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A SYSTEMATIC STUDY ON ADVANCEMENTS OF MULTI-FINGER GRIPPER

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COVER LETTER

ABOUT THE PAPER

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Abstract

Now a days, manipulators are being used for many applications to make works easier or reduce the risk of works which seemed impossible, risky or difficult for human being. Robotic manipulator may be prepared with diverse sorts of end effectors to accomplish various tasks. The grippers being one of the most frequently-used robot end-effectors of arm tools. In robotic hand system for application, various kinds of grippers are required. Hence, proper selection of the grippers plays a very important role in the process of design. There are very low amount of papers which describes the advancements of the grippers. This paper gives an exhaustive review on diverse types of grippers and their state of art. The aim of presented paper is to give a brief idea on diverse classifications, as correct choice of grippers proper plays a crucial role in robot manipulator's proficiency as well as performance.

Keywords—robot, robotic grippers, grasping, end-effector

1. Introduction

As the interest toward humanoid robots is increasing rapidly [1], development of human hand-like robotic hands have become a major objective, and many research projects are being carried to accomplish this. Some examples of this project include, the Robonaut hand 2 by NASA [2], the DLR hand II [3], the ultralight hand by Karlsruhe university [4]. The first robotic gripper was developed by Victor Scheinman, a student of Stanford University in 1969 [5]. Although this was the first computer control gripper, it had its limitations like being uncontrollable and dangerous to handle. In 1990, MIT developed an advanced version of robotic gripper called Barrett hand, which consisted of 3 fingers, servo motor and brushless DC motors [6].

While discussing robotic hand and grippers, an important term that should be noted is dexterity. Dexterity means the propensity of hand to cope with objects and actions. This means we are a step closer in integrating robotics in our daily lives [7]. The artificial hand can be used in so many applications we can't even possibly imagine. This means these systems can be programmed in such a way that they not only make our life easier but can even be used for scientific purposes.

In previous review papers of robotic grippers, the emphasis was more on their specialized applications. In [8,9], the use of grippers in robotized creation measures was talked about. Various kinds of grasping frameworks, as counterfeit vacuum, attractive and mechanical holding, were canvassed in [10]. In [11], just equal controller gripper components were investigated. In [12], grippers utilized in careful practices can be found. Just double arm control was examined in [13]. In [14], space robots were surveyed. Robots utilized in plant creation were canvassed in [15]. In [16], the contact systems for miniature parts were analysed. In [17], end effector control plans were covered. Some cutting-edge instances of grippers incorporate the Kuka KR 1000 Titan; Dexter on the International Space Station; the Explosive Ordnance Disposal controller on the iRobot 510; and the da Vinci Surgical controller [18–21].

The robotic arm is used in multiple industries as well as in the low-cost planetary exploration missions [22], bomb defusal prosthetic [23] and much more. The researchers even suggested that they can be even used as artificial limbs. These arms are also being used in surgeries. Earlier these arms had limited applications and were mostly used in automotive manufacturing and assembling plants. Their application included material handling, welding, drilling, and painting. But today, they can be seen performing multiple tasks in various fields, such as bomb defusal, underwater and planet exploration, surgeries. Prosthetic limbs are now available in different sizes, involve different mechanisms, are lightweight [24] and can be selected with respect to the application. Presently, robots in automotive industries have resulted in a precise and agile manufacturing process [25]. The Asian dream of human beings is to replicate themselves. For years, many universities and researchers have worked extensively on humanoid robotics. The main aim is to develop such machines that are intelligent and more precise.

Our paper focuses on robotic gripper, their classification, and the types of robotic gripper such as vacuum, pneumatic, servo-electric, and hydraulic grippers. Multi-finger grippers and their classification on the basis of the number of fingers has also been discussed in this paper. The arising uses of multi-finger grippers in different spaces, for example, in clinical, horticulture, miniature and nano control is additionally included. We accept this paper will help scientists and industry find advance getting a handle on instruments. We finish up our paper by discussing about the challenges and future opportunities in this area.

The remainder of this paper is coordinated as follows: Section 2 covers a concise presentation about automated grippers coordinated by their grouping, Section 3 exhibits multi-finger grippers with their applications and models, Section 4 examines the future heading and conversation of automated grippers, and Section 5 closes the paper.

