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A Brief Review on Robotic Grippers Classifications

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***Abstract*— Manipulators are used for various applications to make tasks easier or decrease the risk of tasks deemed impossible, dangerous or difficult for humans. A robotic manipulator can be equipped with different types of end effectors to perform diverse tasks. Grippers are one of the most commonly-used robot end of arm tools. Depending on the application in hand for the robotic system, various types of grippers are needed. Therefore, selecting the proper one is a significantly important aspect in the design process. To the best knowledge of the authors, there are not enough scholarly research papers focusing on classification for robot grippers. In this paper, a brief review on different categories of grippers are presented. The goal of this paper is to provide a brief informational summary on different classifications, since proper selection of gripper plays a vital role in robot manipulator's efficiency and performance.**

Keywords—robot manipulator, robotic grippers, soft gripper, hard gripper, robotic grasp, end-effector, classification, review

I. INTRODUCTION

Nowadays, robot manipulators are becoming one of the most important areas of interest for scientists, engineers, and even clinicians, not only as a novel and emerging research area, but also as an applicable and useful tool for many purposes. There are a wide range of definitions for manipulation and grasping, depending on different situations and applications. In general, however, mechanical manipulation may be defined as an act of exerting force or torque on an object causing motion or deformation, whereas holding an object can be termed as grasping [1]. Generally, manipulators have different sorts of applications. One of the common procedures performed by manipulators is grasping. For performance of a grasping task, each manipulator needs a gripper which is mounted on the end effector of manipulator. Manipulation speed, object shape, weight and other characteristics are important factors in choosing the gripper type. However, some smart grippers are designed for general purpose and different object shapes. As an example in [2], a versatile gripper is proposed for grasping objects with different geometries.

There are some scholarly reviews on special types of grippers. Birglen et al. provided a review on industrial grippers and comparison between various types of them [3]. In [3], the stroke, force, weight, power and finger length of industrial grippers are some features that are considered for comparing industrial robots. Minsch et al. in [4] present a review on composite grippers. In [5] and [6], a detailed review of soft robot grippers is presented. Agnus et al. in [7] provide an overview on recently-developed micro grippers. However, there is no published review paper that covers most types and a wide range of robot grippers. Therefore, the main contribution of this paper is to provide a brief and general review on various types of grippers and their classifications.

II. CONFIGURATION-BASED CLASSIFICATION

Based on the number of fingers and configurations of each gripper, various types of grippers are presented according to [8] and [9].

A. Robot Grippers with 2 Fingers

The 2-finger or 2-claw grippers are considered to be the most basic robot grippers as they are easily used and manufactured, cost effective and economical, and appropriate for many industrial applications. These types of robots have the ability to do various tasks such as assembly, pick and place, and simple manipulations.

B. Robot Grippers with 3 Fingers

The three-finger gripper consists of three rigid fingers to grasp an object. This sort of gripper is not as commonly-used as the two-finger type. In most applications the two-finger gripper is good enough to perform a task. However, a need for more accuracy and precision in grasping sensitive and fragile objects makes it reasonable to use this type of gripper in spite of their higher production price and greater complexity. As an example, an adaptive three-fingered gripper is illustrated in Fig. 1 [10]. As shown in Fig. 1, the three-fingered gripper is used to pick up rolled paper without folding, crushing or ruining.

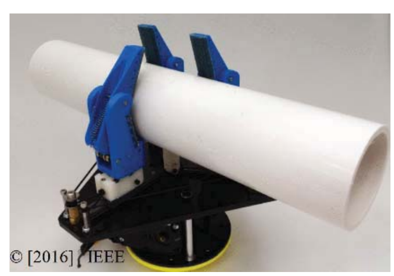

Fig. 1. Adaptive three-fingered gripper [10]

C. Robot Grippers with Flexible Fingers

One of the most innovative grippers are the ones with flexible fingers. Although they are suitable for grasping many types of objects, they are preferred when dealing with fragile objects. They can exert various amounts of force and/or torque on the object, depending on their size and application.

