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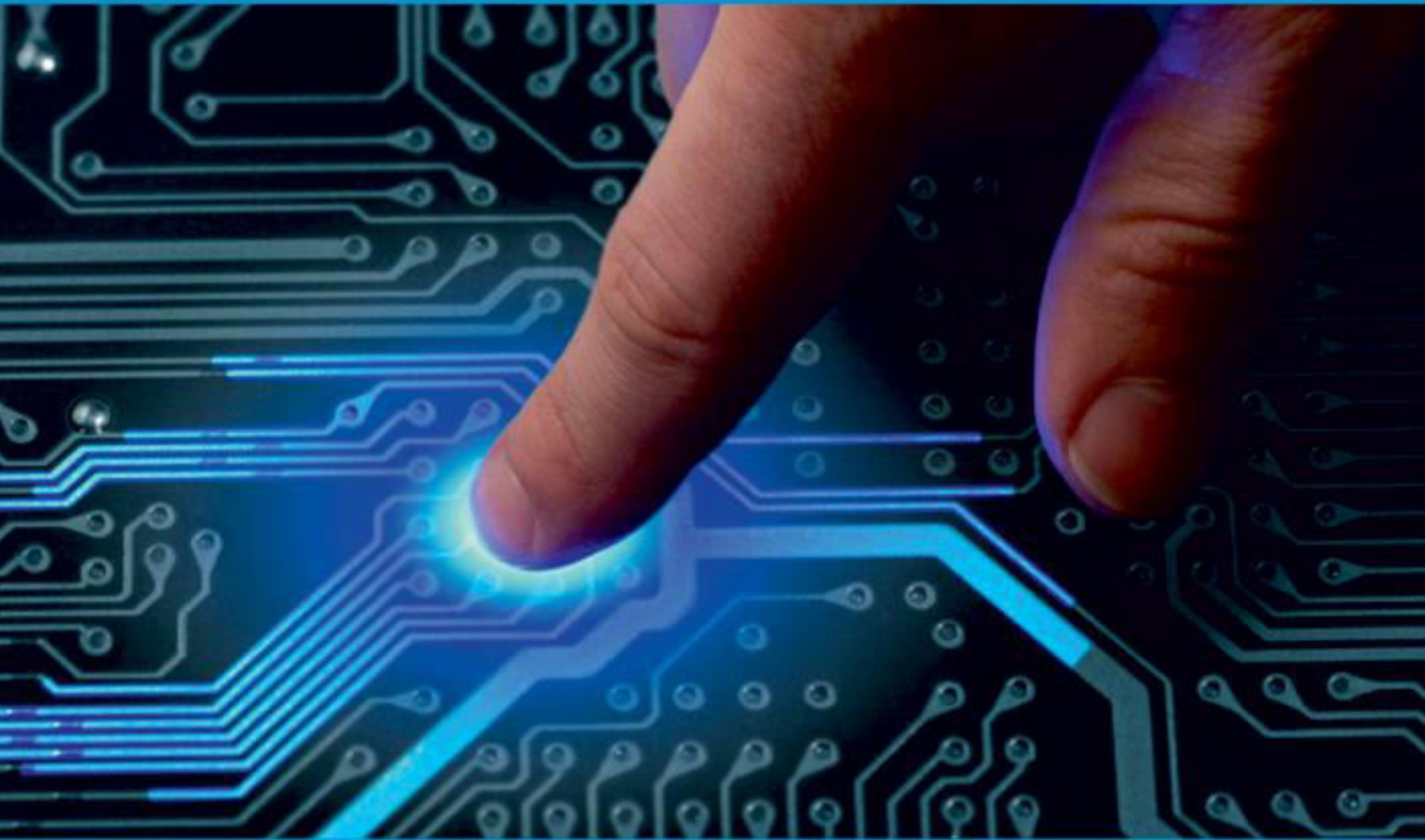

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Robotic Arm for Bomb Disposal: Using LoRa Technology

Satyam Vishwakarma[1], Shivam Tripathi[2], Yash Kumar[3], Yash Pal[4], Yash Sen[5], Dr. Prabhat Sharma[6]

Student, Department of Electronics & Communication, Oriental Institute of Science & Technology, Bhopal, Madhya Pradesh, India[1,2,3,4,5]

