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Effectiveness of Bio-Inspired Robotics in Studying Biological Systems, and Looking for the Mechanisms that May Solve a Problem in the Engineering Field

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Abstract

Bio-inspired robots have been developed for creating natural things insight robots. These kinds of robots have the capability to interact with human easily. Nowadays, many scientists are trying to make an advanced bio-inspired robot that also makes able to have an impact on society or helps individuals. These kinds of development generally use for logistics, manufacturing, surgery, supply, and car driving. Bio-inspired robot use high-capacity sensors, high-resolution cameras, chips, and other major kinds of essential technologies. This study has also focused on the importance of bioinspired robots that plays a significant role in assembling, carrying, sawing, and other essential curriculum. Interaction between robots and human increase the advantages and strength of the activities and it can provide the desired benefits to individuals. Accordingly, this paper also tries to find the impact of the biological system and its significance in the development of bio-inspired robots. Interaction between human and robots make a huge and effective impact on society and people get inspired to adopt technological facilities in their daily life. In a biological system, bio-robotics also help to develop the growth of technological transformation. Biological studies get inspiration to create designs of advanced and intelligent robotics for conducting diverse human-like activities such as swimming, terrestrial movements, and flying. That also helps to understand the evolution of biological organisms within an advanced dynamic environment.

Keywords

Bio-inspired robots, bio-inspired robotic platforms, Robotics Traction Unit (RTU), AI Farming, AI Technology, Magnet-polymer, hybrid continuum cable-driven robot (HCDR), Deep learning models, acrylonitrile-butadiene-styrene, PDMS, ABC, ACO, PSO.

INTRODUCTION

Technologies are developing and this development is happening in robotic engineering. Bio Inspired robotic platform has developed to make natural insights robots. Different kinds of components of robots are to be developed through this platform and the components are to be smarter, safer as compared to existing industrial robots. Research is going on to develop bio inspired robots which can interact with humans easily. Natural intelligence is developing among the robots and this development makes the robots natural and mostly usages of material is to be avoided to make them natural. This kind of development helps the robots to coordinate with humans easily. In the present situation most of the activities such as manufacturing, logistics supply, surgery and even driving cars are done by robots and dependency on robots is rising. Development of technology promotes more usability of robots in regular works and for this reason bio inspired robotic engineering is developing to increase their usability in the society. In the field of biology, bio-inspired is a leading field and many scientists are investing their time to make research on this field. Material science involves bio-inspired fields that lead to the development of new kinds of robots which can make better interactions with humans. In material science, structures of hard, fixed, durable and resilience have been researched and on the other hand, soft structures such as bone have not been analyzed widely. This less research is the motivation for the scientists to put them in research on soft structure material. This kind of research inspires the development of bio-inspired robots. In this proposed study, the impact of the biological system to develop this kind of robotics has been described. Secondary qualitative data has to be collected for gathering information related to bio-inspired robotics in the engineering field to make wide discussion on this proposed topic.

LITERATURE REVIEW

Importance of bio-inspired robots

Collaboration of human and robot is playing a significant role in carrying, assembling and sawing. This collaboration has accelerated these activities and for this reason humans get benefits from making this collaboration. However, collaboration between humans and robots has one increased strength and advantage in doing work that provides benefits to humans. In many critical requirements such as low-volume, high-mix and in large industrial manufacturing robots are solved by robots [1]. Solving these kinds of requirements helps to boost manufacturing activities and for this reason development in the engineering field has been possible. On the other hand, robots provide flexibility in manufacturing activities that play an important role to expand manufacturing in different fields. One of the main facts in the collaboration between humans and robots is how this collaboration can be more effective through increasing human safety.

Figure 1: set up of bio-inspired robots
(Source: [1])

Secure collaboration is needed to increase outcomes from this collaboration. Different kinds of robotics platforms are developing to counter this issue. Bio-inspired platforms are one of those platforms which can provide more safety to humans during collaboration with robots. Energy efficient and much safer robot human interaction development is happening [2]. Bio-inspired robotics platforms are developing to make robots with natural looks and advanced intelligence systems will be implemented. This development helps to make better interaction with humans and as a result safer human-robots collaboration can be developed that can play an important role in various complex requirements. Robots are capable of detecting dangerous tasks and in most of the cases, humans can avoid dangerous situations by using robots.

