International Journal of Enhanced Research in Science, Technology & Engineering
ISSN: 2319-7463, Vol. 13 Issue 2, February-2024, Impact Factor: 8.375

Short Review on Gripper System: Introduction, Types and Applications

Pranav Khadkotkar[1], Ankit Kumar Mishra[2]

[1]Graduate Research Trainee, Department of Research and Development, Astroex Research Association, Deoria-274001, India
[2]Research Advisor, Department of Research and Development, Astroex Research Association, Deoria-274001, India

---

ABSTRACT

This research delves into a comprehensive review on robotic grippers, assessing various technologies through an analysis of diverse materials and resources. The utilization of grippers is widespread in automation and manufacturing industries, with different types, such as mechanical, vacuum, or electromagnetic, being employed based on industry needs. Each gripper type has its own set of merits and drawbacks, and their efficiency in task performance is scrutinized. The study encompasses a wide array of applications where grippers have been deployed.

Keywords: Automation, Grippers, Mechanical, Robots, Vacuum.

INTRODUCTION

A customized mechanical gripper was attached to the manipulator arm of the PUMA-type Industrial Robot and basic operations such as adjustment of height, controlling of path, automatic detection of consumption of electrode were performed. Based on the results, the design of the mechanical gripper effectively supported the in-situ arc welding process [1][2]. For grasping objects of different sizes, a suction cup was used. Based on the results of various tests, this multi-function gripper can grasp different objects effectively[3]. The constant-force mechanism is optimized through finite element analysis and the MOGA method, eliminating the need for time-consuming parameter tuning and complex model design found in traditional constant-force microgripper designs. The proposed approach also achieves a larger constant-force stroke. To facilitate stepless adjustment, a PZT-driven bridge-type amplifier is utilized to provide accurate preload displacement to the constant-force module. The adjusting module and microgripper are subjected to finite element analysis and experimental verification. Simulation and experimental results affirm that the designed microgripper successfully attains the desired constant-force output and exhibits stepless adjustability. The proposed microgripper design framework offers the advantages of compact size and the ability to adjust constant-force output within a specified range. This work contributes to the advancement and promotion of compliant constant-force structures[4]. The design allows for continuous adjustment between high compliance and high stiffness in the gripper fingers, enhancing robustness through its mechanical structure. A linear analytical model is developed to analyze the deflection and stiffness of the parallel beam, particularly suitable for small and medium deflections. The impact of each parameter of the parallel beam on stiffness is thoroughly examined. A prototype of the Variable Stiffness Gripper (VSG) is created, achieving a highly competitive stiffness ratio of 70.9. Additionally, a vision-based force sensing method, employing ArUco markers, is proposed as an alternative to traditional force sensors. This enables the VSG to implement closed-loop control during the grasping process, ensuring efficiency and safety within a well-defined grasping strategy framework. Experimental tests underscore the significance and safety of stiffness variation, demonstrating the VSG's high performance in adaptive grasping for asymmetric scenarios and its capability for flexible grasping of objects with varying hardness and fragility[5]. A design of mechanical tool for robots with two-finger parallel grippers, which extends the functionality of the robotic gripper without additional requirements on tool exchangers or other actuators was developed.Based on the results, it can be concluded that intelligent robots could use the tool through vision and planning to perform complicated tasks[6].

Heinz Frank et.al. carried out design and development of two grippers. The gripper which closes with kinetic energy is better for grasping objects with large masses. On the other hand, the gripper which closes with spring energy is better for smaller objects. Closing time of both the grippers is less than 10ms[7]. Serge Montambault et.al. presented a static and kinematic model of underactuated grippers. A two-degree-of-freedom underactuated finger based on a five-bar planar mechanism has been studied. It is concluded that gripping efficiency is crucial for effective gripping by an underactuated mechanism[8]. Matteo Verotti et.al. conducted a comprehensive study on microgrippers design based mechanical structure. An atlas of microgrippers was generated from recent literature. These designs appear homogeneous, easy to inspect, and quite useful to understand the basic ideas standing behind the reviewed microgrippers[9]. Artur Babiarz et.al. carried out design of underwater manipulator that imitates the movements of the human arm. The developed manipulator is efficient in controlling objects. The control of manipulator is intuitive.

The operator does not need to monitor the indicators continuously. The gripping force and errors are detected and signified by vibrations in glove[10]. Daniel Tortorelliet.al designed soft grippers using simultaneous shape and topology optimization. The simulation-based framework is predicated on hyper elasticity, non-linear kinematics and mixed finite elements. The gripper’s motion is controlled by pressurizing a prescribed number of cavities. As expected, increasing the number of cavities results in increasing performance. The benefit of the simultaneous shape and topology optimization is illustrated by comparing those designs against those obtained using a sequential topology and shape optimization framework [11]. Roy Chenyu Luo putforth the algorithmic approach for designing Miura-ori-based origami manipulators was proposed to grasp objects with complex geometry. A design algorithm forgenerating Miura-ori folds from vertex coordinates of complex shapes was presented, alongwith a 3D- printed prototype gripper using a single actuator [12].Anjaiah Madarapu et.al. worked on the design and simulation of robot gripper and conveyor system for workstations. The software hardware simulation and design construction characteristics, integrating all the major necessities in the design of an industrial automated processing system.