D. Multi-Finger and Adaptive Grippers

As a relatively new development, this design enables robots to grip a wide variety of products that were previously impossible to manipulate reliably. These grippers may provide force feedback to the controller and can also grasp irregularly shaped, soft or spherical objects.

E. Grain-Filled Flexible Ball Grippers

This gripper has a balloon that is filled with grain or other materials to pick something up. To hold the object, the air of the balloon is sucked up, causing a deformation in the gripper shape to match the shape of the object. The inspiration in the Flex-Shape Gripper [11], designed by Festo Company, comes from the way that a chameleon hunts an insect, based on how forces and configurations can fit to each other to build a Grain-filled flexible ball gripper. The Flex-Shape Gripper is shown in Fig. 2 [11]. This gripper with the aid of form-fitting has capability to pick up and grasp many objects of different shape in one grasping process.

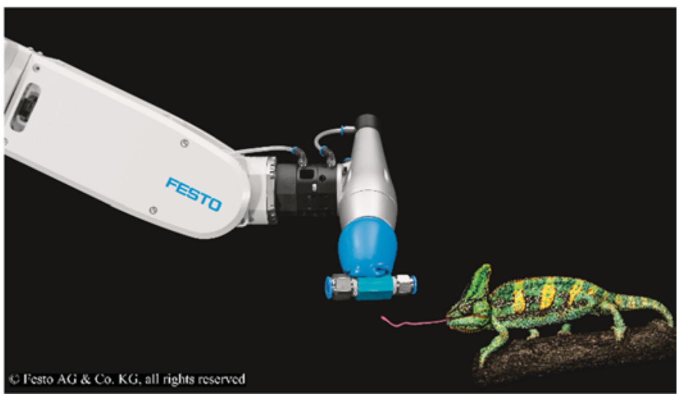

Fig. 2. Flex-Shape Gripper [11]

F. Bellows Grippers

The Bellows gripper is used to grasp a cylindrical surface. This type of gripper is filled with compressed air which results in expansion of the gripper and grasping the object. To drop the object, the air in gripper should be released [9].

G. O-ring Grippers

O-ring type is a special device designed to handle O-ring seals. The O-ring gripper has six or sometimes eight fingers that expand and grab the inside diameter of the O-ring [9].

III. ACTUATION-BASED CLASSIFICATIONS

From the actuation point of view, another type of classification is taken into consideration. The actuation method for each gripper is chosen based on the object characteristics [12].

A. Cable-Driven Grippers

In [13], a cable-driven gripper is designed with coupled 8 degrees of freedom actuated by only three motors as an example. Fig. 3 shows this gripper [13]. This gripper is equipped with force/torque sensors for control purposes. Cable mechanism optimally allocates weight and space to motors.

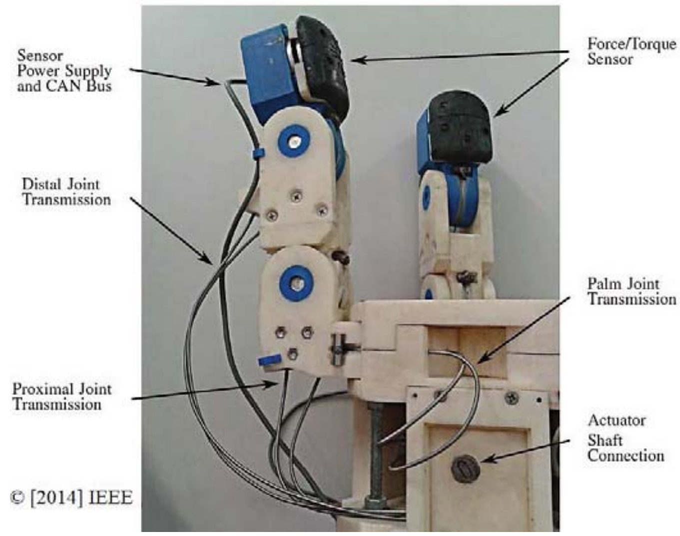

Fig. 3. Cable-driven gripper [13]

