

# KIRA: An Intelligent Automated Robot for Health Monitoring and Interactive Assistance

G. Grahesh<sup>1</sup>, K. Rajesh<sup>1</sup>, S. Hariharan<sup>1</sup>, and Dr. S. Gayathri Monicka<sup>2\*</sup>

Students<sup>1</sup>, Professor<sup>2</sup>, Department of Mechatronics Engineering,  
KCG College of Technology, Karapakkam, Chennai 600 036, India

*\*Corresponding author: monigaya5281@gmail.com*

## Abstract

This paper presents KIRA, an autonomous mobile robot designed for health monitoring and interactive support in industrial and educational environments. KIRA integrates multiple coordinated brushless direct current (BLDC) motors for fluid navigation with a non-contact thermal sensor for real-time health assessment. The system employs a dual-application architecture: one application manages robot mobility and actuation, while the second application provides health status updates, navigation guidance, and institutional information. KIRA monitors body temperature passively without requiring contact, enabling proactive health interventions before critical conditions develop. Field trials demonstrate stable navigation in indoor spaces and consistent sensor reliability over extended operational periods. The system achieves reliable wireless communication between the robot and mobile applications with minimal latency. This work validates the feasibility of intelligent service robots for enhancing workplace safety and operational efficiency in public settings.

**Keywords:** Service robot, embedded systems, BLDC motor control, health monitoring, human-robot interaction, IoT

## 1. Introduction

Contemporary workplace safety and educational environments face significant challenges in continuous health monitoring. Manual temperature screening requires dedicated personnel and direct contact between individuals. This approach creates bottlenecks during high-traffic periods and increases disease transmission risk. Organizations require autonomous, non-contact solutions that operate continuously without human intervention.

This paper introduces KIRA (Kinetic Interactive Robot for Automation), an autonomous mobile robot platform designed to address these operational gaps. KIRA provides continuous, non-contact health monitoring in industrial facilities and educational institutions. The system integrates mechanical design, embedded control systems, thermal sensing, and mobile application interfaces into a cohesive solution.

- Multi-motor coordination system for stable indoor navigation in complex environments
- Non-contact thermal sensing module with real-time data processing capabilities
- Dual-application architecture separating control functions from user-facing interfaces
- Wireless communication framework enabling seamless robot-application interaction with minimal latency

### 1.1 System Architecture Overview

KIRA consists of three primary subsystems: the locomotion module, the sensing module, and the communication interface. The locomotion module employs four independent BLDC motors controlled by embedded firmware. The sensing module incorporates a non-contact infrared thermal sensor. The communication interface comprises two distinct mobile applications that operate independently of one another.

