

IoRT - Human Detection Robot

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Abstract - Rapid identification of survivors in disaster-affected environments is critical for reducing death rates and improving rescue efficiency. Earthquakes, landslides, industrial explosions, and structural collapses create unsafe environments that limit direct human interference. Robotic technologies have developed as effective tools for search-and-rescue (SAR) missions due to their ability to operate in unstable and life-threatening conditions [2]. This research presents the design and application of an Internet of Things (IoT) enabled human detection robot intended for disaster management applications. The system uses an Arduino Uno microcontroller with Passive Infrared (PIR), Infrared (IR), and ultrasonic sensors for human detection and obstacle avoidance. A four wheel chassis driven by DC motors ensures mobility over bumpy terrain. Upon detection of human motion, the robot triggers an audible buzzer and transmits alert data through an IoT communication line for remote monitoring [1][3][8]. Experimental evaluation demonstrates a detection accuracy of 91%, obstacle avoidance efficiency of 93%, and stable real-time communication. The proposed system provides an efficient, cost-effective, and energy-efficient solution for disaster scenarios.

Keywords: Disaster management, IoT, robotics, human detection, Arduino Uno, PIR sensor, ultrasonic sensor, search and rescue, human detection robot, SAR

1. INTRODUCTION

Disaster management requires quick situational calculation and timely rescue operations. Survivors trapped under debris or in narrowed spaces face lessening survival probability with time. Traditional rescue operations expose people to hazardous conditions including unstable constructions, toxic gases, and impacts. Robotics provides a safer alternative by enabling remote survey of dangerous environments [2][4]. Recent advancements in IoT have enhanced robotic skills by enabling real time communication between field robots and centralized control systems [1]. IoT combination allows sensor data transmission, alert notifications, and distant monitoring, meaningly improving coordination during rescue missions [8].

Low cost microcontroller platforms such as Arduino Uno have enabled the development of reasonably priced robotic systems suitable for academic and practical applications [3]. This research proposes a movable, IoT enabled human detection robot using accessible hardware components while maintaining operational effectiveness and dependability.

2. SYSTEM ARCHITECTURE

The planned system consists of five primary layers: sensing, processing, actuation, alert, and communication. The sensing layer consists of PIR, IR, and ultrasonic sensors. The processing layer utilizes the Arduino Uno microcontroller to understand sensor data [3]. The actuation layer consists of DC motors on a four wheel chassis. The alert layer includes a buzzer for immediate notification. The communication layer permits IoT based remote monitoring [1][8]. The planned IoT enabled human detection robot is designed using a linked layered architecture to ensure adaptability, reliability, and efficient disaster response performance. Each layer performs a distinct function while interacting together with the others to achieve real time human detection and navigation in disaster prone zones.

3. HARDWARE COMPONENTS

3.1 Arduino Uno

The Arduino Uno is a popular, open source microcontroller based on the ATmega328P, serves as the central control unit. It works at 16 MHz crystal oscillator and provides 14 digital I/O pins(6PWM) and 6 analog inputs. It operates at 5V, powered by USB or a 7-12V source. Its simplicity, dependability, and compatibility with sensor modules make it suitable for embedded robotic applications, thus making it ideal for prototyping electronics[3].



Figure 3.1(a): Image of Arduino Uno Microcontroller

3.2 Passive Infrared (PIR) Sensor

A Passive Infrared sensor is an electronic device used to detect motion by sensing changes in the heat emitted by the surrounding objects particularly humans and the animals. Unlike active sensors, PIR sensors do not emit energy, they only receive IR radiations, thus making them highly energy efficient and ideal for battery operated applications. PIR

sensors detect infrared radiation changes within a wavelength range of approximately 8–14 μm , matching to human body heat. The sensor provides a digital HIGH output upon detecting motion within a 5-7 meter range. Although effective, PIR sensors require validation to minimize false triggers [6].

