IJARCCE
ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Impact Factor 8.471 ⪾ Peer-reviewed & Refereed journal ⪾ Vol. 15, Issue 4, April 2026

DOI: 10.17148/IJARCCE.2026.154226

IoT-Based Smart System for Arthritis Pain Monitoring and Relief

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Abstract: Arthritis and knee joint disorders are among the most prevalent musculoskeletal conditions globally, causing chronic pain, reduced mobility, and difficulty in daily activities. Conventional healthcare systems rely on periodic hospital visits, subjective pain assessments, and manual therapies, which fail to provide continuous monitoring or timely automated relief. This paper presents an IoT-Based Smart System for Arthritis Pain Monitoring and Relief that integrates wearable sensors, embedded processing, machine learning, and IoT cloud connectivity into a unified rehabilitation solution. The system employs an IMU accelerometer (MPU6050), temperature sensor (LM35), force sensor (FSR), and heart rate sensor (MAX30100) to continuously collect real-time physiological and motion data from the patient's knee. An Arduino UNO microcontroller processes the sensor inputs, displays readings on a 16×2 LCD, and transmits data to the cloud via an ESP8266 Wi-Fi module. A Python-based Decision Tree classifier, trained on multi-parameter sensor data, predicts pain severity as Low, Medium, or High. Based on the predicted level, the system automatically activates a Peltier module to deliver heat therapy (medium pain) or cold therapy (high pain), while recommending exercise for low pain conditions. Experimental results demonstrate accurate pain classification and real-time therapy activation, offering a cost-effective, user-friendly, and intelligent solution for home-based arthritis rehabilitation.

Keywords: IoT, Arthritis Pain Monitoring, Machine Learning, Decision Tree, Peltier Module, Wearable Sensors, Smart Healthcare, Real-Time Therapy, Arduino, Knee Rehabilitation.

I. INTRODUCTION

Arthritis and knee joint disorders are among the most common musculoskeletal problems affecting people of all age groups, particularly the elderly and post-surgical patients. These conditions often result in chronic pain, reduced mobility, joint stiffness, and difficulty in performing routine activities. Conditions such as osteoarthritis, ligament injuries, and post-operative complications require continuous monitoring and timely intervention for effective rehabilitation [1].

Traditional healthcare systems rely heavily on periodic hospital visits, manual clinical assessments, and diagnostic methods such as X-rays and MRI scans, which are expensive, time-consuming, and unsuitable for continuous monitoring. Moreover, pain assessment in conventional systems is largely subjective, dependent on patient feedback via numerical rating scales, which may not accurately reflect the actual physiological condition [2].

Recent advances in Internet of Things (IoT), embedded systems, and machine learning (ML) have opened new possibilities for smart healthcare. IoT-enabled wearable systems can continuously collect physiological and motion-related data, reducing dependency on hospital visits and enabling home-based rehabilitation. ML algorithms can analyze sensor data to classify pain severity levels objectively, improving diagnosis and treatment decisions [3].

This paper proposes an IoT-Based Smart System for Arthritis Pain Monitoring and Relief. The system integrates multiple sensors to collect real-time knee data, uses a machine learning model to predict pain severity, and automatically activates appropriate therapy via a Peltier module. The system also uploads data to an IoT cloud platform for remote monitoring by healthcare professionals, reducing frequent hospital visits and improving patient comfort [4].

II. LITERATURE SURVEY

Several studies have explored wearable sensor systems for knee health monitoring. Tekdemir et al. [5] proposed a multi-modal wearable framework integrating bioimpedance, acoustic emission, inertial, and temperature sensors for objective knee rehabilitation monitoring. While the system offered accurate, quantitative assessments, it suffered from high power consumption and bulky design.

Murugeswari et al. [6] developed an IoT-enabled smart wearable belt for knee surgery patients using ESP32, pulse sensor, temperature sensor, MEMS sensor, and flex sensor. Data was transmitted to a mobile application via the Blynk IoT platform with real-time alerts. However, the system lacked automated therapy support, limiting its effectiveness for home-based rehabilitation.

