IARE
INSTITUTE OF
AERONAUTICAL ENGINEERING

HIGH IMPACT PRACTICES (HIPS)

CORNERSTONE PROJECTS: INTELLIGENT MECHATRONICS SYSTEMS

INFORMATION PACKET

2025 - 2026

I appreciate IARE students who are showing interest **Intelligent Mechatronics Systems – (IntelliMech)** Project Program at the Institute of Aeronautical Engineering.

Cornerstone Projects are comprehensive, application-based projects typically undertaken by students in the second or third year of their academic programs. These projects serve experience that integrates the knowledge, skills, and competencies acquired throughout the curriculum. They are designed for a single semester with a small team upto two students to solve real-world problems through innovative, interdisciplinary.

IntelliMech blends the principles of mechanical systems, electronics, sensors, control engineering, and embedded intelligence to design and build smart machines. These systems can sense their environment, process data, and respond with mechanical actuation in a controlled and intelligent manner. The program promotes hands-on innovation, digital integration, and AI-enhanced decision-making across mechatronic platforms.

Core Goals of Intelligent Mechatronics Systems (IntelliMech) Project Program:

- **Embedded Intelligence in Mechatronic Devices**
  Design intelligent mechatronic systems by integrating MCUs, FPGAs, and AI processors with real-time sensor feedback and adaptive control logic.

- **Sensor-Actuator Integration and Control**
  Implement robust sensor networks, actuator systems, and PID/adaptive control algorithms for responsive and stable operation in dynamic conditions.

- **Human-Machine Interaction (HMI)**
  Develop intuitive interfaces using touchscreens, gesture control, voice commands, and wearable tech for seamless interaction between humans and machines.

- **Predictive Maintenance and Digital Twins**
  Use condition monitoring, vibration analysis, and digital twin modeling to predict failures and optimize maintenance schedules for mechatronic systems.

- **AI-Enhanced Control Systems**
  Apply machine learning and fuzzy/neural control algorithms to optimize the performance of complex electromechanical systems in uncertain environments.

- **Energy-Efficient Mechatronics**
  Design sustainable and low-power mechatronic devices by implementing smart power management, energy harvesting, and lightweight design strategies.

- **Biomedical and Assistive Mechatronics**
  Innovate in rehabilitation robotics, prosthetic devices, and biomechatronic systems that enhance human capability and healthcare outcomes.

- **Mechatronics for Industry 4.0**
  Develop smart systems that integrate with IoT, cyber-physical systems, and cloud/edge computing for intelligent factory automation and real-time decision-making.

The IntelliMech project program addresses key SDGs by promoting clean energy, sustainable innovation, climate action, and community well-being.

Sustainability Development Goals (SDGs) for the Dept. of ME, IARE	
SDG #3	Ensure healthy lives and promote well-being for all at all ages
SDG #4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
SDG #7	Ensure access to affordable, reliable, sustainable and modern energy for all
SDG #8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
SDG #9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
SDG #10	Reduce inequality within and among countries
SDG #11	Make cities and human settlements inclusive, safe, resilient and sustainable
SDG #12	Ensure sustainable consumption and production patterns
SDG #13	Take urgent action to combat climate change and its impacts

The following research domains are recommended for **HIPs- IntelliMech** Projects, and selected students should find the research gap and frame the problem statements from any one of the themes below**.**

1. AI-Based Condition Monitoring in Mechatronic Systems ***(SDG #8, SDG #9, SDG #12)***
2. Intelligent Gripper Design with Tactile Feedback ***(SDG #8, SDG #9)***
3. Gesture-Controlled Wheelchair with Obstacle Avoidance ***(SDG #3, SDG #9, SDG #10)***
4. IoT-Enabled Smart Material Handling System ***(SDG #8, SDG #9, SDG #12)***
5. Digital Twin for Mechatronic Assembly Line Optimization ***(SDG #8, SDG #9, SDG #12)***
6. Low-Cost Modular Robotic Platforms for Education ***(SDG #4, SDG #9, SDG #10)***
7. Smart Exoskeleton for Rehabilitation Support ***(SDG #8, SDG #9, SDG #12)***
8. Autonomous Guided Vehicles (AGVs) for Warehouse Logistics ***(SDG #8, SDG #9, SDG #12)***
9. Fuzzy Logic-Based Temperature and Humidity Control Systems ***(SDG #7, SDG #9, SDG #12)***
10. Voice-Activated Home Automation Using Mechatronic Modules ***(SDG #7, SDG #9, SDG #11)***

In order to participate in **IntelliMech** Projects, you must formally apply and be accepted by the project coordinator. To proceed, please mail to the project coordinator, Dr. VVSH Prasad, Professor, Mechanical Engineering, Email Id:vvshprasad@iare.ac.in. This will bring up all available open positions tagged as **IntelliMech** projects. When submitting a project document and an updated résumé, include a statement regarding why you are interested in working with the team to which you are **applying**. Please note that participation by the **IntelliMech** project team requires registration for the accompanying research statement from any of the specified domains. More information will be provided to all selected **IntelliMech** project applicants who have been offered a position. If you have any questions about a particular team, please contact the team's faculty mentor(s). We encourage you to contemplate this fascinating new opportunity. We look forward to receiving your application submission.