Bio-inspired robots are developing to make better interaction m with humans and for this reason bio-inspired robots may make humans more concerned about the bad impact of any dangerous situation. Robots are not tired and for this reason this technology does not need break and for this reason humans can utilize this technology to fulfill lengthy requirements. Robots are to perform repeatable tasks and for this purpose AI systems are used in robots [3]. In most of the cases robots are used to gain speed in work. Robots have the ability to do a job with accuracy and possibility of error is minimum and for this in various critical requirements robots are used. In monitoring robots can be used and bio-inspired robots may be able to increase effectiveness of employees through building better collaboration by their newly developed system.

Significant research has been noticed in the field of bio-inspired robots. Interaction ability of this kind of robots has developed significantly and this movement helps to move research toward more developments in this field. However, reduction of electromechanical tools costs has boosted overall development of bio-inspired robots [4]. Decreasing cost and increasing accessibility motivate researchers to consider more development in this technology to improve its ability for interaction with humans. On the other hand, in much research it is found that the entire process of bio-inspired robot development is a time-consuming procedure and it is much more critical. The platform is bio-inspired, robots are designed as per the movement of animals and for this reason these kinds of robots would be more capable.

Impact of biological system in the development of bio-inspired robots

Bio-inspired robots have changed the environment of using traditional robots dramatically. Coordination of sensory motor is used in the development of bio-inspired robotic platforms. Bio-inspired robots are developing as per the behavior of animals that remove the typical limitations from the traditional robots. In biology, the structure and function of different kinds of tissue and organs are analyzed [5]. This analysis helps to remove the typical obstacles from the existing robots. However, muscle and skeleton functions are observed through biological analysis that helps to develop new components for the newly developed robots which are more capable as compared to traditional robots. The newly developed components would be included in bio-inspired robots to provide a more advanced structure and for this reason these robots get natural structure. In making interaction with humans this kind of structure helps to make humans more comfortable. Biological systems have been approached in the field of bio-inspired robotics platforms for the purpose of understanding structure of animal tissue and organs.

Considering the growth of scientific studies on biological systems and agricultural operationality, bio-inspired robots are being developed and upgraded in order to meet the demands of the market. Biometric innovations such as the Robotics Traction Unit (RTU) and AI Farming are used for low-cost options for FEA robotic grippers used for harvesting

[6]. On the other hand, hypercomputing (BH) strategies are also incorporated for advancing bio-inspired robots. BH developments Are considered to be an efficient algorithm for genetic and statistical machine translation [7]. Bio-inspired robotics can process communication models for individual interactions with organic agents. In essence, the model for bio-inspired robots can help in the visual investigation based on a BH communication model.

The use of a multi-sensory system can help in developing a bio-inspired robot that has the ability to self-organise and understand individual modalities. Obtaining information regarding the development of a smarter, safer and softer model than the traditional robots consist of creating algorithmic layers which are inspired by the biological system. A self-organising neural architecture with multi-sensory fusion is used with machine learning for building the connections for lateral associative for capturing the co-occurrence in relationships among individual modalities [8]. The audio-visual datasets gathered from these bio-inspired robotics can help in creating an architecture for the formation of effective multimodal representations. Both accuracy and predictability can be ensured with bio-inspired robots based on the natural responses of biological systems.

Studying biological systems for bio-inspired robotics designing

The use of bio-inspired robotics for studying biological systems has witnessed tremendous growth in the age of technological transformations. Using advanced AI Technology, bio-inspired robotics has developed into various categories based on the specific algorithm and neural networks incorporated with it. For example, magnetic soft robots are considered to be beneficial for contact-less activation which does not require any resource for onboard power, embodying flexibility and adaptability in unstructured environments [9]. Magnet-polymer composites are used for the fabrication of soft magnetic parts of the robots, creating 10-35 mT external fields, controlled by six electromagnetic coils. Thus, the design of these robots is shaped as natural life-forms witnesses in nature, enhancing their operational efficiency in the biological environment.

