A Study on Bio Inspired Wire Actuated Robotic Arm with Teleoperation for Biomimicry

Abhendra Pratap Singh[1] and Sahil Khan[2*]

[1] Assistant Professor, Department of Mechanical Engineering, HMRITM, 110006, Delhi, India

[2] B. Tech Student, Department of Mechanical Engineering, HMRITM,110006 Delhi, India

* Corresponding author

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ABSTRACT

In recent years, machine learning and artificial intelligence are essential to all areas of engineering. In this study, we investigate a bioinspired wire-actuated robotic arm that uses artificial intelligence and machine learning techniques to predict the mechanical properties of its material and replicate the motion of a human arm. In this study, flex and gyro sensors detect hand movements, wires allow joint and finger movement, and a microprocessor facilitates teleoperation. Inspired by human anatomy and spider monkeys, this smooth interaction seamlessly connects human intention and robotic action. The flexible and adaptable arm is safe for medical and collaborative applications, such as assisting operators in industrial settings or carrying out medical procedures, and it enhances performance and efficiency.

Keywords: Wire Driven mechanism, Teleoperation, Bio-Inspired, Soft Robotics, Artificial Intelligence, Machine Learning.

1 Introduction

Robotics design and production have undergone a revolution in recent years primarily due to the use of artificial intelligence (AI) technology. AI enables unequalled skills in assessing large datasets, forecasting material behaviour, and streamlining industrial processes. This involves machine learning, neural networks, and optimisation techniques. Researchers and engineers can investigate novel approaches to material composition, structure, and production techniques with previously unheard-of speed and accuracy by utilising AI. The stage for investigating the relationship between artificial intelligence (AI) and composite materials, emphasising how AI-based approaches have the potential to completely transform the design, production, and use of composites. AI promises to open up new possibilities in composite material innovation through automated material selection, predictive modelling, process optimisation, and quality control, launching developments across industries and influencing the future of concerning the engineering of materials. Building robots that imitate biological behaviours and structures is the interesting field of bio-inspired robotics, which draws inspiration from nature. This approach has been particularly successful in the development of wire-actuated robotic arms, for example. Using wires that act as tendons, this technique transmits forces from actuators to the segments. Wire-actuated robotic arms are designed to replicate the skill and movement of human manipulators with guaranteed stability, accuracy, and adaptability [1]. Instead of the hard joints seen in conventional robotic arms, it employs wire-driven actuation. This makes it possible for a more natural, organic motion that is based after how people move. One of the primary advantages of wire-actuated robotic arms is their mobility, which is bio-inspired, flexible, and lightweight [2]. Because of this, they useful in the fields of soft robotics and medical field, where delicate and precise movements are often required. For example, wire-actuated robotic arms can be used in minimally invasive surgery to provide surgeons with greater dexterity and control. Another advantage of wire-actuated robotic arms is their

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adaptability. By drawing inspiration from human arm motion, these robots are more intuitive to use and can be controlled in a variety of ways. For example, An exteroceptive sensor, such as a flex or gyro sensor, can be used by a human operator to control the arm movement rather than assigning the coordinate axes points. The operator controls the robot arm like a human arm by donning a glove that contains a microprocessor. Applications requiring precise control or a delicate touch, like manufacturing or assembly processes, benefit greatly from this method. Robotic biomimicry is the act of designing and creating robotic systems that have comparable behaviours, structures, or functionalities by taking inspiration from biological systems and processes. It is possible to construct robotic systems that are more organic, natural, and user-friendly by employing biomimicry to design robots that mimic biological structures and behaviours. Robotic arms that are wire-actuated are an exciting development in the field of robotics that draw inspiration from both animals and humans.