AI-Based Condition Monitoring in Mechatronic Systems

Dr. Ch Sandeep, Associate Professor & Head, Dept. of ME - Faculty Mentor

GOALS

This project aims to develop an intelligent condition monitoring system for mechatronic components using AI and machine learning. The objective is to detect early signs of faults or degradation in actuators, motors, gearboxes, or other critical components through data-driven analysis of sensor signals. Unlike traditional rule-based diagnostics, AI models enable predictive maintenance, reduce unplanned downtime, and improve system reliability and safety.

Key Goals:

- Design and implement a real-time condition monitoring framework for mechatronic systems
- Acquire and process sensor data (vibration, temperature, current, acoustic) for health assessment
- Train AI/ML models for anomaly detection, fault classification, and remaining useful life (RUL) prediction
- Integrate the monitoring system into embedded platforms or edge devices
- Visualize system health metrics, warnings, and diagnostic reports for users
- Reduce maintenance cost and extend system/component lifecycle in industrial or educational applications

METHODS & TECHNOLOGIES

Methods (Process & Approach):

- **Hardware Setup & Sensor Integration**
  Equip mechatronic systems (motors, gearboxes, actuators) with sensors like accelerometers, temperature probes, current sensors, and microphones. Interface with microcontrollers or SBCs (e.g., Arduino, Raspberry Pi, Jetson Nano)
- **Data Acquisition & Preprocessing**
- Collect time-series data under varying load and health conditions. Apply signal processing techniques (FFT, wavelet transform, filtering) to extract features.

- **Machine Learning-Based Fault Detection**
- Use supervised learning (SVM, Random Forest, Neural Networks) to classify faults. Apply unsupervised learning (Autoencoders, PCA, K-Means) for anomaly detection. Train deep learning models (CNN, LSTM) for pattern recognition and predictive diagnostics
- **Edge AI & Real-Time Inference**
- Deploy trained models on embedded platforms for real-time inference. Use edge computing to minimize latency and enable localized decision-making.
- **Dashboard & Visualization**
- Build dashboards using Streamlit, Grafana, or custom ROS/IoT interfaces. Provide visual indicators, trend analysis, and alerts for maintenance engineers.

Technologies Used:

- **Hardware:** Raspberry Pi, Jetson Nano, Arduino, MEMS accelerometers, DHT sensors, Hall effect current sensors
- **ML/DL Frameworks:** Scikit-learn, TensorFlow, PyTorch, Keras
- **Signal Processing:** SciPy, NumPy, Librosa, Wavelet Toolbox
- **Programming:** Python, C++, MATLAB

MAJORS & AREAS OF INTEREST

This project is ideal for students from Mechatronics, Mechanical Engineering, Electrical Engineering, Electronics and Instrumentation, Computer Science, and Data Science with interests in predictive maintenance, AI-based diagnostics, and smart monitoring systems. Key areas of focus include:

- **Signal Processing & Sensor Data Analysis** – Techniques for analyzing vibration, temperature, current, and acoustic signals for fault detection.
- **Machine Learning & Deep Learning for Diagnostics** – Using ML models (e.g., CNNs, RNNs) for anomaly detection, fault classification, and remaining useful life (RUL) prediction.
- **Embedded Systems & Edge AI** – Deployment of real-time condition monitoring frameworks on microcontrollers, FPGAs, or edge devices.
- **Predictive Maintenance Strategies** – Implementing AI-based frameworks to minimize downtime and maintenance costs in industrial environments.
- **IoT Integration for Smart Monitoring** – Real-time data acquisition and remote monitoring of mechatronic systems.

- **Visualization & User Interface Design** – Developing dashboards to display system health, fault trends, and diagnostic reports.
- **Reliability Engineering & Lifecycle Management** – Extending the service life of critical components through data-driven maintenance.

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Intelligent Gripper Design with Tactile Feedback

Dr. B Vijaya Krishna, Assistant Professor, ME - Dept. of ME - Faculty Mentor

GOAL

This project focuses on the design and development of an AI-powered robotic gripper system integrated with tactile feedback sensors for enhanced object manipulation and dexterity. The intelligent gripper aims to mimic human grasping capabilities by detecting pressure, texture, and object slip in real time, enabling adaptive gripping strategies in dynamic and unstructured environments. Applications span smart manufacturing, medical robotics, warehouse automation, and human-robot collaboration.

Key Goals:

- Design and fabricate a robotic gripper with embedded tactile sensor arrays
- Implement real-time force, pressure, and texture sensing for object interaction
- Train AI/ML models to classify object properties (fragile, soft, rigid, etc.)
- Enable adaptive grip control based on tactile data and object feedback
- Integrate with robotic arms and ROS-based control architecture
- Improve precision, safety, and adaptability of robotic manipulation systems

METHODS & TECHNOLOGIES

Methods (Process & Approach):

- **Gripper Design & Fabrication**
  Create flexible or multi-fingered gripper using 3D printing or compliant mechanisms. Embed tactile sensors: force-sensitive resistors (FSRs), piezoresistive sensors, capacitive arrays, or e-skin patches. Optimize mechanical structure for adaptability and modularity.
- **Sensor Integration & Data Acquisition**
  Acquire tactile data including force distribution, slip detection, and surface response. Interface sensors with microcontrollers or embedded systems (Arduino, ESP32, Jetson Nano). Calibrate sensors for accurate force mapping.
- **AI-Based Grasp Intelligence**
  Use supervised learning for grip type classification based on tactile signatures. Implement reinforcement learning for closed-loop grip optimization. Employ convolutional neural networks (CNNs) to interpret tactile sensor grid data. Predict object slippage and adjust grip in real time.