This attempt has been made to bring out the result-oriented approach in the project, a model has been prototyped that can run using the microcontroller NodeMCU ESP 8266 12 E. This concept can be scaled-up to industrial standards to adjust to larger domains of work, such as packaging or storage industries that employ such systems to boost the process [13].Yuxuan Liu et.al. performed a detailed review which presents various soft gripper designs, including fluidic and mechanical grippers, and introduces five configurations suitable for agriculture product handling: tentacle, finger, hand, envelope, and suction. It explores sensor-based control methods, such as proprioceptive, tactile, and imaging sensors. Advanced control approaches have been developed to achieve intelligent functions, such as object classification and real-time grasping condition evaluation using different sensor categories. As the complexity of soft grippers increases, machine-learning methods become increasingly essential for predicting, designing, recognizing, and controlling their movements [14].L.K. Thakur et.al. have successfully designed and built a robotic arm that possesses five degrees of freedom (DOF). The robotic arm's ability to manipulate and relocate objects is made possible by the presence of a mechanical gripper on the end of the arm. According to the results of the tests that were carried out, our robotic arm has proved that it is capable of moving in five different degrees of freedom (DOF). It is possible to save the coordinates of the robotic arm and then use them later for the purpose of automating processes [15].

OVERVIEW ON GRIPPERS SYSTEM

Robotic grippers are tools attached to a robot’s wrist. They are used to interact with the environment, in particular for operations that involve manipulation and movement of objects. Robotic grippers can hold objects using different principles, among the most common typologies, there are jaw grippers, vacuum grippers, magnetic grippers, and anthropomorphic grippers.[16] A robotic gripper must be versatile and capable of performing reliable grips and manipulations in unstructured environments, for example. The high cost and excessive layout complexity prevent robotic grippers from penetrating the product. To alleviate these limitations, researchers have proposed a low-power robotic gripper with a tendon drive mechanism (TDM). budget. However, designing a robotic gripper is a very complex method involving many parameterized simulations. Automation systems use robotic grippers as one of their main components. The pick-up module allows the robot to pick up, move, and place objects to pick, transport, and place workpieces. Robotic arms usually have sensors mounted near the workpiece. A wide range of tasks can be performed using automation components such as robotic arms and software. This allows the production of multiple product variants. Conversely, capture modules are often customized for specific tasks and come with tools to aid in customization[17].

Soft gripping is categorized in three technologies: i) by actuation, ii) by controlled stiffness, and iii) by controlled adhesion. These three categories are not exclusive, and many devices make use of combinations of two technology classes to reach higher performance. The preferred technology and materials for a given task will depend on properties of the object being manipulated, the operating environment (e.g., wet, dry, clean)required force, required speed, permissible power consumption and weight, biocompatibility, as well as system constraints including the integration or use of external sensors, and control methods. Since soft grippers provide excellent shape adaptation to a broad range of objects, control is dealt with differently than for more conventional grippers based on rigid technologies.

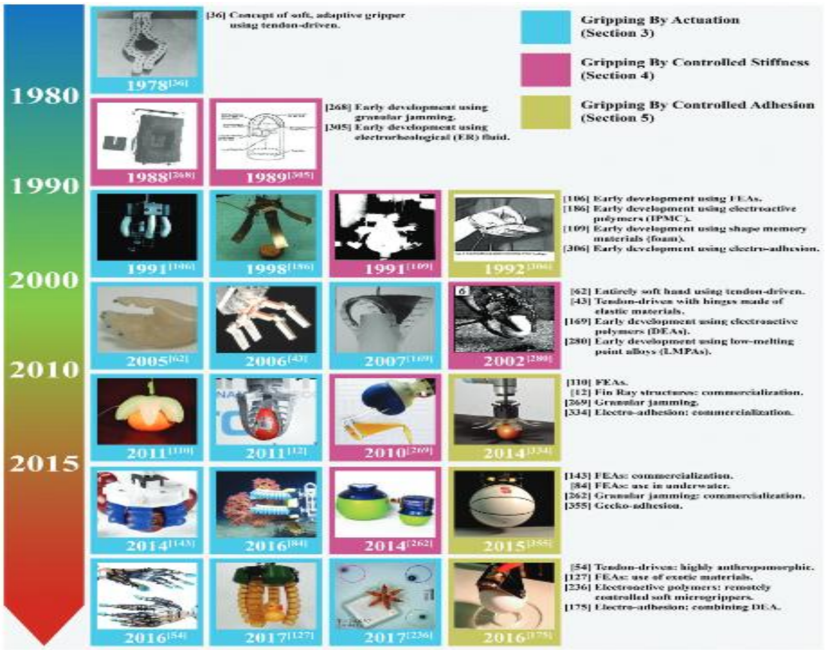

Fig 1. Soft gripper demonstrated using rigid multilink and Tendon-driven[18]