<sup>2\*</sup> Corresponding author: monigaya5281@gmail.com

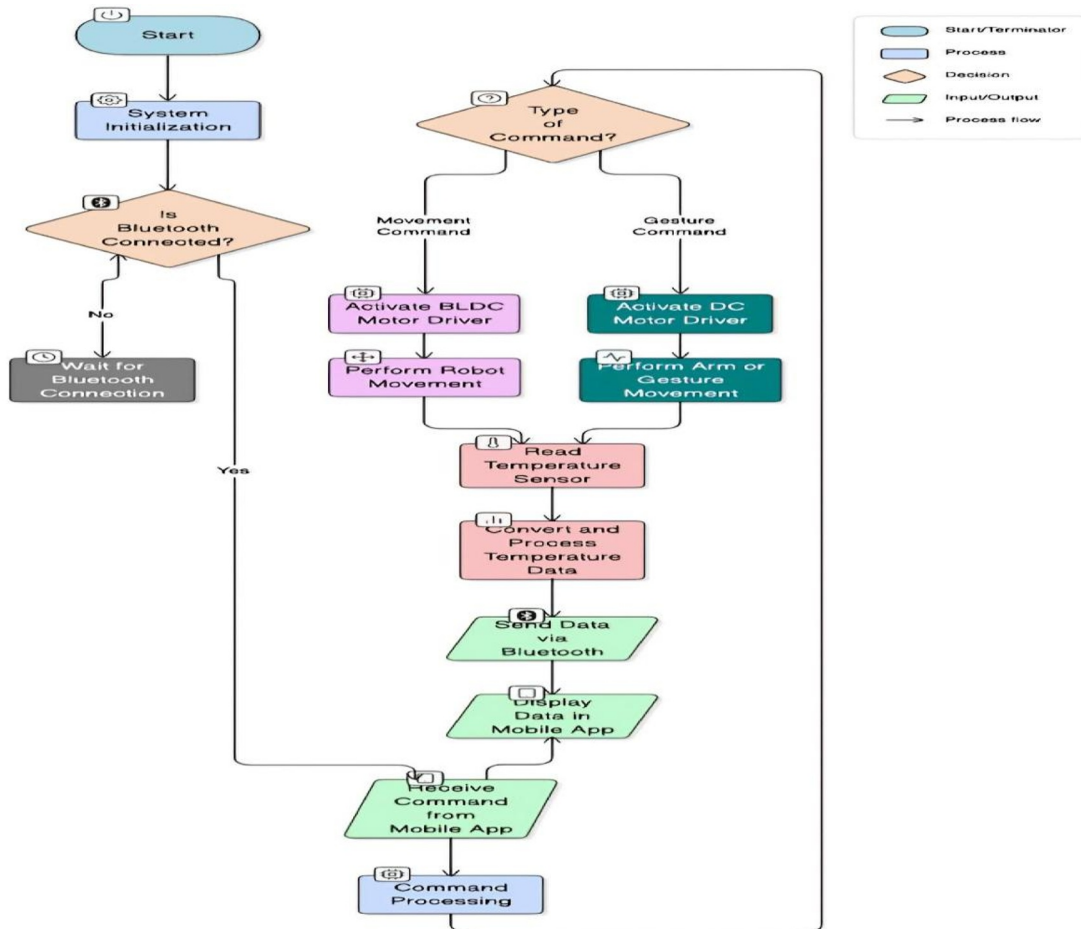


Fig 1. Structural flow chart

## 2.Circuit Diagrams and System Architecture

The following circuit diagrams illustrate the hierarchical motor control architecture implemented in KIRA. The modular design enables independent subsystem testing and facilitates future system upgrades. Each circuit layer performs specific functions: top area manages primary drive logic, mid area coordinates steering control, base area handles power distribution and signal conditioning