- **Real-Time Feedback & Adaptive Control**
  Develop control algorithms to modulate grip force dynamically. Integrate with robotic manipulator (e.g., 4/6 DoF arm) for coordinated action. Use PID or adaptive control for tactile loop feedback.
- **Visualization & Interaction Interface**
  Build GUI dashboards for visualizing force distribution and sensor feedback. Real-time monitoring of grip status, pressure profile, and object classification.

Technologies Used:

- **Hardware:** Arduino, ESP32, Jetson Nano, FSRs, barometric/strain sensors,
- **Software & ML:** Python, Scikit-learn, TensorFlow, Keras,
- **Visualization:** Streamlit, Matplotlib, ROS RViz, Plotly
- **Fabrication:** 3D printing (PLA/TPU), Laser cutting, Silicone molding

MAJORS & AREAS OF INTEREST

This project is well-suited for robotics, AI-powered manipulation, and human-robot interaction. Key focus areas include:

- **Robotic Mechanism Design & Fabrication** – Designing and prototyping gripper mechanisms with advanced kinematics and actuation systems.
- **Tactile Sensing & Signal Processing** – Developing sensor arrays for real-time force, pressure, slip, and texture detection.
- **Machine Learning for Object Classification** – Training AI models to recognize object properties and optimize grip force dynamically.
- **Adaptive Control Systems** – Implementing feedback-based grip adjustment to handle fragile or irregular objects safely.
- **ROS (Robot Operating System) Integration** – Using ROS for communication, motion control, and sensor data fusion with robotic arms.
- **Human-Robot Collaboration** – Enhancing safety and precision for applications in smart manufacturing and healthcare.

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Gesture-Controlled Wheelchair with Obstacle Avoidance

Dr. G Hima Bindu, Assistant Professor - Dept. of ME - Faculty Mentor

GOAL

This project aims to develop an intelligent, gesture-controlled wheelchair system integrated with real-time obstacle avoidance to assist individuals with mobility impairments. Unlike conventional joystick-controlled wheelchairs, this system interprets hand gestures or head movements using computer vision or wearable sensors to control wheelchair motion, offering a hands-free, intuitive interface for users with limited physical abilities.

The integration of autonomous obstacle detection and avoidance enhances user safety, enabling the wheelchair to navigate cluttered or dynamic environments without collisions. This solution is particularly beneficial in healthcare facilities, homes, and public spaces **for** improved independence, safety, and comfort**.**

Key Goals:

- Design a gesture recognition system using camera-based or IMU-based sensing.
- Develop a real-time obstacle detection and avoidance mechanism using ultrasonic or depth sensors.
- Implement gesture-to-motion mapping for forward, backward, left, and right movement commands.
- Integrate the system into a motorized wheelchair with precise motor control and safety features.
- Evaluate the system based on gesture accuracy**,** navigation safety**,** response time, and user comfort.

METHODS & TECHNOLOGIES

- **Gesture Recognition Module**

  Use computer vision (OpenCV + CNN) for hand gesture recognition via RGB/Depth cameras. Alternatively, use IMU-based wearable sensors (accelerometer + gyroscope) for head or hand motion detection. Train machine learning models (e.g., SVM, CNN, or LSTM) for accurate gesture classification.

- **Obstacle Detection and Avoidance**
  Equip the wheelchair with ultrasonic sensors**,** IR sensors, or LiDAR to detect nearby obstacles. Implement path correction algorithms (e.g., potential field, reactive navigation) to avoid collisions in real-time.
- **Wheelchair Control Integration**
  Interface gesture output with motor drivers (L298N, Sabertooth, etc.) to control wheel movement. Use PID control to ensure smooth acceleration, braking, and directional changes.
- **Microcontroller and System Architecture**
  Use Arduino**,** Raspberry Pi**, or** ESP32 for real-time processing and sensor integration. Implement control logic to synchronize gesture input with motion and obstacle handling.
- **Testing and User Evaluation**
  Conduct indoor trials to measure system response, safety in obstacle-rich environments, and usability. Collect feedback from test users to improve gesture intuitiveness and comfort.

Technologies Used

- **Gesture Recognition**: OpenCV, MediaPipe, TensorFlow/Keras, IMU sensors (MPU6050)
- **Obstacle Detection**: Ultrasonic sensors, IR sensors, LiDAR (e.g., RPLIDAR A1)
- **Processing Hardware**: Raspberry Pi 4, Arduino Uno/Nano, NVIDIA Jetson Nano (for CV models)
- **Motor Control**: DC/Servo motors, L298N motor drivers
- **Programming Languages**: Python (for ML and CV), C/C++ (for microcontroller control), ROS (optional)
- **Power and Mobility Hardware**: 12V lead-acid batteries, motorized wheelchair base, H-bridge circuits

MAJORS & AREAS OF INTEREST

This project is well-suited for assistive robotics, computer vision, and intelligent control systems. Key focus areas include:

- **Computer Vision & Gesture Recognition** – Implementing camera-based or IMU sensor-based systems to accurately detect and interpret hand or head gestures.

