Dr. Biplab Banerjee

CONTACT INFORMATION

Assistant Professor,
Centre for Studies in Resources Engineering,
Indian Institute of Technology Bombay,
Powai, Mumbai - 400076,
Maharashtra, India

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*E-mail:*bbanerjee@iitb.ac.in
Google Scholar Profile

RESEARCH INTERESTS

- **Image representation:** Interest points detection, Sparse Bag of Visual Words (BoVW) model, Spatial extension of the BoVW model, Graph based representation of images, Mid level feature mining (local topologies of interest points), Deep Convolutional Neural Network (CNN) based feature learning, Part based representation of visual categories (simulated annealing based techniques for discriminative parts detection from a given object category).
- **Image classification**: Learning part based classifiers (exemplar classifier models), Deep CNN based classification, k Nearest Neighbor (kNN) - Support Vector Machine (SVM) framework for classification, Multi-label classification, Domain adaptation for cross-domain object recognition, Kernel learning theory and Max-Margin classification, Weakly-supervised classification, Zero-shot object recognition.
- **Image segmentation**: Graph based segmentation of images, Minimum spanning tree based pixel clustering, Hidden Markov Random Field (HMRF) based image segmentation with discontinuity prior, Binary Partition Tree (BPT) for image segmentation, Hierarchical segmentation of images, Conditional Random Field (CRF) based semantic image segmentation, Multi-class co-segmentation, *From segments to semantics:* **How can prior knowledge be used to assign semantic tags to the unsupervised segmentation results?**
- **Action recognition from unconstrained videos**: Interaction part mining (tracking of localized regions over the video frames) for action representation, time-series feature pooling to capture the temporal evolution of frame-level contents, Discriminative local feature learning for efficient codebook construction, Zero-shot action recognition, Hierarchical video representation, *Learning to rank* paradigm to model the temporal evolution of human action.
- **Machine learning**: Stochastic Gradient Descent (SGD) based algorithms to solve primal optimization problems, Cutting plane methods, Spectral clustering, Nearest neighbor based classification, Metric learning, Hierarchical classifier design, Semi-supervised learning, Ensemble learning, Transfer learning, Zero/One shot learning, Open-set learning.
- **Deep learning**: Convolutional networks for weakly-supervised learning, Recurrent networks, Deep generative models, Encoder-decoder based deep representation learning.

ACADEMIC APPOINTMENTS

Post-Doctoral Research Scholar From March, 2016 to September, 2016
Pattern Analysis and Computer Vision Group, Istituto Italiano Di Tecnologia, Italy
- **Host:** Professor Vittorio Murino
- **Topics of research:** Interaction part mining for attributes based action representation for improved recognition

Post-Doctoral Research Scholar February 2015 to December, 2015
Image Group, GreyC Laboratory, CNRS UMR-6072, University of Caen Basse-Normandy, France
- **Host:** Professor Frederic Jurie
- **Topics of research:** Co-segmentation for parsing building facade images, Part based for image foreground segmentation

PROFESSIONAL APPOINTMENTS

Assistant Professor October 2016 to May 2018
Indian Institute of Technology Roorkee
- **Department:** Computer Science and Engineering

Assistant System Engineer Trainee September 2010 to December 2010
Tata Consultancy Services
- **Domain:** Core Java, J2EE, Servlet

EDUCATION

Indian Institute of Technology Mumbai, Mumbai, India

Ph.D, Image Analysis January 2011 - June 2015
(***Excellence in Ph.D Thesis*** **award from IIT Mumbai in the** 53^{rd} **Convocation)**
- **Thesis Topic:** The application of graph theoretic machine learning techniques for the analysis of remote sensing images
- **Adviser:** Professor Krishna M. Buddhiraju
- **Area of Study:** Machine Learning, Satellite Image Analysis, Remote Sensing
- **Performance on coursework**: CGPA of 8.50 on a scale of 10
- **Thesis review results**: Accepted by all the three reviewers with two **A** grades (Acceptance as it is) and one **B** grade (Acceptance with minor suggestions) on a scale of **A-F**

Jadavpur University, Kolkata, India

Masters of Engineering, Computer Science & Engineering July 2008 - June 2010
- **Thesis Topic:** A Novel method for image segmentation followed by image object classification using spanning tree based *natural grouping* for image segmentation and SVM for object classification
- **Adviser:** Professor Nirmalya Chowdhury
- **Area of Study:** Machine Learning, Data Mining, Pattern Recognition, Image Processing, Advanced Algorithm Analysis etc.
- **Performance**: CGPA of 8.33 on a scale of 10

West Bengal University of Technology, Kolkata, India

Bachelor of Technology, Computer Science & Engineering July 2004 - June 2008
- **Thesis Topic:** Clustering based information retrieval for Bengali UTF-8 encoded documents
- **Adviser:** Professor Mandar Mitra
- **Area of Study:** Data Structure & Algorithm, Discrete Mathematics, Artificial Intelligence, Operating System etc.
- **Performance**: CGPA of 8.21 on a scale of 10

West Bengal Council of Higher Secondary Education, Kolkata, India

12^{th} standard, General Science July 2002 - June 2004
- **Area of Study:** Mathematics, Physics, Chemistry, Biology etc.
- **Performance**: 81.1%

West Bengal Board of Secondary Education, Kolkata, India

10^{th} standard, General Stream July 2000 - June 2002
- **Area of Study:** Mathematics, Physical Science, Life Science, Literature etc.
- **Performance**: 75.6%

