CAD PROJECT AND PROTOTYPE FOR AN ANTHROPOMORPHIC GRIPPER FOR ROBOTS - SIMULATION AND TESTING

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This paper presents an anthropomorphic gripper intended to equip industrial robots used to achieve low and medium complexity assemblies. The gripper has five fingers and five degrees of mobility; it has a relatively simple structure, but high functionality. Based on the CAD project of the gripper, we obtained a prototype through rapid prototyping. An actuator controlled by a microcontroller activates each finger. The gripper control is possible capturing human hand gestures and transmitting data first in a virtual scene to certify the gripper correctness then to the real gripper. The prototype was tested for gripping objects of different shapes and sizes.

Keywords: anthropomorphic gripper, CAD project, CAD simulation, prototype.

1. INTRODUCTION

Anthropomorphic grippers are grippers inspired by human hand model, with various constructive and functional features. Compared to other classes of grippers, like grippers with jaws [1,2], or tentacular grippers [2], anthropomorphic grippers have obvious advantages because they are more similar to human hand, both constructively and functionally, considering the human hand the most advanced gripper [1]. Currently, there are several versions of anthropomorphic grippers, some of which are in the design stage, others in the prototype stage and some are commercial products [3,4,5,6,7,8]. These grippers differ through more constructive and functional features, including the main ones: the number of fingers that can be: 2, 3, 4, 5 or even 6; the number of phalanges on the finger: 2 or 3; the mechanisms type - significant constructive elements for fingers: articulated bars or rollers or wires; degree of mobility, by which there can be monomobile versions to multimobile versions, with high degree of mobility, equal to the fingers’ number, or even very high, equal to the phalanges’ number, respectively with the joints number, degree of mobility close or equal to the human hand (M = 36); motors type used: electrical or pneumatic; with or without sensors and sensors type used: contact, sliding, proximity; type of control system used: through program instructions, by glove-devices, Data Glove type, through virtual reality, through smartphone, voice, etc.

Comparing a significant number of anthropomorphic grippers’ versions for robots, we can identify the following major drawbacks: excessive complexity compared with low functionality; a low technologicity; high or very high cost and especially price most of the times without high performance and reliability, etc.

In this context, this paper proposes some new approaches, to reduce at least in part the disadvantages outlined above, approaches focused on:

- achievement of technical project, CAD model and functional simulation of an anthropomorphic gripper with five fingers, with a high degree of similarity to the human hand;
- controlling the gripper through a topical solution, namely by capturing configurations-gestures of human hand and data transmission to simulate gripping in a virtual scene and then to the real gripper;
- achieving prototype using a modern and less costly method, namely the method of virtual prototyping.
2. CAD MODEL AND FUNCTIONAL SIMULATION OF AN ANTHROPOMORPHIC GRIPPER WITH FIVE Fingers

2.1. Structural and functional peculiarities of the gripper

To equip the robot from a robotic workstation, looking like other similar ones, for small and medium assemblies [9], we decided to use an anthropomorphic gripper with five fingers, with an increased number of joints above the minimum, to find a resemblance and functionality as close as possible to the human hand. We started from a known model [10], which was adapted to the purpose intended. Each finger consists of three phalanges: \( f_1, f_2, f_3 \), between which there are monomobile rotational couplings, driven by wires (Figure 1a). For driving we use electric motors, one for each finger, so that the gripper has the mobility degree \( M = 5 \). To close the finger, the motor rotates in one direction, and closing is obtained by pulling the thread \( f_i \), and the opening – the return of the finger to the starting position, corresponds to the motor rotation in the opposite direction, and it is obtained by pulling the outer wire \( f_e \) (Figure 1a).

The structural diagram of the gripper was obtained based on 17 monomobile rotational couplings: 10 interphalangeal joints, 3 couplings of the first three phalanges of the thumb, and the first two fingers and the palm, 4 connection couplings between two parts that replace metacarpal bones for the last two fingers, connection couplings with the palm and the first phalanges of these fingers. We highlight the two rotation couplings with the inclined axes reported to the longitudinal axis of the gripper, which provides to a certain degree resemblance to the situation of human hand metacarpal bones existence [2].