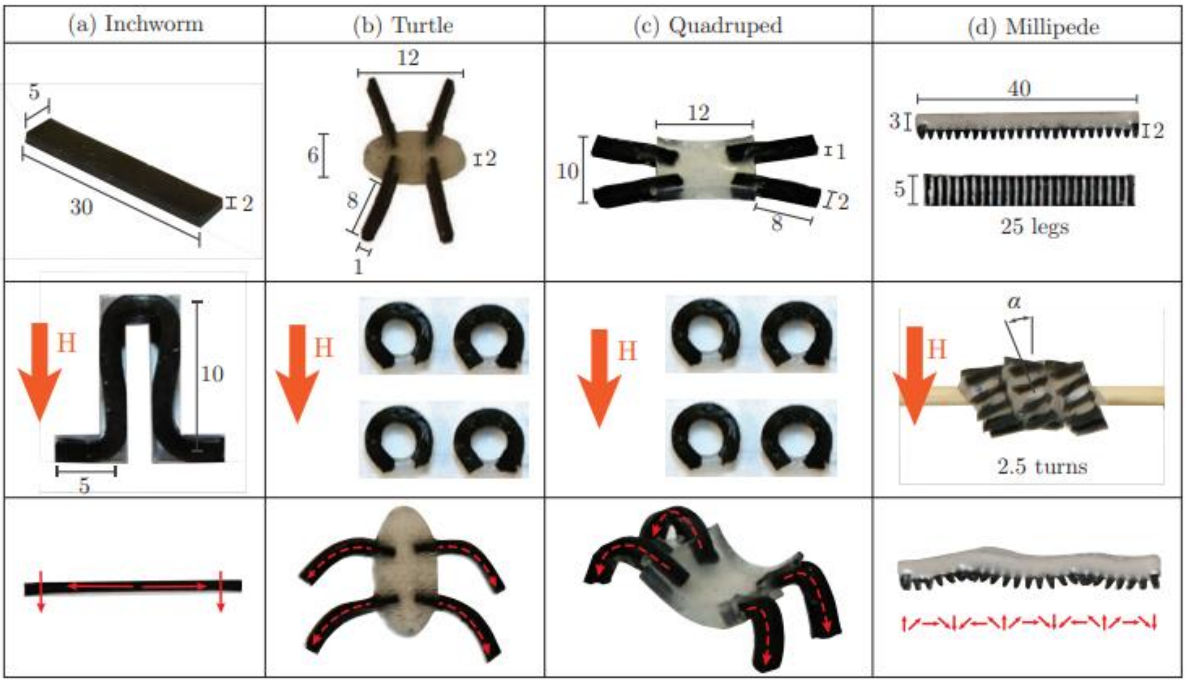

Figure 2: Design of bio-inspired magnetic soft-robots [9]

Studying the complexity of biochemical processes of locomotion among animals can be facilitated by bio-inspired robotics. It is stated that the primary challenge for designing a realistic bio-inspired robot is analysing the patterns of movement among animals such as a swimming snake's movements. A "hybrid continuum cable-driven robot (HCDR)" can be developed for instilling fluidity and adaptability for the motion range of the robots [10]. Improved capability of mimicking the movement of animals such as a snake's locomotion has contributed to the development of bio-inspired robotics that can assist the study of biological systems efficiently. Kinematic movements are compared with the snake's range of movements for creating a prototype that has the ability for autonomous decision-making and adaptable agility. Therefore, studying biological systems with the help of bio-inspired robotics has benefited the sphere of advanced biological research.

The efficiency of the human biological system is a sophisticated one that can resolve multiple issues in the engineering field with the implementation of bio-inspired robotics. Gaining inspiration from biological systems can help to create effective computation which is capable of competing with the original biological system [11]. Deep learning models are used widely to establish a structure based on the workings of the human brain for information processing and analysis. Various deep learning models such as CNN help to process multiple layers with data abstraction to capture the intricate and large-scale structure for data processing, analysis and output [11]. Achieving efficiency, effectiveness, intelligence and cohesion for bio-inspired robotics can help to achieve solutions for positioning soft-designed robotic models for diverse purposes.