2. Robotic Gripper

The easiest way to understand the gripper is to relate it with the human hand as both work in a similar way in holding, tightening, handling, and releasing a work piece [26]. The most distinguished thing about the human hand is that it can manipulate itself according to task [27]. Grippers act as a dynamic link between the robotic arm or grasping equipment and the object to be acquired or work piece [28]. There are secondary systems of handling mechanisms which provide a short-term contact with the work piece or job to be grasped [29]. Various research is being carried out to increase the degree of freedom of robotic grippers so that they can adapt to any task just like the human hand [30]. A robotic gripper system consists of an arm, which is a chain of links that are brought into motion with the help of actuated motors [31]. Then a robotic hand or end-effector is actuated on one end of the chain. The advanced anthropomorphic robotic hand system contains actuators, microcontroller, sensor, and mechanism. In this system grasping is achieved by deploying a set of procedures and operations that must be developed to hold/manipulate the object. The microcontrollers are the processing unit of the robotic arms and drive controllers act as the brain of the robotic system [32]. Since the robotic gripper is a machine, it cannot estimate its state or environment. To get an actual idea of the surroundings in complex environments, these systems are fitted with various sensors [33]. For example, proximity sensors are used to detect nearby objects [34], tactile sensors are used to sense the object via physical touch [35].

2.1. Classification of Grippers

The robotic gripper is extensively arranged into four primary groups [36-37]. Impactive (a direct mechanical force is applied to physically grasp the object), Ingressive (prehension of the object is achieved by physically penetrating the object surface), Astrictive (a binding or attractive force is applied to the surface of object), Contigutive (an immediate contact is required to provide an adhesion force to grasp the object) [38-40].

Table 1: Classification of Grippers

Grasping Technique	Type	Example
Impactive		Clamps (external fingers, internal fingers, chucks, spring clamps). tongs (parallel, shear, angle, radial)
Ingressive	Intrusive	Pins, needles, hackles
	Non-intrusive	Hook and loop
Astrictive	Vacuum Suction	Vacuum suction cup/bellows
	Magneto-adhesion	Permanent magnet, electromagnet
	Electro-adhesion	Electrostatic field

Contigutive	Thermal	Freezing, melting
	Chemical	Permatack adhesives
	Fluid	Capillary action, surface tension

2.2. Types of Grippers

For an operation, to grasp an object a direct contact is made between the gripper and the object, so it is very crucial to select the appropriate type of gripper for the operation to work effectively. Grippers are divided in four categories[41]. These are:

2.2.1. Vacuum Gripper

These types of grippers are very flexible due to which they are widely used in manufacturing processes[42]. In these grippers, rubber or polyurethane suction cups are used to lift the object. In some grippers, a layer of closed cell foam rubber is used in place of suction cups. [43] These types of grippers can handle and pick uneven objects of any type of material using either miniature electromechanical pumps or compressed air driven pumps are used.
Kenos KVG vacuum gripper is show below, [44]

2.2.2. Pneumatic Gripper

These types of grippers are compact in size and have light weight [45]. These grippers are suitable in the manufacturing industry to perform tasks where the space available is very less. In this gripper, the gripping fingers are moved and rotated by the effect of compressed air. They can hold from small objects to large and heavy objects [46].

2.2.3. Hydraulic Gripper

The strength of these grippers is very large and are suitable to perform the operations where a huge amount of force is required[47]. The strength of these grippers is produced by using pumps. Among all the types of grippers, these are strong but heavier than other grippers because of oil used in its operations [48].

2.2.4. Servo Electric Gripper

These types of grippers are widely used in industries because these grippers can easily be controlled by an operator[49]. In this the movement of the gripping finger is controlled by an electric motor. These grippers are very flexible and different objects can be handled using them. They are cost effective as there are no air lines present in them [50-52].

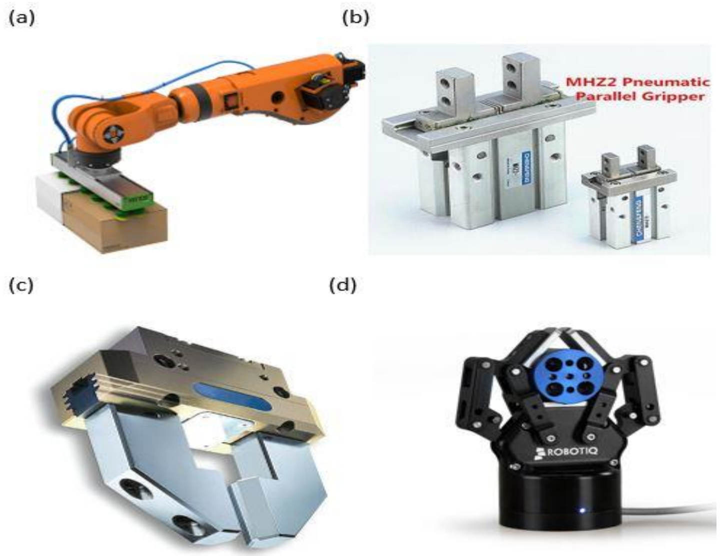

Figure 1: Types of Robotic Grippers; (a) Kenos KVG vacuum gripper, (b) MHZ2 Pneumatic Parallel gripper, (c) Hydraulic Gripper, (d) Servo-Electric gripper