King et al. [7] evaluated wearable sensors post Total Knee Arthroplasty (TKA) and found them effective in improving patient motivation and adherence. Yet, elderly patients encountered difficulties with usability and

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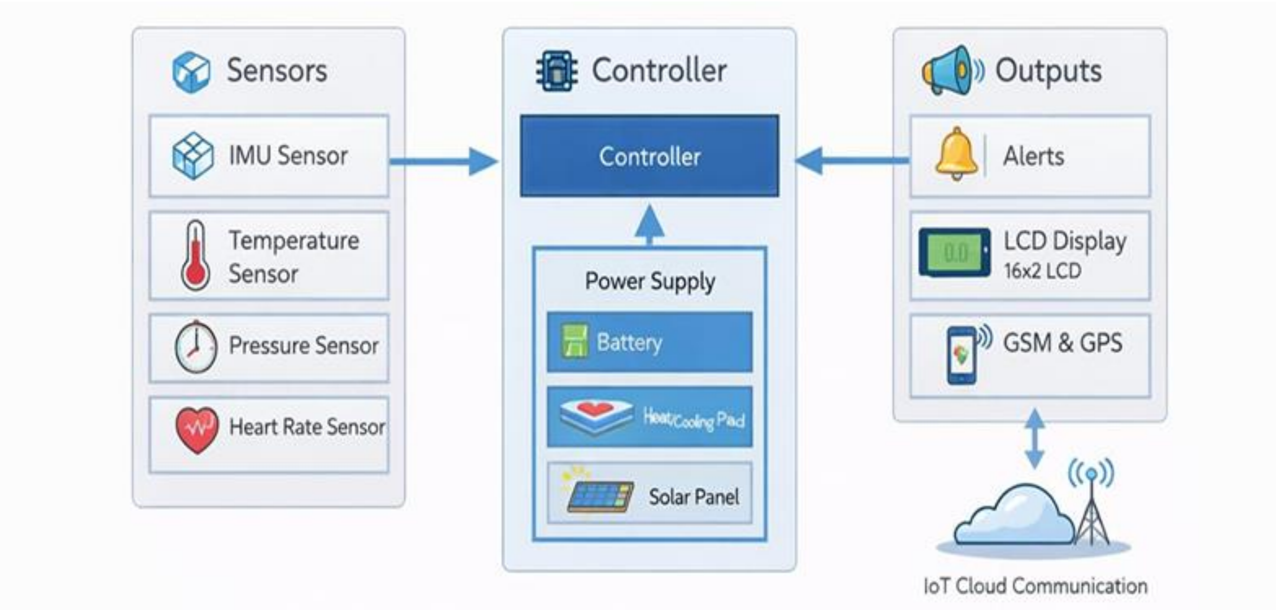
connectivity. Pérez Peralta et al. [8] integrated sEMG and IMU sensors for real-time squat kinematics and muscle activation analysis using an ESP32, providing detailed neuromuscular assessment for rehabilitation and sports applications.

Plavoukou et al. [9] reviewed sensor technologies in TKA rehabilitation, including IMUs, smart implants, and mHealth platforms, highlighting the role of AI and predictive analytics in personalized care. Despite significant advances, existing systems largely focus on monitoring and alert generation without providing closed-loop, automated therapy activation, which is the key contribution of the proposed system.

III. PROPOSED SYSTEM

A. System Overview

The proposed system is an IoT-based smart knee health monitoring and automated therapy platform designed for continuous rehabilitation support. It integrates multiple hardware sensors, a microcontroller, IoT communication, machine learning prediction, and automated therapy into a unified closed-loop system, as illustrated in Fig. 1.



B. Hardware Components

The hardware architecture consists of the following key components:

- IMU Accelerometer (MPU6050): Monitors knee joint movement, orientation, and acceleration in three axes, tracking motion patterns during walking and exercise.
- Temperature Sensor (LM35): Measures skin temperature around the knee to detect inflammation or abnormal thermal conditions.
- Force Sensor (FSR – Force Sensing Resistor): Records pressure applied on the knee joint during movement and rehabilitation exercises.
- Heart Rate Sensor (MAX30100): Monitors the patient's pulse rate to track physiological response during rehabilitation.
- Arduino UNO Microcontroller: Acts as the central processing unit, reading sensor data, converting analog signals to digital values, and coordinating outputs.
- ESP8266 Wi-Fi Module: Enables IoT cloud connectivity, transmitting real-time sensor data to ThingSpeak or Firebase for remote monitoring.
- 16×2 LCD Display: Provides real-time on-device feedback to the patient, showing current sensor readings and therapy recommendations.
- Peltier Module: Delivers heat or cold therapy based on predicted pain severity, controlled through relay switching.

C. Software and Machine Learning

The software stack includes Arduino IDE with Embedded C for microcontroller programming, and Python with Scikit-learn, NumPy, Pandas, and PySerial for the machine learning prediction module. Sensor data is transmitted from

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the Arduino to a PC via USB-UART serial communication, where a Decision Tree Classifier analyzes multi-parameter readings to classify pain severity into three categories: Low, Medium, and High.