- **AI/ML for Motion Control** – Using machine learning algorithms for reliable gesture classification and mapping to wheelchair movements.
- **Obstacle Detection & Avoidance** – Integration of ultrasonic, LiDAR, or depth sensors with real-time path planning to ensure user safety.
- **Embedded Systems & Motor Control** – Designing microcontroller-based control systems for precise, smooth, and safe navigation.
- **Human-Centric Design** – Developing user-friendly, hands-free interfaces to enhance accessibility for people with mobility impairments.
- **Autonomous Navigation & Safety Protocols** – Implementing algorithms for collision-free operation in cluttered or dynamic environments.
- **Assistive Technology & Healthcare Applications** – Creating mobility solutions that improve quality of life for differently-abled individuals.

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IoT-Enabled Smart Material Handling System

Dr. G Sarat Raju, Assistant Professor - Dept. of ME - Faculty Mentor

GOAL

This project aims to design and develop an IoT-enabled smart material handling system that enhances automation, real-time tracking, and decision-making in industrial and warehouse logistics. Traditional material handling systems often rely on manual operations or isolated automation lacking connectivity and adaptability. By leveraging the Internet of Things (IoT), sensor networks, and cloud-based analytics, the proposed system ensures efficient, safe, and intelligent transport of goods within industrial settings.

The system will integrate sensor-equipped conveyors, autonomous mobile carts, and robotic arms with IoT modules to enable condition monitoring, automated routing, and inventory tracking. This approach improves productivity, traceability, and operational flexibility in smart factories and supply chains.

Key Goals:

- Develop a connected material handling system using IoT sensors and wireless communication.
- Automate the movement, sorting, and tracking of materials across warehouse zones.
- Enable real-time monitoring of system performance and material status.
- Integrate cloud-based dashboards and edge analytics for operational intelligence.
- Optimize routes, energy use, and workload balancing using data-driven logic.

METHODS & TECHNOLOGIES

Methods (Process & Approach):

- **System Architecture Design**
  Design a modular framework consisting of conveyors, AGVs/AMRs, robotic arms, and storage units. Use IoT-enabled microcontrollers (e.g., ESP32, Arduino IoT, NodeMCU) for distributed control and sensing.
- **Sensor Integration and Control**
  Attach RFID, load sensors, IR/ultrasonic sensors, and proximity detectors to monitor object presence, position, and weight. Control mechanical actuators (motors, pneumatics) for automated lifting, sorting, or routing.

- **Connectivity and Communication**
  Establish wireless data transmission via Wi-Fi, MQTT, or Bluetooth to transmit sensor data to edge devices or the cloud. Use gateway devices **or** edge processors to aggregate and preprocess data locally.
- **Cloud and Data Management**
  Send collected data to cloud platforms (e.g., Google Firebase, AWS IoT, Blynk, ThingsBoard) for storage, visualization, and alert generation. Implement rule-based or ML-based analytics for predictive maintenance and workload optimization.
- **User Interface and Monitoring**
  Build real-time dashboards to display machine states, material flow, and inventory levels. Enable remote monitoring and control through mobile or web-based applications.

Technologies Used:

- **Microcontrollers & IoT Modules**: ESP32, NodeMCU, Arduino Nano 33 IoT
- **Sensors**: RFID readers, ultrasonic/IR sensors, weight/load sensors, limit switches
- **Communication Protocols**: HTTP, Wi-Fi, Bluetooth
- **Cloud Platforms**: Google Firebase, AWS IoT Core, Blynk, ThingsBoard
- **Control Components**: Servo/Stepper motors, DC motors, Relay drivers, AGV kits
- **Programming Languages**: Python, C/C++, Arduino IDE

MAJORS & AREAS OF INTEREST

This project is well-suited for smart factory automation, IoT, and logistics optimization. Key focus areas include:

- **IoT Architecture & Sensor Integration** – Designing wireless sensor networks for real-time tracking, condition monitoring, and automated control.
- **Automation & Robotics in Material Handling** – Developing robotic arms, conveyors, and autonomous carts for seamless warehouse operations.
- **Cloud & Edge Analytics** – Leveraging cloud platforms and edge computing for predictive analytics, operational intelligence, and inventory management.
- **Data-Driven Routing & Scheduling** – Using AI algorithms to optimize paths, energy consumption, and load balancing.
- **Industrial Communication Protocols** – Implementing protocols such as MQTT, OPC-UA, or Modbus for reliable connectivity between devices and control systems.

- **Smart Logistics & Supply Chain Applications** – Enhancing traceability and operational flexibility in warehouses and manufacturing systems.
- **Human-Machine Interaction** – Developing dashboards and interfaces for real-time decision-making and performance visualization.

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Digital Twin for Mechatronic Assembly Line Optimization

Dr. Ch Sandeep, Associate Professor & Head - Dept. of ME - Faculty Mentor

GOAL

This project aims to design and implement a Digital Twin system for a mechatronic assembly line to optimize its performance, reliability, and adaptability in real-time. A Digital Twin is a virtual replica of a physical system that mirrors its behavior, condition, and operations through real-time data synchronization. By integrating the physical assembly line with its digital counterpart, this system enables predictive maintenance, bottleneck identification, real-time monitoring, and data-driven decision-making.

The project aligns with Industry 4.0 objectives, enabling smart manufacturing environments where assembly operations are optimized using insights from simulation, sensor data, and advanced analytics.

