Construction of Anthropomorphic Grippers with Adaptive Control

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Abstract

The functionality of industrial robots is provided primarily by the capabilities of their end effectors. The limited capabilities of robotic grippers determined the transition to the creation of anthropomorphic grippers. The number of degrees of freedom (DOF) of the end effector in the form of an anthropomorphic hand ensuring reliable grasping and holding the object should be at least nine, preferably twelve. The implementation of such a design is possible only when switching to the principle of construction of an underactuated grippers system. This paper presents the concept of constructing a group drive, which ensures the implementation of the movement of the output links of two or more executive groups from one motor. Technical solutions are based on the development of methods for analyzing complex mechanical systems using functional circuits.

Keywords: Anthropomorphic gripper, underactuated grippers, end effector, robotic grasp

1. Introduction

Today, robotic manipulators are actively used in industrial production [1]. They improve working conditions of employees and reduce enterprise costs ensuring a continuous production. Typical applications include assembly, casting, stamping, cutting, machine loading/unloading, welding and material handling [2]. Generally, a robotic arm functionality is determined by design and properties of an end effector. The most applied end tool is a robotic gripper. The choice of a grip depends on many characteristics, including weight, shape of an object, motion speed, permissible compression force, and a point of contact [3]. Values of each characteristics are often taken into account at a design stage of a robotic arm. Thus, problems arise with an inefficient operation of a robot in case of miscalculations in the design or/and an inability to adjust the arm to a new task. One of the solutions is to unify the hand [4].

The most widely used are universal vacuum suction grippers and multi-fingered hands [5]. The first one is a single mass of granular material that flows around a target object and takes its shape upon applying a pressure on the object. The disadvantage of this approach is a need to return to a neutral state after each grasping. Multi-fingered hands usually possess many independently actuated joints. This design of the end effector has sufficient softness and rigidity for a reliable and stable grip of an object [6]. [7]. MCU Based Edge Computing. The main difficulty of the approach is related to a computational complexity of tactile sensing and computer vision based algorithms [8]. Our research is aimed at developing a concept of a multi-fingered hand using both active and passive joints. Such design allows the hand to envelop an object without complex calculations.

The most common anthropomorphic grippers are structure diagrams of grippers with three [9] or four parallel executive groups of links [10]. Each executive group includes, as a rule, three output links [11]. Collectively, the gripper has nine or more degrees of freedom (DOF). There are two typical layout schemes for installing individual drives for each link. In accordance with the first one, the motors are placed at the output links [10]. In the second case, the motors are located within a single link of the manipulator [12], [13].

Typically, dimensions of output links do not allow internal installation of motors with a sufficient power [14]. Consequently, forces generated at endpoints of the output links do not exceed 1.5 N [10]. Installing motors in a single link involves a significant complication of a design. For instance, a gripper by DLR [15] has 65 pulleys for laying flexible rods on a manipulator link and 38 pulleys directly on the gripper. At the same time, it is also impossible to provide a significant effort at the output link. In a modified DLR version, the maximum force is 9 N [16]. The use of individual drives complicates a control system. In this case, a number of controllers for drives equals to a number of output links.

A group drive solves the abovementioned problems of controllability and complexity of individual drives. In the ASIMO grippers [17] and JPL - Nautilus Gripper [18] a single motor provides a movement of three output links in each executive group. An object is grasped according to the principle of kinematically dependent movements of the links. Thus, the manipulator reliably grips objects of only a certain size with all three links.

2. Related Work

A qualitative change in operational characteristics of a system with a group drive is achieved by using a principle of underactuated grippers. It is based on an implementation of additional passive elements into a structure of each executive group. These can be compression springs [19], [20] or tension springs [21], [22]. At the same time, an adaptive motion control is implemented by output links in the executive group. Links move sequentially, from a proximal link to a distal link. A change of a control object (an output link) is achieved when external conditions change, and a moving link stops after reaching an external object.

A further reduction of anthropomorphic gripper mass is possible by ensuring a motion of output links of adjacent executive groups from a single motor. Using the principle of underactuated grippers, flexible elements should be placed into a group drive system for an entire gripper. Similarly, for the executive group, this will ensure independent motion of the executive groups of links from a single motor. Thus, inspired by [23] we designed a modifiable structure of an anthropomorphic gripper, which is presented in this paper.