In industrial settings, humans primarily perform cable grasping. The inherent challenge lies in the fact that cables are deformable, non-standard components showcasing intricate geometric characteristics. Their pliability, combined with complex geometry, makes the automation of grasping these components a notable challenge in robotic applications. When introducing a scenario where a robot is required to grasp stacked cables, the complexity escalates. Robots must meticulously address the mutual occlusion stemming from cables in varied geometric positions and forms. Advanced robotic manipulation, fortified with collision awareness, becomes paramount to prevent potential damage to products within containers, safeguarding their economic value[19].Learning dexterous manipulation tasks is an open challenge in robotics. These tasks require controlling tens of degrees of freedom (DoF), to deal with possibly imprecise perception of the environment, and to manage hand object interactions. Grasping is the key task to enable the execution of other dexterous manipulation tasks such as object re-orientation [20].

Nowadays, companies are increasingly optimizing their production efficiency by integrating robots and associated peripherals in more uncertain and dynamic production environments. To this end, the expected features of robotic grippers are rapidly rising, because more customized and non-rigid products are assembled and packaged automatically, therewith introducing deliberate or inherent variability in product size and shape. Both industry and academia are therefore stimulated to innovate and develop more advanced grasping principles and strategies, as well as sensors to monitor the grasp's effectiveness. This trend has been confirmed by [4-6] demonstrating that robotic grippers are a billion-dollar industry with the potential to double its market size in the upcoming decade[21]. In recent years, the field of bioengineering has undergone a remarkable transformation, driven by technological advancements in materials science and manufacturing methods. The advent of 3D printing technologies has ushered in a new era of innovation in bioengineering. This category of technology allows for the precise, layer-by-layer fabrication of complex structures, providing unprecedented levels of design flexibility and customization. From prosthetic limbs to robotic grippers, 3D printing has revolutionized the way people approach the development of biomechatronic devices using such advanced manufacturing methods[22].

Handling is one of the most widespread and basic tasks necessary for an automated and efficient production of goods. In order to achieve the handling of objects as effectively as possible, the end effectors and grippers used for these systems have to be capable of securely handling the gripped objects without detachment during the handling process. Typically, this is done by utilizing predefined points on the object's geometry, where the selected grippers characteristics, such as a mechanical or a vacuum-based suction cup gripper are easy to predict and enable high gripping forces. Within these conditions, the gripping strength or vacuum can be adjusted in accordance to the object's weight and the specific handling task. With these widespread conventional grippers, usually fat and uniform surfaces are required, which have to be detected precisely in order to guarantee a secure and faultless grip[23]. Soft robots have widely attracted researchers given their potential in achieving safe, adaptive, and precise interaction with their environment.1 Compared to conventional rigid robotic structures, soft robots are made of compliant and flexible materials that have inherent safety and compliance.2

These properties offer substantial advantages to soft robots especially when it comes to developing robotic grippers that are suitable for applications requiring safe human–robot interaction and grasping and manipulating objects with different weights, shapes, textures, and stiffnesses.3–5 Nonetheless, the inherent compliance of soft robots poses considerable difficulties and challenges in controlling their fully deformable structures, limiting their applicability in areas where accurate and precise control is required, such as grasping fragile objects, due to their infinite degrees of freedom and highly nonlinear dynamics[24].

Recently, the picking up of deformable objects in the medical field (tools, soft tissues) or daily life (food) has benefited from the applications of soft robotics. Since such objects are often situated in wet environments with a liquid film on the surface of the objects, they pose a challenge to robotic grippers in accomplishing stable grasp and manipulation with low squeeze force. Several critical scenarios include autonomously manipulating food samples such as tofu, jelly, konjac, coffee jelly, and a quail egg, in various wet conditions with a soft robotic gripper lifting them from a container and placing them elsewhere, such as into a lunch box. For objects that are wet, deformable, fragile and have surfaces that are slippery, the required grasp force generated by the robotic fingers must be maintained at the minimum value to economically prevent slippage and large deformation of the object[25].

TYPES OF GRIPPERS SYSTEMS

Mechanical Gripper

It is an end effector that uses mechanical fingers actuated by a mechanism to grasp an object. The fingers, sometimes called jaws, are the appendages of the gripper that actually make contact with the object. The fingers are either attached to the mechanism or are an integral part of the mechanism. An example of mechanical gripper is shown in Figure 2[26]. A totally 3D-printed flexible gripper consisting of a flexible electrodehesion and a flexible adaptive gripper to solve the deficiencies of current approaches for creating flexible electrodes and soft grippers. The overall design consists of two components: the execution component and the power component. The executive portion consists mostly of the clamping and EA functions, including a bio-inspired PLA+ spiral spring, a TPU finger, a flexible EA pad, and the power part that produces mechanical clamping force[27].

