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GUI Based 6-DOF Robotic Arm for Radioactive Element Handling

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Abstract: Dealing with radioactive elements while research can be dangerous as it can have acute or passive effects on humans. In present scenario research is conducted on radioactive elements by humans after Wearing personal protective equipment such as coat, gloves, safety glasses and close-toed shoes. This equipment provide protection to some extend but still prolonged exposure to radio-active element or some accident can lead to great loss in human life. We can use 3 joint moving robotic arm controlled by GUI to handle radioactive elements while research. This will stop the human exposure to the harmful waves and also reduce chances of accident. The robotic arm has three joints controlled by Four servo-motors. These three joints allows the robotic arm to move to any point in the 3d plane and pick and place objects. The movement of the robotic arm and each of its joints can be controlled from any device with Wi-Fi & Bluetooth capability. An intuitive GUI is displayed in the browser of controlling device. The remote controlled properties and the control of movement is powered by ESP32 module. ESP32 is a system on chip processor which can be programmed as per requirement and has various I/O ports which allows for different motors and sensor connectivity. The ESP32 module is programmed from computer using Arduino IDE. C program is written & then uploaded on ESP-32. We've also added the functionality of recording action and then playing it once or multiple times by programming function of recording and playing action. The proposed system will reduce the requirement of humans while dealing with radioactive elements. The proposed system can perform various action on radioactive elements controlled from safe distance. Thus it avoids the danger to human in radioactive elements research and handling in nuclear power plant & mines etc. The proposed system improves safety while operation on radioactive elements.
Keywords: DOF, GUI, Robotic arm, Radioactive element, End-Effector, CoppeliaSim

I. INTRODUCTION

In an era where advancements in [1] nuclear science and technology hold the promise of countless benefits, there is a parallel demand for enhanced safety measures to mitigate. The inherent risks associated with handling radioactive elements. The delicate and potentially hazardous nature of radioactive materials necessitates the development of innovative technologies that can safely and efficiently manage these substances. [1] Traditional approaches to handling radioactive elements are often fraught with challenges, such as limited precision, human exposure risks, and the need for specialized training which can hinder operational efficiency and compromise safety. To address this challenge, this research paper introduces a solution Graphical User Interface (GUI)-based 6-Degree of Freedom (6-DOF) Robotic Arm designed specifically for the precision handling of radioactive elements

A. What is Robotic Arm

[3] A robotic arm is a mechanical device that is designed to mimic the functions and movements of a human arm. It is a type of robotic manipulator or manipulative arm that typically consists of multiple joints and segments, allowing it to perform a wide range of tasks and movements. Robotic arms are commonly used in various applications, including manufacturing, industrial automation, healthcare, space exploration, and more.

B. Danger while Dealing with Radioactive Element

Dealing with radioactive materials and elements can pose significant dangers to human health and the environment if not handled properly. Radioactive elements emit ionizing radiation, which can damage living tissue and genetic material, leading to various health risks. Here are some of the key dangers associated with working with radioactive elements:

1) *Radiation Exposure:* The most immediate danger is exposure to ionizing radiation. This can cause acute radiation sickness if exposed to high levels of radiation in a short period. Chronic exposure to lower levels can increase the risk of cancer and other long-term health problems.

2) *Contamination:* Radioactive materials can contaminate surfaces, equipment, and clothing. If not properly contained and controlled, this contamination can spread and pose a risk to individuals and the environment. Contaminated items must be decontaminated or disposed of properly.
3) *Accidents and Spills:* Accidental spills or releases of radioactive materials can occur during handling, transportation, or storage. These incidents can lead to contamination, radiation exposure, and environmental contamination.