2 Overview of AI Techniques used in the prediction of material properties of Robots

AI Algorithms The collected data was evaluated using a number of artificial intelligence (AI) algorithms, which yielded important insights for material design and industrial optimisation. Artificial Intelligence: Support vector machines, decision trees, random forests, and linear regression are examples of supervised and unsupervised machine learning approaches used to predict mechanical properties and material behaviour. Networks of Neural Systems: Deep learning architectures, such as convolutional neural networks (CNNs) and recurrent neural networks (RNNs), were employed for feature extraction, pattern recognition, and predictive modelling tasks, taking advantage of the complexity of composite material datasets. Optimisation Techniques: Process optimisation methods like genetic algorithms, particle swarm optimisation, and simulated annealing algorithms were employed to determine the optimal manufacturing parameters and tooling configurations. The remarkable precision One of the key benefits of AI-based material design is its ability to predict the properties of composite materials. Examples of machine learning models that have been widely used to predict mechanical, thermal, and electrical properties based on the physical properties of the material, the procedure parameters, and the surrounding environment are artificial neural networks (ANNs) and support vector machines (SVMs). These models are capable of producing accurate projections by identifying complex patterns and correlations in previous data on robotics materials. For example, ANNs can currently forecast the tensile strength, flexural modulus, and fracture toughness of composite materials with great precision, allowing engineers to optimise material compositions for specific structural requirements.

3 Configuration of wire- actuated Robotic Arm

The wire-actuated robotic arm design is influenced by human anatomy as well as biological processes. It is useful for applications in soft robotics, minimally invasive surgery, and precise control scenarios because it offers a lightweight, flexible, and bio-inspired motion. This method improves accuracy and dexterity, particularly in delicate tasks. More intuitive control is achieved since the arm's motion closely resembles that of the human limbs in nature [3]. Additionally, because the wire-actuated robotic arms mimic human arm motion, they adapt well to a variety of jobs. The arm's four thin fingers, which resemble a spider monkey's hand, offer superior dexterity and grip. Flexible wires connect each finger to a servo motor, and at the elbow joints, wires connect to two stepper motors that are in charge of hand movement. The arm's motion relies on wire-driven actuation, and flexible monofilament fibres serve as the wires as shown in the Figure 1 and 2.

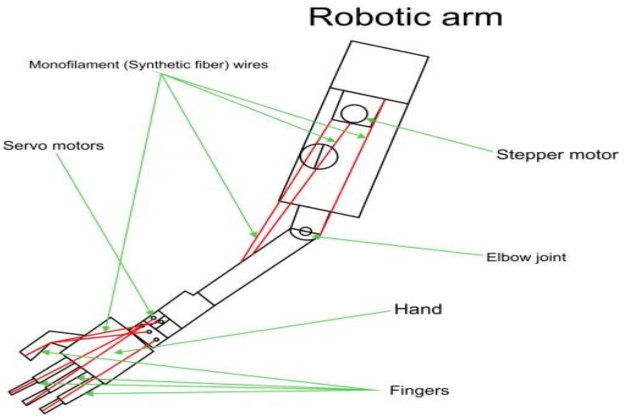

Figure 1: Diagram of wire-actuated Robotic Arm

offering high tensile strength, wear resistance, and low friction. When tension is applied to the wires, they exert forces on the joints, enabling controlled movement similar to a human arm [4][5].

Figure 2: Images of Actuated four fingers

4 Control System and Wireless Teleoperation

By incorporating flex and gyro sensors into a hand glove, allow possible to precisely and intuitively manipulate the robotic arm. NRF24 modules enable wireless communication between the glove and the robotic arm, enabling control signals to be transmitted in real-time. By merging rotation data from gyro sensors and finger movement data from flex sensors, our method makes use of sensor fusion. Microcontrollers process these inputs and use transceivers to transmit commands to the microcontroller of the robotic arm [6]. The system architecture guarantees smooth communication between the robotic arm motions and the operator's hand movements. A custom made glove with flex and gyro sensors is one of the system components for this specific robotic arm. After detecting finger bending, the flex sensors continuously produce an analogue output based on the degree of flexion, while the gyro sensors measure angular velocity and orientation changes, allowing us to track hand rotations [7]. Wireless communication is facilitated through NRF24 modules, which transmit sensor data and control signals between the glove's microcontroller and the robotic arm's microcontroller. As we can see schematic figure 3 a wireless teleoperation between a glove and Robotic arm [8].