Fig 2.Schematic representation of mechanical gripper[26]

A two-finger microgripper made of ionic polymer metal composite (IPMC) is a basic design that is mainly used for micro clamping operations in micro-assembly operations. Researchers designed an underwater hydraulic gripper with a two-finger parallel structure for the deep-sea environment. To ensure the accuracy of operation, it is also equipped with a multi-dimensional force sensor and a tactile sensor. Pneumatic gripper with a two-finger structure optimized for the fingers to achieve maximum bending deformation[28]. Grippers are typically actuated using pneumatics, hydraulics, or servo-electric motors. The choice of actuation method depends on the specifc application's sanitary, payload capacity, precision, safety, and other operational requirements [10]. Pneumatic and hydraulic designs ofer fast response and high force output, but they require a pressure reservoir or generator, which can take up space and produce noise[29]. This section outlines the structure of the proposed end-effector for the robotic arm. The primary constituents of the robot include four silicone SMA actuators (SSAs), two fingers (jaws), a gripper frame, and four tendons, as can be seen in Figure 1. The gripper frame functions as the anchor point for all the components and serves as a crucial interface between the robotic arm and the end-effector. Two fingers are attached to the gripper base, and the surface gap between them is 38 mm in the rest state[30]. The approach selected for manipulation also determines the overall design of the robot and system. If a legged platform is carrying task-specific manipulators, design metrics such as weight, range, strength, and generality are important. If the legs themselves become tools for moving objects, key design trade-offs become impact resistance and sensitivity. Teams of robots can also collaborate to move larger objects together, but each robot then is typically smaller and more dependent on coordination[31]. A pre-strained bilayer thermal actuator is evaluated according to the recent development, due to its fast actuation mechanism. The 4D printing procedure is the same as earlier work of authors (14, 17). Based on this characteristic, these actuators can be effectively used in soft robotic grippers, as the variation in curvature of the structure can be considered an appropriate parameter for the effective deformation calculation of pre-strained bilayer structures. Liu et al. also presented a designation for the bi-stable soft robotic grippers used for the dynamic capture of objects in space [16] [32].

Vacuum Gripper

Suction cups are used to hold flat objects. Using strong suction cups to lift an item, the “vacuum” is used to lift large, flat, smooth sheets of material like wood paneling, metal, plastic and glass. An example of vacuum gripper is shown in Figure 6[26]. Suction is a popular grasping method; however, it is often limited to small objects with a single suction cup or fat objects with multiple cups. Suction has low adaptability to complex shapes. Researchers have attempted to integrate suction and mechanical gripping to achieve versatility; for example, Park et al. [17] designed a parallel gripper with suction cups attached at the tip of the jaws, but the cups can obstruct the grasping of small items[29].

Fig 3.Schematic representation of vacuum gripper [26]

A possible solution for versatile handling is granular grippers. Usually, these grippers consist of an airtight membrane or’cushion’ filled with granulate material. In an unactuated state, this gripper is deformable and capable of adapting to a wide range of geometries. When the system is actuated and a vacuum is applied to the gripper, both the membrane and the granulate fling contracts, referred to as a ‘jammed’ state[33]. An adaptable mechatronic device was designed for 10 types of packing matrix, with the capacity to transport a maximum of 30 eggs at a time. It is important to keep the feed pressure stable, otherwise the supply capacity will be lost. Likewise, the reference point must be fixed with high precision for the correct coupling of the product with the final effector, controlling the displacement of the gripper along the Z axis of the referential coordinate system used[34].Vacuum grippers, or suction grippers, are widely used in industry for simple pick and place operations. Relying on negative internal pressure that forms when sealed against a surface, the suction gripper can gently handle an object without applying squeezing force, which allows an astrictive handling of various types of objects. If the item to be grasped is smooth and well modeled, as in manufacturing lines, the gripper can repeatably and predictably handle it with high reliability[35].

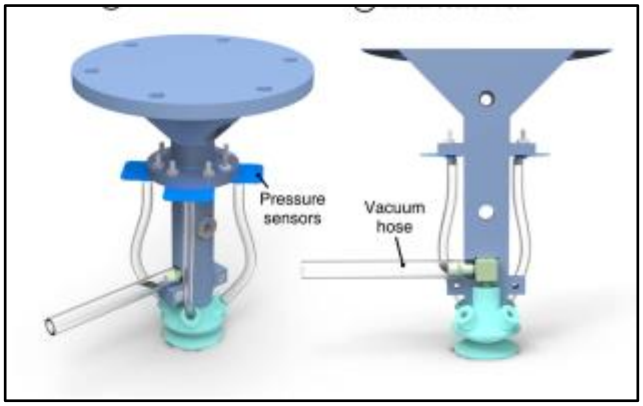

Fig 4.Components of vacuum gripper[35]

Magnetized Devices

Making use of the principles of magnetism, these are used for holding ferrous work parts. An example of magnetic gripper is shown in Figure 7. Also, the Figure 5 represents about multiplefingered gripper andfigure 6 aboutvacuum gripper respectively. The robot arm moves into position and securely plants one or more airtight suction cups to the material, and then activates a powerful inward suction force. The vacuum requires less power than either of the other two designs, but is also more prone to mishaps due to misaligned suction cups that fail to achieve an airtight seal.