Key Goals:

- Model a real-world mechatronic assembly line as a virtual digital twin using simulation tools.
- Integrate real-time sensor data from actuators, conveyors, and robotic components into the virtual model.
- Enable predictive diagnostics and performance analytics through continuous monitoring.
- Identify and resolve bottlenecks, inefficiencies, and downtime using digital simulations.
- Implement feedback mechanisms to optimize cycle time, resource utilization, and energy consumption.

METHODS & TECHNOLOGIES

Methods (Process & Approach):

- **Assembly Line Modeling**
  Create a 3D model of the mechatronic assembly line using tools like Siemens Tecnomatix, Unity, or MATLAB Simulink. Simulate actuators, sensors, conveyor belts, robotic arms, and programmable logic controllers (PLCs).

- **Sensor Integration and Data Acquisition**
  Install IoT sensors (e.g., temperature, vibration, proximity, current sensors) on physical components. Use microcontrollers or edge devices to collect and transmit sensor data in real time.
- **Digital Twin Synchronization**
  Establish bidirectional data flow between the physical system and digital model using OPC UA**,** MQTT**, or** REST APIs. Sync operational parameters such as motor speed, cycle time, fault states, and product count.
- **Analytics and Optimization**
  Use data analytics or ML models to detect anomalies, forecast failures, and suggest optimizations. Simulate different operational scenarios in the twin model to improve throughput and reduce delays.
- **Visualization and Control Interface**
  Develop interactive dashboards using Grafana**,** Power BI**, or** custom web interfaces for operators. Allow real-time remote control and configuration via the digital twin platform.

Technologies Used:

- **Simulation Tools**: Unity 3D, MATLAB Simulink
- **IoT & Data Acquisition**: Arduino, ESP32, Raspberry Pi, NI DAQ, PLCs
- **Communication Protocols**: TCP/IP, HTTP
- **Cloud & Edge Platforms**: Azure Digital Twins, AWS IoT, ThingsBoard
- **Programming Languages**: Python, C/C++, Ladder Logic, JavaScript

MAJORS & AREAS OF INTEREST

This project is well-suited for Industry 4.0, smart manufacturing, and digital twin technology. Key focus areas include:

- **Digital Twin Modeling & Simulation** – Creating virtual replicas of mechatronic assembly lines using simulation tools such as Siemens Tecnomatix, MATLAB Simulink, or AnyLogic.
- **IoT & Real-Time Data Integration** – Synchronizing live sensor data (from actuators, conveyors, and robotics) with the digital twin environment.
- **Predictive Maintenance & Diagnostics** – Using AI/ML algorithms for early fault detection, performance forecasting, and downtime reduction.

- **Process Optimization & Bottleneck Analysis** – Identifying inefficiencies and improving throughput, cycle time, and energy consumption.
- **Cloud & Edge Computing in Manufacturing** – Deploying scalable digital twin solutions for real-time analytics and decision-making.
- **Data Engineering for Smart Factories** – Building pipelines for collecting, cleaning, and analyzing industrial data streams.
- **Industry 4.0 Applications** – Enabling smart factory ecosystems through cyber-physical systems, advanced analytics, and adaptive automation.

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Low-Cost Modular Robotic Platforms for Education

Dr. G Hima Bindu, Assistant Professor - Dept. of ME - Faculty Mentor

GOAL

This project aims to design and develop affordable, modular robotic platforms tailored for educational use in schools, colleges, and STEM training programs. Unlike expensive industrial-grade robots, these platforms will be cost-effective, easy to assemble, and highly customizable, allowing students to explore key concepts in robotics, electronics, programming, and control systems through practical experimentation.

The modular design enables different configurations—such as line-following robots, obstacle-avoiding bots, robotic arms, and swarm robots—making the platform adaptable across various educational levels and curricula. The goal is to promote experiential learning, creativity, and interdisciplinary thinking in science and engineering education.

Key Goals:

- Design low-cost, open-source robotic kits with modular components.
- Enable plug-and-play functionality for sensors, actuators, and controllers.
- Provide students with hands-on experience in robotics assembly, coding, and testing.
- Create curriculum-aligned projects and tutorials for various education levels.
- Promote scalability for group projects, competitions, and research-oriented prototyping.

METHODS & TECHNOLOGIES

Methods (Process & Approach):

- **Mechanical and Modular Design**
  Use laser-cut acrylic**,** 3D-printed parts**, or** aluminum chassis to create customizable robot frames. Design interchangeable modules (e.g., wheels, arms, sensor holders) to support multiple configurations.
- **Electronics and Sensor Integration**
  Utilize Arduino**,** Raspberry Pi**, or** ESP32 as the main controller boards. Support various sensors: ultrasonic, IR, light, temperature, IMU, encoders for sensing and feedback.
- **Programming and Control**
  Develop control software in Arduino IDE**,** Python**, or** Scratch for different age groups. Support wireless control via Bluetooth, Wi-Fi, or mobile apps.

- **Educational Content Development**
  Create step-by-step guides, tutorials, and challenge-based learning modules. Align activities with STEM/STEAM learning goals, from beginner to advanced.
- **Testing and Evaluation**
  Deploy kits in educational settings for feedback. Evaluate based on ease of use, student engagement, learning outcomes, and cost efficiency.