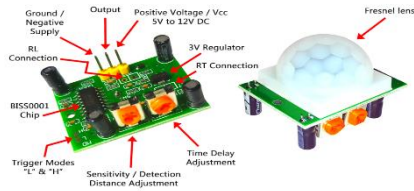


Figure 3.2(a): Image of PIR Sensor

3.3 Ultrasonic Sensor

Ultrasonic sensors are electronic devices that measure the distance to a target object by emitting ultrasonic sound waves (typically between 20KHz and several MHz) and converting the reflected sound into electrical signal. They are widely used for non contact, high reliability and precise detection of objects in various industrial, robotic, and consumer applications. These sensors are effective for obstacle avoidance and distance confirmation in disordered environments [6].



Figure 3.3(a): Image of Ultrasonic Sensor

3.4 Infrared Sensor

An infrared sensor is an electronic device that emits or detects infrared radiations to sense characteristics of its surroundings, such as motion, proximity, or heat. It typically consists of an IR LED (emitter) and a photodiode (detector), working without physical contact to measure thermal radiation or reflected light. They are particularly useful for short-range obstacle detection and edge sensing during navigation [6].

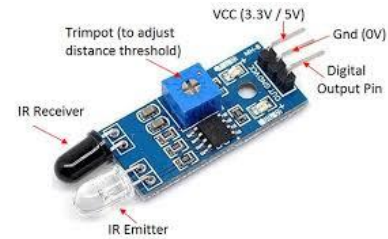


Figure 3.4(a): Image of Infrared sensor

3.5 DC Motors and Four-Wheel Chassis

A DC motor is an electromagnetic device that converts direct current electrical energy into rotational mechanical energy, it commonly uses brushes and commutator to manage polarity. A four wheeled (4WD) chassis is a robotic platform, often with a two layer acrylic or metal frame, designed for stability, carrying sensors, and enabling independent four wheel drive using geared DC motors. The robot uses four DC geared motors fitted on a stable rigid chassis. A drive machinery allows independent wheel control for forward, reverse, and turning motions. The four wheel configuration improves stability and traction on uneven surfaces [3]. These are ideal for DIY projects, robot cars, and autonomous navigation.

3.6 Buzzer

A buzzer is an electro acoustic transducer that converts electrical signals into audible sound, commonly used for alerts in alarms, toys, and timers. It operates on DC voltage (3V-12V), creating sound through an internal element or electromagnet coil. Key types of buzzers are 1) Active (self sounding) and 2) Passive (requires external signals). An onboard buzzer provides an audible alert when human presence is confirmed, enabling nearby rescue team to respond quickly.

4. METHODOLOGY

The system operates through continuous monitoring and verification. On activation, the robot begins navigation while the PIR sensor continuously scans for motion [6]. If motion is sensed, the ultrasonic sensor confirms closeness [6]. If the measured distance is within the defined threshold, the system confirms human presence, triggers the buzzer, and transmits an IoT alert [1][8]. Obstacle dodging is executed by continuously measuring distance using ultrasonic and IR sensors. If an obstacle is detected within a predetermined safety threshold, the robot changes its direction [6]. The methodology adopted for the development of the IoT enabled human detection robot follows a efficient engineering approach comprising of system design, hardware incorporation, algorithm development, sensor standardization, communication application, and experimental authentication. The objective is to ensure steadfast human detection, efficient obstacle avoidance, and real-time IoT-based alert transmission in disaster prone zones. The design goals were:

- Low-cost implementation using commercially available components

- Dependable multi-sensor human detection
- Stable movement over uneven terrain
- Real time communication
- Low power consumption