3. Multi-Finger Robotic Gripper

Much research have been done and still going on in developing multi-finger grippers [53]. Multi finger grippers are defined as the grippers having fingers more than one, these types of grippers are used for service sectors where the handling objects did not have the specific shape and also called as exterior grasping [54]. In grasping an object, a multi-finger gripper is suitable because it provides more contact area for gripping. For gripping an object, the jaws are initially open and then close around the central pivot, having an arc motion. Angular grippers are generally used where the working space is limited. [55]. When jaws are required to move up or out of the way. External gripping is the most widely recognized approach to hold the end power of the gripper which is utilized to hold the part.

Robotic three-fingered hand, Shadow robot hand and IH2 Azzurra hand are the examples of Multi-fingered grippers [56][57].

3.1. Classification of Multi-Finger Gripper

On the basis of fingers, multi-finger robotic grippers are classified as below.

3.1.1 2-Finger Robotic Gripper

The two-finger robotic grippers consist of two jaws or fingers to grip the objects, it is easy to operate in performing automation activities in industries. It is able to handle objects which vary in shape and size. The 2- finger robotic gripper is well suited for the process of manipulation in industry, it is used to grip the object and then place it to the predefined location in different activities performed in industries like assembling, quality check, etc. Many other tasks are also achieved by using these grippers because of having 2 different grip strokes and highly adaptive nature [58][59].

The mechanism used in driving the gripping fingers is enhanced to get two discrete contact regions, in which the one region is named as encompassing grip region, and it is located at the bottom of the fingers, and the other region known as pinch grip region, and is located on the top of the finger. There is an equilibrium boundary between these regions[60].

During grasping an object, if the contact between the gripper and object is made in an encompassing grip region, then the gripping fingers will automatically curl around the object according to the object's shape and size.

On the other side, if the contact lies in the pinch grip region, fingers will continue its parallel motion whereas the object will pinch [61].

3.1.2 3-Finger Robotic Gripper

A 3-finger robot hand with force torque sensor which can hand pick an object. It has the 5 degree of freedom., and 5 possible numbers of acts (flexion-03, fingertip-01, rotation-01). All the fingers can be controlled independently, and the fingertip angles of all fingers are controlled by one motor. The 3 –fingers are moving towards the central axis to grip the object at the centre of its axis. 3-finger grippers are found to be the best option because of having very good versatility and flexibility. These grippers can grip objects having different shape and size. 3-finger grippers are compatible with most industrial robot manufacturers. Because of its versatility with the position, force, and speed control for every finger and four different grip modes, it can almost grip any type of object. The values of grasping force and its speed can be pre-set, where the capability of the robot is to produce a grasping force of up to 60N.

The grasping performance of a 3-fingered gripper can be analysed in four different grasping modes. The very first one is cylindrical mode (also called basic mode) and is used for the objects having one side longer than the other. The second one is called spheroid mode (wide mode), it is used for round or long objects. The third one called pinch gripping mode is perfect for small brackets that have to grip precisely. Fourth, scissor grasp mode is intended for very small objects. This mode is not much more powerful than the other modes because of the involvement of only two tips in this mode. For most of the grasping mode we can do Fingertip Grasp or Encompassing Grasp. To speed up the grasping mode we have partial open-close features available.

One three-finger robotic gripper was developed [62] and then improved by integrating this with a feedback sensor system [63], this contains 87 touch sensors distributed over the end effector's surface.

3.1.3. 4-Finger Robotic Gripper

The four-finger robotic gripper can grasp an object with the help of two fingers having the same rotating centre, and then the base joint is rotating until the object reaches its pre-set position. After these the remaining two fingers come in action to perform the task. These grippers can be used for tasks like opening and closing of a bottle's cap . Both human and robotic hands realize the same task, but the execution of the task is different. Main difference is that the human hand requires both hands for the completion of a task successfully, but in the case of a robotic hand, it utilizes a pair of hands with an arm.

For 4-fingered robotic grippers, the dual turning mechanism was introduced to generate the common rotating axis for the base joints, in this the fingers work in pairs of two, meaning rotating of inner and outer circles using gear trains. Around the axis manipulation is fully decomposed into the velocity control (around the axis) and the internal force control (in the contact line). So, the rotating motion of the object can be attain around the axis, through velocity control for base actuators, along with the internal forces imparting by other actuators. [64]

PZV is a four-finger concentric gripper developed by SCHUNK. This gripper comes into use when two and three finger grippers are not able to grip the object, for example to grip a cylinder [65].