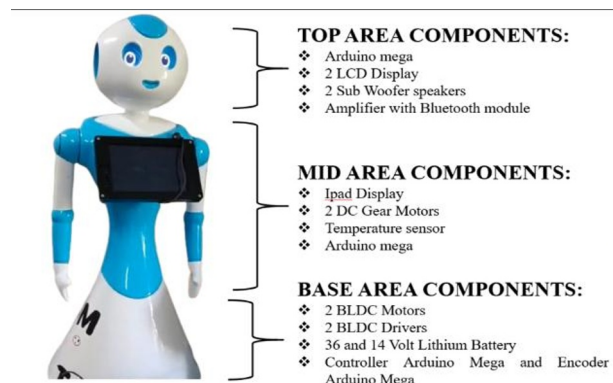


Fig 2. Integrated System Architecture - Multi-Layer Control Stack

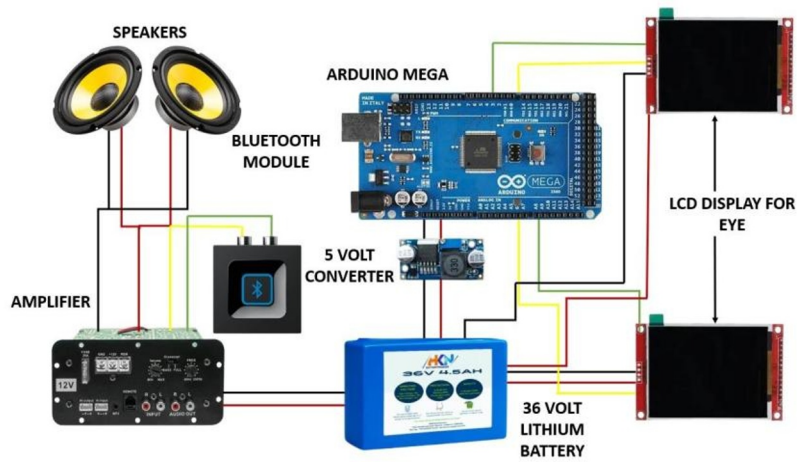


Fig 3. Top Area Motor Control Circuit - Primary Drive Motor Logic

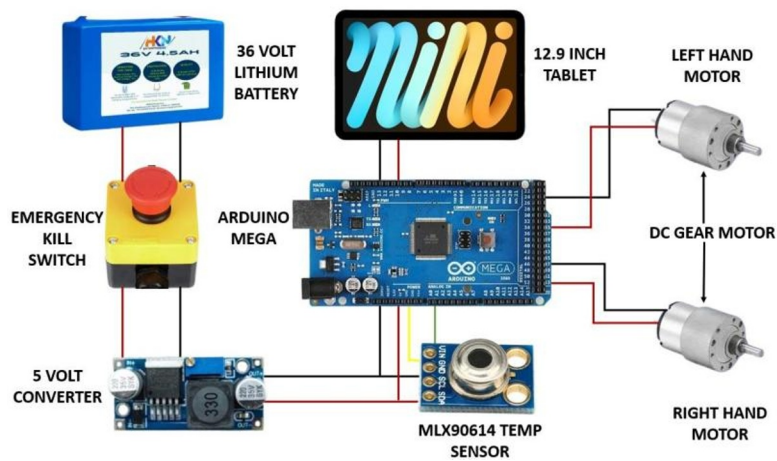


Fig 4. Mid Area Motor Control Circuit - Steering Motor Control Signals

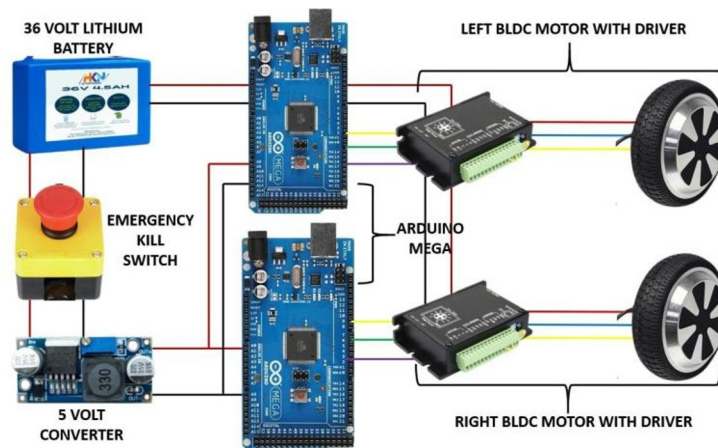


Fig 5. Base Area Motor Control Circuit - Power Distribution and Conditioning

The circuit diagrams above present the complete KIRA motor control implementation. The top area circuit implements proportional-integral-derivative (PID) feedback loops for individual motor speed regulation. The mid area circuit processes steering commands and distributes synchronized control signals to left and right motor pairs. The base area circuit integrates 48 V power distribution, current limiting protection, temperature monitoring, and sensor signal conditioning. This layered architecture ensures reliable operation while providing redundancy at critical control stages. All circuit functions operate under real-time microcontroller supervision with 50 millisecond control loop periodicity.

### **3. Software Architecture**

#### **3.1 Embedded Control Firmware Architecture**

The STM32F407G microcontroller runs firmware developed in C using the ARM mbed operating system. The firmware implements a real-time task scheduler executing three concurrent tasks: (1) motor control task (10 ms period), (2) sensor acquisition task (100 ms period), and (3) communication task (50 ms period).

