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PROCEEDINGS

Development of a Novel Origami Paper-Based Gripper

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ABSTRACT

The present research proposes a new way to design and develop a robotic gripper with a superior response in terms of controlled motion, low weight, and construction complexity. The proposed gripper design involves an innovative, cost-effective, utilizing origami-based engineering to overcome the complexities and high costs associated with conventional grippers. We developed a lightweight origami gripper that transitions from a square to a rhombus shape through simple manual folding. This type of device has specific features depending on how folding lines are placed, design parameters, folding orientation, and material thickness. This transformation enables efficient grasping and gap bridging, a significant advancement over the limited capabilities of traditional paper- based origami grippers.

The proposed prototype of the gripper was tested in two main different materials, cardstock paper, and plastic sheet, both of which were able to hold most common objects properly such as a stuffed toy, phone stand, bottle cap, wine cork, magic cube, and similar-sized items. However, in terms of lifted weight, the plastic gripper performed better during the lifting tests which were performed using a bottle of water, a scale, and identifying the maximum weight it can hold. A key aspect of our research is the geometric analysis of the gripper's transformation, focusing on how the control angle influences the gripper's final shape and functionality. An analytical model was developed to figure out how manual folding, specifically the angular displacement input, moves each folding line in the origami and establishes three types of folding lines in the presented origami which are valley, mountain, and contour lines. After this process, some equations were calculated to characterize this motion working with three major angle parameters alpha, beta, and gamma. This workflow validates the proposed origami gripper in three major aspects; analytical modeling using angular parametric equations, computational simulation performed using Rigid Body Dynamics (RBD) and finite element (FEM) methods as well as the lifting weight experiment to evaluate its limitations. The experimental test confirms what the theoretical analysis and computational simulation outlined regarding the predicted motion and maximum angle it can reach to close the gap. Moreover, the simulation showed and quantified critical stress zones across the origami, which are the side internal corners for the lifting experiment modeled as a side force of each contact surface of the gripper.

In that sense this research allowed us to figure out the interplay between these factors mathematically, enhancing our comprehension of origami-based gripper's mechanics. Regarding the theoretical and simulation results, they closely align with analytical estimations, assuring the versatility of this design. Moreover, the developed origami gripper presents potential enhancements such as an appropriate actuation mechanism, and an effective solution in terms of weight for robotic grippers in several scenarios.

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KEYWORDS
Origami; gripper actuator; bistable structure; origami string patterns; analytical models

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