3.1.4. 5-Finger Robotic Gripper

The 5-finger robotic grippers are very much similar to the human hand which are equipped with four fingers (little finger, index, middle, fourth) and one thumb of a human hand. Every finger has an installed actuator which makes the finger start moving. Each finger has one DOF which is responsible for its rotational movement. The thumb is designed in such a way so that the gripping is strong, for having good gripping control and appearance a thumb is provided with two degrees of freedom, means that the thumb is able to flex as well as extend. All fingers except the thumb have been designed such that each finger has 1 degrees of freedom. Servo DC motors attached to it which provides the motion to the fingers. DC servo motor also controlled the extension fingertip in order to drive the rack and pinion. [66]

SCHUNK has developed the world's first robotic gripper named SVH having five fingers, which is nearly similar to that of the human hand, it contains nine drivers due to which different gripping tasks can be done with high accuracy and sensitivity. A reliable gripping is done by using elastic material for the gripping surface of the fingers. All electronic parts are integrated into the wrist. The design of SVH is compact [67].

Figure 2: Multi-finger Robotic grippers; (a) 2-finger Robotic gripper, (b) 3-finger Robotic gripper, (c) 4-finger Robotic gripper, (d) 5-finger Robotic gripper

3.2. Applications of Multi-Finger Robotic Gripper

As discussed above, there are various fields where the robotic grippers are used. Some applications of robotic grippers are discussed below:

3.2.1 Industrial Grippers

At the very beginning of the robotic world, the grippers were produced for modern applications. The fundamental goal of developing the grippers is for mass production in the industry. Some points to be considered for developing an industrial gripper are, i.e., structure of the gripper and its orientation, both static and dynamic equilibrium of the gripping object [68][69].

In 1961, the first industrial robot named UNIMATE was developed and General Motors invested in it to use in their assembly plant [70]. This manipulator was so rigid as able to grip the hot die cast iron[71].From that point forward, a considerable lot of the organizations began utilizing mechanical holding innovation and they likewise built up their diverse drive instruments[71].

Industrial grippers are divided into two categories:

3.2.1.1 Grippers for Familiar Environment

In this the surrounding conditions are well known the specific task grippers are used for this condition. Assembly line of an industry lies under this condition, where information like position of the object, and the path on which the gripper is to move to place the object are predefined and the gripper can easily pick and drop the object. Different types of sensors like ultrasonic, accelerometers and photoelectric are used to determine variables like position, force, velocity, torque and acceleration [72].For a functioning forecast, arranging, and execution of the framework for catching moving articles vicinity sensors have been mounted on grippers. Schunk DPG-in addition to and Robotiq 2-finger grippers are some popularized grippers[73][74].

3.2.1.2. Grippers for Unfamiliar Environment

In certain applications, grippers are needed to work in an unexplored environment. In designing grippers suitable for working in unknown conditions, different systems such as feedback system, vision systems are used. Cameras can also be used to detect the objects near it during an operation. A gripper was developed which includes a camera system and was used to grip the random objects from bin [75].

Many improvements have been done and still much research are going on in vision systems and other devices to make the grippers suitable to grip the objects in an unknown condition[76][77]

3.2.2. Grippers to grip Fragile material

As lots of improvement is carried out in the sensors used in grippers, now the work is carried out in gripping the fragile material. An end-effector sensor was developed for the purpose of harvesting the lettuce [78]. In this gripper a machine vision device is used along with six photoelectric sensors and fuzzy logic controllers. By introducing this robotic gripper in harvesting the lettuce, the rate to plant the lettuce was increased to 5 second / lettuce and the success rate of 94.02% was achieved.

A gripper was developed to grip the food, it contains a feedback system to track whether the task is going on effectively or not [79]. This gripper works on the principle of magnetic field, making one finger at rest and the other finger will start moving when the magnetic field comes into action. The actuator is introduced inside alongside the inward magnet and the external magnet is dependable to turn the finger. One more design was developed for the purpose of gripping fruits [80]. This gripper was developed for both the purpose of holding and chopping fruits, these grippers are effective because it does not damage the fruits during chopping.

After achieving success in developing a gripper for gripping and chopping the fruits, a new design of gripper was developed which works on the principle of Bernoulli for the purpose of gripping the chopped fruits and vegetables [81]. In this air was used as the working fluid to lift the fruits, the contacting area was reduced by making the air to flow on the surface of the fruit. It is also able to decrease the moisture content present on the surface of the fruits and vegetables, which can be considered as one of its advantages.

