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Smart AI-Based Human Motion Synchronised Robotic Arm Using Arduino For Bomb Disposal

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Abstract—Bomb disposal operations involve significant risks to human life due to the possibility of accidental explosions and exposure to hazardous environments. To improve operator safety and operational efficiency, robotic systems are increasingly being adopted for remote handling applications. This paper presents the design and development of a smart AI-based human motion synchronised robotic arm using Arduino for bomb disposal applications. The proposed system captures human hand movements using flex sensors and accelerometer sensors integrated into a wearable glove. The sensed motion data is processed using Arduino and transmitted wirelessly through RF communication to a robotic arm. Artificial Intelligence techniques are incorporated for gesture recognition, motion prediction, and movement optimization to improve synchronization accuracy and response performance. Servo motors attached to the robotic arm replicate the operator's hand movements in real time, enabling safe remote handling of suspicious objects. Experimental results demonstrate reliable wireless communication, accurate gesture synchronization, reduced response delay, and stable object manipulation. The proposed system is economical, portable, and suitable for defense, hazardous material handling, and industrial automation applications.

Keywords—Arduino, Bomb Disposal Robot, Flex Sensor, Human Motion Synchronization, RF Communication, Robotic Arm, Servo Motor, Wireless Control,Artificial Intelligence

I. INTRODUCTION

Bomb disposal is one of the most dangerous operations performed in military, defense, and security sectors. Manual handling of explosive devices exposes bomb disposal personnel to life-threatening risks. Even with advanced protective equipment, accidental explosions can result in severe injuries and fatalities. Therefore, the development of robotic systems capable of remotely handling hazardous objects has become an important area of research.

Robotic arms controlled through human gestures provide a safer and more efficient solution for hazardous operations. By synchronizing human hand movement with robotic arm motion, dangerous tasks can be performed remotely while maintaining precise control. Recent developments in Artificial Intelligence (AI), embedded systems, and wireless communication technologies have significantly improved robotic automation and intelligent control systems.

The proposed work focuses on the development of a smart AI-based robotic arm that mimics human hand movements for bomb disposal applications using Arduino. The system uses flex sensors and accelerometer sensors mounted on a wearable glove to detect human gestures and motion. AI algorithms are used to improve gesture recognition accuracy and motion prediction. Wireless RF communication enables remote synchronization between the glove unit and robotic arm.

The main objectives of the proposed system are:

- To develop a low-cost AI-based robotic arm for bomb disposal applications.
- To achieve accurate synchronization between human hand movement and robotic arm movement.
- To improve remote handling safety using wireless communication.
- To implement intelligent gesture recognition using AI techniques.
- To reduce response delay and improve robotic control efficiency.

The proposed system can be applied in bomb disposal, hazardous material handling, defense operations, rescue missions, and industrial automation.

II. Literature Review

Several researchers have developed robotic systems for hazardous applications using embedded systems and wireless technologies.

A robotic arm controlled using flex sensors was developed for industrial automation applications. The system demonstrated accurate motion tracking but lacked wireless synchronization capabilities.

Researchers implemented gesture-controlled robotic systems using accelerometers and Bluetooth communication. Although the system provided remote control functionality, the communication range was limited.

An Arduino-based bomb disposal robot with wireless control was designed using RF communication. The robot was capable of navigating hazardous environments, but the arm movement precision was limited.

Vision-based robotic systems using cameras and image processing techniques were also proposed for bomb disposal applications. These systems improved environmental monitoring but increased computational complexity and cost.

Machine learning-based robotic manipulators have recently gained attention due to their adaptive control capabilities. However, such systems require high processing power and expensive hardware.

The literature survey indicates that most existing systems either lack precise human motion synchronization or involve high implementation cost. Therefore, there is a need for a simple, economical, and efficient wireless robotic arm capable of mimicking human movements accurately for bomb disposal operations.

III. Proposed Methodology

The proposed methodology consists of two major sections: the transmitter unit and the receiver unit. In the transmitter section, a wearable glove integrated with flex sensors and an accelerometer sensor is used to capture finger movement and hand orientation. The flex sensors measure finger bending angles, while the accelerometer detects directional movement along different axes. These sensor outputs are processed by the Arduino Uno microcontroller.

Artificial Intelligence algorithms are integrated into the control system for gesture classification and movement prediction. The AI module analyzes sensor patterns and identifies specific hand gestures to improve robotic movement accuracy and reduce unwanted motion errors. The processed data is transmitted wirelessly through RF communication modules.