Fig 5.Schematic representation of magneticgripper[26]

Magnetic grippers are pickup different sizes very fast. Electromagnetic grippers are easier to control, but require a DC power and an appropriate controller unit. Permanent magnets have the advantage of not requiring an external power source to operate the magnet[26]. Soft robotic hands and grippers often use electric actuators to grasp objects. The force of an electric actuator can be increased by adding more copper to the winding or injecting more current. However, adding more copper increases the actuator's weight and size, making it unsuitable for our study. Injecting more current does not increase the size of the actuator, but it can increase its temperature and cause permanent damage. To address this issue, several techniques have been developed to integrate cooling liquids into electric actuators, which are used in industrial electrical machines, electric vehicles [1], and robotic arm joints[36].

APPLICATIONS OF GRIPPERS

Grippers for Industry

The earliest grippers were first developed for industrial applications. They are commonly defined as grippers used for mass production purposes that are mounted on a stationary platform. The industrial grippers can be studied through different aspects such as geometrical condition of grasping, position and orientation of grasping, static equilibrium of grasped objects, and dynamic conditions. We mainly focus on the performance, adaptability and flexibility of the grippers. The first industrial robot was the UNIMATE installed in a General Motors assembly plant in 1961. This was a rigid parallel manipulator that grasped hot pieces of die cast metal. Since then, many companies have embraced robotic gripping technology and have developed different drive mechanisms. These were typically driven by electric motors or hydraulic actuators, but more recently piezoelectric and shape memory alloys are being used for actuation. Industrial grippers can be split into different categories such as grippers used in known environments and grippers used in unknown environments[37].Industrial robotic grippers have a pivotal role in modern automation since they constitute the end-of-arm of robotic manipulators and thus, they are in direct contact with the workpiece to noddled. Grippers as end-of-arm tools have to perform their tasks under demanding requirements in modern mass production because handling operations do not directly increase the market or intrinsic values of the workpieces. Therefore, grasping and manipulation should be achieved not only securely but as fast as possible to reduce cycle times[38].

Grippers for Known Environments

Grippers that are used in known environments typically have parts that come on an assembly line. The parts are positioned in predefined orientations, which make it easier for the gripper to pick up the object. These grippers can use servos, non-contact, contact, or a combination of sensors for feedback. Sensors can include hall sensors, accelerometers, ultrasonic, or photoelectric sensors to name a few. This can be used for detecting many variables such as: position, force, torque, velocity, and acceleration. These sensors prove useful in many situations such as detecting whether objects are being grasped, or by providing information to a supervisory computer to control an assembly line process[37]. Today, manual pick and place is a very repetitive task for human workers. Several Cartesian, six-axis and selective-compliance-articulated (*SCARA*) robots were proposed to accomplish a specific manipulation objective. These robots, in a seamless way, repeat cyclically the same exact sequence of actions for a targeted object and are not engaged in human interaction. Pick and place task is of fundamental relevance in automated manufacturing companies. Even if pick and place is one of the main operations in programmable assembly, its applications span other processes like packaging, palletizing, warehousing, loading/unloading of machines, and sorting[39].

Grippers for Unknown Environments

In many cases, grippers might be tasked for pick-and-place operations without knowing the conditions of the environment. Different design and techniques have been developed to increase the flexibility of grippers in unknown environment such as using vision systems, sensory feedbacks, and novel mechanism with flexibility in gripping.[37]

Grippers for Fragile Objects

With the improvement of end-effector sensors, the idea of picking up fragile objects was explored. An end-effector was designed for harvesting lettuce. This design included a machine vision device, six photoelectric sensors and a fuzzy logic controller. The designed end effector was able to harvest lettuce at a rate of 5 s per lettuce with a success rate of 94.12%[37]. The Department of Automatic Control (DAC) of Industrial Automation Institute (IAI) has developed a new integrated system for high speed manipulation of pastries that incorporates the recent technical advances. This system is composed of one three degrees of freedom Cartesian robot, driven by linear motors [19-20], one special gripper with one extra degree of freedom, one vision system, and an overall control system. The objective of the vision system is to determine the center of the objects and their orientation, being the acquired data, subsequently used by the control system to enable real time object manipulation. The fundamental characteristics of the developed system are based in the robustness of its construction, its versatility, and the reliability of the overall control system[40].

Grippers for Medical Applications

In use of robotic grippers in surgery, one of the main issues is the lack of force feedback and damaging the biological tissues. Soft bodied grippers are very suitable in the medical field based on their self-limiting and intrinsic safety features, which provides safe interaction with biological tissues.