A gripper was developed to evaluate the durability of the mangoes [82]. To test the ripeness of the mangoes, a sensor named accelerometer is used which was encased in the fingers of the gripper. Furthermore, for deciding the adequacy of the gripper, the experimental values are compared to the ripeness index.

There are lots more grippers developed for picking different materials like, different grippers are developed to grip material like tomato and cherry [83][84], both have different gripping designs.

And many more developments and improvements are carried out for the task of gripping different fragile objects, in all these the main focus was on designing the feedback system and making the gripper flexible so that we can apply them in gripping different fragile objects.

3.2.3. Medical applications of Grippers

In early stages of robotic grippers, the grippers developed are only for specific work, there is no feedback system available to manipulate the output as per the input conditions, this became the major problem with these grippers in the medical field and due to this the tissues in humans can be damaged during a surgery.

Development of soft grippers was started to conduct surgeries efficiently without harming the tissues. This gripper makes secure contact with the tissues during the operation.

For the surgeries which are performed through tiny incisions, a soft body gripper was developed which makes the secure contact with the tissues to perform the surgeries in an effective manner [85]. This gripper was able to generate a force of up to 1 N to grip during the surgery. The design of this gripper can easily scale to develop different sizes of grippers and the elastomeric material was used in the process of fabrication.

One more application of the robotic gripper in the medical field are the surgeries where the robots are assisting the doctors in performing different tasks. In surgeries using robotic grippers, the main concern is in the automation system and the safety of these grippers, as any failure or time lag in the control system can cause injuries to the patients and sometimes may lead to death.

A micro gripper was developed having the star shape for the purpose of removal of tissues [86]. After performing many experiments on living test animals, this was proven effective in removing the tissues in an operation without affecting the other inner organs of the body. A Conventional process of multilayer microfabrication was used to fabricate this, and the actuation process was based on the principle of magnetism.

For some applications in the medical field, grippers are developed which were based on the methodology of suction [80] and the purpose was to grip and lift both small and large intestines which are very flexible and slimy organs in the body. Manual pump and vacuum pump both are used for suction processes, but it is not determined which one is more effective for this application.

A small-scale gripper was developed for the task of revoking the process in minimal invasive surgery [87]. It can produce a gripping force which is up to 5.3 N. Brushless motors were introduced for adding one more degree of freedom to improve the overall performance.

A gripping device was developed using a soft pneumatic system for the purpose of manipulating the tissues [88]. This gripper is able to lift the object up to 2 mm at very small gripping force.

Many experiments are carried out in improving these medical grippers for making them more effective and easier to use in different surgeries. And the main focus is to control the gripping force for different operations to make surgery effective without affecting other organs.

3.2.4. Grippers of micro and nano size

Lots of research is carried out in developing grippers which are capable in gripping and lifting the micro and nano sized objects.

Micro-electromechanical Systems (MEMS) were designed for gripping the objects at micro level. The major application of these grippers is in semiconductor industries where assembling process is performed on wafer substrate [89]. These grippers are also effective for the tasks where biomaterials and nanomaterials are used [90].

Micrograppers are designed by hybrid the micro-electromechanical systems which includes the comb drive actuators having integrated vacuum devices [91]. A deflection of 25 μm can be achieved at the top of the arm and can easily pick the objects having the size between 100 to 200 μm.

A gripper was created in which the actuation process was done by thermal bimetallic material [92]. The designing of this gripper was carried out by integrating the nanofabrication technology with conventional microlithography in fabricating the gripper having size less than or equal to 100 μm.

An electrostatic gripper was developed which was able to sense the contact of the gripper with the object using the capacitive sensors [93]. It can easily grasp the object of size as small as of 12 μm at 55 V as driving voltage.

A microgripper was fabricated using polymer which was manufactured from SU-8 [94]. A sensor is embedded in it to determine the tensile force, and the actuation process is based on the principle of electro thermal effect. This gripper can displace the object up to the distance of 100 μm per 50 cycles and the force developed by this also varies.

A microgripper is developed having two fingers, Furthermore, ready to play out the assignment of controlling the position of the object at high velocity [94].

Electrostatic gripper was designed to grip the standard micro sized components [95]. This gripper was able to pick and drop the materials of different shapes and of dimensions which varies between 0.3mm to 0.1mm.

A contiguous gripper was developed in which the layer of liquid water is used between the object and the gripping finger [96]. In this the water gets frozen to ice, and this ice sticks to surfaces of both the object and the gripping finger.

