IITB-Monash Research Academy

An Indian-Australian research partnership

Indian Institute of Technology Bombay | MONASH University

Project Title: **Physiotherapy-Assisting mmWave Radar Technology**

Project Number	**IMURA1058**	
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IITB Department:	Electrical Engineering	

Research Clusters:

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

Research Themes:

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	*Artificial Intelligence and Advanced Computational Modelling*
2	*Circular Economy*
3	*Clean Energy*
4	Health Sciences
5	*Smart Materials*
6	*Sustainable Societies*
7	*Infrastructure*

The research problem

The rehabilitation cost due to falls, brain strokes and road accidents is in the order of billions of dollars. For many paralysed and injured patients, body movements are restricted due to effect of paralysis and/or accidents. After injury or paralysis recovers, doctors refer the patient to a physiotherapist in order to achieve muscle correction and strength. The physiotherapist provides the patient with a set of movements and exercises to rebuild the muscle and regain strength.

The existing methods include mechanical help from a caregiver, a physiotherapist, and/or a tool to provide a guided movement of the patient. However, the physiotherapist cannot continuously monitor the patient, and the tools cannot monitor the progress of individual muscles and limbs. This increases the recovery time of a patient. This problem can be solved with an innovative technology incorporated in a smart wearable device. This smart wearable device with embedded sensors and actuators will monitor and control the movements. A mobile App will be embedded in the 2nd part of the smart device to send the data to the physiotherapist and a doctor to monitor the rehabilitation of the patient remotely. However, the wires attached to the number of sensors creates hazard and restricts the movements of limbs.

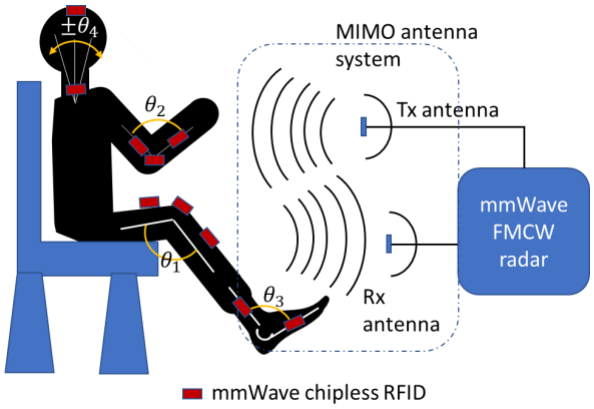
In the first phase of the IITB Monash Research Academy, a wired system with motion sensors are being developed by a PhD student under the supervision of both Monash and IIT Bombay chief academics. Getting promising results for the research project, both academics comes to a contentious decision to make the system wireless using a mmWave radar system. The wireless system will provide accurate such measurements without wire hence will be a popular product in the biomedical industry specific applications to rehabilitation.

Project aims

The aims of the project are two folds.

1. The radar system hardware, detection algorithm and integration. To fulfil the goal the following tasks are identified that meet Ph.D. level technical challenges.

1. A printable mmWave chipless RFID tag design. The tag can have smart sensing of temperature, pH and relative humidity measurement to indicate inflammation and perspiration of the joints.
2. A fully printable multiple input multiple output (MIMO) phased array antenna and beamforming algorithm development that collect data and provide signal processing methods accurately in body area noisy environment. Also, MIMO reduces the antenna hardware requirements.
3. A mmWave transceiver development for 77 an/or 94 GHz radar for precision data collection. Multiple bands can enhance the resolution of the angular measurement. It will provide a high resolution mmWave imaging of the movements of the limbs and joints of the patient in real time.
4. Advanced denoising and filtering, formal and machine learning algorithms for the *separation of noise, artefact induced anomalies and accurate measurements and detection of movement of limbs.*
5. And finally, a system level integration of the above and demonstration of the system with the measurement results and angle estimation.



In this project, a mmWave radar augmented with a set of chipless RFID tags and a mmWave multiple input multiple output (MIMO) antenna system will be implemented to analyse the joint movements of a rehabilitation patient. A set of ECG dot like fully printable mmWave chipless RFID tag nodes are affixed at different joints as shown in Figure 1. As illustrated in the figure the chipless RFID mmWave tags that are placed on key points on and near the joints of neck, elbow, knee and ankle. A FMCW transmitted signal from the radar hits the chipless RFID targets and the data from returned echoes for the specific RFID nodes are collected in both x, y, z coordinates, time and frequency f(x,y,z,t,f). This forms the 3D location capabilities of the tag. The MIMO antenna processed the return echoes. The RFID not only gives the position, time and frequency data but also specific identifications of the joints. This enhanced information helps the doctors, physiotherapists and rehabilitation technicians and carers interpret the progress of the patients.