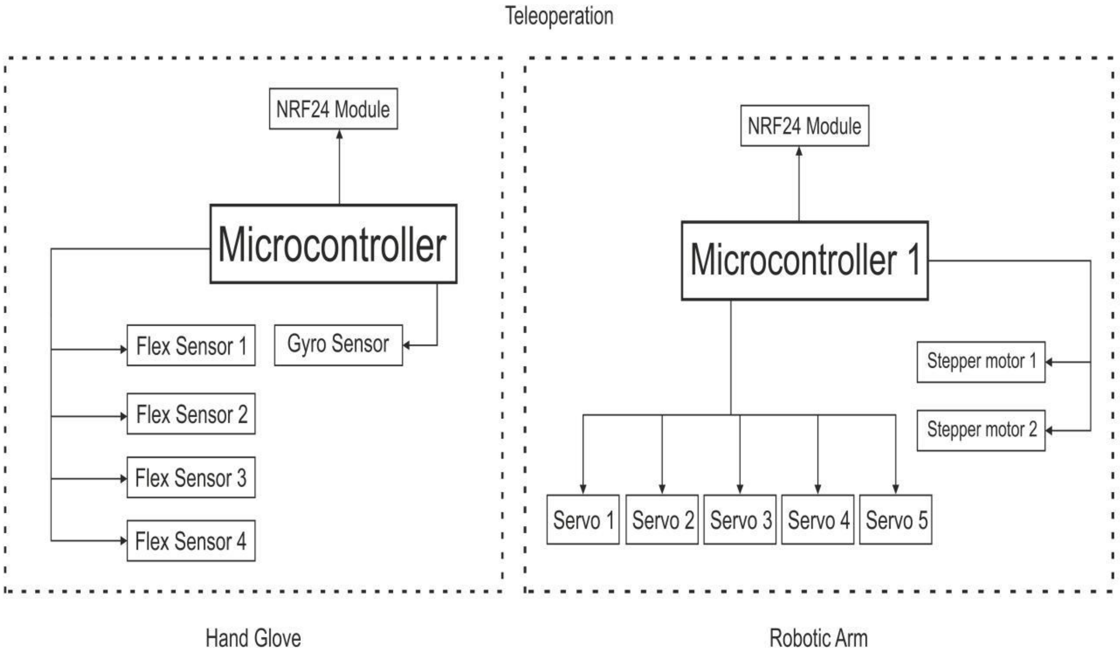

Figure 3: Schematic diagram illustrating the teleoperation of a robotic arm via a hand glove

A more comprehensive understanding of hand movements is made possible by combining data from flex and gyro sensors, and sensor fusion algorithms combine these inputs to produce an all-encompassing control signal [9]. In order to guarantee modularity and scalability, the robotic arm uses a separate microprocessor to execute movements in response to commands from the glove.The system involves a glove equipped with flex sensors and gyro sensors that accurately capture the operator's hand movements, including finger bending and rotation. These sensor data are processed by a microcontroller integrated into the glove, which then generates precise control signals. These signals are transmitted wirelessly to the robotic arm using NRF-24 modules, enabling seamless communication between the operator's hand movements and the robotic arm Upon receiving the control signals, the robotic arm's microcontroller interprets the commands and executes the corresponding actions. This real-time communication ensures that the robotic arm responds immediately and accurately to the operator's inputs, creating a seamless and intuitive interaction between the operator and the robotic arm[10].

