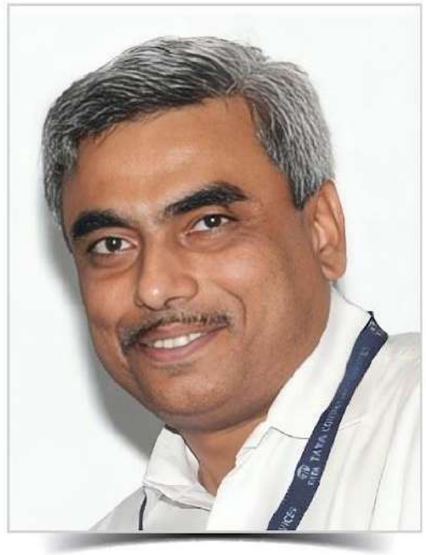
Welcome to Session By Technical Education and Skilling on

Empowering Bengal: Nurturing Future Ready Skills For A High Precision Work Force

BENGAL GLOBAL BUSINESS SUMMIT
5-6 February '25



Dr. Arpan Pal

Arpan Pal has more than 32 years of experience in the area of Intelligent Sensing, Signal Processing &AI, Edge Computing and Affective Computing. Currently, as Distinguished Chief Scientist, TCS Research, he is working in the areas of Connected-Health, Smart-Manufacturing and Remote-Sensing.

He has filed 190+ patents (100+ granted in different geographies) and has published 170+ papers in reputed conferences/journals. He is listed among the top 15 innovators in India in terms of patents filed. He is two times winner of Tata Group top Innovation award in Tata Innovista under Piloted technology category. He has also written three complete books on IoT, Digital twins in Manufacturing and Application of AI in Cardiac Disease screening.

Prior to joining Tata Consultancy Services (TCS), Arpan had worked for DRDO, India as Scientist for Missile Seeker Systems. He is a B.Tech and M. Tech from IIT, Kharagpur, India and PhD. from Aalborg University, Denmark.