SELECTED PROJECTS

Indian Institute of Technology Bombay, Mumbai, India

Center for Studies in Resources Engineering — January 2019 -

- **Project Title:** Deep multi-task learning
- **Other Members:** Professor Subhasis Chaudhuri
- **Project in brief:** We explore the attention mechanism in performing the multi-task learning within a deep learning framework. We find that the notion of task-specific attention learning largely boost the task performance.
- **Supported by**: IIT Bombay

Indian Institute of Technology Bombay, Mumbai, India

Center for Studies in Resources Engineering — June 2018 -

- **Project Title:** Modality hallucination using deep learning
- **Other Members:** Professor Subhasis Chaudhuri
- **Project in brief:** We explore the possibility of hallucinating missing modalities during inference time for multi-modal remote sensing image classification. We deploy the deep generative models and the encoder-decoder based representation learning strategies for this purpose.
- **Supported by**: IIT Bombay

Indian Institute of Technology Roorkee, Roorkee, India and **Indian Institute of Technology Bombay**, Mumbai, India

Center for Studies in Resources Engineering — January 2017 -

- **Project Title:** Zero-shot learning for visual classification
- **Other Members:** Professor Subhasis Chaudhuri
- **Project in brief:** We explore developing novel functional mappings for zero-shot classification, a learning setting where the training and test classes are disjoint to each other. We are interested in exploring some primitive properties of both the image space and class representations in modeling such mapping functions.
- **Supported by**: Science & Engineering Research Board (SERB), GoI

Indian Institute of Technology Roorkee, Roorkee, India

Dept. of Computer Science — January 2017 - June, 2017

- **Project Title:** Discriminative representation learning
- **Other Members:** Professor Subhasis Chaudhuri
- **Project in brief:** We design novel encoder-decoder framework for learning representations of visual concepts. The main highlight is to ensure discrimination in the learned representation focusing primarily on fine-grained visual categories.
- **Supported by**: Science & Engineering Research Board (SERB), GoI

Indian Institute of Technology Roorkee, Roorkee, India

Dept. of Computer Science — August 2016 - December, 2016

- **Project Title:** Hierarchical subspace learning based domain adaptation (DA)
- **Other Members:** Professor Subhasis Chaudhuri
- **Project in brief:** The traditional subspace projection based domain adaptation techniques do not take into account the *semantic (dis)similarity* of the target classes for constructing the classifier model. This causes degradation in the performance of the classifiers when *data are overlapped*. Instead, we propose a *hierarchical tree based organization* of the target classes by exploring their semantic (dis)similarity and introduce subspace projection based DA at each node of tree. This essentially minimizes the

shortcomings incurred when a single subspace is learned for all the classes in both the domains.
We obtain state-of-the art results for a number benchmark multi-temporal remote sensing image sequences for the task of cross-domain image classification with the proposed hierarchical subspace learning model.

- **Supported by**: Indian Institute of Technology Bombay and Indian Institute of Technology Roorkee

Istituto Italiano di Tecnologia Genoa, Genoa, Italy

Pattern Analysis and Computer Vision Group — March 2016 - Present

- **Project Title:** Analysis of human actions in videos by discovering local mid-level concepts
- **Other Members:** Professor Vittorio Murino
- **Project in brief:**
  - The goal of this project is to design efficient local features incorporating category independent region proposals and a deep model. Given substantial intra-category variations of human action classes and fine-grained nature of different related actions, it is essential to separately model the evolution of the human body parts for the sake of effective action recognition. Towards this goal, we develop a new and efficient video representation that can model the evolution of different body parts over the frames. This is accomplished by defining *separate chain graphs of category independent region proposals* selected from all the frames in an unsupervised manner. We pose the same as a *recursive bipartite graph matching* problem of each pair of consecutive frames. Once the chains are found, we employ a 3D CNN model, trained end to end, in order to extract fixed length features from the chains. We refer to the chains as *concepts*.
    The next part of the framework aims at highlighting *discriminative concepts* specific to the action classes. We develop a *information theoretic ranking measure* to select such discriminative concepts which are further used for the purpose of action recognition.
  - We also explore efficient pooling based feature representation techniques and proposed a *time-series pooling of the feature dimensions* over consecutive video frames. The proposed pooling sharply outperforms traditional pooling techniques including max and average pooling.

  We validate the aforementioned representations on the challenging UCF-50, KTH, HMDB 51 etc. datasets and obtain enhanced action recognition performance measures.
- **Supported by**: Istituto Italiano Di Tecnologia

GreyC, CNRS UMR-6072, Caen, France

Image Group — August 2015 - December 2015

- **Project Title:** One-shot foreground segmentation based on patch matching
- **Other Members:** Professor Frederic Jurie
- **Project in brief:** This project deals with the problem of weakly-supervised foreground extraction from images from very few training samples. The proposed framework is composed broadly of four stages as follows:
  - *Extraction of category independent region proposals from both the training and test images*.
  - *A saliency detection based pre-processing to prune region proposals corresponding to background*.
  - *Segmentation propagation to transfer segmentation masks from the proposals of the training set to that of the test data*.

The segmentation propagation is performed in terms of efficient *patch matching* and *active contour based edge delineation*. Specifically, for each region proposal in the test image, we obtain the matching proposal from the training set and we initialize the segmentation of the test proposal from that of the training one. Further, the active contour model is used to roughly segment the test proposal.

