acoustics, Speech and Signal Processing (**ICASSP**) 2020
Author(s): ***Megh Shukla***, Biplab Banerjee, KM Buddhiraju (IEEE Xplore)

Visualizing high-dimensional datasets may become tricky due to the **curse of dimensionality**. The number of samples required to adequately represent the hypervolume increases exponentially with dimensionality, rendering euclidean distance as a metric ineffective. We argue why t-SNE is suboptimal for such inputs and propose a novel algorithm, LEt-SNE, to circumvent the curse of dimensionality. We do so by **creating an illusion of stretched inter-sample distances**, where nearest neighbors appear closer and farthest samples appearing much more distant. Our results show that the proposed algorithm outperforms t-SNE, UMAP and autoencoders by a significantly large margin on publicly available hyperspectral datasets.

EXPERIENCE

Mercedes-Benz R&D India | *Computer Vision Research Engineer, MBUX Interior Assistant* 2019-Present

- **Module owner: Active learning for human pose estimation**; responsible for devising and executing end-to-end R&D cycle
- Active Learning intelligently selects images for annotation, **annotation costs/model deployment time reduced by 30-50%**
- Performed feasibility study; implemented and optimized existing research for active and **incremental learning** pipeline
- Designed algorithms to improve: a) Overall performance [1] b) Pre-empting failures [2] c) Explainability [3] in active learning
(a) *EGL++* [1] improves performance by quantifying the dissimilarity between an unlabelled sample and its labelled neighbors
(b) *LearningLoss++* [2] provides a theoretical background for Learning Loss, highlighting the ability to pre-empt failure cases
(c) *Bayesian Nets* [3] maximize the likelihood over poses seen by the model, and acts as a visual prior for heatmap predictions
- Involved in on-campus interviews (2021, 2022 joining cycles), providing mentorship for research interns and campus recruits

HARMAN India, a Samsung Company | *Research Intern, HARMAN X* May '18 - Jul' 18

- Explored *Capsule Networks* and Whitebox/Blackbox techniques for **Adversarial Learning** in autonomous driving
- Experimented with Reconstruction and Dithering using *TensorFlow* to prevent white box attacks on the model
- Parallelized the serial implementation of gradient computation in *cleverhans*: Jacobian augmentation function
- Devised PCA augmentations to increase similarity between Substitute and Oracle (blackbox) outputs from 92% to 95%

GITHUB

Open-Source Library: Active Learning for Human Pose Estimation | *Ongoing* May '20 - Present

- Created a Jupyter notebook to visualize MPII 2D Human Pose Dataset natively; existing tools abstracted the native format
- Developing a library with **optimized implementations** of popular active learning algorithms for human pose estimation

GPU Acceleration Using CUDA-Python | *Advanced Satellite Image Processing (GNR602)* Apr '18

- GPU optimization for Maximum Likelihood and Relaxation Labelling for image pixel-wise classification and smoothing
- Defined **CUDA** kernels for thread-level control in Python using **Numba** library, with **Qt** based GUI packaged in an executable
- Performance improvement: *CPU* (Intel i5-8250U): *~2:30 mins* *CPU+GPU* (NVIDIA MX150) : *~5 seconds*

Cross-Platform App For Dynamic Entity Navigation | *Geographic Information Systems (GNR605)* Nov '17

- Designed a prototype app for routing between moving entities (eg: food carts) and campus pedestrians
- Used Qt Framework to make a cross platform app (Android/iOS), OpenStreetMap used for map rendering
- App provides Geocoding/Reverse Geocoding features with navigation, planned usage limited to IIT Bombay area

COURSEWORK

Computer Vision: Introduction to Machine Learning (EE 769), Neural Networks (ETE 703), Advanced Machine Learning (CS 726 - Audit), Principles (GNR 607) / Advanced (GNR 602) Satellite Image Processing, Image and Video Processing (ETC 701), Applied Mathematics - (I, II, II, III, IV), Random Signal Analysis (ETC 503), Data Analysis for Geospatial Applications (GNR 653), Geospatial Predictive Modelling (GNR 627), Signals and Systems (ETC 405), Discrete Time Signal Processing (ETC 602), Speech Processing (ETE 801), Structured Programming Approach (FEC 205), Object Oriented Programming (ETSL 304)
Information theory has been covered throughout courses related to communication engineering

SKILLS

Programming Languages	*Experienced*: Python	*Familiar*: C C++ Matlab Lua
Frameworks	PyTorch TensorFlow Numba-CUDA	