robotics

MDPI

Article

Design, Implementation, and Kinematics of a Twisting Robot Continuum Arm Inspired by Human Forearm Movements

Alaa Al-Ibadi [1,2,*], Khalid A. Abbas [1], Mohammed Al-Atwani [1] and Hassanin Al-Fahaam [1]

[1] Computer Engineering Department, University of Basrah, Basrah 64001, Iraq; khalid.abbas@uobasrah.edu.iq (K.A.A.); mohammed.kade@uobasrah.edu.iq (M.A.-A.); hassanin.husein@uobasrah.edu.iq (H.A.-F.)
[2] School of Computing, Science and Engineering, University of Salford, Salford M5 4WT, UK
* Correspondence: alaa.abdulhassan@uobasrah.edu.iq or a.f.a.al-ibadi@edu.salford.ac.uk

Abstract: In this article, a soft robot arm that has the ability to twist in two directions is designed. This continuum arm is inspired by the twisting movements of the human upper limb. In this novel continuum arm, two contractor pneumatic muscle actuators (PMA) are used in parallel, and a self-bending contraction actuator (SBCA) is laid between them to establish the twisting movement. The proposed soft robot arm has additional features, such as the ability to contract and bend in multiple directions. The kinematics for the proposed arm is presented to describe the position of the distal end centre according to the dimensions and positions of the actuators and the bending angle of the SBCA in different pressurized conditions. Then, the rotation behaviour is controlled by a high precision controller system.

Keywords: soft robotics; pneumatic muscle actuators (PMA); twisting; kinematics; human forearm

check for updates

Citation: Al-Ibadi, A.; Abbas, K.A.; Al-Atwani, M.; Al-Fahaam, H. Design, Implementation, and Kinematics of a Twisting Robot Continuum Arm Inspired by Human Forearm Movements. *Robotics* **2022**, *11*, 55. https://doi.org/10.3390/robotics11030055

Academic Editor: Po-Yen Chen

Received: 7 April 2022
Accepted: 19 April 2022
Published: 22 April 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

Biological inspiration leads to an extensive number of inventions around the world. A rigid robot is just one example of an invention that has benefited us, either in industrial applications or in our social lives. However, using these machines in close proximity to humans has dramatically increased during the last decade, which has led to an increased risk of injury. Soft robots are a good alternative to rigid robots when it comes to health and safety due to their impressive advantages.

The softness of the material that is typically used to build soft robotics provides the term 'soft' and is normally used to cover the entire robot body without any rigid joints. One widely-used soft actuator is the pneumatic muscle actuator (PMA), which offers various benefits, such as being lightweight, having the variety and flexibility to be built into different structures [1–5], having high degrees of freedom (DoF) [6–8], safe to individuals and can be implemented by various dimensions [2,5].

However, the PMA behaves at high nonlinearity [4,5,9–11], such as hysteresis and time dependence. The inner rubber tube elasticity properties and the braided mesh [2,4] These concerts make the modelling and controlling of the soft systems more complicated [1,12,13].

Despite the general similarity in soft PMAs, each design can show a unique performance, one of these prototypes is the OctArm by [14], which shows adaptability, flexibility and efficient performance. Nevertheless, it is not easy to build and control as it is constructed from many actuators. This design shows mechanical difficulties. The Air-Octor soft arm in [15] is noticeably less complicated to build and control because the body of the arm is a single soft PMA and it is actuated by tendons. Though, the friction of the cables decreases its performance, which produces unpredicted changes in cable binding and moves the trunk in indefinite performance. A soft arm of three sections of six extensor PMA in the first two sections and three extensor actuators in the Section 3 is proposed