- We combine the results of all the region proposals in the test image using majority voting and further modify it using the *hidden MRF* model. In particular, we consider the foreground and background classes to be Gaussian distributed and employ a pairwise MRF model to obtain the *Maximum A Posteriori* (MAP) solution.

We obtained state-of-the art results in terms of pixel level classification accuracy on the benchmark Butterfly and Horse datasets.

- **Supported by**: This is a part of the Semapolis (ANR-13-CORD-0003) project funded by CNRS and ANR

Image Group — February 2015 - August 2015

- **Project Title:** Unsupervised segmentation of building facade images
- **Other Members:** Professor Frederic Jurie, Dr. Loic Simon and Professor Nikos Komodakn
- **Project in brief:** This project deals with the unsupervised segmentation of the building facade images into its constituent assets. To the best of our knowledge, this is the first attempt towards building facade segmentation using an unsupervised approach. The proposed framework is composed of three stages as follows:
  - *Facade decomposition*: Given an image of a building facade, we propose an unsupervised technique to horizontally and vertically segment the facade image by analyzing the *gradient profiles* and the *distribution of corner points*. This essentially segments the facade into rectangular blocks and it is further ensured that each block contains single asset (window, balcony, wall etc.).
  - *Hidden MAP - MAP (HMRF-MAP)* based iterative segmentation using the segmentation lines found in the previous stage as discontinuity prior to obtain a smooth segmentation of the facade image.
  - *Extraction of repeated assets from the segmentation results*: The segmentation essentially allows the extraction of repeated facade assets like window by the application of simple architecture specific heuristics.

  We validate the proposed framework on the publicly available ECP and Zurich facade datasets and observe that the proposed framework attains comparable performance as compared to the supervised facade segmentation pipeline from the literature (based on supervised MAP-MRF models).
- **Supported by**: This is a part of the Semapolis (ANR-13-CORD-0003) project funded by CNRS and ANR

University of Trento, Trento, Italy

Remote Sensing Lab — September 2013 - December 2013

- **Project Title:** Unsupervised domain adaptation (DA) for classifying a pair of remote sensing images
- **Other Members:** Professor Lorenzo Bruzzone, Dr. Francesca Bovolo and Professor Subhasis Chaudhuri
- **Project in brief:** Consistent classification of all the images in a multi-temporal sequence is a challenging problem frequently encountered in remote sensing. Given a *source domain with ample training samples*, the traditional unsupervised DA method aims at constructing a classifier that works equally well for a *target domain where only unlabeled samples are present*. The domains, though contain the same set of semantic classes, are characterized by *domain specific distribution functions* which are *largely*

different from each other. Further, the traditional unsupervised DA techniques inherently consider that both the domains contain the *same set of semantic classes*. In contrast, we propose a novel method based on *subgraph isomorphism* to detect the cases involving added/deleted target domain classes. Further, we introduce an *Expectation-Maximization* (EM) based probabilistic model to update the statistical parameters of the source domain data to fit the characteristics of the target domain samples.
Exhaustive experiments conducted on a large number of multi-temporal satellite images of varied spatial and spectral resolutions establish the robustness of such a technique.

- **Supported by**: This is a part of the India-Trento Programme for Advanced Research (ITPAR) project funded by Department of Science & Technology, Govt. of India and the Province of Trento, Italy

Indian Institute of Technology Mumbai, Mumbai, India

Satellite Image Analysis Lab — January 2013 - April 2013

- **Project Title:** Higher order conditional mutual information based feature dimensionality reduction from Synthetic Aperture Radar (SAR) decomposition images
- **Other Members:** Professor Krishna Mohan Buddhiraju and Professor Avik Bhattacharya
- **Project in brief:** *Sub-space projection* based dimensionality reduction techniques are popular in the machine learning literature. However, traditional *variance based subspace projection* techniques like Principal Component Analysis (PCA) fails to capture *higher order dependencies* of the input features as well as their discriminative potentials. Mutual information serves as a better candidate than the variance in this respect. We propose a number of novel measures to *rank the feature dimensions* based on the concepts of *conditional mutual information* that jointly takes into account the *correlation between the feature dimensions as well as the correlation between the feature dimensions and class labels*. Such an extension of the traditional variance based dimensionality reduction techniques appears to be efficient for SAR images which have some specific inherent statistical properties. We further propose a novel data normalization strategy for SAR data which projects the decomposition parameters of different physical significance into a common space.
  We evaluate the proposed feature selection strategy to a number of ALOS / PALSAR images and observe enhanced classification performance than the traditional variance based feature selection techniques.
- **Supported by**: This work was partly supported by the India-Trento Programme for Advanced Research (ITPAR) project funded by Department of Science & Technology, Govt. of India and the Province of Trento, Italy

Indian Institute of Technology Mumbai, Mumbai, India

Vision and Image Processing Lab — January 2013 - September 2013

- **Project Title:** Detection and classification of vehicles from traffic videos
- **Other Members:** Professor Tom Mathew and Professor Subhasis Chaudhuri
- **Project in brief:** In this project, we deal with the traditional *background subtraction* based vehicle detection and *mean-shift based tracking* from real-time traffic videos. Furthermore, we explore the *co-occurrence of local features* and introduce an improved *dictionary learning* strategy by incorporating the spatial extent of the local features.
- **Supported by**: This work was supported by the CDAC, Department of Electronics and Information Technology, Govt. of India