Soft Fabric Grippers

An ongoing challenge in gripper design is in picking up fabrics. In order to do this, penetrating grippers have been designed which are also called ingressive grippers. They are used in the textiles industry to hold fabrics since suction cups cannot vacuum to the material due to the porosity. Textiles however can be penetrated while being moved with minimal underlying damage to the woven structure[37]. Researchers have begun developing “soft robotic grippers” that use compliant materials like soft silicone elastomers. Soft robotic grippers with high deformability and energy-absorbing properties can grasp objects with varying structures, sizes, surface textures, and fragility without damaging them, as well as facilitating safe human-robot collaboration. As a result, numerous active actuation mechanisms for soft grippers have been studied in recent years, including actuation based on cables, pressurized fluid, electrostatic forces, magnetic fields, and shape memory alloys and polymers. Among many fabrication methods to create soft grippers, such as silicone molding or multi-material 3D printing, fabric-based fluid-driven grippers have several advantages such as being lightweight, robust, having a high power-to-weight ratio, large strain and force production, simple fabrication, and use of low-budget materials[41].

The robot has a robotic arm with a gripper that can pull out weeds from the soil. The robot is built on ROS Noetic and can run for up to 10 hours on battery. The image’s background was removed, and the plant leaves and stems were categorized. The robot used a fast pick and place electric gripper to remove the categorized leaf along with stem from the soil if it belonged to the weed family. It can also work for long hours and in various weather conditions[42]. The performance of the robotic manipulator in the casting industry is critical in ensuring that the shell adapter is managed effectively. The robotic manipulator is programmed to perform specific tasks, including gripping and releasing the shell adapter, rotating the shell adapter, and moving the shell adapter to the desired location. The manipulator's performance is measured based on its accuracy, precision, and speed. In developing the product, we experimented with different designs and finally found the most effective grip [43].

In particular, soft finger of the dexterous grasping method has good flexibility and adaptability in the process of fabric grasping, which provides a new solution for garment production automation. Up to now, the reviewed method in general exhibit good grasping speed, high grasping stability and flat grasping process. However, in the face of complex fabric materials which are thin and flexible and do not return their original shapes when deformed in practical applications, the gripper for automatic fabric grasping need new technological breakthroughs in the positioning accuracy, grab efficiency and flexible grasping[44]. The development of MANUS exemplifies the potential for providing viable solutions that meet these demands across various domains. The Adaptability of its fingers and thumb enables precise and secure manipulation, allowing it to firmly grip objects of varying sizes and configurations. Combined with the emergence of commercially available production methods like 3D printing, this technology will inspire others to contribute to its further development, expanding its availability for more applications[4].

CONCLUSION &FUTURE SCOPE

This study leads us to the conclusion that robotic grippers have been extensively utilized in the automation and manufacturing sector. Their deployment dates back to the 1980s, and over the years, they have undergone significant evolution. Various types of grippers have been specifically crafted for industry-specific applications. The effectiveness of these grippers is evaluated through the examination of each paper reviewed. The future scope of this research includes an in-depth investigation into the electronics and software essential for the proper functioning of robotic grippers.

REFERENCES

[1]. Silvia Terrile, Miguel Argüelles, Antonio Barrientos, Comparison of Different Technologies for Soft Robotics Grippers, Centre for Automation and Robotics (CAR), Universidad Politécnica de Madrid—Consejo Superior de InvestigacionesCientíficas, 28006 Madrid, Spain

[2]. Rishabh Chaturvedi, Anas Islam, Aman Sharma, Kamal Sharma, Rohit Sharma, Design and Analysis of Mechanical Gripper of AristoRobot for Welding, IET, Department of Mechanical Engineering, GLA University Mathura 281406, India

[3]. Long Kang, Jong-Tae eo, Sang-Hwa Kim, Wan-Ju Kim, Byung-Ju Yi,Design and Implementation of a Multi-Function Gripper for Grasping General Objects,Department of Industry-University Cooperation Foundation, Hanyang University ERICA, 55 Hanyangdaehak-ro, Sangnok-gu, Ansan, Gyeonggi-do 15588, Korea

[4]. Jiahang He, Yinong Liu, Chunbiao Yang, Zongdi Tong, Guangwei Wang, Design and Evaluation of an Adjustable Compliant Constant-Force Microgripper, School of Mechanical Engineering, Guizhou University, Guiyang 550025, China

[5]. Jiaming Fu, Ziqing Yu, Qianyu Guo, Lianxi Zheng, Dongming Gan, A variable stiffness robotic gripper based on parallel beam with vision-based force sensing for flexible grasping, School of Engineering Technology, Purdue University, West Lafayette, IN, 47907, USA and 2Department of Mechanical and Nuclear Engineering, Khalifa University, Abu Dhabi, 127788, UAE

[6]. Zhengtao Hu, Weiwei Wan, Kensuke Harada, Designing a Mechanical Tool for Robots With Two-Finger Parallel Grippers, IEEE ROBOTICS AND AUTOMATION LETTERS, VOL. 4, NO. 3, JULY 2019

[7]. Heinz Frank, Dennis Barteit, Norbert Wellerdick-Wojtasik, Thorsten Frank, Gregor Novak, Stefan Mahlknecht, Autonomous Mechanical Controlled Grippers for capturing Flying Objects,IEEE

