ANTHROPOMORPHIC MODULAR RECONFIGURABLE GRIPPERS WITH THREE AND FOUR FINGERS – DESIGN AND PROTOTYPE

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ABSTRACT. In this paper one class of anthropomorphic modular reconfigurable grippers for robots are described, including a prototype. For the first time the stages of synthesis, analysis design and functional simulation are presented. We choose two versions: with three and four identical fingers with three phalanxes on finger. The kinematic synthesis is used to obtain a correct closing of the finger and of the gripping mechanism. With the constructive dimensions a 3D model can be obtained using CATIA soft. Some aspects regarding functional CAD and virtual simulations are shown too. For one variant of this type of gripper, with three fingers, the technical documentation is completed and the technical project has all the conditions for practical achievement and a prototype was made. There are two main constructive modules: the support – the palm and the finger. Main technical characteristics of the prototype are indicated.

Keywords: anthropomorphic gripper, structural synthesis, structural analysis, structural synthesis, cinematic synthesis, design, functional simulation, prototype.

1. INTRODUCTION

The anthropomorphic grippers are of increased interest due to raising applicability to industrial robots but also to other types of robots, especially humanoids service robots.

Currently there is a relatively large variety of such grippers [1], [2], [3], which have a high price, even in some cases very high, which discourages attempts to introduce them in current applications.

The paper first briefly refers to the class of modular reconfigurable anthropomorphic grippers proposed by the author.

In terms of modularization, this class is based on a generic version, which may have a variable number of fingers. This number ranges from 2 to 6, but there is as well the opportunity to make a gripper in a wide range of sizes, from small sizes (0.75, 0.5, 0.25, etc. reported to the human hand) to larger versions (1.5, 2, 2.5, etc. reported to the human hand). Thus, a wide range of weights (from several grams to several kilograms, or even tens of kilograms) can be manipulated.

The possibility of being reconfigurable refers to the use of a platform where fingers (three or more) can have more relative positions only through disassembling and assembling elsewhere, without removing the platform off the robot arm. Thus, such a gripper, at a lower price, can replace several separate grippers or may cover a significant percentage, even up to 60% of the usefulness of a continuously reconfigurable gripper, and in this case economic efficiency is ensured (generally at a price of 20% or even lower, utility can be up to 50% or even 70%).
In this paper for a variant of this class of anthropomorphic grippers, that is a gripper with three fingers, the main theoretical and construction features are illustrated and a prototype is described as well.

Obviously, all considerations can be extrapolated to variants with fewer fingers, respectively, two or more fingers, four, five or even six.

2. STRUCTURAL AND KINETOSTATIC SYNTHESIS

2.1. Structural Synthesis

The structural synthesis seeks to set possible configurations and the structure of a finger so that it has the largest degree of utility possible.

Looking at possible configurations four are considered significant (see Figure 1,a), which can be obtained by proper installation of the three fingers on the same platform, and five configurations can be obtained with four fingers with the same fingers and another platform (see Figure 1,b).

In connection with the structure of a finger it may have two or three phalanxes, possibilities of which we opted for three phalanxes, for a greater degree of utility. There is the possibility of using four phalanxes too, or even five, which must be duly justified, however, as there are clearly higher prices.

2.2. Kinetostatic Synthesis

In this phase we determine linear and angular dimensions of components so that the fingers close properly (kinematic synthesis purpose), and the given weight can be gripped and handled (static synthesis purpose). This situation is obtained with a good correlation between the dimensions of the phalanxes and a good relative position of the fingers.

3. STRUCTURAL ANALYSIS

The mechanism of the finger (see Figure 2) is a poly-contour mechanism with two outside connection $L = 2 (v_1, F_1; v_{p1}, F_{p1} – see Figure 5,a)$ and degree of freedom $M=1$.[4]

The degree of freedom is obtained with $M = \sum M_i - \sum f_i$, where $M_i$ is the degree of freedom for mono-contour i mechanism and $\sum f_i$ is the degree of freedom for common joints (see Figure 3,b).

For each mono-contour mechanism the degree of freedom is obtained with $M = \sum f_i - \chi_k$ (where $\sum f_i$ is the degree of freedom of the joints and $\chi_k$ is cinematic degree of the mono-contour $k$ mechanism[4]).