Telecom ParisTech, France, Paris, France

Radar Image Analysis Group — April 2012 - June 2012

- **Project Title:** Information theoretic approaches for image registration
- **Other Members:** Professor Florance Tupin

- **Project in brief:** In this project, we work towards the development of an *information theoretic measure for patch matching* in order to perform image registration for a pair of multi-temporal SAR data.
- **Supported by**: This work was supported by the ParisTech group, France under a bilateral agreement between IIT Bombay and Telecom ParisTech

Indian Institute of Technology Mumbai, Mumbai, India

Satellite Image Analysis Lab — January 2012 - July 2012

- **Project Title:** Road and building extraction from high resolution satellite images
- **Other Members:** Professor Krishna Mohan Buddhiraju
- **Project in brief:** Detection of man-made structures likes buildings or road-networks from high resolution satellite remote sensing images is an important tasks with varied applications. In this work, we develop a sequential framework for automatically extraction road networks and buildings from satellite images. In particular, we define a number of heuristics specific to the properties of the road or building regions and apply such rules to recognize those semantic classes.
  We evaluate the method on a number of high resolution *QuickBird and World-View* images and observe that the heuristics are highly precise in properly classifying the segmented regions. However, the performance of the system is largely dependent on the initial segmentation of the images.
- **Supported by**: This work was partly supported by the Indian Space Research Organization (ISRO)

Jadavpur University, Kolkata, India

Department of Computer Science — July 2009 - July 2010

- **Project Title:** Active learning based semi-supervised content based image retrieval
- **Members:** Professor Nirmalya Chowdhury
- **Project in brief:** We develop a Support Vector Machines (SVM) based *active learning* framework for the purpose of *outdoor image retrieval*. We initially assume the presence of *a small number of labeled samples* in addition to *a large pool of unlabeled samples* for training. A multi-class SVM is modeled using the available labeled training samples. A few confusing images close to the SVM hyperplane are selected for further assessment and are subsequently *labeled by the external agent*. The SVM hyperplane is recomputed iteratively until there is no change in the position of the hyperplane. Once the hyperplane is fixed, given a query image, we apply the *nearest neighbor ranking scheme* in order to generate a ranked list of retrieved images for the query.
- **Supported by**: This work was partly supported by the Department of Computer Science, Jadavpur University

Indian Statistical Institute, Kolkata, India

Department of Computer Vision and Pattern Recognition — January 2007 - July 2008

- **Project Title:** Corpus development for *Forum of Information Retrieval Evaluation (FIRE)*
- **Members:** Professor Mandar Mitra
- **Project in brief:** We worked towards the development of the corpus for Bengali UTF-8 encoded documents using *relevance feedback based active learning* framework. The final goal of the project was to develop a search engine for Bengali text documents.
- **Supported by**: This work was supported by the Department of Science & Technology, Govt. of India

RESEARCH VISITS **TU Munich**, Munich, Germany

Signal Procesing in Remote Sensing June-July, 2019

- **Research Topic:** Machine Learning in Remote Sensing
- **Host:** Professor XiaoXiang Zhu
- **Area of Study:** Machine Learning, Satellite Image Analysis
- **Supported by**: Bavarian Govt., Germany

Kyungpook National University, Gumi, South Korea

Convergence & Fusion System Engineering September, 2018

- **Research Topic:** Machine Learning in Remote Sensing
- **Host:** Professor Youkyung Han
- **Area of Study:** Machine Learning, Satellite Image Analysis
- **Supported by**: Kyungpook National University, South Korea

Ghent University, Ghent, Belgium

Dept. of Tele-communication and Information Processing (Telin) December, 2017

- **Research Topic:** Representation learning in remote sensing
- **Host:** Professor Aleksandra Pizurica
- **Area of Study:** Machine Learning, Satellite Image Analysis
- **Supported by**: University of Ghent, Belgium

University of Trento, Trento, Italy

Remote Sensing Lab, Information Engineering September 2013 - December 2013

- **Research Topic:** Graph matching based domain adaptation for classifying multi-temporal remote sensing images and Ensemble clustering paradigm in remote sensing image segmentation
- **Host:** Professor Lorenzo Bruzzone
- **Area of Study:** Machine Learning, Satellite Image Analysis, Remote Sensing
- **Supported by**: Department of Science & Technology, Govt. of India under the India-Trento Programme for Advanced Research (ITPAR) bilateral agreement

Telecom ParisTech, Paris, France

Radar Image Lab, Department of Image and Signal Processing April 2012 - June 2012

- **Research Topic:** Patch matching based registration of Synthetic Aperture Radar (SAR) images
- **Host:** Professor Florance Tupin
- **Area of Study:** Machine Learning, Satellite Image Analysis, Remote Sensing
- **Supported by**: ParisTech group, France under the IIT Bombay - ParisTech bilateral agreement

TALKS

[1] Biplab Banerjee, *Zero-shot learning - an overview*.
Place: University of Applied Sciences Munich, Germany, July, 2019.

[2] Biplab Banerjee, *Advances in deep adversarial domain adaptation*.
Place: DLR Munich, Germany, June, 2019.

[3] Biplab Banerjee, *Introduction to deep CNN*.
Place: IIT Roorkee, India, May, 2019.

[4] Biplab Banerjee, *Deep learning for business intelligence*.
Place: School of Management, IIT Bombay, India, May, 2019.