BGBS 2025

Precision Robotics

Dr. Arpan Pal

Distinguished Chief Scientist & Research Head

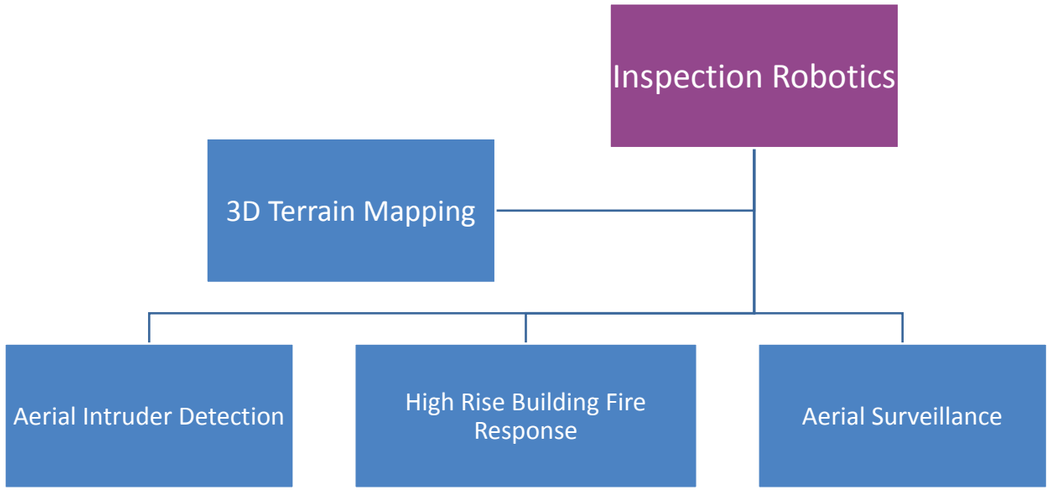
Embedded Devices & Intelligent Systems

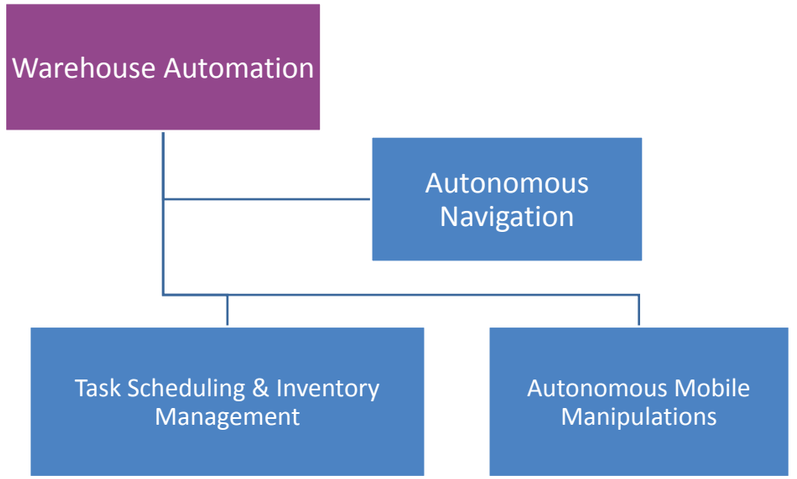
TCS Research

Tata Consultancy Services (TCS)

Feb 2025

Precision Robotics: Opportunities and Challenges





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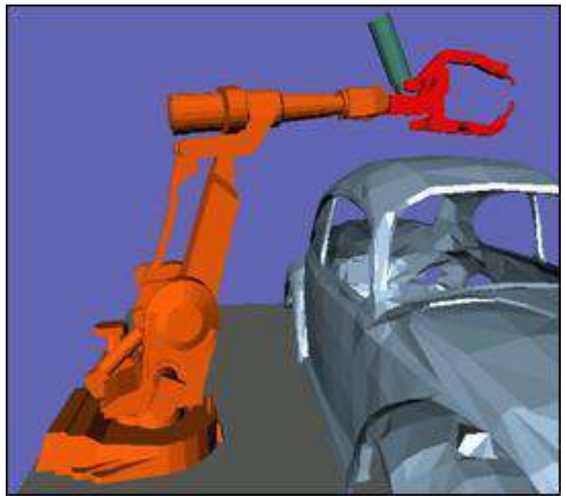
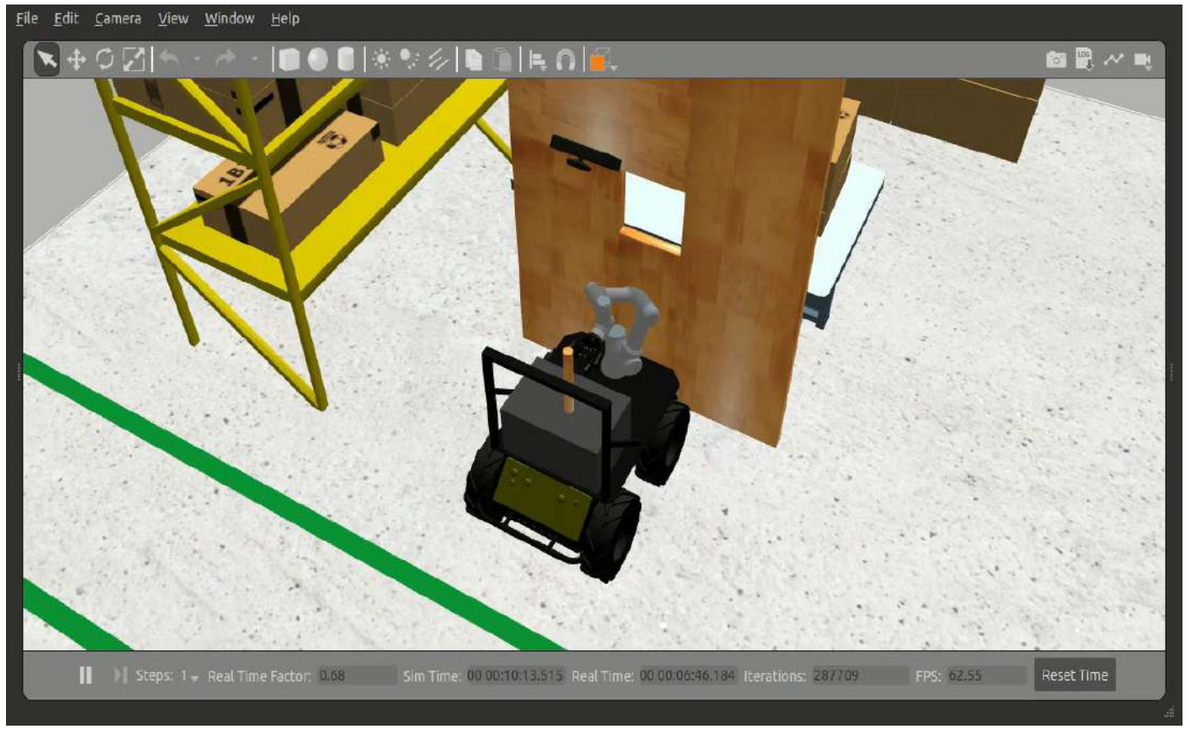
Inspection Robotics - Manipulation Use Case