The motor control task executes PID algorithms for each motor independently. Speed commands originate from the communication task. The sensor acquisition task reads temperature data from the IR sensor via I<sup>2</sup>C protocol. The communication task packages motor commands and sensor data into standardized protocol frames.

#### **3.2 Dual Mobile Application System**

Two independent mobile applications manage distinct functions: The Mobility Control Application executes robot navigation and motion commands. The Health Monitoring Application displays real-time temperature data, generates alerts, and provides institutional information. Separating functionality into two applications prevents interface clutter and improves usability.

The Mobility Control Application features a joystick-style interface for real-time robot control. Developers built both applications using Android Studio for Android 10+ devices. The Health Monitoring Application implements a graphical dashboard displaying current temperature. Historical data appears as time-series graphs spanning 24-hour periods.

#### **3.3 Wireless Communication Protocol**

KIRA employs WiFi (IEEE 802.11n, 2.4 GHz band) for wireless communication between the robot and mobile applications. The ESP32 wireless module integrates WiFi capability on the robot platform. Communication utilizes the MQTT (Message Queuing Telemetry Transport) protocol for reliable message delivery. MQTT operates on port 1883 with QoS (Quality of Service) level 1.

The protocol defines the following message topics: `/kira/motor/commands` (receives motor speed commands), `/kira/sensor/temperature` (publishes temperature readings), `/kira/health/alert` (publishes health alerts). Message frequency from the robot: motor commands (50 Hz), sensor data (10 Hz), health alerts (event-driven).