[5] Biplab Banerjee, *Deep face recognition*.
Place: Center for Artificial Intelligence Research, Defence Research & Development Organization (DRDO), India, October, 2018.

[6] Biplab Banerjee, *Introduction to machine learning for geo-spatial applications*.
Place: VJTI Mumbai, India, October, 2018.

[7] Biplab Banerjee, *Zero-shot learning for visual classification*.
Place: National Institute of Technology Silchar, India, July, 2018.

[8] Biplab Banerjee, *Generative models in deep learning*.
Place: Indian Institute of Technology Roorkee, India, February, 2018.

[9] Biplab Banerjee, *Visual recognition using deep learning*.
Place: G. L. Bajaj College of Engineering Noida, India, November, 2017

[10] Biplab Banerjee, *Introduction to Convolutional neural networks*.
Place: IMS Engineering College Ghaziabad, India, November, 2017.

[11] Biplab Banerjee, *Introduction to deep learning*.
Place: Indian Institute of Technology Roorkee, India, September, 2017.

[12] Biplab Banerjee, *Image foreground extraction under one-shot learning using mid-level feature mining*.
Place: International Institute of Information Technology Bangalore, Bangalore, India, February, 2016.

[13] Biplab Banerjee. *Visual domain adaptation*.
Place: Indian Institute of Technology Indore, Indore, India, January, 2016.

[14] Biplab Banerjee, *Visual domain adaptation*.
Place: Siemens Research India, Bangalore, India, August, 2015.

[15] Biplab Banerjee. *Spectral clustering techniques*.
Place: Quality Improvement Program (QIP) organized by Ministry of Human Resource (MHRD), Govt. of India at IIT Bombay, Mumbai, India, November, 2014.

[16] Biplab Banerjee. *Self organizing feature map*.
Place: Sardar Patel College of Engineering, Mumbai, India, August, 2013.

[17] Biplab Banerjee. *Unsupervised image segmentation techniques*.
Place: Quality Improvement Program (QIP) organized by Ministry of Human Resource (MHRD), Govt. of India at IIT Bombay, Mumbai, India, June, 2013.

[18] Biplab Banerjee. *Domain adaptation - a general perspective*.
Place: Oxford University, United Kingdom, June, 2012.

[19] Biplab Banerjee. *Kernel density estimation techniques in image smoothing and segmentation*.
Place: Quality Improvement Program (QIP) organized by Ministry of Human Resource (MHRD), Govt. of India at IIT Bombay, Mumbai, India, June, 2011.

[20] Biplab Banerjee. *Support Vector Machines and its variants*.
Place: IIT Bombay, Mumbai, India, May, 2011.

[21] Biplab Banerjee. *Object based image analysis*.
Place: Jadavpur University, Kolkata, India, June, 2009.

[22] Biplab Banerjee. *Ranking algorithms for web mining*.
Place: RCC Institute of Information Technology, Kolkata, India, July, 2008.

WORKSHOPS, TUTORIALS

[1] Organized a CEP course on *Deep learning in Remote Sensing Image Analysis* at IIT Bombay in November, 2019.

[2] Organized a summer school on *Topics in Machine Learning* at the G. L. Bajaj Institute of Engineering in November, 2017.

[3] Organized a national level course on *Database Management System* at Indian Institute of Technology Roorkee in March, 2017.

[4] Attended the summer school on *Regularization techniques in machine learning* (REGML) at University of Genova, Italy in August, 2016.

[5] Organized a two-days workshop on *Soft computing techniques* at Sarvajanik College of Engineering Technology, Surat in August, 2014.

[6] Organized a one-day pre-conference tutorial on *Segmentation techniques for high resolution remote sensing images* as a part of national level conference Geomatrix 14' at CSRE, IT Bombay, India in June, 2014.

[7] Organized an institute level workshop on LaTeX at IIT Bombay in April, 2012.

[8] Attended the international workshop on *Synthetic-Aperture Radar*, organized by American Society of Photogrammetry and Remote Sensing (ASPRS) at Sacramanto, USA in March, 2012.

[9] Attended the workshop on *Kinect for Windows*, organized by Microsoft Research India and VIGIL group, Department of Computer Science & Engineering, IIT Bombay in March, 2012.

[10] Attended the national workshop on Python, *Scipy*, organized by IIT Bombay, Enthought Technology and MHRD, Govt of India in December, 2011.

[11] Attended the national workshop on *Recent Advances on Network Security using Cryptography*, organized by Cognizant Technology Solutions and RCC Institute of Information Technology, Kolkata in June, 2007.

TEACHING EXPERIENCE

CSRE, IIT Roorkee, Mumbai, India

Main or Co course adviser (June, 2018 - Present)

- Machine Learning for Remote Sensing II (Deep learning for computer vision)
- Machine Learning for Remote Sensing I (Introductory machine learning)
- Remote Sensing & Image Analysis (co-faculty)
- Data Analytic (co-faculty)

Dept. of CSE, IIT Roorkee, Roorkee, India

Main course adviser (January, 2017 - June, 2018

- Compiler Design
- Computer Vision
- Machine Learning
- Data Structure & Algorithm
- Data Structure lab

CSRE, IIT Bombay, Mumbai, India

Teaching Assistant

- **Subject:** Basic Satellite Image Processing
- **Main adviser:** Professor Krishna Mohan Buddhiraju
- **Topics covered:** Introduction to Machine Learning, Image Segmentation
- **Duration**: July to December 2011, 2012 and 2014