Autonomous Complex Precision Manipulation



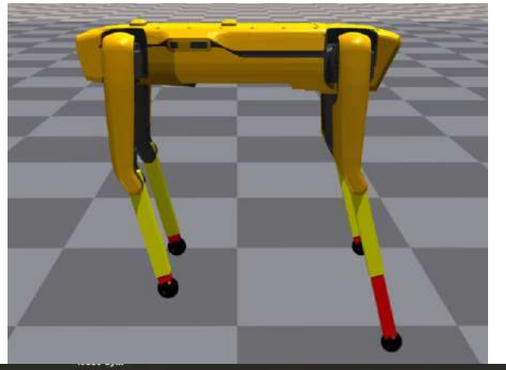


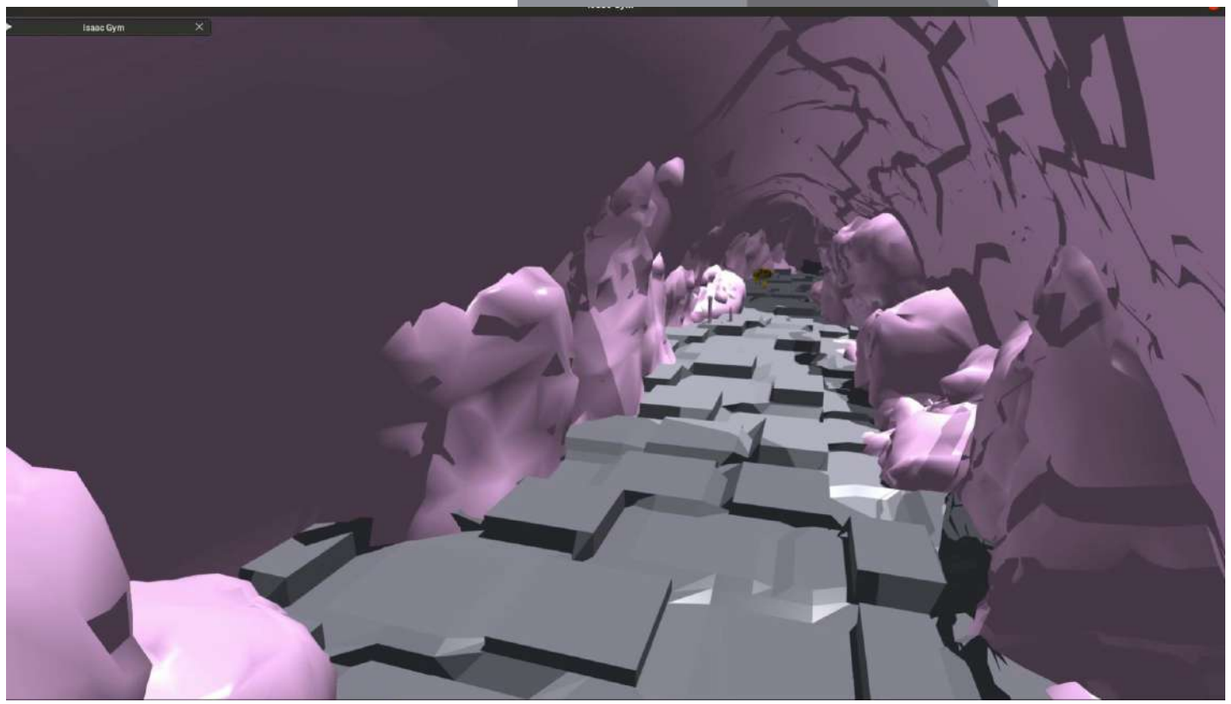
- Complex manipulator motion planning is NP-Hard.
- State of the Art methods uses Randomized Sampling based algorithms.
- A key problem of randomized sampling-based motion planning is the problem of configuration space narrow passage.
- A Levy flight-based manipulator motion planner

