

**Project Title:** **Reliable Deep Learning and Statistical Inference for Medical Image Analysis**

**Project Number** **IMURA1010**

**Monash Main Supervisor**  
(Name, Email Id, Phone) **Dr. Zhaolin Chen**  
[zhaolin.chen@monash.edu](mailto:zhaolin.chen@monash.edu) *Full name, Email*

**Monash Co-supervisor(s)**  
(Name, Email Id, Phone)

**Monash Head of Dept/Centre** (Name,Email) **Prof. Jianfei Cai**  
[Jianfei.Cai@monash.edu](mailto:Jianfei.Cai@monash.edu) *Full name, email*

**Monash Department:** **Department of Data Science and AI**

**Monash ADGR**  
(Name,Email) **Prof Bernd Meyer**  
Bernd.Meyer@monash.edu *Full name, email*

**IITB Main Supervisor**  
(Name, Email Id, Phones) **Prof. Suyash P. Awate**  
[suyash@cse.iitb.ac.in](mailto:suyash@cse.iitb.ac.in)  
<https://www.cse.iitb.ac.in/~suyash> *Full name, Email*

**IITB Co-supervisor(s)**  
(Name, Email Id, Phone)

**IITB Head of Dept**  
(Name, Email, Phone) **Prof. Umesh Bellur**  
[umesh@cse.iitb.ac.in](mailto:umesh@cse.iitb.ac.in) *Full name, email*

**IITB Department:** **Computer Science and Engineering (CSE) Department**

### Research Clusters:

### Research Themes:

<b>Highlight which of the Academy's CLUSTERS this project will address?</b> <i>(Please nominate JUST <u>one</u>. For more information, see <a href="http://www.iitbmonash.org">www.iitbmonash.org</a>)</i>		<b>Highlight which of the Academy's Theme(s) this project will address?</b> <i>(Feel free to nominate more than one. For more information, see <a href="http://www.iitbmonash.org">www.iitbmonash.org</a>)</i>	
1	Material Science/Engineering (including Nano, Metallurgy)	1	<b>Advanced computational engineering, simulation and manufacture</b>
2	Energy, Green Chem, Chemistry, Catalysis, Reaction Eng	2	Infrastructure Engineering
3	Math, CFD, Modelling, Manufacturing	3	Clean Energy
4	<b>CSE, IT, Optimisation, Data, Sensors, Systems, Signal Processing, Control</b>	4	Water
5	Earth Sciences and Civil Engineering (Geo, Water, Climate)	5	Nanotechnology
6	Bio, Stem Cells, Bio Chem, Pharma, Food	6	Biotechnology and Stem Cell Research
7	Semi-Conductors, Optics, Photonics, Networks, Telecomm, Power Eng	7	Humanities and social sciences
8	HSS, Design, Management	8	Design

## The research problem

### Background:

Advances in computational image analysis are crucial for advancing the state of the art in medical imaging towards faster, safer, and higher-quality imaging. The current state of the art in image analysis relies on rigorous statistical modelling and inference that leverages the ability of deep neural networks (DNNs) for modelling complex nonlinear mappings and distributions. Applications in medical imaging offer interesting challenges for image analysis by pushing the boundaries of the imaging devices for improved diagnosis, therapy, and monitoring.

### Project Aims and Scope:

This project deals with challenging problems within the domain of image quality enhancement as well as image reconstruction and analysis in medical imaging, specifically positron emission tomography (PET) and magnetic resonance imaging (MRI). One of the major developments in this area has been the innovation of scanners that enable simultaneous capture of PET and MRI data, where MRI images provide structural/anatomical information and PET images provide functional/metabolic information associated with the underlying tissue. In order to push the boundaries of the imaging devices to obtain higher-quality images with reduced scan times (in both PET and MRI) or reduced radiation dose (in PET), we need novel mathematical formulations for learning, novel inference algorithms, and the associated computational methods to address problems in image reconstruction and image quality enhancement through reduced noise, reduced artifacts, improved resolution, ability to learn with limited data, etc. Such tasks also extend to spatiotemporal image sequences in both PET and MRI modalities.

While methods relying on DNN models hold tremendous promise in pushing the state of the art, an important practical consideration is the reliability of the methods in applications various, e.g., where the test data exhibits characteristics different from the characteristics of the training data, where the training data is limited or low quality, etc. Methods that model the variation and artifacts in the data and methods that output the uncertainty in the processed images can aid in improved modelling, inference and clinical decision making.

The project has two main aims. One aim of the project is to design novel methods in statistical machine learning involving DNN models. Another aim of the project is to validate the novel methods on human PET and MR data. We encourage application of the methods towards clinical/scientific studies.

### For the PhD candidate:

The candidate will plan the curriculum to satisfy all coursework-related criteria specific to the Computer Science and Engineering (CSE) Department at IIT Bombay (additional details available at the CSE department website). The candidate will need to fulfil the requirements of Monash University for PhD candidature. For a part of the project, the candidate is required to travel to Monash University to undertake research.

### References:

1. Wadhvani, K., and Awate, S.P., Pattern Recognition 2021, 118:108001.
2. Sudarshan, V.P., et al., Medical Image Analysis 2021, pp. 73:102187.
3. Jena, R, and Awate, S.P., Info. Proc. in Med. Imag. 2019.
4. Chen, Z., et al. Human Brain Mapping, 2018. 39(12).
5. Wehrl, H.F., et al., Nat Med, 2013. 19(9): pp. 1184-9.

## Project aims

1. Novel mathematical formulations, statistical models, and inference algorithms for deep learning schemes for image quality enhancement in PET and MRI modalities, focusing on various challenges related to robustness, reliability, reproducibility, uncertainty, training data, etc.
2. Application of deep learning to real-world clinical/scientific medical PET and MRI datasets for problems within the theme of image quality enhancement.

## Expected outcomes

1. Novel learning schemes, novel models that are favorable over the state of the art in specific ways.
2. Publications in top-tier conferences and journals in medical image analysis and machine learning.

## How will the project address the goals of the above themes?

Selected Theme: Advanced computational engineering, simulation and manufacture

The core of the proj

ect relies on advanced statistical modelling and computational image analysis. It will lead to novel models and learning schemes for problems in image quality enhancement within the themes of medical imaging involving PET and MRI. The resulting models and algorithms will have the potential to be translated to MRI and PET scanning devices.

## Capabilities and degrees required

Candidate should have a Master's degree or a Bachelor's degree related to Computer Science, Computer Engineering, Computing, or Electrical/Electronics/Telecommunication Engineering.

Candidates should have the following knowledge/skills:

- \* a strong understanding of key concepts in probability, statistical modelling, linear algebra, optimization;
- \* a good understanding of key concepts in image processing and machine learning;
- \* good skills in coding and data analysis, including python programming;
- \* (not mandatory, but preferred) exposure to coding environments for deep learning.

## Potential collaborators

Please visit the IITB website [www.iitb.ac.in](http://www.iitb.ac.in) OR Monash Website [www.monash.edu](http://www.monash.edu) to highlight some potential collaborators that would be best suited for the area of research you are intending to float.

Select up to **(4)** keywords from the Academy's approved keyword list (available at <http://www.iitbmonash.org/becoming-a-research-supervisor/>) relating to this project to make it easier for the students to apply.

Data science, optimisation, algorithms.

Additional keywords: medical image computing, machine learning, image analysis.