C. Robotic arm in Radioactive Element Handling

Robotic arms can be used in the handling and manipulation of radioactive materials and elements, primarily because they can minimize the risks associated with radiation exposure to human operators. Here's how robotic arms are utilized in handling radioactive elements:

1) *Remote Operation:* Radioactive materials are often handled remotely using robotic arms. Operators control the robotic arm from a safe distance, reducing the risk of radiation exposure. This can be done using specialized control interfaces that allow precise movements.
2) *Precision and Dexterity:* Robotic arms can be highly precise and dexterous, which is essential for delicate and precise tasks such as handling radioactive samples or conducting experiments.
3) *Remote Handling Equipment:* Alongside robotic arms, other remote handling equipment such as manipulators, grippers, and specialized tooling are used to safely hold, move, and process radioactive materials.
4) *Sensors and Feedback:* Robotic systems may be equipped with sensors and cameras to provide real-time feedback to operators. This helps in precise positioning and manipulation, especially when visibility is limited due to shielding.

D. Components of Robotic Arm

A 6-DOF (Degrees of Freedom) robotic arm is a versatile system designed to perform tasks in three-dimensional space, and it typically consists of several key components. These components enable the arm to move with six degrees of freedom, allowing it to position and orient an end-effector accurately. Here are the fundamental components of a 6-DOF robotic arm [2]:

1) *Base:* The base serves as the foundation of the robotic arm, connecting it to a stable surface or a mobile platform. It houses the first joint and provides stability to the entire system.
2) *Joints:* A 6-DOF robotic arm features six joints, each allowing for a specific type of movement or degree of freedom.
3) *End-Effector:* The end-effector is the tool or device attached to the last joint of the robotic arm, which interacts with objects or performs specific tasks. Examples of end-effectors include grippers, welding tools, vacuum cups, cameras, sensors, or any tool suited for the application.
4) *Actuators:* Actuators are essential for moving and controlling the joints of the robotic arm. These can be electric motors (e.g., servo or stepper motors) or other types of actuators, depending on the design and application.
5) *Control System:* The control system, often computer based, manages the robotic arm's movements and coordination. It uses control algorithms and software to plan trajectories, respond to sensor feedback, and execute tasks with precision.
6) *Power Supply:* A reliable power supply is necessary to provide energy to the actuators and other electronic components of the robotic arm.
7) *User Interface:* A user interface, such as software or a Human-Machine Interface (HMI), allows operators to program and control the 6-DOF robotic arm, define tasks, and monitor its status.

II. LITERATURE SURVEY

According to the [1] Ivan Vitanov a need of software framework arises which is data driven and could simulate the robotic arm which is used as remedial solutions for the decommissioning of Radioactive waste, such as it can operate in inaccessible sources of nuclear radiations keeping its electronic outside the radioactive environment. He proposed a robot with an arm equipped with sensors and specific protocols can be employed to inspect the surfaces of the walls and the waste containers, either using touch or a combination of vision and touch to evaluate their structural integrity, the robot can be equipped with a gripper to grasp and manipulate objects inside the building and the movements of the robot can be controlled by human teleoperation with haptic feedback or can be programmed to be autonomous.

[3] Gaurav sen Gupta proposed a design of a controller intended for teleoperation. It is capable of controlling a robotic arm through a LAN or via the Internet. It uses Wi-Fi technology as its wireless communication medium. User can control the robotic arm remotely and access its sensory feedback signals as well.

It provides the remote vision as well through the camera mounted on the robot arm takes images and transmits to the control station. Its software program runs on both the server and client computers however one is set as the server and the other as client at run-time. The server listens to its set ports waiting for a connection from the client. The client needs the IP address of the server and the port number it is listening to, and then can establish a link between them for functioning.

[5] S Rooban proposed the design of the robotic arm through the coppeliaSim. CoppeliaSim is basically a simulator with few toolboxes which are necessary to simulate a robot. By using these types of simulations, software-based model can be created based on the project requirements. With the help of this simulator various parameters of the software robot are verified virtually with various terrain. He says how better the program controls the end effector (the arm) decides the performance of the robotic arm in pick and place of object. coppeliaSim improves the behaviour of real time robot performance, functioning, hardware limitations and restrictions.

