M. Usman Rafique

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Research Areas

Computer Vision and Machine Learning for Autonomous Systems. Recent work focuses on weakly supervised machine learning for autonomous driving, LLMs, scene understanding, and semantic segmentation.

Education

Ph.D. Electrical Engineering **University of Kentucky, USA** 2016 - 2021
M.S. Mechatronics **National University of Sciences and Technology, Pakistan** 2008 - 2010
B.E. Mechatronics **National University of Sciences and Technology, Pakistan** 2003 - 2007

Work Experience

Senior Machine Learning Engineer, Zoox, CA, USA Feb 2024 - present

Researching and deploying on-vehicle features for L5 autonomous driving. Leading training data releases and scaling strategies, focusing on data curation to iteratively refine the trajectory model and improve robotaxi behavior.

Machine Learning Engineer III, Bastian Solutions, USA Aug 2023 - Feb 2024

Developed state-of-the-art computer vision models for an autonomous pick-and-place robotic system and automatic depalletizing.

Senior Research and Development Engineer, Kitware Inc., USA Aug 2021 - Apr 2023

Research on change detection from overhead images, person identification, novel view synthesis, and atmospheric turbulence correction.

Graduate Research Assistant, University of Kentucky, USA Aug 2016 - Jul 2021

Dissertation "Weakly Supervised Learning for Multi-Image Synthesis," supervised by Dr. Nathan Jacobs and Dr. Samson Cheung. Taught courses including Capstone Design for Electrical Engineering.

Research Assistant, Hong Kong Polytechnic University, Hong Kong Jun 2015 - Jul 2016

Research on software defined battery and control of manipulators using recurrent neural networks.

Lecturer, Air University, Pakistan Sep 2010 - Jun 2015

Taught courses on robotics and embedded systems. Organized autonomous robot competitions.

R&D Engineer, SUPARCO (National Space Agency), Pakistan Jul 2007 - Aug 2008

Worked in Attitude and Orbit Control System (AOCS) Lab.

Research Projects

Vision System for Pick-and-Place Robotics [Site Test: Oct 2024]

Developing computer vision pipeline for autonomous robots in warehouses, moving small objects and shipping boxes. Working on multiple color and depth cameras, training models (for segmentation and grasping). Training pipeline includes tools like vision language models (VLMs) and foundation models like segment anything (SAM).

Improving Near-Remote Sensing Project page

Given a satellite image and some ground-level images, our method supports several segmentation tasks including building function and building height estimation. Our Geopsatial attention improved performance by 15%. (CVPR 2022)

Large Language Models (LLMs) Github repo

Implemented the building Transformer architecture from scratch in PyTorch. I pretrained a light-weight model, termed NanoGPT, that follows the same architecture and objective as GPT-2 and GPT-3. Fine-tuned a pretrained GPT-NeoX (a 20 billion parameter model) on a single GPU using Low-Rank Adaptation (LoRA) with 4-bit quantization. Also developed zero-shot classification with vision-text BLIP-2 model.

Change Detection from Remote Sensing

Worked on a project to train deep learning models for automatic change detection over large areas. The solution consisted a broad area search for change detection (using low-res satellite images) and characterizing types of changes using (high-res aerial images). Trained models were optimized for inference speed and deployed on AWS.

Identifying Sinkholes from Remote Sensing Data Research paper

Proposed a deep learning-based solution for locating sinkholes from digital elevation models (DEM) and aerial imagery. We evaluated several normalization methods for preprocessing the DEM data, improving accuracy from 67% to 80%. Models trained on data from Kentucky were able to locate sinkholes in Missouri.