Technologies Used:

- **Microcontrollers**: Arduino Uno/Nano, ESP32
- **Sensors & Actuators**: Ultrasonic sensors, IR modules, motor drivers (L298N), servos, encoders
- **Chassis Materials**: 3D-printed PLA, acrylic sheets, metal brackets, LEGO-compatible parts
- **Programming Platforms**: Arduino IDE, Python
- **Communication**: Bluetooth HC-05, ESP32 Wi-Fi, NRF24L01
- **Power Supply**: Rechargeable Li-ion or Li-Po batteries, USB charging modules

MAJORS & AREAS OF INTEREST

This project is well-suited for robotics, STEM education, and affordable automation solutions. Key areas of interest include:

- **Robotic Design & Prototyping** – Developing modular and low-cost mechanical structures for robotics platforms.
- **Sensors, Actuators & Embedded Systems** – Implementing plug-and-play electronics for various robotic configurations.
- **Programming & Control Logic** – Creating software modules for line-following, obstacle avoidance, robotic arms, and swarm coordination.
- **Open-Source Hardware & Curriculum Development** – Building educational robotics kits aligned with school/college STEM programs.
- **Interdisciplinary Learning Platforms** – Encouraging cross-domain skills in electronics, mechanical systems, AI, and coding.

- **DIY & Competition-Ready Robotics** – Enabling students to build, customize, and test robots for academic projects or contests.
- **Scalable Educational Solutions** – Designing cost-effective kits for group learning, workshops, and research prototyping.

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Smart Exoskeleton for Rehabilitation Support

Dr. G Hima Bindu, Assistant Professor - Dept. of ME - Faculty Mentor

GOAL

This project aims to develop a smart exoskeleton system designed to assist patients undergoing physical rehabilitation due to injury, stroke, or mobility disorders. The exoskeleton will support lower-limb or upper-limb movement, providing adaptive mechanical assistance based on the user's needs and therapy goals. Equipped with embedded sensors, intelligent control algorithms, and real-time feedback mechanisms, the system enhances muscle reactivation, motor learning, and mobility recovery.

Unlike passive orthotic devices, this smart exoskeleton integrates biomechanical sensing, motion intention detection, and AI-enhanced actuation to deliver personalized, safe, and effective therapy—either under clinical supervision or in home settings.

Key Goals:

- Design a wearable robotic exoskeleton to assist or augment limb movements during rehabilitation exercises.
- Integrate EMG, IMU, and force sensors to detect user movement intention and physiological state.
- Implement adaptive control strategies to modulate assistance based on real-time feedback.
- Enable data collection and visualization to track patient progress and optimize therapy sessions.
- Ensure safety, comfort, and usability for diverse users through ergonomic and human-centered design.

METHODS & TECHNOLOGIES

Methods (Process & Approach):

- **Mechanical and Ergonomic Design**
  Design lightweight, modular structures using aluminum alloys, carbon fiber, or 3D-printed plastic components. Use jointed linkages and wearable frames tailored for the human body's kinematics.

- **Sensor Integration and Signal Processing**
  Integrate EMG sensors to capture muscle activity, IMUs for joint orientation, and **force sensors** for load detection. Filter and analyze signals in real time using digital signal processing (DSP) techniques.
- **Control System Development**
  Develop adaptive or impedance-based control algorithms that respond to the user's movement patterns and effort. Implement assist-as-needed strategies to promote user engagement and neuroplasticity.
- **Actuation System**
  Use brushless DC motors, pneumatic actuators, or series elastic actuators (SEAs) to deliver smooth, controlled motion. Design transmission systems using belts, gears, or tendon-driven actuation.
- **Feedback, Monitoring & Interface**
  Provide real-time biofeedback via visual/audio cues for users and therapists. Log data for performance analysis, using wireless communication to transmit data to a mobile or desktop dashboard.

Technologies Used:

- **Sensors**: EMG (e.g., MyoWare), IMU (MPU6050), Force-sensitive resistors, Strain gauges
- **Actuators**: Servo motors, Brushless DC motors, Pneumatic cylinders, SEAs
- **Control Hardware**: Arduino Mega, STM32, Raspberry Pi
- **Software Platforms**: MATLAB/Simulink, LabVIEW, Python
- **Communication**: Bluetooth, Wi-Fi, CAN bus
- **Power Supply**: Li-ion battery packs with motor controllers and safety shutoffs

MAJORS & AREAS OF INTEREST

This project is well-suited for wearable robotics, assistive devices, and AI-driven healthcare solutions. Key focus areas include:

- **Wearable Robotics & Mechanism Design** – Developing ergonomic exoskeleton structures for lower-limb or upper-limb rehabilitation.
- **Biomechanics & Human Factors** – Studying motion kinematics, muscle activation, and user comfort for therapy-based applications.

- **Sensor Integration & Motion Intention Detection** – Using EMG, IMU, and force sensors for real-time detection of user intent.
- **AI & Adaptive Control Systems** – Implementing intelligent algorithms to provide personalized and safe mechanical assistance.
- **Data Analytics & Patient Progress Monitoring** – Visualizing therapy data for clinicians to optimize recovery plans.
- **Human-Centric & Ergonomic Design** – Ensuring comfort, usability, and safety for diverse patient groups.
- **Rehabilitation and Healthcare Applications** – Creating solutions for clinical and at-home physiotherapy use cases.

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AI-Enabled Social Robots for Education and Elder Care

Dr. V Mahider Reddy, Assistant Professor - Dept. of ME - Faculty Mentor

GOALS

This project aims to design and develop Autonomous Guided Vehicles (AGVs) for automating material transport and logistics operations in warehouses and industrial environments. Unlike manually operated forklifts or conveyor systems, AGVs use navigation sensors, mapping algorithms, and intelligent control systems to move goods efficiently, safely, and autonomously.

