IITB-Monash Research Academy

An Indian-Australian research partnership

Indian Institute of Technology Bombay | MONASH University

Project Title:	**Machine Learning for Joint Radar Communication Systems**	
Project Number	**IMURA1019**	
Monash Main Supervisor (Name, Email Id, Phone)	Dr. Nikola Zlatanov, nikola.zlatanov@monash.edu	*Full name, Email*
Monash Co-supervisor(s) (Name, Email Id, Phone)		
Monash Head of Dept/Centre (Name,Email)	Prof. Scott Tyo, Scott.Tyo@monash.edu	*Full name, email*
Monash Department:	Electrical and Computer Systems Engineering	
Monash ADGR (Name,Email)	A. Professor Timothy Scott, Timothy.Scott@monash.edu	*Full name, email*
IITB Main Supervisor (Name, Email Id, Phone)	Prof. Manjesh K. Hanawal, mhanawal@iitb.ac.in	*Full name, Email*
IITB Co-supervisor(s) (Name, Email Id, Phone)		*Full name, Email*
IITB Head of Dept (Name, Email, Phone)	Prof. Jayendran Venkateshwaran, head.ieor@iitb.ac.in	*Full name, email*
IITB Department:	IEOR	

Research Clusters:

Research Themes:

Highlight which of the Academy's CLUSTERS this project will address? *(Please nominate JUST **one.** For more information, see www.iitbmonash.org)*		**Highlight which of the Academy's Theme(s) this project will address?** *(Feel free to nominate more than one. For more information, see www.iitbmonash.org)*	
1	*Material Science/Engineering (including Nano, Metallurgy)*	***1***	***Artificial Intelligence and Advanced Computational Modelling***
2	*Energy, Green Chem, Chemistry, Catalysis, Reaction Eng*	2	*Circular Economy*
3	*Math, CFD, Modelling, Manufacturing*	3	*Clean Energy*
4	***CSE, IT, Optimisation, Data, Sensors, Systems, Signal Processing, Control***	4	*Health Sciences*
5	*Earth Sciences and Civil Engineering (Geo, Water, Climate)*	5	*Smart Materials*
6	*Bio, Stem Cells, Bio Chem, Pharma, Food*	6	*Sustainable Societies*
7	*Semi-Conductors, Optics, Photonics, Networks, Telecomm, Power Eng*		
8	*HSS, Design, Management*		

The research problem

The objective of this project is to innovate a joint radar-communication (JRC) framework for beyond 5G (i.e. 5G in millimeter wave (mmWave) and beyond). 5G mmWave protocols support the transmission over large bandwidths over focused beams to the mobile users in order to obtain high data rates at low latency. However, its practical realization faces several challenges such as efficient localization, beam alignment, and tracking. In this project, we propose to augment the PHY and MAC layers of the communication protocols with radar functionality without increasing the communication protocol overheads. The specific objective of the radar is to intelligently detect and localize mobile users, thereby eliminating the requirement of auxiliary sensors and dedicated channel estimation overheads. We aim to explore conventional signal processing approaches as well as recent artificial intelligence and machine learning approaches to improve localization accuracy of joint radar communication systems.*

Beam alignment and tracking of mobile users in mmWave bands is challenging as the number of candidate beams can be very large and there could be propagation blockages. We propose to explore radar augmented with artificial intelligence capabilities to identify the suitable beam under the given latency constraints.

Our next goal is to efficiently implement the algorithms for the joint radar communication framework on reconfigurable architecture for the heterogeneous system-on-chip and validate their performance on real-world hardware. Since a common spectrum is used, there will be no interference between the radar and communication systems and only a marginal increase in the overall system cost and complexity.

Project aims

The aims of the project are:

1) Signal processing and machine learning-based algorithms for supporting radar-based detection and localization of mobile users as well as the estimation of channel conditions. Theoretical and experimental evaluation of algorithms' real-time performance in quasi-static channel conditions.

2) Reinforcement learning algorithms for transmitter parameter selection such as carrier frequency, transmission bandwidth, beam direction, beamwidth, etc.

3) Extension to multiple user networks in which beam direction and beam width selection must be done so as to minimize the interference to adjacent users

4) Efficient mapping of the proposed algorithms on system-on-chip via hardware-software co-design. This also includes word length optimization and experiments in a real radio environment via the RFSoC platform

5) Evaluation of improvement of the communication link metrics (throughput, bit error rate, signal-to-interference-plus-noise ratio (SINR)) with the augmentation of the radar functionality. This will be done in the presence of various RF impairments, fixed-point configurations, wireless channels as well as interference.

How skills/experience of the IITB and the Monash supervisor(s) support the proposed project

Prof. Manjesh K. Hanawal works in the area of learning theory and their applications. Dr. Nikola Zlatanova is an expert in wireless networks. The study of Joint Radar Communication (JRC) problems requires tools from wireless communication and machine learning. Both the members bring required complementary skills to address the main challenges.

Both Prof. Manjesh K. Hanawal and Dr. Nikola Zlatanov will the working closely with Prof. Sumit J. Darak who has rich experience in efficient implementation of learning algorithms on hardware.

What is expected of the student when at IITB and when at Monash?

The student will start working with both Prof. Manjesh K. Hanawal and Prof. Nikola Zlatanova right from the beginning as both learning algorithms will be based on properties of the wireless networks. All the work will carried about in collaboration.

Expected outcomes

1) Signal processing and machine learning-based algorithms for localization along with their hardware implementations leading to standalone products.

2) Reinforcement learning algorithms for decision-making in single and multi-user networks with stationary and non-stationary radio environments along with theoretical performance guarantees.

3) Demonstration on RFSoC platform comprising of the ARM processor, FPGA, and RF Front End in sub-6 GHz spectrum

4) Simulation and experiment results demonstrating the performance gain of proposed intelligent JRC system over conventional JRC and non-JRC systems

How will the project address the Goals of the above Themes?

The project addresses the problem of improving the performance of 5G networks using techniques from Signal processing, machine learning and artificial intelligence. This strongly aligns with the theme ***Artificial Intelligence and Advanced Computational Modelling***

Capabilities and Degrees Required

1. *Degree in computer or electrical and communication engineering*
2. *Good understanding of wireless networks*
3. *Good understanding of basic probability and statistics*
4. *Exposure to basic machine learning algorithms*
5. *Good analytical skills*

Necessary Courses

Name three tentative courses relevant to the project that the student should complete during his/her coursework at IITB (the student will require to secure 8 point in these courses)

1. *Wireless communications*
2. *Engineering Statistics*
3. *Introduction to Machine Learning*
4. *Online Machine Learning and Bandit Algorithms*
5. *Reinforcement Learning*

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.

Networks and Telecommunications
Data Science,optimisation,algorithms
Maths
Signal Processing