Outdoor Image Synthesis Project page

Given a source image, our method synthesizes novel images of the same scene under different conditions, which could include changes in the time of day, season, or weather conditions. Our model improved SSIM from 0.49 to 0.55. Prepared a large-scale dataset of over 23,000 outdoor images. (CVPRW 2021)

Novel View Synthesis Project page

Developed a convolutional network-based hybrid approach that gets state-of-the-art results on KITTI benchmark improving SSIM from 0.56 to 0.61. Released a new dataset, BPS, containing 44,000 image pairs. (BMVC 2020)

Fusion of Remote Sensing Images Project page

Designed a fusion method that combines multiple noisy overhead images to make a single cloud-free image. Our proposed weakly supervised fusion method is trained without annotations of clouds, improving accuracy from 62% to 72%. (EARTHVISION 2019)

Peer-Reviewed Publications

Journal Articles

1. "Efficient Training on Alzheimer's Disease Diagnosis with Learnable Weighted Pooling for 3D PET Brain Image Classification," Electronics, 2023, Xing, Xin; **Rafique, Muhammad Usman**; Liang, Gongbo; Blanton, Hunter; Zhang, Yu; Wang, Chris; Jacobs, Nathan; Lin, Ai-Ling.
2. "Automatic Segmentation of Sinkholes Using a Convolutional Neural Network," Earth and Space Science, 2022, **Rafique, Muhammad Usman**; Zhu, Junfeng; Jacobs, Nathan.
3. "Tracking Attacks on Virtual Reality Systems," IEEE Consumer Electronics Magazine, 2020, **Rafique, Muhammad Usman**; Cheung, Sen-Ching S.
4. "Integrating Open-Source Tools for Embedded Software Teaching: A Case Study," Advances in Engineering Education, 2019, **Rafique, Muhammad Usman**; Mohammed, Aquil Mirza; Li, Shuai;

Khan, Ameer Tamoor; Kadry, Seifedine.

5. "Reconfigurable Battery Systems: A Survey on Hardware Architecture and Research Challenges," ACM Transactions on Design Automation of Electronic Systems (TODAES), 2019, Muhammad, Shaheer; **Rafique, Muhammad Usman**; Li, Shuai; Shao, Zili; Wang, Qixin; Liu, Xue.
6. "A Novel Recurrent Neural Network for Manipulator Control with Improved Noise Tolerance," IEEE Transactions on Neural Networks and Learning Systems, 2017, Li, Shuai; Wang, Huanqing; **Rafique, Muhammad Usman**.
7. "A Robust Algorithm for State-of-Charge Estimation with Gain Optimization," IEEE Transactions on Industrial Informatics, 2017, Muhammad, Shaheer; **Rafique, Muhammad Usman**; Li, Shuai; Shao, Zili; Wang, Qixin; Guan, Nan.
8. "Distributed Recurrent Neural Networks for Cooperative Control of Manipulators: A Game-Theoretic Perspective," IEEE Transactions on Neural Networks and Learning Systems, 2016, Li, Shuai; He, Jinbo; Li, Yangming; **Rafique, Muhammad Usman**.
9. "Mobile Robot Path Planning in Static Environments Using Particle Swarm Optimization," International Journal of Computer Science and Electronics Engineering (IJCSEE), 2015, Alam, M Shahab; **Rafique, Muhammad Usman**; Khan, M Umer.