By deploying AGVs in smart warehouses, industries can optimize workflow, reduce human effort, and enhance operational scalability. The project focuses on building cost-effective AGV prototypes with modular architecture for real-world logistics challenges such as inventory movement, route planning, and dynamic obstacle avoidance.

Key Goals:

- Design and build functional AGV prototypes for indoor logistics and goods transportation.
- Develop autonomous navigation systems using SLAM, path planning, and obstacle avoidance algorithms.
- Integrate sensor-based control and real-time mapping for adaptive route following.
- Enable task scheduling, load detection, and multi-AGV coordination.
- Evaluate system performance based on navigation accuracy, delivery efficiency, and collision-free operation.

METHODS & TECHNOLOGIES

Methods (Process & Approach):

- **AGV Mechanical Design**
  Design chassis with modular payload platforms, differential or omni-wheel drive systems. Implement loading/unloading mechanisms using actuators or lift modules.
- **Localization and Mapping**
  Use Simultaneous Localization and Mapping (SLAM) with LiDAR, camera, or **IMU** data to map the warehouse. Apply algorithms like Gmapping, Cartographer, or ORB-SLAM2.
- **Autonomous Navigation and Control**
  Develop path planning using A*, D*, or RRT algorithms. Use ROS Navigation Stack for real-time motion planning and recovery behaviors.

- **Sensor Integration and Obstacle Avoidance**
  Integrate ultrasonic sensors**,** LiDAR**,** IR sensors, and depth cameras for detecting dynamic/static obstacles. Implement **reactive navigation** strategies for safe movement in shared spaces.
- **Communication and Coordination**
  Use Wi-Fi or Zigbee to coordinate AGVs and communicate with the central control system. Implement task allocation algorithms for multi-AGV environments.
- **Monitoring and Evaluation**
  Build web/mobile interfaces for tracking AGV status, routes, and error reports. Evaluate KPIs: travel time, idle time, collision count, load accuracy, and energy usage.

Technologies Used:

- **Controllers & Platforms**: Raspberry Pi, Arduino Mega
- **Sensors**: LiDAR (RPLIDAR), ultrasonic, IR sensors, encoders, IMUs
- **Path Planning**: ROS MoveBase, A*/D* Lite, Dynamic Window Approach (DWA)
- **Communication Protocols**: MQTT, HTTP, Wi-Fi, Zigbee
- **Power & Drive Systems**: BLDC/DC motors, battery packs, motor drivers (L298N, VNH2SP30)
- **UI & Monitoring**: Node-RED, Grafana, custom dashboards or mobile apps

MAJORS & AREAS OF INTEREST

This project is well-suited for Biomedical Engineering, human-robot interaction (HRI), social robotics, and AI for assistive technologies. Key focus areas include:

- **Human-Robot Interaction (HRI)** – Designing robots capable of natural communication and interaction with humans using voice, gestures, or facial expressions.
- **AI for Personalized Assistance** – Implementing machine learning models to adapt to individual needs of students or elderly users.
- **Speech Recognition & Natural Language Processing (NLP)** – Developing voice-controlled interfaces for conversations and task execution.
- **Emotion Detection & Affective Computing** – Using computer vision and AI algorithms to interpret emotions and respond appropriately.
- **Social and Educational Applications** – Creating robots for interactive learning, therapy, and companionship.

- **Embedded Systems & IoT Integration** – Building hardware and control systems for autonomous and safe operation.
- **User-Centric Design & Ethics** – Ensuring comfort, safety, privacy, and trust in human-robot interaction, especially for vulnerable groups.

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Fuzzy Logic-Based Temperature and Humidity Control Systems

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GOALS

This project aims to develop a fuzzy logic-based control system for precise and adaptive temperature and humidity regulation in indoor environments such as smart homes, greenhouses, data centers, and laboratories. Unlike conventional on/off or PID controllers, fuzzy logic controllers (FLCs) emulate human reasoning to make smooth, adaptive decisions even in the presence of uncertainty or non-linearity.

By integrating sensor data, rule-based fuzzy inference, and actuator control, the system provides energy-efficient, responsive, and user-comfort-focused climate control. This project promotes soft computing approaches in embedded automation and demonstrates real-world applications of artificial intelligence in control engineering.

Key Goals:

- Design a fuzzy logic controller for regulating temperature and humidity within defined comfort or process thresholds.
- Integrate environmental sensors and actuators for real-time measurement and regulation.
- Implement fuzzy rules and membership functions to mimic expert decision-making.
- Deploy the system on embedded hardware for real-time autonomous control.
- Evaluate system performance in terms of response time, stability, and energy efficiency.

METHODS & TECHNOLOGIES

Methods (Process & Approach):

- **System Design and Modeling**
  Define system variables (e.g., current temperature/humidity, rate of change, error) and control outputs (fan speed, heater state, humidifier intensity). Develop a linguistic rule base and membership functions for fuzzy inputs and outputs.
- **Fuzzy Logic Controller Implementation**
  Use Mamdani or Sugeno-type fuzzy inference systems. Encode rules such as: *“If temperature is high and humidity is low, then increase fan speed and turn on humidifier.”*
- **Sensor and Actuator Integration**

Use DHT22, BME280, or similar sensors for accurate environmental data. Interface fans, heaters, dehumidifiers, or coolers through relay modules, PWM drivers, or MOSFET circuits.