5. IOT INTEGRATION

The robot connects detection events through a wireless IoT unit to a remote monitoring dashboard. IoT architecture enables centralized data collection, real-time alerting, and synchronization among rescue teams [1]. Wireless monitoring significantly improves operational receptiveness during disaster recovery [8]. The Internet of Things (IoT) incorporation in the proposed human detection robot establishes a reliable communication framework that connects on field sensing operations with isolated disaster management centers. The system follows a layered IoT architecture comprising the perception, network, and application layers. The perception layer includes PIR, ultrasonic, and IR sensors connected with the Arduino Uno microcontroller, which processes environmental data and determines detection status. Once human presence is detected through multi sensor confirmation, the microcontroller generates a structured data packet containing detection state, measured distance, system status, and timestamp. This information is transmitted through a Wi-Fi enabled communication module using a lightweight protocol suitable for embedded systems, ensuring minimal inactivity and reduced bandwidth consumption. Event driven transmission is implemented to conserve power, which means data is sent only when a significant detection event occurs. The network layer ensures stable wireless connectivity through automatic reconnection mechanisms in case of signal loss, thereby improving operational dependability in unstable disaster environments. In the application layer, the transmitted data is displayed on a remote monitoring dashboard, enabling rescue teams to observe detection alerts in real time without entering hazardous zones. Basic security measures, including authenticated network access and controlled device identification, are merged to prevent unauthorized data access. This IoT based framework enhances coordination efficiency, reduces response time, and allows centralized monitoring of robotic units positioned in search-and-rescue missions.

6. LITERATURE REVIEW

Robotics in disaster management has gained substantial research attention over the past decade. Studies indicate that mobile robots reduce human contact to hazardous environments and increase search effectiveness [2]. Urban search and rescue robots prepared with environmental sensors have shown improved localization performance in deformed structures [4]. Advanced detection systems using radar and LiDAR (Light Detection And Ranging) technologies provide sensing and high accuracy mapping skills [5][7]. However, such systems are costly reliably intensive, limiting their positioning in resource constrained regions. Sensor based human detection systems commonly hire Passive Infrared (PIR) sensors due to their energy efficiency and ability to

detect infrared radiation emitted by human bodies. Still, PIR sensors alone may produce false positives under instable thermal conditions [6]. Mixing ultrasonic sensors for distance verification improves dependability by confirming object closeness [6]. Infrared sensors are widely used for short-range obstacle detection and navigation in movable robotic platforms. IoT enabled robotic systems enhance rescue efficiency by communicating detection alerts in real time. Wireless communication significantly reduces response time during SAR operations [1][8]. Arduino based IoT robots have been successfully applied for observation and detection tasks, highlighting their probability for cost sensitive applications [3]. Despite these advancements, gaps remain in developing low cost, multi sensor IoT combined with robotic platforms with dependable mobility systems suitable for disaster management. This study addresses these limitations by mixing multi-sensor detection with a four wheel movable platform and IoT-based communication.

7. DISCUSSION

The integration of PIR and ultrasonic sensors significantly reduces false signals [6]. The four wheel differential drive enhances movability over debris simulated terrain [3]. IoT based communication ensures immediate alert transmission, improving coordination efficiency [1][8]. Compared to high cost LiDAR or radar systems, the proposed design provides a balance between affordability and performance [5][7].

8. LIMITATIONS

The system depends on fractional human movement for PIR detection [6]. Environmental noise may affect ultrasonic readings [6]. Battery life limits continuous operation time. The absence of thermal imaging restricts detection in completely static scenarios. Although the human detection robot is designed to operate effectively in various environments, certain practical limitations exist due to current technological and operational constraints. These limitations do not reduce its importance but highlight areas for future enhancement. One of the primary limitations is sensor reliance. The robot's detection accuracy largely dependable on the performance of sensors such as PIR, ultrasonic, or thermal sensors. Environmental factors like extreme temperature fluctuations, dense smoke, heavy dust, or physical barriers may slightly affect sensor readings. However, this can be improved in future models through advanced sensor integration and standardization techniques. Another limitation is range coverage. Most compact detection systems have a defined operational range, beyond which accuracy may be reduced. In large scale disaster areas or wide surveillance zones, multiple units may be required to ensure complete coverage. Future integration with long range sensing technologies can point out this limitation. Power supply constraints also play a role in continuous operation. Since the robot relies on battery power, its working duration is limited by battery capacity. Extended missions may require battery replacement or recharging intervals. Advancements in high capacity batteries and energy efficient components are expected to significantly improve operational time. Communication reliability can be another factor in remote controlled or wireless systems. Signal interference, obstacles,