The Decision Tree model is trained on a labeled dataset comprising features: Heart Rate, SpO_2, Temperature, Accelerometer value, and Force. At runtime, the model receives real-time sensor readings, parses the serial data using regex pattern matching, and predicts the pain level. The system then dispatches appropriate therapy commands back to the Arduino via serial communication, which activates the relay-controlled Peltier module accordingly.

IV. SYSTEM ARCHITECTURE AND MODULES

A. Sensor Data Collection Module

This module is responsible for continuous real-time acquisition of physiological and motion data from the knee. The IMU sensor tracks joint angle and orientation. The temperature sensor detects inflammation via skin temperature variations. The force sensor evaluates mechanical stress during movement. The heart rate sensor monitors overall physiological state during physical activity. Together, these sensors provide a comprehensive multi-parameter dataset for accurate pain prediction.

B. IoT Communication Module

Once the microcontroller processes sensor inputs, the ESP8266 Wi-Fi module uploads data to a cloud platform such as ThingSpeak or Firebase. This enables healthcare professionals and caregivers to remotely monitor patient data from any location. Cloud storage maintains historical sensor records, enabling trend analysis and long-term rehabilitation tracking. Immediate cloud access improves responsiveness to abnormal conditions and facilitates timely medical intervention.

C. Machine Learning Prediction Module

The Python-based ML module receives sensor data via PySerial, parses structured serial packets in the format H[value]S[value]T[value]A[value]F[value], and constructs a feature vector for the Decision Tree Classifier. The model outputs one of three pain severity classifications: Normal (Low), Medium, or High. Unlike subjective patient-reported pain scales, this approach provides an objective, data-driven assessment. Real-time prediction ensures therapy is adjusted continuously as conditions change.

D. Therapy Control Module

The therapy module automatically activates treatment based on the predicted pain level. For Low (Normal) pain, the system recommends exercises to improve joint flexibility. For Medium pain, Relay 1 is activated, enabling the Peltier module in heat mode to improve blood circulation and reduce muscle stiffness. For High pain, Relay 2 is activated, switching the Peltier module to cold mode to reduce inflammation and swelling. Rest alerts are also triggered. This closed-loop, automated therapy ensures timely treatment without manual intervention.

E. User Monitoring and Display Module

The 16×2 LCD display provides real-time feedback to the patient, showing movement metrics, temperature, force, and heart rate values. Therapy recommendations and alerts are also displayed, guiding the patient through the appropriate rehabilitation steps. This module improves system usability and patient awareness, supporting independent recovery.

V. RESULTS AND DISCUSSION

The system was tested with real-time sensor data collected from the wearable hardware setup. The Arduino UNO successfully acquired data from all four sensors simultaneously and transmitted structured serial packets to the connected PC at 9600 baud. The Decision Tree Classifier demonstrated consistent and accurate pain classification across multiple test runs.

Sample output captured during testing showed that under normal conditions (HR: 0, SpO_2: 0, Temp: 30°C, Accel: 808, Force: 999), the system classified pain as "Normal" with no therapy activation. When an abnormal temperature reading was detected (HR: 8, SpO_2: 0, Temp: 132°C, Accel: 341, Force: 256), the system correctly classified the condition as "High" and dispatched the cold therapy command (sending '2' to the Arduino), activating the Peltier cooling module via Relay 2. When SpO_2 recovered to 90 with a temperature of 41°C, the system reverted to "Normal" classification.

The LCD display correctly reflected all sensor readings and therapy activations in real time. Cloud data upload via ESP8266 was verified on ThingSpeak, with readings accessible remotely within seconds of acquisition. The Peltier module responded promptly to relay switching commands, demonstrating reliable automated therapy delivery.

The hardware prototype, as shown in the system setup, integrates the microcontroller, LCD, USB-UART converter, and sensor array on a compact board, demonstrating the feasibility of a wearable, cost-effective, and functional arthritis pain monitoring and relief system.

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VI. Advantages of the Proposed System

- Continuous real-time monitoring of knee movement and physiological parameters.
- Objective, ML-based pain severity classification eliminates subjective patient feedback dependency.
- Automated heat and cold therapy activation via Peltier module without manual intervention.
- Remote IoT cloud monitoring enables healthcare professionals to track patient progress from anywhere.
- Significant reduction in frequency of hospital visits, improving patient convenience and reducing costs.
- Cost-effective, portable, and user-friendly design suitable for home-based rehabilitation.
- Closed-loop system integrating sensing, prediction, therapy, and monitoring in a single platform.