B. Vacuum Grippers

The Vacuum gripper is composed of a rubber or foam suction part to hold the object [12]. The advantage of vacuum grippers is that they have a high level of flexibility, while providing a good grip of an object. As air is clean and can be transmitted through tubes and hose, this type of gripper is preferred in applications in which contamination might be a problem.

C. Pneumatic Grippers

The Pneumatic robot gripper is a kind of bang-bang actuator. The benefit of pneumatic grippers are their small dimensions and low weight [12]. They have the same benefit as mentioned for vacuum grippers in terms of contamination.

D. Hydraulic Grippers

The Hydraulic grippers gain strength with the aid of hydraulic pumps. These types have a great capacity to produce high amount of force compared to other types of grippers. The force is generated based on the pressure buildup in different chambers of the actuator. The disadvantage of hydraulic grippers is that they need constant maintenance [12]. The advantage of hydraulic grippers is in holding the object even when the pressure supply is cut off, i.e., there is no need to supply energy when the gripper is in *still* mode, thus reducing the amount of energy in applications, in which, an object should be held for a long period of time without any motion.

E. Servo-Electric Grippers

The servo-electric gripper has a high level of flexibility. Therefore, it is not limited to deal with a special object. The most important part of the servo-electric gripper is an electronic motor used to control fingers or jaws. Easily controllable, low maintenance cost and high flexibility are the main advantages for these type of grippers [12].

TABLE I. compares grippers based on their actuation methods.

TABLE I. COMPARISION OF DIFFERENT ACTUATION METHODS

Gripper type	Advantages	Disadvantages
Cable-driven	Optimal weight and space	Control Complexity
Vacuum	Highly flexible Clean	Some operational issue
Pneumatic	Small dimension Low weight Clean	Not precise enough High operating cost
Hydraulic	High force	Not clean enough high maintenance cost
Servo-Electric	Highly flexible Low maintenance cost Easily controllable Clean	Low force

IV. APPLICATION-BASED CLASSIFICATION

Grippers are used for a wide range of applications from inspecting power lines [14] to grasping underwater objects. Therefore, some examples of application-based categories are provided in this section.

A. Surgical Application

Evolution in the development of grippers and advancement in their technologies help minimally invasive surgical techniques to benefit from the advantages of surgical grippers. In [15], the Minimally Invasive Surgery (MIS) gripper design with four degrees of freedom is investigated.

B. Assistive Application

Alqasemi et al. [15], designed grippers for people with disabilities [16]. Other examples of assistive grippers are mounted on Unmanned Aerial Vehicle (UAV) for search and rescue and the ones used in exoskeleton [17-18].

C. Industrial Application

It is important to achieve fast and secure manipulation. The requirement for speed becomes significant when the grasped objects are variable. As a result, commercial grippers come in different configurations [2].

D. Underwater Application

In [13], a few examples of systems for undersea grasping and manipulation purposes are presented. These grippers should be designed in a way that they can work well under water pressure and other conditions associated with manipulation of objects in such environment. An example of underwater grippers is illustrated in Fig. 4 [13]. The under water vehicle in Fig. 4 has a redundant arm and gripper and is used in [13] to show the efficiency of such grippers.