HOD, Department of Electronics & Communication, Oriental Institute of Science & Technology, Bhopal, Madhya Pradesh, India[6]

ABSTRACT: The increasing demand for robotic systems in hazardous and inaccessible environments has led to the development of a robotic arm capable of performing tasks without direct human intervention. This research focuses on designing a robotic arm that can be controlled through natural human arm movements, captured using accelerometers, or via manual input, ensuring flexibility and adaptability. Built on ATmega32 and ATmega640 microcontroller platforms and integrated with Arduino UNO or MEGA, the system employs serial communication for seamless interfacing and a personal computer for signal processing. The prototype is designed to address challenges such as handling hazardous objects, moving heavy materials, and automating complex tasks in industrial and high-risk scenarios, offering a cost-effective, precise, and reliable solution for critical applications.

I. INTRODUCTION

Human arms and hands are marvels of natural engineering, capable of tasks requiring immense speed and strength, such as swinging a baseball bat, as well as delicate precision, like threading a needle. Recreating this dexterity and versatility in a robotic arm is a challenging Endeavor. However, robots often surpass humans in specific tasks, particularly repetitive ones, as they do not tire or lose focus. This is why robotic arms are extensively used in industries like manufacturing, where they perform repetitive tasks with unmatched precision and consistency.

Robotic arms also play a critical role in environments where human access is challenging or unsafe. For instance, the Canadarm, mounted on the Space Shuttle, assisted in deploying satellites and performing maintenance tasks in space. Similarly, Mars rovers like Perseverance utilize robotic arms to collect and analyse Martian soil samples. In addition to exploration, robotic arms serve as prosthetics, enhancing the quality of life for individuals by mimicking natural arm movements. These arms vary in their design, offering different degrees of freedom to meet the demands of diverse applications.

The construction of a robotic arm involves precise control over its movements, often achieved using stepper motors, which allow incremental motion for exact positioning. The arm's primary function is to move an end effector—a tool or mechanism at the arm's tip—to execute specific tasks like gripping, welding, or spinning. Depending on the application, end effectors can be interchanged and are often equipped with pressure sensors to prevent damage to objects being handled, ensuring optimal grip and safety during operations.

Robotic arms have also found critical applications in defence, particularly in bomb disposal. Systems like the TEODOR (Telemax Explosive Ordnance Disposal Robot) and CUTLASS have demonstrated high effectiveness in military operations, while the Indian Daksh Remotely Operated Vehicle (ROV) has bolstered the Indian Army's capabilities. These innovations highlight the growing significance of robotic arms in domains that demand precision, adaptability, and safety in high-risk scenarios.

II. LITERATURE SURVEY

Robots have long been utilized to perform tasks that are too dangerous or undesirable for humans. One of the earliest and most critical applications of robotics has been bomb disposal, a profession fraught with risk, especially in battlefield scenarios. In the 1970s, the development of drones for disarming explosives marked a significant leap forward in safety and innovation. Early bomb disposal robots, such as the Wheelbarrow units, relied on rudimentary methods like rope-controlled operations, showcasing the simplicity of initial designs. Over the decades, these robots have evolved into sophisticated systems equipped with virtual reality interfaces and advanced sensory feedback, dramatically improving their functionality and precision.

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The field of robotics has seen remarkable advancements over the past two decades, driven by intensive research and development. According to Jonathan DiGiacomandrea, application engineering manager at Ultra life Corporation, the rapid evolution of robotics has significantly benefited bomb disposal technologies. Modern robots are far more reliable and precise than their predecessors, enabling safer and more efficient handling of explosive devices. These improvements have elevated the potential and performance of bomb disposal robots, ensuring their continued importance in mitigating risk.

Despite these advancements, early robots had significant limitations. They allowed operators to handle explosives remotely, but their deployment required direct sightlines and relatively flat terrain. This posed challenges in accessing bombs located in complex environments, such as upper floors of buildings or other obstructed areas. While improvements in cameras and sensors have addressed some of these issues, mobility remains a critical challenge in enabling robots to reach their targets without jeopardizing safety.