2.2. CAD model of the gripper

The CAD model of the gripper was obtained using CATIA software [11] and it is shown in Figure 1b.

![Figure 1. Scheme of a finger (a) and CAD model of the anthropomorphic gripper designed (b)](image)

The same software can be used for the functional simulation of the gripper to check the correct closure without a part to grip or with gripping parts of various shapes and sizes (Figure 2).
Based on the CAD model of the gripper, we obtain the technical documentation necessary to achieve the appropriate prototype.

3. GRIPPER CONTROL

The gripper control is possible using a method of capturing the human hand configurations. On this purpose, we use a Leap Motion device (Figure 3) [12]. In Figure 3b there is the interaction cube, area where human hand finger movements can be captured.

It has the ability to capture the configuration of the fingers, Figure 4a, similar to the configuration, which would grip a specific object. Data obtained, Figure 4b, and validated by gripping a virtual object similar to the real one, by a similar virtual gripper, Figure 4c, are transmitted finally to the real gripper [12].

Figure 2. CAD simulation of gripping using the designed anthropomorphic gripper

Figure 3. Functional peculiarities of the Motion Leap device

Figure 4. Configuration of the fingers (a) and grip control (b)
This method can be improved both by increasing functional performances of the Motion Leap device, increasing its accuracy and by optimizing gripping simulation in virtual environment, including by increasing the number of constructive details of the virtual gripper, to have construction and operation identical to those of the real gripper.

4. GRIPPER PROTOTYPE AND TESTING ITS PERFORMANCE

Based on the technical project a prototype of the anthropomorphic gripper was made. The parts were obtained by rapid prototyping using a 3D printer. In Figure 5 we can see the components of a finger (Figure 5a) and part of the palm where we can notice the area of the inclined joints (Figure 5b) [12].

Each finger is operated via a wire, with one actuator type Tower Pro MG 995 (Figure 6a) controlled by a microcontroller ATMega32u4 type (Figure 6b). The actuator has the following technical characteristics: working voltage: 6V, torque: 180N / cm, dimensions: 44x23x25, weight: 35 grams, and the controller has the following main features: working voltage: 5V digital input and output pins: 20, PWM channels: 7, input analog channels: 12, flash memory: 32 Kb, processor frequency: 16 Hz [12]
The operation of each finger is possible through a single tendon, which is pulled by the motor and induces rotation to rollers in interphalangeal rotation joints, and to the phalanges as well. On the rotation of the actuator in one direction, the finger closes, and on moving in the opposite direction, the finger returns to the initial position (position rectilinear-open finger). In Figure 7 it is shown the prototype achieved, and in Figure 7b, a functional simulation where it is observed good handling of fingers. Functional testing was performed for several objects – parts out of which we have two examples, namely: gripping a spherical object (a tennis ball) in Figure 7c and gripping an axis (Figure 7d) [12].

From these examples results the high functionality of the gripper compared to other types of grippers, such as jaw-grippers [2].

5. FUTURE DEVELOPMENTS

To continue presenting our achievements, we seek to obtain a functional subsystem where the gripper obtained is controlled by capturing human hand gestures with a Motion Leap device, via gripping simulation in virtual scene, and the robot can be controlled by capturing human arm movements with a Kinect device. The main software interfaces required are Robocommader, already made, in the case of the gripper and ABBcommander, in progress, in the case of the ABB type robot.
6. CONCLUSIONS

On the basis of this work the following conclusions can be drawn:
- to eliminate the disadvantages of the jaw-grippers, of which the most important is reduced gripping possibility, sometimes limited to a single workpiece size, the use of anthropomorphic grippers with three or more fingers, with relatively simple structures but high functionality, is recommended;
- to equip the robot or the robots, we can use anthropomorphic grippers with five fingers, as shown in the paper, which can be obtained at low cost, using modern techniques such as rapid prototyping;
- to optimize the robot and gripper operation control, advanced methods can be used, such as capturing fingers movements to control the gripper, and human arm movements for the robot control.

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