3. A gripper design

The proposed design is based on an anthropomorphic gripper with two parallel executive groups of links (Fig. 1). From motor 1 that is installed at the basis of the gripper, the movement is transmitted by two parallel streams to two executive groups. A flexible twisting spring is integrated into a kinematic scheme of each stream, connecting coaxial shafts *a* and *b*. Links 2 and 3 transmit movement through transmission systems to the output links using the shafts. The installation of flexible elements adds a relative rotation of the coaxial shafts to a motion transmission system.

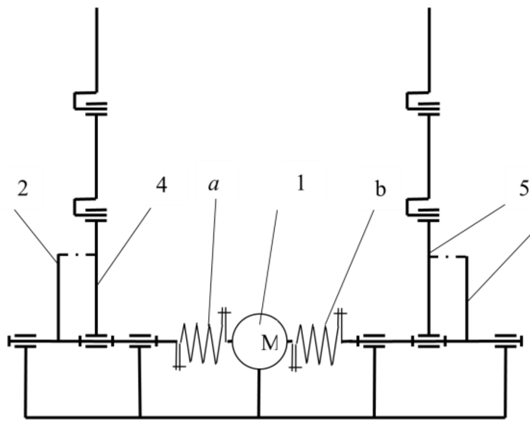

Fig. 1. Structure diagram of an anthropomorphic gripper with two parallel executive groups of the output links.

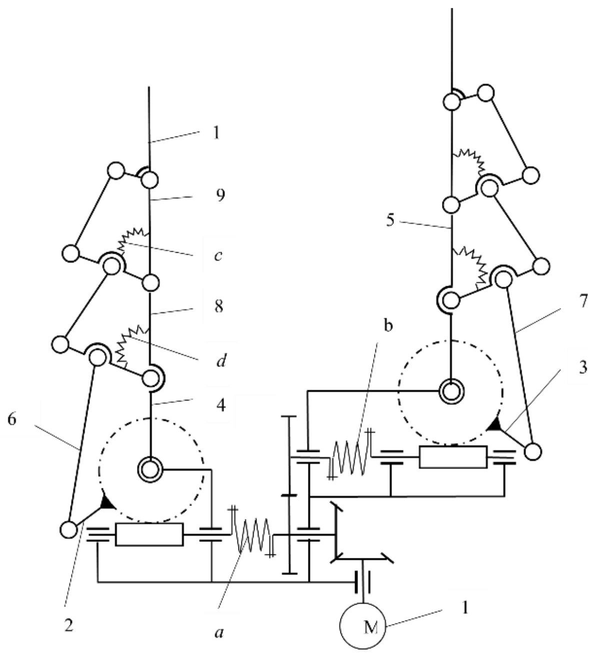

Fig. 2. Structure diagram of an anthropomorphic gripper with two opposite executive groups of the output links.

Fig. 2 shows a structure diagram of the anthropomorphic gripper with opposite executive groups of links 4, 5 and a lever system for motion transmitting [24]. The movement is transmitted from motor 1 in two parallel streams to driving links 2 and 3 involving twisting springs *a* and *b*. Then links 2 and 3 set into motion lever mechanisms 6 and 7. Executive groups 4 and 5 are constructed using the principle of underactuated grippers. Compression springs *d* and *c* are installed between the links of the motion transmission system and the driving links.

Executive groups 4 and 5 move from initial position synchronously in a direction of an object located between them, which should be grasped. A grasp can shift towards one of the executive groups, depending on a shape of the object. As the object is gripped by link 8, a rotational movement of leading link 2 decreases and spring *a* gets partially deformed. After grasping the object with all links 8-10, the transmission of rotation through spring *a* stops and the spring gets twisted. The movement of executive group 5 is maintained until its links completely encircle the object. The rotation of the motor stops after reaching a preset torque value. Deformed springs *a* and *b* retain a force corresponding to an end of the grasping process. This provides a given force effect on the object.

Fig. 3. The constructed anthropomorphic gripper with three executive groups of links.

Fig. 3 shows the constructed anthropomorphic gripper with three executive groups of links. The single motor provides the movement of the output links. The distal link possesses 10.5 N force for the entire length of the executive group links of 100 mm.

4. Conclusion

The paper proposed a new design an anthropomorphic hand with an underactuated gripper. A movement of output links of several executive groups of the gripper is performed using a single motor. A number of implemented flexible links equals to a number of executive groups. A shape of an object to be grasped determines a resulting motion of executive group links and a sequence of their motion. Experimental validation confirmed feasibility of the proposed construction of the anthropomorphic gripper.

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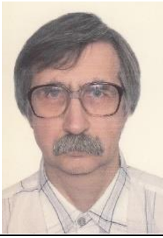

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