- **Embedded System Development**
  Implement fuzzy logic algorithms on Arduino, ESP32, or Raspberry Pi. Use real-time monitoring and control loops for smooth operation.
- **Testing and Evaluation**
  Conduct experiments under varying environmental conditions. Measure performance based on setpoint tracking, overshoot, settling time, and energy usage.

Technologies Used:

- **Microcontrollers**: Arduino Uno/Nano, ESP32, Raspberry Pi Pico
- **Sensors**: DHT11/DHT22, BME280, SHT31, analog temperature/humidity sensors
- **Actuators**: DC fans, heating elements, humidifiers, relays, PWM circuits
- **Programming Tools**: Arduino IDE, MATLAB Fuzzy Logic Toolbox, Python
- **Control Algorithms**: Mamdani/Sugeno Fuzzy Inference Systems, Rule-based FLCs

MAJORS & AREAS OF INTEREST

This project is well-suited for intelligent control systems, embedded automation, and AI-based decision-making. Key focus areas include:

- **Fuzzy Logic & Soft Computing** – Designing fuzzy inference systems, membership functions, and rule bases for adaptive control.
- **Control System Design** – Implementing temperature and humidity regulation strategies beyond conventional PID or on/off controllers.
- **Embedded Systems & IoT** – Deploying the control logic on microcontrollers, edge devices, or IoT modules for real-time automation.
- **Sensor Integration & Calibration** – Working with temperature, humidity, and environmental sensors for accurate data acquisition.
- **Energy-Efficient Smart Automation** – Optimizing climate control for greenhouses, smart homes, and data centers to reduce energy consumption.
- **Artificial Intelligence in Control Engineering** – Applying AI principles to achieve intelligent and robust decision-making in dynamic environments.

- **Real-Time Performance Evaluation** – Testing stability, response time, and accuracy of the fuzzy logic controller under varying conditions.

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Voice-Activated Home Automation Using Mechatronic Modules

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GOALS

This project aims to develop a voice-activated home automation system that integrates mechatronic modules for controlling household devices such as lights, fans, doors, and appliances. By using natural language voice commands, the system enables intuitive, hands-free interaction, improving accessibility, comfort, and energy efficiency in smart homes.

The project combines speech recognition, embedded systems, and actuator control to create a modular and scalable automation platform. It is especially useful for elderly care, assistive living, and smart building applications, providing a seamless human–machine interface through voice.

Key Goals:

- Implement voice recognition using cloud-based or offline speech-to-text systems.
- Interface mechatronic modules with household devices for voice-activated control.
- Ensure real-time response, reliability, and security in command execution.
- Enable modular design for easy addition/removal of automation features.
- Test usability across different environmental conditions and user profiles.

METHODS & TECHNOLOGIES

Methods (Process & Approach):

- **Voice Interface Design**
  Use APIs like Google Speech-to-Text, Amazon Alexa SDK, or offline engines like Vosk, CMU Sphinx for voice command recognition. Define a command set for common tasks (e.g., "Turn on the light", "Open the door").
- **Microcontroller Integration**
  Process recognized commands using a microcontroller (Arduino, ESP32) to control output devices. Use serial or MQTT communication between voice module and control board.
- **Mechatronic Module Development**
  Interface actuators (e.g., servo motors for door locks, relays for appliances, LEDs, fan control). Design and assemble physical modules that respond to voice commands.

- **System Architecture & Connectivity**
  Implement communication over Wi-Fi, Bluetooth, or local networks for distributed control. Secure system from false triggering or unauthorized access using keyword activation and validation.
- **Testing and Evaluation**
  Evaluate system response time, command accuracy, and user satisfaction. Test under various noise levels, accents, and command phrasing for robustness.

Technologies Used:

- **Speech Recognition**: Google Assistant SDK, Vosk API, CMU Sphinx, Amazon Alexa, OpenAI Whisper
- **Microcontrollers**: ESP32, Raspberry Pi, Arduino Uno/Nano
- **Actuators**: Servo motors (e.g., SG90 for doors), relays (for fan/light control), motor drivers
- **Sensors**: IR sensors, PIR motion detectors (for automation triggers)
- **Communication Protocols**: Wi-Fi (MQTT, HTTP), Bluetooth, Serial UART
- **Programming Languages**: Python, Arduino C/C++

MAJORS & AREAS OF INTEREST

This project is well-suited for smart home technologies, IoT, and human–machine interaction. Key focus areas include:

- **Voice Recognition & Natural Language Processing (NLP)** – Implementing cloud-based or offline speech-to-text systems for reliable command recognition.
- **Embedded Systems & Microcontroller Programming** – Interfacing mechatronic modules (relays, actuators, and sensors) with household appliances.
- **IoT Integration & Smart Home Automation** – Designing scalable, modular frameworks for intelligent device control and monitoring.
- **Human-Centric Design** – Creating user-friendly, hands-free interfaces for elderly care and assistive living applications.
- **Energy Efficiency & Sustainability** – Optimizing device usage patterns to minimize energy consumption in smart homes.
- **Cybersecurity for Smart Devices** – Ensuring secure and reliable communication between user commands and devices.

- **System Testing & Usability Evaluation** – Assessing response time, reliability, and adaptability under different conditions and user scenarios.

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