On the other hand, strategies for emulating the range for human locomotion are considered to be an effective solution for the development of bio-inspired robotics. In essence, assessment of locomotion, kinematics, mechanisms, patterns and dynamicity are conducted for establishing strategies for implementation [12]. Biological studies for gaining inspiration to design advanced and intelligent robotics for conducting diverse human-like activities such as terrestrial movements, swimming and flying are conducted by engineers to understand the evolution of biological organisms within a dynamic environment. Improvement in sensory data transmission and reception based on the human nervous system is also seen, indicating a paradigm shift for bio-inspired robotics engineering. For example, the incorporation of signal processing algorithms and event-based neuromorphic vision for autonomous driving and assistance can increase capacity for intelligent robotic designs [13]. In essence, as the market for autonomous driving cars is increasing, the application of sensory-based data processing and neuromorphic vision in bio-inspired robotics enhances the scope for mitigating the issues of accuracy of movement and operations. Therefore, bio-inspired robotics can gain efficiency with sophisticated designs, inspired by biological systems that can perform within an uncertain and dynamic environment.

METHODOLOGY

The methods and materials for creating a prototype of soft robots are discussed here, to indicate the potential designs that can be implemented to develop an efficient robotic engineering plan, fulfilling the objectives of challenge mitigation in the field of bioengineering and robotics development.

Research methods

A secondary, deductive approach is adopted for the research to analyse the effectiveness of bio-inspired robotics in studying biological systems and identification of mechanisms that may be capable of resolving the issues in the engineering field. The deductive study approach has helped the researcher to develop a clear understanding of the subject. A descriptive study design is also adopted for aiding the comprehensiveness of data collection and analysis processes. On the other hand, purposive sampling is also adopted to ensure the data collection process is conveyed based on the specific objectives of the paper. The inclusion-exclusion criteria set for the paper have helped to gather authentic, relevant and scientific materials based on which the paper presents conclusive ideas on bio-inspired robotics. The validity and reliability of the paper are also demonstrated by adhering to the methodological structure as described, ensuring that consistency and accuracy are present in the paper.

Materials

The adoption of magnetic materials is used for prototyping the soft model design. The magnetic material is essentially praseodymium-iron-boron (PrFeB)-based isotropic powder, with a 5 µm mean particle size. Along with that, another material is praseodymium (Pr) which possesses a high degree of magnetic remanence (hard material) and is also used for maintaining strength and magnetism during dipole moments (µ) [9]. The technique for magnetic actuation is highly beneficial when using these properties for designing a prototype. On the other hand, a silicon rubber mix is used for the magnetic particles in the polymer which is used for constructing the non-magnetic segments of the robots. The materials should possess appropriate properties such as high elongation at 800% break and low elastic modulus. Finally, the polymer needs to be cured for obtaining the silicon rubber which is later mixed with the magnetic powder in a 1:1 ratio. Therefore, the proposed materials for the soft robots are selected based on the developmental criteria for the prototype robots.

Fabrication

The process of fabrication is based on the designing of prototype soft robots, initiating with polymer (liquid) degassing in a high-capacity vacuum chamber in order to remove any air bubbles, prior to curing in acrylic moulds. Prototypes for millipede, turtle and quadruped are selected by the researcher. The magnetic and non-magnetic parts are included step-by-step in the moulds. The magnetisation profile is introduced by subjecting the magnetic parts to 1T fields ((B-E 25 electromagnet). Different magnetization profiles were used by the researcher for each different shape of soft robots such as a U-shape for millipede, circular arcs for quadruped and turtle. Each shape is also designed to match the natural biological shapes of its bio-inspired animals such as quadruped were designed to have legs perpendicularly bent to the ground level. A 2.5-turn cycle and tilt at a helix angle are also incorporated to ensure higher manoeuvring for turning and straightening. Thus, the process of fabrication for robotics helped to derive a prototype that is inspired by the biological system, to indicate agility and a wider range of accurate motion.