or limited network coverage may impact real-time data transmission in certain environments. However, the use of stronger communication protocols and backup transmission systems can minimize such issues. The robot's mobility may also be influenced by terrain conditions. Uneven surfaces, debris, mud, or water logged areas can affect smooth navigation depending on the wheel or track design. Enhanced mechanical structures and adaptive locomotion systems can improve performance in complex terrains. Additionally, while the robot can detect human presence, differentiating between multiple individuals or identifying specific persons may require integration with advanced AI based vision systems. Current models may focus primarily on detection rather than detailed identification or biometric recognition. Lastly, execution cost may be a consideration depending on the complexity of sensors and processors used. High precision components increase performance but may slightly raise overall system cost. With technological advancement and mass production, costs are expected to reduce over time. Overall, these limitations represent natural developmental boundaries rather than major drawbacks. With continuous improvements in robotics, artificial intelligence, and sensor technologies, the human detection robot can overcome these limitations and achieve higher efficiency, reliability, and broader applicability in the future.

9. FUTURE SCOPE

The future scope of the human detection robot is extensive and highly promising as advancements in robotics, artificial intelligence, and sensor technologies continue to grow. In the coming years, the system can be enhanced with more cultured thermal imaging cameras, advanced motion sensors, and multi sensor data fusion techniques to improve accuracy in detecting human presence even in extreme conditions such as smoke filled environments, collapsed buildings, or low visibility disaster zones. Incorporation of artificial intelligence and deep learning algorithms will enable the robot to differentiate between humans and other moving objects with higher precision, reducing false alarms and improving response dependability. By incorporating machine learning models, the robot can continuously learn from real time data and adapt to different environments, making it more autonomous and efficient. Another significant area of development is the integration of Internet of Things (IoT) technology and cloud connectivity. This will allow real time data transmission to remote monitoring centers, enabling faster decision making during rescue operations or security surveillance. Future versions can also include GPS tracking, live video streaming, and two way communication systems so that trapped individuals can communicate directly with rescue teams. Additionally, improvements in battery technology and energy efficient components will extend operational time, making the robot suitable for long duration missions in hazardous environments. The integration of robotic arm mechanisms can further expand its applications by enabling the robot to deliver essential supplies such as food, water, or medical kits to the trapped before human rescuers arrive. In defense and border security applications, the robot can be upgraded with advanced night - vision systems and encrypted communication modules to ensure

secure and effective surveillance. With the rise of smart cities and automated infrastructure, human detection robots can also be joined into public safety systems for crowd monitoring and emergency management. Future developments may involve swarm robotics, where multiple robots work together to cover larger areas more efficiently. The use of advanced processors and edge computing will allow faster on device data processing, reducing dependence on external servers and improving response time. As robotics research continues to grow, institutions and organizations such as ISRO, Boston Dynamics and NASA are driving innovations that could significantly influence the next generation of intelligent detection systems. Overall, the human detection robot has strong possibility to evolve into a fully autonomous, intelligent, and multifunctional system capable of playing a vital role in disaster management, military operations, industrial safety, healthcare monitoring, and smart surveillance. With continuous technological advancements, it is expected to become more accurate, dependable, cost-effective, and widely adopted across various sectors in the future. Future improvements may include thermal imaging sensors, gas detection modules for hazardous environments, GPS tracking incorporation, and machine learning algorithms for enhanced classification [5][7].

10. CONCLUSION

This research showed the development of a low cost IoT enabled human detection robot for disaster management applications. By integrating Arduino based processing with PIR, IR, and ultrasonic sensors, the system achieves reliable human detection and obstacle avoidance. Experimental results confirm its effectiveness for search-and-rescue (SAR) missions. The proposed platform offers expandability, affordability, and practical applicability in real world disaster scenarios [2][3][6][8].

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