The MIMO antenna reduces the hardware requirement by reducing the number of antennas in the system and improves the detection efficiency. Thus, the compact system would provide accurate elevation and azimuth angles of the joints. Moreover, being the conducting strips, the chipless RFID tags would improve the signal to noise ratio (SNR) filtering out the clutters in the returned echoes from the joints. A separate DPS chain would be used for RFID to process the identification data separately. Three first Fourier transform (FFT) chain will provide the range, azimuth and elevation angular resolutions.

A time versus frequency spectrogram of the detected signal will be developed and real time joint movements will be recorded for accurate angular motion measurements of joints and movement of the targeted areas. The transceiver and antennas will operate at either 77 or 94 GHz bands. These mmWave band radar will provide very high-resolution detection of the joint movement. A polarisation diversity chipless tag and I/Q demodulation in the receiver provides common-mode signal rejections so that on-body and surrounding noises can be mitigated. A moving target detection methods and noise filtering method will differentiate the static and moving parts of the human body. The data will be analysed using advanced denoising techniques such as Wavelet decomposition methods and deep learning algorithm for further accuracy in detection.

2. The project addresses various practical challenges in the target emerging application that are as follows:

1. The investigation starts from the focus on Knee joint and is extended to the multiple locations with a greater number of tags. Therefore, the number of RFID tags considering inter-tag interference must be mitigated with the polarisation diversity of the tag and MIMO antenna.
2. Positioning of the transmitter with respect to the RFID tags is the key since the purpose is not only the movement but estimation of the angle with an acceptable accuracy. Design of the transmitter antenna setup in a MIMO antenna configuration and its line of sight with respect to the tag are addressed with propagation studies and shape and positions of the antenna elements. The transmitter's position will be adjustable by the design of a setup for the positioning of the transceiver module.
3. Investigation of sources of error and how to mitigate them. The advanced adaptive filtering techniques would mitigate the errors.
4. Modelling and algorithms for the extraction of time varying angle. A deep learning-based training algorithm would provide high accuracy.

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

IIT-Bombay

- Design and development of the sensory system, signal denoising, algorithms and a part of the base monitoring system.

Monash University

- Complete base monitoring system, actuators, transceivers, antennas and communication link as well as interfacing and complete integration of all system modules and test.

Expected outcomes

This research would lead to the following outcomes:

1. Design of a mmWave radar-based network of chipless RFID sensors to sense the movements.
2. Design of an optimal bi-directional wireless communication link between transceivers and the base monitoring system.
3. Development of algorithms for processing and denoising sensors data as well as providing specific guided movements.
4. Design, develop and demonstration of all the modules as defined in (1) to (3).

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

The project is defined based on the current needs of the paralyzed and injured patients in the rehabilitation centers, and the complementary expertise of IIT-Bombay and Monash supervisors. The project has well defined modules with adequate flexibility to meet the required detailed specifications of the sub-systems. The supervisors would consult with physiotherapists in the choice of movements. Appropriate ethical clearance will be obtained from both institutions to conduct the research.

Potential RPCs from IIT Bombay and Monash

Potential RPC members from IIT Bombay

1- Prof. Laxmeesha, Department of Electrical Engineering, IIT-Bombay
2- Prof. Neeta Kanekar, Department of Bioscience and Bioenegineering, IIT-Bombay
3- A/Prof. Mehmet Yuce, Department of ECSE, Monash

Capabilities and Degrees Required

- MIMO antennas, mmWave technology, FMCW radar, machine learning
- Background in Sensor-System Design, Implementation and Test
- Background in Embedded System Design
- Background in Signal Denoising, Signal Processing and Preferably Machine Learning
- Background in Integration of Wireless Transmitter and Receivers

Necessary Courses

1- One of the courses related to signal processing (EE630 or EE750)
2- Electronic System Design (EE616)
3- Sensors in Instrumentation (EE617)
4- Embedded Systems Design (EE712)
5- Microwave Integrated Circuits (EE611)

Potential Collaborators

Please visit the IIT Bombay website www.iitb.ac.in OR Monash Website 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.

BioScience, Bio Medical Engineering
Sensor and Sensor Networks
Signal Processing
Antennas and Microwave/mm-wave Engineering/Radar/Machine learning
Modelling and Simulation