As the technology is advancing daily and lots of inventions and improvements are going on using micro and nano sized particles. So, to handle these particles manually is very difficult and to overcome this problem many researches are carried out and a lot more are going on in developing these types of grippers which are reliable, cost effective and easy to use.

3.2.5. Grippers for Soft Fabric

It is difficult to grip the fibric material by using normal grippers. So, it was a big challenge for the researchers to develop a gripper which is effective in gripping the fabric material having very small thickness. These grippers are also known as ingressive grippers and the application of this gripper is in textile industries to grip the fabric.

A spur wheel was used in developing one of the initially developed grippers, it easily detaches the different sheets of the fabric from each other [97]. At that point the improvement was finished by changing the plan of the gripper [98], and it had the option to isolate the back-cover sheets from the material[97].

Suction-Cup grippers were designed for gripping the fabric material [98]. Designing of this gripper was problematic because during the cutting of fabric, the fabric material should not deform. This has holes on a flat surface of 0.5cm diameter for the process of suction and the outer holes of 0.1cm diameter to maintain positive pressure. Part handling can be improved by using a proper feedback system.

To grip the profiles of different shapes like C and L, the grippers having suction cups was improved, it grips the fabric material by unfolding the fabric in different phases. Also, by revising the shape of the gripper we can achieve various shapes of the fabric [99]. For picking leather plies a suction cup was designed which was highly reliable [99]. Advantage of this adaptable attractions cup was that it does not leave any stamp on the calfskin.

A direct contact gripper called constitutive grippers is also used for gripping the fabric material, in this the gripping is done due to the chemical adhesion. Grip interaction can likewise be performed thermally by liquefying the surface to stay with the fibric. A permatack cement alongside contact cushion is utilized in textile industries[100].

As discussed above, suction cup grippers are very effective for gripping the fabric material and the methods to make the gripping fingers stick with the fabric is continuously improving for getting better results[101].

3.3. *Anthropomorphic*

Anthropomorphic grippers contains more than two grasping organs, and their design resembles that of the human hand. The fingers may be solid or adaptable and their numbers vary from 3 to 6. Fully anthropomorphic hands with multi-connected jointed fingers possess great technical capabilities but has little industrial relevance [102].

3.3.1. *Jointed Finger Gripper*

The getting a handle on and control capability of the jointed finger hand is resolved generally by its kinematic structure. The ideal number of joints is three for each finger. The driving components are more convoluted for multi-jointed fingers since they should be initiated past a solitary level of opportunity. The drives and their interconnections should be acknowledged so that it is unimaginable for any piece of the component to arrive at a "dead point" along these lines hindering other joint developments. [103]

3.3.2. *Jointless Finger Gripper*

The grippers fingers depicted in the accompanying have no mechanical joints. Their construction depends on extraordinary materials, i.e., they have adaptable material joints. This impressively lessens the quantity of segments and therefore the cost. Notwithstanding, the heap conveying limit of such grippers isn't exceptionally high [104].

3.4. *Dextrous*

The robotic hand is also a type of robotic gripper which resembles a human hand. While discussing robotic hand and grippers, an important term is to be noted for dexterity. This means the ability of the hand to cope with objects and actions. Multi-finger grippers with moving finger joins are planned chiefly for control assignments requiring a specific measure of mastery like that of the human hand. Thus, these grippers are regularly known as dextrous hands [105].

Table 2: Examples of Prosthetic Hand

NAME	YEAR	FINGERS	DOF	CONTROL TYPE
i-limb[106]	2007	5	6	This prosthetic hand is myoelectric and employs five individually powered digits. Muscle signals called triggers are used to command the hand for activating a specific grip.
Vanderbilt hand[107]	2009	5	16	This hand uses brushless DC motors and servos. Joint coupling method = single cable for each finger
MLR/MPL hand[108]	2012	5	26	The arm and hand employs more than 100 sensors. At the individual joints, sensors measure angle, velocity, and torque. Sensors are present on the fingertips which measures force and vibration and temperature.
Osprey hand[109]	2015	5	5	Wrist flexion
Cyborg beast hand [120]	2015	5	5	Wrist flexion

K1 hand [121]	2015	5	5	Wrist flexion
Odysseus hand [123]	2015	3	3	Wrist flexion
Imma hand[110]	2017	5	6	Wrist flexion
Luke arm[111]	2017	5	18	This hand uses 100 microelectrodes that are attached to the nerves in the upper arm, and to an external computer. When in contact with an object, a burst of signals is immediately sent up the nerves to the brain, after which it stops gradually.
Taska hand [124]	2018	5	8	This hand uses myoelectric sensors to detect muscle movements.
Vincent evolution 3 [125]	2018	5	6	It uses adaptive grip, vibrotactile feedback and EMG sensors.
Bebionic hand[112]	2019	5	6	This hand uses 5 actuators and is controlled by sensors placed all over the muscle.
Hero arm[113]	2019	5	5 (for 3 motor hand) 6 (for 4 motor hand)	There are special sensors present within the arm socket that helps in detecting muscle movement and flexes. This results in an effortless and easy control of the bionic hand.

