Aspects regarding the development of a gripper with variable geometry

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Abstract - In recent years robotics is constantly changing, adapting to the needs of the industry and therefore lately the design of gripping devices is also in a continuous process of development, adaptation, discovery of new ways to catch and manipulate an object and therefore different constructive models have been made. The main purpose of the paper is to present the design of a gripper with variable geometry intended to be used for the purpose of industrial handling.

1. Introduction

In the last decades the robots became more and more present in applications that targeted industry, space exploration, bioengineering or home care and entertainment. In this context the interaction between the work environment and the robot is one important challenge that the designers have to deal with. The grippers are the main elements that are used in the interaction process, from this perspective they came in different shapes, dimensions and functionalities depending on the application [1].

Even though the field of designing grippers is not new, there are still many challenges that need to be solved regarding the advanced grasping of objects with irregular forms, dimensions-force ratio of the gripper, implementing new materials, sensors and actuator in the design of these systems etc. [1].

Handling objects with irregular form is a challenge addressed in multiple research works in recent years [2], [3], [4]. When it is necessary to handle delicate objects with power and precision, three-finger gripping devices are one of the preferred solutions, with the possibility of adapting irregular surfaces with the help of articulated fingers [4]. This type of gripping device is essential when there are several different gripping objects, requiring a versatile and adaptable gripping device.

The current paper addresses the development of a gripper that adapt its geometry so that it can grasp elements with irregular forms. In order to implement these characteristics new approaches regarding the grasping elements and their position during the operation are taken in account.

Most grippers are designed to hold a single type, shape or size of object. Lately, different constructive forms of grippers have been made in order to adapt to the most variable diversity of shapes and sizes of objects.

The paper presents the possibility of making a gripper with new openings in the field of object handling. The gripper has as an essential advantage, the possibility to change the orientation of two of the three fingers, thus having the possibility to achieve a firm grip for a wide range of objects, of different sizes, shapes and materials, these having a hardness higher or lower.
The gripper is intended to be used in handling waste materials from construction sites that have different sizes and shapes. In the next chapters the proposed design solution is presented and the experimental results are shown.

By the possibility of changing the orientation of the moving fingers, the gripper is no longer constrained by the type, shape and size of the objects, it comes out of the pattern of ordinary grippers. It has the possibility to manipulate ordinary geometric shapes, cubic, square, as well as cylindrical shapes and most importantly has the ability to handle irregular shapes.

2. Theoretical considerations and gripper design

In order to be able to adapt to different irregular shapes, the gripper has been designed so that two fingers can change their orientation according to the information received from the sensory system regarding the size and geometry of the object to be handled. In Figure 1. (b) the gripper is shown in two operating positions, where the two movable fingers are positioned at the extreme operating positions.

![Structural topology](image1.png)  
![Gripper extrem positions](image2.png)

Figure 1.

The gripper can handle irregularly shaped objects whose diameter or size in the grip area of the object is 520 [mm]. The gripper will be designed so as to allow the manipulation of an object with a mass of up to [8 Kg], reaching a 3D structural. The gripper has three fingers operated by three direct current motors, with textile thread, two of them having the possibility to change the angular position, the initial positioning being performed with the help of optical sensors.

The gripper has 3 pairs of horizontal rotation couplings (figure 1. (a)) for closing the phalanx grip: J-I-H, C-B-A, D-E-F. Also, the vertical kinematic couplings G and K orient the 2 mobile fingers.

Due to the G and K couplings, which offer the possibility of orienting the moving fingers, the gripper has the advantage of providing a grip from several perspectives on the manipulated object.

The elements considered for determining the tension of the wires are Gi - the weight of the phalanges, Fa- the forces in the springs, Fg- the force necessary to grip.

To determine the tension, the sum between the gripping forces with the weight of the phalanges and the cosine of the forces in the springs was made.

For the return of the phalanges to the initial position, galvanized steel traction springs were used. All these being represented in Figure 2. (a), (b).

In this case Fa =14[N] Gi =0.3[N] Fg =92[N], thus reaching a wire tension F =135[N].

To determine the motor torque a pulley with r = 10 [mm] is multiplied with the wire tension and the result is M =1,35[Nm].
Control algorithms for the system were developed using the Matlab-Simulink environment and the Waijung library. The block diagram used for gripper is shown in Figure 3. A global control algorithm has been developed for the system through the Stateflow library in the Simulink environment. The global control system manages the initialization stage, operation and possible malfunctions of the gripper. In the model are implemented local control loops for the control of the force with which each phalanx acts and the control of the position of the mobile phalanges. The model thus obtained is automatically compiled and loaded on the Discovery STM32F4 board via Real time workshop libraries.

2.1 Experimental and numerical results
The designed model was made and a series of experiments were performed, the grip was mounted on the final effector of a Mitsubishi RV2 serial robot. The functional evaluation of the gripper was done in two stages. The first stage aimed at evaluating the response of the system for different positioning angles of the mobile phalanges. This aspect is important because the positioning of the phalanges is an important component in the strategy developed for the robotic cell to be able to manipulate objects with irregular geometric shapes. In this sense, a series of experiments were elaborated in which the
response of the system to the variations imposed for references with and without external disturbances was followed.

Figure 4. Experimental results - positioning mobile phalanges

Figure 4 shows a set of graphs describing the answer for the positional variation of the two phalanges. The control algorithms used to control the position of the two phalanges is PID. From the response of the system it is observed that the positioning errors do not exceed 8 degrees, this representing an absolute error of 4.5% for the entire operating range. Presented with a blue line is the answer expected from the gripper, the reference, and with a red line is the answer received from the gripper in real time. The finger orientation motors are marked with references M4 for finger 2 and M5 for finger 3, and the finger trigger motors are marked with M1 for finger 1, M2 for finger 2 and M3 for finger 3 (Figure 1 and Figure 3).

Figure 5. Experimental results - gripping cylindrical objects

Figure 6. Experimental results - grasp parallelepiped elements
The second stage of experiments aimed at testing the gripping system for different materials and their shapes. The following Figures (5-7) show the results obtained from the experiments. For each case, the current consumed by each of the three motors that drive the phalanges to measure the clamp was measured. This current is directly proportional to the force with which the gripper's fingers act on the manipulated object.

![Experimental setup](image)

**Figure 7.** Experimental results - gripping deformable elements

3. Conclusions

Following the experiments, it was observed that an important factor for the success of the manipulation operation is given by the coefficient of friction between the two surfaces that come into contact: phalanges-manipulated object. In order to increase this coefficient, the initial prototype of the gripper was modified by introducing a rubberized material in the contact area of the gripper with the manipulated objects.

It was observed that for the manipulated objects that fall within the constructive parameters initially imposed, the system manages to successfully perform the manipulation operation in a ratio of 100% of the time.

Following the realization of the project, it was determined that 3D printing can make an important contribution to the design and construction of industrial mechanical structures.

During the development of the project, various difficulties could be observed in view of the filling factor of the printed elements, especially the fact that solid parts give the necessary strength to the parts not to yield under the action of the weight of the manipulated objects but also under the action of screwing assemblies, as well as the fact that not all elements require a maximum filling factor, such as the gripping elements of the orientation motors, the top cover, the gears.

4. References

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Acknowledgments

This work was supported by a grant of the Romanian Ministry of Research and Innovation, CCDI-UEFISCDI, project number PN-III-P1-1.2-PCCDI-2017-0086 / 22 /2018, within PNCDI III. Each author has contributed equally for the paper.