Conference Papers

1. "Handling Image and Label Resolution Mismatch in Remote Sensing," IEEE/CVF Winter Conference on Applications of Computer Vision (WACV), 2023, Workman, Scott; Hadzic, Armin; Rafique, Muhammad Usman
2. "CrossAdapt: Cross-Scene Adaptation for Multi-Domain Depth Estimation," IEEE International Geoscience and Remote Sensing Symposium (IGARSS), 2023, Zhang, Yu; Rafique, Muhammad Usman; Christie, Gordon; Jacobs, Nathan
3. "CrossSeg: Cross-Scene Few-Shot Aerial Segmentation using Probabilistic Prototypes," IEEE International Geoscience and Remote Sensing Symposium (IGARSS), 2023, Zhang, Yu; Rafique, Muhammad Usman; Jacobs, Nathan
4. "Revisiting Near/Remote Sensing with Geospatial Attention," IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR), 2022, Workman, Scott; Rafique, Muhammad Usman; Blanton, Hunter; Jacobs, Nathan
5. "Hierarchical Probabilistic Embeddings for Multi-View Image Classification," IEEE International Geoscience and Remote Sensing Symposium (IGARSS), 2021, Brodie, Benjamin; Khanal, Subash; Rafique, Muhammad Usman; Greenwell, Connor; Jacobs, Nathan
6. "Unifying Guided and Unguided Outdoor Image Synthesis," IEEE/CVF Conference on Computer Vision and Pattern Recognition Workshops (NTIRE), 2021, Rafique, Muhammad Usman; Zhang, Yu; Brodie, Benjamin; Jacobs, Nathan
7. "Single Image Cloud Detection via Multi-Image Fusion," IEEE International Geoscience and Remote Sensing Symposium (IGARSS), 2020, Workman, Scott; Rafique, Muhammad Usman; Blanton, Hunter; Greenwell, Connor; Jacobs, Nathan
8. "Dynamic Image for 3d MRI Image Alzheimer's disease classification," European Conference on Computer Vision Workshops, 2020, Xing, Xin; Liang, Gongbo; Blanton, Hunter; Rafique, Muhammad Usman; Wang, Chris; Lin, Ai-Ling; Jacobs, Nathan
9. "Generative Appearance Flow: A Hybrid Approach for Outdoor View Synthesis," British Machine Vision Conference (BMVC), 2020, Rafique, Muhammad Usman; Blanton, Hunter; Snavely, Noah; Jacobs, Nathan

10. "Weakly Supervised Fusion of Multiple Overhead Images," IEEE/CVF Conference on Computer Vision and Pattern Recognition Workshops (EARTHVISION), 2019, Rafique, Muhammad Usman; Blanton, Hunter; Jacobs, Nathan
11. "Weakly Supervised Building Segmentation from Aerial Images," IEEE International Geoscience and Remote Sensing Symposium (IGARSS), 2019, Rafique, Muhammad Usman; Jacobs, Nathan
12. "Privacy-Preserving Distributed Deep Learning with Privacy Transformations," IEEE International Workshop on Information Forensics and Security (WIFS), 2018, Sen-ching, S Cheung; Rafique, Muhammad Usman; Tan, Wai-tian
13. "A weakly supervised approach for estimating spatial density functions from high-resolution satellite imagery," ACM SIGSPATIAL International Conference on Advances in Geographic Information Systems, 2018, Jacobs, Nathan; Kraft, Adam; Rafique, Muhammad Usman; Sharma, Ranti Dev
14. "RGB-D Camera Network Calibration and Streaming for 3D Telepresence in Large Environment," IEEE Third International Conference on Multimedia Big Data, 2017, Su, Po-Chang; Shen, Ju; Rafique, Muhammad Usman
15. "Swarm intelligence based multi-objective path planning in environments cluttered with danger sources," International Conference on Mechatronics-Mechatronika, 2016, Alam, Muhammad Shahab; Rafique, Muhammad Usman; Kauser, Zareena; Saleem, Muhammad
16. "Mobile robot path planning in environments cluttered with non-convex obstacles using particle swarm optimization," International Conference on Control, Automation and Robotics, 2015, Alam, Muhammad Shahab; Rafique, Muhammad Usman
17. "Modified trajectory shaping guidance for autonomous parallel parking," IEEE Conference on Robotics, Automation and Mechatronics, 2010, Rafique, Muhammad Usman; Faraz, Kunwar
18. "Guidance based autonomous parking assistant," International Conference on Industrial Mechatronics and Automation, 2010, Rafique, Muhammad Usman; Faraz, Kunwar