In recent years, significant progress has been made in enhancing the mobility and dexterity of bomb disposal robots. Collaboration between the University of Greenwich at Medway and NIC Instruments, for example, resulted in the development of robots capable of climbing stairs and opening doors. Similarly, Boston Dynamics has tested robots that can leap over walls to access previously unreachable areas, further expanding the scope of bomb disposal applications.

As robots become more sophisticated, their ability to perform intricate and precise tasks continues to grow. Modern bomb disposal robots are now designed with interfaces that mimic human hands or surgical tools, offering unprecedented dexterity and control. This has enabled them to perform tasks such as opening car trunks to disarm explosives or handling complex mechanisms within bomb casings.

The transition from crude methods, such as poking or dragging bombs to detonate or remove them, to advanced disarming techniques highlights the evolution of bomb disposal robots. Today’s systems emphasize precision, safety, and adaptability, leveraging cutting-edge technologies to neutralize threats effectively. These advancements underline the critical role of robotics in ensuring human safety in high-risk scenarios.

III. PROPOSED ALGORITHM

I. Component Selection and Preparation

Arduino Board: The microcontroller that serves as the valuable controller for the robot arm, deciphering code and sending alerts to the servo cars. An Arduino Uno, Mega, or Nano can be used.

Servo Motors: These are important for enabling joint movement in the robotic arm. At least four servo vehicles are advocated, although extra vehicles can boom the tiers of freedom, improving movement precision and flexibility.

Jumper Wires: Used to set up connections between the Arduino board and the servo cars, permitting signal transmission.

Power Supply: Provides the vital cutting-edge to operate both the Arduino board and servo motors. A battery percent or USB power financial institution is used to ensure constant electricity.

Structural Materials: Components like plastic, timber, or steel rods, together with connectors and fasteners, are used to bring together the frame and segments of the robot arm.

II. Designing the Robotic Arm Structure

The layout phase focuses on developing a purposeful and solid robot arm shape. Depending at the favoured talents, designs can range from easy to complex.

Simple Robotic Arm Design: This design uses 3 or 4 servo vehicles, every attached to rigid segments, permitting basic movement thru a series of joints. Each joint is answerable for motion alongside a unmarried axis, offering sufficient flexibility for easy duties, together with selecting up or moving small items.

Complex Robotic Arm Design: This layout involves greater servo automobiles, normally round 5, to create a greater range of motion that extra carefully resembles a human arm. In addition to the base and shoulder joints, a wrist joint and an cease-effector (gripper) are incorporated, allowing the arm to perform difficult responsibilities which include assembling components, sorting items, and coping with sensitive items.

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III. Programming the Arduino Board
Once the design is finalized, the Arduino board need to be programmed to govern the robot arm's movement. The programming is completed through the Arduino Integrated Development Environment (IDE), wherein the code is written and uploaded to the board.
Setting up the Arduino IDE: The IDE can be downloaded from the Arduino website. Once installed, the Arduino board is connected to a computer using a USB cable. The appropriate board type (e.g., Arduino Uno) and port are selected from the IDE's "Tools" menu.
Using the Servo Library: Arduino's integrated Servo library (Servo H) simplifies controlling the servo motors. By growing Servo items within the code, each motor can be managed in my view, with unique Servo gadgets representing exclusive automobiles.
IV. Integrating and Testing the Robotic Arm
After coding the motion for man or woman servo motors, the next step is integrating all additives and trying out the entire robot arm. This entails connecting every servo motor to its precise joint on the arm structure and ensuring that the Arduino board can accurately manipulate every joint's function.