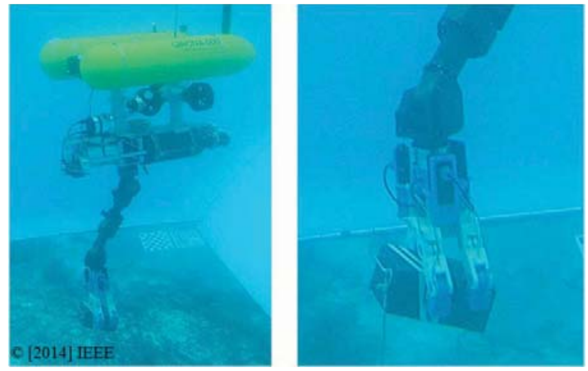

Fig. 4. Underwater gripper [13]

V. SIZE-BASED CLASSIFICATION

Robotic tools attached to the end-effector of the robotic manipulators are designed and manufactured in different sizes, from miniature and micro size to huge grippers. Their size is determined based on manipulation scale, accuracy, and precision needed. For example, for surgery, pick and place or other delicate tasks, accuracy of hundreds of micrometers is needed. At these scales, surface forces become dominating in comparison with other forces [7]. Fig. 5 indicates a sample of a micro gripper [7]. Therefore, from this point of view, design of micro grippers become a challenging issue. On the other hand, big robot grippers are commonly used for industrial purposes and suitable for bulky objects [8].

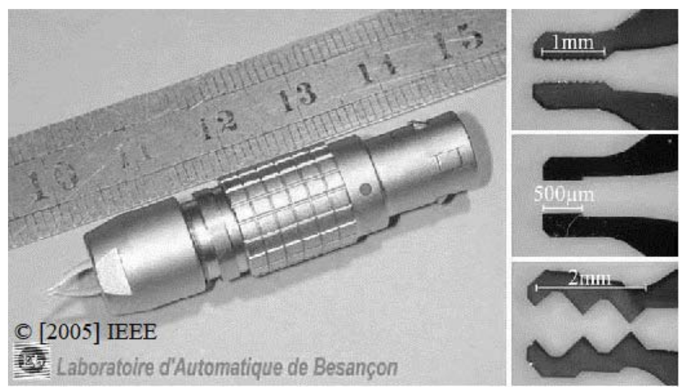

Fig. 5. Micro-gripper (left) and finger tips (right) [7]

VI. STIFFNESS-BASED CLASSIFICATIONS

Based on grippers material stiffness, they can be allocated into two main groups.

A. Rigid Grippers

Traditional robotic grippers mostly consist of a set of rigid joints and links. Since these grippers were used in industrial applications, they comply with the industrial environment to provide high precision and large force with less necessity to be flexible [6].

B. Soft Grippers

When comparing soft grippers or flexible grippers to rigid grippers, end-effectors fabricated from flexible and soft components can often grasp or manipulate a larger variety of objects. The soft end of effector is an essential device for medical robots where soft and gentle motion is required [19]. In [5], a detailed review of soft grippers is presented. In Fig. 6, a soft-bodied gripper with integrated curvature sensors for shape control is presented [20]. The flexibility of grippers allows different possible configuration to pick various shape objects.

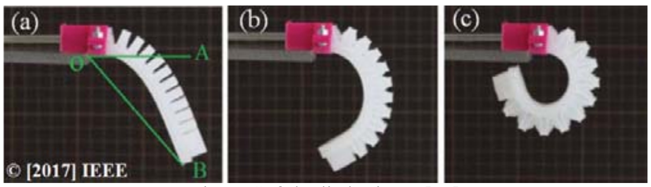

Fig. 6. Soft-bodied gripper [20]

VII. Conclusion

There are many sorts of classifications for robot grippers. Each can be used for different purposes. To design a gripper, there are some factors and requirements that need to be considered. The amount of force and torque that should be produced is one of the main factors. Also, it is important to have enough knowledge about the object to be grasped, including its shape, geometry, material, stiffness and weight, which are some characteristics that seem significant in designing and choosing a gripper type. Considering manipulation criteria and its limitations such as speed of manipulation is another important factor to be considered in choosing a suitable design for a gripper. This paper provided a brief summary and classification of different types of robotic grippers as a helpful guideline for design engineers.

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