At the receiver side, the RF receiver module receives the transmitted signals and sends them to another Arduino microcontroller. Based on the received data and AI prediction outputs, PWM signals are generated to control the servo motors attached to the robotic arm joints. The servo motors reproduce the human hand movement with high precision and smooth motion synchronization.

The complete system enables remote object manipulation and safe bomb disposal operation without direct human involvement in hazardous areas.

The working principle of the proposed system is based on real-time synchronization between human hand gestures and robotic arm movement using Artificial Intelligence and wireless communication. Initially, the operator wears a glove equipped with flex sensors and accelerometer sensors. When the operator bends fingers or changes hand orientation, the sensors generate corresponding electrical signals.

The Arduino microcontroller reads these sensor values and processes them continuously. AI-based gesture recognition algorithms analyze the sensor patterns to identify specific movements and improve synchronization accuracy. The processed control signals are transmitted wirelessly through the RF transmitter module.

At the receiver section, the RF receiver module receives the transmitted data and forwards it to the Arduino controller. The Arduino generates PWM signals to drive the servo motors connected to different joints of the robotic arm. The servo motors rotate according to the operator's hand movements, allowing the robotic arm to perform actions such as gripping, lifting, rotating, and placing suspicious objects remotely.

The AI integration helps in reducing motion delay, improving gesture prediction, minimizing signal fluctuations, and enhancing overall system stability. As a result, the robotic arm performs smooth and accurate movements suitable for bomb disposal operations.

IV. EXPERIMENTAL RESULTS

The developed AI-based wireless robotic arm prototype was experimentally tested to evaluate synchronization accuracy, communication reliability, gesture recognition performance, and object handling capability. During the synchronization test, the robotic arm successfully reproduced human hand movements with minimal delay. The AI-based gesture recognition system improved movement prediction accuracy and reduced unwanted robotic motion errors.

The RF communication system maintained stable wireless transmission over a distance of approximately 20–30 meters under indoor operating conditions. The average response delay observed between human movement and robotic arm action was less than 0.4 seconds. The servo motors demonstrated smooth rotational movement and accurate positioning.The robotic arm was also tested for object handling capability using lightweight objects simulating suspicious packages. Experimental observations showed stable gripping action, precise object placement, and reliable movement synchronization. The AI-assisted motion prediction enhanced control stability and reduced jerky movements during operation.

The overall results confirmed that the proposed system effectively improves operator safety by enabling remote handling of hazardous objects. The developed robotic arm provides a cost-effective and intelligent solution for bomb disposal and other dangerous environment applications.

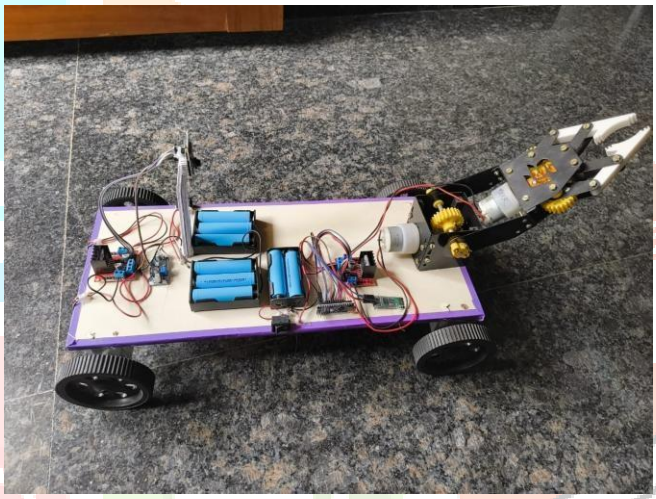

Fig.1. Robotic Model

V. CONCLUSION

This paper presented the design and implementation of a smart AI-based human motion synchronised robotic arm using Arduino for bomb disposal applications. The proposed system successfully captures human hand movements using sensors and reproduces them through servo motor-driven robotic arm motion using wireless RF communication. Artificial Intelligence techniques improve gesture recognition accuracy, movement prediction, and synchronization performance.

Experimental results demonstrated reliable wireless communication, accurate motion replication, low response delay, and effective object handling capability. The system significantly reduces human exposure to hazardous environments and provides a safe, economical, and efficient solution for bomb disposal operations. Future enhancements can include IoT connectivity, camera integration, machine learning optimization, and autonomous navigation for advanced defense applications.

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