IV. PROPOSED METHODOLOGY

We goal to layout a robotic arm able to appropriately casting off explosive devices. The gadget will leverage LoRa (Long Range) communication generation to beautify operational safety by means of permitting far flung control from a secure distance(100m), minimizing the chance to human operators.
Components and Hardware:
Arduino Board: Controls the entire robotic system, handling inputs from sensors and sending commands to actuators.
Servo Motors: Control the arm's joints, enabling movement and precision in handling objects.
Wheels or Tires: Allow the robotic arm to move on different terrains. Choose robust tires for stability and terrain adaptability, or use tank treads for increased traction.
Camera: Mounted on the arm or base, the camera allows for real-time video streaming, enabling remote monitoring and situational awareness.
Sensors:
Ultrasonic or Infrared Sensors: Help with object detection and avoid obstacles during movement.
Proximity Sensors: Detect nearby objects to prevent accidental collisions.
Metal Detector: Essential for identifying the presence of metallic bomb casings.
Gas Sensors: Detect explosive materials or dangerous gases in the environment.
LoRa Module: Allows for long-range wireless communication, enabling control from a safe distance without relying on standard wireless networks.
Power Supply: A reliable battery pack or power source suitable for powering the entire robotic system, especially the motors and sensors.
Gripper or Claw: End-effector attached to the arm for picking up or manipulating objects, with enough strength and precision to handle explosive materials delicately.
Frame and Structural Materials: Strong and lightweight materials like aluminium, plastic, or carbon fibre for building the arm structure, ensuring durability and mobility.
Lighting (optional): LED lights mounted near the camera to enhance visibility in low-light conditions.
LoRa Communication Implementation:
LoRa era is chosen for this challenge due to its capacity to talk over lengthy distances with low power consumption. A LoRa transmitter on the operator's stop and a receiver at the robot arm will permit the operator to control the arm from a distance, reducing the hazard of being near the dangerous location. This approach ensures that commands may be sent efficaciously even in tough environments or over barriers.

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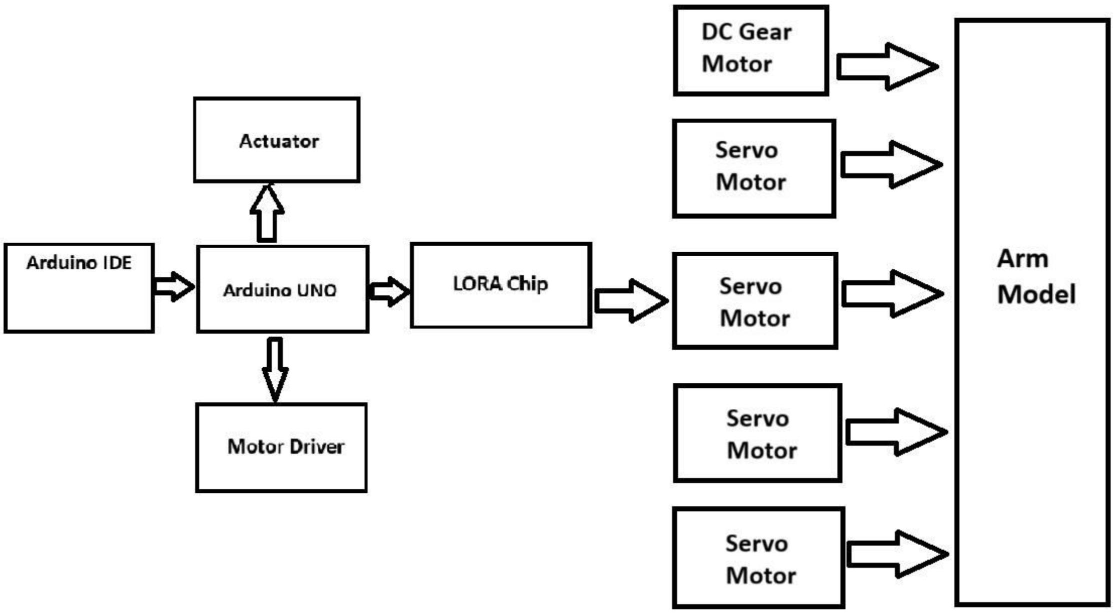

Block diagram of robotic arm using LORA technology

ALGORITHM AND FORMULAS

Input Processing:
Acquire sensor inputs (e.g., camera, infrared, or ultrasonic sensors) for obstacle detection and bomb identification.
Read control commands from the operator or an AI system.

Path Planning:
Use algorithms like Dijkstra, A*, or RRT (Rapidly-exploring Random Tree) for navigating to the bomb location while avoiding obstacles.
Incorporate a kinematic model to calculate safe paths for arm movement.