5 Prototype

study includes the design of a prototype that combines software and hardware. Through the use of wires, servo motors regulate the robot's finger movements. As seen in Table 1, we integrated two NRFL01 devices to enable wireless teleoperation. These gadgets allow the human operator's glove to wirelessly transmit signals to the wire-actuated robotic arm.In order to program the prototype, we used the Arduino IDE. To declare sensors and motors, we used Embedded C++. In order to facilitate signal transmission between the sensors and motors, we also coded two microcontrollers. PVC sheets were utilised in the development of our prototype arm. With so many different material alternatives, we used cutting-edge AI to thoroughly analyse PVC's properties. Employing sophisticated machine learning and AI algorithms. This allowed to ascertain whether PVC was a good option for prototype requirements. This procedure allowed to make sure the material chosen would satisfy the prototype arm's mechanical and physical specifications. A black glove with electronic components is shown in Figure 4 as a component of a teleoperation system for a wire-actuated robotic arm.

Table 1: Components Used

Arduino MEGA	4-flex sensors with glove	Aluminium frame	Gyro sensor
2-Nema17stepper motors	5-servo motors	PVC sheets	Arduino Uno
2-NRFL01 Transceiver	Monofilament fibre-wire	18volts battery DC	6volts battery DC

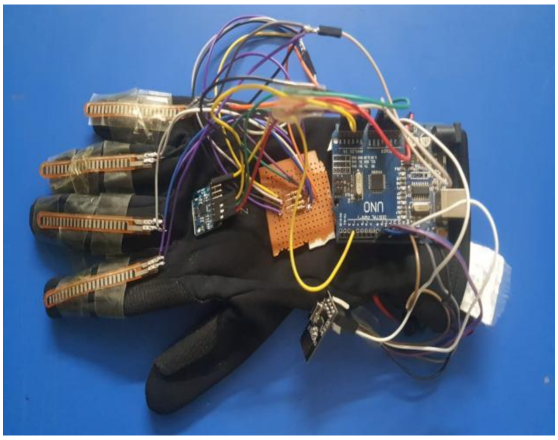

Figure 4: Flex sensor glove for controlling the arm We have an image of our prototype hand.

As illustrated in figure 5, the fingers of the hand are attached to tiny motors known as servos, which are controlled by monofilament wires. The nuts and bolts that make up the finger joints give the fingers the stability and flexibility they require. As seen in figure 6, the wrist portion includes a strong aluminium frame that holds the servos firmly in place, while the hand itself is composed of tough PVC.