[8]. Serge Montambault, Cle´ment M. Gosselin, Analysis of underactuated mechanical grippers, Journal of Mechanical Design SEPTEMBER 2001, Vol. 123

[9]. Matteo Verotti, Alden Dochshanov, Nicola P. Belfiore, A Comprehensive Survey on Microgrippers Design:Mechanical Structure, Journal of Mechanical Design, JUNE 2017, Vol. 139

[10]. Artur Babiarz, Robert Bieda, Tomasz Borowik, Tomasz Grzejszczak, Tomasz Hartwig, Krzysztof Jaskot, Andrzej Kozyra, Piotr Ściegienka, Underwater manipulator that imitates the movements of the human arm, Department of Automatic Control and Robotics, Silesian University of Technology, Gliwice, Poland

[11]. Anna Dalklint, Mathias Wallin, Daniel Tortorelli, Simultaneous shape and topology optimization of inflatable soft robots, Computer Methods in Applied Mechanics and Engineering, Volume 420, 15 February 2024

[12]. Roy Chenyu Luo , Design of an origami-based manipulator for grasping objects with complex geometries, January 6, 2024

[13]. Anjaiah Madarapu, Jai Sai Ganesh Singh Rajaputra, Tirupati Sai Hitesh, Yadavalli Phani Bhaskar, Design and Simulation of Robot Gripper and Conveyor System for Workstations, International Journal for Research in Applied Science & Engineering Technology (IJRASET)Volume 11 Issue X Oct 2023

[14]. Yuxuan Liu, Jixin Hou, Changying Li, Xianqiao Wang, Intelligent Soft Robotic Grippers for Agricultural and Food Product Handling: A Brief Review with a Focus on Design and Control, 06 October 2023

[15]. L.K. Thakur, A.K. Kashyap, B.K. Patle, Design and development of 5-dof robotic arm with a mechanical gripper, MIT ADT UNIVERSITY

[16]. Antonio TROIANO, Mechanical and Control Design of a Flexible Modular Gripper, POLITECNICO DI TORINO,December 2023.

[17]. Dr.C. Nithyanandam, Dr. S. Deepa Shri, Dr.V. Senthil Murugan, A Robotic Manipulator's Design and Performance Using in Casting Industry to Manage a Shell Adapter, TECHNOARETE TRANSACTIONS ON INDUSTRIAL ROBOTICS AND AUTOMATION SYSTEMS,Vol-3, Issue-2, June 2023