Table 3: Examples of Advance Grippers

NAME	YEAR	FINGER	DOF	CONTROL TYPE
DLR HIT hand 2[114]	2008	5	15	This hand involves the use of super flat brushless DC motors and small harmonic drives. Serial communication system which connects inside the finger to attach the finger links with a minimum number of cables.
Dexhand[115]	2012	4	12	The actuation system of this hand is based upon the geared motors which is followed by a tendon transmission system. The motors are controlled using a combination of a DSP, FPGA and motor controllers.
Shadowhand [116]	2012	5	20	Motor hand uses 20 DC motors in the forearm Pneumatic muscle hand is powered by 20 opposing pairs of 20 air muscles in the forearm. The motor hand employs force sensors for each degree of freedom.

Mac hand [117]	2014	4	12	Each finger in this hand is independently actuated with the help of four motors. The control is operated by four microcontrollers ie. one for each finger. The coordinated control of the hand is attached to a supervision computer which is connected through a CAN bus link.
EH1 Milano hand [122]	2015	5	11	In this hand, the modular actuation units are kept in flanges and customized for the operation. The cable transmission permits the remote actuation which results in enabling the use of a low payload arm.
Mia hand [118]	2018	5	5	In this hand, there are three motors embedded within the hand which permits the hand to interact with the surroundings. Embedded functions and a simple control interface based on RS-232 makes integration seamless.
DLR CLASH 3F hand[119]	2018	3	7 (3 DOF for thumb)	This hand employs two Arduino Micros (Atmel ATMega32U4) which can control up to five servos with their timers. The servos used in this hand are Bluebird BMS-3900 MH.

Figure 3: Examples of Robotics Hands; (a) Osprey han, (b) Cyborg beast hand, (c) Mia Hand,

(d) DLR HIT Hand -II

4. Discussion and Future Scope

Ongoing headways in the field of mechanical and electronic designing just as material science have made the gripper more dependable, quicker, more secure, and heartier. These advances have brought about presentation of robots in applications zones like versatile climbing robots (e.g., JPL's Rock-Climbing Robot), bouncing robots, space satellites, submerged robots being utilized in investigation and pipeline fix, fast assembling, and automated medical procedure. These advancements have acquainted fields for researchers with research on utilizing new materials and plans just as joining new innovations in automated frameworks. Ongoing headway in automated gripper are examined beneath:

Versatile and self-versatile grippers: these grippers furnish adaptability in getting a handle on objects with various shapes in modern frameworks, for example, Festo Power Gripper, Finger Adaptive Robotiq, SARAH in global space stations.

Measured grippers: they comprise of standard parts, for example, finger type grippers, vacuum cups, and finding pins. These grippers are being utilized in regions where superior and adaptability are required, for example, gathering activity in space. They can cling to changes in physical, mathematical, compound, and mechanical properties of the items essentially by utilizing distinctive standard grasping segments.

Reconfigurable grippers: these grippers can change into various explicit setups and pick various articles. These grippers have applications in the car industry and space advanced mechanics.

Brilliant material-based grippers: these grippers utilize keen materials for getting a handle on objects with separate shapes, for example, getting a handle on by molecule sticking (e.g., granule-filled sack), electrorheological (ER) liquids, Giant ER Fluid, ER liquid with electro bond, pneumatic actuators, and shape adaptive paddings. Albeit these grippers are being utilized in industry since long time, on account of their straightforward activation system and low weight, executing this innovation in mechanical getting a handle on is as yet testing because of their lower holding powers contrasted with regular grippers, these are moderate actuators, and there is a control issue in accuracy incitation of these materials. The examination is proceeding to build the holding power and accuracy. This incorporates creating regulators, for example, awful power control, sliding mode control, and ANFIS regulators. It ought to be noticed that electrostatic fascination gives more noteworthy aptitude since they utilize film like layers.

Novel system plan grippers: these grippers give adaptability with a base required management by executing keen components, for example, bionic taking care of associates into the grippers. The essential target of these plans is to have superior with less control exertion.