III.PROPOSED SYSTEM

A. GUI Based robotic arm controller: Steps to Create a Wi-Fi-Based GUI for Robotic Arm Control

[3] Connect Wi-Fi Module: Integrate the Wi-Fi module with your microcontroller. You will need to configure it to connect to your local Wi-Fi network and possibly open a web server for communication. Design the GUI: Create a graphical user interface for controlling the robotic arm. You can build a web-based GUI or a mobile app. popular platforms and frameworks for this purpose include HTML/CSS/JavaScript for web applications and platforms like MIT App Inventor, Flutter, or React Native for mobile apps. Communication Protocol: Establish a communication protocol between your GUI and the robotic Arm. This protocol should include commands for controlling the arm's movement, monitoring its position, and receiving feedback. Implement Control Logic: On the microcontroller, write the code to interpret and execute commands received from the GUI. Ensure that your code handles the arm's movements safely and accurately. Feedback and Monitoring: If you’re robotic arm has sensors or encoders for position feedback, make sure to integrate this data into the GUI for real-time monitoring. Safety Features: Implement safety features within the code to prevent collisions and ensure safe operation of the robotic arm. Testing: Thoroughly test the system to ensure reliable and safe operation. Make sure that the GUI responds correctly to your control inputs and provides adequate feedback.

B. Pick and Place Module[3]

Ensuring the stable operation of a robot when handling objects of varying shapes is crucial. Effective path planning is essential to maintain stability while picking up objects and reduce any irregularities in the robot's movement. CoppeliaSim, a robust software platform simulator, offers a range of tools for simulating robots. This software is designed to create virtual 3D models, utilizing real-time features. CoppeliaSim supports various objectives, including simulating movable vehicles, pick and place robots, interactions between vehicles and robots, and object creation. The software encompasses a wide array of tools, robots, libraries, objects, and top-performing features for simulations.

C. Types of Joints

Two fundamental types of joints are commonly used:

Revolute Joints [2]: Also known as pivot joints or hinge joints, revolute joints allow for uniaxial rotational motion. They are employed in applications like door hinges and mechanical Components to describe rotational movement between objects. The configuration of revolute joints is defined by the degree of rotation around the reference frame's z-axis.

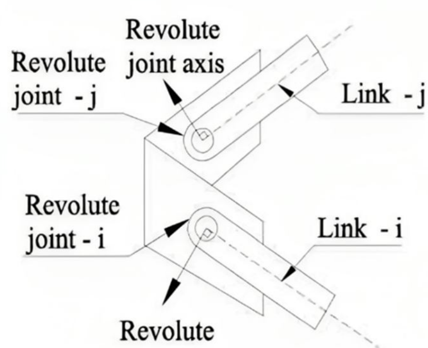

Fig. 1 Revolute Joints [2]

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1) *Prismatic Joints [2]:* Prismatic joints enable relative movement along a single axis between two connected objects. Often referred to as a slider crank-slider linkage, the position of two bodies connected by a prismatic joint is defined by the amount of linear slide of one relative to the other. This one-parameter motion characterizes the joint's operation.

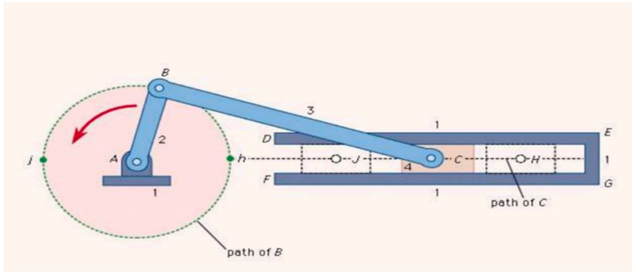

Fig. 2 Prismatic Joints [2]

D. Degrees Of Freedom (DOF) in Robotic Systems[2]:

Degrees of freedom determine a robot's capability within a 3D space. Generally, there are six degrees of freedom, three of which correspond to rotational motions along the x, y, and z axes, commonly known as pitch, yaw, and roll, respectively. These DOF represent the number of fundamental ways a rigid object can move through 3D space.