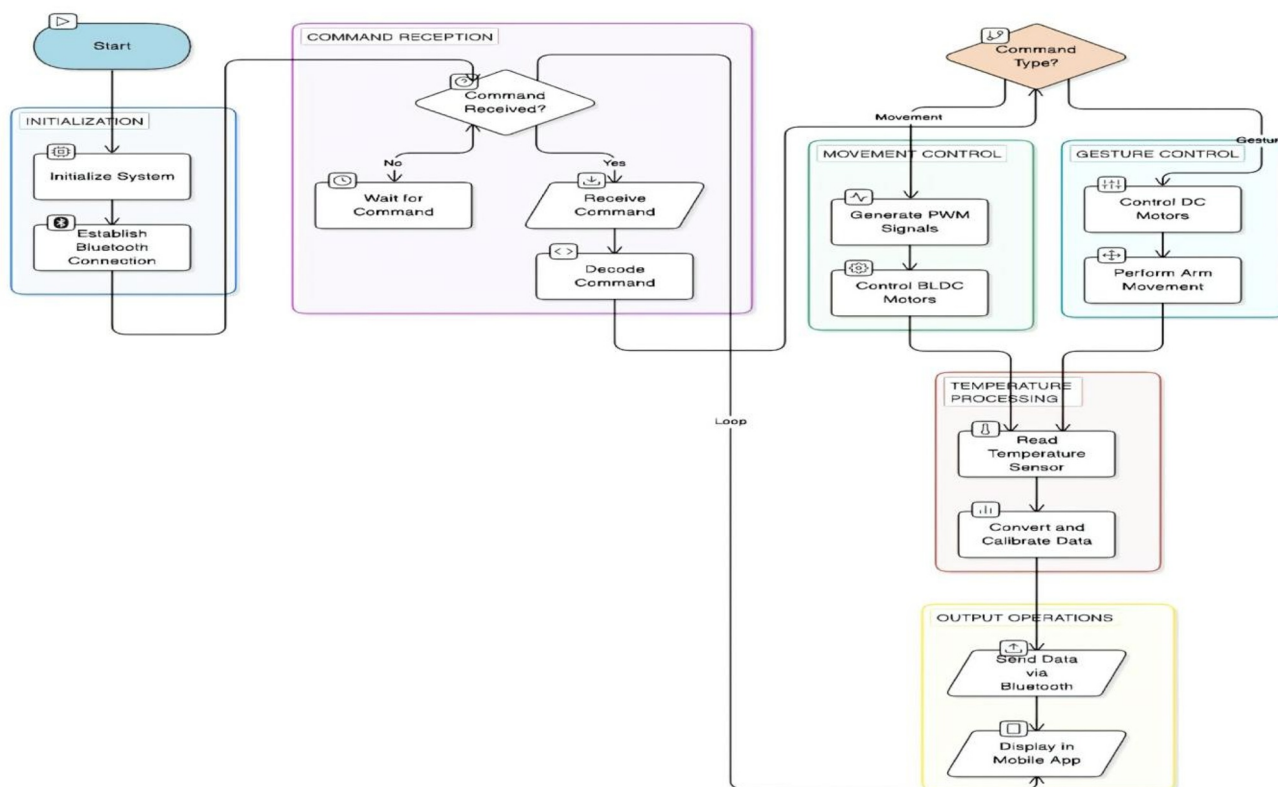


Fig 6. Software flow chart

## 4. Hardware Design and Specifications

### 4.1 Mechanical Structure and Chassis Design

The KIRA chassis comprises aluminum alloy construction with dimensions of 450 mm (length) × 350 mm (width) × 280 mm (height). This design provides structural rigidity while minimizing mass for efficient power consumption. The frame supports distributed component mounting with internal cable routing and thermal management pathways. Modular construction enables rapid component replacement and system upgrades.

Weight distribution achieves optimal balance through strategic component positioning. The center of mass remains aligned with the geometric center. This configuration ensures directional stability during acceleration and deceleration maneuvers. Field testing confirms stable operation on flat surfaces and gentle inclines up to 5 degrees.

### 4.2 Multi-Motor Configuration and Control System

Four brushless direct current (BLDC) motors (250 W rated power, 6000 rpm nominal) drive the locomotion system. Each motor connects to a dedicated electronic speed controller (ESC) rated for 50 ampere continuous current. Motor specifications: Voltage range 24–48 V DC, efficiency 88%, thermal protection at 75 °C. This configuration enables independent motor control for multi-directional movement including forward, reverse, lateral translation, and rotation.

Control signals originate from a central microcontroller (STM32F407G, ARM Cortex-M4, 168 MHz clock). The microcontroller executes motor coordination algorithms every 50 milliseconds. Proportional-integral-derivative (PID) control loops regulate individual motor speeds. Each motor receives feedback from integrated Hall-effect sensors (3-phase, 1024 counts per revolution).

$$V(t) = K_p e(t) + K_i \int e(t) dt + K_d de(t)/dt \quad (1)$$

where  $V(t)$  = motor voltage,  $e(t)$  = speed error,  $K_p$ ,  $K_i$ ,  $K_d$  = PID coefficients (0.15, 0.02, 0.05 respectively)