Inspection Robotics- Mining Use Case

Target Solution

ROCKSAR : mm wave RADAR based Mine Safety Inspection

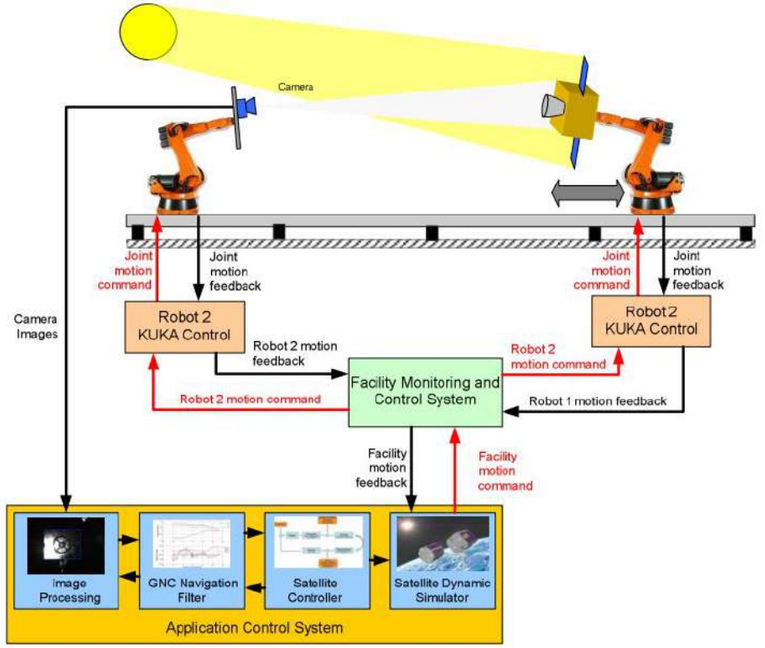




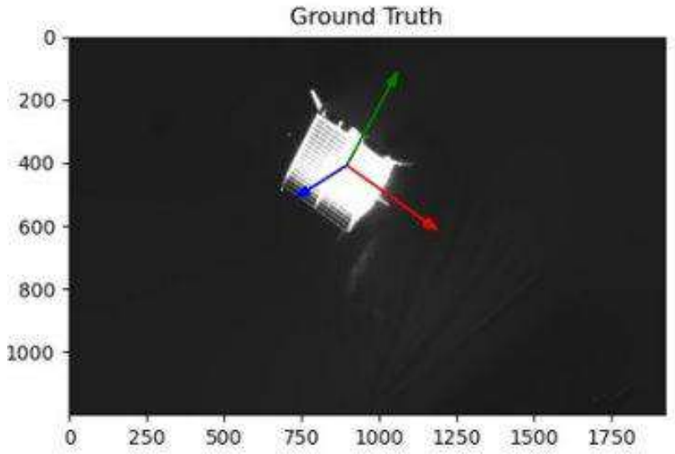
Requirements

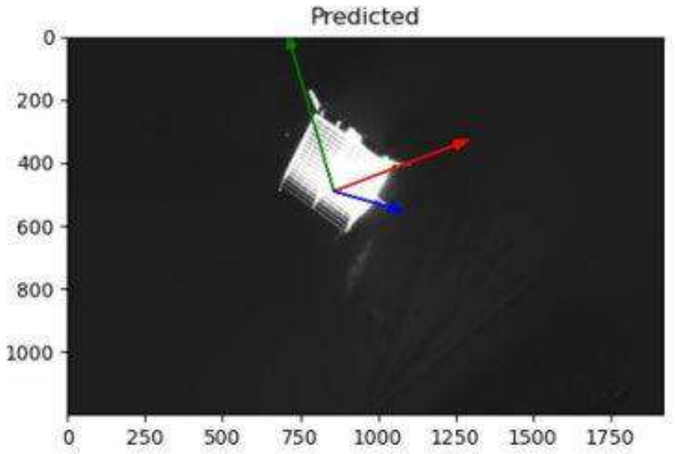
1. **Enhancement of existing legged loco-manipulation technique**
2. **Specific Use-case based targeted application**
3. **Research by-products**