Delicate grippers: Multiple plans of delicate grippers have been grown, for example, electro attachment grippers, single and multi-fragment grippers, counterfeit muscle delicate mechanical grippers have been created. These grippers can mirror a human's hands. Adaptable, tiny hand-like gripper can help specialists in distantly directing surgeries or performing biopsies. A considerable lot of these plans join delicate mechanical technology and fake skins for easier control and uninvolved variation. Delicate materials empower grasping robotization past the limits of current innovation. A benefit of delicate automated grippers is halfway assuming liability of the preparing part by the actual properties of delicate grippers not at all like inflexible grippers. Be that as it may, utilizing delicate quality into the plan of grippers requests another variety of plan and control standards contrasted with hard grippers. There are continuous endeavours to improve grippers in two-overlay: execution and adaptability. Execution shows accuracy, spryness, coherence, holding strength, versatile, and adaptability imply an assortment of articles that can be gotten a handle on. The vast majority of the test in this angle is whether articles are known or obscure. At the point when one is working in obscure items, the goal is to execute adaptable grippers, while in working in known conditions, the goal is to build the exhibition. Achieving adaptability and execution at the same time is as yet testing as expanding execution, diminishes the adaptability.

New advances are being done to build adaptability: grippers having fingers like human hands are one of the models, which fuses control frameworks receiving input from the collaboration between the gripper and the climate to imitate people getting a handle on. Nonetheless, doing this requires a lot of calculation and it is unpredictable as far as preparing. Albeit creating automated grippers like human hands is as yet troublesome because of detecting and activation, the utilization of counterfeit robots in enterprises and society will increment altogether later on.

Execution improvement is application subordinate. Expanding execution can be accomplished through a plan of hearty regulators, usage of sensors and amazing actuators just as actual plan. Regarding detecting, scientists will keep on imitating the human holding capacities. Vision detecting is foreseen to develop to build the learning capacities of mechanical grippers with deficient information on the general climate. What is more, consolidating visual criticism in the plan of grippers empowers them to adequately speak with obscure conditions making them powerful. For activation, fake muscles actualized in mechanical hands would possess the power and thump of the characteristic muscle and are equipped for copying the versatility of human hands. This will make holding simpler as well as more intelligent and more secure. By presenting the headways in materials just as innovations in detecting and activation, clearly the presentation and versatility of robot grippers will be extended.

Grippers having mechanical effortlessness and power like double arm gripper versus grippers with adaptability and versatility like fake hands are extraordinary targets in automated holding. Effortless mechanical grippers need simple control design and hence broadly utilized in light of low cost and straightforwardness of usage. Furthermore, their applications become restricted with regards to getting a handle on articles with power control, getting a handle on items with odd shapes, or explicitly getting a handle on conditions. In these applications, utilization of grippers with greater flexibility as that in multi-fingered grippers gets helpful with the expense of control design intricacy.

Continuous movements and applications exhibit that fragile grippers are one of the backcountry later on in robot grippers for certain applications. The emerging applications are by and large in industry and clinical. Using these movements in industry will improve the introduction through and through as definite; regardless, the cost of changing the current advancement and reviving them with the new degrees of progress is high. In clinical applications especially in mechanical operation research is at this point going to outfit operations with ensured, overwhelming or more all strong parts.

5. Conclusion

In studying about the robotic grippers, we found that the need for robots in different fields like automobile industries, medical field, individual use and for industries working with micro and nano particles is increasing continuously. In today's world the main focus is to design and develop the grippers to perform different types of tasks. We have discussed different types of grippers each have their own advantages and limitations. There are so many grippers developed and improved for specific tasks. Soft grippers are developed to grip fragile materials and for medical surgery. The most difficult task in the robotic industry is to develop the robotic gripper to handle the fabric materials in the textile industry and there are grippers developed which are suitable to grip and handle these fabric materials.

The robotic industry is focusing on developing multi-finger robotic grippers which will be replicas of the human being's hand and can be used in place of humans for performing all types of work to increase the efficiency of the task and to save the human being's life by performing dangerous tasks. We have discussed different types of multi-finger grippers. We have not yet developed the gripper which has the same number of degrees of freedom as a human hand has.

Prosthetic hands are also being developed using Additive manufacturing. In future, the performance of these grippers can be improved in different applications by using advanced controllers, effective feedback system and by designing the effective design of the grippers. Artificial Intelligence can also be used to control these grippers for performing different tasks in unknown environments by using AI these robotic grippers can adopt themselves according to the surrounding to perform the tasks effectively.

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Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☒The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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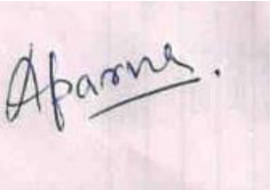

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