For the mechanism shown in Figure 4, in accordingly with the graph of Figure 5,b, are obtained: $M=1$ has the following significance: one independent movement (speed): $v_1 = s_1$ and one function of the external forces: $F_1 = F_1(F_{p1})$. $L - M = 1$ represents one function of movement: $v_{p1} = v_{p1}(v_1)$ and one independent force: $F_{p1}$ – the contact force between finger and grasped object.

![Fig. 1. Significant configuration of three and four fingers.](image1)

![Fig. 2. The structural scheme of the finger.](image2)

![Fig. 3. The block scheme and the graph of the mechanism.](image3)
4. CONSTRUCTIVE DESIGN AND 3D CAD MODEL

The calculation of strength was made in function of the internal forces which act between elements.

With the constructive dimensions a 3D model can be obtained using CATIA soft. There are two main constructive modules: the support – the palm (see Figure 4,a, for three fingers and Figure 4,b for four fingers) and the finger (see Figure 4,c) [5, 6, 7, 8, 9].

With these modules four three-finger versions can be obtained (see Figure 1), two are main versions: the fingers having possible parallel (see Figure 5,a) or concurrent movements (see Figure 5,b).

A functional CAD simulation (see Figure 6) was made to check the correct work and to identify the solutions to obtain the optimum variant for this gripper.

With the same finger and the second platform five four-finger versions can be obtained (see Figure 1,b and Figure 7,a): one variant with fingers with parallel axes; one variant with fingers with parallel axes but with a interval; crossing axis; three fingers with one in opposite and central position and three fingers with one in opposite and lateral position. The CAD model of this version are shown in Figure 7,a without piece and a CAD simulation with one grasped piece is shown in Figure 7,b.

![Fig. 4. The main constructive modules.](image)

![Fig. 5. Modular anthropomorphic grippers with three finger.](image)

![Fig. 6. The CAD functional simulation.](image)

![Fig. 7. Modular anthropomorphic gripper with four fingers.](image)
These grippers, with one specific intermediary piece, can be mounted on any industrial commercial robot (see CAD simulation in Figure 8). One of its configurations can be obtained, during the gripper is mounted on robot, with change the relative position of the fingers only, regarding the form of the grasped object.

For functional simulation of the grasped operations, the robot with the gripper were transferred in virtual reality – VRML soft (see Figure 9). Here we can test different grasping operations for different objects. Then, the results, for one correct grasp, can be used for programming the real gripper.

5. PROTOTYPE-PERFORMANCE AND TEST

On the basis of the technical documentation prepared in accordance with technical rules in force a prototype of the gripper analyzed in this paper was issued (see Figure 10,a). In Figure 10,b, as a first experimental form and functional testing, gripping a spherical body with this prototype is exemplified.

The main technical characteristics of this prototype are:
- degree of freedom: $M = 3$;
- weight hand: 12 N;
- payload: 40 N;
- gripping force: $\sim 30$ N/finger;
- dimensions: finger: 1:1 human fingers size and hand: $140 \times 140 \times 100$ mm.

For the drive, pneumatic linear motors are used. The prototype can be equipped with contact sensors (for example, type CZN-CP15), and command and control can be ensured through appropriate equipment [10].

After providing corresponding equipment, the prototype will be mounted on a robot and will be fully tested in various gripping operations, including handling. In the first stage testing will be done in CAD environment (including gripping phase), test done in a preliminary stage without the object to grip (see Figure 8), then functional simulation will be possible in virtual environment (e.g. VRML) in order to establish data for accurate virtual gripping and their transmission to the real gripper – the prototype [10].

6. CONCLUSION

In according to the considerations presented the next conclusion can be formulated:

a) For to design the anthropomorphic mechanical grippers the main stages are: structural synthesis and analysis, cinematic synthesis and analysis, static synthesis and analysis, constructive design and 3D model and functional CAD simulation.

b) The family of the mechanical anthropomorphic modular reconfigurable grippers for robots with two, three, four and five identically fingers has more variants, what can be obtained in accordance with the number and the relative position of the fingers.

c) The grippers with three and four fingers can be obtained using two main modules: the support – the palm, one for each type of gripper and the finger, one type only. With these two modules can be obtained any variants with three, with four fingers and with two fingers too(eleven versions).

d) Discontinuous modular reconfigurable anthropomorphic grippers have certain advantages, especially on the cost, but also functional, compared to other anthropomorphic grippers, including those with continuous reconfiguration possibility.
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BIBLIOGRAPHY


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