Space Robotics- Debris Management Use Case



Test facility development, TCS Innovation Labs, Bangalore, Kolkata

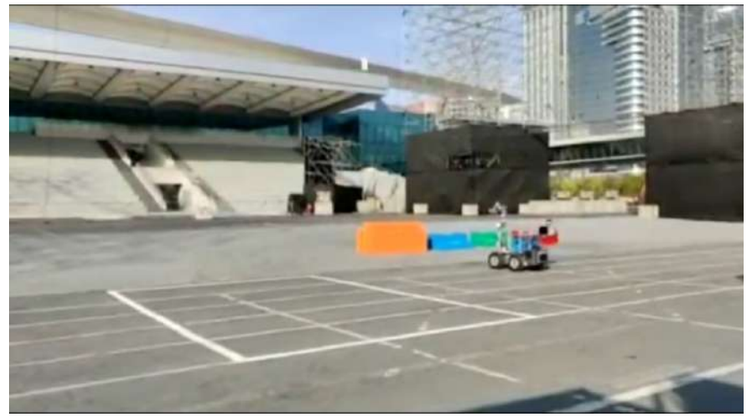


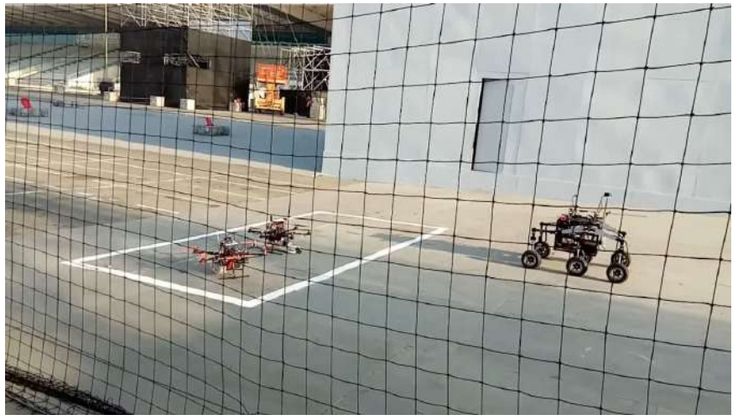
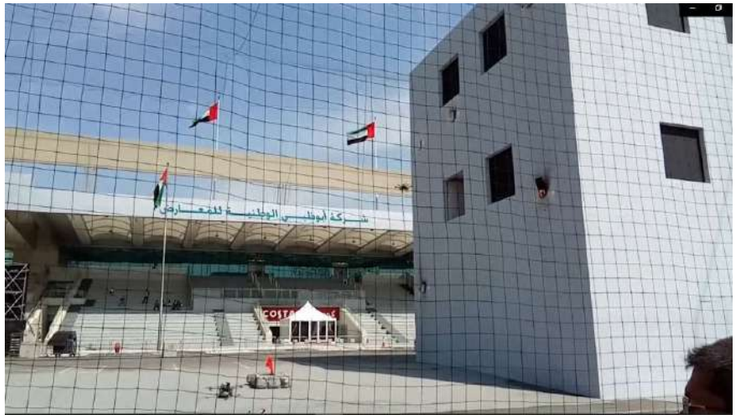