Skills

Image Synthesis	Text-to-image, image-to-image, novel view synthesis, GANs, diffusion models
Remote Sensing	Multi image fusion, cloud removal, image segmentation, change detection
Tools	Python, PyTorch, Keras/Tensorflow, OpenCV, MATLAB, Simulink
Cloud GPUs	AWS, Google cloud (GCP), Huggingface
Robotics	Localization (Particle and Kalman Filters), Motion Planning (Bug algorithm, artificial potential field, probabilistic road map, VFH, velocity obstacle)
Filtering&Estimation	Kalman and Extended Kalman Filter, H_∞ and Particle Filter. Optimization (Particle Swarm Optimization, convex optimization using linear matrix inequality)
Embedded Systems	Worked on several microcontrollers (PIC, Intel/Atmel, Arduino), Altera FPGA boards (Verilog HDL and NIOS II Soft Processor)

Teaching

Capstone Design I and II, University of Kentucky, USA Contributed as a member of a 4-person teaching team, instructing and guiding undergraduate Electrical and Computer Engineering seniors through capstone design projects. Responsibilities included lectures, student support, grading, and presentation evaluations.

Introduction to Robotics, The Hong Kong Polytechnic University, Hong Kong As a Teaching Assistant for a graduate-level robotics course, I guided students in building mobile robots and coordinated a mini competition showcasing light-seeking robot designs.

Embedded Systems, Air University, Pakistan Instructed undergraduate students in embedded systems courses, which encompassed comprehensive studies of Intel 8086 microprocessor, Intel 8051 microcontroller, as well as Microchip PIC18F and PIC30F microcontrollers.

Mechatronics Design / Robotics, Air University, Pakistan Designed and taught mechatronic system design courses, covering sensors, actuators, motor control, and control systems. Students' final project involved creating an autonomous mobile robot for indoor navigation.

Professional Service

Area Chair

- IEEE/CVF International Conference on Computer Vision, ICCV (2025)

Program Committee / Reviewer

- IEEE/CVF Conference on Computer Vision and Pattern Recognition, CVPR (2021 -)
- IEEE/ISPRS EARTHVISION, held at CVPR (2021 -)
- IEEE Winter Conference on Applications of Computer Vision, WACV (2021 -)
- The British Machine Vision Conference, BMVC (2020 -)
- The European Conference on Computer Vision, ECCV, (2024 -)
- IEEE/CVF International Conference on Computer Vision, ICCV (2023 -)
- IEEE Transactions on Pattern Analysis and Machine Intelligence, TPAMI (2022, 2023)
- ISPRS Journal of Photogrammetry and Remote Sensing (2020 -)
- IEEE Transactions on Geoscience and Remote Sensing, TGRS (2020 -)
- IEEE Transactions on Image Processing, TIP (2019 -)
- IEEE Transactions on Multimedia, TMM (2019 -)

Achievements

- Outstanding reviewer IEEE Conference on Computer Vision and Pattern Recognition, CVPR 2021, 2023, 2024
- Outstanding reviewer the British Machine Vision Conference, BMVC 2021
- Outstanding reviewer IEEE/CVF Winter Conference on Applications of Computer Vision, WACV 2025
- Nominated by the Department of Electrical and Computer Engineering for the College of Engineering Outstanding PhD student award, 2020
- Recipient of graduate fellowship by Department of Electrical and Computer Engineering, University of Kentucky, 2016 - 2021
- Received President's Gold Medal in MS Mechatronics Engineering 2008 - 2010 batch with CGPA of 3.95 / 4.00, 2010
- Organized robotic competitions in Air University: 2010, 2012, 2013 and 2014
- Participated in Shell Eco-Marathon Asia in Malaysia 2011, Philippines, 2015
- Won 1st Prize in the National Engineering Robotics Contest (NERC), 2006
- Won Higher Education Commission grant of 18,500 USD for Final Year Project in Bachelors of Engineering at NUST, 2006
- Received Academic Scholarship during Bachelors of Engineering at NUST, 2006