# RESEARCH STATEMENT

**RAJDEEP PAL**

The goal of my research is to design **intelligent computational systems** that can perceive, understand, and analyze complex real-world data, with a particular emphasis on **visual information processing**. My recent work has focused on developing **machine learning and deep learning models** that interpret and quantify visual structures in biomedical images. During my project on trabecular bone topology analysis, I applied image processing and learning techniques to study the micro-architecture of bones using micro-CT datasets. My primary task was to differentiate the structural orientation of trabecular bone between young and elderly individuals to investigate how age-related morphological changes contribute to reduced bone strength and delayed recovery. This research strengthened my interest in combining computational perception with biological interpretation, and I now aim to expand this line of work at **EPFL**, focusing on the intersection of **machine learning, visual analysis, and intelligent modeling**.

## 1. Foundations

My academic foundation in **Computer Science** has given me exposure to key computational principles, including algorithms, data structures, and system design. I have complemented this with focused exploration in **Machine Learning, Deep Learning, and Visual Computing**.

During my **IAS–INSA–NASI Summer Research Fellowship at IIT Ropar**, I worked under *Prof. Navin Kumar* on the project *"TRABECULAR — Bone Topology Analysis and Segmentation."* The work involved applying **image processing and machine learning** techniques to analyze trabecular bone micro-architecture from micro-CT data. I implemented segmentation pipelines, feature extraction, and topology analysis, automating the process using Python, OpenCV, and NumPy. This project deepened my understanding of the geometric and morphological challenges of biomedical imaging and how ML-driven segmentation can extract meaningful structural information from complex data.

## 2. Applied Research and System Development

Parallel to academic research, I actively develop **AI-driven applications** that integrate learning algorithms into real-world decision systems.

One of my current projects is a **Bengali-language book and article retrieval model**, which leverages natural language understanding and embedding-based retrieval to improve access to regional literature. Another ongoing project focuses on designing an **AI-based Railway Station Management System**, aimed at **crowd prediction, delay forecasting, and dynamic platform allocation** through machine learning and reinforcement learning principles. These efforts demonstrate my interest in creating **context-aware and scalable AI systems** that connect algorithmic insights with practical, deployable intelligence.

In addition, I built a **Deep Learning Image Classification model** using PyTorch that achieved 91.22% accuracy on the Cats vs. Dogs dataset, and a **Diabetes Prediction model** using TensorFlow, exploring the interpretability of AI models in healthcare. These works have strengthened my understanding of model design, evaluation, and optimization for constrained environments.

## 3. Compiler Design and Abstraction

Beyond applied ML, I maintain a strong interest in **compiler architecture and language design**. My **Java-based Compiler Development Project** explores lexical analysis, parsing, and code generation, focusing on the internal mechanics of language processing. I view compilers as conceptually parallel to ML pipelines: both transform high-level abstractions into executable intelligence. This project has strengthened my grasp of symbolic reasoning, modular design, and abstraction—principles that also underlie the interpretability of modern neural architectures.

## 4. Future Directions

In the future, I aim to expand my research at EPFL in collaboration with **Prof. Pascal Frossard** and **Dr. Anirudh Raju Natarajan**, focusing on **representation learning, efficient visual reasoning, and robotics-oriented perception models**. I am particularly interested in exploring how **multi-modal fusion and lightweight neural architectures** can enhance real-time decision-making and perception in autonomous systems.

My long-term goal is to pursue a career in **applied AI research and development**, bridging academic innovation with system-level implementation. EPFL's interdisciplinary environment—where theoretical rigor meets practical impact—aligns perfectly with my vision of designing intelligent visual systems that not only *learn* but also *understand*.

## References


1. Pal, R. *TRABECULAR — Bone Topology Analysis and Segmentation*, IAS–INSA–NASI SRFP Report, IIT Ropar, 2025.
2. Pal, R. *Bengali-Language Book and Article Retrieval Model*, Independent Research Project, ongoing.
3. Pal, R. *AI-Based Railway Station Management System*, Independent Research Project, ongoing.
4. Pal, R. *Compiler Design and Abstraction Project*, Java Implementation Repository, 2024.