Muhammad bin Zayed International Robotics Competition, Abu Dhabi 2020

Fire rescue in high rises



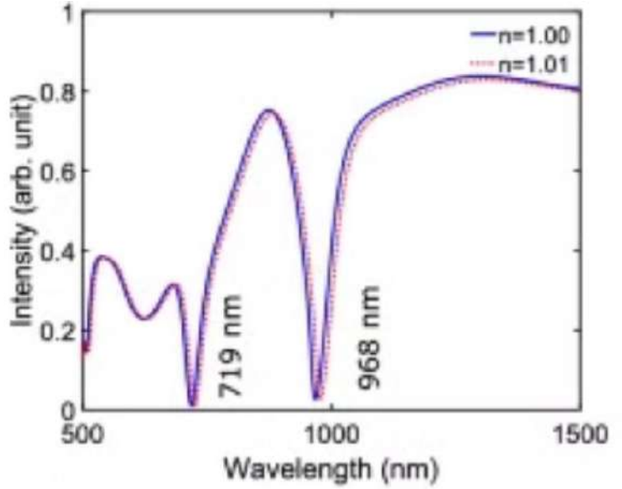


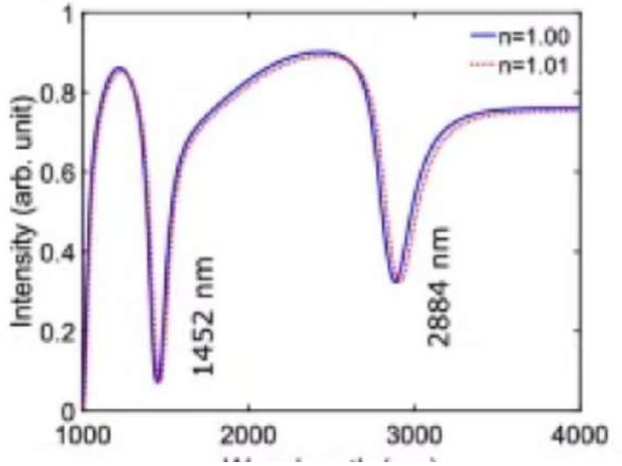



TCS-IISc Team Ranking – Global 6th in Grand Challenge

Unlocking the Future of Precision Robotics

- *Precision Manipulation and Actuation*
- *Precision AI on the Edge*
- *Precision Sens*



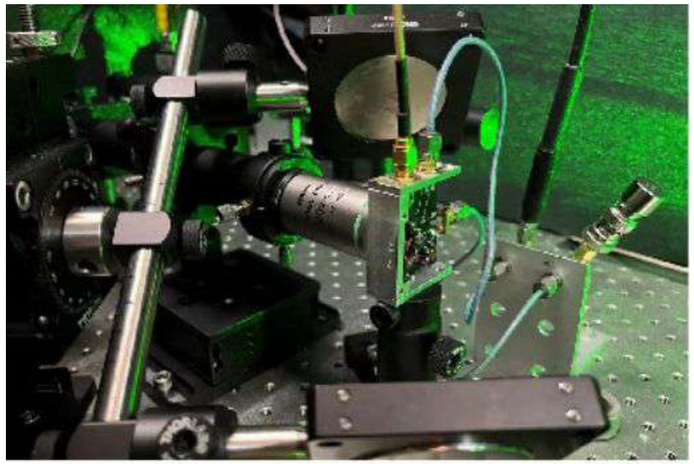


Precision and Balance in Sensing

Sensor Sensitivity and Accuracy

Advanced sensing technologies now enable micro-scale detection, such as measuring molecular changes or detecting minute environmental shifts as small as one part per trillion.

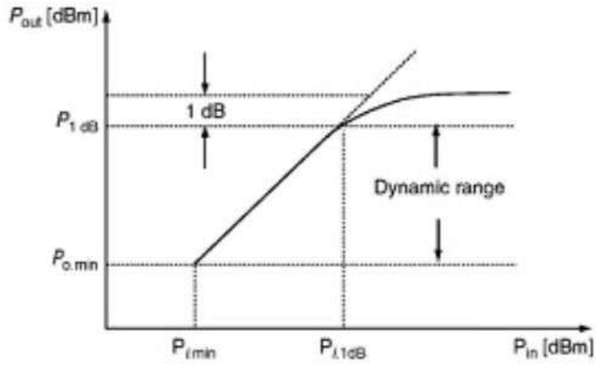
Cutting-edge nanosensors and quantum sensing techniques are pushing the boundaries of sensitivity, allowing unprecedented precision in fields like medical diagnostics, environmental monitoring, and materials science.

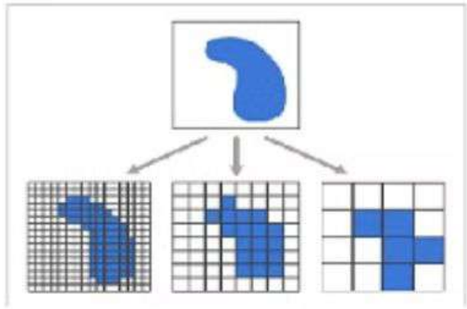


Dynamic Range and Resolution

The intricate balance between dynamic range and resolution presents complex engineering challenges. For example, in medical imaging, sensors must simultaneously capture both high-contrast details and broad-spectrum information.

Emerging adaptive sensor technologies use AI and machine learning algorithms to dynamically adjust sensitivity, creating more intelligent and responsive sensing systems that can optimize performance across varied input conditions.