Experiment set-up

The experiment setup consisted of electromagnetic coils for demonstrating the range of motion for the proposed robotics. The experimental setup consisted of magnetic fields with specified directions at a 40 Hz bandwidth. The centre of a wooden square of 100⇸100 mm Was used for locomotion testing. rotating the fields of magnetised parts, various patterns of movement can be seen. The functionality of the patterns of movement is assessed based on real-time demonstration of the prototype robots. Analysis of the helix angle as well as straight line motions are seen during the experiment based on which the proficiency of soft robots is discussed. On the other hand, the motion patterns identified for the robots are based on observations and predictions. Therefore, the entire process of establishing a prototype for bio-inspired robotics enables the researcher to develop new ideas in alignment with other secondary resources used in this paper.

FINDINGS AND DISCUSSION

Findings

Designing symmetry for bio-inspired robotics can be critical as the proportion of each path must be in alignment with the biological organism it emulates. For example, the asymmetrical design of the millipede soft robot is capable of reversing the direction of its motion however in order to fabricate the full range of motion for the same robot stability of the lateral direction becomes complicated to ensure [9]. Rotating fields for bio-inspired robotics can be archived in one direction, especially for a Turtle design, due to the biases of the magnetic field. The body composition of soft robots is gaining successful improvements based on the use of spring-body and memory alloy wire composite [14]. The softness of polymers is achieved by incorporating a "polydimethylsiloxane (PDMS) matrix" as well as parallel multi-SMAWs and "acrylonitrile-butadiene-styrene" (ABS) based on 3D printing [14]. In essence, designing soft robots with proper locomotive abilities and sensors for assessing the tuning and straightening actions can cause rapid development within the field.

On the other hand, the quadruped model is capable of achieving two phases of the actuation cycle such as limbs moving forward and lifting the rear end. Inverting the magnetic field can help in redirecting the motion of these robotics, exhibiting a high range of motion within the xy-plane. The speed of these robots is also tested based on the derivation of lateral direction and iterations in the motion test. The quadruped robot exhibits the slowest range of movement whereas the millipede design of the soft robots exhibits reliability of movements. Testing movement efficiency in non-smooth and curvy surfaces is also conducted to indicate that the millipede design, due to its design efficiency of multiple legs, can perform optimally. Therefore, researchers gain insight from biological systems to demonstrate efficiency in designing soft robots, emulating organic shapes and motion patterns.

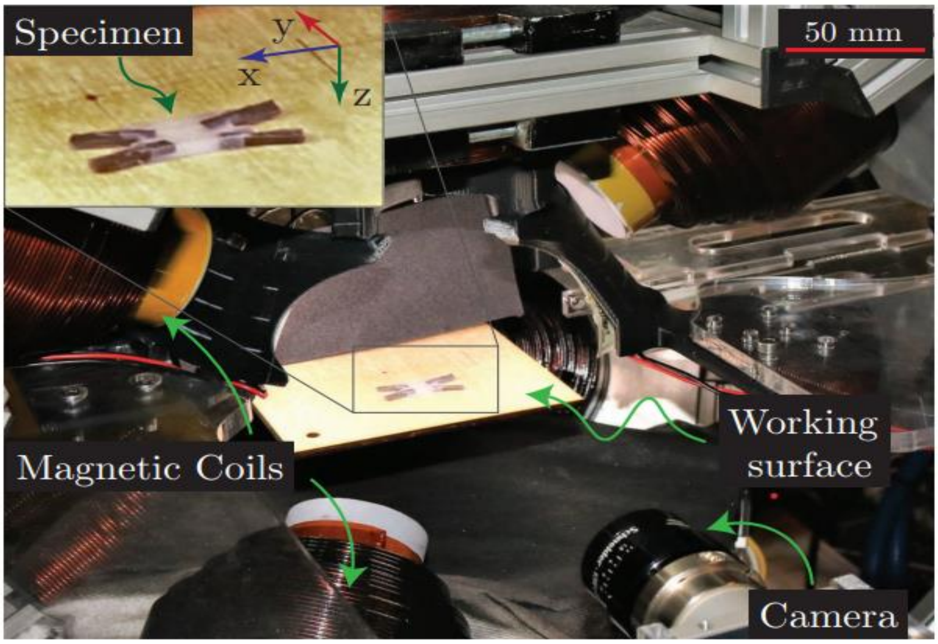

Figure 3: testing set-up of differently shaped soft robots [9]