Arm Positioning:
Implement Inverse Kinematics (IK) to determine joint angles for precise end-effector positioning:

$$\theta_i = \arctan\left(\frac{y_i}{x_i}\right), \quad \text{where } x_i, y_i \text{ are target coordinates of joint } i.$$

Ensure motion stability by solving the Jacobian matrix for velocity and acceleration

$$J(\theta)\dot{\theta} = \dot{x}, \quad \text{where } J(\theta) \text{ is the Jacobian matrix.}$$

Gripper Control:
Use force sensors to control gripper pressure for safe handling of bombs without detonation:

$$F_{\text{grip}} \leq F_{\text{threshold}}, \quad \text{where } F_{\text{threshold}} \text{ is bomb-safe handling force.}$$

Defusal Assistance:
Incorporate robotic tools for defusing, like cutters or disrupters, guided by precise coordinates and timing algorithms.

Feedback Loop:
Continuously monitor arm position, force applied, and environmental inputs to adjust movements dynamically.

Kinematic Equations for Joint Angles:

Forward Kinematics:

$$x = \sum_{i=1}^{n} L_i \cos(\theta_i), \quad y = \sum_{i=1}^{n} L_i \sin(\theta_i)$$

Where L_i is the length of the arm segment and θ_i is the joint angle.

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V. EXPECTED RESULT

The Robotic Arm for Bomb Disposal project pursuits to create a far off-controlled robotic gadget which could accurately locate and manage explosive devices, improving operator safety via LoRa (Long Range) communication generation. Operable from up to 100 meters away, the system minimizes human hazard at the same time as handing over specific manage and real-time remarks.
Key Objectives:
Remote Operation for Safety: Controlled thru LoRa era, the robot arm allows operators to manage it from a steady distance, reducing publicity to unsafe areas.
Precision Handling and Mobility: Equipped with servo cars and a gripper, the arm handles object cautiously. Durable tires or tank treads allow for terrain adaptability and stable mobility.
Real-Time Monitoring: A digital camera provides live video, and optionally available LED lights complements visibility, permitting operators to screen environment in actual-time.
Obstacle and Hazard Detection: Ultrasonic, proximity, steel, and fuel sensors discover obstacles and potential threats, making sure secure operation and correct goal identity.
Efficient Power and Communication: A battery % powers the device, and the LoRa module offers dependable long-range communication, even in obstructed areas.

VI. FUTURE SCOPE

Advanced Manipulation: Future robotics arms will focus on developing dexterous fingers with near-human flexibility and greater-than-human strength, enabling them to grasp and manipulate objects with precision and control.
Force Feedback and Haptic Feedback: Intuitive systems controllers with force feedback and haptic feedback will be integrated into the robotic arms, allowing bomb disposal experts to operate the arms with greater ease and precision.
Integration with Unmanned Ground Vehicles (UGVs): Robotics arms will be designed to work seamlessly with UGVs, enabling bomb disposal experts to detect, identify, disable, and dispose of CBRN explosives from a safe distance.
Increased Automation: Future robotics arms will incorporate advanced algorithms and sensors to automate tasks, reducing the risk of human error and increasing the speed and efficiency of bomb disposal operations.
Multi-Sensor Capabilities: Robotics arms will be equipped with a broad palette of sensors, including cameras, spectrometers, and gas detectors, to detect and investigate chemical, biological, explosive, or toxic substances (CBRNE).
Compact and Lightweight Design: Future robotics arms will be designed to be compact and lightweight, allowing them to operate in confined spaces and be easily transported by UGVs.
Modularity and Customizability: Robotics arms will be designed with modularity and customizability in mind, enabling bomb disposal experts to adapt the arms to specific scenarios and environments.

VII. INDUSTRY AND GOVERNMENT INITIATIVES

The US Army is seeking industry input on designing a robotic manipulator arm for bomb disposal, with a focus on mature enabling technologies for dexterous fingers and advanced control systems. Companies like iRobot and FLIR are already providing robotic systems for bomb disposal, with ongoing contracts and developments in this area. Cobham Unmanned Systems has a range of mobile unmanned sensor platforms with manipulators for taking samples of suspicious substances, supporting bomb disposal officers and first responders worldwide.

VIII. CONCLUSION

The future scope of robotics arms for bomb disposal will focus on developing advanced manipulation capabilities, integrating with UGVs, and incorporating multi-sensor capabilities, automation, and modularity. Industry and government initiatives will drive innovation in this area, enabling bomb disposal experts to operate more safely and efficiently in a wide range of scenarios.

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