Teaching Assistant

- **Subject:** Advanced Satellite Image Processing
- **Main adviser:** Professor Krishna Mohan Buddhiraju
- **Topics covered:** Support Vector Machines, Mean-Shift Clustering, Statistical Learning Thory
- **Duration**: January to May 2011, 2013 and 2014

Jadavpur University, Kolkata, India

Teaching Assistant

- **Subject:** System Software
- **Adviser:** Professor Ujjwal Maulik and Professor Nirmalya Chowdhury
- **Topics covered:** Parsing in Compiler Design, File handling in C
- **Duration**: January 2010 to June 2010

The Gate Academy, Thane, India

Visiting Faculty for All India Master's entrance program (GATE)

- **Subjects taught:** Operating Systems, Data Structure, Discrete Mathematics
- **Duration**: January 2013 to July 2013 and January 2014 to December 2014

STUDENTS MENTORED

- Mr. Sayan Rakshit (Pursuing Ph.D, **Place**: IIT Bombay, India)
- Mr. Shivam Pande (Pursuing Ph.D, **Place**: IIT Bombay, India)
- Mr. Ankit Jha (Pursuing Ph.D, **Place**: IIT Bombay, India)
- Mr. Debabrata Pal (Pursuing Ph.D, **Place**: IIT Bombay, India)
- Mr. Vikram Roday (Pursuing Ph.D, **Place**: IIT Bombay, India)
- Miss. Renuka Sharma (Pursuing PhD, **Main guide**: Prof. Rusikesh Joshi, **Place**: IIT Bombay, India)
- Mr. Omkar Gune (Pursuing Ph.D, **Main guide**: Prof. Subhasis Chaudhuri, **Place**: IIT Bombay, India)
- Mr. Saurabh Kumar (Pursuing Ph.D, **Main guide**: Prof. Subhasis Chaudhuri, **Place**: IIT Bombay, India)
- Miss. Ushasi Chaudhuri (Pursuing Ph.D, **Co-guide**: Prof. Avik Bhattacharya, **Place**: IIT Bombay, India)
- Miss. Swati Gupta (Pursuing Ph.D, **Co-guide**: Prof. Sugata Gangopadhayay, **Place**: IIT Roorkee, India)
- Mr. Abhinaba Roy (Pursuing Ph.D, **Main guide**: Prof. Vittorio Murino, **Place**: Istituto Italiani di Tecnologia Genoa, Italy)
- Mr. Aditya (Co-Supervised during M-tech at CSE, IIT Bombay, India (2019-2020). **Co-guide**: Prof. Shivakumar.
- Mr. Gyan (Co-Supervised during M-tech at CSE, IIT Bombay, India (2019-2020). **Co-guide**: Prof. Shivakumar.
- Mr. Pankaj (Co-Supervised during M-tech at CSE, IIT Bombay, India (2019-2020). **Co-guide**: Prof. Shivakumar.
- Mr. Nimit (Co-Supervised during B-tech + M-Tech at EE, IIT Bombay, India (2019-2020). **Co-guide**: Prof. Subhasis Chaudhuri.
- Mr. Satyam (Co-Supervised during B-tech at EE, IIT Bombay, India (2019-2020). **Co-guide**: Prof. Subhasis Chaudhuri.
- Mr. Ashwini (Co-Supervised during B-tech at EE, IIT Bombay, India (2019-2020). **Co-guide**: Prof. Subhasis Chaudhuri.
- Mr. Koushik (Supervised during M.Tech at CSRE, IIT Roorkee, India (2019-2020).
- Mr. Punit (Supervised during M.Tech at CSRE, IIT Roorkee, India (2019-2020).
- Mr. Megh (Co-Supervised during M-tech at CSRE, IIT Bombay, India (2018-2019). **Co-guide**: Prof. Krishna Mohan.

- Miss. Nagma Khan (Supervised during M.Tech at EE, IIT Bombay, India (2015-2016). **Co-guide**: Prof. Subhasis Chaudhuri.
- Miss. Renuka Sharma (Supervised during M.Tech at CSE, IIT Roorkee, India (2017-2018).
- Miss. Manpreet kaur (Supervised during M.Tech at CSE, IIT Roorkee, India (2017-2018).
- Miss. Sheetal Yadav (Supervised during M.Tech at CSE, IIT Roorkee, India (2017-2018).
- Miss. Deepika Kadam (Supervised during M.Tech at CSE, IIT Roorkee, India (2017-2018).
- Mr. Bhupendra Meena (Supervised during M.Tech at CSE, IIT Roorkee, India (2017-2018).
- Mr. Akashdeep Goel (Supervised during B-Tech at CSE, IIT Roorkee, India (2017-2018).
- Mr. Sanatan Sharma (Supervised during B-Tech at CSE, IIT Roorkee, India (2017-2018).
- Mr. Rahul Kumar (Supervised during B-Tech at CSE, IIT Roorkee, India (2017-2018).
- Mr. Saurabh Goyal (Supervised during B-Tech at CSE, IIT Roorkee, India (2017-2018).
- Mr. Gurwinder Singh (Supervised during B-Tech at CSE, IIT Roorkee, India (2017-2018).
- Mr. Hanumant Mittal (Supervised during B-Tech at CSE, IIT Roorkee, India (2017-2018).
- Mr. Jaisingh (Supervised during B-Tech at CSE, IIT Roorkee, India (2017-2018).