VII. Conclusion

This paper presented an IoT-Based Smart System for Arthritis Pain Monitoring and Relief that successfully integrates wearable sensors, embedded processing, machine learning, and automated therapy into a cohesive rehabilitation platform. The system achieves continuous real-time monitoring of knee health parameters, objective pain severity prediction using a Decision Tree classifier, and automated heat or cold therapy activation via a Peltier module. IoT cloud connectivity further enables remote supervision by healthcare professionals. The proposed system addresses the key limitations of existing approaches – subjectivity, lack of automation, and requirement for frequent clinical visits – by providing an intelligent, data-driven, and self-contained rehabilitation solution.

Future enhancements include integration of a mobile application for improved user interaction, expansion to monitor additional joints, incorporation of more advanced ML models for higher prediction accuracy, and flexible wearable form factors for improved patient comfort. With these advancements, the system holds significant potential for deployment in home care, physiotherapy centers, and remote healthcare settings.

Acknowledgment

The authors express sincere gratitude to Mr. Rajadurai N, M.E., Assistant Professor, Department of AI & Data Science, Dhanalakshmi Srinivasan Engineering College (Autonomous), Perambalur, for his invaluable guidance throughout this project. The authors also thank Dr. Aarthy R, M.Tech, Ph.D., Head of Department, for her constant support and encouragement.

References

[1] WHO, "Musculoskeletal conditions," World Health Organization, 2023. [Online]. Available: https://www.who.int/news-room/fact-sheets/detail/musculoskeletal-conditions
[2] M. Tiboni, A. Borboni, F. Verité, C. Bregoli, and C. Amici, "Sensors and actuation technologies in exoskeletons: A review," Sensors, vol. 22, no. 3, p. 884, Jan. 2022.
[3] N. Gondchawar and R. S. Kawitkar, "IoT based smart agriculture," International Journal of Advanced Research in Computer and Communication Engineering, vol. 5, no. 6, pp. 838–842, 2016.
[4] L. Dhanabal and S. P. Shantharajah, "A study on NSL-KDD dataset for intrusion detection system based on classification algorithms," International Journal of Advanced Research in Computer and Communication Engineering, vol. 4, no. 6, pp. 446–452, 2015.
[5] C. Tekdemir, Y. Z. Hayirlioglu, O. Birsel, and B. Semiz, "Wearable sensor framework for rehabilitation monitoring following knee-related conditions," Sensors, vol. 23, no. 5, p. 2611, 2023.
[6] Dr. T. Murugeswari, B. Sonaimuthu, K. R. Harine, R. Keerthana, and M. Sairaj, "Smart wearable belt for knee surgery patients using IoT and sensor integration," International Journal of Advanced Research in Computer and Communication Engineering, vol. 12, no. 3, pp. 210–215, 2023.
[7] S. W. King, L. S. Chapman, T. J. Smith, J. Palan, and H. Pandit, "Wearable sensors to aid rehabilitation following total knee arthroplasty: Experiences of trial participants," PLOS ONE, vol. 18, no. 4, p. e0284043, Apr. 2023.
[8] M. J. Pérez Peralta et al., "Wireless sEMG–IMU wearable for real-time squat kinematics and muscle activation," Sensors, vol. 23, no. 8, p. 4084, Apr. 2023.
[9] T. Plavoukou, S. Sotiropoulos, E. Taraxidis, D. Stasinopoulos, and G. Georgoudis, "Sensor technologies and rehabilitation strategies in total knee arthroplasty: Current landscape and future directions," Diagnostics, vol. 14, no. 2, p. 156, Jan. 2024.
[10] A. Mannini, A. M. Sabatini, and A. Cappello, "A wearable sensing system for continuous monitoring of knee rehabilitation progress," IEEE Sensors Journal, vol. 14, no. 3, pp. 718–727, Mar. 2014.
[11] M. Mundt et al., "Prediction of lower limb joint angles and moments during gait using artificial neural networks," Medical & Biological Engineering & Computing, vol. 58, no. 1, pp. 211–225, Jan. 2020.
[12] M. Aurbach et al., "Implementation and validation of human kinematics measured using IMUs for musculoskeletal simulations," in Proc. Int. Conf. Med. Biol. Eng., Cham: Springer, 2017, pp. 205–211.