DISCUSSION

The challenges encountered during the development of bio-inspired robotics with adequate intelligence and locomotive capabilities can be mitigated with the development of a sophisticated design pattern that locates required hardware and software. Technological development for assessing real-time human movement has contributed significantly to the construction of soft robotic suits that support the requirements of motion and function [15]. Lightweight and sustainable materials are used to obtain soft and flexible limbs for bio-inspired robotic designs. Compared to a traditional hard robot, the flexibility and agility of these soft robots built in the image of humans and animals are significantly higher.

On the other hand, the challenges of modelling soft robots and positioning them in a volatile environment can be critical. Sensory-based data-gathering technologies and deep-learning algorithms are incorporated to identify the challenges of distortion and displacements that may be mitigated later. For example, an octopus tentacle-shaped soft robotic arm, operating underwater, is examined during its perception-guided tracking of a real octopus, to indicate the critical difference of underwater visual projections due to multi-refraction effects [16]. In such cases adaptive models are proposed for distortion correction, aiding the controllability issues faced by bio-inspired robots in unpredictable underwater environments.

The design optimization for soft robots has gained profound improvement in the last decades based on research regarding biological movements in the natural environment. It is further stated that theories of dynamics and kinematics are used widely by researchers for designing and controlling soft robots [17]. On the other hand, the integration of problem-solving algorithms within the neural network for intelligent robotics has helped in accommodating robust data, ensuring the challenges within the engineering field are minimised. Robotic designs based on the communication pattern of swarms and insects are studied to develop algorithms such as Artificial bee colony (ABC), Ant Colony Optimization (ACO), Particle Swarm Optimization (PSO), Bacterial Search, Rhododendron Search, Fireflies, BAT, Frog and so on [18]. Studying the biological system helps engineers and researchers to develop an intricate understanding of the patterns among different species of animals and insects that can be used for bio-inspired robotics. Therefore, the effectiveness of a bio-inspired robot is dependent upon the designing efficiency, imitating the patterns of movement as closely as possible.

Considering the resilience and agility to perform efficiently in an uncertain environment enhances the effectiveness of bio-inspired robots. The compliant mechanisms for robotics are considered to be essential during the designing process. For example, a flexure hinge is used to demonstrate the compliant mechanism of a bio-inspired robot, indicating both linear and non-linear movements for each segment of the robotic body, using a framework of finite element method (FEM) [19]. Tendon-driven mechanisms are used to derive flexibility and agility of model displacements.