Mapping the Unseen: BioRadar and MIMO Radar

1

2

Bio Radar

Revolutionary non-invasive imaging technology using high-frequency electromagnetic waves promising to generate three-dimensional maps of biological structures, enabling unprecedented visualization of vascular networks, organ interactions, and anomalies without safety disruption.

MIMO Radar

Multi-Input Multi-Output (MIMO) Radar systems leverage advanced signal processing and machine learning algorithms to create dynamic, real-time spatial mapping with centimeter-level precision, transforming navigation, emergency response, and environmental monitoring in complex, obstructed environments.

Quantum sensing: overview & applications

Quantum sensors are dramatically expanding measurement precision with vision to approach the fundamental Heisenberg limit—a quantum mechanical threshold that represents the ultimate precision possible in physical measurements, transcending classical technological constraints.

Future of AIoT - AI Enabled Nano-Sensing

Nano-sensing for AI

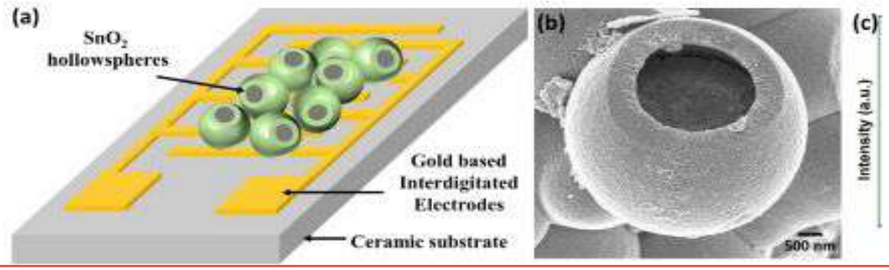
- Nanomaterials-based sensors – **improved sensitivity and specificity**
- **Increased specificity** - functionalization with chemical and biological molecules, with recognition events that cause detectable physical changes.
- **Increased sensitivity** - high surface-to-volume ratio of nanomaterials, as well as novel physical properties of nanomaterials

AI for Nano-sensing

Selective Discrimination of Nano-sensed outputs is hard for **complex input mixtures –** potential for **AI based inferencing**

AIoT Nano-systems

Nanosensors can also potentially be integrated with **nano-electronics** to add **native real-time processing capability to nano-systems (true miniaturized AIoT)**



Diabetes screening system based **on human breath analysis**

- **Single Chemiresistive sensor** developed to detect multiple VOCs – using **AI to discriminate**
- **First POC device and patient trial ongoing**
- **With IIT Kharagpur**

"Selective Discrimination of VOCs Applying Gas Sensing Kinetic Analysis over a Metal Oxide-Based Chemiresistive Gas Sensor" **ACS Sensors** 2021 6 (6), 2218-2224

Also exploring a nano-sensor based pathogen detection platform with **IIT Kharagpur**

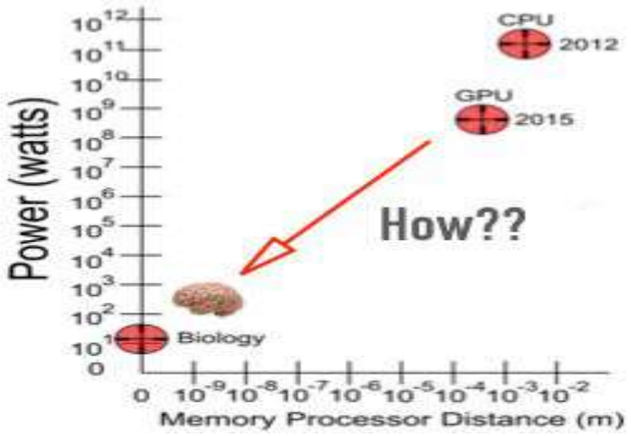
and

A Sepsis Detection system with **IIT Jodhpur** and **AIIMS-Jodhpur**

Low power AI at the Edge

Edge computing reduces energy cost of data movement

Beyond that - Can we replicate mammal brain-like energy-efficiency in Computing and also have low latency?



https://knowm.org/a-brief-history-of-neuromorphic-computing/

- von Neumann systems consume more power
- Neuromorphic systems co-locate computation and memory based on a non von Neumann architecture with billions of neurons and synapses
- **Neuromorphic Computing**
  - Spiking Neural Networks (SNN) operate on spikes/events (sparse in time)
  - Up to 1000x reduction in energy consumption

with **IIT Delhi**

Thank you

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