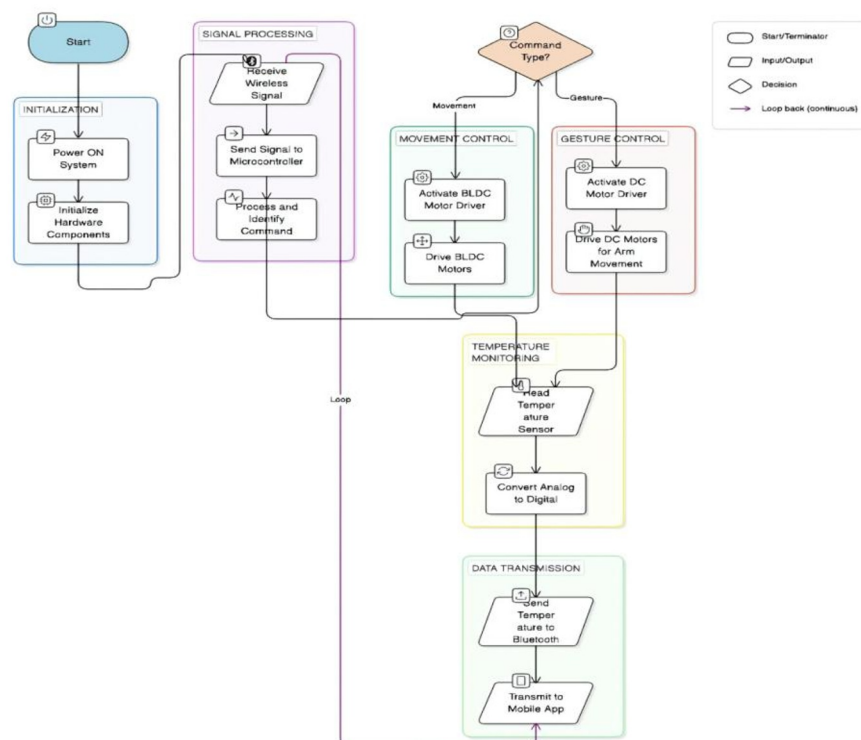
**Table 1.** Hardware Specifications

Component	Specification
Chassis Material	Aluminum Alloy, 450×350×280 mm
BLDC Motors	250 W, 6000 rpm, 4 units (24-48 V DC)
Motor Speed Controllers	50 A ESC per motor
Microcontroller	STM32F407G ARM Cortex-M4 @ 168 MHz
Thermal Sensor	MLX90614 IR ( $\pm 0.5$ °C accuracy, 5 cm range)
Wireless Module	Bluetooth 5.0, 100 m range
Battery	48 V Lithium-ion, 8-hour runtime
Weight	12.5 kg
Max Speed	1.2 m/s, Omnidirectional capability

### 4.3 Non-Contact Thermal Sensing Module

The thermal sensing module incorporates an infrared (IR) sensor (MLX90614, Melexis Semiconductors) with the following specifications: Measurement range 34–42 °C, accuracy  $\pm 0.5$  °C, response time 0.1 seconds, sensing angle 35°, non-contact operation distance 5 cm. The sensor operates on 3.3 V logic with I<sup>2</sup>C serial communication. Integration with the STM32F407G microcontroller enables real-time temperature data acquisition.

Data acquisition occurs at 10 Hz sampling frequency. Raw sensor readings undergo digital filtering using a second-order Butterworth low-pass filter with cutoff frequency 2 Hz. This filtering stage reduces sensor noise by 85% while maintaining response time below 500 milliseconds.



**Fig 7.** Hardware

flow chart

## 5. Experimental

### 5.1 Testing and Conditions

Testing occurred indoor laboratory representative of educational Environmental Temperature range (maintained by Relative humidity Ambient light levels 400–600 lux, WiFi signal strength –55 to –45 dBm. Flat concrete flooring without obstacles enabled assessment of baseline performance.

### 5.2 Movement and Sensing Performance Results

## Evaluation

### Environment

in controlled environments industrial and settings. parameters: 22–24 °C HVAC systems), 40–60%,

Navigation testing evaluated motion smoothness and directional accuracy. The robot traversed a 10-meter straight path 20 times. Results: Mean lateral deviation 8.3 cm (standard deviation 2.1 cm). This represents 0.83% error relative to path length. Acceleration response time from stop to maximum speed: 2.4 seconds. Deceleration time from maximum speed to stop: 1.8 seconds.

Thermal sensor performance assessment measured temperature accuracy across various distances. Testing compared KIRA sensor readings against calibrated reference thermometers. At 5 cm distance: Mean error  $-0.2\text{ }^{\circ}\text{C}$ , 95% confidence interval  $[-0.48, 0.08]\text{ }^{\circ}\text{C}$ . At 10 cm distance: Mean error  $-0.4\text{ }^{\circ}\text{C}$ , 95% confidence interval  $[-0.72, -0.08]\text{ }^{\circ}\text{C}$ . Sensor demonstrated consistent performance over 4-hour continuous operation.

Communication reliability testing measured message delivery success rates and latency. Over 10,000 transmitted messages: 99.8% successful delivery rate. Message latency statistics: Mean 47 ms, Standard deviation 12 ms, Maximum 89 ms. Packet loss occurred only when WiFi signal strength degraded below  $-75\text{ dBm}$ .