PROFESSIONAL SERVICE

Referee Service

- *IEEE Signal Processing Letters*
- *IEEE Access Journal*
- *IEEE Transactions on Cybernatics*
- *IEEE Transactions on Image Processing*
- *IEEE Transactions on Geoscience & Remote Sensing*
- *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*
- *IEEE Access*
- *IEEE Geoscience and Remote Sensing Letters*
- *SPIE Journal of Applied Remote Sensing*
- *International Journal of Remote Sensing*
- *Remote Sensing Letters (Taylor & Francis)*
- *Neural Computing & Applications (Springer)*
- *Journal of Indian Society of Remote Sensing (Springer)*
- *Computer Vision and Image Understanding (Elsvier)*
- *Optik (Elsvier)*
- *Pattern Recognition (Elsvier)*
- *Internal Journal of Computer Vision (Springer)*
- *IEEE International Conference on Pattern Recognition, 2018*
- *International Journal for Light and Electron Optics (Elsvier)*
- *National Conference on Communication (NCC) - 2014, India*
- *Proposals under Science & Engineering Research Board (SERB), DST, GoI*
- *PhD and Masters thesis from IIT Kharagpur, IIT Kanpur, IIIRS Dehradun*

Conference and Symposium Service

- **Program Committee:** IEEE CVPR workshop on Diagram Image Retrieval and Analysis (DIRA), 2020.
- **Program Committee:** National Conference on Computer Vision Image Processing and Graphics (NCVPRIPG), 2019.
- **Program Committee:** IEEE ICCV workshop on Graphs in Vision, 2019.
- **Program Committee:** Indian Conference on Computer Vision Graphics and Image Processing (ICVGIP), 2018.
- **Plenary Chair:** International Conference on Computer Vision and Image Processing (CVIP), 2018.
- **Program Committee:** Young Researchers Symposium at CODS-COMAD 2018 , Goa India, January, 2018.
- **Program Committee:** International Workshop on Foundations of Big Data Computing (in conjunction with HiPC), 2017, Jaipur, India, December, 2017.
- **Program Committee:** Mining Intelligence and Knowledge Exploration (MIKE), 2017, Hy-

derabad, India, December, 2017.
- **Program Committee:** International Conference on Computer Vision and Image Processing (CVIP), 2017, Noida, India, September, 2017.
- **Program Committee:** Tenth International Conference on Contemporary Computing (IC3 2017), JIIT, Noida, Noida, India, August 10 - 12, 2017.
- **Program Committee:** Research Scholar and Alumni Symposium (RSAS 2014), IIT Bombay, Mumbai, India, March 7 - 8, 2014.
- **Technical Committee:** National Conference on Application of Geoinformatics in Rural, Urban & Climatic Studies (Geomatrix 2014), IIT Bombay, Mumbai, India, September 6-7, 2014.
- **Local Organizing Committee:** Indian Conference of Computer Vision Graphics and Image Processing (ICVGIP 2012), IIT Bombay, Mumbai, India, December 16 - 19, 2012.
- **Local Organizing Committee:** International Conference on Geospatial Technologies and Applications (Geomatrix 2012), IIT Bombay, Mumbai, India, February 26 - 29, 2012.
- **Session Chair for *Pattern Recognition***: Annual Conference of American Society of Photogrammetry and Remote Sensing (ASPRS), 2012 in Sacramento, California, USA.

Other Positions of Responsibility
- Served as the *M-Tech in Geo-Informatics Faculty Adviser* for the batch 2019-2021.
- Served as the *steering commitee member* for initiatives in data science and artificial intelligence at IIT Bombay.
- Served as the *Departmental academic programme committee member*, IIT Roorkee for the academic year 2017-2018.
- Served as the *institute level research scholar academic council member* at IIT Bombay for the academic year 2013-2014.
- Served as the *departmental Ph.D. representative for Centre of Studies in Resources Engineering (CSRE)* for the academic year 2011-2012.

APPLICATION AREAS

Parsing of building facade images, Road and building extraction from high resolution satellite images, Land cover classification from multi-spectral and hyper-spectral images, Content based image retrieval, Large scale image classification, Object detection and localization in still images, Image geo-localization, Machine learning techniques for forecasting.

SUBJECT SKILLS

Image Processing:
- Image acquisition, filtering, Image registration, Image denoising, Image compression, Image segmentation, Hierarchical segmentation of images, Color image processing, Morphological image processing, Super-resolution imaging

Computer Vision:
- Interest points detection from images (Corners, SIFT, Dense sampling), Interest point descriptors (SIFT, SURF, HOG), Image representation (Bag of visual words, Graph based representation, Contour based representation, shape-context features), Feature matching in multiple images (Self-similarity, SIFT matching), Image classification, Image retrieval, Part based object category recognition, Motion analysis under optical flow, Continuous shot detection in videos, Action and activity recognition, Foreground-background co-segmentation, Object based image and video analysis

