



Designing an underactuated mechanism for a 1 active DOF finger operation

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ABSTRACT

In this paper a novel finger mechanism with 1 active DOF is proposed for an underactuated operation. The underactuation mechanism design is based on spring elements within the mechanism structure. The feasibility of the mechanism is verified through suitable kinematic and static analysis to give performance characteristics. The finger mechanism is able to obtain a human-like grasping operation and it can be embedded within the finger body with human-size mechanical design. The proposed finger mechanism is presented also as obtained from a synthesis procedure which is based on the analyzed characteristics. A design solution is proposed and tested through numerical simulation.

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1. Introduction

A finger with an underactuated driving mechanism has the capability to adapt its shape to envelope grasped objects although the finger is controlled by a reduced number of actuators. This is a very useful feature in grasping task with objects having various shapes and sizes. In addition, finger with a reduced number of DOFs (degree-of-freedom) and actuators can be built with low-cost and easy-operation features. Currently, few underactuated fingers have been reported in the literature. There are two main types of underactuated finger mechanisms, namely tendon-actuated mechanisms and linkage-based mechanisms as outlined in [1].

In addition to some patents [2,3], development of an underactuated prosthetic hand based on tendons mechanisms is reported in [4,5]. In [6] an optimal design problem is discussed as related to the diameter and location of the pulleys. A two degree-of-freedom/one-actuator finger is presented with isotropic force characteristics in [7]. Here force-isotropic means that the intensity of the forces exerted at the center of each phalanx, and on the grasped object, are identical. A design of an underactuated finger mechanism in TBM (Toronto/Bloorview MarcMillan Hand) hand is presented in [8]. Some preliminary results on a cosmetic prosthetic hand with tendon driven underactuated mechanism and compliant joints are also presented in [9]. Tendon-actuated mechanism can only support rather small grasping forces. The other disadvantage of tendon system is to lead to friction and elasticity as pointed out in [10].

Linkage-based mechanisms are usually preferred for applications where large grasping forces are demanded. Gosselin et al. published an US Patent [11] in 1998 and an improved version [12] in 2003. In [13], architectures of two-DOF underactuated fingers are proposed and a simulation tool is designed to analyze their behaviors. Then, the relationship between the input torque of the finger actuator and the contact forces on the phalanges is discussed in [14]. A five-fingered underactuated prosthetic hand controlled by surface electromyographic signals is presented in [15]. The thumb of TH-1 hand of Tsinghua

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University has a prismatic passive joint that is driven by a spring [16]. A procedure is presented in [17] to analyze the grasp stability of two-phalanx underactuated fingers.

In this paper, a novel finger mechanism with springs is proposed by improving an existing prototype at LARM: Laboratory of Robotics and Mechatronics, in Cassino. The kinematics and statics features of the proposed mechanism are analyzed in Sections 4 and 5 as a base for a simulation and mechanism design. In Section 6 a method is proposed to size the structure parameters and the coefficient of the springs. Finally, in Section 7 a typical grasp for wrapping a cylinder is simulated by means of a code in Matlab®. Conclusions are summarized in Section 8.

2. LARM hand and finger mechanism

Since the early 90s, LARM has devoted a research line for designing low-cost easy-operation grasping devices with 1-DOF anthropomorphic fingers. A series of 1-DOF anthropomorphic fingers have been developed and prototypes have been built as reported in [1,18–20]. Fig. 1 shows a prototype of anthropomorphic LARM hand version 4, with three 1-DOF fingers as it has been designed and built at LARM, [21]. The size of this prototype is 1.2 times bigger than an average human hand. Its main features are low-cost design and easy-operation. In particular, the built prototypes make wide use of commercial components such as standard aluminum plates and low-cost standard DC motors. Even the control strategies have been developed so that they can be implemented with a commercial PLC LOGO!. One of the most complex issues for achieving the above-mentioned results has been the design of a suitable driving mechanism that is embedded in the finger body and remains within the finger body also during its movement. Fig. 2 shows a scheme of a finger including a kinematic model of its finger mechanism. Each finger is basically composed of two four-bar linkage mechanisms as shown in Fig. 2a. The phalanx 1 is the input bar of the first four-bar linkage mechanism. The phalanx 1 is also the base frame of the second four-bar linkage mechanism. The phalanx 2 is the input bar of the second four-bar linkage mechanism and it is also the coupler of the first four-bar linkage mechanism. Then, the phalanx 3 is the coupler of the second four-linkage mechanism.

An optimal design method for finger mechanisms of anthropomorphic fingers with 1 DOF is reported in [18]. The current LARM hand was built with cross four-bar linkages. A human-like grasping is obtained by each finger with 1 DOF motion. In

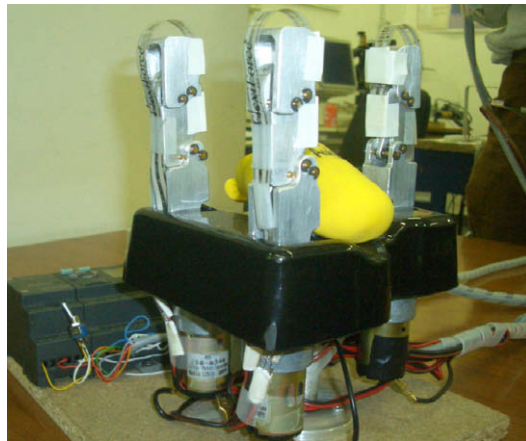


Fig. 1. A prototype of LARM hand 4 at LARM in Cassino, Italy.

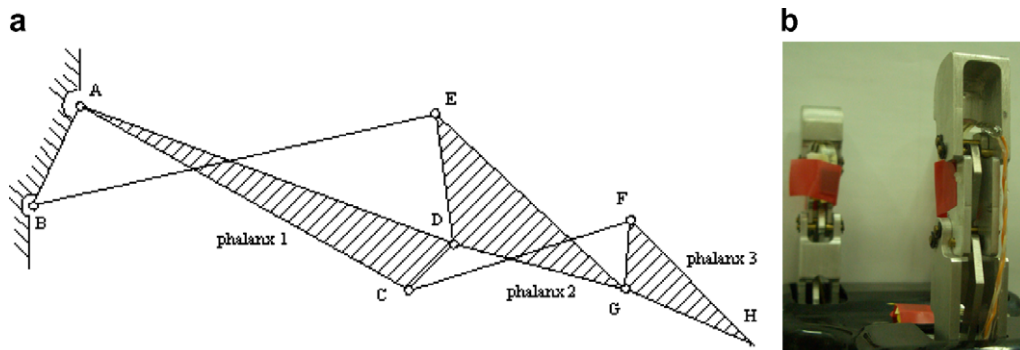


Fig. 2. Finger mechanism of LARM hand: (a) a kinematic scheme; (b) a built prototype.

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