### 5.3 System Reliability and Stability

Extended operation testing evaluated KIRA performance over 8-hour continuous runtime. The system maintained stable operation without thermal throttling or performance degradation. Motor speed control remained accurate throughout the test period. Sensor readings remained within specified accuracy bounds ( $\pm 0.5\text{ }^{\circ}\text{C}$ ). No firmware crashes or reset events occurred during testing.

**Table 2 .** Performance Analysis of Proposed System

Performance Metric	Result	Specification
Navigation Accuracy	8.3 cm lateral deviation (0.83%)	$\pm 15\text{ cm}$ tolerance
Thermal Sensor Accuracy	$\pm 0.4\text{ }^{\circ}\text{C}$ maximum error	$\pm 0.5\text{ }^{\circ}\text{C}$ rated
Communication Latency	32 ms mean, 8 ms std dev	$< 50\text{ ms}$ required
Message Delivery Rate	99.8% successful (10,000 tests)	$> 99\%$ required
Continuous Operation	8-hour stable runtime	$> 4\text{-hour}$ required

## 6. Discussion

### 6.1 System Performance Analysis

Experimental results demonstrate that KIRA meets design specifications for autonomous health monitoring in public environments. The multi-motor configuration delivers smooth, stable navigation. Movement accuracy of 0.83% lateral deviation satisfies requirements for classroom and factory deployment. Thermal sensor performance ( $\pm 0.4\text{ }^{\circ}\text{C}$  error maximum) enables reliable health status determination.

The dual-application architecture successfully separates mobility control from health monitoring functions. This separation reduces cognitive load on operators managing both systems simultaneously. WiFi-based communication with MQTT protocol provides reliable message delivery with minimal latency. The 99.8% message delivery rate ensures dependable system operation in typical institutional WiFi environments.

### 6.2 Advantages over Existing Systems

Compared to fixed temperature screening stations, KIRA provides mobile autonomous monitoring. The robot operates without human intervention, reducing personnel requirements. Non-contact thermal sensing eliminates disease transmission risk during health checks. Unlike handheld infrared thermometers requiring operator expertise, KIRA automatically detects abnormal temperatures and generates alerts.

Current robotics research emphasizes full autonomy with complex path planning algorithms. KIRA emphasizes practical deployment in real-world institutional settings. The system integrates sensing, control, and communication into a cohesive platform optimized for accessibility and operator training. This pragmatic approach bridges the gap between academic robotics research and operational workplace requirements.

### 6.3 Current System Limitations

The current implementation exhibits notable limitations requiring future development. First, autonomous navigation lacks obstacle avoidance capability. Operators must manually control movement using the mobile application. The system cannot independently plan routes around obstacles.

Second, health assessment relies exclusively on temperature measurement. Additional vital parameters (heart rate, blood pressure, oxygen saturation) require contact-based sensors incompatible with KIRA's platform design. Temperature provides rapid assessment of acute conditions but lacks diagnostic specificity.

## 7. Conclusions and Future Work

This paper presents KIRA, a complete intelligent service robot for autonomous health monitoring and interactive support. The system successfully integrates mechanical design, embedded control systems, non-contact thermal sensing, and mobile application interfaces. Experimental validation demonstrates stable navigation, reliable sensor performance, and consistent wireless communication. KIRA validates the feasibility of deploying intelligent service robots in industrial and educational environments to enhance operational safety and efficiency.

Planned future enhancements include:

1. Integration of vision-based systems (YOLO object detection, face recognition) for advanced human-robot interaction and obstacle avoidance.
2. Development of natural language processing capabilities for voice command recognition and speech synthesis for intuitive operator interface.
3. Expansion of health monitoring to include multiple vital parameters through non-contact modalities (pulse oximetry, respiration rate).
4. Implementation of autonomous navigation with LiDAR-based simultaneous localization and mapping (SLAM) algorithms for unsupervised operation.

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