Machine Learning:
- **Supervised learning**: Bayesian classifier, Nearest neighbor based classifier, Maximum margin classifiers including SVM, Decision tree classifier, Multi-layer neural networks, Classifier ensemble, Regression, Statistical learning theory, Graphical modeling (Markov random field, Conditional random field), Image classification with neighborhood consistency
- **Unsupervised learning**: Clustering (k-means, Fuzzy clustering, Density based clustering, Graph based clustering including spectral clustering), Density estimation including non-

parametric kernel density estimation, Mean-shift algorithms, Gaussian mixture models and Expectation Maximization (EM), Co-clustering, Cluster ensemble
- **Semi-supervised learning**: Self learning, Active learning, semi-supervised learning using mixture models, Transductive learning, Graph-cut based semi-supervised learning
- **Transfer learning**: Supervised and unsupervised domain adaptation (Instance weighting, Metric learning, Sub-space learning, Domain adaptive SVM)
- **Dimensionality reduction of high-dimensional data**: Wrapper based techniques (PCA, LDA, LLE, Mutual information based approach, dense sub-graph based approach), Supervised dimensionality reduction techniques
- **Deep learning**: Convolutional Neural Networks (CNN), Recurrent Neural Networks (RNN) (Gated Recurrent Networks (GRU) and Long-Short Term Memory (LSTM)), Restricted Boltzman Machines (RBM), Deep Belief Networks (DBN)

Data Structures and Algorithms:
- Static data structures (Arrays, lists), Dynamic data structures (Linked list, Stack, Queue), Graph based data structures (Complete graph, Spanning tree, Neighborhood graphs), File handling, Searching and Sorting
- Brute force algorithms, Greedy algorithms, Dynamic programming, Super-polynomial algorithms and the NP class problems, Approximation algorithms

Computer Programming:
- C, C++, Python, SQL, HTML, UNIX Shell scripting (including POSIX.2)

Numerical Analysis:
- MATLAB

Version Control and Software Configuration Management:
- DVCS (Mercurial/MQ, Git/StGit)

MATLAB skill set:
- Linear algebra, Fourier transforms, Nonlinear numerical methods, Polynomials, Statistics, N-dimensional filters, Visualization
- Toolboxes: Communications, Image processing, Filter design, Genetic algorithm and direct search, Signal processing

Desktop Editing and Productivity Software:
- Vim
- TEX (LATEX, BIBTEX),
- Microsoft Office, OpenOffice.org, LibreOffice, Google Docs
- GIMP, InkScape

Operating Systems:
- Microsoft Windows family, Linux, BSD, IRIX, AIX, Solaris, and other UNIX variants

MAJOR SCHOLARSHIPS

[1] Awarded the *International Travel Support (ITS)* from *SERB, DST* for attending IEEE ICASSP 2017 in New Orleans, USA.

[2] Awarded the post-doctoral net monthly allowance of 2050 Euro by *IIT Genova* during the entire period of the stay at Genova, Italy. (March, 2016 to Present).

[3] Awarded the post-doctoral net monthly allowance of 2370 Euro by the *Centre National de la Recherche Scientifique (CNRS)* during the entire period of the stay at Caen, France. (February, 2015 to December, 2015).

[4] Awarded the monthly allowance of 900 Euro by the *India Trento Program for Advanced Research (ITPAR)* project grant during the entire period of the research stay at Trento, Italy (September, 2013 to December, 2013).

[5] Awarded the monthly allowance of 1200 Euro by *ParisTech group, France* during the entire period of the research stay at Telecom ParisTech, France (April, 2012 to June, 2012).

[6] Awarded the Junior Research Fellowship (JRF) and the Senior Research Fellowship (SRF) by *MHRD, Govt. of India* for pursuing the Ph.D. at IIT Bombay (January, 2011- December, 2014).

[7] Awarded the GATE scholarship by *MHRD, Govt. of India* for pursuing Masters of Engineering. at the jadavpur University, Kolkata, India (July, 2008 to June 2010).

RECOGNITION

- Served as one of the *guest editors* for the special issue *Deep Learning in Remote Sensing Data Analysis* by the journal MDPI Remote Sensing (2019 I.F 4.2).
- Selected as the *Best Reviewer* for the year 2018 by IEEE Journal of Selected Topics in Earth Observations and Remote Sensing (IEEE JSTARS) (2019 I.F 3.4).
- Awarded the *Person of the Year, PhD*, at CSRE, IIT Bombay, 2013-2014 for research excellence.
- Selected for the *INRIA best poster award* at Geomatrix 2012, an international conference arranged by CSRE, IIT Bombay.
- Selected as one of the student assistants for the annual conference of American Society of Photogrammetry and Remote Sensing (ASPRS), 2012 in Sacramento, California, USA.

RESEARCH GRANTS

- **Indo-France** bilateral research fund from CEFIPRA, GoI (2020-2023) (INR 30 lakhs).
- **ISRO** fund (2020-2023) (INR 40 lakhs).
- **AWL Inc., Japan** for sponsored research (2020-2022) (INR 27 lakhs).
- **India-UK** bilateral research fund from DST, GoI (2019-2021) (GBP 16,000).
- **Seed grant** from IIT Bombay (2018-2021) (INR 20 lakhs).
- **Early Career Research Award** from SERB, DST, GoI (2017-2020) (INR 20 lakhs).
- **Nvidia Academic collaboration programme** (2017-) (1.5 lakhs).

PERSONAL DETAILS

- **Date of birth:** 10^{th} June, 1987
- **Father's name:** Mr. Sanat Kumar Banerjee
- **Mother's name:** Mrs. Kaberi Banerjee
- **Marital status:** Single
- **Permanent address:** 106/B, Indira Gandhi Road, Post: Konnagar, District: Hooghly (West Bengal), Pin: 712235, India