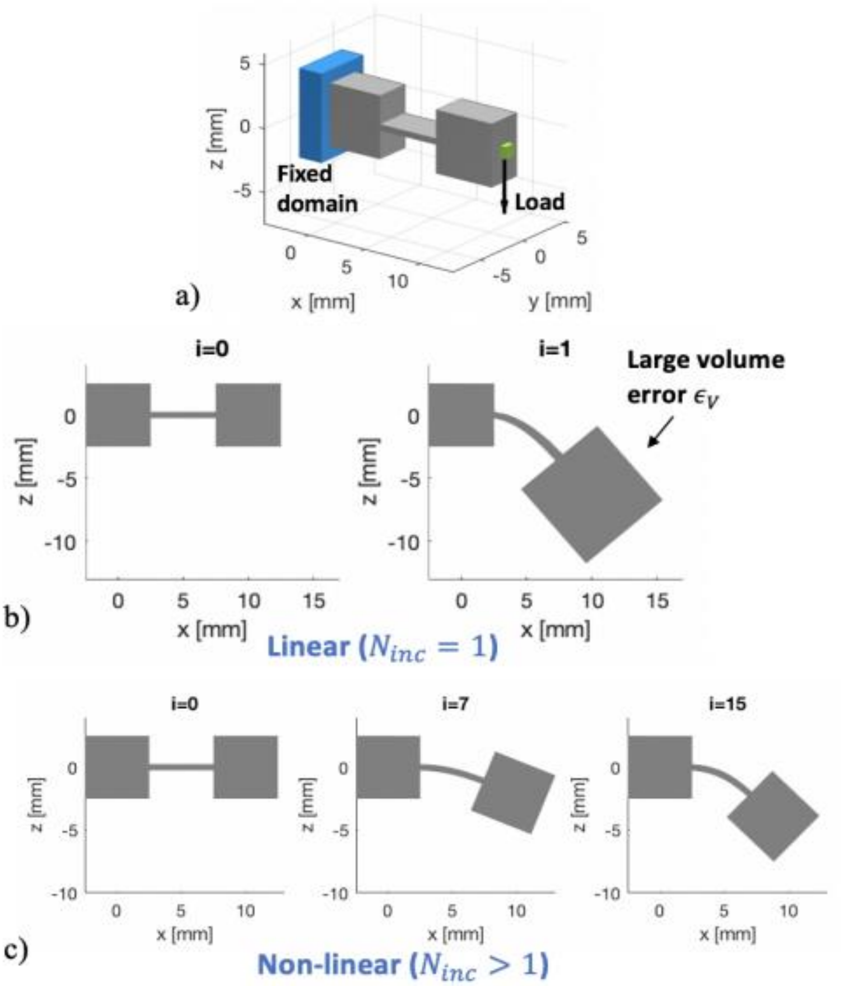

Figure 4: a compliant mechanism by large-displacement modelling [19]

Modelling an effective bio-inspired robotic design is used for studying different biological environments which in turn can contribute to the development of advanced and intelligent robotics for mitigating the challenges in the engineering field. Based on the above analysis, it can be stated that the effectiveness of a bio-inspired robot is dependent on the agility of the physical design as well as the capacity for collecting sensor-based data to conduct automated analysis of information.

CONCLUSION

Analyzing the effectiveness of bio-inspired robots based on the study of the biological environment indicates that the designing process for these robots is to be closely in alignment with the patterns of motion seen within the animal kingdom such as humans, animals and insects. In essence, bio-inspired robots are capable of functioning under uncertain biological conditions. The construction of advanced hardware and software for bio-inspired robotics can help mitigate the issues of remote data collection, processing, analytics, network integration and so on. Demonstrating the functionality of soft robots in different shapes such as turtle, millipede and quadruped, the paper provides an insight into the designing process of such prototypes using magnetization. Capacity for agility and motion is also dependent on the compliant mechanisms as these robots are used in adverse graphical locations for engineering purposes.

Nowadays bio inspire robot to develop the economic system of the nation and expand the area of research. In that case, it can be said that bio-inspired robots are able to make a renaissance in the biological system and it also helps to create a technological transformation. This study has discussed the significance of bioinspired robots and also shed light on the collaboration of robots and humans. The iteration between humans and robots helps to increase the advantages and strengths of doing the work. Accordingly, it is also able to increase the level of activities. This collaboration also provides the desired outcomes to the individual. Many scientists trying to develop a robotic system that helps individuals in their daily life with more efficiently. From this study, it has been seen that artificial intelligence has an interconnection with the robotic system. These kinds of development have the capability to do the job with accuracy with zero human error. On the other hand, this study has shone a light in the impact of the biological system in the improvement of bio-inspired robots. In this context, it has been seen that sensory motors are the essential component used in the development of bio-inspired robots. On the other hand, studying biological system for developing bio-inspired robotics design is also a major part of these studies. There are various kinds of designs based on soft robots. At last, it can be portrayed that bioinspired robots can bring a revolution in the entire world and also be a blessing for the future world.

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