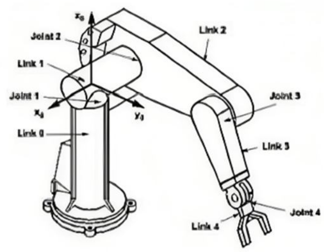

Fig. 3 Frame allocation for joint [4]

The number of DOF remains consistent for the same type of joints, regardless of their position in the robotic arm. However, the overall degree of freedom of the arm depends on the cumulative DOF provided by all its joints. This degree of freedom is essential for determining the range of orientations and approaches that the robotic arm can achieve.

Ensuring stability is a critical aspect when handling objects of different shapes, and path planning is employed to maintain balance when lifting objects, minimizing any abrupt movements. The robotic arm operates based on commands programmed using the high-level Lua programming language. The robot's mobility is achieved through a combination of prismatic and revolute joints in its wheels, allowing horizontal movement (left or right). Commands are used for automating the arm’s actions, such as picking up objects and placing them at specific destinations.

The versatility of a robotic arm with different joint types allows it to handle objects of varying shapes, making it highly efficient in industries and factories compared to human labour for the Same tasks. The proposed robotic arm features 5 revolute joints and 1 prismatic joint, offering total of 6 degrees of freedom, which is the standard for such systems.

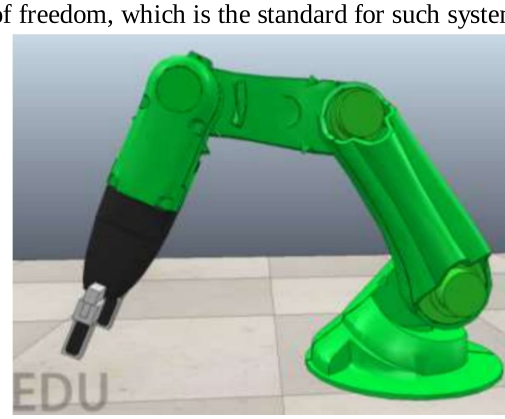

Fig. 4 Fixed Robotic Arm[1]

E. Mechanism Overview[4]

A fixed robotic arm operates under Lua commands, particularly for tasks involving object retrieval from a moving environment, such as a conveyor belt. It's also used for precise placement of Specific objects picked from one moving conveyor, based on sorting commands programmed into the robot.

This involves the creation and integration of various modules, objects, parts, links, joints, and shapes, while also interfacing the locomotion or vehicle component with the robotic arm. The Robotic arm, in this configuration, possesses 3 degrees of freedom, which, when combined, offer wide range of achievable positions.

The simulator-designed robot can move forward, backward, left, and right with precision, ensuring minimal deviation. Two key design elements include the robotic arm and a mobile locomotion or vehicle component. Using a user interface, manual commands can be sent to the robot to initiate its movements, facilitating object collection and delivery between locations.

In contemporary manufacturing, robotic arms with extensive reach are utilized across various scales of production, from highly precise circuit board assembly to large-scale heavy industries, such as automobile production lines.

The robotic simulator CoppeliaSim is grounded in manipulator design and embedded scripting, providing flexibility and multi robot program control using the Lua language. CoppeliaSim is Instrumental in factory automation and the validation of robotic designs.

IV. CONCLUSIONS

Through the research we have conducted and the result we have drawn we can conclude that the use of 6 DOF Wi-Fi based robotic arm can prove to give us various advantages over currently used system. Advantages such as more precision and less danger can be considered as leap ahead of the currently used system. In the research paper we have discussed the previous work, implementation and all other required resources and information regarding the purposed system.