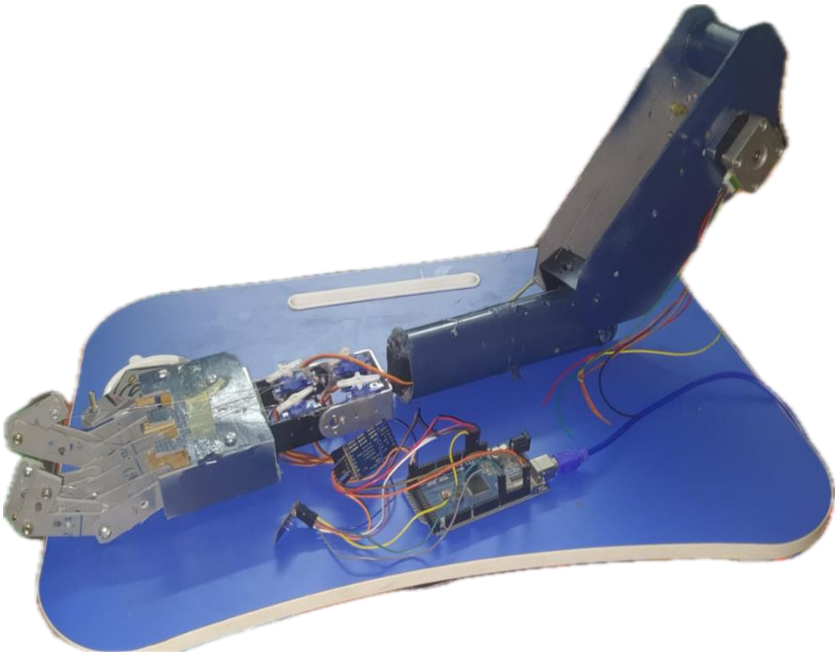

Figure 5: Wire-actuated Robotic Arm

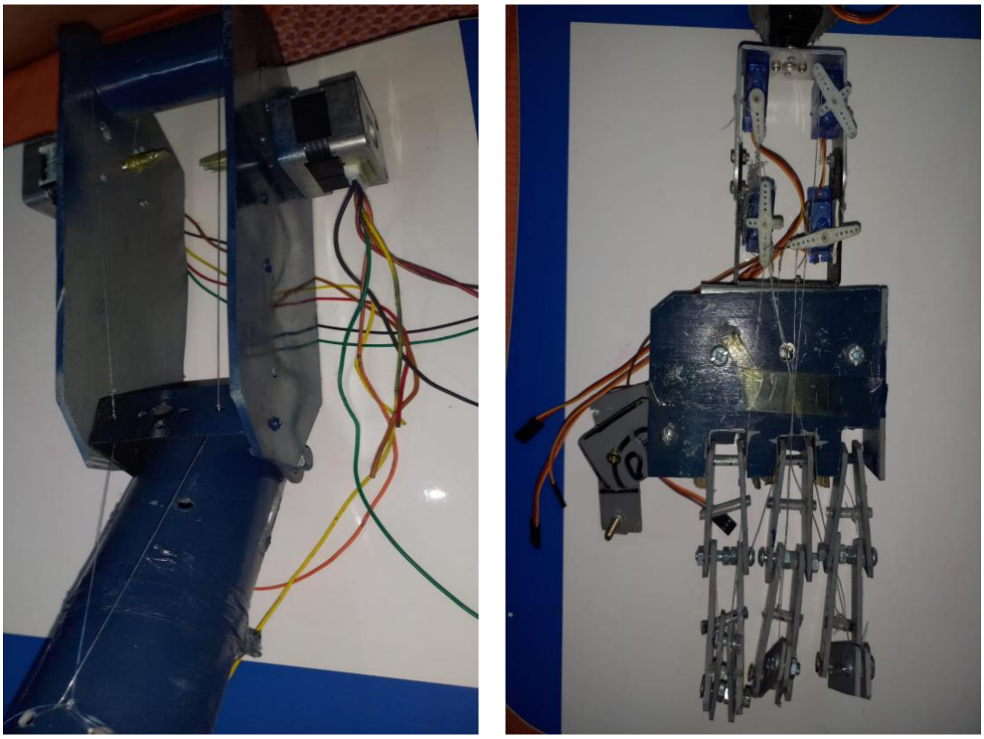

Figure 6: Images of the upper portion and wire-actuated hand

6 Conclusion

The promise of wire-actuated robotic arms in the domains of soft robotics, medicine, and precision control scenarios is highlighted by this work on Bio-Inspired Wire-Actuated Robotic Arm with Teleoperation for Biomimicry. In robotics design and manufacturing, researchers and engineers can investigate new possibilities for material composition, structure, and fabrication procedures with previously unheard-of speed and accuracy by integrating artificial intelligence and machine learning approaches. This arm offers a lightweight, flexible, and bio-inspired motion that closely resembles the natural movement of human limbs, leading to more intuitive control. It does this by taking inspiration from biological processes and human anatomy. Wireless teleoperation and accurate and user-friendly control of the robotic arm are made possible by the incorporation of flex and gyro sensors into a hand glove. Through automated material selection, predictive modelling, process optimization, and quality control, AI promises to unlock new frontiers in composite material innovation. This seamless interaction between human intention and robotic action bridges the gap and enhances efficiency and performance in various applications.

7 Declarations

7.1 Competing Interests

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

7.2 Publisher's Note

How to Cite

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