[18]. Jun Shintake, Vito Cacucciolo, Dario Floreano, and Herbert Shea, Soft Robotic Grippers, ADVANCED MATERIALS, 07 May 2018
[19]. Lei Zhang, Kaixin Bai, Qiang Li, Zhaopeng Chen, Jianwei Zhang, A Collision-Aware Cable Grasping Method in Cluttered Environment
[20]. Federico Ceola, Lorenzo Rosasco and Lorenzo Natale, Speeding-up Multi-fingered Grasping with Residual Reinforcement Learning, IEEE ROBOTICS AND AUTOMATION LETTERS. PREPRINT VERSION. ACCEPTED JANUARY, 2024
[21]. Jeroen Cramer, Bieke Decraemerc, Muhammad Raheel Afzald, Karel Kellens, A user-friendly toolkit to select and design multi-purpose grippers for modular robotic systems, 10th CIRP Conference on Assembly Technology and Systems
[22]. Use of high-performance polymeric materials in customized low-cost robotic grippers for biomechatronic applications: experimental and analytical research Răzvan Ioan Păcurar1 , Filippo Sanfilippo2 *Martin Bjaadal Økter2 , Diana-Irinel Băilă3 , Cătălin Zaharia3 , Adrian Ionuţ Nicoară, Ionuț Cristian Radu, Tom Savu, Filip Górski, Wiesław Kuczko, Radosław Wichniarek, Dan Sorin Comşa, Martin Zelenay and Paweł Woźniak
[23]. Christian Wacker, Niklas Dierks, Arno Kwade and Klaus Dröder, Experimental assessment and prediction of design parameter infuences on a specifc vacuum-based granular gripper, ROBOMECH Journal
[24]. Omar Faris, Charbel Tawk, and Irfan Hussain, A Three-Dimensional Printed Soft Finger with Pneumatic Chambers for Simultaneous Actuation, Sensing, and Controlled Grasping, Robotics Reports Volume 2.1, 2024
[25]. Van Pho Nguyen, Picking food by robot hand with tree-frog like pad in various wet conditions,School of Materials Science, Japan Advanced Institute of Science and Technology (JAIST), Nomi, Ishikawa, Japan
[26]. Patakota Venkata Prasad Reddy and V V N Satya Suresh, A REVIEW ON IMPORTANCE OF UNIVERSAL GRIPPER IN INDUSTRIAL ROBOT APPLICATIONS,Int. J. Mech. Eng. & Rob. Res.
[27]. Chaoqun Xiang, Zhiwei Li, Fei Wang, Yisheng Guan, Weibin Zhou, A 3D printed flexible electroadhesion gripper, Sensors & Actuators: A. Physical 363 (2023) 114675
[28]. Juntian Qu, Zhenping Yu, Wei Tang, Yining Xu, Baijin Mao, and Kunyu Zhou, Advanced Technologies and Applications of Robotic Soft Grippers, Adv. Mater. Technol. 2024, 2301004
[29]. Antonio P. Doroliat, Tung-Ying Ku, Chih-Hung G Li, Innovative grasping system with versatility and automation , The International Journal of Advanced Manufacturing Technology (2023) 126:5339–5352
[30]. Phuoc Thien Do, Quang Ngoc Le *, Quoc Viet Luong * , Hyun-Ho Kim, Hyeong-Mo Park and Yeong-Jin Kim *, Tendon-Driven Gripper with Variable Stiffness Joint and Water-Cooled SMA Springs , Department of Mechanical Engineering, Incheon National University, Incheon 22012, Republic of Korea
[31]. Yifeng Gong, Ge Sun, Aditya Nair, Aditya Bidwai , Raghuram CS, John Grezmak, Guillaume Sartoretti and Kathryn A. Daltorio, Legged robots for object manipulation: A review,
[32]. Ali Zolfagharian, Mohammad Lakhi , Sadegh Ranjbar, Morteza Sayah Irani, Marwan Nafea, Mahdi Bodaghi, 4D printing parameters optimisation for bi-stable soft robotic gripper design Journal of the Brazilian Society of Mechanical Sciences and Engineering (2023) 45:224
[33]. Christian Wacker, Niklas Dierks, Arno Kwade and Klaus Dröder, Experimental assessment and prediction of design parameter infuences on a specifc vacuum-based granular gripper Wacker et al. ROBOMECH Journal (2024) 11:1
[34]. Brad Calderón, Leonardo Vinces, and José Oliden, An adaptable vacuum gripper design for egg packaging, attached to the KUKA KR 60-3 industrial robot, 21st LACCEI International Multi-Conference for Engineering, Education, and Technology
[35]. Jungpyo Lee, Sebastian D. Lee, Tae Myung Huh and Hannah S. Stuart, Haptic Search With the Smart Suction Cup on Adversarial Objects, IEEE TRANSACTIONS ON ROBOTICS, VOL. 40, 2024
[36]. Mauricio Rodríguez, Graduate student member, IEEE, Toshihiro Nishimura, Tetsuyou Watanabe, Member, IEEE , A Liquid-Cooled Laminar Electromagnet for a soft robotic gripper and heavy object grasping , IEEE Xplore.
[37]. Kevin Tai, Abdul-Rahman El-Sayed, Mohammadali Shahriari , Mohammad Biglarbegian and Shohel Mahmud, State of the Art Robotic Grippers and Applications, School of Engineering, University of Guelph, Guelph.
[38]. Lionel Birglen, Thomas Schlicht, A statistical review of industrial robotic grippers, Robotics and Computer-Integrated Manufacturing Volume 49, February 2018.
[39]. Salvatore D'Avella, Paolo Tripicchio, Carlo Alberto Avizzano, A study on picking objects in cluttered environments: Exploiting depth features for a custom low-cost universal jamming gripper, Robotics and Computer-Integrated Manufacturing Volume 63, June 2020.
[40]. Javier Sarria, Hector Montes, Manuel Prieto & Manuel Armada, High Speed Fragile Object Manipulation, Advances in Intelligent Systems and Computing book series (AISC,volume 253)

[41]. Trung Thien Hoang, Jason Jia Sheng Quek, Mai Thanh Thai, Phuoc Thien Phan, Nigel Hamilton Lovell, Thanh Nho Do, Soft robotic fabric gripper with gecko adhesion and variable stiffness, Sensors and Actuators A: Physical Volume 323, 1 June 2021
[42]. Dr. Narmada Alaparthi1 Jyoti Kushwaha2 , V Lakshmi Priya3, DESIGN OF SMART WEED REMOVAL ROBOT, IJARST Volume:13, Issue10,Oct 2023
[43]. Dr.C. Nithyanandam, Dr. S. Deepa Shri, Dr.V. Senthil Murugan, A Robotic Manipulator's Design and Performance Using in Casting Industry to Manage a Shell Adapter, Technoarete Transactions on Industrial Robotics and Automation Systems Vol-3, Issue-2, June 2023
[44]. Jianping Wang, Jinzhu Shen, Xiaofeng Yao, Fan Zhang , Research progress of automatic grasping methods for garment fabrics , International Journal of Clothing Science and Technology ISSN: 0955-6222
[45]. Ravi Kumar, Jørgen Dale, Jayant Singh,Jing Zhou , Design and Development of an Anthropomorphic Gripper for Service Robotics and Prosthetic Applications, 2023 11th International Conference on Control, Mechatronics and Automation