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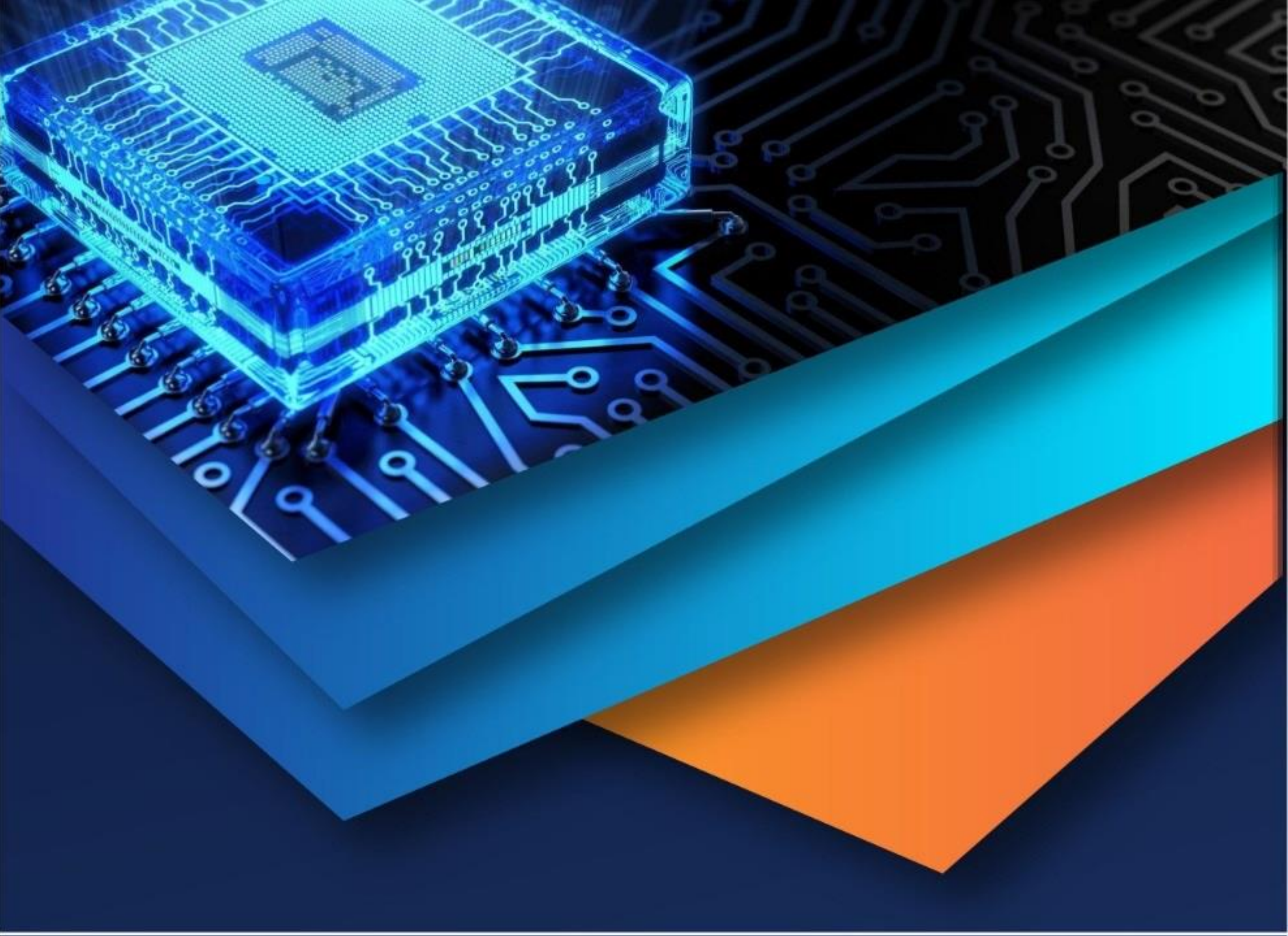

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